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PRINCIPLES

OF

MODERN CHEMISTRY,

SYSTEMATICALLY ARRANGED,

BY

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TRANSLATED FROM THE GERMAN;

WITH

NOTES AND ADDITIONS, CONCERNING LATER DISCOVERIES,
BY THE TRANSLATOR, AND SOME NECESSARY TABLES.

ILLUSTRATED BY PLATES.

VOLUME I.

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PREFACE.

THE book which is here offered to the public in Engliſh dreſs, is an abſtract made by the late celebrated Dr. Gren himſelf, in the year 1796, from his *Syſtem of Chemiſtry*, *Halle*, 1794, in 4 vols. 8vo. the moſt complete and ſyſtematical work ever publiſhed on this ſcience.—It was not deſtined, as he ſays himſelf in his Preface, to be a *mere ſkeleton of that larger work, but to be uſeful without it, and to form a complete introduction to Chemiſtry.*—Hence all the principal experiments have been circumſtantially deſcribed, and all the fundamental and leading principles properly explained.

WITHOUT anticipating the opinion of the public, or encroaching upon the department of the ſober Critic, it may be ſaid that this book, ſmall as it is, embraces the whole of this ſcience in the moſt ſyſtematical order, proceeding from the firſt notions, ſtep by ſtep, to the moſt complicated doctrines, and arranged with the greateſt clearneſs and preciſion.—Some parts, however, of the *vegetable* and *animal kingdom*, more intereſting to the Phyſician than the public at large, have been rather ſhortly treated of; but they have been explained in a very ample and maſterly manner in the ſecond volume of his Syſtem of Chemiſtry.—Beſides, the Author declares, that his chief attention, in writing it, was beſtowed on the *practical* uſe and application of Chemiſtry. For this reaſon he has introduced a number of valuable matters relating to *pharmacy*, *arts*, *manufactures*, and the *operations of common life*; ſuch as the making of *glaſs*, *pottery*, *enamelling*, *making of ſugar*, *ſtarch*, *art of dyeing*, *bleaching*, *making of wines*, *brandy*, *beer*, *vinegar*, *baking of bread*, *production of nitre*, *refining metals*, &c.

To thoſe, who for the firſt time ſtudy this ſcience, it is immaterial to ſtate what new diſcoveries they may expect from this work; beſides that it would require too long a detail. But the experienced Chemiſt, who honours it with a peruſal, will readily find a number of new lights, hints, and improvements, modeſtly propoſed, without the leaſt affected ſhew of novelty.

It remains to be obſerved in this place, that Dr. *Gren*, at the time of writing this work, had renounced the *Atomiſtical Syſtem* of Natural Philoſophy, which in latter times has been extended to great ſubtleties by *Le Sage* and *De Luc*; and that, in its ſtead, he has adopted the *Dynamic Syſtem*, illuſtrated by *Kant* in his *Metaphyſical Elements of Natural Philoſophy*. — According to the former, 1ſt. matter fills its *ſpace* merely by its *exiſtence*; 2dly, it is *abſolutely impenetrable*; 3dly, its *diviſion* can be carried to a certain length only, ending in *atoms*, which, though extended, are not farther diviſible; 4thly, there are *empty interſtices* between the atoms; 5thly, the particles of elaſtic fluids, as air, vapours, caloric, &c. do not touch each other, and conſequently they form what is called *diſcrete fluids*; 6thly, the *rarity* or *denſity* of a body depends ſolely on the quantity of empty interſtices in a certain volume of ſpace occupied by the matter conſtituting that body.—On the other hand, according to the *Dynamic Syſtem*, matter fills its ſpace by its *primitive powers of attraction and repulſion*; its impenetrability is only *relative*; it it is *diviſible in infinitum*; it fills its ſpace as a *continuum*, or with *continuity*, ſo that the *objective vacuum* is a mere imaginary being, conſequently there are no *diſcrete fluids*, and even the particles of caloric and light form a continuum; laſtly, the *greater* or *leſs denſity* of a body is only an expreſsion indicating the *greater* or *leſs intenſity* of the *primitive, attractive, and repulſive powers*; which conſtitute the nature of matter, and which muſt decreaſe together with the *extenſion* of a certain body, according to certain laws; and therefore matter is ſuppoſed, even at the greateſt rarity or leaſt denſity, to fill its ſpace with continuity.

FROM theſe tenets of the *dynamic* doctrine, the expreſsions *continuum*, *continuity*, *diſcrete fluids*, &c. not uſed in this country in that ſenſe, occur in the earlier part of the preſent book, which the Tranſlator could not ſuppreſs without altering the ſenſe of the text.

BESIDES, it is well known, that, in the *Syſtem of Chemiſtry* quoted above, the Author did not ſo much adhere to the old *phlogiſtic ſyſtem*, as was objected by ſome, but rather that he has framed a ſyſtem of his own, which he called *ecclectic* (mentioned in this work, § IX. Introd.); though he there explains every phenomenon,

phenomenon, not only according to his own doctrine, but alſo *hiſtorically*, according to that of both the *phlogiſtian* and *anti-phlogiſtian philoſophers.*—To that *ecclectic* ſyſtem the Author adhered to his death; but the reader is requeſted to obſerve, that in the preſent work Dr. *Gren* has merely ſtated the grounds of his favourite chemical creed, and continued throughout the reſt to explain all the phenomena treated of according to the modern ANTI-PHLOGISTIC SYSTEM in the ſtricteſt ſenſe.—Conſult § 213.

Thus far concerning the original. The Tranſlator will now ſtate what he has done in the preſent publication.

I. He has endeavoured to give the meaning of the text as cloſely, faithfully, and literally, as the nature of the two languages would allow. He has taken no liberties with his Author; only, in a very few places, he thought proper to transfer a line or two from the Author's own larger book, or in notes, beſides a few of his own, marked *Ed.*—He has alſo ſtudiouſly retained the references in the §§, or rather increaſed their number, in order to aſsiſt the recollection of the reader.

II. SINCE the German publication of this work, ſome valuable diſcoveries have been made in the ſcience. All of them do not come within the compaſs of an elementary treatiſe. Such as may have been occaſionally added in notes, diſtinguiſhed by *Ed.* from thoſe of the Author. The new earth, *glucine*, or rather *glycine*, the two new metals, *tellurium*, or ſylvanite, and *chrome*, have been added in the text in their proper places.

III. WITH regard to *terminology*, the Tranſlator has made uſe of the *new Nomenclature*, as propoſed by the French Chemiſts, and tranſlated into Engliſh, under the title, *Method of Chemical Nomenclature, propoſed by De Morveau, Lavoiſier, Berthollet, and Fourcroy.* Tranſlated by *James St. John*, M. D. 8vo. London, 1788. —Well aware of ſome inaccuracies obſervable in that Nomenclature, and of the improvements that might be made in it, he thought it more reaſonable to keep, as it were, to a certain *ſtandard*, now almoſt generally adopted, than to fall into the faſhionable mania of fabricating or adopting new terms. For if we go on, as ſome of the learned in this and other countries do, there is great danger that, after ten years, no Chemiſt will underſtand another.—

ther.—If the Tranſlator's orthography ſhould be objected to, although he is able to defend it againſt all cavils, he is far from entering into any grammatical diſcuſsion. Surely, loſing time about words is not the way of improving any ſcience!

By this, however, it is not meant to preclude the farther improvement of the new Nomenclature, of which it is certainly capable; but, inſtead of adopting directly new-framed terms in books, let them be fairly propoſed, as Dr. *Pearſon* has done, ſupported by proper reaſons, wherever opportunity preſents itſelf; and when a ſufficient number of facts, diſcoveries, and arguments for that purpoſe are collected, it will then be time to offer to the *chemical* public a *corrected* Nomenclature for their approbation.

By way of example, Dr. *Gren* himſelf has in this work propoſed and uſed the terms *muriatous* inſtead of muriatic, and *muriatic* inſtead of oxygenated muriatic acid, by fair analogy from *ſulphureous* and *ſulphuric*, *nitrous* and *nitric* acids, &c. becauſe what is now called muriatic is not a perfect, but only an imperfect acid, § 534; while, on the other hand,

hand, the oxygenated muriatic is the perfect acid of that kind, § 567. In conſequence of this, by the ſame analogy, he uſes *muriatous pot-aſh*, *muriatous ſoda*, &c. inſtead of muriat of pot-aſh, of ſoda, &c. and *muriat of pot-aſh*, &c. inſtead of oxygenated muriat of pot-aſh now employed.—Certainly the terms *oxygenated muriatic*, or *oxy-muriatic* acid, are not very ſucceſsfully contrived, are long, and imply a tautology. The firſt ſignifies only *acidified muriatic acid*, and the other *acid muriatic acid.*

Another inſtance—beſides many others occaſionally mentioned in the book—the metallic oxyds, according to §§ 1220—27, ſhould not be called *ſulphat*, *nitrat*, *muriat of iron*, *copper*, *tin*, &c. but *ſulphated*, *nitrated*, *muriated oxyd* of iron, copper, tin, &c.—All theſe improvements, however, have been only pointed out by the Tranſlator; and the modern Nomenclature, hitherto in uſe, has been preferred, in order to prevent being miſunderſtood.

Fearing to be found guilty of having himſelf treſpaſſed the rules juſt before recommended, the Tranſlator begs leave to obſerve, that according to his Author's own literal expreſsions, he has introduced the words *mingled* inſtead

inſtead of the complex terms mechanically united, and *mixed* inſtead of chemically combined; as alſo *liquid fluids*, to preſerve the *generic* word *fluid*, and to diſtinguiſh them from another *ſpecies*, called *elaſtic*. Several more of that kind are here omitted for the ſake of brevity. But, beſides that thoſe terms have been ſufficiently defined, they are conſtantly uſed in the ſame ſenſe, and are more preciſe; hence, it is hoped, they will be tolerated by men who know how to eſtimate preciſion and brevity of language in a ſcientific book, where ſimplicity is as much required as equivocation of terms to be avoided. The words *oxygen*, *hydrogen*, *azot*, *carbonic acid*, &c. were not long ſince offenſive to many individuals, but are now generally accepted.

THERE alſo does not appear any reaſon for diſregarding popular expreſsions, when they convey to the mind any proper idea clearly and diſtinctly, ſuch as *glowing*, *glow-heat*, &c. literally tranſlated from the Author, which certainly are leſs equivocal and more diſtinct than *ignition*, *ignited*, &c. ſince a body may be ignited to a high degree without reaching even that of a *low red-heat*. However, theſe and many others the Tranſlator did not dare to employ; and at this opportunity he begs leave to ſay, that he has ſuppreſſed a number of good, clear, and energetic expreſsions, to avoid giving offence to the delicate ear of the over-chaſte Critic.

One word more on this head. The reader will obſerve, that at the beginning of the work, the *ancient terminology* has been uſed; but, after every particular ſubſtance and its conſtituent parts had been explained, its name has been given according to the *new Nomenclature*, and then for ſome time both have been promiſcuouſly uſed; however, ſo, that towards the latter part, the preference has almoſt always been given to the new Nomenclature.—This has been purpoſely obſerved by the Author himſelf, but rather more ſo by the Tranſlator; and the reaſon of it is, that in common life, even among the Druggiſts, the old names of the various ſubſtances and *præparata* are better known than the new ones, and that the reader may gradually, and without any trouble, become acquainted with both Nomenclatures.

For a ſimilar motive, the *Latin names*, inſerted by the Author in brackets, though they

ſeem

ſeem uſeleſs in an Engliſh tranſlation, have not been always eraſed, for the ſake of thoſe who, acquainted only with the new ſtyle, may, after ſome time, turn their attention to the works of former Chemiſts moſtly written in that language, and ſome of which are ſtill valuable on many accounts.

IV. The German original having been written to be commented on in public lectures, where the chemical apparatus is exhibited in making the experiments, had no Plates. But as the ſubject of this work has been treated and explained by Dr. *Gren* ſo clearly, and in ſo eaſy a manner, that any common underſtanding may be ſufficiently initiated in this ſcience without much farther aſsiſtance, the Publiſhers went liberally, hand in hand, with the wiſhes of the Tranſlator, to gratify the *Amateur*, and had ſeven Plates engraved by the maſterly hand of *Lowry*.—The *firſt ſix* repreſent the moſt neceſſary and uſeful *chemical inſtruments*, and belong to the firſt volume: a *ſeventh* was added to the ſecond, exhibiting a ſufficient number of ſpecimens of the new *chemical ſymbols*, progreſsively from the primitive and ſimple to the compounded.

V. After the cloſe of the book, the Tranſlator made free to offer, in the *Appendix*, diſtinguiſhed from the main work by different types, ſome matters, which he hopes will be acceptable to the reader. They relate to the *Tables of Affinities*, the new *Chemical Symbols*, the *ſpecific and abſolute Gravity of Bodies*, the compariſon of *Farenheit's* with *Reaumur's Thermometer*, of the *former French Meaſures* and *Weights*, and of the preſent *Metre, Litres, and Grammes*, recently adopted in *France* for meaſures and weights, with the Engliſh.—Laſtly, a ſmall *Chemical Library* was added.—He flatters himſelf the reaſons for doing ſo, alleged under each of theſe heads, will be ſufficient to excuſe him for thus intruding upon the public.

Nothing has been ſaid in particular on the new *Chemical Nomenclature*, becauſe the Author himſelf has ſufficiently explained it in the courſe of the work; and the reader will be much better informed by referring to Dr. *Pearſon's Tranſlation of the Table of Chemical Nomenclature propoſed by Guyton, Lavoiſier*, &c. 2d Edit. Lond. 1799. 4to.

VI. Finally, it may ſeem rather ſtrange to meet with ſo large an Index at the end of ſo ſmall a book; but it was made to anſwer two purpoſes.—Firſt, it ſhould be as complete as poſsible, to aſsiſt the memory, and to facilitate the finding of any ſubject treated of in the work.—Secondly, it was intended to ſerve in lieu of a compendious Dictionary of both the old and new Nomenclature; the former, as mentioned before, being ſtill moſt known in common life, and the latter only among the learned. The Tranſlator has many times witneſſed an article being aſked for in the new ſtyle, and the ſhopman not being able to comprehend what was meant; while, on the other hand, the pupil of modern Chemiſtry, unacquainted with the old name of the ſubſtance, was unable to explain what he wanted.

This inconvenience is eaſily remedied by an Index of that kind.—*Sulphat of magneſia* is wanted, for inſtance: by referring to Vol. I. p. 233, quoted in the Index, its ſynonymous term, *Epſom-ſalt*, is found. Or, on the contrary, *tartar emetic* is preſcribed by the Phyſician, by referring to Vol. II. p. 390, again quoted in the Index, it is found to be the

antimoniated

antimoniated tartrite of pot-aſh. For this very reaſon the *London College of Phyſicians* have prudently accompanied their *Pharmacopœia* with a double index.—It is on account of theſe circumſtances that the Index has turned out rather more copious than might be thought neceſſary.

Some inaccuracies have, no doubt, unwillingly eſcaped the induſtry of the Tranſlator. Theſe, and ſome typographical errors, not noticed in due time, the candid reader is requeſted kindly to forgive.

THE TRANSLATOR.

London,
15 *February*, 1800.

CONTENTS

OF THE

FIRST VOLUME.

Page

CHAPTER I.

Preliminary Matters.

CHAPTER II.

Of the more common, ſimple, and compound Subſtances.

CHAPTER III.

Of Salts in general.

CHAPTER IV.

Of Earths.

Of Earths in particular.

CHAPTER V.

Mineral Acids, and their Combinations with Alkalis and Earths.

Fluoric

CHAPTER VI.

Conſtituent Parts of Vegetables.

Particular Examination of the conſtituent Parts of Vegetables, § 651.

ERRATA.

ERRATA.

Page		*Line*		*Read*	
18	—	27	*porpyhry*	—	porphyry.
146	—	13		*dele*	*gangues.*
Page		*Line*		*Read*	
332	—	21	*cream of lime*	—	milk of lime.
384	—	27	*Yaquin*	—	Jacquin.
436	—	5	*Guatamala*	—	Guatimala.

TO THE BOOK-BINDER.

The firſt Six Plates to be bound at the end of the firſt volume. The Tables of Explanation to front their reſpective plates.

The Seventh Plate (guarded) in the ſecond volume, after page 466.

INTRODUCTION.

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I.

CHEMISTRY (*Chemia*) teaches us the reciprocal actions of natural ſimple ſubſtances, the compoſition of bodies from them according to their proportions, and likewiſe the manner of ſeparating or combining them again to compound new bodies.

Synonyma: *Spagiric Art, Hermetic Art, Pyrotechny.*

Chemiſtry is conſidered as a *Science,* and as an *Art.*

II.

Chemiſtry is therefore a part of *Natural Philoſophy*. Its objects are all the beings of the ſenſible world; its baſis is *Experience*, from which by regular concluſions it deduces the *Theory*, which connects the facts to form a ſcientific ſyſtem. Its purpoſe is not merely to conſider the nature and mixture of bodies, but alſo to make them uſeful to our wants by means of ſuitable operations.

The particular uſe made of chemiſtry as an art, has given riſe to various appellations, as *Halurgy* or *Halotechny*, *Lithurgy*, *Hyalurgy*, *Phlogurgy*, *Zymotechny*, *Metallurgy*, *Docimaſy*, or *Art of Aſſaying metals, and metallic ores.*

Alchemy has nothing in common with our ſcience, but the ſimilarity of name. It is indeed the mother of Chemiſtry, but it is not the fault of the daughter, if her mother is abſurd.

III.

Chemiſtry, conſidered as a ſcientific ſyſtem, had its beginning only in modern times. The diſcovery of facts on which Chemiſtry is grounded, is the mere work of the ſenſes; and it is no wonder that ages could paſs, before either by accident or neceſſity, attention was paid to ſome of thoſe facts; and ſtill more ſo, before ſo many of them were collected, as could furniſh the baſis of a ſcientific ſyſtem.

The neceſſities of even the firſt inhabitants of the globe, could not but force them to attempt various alterations with certain bodies to ſatisfy thoſe wants; and theſe muſt have naturally been augmented, in proportion as, by the increaſe of nations on confined territories, the means of ſubſiſtence were rendered difficult, and the manners of living multiplied. The ſatisfying of theſe wants abſolutely preſuppoſes various chemical operations in the alteration of the mixture of bodies. *Baking of* *bread, caſting of iron, making of wine, &c.* are truly chemical operations. Yet the chemical operations, rendered neceſſary by theſe wants, how various ſoever they may have been even with the nations of remote antiquity, and were really ſo according to the remaining dates and monuments of hiſtory, reſted all, no doubt, on a mere empirical practice.

Thus alſo was the Chemiſtry of the Egyptians, which in the hiſtory of ſciences in general, and that of Chemiſtry in particular, is always firſt mentioned, nothing elſe, in fact, than an imperfect art, a mere practice of certain chemical operations, as is perhaps at preſent the caſe with the Chineſe, and with our common artificers. No doubt the Egyptians were, before other nations of high antiquity, acquainted with a great number of ſuch experiments, and practiſing ſuch operations, as may be called chemical. Their country has undoubtedly, in the courſe of time, given birth to the name *Chemia.*

But it was chiefly the Chriſtian Myſtics, and the New-Platonics, that occaſioned the high opinion of the chemical knowledge of the Egyptians; and the propenſity of man to the wonderful and myſterious, has given currency to this belief. Several *alchemical writings*, that were attributed to ſome remarkable perſons of the higheſt antiquity, as to *Hermes*, are ſpurious productions of thoſe New-Platonics.

Plutarch ſays (Iſis et Oſiris, page 364. C.) ἔτι τὴν Αἴγυπτον ἐν τοῖς μάλιστα μελάγγειον ὄυσαν, ὥσπερ τὸ μέλαν τοῦ ὀφθαλμοῦ, ΧΗΜΕΙΑ καλοῦσι. Præterea Ægyptum, quæ vel maxime nigram habet terram, tanquam nigram oculi partem, *Chemia* vocant. In the Pſalms (cv) Egypt is called *Terra Chami.*

Chemia ſignifies therefore, according to the original ſenſe, the *black of the eye*; but alſo the *hidden* or *ſecret* has been hieroglyphically ſignified by this word, as in the Arabic, according to *Bochart*, χημᾶ ſignifies *occultare.* In latter times only, when among the *New-Platonics*, the phantoms of *Theoſophy*, *Magic*, *and Alchemy*, occupied the authors, the term *Chemia* was made uſe of to ſignify the *Science of Nature*, or rather *Magic* (διδασκαλίαν πάντων τῶν τῆς φύσεως ἔργων) according to *Zoſimus Panopolita*, quoted by *Borrichius* (De ortu et progr. chemiæ, p. 12.) and eſpecially the *art of making* gold and ſilver (χημέια ἡ τοῦ ἀργύρου, καὶ χρύσου κατασκευή according to Suidas). Before the New-Platonics, this word is never mentioned under ſuch ſignification, neither by the Greeks nor by the Romans. *Julius Maternus Firmicus*, who lived in the age of *Conſtantine the Great*, is the firſt author among the New-Platonics, where the word *Alchemy* appears, and of which he makes mention as of a very well known art. He ſays (l. iii. Matheſeos, c. 15.) “ *Si fuerit hæc domus Mercurii, dabit Aſtronomiam*; *ſi Veneris, cantilenas et lætitiam*; *ſi Martis, opus armorum et inſtrumentorum*; *ſi Jovis, divinum cultum, ſcientiamque in lege*; *ſi Saturni*, “ Scientiam Alchemiæ.”

IV.

The problem of making gold and ſilver by art, took its origin only among the New-Platonic ſect of philo-

philoſophy, and the name of this pretended art appeared, for the firſt time, in the fourth century after Chriſt. Engaged by this, the pretended inveſtigators of nature ſoon loſt ſight of all other objects; the transformation of metals was the only central point round which the then chemiſts, if we may call them ſo, were revolving; their writings became obſcure and full of myſteries, and for that very reaſon, even in ſuch phenomena as they have occaſionally obſerved, of no uſe in the true Chemiſtry, which inquires into nature.

To theſe authors belong *Jamblichus* and *Heliodorus* (in IVth Cent.) *Zoſimus Panopolita*, *Syneſius* and *Olympiodorus* (in Vth Cent.) *Stephanus Alexandrinus* (in VIIth) *Michael Pſellus* in the XIth Cent.

V.

After the Sciences had been oppreſſed in the Weſt, by barbarity, the *Arabians* proved to be their cultivators, and inherited from the latter Greeks the paſſion for alchemy; their inclination to the marvellous made them the moſt zealous promoters of every branch of Theoſophy. It is in their writings, we find firſt the application of *alchemical operations* to the preparing of medicines, and ſeveral *chemically* prepared medicaments, ſo that we are entitled to trace from the Arabs the origin of *Medicinal Chemiſtry.*

Geber or *Dſchaſar* (born 702, d. 765) *Rhazes*, or properly *Muhammed Ebn Sacharjah Abu Bekr Al-Raſi* (in the Xth Cent.); *Avicenna*, or *Al Huſſain Abu Ali Ben Abdallah Ebn. Sina* (born 978, d. 1036); *Meſne*, the younger (died 1028), are among the Arabian chemiſts.

VI.

When in the thirteenth Century the Chriſtians in the Weſt began again by degrees to pay more attention to Chemiſtry, there were then no other Chemiſts to be found, than the operative Alchemiſts; and the Philoſophers-ſtone was the whole aim of their endeavours, notwithſtanding the encouragements which the ſtudy of nature had received, and the increaſe of knowledge which the greater communication between nations by means of commerce and navigation had procured.—The ſcholaſtic ſyſtem prevailing in philoſophy was unable to improve the phyſics and chemiſtry, learnt from the Arabs, or to cultivate them with the proper method, by experimental inveſtigation of bodies.

We ſhould, however, not be too ungrateful towards this middle age, as it is called, nor judge of the ſum as well as of the value of its practical and truly uſeful knowledge by the rubbiſh and nonſenſe of its ſpeculative learning.

The practical knowledge, which conſtitutes the true ground-work of all ſcience of nature, had nevertheleſs

vertheleſs very conſiderably advanced; the *progreſs* of trades, arts, and manufactures, was ſilently and imperceptibly enlarged and perfected; and, in ſhort, the moſt important chemical operations, which would never have been diſcovered by the learned ſpeculators, either of thoſe or of our times, and which are the baſis of all our Chemiſtry, were practiſed in all the various branches of human induſtry.

Conſequently the facts belonging to Chemiſtry were already exiſtent in thoſe times, called barbarous of the middle age; but Chemiſtry itſelf was not. The contempt and indifference, wherein the artificers and tradeſmen of thoſe times were held by the learned ſpeculators, as is partly the caſe at preſent, have left theſe laſt in ignorance of a number of facts, whereon the ſyſtem of Chemiſtry was erected in a ſubſequent age.

Why the inventors of the moſt important and uſeful diſcoveries, as well as the time of their diſcovery, are thoroughly unknown, may be accounted for by the very gradual progreſs of practical knowledge in the ſeveral profeſſions and trades, by the merely verbal inſtructions in the teaching of them, and by the want of *authors* among the tradeſmen and artiſts. Of the chemical writers of that period there are certainly ſome, that were acquainted with a great variety of facts belonging to phyſical Chemiſtry, yet there were none quite free from the madneſs of Alchemy, and all the reſt of their performances were rendered obſcure by the obſtacles, which their alchemical labours oppoſed to true Chemiſtry.

Albert. von Bollſtaedt (born 1193, d. 1280) *Roger Bacon* (born 1214, d. 1294) *Raimund. Lullius* (born 1235, d. 1315) *Alnold. of Villanova* (born 1250, d. 1313) *JſaacHolland*, and the pſeudonymous *Baſilius Valentinus*, belong to the authors of this age.

VII.

In the fifteenth century, philoſophy was greatly enlightened by the ſtudy of the originals of ancient Greek learning, and theſe advances received beſides from the then invented art of printing a very powerful ſupport, and an uncommon facility of being propagated. Many learned men of better underſtanding began then to diſpoſſeſs the *ſcholaſtic* philoſophy of its credit, to diſperſe more effectually the clouds of ſuperſtition, and to tread the paths of experimental inquiry into nature.

Many particular chemical arts and operations had even then advanced to a high degree of perfection, of which the deſcription of the metallurgic labours given by *George Agricola* (born 1494, d. 1555) may ſerve as an inſtance. Yet, notwithſtanding this, the diſcoveries of many deſerving men, in other branches of natural ſcience, were not ſo beneficial to chemiſtry as they might have been. In ſpite of the rapid and laudable progreſs of the former, aſſiſted by the labours of *Galileo* (born 1564, d. 1641)

John

John Keppler (born 1571, d. 1630) *René des Cartes* (born 1596, d. 1650) *Francis Bacon, of Verulam* (born 1560, d. 1626) *Otto von Guericke* (born 1602, d. 1686) *Evangeliſta Torricelli* (born 1608, d. 1647) *Robert Boyle* (born 1626, d. 1691) and *Iſaac Newton* (born 1642, d. 1727.) Chemiſtry could not then reſcue itſelf from the Myſtics and Alchemy.

The famous *Aureolus Philippus Paracelſus Theophraſtus Bombaſtus von Hohenheim* (born 1493, d. 1541), who as to oſtentation and lies has ſurpaſſed all his predeceſſors in Alchemy, and who to the chimerical transformation of metals has added the phantom of an univerſal medicine, ſtill found imitators and defenders; though ſome of them, of whom I mention only *John Baptiſt Van Helmont* (born 1577, d. 1644) *Rudolph. Glauber* (who wrote about the middle of the 17th century) and *John Kunkel von Loewenſtern* (born 1630) did, by their particular labours and diſcoveries, a great deal of uſeful ſervice to genuine Chemiſtry.

The beneficial influence of the Paracelſians on the diſcovery, introduction and preparation of a great many very efficacious medicines, and on laying the foundation to a *medicinal* chemiſtry, and *chemical* pharmacy, ought not indeed to be diſregarded. Two men, Father *Athanaſius Kircher* (born 1599? d. 1680) and the learned *Hermannus Conring* (born 1606, d. 1682) oppoſed Alchemy with much glory and ſucceſs.

VIII.

Till then no pains were taken to arrange a philoſophic ſyſtem, or to infer general theoretic principles, and fundamental truths from the many chemical facts, diſcovered partly by accident, partly by neceſſity, in the various trades, profeſſions and arts, or in alchemical operations. Chemiſtry had not then exiſted, but the facts belonging to it had. The eſtabliſhing of a ſcientific ſyſtem of phyſical Chemiſtry took place only in the latter half of the ſeventeenth century.

John Joachim Beccher (born 1635, d. 1682) laid the firſt and extenſive ground, upon which *George Erneſt Stahl* (born 1660, d. 1734) continued to raiſe the edifice, endeavouring to collect the principal facts then known into a coherent ſyſtem, by connecting them by means of general principles. With theſe men the new epocha of Chemiſtry begins.

From that time the learned began to reduce this ſcience to more determinate principles and language; they examined the reſults of experiments with greater accuracy and ſeverity; they conſidered henceforth *Chemiſtry* as a *branch of natural Philoſophy*, and enlarged thereby its horizon, formerly ſo much confined by Alchemiſts; they called the aſſiſtance of other kindred ſciences to its improvement; the myſterious language was more and more ſet aſide, and Chemiſtry was not only more philoſophically

phically treated, but alſo rendered more uſeful to the community.

By laying the baſis of a rational Chemiſtry, this ſcience was enriched with facts, one experiment ſupported another, and an accidental diſcovery led to thoſe made by deſign. The concurrence of ſeveral favourable circumſtances animated the ſpirit of inquiry of many great men; their co-operating induſtry ſoon brought forth an aſtoniſhing multitude of new facts, as alſo the knowledge of new, till then unknown ſubſtances, and raiſed the ſcience rapidly to greater perfection.

Among the number of men, who ſince that period have in the preſent century acquired to themſelves laſting fame, by cultivating this ſcience, I can only ſelect here the moſt celebrated. As of the

GERMANS: Frederic *Hoffman*, John Henry *Pott*, Caſpar *Neuman*, John Fred. *Cartheuſer*, John Andr. *Cramer*, Chriſtopher Ehregott *Gellert*, John George *Model*, John Gottlieb *Lehmann*, Andr. Sigiſm. *Marggraf*, John Fred. *Meyer*, John Reinbold *Spielmann*, John Chriſtoph. Polycarp. *Erxleben*, Ignatius de *Born*, Charles Count de *Sickingen*, Charles Wm. *Scheele*, Charles Fred. *Wenzel.**

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* To theſe muſt be added the learned *Dr. Gren*, author of the preſent book, deceaſed on the 26th November, 1798.—Ed.

Not

Not to offend, I mention none of the German Chemiſts * now living.

DUTCH: Herman. *Boerhaave,* Hieron. David *Gaubius,* John *Ingenhouſs,* Van *Mons.*

FRENCH: The two *Geoffroys; Reaumur;* du *Hamel* du *Monceau*; *Hellot,* the two *Rouelles,* Petr. Jos. *Macquer, Baumé, Sage, d'Arcet, Guyton de Morveau, Lavoiſier, Berthollet, Boſc. d'Antic, Bayen, Monge, Fourcroy, Chaptal, Prieur Adet, Haſſenfratz, Seguin, Vauquelin.*

BRITISH: Stephen *Hales,* Wm. *Lewis,* Jos. *Black,* Henry *Cavendiſh,* Jos. *Prieſtley,* Adair *Crawford,* Richard *Kirwan,* Drs. *Pearſon, Higgins, Crichton,* and *Bancroft,* Sir Charles *Blagden, Nicholſon, Hatchet, etc.*

SPANISH: Juan Joſeph and Fauſto d'*Elhuyar.*

ITALIANS: John Ant. *Scopoli,* Felix *Fontana,* Marſiglio *Landriani,* Tiber. *Cavallo,* Alex. *Volta,* Lazaro *Spallanzani.*

SWEDES: George *Brandt,* John Gottſch. *Wallerius,* Axel Fred. *von Cronſtedt,* Swen *Rinman,* H. T. *Scheffer,* Henry *Gahn,* Torbern *Bergman.*

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* The tranſlator makes free to add the names of *Klaproth,* who and *Vauquelin* may be reckoned the beſt analyſts; and beſides *Crell, Hermſtaedt, Goettling, Leonhardi, Wiegleb, Tromſdorf, Weſtrumb, Gmelin, Hagen, Jaquin, Succow, Weigel, Richter, Scherer, Gerhard, Achard, Lowitz,* &c.

IX.

What principally conſtituted the baſis of the ſyſtem, ſet up by *Stahl* (VIII.), were the phenomena which take place in combuſtion; or the diſengaging of fire in combuſtible bodies.—Stahl preſuppoſed in theſe the exiſtence of a particular ſubſtance, which he called *Phlogiſton*, and which he conſidered as the principle of fire or combuſtion. It was by the aſſumption of this ſubſtance, that the principal tenets of Chemiſtry were connected.

Stahl was utterly unacquainted with the influence of air on combuſtion; yet on the further progreſs in the knowledge of this influence, and on the intereſting and important diſcoveries of gaſes in general, the former explanation could not but be found inſufficient, to put into mutual agreement all the circumſtances accompanying this phenomenon. It was obſerved, that in the combuſtion of bodies in general, as well as in the calcination of metals in particular, vital air diſappears, and beſides, that it may be re-produced, merely by making calcined mercury red-hot, whereby this laſt is at the ſame time revived in the metallic ſtate. And this diſcovery furniſhed the firſt reaſon to doubt the exiſtence of Phlogiſton, as the principle of fire in combuſtible bodies and metals.

Lavoiſier *, whom I have already named, (VIII.) among the French Chemiſts of the preſent age, was the author of this great and total revolution, in the method of explanation till lately adopted in Chemiſtry, and founded on the *hypotheſis* of phlogiſton. He has eſtabliſhed a new ſyſtem, which, as it denies the exiſtence of phlogiſton, is called the *Antiphlogiſtic Syſtem*; and which in combuſtion does not place the principle of fire in the combuſtible body itſelf, but in the vital air, which is a neceſſary requiſite to combuſtion, which itſelf is thereby decompoſed, and whoſe latent fire is diſengaged, while the combuſtible ſubſtance abſorbs its baſis.

However, what in the records of Chemiſtry will give immortality to *Lavoiſier*'s name, is not ſo much this *Antiphlogiſticiſm* or rejection of phlogiſton, as the diſcovery of facts of the utmoſt importance, whereupon his ſyſtem is eſtabliſhed; or whoſe diſcovery it occaſioned.—The *Sectariſm*, from which it aroſe, muſt be uſeful to the ſcience, keep the ſpirit of inquiry more alive, and lead to a ſeverer ſcrutiny of the concluſions drawn from experiments.

Yet

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* The hiſtory of ſcience, on recording his too early death, will never fail to ſtigmatize thoſe revolutionary murderers, who cauſed the head of this innocent man to drop, on the 7th of May, 1794, under the axe of the guillotine.

Yet whoſoever examines the whole, impartially and without predilection, will find that on adopting the antiphlogiſtic ſyſtem, there ſtill remain chaſms in the explanation of many phenomena, and eſpecially with regard to the extrication of *light*, (in combuſtion as well as without), its fixation, its developement, and its changes. It is quite in vain to deduce light from a modification of caloric.—This expreſſion, if it does not involve a modifying cauſe, means nothing at all. But if it be neceſſary to admit ſuch a cauſe, modifying the caloric ſo as to become light; and, if it may be allowed to call this cauſe *phlogiſton*, it is eaſy to conceive, firſt that it is poſſible to reconcile the antiphlogiſtic ſyſtem with the adoption of phlogiſton, and then that the latter becomes even neceſſary, in order to explain ſatisfactorily *all* the circumſtances of its various phenomena.

In the ſequel I ſhall explain the fundamental principles of this united ſyſtem, which might be called *Eclectic*, as well as thoſe of the ſtrictly *antiphlogiſtic* ſyſtem.

X.

As a practical ſcience, Chemiſtry is founded on obſervations and experiments. On this account, its method of inſtruction, to be uſeful, ought not to be merely ſpeculative, but muſt likewiſe offer knowledge in matters of fact.—I ſhall endeavour to diſplay the principles of Chemiſtry taken in its full extent, to deliver them in a coherent order, and to blend the theory with the experiments, whereon it reſts, or by which it is confirmed.

CHEMISTRY.

CHAPTER I.

Preliminary Matters.

Elements of Bodies.

§ 1.

Experience teaches, that ſuch natural bodies as are the objects of our ſenſations, are compoſed of divers *heterogeneous* parts, or of different kinds in various proportions, and this even when they appear to be an *homogeneous* total, or of the ſame kind.

§ 2.

To ſeparate theſe heterogeneous ſimple parts of bodies, or to combine them again in a different way, and to learn what may be their mutual actions into, and their proportions to one another in theſe combinations, is the purpoſe of Chemiſtry.

§ 3.

This *chemical ſeparation* of the *heterogeneous parts (partes diſſimilares)* of compound or mixed bodies, we diſtinguiſh from the *mechanical ſeparation* of their *homogeneous parts (partes ſimilares).* The homogeneous parts reſemble the whole, from which they are derived, and differ from it merely as to magnitude, but not as to their nature. They are likewiſe called *original*, or *primitive maſſes (molecules)*, and by ſome, *integrant parts*. The heterogeneous parts, on the contrary, are different in their properties, as well from one another, as from the total, whoſe parts they are; yet in a proper combination, and in due proportions, they produce a whole, which to us appears to be homogeneous. In this reſpect they are called *principles*, *conſtituent parts (partes conſtituentes)*; *(particules* by the French), and alſo *radicals*, if they be not themſelves a compound.

Illuſtration of this, by the examples of *atmoſpheric air*, *glaſs*, *cinnabar*, *water*.

§ 4.

If heterogeneous parts are combined in ſuch a manner, that the whole preſents itſelf even as to its minuteſt parts in the ſhape of an homogeneous body, or that in the compound they cannot be diſtinguiſhed from each other by our ſenſes, the body which they thus form is called *mixed*, or *chemically combined*. If the reverſe be the caſe, that is to ſay, if the body be made up by a mere appoſition of diſtinguiſhable parts, it is called a *mingled maſs*, or *mechanically united*.—This diſtinction ought to be carefully remembered.

Inſtances of *mingled bodies*. The *granite*, *porpyhry*, *blood*, *wheaten flour*.

Some-

Sometimes the parts of a mingled body are not diſtinguiſhable from each other by the naked eye, and ſuch would be apt to be miſtaken for a *mixed body*, did not other circumſtances ſhew the contrary.

§ 5.

Heterogeneous ſubſtances, when merely *mingled*, or made up by mere appoſition of parts, preſerve their former nature and qualities: on the contrary, if they be *mixed*, they then conſtitute a body with properties totally different from thoſe of its conſtituent parts.

Examples: A *mingled maſs* of ſulphur and calx of arſenic, and their *mixture*, or yellow arſenic, which laſt is a chemical compound produced by ſublimation.—A *mingled maſs* of mineral alkali and ſiliceous ſand, and their *mixture*, or chemical combination, glaſs.

Experiment: Blend or mingle accurately together, two parts of fine white quartz-ſand with three parts of mineral alkali, that has loſt its water of cryſtallization. The mingled parts will ſtill exhibit their former nature unchanged.—Melt them with the aſſiſtance of the blow-pipe into a clear tranſparent glaſs; the mineral alkali will no longer ſhew in this compound its taſte nor its ſolubility in water.

§ 6.

The combination of *heterogeneous* parts, ſo as to conſtitute an homogeneous total, is called a *chemical combination*, or ſimply *mixture*, *compoſition (ſyntheſis)*; and the ſeparation of ſuch parts is called *decompoſition (analyſis)*. But if *homogeneous*

parts

parts are only added together, the proceſs is called *mechanical combination*, or ſimply *aggregation*, and the product has the name of *aggregate*; *vice verſa*, if homogeneous parts are mechanically removed from each other, the term *ſeparation*, or alſo *diviſion* of the body is made uſe of. Theſe two laſt operations do not produce a new body, but a body of an augmented or diminiſhed maſs; ſince then only integrant parts (§ 3) are joined, or ſeparated.

§ 7.

If the conſtituent parts, obtained from a *mixed*, or from a *mingled* body (§ 4) are ſtill a compound, and did as ſuch pre-exiſt in the body, and are not altered by the ſeparation, they go by the name of *proximate conſtituent parts (partes proximæ)*; and the heterogeneous parts, of which they are compoſed, have obtained the name of remote conſtituent parts *(partes remotæ)* of that body.

Examples. A. Of *Mixed* bodies.

1. Common Pump-water.

- Water.
  - Oxygen.
  - Hydrogen.
- Carbonat of lime.
  - Carbonic Acid.
    - Oxygen.
    - Radical Carbon.
  - Lime.
- Gypſum.
  - Sulphuric Acid.
    - Oxygen.
    - Radical Sulphur.
  - Lime.

2. Brandy.

- Alkohol.
  - Phlogiſton or Radical of light.
  - Hydrogen.
  - Radical Carbon.
  - Oxygen.
- Water.
  - Oxygen.
  - Hydrogen.

B. Of a *Mingled* body.

Granite.

Feldſpar.	Quartz.	Mica.
Silex. Argil.	Silex. Argil.	Argil. Silex. Magneſia.

§ 8.

The firſt original ſubſtances, of which bodies conſiſt, and which are not themſelves compounded of heterogeneous parts, are called *elements, firſt principles, radicals.* Many ſubſtances cannot be farther decompoſed by the chemiſt into conſtituent heterogeneous parts; but this does not entitle us to rank them among the elements. Though they are as yet *undecompoſed*, it does not follow that they are *undecompoſable*; as perhaps neither our ſenſes nor our inſtruments will ever reach thoſe ſubſtances which by their nature admit of no ſort of decompoſition. Of thoſe bodies that are known to us as ſimple ſubſtances, and whoſe number amounts to *forty*, ſome may be ſenſibly exhibited in their ſimple ſtate uncombined with other matters *(oſtenſible, producible, ſimple ſubſtances)*; others may not, and their exiſtence or preſence is only inferred from facts (*unoſtenſible, unproducible ſimple ſubſtances*).

The following is the liſt of *ſimple ſubſtances*, at preſent known:

A. Unproducible Simple Subſtances.

1. *Phlogiſton*, or baſis of light
2. *Oxygen*
3. *Hydrogen*
4. *Azotic*
5. *Carbonic*
6. *Sulphuric*
7. *Phoſphoric*
8. *Muriatic*
9. *Fluoric*
10. *Boracic*

} Radical.

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11. Radical of *Gold*
12. ——— *Platina*
13. ——— *Silver*
14. ——— *Mercury*
15. Radical of *Lead*
16. ——— *Copper*
17. ——— *Iron*
18. ——— *Tin*
19. ——— *Zinc*
20. ——— *Biſmuth*
21. ——— *Antimony*
22. ——— *Nickel*
23. ——— *Cobalt*
24. ——— *Arſenic*
25. ——— *Manganeſe*
26. ——— *Molybdena*
27. ——— *Wolfram*
28. ——— *Uranium*
29. ——— *Titanium.*

B. Producible, Oſtenſible, Simple Subſtances.

30. *Caloric*

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31. *Siliceous*
32. *Calcareous*
33. *Magneſian*
34. *Ponderous*
35. *Strontion*

} Earth.

36. *Argillaceous*
37. *Circon*
38. *Auſtral*

} Earth.

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39. *Vegetable*
40. *Mineral*

} Alkali.

According to Lavoiſier's Syſtem, the liſt is,

Unproducible Simple Subſtances.

1. *Oxygène*
2. *Hydrogène*
3. *Azote*
4. *Radical muriatique*
5. *Radical fluorique*
6. *Radical boracique.*

Producible

Producible Simple Subſtances.

7. *Calorique*
8. *Lumière*
9. *Carbone*
10. *Soufre*
11. *Phoſphore*

12. *Or*
13. *Platine*
14. *Argent*
15. *Mercure*
16. *Plomb*
17. *Cuivre*
18. *Fer*
19. *Etain*
20. *Zinc*
21. *Biſmuth*
22. *Antimoine*
23. *Nickel*
24. *Cobalt*
25. *Arſenic*
26. *Manganèſe*
27. *Molybdène*
28. *Tungstène*
29. *Uranic*
30. *Titan*

31. *Silice*
32. *Chaux*
33. *Magnéſie*
34. *Baryte*
35. *Terre de Strontion*
36. *Alumine*
37. *Terre de Circon*
38. *Terre auſtrale*

39. *Potaſſe*
40. *Soude.*

The difference in theſe two liſts, ariſes from the *Author's* attempt to unite the two ſyſtems (IX. Introd.) by adopting a Phlogiſton, though in a different way from *Stahl* (§ 182, 189.—194).—Alſo, from latter diſcoveries, the *auſtral earth* ſhould be omitted; and among the metals, the *tellurium*, and *chrome* added.——Edit.

§ 9.

The impoſſibility of producing ſome of theſe elementary principles ariſes, no doubt, from their great tendency to unite with other ſubſtances, and from the opportunity to meet with them at every ſeparation; ſo much ſo, that we know them merely by the particular oſtenſible compoſitions which they form. On this circumſtance alſo depends the cauſe why we are able to ſeparate, by art, various compounds, but not to reproduce them.

> *Examples* are furniſhed by *ſpirit of wine*, *wine* itſelf, and a vaſt number of other ſubſtances.

§ 10.

In the decompoſition of one or more bodies, it frequently happens, that ſeveral of their heterogeneous conſtituent parts unite in different proportions from thoſe they had before, and thus generate a new body, which owes its exiſtence merely to the operation that was performed. Such body is called a *product (productum)* in oppoſition to *educt (eductum)*, which pre-exiſted in that body before the decompoſition as ſuch a ſubſtance, and of the very ſame properties with which it is obtained. Hence it follows, that every product muſt be a compound; educts may be ſimple or compound ſubſtances.

> *An Inſtance* in *carbonic acid gas*, that makes its appearance on mixing a ſolution of potaſh with an acid; in *ſpirit of wine*, on the fermentation of ſaccharine juices; in the *empyreumatic oil* at the eliquating of tar from pines, firs, and the like.

Mechanical Diviſion and Separation.

§ 11.

The diviſion of bodies into homogeneous parts, and the ſeparation of mingled heterogeneous parts is properly no object of chemiſtry; it is, however, of great aſſiſtance in the chemical examination of bodies. It is performed by *mechanical means*, as they are called, when by an exterior force the coheſion of parts is overcome, and thus the body reduced to pieces. Various inſtruments are made uſe of for this purpoſe, according as the coheſion of the component parts is different.

§ 12.

To the methods of ſeparating homogeneous parts belong, the *breaking* of hard and brittle bodies by the *hammer*, *pounding* and *pulverization* with the *peſtle* in metallic *mortars*; the *pounding* in *ſtamp-mills*; the *grinding* in mills of various kind; the *trituration* in *triturating-mortars* of agate, glaſs, ſerpentine, with a *peſtle* of the ſame materials; the *levigation* and *preparation* on a *grinding-ſtone*, and a *muller* of ſome hard ſtone; the *ſoftening* of hard and brittle ſtones and glaſſes, by making them firſt *red-hot*, and then *quenching* them in cold water.

As to bodies of a tougher nature of the animal and vegetable kingdom, *cutting*, *planing*, *grating*, *raſping* and *ſtamping*, are means of comminution. As to the ductile metals, the *filing* in a *hand vice*, the *reducing* them to *ſhavings* on the *turner's lathe*, their *lamination* with the hammer on the *anvil*, or by *rollers* and *ſtretching-mills*, and *clipping* the obtained laminas with the *ſhears*, or *graining* and *granulating* like leaden *ſhot*.

Such pieces as are not ſmall enough, are ſeparated from the finer particles by *ſieves* and *ſtrainers*, to be, if neceſſary, farther attenuated. For this purpoſe alſo ſerves the proceſs of *elutriation*, founded on the experience, that heavier bodies ſooner ſink in water, than lighter ones.

§ 13.

Blended parts of extraneous matter, and of different ſpecific gravity, are parted in ſmelting houſes by *ſtamping* and ſubſequent *waſhing*; which operations reſt on the ſame principle as elutriation.

Solid bodies, when intermingled with liquids, and when of a greater ſpecific gravity, ſeparate by reſt; after which the clear liquid may be obtained in a *depurated* ſtate by *decanting*, or may be drawn off by means of a *ſyphon*. Or elſe liquids are *ſtrained (percolare, filtrare)* to ſeparate the ſolid bodies

bodies which are mingled with or diffuſed in them; and to this end ſeveral *filtering inſtruments* are uſed, as layers of *ſtraw* in caſks with perforated bottoms; *conically* twiſted *filtering* or *printing paper*, placed in *funnels* or *filtering-baſkets*; *linen*, and *tent-cloth*, ſtretched on a *frame (tenaculum)*; looſe *hemp*, or *flax*, ſpread over an expanded net.

Quickſilver is cleaned from filth by being ſqueezed through a *bag of ſhammoy-leather*.

What remains in the filtering-inſtruments is farther freed from the ſtill adhering particles of the fluid, by pouring on it a ſuitable liquid, commonly water; and this is called *edulcoration (edulcorare)*; it is alſo called *lixiviation (elixivare)*, if it be intended to make uſe of the filtered fluid.

To *clarify* ſuch liquids as do not admit of being filtered, an ingenious proceſs is employed to ſeparate from them the fine floating particles of extraneous matter. For this purpoſe ſuch ſubſtances are added, as in a cold temperature may be diſſolved in the liquor, but riſe to the ſurface by coagulating at an increaſed heat, as the white of eggs, bullock's-blood, &c. By theſe the impurities are enveloped, and may therefore be *ſkimmed* off together.

Primitive Powers, and the Forms of Matter depending thereon.

§ 14.

The ſeparation of bodies into heterogeneous parts; as well as their compoſition from them, cannot be effected by any outward force, which only deſtroys the accumulation, but not the mixture of bodies.—By the moſt ſubtile comminution of mixed bodies we never obtain their conſtituent, but merely their integrant parts, or original maſſes (*molecules*). Therefore, if we intend to deſtroy the combination of heterogeneous parts, we muſt rather employ thoſe powers which are inherent in corporeal ſubſtances, and by the actions of which they combine among themſelves. This primitive power, inherent in all matter, by which homogeneous and heterogeneous parts mutually attract each other, becomes alſo the means of ſeparating them; becauſe the powers of attraction are of different intenſity in the various original ſubſtances, as will be ſhewn hereafter.

§ 15.

We know, by experience, that in the corporeal world changes take place in the condition of beings: changes with regard to place and motion.

Theſe

Theſe we underſtand by the expreſſions, *natural events, phenomena*; and the efficient cauſes of theſe changes go by the name of *powers.*

§ 16.

On conſidering the ſeveral matters of this viſible world more cloſely, on ſcrutinizing carefully their actions and effects, and on purſuing the phenomena up to their firſt cauſes, we meet at laſt with a ſtop at ſome effects, which it is impoſſible for us to analyſe farther. To account for theſe, we are obliged to aſſume *three primitive powers*, eſſentially different from one another, inherent in the reſpective matters of our ſenſible world; and which, in the preſent ſtate of our knowledge, are regarded as the firſt innate cauſes of all the multifarious phenomena among corporeal beings.

§ 17.

Theſe three primitive cauſes are: *gravitation*, or power of *gravity*; the *power of coheſion*, or *attractive power*; and the *power of expanſion*, or *repulſive power*. They differ eſſentially from each other, and act upon totally different laws on the ſubſtances ſubjected to their influence.

> The *power of gravity* is uſually conſidered as not eſſentially different from the *power of coheſion*; and both are comprehended under the common name of *power of attraction*; yet the proofs of this do not ſeem to me convincing.

§ 18.

The phenomena that are occaſioned by *gravitation*, or the *power of gravity (vis gravitatis)*, are not objects of chemiſtry; they belong to the province of phyſics. But ſince the two other primitive powers afford the means of chemical analyſis and combination, it is neceſſary to be acquainted with their phenomena.

§ 19.

The *power of coheſion, (vis cohæſionis, adhæſionis, attractionis)*, is that force of matter, whereby its parts are connected in ſuch a way, that they reſiſt upon their removal or ſeparation; in other words, that they diminiſh the force employed to effect their ſeparation.

§ 20.

The *power of expanſion (vis expanſiva, repulſionis)*, is that force of matter, by which its parts reſiſt when it is attempted to bring them nearer together, or whereby they ſtrive to ſecede from each other.

§ 21.

Hence, by the coheſive force, the particles of matter are making efforts to approach one another, and by the expanſive force they are ſtruggling to ſeparate from each other. Both theſe forces are conſequently in *direct oppoſition*. If both are equally great, or of equal intenſity, they naturally do not cauſe any motion; that is to ſay, the reſult of their reciprocal actions is—reſt of the parts. It is in this caſe only that the body fills its ſpace with *continuity.*

§ 22.

We have reaſons to ſuppoſe, that the eſſential and ſpecific difference of the principles (§ 3) in this ſenſible univerſe is grounded on the different intenſity of their primitive, innate powers, which cauſes the greater or leſs degree of activity in the various ſpecific original ſubſtances.

Kant's Metaphyſical Elem. of Nat. Philoſophy, p. 100.

§ 23.

On the reciprocal influence of theſe primary powers, and their reſpective intenſity, particularly depends the *form of aggregation* which we obſerve in bodies, wherefore we diſtinguiſh three ſpecies of aggregation: *ſolid bodies*, *liquid fluids*, and *expanſible* or *elaſtic fluid bodies.*

§ 24.

Solid bodies (corpora ſolida), (§ 23) are thoſe which, by the greater intenſity of the coheſive force acting in their primary maſſes, preſent an apparent and conſiderable reſiſtance, when their parts are removed from the ſpaces which they occupy. Yet

Yet the ſtrength of the coheſive power has, even in different ſolid bodies, manifold gradations with regard to the ſurfaces of their original maſſes; and this again gives riſe to particular ſubdiviſions, which, however, are ſo little diſtinguiſhed by fixed lines, that the different ſpecies, which thereby ſhould be determined, rather imperceptibly run into one another.

§ 25.

Thus we diſtinguiſh *hard (corpora dura)* from *ſoft bodies (mollia)*, by the greater or leſs reſiſtance they exert on the ſeparation of their parts. Here we obſerve numberleſs degrees; and we are in abſolute want of a ſcale by which properly to mark their limits. Such ſolid bodies as admit of their parts being conſiderably moved upon one another by an external force, without loſing their coheſion, are *ſupple, tenacious, ductile, malleable (ductilia)*; and, on the contrary, *brittle (fragilia)*, if their parts cannot be diſplaced without being disjoined, or without deſtroying their coheſion. The increaſe of the brittleneſs of bodies attending their increaſe of denſity is, doubtleſs, an evident effect of the repulſive force that now becomes more active.

It is a common, but falſe conception, that by the diſtenſion of tough bodies, for inſtance, the drawing of wire, lamination of metals, &c. the parts are, in general, removed more aſunder. On the contrary, they approach nearer, when by diſtenſion they are moved

moved upon one another, as the increaſe of ſpecific gravity ſhews on the drawing of wire, or laminating of metals. Hence it follows, that the volume or bulk muſt, in this caſe, decreaſe; and that a drachm of gold drawn into wire, or beaten into leaves, takes up leſs room than if caſt in the form of a ball.

§ 26.

Contractility, which is likewiſe called *elaſticity*, is the effect of the power of coheſion; it is an *attractive elaſticity*, and materially different from *expanſive elaſticity*. It is met with only in ſolid bodies; it always pre-ſuppoſes ductility, and manifeſts itſelf only by this, that the parts removed by an outward force ſtruggle to reſume their former propinquity, and do really reſume it, whenever that force gives way.

§ 27.

Fluid bodies (corpora fluida) are thoſe whoſe parts may be moved upon each other by any force, however ſmall. Of theſe there are two ſpecies, eſſentially different, to be diſtinguiſhed: *liquid* and *expanſible fluids*.

§ 28.

Liquid fluids, or ſuch as are capable of dropping *(corpora liquida)*, (§ 23, 27) preſent themſelves to our ſenſes in the form of a coherent aggregate, and aſſume, when in ſmall maſſes, a ſpherical figure; or they form drops, as often as the mutual attraction of their parts is not diſturbed by other bodies. They undoubtedly poſſeſs a certain degree of compreſſibility, and manifeſt, when compreſſed, expanſive elaſticity.

§ 29.

Expanſible, or ſtrictly elaſtic fluids (fluida elaſtica expanſibilia), ſhew no coheſion of parts obſervable by our ſenſes; or the attractive power of their parts is deſtroyed by their repulſive power, poſſeſſed of a ſtronger activity. On account of this ſuperior expanſive force, they muſt neceſſarily ſpread out on all ſides without bounds, if the gravi of ſome parts, or the ſuperior attraction of extraneous ſubſtances for them, does not prevent it, and ſet limits to their expanſion.

§ 30.

Theſe expanſible fluids (§ 29) I ſubdivide again in a double point of view: firſt, into *pure expanſible*, and *ponderous expanſible*; and then into fluids *expanſible by their own nature*, and *expanſible* by *communication* or *derivation*. In the firſt, the motion of their parts is actuated by no other force than the expanſive power, either original or derivative; and they expand from the place where the repelling force begins to be active, in all directions, with equal facility; and it is only the counteracting force of attraction in other primary ſub-

ſubſtances, that is able to ſet limits to their expanding infinitely. Theſe pure elaſtic fluids are alſo ſtyled *radiant.* Fluids, elaſtic by themſelves, poſſeſs originally their expanſive elaſticity, ſuch as caloric; at leaſt we know, as to the latter, no ſubſtance, and our ſenſes offer us none, wherefrom we could derive its power of expanſion.

Though, in order to facilitate the geometrical repreſentation of the ideas that occur on explaining the phenomena preſented by pure expanſible fluids, it is allowable to repreſent their propagation in the manner of rays; *viz.* to imagine the propagation of their ſmall ſpherical particles in ſtraight lines; yet there is nothing that can prove the reality of this *atomiſtical* manner of repreſenting. Like all other bodies, they rather fill their ſpace, even on greateſt rarefaction, with continuity; and the appellation of greater rarity, is but an expreſſion to ſignify their weaker expanſive or repulſive force, which decreaſes in the ratio, as the ſquare of the diſtances from the place where their activity begins, increaſes. I therefore no longer admit *diſcrete* fluids, as they are termed.

§ 31.

The *ponderous expanſible fluids* (§ 30) the different kinds of air, for inſtance, poſſeſs all a derivative expanſive elaſticity. It will be proved, in the ſequel, that every one of them conſiſts of a *ponderable baſis*, which is not expanſible of itſelf; but ſuch as, by the reciprocal action of its own attracting and repelling forces, would have the aggregation of ſolidity: and beſides, of a *ſubſtance expanſive by its own nature*, the caloric, by the ſuperior expanſive power of which, the original attractive forces of the baſis muſt neceſſarily diſappear. The gravity of their parts prevents them from expanding in the manner of pure elaſtic fluids.

§ 32.

The ponderous elaſtic fluids (§ 30, 31) may be farther ſubdivided into *aeriform*, or *gaſeous (fluida aeriformia—fluides gazeux)*, and into *vaporous*, or *vapours (vapores)*. The former preſerve their elaſtic form on whatever compreſſion we are able to employ, and at any degree of cold that we are acquainted with; the elaſticity of which they were poſſeſſed, is therefore, under theſe circumſtances, permanent; and their combination (§ 31) is not deſtroyed by mechanical compreſſion. The latter, on the contrary, *viz.* the vaporous fluids, loſe their form of elaſtic aggregation in both ways, by compreſſion and by cold; the innate attractive powers of the parts of their baſis will again predominate; and theſe parts, receding from the caloric, unite to form either ſolid or liquid bodies.

§ 33.

The liquid-fluid bodies, known to us, are not indebted for this form of aggregation to their original innate powers; by theſe they would, without exception, rather be ſolid bodies. Their liquidity is communicated, and it is an effect of the influence exerted by the expanſive caloric, as hereafter will be proved more fully by experiments. Hence caloric has, by its expanſive force, a ſhare in producing the form of all ponderous expanſible, and of all liquid bodies.

> Thus water is, under o *Reaum*, a *ſolid body (ice)*; above o till 80° at the common preſſure of the atmoſphere, a *liquid* (properly *water)*; at 80°, and above, again at the ſame common preſſure of the atmoſphere, an *elaſtic fluid, (aqueous vapour, ſteam)*.

§ 34.

A great many liquid bodies would, in the uſual degree of heat which we live in, not at all appear in that form of liquidity, were it not for the preſſure of the atmoſphere, by which the original attractive forces of the particles are aſſiſted. We certainly ſhould not even know them as ſuch; but by the expanſive power of the caloric combined with them, unleſs overbalanced by that preſſure, they would be transformed into expanſible fluids.

> Without the preſſure of the atmoſphere, water would, directly at the point of thawing, aſſume the form of elaſtic fluidity, and in no way acquire the intermediate ſtate of liquidity.

> *Experiment* to prove this aſſertion by means of *ether*, vide *Lavoiſier Traité Elem.* Tom. I. page 9 & ſeq.

§ 35.

One remarkable phenomenon relative to the power of attraction inherent in matter, is the determined *figure* aſſumed by its parts, if that force can act upon them freely and unimpeded. Concerning liquid bodies, it is the *formation of drops*, and concerning ſolid bodies, it is the *cryſtallization* or *texture*, which in this view deſerve our cloſer conſideration.

§ 36.

All liquid bodies aſſume, as we have already remarked (§ 28) when in ſmall maſſes, a ſpherical figure, and form *drops*, provided they do not unite ſo much with ſome other body as to ſpread upon it. Thus, finely divided quickſilver forms globules on wood, on glaſs, on ſtone, and ſimilar matters. The ſame holds good as to water and wine on wood, glaſs, paper ſprinkled with the ſeed of the common *club-moſs (lycopoduim clavatum)*; and all liquid bodies aſſume the ſpherical figure, when falling in ſmall maſſes through the air, with which they do not cohere. A mere inert fluid maſs would, in any caſe, retain the figure it once poſſeſſed, and not form drops. If it be not at firſt ſhaped in this figure, it will never be endowed with a globular form, unleſs a motion of its parts takes place.

Thus the very formation of drops demonſtrates, that there muſt exiſt a cauſe which produces that effect.

This

This cauſe cannot be gravity, for this, agreeably to experience, is rather an obſtacle to the forming of drops; ſince, by the weight of the particles, larger drops reſting on ſolid bodies are flattened, and the regular ſpherical form prevented. The ſmaller the drops are, and the leſs their weight is, the more perfect is the ſphere which they form.

To explain this phenomenon in a ſatisfactory way, there remains only the power of attraction between the particles of the liquid body; *viz.* if it is ſuppoſed that the elementary particles of a corporeal ſubſtance reciprocally attract each other with equal force, and that their aptitude for being moved upon one another be great enough to put no impediment to their motion, it follows, by the true principles of mechanics, that the equilibrium of the attractive forces can only take place when the maſs has received a globular ſhape.

§ 37.

The parts of *ſolid bodies* likewiſe aſſume a determined form, and compoſe groups of a peculiar figure, when ſuffered to follow, unimpeded and freely, that motion which, by the power of attraction, is produced among them in determined directions. But here this remarkable circumſtance interferes, that the particles do not attract each other in all directions with equal force; and hence ſmaller groups already formed, as alſo primitive figures with certain ſurfaces, exert a ſtronger attraction than others; thus forming polyedral ſolids, which are called *cryſtals.*

§ 38.

In order that ſolid bodies may form cryſtals of determined and regular figures, or, in other words, that they may regularly *cryſtallize*, it is required, 1ſt. that they be brought into the ſtate of fluidity, in order that their parts may acquire, in a high degree, the capacity of being moved one over the other; and, 2d. that they do again congeal gradually, and without being diſturbed; or, what is the ſame, do gradually paſs from the ſtate of fluidity to that of ſolidity, during which tranſition their parts join together in determined directions, and form in that manner bodies, if not always of certain fixed outlines, at leaſt of a determined texture.

Under theſe conditions it may indeed be ſaid of all ſolid bodies, that they aſſume a peculiar decided figure, or that they cryſtallize: and nature ſhews us this determined form and texture in numberleſs ſolid bodies of the mineral kingdom, and in endleſs varieties, in ſtones, ſalts, metals, ſulphur, and congealed water; ſo much ſo, that the very formation of organic parts may be derived from ſimilar cauſes.

If many foſſil bodies do not appear in ſuch regular form and determined texture, we may nevertheleſs, from their being met with elſewhere, conclude, that on their concretion, only thoſe conditions were wanting on which this phenomenon depends. Art, it muſt be admitted, cannot imitate nature in the configuration of many bodies, as it does not poſſeſs the means of bringing many ſubſtances into the requiſite ſtate of fluidity.

Examples: In the cryſtallization of *ſaltpetre, Glauber's* and other *ſalts.*

Cryſtallization of various ſalts in ſingle drops, that may afterwards be viewed by a microſcope.

The *ſilver-tree,* or *arbor Dianæ*—the *lead-tree*—the *tin-tree.*

§ 39.

The firſt condition neceſſary to the formation of cryſtals (§ 38) mobility, and capacity of being eaſily diſplaced, is procured, with reſpect to ſolid bodies, by fuſion, or by ſolution in a liquid, or by transformation into vapours; or alſo, laſtly, by a very ſubtile diviſion in a fluid medium.

The ſecond condition, the removing of what has cauſed the fluidity, in other words, the concretion is effected either by refrigeration or congelation, or by evaporation of the menſtruum, or by precipitation, or by repoſe and ſubſidence. Yet here the attraction of the coagulating particles muſt by no means be diſturbed or hindered by any kind of motion, ſuch as ſtirring, ſhaking, &c. If the tranſition from liquidity to ſolidity be too ſudden, the particles then have not ſufficient time to unite, as ſuits the attraction of their ſurfaces, and the form becomes irregular.

> *Examples:* In the formation of cryſtalline ſolid bodies, by paſſing from the fluid to the ſolid ſtate; 1ſt. (after preceding liquefaction by cooling) *ſnow, ice, ſulphur, antimony, biſmuth*; 2d. (after preceding ſolution, by evaporating the ſolvent medium, or by its frigefaction) the numerous *ſalt-cryſtals, realgar,* (by precipitation) the *metallic tree-like cryſtallizations*; 3d. (after preceding converſion into vapour) the *cryſtalline ſublimates,* and, as they are called, *chemical flowers*; and, 4th. (after preceding fine diviſion in a fluid) the *ſtalactites,* or drop-ſtones.

§ 40.

A vaſt multitude of larger cryſtals may be mechanically divided into ſmaller ones, which then, with regard to figure, may, or may not, reſemble the greater. The firſt is the caſe, when the ſeparation of the larger cryſtal can be made in a direction parallel to all its ſurfaces; otherwiſe they have no reſemblance to it, or the *primitive form* is different from the *ſecondary.* Abbé Hauy has, in many foſſils, inveſtigated this ſubject with great accuracy; and has, from the accumulation of certain primi-

primitive forms, according to ſome fixed laws, very ſucceſsfully illuſtrated the manner in which larger cryſtals are formed out of ſecondary figures.

According to Hauy, all the primitive forms of cryſtals, hitherto diſcovered, may be reduced to ſix, namely: the *parallelopipedon*; to which belong the cube, the rhomboid, and all ſolids terminated by ſix ſides, of which two are always parallel; the *regular tetrahedron*; the regular *octahedron*; the *ſix-ſided column*; the *dodecahedron*, with equal and *ſimilar trapeziums*; and the *dodecahedron, with iſoſcelic-triangular ſurfaces.*

The editor would not forego the uſe of language adopted by chemiſts and mineralogiſts; he hopes, therefore, not to be blamed, if, in deſcribing cryſtals, he frequently uſes the term *column*, where rather that of *parallelopipedon*, or *priſm*, ſhould be employed.

§ 41.

Not only the parts of certain bodies cohere together, but likewiſe entire and different bodies, placed in contact; and this coheſion is, among bodies of the ſame kind, the ſtronger, in proportion to the cloſeneſs and number of points which touch one another: ſo likewiſe do bodies of different kinds cohere among themſelves. However, the ſtrength of coheſion between various heterogeneous bodies is very different, notwithſtanding that the dimenſions of the ſurfaces placed in contact may be the ſame.

Two poliſhed braſs or glaſs plates cohere together; but they cohere ſtill more if they be moiſtened with water, or greaſed.

Experi-

Experiments towards determining the ſtrength of coheſion of metallic or glaſs plates with water and quickſilver.

Guyton de Morveau had round plates, of equal ſize and figure, made of various metals. They were of one inch in diameter; and he aſcertained the force with which they adhered to quickſilver, upon the ſurface of which they were ſuſpended. The plate of

Gold adhered with a force of	446 grains.
Silver	429 —
Tin	418 —
Lead	397 —
Biſmuth	372 —
Zinc	204 —
Copper	142 —
Antimony	126 —
Iron	115 —
Cobalt	8 —

It is upon this coheſion of heterogeneous ſubſtances, in cloſe contact, that *glueing*, *cements*, *mortar*, *ſoldering*, *tinning*, *ſilvering*, and *gilding*, are founded.

§ 42.

If the particles of a fluid mutually attract each other leſs ſtrongly than they are attracted by a ſolid body, they will, when in contact, ſtick to the latter, and make it *wet*, or diffuſe themſelves upon it; but, if the contrary take place, they will form ſmall globules or drops.

Upon this greater or leſs ſtrength of coheſion, which the particles of a fluid have among themſelves, in oppoſition to their coherence with any ſolid body, depends

pends the concave or convex ſurface of the fluid in a veſſel, its flowing or not flowing down the ſide of a veſſel, on being poured out from it, when quite filled, and its brim not turned downwards; and other ſuch incidents, as that of glaſs globules ſwimming upon a fluid, and being ſeemingly repelled from, or drawn towards the edge of the veſſel.

The phenomenon of the *capillary tubes* belongs to this place.

§ 43.

As the different heterogeneous bodies do not cohere together with equal force, ſo do likewiſe the different heterogeneous primary ſubſtances and conſtituent parts of bodies ſhew an unequal ſtrength of attraction for each other. We are taught by experience, that two ſubſtances of different kinds, which are combined and united into an homogeneous whole, may be ſeparated, if a third ſubſtance be added, towards which either of the two exerts a ſtronger attraction than it had to its former aſſociate.

Experiments: To a ſolution of chalk in nitric acid add a ſolution of pot-aſh; the chalk will re-aſſume its original form.

Into a ſolution of gold pour ſome naptha; ſhake the whole well, and let it again remain at reſt: the naptha will then deprive the ſolution of all the gold.

Cauſe *quickſilver*, diſſolved in nitric acid, to re-appear by the addition of *braſs* or *copper*, or *copper* diſſolved in ſulphuric acid, by the addition of iron.

§ 44.

§ 44.

Let us then ſuppoſe, that to a body, compoſed of two heterogeneous conſtituent parts, A and B, a third ſubſtance C be added, and that A has a ſtronger attraction to C than it has to B, with which it was before combined; in this caſe A and C will naturally unite. If, now, the combination A C has no longer any attraction to B, this latter will of courſe be excluded from it. Here, therefore, a chemical ſeparation and compoſition takes place; and it appears from this, that the attractive and repulſive powers inherent in matter, are means to produce chemical ſeparations and compoſitions, which by mechanical means cannot be effected.

Chemical Affinities.

§ 45.

In chemiſtry, the action of that power which is naturally inherent in heterogeneous ſubſtances, and by virtue of which they unite together in various degrees of intenſity, goes by the name of *chemical affinity*, or *elective attraction*; and that ſubſtance is ſuppoſed to poſſeſs a *nearer* or greater affinity with another, which is more ſtrongly attracted by it, than to a third which is leſs.

§ 46.

§ 46.

On a review of the various phenomena which obtain, when ſubſtances of different kinds are combined or ſeparated, we cannot help diſtinguiſhing ſeveral ſpecies of affinities, all which may be brought under *three heads:*

1. The *affinity of compoſition*, or mixing affinity *(affinitas ſynthetica)*, whereby two or more heterogeneous ſubſtances unite, to conſtitute a new and thoroughly homogeneous whole.

Examples: *Water* and *Salt.*
Alkohol and *Reſin.*
Sulphuric Acid and *Argil.*
Nitric Acid and *Potaſh.*
Silver and *Sulphur.*
Silver and *Gold.*
Silver, Gold and *Copper,* &c.

§ 47.

To this firſt ſpecies belongs the *appropriation (intermediate affinity)*, when two ſubſtances of different kinds, that ſhew to one another no component affinity, do, by the aſſiſtance of a third, and together with this laſt, combine and unite into an homogeneous whole. The *preparing affinity*, ſo called by ſome, is as little to be conſidered as a ſeparate ſpecies, as the appropriating affinity.

Examples of appropriation.
Fat Oil, Water, Alkali.
Sulphur, Water, Alkali.

§ 48.

2. The *ſimple affinity (affinitas electiva ſimplex, analytica cum ſyntheſi ſimplici)* takes place, when two heterogeneous ſubſtances, united to one homogeneous total, are parted by adding a third, which more forcibly attracts either of the two united than they do each other, and the one is by this proceſs ſeparated from the other.

Examples. 1.

Preceding compoſition.

Reſin *Alkohol*
Water } new compoſition.

2.

Preceding compoſition.
(*Alum*)

Argil *Sulphuric Acid*
Vegetable Alkali } new compoſition.

3.

Preceding compoſition.
(*Soap*)

Fat oil *Mineral alkali*
Sulphuric acid } new compoſition.
(Glauber's ſalt.)

§ 49.

Hitherto it has in vain been attempted to find out a general law by which theſe affinities act; for there has not yet been collected a ſufficient number

ber of facts to diſcover that law. Yet towards a general view of the experiments belonging to this ſubject, we are greatly aſſiſted by the *Tables of ſimple affinities*, where the various ſubſtances are arranged in ſucceſſion, according to the greater or leſs elective attraction which each of them has for any particular ſubſtance.

> Theſe *graduated arrangements* of the ſimple affinities may be ſeen in the tables added to the end of the ſecond volume.

§ 50.

3. The third ſpecies is the *double affinity*, whereby not one only, but more new combinations are cauſed, or by which two combined ſubſtances are ſeparated on the addition of two others (no matter whether combined or uncombined) by virtue of their reſpective attractions; and whence, conſequently, two new combinations ariſe, though at times only one ſeparation takes place. This double affinity often cauſes a decompoſition, which the ſimple affinity is unable to effect.

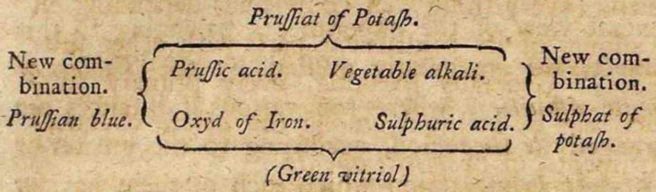
Examples. 1.

Former combination.
(Salt of Glauber)

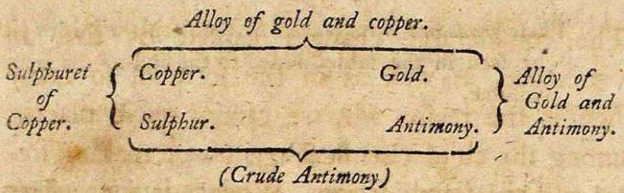
New combination. *Gypſum.*	*Sulphuric acid.*	*Mineral alkali.*	New combination. *Common ſalt.*
	Calcareous earth.	*Muriatic acid.*	

Former combination.
(Muriated lime)

2.



3.



§ 51.

Every chemical decompoſition is performed by the aſſiſtance of affinities, and two ſubſtances united into one homogeneous compound, can never be ſeparated, unleſs one of them undergoes a new combination.

Chemical Operations and Inſtruments.

§ 52.

By *chemical operations* or *proceſſes*, we mean the application of proper means to effect a decompoſition or compoſition. Every one of them is grounded on the various degrees of affinities of heterogeneous ſubſtances amongſt each other, without even excepting the application of fire, whoſe influence is

likewiſe

likewiſe (every thing well conſidered) depending on the affinity of its conſtituent parts with other ſubſtances. Generally ſpeaking, every primary ſubſtance may be counted among the *active* chemical inſtruments, or *chemical agents*.

§ 53.

The conſiderable changes cauſed by fire, in the mixture, as well as in the form of ſo many bodies, is the reaſon why we cannot avoid placing it among the chief chemical agents, or making frequent uſe of its application. Whence it is neceſſary to learn in this place the means of properly maintaining and managing fire; both of which are required, to attain the purpoſes on account of which fire is applied.

§ 54.

Wood is, on account of its ſmoke and unequal heat, in few caſes only made uſe of as a fuel, or means of producing fire. *Charcoal* gives the moſt uniform and beſt manageable heat, and is moſt commonly employed. *Pit-coal* affords, indeed, when aſſiſted by a ſufficient and ſtrong current of air, a more intenſe heat than *charcoal*, yet it is in many caſes inferior to the latter, as to convenience of application. To obtain a gentle, ſteady degree of heat, the *fire of a lamp*, maintained by ſpirit of wine, may ſerve when *Argand's lamp* cannot be uſed.

§ 55.

In order to apply fire, to manage and to direct it where it is to act, *furnaces* are convenient, and they are the moſt neceſſary and indiſpenſable inſtruments to chemiſts. The materials of which they are conſtructed ought to be ſufficiently proof againſt that degree of heat, which they are intended to be expoſed to. Commonly they are built of bricks made of ſand and clay, or of caſt-iron, or of iron plates, which, the better to be defended againſt the fire, are *coated* (in the inſide) to the thickneſs of an inch, with Windſor loam. According to *Lewis* *, various kinds of fire-proof furnaces, for ſmall experiments, may be prepared from black-lead crucibles.

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* The contrivance is indeed very excellent; as they ſerve all the purpoſes of philoſophical enquiries. *Lewis* has given a detailed deſcription of them, and plain delineations, in his *Philoſophical Commerce of Arts*, 4to. London, 1763, page 1—137, which it is worth the Reader's while to conſult.—Excellent *portable furnaces of black lead* are alſo manufactured at Meſſrs. *Pugh* and *Speck*'s, Spital-fields, London, and ſold at Meſſrs. *Moſer* and *Jackſon's*, Frith-ſtreet, Soho.—Ed.

Guyton de Morveau has likewiſe very ſucceſsfully employed *Argand's lamps* for chemical operations, as an *œconomical laboratory*. The paper relating to it is inſerted in *Nicholſon's Chemical Journal*, Vol. II. page 209.—*Frederic Smith*, tin-man, of Gerrard-ſtreet, Soho, has accommodated this apparatus for the ſtudent at a moderate price.—Ed.

§ 56.

The burning of the fuel is kept up in the furnace either by a natural current of air, which is cauſed by the fire itſelf, and ſuch a furnace is called a *wind-furnace (furnus anemius)*; or it is done by compreſſed air, conveyed to the furnace, as in *blaſt-furnaces*.

§ 57.

Every wind-furnace (§ 56) * conſiſts of two eſſential parts: the *fire-place, hearth (focus)*, or that where the material deſtined for the fuel is placed; and the *aſh-pit (cinerarium)* that receives the aſhes of the conſumed fuel, admits the air through its aperture *(aſh-hole)*, and is ſeparated from the hearth by the *grate (craticula)*.

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* Plate I. Fig. 1.

§ 58.

If the bodies to be examined be not immediately placed upon the fire, but either on iron bars, or in veſſels to be heated by the fire, then a third ſpace, the *laboratory (ergaſtulum)*, is formed in the wind-furnace. If by the laboratory the fire-place is thoroughly cloſed, it muſt be provided with ſome *vent-holes*, or *regiſters (ſpiracula)*, to allow acceſs of air.

§ 59.

Such wind-furnaces as are cloſed by a *vaulted cover (cap, dome,* or *cupola)* and have, either at top or on the ſide, a narrow *vent-pipe,* or *chimney (caminus),* are called *reverberatory furnaces, cuppelling furnaces (furni reverberii)* *. Sometimes the fire-place is a part of a ſeparate furnace, from which, however, by the draught of air, the flame of the fuel is forced over, ſtriking upon the hearth of the cuppelling-furnace, which then is to be conſidered as the laboratory.

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* Plate II. Fig. 1 and 2.

§ 60.

The natural current of air, in wind-furnaces, ariſes from the increaſed elaſticity of that portion of air which is contained in the upper cavity of the fire-place; it being there heated by the fire, and thereby naturally cauſed to expand. When this air riſes by its increaſed elaſticity, the denſer and colder air below the grate muſt, of courſe, force its way to the hearth, blow the fire, and thus maintain the combuſtion.

§ 61.

The perfection of a wind-furnace conſiſts, 1, in a good current of air; 2, in keeping the heat together, without loſing too great a quantity of it unuſed; and, 3, in the facility with which the heat may be increaſed or weakened. The heat, in wind-furnaces,

furnaces, is increaſed partly by an additional ſupply of fuel, partly by accelerating the draught of air. The laſt is effected by opening the door of the aſh-pit wider, by ſhutting that of the fire-place, by opening the regiſters, and lengthening the chimney by additional vent-pipes, and alſo by applying the action of the bellows.—By diminiſhing the quantity or celerity of the current air; hence, by ſhutting the aſh-hole, the regiſters, and vent-pipes, the heat is diminiſhed, and the action of fire weakened, or thoroughly ſuppreſſed.

§ 62.

Blaſt-furnaces (§ 56) are of a ſimpler conſtruction than wind-furnaces, and their aſh-pit, hearth, and laboratory, are commonly but one and the ſame part. The *blowing* is moſt frequently done by *bellows*, which for ſmall experiments are always made of *leather*, and, to act without interruption, ſhould be *double*. At the ſmelting works, *wooden bellows* are uſed; but theſe being *ſingle*, there are always, at the ſame time, two of them employed, alternately opening and ſhutting. The *cylinder-bellows* are a diſcovery of modern times, and exceed the common by many advantages.—*Water-drums*, as they are called, may likewiſe ſerve for theſe purpoſes.

Of Mr. *Baader's Water-blaſt.*—He has given a deſcription of it, with five plates. Göttingen. 4to. 1794.

Blaſt-furnaces, as uſed in ſmelting-houſes, may be ſeen in *Jar's Voyages Metallurgiques*, 4to. Lyon, 1774. Vol. III. See Tome I. Plate 1. 2. 3. 4. 6.—Ed.

§ 63.

When the veſſels in which bodies are expoſed to the action of heat, are not placed in immediate contact with the fire in the wind-furnace, but receive the required degree of heat by another intermediate body, ſuch apparatus is called a *bath (balneum)*. The proper inſtrument for this purpoſe is the *ſand-furnace (furnus catini)*, or a wind-furnace, whoſe upper aperture is ſhut by the *ſand-pot (catinus)*. * Sand-pots are cylindrical veſſels having an outwardly convex bottom, and made of caſt or ſheet iron, and at times of baked clay. Glaſs veſſels, however, containing bodies that are to be expoſed to heat, are not placed in the pot while empty; but in order that they may be heated uniformly, this laſt is filled with ſome other body, into which the veſſels are lodged. The matter moſt commonly employed in this caſe is dry, finely-ſifted ſand; and the pot filled with it is called *ſand-bath (balneum arenæ)* † Of all baths, the ſand-bath is the moſt convenient, and ſufficient to apply any degree, from gentle warmth to red-heat. Crucibles *(crucible-bath)* placed between coals, are alſo uſed for a ſand-bath, inſtead of ſand-pots.

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* Plate III. Fig, 1. C.

[†] Sometimes, when a low heat is required, the pot is filled with wood-aſhes; as *vice verſa* the heat may be increaſed by mixing the ſand with iron filings, or employing ſimply theſe latter.—Edit.

§ 64.

If veſſels be heated by means of hot water, in which they are immerſed, it is called a *water-bath (balneum mariæ)*[*]; but if they be heated merely by the ſteam of boiling water, it is called *vapour-bath.* Since water, boiling in the open air, is capable of receiving only a determinate degree of heat, it becomes thereby a ſure means to impart heat, without danger of exceeding a certain degree.

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[*] For this purpoſe the ſand-pot, or any other veſſel filled with water, may be uſed; even the common ſtill, by ſinking into its body holding water, another veſſel that contains the ſubſtance to be heated.—The water-bath, therefore, requires no particular furnace, or apparatus. (Plate V. Fig. 1. G).—Edit.

They alſo formerly diſtinguiſhed four degrees of heat.—That of *evaporation* and *digeſtion* ending at 90° Farenheit; that of *diſtillation* and *boiling* fixed at 212°; that of *ſublimation* at 600°; that of *melting* and *vitrification* at 1600°.—However, there is no certain dependance upon theſe; mercury and fat oils require a greater heat to boil than water; lead fuſes at the 540th degree; ether and ammoniac riſe by a very gentle heat.—Edit.

§ 65.

Of the various means that ſerve for chemical inquiry into the nature of bodies, and which are all founded on the affinities and the action of fire, we ſhall now conſider the proceſſes of *ſolution*, *precipitation*, *fuſion*, *volatilization*, *diſtillation*, and *ſublimation*, as on theſe the chief operations in Chemiſtry depend.

Solution.

§ 66.

If any ſubſtance unite with another of a different kind, or heterogeneous, in ſuch a manner as to make with it a maſs entirely homogeneous, in which we are no longer able to diſtinguiſh the parts of the one ſubſtance from thoſe of the other, we call it *ſolution.*

§ 67.

Of the two ſubſtances, that which ſeems, by its fluidity or quantity, to be the moſt active, and to take up the other between its ſuppoſed interſtices, is called the *ſolvent medium* *(ſolvens* or *menſtruum)* and the other, which, in this caſe, appears to be rather in a paſſive ſtate, is called *ſolvend*, or the *body to be diſſolved (ſolvendum).* This diſtinction, however, is not ſupported by truth; on the contrary,

contrary, both matters are really active. It may nevertheleſs be kept for convenience of language.

§ 68.

In any ſolution, not only the coheſion by which the parts of the ſolvend (§ 67) were united is deſtroyed, but this laſt is ſo united with the menſtruum, as to make up together a perfectly homogeneous body; in which, though aſſiſted by the beſt microſcopes, we cannot diſtinguiſh the heterogeneous parts from each other. For this reaſon, among the parts of the ſpecifically different matters, diſſolving each other, there muſt neceſſarily ſubſiſt a reciprocal attraction, which is ſtronger than the attraction between their reſpective homogeneous parts. In other words, the affinity of the ſaid parts muſt act in a ſtronger way than their reſpective coheſion.

§ 69.

" In order that a mutual ſolution of ſubſtances, ſpecifically different, be perfect, it is required, that in it no part of the one ſubſtance be found which is not alſo united with a part of the other, in the ſame proportion which thoſe ſubſtances had to each other before the ſolution.

" On the other hand, it is evident, that as long as the parts of any ſubſtance continue to be heterogeneous aggregates (§ 3), though in a divided ſtate, a ſolution of them is as impoſſible as that of larger maſſes,

maſſes. It is likewiſe obvious, that, ſuppoſing the ſolvent power of the menſtruum to remain; the ſolution muſt go on, till every part is compoſed of the ſolvent as well as of the ſolvend, in the ſame proportion in which they were added to each other.

" Since, therefore, in this caſe, there can exiſt no part of the *volume*, or ſpace taken up by the ſolution, which does not contain a part of the *menſtruum*; the latter muſt entirely fill the ſpace as a *continuum*, or what means the ſame, no interſtices can be left between its parts. Thus alſo, becauſe there cannot exiſt any part of the volume of the ſolution which does not alſo contain a proportional part of the *diſſolved matter*, the ſolution itſelf muſt fill with *continuity*, that is to ſay, without interſtices, all the ſpace occupied by the mixture.

" But if two ſubſtances occupy the ſame individual ſpace, in ſuch a manner that each of them fills it entirely, they then penetrate each other.— Hence a perfect chemical ſolution is a penetration of matter; which, no doubt, implies a *diviſion in infinitum*. That we cannot comprehend this laſt, is owing to the impoſſibility, we lie under, of comprehending the endleſs diviſibility of a continuum, of whatever kind it be."

Kant's Metaph. Elem. of Nat. Philoſ. page 95 *ſeq.*

It is, however, ſtrange, that *Kant*, from whom the Author has tranſcribed this paſſage, could, by ſuch reaſoning, attempt

attempt to revive the obliterated doctrine of the *continuity of matter*, and the *diviſibility of bodies in infinitum.* The abſurdity is too glaring to need refutation.—Beſides, that doctrine has nothing to do with chemiſtry; at moſt, it might have ſerved among the antient *Scholaſtics* as a diſputation exerciſe for their pupils. The obſcurity of the above paſſage could not be remedied by the tranſlation; it is congenial to all writings of Kant, whoſe fame more depends on abſtruſeneſs than real philoſophical merit —Edit.

§ 70.

By the principles of that *ſyſtem* of natural philoſophy which is called *Atomiſtical*, no ſolution would be poſſible. What is called ſolution would be nothing elſe than a placing together of the ſmall heterogeneous particles. Only *mingled* bodies, not *mixed* (§ 5) could by that theory exiſt.

§ 71.

The volume of two bodies that have mutually diſſolved each other, is commonly ſmaller than the ſum of their volumes before ſolution. It rarely happens, that the new mixture or compound fills a larger ſpace than was occupied, before ſolution, by the heterogeneous ſubſtances.—Both theſe circumſtances prove that modification, which the attractive and repulſive powers have been cauſed to undergo by ſolution.

Examples:

1. *Before* ſolution at 60° Fahr.

100 grains of Alkohol, of 0,825 ſpecific grav. fill a volume = 100.

100 grains of water, of 1,000 ſpecif. grav. fill a volume = 82,5.

2. *After* ſolution at the ſame temperature.

$$200\text{ grs.}\left\{\begin{array}{l}100\text{ gr. Alkohol}\\ 100\text{ gr. Water}\end{array}\right\}\begin{array}{l}\text{of } 0{,}93002\text{ ſpecif. grav.}\\ \text{fill a volume} = 177{,}41.\end{array}$$

The ſum of the two volumes was = 182,5.

Hence the diminution of volume is = 5,09.

§ 72.

Diſſolved bodies poſſeſs different properties, and prove to be, in their nature, totally different from the ſingle ſubſtances of which they conſiſt.

§ 73.

Two bodies cannot diſſolve each other, unleſs one at leaſt be in the fluid form. The ancient chemiſts, therefore, had already adopted the maxim, *corpora non agunt, niſi fluida.* The ſum of attractive powers among the reſpective homogeneous parts of two ſolid bodies is greater than their affinity. Hence the former muſt be diminiſhed by liquefaction.

§ 74.

On this account a diſtinction is made between ſolutions in the *humid way* (*via humida*), and thoſe

thoſe in the *dry way* (*via ſicca*). In the firſt, one at leaſt of the diſſolving ſubſtances is already in the liquid form; but in the latter, theſe ſubſtances muſt firſt be brought to the ſtate of fluidity, by melting, before a reciprocal ſolution can take place.

§ 75.

The ſolutions of ſeveral bodies are attended with noiſe and frothing, which is called *effervescence*, and is cauſed by a copious and rapid extrication of aeriform ſubſtances. This air, however, did not pre-exiſt in thoſe bodies in the form of air; but aſſumes this form at the inſtant in which it is generated. Nor is the effervеſcence an argument for the power and violence wherewith the parts of bodies, under reciprocal ſolution, attract each other.

§ 76.

When a fluid menſtruum has taken up as much as it can diſſolve of a ſolid body, it is ſaid to be *ſaturated*. As the nature of the bodies to be diſſolved is various, ſo, in the very ſame ſolvent medium, are the limits of ſaturation greatly different; and, in moſt caſes, theſe limits are, reſpecting the individual ſubſtance, greatly varied by the temperature; becauſe the *ſolvent* aſſumes to itſelf, before it is ſaturated, a greater quantity of the *ſolvend* in heat than in cold.

§ 77.

We muſt farther conſider, in this place, the difference between a *partial* and a *total ſolution* of a body. In the firſt, the whole body is not taken up by the fluid menſtruum, but only ſome of its conſtituent parts, leaving others behind, to which the ſolvent has no affinity. This partial ſolution is likewiſe called *extraction*, and its product an *extract.* Yet in theſe extractions, by the aſſiſtance of *appropriation*, (§ 47) ſuch conſtituent parts may be taken up by the ſolvent medium, as otherwiſe would not be diſſolved by it.

As *examples*, ſerve the *extracts* from vegetable ſubſtances by water and ſpirit of wine; the ſeparating of gold from ſilver by *quartation*.

§ 78.

This extraction is performed in various ways, and the application of this proceſs has received various names. If the ſubſtances remain in the menſtruum without warming it, it is called *ſoaking*, or *maceration*; but if the extraction be aſſiſted by a moderate heat, not reaching the point of boiling, it is called *digeſtion.* Another ſpecies of extraction is *infuſion*, where the menſtruum is poured, when hot, on the body under extraction. This is conveniently uſed when the body contains eaſily ſoluble or volatile parts, that would be loſt on applying a heat of longer duration, or by boiling.

Laſtly,

Laſtly, when the menſtruum together with the ſubſtance, from which an extract is to be made, is heated to boiling, the operation is called *decoction*; and the extract thus obtained a *decoction* (*decoctum, apozema*); in which it is not expected to detain thoſe parts that become volatile by the boiling heat of the ſolvent.

§ 79.

It is neceſſary that the veſſels wherein a ſolution of any kind is attempted, be not acted upon by the ſolvent, and the ſolution thereby defiled. The moſt uſual veſſels employed in ſmall experiments, for ſolutions in the humid way, are of *glaſs* variouſly ſhaped. Such are *matraſſes*, or *cucurbits* (*cucurbitæ*); which, as to their ſize, are ſubdivided into *ſeparating*, *common*, *maſter*, or *large matraſſes* (*cucurbitæ ſeparatoriæ, vulgares, magiſtrales*); and *balloons*, *recipients*, or receivers, (*excipula*); beſides *phials* (*phialæ*)*, *glaſs cylinders*, or jars, and *flaſks*, or bottles. Uſe is alſo made of *earthen pots* and *pans*, manufactured of common pottery, ſtone ware, Staffordſhire ware, and China ware, or porcelain. When the quantities are great, *metallic kettles*, or *caldrons*, and *pots*, are employed; and in theſe the choice of the metal depends on the nature of the menſtruum.—Solutions in the dry way (§ 74) are performed in melting veſſels, of which we ſhall ſpeak when treating of fuſion.

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* Plate IV.

§ 80.

The ſolution is promoted by reducing the ſolvend to ſmall pieces; alſo by digeſtion, by boiling, by ſhaking, and agitating the mixtures. In ſolutions that are accompanied with effervеſcence, the body to be diſſolved ought to be conveyed only by degrees, little by little, into the ſolvent medium.

§ 81.

A particular ſpecies of ſolution is the *ſolution by means of vapour (ſolutio vaporoſæ)*. To aſſiſt either the partial or the total ſolution of any ſolid body, the menſtruum is in this caſe, in an air-tight veſſel, converted into vapour, and in this ſtate it acts on the ſubſtance incloſed. By this management the ſolvent is rendered more efficacious; becauſe, its vapours finding no means to eſcape, it is made capable of receiving a ſtronger degree of heat than in open veſſels. This kind of ſolution is performed in *Papin's digeſtor (machina & digeſtor Papini)* *; and thoſe fluid menſtrua are employed, by which metals are not diſſolved or otherwiſe affected.

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* Plate IV. N.

§ 82.

If, in ſuch ſolutions, the vapours produced by heat originate from a ſolid body, the partial or total ſolution, which is the reſult of that proceſs, is is called *cementation*; and the ſubſtance, which gives out the vapours, is named *cementing-powder*. With this laſt the body to be diſſolved, divided, or otherwiſe changed, is put by *layers* (*ſtratum ſuper ſtratum*) into the *cementing-pot* (*pyxis cementaria*) made of fire-proof, baked clay; and in that ſtate expoſed to heat.

§ 83.

The *deliquation* (*deliquium*) of ſome concrete ſalts, which, on imbibing moiſture from the air, form with it a liquid ſolution, cannot be regarded as a ſeparate ſpecies of ſolution. Neither can the ſolution of metals by quickſilver, or *amalgamation*, be conſidered as ſuch.

Precipitation.

§ 84.

The recovering, or ſeparation of a body from its ſolvent, by the addition of a third ſubſtance, ſo that the former re-appear in a ſolid ſtate, however divided, is called *precipitation*. The ſubſtance thus recovered is called *a precipitate*; and the ſuper-added body, that occaſioned the precipitation, is called *precipitant*.

Examples. Vide above, § 48.

§ 85.

Precipitations are effected by virtue both of ſimple and double affinity. In the firſt caſe, either the menſtruum has a greater affinity with the precipitant than with the body diſſolved, and for this reaſon, uniting with the former, throws out the latter; or *vice verſa*, the diſſolved body poſſeſſes a greater affinity with the precipitant than with its menſtruum; and, therefore, parting from the latter, forms with the precipitant a powder inſoluble in the ſolvent medium.

§ 86.

It follows from this, that the precipitates, though obtained from the ſame ſolution, may be various; and it is poſſible to precipitate a body from the very ſame menſtruum in a great variety of forms, accordingly as we chooſe to employ different precipitants.

§ 87.

Precipitations are alſo, like the ſolutions (§ 74) ſubdivided into *precipitation* in the *humid* and in the *dry way*.

§ 88.

Every precipitation is performed by means of affinity, either ſimple (§ 48), or double (§ 50); and there are, in the ſtrict ſenſe, no *ſpontaneous precipitates* (*præcipitationes ſpontaneæ, ſpuriæ*) as they are ſtyled by ſome.

Fuſion.

§ 89.

The action of fire, or, more properly, of caloric, on ſolid bodies, by which they are cauſed to paſs into the ſtate of fluidity, is called *fuſion*; and a body rendered liquid by fire is ſaid to be *in fuſion, to flow, to melt.*

§ 90.

From what has been ſaid above (§ 24, 28) of the difference between ſolid and fluid bodies, it follows, that the active expanſive power of the caloric is the principle or true cauſe of fuſion; ſince, by combining with the ſolid ſubſtance, it diminiſhes and deſtroys, in a high degree, the attractive force of its particles.—The fluidity of all liquid bodies, we know at preſent, is merely derivative, and the effect of the influx of caloric. (§ 33.)

§ 91.

If we attend to the different ſtrength of the attractive power which the particles of ſubſtances, ſpecifically different, exert on one ſide amongſt themſelves, and on the other towards the caloric, we find no ground to wonder why ſome bodies require a lower, others a higher, temperature to be fuſed; and that it is poſſible to meet with ſome bodies, which, at any degree of temperature, we hitherto know in our atmoſphere, continue in the liquid

liquid ſtate. According to the various degrees of fuſibility, bodies are diſcriminated into *refractory*, or of *difficult fuſion*, which require the utmoſt violence of fire to be melted; and ſimply *fuſible*, or of *eaſy fuſion*, that will flow in leſs heat; yet the limits between theſe have not yet been aſcertained by any fixed ſcale.

§ 92.

Some mixtures melt with greater eaſe than the ſingle ſubſtances of which they are compoſed.

As for inſtance: the *ſolder* of the tin-men, Mr. *Roſe's* metallic mixture, (of 2 parts biſmuth, 1 lead, and 1 tin) that becomes fluid even in boiling water.

§ 93.

Some bodies cannot be rendered fluid by any degree of heat which we are able to produce.—Theſe are called *infuſible, apyrous, fire-proof*. Several of them may, however, be fuſed by adding other bodies, which on account of this property are called *fluxes*. Such addition is called at the ſmelting works, *dreſſing of the ores*. It is worth remarking, that ſometimes theſe additions are of themſelves infuſible.

§ 94.

The true fuſion ought not to be confounded with the melting of ſome ſalt cryſtals by heat. The laſt is cauſed by the aqueous particles contained in in them diſſolving the ſalt at an increaſed heat, which they cannot at a weaker. (§ 76.)

§ 95.

When melted bodies by a circumambient medium of a lower temperature, are deprived of ſo much caloric that the original attractive forces of the bodies of which they are compounded acquire again the degree of intenſity requiſite to produce the form of ſolidity; or when, by this loſs of caloric, the native attraction among the ſurfaces of the primitive molecules becomes again active, they *concrete*, or *congeal.*

§ 96.

All bodies muſt, in conſequence of the explanation given (§ 90) of fuſion, aſſume in fuſion a greater volume than that which they had in their former ſtate of ſolidity. This is in every reſpect confirmed by experience. The exception which ſome bodies, as ice, biſmuth, antimony, ſulphur, ſeem to make, may be eaſily explained by the cryſtallization of their parts on concreting.

§ 97.

Since no ſolution takes place without liquidity, (§ 73.) fuſion becomes one of the moſt effectual operations for ſolutions and precipitations in the dry way (§ 74, 87). Fuſion is, beſides, of importance in ſeparating heterogeneous parts ſimply mingled (§ 4, 5) by means of their different degrees of fuſibility; as alſo by the circumſtance, that various ſhapes may be given to bodies by caſting them into *moulds*, while in a fluid ſtate.

§ 98.

Fuſion is ſometimes performed without any veſſels at all, and then in ſmall quantities, by the flame of a candle or lamp, *with the aſſiſtance of the blow-pipe*; but, in larger quantities, by placing the bodies to be fuſed amongſt the coals in a *melting-furnace*. At other times, the operation is done in veſſels, ſubjected to the requiſite heat, in the furnace.

§ 99.

When the *blow-pipe* (*tubus ferruminatorius*)*, made of glaſs or metal, is employed, the air compreſſed by the mouth is directed on the flame; and the heat, by that means increaſed, is communicated to the ſubſtance to be fuſed, which generally reſts on a ſupport, in a cavity made in a lump of charcoal. The apparatus by which the air is made to ſtream through the blow-pipe, by means of double bellows, renders this uſeful inſtrument capable of being employed by perſons whoſe weak lungs do not permit them to continue the blowing long, or who are not ſufficiently ſkilled in its management. Laſtly, the heat of a lamp-flame may be raiſed to the higheſt degree, by conducting oxygen

oxygen gas (vital air) through the blow-pipe, by means of a peculiar apparatus †.

§ 100.

In ſmelting-houſes, the fuſion without veſſels is performed in a very ſimple way, by placing the ſubſtances to be fuſed immediately betwixt burning charcoal in the *melting-furnaces.* In theſe the fuſion is urged by bellows; and they are of various conſtructions, to ſuit a variety of purpoſes. Hence alſo they have received different denominations.

§ 101.

Other kinds of fuſion, eſpecially in ſmall quantities, are performed in veſſels of various ſhape and materials. Their moſt eſſential properties are, their being infuſible at any degree of heat required

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* Plate I. Fig. 6.

† A deſcription of an apparatus ſuitable for that purpoſe, together with a *pocket-laboratory,* is given by *Magellan,* in his Appendix to *Cronſtedt's* Mineralogy. Such apparatus was ſold by Mr. *Brown,* bookſeller, Eſſex-ſtreet, Strand.—As the action of the blow-pipe will be oftener mentioned, it is to be obſerved here, once for all, that the flame of the candle or lamp urged by it conſiſts of a neat luminous blue cone, ſurrounded by another of a white and more faint appearance, and that the ſtrongeſt heat is at the *point of the inner flame.*—Edit.

quired for melting the bodies to be fuſed in them; and, beſides, their inſolubility in that body when melted.

The moſt uſual melting-veſſels are *crucibles* (*crucibula*)*, manufactured of refractory clay and ſand; the moſt perfect of which are made at *Groſſallmerode* and *Ellrode* in *Heſſe*. Some of them are *larger*, and preſent, on being cut acroſs, circular outlines; others are *ſmaller*, called *ſet-crucibles*, becauſe they are of different ſizes, to fit into one another like ſets of chip-boxes, and have a triangular top. In ſome caſes, *iron* or *ſilver crucibles* are employed. Thoſe of *Ips* in Upper Auſtria, or of Hafnerzell near *Paſſau* (*black-lead crucibles*), conſiſt of black-lead and ſand; they are made of very different ſizes, and are very durable under every change from heat to cold, but improper for melting many ſaline ſubſtances.

We do not as yet poſſeſs melting-veſſels that in every reſpect have the qualities mentioned above.—*Crucibles* made *of platina* would, however, in many caſes, remedy this inconvenience.

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* Plate I. Fig. 3. 4.—Crucibles, of both the Heſſian ſort and black-lead, as alſo *portable furnaces* of black-lead, are manufactured near this metropolis by Meſſrs. *Pugh* and *Speck*, Booth-ſtreet, Spitalfields, and the late Mrs. *Hempel's*, King's-road, Chelſea.—Ed.

§ 102.

For the melting of ores in ſmall quantities for docimaſtic purpoſes, *aſſaying-crucibles* (the *probirtuten* of the Germans) * are employed, made of the ſame materials as the earthen ones. They have, in their inner cavity, the form of a double cone; bellying out in the middle, and contracted at both ends, and a proper ſtand is provided for them. Another ſpecies of theſe are the *chalice-form crucibles* (*kelch-tutten* of the Germans). The *ſcorifying teſts* (*anſiedſcherben* of the Germans) and *capſules*, likewiſe belong to this place.

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* Plate I. Fig. 5.

§ 103.

The melting-veſſels are placed amongſt live-coals, either in a *ſimple wind-furnace**, or, if they contain refractory ſubſtances, in a *melting-furnace*, properly ſo called, whoſe ſtrength of action depends on the ſtrength of the current of air, cauſed by its peculiar conſtruction; or alſo on a *forge-hearth*, before the nozzle of the bellows, in which caſe the effect of blowing, and hence the heat, is increaſed, by weights laid on the bellows. The larger earthen crucibles muſt not be heated or cooled too ſuddenly; nor ſhould they be placed on the bare grate, but on a ſtand or fragment of a brick; and likewiſe the cold *blaſt*, or guſt of air ſtreaming from the

the *bellows*, ſhould not ſtrike them directly while red-hot, or elſe the cold air, coming in contact, will make them burſt.

[*] Pott has conſtructed an excellent portable melting-furnace, in imitation of that of *Becher* in his *Tripode Hermetico*, page 32; to which the editor wiſhes by this note to turn the attention of chemiſts. It is conſtructed of wrought-iron, coated in the inſide with *raw clay* and *brick-duſt*, worked up with bullock's-blood. He increaſes the current of air, and conſequently the intenſity of heat, by means of a pipe ſimilar to that delineated Plate I. relating to the wind-furnace, conveying cold air to the aſh-pit from without the window of the laboratory. By this furnace Pott fuſed *Oriental* and *Bohemian garnets*, and even *hyacinths*, in two hours, which could not be fuſed in porcelain fire continued for ſeveral days.—See *Pott's Lithogeognoſia*, Part II.

§ 104.

The *docimaſtic*, or *aſſaying-furnace (furnus docimaſticus)* is uſed when ſmall quantities are to be fuſed under the *muffle*, which is an earthen caſe, in figure half-cylindrical, open on the front, cloſed behind, provided with a bottom and ſide-apertures. The uſe of the muffle is, to put under it in ſmall veſſels, called *aſſaying-teſts*[*], or *cupels*, ſuch bodies as are to be fuſed without being ſecluded from the acceſs of air; but muſt be prevented from being defiled by coals or aſhes.

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[*] Plate II. Fig. 2.——Theſe are not to be confounded with the ſcorifying-teſts. (S. 102.) The *cupels* are ſmall ſaucers, from 2 to 3 inches broad, made of cal-

cined

cined bones and wood-aſhes; the *ſcorifying-teſts* are about half a foot broad, and made of mere elixated wood-aſhes.—See Plate II. Fig. 11. M.——Edit.

§ 105.

Fuſed bodies are either ſuffered to congeal in the melting-veſſels, or they are poured into the cavity of a warmed ſtone, or in an inverted *metallic cone* (*conus fuſorius*), or in *ingots* (*lingo*). In theſe laſt the fuſed metals are ſuffered to congeal in the ſhape of roundiſh oblong maſſes, called *pigs*, or of *bars*; or elſe fuſed bodies are caſt into moulds, to receive a particular figure. To the inſtruments for fuſion already mentioned are to be added, *iron-peels*, *ſtirring-hooks*, *beaked-tongs*, *cupel-tongs*, *common-tongs*, *lifting-tongs*, *pincers*, *tweezers*, *nippers*, &c.

Volatilization.

§ 106.

The tranſmutation of ſolid bodies into fluids is not the only change of form produced by caloric; but this principle, if combining in greater proportion, is alſo capable of reducing many of them into the ſtate of *elaſtic or expanſible fluids*, into *vapours*, and into *gaſes*. To expoſe a ſubſtance to the influence of caloric for the purpoſe of converting it into an expanſible fluid, into vapour, or gas, is termed *volatilizing*; and thoſe ſubſtances are called *volatile* which by heat may be transformed into vapours, or to a ſpecies of air.

§ 107.

It is likewiſe by the expanſive power of caloric that all vapours and kinds of gaſes are formed. Their expanſibility is only derivative; and every one of them may be looked upon as a combination of a baſis not expanſible of itſelf, with caloric, which is expanſible by its own nature.

§ 108.

But there is this difference between the vapours and gaſes, that the firſt loſe their elaſtic form by compreſſion, or by cold, and are thus decompoſed; while the gaſes undergo no ſuch change by theſe cauſes. Any ſubſtance of a lower temperature may again decompoſe the vapour, by depriving its baſis of the caloric. The baſis, which is thus parted from the vapour, and on its decompoſition becomes again perceptible, is on account of the great volume to which it was before diſtended, in a ſtate of the moſt ſubtile diviſion; and in this ſtate it exiſts, either in the remaining part of undecompoſed vapour, or alſo in the air, forming *ſmoke* or *fog*. Yet this is no longer a vapour, and is wrongly called ſo; on the contrary, it conſtitutes a ſolid or liquid ſubſtance, in the ſtate of a moſt minute diviſion.

§ 109.

In the actual formation of vapours the atmoſpheric air has no ſhare at all; it is rather, by its preſſure, an impediment to it, or it is the occaſion that a greater quantity of caloric is neceſſary to reduce, at an equal temperature, a determinate quantity of the baſis into the very ſame elaſtic form as the air poſſeſſes; and, beſides, to deſtroy the attractive powers of the ſubſtance, which had been increaſed by the preſſure of the air (§ 34). In a vacuum, therefore, (or ſpace exhauſted of air) evaporation is more readily accompliſhed, and at a lower degree of heat, than when a ponderous elaſtic fluid preſſes on the body to be evaporated.

§ 110.

The atmoſpherical air may, indeed, diſſolve the vapour that is forming; however, the formation of a vapour is not a ſolution of its baſis in the air. Hence the diſtinction made between *real evaporation* and *natural exhalation* is not ſupported by nature; nor can it be proved. Every exhalation is rather a real evaporation, which at a lower temperature goes on more ſlowly and in ſmaller quantity, merely becauſe its baſis then requires a longer time before it can receive and abſorb ſo much caloric as is neceſſary to form with it a fluid, equally elaſtic as the air.

§ 111.

To the volatile (§ 106.) are oppoſed the *fixed bodies* (*corpora fixa*) which reſiſt volatilization in the fire, or which do not admit of being converted into elaſtic fluids by caloric. The efficient cauſe of this property conſiſts, doubtleſs, in the greater intenſity of the attractive powers of their parts to each other, and in the leſs affinity they have with caloric. Many ſubſtances that are fixed by their own nature, may nevertheleſs be volatilized by the aſſiſtance of other volatile ſubſtances, with which they chemically combine and riſe together. This is termed *co-volatilization.*

§ 112.

Volatilization is a chemical expedient to ſeparate volatile from fixed bodies, or even to part volatile ſubſtances from each other, if their volatility be of unequal degrees. When liquid mixtures are expoſed to the action of heat, for the purpoſe of ſeparating the fluid menſtruum from the leſs volatile, or from a fixed body diſſolved in it, the proceſs is called *evaporation.*

§ 113.

Evaporation is accelerated by increaſing the heat, by facilitating the exhalation of the vapours already formed, by enlarging the ſurface of the body to be evaporated, and alſo by agitating and ſtirring the liquid.

Diſtillation.

§ 114.

When the vapours riſing in volatilization by fire, which otherwiſe would diſperſe in the open air, are directed into a colder place, they loſe their elaſtic form, as they are by that means robbed of their caloric. Their baſis then ſeparates, and forms, according to its various nature, either a liquid or a *fixed ſubſtance.* In the firſt caſe, the proceſs is called *diſtillation;* in the ſecond, *ſublimation.*

§ 115.

It is of little moment to diſcriminate the *humid* from the *dry* diſtillation. The matter to be diſtilled is a liquid in the former, but in the latter it is a ſolid ſubſtance; and in both caſes a liquid product is formed by the action of fire. The firſt has likewiſe, in conſequence of the different purpoſes intended by it, obtained the particular names of *abſtraction, cohobation, rectification*.*

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* *Abſtraction* is particularly uſed when a fluid body is again drawn off from the ſolid, which it has diſſolved; *cohobation,* when a diſtilled fluid is poured afreſh upon a ſubſtance of the ſame kind as that upon which it was diſtilled, and drawn off again, and this repeatedly, to make it more efficacious; *rectification,* when ſpirituous parts, coming firſt over, are ſeparated from the aqueous by diſtillation.—Analogous to this is *dephlegmation,* or diſtilling over the aqueous part,

part, including *concentration*; which, with reſpect to acids, is frequently done alſo by evaporation or boiling.—Ed.

Former denominations of certain products obtained by diſtillation: *ſpirit, oil, butter, phlegm, caput mortuum.*

§ 116.

By *diſtilling apparatus* are meant the inſtruments uſed in diſtillation; and they are accordingly, as the heat employed, or the product obtained by this proceſs is different, conſtructed in various forms, and of various materials. Humid diſtillations, in which the requiſite degree of heat does not ſurpaſs that of boiling water, are performed in the *common ſtill* (*veſica*), uſually made of copper, and in the *diſtilling-furnace* (*furnus veſicæ*)*. The vapours riſe through the *alembic, head,* or *capital* (*alembicus, capitulum*), and paſs obliquely into its *neck.* This alembic is either of tinned copper, or of pure tin, and in many caſes very conveniently made of ſtone-ware. Such alembics as are provided with an inſide *gutter*, are preferable to the common ones. Concerning theſe Meſſrs. *Weſtrumb* and *Neuenhahn* have propoſed ſome advantageous alterations.

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* Plate V. Fig. 1.

Chaptal Elements de Chymie, Tome 3. Sect. 5. Chap. 6. Art. 1. has made an improvement on the common ſtill, by making its bottom in ſome manner ſpherical (*bombè*),

(*bombè*), that the fire may equally ſtrike on all parts, and by making it wider than it is high. By this the ſurface is increaſed, and hence the evaporation facilitated. Beſides, the ſides of the ſtill are upright like a cylinder. He alſo gives it a very wide neck. The head he employs is of a conical form, whoſe ſides make with the baſe an angle of 75 degrees; as he found by experience, that the water naturally runs down along the ſides of ſuch inclination. A little under the conveying tube of the head there is a ſmall projecting gutter. In this manner no drop of the liquid, condenſed in the head, falls back into the ſtill.—Edit.

§ 117.

To decompoſe the vapours paſſing through the alembic, to ſeparate and to collect their baſis when parted from its caloric, *cooling-utenſils* (*refrigeratoria*) have been deviſed. Either the neck of the alembic joins with the *worm*, in the *cooling-tub* * filled with cold water, or the alembic itſelf is united to and ſurrounded by a veſſel full of cold water. This laſt is then called *Black-a-Moor's-head* (*caput Æthiopis*) †.

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* Plate V. Fig. 2.

† This laſt ſpecies is inconvenient, as the water grows warm too ſoon and too often; ſo that the condenſation of the vapours is impeded. The remedy afforded by renewing the water is troubleſome; and, if neglected, endangers the ſpoiling of the product.—See Plate V. Fig. 1. H.

§ 118.

The proper inſtruments for diſtilling fluids of eaſy volatilization are *glaſs-matraſſes* (§ 79) with an *alembic* or head of the ſame materials *. This alembic is always provided with a gutter: in it the vapours, refrigerated by the external air, are decompoſed, or deprived of part of their caloric, and converted into a liquid, which paſſes through its neck into the *receiver* (*excipulum*). The matraſſes are lodged in a ſand or water-bath (§ 63, 64).

§ 119.

The diſtillation by means of a common ſtill, or matraſs, with their heads, (§ 116, 118) has been denominated the *direct* or *aſcending diſtillation* (*deſtillatio recta per aſcenſum*), in oppoſition to the *oblique* by inclination, or *lateral* (*deſtillatio obliqua, per latus*), and the *downwards acting*, or deſcending diſtillation (*deſtillatio per deſcenſum*), which is at preſent ſeldom uſed.

§ 120.

Oblique diſtillations are performed in *retorts* of *glaſs*, *potter's-clay*, or *iron*. With this view, the firſt are placed in a ſand-bath; the two latter ones are brought in immediate contact with the

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* Plate IV. Fig. D.

The *pelican* of the ancients. (Plate IV. Fig. F.) *Vaſes de rencontre* of the French.

the fire; though this is likewiſe done with glaſs-retorts, after they have been armed, or *coated**. Such retorts as have a hole drilled in their upper convexity, which may be cloſed by a ſtopper, are ſtyled *tubulated retorts.* (Plate IV. Fig. B.)

* Windſor loam, or a mixture of ſand and clay, well worked with water and cow's-hair or horſe-dung, to the conſiſtence of a paſte, is laid upon the veſſel in ſucceſſive thin coatings, the preceding being firſt ſuffered to dry before it is covered with a freſh layer. By this the retorts are defended from loſing their form by the violence of fire, and from cracking by the ſudden variations of heat and cold.—Ed.

§ 121.

In diſtillations with retorts, inſtead of receivers, cucurbits or matraſſes are employed; and then either the neck of the retort is immediately inſerted into their aperture, or the retort is otherwiſe combined with them, by means of an intermediate veſſel, called *adopter** (*tubus intermedius*). There is no particular cooling-apparatus uſed in this caſe. A reverberatory furnace, wherein ſeveral large iron or earthen retorts may be placed at once, goes by the name of *galley-furnace.*

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* Adopters differ from the *aludels* uſed in former times in the ſublimation of ſeveral ſubſtances. They were hollow ſpheres of ſtone, or earthen-ware, with a ſhort neck projecting at each end, by means of which one globe might be ſet upon the other. The uppermoſt

moſt had no opening at top. The *adopters* are tubes growing narrower at one end, from half a foot to three long, and open at both ends. The aludels were ſet upright; the adopters are joined in a collateral oblique ſituation. (Plate IV. Fig. K. L.)—Edit.

[*] Chemiſts have alſo made uſe of the *ſluggard's-furnace (athanor)*, by which ſeveral operations may be carried on at once in various furnaces, joined together in the building, and the heat kept on for a conſiderable time without attendance. The contrivance conſiſts in a high tower, containing a quantity of fuel, and from which the fire may be diſtributed into all thoſe different furnaces. The curious reader will find a full deſcription, with a ſufficiently detailed engraving of this apparatus, at the end of *Wiegleb's General Syſtem of Chemiſtry*, tranſlated by Dr. *Hopſon*, 4to. Lond. 1789.—Edit.

§ 122.

The junctures of the diſtilling-veſſels are cloſed with various *lutes* or *cements* (*luta*) accommodated to the nature of the products (*deſtillata*) thereby obtained. If they be aqueous, ſpirituous, or oily fluids, a wet bladder, or wheaten-flour-paſte ſpread on ſlips of paper or linen, are found convenient. The reſidue of almonds (paſte of almonds) from which the oil has been expreſſed, mixed with water, affords likewiſe a very good lute. If the ſubſtances be acid and corroſive, or if they be ſuch as demand a ſtrong heat to be diſtilled, lutes made of plaſter and water, or of quick-lime and whites of eggs, or of clay and loam, or of glazier's glazier's putty, (linſeed-oil and whiting worked and beaten up to a thick paſte) are required.

§ 123.

If in diſtilling, together with other ſubſtances, there are aeriform fluids or gaſes produced; in that caſe, the joints of the diſtilling-veſſels muſt not be entirely cloſed, or the gaſes extricated in the beginning muſt be firſt ſuffered to eſcape through an hole drilled in the receiver. This purpoſe is beſt anſwered by Mr. *Woulfe's apparatus*, and by the diſtilling apparatus of Mr. *Lavoiſier*[*].

[*] A delineation and explanation of this is given Plate VI.

§ 124.

The method of diſtilling *per deſcenſum* (§ 119)[*] is at preſent no longer reſorted to by chemiſts. The extracting of tar from firs, and the ſeparating of quickſilver, after *Born's* manner, may ſerve as examples.

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[*] An inſtance of this is the method recommended by *Macquer* for obtaining the oil of lemons, oranges, cloves, nutmegs, &c. He places them between fine linen; and if they be of a dry and hard nature, as the *cloves*, he expoſes them to the ſteam of boiling water. The linen, together with their contents, are then ſunk nearly half an inch deep into the orifice of a cylindrical glaſs, which is placed in a larger veſſel holding cold water, reaching to half the height of the former. A hollow lid of copper or iron, cloſely

cloſely fitting by an under rim into the inner aperture of the glaſs-cylinder, is put on. This capſule is firſt filled with hot aſhes, upon which ſome pieces of charcoal are afterwards kept burning.—*Macquer's Elem. de Chymie Pratique,* Tome II. Chap. 4. Proc. 4. —Edit.

Pneumatic Apparatus.

§ 125.

The diſcovery of aeriform fluids has, in modern chemiſtry, occaſioned the neceſſity of ſome peculiar inſtruments, by means of which thoſe ſubſtances may, in diſtillations, (§ 106, 123) ſolutions, (§ 75) or other operations, be caught, collected, and properly managed. The proper inſtruments for this are ſtyled the *pneumatic apparatus.*

§ 126.

Any kind of air is ſpecifically lighter than any liquid; and, therefore, if not decompoſed by it, riſes through it in bubbles. On this principle reſts the eſſential part of the apparatus adapted to ſuch operations. Its principal part is the *pneumatic-trough,* which is a kind of reſervoir for the liquid, through which the gas is conveyed, and cauſed to riſe, and is filled either with *water* or with *quickſilver* *. Some inches below its brim an horizontal ſhelf is faſtened, in dimenſion about half or the third part of the width of the trough, and provided on its foremoſt edge with a row of holes, into which, from underneath, ſhort-necked funnels are fixed. The trough is filled with water, ſufficient to cover the ſhelf to about the height of an inch. The uſe of the ſhelf is to ſupport the receivers, which, being previouſly filled with water or mercury, are placed invertedly, their open end turned down, upon the above-mentioned holes; through which afterwards the gaſes, conveyed there and directed by means of the funnels, riſe in the form of air-bubbles.

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* See Plate V. Fig. 2. and 3.

§ 127.

In ſome caſes the trough muſt be filled with quickſilver, becauſe water decompoſes ſome kinds of air by abſorbing their baſis. The price and ſpecific gravity of that metal make it neceſſary to give to the *quickſilver-trough* ſmaller dimenſions. It is either cut in marble, or made of wood well joined. The late *Karſten* has contrived an apparatus, which, to the advantage of ſaving room, adds that of great conveniency

§ 128.

To diſengage gaſes, retorts of glaſs, either common or tubulated, are employed, and placed in a ſand bath, or heated by the fire of a lamp. Earthen or coated glaſs-retorts are put in the naked fire.

If neceſſary, they are joined with a metallic or glaſs-*conveying pipe**. When, beſides the aeriform, other fluids are to be collected, the *middle* or intermediate *bottle* finds its uſe; and to prevent, after cooling, the riſing of the water from the trough into the diſengaging-veſſels, the *tube of ſafety* is employed. For the extrication of gaſes taking place in ſolutions, for which no external heat is required, the bottle called *diſengaging-bottle*, or *proof* †, may be uſed.

* See Lavoiſier's apparatus, Plate VI.

† Plate IV. Fig. G. H.

§ 129.

For receivers, to collect the diſengaged airs, various cylinders of glaſs are uſed, whether graduated or not, either cloſed at one end, or open at both; and, in this laſt caſe, they are made air-tight by a ſtopper fitted by grinding. Beſides theſe, glaſs-bells and common bottles are employed.

> The moſt advantageous manipulations on extricating, collecting, and managing the ſeveral gaſes, are beſt ſhewn by actual experiment.

§ 130.

To combine with water, in a commodious way, ſome gaſes that are only gradually and ſlowly abſorbed

ſorbed by it, the *glaſs-apparatus* of *Parker* is ſerviceable *.

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* Plate V. Fig. 5.—*De Vigne* has invented a new apparatus for impregnating waters; of which is given an exact account, and neatly-engraved plate, in *Tilloch's Philoſophical Magazine* for June, 1798.

Sublimation.

§ 131.

When vapours, or bodies, volatilized by heat, condenſe again by cooling into a ſolid body, *ſublimation* (§ 114) takes place. In many caſes, together with the ſublimation, diſtillation is combined.

§ 132.

Moſt of the diſtilling-veſſels are applicable to ſublimation; and the proceſs is conducted in matraſſes with their alembics, or in retorts and receivers. For ſmall quantities, common medicine-phials are frequently made uſe of, and for this purpoſe ſet in the ſand of a crucible-bath, (§ 83) in ſuch a manner, that the body ſublimed adheres to their prominent and cooler part. In particular operations ſpherical glaſs-veſſels and balloons are employed. The

The ſubliming parts, or *aludels* *, as they are called, are at preſent out of uſe. No peculiar refrigerating-veſſels are uſed in ſublimation.

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* Plate IV. Fig. K. Conſult note to 121.—Ed.

§ 133.

Sublimations in the manner of *Geber*, or *Glauber*, are performed with a free acceſs of air. The adhering of the ſoot on our chimneys, the making of lamp-black, the gathering of white arſenic in the proper flues (*poiſon-houſes*), and the preparing of zinc-flowers, are various inſtances of this proceſs.

§ 134.

If the body ſublimed preſent itſelf in the form of a ſolid, hard, concrete maſs, it is called a *ſublimate* in the ſtricter ſenſe of the word; but it has the appellation of *flowers* (*flores*) if it be of a porous, looſe texture, and beſides of a pulverulent appearance.

Chemical Inſtruments.

Balances. Weights, &c.

§ 135.

Beſides the implements hitherto mentioned, there are others in uſe, which may be beſt explained when treating of the particular proceſſes. Several others require no deſcription. To this claſs belong *bottles* of *glaſs*, or *earthen-ware*, of various ſize and figure, and deſtined to preſerve a variety of fluid matters; *ſugar* and *powder-glaſſes*, *ſtone* and *wooden-boxes*, and *chip-boxes*, for ſolid ſubſtances; *metallic* and *glaſs-funnels*, *ſeparatory-glaſſes* and *funnels* *, *cutting-rings*, *levers*, ſmall *glaſs-ſyringes*, *ſpatulas* of wood, ivory, and metal; *metallic ſpoons* of different magnitudes, *glaſs-tubes* for ſtirring, and the like.

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* Plate IV. Fig. M. O.

§ 136.

Beſides theſe, ſome phyſical inſtruments are of abſolute neceſſity to the chemiſt. Among the latter are good *barometers* and *thermometers*, whoſe various ſcales ought to be well known; good *areometers* and *hydroſtatic balances*; an *air-pump*, with the neceſſary implements; a pretty large *burning-lens*; *load-ſtones*, or *magnets*; *microſcopes*; and, laſtly, an *electric-machine*.

§ 137.

Finally, of all the chemical apparatus, *balances* and *weights* are the moſt neceſſary. The former muſt be procured of various ſizes; and it is obvious that they ſhould be very exact, and very ſenſible. Theſe properties are more eſpecially requiſite in the *docimaſtic-balance*, in the uſe of which careful regard muſt be had to the ſenſibility and length of its beams.

> *Nicholſon* has very ably treated on the conſtruction, uſe, and ſeveral ſpecies of balances, in his *Firſt Principles of Chemiſtry*, 8vo. Lond. 1796.—Editor.

§ 138.

The chemiſt cannot diſpenſe with being thoroughly acquainted with the various *weights* and their ſubdiviſions. To compare theſe with one another, the normal, or *ſtandard-penny parts of the Cologne mark-weight* are very commodious. The German chemiſts uſe moſt commonly the *medicinal weight of Nüremberg*. In *commerce* the *pound* is eſtimated at ſixteen ounces (133898 St. P. pts.); but in *medicine* only at twelve ounces. The *ounce* is divided into eight drachms; the drachm into three ſcruples; the *ſcruple* into twenty grains.

> The editor was at a loſs, in what ſhape to inſert this and the following three ſections; whether to reduce them all at once to the Engliſh, or to the former French weight, which laſt is repeatedly mentioned in this work. After ſome heſitation, he reſolved to leave them as they are; becauſe they ſerve as a comparative ſtatement of the ſeveral weights in uſe, with regard to the German, not much known in this country; and becauſe their compariſon with the French is met with almoſt in every book. He will only add their value

value in Engliſh weight, yet neglecting very ſmall and inſignificant fractions.

Thus, according to *Kruſen's* Hamburger Contoriſt, 71 lb. or grains, Engliſh *Troy weight*, are equal to 74 lb. or grains, *German apothecaries weight*;

and

1 *ounce* of the Nueremberg medicinal weight is = 7 drach. 2 ſcrup. 9 grains Engliſh ditto.

§ 139.

Accounts are alſo made by the *Cologne mark-weight*, where the *pound* (131072 St. P. pts.) is divided into two marks; the *mark* into ſixteen loths, or half-ounces; the *loth* into four quentchens, or drachms; the *quentchen* into four pennies; and the *penny* into 256 normal, or *ſtandard penny-parts*; though likewiſe in 17 *eſchen*.

This diviſion takes its origin from the *Regulation of the Mint* by Emp. *Charles the V.* 1524; and by it all very ſmall weights of gold and ſilver are aſcertained in Germany.

In a groſs way, 829 lb. *Cologne* are equal to 1038 lb. *Engliſh Troy*;

and

1 mark Cologne = 7 ounc. 2 dwt. 4 gr. Engliſh Troy.

§ 140.

By the French *Troy-weight*, or *poids de marc*, the *pound* (137458 Stand. Pen. pts.) is divided into

into ſixteen ounces; the *ounce* into eight gros, or drachms; the *gros* into three deniers, or ſcruples: each *denier* into 24 grains. A *grain* is farther divided into 24 *carobes.*

In a groſs way, according to *Kruſe,* 792 French lb. *poids de marc,* are equal to 1038 Engliſh lb. Troy;

and

1 lb. French Troy-weight of 16 ounces is equal to 1 lb. 3 ounc. 15 dwt. 3 gr. Engliſh Troy.

With this French weight thoſe of other countries are compared in moſt books of Natural Philoſophy and Chemiſtry. But as there generally prevailed a great variation in theſe compariſons, *Tillet* has compared the moſt exact ſtandard-weights of many European countries with the ſtandard-marc, in the Pile preſerved at Paris, and called *Poids de Charlemagne.* He has publiſhed the reſult of his reſearches in the *Memoires de l'Academie des Sciences* for the year 1767. His ſtatements may, by the exactneſs and ſenſibility of the balance, he uſed, and by the induſtry of his exertions be depended on for accuracy.

Of late, quite different weights, as well as meaſures, have been introduced in France. As it would be too long to explain them here, the reader is referred to *Nicholſon's Phyſical and Chemical Journal,* Vol. I. p. 193, and p. 332, where a table is given for reducing the *unities* of the *metre* or length, *litre* or capacity, and *gramme* or weight, to Engliſh *inches, gallons,* and *grains.*

Of

Of the *Dutch Troy-weight* the *pound* (137970 St. P. pts.) contains ſixteen ounces; the *ounce* 20 engels; the *engel* contains 32 aaſes.

In a groſs way, 787½ Dutch Troy lb. are equal to 1038 Engliſh ditto;

and

1 lb. Dutch Troy is = 1 lb. 3 ounc. 16 dwt. 7 gr. Engliſh Troy.

By the proportions given in theſe notes, it is eaſy to reduce the German, French, and Dutch weights to the Engliſh, and *vice verſa*, by the ſimple rule of three.

In the *Engliſh Troy-weight* the *pound* weighs (104688 St. P. pts.), and is divided into twelve ounces; the *ounce* into twenty penny-weights, marked *dwt.*; the *penny-weight* into 24 grains; the *grain* into twenty mites.

The *pound* of the Engliſh *apothecaries* is the ſame with the Engliſh Troy weight; only the ſubdiviſions of the *ounce* are different. This laſt is by them divided into 8 drachms; the *drachm* into 3 ſcruples; the *ſcruple* into 20 *grains*: making in either ſubdiviſion 480 grains, each of equal weight for the ounce. By theſe medicinal preſcriptions are prepared; but the drugs are bought and ſold by the common Avoirdupoiſe weight.

The *Avoirdupoiſe* weight has 16 ounces in the *pound*, and the *ounce* is divided into 16 drachms.

1 lb. *Avoirdupoiſe* is equal to 14 *oz.* 11 *dwts.* 15½ *grs. Troy.*

§ 141.

Gold and *ſilver* are commonly weighed by the *mark of Cologne.* When *gold* is weighed, the mark (65536 St. P. pts.) is divided into 24 carats, and the *carat* into 12 grains. When *ſilver* is weighed, the mark is divided into 16 loths, or half-ounces; the *loth* into 18 grains.

The ſame proportion holds good with any ſmall portion of metal; one ounce, or a drachm, for inſtance. Hence the expreſſion of *gold of* 21 *carats* denotes, that in a compounded metal there are 21 parts of pure gold, and 3 parts of another alloyed metal in 24 parts, whatever may be the abſolute weight of the compound. In a ſimilar way the expreſſion of *ſilver of* 16 *loths* is to be explained.

In England, gold and ſilver are weighed by the Troy weight, (§ 140) and the *ounce* of *ſtandard gold* for coinage, &c. conſiſts of 22 carats of fine gold, and 2 of copper.—The *pound* of *ſtandard ſilver* is 11 *oz.* 2 *dwts.* of fine ſilver, and 18 *dwts.* of copper.

§ 142.

The *docimaſtic*, or aſſaying *weight*, is a weight proportionally reduced to ſmall quantities; ſo that, for inſtance, one ounce may ſerve in lieu of a *centener*, or *quintal*, or hundred pounds (marked *cwt.*) The proportional diviſions of that ounce will then give pounds, ounces, drachms, grains, &c. In Germany the *docimaſtic centener*, or *cwt.* is uſually

of

of the ſame weight, as the drachm, or *quentchen* (1024 St. P. pts.) of the Cologne mark-weight.

§ 143.

The quantities of *fluid matters*, whenever exactneſs is required, which always ought to be moſt carefully attended to in chemical enquiries, ſhould never be determined by meaſure, but merely by weight.

> The meaſuring of fluids may, in ſome few caſes, be allowed; but then it ſhould be always mentioned for the information of thoſe that will repeat the experiment, or reaſon on its reſults; and the more ſo, when the ſame kind of fluid is of various ſpecific gravities, as water or ſpirit of wine; or when, by their nature, particular accuracy is required. Thus the *London College* have, in their *Pharmacopœia*, wiſely diſtinguiſhed the quantities of fluids by meaſure, (M) and by weight, (P).—Edit.

Re-agents.

§ 144.

Beſides the inſtruments before treated of, the chemiſt has occaſion for a great variety of materials, as means to perform his examinations of the various bodies. Such ſubſtances as enable the chemiſt to draw concluſions reſpecting the nature and properties of the bodies to be examined, by means of thoſe alterations which they ſuffer themſelves, or produce in others, are called *teſts*, or *re-agents* (*reagentia*). That we may, by means of them, deduce reſults to be depended on, they muſt be procured and employed in the ſtate of utmoſt purity.

Theſe go likewiſe by the name of *active inſtruments*, to which alſo fire, water, air, &c. belong; and are thus diſtinguiſhed from the *paſſive inſtruments*, *viz.* furnaces, veſſels, mortars, &c. *Chemical agents* is another expreſſion for active inſtruments.—Edit.

CHAPTER II.

Of the more common, Simple and Compound Subſtances.

§ 145.

BEFORE we attempt an inquiry into the conſtituent parts of bodies claſſed under the three kingdoms of nature, we muſt firſt beſtow our attention on thoſe ſubſtances, which do not belong excluſively to any one kingdom in particular, but are diſperſed through them all.

Caloric.

§ 146.

The external cauſe of the ſenſation which every body knows by the name of *warmth* or *heat (calor)* is what we call *caloric.*

§ 147.

The firſt and moſt common phenomenon, which we perceive in bodies that are brought to the particular ſtate, in which they excite in us the ſenſation of warmth or heat, is the increaſe of bulk, or dilatation.

§ 148.

We employ this change of volume of certain ſubſtances, as a meaſure to determine the increaſing or decreaſing quantity of that principle which produces warmth; and on this change of bulk is the conſtruction of *calorimeters*, and *thermometers* founded.

§ 149.

Caloric (§ 146) is an *expanſible fluid* (§ 29). The action of the calefying ſubſtance on our ſenſations, and on the thermometer, (from both of which we infer the preſence of caloric) does, according to experience, manifeſt itſelf on all ſides of the body which it iſſues from, ſpreading in all directions, but with decreaſing intenſity. Around the heated body we may, therefore, imagine a ſphere of caloric, the expanſive power of which decreaſes in proportion as the ſquare of the diſtance from the heating point increaſes.

§ 150.

Caloric is alſo a *pure expanſible fluid* (§ 30). It cannot be proved by any argument, that its particles are acted on by the force of gravity. It is therefore abſolutely impoſſible to aſcertain the quantities of caloric by weight, and it muſt in all reſpects be conſidered as an *imponderable ſubſtance*.

§ 151.

Caloric is, laſtly, a *fluid expanſible of itſelf* (§ 30). We are not acquainted with any ſubſtance, neither does one ſingle experiment ſhew us any, from which we can deduce the expanſibility of caloric.

§. 152.

By virtue of theſe properties caloric ſhould diſtend in infinitum; and it would really do ſo, were it not for other ſubſtances, which by their attractive force for it, render its power of expanſion inactive, and thus ſet limits to its dilatation.

§ 153.

To explain certain phenomena in a more perſpicuous way, it may be allowed to imagine the dilatation of caloric in the manner of *rays*, as if its particles expanded divergingly in ſtraight lines from their origin. Yet this way of repreſenting it is not ſupported by fact. Caloric, though in the ſtate of the greateſt rarefaction, rather fills the ſpace which it occupies in *continuity*; that is, as a *continuum* without interſtices. By the greater or leſs denſity of caloric, nothing more is underſtood, than the greater or leſs manifeſtation of its activity, or of its expanſive power. The intenſities, aſcertained by its actions on the thermometer, are called its *temperatures*.

§ 154.

For want of proper experience, we are not able to ſtate the degree of celerity, with which pure caloric might expand, if no impediment were put in the way of its expanſive power. Yet it cannot well be leſs than that of light.

§ 155.

It is known by experience, that all bodies heated, but not expoſed to a laſting cauſe of warmth, gradually loſe again the exceſs of temperature which they have over bodies around them; and there are no ſubſtances on this globe known, that are capable of preſerving a heated body included in them, at a temperature higher than that of the circumambient medium. Hence caloric penetrates all bodies.

§ 156.

The production of warmth in bodies, and the increaſe of their temperature, is, in the *atomiſtical theory*, explained by the caloric penetrating into their unoccupied interſtices, and pervading theſe bodies by its increaſing quantity. But if this were the caſe, thoſe ſuppoſed empty ſpaces only would be warm, and the particles of matter themſelves would remain cold. For this reaſon it ſeems rather, that in this caſe a chemical penetration takes place, as in ſolutions (§ 69); with this only difference, that the heated matter is not decompoſed and actually diſſolved by the caloric.

Kant's Elem. of Nat. Philoſ. p. 99.

§ 157.

That portion of caloric only is really calorific, or producing warmth, the expanſive force of which is active, and is not checked in its expanſion by the oppoſing attractive powers of the matter, which compoſes the bodies which it warms. It is only this ſpecies of caloric that operates upon the ſenſation, and on the thermometer; and is, for that reaſon, called *free caloric*. As long as it is free, from its very expanſion, it is not detained in the place which it occupied; this only happens when its tendency to expand is ſo reduced to inactivity by the attractive powers of other ſubſtances, that it coheres and forms with them a chemical combination. In this ſtate it is called *unperceivable, latent, fixed caloric.*

§ 158.

Hence the temperature of a body (§ 153.) does not indiſcriminately depend on the quantity of caloric which it contains, but principally on that portion of free caloric, which is ſtreaming through, and iſſuing from it.

§ 159.

When a body is at a higher temperature than another with which it is brought into conjunction, the warmth is propagated from the firſt to the ſecond, and the colder body deprives the warmer of its exceſs of heat. The temperature of the one, therefore, is lowered, and that of the other is raiſed. And this change goes on, till both bodies are brought to the ſame degree of temperature. It is now ſaid, that the warmth of a body, or of its ſurrounding medium, keeps the *equilibrium* with another body of the ſame degree of heat.

§ 160.

The equilibrium of warmth, amongſt contiguous bodies, conſiſts in the equal intenſity of the ſtreams of free caloric, which they reciprocally impart to each other.

§ 161.

If therefore a body ſend out, at the very ſame time, as much free caloric as it receives, *its temperature is laſting*. But if at the ſame time it receives more than it diſcharges, and does not fix the free caloric which it receives, then its temperature is raiſed, or the body *is heated.* And, on the contrary, if it emit more than is communicated to it, it is *refrigerated.* The becoming hot, or being cooled, is conſequently nothing else, than the difference of the quantity of free caloric eſcaping from a body or flowing into it.

§ 162.

The human body contains within itſelf, as long as it is living, a principle of warmth, in the ſame manner as the bodies of all other warm-blooded animals. In other words, as long as we live, there is a portion of fixed caloric continually ſet free from our body. This ſubject can hereafter only be inveſtigated. If, therefore, ſome other body, being in contact with us, does at one and the ſame time impart to us more free caloric than it obtains from us, we call it *warm*, or *hot*; but *vice verſa* we call it *cold*, if the quantity of caloric which it receives from us be greater than what it remits to us. *Coldneſs* is nothing poſitive, but ſomewhat of a negative kind, or a privation. We do not know what is abſolute cold, or the true zero (0) of the thermometer.

Relative-notion of the word *coldneſs*.
Of the *equilibrium* of animal heat.

§ 163.

As long as two bodies continue to be *perfectly homogeneous* (§ 3.) and at the ſame time their *temperatures* be *equal*, in this caſe, equal quantities of thoſe bodies muſt alſo contain quantities of free caloric, preciſely equal; or the quantities of the latter muſt, at equal temperatures, be in the ſame proportion as the volumes of thoſe bodies. When, therefore, two *homogeneous* ſubſtances of *different*, or unequal *temperatures*, are either mingled or mixed

mixed together (§ 4.) the diſtribution of the caloric of the warmer body among both, muſt be proportional to their volumes, or their maſſes; as is alſo proved by experiment.

§ 164.

On the contrary, when *heterogeneous* bodies (§ 3.) and of *different temperatures* are blended with each other, then the exceſs of the caloric of the warmer body is not diſtributed in the proportion of their maſſes; but unequal quantities of free caloric are required, to effect in equal maſſes of ſuch bodies an equal change of temperature.

For inſtance: If 1 ℔ of *quickſilver* be poured on 1 ℔ of *water* of a higher temperature, the heat of the whole maſs will be greater than the arithmetical mean between their former temperatures.—But if the quickſilver be the hotter body, the new temperature will be lower than the ſaid arithmetical medium.—If, for example, the quickſilver be at 110° Farenh. and the water at 44°, the temperature of the blended fluids will not be raiſed to 77°, as it ſhould, if the ſurplus of free caloric were divided among thoſe fluids in the proportion of their quantities. It will be only at 47°.—Let now the pound of quickſilver be heated to 44°, and that of water to 110°, then, on ſtirring them, the common temperature will be 107°.—Hence if the quickſilver loſes by this diſtribution 63° of its warmth, an equal weight of water gains only 3 from this loſs of 63° degrees of heat. On the contrary, if the water loſes 3°, the quickſilver gains 63°.

It need not be told, that pains have been taken to eſtimate on theſe experiments, that portion of caloric which tranſmigrates into the air, or into the veſſel where the water and quickſilver are blended. As, however, ſuch valuation cannot be made with complete accuracy, the numbers ſtated above are a mere approximation to truth.

§ 165.

Hence if bodies be of different kinds, it would be wrong to conclude from the equality of their temperature, that the quantities of free caloric contained in them, bear the ſame proportion to one another as the maſſes of thoſe bodies.

From the preceding example we may infer, that a certain quantity of free caloric, which might warm water of a given temperature to 1 degree higher, would alſo warm an equal weight of quickſilver of the ſame temperature to 21 degrees more; and conſequently we may conclude from it, that equal quantities of quickſilver and water, both of equal heat, would contain the abſolute quantities of free caloric in the proportion of 1 : 21; or as 0,047 : 1,000.

§ 166.

The proportion of the quantities of free caloric, by which heterogeneous bodies of equal temperature and of equal weight are penetrated, is called the *ſpecific* or *comparative warmth*, or heat, and, after *Crawford*, the *capacity of bodies for heat*. If this proportion be determined with reſpect to the ſame

ſame volume of bodies, *Wilke* calls it *relative heat.*

§ 167.

This ſpecific heat of bodies is aſcertained by the change of temperatures, which they ſhew, when from being firſt taken of different degrees of warmth, they are afterwards reduced to a common temperature, either by mixing, in the ſtrict ſenſe, or by mere mingling. *Videlicet;* if the weights of both ſubſtances are equal, then their ſpecific warmth, after being brought to a common temperature, will be in the inverſe ratio of the changes undergone by their former reſpective temperatures. If the weights of matters to be mingled or mixed are unequal, in that caſe their ſpecific heats will be inverſely, as the products of the changes in their reſpective temperatures multiplied by their weights.

Example: 1 ℔ *quickſilver* of 110°, blended with 1 ℔ *water* of 44°, gives 47° (§ 164); hence the change in the temperature of the quickſilver is $110-47=63$ degr. and that of water is, $47-44=3$ deg. In conſequence of this ſtatement, the ſpecific heat of quickſilver is to that of water as $3:63=1:21=\frac{1}{21}:1$.

§ 168.

Many experiments have been made on this head, and tables of the ſpecific heat of bodies have been made out.

The main point in ſuch experiments is, that bodies ſhould never be mingled or mixed together, whoſe form is altered, or ſuch as either fix the free, or diſcharge the fixed caloric (§ 157) during that operation. As this has not been always carefully obſerved, we may fairly miſtruſt the numbers given in all theſe tables. Beſides, it is hardly poſſible to value with accuracy that loſs of free caloric, which, in other reſpects, may happen on blending or mixing theſe ſubſtances.

On this account, I think, *Boerhaave* has not as yet been refuted for having ſuppoſed, that in heterogeneous bodies of equal temperatures, the abſolute quantities of free caloric, which they reſpectively contain, are to one another in the ratio of their reſpective volumes, and therefore inverſely as the weights of the bodies to each other.

In the above example, on blending of 1 ℔ quickſilver of 110° Farenh. and 1 ℔ water of 44°, the common temperature might turn out to be, inſtead of 47, not lower than $48\frac{1}{4}$° Farenh. (which may indeed be the fact, if the vapours of the water abſorb no heat, or if the heat loſt may otherwiſe be better accounted for) and then, by calculation, the ſpecific heat of the quickſilver would be to that of the water, as $48\frac{1}{4} - 44 : 110 - 48\frac{1}{4} := 4{,}25 : 61{,}75 = 1{,}00 : 14{,}52$; and hence very nearly in the inverſe ratio of their own reſpective weights.

Frequently the ſpecific warmth and fixed caloric are miſtaken for each other.

The

The *Calorimeter* of Meſſrs. *Lavoiſier* and *de la Place*. (*Traité Elementaire de Chimie*. Pl. 3.)—The obſervations and experiments made with that inſtrument do not always ſhew the ſpecific heat of bodies; but they point out the relative quantities of fixed caloric, which, on certain changes of bodies, is diſengaged.

§ 169.

Free caloric, which is tranſmitted to other bodies, does not always remain free as to its whole quantity, but a portion of it, more or leſs, becomes fixed, and it is this fixed portion that cauſes the changes of form which bodies undergo, when expoſed to the influx of a greater ſtream of heat. Solid, liquid, and elaſtic bodies are thereby dilated; ſolid bodies turn liquid, and both may by it become elaſtic. Theſe changes cannot happen, except the attractive powers of matter to the caloric weaken and deſtroy its expanſive force; as again, on the contrary, the power of attraction of other ſubſtances is altered by the tendency of the caloric to expand, and by that very means a change in their form is effected.

§ 170.

That portion of free caloric, therefore, which is the cauſe of the effects already mentioned (§ *preced.*) in bodies, loſes its calorific power on our ſenſation, as well as the effect of its action on the thermometer, and becomes fixed, or imperceptible (§ 157); and this, during all the time that it produces the alteration

tion of form in bodies, or is fettered by their attractive forces.

1. Suppoſe a maſs of pounded *ice*, or *ſnow*, be ſo much refrigerated in a veſſel, that a thermometer placed therein points to 10° Farenh. Let the veſſel be now brought into a warmed chamber, in order to expoſe the cold maſs to a laſting and intenſer ſtream of heat. The quickſilver of the thermometer will in this ſituation gradually riſe to 32 degrees; but here it will remain, though the ſtream of heat flowing to the ice be of a much higher temperature. Conſequently, the temperature of the ice, while melting, riſes not higher than to 32°, whatever quantities of warming particles may be conveyed to it; but it melts by degrees, and it is only when it has thoroughly done melting, that the thermometer riſes. Thus the ſtream of free caloric, acting on ice of 32° Farenh. does not raiſe its temperature above the point of freezing; and its action extends no farther, than to change the form of *ſolid* into *liquid* water, and the caloric ſpent on ſuch changes becomes unperceivable and fixed.

2. Mix 1 pound of ſnow at 32° Farenh. with 1 pound of water at 120°; the temperature of the mixture will not be elevated to 76°, but continue at 32°.

3. Put ſome water of 32° Farenh. in which a thermometer is ſuſpended, in an open veſſel upon the fire; the thermometer riſes ſucceſſively higher and higher, and reaches at laſt to 212°. At this moment the water is boiling, and the thermometer continues ſtanding at that degree, as long as it is encompaſſed by the boiling water, let the current of heat conveyed to the water be ever ſo great. From this it

follows, that the action of the calorific particles on liquid water, does not raiſe its temperature above 212°, though their own temperature be higher; but that the flowing caloric, directed to the *liquid water*, becomes in this caſe fixed, and changes the water into *aqueous vapour*. While this change laſts, the thermometer remains at 212°, the point of boiling.

4. Mingle 8 ℔ of iron-filings at 300° Farenh. with 1 ℔ of water at 212°; the temperature of the united matters will not reach 290 $\frac{2}{9}$°, but remain at 212°.

§ 171.

Yet *fixed caloric* muſt be diſtinguiſhed in a double point of view: into the *adhering*, and into ſuch as is *chemically combined*. The firſt ſpecies of fixation takes place on the mere dilatation of bodies, as alſo on the fuſion of ſolid bodies, and on their changing into vapours; and the other ſpecies on the transformation of a ſubſtance into air or gas. In the firſt caſe, the mere mechanical compreſſion is ſufficient to ſet the fixed caloric free, and any body of a lower temperature is capable of depriving another ſubſtance of it.—But in the ſecond caſe, neither the one nor the other happens.

§ 172.

That caloric, which on the formation of liquid, and of elaſtic fluid bodies, is fixed, and becomes imperceptible, muſt of courſe again preſent itſelf in the character of ſenſible or free caloric, and cauſe an increaſe of temperature, whenever elaſtic fluid bodies are transformed into liquid or ſolid ones; or when liquid are changed into ſolid bodies.—Upon this principle the following laws may be eſtabliſhed.

§ 173.

I. *Free Caloric is fixed by bodies, that paſs from the form of ſolidity into that of liquidity.*

This law explains:

1. The fixity of the freezing point at the melting of ſnow or ice (§170, note 1).

2. The experiment of note 2, § 170. One pound of water muſt be heated above 162° Farenh. in order to melt totally one pound of ſnow at 32°. If the water be hot above 162°, nothing more than the exceſs of heat which it has above 162°, is divided among the two pounds of water procured by that way.

3. *Pictet's* reflection of cold, as it is ſtyled.

4. The intenſe cold, produced by mingling ſnow and ſmoking ſpirit of nitre.

5. The great refrigeration attending the ſolutions of all cryſtalline ſalts.

6. The great cold, cauſed by the thawing of ſnow blended with ſalts.

The greateſt poſſible cold, produced by melting pounded ice or ſnow, together with ſalts, takes place with regard to any ſalt, where a ſaturated ſolution of that ſalt freezes. For after this the cauſe of refrigeration no longer exiſts.

7. The great cold, ariſing when cryſtalline ſalt of Glauber is diſſolved in concentrated nitric acid.

§ 174.

II. *The fixed Caloric becomes free, when bodies paſs from the ſtate of liquidity into that of ſolidity; and alſo when they are brought to a thicker conſiſtence.*

This law is the reverſe of the laſt, and its natural conſequence. When, therefore, water freezes, it again gives out that heat by which it was made to liquefy. When the congealing goes on only gradually, it is indeed not poſſible to perceive, by the ſenſation and thermometer, that portion of the caloric, which every moment is diſengaged in ſmall unperceivable quantities only.—Yet on this very calorific matter, now becoming free, depends the reaſon,

1. Why water, at the freezing point of the atmoſphere, does not freeze on a ſudden and entirely.

2. Why water, that freezes in a cold greater than of 32°, does neverthele'ſs retain the temperature of 32° without lowering, till its whole maſs be frozen.

By this law is farther explained:

3. Why the quickſilver of a thermometer ſtanding in water, contained in a veſſel of a narrow neck, and covered with oil, is raiſed to 32°, when the water is made to freeze by agitation or ſtirring; though be-

fore

fore this, during repoſe, the intenſity of its cold was below the point of freezing.

4. Why, for inſtance, if 1 ℔ of water at 32° be mixed with 1 ℔ of ſnow at 4°, nearly $\frac{1}{3}$ pound of the water congeals, and the whole maſs is raiſed to 32°.

5. Why a ſaturated warm ſolution of Glauber's ſalt, contained in a corked bottle, if grown cold in perfect reſt, without cryſtalizing, gets hot in the very moment of cryſtalization, if then agitated.

6. Why deliquated Glauber's ſalt, deliquated Epſom ſalt, deliquated carbonat of mineral alkali, and burnt alum, produce heat on being mixed with water; whereas theſe very ſalts, when in their cryſtalline ſtate, produce cold with it.

7. Why burnt plaſter, and ſtill more ſo, burnt lime, are heated upon the addition of water.

8. From what cauſe the ſtrong heat ariſes on mixing oil of vitriol with calcined magneſian earth.

9. The ſpontaneous inflammation of oils with concentrated nitric acid.

10. The increaſe of temperature taking place on mixing vitrolic acid with water, vinegar with water, alkohol with water.

11. The ſlow cooling of melted tallow, fat, reſin, and bees-wax.

§ 175.

III. *Free Caloric is rendered imperceptible, or is fixed, on the paſſing of liquids into the ſtate of elaſtic fluidity.*

This law explains:

1. The fixity or unchangeableneſs of the boiling point in open veſſels, whenever there is no alteration in the preſſure of the atmoſphere on the boiling water (§ 170).
2. The phenomenon mentioned before. (§ 170. note 4).
3. Why uncovered veſſels, wherein water is boiling, are not ſenſibly heated above the point of boiling.
4. Why a linen-thread, if wound tightly around a glaſs full of water, and cloſed by a ſtopper, does not burn, when held over the flame of a burning candle.
5. The refrigeration of rooms, in the ſummer ſeaſon, by ſprinkling them with water.
6. The artificial making of ice at *Benares* in the Eaſt-Indies.
7. The great cold produced by the evaporation of ether, and the freezing of water by that means. (*Franklin*'s Problem).
8. The frigorific power, as they term it, of a living man ſituated in a medium, whoſe temperature is higher than the warmth of blood.
9. Many phenomena conſpicuous on the formation of gas, but which cannot yet be explained in this place.

§ 176.

IV. *Fixed Caloric is ſet free, on the decompoſition of elaſtic fluids, and on their return to the ſolid or the liquid form.*

This law is again the reverſe of the preceding, and explains:

1. Why a ſmall quantity of water in the ſtate of vapour gives out much more heat than an equal quantity of liquid water of the ſame temperature.
2. Why the decompoſition of every kind of air, or gas, is always accompanied by the extrication of free caloric, or heat.

§ 177.

Thus may the calefaction and refrigeration be effected, merely by the changes which bodies endure with regard to their form.

§ 178.

If there were a cover, impenetrable to free caloric, any hot body confined therein would for ever preſerve that higher temperature which it is once poſſeſſed of; becauſe the intenſity of its caloric would not be enfeebled by expanſion. But there exiſts no matter or ſubſtance that is not penetrated by caloric.

§ 179.

It is, however, known by experience, that various bodies do not tranſmit the caloric with equal celerity, and that though placed in the ſame medium, they do not allow a certain ſubſtance, which they hold

hold incloſed, to cool in equal times in an equal number of degrees; notwithſtanding that both the temperature and volume are the ſame.

Application of this obſervation to various phenomena in common life.

§ 180.

This faculty of bodies, of admitting under equal circumſtances, the refrigeration of a heated body contained therein, within a ſhorter or longer time, is called the *faculty or power of conducting heat*; and ſuch body is ſaid to be a *better, or worſe conductor of heat*, as allows the refrigeration to go on quicker or ſlower. Thus ſtraw, charcoal, wood, aſhes, wool, feathers, cotton, are worſe conductors of heat than water, ſtone, metals; and we give alſo in common language, the name of *warm bodies*, or *bodies preſerving warmth*, to the former. The powers to conduct heat, in the various bodies, are to each other inverſely, as the times during which other bodies, ſhut up in them, grow cold.

Illuſtration by experiments made with cotton, ſeed of lycopodium, quickſilver, concerning their power of conducting heat, &c. by Sir *Benjamin Thompſon*, now *Count Rumford*.

§ 181.

The greater degree of that faculty which ſome bodies have of tranſmitting heat, depends chiefly

on

on their power of fixing the free caloric by a greater or ſpeedier dilatation, fuſion, or evaporation.

Light. Phlogiſton.

§ 182.

The external cauſe of the ſenſation called *Seeing*, is indicated by the expreſſions *light*, or *matter of light (Lux)*; and that ſtate or condition of bodies by which the ſenſation of ſeeing is produced in our organ of ſight, is ſtyled *Illumination* or *Brightneſs (Claritas)*.

§ 183.

Such bodies as diſplay light of themſelves, and are a ſource or cauſe producing light, as, for example, the ſun and burning bodies, are called *luminous*, or *illuminating bodies*. But ſuch bodies as become viſible merely by the light communicated to them by the former, are called *illuminated* or *enlightened bodies*; in caſe they produce in us the ſenſation of ſeeing.

§ 184.

Bodies which do not prevent the perception, by the ſenſe of ſight, of other illuminating or illuminated bodies, when placed in a direct line between the latter and the eye, are called *diaphanous, tranſparent bodies*. To theſe are oppoſed the *adiaphanous*,

phanous, untranſparent, opake bodies. But among theſe laſt, manifold gradations, of greater or leſs opacity, take place.

§ 185.

The phenomena belonging to optics prove, that light as a pure elaſtic fluid (§ 30) ſpreads about, in all directions, from every illuminating or illuminated point; and that around every point, giving or receiving light, a luminous ſphere of undeterminate magnitude may be imagined, where the intenſity of the ſtream of light decreaſes in proportion to the ſquare of the diſtance from the luminous point. The repreſentation of light, as if it were a *diſcrete* fluid diſtending itſelf in rays, is doubtleſs uſeful, to make the optical phenomena more conſpicuous. Yet this by no means prevents us from conſidering that matter, though rarefied to the utmoſt, as a *continuum;* and to obtain its greater rarety merely from a diminiſhed activity of its inherent force, by which it acts upon us.

§ 186.

Light is eſſentially different from caloric. If light were caloric very ſtrongly condenſed, or, in other words, if caloric became luminous at a certain degree of intenſity, it would naturally follow, that no glimpſe of light could take place, except at that high temperature; but this is contradicted by experience. Boiling water gives no light, and the temperature of ſhining phoſphorus is far below that of boiling water. But to explain the nature of light by a modification of caloric, without adopting a modifying principle, is to aſſert the exiſtence of an effect without any exiſting cauſe.

§ 187.

Light may as to its expanſive power, like caloric, be made inactive by affinity with other matters. It may be fixed, and become a conſtituent part of other bodies, ſo as to be unable to make an impreſſion on our organ of ſight; which it can only do when it is a free or expanſible fluid.

§ 188.

This propoſition, by means of which many phenomena in nature may be explained, is confirmed by the experience that we can extricate light from ſuch bodies as by themſelves do not produce the luminous ſtate, and this in various ways: by *burning* combuſtible bodies, by *electricity*, and by *calefaction* or heating of many ſubſtances, in other reſpects incombuſtible.

§ 189.

But from the circumſtance, that in all theſe caſes (§ 188), where light is to be diſplayed in a free ſtate, there always is a certain degree of warmth neceſſary, or at leaſt co-exiſtent, I am inclined to conclude, that light is not a fluid originally elaſtic (§ 30); but that its expanſibility is derived from caloric, and conſequently, that light is a compound of a *baſis of its own*, and *caloric.*

§ 190.

This doctrine of the compoſition of light of a peculiar baſis and caloric, explains alſo the difference between the various kinds of *coloured light*; in which we may imagine a difference in the proportion of the baſis to the caloric. But there is, undoubtedly, a certain fixed proportion of this baſis to the caloric required, in order that a luminous product, obſervable to our organ of ſight, ſhould reſult from their combination. Nor is there any cauſe to wonder, how it happens, that the portion of caloric, which by this baſis is ſo modified as to produce light with it, is no longer able to excite heat.

§ 191.

It is this baſis of light which ought to be diſtinguiſhed by a particular name; what I call, with *Leonhardi* and *Richter: matter of heat*, *principle of combuſtion*, or *phlogiſton.*

§ 192.

The *abſorption of light*, as it is called, is therefore a real decompoſition of light, where its baſis, by the attraction of other ſubſtances, is diſlodged from the caloric, which then is either made free, or again fixed in ſome way or other; or, laſtly, if combined with a ſmaller portion of the baſis of light, is reflected in the form of a differently coloured ſpecies of light.

§ 193.

The *extrication of light* from bodies, which before were not luminous (§ 183), is the combination of the baſis of light (§ 189), they contain,—with caloric.

§ 194.

The moſt remarkable inſtance of the diſengaging of light is in *combuſtion* (§ 188); that is to ſay, the extrication of both the light and caloric, from bodies in conjunction with and by the decompoſition of vital air, and ſome other ſpecies of gaſes. Bodies qualified for this change are called *combuſtible* or *inflammable*.

By *this ſyſtem*, therefore, all combuſtible bodies are compounds, for all of them contain the *baſis of light*, i. e. *phlogiſton*. By the *antiphlogiſtic ſyſtem* the combuſtible bodies may likewiſe be ſimple ſubſtances.

Combuſtible ſubſtances that are ſimple according to the *antiphlogiſtic* ſyſtem, are

	Compoſed, agreeably to the ſyſtem of phlogiſton, of
1. Phoſphorus -	Phlogiſton and phoſphoric radical.
2. Carbon - -	Phlogiſton — carbonic radical.
3. Sulphur - -	Phlogiſton — ſulphuric radical.
4. Baſis of inflammable gas (Hydrogen) - -	Phlogiſton — hydrogen.
5—23. The 19 metals	Phlogiſton and the reſpective baſis of each metal.

Phenomena

Phenomena of Combuſtion in atmoſpheric Air.

§ 195.

Take a cylindrical veſſel of thin glaſs, that may be cloſed at top air tight, by means of a braſs ſcrew and interpoſed leather, and whoſe capacity may be meaſured, into ſufficiently ſmall portions, by a graduated ſcale fixed to it from without.

Put into this veſſel, full of atmoſpheric air, a piece of dry phoſphorus (at leaſt $\frac{1}{3}$ grain for every three cubic inches of the veſſel's capacity); cloſe it then air-tight; heat it gradually by the flame of a candle, firſt on the ſide near the bottom, and afterwards the bottom itſelf. As ſoon as the phoſphorus has been heated to a certain degree, it takes fire of itſelf, burning with a flame and thick white ſmoke; but it ſoon ceaſes to burn. Continue heating the veſſel repeatedly, and let it cool again. The ſmoke precipitates in the form of flakes, if the veſſel and the air contained in it were thoroughly dry, or elſe theſe flakes will melt in the moiſture.

After every thing has returned to the former temperature, plunge the mouth of the veſſel into water or quickſilver, and open its ſcrew. It will be found that the water riſes in it; and hence, that *a portion of air*, which it contained, *has diſappeared.*—The water which has riſen ſhews what quantity of air has been deſtroyed, if its cubic content be compared with that of the whole veſſel. This portion of air thus vaniſhed will, in moſt caſes, be about 0,25 to 0,27 of the whole volume that had been employed of atmoſpheric air. The water forced up in the veſſel is *four*. The *remaining air is as unfit for the burning of phoſphorus as of every other combuſtible matter ; animals are alſo ſuffocated in that air.* We ſhall hereafter ſpeak again of this remainder of air.

If the veſſel, after the phoſphorus was incloſed in it, has been weighed before the combuſtion, and is again after this, when cold, put on the balance, no difference of weight will be obſerved.

If this experiment be made in a ſpacious and very dry glaſs-jar, cloſed with mercury, and if it be ſo managed, that the phoſphorus ſwimming on that metal is ſet on fire by a convex lens, in that caſe the white flakes, which precipitate from its ſmoke, and are the *phoſphoric acid*, if carefully collected, will be found, on being weighed before they melt, to be heavier than the phoſphorus employed; that for each grain of burnt phoſphorous $2\frac{1}{2}$ of this concrete phoſphoric acid are obtained, and hence that each grain of it has obtained an additional weight of about $1\frac{1}{2}$ grains.

Twelve

Twelve cubic inches (Paris) of atmoſpheric air are required for the burning of about 1 grain of phoſphorus; and this air is reduced in dimenſion about 1½ cubic inches, or in weight about 1½ grains; in ſuch a manner, that the loſs in the weight of air wherein phoſphorus burns, exactly correſponds with the increaſe of weight in the phoſphoric acid then generated.

> *Experiments* by burning phoſphorus in larger metallic veſſels, exactly cloſed. Other experiments by the burning of a *candle.*

§ 196.

The phenomena mentioned in theſe experiments obtain, not only when phoſphorus is burnt, but on any combuſtion whatever ſimilar circumſtances occur.

1. Every combuſtible ſubſtance, in order to be inflamed, muſt be heated to a certain degree; more or leſs ſo, according to its particular nature. Thus phoſphorus, for example, requires about 30 degr. *Reaum.* of heat.

2. Without air no combuſtion is effected, and it goes on the more briſkly the more acceſs of air is granted.

3. In a given quantity of atmoſpheric air only a certain quantity of the combuſtible body can be conſumed.

conſumed. For inſtance: of a piece of phoſphorus no more than about one grain will be burnt in 12 cub. inches of that air, all the reſt remains untouched.

4. The atmoſpheric air, wherein a body is conſumed by fire, loſes part of its weight, and is rendered unfit for preſerving animal life by reſpiration, and for promoting combuſtion.

5. The reſidue of the burnt matter (whether ſolid, liquid, or elaſtic fluid) is as much heavier, as the weight of that portion that has diſappeared of atmoſpheric air.

Compoſition of atmoſpheric Air.

§ 197.

It is therefore evident, that the *atmoſpheric air* (which in this place we diſcriminate from the atmoſphere itſelf) is a compound of two different kinds of air. Firſt, of ſuch as alone is capable of ſupporting combuſtion; which itſelf is decompoſed in the proceſs of combuſtion; which alone is proper for the functions of animal reſpiration; which at moſt amounts to about 0,27 parts of the atmoſpheric air; and which (for reaſons hereafter to be explained) we diſtinguiſh by the name *vital air*, or *oxygen gas.*—It is ſecondly compoſed of another kind of air, which is unable to maintain combuſtion,

tion, wherein animals are ſuffocated; which at leaſt makes up about 0,73 parts of the atmoſpheric air, and has received the name of *azotic*, and alſo *nitrogen gas*.

§ 198.

Of theſe two kinds of gas the atmoſpheric air is not in all places compoſed in the very ſame proportion: nor can it be otherwiſe, if we conſider, that in the atmoſphere there are continually, more or leſs, thoſe proceſſes going on, whereby the vital air is decompoſed. But it is no leſs certain, that the vital air muſt always be again reſtored and generated, to prevent the atmoſpheric air from becoming quite improper to live in, for animals that reſpire. We ſhall hereafter, treating on the growth of plants, become acquainted with a means that ſupplies the atmoſphere with vital air.

§ 199.

Before we proceed to the theory of combuſtion, it is neceſſary to examine more cloſely the properties of vital air.

Vital Air, or OXYGEN GAS. *Oxygen.*

§ 200.

We know at preſent a great number of bodies, from which we may, by art, produce *vital air*. It is moſt amply obtained from nitre and the oxyds of mangaueſe, or mercury, if they be ignited.

§ 201.

With this view, fill a ſmall earthen retort with powdered black oxyd, (or native calx of manganeſe); lute to the orifice of its neck a tin-tube, put the retort amongſt charcoal in a wind furnace, placing the mouth of the tube under the funnel of the ſhelf in the pneumatic trough (§ 126) filled with water, and heat the retort gradually to redneſs. At firſt the atmoſpherical air of the veſſels comes over; but upon the manganeſe beginning to be ignited, vital air is diſengaged, manifeſting its preſence by inflaming a wooden ſplinter, that in a glimmering ſtate is brought into contact with it. When no more vital air appears, the orifice of the tube is removed out of the water, and the retort ſuffered to cool.

§ 202.

This ſpecies of air, here obtained, is conſpicuouſly different from the common air of the atmoſphere. It is ſomewhat ſpecifically heavier than the laſt; a Pariſian cubic inch of it weighs, according to *Lavoiſier*, at 10° Reaum. and 28° barometer's height, 0,50694 grains (French); whereas an equal volume of atmoſpheric air weighs, in like circumſtances, only 0,46005 gr. It has no ſmell, no taſte, and it ſhews no trace of an acid.

Its moſt ſtriking and moſt characteriſtic mark is that of being fit for the reſpiration of animals, and the combuſtion of inflammable ſubſtances. An animal confined in a ſpace, filled with this vital air, is not nearly ſo ſoon ſuffocated as when placed in an equally large ſpace of atmoſpheric air.

A combuſtible body that would require about four cubic feet of atmoſpheric air, to be totally burnt, requires for the ſame effect no more than one cubic foot of this air, or oxygen gas. The intenſity of combuſtion, or the extrication of light and heat, in this gas, by far exceeds that which obtains in atmoſpheric air. A wax candle burns in it with a greater and more vivid flame, and with a crackling noiſe; its dying wick is again inflamed by it. A glowing ſplinter of wood, a glimmering paper is thereby immediately ſet in the flaming ſtate; tinder, or touch-wood, which otherwiſe only glimmers, burns in it with a blue flame. Red-hot coals are more rapidly conſumed, and burn with greater brightneſs. A pointed ſteel watch-ſpring, whoſe point has been ignited, is burnt in it with great ſcintillation. But exceedingly ſtrong and uncommonly brilliant is the flame of phoſphorus, burnt in this kind of air.

§ 203.

When phoſphorus is burnt in this vital air, and in a ſimilar manner as in the atmoſpheric (§ 195), (but

(but taking to 9 cub. inch. of vital air about 4 grains of phoſphorus) we obſerve the ſame phenomena taking place, as in the proceſs performed with atmoſpheric air; and that phoſphoric acid is produced, which is afterwards diſſolved by the water, when ſuffered to enter the veſſel. But it will alſo appear, that the intenſity of heat and light is greater, that more phoſphorus is conſūmed in an equal bulk of this air, and, beſides, that this air, if pure, totally diſappears. (Uſually, however, there is found a ſmall reſidue of azotic gas).

The phoſphoric acid obtained, weighs, even before liquefaction, nay, even after ſubſequent ignition, more than the phoſphorus employed therein. The increaſe of weight is in exact proportion with the weight of vital air, which has diſappeared. Agreeably to *Lavoiſier*'s accurate ſtatement, 138¾ cub. inch. (French), or 69,375 grains of vital air are loſt in this operation, if 45 grains (French) of phoſphorus were fully conſumed; or 100 parts of phoſphorus deſtroy by combuſtion 154 parts of oxygen gas, by weight, and yield 254 parts of concrete phoſphoric acid,

§ 204.

The deſtruction of vital air in the burning of phoſphorus incloſed in a quantity of that gas, as well as its reproduction from manganeſian oxyd, are ſufficient arguments to ſhew that it cannot be an elaſtic fluid originally ſuch (§ 30), but that its form of elaſticity is entirely owing to caloric (§ 31). It conſiſts, like every other kind of air, of a peculiar *ponderable*, and not of itſelf elaſtic *baſis of its own*, and of the *imponderable caloric*, which is chemically combined with this baſis, and transforms it into an elaſtic fluid.

§ 205.

As this peculiar or appropriate baſis of oxygen gas ought to be diſtinguiſhed by a particular denomination, *Lavoiſier* has given it the name of *Oxygen*, or *Acidifying Principle*; partly becauſe ſeveral combuſtible bodies are changed into acids by being burnt in it, and partly becauſe it is a conſtituent part, or rather the principle of all acidity, as will appear from what follows.—Vital air conſiſts therefore of oxygen and caloric, which are both chemically combined into a new total, and for this reaſon it is denominated *oxygen gas*.

Synonyma: *Vital air, dephlogiſticated air, pure air, fire air, (Aër vitalis, dephlogiſticatus, purus).*

§ 206.

The *oxygen gas* itſelf is not contained in the oxyd of manganeſe and other ſolid or liquid bodies, by means of which we may procure it; but only its ponderable conſtituent part, the *radical oxygen*, by the combination of which with caloric, that gas is firſt generated. By mere red-heat it is not poſſible to free the manganeſian oxyd from all its oxygen.

§ 207.

The combuſtion of phoſphorus and other inflammable bodies, either in atmoſpherical air (§ 195), or in oxygen gas (§ 203), is, in both caſes, a decompoſition of the oxygen gas, in which proceſs the caloric is deprived of the oxygen, by the combuſtible ſubſtance having a ſtronger attraction for it.

§ 208.

Oxygen is with us a ſimple ſubſtance (§ 8), ſince we are unable to decompoſe it any farther. It is, beſides, not exhibitable by itſelf, or it cannot be ſeparately produced in its ſimple ſtate; for at the inſtant that it might become free, it would again unite with the caloric of the ſurrounding medium, and form oxygen gas. We know it, therefore, in no other way than by its combinations. It exiſts very generally diſperſed in nature, and is a conſtituent part of the atmoſpheric air, of water, of all acids, of all metallic calces or oxyds, and of all bodies of the vegetable and animal kingdoms.

Theory of Fire and Combuſtion.

§ 209.

I take here the word *fire* in the uſual ſenſe of common language, and underſtand by it that light which is combined with free caloric. *Combuſtion* is the extrication of fire with and by the decompoſition of oxygen gas. We ſhall keep to the example quoted of phoſphorus (§ 195, § 203). On its combuſtion two new products, the phoſphoric acid and fire, ariſe from phoſphorus and oxygen gas.

§ 210.

In order that the theory of combuſtion be admiſſible, it muſt explain every circumſtance by which this phenomenon is accompanied, and be in contradiction with none of them. It, beſides, muſt not be inconſiſtent with any other fixed invariable law of nature.

§ 211.

According to the *antiphlogiſtic ſyſtem* (§ IX. Introd.) a combuſtible body is ſuch (§ 194) as is poſſeſſed of the power of attracting, in a certain temperature, the oxygen of vital air more ſtrongly than it is attracted by the caloric. Beſides, in that ſyſtem, oxygen gas does not merely conſiſt of oxygen and caloric, but it likewiſe contains light, in a fixed ſtate (§ 187), as a conſtituent part.

If, therefore, phoſphorus, at the temperature requiſite to its inflammation, be brought into oxygen gas, it robs the latter of its oxygen, and makes with it phoſphoric acid; whilſt the caloric and the baſis, or matter of light, previouſly *latent* in the gas, are reſtored to liberty; and, combining together, produce the fire which flies off. Thus the oxygen gas is decompoſed.

A new body, the phoſphoric acid, is now generated; and, becauſe in many caſes an acid is produced by the combuſtion of inflammable matters this circumſtance has induced modern chemiſts to denote the baſis of vital air by the words *acidifying principle*, or *oxygen*; not on the ground that it is ſuppoſed to be ſour of itſelf, but becauſe it forms an acid only when combined with an *acidifiable baſis*, as in our experiment with phoſphorus. And it is on this account that, in this ſyſtem, combuſtion has likewiſe received the name of *oxygenation*. But in the caſe (very often occurring) where the combuſtible matter imbibes oxygen, yet without becoming thereby an acid, the product is called *oxyd* (alſo denominated *half-acid*), and the proceſs is termed *oxydation*.

Since the combuſtible ſubſtance takes up the ponderable baſis of oxygen gas, and ſince, according to this ſyſtem, both the caloric and light are imponderable, it is thereby accounted for, why the reſidue of burnt matters, the phoſphoric acid, for inſtance, acquires an increaſe of weight equal to that portion of vital air which was decompoſed.—If the inflammable ſubſtance be ſaturated with oxygen, it is rendered incapable of decompoſing more oxygen gas, and the combuſtion is ended.

When the combuſtion is performed in atmoſpheric air, it is then the azotic, either mingled or mixed with the oxygen gas, that prevents theſe phenomena from going on with the ſame vivacity as in pure oxygen gas; and likewiſe, as the azotic gas is not affected or acted on by the inflammable body, it is left as the reſidue of the atmoſpheric air.

§ 212.

Hence, by that ſyſtem, the combuſtion of phoſphorus in oxygen gas is effected by a ſimple affinity (§ 48), and the principle of fire is not in the combuſtible body, but in the oxygen gas.

However, from what I have ſtated of the compoſition of light, I cannot help thinking, that in combuſtion a double affinity takes place; and to explain this theory I ſhall ſelect the example of phoſphorus. That ſubſtance conſiſts of the baſis of light, called by me *phlogiſton*, and making a conſtituent part of all combuſtible bodies (§ 191) united to a peculiar body, the *phoſphoric-radical.* —*Oxygen gas* is a compound of *oxygen* and *caloric* (§ 204, 205).

Now, when phoſphorus is heated in this gas, and by this means the force of attraction between the phlogiſton and the phoſphoric-radical is ſufficiently weakened, ſo that the attractive power between the

radical

radical of phoſphorus and the oxygen may prevail, then the act of combuſtion enſues. The phoſphoric baſis attracts the oxygen, while the phlogiſton of the phoſphorus is attracted by the caloric of the oxygen gas. Thus, by virtue of this double affinity, two new compounds, the phoſphoric acid and fire, ariſe from the two former combinations, phoſphorus and oxygen gas.

When the radical of phoſphorus, and in general of any combuſtible body, has abſorbed ſo much oxygen, that it is ſaturated with it, the combuſtion is arrived at its higheſt degree; and in the ſame manner it is ended, at the moment when all the quantity of oxygen gas, capable of being decompoſed, is exhauſted. By this it is explained, why, in a given volume of oxygen gas, only a certain quantity of phoſphorus, and in general of every other combuſtible matter, can be conſumed by fire.

The increaſe of weight in the reſidue of the burnt ſubſtance is, in this phlogiſtic, or rather *eclectic ſyſtem* (§ IX. Introd.), likewiſe explained by the acceſs of oxygen; and the caloric and baſis of light are likewiſe ſuppoſed to be both imponderable. The remaining azotic gas, not being acted upon by the combuſtible matter, is merely the reſidue of the atmoſpheric air.

§ 213.

Thoſe that wiſh to be impartial, muſt allow that the light, in the *antiphlogiſtic ſyſtem*, acts a part quite ſuperfluous; that it may be thoroughly ſet aſide without impairing the ſyſtem; that by this ſyſtem thoſe phenomena cannot be explained, where light iſſues from combuſtible bodies without any acceſs of vital air, ſome inſtances of which will hereafter be given; that the influence of light upon the growth and thriving of plants, upon the changes of their mixture during vegetation, and upon the alteration in the mixture of many other bodies (of the white ſilver-calx, for example), is by far too great, to allow oxygen gas to be conſidered as its only reſervoir. Finally, it muſt be granted (an important point) that the antiphlogiſtic ſyſtem does in no way explain the incidents preliminary to the proceſs of combuſtion; and that it affords no argument to ſhew why a certain degree of heat is neceſſary, in order that the combuſtible body be inflamed.

However, as young ſtudents are eaſily perplexed, by ſtating, throughout the whole ſyſtem of chemiſtry, every explanation variouſly, according to both theories, I ſhall henceforth explain each phenomenon merely according to the *ſtrict* antiphlogiſtic ſyſtem; eſpecially as a thorough acquaintance with this laſt, obtained by ſuch a method, will make it eaſy to apply afterwards the principles of the *eclectic ſyſtem*, explained above, to any phenomenon.

§ 214.

It appears by experiment, that combuſtible bodies are burnt either by mere *glowing* or *ignition*, or accompanied with *flame*. Chemical analyſis ſhews, that all bodies burning with flame are either themſelves volatile, or contain volatile conſtituent parts, capable of being transformed by heat into elaſtic fluids, and particularly into vapours. The flame of burning bodies is, for this reaſon, the burning vapour or burning gas ariſing from ſuch bodies.

§ 215.

Subſtances, different in the utmoſt degree, may conſtitute the flame of bodies under combuſtion. Even the colour of the flame, ſo various, may be accounted for by this obſervation.

Examples of coloured flames:

Spirit of wine burns with a *blue* flame; the ſolution of borax in alkohol with a *green*; the ſolution of the muriat of ſtrontion-earth with a *red*.

§ 216.

When ſubſtances are mixed, which by their mutual re-actions diſengage a ſufficient quantity of caloric, and if ſome inflammable matter be then

preſent,

preſent, a *ſpontaneous inflammation* may take place on the acceſs of atmoſpheric air.

> *Such inſtances* are the inflammation of oils by concentrated nitric acid, and of the vitriolic acid by calcined magneſia.

§ 217

Inflammable mixtures may likewiſe be ſpontaneouſly inflamed, if caloric be diſengaged either by the gradual action of certain conſtituent parts upon one another, or on the alteration of their form, occaſioned by external cauſes.—Examples of this are: *Homberg's pyrophorus*; the ſpontaneous inflammation of pyrites, of hemp, lamp-black, or wool, with hemp-ſeed oil; of the bran of rye ſtrongly roaſted, and wrapt up in a packet; as alſo torrefied root of ſuccory, ſaw-duſt of mahogany wood, &c.*

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* In the year 1781 a frigate took fire in the port of Cronſtadt, juſt as ſhe was preparing to ſet ſail, though no fire had been made in her for ſeveral days before. By this Mr. *Georgi*, of the Imperial Academy of Peterſburgh, was induced to make a number of experiments to account for that ſpontaneous inflammation, and of which are thoſe alluded to by the author. Mr. *Georgi's* whole paper is inſerted in the French *Journal de Phyſique* for July 1782.—Mr. *Nicholſon* has given a conciſe and inſtructive abſtract of that paper in his Principles of Chemiſtry, B. II. Sect. 5. Ch. 6. —Edit.

AZOTIC, *or Nitrogen Gas.—Azot.*

§ 218.

We return to the reſidue, left, after the combuſtion of phoſphorus, in a confined bulk of atmoſpheric air (§ 195). This remaining air has not in the leaſt the properties of atmoſpheric air; it is no longer able to ſupport combuſtion, or to maintain life by reſpiration. Animals die in it. Its ſpecific gravity is ſomewhat leſs than that of atmoſpheric air. A Pariſian cubic inch of it weighs at 28 inch. of the barometer, and at 10 degr. Reaum. 0,4444 grains (French). We have already diſtinguiſhed it by the name of *azotic gas*.

Synonyma: *Phlogiſticated air, corrupted air, mephitic air, nitrogen gas (aër phlogiſticatus, vitiatus, mephiticus).*

§ 219.

By the analogy of the azotic with other gaſes, it is obvious that it muſt be a compound of a ponderable baſis and caloric. To the firſt of theſe conſtituent parts we give the name of *azot*. It is not producible by itſelf alone; and it has never yet been decompoſed. Hence it is ranked among the ſimple ſubſtances. It is not only a radical principle of our atmoſpheric air, but alſo of many other bodies of the vegetable, and eſpecially of the animal kingdom;

dom; upon which account azotic gas may be obtained from them by various operations. This gas is, beſides, met with in the air-bladder of fiſhes. Laſtly, azot is one of the conſtituent parts of nitric acid, of ammoniac, and probably of crude clay, and ſome other ſpecies of earth or ſtones.

According to the phlogiſtic ſyſtem, *azot* is a compound of *phlogiſton,* and the peculiar *ſubſtratum,* or *radical principle of azot.*

Eudiometer.

§ 220.

As that property of atmoſpheric air, by which it is conducive to the maintenance of animal life on breathing, ſolely depends on the quantity of oxygen gas which it contains; and as, beſides, a variety of proceſſes, whereby vital air is decompoſed or formed, are carried on in the atmoſphere (for which reaſon the atmoſphere cannot every where, and at all times, contain an equal portion of vital air), it of courſe became intereſting to inveſtigate, what might be the proportional quantity of oxygen gas contained in the atmoſphere, and hence to learn the fitneſs of air for reſpiration, which depends on it.

No ſooner were the means of decompoſing vital air diſcovered, than pains were taken to find out a method by which the above purpoſe might be obtained.

tained. The inſtrument wherein the oxygen gas, of a given volume of air ſubjected to examination, may be decompoſed, and its quantity meaſured, is called an *eudiometer.*

Prieſtley is the inventor of this inſtrument. For this purpoſe he propoſed the nitrous gas, which hereafter will be more fully attended to. *Scheele* employed the ſulphuret of iron; and thus we have become acquainted with ſeveral eudiometrical proceſſes, which will be explained in their proper places.

Of all theſe methods, I think the ſureſt, the moſt ſimple, and commodious, to be that which has been already deſcribed; namely, to decompoſe the oxygen gas contained in a definite quantity of atmoſpheric air by the combuſtion of phoſphorus, and to meaſure the portion of gas which has diſappeared (§ 195). The whole apparatus may be made ſo ſmall and portable as to ſerve for a pocket-eudiometer. If the inſtrument be deſtined merely for examining atmoſpheric air, it will be ſufficient to apply the ſcale (§ 195) from the orifice of the cylindrical tube down to but half its length, or its cubic contents; to ſketch that ſcale on a ſlip of paper, paſted on the outſide of the eudiometrical tube, and to varniſh it over. This half is divided into *fifty* equal parts, which in this caſe indicate hundredth parts of the whole capacity of the inſtrument.

§ 221.

However, though by theſe eudiometrical experiments the quantity of reſpirable air in one kind of air may be found, it is, nevertheleſs, not practicable to aſcertain by them the abſolute goodneſs and ſalubrity of ſuch air with regard to reſpiration. It would be a good deal more uſeful, had we any means to diſcover, with certainty and accuracy, thoſe principles, or conſtituent parts of the air we breathe, which have a noxious influence on our health and manner of living, and were we thus enabled to combine a *cacometer* with the eudiometer.

Of the vapours and choke-damps of the mines, in the ſhafts, gangues, and pits.

§ 222.

The burning of a body, a candle for inſtance, is an unqueſtionable proof of the preſence of oxygen gas in the atmoſpheric air ſubjected to examination. We may, therefore, advantageouſly make uſe of that teſt, at leaſt to learn whether the air, for example, of ſubterraneous caverns, pits, mines, and the like, may be inhaled without danger.

§ 223.

Finally, whether our atmoſpheric air be ſimply mingled of azotic and oxygen gaſes, or whether it be a true *mixture* (meaning thereby a chemical com-

combination or compound of theſe two kinds of air) ſeems to me not yet fully decided.

Carbonic Acid Gas.—Carbonic Radical.

§ 224.

On the burning of charcoal, or a great many other ſubſtances, in vital air, another circumſtance occurs; namely, the generation of a peculiar kind of gas, which does not take place in the combuſtion of phoſphorus.

When charcoal, well charred, is employed, and the proceſs performed in a glaſs-bell full of oxygen gas cloſed with mercury, and the coal, having ſome touch-paper or phoſphorus ſtuck on, is lighted from without by a lens collecting the ſun's rays, it will be found that the elaſtic fluid under the bell does not diſappear, as is the caſe on the burning of phoſphorus, but that a new and peculiar kind of gas is formed. This air is unfit for reſpiration, as well as for maintaining combuſtion; but is abſorbed by cold water, and ſtill more readily by a ſolution of cauſtic alkali and lime-water, which laſt is rendered turbid by it. Hence, if lime-water be brought under the bell above the ſurface of the quickſilver by which the gas is confined, the volume of air is diminiſhed; and whatever remains of it is the portion

tion of oxygen gas, which during the combuſtion had eſcaped the influence of the coal.

This experiment performed in a different way.

§ 225.

According to *Lavoiſier's* accurate ſtatement, 72 parts (by weight) of oxygen gas are in this experiment conſumed by 28 parts of charcoal; and both form together a new compound, conſiſting of 100 parts (by weight) of this kind of gas, which is abſorbed by lime-water and cauſtic alkaline lye.

§ 226.

This gas, thus generated by the burning of charcoal in vital air, is called *carbonic-acid gas.* It is remarkably different from others by its greater ſpecific gravity (a Pariſian cubic inch of it weighing 0,68985 French grains); by its unfitneſs for reſpiration, and the maintenance of combuſtion; by its acidity, detecting itſelf by reddening the tincture of litmus; and by being abſorbed by cold water, and (what is done by no gas hitherto treated of) by its making lime-water turbid.

Synonyma: *Fixed air, aerial acid gas, aerial acid, chalky acid gas (aër fixus, gas acidum aëreum, acidum aëreum, gas acidum cretæ)* gas ſylveſtre, vinoſum muſti of *Van Helmont.*

§ 227.

Like all other kinds of air, the carbonic-acid gas has for its principles a peculiar ponderable baſis and caloric. The firſt has obtained the name *carbonic acid.* The abſorption of this gas by cold water, lime-water, and cauſtic lye, conſiſts in theſe liquids taking in within themſelves its ponderable baſis, while at the ſame time they diſengage its caloric, and conſequently the gas is decompoſed. Free carbonic acid, at the preſſure of air, and at the temperature which we live in, is aeriform. On its extrication, it immediately aſſumes the aerial ſtate.

§ 228.

Carbonic acid (§ 227) is one of the radicals, or conſtituent parts of a vaſt many bodies. It exiſts in ſeveral foſſils, and eſpecially in crude calcareous earths, as chalk, common lime-ſtone, and marble; from which it may be extricated in the form of gas by other acids of ſuperior affinity with calcareous earth; and thus chalk is advantageouſly employed to produce carbonic-acid gas. This acid may likewiſe be extricated by fire from bodies containing it, as will be ſeen hereafter: and it is this ſame acid which cauſes the frothing in ſome acidulous ſprings, in ſparkling wines (*vins mouſſeux*) as Champaign, in bottled beer, and at every vinous fermentation. It is, beſides, generated by breathing; and the exhaled air never fails to contain ſome carbonic-acid gas.

§ 229.

The carbonic acid itſelf is evidently a product from *coal*, or *radical carbon* and *oxygen*; becauſe the carbonic-acid gas, generated when charcoal is burnt in vital air (§ 224), weighs exactly as much as the ſum of the weights of the coal (not accounting its aſhes) and of the oxygen gas that were conſumed in the proceſs. At the temperature requiſite to ignition, it attracts and takes into its bulk the oxygen, or baſe of oxygen gas, and diſengages the fire of the latter, *viz.* the caloric combined with light (§ 209).

§ 230.

Carbon, or pure coal (§ 229), is in the antiphlogiſtic ſyſtem a ſimple ſubſtance (the earthy and ſaline particles making its aſhes being conſidered as foreign, and intimately mingled with it). *Coal* is taſteleſs, inſoluble in water, not volatile, infuſible, and indeſtructible in the moſt vehement fire, if air be excluded. It requires a high temperature in order to decompoſe oxygen gas; and its affinity with oxygen is ſo great, that even in a red heat it deprives a vaſt multitude of other burnt bodies of their oxygen, rendering them again ſuſceptible of ignition;

ignition; whence it is ſaid to *diſoxyde* thoſe bodies. This radical abounds in all animal and vegetable bodies, and in their proximate conſtituent parts (§ 7). It exiſts alſo in crude iron, ſteel, and eſpecially in graphite, or black-lead. From this cauſe it is that ſome carbonic acid is formed in the conflagration of all combuſtible matters, of both the animal and vegetable kingdoms.

According to the *phlogiſtic ſyſtem, carbon* is not a ſimple ſubſtance, but a compound of *phlogiſton,* and the peculiar *ſubſtratum* or baſis of *carbon,* which in the liſt ſubjoined to § 8 we have called *carbonic radical.* Hence alſo, in the opinion of phlogiſtians, *carbonic-acid* is a compound of this *baſis of carbon* and *oxygen.*

§ 231.

When charcoal is burnt in common air, there remains not only the azotic-air, but alſo the then newly generated carbonic-acid gas. This formation of the latter is the true cauſe why coal burning in an incloſed ſpace of air, whether atmoſpherical or of oxygen gas, is extinguiſhed before all the vital air is decompoſed. From what has been mentioned before, it is eaſy to judge of the pernicious effects upon the life and health of men, ſo frequently cauſed by the burning of charcoal, or, as is the common expreſſion, by the *vapours of charcoal,* in cloſed apartments.

Water.—HYDROGEN.—*And Inflammable Air,* or HYDROGEN GAS.

§ 232.

Water exiſts in nature in a triple form: as ſolid water, or *ice*; as a liquid fluid, or *water*, properly ſo called; and as an elaſtic fluid, or *aqueous vapour.*

§ 233.

Ice is a tranſparent, brittle body, more or leſs regularly cryſtallized, and melting at 32° Farenheit. Its cryſtals, if regular, are needle-ſhaped, croſſing one another at angles of 60 degr.

§ 234.

When ſolid water or ice melts, a conſiderable quantity of caloric is fixed by it (§ 170); which, if it were at once ſuddenly diſcharged from the liquefied water at 32° Farenh. would heat water of the ſame temperature, and of equal weight, nearly to 163° Farenh. Liquid water, therefore, is to be regarded as a combination of a limited quantity of caloric and ice.

§ 235.

Pure water is an uninflammable fluid, without colour, taſte, or odour, and certainly capable of being

ing ſomewhat compreſſed. As has been already obſerved, it is merely by the preſſure of air that water is retained in the ſtate of liquidity at the temperature above the freezing-point.

§ 236.

At the preſſure of the atmoſphere of 28 inches of the barometer, water requires an intenſity of the caloric expreſſed by 212° Farenh. in order to boil, and to be converted into an elaſtic fluid, or *aqueous vapour*. The quantity of caloric fixed by water on its tranſition into the vaporous ſtate, at the uſual preſſure of common air, is very conſiderable.

§ 237.

The aqueous, like every other vapour, loſes its elaſtic form by cooling and compreſſion, and is by them decompoſed. Its baſis parts from the caloric in a moſt finely-divided ſtate, and forms *fog*, which ſhould no longer be called vapour.

Hence are explained the formation of *clouds*, of *fog*, *dew*, and *hoar-froſt*; the viſibility of our breath in winter; the tarniſhing, or, as it is termed, the ſweating of cold bodies in warm and damp rooms; the ſweating of windows, and their freezing in ſuch rooms; the icy incruſtations or hoarineſs of buildings, upon thawing, after froſt has continued for ſome time.

Of the *Hygrometer*.

§ 238.

The atmoſphere is never free from aqueous vapour, which, however, does not injure its clearneſs; it is only the decompoſed vapour, or fog, that makes it thick *. Theſe vapours, by the continual changes of preſſure and temperature of the atmoſphere, are inceſſantly, by turns, decompoſed and regenerated.

§ 239.

It is not only by having its temperature lowered beneath the point of congelation that water loſes its form of liquid fluidity, but it may likewiſe become ſolid by the attractive powers of other matters. In this laſt caſe it alſo gives out part of its fixed caloric, as clearly appears from the *water of cryſtallization* of ſalts and earths.

§ 240.

Water is a ſolvent or menſtruum of a vaſt number of bodies; particularly of ſalts, and ſeveral earths. By means of theſe ſalts it likewiſe becomes a menſtruum for other bodies, which cannot be diſſolved by water alone.

§ 241.

It is from this fact, that only a ſmall quantity of water perfectly pure is met with in nature. To the

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* The reaſon of it is, that it is only the *baſis* of the aqueous vapour, *viz.* water, but not the *vapour* itſelf in *pure elaſtic ſtate*, which produces moiſture.—Edit.

the pureſt waters belong the *atmoſpherical*, eſpecially *ſnow* and *rain-water*; and next to theſe the taſteleſs *ſpring* and *pump-water*, the *ſofter* kinds of which are purer than the *harder*; which laſt derive their hardneſs, as it is ſtyled, from diſſolved earthy neutral ſalts. The waters, called *mineral waters*, are, with reſpect to their predominant contents, ſubdivided into *Acidulous*, *Chalybeate*, *Alkaline*, *Bitter*, *Vitriolic*, *Cement-water*, and *Salt brine-ſprings*; to the laſt of which the *Sea-water* belongs.

§ 242.

To procure pure water, diſtillation is the only effectual means we have. It is neceſſary that this diſtillation ſhould be performed, in veſſels which do not themſelves contaminate the *diſtilled water*.—Pure water is not ſubject to any kind of putrefaction, provided it do not happen to be in contact with organic bodies.

Guyton de Morveau recommends a cheaper and more expeditious way to obtain pure water. *Annales de Chimie* Tome XXIV. p. 317. He collects rain-water, which by its nature is only defiled by ſulphat of lime taken up from the plaſter of the chimneys, tiles, and other pointings of the ridges of the roofs (in France).—Which to diſengage, he filters it firſt, and drops into it a ſolution of barytes, prepared after the manner of Vauquelin's (vid. § 343. n.); until after the precipitation has ſubſided, the laſt drop exhibits no alteration of tranſparency. By the addition of water impregnated

pregnated with carbonic acid, (which however muſt not be in exceſs) the precipitation may be ſuddenly effected.—— *Ed.*

§ 243.

The very old opinion that water might be tranſmuted into earth, which in latter times has been endeavoured to be proved by the growth of plants in ſimple water, and by its earthy ſediment on repeated diſtillations from glaſs veſſels, is at preſent completely done away *.

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* Some plants, even of the moſt ſucculent kind, and in the hotteſt climates, as the *Agave, Cactus, Aloë, Cacalia,* grow on the dryeſt ground *without water.*—The reſiduary matters originated from the diſtillatory veſſels, or were held in ſolution by the water employed.—*Edit.*

§ 244.

Contrary to the ancient idea, water is not a ſimple ſubſtance, but it may be decompoſed or reſolved into heterogeneous principles, and be again compoſed of them.

§ 245.

Take a coated tube made of hard glaſs, put into the middle of its cavity 274 French grains of iron wire, rolled in a ſpiral form, lute to its upper orifice the neck of a ſmall glaſs retort, containing *nearly two ounces* of water, and place this laſt on a ſand bath.—Cauſe then the middle part of the tube,

tube, where the wire is lodged, to paſs ſomewhat inclined through a pan of coals, and lute to its lower end the middle bottle (§ 128.) ſtanding in cold water, and from which the conveying pipe (§ 128.) iſſues, having its other extremity carried under the funnel of the pneumatic trough.—Theſe things being prepared, the middle of the glaſs tube is heated to redneſs, but gradually, while the water in the retort is made to boil, and its vapours thus forced to paſs through the red-hot wire.

By this proceſs, a quantity of a peculiar kind of air, inflammable, and extremely light, is generated. —If there be no defect in the operation, about 416 Paris cubic inches of this inflammable air, weighing 15 French grains will be obtained, after the atmoſpherical air has been ſubtracted. The iron is changed in the tube, being now friable and brittle, or converted into an oxyd (§ 211.) and it weighs 85 grains more than before the operation. The water collected in the intermediate bottle, after the whole quantity is diſtilled over, falls 100 grains ſhort of what has been employed.

If the computation of the quantities be diſregarded, the inflammable air may likewiſe be prepared in a ſurer way, by placing in the middle of a gun-barrel ſome iron wire twiſted ſpirally; by luting to its higher aperture a glaſs retort filled with water; by making then the middle part of the iron tube red hot, and directing its lower end under the funnel of the pneumatic trough.

§ 246.

The inflammable air hereby obtained, is, for reaſons that will ſoon appear, denominated *Hydrogen gas*

This kind of air is the lighteſt of all gaſes that we know of. A Pariſian cubic inch of it weighs at 10° Reamur, and 28 inches of the barometer 0,03539 French grains, and a cubic foot weighs 61,15 grains. It poſſeſſes a peculiar diſagreeable ſmell; is not reſpirable, and extinguiſhes a light immerſed within it; but it is inflammable, and may be ſet on fire by an ignited body, if vital or common air find acceſs to it. In this manner it burns with a flame at the orifice of a bottle, deſcending quicker into the veſſel the wider its aperture is.

Hence if this gas be mixed with about three parts of atmoſpherical air (by bulk), the inflammation cauſed at the mouth of the flaſk by a lighted candle, ſpreads in one moment throughout its whole capacity, and a ſtrong exploſion takes place:—ſtill ſtronger, if one part of oxygen gas be mixed with two parts (by meaſure) of inflammable air. The ſafeſt way of making this experiment is in a bottle of gum-elaſtic.—Theſe mixtures may alſo be made to catch fire by an electric ſpark. Water does not imbibe nor alter hydrogen gas.

§ 247.

In the proceſs by which this gas is generated (§ 245.) the increaſe of weight of the remaining iron, added to the weight of the obtained inflammable air, exactly correſponds to the weight of water which has diſappeared. The natural conſequence of this agreement is, that this part of the water muſt have been ſpent, partly on the alteration of the iron; partly on the formation of hydrogen gas. The changes which the metal had undergone are exactly the ſame with thoſe that take place when it is burnt in vital air; hence *oxygen* muſt be one of the conſtituent parts of water, and the other is the *ponderable baſis of the inflammable air*, thus produced.

By a farther inference, therefore, water muſt again be generated by combining inflammable air with oxygen; and the fact ſupports this concluſion. It is on this account, that this baſis of inflammable air, being the radical of water, has obtained the name of *Hydrogen.*—Conſequently water is a compound of *Hydrogen* and *Oxygen*; and agreeably to the laſt quoted, and other experiments, conſiſts of 0,15 of the former, and of 0,85 of the latter.

§ 248.

The rationale of the proceſs, quoted from § 245, is then the following. In a red heat, iron deprives water of its oxygen, and is thereby reduced to the ſtate of an imperfect calx of iron, whilſt the hydrogen of the water combines with the caloric, and forms hydrogen gas.

§ 249.

This is confirmed by a variation in the foregoing experiment (§ 245). If inſtead of iron, 28 grains (French) of charcoal, well charred and groſsly powdered, are introduced into the tube, 524 Pariſian cubic inches of gas will be obtained, not reckoning the atmoſpheric air of the veſſel; and after the end of the experiment, the coal will be found to have diſappeared, leaving only a ſmall portion of aſhes.—The volume of air obtained conſiſts of 144 cubic inches of *carbonic-acid gas*, ſeparable from the maſs by lime-water or cauſtic lye, and of 380 cubic inches of *hydrogen gas*. The weight of the firſt is nearly 100 grains; and of the ſecond, $13\frac{7}{10}$ grains. The water collected in the intermediate veſſel is $85\frac{7}{10}$ grains leſs than the quantity uſed for the experiment.

As in this inſtance $85\frac{7}{10}$ grains of water diſappear, and 100 grains of carbonic acid are formed; and farther, as the laſt cannot be generated but by the

oxygen,

oxygen, and as 28 parts of carbon require for that purpoſe 72 parts of oxygen (§ 225), it follows, that the 85 $\frac{7}{10}$ grains of water loſt, muſt have transferred 72 grains of oxygen to the coal; and that the remaining 13 $\frac{7}{10}$ grains muſt have formed the ponderable baſis of the inflammable gas, or muſt have been the hydrogen, *viz.* the radical principle of water.—All this agrees again pretty nearly with the above proportion of 85 parts of oxygen to 15 of hydrogen.

§ 250.

In this experiment, therefore, the carbon, aſſiſted by a red heat, robs the water of its oxygen, forming with it the carbonic acid, which flies off in the ſtate of carbonic acid gas; while the other radical of water, the hydrogen, is ſet at liberty, and uniting with the caloric, eſcapes in the elaſtic form, or as hydrogen gas.

§ 251.

The evidence of this concluſion, drawn from analytical experiments, is fully completed by ſyntheſis, or the reproduction of water, by combining the baſis of oxygen gas with the baſis of hydrogen gas.—If with this intention both kinds of air, in the proportion of 15 parts of hydrogen— to 85 of oxygen gas, are ſet on fire in a cloſe veſſel, both gaſes are deſtroyed, and water is again generated, amounting to 100 parts by weight. To perform this combuſtion with proper conveniency, ſome particular kinds of apparatus, called *gazometers*, have been contrived.—That propoſed by Mr. *Van Marum** is the moſt ſimple and commodious.

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* The *Philoſophical Magazine*, Vol. II. for October 1798, page 85, contains a deſcription of it; to which is added, a moſt beautiful copper-plate engraving, executed by the maſterly hand of Mr. *Lowry*. It is much preferable to Lavoiſier's very complicated gazometer.—Ed.

§ 252.

The theory of combuſtion of hydrogen---, in conjunction with oxygen gas, is, according to the tenets of *antiphlogiſtian philoſophers*, as follows:—When both gaſes are mixed at a temperature lower than that of ignition, or red heat, the attraction of their reſpective baſes to the caloric is, in that caſe, ſtronger than their attraction to each other; and, therefore, they are not decompoſed. But, in the heat of ignition, their baſes, namely, oxygen and hydrogen, again attract each other more ſtrongly; and hence they unite to produce water; and both the caloric and light, by which they were retained in the aerial form, are again diſengaged from them, and conſtitute the fire.

In the ſyſtem of the *phlogiſtians*, the baſis of hydrogen gas is compoſed of phlogiſton and hydrogen.

§ 253.

If we eſtimate a Pariſian cubic foot of water at 70 pounds (French) and an equal bulk of hydrogen gas at 61 grains, it then follows, from the preceding proportion of hydrogen to the oxygen in their compound, water, that a cubic foot of water contains 10½ pounds of hydrogen, capable of affording more than 1569 cubic feet of inflammable air.

§ 254.

Water can be decompoſed only when placed in contact with ſuch a body as has an attraction to its oxygen, and of ſuperior force to that with which this laſt is attracted by the hydrogen. For this reaſon water is not decompoſed on its paſſage through ignited ſilver, gold, glaſs, porcelain, or any other incombuſtible matter, but continues to be water.

§ 255.

We are as yet unacquainted with any body capable of decompoſing water by attracting its hydrogen more ſtrongly than it is attracted by the oxygen. Nature, however, ſeems to adopt that way in the vegetation of plants, which, expoſed to the ſun's light, decompoſe the water, abſorb its hydrogen, and ſet free the oxygen, which is extricated from the leaves in the form of oxygen gas *.

* Eſpecially about noon, when they give it out as pure as that obtained from manganeſe. In the night-time they imbibe and digeſt more carbon, and hence yield more carbonic-acid gas.—Edit.

§ 256.

In the ſequel, we ſhall ſhew ſeveral other methods of producing hydrogen gas, and become acquainted with ſeveral varieties of this laſt; all ariſing from this circumſtance, that the hydrogen finds opportunity of diſſolving various other ſubſtances, as ſulphur, carbon, and phoſphorus, which of courſe alter the nature of the hydrogen gas which is generated.

§ 257.

Hydrogen is a ſimple ſubſtance, and not producible by itſelf. It enters not only into the compoſition of water and hydrogen gas, but is likewiſe a conſtituent part of a great variety of other bodies. It is one of the ingredients in the mixture of bitumens, of oils, of fats, of ardent ſpirit, and of all the proximate conſtituent parts of animal and vegetable bodies. Hence it is that all combuſtible ſubſtances of the two organic kingdoms yield, on combuſtion, not only carbonic-acid (§ 230), but alſo water.

CHAPTER III.

Of Salts in general.

Acids.—Alkalis.

§ 258.

THE properties of *common*, or culinary *ſalt*, to be ſoluble in water, and to excite the ſenſation of taſte, are likewiſe poſſeſſed by ſeveral other bodies, which on this account are called *ſalts (ſalia, ſales)*. Yet, to diſtinguiſh them from other bodies, ſeveral earths, for example, not claſſed among the ſalts, we are obliged to characterize the true ſalts more diſtinctly, by ſaying, that they are matters ſoluble in leſs than 200 times their weight of boiling water, and that they excite a taſte on the tongue.

§ 259.

Some ſalts require more, others leſs, of water for ſolution. Moſt of them diſſolve in greater quantities in boiling than in cold water. Some are fixed in the fire, others volatile. Of the laſt there are ſome that by themſelves can never be ſeparated from water.

§ 260.

§ 260.

Solid ſalts ſeparate from their diſſolvent water when its degree of ſaturation is diminiſhed by cooling, or by evaporation, in cryſtalline figures (§ 37); and theſe *ſalt-cryſtals* exhibit a great variety of forms.

§ 261

The cryſtallization of ſalts is effected either by the cooling of their ſolutions that were ſaturated, or nearly ſaturated, when hot; or by the evaporation of their ſolvent medium. The firſt method is not applicable to ſuch ſalts, as do not diſſolve in hot water in far greater quantities than in cold water.

Particular managements on cryſtallizing ſalts in large and ſmall quantities.

§ 262.

The benefit derived from the cryſtallization of ſalts is, that they are obtained in their own peculiar ſhapes, whereby they are externally diſtinguiſhed; that, by this proceſs, they part with all thoſe impurities which either are inſoluble in water, and hence are left behind at the ſolution and filtration, or do not enter into the cryſtals; and, finally, that by this means ſalts of different natures may be ſeparated, becauſe they ſhoot into cryſtals at different times, according to their various degrees of ſolubility.

§ 263.

Salt-cryſtals loſe in heat, and ſome of them even in dry and warm air, their figure and tranſparency, and *fall to powder*, loſing thereby much of their weight. They are then ſaid to *effloreſce*; and this change of form is called *effloreſcence*.

> *Examples:* Cryſtals of Glauber's ſalt, green vitriol, and carbonated or mild mineral alkali.

§ 264.

Since effloreſcent cryſtals regain their former weight and figure by being again diſſolved in water and cryſtallized; and ſince, by diſtilling ſalt-cryſtals, water is driven over into the receiver; this laſt muſt of courſe be one of their conſtituent parts, and be combined with them in the concrete or ſolid ſtate. Such water is, therefore, called *water of cryſtallization*; and is in different ſaline cryſtals united in larger or ſmaller quantities, and in the ſtate of greater or leſs fixity.

§ 265.

The ſpecies of ſalts produced by art and nature are conſiderably numerous; and remarkable differences relative to their properties and actions on other bodies have been diſcovered. Whence it is neceſſary, for a better view of them, to divide this *claſs* of bodies into *orders*, *genera*, and *ſpecies*. I divide them (with regard to their *proximate* conſtituent parts) into two orders: that of the *ſimpler*, and that of the *more compound* ſaline ſubſtances. The genera of the firſt order are: the *acids* and the *alkalis*. Thoſe of the ſecond order are: the *neutral ſalts*, the *middle ſalts*, the *metallic ſalts*.

The *ſweet* ſalts *(ſugar)* are a genus belonging to the firſt order.

Acids.

§ 266.

Acids (acida) are ſalts of a ſour taſte, changing the blue colour of various vegetable pigments to a red.

§ 267.

The blue vegetable pigments are not all, however, turned red by acids.—The *ſyrup of violets*, the *tincture of litmus*, or paper ſtained with it, and alſo the *tourneſol-rags*, as they are called in commerce, are uſed as *re-agents* (§ 144) to diſcover whether a ſubſtance be an acid.—The tincture of litmus, ſo largely diluted with water as to have the appearance of ſky-blue, is of all re-agents the moſt readily affected by acidity.

§ 268.

Some *ſpecies* of acids ſhew their eſſential diſtinction from each other by the different nature of their actions

actions on other bodies. Acids are commonly ſubdivided into *mineral*, *vegetable*, and *animal acids*; yet ſome acids are common to ſeveral bodies of one or more kingdoms in nature.

In the ſequel, we ſhall conſider the following as eſſentially different ſpecies of acids:

1. *Carbonic*
2. *Sulphuric*
3. *Nitric*
4. *Muriatic*
5. *Fluoric*
6. *Boracic*
7. *Phoſphoric*
8. Of *Arſenic*
9. *Molybdic*
10. *Tungſtic*

acid.

11. *Succinic*
12. *Tartareous*
13. *Citric*
14. *Oxalic*
15. *Malic*
16. *Gallic*
17. *Benzoic*
18. *Acetic*
19. *Saccho-lactic*
20. *Pruſſic*

acid.

To which the *Chromic-acid* is now to be added.—Ed.

§ 269.

All acids are compound ſubſtances, and conſiſt of an *acidifiable ſubſtratum* or *radical*, and of *oxygen*, which is regarded as the *acidifying baſis*, or principle of acidity.

Exemplified by the phoſphoric and carbonic acids. The principles of the firſt are phoſphorus and oxygen; thoſe of the ſecond, radical carbon and oxygen.

§ 270.

Acids may, therefore, be decompoſed and compounded. The laſt takes place when an acidifiable radical

radical is under combuſtion, and abſorbs the oxygen of vital air, as was the caſe in the burning of phoſphorus (§ 195. 203), and charcoal (§ 224). The firſt happens when the acid is again deprived of its oxygen by another acidifiable ſubſtance of ſuperior affinity with oxygen; and thus the acidifiable baſis, or the radical of that acid, is reproduced in a ſeparate ſtate.

§ 271.

Some few acids, however, of thoſe that we know at preſent, have not yet been either compoſed or decompoſed; and hence their radical is ſtill unknown.

To theſe belong No. 4, 5, and 6, of the foregoing liſt (§ 268).

§ 272.

Several acids may be compoſed by art, but not again decompoſed.

§ 273.

The different acids are diſtinguiſhed from each other by the nature and diverſity of their acidifiable radicals (§ 269).

§ 274.

The acidifiable baſis of acids is either *ſimple* or a *compound.*

1. To acids having a *ſimple radical* belong, according to the antiphlogiſtic ſyſtem, the

    1. *Carbonic*, whoſe radical is *Carbon.*
    2. *Sulphuric* - - - *Sulphur.*
    3. *Nitric* - - - - *Azot.*
    4. *Phoſphoric* - - - *Phoſphorus.*
    5. Ac. of *Arſenic* - - *Arſenic.*
    6. *Tungſtic* - - - *Tungſten.*
    7. *Molybdic* - - - *Molybdena.*

2. The acids with *compounded radicals* are, all thoſe mentioned above (§ 268, note) from No. 11 to No. 19 incluſive. Their radical is compoſed of *carbon* and *hydrogen.* The acid, No. 20, has a compound quadruple baſis, conſiſting of *carbon, hydrogen, phoſphorus, and azot.*

3. The *unknown radical* of ſome acids (§ 271) is only by conjecture conſidered as *ſimple.*

§ 275.

Acids, whoſe radicals are compoſed of the ſame principles (§ 274, note 2) are diſtinguiſhed from each other only by the various proportions of their component parts; and may, therefore, by altering thoſe proportions, be converted into one and the ſame acid.

§ 276.

The acidifiable baſes are capable of being ſaturated with oxygen in various degrees. If the ſaturation be complete, they are called *perfect acids.* In the *ſcientific nomenclature* the name of theſe

end

end in Latin by *icum*, in Engliſh by *ic*. But if the acidifiable radicals have not taken up as much oxygen as they poſſibly can, they moſtly appear in a ſtate of leſs acidity, and go by the appellation of *imperfect acids*. Their names are ended in Latin by *oſum*, in Engliſh by *ous*.

Examples:

Perfect Acids.		*Imperfect Acids.*	
1. *Sulphuric*	acid.	*Sulphureous*	acid.
2. *Nitric*		*Nitrous*	
3. *Phoſphoric*		*Phoſphoreous*	

§ 277.

It is thought by ſome, that ſeveral acidifiable radicals admit of being over-ſaturated with oxygen; hence ſuch acids have been called *oxygenated acids*, and ſometimes *ſuper-oxygenated*. But they are in fact nothing more than perfect acids (§ 276); for ſuch an over-ſaturation is impoſſible, becauſe oxygen no where exiſts in an uncombined ſtate alone (§ 208).

Thus, in the methodical nomenclature, the *dephlogiſticated muriatic-acid*, as it was formerly called, has obtained the name of *oxygenated muriatic-acid*; but it is only the *perfect muriatic-acid*. The *common muriatic-acid*, which till lately has been taken for a perfect marine-acid, muſt be conſidered merely as an *imperfect muriatic-acid*.—(Note of the *author*.)—Yet the ſame terms are made uſe of in this tranſlation for reaſons ſtated in the preface.—Edit.

§ 278.

If the acidifiable baſis be combined with oxygen, yet without ſhewing any of the properties of an acid, the product is then called *oxyd*. Many ſubſtances, by the abſorption of oxygen, are converted into *oxyds*, but not into *acids*, of which water is a ſtriking inſtance.

Alkalis.

§ 279.

Alkalis (alcalia) poſſeſs a pungent, urinous taſte, and change various blue vegetable pigments to a green; red to a violet, or blue; and yellow to a brown. Blue pigments, that have been turned red by acids, are again reſtored by alkalis to their original colour; and *vice verſa*, the actions of alkalis on ſuch pigments are deſtroyed by acids.

§ 280.

Not all the blue vegetable pigments, for inſtance not the litmus, are converted into a green, by alkalis.—As *teſts*, or *re-agents for alkalis*, are employed the *blue ſyrup of violets*; *paper ſtained red* with a decoction of *Fernambuc*, or *Braſil-wood*; or ſtained *yellow* by the tincture of *turmeric-root*; and, beſides, the *tincture of litmus* reddened by a very weak acid, and alſo the *red alkanet-tincture.*

§ 281.

Theſe ſalts are not found pure in nature, but always combined with other ſubſtances, ſuch as the carbonic or other acids. It is the buſineſs of art to ſeparate them from thoſe matters. Here we ſpeak only of the pure alkalis, which, for their ſolvent power on the cellular membrane and animal fibre, are alſo denominated *cauſtic alkalis.* The means of producing them will be mentioned hereafter.

§ 282.

We are acquainted with three *ſpecies of alkalis:* 1. the *vegetable alkali;* 2. the *mineral alkali;* and, 3. *ammoniac.* The two firſt are compriſed in the common appellation of *fixed alkalis*, as they are not diſſipated by fire; and the laſt is called *volatile alkali*, from its being eaſily raiſed by heat.

§ 283.

1. The *vegetable alkali*, or *pot-aſh*, is a white ſolid ſalt, cryſtallizing in ſtrongly truncated four-ſided pyramids. When in the cryſtalline form it diſſolves in water, producing a conſiderable coldneſs; but after having been dried by fire, or having loſt its water of cryſtallization, it diſſolves with production of heat. The dried ſalt rapidly attracts moiſture from the atmoſphere, and liquifies, or *deliqueſces*; it is alſo eaſily fuſed in the fire, even at a temperature ſo low as 360° Farenh. Its ſolution in

in water exhibits an odour like that of a room newly white-waſhed with lime. It cannot be volatilized by fire. In the ſtate of fuſion it readily diſſolves the ſiliceous earth.

Synonyma: Vegetable alkaline ſalt, alkaline cauſtic-ſtone, ſoap-lees *(alkali vegetabile, lapis cauſticus alcalinus, lixivium ſaponariorum).*

§ 284.

The vegetable alkali has not yet been decompoſed. It is obtained from the aſhes of plants, and from ſeveral other products of the vegetable kingdom; but in theſe it is always united with carbonic-acid.

The tranſlator cannot help adding, that the vegetable alkali has likewiſe been diſcovered in the *leucite,* an earth of the ſiliceous kind, found near Bolzena, Rome, Naples, on Mount Veſuvius, &c. in Italy: the firſt inſtance, indeed, of this alkali being a conſtituent part of a foſſil. We are indebted for that diſcovery to Mr. *Klaproth's* ingenious and induſtrious analyſes of the leucite, who by repeated decompoſitions found that this mineral conſiſts, taking a middle number in 100 parts, of 54 ſilex, 24 argil, 21 pot-aſh.—Vide *Klaproth's Beytrage zur chemiſchen Kentniſs der Mineralkoerper,* 8vo. Berlin, 1797, vol. II. page 39, of which a tranſlation is preparing.

§ 285.

2. The *mineral alkali,* or *ſoda* (*natrum*), with regard to the properties above-mentioned, ſo much

reſembles the vegetable alkali (§ 283), that its eſſential difference from it cannot be ſhewn, except by its combinations with acids, and by its affinities; both different from thoſe of the former, and ſhewing this difference in a very ſtriking manner.

§ 286.

Soda, or mineral alkali, has likewiſe not yet been decompoſed. It is obtained partly from the aſhes of ſome plants growing on the ſhores waſhed by the ſalt-waters of the ſea, or the *ſoda*, as thoſe aſhes are ſtyled in commerce; partly from neutral ſalts, met with in the mineral kingdom, and in which we find it combined with an acid, as for inſtance with the muriatic, in the common culinary ſalt.

§ 287.

3. *Ammoniac (ammoniacum)* is diſtinguiſhed from the former alkalis by a very ſharp, irritating, pungent ſmell, and by its great volatility. We are not able to produce it (pure) in the ſolid form; but it always appears either combined with water, in a liquid form *(liquid ammoniac)*, in which ſtate it is known by the name of *cauſtic ſpirit of ammoniac**; or in the aerial form, and then it is called *ammoniacal gas*. Its compounds are ſolid only when it is combined with acids.

Synonyma: Volatile alkali, urinous ſalt *(alcali volatile, ſal urinoſum)*.

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* The *aqua amoniæ puræ* of the London pharmacopœia.

§ 288.

When very ſtrong *cauſtic ſpirit of ammoniac* is gently heated by the fire of a lamp in a retort of glaſs, placed in communication with the pneumatic quickſilver apparatus (§ 127) the pure ammoniac contained in the liquid ammoniac combines with the caloric, aſſumes the aerial form, and parts from the water. By this means the ammoniacal gas, or alkaline air, as ſome call it, is obtained (§ 287), ſhewing itſelf to be a peculiar ſpecies of air.

§ 289.

The ammoniacal gas is poſſeſſed of a ſtrong, pungent, and almoſt ſuffocating ſmell. Like other alkalis, it produces changes on vegetable colours (§ 274). It is inſtantaneouſly decompoſed by water, which abſorbs its baſis, *viz.* the pure ammoniac, and is thereby transformed into cauſtic ſpirit of ammoniac. It is unfit for reſpiration, and ſpecifically lighter than common air; for a Pariſian cubic inch of this gas at 10° Reaumur, and 28 inch barometer, weighs only 0,27488 French grains. It is diſſolved by the vital, atmoſpheric, and azotic gaſes; but when carbonic acid gas is brought into contact with the ammoniacal, and heated, both gaſes loſe their elaſtic ſtate, and become a concrete ſolid ſubſtance; namely, *carbonat of ammoniac* *, becauſe in this caſe the baſes of the two gaſes combine with each other, and form a product, which at the uſual temperature and preſſure of our atmoſphere does not appear in the aerial form.

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* The *ammonia præparata* of the London pharmacopœia.

§ 290.

Ammoniac is an inflammable ſubſtance. If ammoniacal gas be mixed with oxygen gas, the mixture may be ſet on fire, even by the electric ſpark. Both kinds of air are then decompoſed, and the product of their combuſtion is water and azotic gas.

§ 291.

From this it appears, that ammoniac is a compound of hydrogen and azot. According to Mr. *Berthollet's* experiments, its component parts are 0,807 of azot, and 0,193 of hydrogen.

By the phlogiſtic ſyſtem, ammoniac conſiſts of phlogiſton, azot, and hydrogen.

§ 292.

Such ammoniac as is produced from animal bodies by dry diſtillation (§ 115), or by their putrefaction, did not pre-exiſt in them ready formed; but is only generated by theſe proceſſes, and compoſed of the hydrogen and azot contained in thoſe ſubſtances.

Neutral Salts.

§ 293.

Alkalis and acids ſhew ſtrong attractions for each other; and they combine to form together new ſpecies of bodies, which do not exhibit the properties of their conſtituent parts; and where both the acids and alkalis no longer act, or ſerve as re-agents, in the capacity of acid or of alkali. The product ariſing from the combination of an acid with an alkali, and where neither the one nor the other has any exceſs, is called a *neutral ſalt.*

Experiment: By ſaturating nitric-acid with pot-aſh.

§ 294.

Each acid produces with each of the three alkalis a particular neutral ſalt. The number of the laſt may therefore be found by multiplying the number of the acids which we know, by *three*, the number of the alkalis.

§ 295.

The diſtinctive properties of the different neutral ſalts are their taſte, figure, ſolubility, and fixity, or volatility.

§ 296.

All acids have, in every reſpect, a nearer affinity with the fixed alkalis (§ 282) than with ammoniac; and in many caſes they likewiſe poſſeſs a ſtronger attraction for the vegetable than for the mineral alkali.

CHAPTER IV.

Earths.

§ 297.

EARTHS (Terræ) are incombuſtible bodies, fixed in the fire, and, without ſome intervening medium, inſoluble in 200 parts (by weight) of boiling water.

§ 298.

Simple Earths (Terræ ſimplices) are thoſe which do not admit of any farther decompoſition into heterogeneous conſtituent parts. In nature they are always found united amongſt themſelves, or with other ſubſtances.

§ 299.

We are at preſent acquainted with *eight* different ſimple earths: 1. The *Siliceous*; 2. *Calcareous*; 3. *Magneſian*, or Talcy; 4. *Argillaceous*, or Aluminous; 5. *Ponderous*, or Barytic; 6. *Strontian*; 7. *Circon*; 8. and *Auſtral Earth.*

The Auſtral earth ſhould be eraſed from this liſt § 349. n. and *Glucine* added.—Ed.

Middle

Middle Salts.

§ 300.

Moſt of theſe earths unite with acids in a way ſimilar to that of alkalis. They deprive them of their acidity, and render them incapable of acting as acids. Such earths are, the calcareous, magneſian, argillaceous, and ſtrontian. For this property they are alſo ſtyled *alkaline* or *abſorbent* earths, and the product ariſing from their combination with an acid is called a *middle ſalt (ſal medium)*.

§ 301.

The middle ſalts are, as to their external qualities, very analogous to neutral ſalts (§ 293). They are diſtinguiſhed from each other as well by the difference of their earthy baſis as by that of their acid; and each alkaline earth produces with each different acid a particular middle ſalt. Yet ſome of theſe combinations are of ſo difficult a ſolubility as prevents them from being claſſed with ſalts (§ 258), and aſſigns them a place among ſtones and earths*.

* For inſtance: *Gypſum, Lime-ſtone.*

§ 302.

Each of the acids takes up only a certain fixed quantity of any alkaline earth. A middle ſalt, to be a true perfect ſalt of that kind, muſt contain no exceſs

ceſs either of the acid or of the earth. There are, however, ſome middle ſalts, that are employed only when they have a redundancy of acid.

§ 303.

The alkaline earths do not all poſſeſs an equal degree of affinity with acids. Some of them ſurpaſs, others are in this reſpect ſurpaſſed, by the alkalis.

Of Siliceous Earth. Glaſs.

§ 304.

The *ſiliceous earth (ſilex)*, or *flint*, is the predominant conſtituent part of thoſe earths and ſtones, called ſiliceous. It is found in its pureſt ſtate in *quartz*, *quartz-ſand*, and *rock-cryſtal.* By itſelf it is inſoluble in water and acids, except the fluoric; it is deſtitute of taſte, and infuſible.

§ 305.

Yet however refractory in the fire the ſiliceous earth may be when alone, it is eaſily rendered fuſible by the aſſiſtance of fixed alkalis, pot-aſh, or ſoda. Theſe diſſolve it in a heat ſtrong enough for fuſion, and unite with it to form a new compound, *glaſs.*

§ 306.

Whence *glaſs (vitrum)* is a combination of the ſiliceous earth and a fixed alkali. The earth acquires fuſibility from the alkali, and the alkali loſes thereby its ſolubility in acids and in water. The more alkali is added to the compoſition, the ſofter and more fuſible becomes the glaſs ; but at the ſame time it is rendered leſs capable of reſiſting the action of water and acids. The goodneſs of glaſs depends on the purity of its ingredients, on their juſt proportion to each other, and on their being long kept very liquid during the fuſion.

§ 307.

Common *green glaſs* is made by fuſing together ſand and aſhes containing alkali. For the whiter and finer *cryſtal glaſs*, pot-aſh, ſoda, and the purer kinds of ſiliceous earth, quite free from ferruginous matters, are uſed. Some other additions are at times admixed, partly to ſerve as fluxes to the ſilex, partly to give a greater denſity to the glaſs, and partly to deſtroy the combuſtible matters of the ingredients. Theſe additions are various in the different glaſs-manufactories, ſuch as gypſum, litharge, nitre, white arſenic, and the black oxyd of manganeſe.

§ 308.

The ingredients deſtined for the compoſition of glaſs by melting are previouſly well comminuted and

and mingled.—This maſs, called *frit*, is firſt, by continued agitation, thoroughly ignited and calcined in the calcining furnace, for the purpoſe of driving off the carbonic acid gas, which otherwiſe would cauſe ſmall cavities, or air-bubbles in the body of the glaſs. The *glaſs pots* or veſſels made of baked and refractory clay, are then filled with the *calcined frit*, ſtanding in the *glaſs-furnace* on an elevated flooring, called the *bench*, in ſuch a manner that they may be come at by the glaſs-maker by means of *holes*, or *apertures*, in the furnace. The frit is here melted by the fire, and its fuſion kept up until the whole is well incorporated, and flows in a ſufficiently thin ſtate as an homogeneous maſs, called *glaſs-metal*, and until, on trial, no more bubbles appear. The extraneous ſalts that are contained in the pot-aſh, and are not vitrified by the fuſion, but float above the metal, are carefully taken off with a ladle, and have received the name of *glaſs-gall (ſel vitri)*.

The glaſs-metal, thus well purified from foreign matters, and in full fuſion, is formed into veſſels of the requiſite ſhape, by blowing and other manual treatment, and alſo ſometimes by being caſt in moulds. To diminiſh the brittleneſs of glaſs thus manufactured, it is again heated in the *cooling furnace*, and then gradually ſuffered to *cool*; which is called *tempering* or *annealing*.

§ 309.

If metallic calces be melted with glaſs they tinge it of various colours:—Thus the common green glaſs acquires its tinge chiefly from the particles of iron, interſperſed in the ſand and aſhes made uſe of. To this ſubject belong the *glaſs-paſtes*, as they are denominated, and the *artificial gems*. Their chief ſubſtance is a pure, hard, *cryſtal-glaſs*, coloured by metallic oxyds. The addition of calx of lead renders the glaſs more fuſible. When oxyd of tin is added, it becomes thereby more or leſs opake. To theſe glaſs-paſtes the *enamel* likewiſe belongs, wherewith metals are covered, and which is either tranſparent or opake, white or coloured; and alſo the pigments uſed in *porcelain* or *enamel-painting*.

A recipe for cryſtal-glaſs.—Take one ounce of pure quartz, make it red hot in a crucible, quench it afterwards in water, and repeat this until it be ſufficiently ſoft to admit of being triturated. Levigate it then finely, and mingle it accurately with half an ounce of pure ſalt of tartar, three drachms of calcined borax, one drachm and a half of flake white, and a ſcruple of nitre.—Put this powder into an aſſaying crucible, luted, and gradually heated. When the frit has been for one hour in fuſion, let it cool by degrees, break the crucible, and take off the clear glaſs.

§ 310.

The more alkali is added to the frit, the more readily the glaſs flows, but ſo much the leſs will it reſiſt the action of acids and water, and the influence of the atmoſphere. Nay, by an over proportion of alkali the nature of glaſs may be ſo changed as to be totally ſoluble in water, and even to deliqueſce in the air.

§ 311.

When, therefore, one part of quartz-ſand, and four parts of purified pot-aſhes are melted, in an iron pot placed before the bellows, till the whole maſs flows uniformly and thinly, a glaſs is obtained which excites a ſharp and cauſtic ſenſation on the tongue; is completely diſſolved by water, and deliqueſces by the mere moiſture of the atmoſphere. The maſs of glaſs thus deliquated in the air, and diſſolved in water, is ſtyled *liquor of flints (Liquor ſilicum).*

§ 312.

Every acid precipitates the ſiliceous earth from the liquor of flints (§ 311); and the precipitate has the appearance of a jelly, as long as it continues moiſt. If the liquor of flints be diluted with a great quantity of water, as for inſtance, in the proportion of 24 parts to one of the vitreous matter, and in this ſtate an acid be poured upon it, no perceptible precipitate will ſubſide, but the ſiliceous earth continues ſuſpended in the fluid, and is inviſible on account of its tranſparency. It may be made to appear by evaporating part of the water.

The

The liquor of flints, on account of its affinity with the carbonic acid, is alſo, in courſe of time, decompoſed by mere contact with air.

Of Calcareous Earth.

§ 313.

Calcareous earth (Calx), or *lime*, is in nature never met with pure, but always combined with an acid, and very frequently with the carbonic, as in chalk, common lime-ſtone, marble, and calcareous ſpar; hence the carbonat of lime is uſually called *crude calcareous earth.* Since the carbonic acid may be ſeparated from it by ignition, this becomes a means to exhibit the calcareous earth in its pure ſtate.

§ 314.

For this purpoſe an earthen retort is filled with clean powdered marble, or other pure lime-ſtone, and being firſt joined with the pneumatic apparatus, it is heated by degrees till the whole maſs is red-hot.—A quantity of carbonic acid gas is diſengaged. The fire muſt be kept up till no more gas comes over. The remainder of the calcareous earth in the retort is now remarkably altered; it effervеſces no longer with acids on ſolution, as it did before; and it has an acrid, burning, alkaline taſte, which it did not poſſeſs before ignition. In this ſtate it is called *burnt*, or *quick lime (calx viva, uſta).*

§ 315.

This quick-lime is to be looked upon as pure calcareous earth; now freed by burning from the carbonic acid and water, with which it was naturally united. Burnt lime produces a ſtrong heat with the water by which it is *ſlacked*; it imbibes and fixes it very firmly; on adding more water it is at laſt compleatly diſſolved, but requires 680 times its weight for ſolution. This ſolution is called *lime-water (aqua calcis vivæ)*, poſſeſſes a pungent alkaline taſte, and acts on vegetable pigments (§ 279) like an alkali.

§ 316.

Lime-water remains unchanged in well-cloſed veſſels; but when expoſed to open air, it is covered with a thin pellicle, called *cream of lime*, which on becoming thicker breaks and falls to the bottom, making room for another new cruſt, till at laſt all the lime is ſeparated.

§ 317.

This cream, formed on the ſurface of lime-water, is again a crude calcareous earth; *i. e.* a carbonat of lime, of no taſte, inſoluble in water, and again effervеſcing with acids. The cauſe of the alterations undergone by lime-water expoſed to air, originates from the carbonic-acid of the atmoſphere, which is powerfully attracted by the pure earth of the lime-water, and whereby the earth is reduced to its former ſtate of crude lime.

§ 318.

The ſame changes take place with quick-lime itſelf when in contact with common air. It gradually attracts not only fixed air, but alſo moiſture from the atmoſphere; and being thereby gradually ſlacked, it falls to powder, and loſes its ſharpneſs.

§ 319.

Calcareous earth is infuſible without addition, even in the ſtrongeſt fire. Added to glaſs-frit it may be melted, and yields with it a milk-white, pellucid glaſs.

§ 320.

The nature of *mortar*, or paſte of lime, ſand, and water, whoſe hardening is a ſpecies of cryſtallization, depends on the abſorption of water by quick-lime, which not only imbibes, but alſo fixes, or tranſforms it into water of cryſtallization. A well-proportioned addition of ſand increaſes the firmneſs of the mortar by adheſion to the calcareous earth. The mortar, to be of good quality, ought to be made of lime properly burnt, which after ſlacking has been carefully excluded from the acceſs of air, and prevented from drying, before it be worked up with ſand. It is only by a thorough drying, after the abſorption of carbonic-acid, that mortar acquires its

its hardneſs. Before drying it is greatly injured by froſt.

Magneſia, or Talcum.

§ 321.

The *magneſian-earth (magneſia)** is a conſtituent part of talc, ſoap-rock, ſteatites, ſerpentine, aſbeſtus, &c. and is never found pure in nature. It exiſts beſides, neutralized, in the Epſom or bitter ſalt, in the mother-lye of moſt brine-ſprings, and in ſea-water.

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* *(Terra muriatica, magneſia ſalis Epſomienſis).* The author, as the reſt of Germans, at preſent, calls it *earth of talc.*—Edit.

§ 322.

The uſual method of procuring pure magneſian-earth is to precipitate it by means of pot-aſh from Epſom ſalt, wherein it is combined with the ſulphuric-acid into a middle ſalt, and is thrown down by the alkali as a carbonat of talc, or *aërated magneſia.*

To effect this any portion, at pleaſure, of Epſom ſalt is diſſolved, by boiling in a large quantity of clean water, and to the ſtrained ſolution a lixivium of purified pot-aſh is ſucceſſively added, till no more precipitate is afforded. The next ſtep is, to boil the

the whole maſs, and to let its fluid parts run through a linen-cloth ſewed in a conical form (the *manica Hippocratis* of former chemiſts). The earth remaining behind in the cloth is once more boiled with much clear water, and returned on the filter. After which it is freed, by edulcoration (§ 13), from all adhering ſaline particles, and laſtly dried.

Magneſian-earth thus obtained is ſtill combined with carbonic-acid, taken up from the alkali, and which is expelled by ignition in a covered crucible. It is now called burnt or *calcined magneſia (magneſia uſta)*; and in this ſtate only, when no longer effervеſcing with acids, it may be conſidered as pure magneſian-earth.

§ 323.

Burnt magneſia is neither cauſtic nor acrid, like burnt calcareous earth (§ 314); it is neither ſoluble in water, nor becomes hot when added to it. It abſorbs again the carbonic-acid gradually from the atmoſphere, and is thereby again rendered effervеſcent with acids. By alkalis it is not diſſolved in the humid way. When alone it does not melt in common fire. Mingled with ſiliceous and calcareous earths, it melts in a ſtrong heat.

Of Alumine, or Argillaceous-Earth.

§ 324.

Argillaceous earth, or *alumine (argilla)*, is a component part of argil and every ſpecies of clay; but ought not to be confounded with the *clay* itſelf, in which it is always united to ſiliceous-earth. Hitherto it has not been found pure any where, except in the gardens of the *Pædagogium* (public ſchools) at Halle.

> *Synonyma:* Aluminous-earth *(terra aluminis)*; pure argil, pure clay *(argilla pura)*.

§ 325.

Though argillaceous-earth may be diffuſed, ſuſpended, or divided in water into uncommonly fine particles, it is, however, not ſoluble in it. With a ſmall quantity of water it forms a tenacious, ductile, kneadable paſte, which ſhrinks very much by drying, and proportionally in all its dimenſions; and when ſuddenly brought into ſtrong fire, before it is completely dry, it cracks, burſts, and flies in pieces. If, after being thoroughly dried, it be baked in the fire, it contracts a great deal, and receives by burning ſuch a degree of hardneſs as to ſtrike fire with ſteel. Clay, when baked, however finely pulverized, is no longer capable of being kneaded with water into a ductile paſte.

§ 326.

With carbonic-acid the aluminous-earth has no affinity. One of its moſt characteriſtic properties is, that it is diſſolved by alkalis in the humid way, and conſtitutes with them ſeveral compounds, which again are decompoſed by acids, though ſome of them only in part.

To theſe belong

1. *Argillaceous pot-aſh*;
2. *Argillaceous ſoda*;
3. *Argillaceous ammoniac.*

§ 327.

Alumine poſſeſſes a powerful attraction to calcareous-earth, ſo much ſo, that it deprives lime-water of it entirely, if, when recently precipitated and pure, it be mingled and agitated with it.

§ 328.

The moſt intenſe heat of a furnace is not able to melt argillaceous-earth alone; but it becomes fuſible when lime is added.

Uſe of Clay for Pottery-Ware.

§ 329.

Clay is indebted to the argil which it contains for ſome of its principal characters, ſuch as its ſoftneſs and greaſy feel, its ductility or clammineſs on being worked up with water, its ſhrinking and contraction while drying and baking. It is always united with ſiliceous-earth, which, even without exception, is its predominating conſtituent part. *Pure clay* conſiſts only of argillaceous and ſiliceous-earth; it is *fatter* in proportion as it contains more of the firſt, and *poorer* or more *meager* according as the ſilex abounds. By itſelf it is not fuſible in fire, does not efferveſce with acids, and turns completely white by burning. Lime, magneſia, gypſum, ſparry fluor, and ponderous ſpar, promote its fuſion.

§ 330.

Clay is commonly mingled with more or leſs of calcareous, ſiliceous, ferruginous, and alſo fine bituminous particles; and for this reaſon all ſorts of clay are not infuſible and colourleſs. The yellow or red colour, after baking, always proves the preſence of iron. Clay may be purified from ſand and groſſer ſiliceous parts by elutriation (§ 12).

What is the cauſe of the odour of ſome ſpecies of clay on breathing upon them?

§ 331.

In common life clay is uſed for a variety of purpoſes, according to its greater or leſs purity; and, what depends on this, according to its colour and capacity, or incapacity of fuſion.

§ 332.

The baſer ſorts of clay, eſpecially the coloured ones, are employed for making *tiles* and *bricks.* With this view the clay is wrought with water, interſperſed and mingled with ſand, ſhaped in moulds, dried in the air, and burnt either in particular *brick-kilns*, or in ſuch as are united with lime-kilns. In bricks that are commonly ſold this great defect occurs, that they are manufactured of clay containing too much calcareous-earth; which, therefore, melts in the fire. For this reaſon theſe bricks are but ſlightly burnt; whence they do not reſiſt moiſture and the decay produced by the influence of air.

§ 333.

The common fire-proof, or refractory clay, is uſed in the manufactures of *common pottery.* After having undergone the proper preparations by waſhing, and kneading with water to a due conſiſtence and fineneſs, it is formed on the wheel into veſſels, which, after being gradually dried in the ſhade, are coated with oxyds of lead, as litharge, on ſuch parts as are intended to be glazed, and finally baked

in

in the potter's furnace or kiln; where, at the ſame time, the calces of lead melt to a glaſs, which covers the ſurface of the veſſel like a varniſh. The common fault found with ſuch goods is their not having been ſufficiently burnt.

Of glazing with lead in regard to health, and its remedy.

§ 334.

Good refractory clay, with an addition of ſand, is likewiſe the material for *melting-veſſels* (§ 101). Pure, uncoloured clay, which is not too meager, is employed for making *tobacco-pipes*.

§ 335.

Such pottery-ware as is manufactured of purer and finer clay, and coated with better glazing, is what is termed *fayence*, or *ſpurious porcelain.* For this manufacture the clay is firſt properly prepared by waſhing and kneading. The veſſels formed of it are then fully dried in the air, and firſt ſlightly burnt, to be afterwards coated with the *glazing-powder.* This laſt is done by dipping the veſſels into water, which holds the finely-pulverized glazing materials diffuſed; the veſſels, when withdrawn, imbibe the water, and the glazing materials remain uniformly fixed on their ſurface. When again completely dry, they are placed in earthen *ſaggars (caſſettes)*, or covered pots, and once more expoſed to a heat ſufficiently ſtrong to flux the fuſible parts of the glazing ingredients; while, at the ſame time, the clay-veſſel under them is burnt to hardneſs. The glazing of pottery, owing to its calx of tin, is not tranſparent.

> *The uſual compoſition for glazing:* 1 part of quartz-ſand, $\frac{3}{4}$ parts of pot-aſh, 2 parts of calx of lead, and 1 to $1\frac{1}{4}$ part of calx of tin.

§ 336.

The genuine *ſtone-ware*, or *ſtone-porcelain*, is compoſed of that kind of clay which in a ſtrong fire, either by its own nature, or by virtue of ſome additions, gently ſhrinks, but without abſolutely melting. The ſurface of thoſe wares is glazed by volatilizing, in the white heat of the furnace, a certain quantity of common ſalt, the vapours of which produce a kind of glazing on the ſurface of the clay. The *ſaggars* in which this manufacture is burnt are perforated. If the clay be too fat, or contains too much argil to make it fit for ſtone-ware, it is corrected by adding powdered flint, or ſometimes marle, fluor-ſpar, or chalk. A great deal of what is at preſent ſold for porcelain, is nothing but ſtone-ware. It is eaſy to diſcern theſe two ſpecies by their fracture. The bottles intended for holding Seltzer-water are true ſtone-ware, though of an inferior kind.

§ 337.

By *genuine*, or true *porcelain*, ſuch pottery-ware is underſtood as is infuſible in the ſtrongeſt fire excited in furnaces, is hard, but not ſo brittle as glaſs; proof againſt any ſudden and great changes of heat and cold; finely grained, denſe, and without gloſs on the fracture, not glaſſy, and of a peculiar tranſparency.

§ 338.

Several compoſitions of mingled earths may yield a true porcelain by being burnt; and the porcelains of various countries differ really in their mixtures. But the principal baſis of any true porcelain is that kind of clay which becomes white by baking, and which, either by intermingled heterogeneous-earths, or by particular additions, undergoes in the fire an incipient *vitrifaction*, in which the true nature of porcelain conſiſts. Feld-ſpar and gypſum, if added, may give that property to infuſible clay.

§ 339.

When porcelain is to be made, the clay is properly ſelected, carefully elutriated, and again dried. It is then finely ſifted, and moſt accurately mingled with quartz, ground very fine; to which there is beſides added ſome burnt and finely pulverized gypſum. This maſs is worked with water to a paſte, and duly kneaded; it is uſually ſuffered to lie in this ſtate for years; and is, beſides, wetted with certain (perhaps quite unneceſſary) *corroſives*, that are kept ſecret. The veſſels and other goods formed of this maſs are firſt moderately burnt in earthen pots to receive a certain degree of compactneſs, and to be ready for glazing.—This glazing conſiſts of an eaſily melting mixture of ſome ſpecies of earths, as the petroſilex or chert, fragments of porcelain, and gypſum, which, when fuſed together, produce a cryſtalline, or vitreous maſs, that after cooling is very finely ground, and ſuſpended in a ſufficient quantity of water. Into this fluid the rough ware is dipped, by which the glazing matter is depoſited uniformly on every part of its ſurface. After drying, each article is placed in a ſeparate *caſſette*, and thoroughly baked or burnt in the violent heat of the *porcelain-furnace*.—It is uſual to decorate porcelain by paintings; for which purpoſe enamels or paſtes, coloured by metallic oxyds (§ 309), are uſed, ſo eaſy of fuſion as to run in a heat leſs intenſe than that in which the glazing of the ware melts.

§ 340.

To the above the *porcelain* invented by *Reaumur* is analogous, which may be made of glaſs by a kind of *devitrifaction*; that is, by depriving it in part of its vitreous qualities. For when glaſs, beſt of all hard and green glaſs, is put into a veſſel, and covered all over with burnt gypſum, or ſand, or lixiviated aſhes, or calcined and pulverized bones, or lime *, and in this ſituation expoſed to fire, increaſing

creaſing its vehemence gradually till the glaſs be thoroughly ignited, firſt for a ſufficient time in red-heat, and at laſt in white-heat; it will then be found converted into a ſpecies of porcelain.

§ 341.

To explain the cauſe of the formation of this porcelain, we muſt recollect that glaſs is a compound of fixed alkali and ſiliceous earth (§ 306, ſeq.) When, therefore, in the above proceſs (§ 340) the red-heat is long continued, part of the alkali melted by heat exſudes, and the remaining part is incapable of effecting a total vitrification of the ſiliceous-earth in the glaſs uſed for the experiment. Hence the glaſs is compelled to aſſume the ſtate of porcelain, or ſemi-vitrification. The cementing ſubſtances are, in this caſe, of no other ſervice than that of preſerving the figure of the body intended to be *devitrified.*

Ponderous Earth, or BARYTES.

§ 342.

Ponderous or heavy *earth (barytes)* * is always found in combination with acids; as with the ſulphuric *(ponderous ſpar)*, or with the carbonic *(witherite).*

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* Theſe bodies are in this caſe called *cementing ſubſtances,* not to be confounded with the *cementing powders* (§ 82).—Edit.

(witherite). To procure it pure, art muſt be employed.

* *Terra ponderoſa officin.*

§ 343.

For this purpoſe one part of white and pure ponderous ſpar, reduced to a ſubtile powder, is accurately blended with three parts of ſalt of tartar, and together with this addition kept in a covered crucible for ſome hours in a red-heat. After the concrete maſs has grown cold, it is pulverized, and boiled in diſtilled water, till the filtered lye abſolutely ceaſes to give any ſaline taſte: The earth remaining in the filter is then diſſolved in muriatic-acid, and ſuffered to cryſtallize. The tabular cryſtals are ſelected and diſſolved in diſtilled water, and precipitated from the ſolution by means of pure carbonated alkali; whereupon the precipitated earth is properly edulcorated. It is now pure ponderous earth, combined only with carbonic-acid, of which it may be freed by continued ignition.

> The beſt method of obtaining ponderous earth in its utmoſt purity ſeems to be that of *Vauquelin* and *Fourcroy*, in the *Annales de Chimie*, Tome XXI. page 276, by decompoſing nitrat of barytes (§ 489) by the action of fire. *Nicholſon* has given a tranſlation of that method in his excellent *Journal of Natural Philoſophy, Chemiſtry, and the Arts*, Vol. I. page 535. —Edit.

§ 344.

This pure and burnt barytes is not fuſible by itſelf. Water diſſolves it in but very ſmall quantity; one part of the earth requiring 900 parts of water to be diſſolved *. The ſolution is pungent to the taſte, and acts as an alkaline ſubſtance on vegetable colours. By expoſure to the air it is rendered turbid, becauſe the ponderous earth attracts the carbonic-acid, and is rendered thereby inſoluble.

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* Yet, when prepared in the manner of *Vauquelin* (§ preceding, note,) it abſorbs water with extreme avidity, melts with a hiſſing noiſe, heats conſiderably, ſolidifies the water, and forms compages like beaten plaſter. Cold water diſſolves one twenty-fifth part of its weight; boiling water more than half.—Edit.

Strontian-Earth.

§ 345.

The *Strontian-earth* exiſts in a foſſil, which, from its native place *Strontian*, in Scotland, has obtained the name *Strontianite*, and in which this earth is combined with carbonic-acid. But it is likewiſe one of the conſtituent parts of ponderous ſpar, from which it may be ſeparated, if the fluid muriat of barytes, made for obtaining this earth according to § 343, be farther cryſtallized after the firſt cryſtals in the ſhape of tables, which are the cryſtallized muriat of barytes, have ſhot, and been removed.

For then new cryſtals, needle-ſhaped and radiated, will be formed; and theſe are the muriat of *Strontian-earth*. From this ſolution in muriatic-acid the Strontian-earth may be precipitated by aërated or carbonated alkali.

§ 346.

The natural carbonat of Strontian-earth does not part with its carbonic-acid even in a very ſtrong calcining fire but with exceſſive difficulty. If this acid be artificially combined with it, it may be more eaſily ſeparated. This Strontian-earth, when pure, and conſequently deprived of carbonic-acid, poſſeſſes a corroſive or cauſtic taſte. It is ſoluble in a large quantity of boiling water, *viz.* in 250 times its weight; but it requires more of cold water to be diſſolved. The ſolution taſtes like ſtrong lime-water, and loſes its clearneſs in the air by attracting from it carbonic-acid. The ſaturated ſolution of Strontian-earth made in boiling water, if, after filtration, it be immediately and carefully preſerved in a glaſs-bottle, ſhoots into clear, pellucid cryſtals, of a rhomboidal form and cauſtic taſte; which, however, loſe their tranſparency on expoſure to air.

§ 347.

Strontian-earth is, without addition, infuſible even in the moſt violent fire; but in a crucible made of clay, it melts with the argil, forming with it a glaſs.

Circon-

Circon-Earth.

§ 348.

The *Circon-earth (circonia)* was diſcovered by Mr. *Klaproth* firſt in the *circon (jargon of Ceylon)*, and afterwards in the *hyacinth*, as a predominant principle and a peculiar ſpecies of earth. It is not ſoluble in water. Acids diſſolve it; yet with the carbonic it has no affinity. By cauſtic alkalis it is not diſſolved in the humid way; it does not melt by itſelf, nor with fixed alkalis; yet with borax it melts, and is converted into glaſs.

Auſtral-Earth.

§ 349.

The *Auſtral-earth (Cambria)* was diſcovered by the late Mr. *Wedgwood* in a kind of earth from *New South-Wales.* It is inſoluble in water, in cauſtic lye, and in acids, with exception of the concentrated muratic-acid, aſſiſted by heat. Simple water precipitates it again from this ſolution. Without addition, the ſtrongeſt fire will not fuſe it.

Terra Sydneia Auſtralis are other appellations for this earth. It is at preſent no longer conſidered as a different ſpecies of earth, ſince Mr. *Klaproth* has by his analyſis found that it is not ſo. Mr. *Charles Hatchet* has alſo examined two ſpecimens, received from Sir *Joſeph Banks,* Preſident of the Royal Society; and the reſult of his ingenious reſearches is, that *this earth has not the properties announced by Wedgwood, but contains much ſilex with alumine, carbonat of iron, and a*

ſmall

ſmall portion of water, or volatile matter, but no other ſubſtance. His paper on this head is inſerted in the Philoſophical Tranſactions for the year 1798, and alſo in *Nicholſon's Journal,* Vol. II. page 72.——Tranſlator.

Glucine-Earth.

To the above earth *glucine* is at preſent added. It is white, inſipid, inſoluble in water, but ſoluble in moſt of acids, and likewiſe in fixed alkalis; adheſive to the tongue, infuſible *per ſe*, but with borax fuſible into a tranſparent glaſs.—The following are ſaid to be its *ſpecific characters:* 1. Its ſalts are ſaccharine; 2. it is very ſoluble in the ſulphuric-acid by exceſs; 3. it decompoſes the aluminous ſalts; 4. is ſoluble in carbonat of ammoniac; 5. is completely precipitated from its ſolutions by ammoniac; 6. and its affinity for the acids is intermediate between magneſia and alumine.

As none of the known earths unite the laſt-mentioned ſix properties, *Vauquelin* conſiders it as a diſtinct earth. He diſcovered it on analyſing the beryl, and called it *earth of beryl,* of which it conſtitutes 16 parts in 100. He alſo found it in the *emerald of Peru.* It has ſince been called *glucine,* from the Greek word *γλυκυς* (ſweet), on account of its moſt characteriſtic property of forming ſaccharine ſalts. Future experiments muſt ſhew whether this ſubſtance may maintain its place among the earths as a diſtinct ſpecies.—See Annales de Chimie XXVII. page 155 and 170 ſeq.; or *Nicholſon's Journal,* Vol. II. p. 358 and 393.—Edit.

CHAPTER V.

Mineral Acids, and their Combinations with Alkalis and Earths.

Carbonic Acid.

§ 350.

WE have already (§ 227) become acquainted with the *carbonic acid*, as the baſis of carbonic acid gas. This acid is always in the aërial ſtate, at any temperature and at any preſſure of the atmoſphere which we know of, and cannot be produced, or exhibited by itſelf in a denſe, concentrated, fluid ſtate.

Dr. *Black*, of Edinburgh, in the year 1755, firſt noticed this air in crude lime. *Macbride*, in 1764, and *Jacquin* confirmed it by new experiments. *Prieſtley* ſet the matter in the fulleſt light, and *Bergman*, in 1772, demonſtrated that this gas was of an acid nature, and called it *aërial acid*.—Ed.

§ 351.

The aëriform carbonic acid is procured, in the eaſieſt way, by diſſolving chalk or marble in diluted ſulphuric acid; and the proceſs is performed in a *diſengaging bottle* (128) placed in conjunction with the pneumatic apparatus.

§ 352.

Fixed air, or carbonic acid gas, is abſorbed by cold water; that is to ſay, cold water deprives the caloric of its baſis (§ 227), and conſequently decompoſes the carbonic acid gas. Water imbibes, at the temperature of 50° Fahr. about an equal volume of this gas. This kind of ſolution is promoted by ſhaking. By warmth and heat the attraction of carbonic acid for caloric is made ſtronger than for water; and hence the acid is again extricated from the water, in the form of bubbles. *Carbonated water* [*], or water impregnated with fixed air, therefore loſes, by boiling, all its carbonic acid; which, beſides, is ſeparated from it by freezing, or by the action of the *air-pump.*

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[*] Alſo called aërated water *(aqua aërata).*

§ 353.

The ſourneſs or acidity of carbonic acid, in water ſaturated with it, is but weak; and the acid ſhews its preſence by turning the blue tincture of litmus red. The *acidulous mineral waters,* as that of *Eger, Seltz, Pyrmont,* &c. are natural ſolutions of carbonic acid in water; which, by virtue of this acid, hold ſome other matters in ſolution, which could not be diſſolved by pure water.

Artificial preparation of aërated acidulous waters.

§ 354.

Carbonic acid combines with alkalis and earths to form neutral and middle ſalts called *carbonats*, or carbonated ſalts; whoſe diſtinguiſhing characters are, to efferveſce with thoſe acids which are poſſeſſed of greater affinity with alkalis than carbonic acid. Alkalis neutralized by carbonic acid have alſo been called *mild*, in contradiſtinction to *pure* or *cauſtic* alkalis.

§ 355.

It is on account of this ſtronger attraction to carbonic acid, that this gas is more rapidly decompoſed by alkalis and alkaline earths than by ſimple water (§ 352). If therefore cauſtic lye, or lime-water, be poured into a glaſs containing this gas, and the veſſel be corked and well ſhaken, a vacuum immediately takes place. In this way it is eaſy to ſaturate cauſtic lye with carbonic acid, and ſtill more commodiouſly by the apparatus of *Pelletier* *.

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* *Neues Journal der Phyſik*, Vol. I. page 265. (Publiſhed by the author).—*Welther* has deſcribed an apparatus for ſaturating pot-aſh and ſoda with carbonic acid. The intention of this apparatus is to afford an uninterrupted contact between the alkali and carbonic-acid gas, and to proportion the diſengagement of the gas to its fixation.—*Welther*'s paper has been given tranſlated from the *Annales de Chimie* XXVII. p. 53. in *Nicholſon*'s Journal, Vol. II. p. 369.—Ed.

§ 356.

1. *Carbonat of Potaſh*, or the mild vegetable alkali, cryſtallizes in four-ſided oblique columns,

terminated by two ſurfaces obliquely truncated. The cryſtals do not deliqueſce, or decay in air. Their taſte is alkaline, but not cauſtic. They ſtill act on vegetable pigments as if they were mere alkali. Water diſſolves at 50° Farenh. $\frac{1}{4}$ of its own weight of them, but in heat $\frac{5}{6}$. The cryſtals of this ſalt contain, according to *Pelletier*, 0,40 parts of pure vegetable alkali, 0,43 of carbonic acid, and 0,17 of water.

> *Synonyma:* Aërated vegetable alkali (*alkali vegetabile aëratum*).

§ 357.

Common pot-aſh (cineres clavellati) or mild vegetable alkali, obtained by lixiviation from the aſhes of plants, is already by nature combined with carbonic acid, becauſe that acid is produced in the combuſtion of plants (§ 230); and for that reaſon it effervesces with acids. *Pearl-aſhes,* or *depurated pot-aſh (cineres clavellati depurati),* and *ſalt of tartar (ſal tartari),* are only in part carbonats; and hence are deliqueſcent in the air, *(oil of tartar, oleum tartari per deliquium)* and, beſides, of a more acrid taſte.

§ 358.

Our atmoſphere is always impregnated with a portion of carbonic acid gas; hence a lixivium or lye of pot-aſh is, by long expoſure to air, converted into a carbonat, and becomes cryſtallizable.

§ 359.

By heat, the carbonat of pot-aſh is deprived of its carbonic acid, and water of cryſtallization. Nevertheleſs it is difficult totally to diſcharge the alkali of that acid by a mere red-heat.

§ 360.

2. The *carbonat of ſoda*, or the mild mineral alkali, forms cryſtals of four-ſided columns, having their ends, in oppoſite directions, obliquely truncated. By this, all the lateral ſurfaces of the column are pentagons. According to *Bergman*'s ſtatement, they contain 0,20 of mineral alkali, 0,16 of carbonic acid, and 0,64 of water; they effloreſce in dry and warm air, or fall to a white powder; they excite an alkaline taſte on the tongue; are re-agents with vegetable colours; and require, at the temperature of 50° Farenh. 2,4 parts of water for ſolution, but ſcarcely an equal quantity of it when boiling.—The properties of this neutral ſalt, when expoſed to fire, are like thoſe of the laſt § 359.

Synonyma: Salt of ſoda (*ſal ſodæ*), aërated mineral alkali (*alkali minerale aëratum*).

§ 361.

The carbonat of ſoda (NATRON, *Trona* of the Egyptians) * is found ready formed by nature in various

various countries: in upper *Hungary*, *Egypt*, *Fezzan*, *Perſia*, the *Eaſt Indies*, *Siberia*, and eſpecially at the bottom of *ſalt-ſeas*, dried up by the ſun's heat; and alſo in ſome mineral waters, as in that of *Eger* on the frontiers of *Bohemia*. It is, beſides, obtained by lixiviation from *ſoda*, or the aſhes of various plants growing on the ſea-ſhore and impregnated with ſalt.

By the word *natron*, the ancients probably underſtood the ſame ſubſtance; and this name of *natron præparatum*, procured from the lye of the *Barilla*, is given to it in the *Lond. Pharmac.*—Edit.

§ 362.

According to *Bergman*, the carbonic acid has not ſo near an affinity with the mineral as with the vegetable alkali.

§ 363.

When ammoniacal (§ 287) and carbonic acid gas are mixed over mercury, in the pneumatic apparatus, both gaſes quit their elaſtic ſtate, and their baſes unite into a concrete ſalt, *the carbonat of ammoniac*; while at the ſame time their fixed caloric is ſet free. If very ſtrong liquid ammoniac (§ 287) be poured into a bottle filled with carbonic acid gas, and afterwards ſtopped up, a carbonat of ammoniac will be formed, ſhooting into cryſtals, and the gas diſappears.

Synonyma: Aërated volatile alkali (*alkali volatile aëratum*), volatile ſalt of ammoniac (*ſal volatile ſalis ammoniaci*).

The London College of Phyſicians orders this ſalt to be prepared by depriving muriat of ammoniac of its marine acid by chalk; which in the proceſs exchanges for it its carbonic acid. It calls the product, *ammonia præparata.*—Edit.

§ 364.

The cryſtalline figure of carbonated ammoniac is not well decided: *Romé de Liſle* aſſerts it to be a four-ſided, compreſſed, truncated column, terminated by a dihedral ſummit. Theſe cryſtals have a ſtrong, pungent taſte and odour; vegetable colours are affected by them; and they contain, as appears by *Bergman's* analyſis, 0,43 ammoniac, 0,45 carbonic acid, and 0,12 of water. This ſalt is volatile in heat; yet without being decompoſed.

§ 365.

Ammoniac has not ſo ſtrong an attraction for carbonic acid, as the two fixed alkalis have.

§ 366.

The carbonic acid gas is no leſs decompoſed by lime-water than by cauſtic alkalis, ſince the carbonic acid combines with calcareous earth. And becauſe the carbonat of lime ariſing from this combination is inſoluble in water, the lime-water muſt, of courſe, be thereby rendered turbid (§ 317.)

§ 367.

§ 367.

4. This *carbonated calcareous earth*, known likewiſe by the name of *crude calcareous earth (calx cruda)* abounds in nature, in the various forms of chalk, lime-ſtone, marble, calcareous ſpar, &c. It is devoid of taſte, and inſoluble in water. It is therefore beyond the power of art to exhibit it in the cryſtalline form, as is often done by nature. The component principles of the tranſparent calcareous ſpar are ſaid by *Bergman* to be 0,54 calcareous earth, 0,36 carbonic acid, and 0,10 of water.

Synonyma: Aërated calcareous earth, or aërated lime *(calx aërata)*, mild calcareous earth.

§ 368.

Carbonat of lime may become ſoluble in water, by an exceſs of carbonic acid; as alſo for this reaſon, water impregnated with fixed air diſſolves the calcareous carbonat. This ſolution is again decompoſed by boiling; as the ſuperabundant carbonic acid is cauſed, by heat, to fly off in the form of gas (§ 352).—On this ground depends the formation of calcareous ſediments or incruſtations on the bottom and around the inſide of veſſels, wherein water holding calcareous particles is often boiled.

§ 369.

The carbonat of lime in a continued red-heat, parts with its carbonic acid, and is thus converted into burnt or quick-lime (§ 314).

§ 370.

The carbonic acid has a greater affinity with calcareous earth than with alkalis; and hence the latter are deprived of their carbonic acid by lime. For this reaſon a turbidneſs directly takes place in clear lime-water, when mild, or carbonated alkali is added.

§ 371.

Upon this principle reſts the preparation of cauſtic alkaline lyes, and of cauſtic alkali. For this purpoſe, one part of depurated pot-aſh is boiled with two parts of lime recently burnt, and previouſly ſlaked in a ſufficient quantity of water, and the hot lye is ſtrained through a white linen cloth. This lye ſhould not efferveſce with acids, or cauſe a cloudineſs in clear lime-water, otherwiſe it ſtill contains a portion of carbonic acid.—As a general rule, the proportion of burnt lime to the alkali ought to be regulated by the greater or leſs portion of fixed air contained in the alkali.

> The vegetable alkali thus rendered cauſtic is the *kali purum* of the London College of Phyſicians, to diſtinguiſh it from common potaſh (§ 357), or the *kali impurum*, which, beſides, is in moſt caſes contaminated with vitriolated tartar.—Edit.

§ 372.

Cauſtic alkali precipitates the carbonat of lime, diſſolved in water impregnated with carbonic acid;

but the precipitate is what it was before the ſolution (§ 367), carbonat of lime, or crude calcareous earth.

§ 373.

5. The *carbonated talc or magneſia* has an earthy appearance, is taſteleſs, and ſcarcely, if at all, ſoluble in water. It is procured by the method ſtated above (§ 322), viz. by precipitating a ſolution of Epſom-ſalt by means of a carbonated fixed alkali. On being burnt, it loſes its carbonic acid (§ 322), like calcareous earth.

> *Synonyma:* Aërated talc, or aërated magneſian earth (*magneſia aërata*) *magneſia alba offic.*

§ 374.

By an over-proportion of carbonic acid, the carbonat of magneſia acquires a greater degree of ſolubility in water. When ſuffered to evaporate ſlowly and imperceptibly, this middle ſalt ſeparates from its ſolution in cryſtals of hexagonal priſms, with hexagonal pyramidal terminations, pellucid and taſteleſs, and efloreſcing in a warm air. Their ingredients, according to *Fourcroy*, are 0,25 water, 0,25 earth of talc, and 0,50 of carbonic acid. At a moderate temperature, water diſſolves no more of them than $\frac{1}{48}$ of its weight.

§ 375.

The fixed alkalis, and calcareous earth, exert a ſtronger attraction for the carbonic acid than is ſhewn by magneſia. But *vice verſa*, the attractive power of ammoniac for that acid is weaker than that of magneſia.

§ 376.

6. *Carbonated ponderous earth*, which may be obtained by precipitating it from its ſolution in oxygenated muriatic acid, by the carbonat of pot-aſh (§ 343), is earthy, hardly ſoluble in water, and without taſte. It is likewiſe found ready formed by nature (*Witherite*, from Dr. *Withering*, who firſt analyzed it. Philoſ. Tranſact. Vol. LXXIV). It is only with extreme difficulty that carbonat of barytes is deprived of its carbonic acid by fire alone. That which is combined by art is eaſier deprived of it. An exceſs of acid renders it more ſoluble in water.

Synonyma: Aërated ponderous earth (*baryta aërata, terra ponderoſa aërata*).

§ 377.

The carbonic acid poſſeſſes a greater affinity with barytes than with alkalis, calcareous earth, and magneſia.

§ 378.

Carbonated Strontian-earth has an earthy texture, is not at all diſſolved by water, and is deſtitute of taſte.

taſte. This middle ſalt is likewiſe procured by ſolution and precipitation. The ſolvent employed is oxygenated muriatic acid, and the precipitant is mild vegetable alkali. It is found native (*Strontianite* (§ 345) in granite rocks; and according to *Klaproth*, it has for its conſtituent parts 0,695 Strontian-earth, 0,300 carbonic acid, and 0,005 water. Like the natural carbonat of barytes, in a calcining fire, it parts but with difficulty with its carbonic acid; yet from an artificial combination of theſe two ſubſtances, the acid may be ſeparated with leſs difficulty.

§ 379.

The Strontian-earth ſeems to have a nearer affinity with carbonic acid than the alkalis, lime and magneſia.

§ 380.

The carbonic acid does not combine with *alumine* or argillaceous earth, with the *ſiliceous*, *circon*, and *auſtral earths*. *

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* This laſt falls off, of courſe. Vide note to § 349.

§ 381.

If we had a ſubſtance poſſeſſing a ſtronger affinity with oxygen than that which carbon has with this acidifying principle, we ſhould then be enabled to decompoſe, by means of that ſubſtance, the carbonic acid, and to educe from it, or exhibit ſeparately, the carbonic radical. For the preſent, we know no ſuch ſubſtance. Yet Mr. *Tennant* and Dr. *Pearſon* have ſo far ſucceeded, as to decompoſe the carbonic acid by means of double affinity (§ 50). For that purpoſe they expoſed phoſphorus with carbonat of lime, or with carbonat of ſoda, in a glaſs tube, to a ſtrong red-heat. The reſult was, that carbon was formed; and, beſides, phoſphat of lime, or phoſphat of ſoda. The experiment deſerves well to be farther examined.

§ 382.

Is there ſuch a thing in nature as *imperfect carbonic acid*, or *oxyd of carbon?** I ſuſpect its exiſtence in the venous blood of warm-blooded animals.

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* *Charcoal* ſeems to be ſuch an oxyd, in the opinion of *Guyton*. See note to § 1163.—Ed.

Sulphur.

§ 383.

Sulphur is a ſimple, inflammable, acidifiable ſubſtance, of a yellow colour, inſoluble in water, without odour, except by friction, or on being heated, and of a peculiar, faint taſte.

§ 384.

All the brimſtone, or ſulphur, of commerce, is the product of nature, and merely ſeparated by art from other extraneous matters. Beſides, that now and then pure native ſulphur *(ſulphur nativum virgineum)* is found, it is frequently met with combined

combined with metallic ſubſtances that are mineralized by it; more eſpecially in *pyrites (pyritæ)*, from which it is extracted by a particular kind of fuſion or diſtillation. By another method it is alſo obtained, as an acceſſory product, on the roaſting of other minerals, in which it is an ingredient. Sulphur, whatever way procured, is caſt into *rolls* for ſale, and then called *roll-brimſtone (ſulphur commune, citrinum)*.

§ 385.

Sulphur, when heated, becomes firſt ſoft before it melts, and its fuſion commences at 224° Farenh. At this degree of heat, and ſomewhat higher, it begins to riſe in vapours, which readily kindle, as may be eaſily perceived in the dark. When melted ſulphur, in maſſes of not too ſmall a ſize, cools undiſturbed, it readily cryſtallizes in the ſhape of thin needles. Native brimſtone is moſtly found in octahedral cryſtals, though with ſome variations of figure.

§ 386.

In the beginning of fuſion ſulphur is very fluid; but, by continuing the heat, it grows tougher, and of a red-brown colour; in which ſtate it has already taken up a portion of oxygen, and paſſes with it into the ſtate of beginning oxygenation *(oxyd of ſulphur)*. If, in this condition, it be poured into water, it remains as ſoft as wax, and yields to any impreſſion. In time it hardens again, and recovers its former conſiſtence and colour.

§ 387.

If, to prevent inflammation, melted ſulphur is debarred from the acceſs of external air, it ſublimes in vapours, adhering to the veſſel in the form of ſlender needles, which have obtained the name of *flowers of ſulphur (flores ſulphuris).* But they are ſeldom quite free from ſulphuric acid, which has been generated in the ſubliming-veſſel by the decompoſition of vital air.

§ 388.

If melted ſulphur be expoſed in open air to an increaſed heat, it takes fire, is entirely conſumed, and burns with a flame, and an acid, ſuffocating vapour. The ſulphur is by this combuſtion changed to an acid. If the heat by which burning ſulphur is conſumed be only weak, its flame is blue, and the acid then generated is imperfect (§ 276), very volatile, and aëriform. This *imperfect ſulphuric acid* we ſhall preſently examine more cloſely under the name of *ſulphureous acid.* But if the heat be ſtronger, the flame of the ſulphur is white and lively, and a *perfect ſulphuric acid,* in the vaporous ſtate, is formed.

§ 389.

Put ſome threads, previouſly dipped in brimſtone, into a capſule, or ſmall ſhallow veſſel made of tin, and placed in a cup floating on water; ſet fire to the threads, and cover the whole with an inverted glaſs-bell filled with vital air. A part of the ſulphur only will be burnt; the oxygen gas will be decompoſed, and the water will riſe in the bell. The oxygen gas, though abſolutely pure, is not, however, all decompoſed; becauſe, by the vapours of the acid, and the ſulphureous gas thus generated, the ſulphur is extinguiſhed before it can be totally conſumed. The water that has riſen in the bell is now ſour, and reddens the tincture of litmus in the moment of contact. It is, however, impregnated with imperfect, as well as perfect, ſulphuric-acid (§ 388); the former of which, if expoſed to air, is, after ſome time, transformed into the latter.

Of the *ſpiritus ſulphuris per campanam.*

§ 390.

According to *Berthollet*, 69 parts of ſulphur abſorb on combuſtion 31 parts of oxygen, and form with it 100 parts of concentrated ſulphuric acid; that is to ſay, as free from water as its nature will allow. This ſtatement, however, is not quite unqueſtionable. It appears from this, that the ſulphuric acid is compoſed of ſulphur and oxygen. The firſt takes up the latter from the vital air during

ing the heat of inflammation; thus decompoſes the oxygen gas, and diſengages its caloric.

Sulphuric-Acid.

§ 391.

The *ſulphuric-acid*, which is alſo called *vitriolic-acid (acidum vitrioli)*, is likewiſe frequently obtained, in great quantities, by the combuſtion of ſulphur. In this way it is principally prepared in England; for which purpoſe peculiar apartments, with their inſides lined all over with lead, are conſtructed, in order to incloſe the burning ſulphur. But becauſe the ſulphur would in that ſituation be ſoon extinguiſhed, and never burn with due vivacity, about the eighth part of its weight of nitre is mingled with it to ſupply the vital air, without which no combuſtion can exiſt (§ 196).—Both the water at the bottom of the chamber, and alſo the aqueous vapours conveyed into it, imbibe the ſulphuric-acid as it forms.—The weak or diluted acid thus obtained is collected and concentrated, by evaporating the ſuperfluous water in glaſs-veſſels.

§ 392.

Sulphuric acid, concentrated in this manner, is ſold under the name of *oil of vitriol (oleum vitrioli)* *, and particularly with the appellation *Engliſh*, to diſtinguiſh it from another ſpecies that is called *Saxon oil of vitriol*, or of *Nordhauſen*, and which is obtained from green vitriol by diſtillation. Every kind of concentrated ſulphuric acid, formerly found in commerce, was prepared in this laſt method; and it is on this account that the ſulphuric-acid is generally called *vitriolic-acid.*

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* The unctuous and oleagineous appearance exhibited by this acid, and the little noiſe which it makes when poured from one veſſel into another, together with its production from vitriol, have been aſſigned, for the cauſe of the denomination, *oil of vitriol*—Edit.

§ 393.

The vitriol itſelf, from which ſulphuric acid is ſtill occaſionally extracted, is a metallic ſalt, compoſed of calx of iron and ſulphuric acid, with or without calx of copper; it has a green colour, forms rhomboidal cryſtals, and excites an aſtringent, bitter taſte. It is commonly named *green vitriol*, or *copperas*, though in its pure ſtate it contains no copper.

The ſulphuric acid of this, as well as every other kind of vitriol, derives its origin from ſulphur, ſince this vitriol is obtained from *pyrites*, a combination of ſulphur and iron, at times interſperſed with copper. This pyrites, eſpecially when roaſting, decompoſes, even at a moderate warmth, the oxygen gas of the atmoſphere. For its ſulphur abſorbs oxygen from the atmoſphere, and is converted into ſul-

ſulphuric-acid; while the iron, on the other hand, likewiſe takes up part of the oxygen, is thereby oxyded, and unites with the ſulphuric-acid, to form with it the metallic ſalt, *vitriol.* The pyrites loſes by this proceſs its hardneſs and metallic ſplendour; it is reduced to a pulverulent ſtate, and now exhibits a harſh taſte. The vitriol is laſtly procured from it, ready for uſe, by lixiviation with water and cryſtallization.

§ 394.

This vitriol, or *ſulphat of iron*, is ſeparated by heat from its ſulphuric acid. But as in the cryſtalline ſtate it contains a large quantity of water of cryſtallization (§ 239), this laſt would greatly weaken the acid to be obtained by diſtillation, and the operation would unneceſſarily be prolonged. The water is, for this reaſon, firſt expelled by roaſting the vitriol in iron-pots till its colour is red; which when done, it is diſtilled from large earthen and coated retorts by a reverberatory fire (§ 59). Strongly concentrated ſulphuric-acid (partly in ſmoke-grey vapours, partly in drops) paſſes then over into the receivers, which are fitted and well luted (§ 122) to the retort.

§ 395.

Oil of vitriol is a very ſtrong acid; it burns and corrodes the ſkin. When pure, it has neither colour nor ſmell, but is very apt to turn more or leſs brown, and of a ſulphureous odour, by combuſtible, animal, and vegetable matters, as is uſually the caſe with what is ſold in the ſhops. Its ſpecific gravity is from 1,800 to 2,000. It is of conſiderable fixity in fire, and requires a ſtrong heat for ebullition. On account of this property a weaker oil of vitriol may be made ſtronger, by evaporating part of its water. Notwithſtanding this, the ſtrongeſt ſulphuric-acid always contains ſome water.

§ 396.

Sulphuric-acid procured from vitriol, or the *Saxon oil of vitriol*, emits whitiſh grey vapours, which is not the caſe with the Engliſh, prepared by burning ſulphur.

If the firſt be ſubjected to a gentle ſand-heat, in a retort of glaſs having a very dry recipient luted on, a ſtrong white ſmoke comes over, and is there, eſpecially in froſt, concentrated to a concrete gloſſy ſubſtance, which adheres to the veſſel in a ſtar-like or radiated figure; ſmokes exceedingly much in a warm air; produces great heat with water, forming with it diluted ſulphuric-acid; attracts the moiſture of the atmoſphere; and liquefies, becoming thereby common ſulphuric-acid. What remains of the oil of vitriol in the retort has now loſt its fuming qualities; and on this volatile ſubſtance depends the property of the Saxon oil of vitriol

vitriol to congeal in a moderate cold to a cryſtalline maſs, *(glacial oil of vitriol).*

By evaporating that volatile matter the oil of vitriol is deprived of this property; and pure white ſulphuric-acid does not freeze, unleſs in a conſiderable cold. The volatile ſubſtance juſt mentioned is, according to late experiments, a combination of concentrated ſulphuric with ſulphureous-acid; which laſt we ſhall farther make an object of our enquiries.

§ 397.

Sulphuric-acid has a ſtrong tendency to unite with water, and it attracts moiſture from the air. Smoking oil of vitriol loſes, for this reaſon, its fuming property, as well as its icy or glacial appearance. The ſulphuric-acid produces, on being mixed with water, an inſtantaneous and very great heat; and for this reaſon, when it is to be diluted, it ſhould be dropped little by little into the water, and not the water poured upon the acid. The ſulphuric-acid thus weakened is called in the ſhops *ſpirit of vitriol.*

§ 398.

Oil of vitriol, as it is ſold, is not entirely pure ſulphuric-acid. Though by boiling in open veſſels it may be freed from its brown colour, and thereby made whiter; however, this is by no means competent to purify it completely, but it requires to be rectified

rectified (§ 115). This rectification, in ſmall quantities of about half a pound, is performed in the beſt way in ſmall glaſs-retorts, placed in the crucible or ſand-bath (§ 63). The heat applied in this caſe muſt be moderate and well regulated; and the receivers are joined without any lute.

§ 399.

With alkalis and earths the ſulphuric-acid affords ſome peculiar combinations of the neutral and middle ſaline kind, called *ſulphats*. Of which,

1. The *ſulphat* of pot-aſh, or ſulphated *vegetable alkali*, ſhoots into ſmall cryſtals, which in their regular ſtate are a ſix-ſided column, or priſm with ſix-ſided pyramidal terminations. Yet commonly it forms only a cohering lump or cruſt of ſalt, on whoſe ſurface the polyedral ends of the cryſtals protuberate. This neutral ſalt is of a bitteriſh taſte, of difficult ſolubility in water, and requires for ſolution, at a moderate temperature, 12 parts by weight, and of boiling water 4,120 parts. According to *Bergman's* analyſis, it contains in the cryſtalline ſtate 0,40 of concentrated ſulphuric-acid, 0,52 of vegetable alkali, and 0,08 of water of cryſtallization. The cryſtals are permanent in the air. By mere heat, without contact with coal, the ſulphuric-acid cannot be ſeparated from them. It melts only in a white heat.

Synonyma: *Vitriolated tartar* (*tartarus vitriolatus*); *ſal de duobus, arcanum duplicatum, ſal polychreſtum* Glaſeri; *kali vitriolatum* of the London college.

§ 400.

The ſulphat of pot-aſh, in commerce, is not prepared by direct combination of its two principles; but is moſtly obtained accidentally, as on the decompoſition of ſaltpetre by ſulphuric-acid, and the like; and ſometimes alſo on decompoſing ſulphat of iron, or vitriol, by means of pot-aſh. This neutral ſalt is but ſeldom found ready formed by nature. It is, indeed, frequently an ingredient in the aſhes of various plants, and hence met with in pot-aſhes; but it does not follow from this, that it had pre-exiſted as ſuch in the plant.

§ 401.

The vegetable alkali may be over-charged with ſulphuric-acid, if that acid be diſtilled upon it with a continued heat ſo as to render the alkali red-hot and completely dry.

§ 402.

2. The *ſulphat of ſoda*, or *ſulphated mineral alkali*, forms large, well-ſhaped, tranſparent, flattened cryſtals, of ſix-ſided columns, with ſtriated ſurfaces, and ſix-ſided pyramidal terminations. It excites a cooling, bitteriſh ſenſation on the tongue; is very ſoluble in water, requiring, at a moderate tem-

perature, hardly three times, and of boiling water hardly its own weight, for ſolution. Theſe cryſtals effloreſce in warm dry air, falling to a white powder; and, when in a perfect ſtate, contain, as *Bergman* ſtates, 0,15 of mineral alkali, 0,27 of ſulphuric-acid, and 0,58 of concrete water. This laſt cauſes them to melt in heat; but after the water has gone off in vapours, a white heat is required to fuſe the ſalt in the ſtrict ſenſe. Nor is heat alone ſufficient to expel from it the ſulphuric-acid.

Synonyma: *Glauber's ſalt (ſal mirabile Glauberi) natron vitriolatum* of the London college.

§ 403.

We certainly find this neutral ſalt in the foſſil kingdom formed by nature; ſuch, however, as is ſold, is the product of art, and is either obtained from the cruſty ſediment of ſuch brine-ſprings as contain Epſom-ſalt, by lixiviating that matter, and cryſtallizing the filtered lixivium in a freezing cold; or it is obtained in great laboratories as a profitable refuſe matter, after the preparation of other ſalts.

§ 404.

Soda, or mineral alkali, has with the ſulphuric-acid an affinity inferior to that of pot-aſh; hence the ſulphat of ſoda is decompoſed by the latter in the humid way.

§ 405.

3. The *ſulphat of ammoniac*, or *ſulphated volatile alkali*, likewiſe cryſtallizes in compreſſed ſix-ſided priſms, with ſix-ſided, more or leſs regular, pyramidal terminations. Its taſte is of the bitteriſh, acrid kind; it eaſily diſſolves in water; and, in the cryſtalline ſtate, it is ſaid by *Kirwan* to be compoſed of 0,40 of ammoniac, 0,42 of ſulphuric-acid, and 0,18 of water. Theſe cryſtals do not decay in air. By heat this neutral ſalt is decompoſed. It has been found native in the neighbourhood of ſome volcanos.

> Synonyma: *Glauber's ſecret ſalt of ammoniac* (*ſal ammoniacum ſecretum Glauberi*); *vitriolic ſalt ammoniac* (*ſal ammoniacum vitriolatum, vitriolum ammoniacale*).

§ 406.

Sulphat of ammoniac is decompoſed by both the fixed alkalis, ſoda and pot-aſh, theſe having a ſtronger attraction for the ſulphuric-acid.

§ 407.

4. The combination of ſulphuric-acid with lime is of very difficult ſolubility, ſo much ſo, that if the acid be not largely diluted with water, all the diſſolved maſs is directly thrown down again as a white precipitate. This *ſulphat* of *lime* is of the ſame nature with *native gypſum*, or *plaſter of Paris*. Art cannot produce it in ſuch cryſtalline forms,

forms, and with that tranſparency as nature frequently preſents it to our view in the *ſelenitic-ſpar (lapis ſpecularis, glacies mariæ).*

Synonyma: *Gypſum, ſelenites, calx-vitriolata.*

§ 408.

Sulphat of lime, to be diſſolved, requires nearly 470 parts of boiling water; and this very difficult ſolubility is the cauſe why chemiſts are unable to exhibit their artificial ſulphat of lime in ſo large and beautiful cryſtals, as are frequently preſented by the natural ſelenitic-ſpar. This laſt, when cryſtallized, contains, after *Bergman*, 0,32 of calcareous earth, 0,46 of ſulphuric-acid, and 0,22 of water of cryſtallization.

§ 409.

If gypſum be burnt, its water is driven out, and it is then called *burnt gypſum.* In this ſtate it imbibes water, and completely cryſtallizes with it; and on this property depends the uſe of burnt gypſum for a ſpecies of mortar, called *plaſter-mortar*, and in *ſtucco-works.*

§ 410.

Heat alone is not ſufficient to expel the ſulphuric-acid from gypſum; yet, when expoſed to a white heat in a *crucible made of clay*, this ſulphat of lime melts at laſt, and vitrifies.

§ 411.

The ſulphuric-acid is not ſo ſtrongly attracted by alkalis as by calcareous-earth. Sulphat of lime may, indeed, be decompoſed by carbonated alkalis; but this is effected by double affinity.

§ 412.

5. Magneſian-earth is eaſily diſſolved by ſulphuric-acid, and affords with it, though but moderately diluted with water, a clear ſolution. By this property it is eaſily diſtinguiſhed from calcareous-earth (§ 407). The *ſulphat of magneſia*, or *bitter ſalt (ſal amarum)*, taſtes bitter, cryſtallizes in regular four-ſided columns, whoſe ends are obliquely truncated, but whoſe ſurfaces are not ſtriated. In time, and by warmth, its cryſtals give out their water, and effloreſce. Their conſtituent parts are 0,19 of magneſian-earth, 0,33 of ſulphuric-acid, and 0,48 of water, as *Bergman* aſſerts. To effect their ſolution, at 50° Farenh. about twice their weight of water, but of boiling water only $\frac{2}{3}$ are neceſſary.

Synonyma: *Epſom ſalt*; *vitriolated magneſia.*

§ 413.

The ſulphuric-acid cannot be diſengaged from Epſom-ſalt, or ſulphat of magneſia, by ſimple application of heat; yet this middle ſalt is decompoſed

poſed by the fixed alkalis, as well as by lime-water, by whoſe ſtronger affinity with ſulphuric-acid this laſt is ſeparated from magneſia. From the ſulphat of ſoda this ſalt is readily diſtinguiſhed by the turbidneſs which it cauſes if one of its cryſtals be diſſolved in lime-water. Ammoniac decompoſes but a ſmall part of Epſom-ſalt; there rather ariſes from their mixture a triple ſalt (*Magneſia ammoniaco-ſulphurica*).

§ 414.

The ſulphat of magneſia is found native in ſeveral places, partly as a concrete ſaline efflorescence, partly diſſolved in mineral waters, as in *bitter ſaline-ſprings*, and ſometimes in other ſalt-ſprings, from the mother-water of which it is extracted with profit. Much of the bitter-ſalt of commerce is, however, the product of art.

§ 415.

When concentrated ſulphuric-acid is poured upon magneſia recently burnt, it produces with it ſo ſtrong a heat, that in a dark place it is perceived to throw out ſparks.

Conſult § 174, note 8.

§ 416.

6. The reſult of the combination of ſulphuric acid with pure argil (§ 324) is *alum*, or *ſulphat of alumine (alumen)*. This middle ſalt has a ſweetly-auſtere and aſtringent taſte; it forms octahedral cryſtals, of which ſeveral are bundled together in

groups,

groups, in ſuch a manner as to repreſent a notched or indented column. It is not very ſoluble in cold water, and requires more than 18 parts of it to be diſſolved; of boiling water not quite two parts are neceſſary. Alum, perfectly pure and in the cryſtalline form, contains, according to *Bergman*, 0,18 of alumine or pure argil, 0,38 of ſulphuric-acid, and 0,44 of water. The cryſtals do not eaſily decay in the air.

Synonyma: *Vitriolated argil.*

§ 417.

Alum, when on the fire, melts in its own water of cryſtallization. While this laſt is evaporating, the fluid alum gets tougher; froths and ſwells up exceedingly; and, when completely dry, it affords a looſe white and very friable maſs, called *burnt alum* (*alumen uſtum*). By a red-heat, part of the ſulphuric acid may be driven out of the alum, but not the whole.

§ 418.

Sulphat of alumine is a middle ſalt over-loaded with acid; and for this reaſon it not only reddens the tincture of litmus, but alſo takes up more argil, if an aqueous ſolution of that ſalt be boiled upon clay newly precipitated. The ſulphat of alumine is then completely ſaturated, and conſtitutes a ſalt (the *glaſs-ſelenite* of *Baumé)* almoſt inſoluble, of hardly any taſte, and exhibiting cubic cryſtals.

§ 419.

The more ſulphuric-acid is added to alum, the leſs it is capable of cryſtallizing.

§ 420.

Alum is certainly found ready formed in ſome mineral waters, in coal-mines, and in the lavas of volcanos; yet the greateſt part of what is ſold is made by art.

The moſt uſual foſſils from which it is obtained in large quantities are the *aluminous ſhiſti*, which do not contain this ſalt ready formed, but are a kind of bituminous argillaceous ſlate, interſperſed with pyrites. By the decay of this laſt only, the ſulphuric-acid is formed, which unites with the argil to form alum, and with the calx of iron to form vitriol. If the argillaceous ſhiſti are impregnated with much bitumen, they are firſt torrefied; but, if otherwiſe, they are ſimply left to moulder in the air, and afterwards are lixiviated, when this decay has reached the due degree. Such of the raw lixivia as, by its ſaline contents, is thought worth boiling, is evaporated in leaden pans; and then, by cooling and agitation in wooden ciſterns, cauſed to precipitate in ſmall cryſtals.

That part which remains of it, or the *mother-water*, is mixed with freſh lixivium, and again eva-

evaporated and cryſtallized as before. But as the aluminous lixivium always contains ſome green vitriol, and as, beſides, by the very treatment of the lye, the iron is completely oxyded, and hence decompoſed, there is in this proceſs always an overplus of ſulphuric-acid generated, which is unneceſſary to ſaturate the alum, and which prevents it from ſhooting into cryſtals (§ 419). To remedy this inconvenience, the inſpiſſated lye is combined with muriat of pot-aſh, called *ſoap-maker's flux*; whereby the redundant ſulphuric-acid, which prevents cryſtallization, is taken off, and combines with the vegetable alkali to ſulphat of pot-aſh; which laſt does not cryſtallize ſeparately, but enters into the cryſtals of alum.

For this reaſon the alum of commerce is a triple ſalt, conſiſting of ſulphuric-acid, argil, and pot-aſh. In moſt caſes it is alſo contaminated with iron. The pulverulent cryſtals that are obtained by the firſt refrigeration and agitation of the aluminous lye are ſtyled *flour of alum*; and, being firſt purified by waſhing, made to form larger cryſtals by a ſubſequent ſolution, and a gradual tranquil cooling.

§ 421.

With the argillaceous ſhiſti the *ſidero-pyritous-clay* agrees ſo far, that alum is likewiſe generated by the mouldering of its pyritous part, and extracted from it in the ſame manner as from the alu-

aluminous ſhiſti (§ 420). The *aluminous-rock*, from which, at *La Tolfa* near *Civita-vecchia*, the *Roman alum*, or rock-alum, is obtained, is a ſulphurated clay, whoſe ſulphur, by roaſting and ſubſequent decay in the air, is firſt converted into ſulphuric-acid; and this laſt uniting with the argil, forms the ſulphat of alumine, which, by lixiviation and cryſtallization, is afterwards ſeparated from extraneous matters. The cryſtals of this alum are covered with a reddiſh cruſt. Laſtly, the *alum of Solfatara* is extracted by lixiviation from a white earth that contains alum ready formed, and originates from a black lava, which has been penetrated by ſulphureous vapours.

§ 422.

Alumine, or argillaceous-earth, has not ſo great an affinity with ſulphuric-acid as the alkalis, the calcareous, magneſian, and other earths, poſſeſs.

§ 423.

7. Ponderous earth and ſulphuric acid have a very ſtrong attraction for each other. Neverthleſs, this earth affords no clear ſolution with that acid, even when diluted with a very great quantity of water: on the contrary, the whole compound ſinks to the bottom as an inſoluble ſediment. This precipitate is called *ſulphat of barytes*, or native *ponderous ſpar* (*ſpatum ponderoſum*). It is found in cryſtalline ſhapes of great diverſity; which, how-

ever, on account of the above-mentioned inſolubility, we are not able to produce by an artificial combination of theſe two ſubſtances. Ponderous ſpar is taſteleſs, and of a remarkably great ſpecific gravity. In fire it parts with its water of cryſtallization; but the ſulphuric-acid cannot be driven out from it by heat alone. When put into a crucible made of clay, and ſubjected to heat of ſuch intenſity as to ignite it to incandeſcence, this ſpar runs into glaſs.

Synonyma: *Vitriolated ponderous earth.*

§ 424.

Neither the alkalis, nor the calcareous, nor any other earth, decompoſe the ſulphat of barytes. Of all ſubſtances, barytes poſſeſſes the neareſt affinity with ſulphuric-acid. The decompoſition of ponderous ſpar by carbonat of pot-aſh (§ 343) is the effect of double affinity.

§ 425.

Concentrated ſulphuric-acid, aſſiſted by heat, diſſolves a portion of ponderous ſpar; yet the ſolution is decompoſable by a ſmall quantity of water.

§ 426.

8. The *ſulphat of Strontian-earth* is likewiſe earthy, has no taſte, and is ſcarcely ſoluble in 1000

times its weight of boiling water. If an exceſs of ſulphuric-acid be poured upon Strontian-earth reduced to an impalpable powder, it will diſſolve it totally. But as ſoon as a little water is added to the ſolution, the ſulphat of Strontian-earth is again precipitated.—The attraction of Strontian-earth to ſulphuric-acid ſeems to be not much leſs than that of barytes.

§ 427.

9. The *ſulphat of Circon-earth* is, like the former ſulphat, earthy and taſteleſs. It becomes ſoluble by a ſurplus of ſulphuric-acid, and forms, by inſenſible evaporation, cryſtals of four-ſided columns, accumulated in cluſters, and poſſeſſing an aſtringent taſte. This combination wants yet a farther inveſtigation.

§ 428.

In the graduated arrangement of the affinities of alkalis and earths, the carbonic-acid is far exceeded by the ſulphuric.—Of the reciprocal decompoſitions of the ſulphats and carbonats, we mention in this place only that of the *ſulphat of ſoda* by carbonat of pot-aſh; that of *gypſum* by carbonated alkalis; that of *Epſom-ſalt* by carbonat of pot-aſh; that of *ponderous ſpar* by carbonat of pot-aſh; and, in general, the decompoſition of *all the ſulphats* by a ſolution of witherite, or carbonat of ponderous earth, in water impregnated with carbonic-acid (§ 376); which ſolution may, in this reſpect, ſerve as a very ſenſible re-agent for diſcovering the ſulphuric-acid, whether free or chemically combined with other ſubſtances.

Sulphureous-Acid.

§ 429.

Sulphur is capable of being oxygenated in different degrees (§ 276). In the ſulphuric-acid it is ſaturated, or nearly ſaturated, with oxygen; and this is therefore to be reckoned a *perfect* acid. With a ſmaller portion of oxygen it exhibits an acid of a different nature, and of different properties, which ought to be regarded as an *imperfect* ſulphuric-acid, and to which we give the name of *ſulphureous-acid.*

Synonyma: *Phlogiſticated vitriolic-acid*; *volatile ſulphuric-acid*; *volatile-acid of vitriol.*

§ 430.

This ſulphureous-acid is obtained by a ſlow combuſtion of ſulphur, when it burns only with a blue flame. The acid generated by this proceſs is of much leſs acidity than ſulphuric-acid (§ 388, 391); and it is at the ſame time exceedingly volatile, as is apparent from the very ſuffocating ſmell iſſuing from the combuſtion, and even aſſuming the aerial form, if moiſture is excluded.

§ 431.

Beſides, this ſulphureous-acid is alſo procured, when to ſulphuric-acid a body is preſented that, by its attraction for oxygen, deprives the ſulphur of part of that acidifying principle, in combination with which it conſtituted the ſulphuric-acid. If ſome olive-oil be brought in contact with oil of vitriol, a ſulphureous-acid is immediately generated; and an odour is given out like that of burning brimſtone. The ſame thing happens if a red-hot coal be quenched in ſulphuric-acid. In both caſes the acid is robbed by the carbon of part of its oxygen, and carbonic-acid gas is at the ſame time generated.

§ 432.

The ſulphureous-acid is produced, in the pureſt ſtate, upon the ſolution of ſeveral metals in ſulphuric-acid, aſſiſted by a boiling heat.—By way of experiment, pour together equal parts of mercury and oil of vitriol in a retort of glaſs, connected with the pneumatic quickſilver-trough (§ 127), and heat the mingled fluids in a ſand-bath to 212° Farenh. In that heat the mercury deprives the ſulphuric-acid of a portion of its oxygen, and is thereby oxyded; on the other hand, the ſulphuric-acid is changed to ſulphureous, and comes over into the receivers in the ſtate of gas.

§ 433.

This gas has been called *ſulphureous-acid gas.* It is ſpecifically heavier than common air; one cubic Pariſian inch of it weighs 1,03820 French grains, at 10° Reaum. and 28 inch. Barom. Its ſmell is ſuffocating, and its taſte feebly ſour; it is improper for reſpiration, and incapable of maintaining combuſtion. It cannot be confined by water, being abſorbed by it; or, more properly ſpeaking, it is decompoſed by water, which takes away the ſulphureous-acid from the caloric.

Synonyma: *Vitriolated air*; *ſulphureous air.*

§ 434.

Water, that has diſſolved or abſorbed ſulphureous-acid, is to be looked upon as liquid ſulphureous-acid. It poſſeſſes a ſulphureous ſmell, and an acidulous taſte. Though at firſt it only reddens the ſyrup of violets, yet at laſt it totally deſtroys its colour. The tincture of roſe-leaves, and ſeveral other pigments, loſe by it all their colour. On this property reſts the proceſs of ſtoving ſilk with brimſtone, for the purpoſe of making it white.

§ 435.

When expoſed to air, the ſulphureous-acid gradually takes up more oxygen from the vital air, loſes thus its characteriſtic marks, and is converted into ſulphuric-acid.

§ 436.

The neutral and middle ſalts, which the ſulphureous-acid forms by combination with alkalis and earths, or the *ſulphites*, are very ſtrikingly different from the ſulphats, or thoſe that are formed by ſulphuric-acid with the ſame ſubſtances. Such ſalts are obtained in another way, if linen or woollen cloths are ſoaked in an alkaline lye, and afterwards hung up extended over brimſtone burning weakly and ſlowly; though, in this caſe, there is always along with the ſulphureous ſome ſulphuric-acid produced.

§ 437.

As no uſe is made of the ſulphites in arts and trades, it will in this place be ſufficient juſt to mention their names:

1\. *Sulphite of pot-aſh*, or of vegetable alkali.

Synonyma: *Stahl's ſulphureous ſalt (ſal neutrum ſulphuris Stahlii)*; *ſulphureous tartar*; *volatile vitriolated tartar.*

2\. *Sulphite of ſoda*, or of mineral alkali.
3\. *Sulphite of ammoniac*, or of volatile alkali.
4\. *Sulphite of lime*, or of calcareous-earth.
5\. *Sulphite of magneſia*, or of magneſian earth.
6\. *Sulphite of barytes*, or of ponderous earth.
7\. *Sulphite of Strontian-earth.*
8\. *Sulphite of alumine*, or of argil.
9\. *Sulphite of Circon-earth*, or of jargon of Ceylon.

§ 438.

By ſulphureous-acid the carbonic is expelled from earths and alkalis; but the firſt is itſelf diſengaged from ſuch combinations by the ſulphuric as well as by moſt other acids.

§ 439.

Concentrated ſulphuric-acid imbibes the ſulphureous gas; receiving thereby, if the air find acceſs to it, the property of emitting white fumes, and the glacial nature of the oil of vitriol of Nordhauſen (§ 396).

Sulphur, with ſome other Subſtances.

§ 440.

Water and brimſtone are not reciprocally acted upon by each other; nor is there any probability that ſulphur alone is able to decompoſe water. Hence oxygen has a nearer affinity with water than with ſulphur.

§ 441.

Azot and carbon have likewiſe no apparent attraction to ſulphur. Hydrogen may enter into combination with it, as will ſoon be farther explained.

§ 442.

Alkalis are eminent ſolvents of ſulphur in the humid as well as the dry way. If one part of cauſtic pot-

pot-aſh or of ſoda, and one part of ſulphur, be melted in moderate heat in a covered pot, a mingled maſs is obtained, which, after cooling, exhibits a liver-brown colour, and gives out no odour ſo long as it remains dry; but which, on being moiſtened, immediately ſends forth a nauſeous ſmell, like that of rotten eggs; deliqueſces in the air; and is entirely diſſolved by water, the ſolution exhibiting a yellow gold-colour. This combination has been called *liver of ſulphur* (*hepar ſulphuris*). Its general name is, by the new methodical nomenclature, *alkaline ſulphuret*; and I ſhall treat here firſt of the *ſulphuret of pot-aſh*, and of the *ſulphuret of ſoda*.

> The modern French Chemiſts ſtyle ſuch combinations by the general term *ſulſure*, which is ſufficient to diſcriminate it from *ſoufre*, by which laſt they tranſlate the Latin word *ſulphur*; but Dr. St. John properly ſubſtituted the word *ſulphuret* for that of *ſulfure.*—Edit.

§ 443.

Theſe combinations are alſo effected by boiling powdered ſulphur in a lye of the cauſtic fixed alkali.

§ 444.

If to a ſolution of alkaline ſulphuret in water any acid be added, the ſulphur is ſeparated by it, becauſe of the ſtronger attraction of the alkali for the acid; and the ſulphur is thrown down in the

the form of a fine white powder, called *milk of ſulphur* (*lac*, or *magiſterium ſulphuris*).—The carbonic-acid likewiſe ſeparates the ſulphur.

§ 445.

By pouring the acid into the alkaline ſulphuret, the diſguſting ſmell which the ſolution already poſſeſſed by itſelf becomes ſtill ſtronger and truly inſupportable. If dry ſulphuret of alkali be employed, an effervefcence takes place that cannot be perceived when the acid is added in the cold to the ſolution of pure alkaline ſulphuret in water. The fetor mentioned before ariſes from the extrication and expanſion of a peculiar gas, which deſerves a cloſer conſideration.

§ 446.

Take alkaline ſulphuret, recently prepared and pulverized; put it into a tubulated glaſs-retort (§ 120) lodged in a warm ſand-bath, and whoſe neck is joined to the pneumatic apparatus; next pour upon it ſome diluted ſulphuric-acid, and urge the heat, by degrees, till the contents of the retort are boiling. If the hydro-pneumatic apparatus be made uſe of, it is adviſable to put warm water in the trough.

§ 447.

The gas obtained in this manner is called *ſulphurated hydrogen-gas*. It is diſtinguiſhed by a very diſagreeable ſmell; it is not reſpirable; it extinguiſhes a lighted candle immerſed in it; is, however, itſelf inflammable, and burns after ignition, if mixed or in contact with oxygen-gas. This mixture may alſo be ſet on fire by the electric ſpark. If ſulphurated hydrogen—, mixed with oxygen-gas, be kept in a bottle well ſtopped, the ſulphurated hydrogen-gas will, after ſome time, be found decompoſed, and the ſides of the veſſel caſed with a thin lining.

Synonyma: *Hepatic gas* by *Bergman*, and *ſulphureous alkaline air*.

§ 448.

Cold water abſorbs the ſulphurated hydrogen-gas, by degrees, and becomes poſſeſſed of its taſte and ſmell. Water ſaturated with this gas is of the ſame nature as the *mineral ſulphureous* or *hepatic waters (thermæ hepaticæ)*; for inſtance, that of Aix-la Chapelle. Such waters may artificially be imitated by means of Parker's apparatus (§ 130). Expoſed to the air, they become cloudy, depoſite ſulphur, and change the blue colour of ſyrup of violets to a green. Lime-water is not rendered turbid by them, provided they are not alſo impregnated with carbonic-acid. By boiling they are deprived of their ſmell and taſte, and of their ſulphur.

§ 449.

The baſes of the gas now deſcribed are hydrogen and ſulphur, or *ſulphurated hydrogen*; for ſulphur obtains,

obtains, by being combined with alkalis and earths, the faculty of decompoſing water by attracting its oxygen, which it cannot do uncombined (§ 440). As ſoon, therefore, as the alkaline ſulphuret encounters water, it robs it of oxygen, which, with part of the ſulphur, generates ſulphuric-acid, that combines with the alkali. The hydrogen, diſengaged in this proceſs, takes up another part of the ſulphur, and forms with it *ſulphurated hydrogen*, the baſis of this gas, but which is retained by the ſeparated portion of alkali; and it is only by the addition of an acid, and aſſiſtance of heat, that it is extricated from the alkali, and flies off in the form of *gas*.

Thus an *alkaline ſulphuret diſſolved in water* contains *ſulphuret of alkali*, properly ſo called, beſides *ſulphated alkali*, and *ſulphurated hydrogen*, diſſolved by the alkali. When dry alkaline ſulphuret is diſſolved in water, a decompoſition of water enſues, but no longer than until the alkaline ſubſtance is ſaturated with the ſulphurated hydrogen. If a diluted acid be poured upon alkaline ſulphuret while in the dry ſtate, it is then the water of the acid only that has a ſhare in the formation of this gas; and the acid acts no other part than that of extricating the baſis of the gas from the alkali, by which it is diſſolved.

The decompoſition of *hepatic*, or *ſulphurated hydrogen gas*, by vital air, may be explained by the mutual attractions of oxygen and hydrogen then taking place; whereby water is formed, and the ſulphur precipitated. This is likewiſe the reaſon why water, holding ſulphurated hydrogen gas in ſolution, lets fall the ſulphur on expoſure to open air.

§ 450.

When hepatic air is incloſed with cauſtic alkaline lye, it is rapidly and in great quantity abſorbed; and ſulphuret of alkali, or liver of ſulphur, is again produced by this combination.

§ 451.

Alkaline ſulphuret, diſſolved in water, undergoes, when expoſed to the atmoſphere, a total decompoſition. The ſolution, which was clear before, grows turbid; ſulphur is precipitated, and the remaining lye contains at laſt nothing elſe but ſulphated alkali, mingled with more or leſs carbonated alkali. Dry alkaline ſulphuret likewiſe decays in open air, loſing all its peculiar properties ſo far that, finally, nothing elſe remains but ſulphur and ſulphated alkali, together with carbonated alkali in different proportions.

§ 452.

If a cup, containing alkaline ſulphuret, be placed under a bell of glaſs, filled with oxygen gas confined by water, it will be found that the vital air gradually diſappears, while the ſulphuret of alkali endures the changes mentioned before. It was on account of this property of the alkaline ſulphuret upon oxygen gas, that *Scheele* employed it for eudiometrical purpoſes (§ 220).

§ 453.

The ground of the reciprocal actions of liver of ſulphur and vital air upon each other lies in the attraction which both ſulphur and hydrogen have for oxygen; and by this it is eaſy to explain why the alkaline ſulphuret is after ſome time converted into a ſulphat.—Another cauſe of the deſtruction of the ſulphuret of alkali in common air is to be ſought for in the carbonic acid. The alkali attracts this acid, met with in the atmoſphere; is by it tranſformed into a carbonat; and hence rendered incapable of holding ſulphur in ſolution, which of courſe muſt precipitate.

§ 454.

When dry ſulphuret of alkali is roaſted over a gentle fire, and with inceſſant ſtirring, there remains at the end a whitiſh-grey powder, containing partly uncombined alkali, partly ſulphat of alkali. By this torrefaction part of the ſulphur flies off ſublimed; and another part, by taking up oxygen from the atmoſphere, is converted into ſulphuric-acid, which combining with the alkali forms the ſulphat.

§ 455.

§ 455.

Ammoniac alſo combines with ſulphur. *Sulphuret of ammoniac* is obtained by the following method:—Two parts of finely pulverized quicklime are put into a dry glaſs-retort; upon this lime one part of ſal-ammoniac, well mingled by trituration, with half a part of ſulphur, is poured, and the whole well incorporated by ſhaking; the retort is afterwards connected with *Woulf's* apparatus (§ 123); putting, however, into its firſt intermediate and laſt receivers but a very ſmall portion of water. Finally, the diſtillation is carried on in ſand-bath, and with precaution.

Synonyma: *Volatile liver of ſulphur* (*hepar ſulphuris volatile*); *Boyle's ſmoking liquor* (*liquor fumans Boylei*); *Hoffman's volatile tincture of ſulphur* (*tinctura ſulphuris Hoffmanni*).

§ 456.

The ammoniacal ſulphuret cannot be produced otherwiſe than in the liquid ſtate. It poſſeſſes a yellow gold-colour, a volatile and diſagreeable ſmell, and fumes ſtrongly in contact with air. In other reſpects its properties are like the combination of ſulphur with fixed alkali.

§ 457.

Lime-water diſſolves likewiſe a ſmall quantity of pulverized ſulphur. Hence ariſes the *ſulphuret of*

lime,

lime, which is beſt prepared in the dry way, by mingling moſt intimately equal portions of chalk and powdered brimſtone, and by igniting this maſs throughout in a covered crucible. The carbonic-acid is driven out from the chalk by this operation, while the calcareous-earth unites with the ſulphur, and remains in the veſſel as a whitiſh powder. Towards water, acids, and vital air, this combination is diſpoſed in the ſame manner as the alkaline ſulphuret; and muſt likewiſe, in order to remain unaltered, be preſerved in well cloſed veſſels.

Synonyma: *Liver of lime; calcareous liver of ſulphur* (*hepar ſulphuris calcareum*).

§ 458.

Sulphur may be combined in a ſimilar way with ponderous earth; yet the ſulphur does not ſeem to mix with pure magneſian earth ſo as to be ſoluble in water; nor does it unite in this manner with argillaceous earth.

Decompoſition of the Sulphuric-Acid.

§ 459.

The transformation of ſulphuric-acid into ſulphureous by the means which we have mentioned above (§ 431, ſeq.) is an actual but incomplete decompoſition of that acid. If it be intended to deprive it entirely of all its oxygen, and conſequently to ſeparate again the ſulphur from it, it will be neceſſary that the carbonic-radical, by whoſe ſtronger attraction to oxygen this decompoſition is chiefly to be effected, ſhould be enabled to act on the ſulphuric-acid at the temperature of ignition; and hence, alſo, that this acid be rendered ſufficiently fixed to be capable of bearing ſuch an intenſe heat. It poſſeſſes this laſt property when it is intimately combined with a fixed alkali, or with an earth.

§ 460.

When, therefore, equal parts of fixed alkali and of ſulphat of pot-aſh are moſt intimately blended with powdered coal, amounting in weight to one-fourth of the whole maſs, and melted together in a covered crucible, an alkaline ſulphuret is obtained; from which, being firſt diſſolved in water and filtered, the ſulphur may be precipitated by means of an acid.

§ 461.

In this proceſs the ignited carbon, by virtue of its ſuperior affinity, attracts and takes up the oxygen of the ſulphuric-acid, and flies off in the character of carbonic acid gas; and the regenerated ſulphur combines with the alkali, forming alkaline ſulphuret, from which it is again ſeparable by an acid. The portion of free alkali that was added ſerves only to promote the fuſion. The ſuperfluous part

part of the coal employed for this operation remains behind upon ſolution.

Application of this proceſs to a cheap ſeparation of mineral alkali from Glauber's ſalt.

§ 462.

By a method like this the ſulphuric-acid contained in gypſum and ponderous ſpar may be decompoſed by means of charcoal-duſt.

§ 463.

Upon this transformation of the ſulphuric-acid into ſulphur, by means of ignited charcoal, is likewiſe founded the generation of the *Bononian phoſphorus* from ponderous ſpar, in which *Vincenzo Caſciarolo* for the firſt time obſerved the luminous property.—For this end ſulphat of barytes is firſt made red-hot in a crucible to render it friable; which when done, it is reduced in a ſtone or glaſs-mortar to a ſubtile powder, and mixed with mucilage of gum-tragacanth. Of this paſte ſmall circular plates, and other various figures, are formed. Theſe are well dried, and expoſed to red-heat between burning coals in a wind-furnace, with a good current of air, and taken out after the coals are conſumed.—If theſe cakes be expoſed for ſome time to day-light, they obtain the property of giving light in the dark; but they loſe it again in courſe of time, and recover it by heat. If they be moiſtened with water, they emit a ſmell reſembling that of ſulphurated hydrogen-gas.

§ 464.

In my opinion, it is very probable that this phoſphorus is a ſlow combuſtion of the ſulphur, ſeparated in this proceſs from the ſulphuric acid that was combined with the barytes; the ſulphur uniting now with this earth, and being, as it ſeems, in this combination, more diſpoſed to decompoſe the oxygen gas than when ſingle. The extrication of caloric is, in this caſe, during each inſtant of obſervation, too inconſiderable to be perceptible.

§ 465.

Canton's phoſphorus is of a ſimilar nature with the preceding, and is moſt ſucceſsfully prepared by mingling, as accurately as poſſible, equal parts of pulverized oyſter-ſhells and ſulphur, and keeping them in a covered crucible for ſome hours in white heat. The concrete maſs is afterwards broken into ſmall pieces, and put in a dry glaſs-tube, which muſt be well corked. It will be found to give light in the dark, if previouſly expoſed for a ſhort time to day-light.

§ 466.

Finally, to this place belongs the *pyrophorus* of *Homberg*, which in open, and eſpecially in moiſt air, inflames by itſelf, and burns with a ſulphureous odour.

odour.—Take five parts of burnt alum (§ 417), and one part of coal finely powdered, mingling them with the utmoſt accuracy. With this powder fill a ſmall earthen bottle with a narrow orifice, but no more than to about two-thirds of its capacity, and place the bottle in a pot, ſurrounding it with ſand up to the neck. The pot muſt then be expoſed to fire, and the heat gradually increaſed, until the bottle be red hot. Sulphur is now formed, ſubliming and burning at the aperture of the bottle with a blue flame. When that flame is no more perceived, the pyrophorus is complete. The bottle, while yet in the fire, is firſt cloſed with a ſtopper of clay well fitting; whereupon the pot is removed from the fire; and when the bottle is farther cooled, it is ſtopped very tightly with a good cork.

§ 467.

If the pyrophorus has ſucceeded well, and ſome of it be poured upon paper, it will grow hot of itſelf; eſpecially when breathed upon, and then begin to catch fire ſpontaneouſly. It is totally conſumed, emitting a ſtrong ſulphureous ſmell. When kept in bottles not well corked, it loſes by time its ſpontaneous inflammability.

§ 468.

It is demonſtrated by experiments, that alum yields pyrophorus only from the circumſtance of its containing vegetable alkali (§ 420); and that the argillaceous earth contributes nothing to that preparation.

The phenomenon exhibited by the pyrophorus may be thus accounted for. The carbonic radical decompoſes in a red-heat the ſulphuric acid of the ſulphat of alumine, and becomes carbonic acid gas, which eſcapes; the ſulphuric acid is converted into ſulphur, which ſublimes and burns. During theſe changes, the pot-aſh, by which the alum of commerce is adulterated, fixes a part of the ſulphur and retains it, eſpecially as the calcining heat is not vehement enough totally to volatilize all the ſulphur; and there remains the ſuperfluous part of the coal that had been blended with the ſulphat of alumine.

The conſtituent parts of the pyrophorus are conſequently exceedingly dry cauſtic pot-aſh, ſulphur, carbon, and alumine.—On expoſure to air, the firſt attracts rapidly its moiſture, and is heated with it (§ 283) And this heat is ſufficient to inflame the ſulphur, becauſe ſulphur is already, by its own nature, when combined with alkaline ſubſtances (§ 452), by far more diſpoſed to decompoſe oxygen gas. Laſtly, this ignition of the ſulphur in the pyrophorus is communicated to the coaly particles, that, at the beginning of its preparation, were mingled with the ſulphat of alumine.

Nitric

Nitric Acid.

§ 469.

If ſulphuric acid be poured upon *nitre*, an effervescence enſues, accompanied by heat, and immediate extrication of a quantity of reddiſh-yellow fumes, which by diſtillation may be condenſed into a liquid. Purified dry and finely pulverized nitre is put into a glaſs retort, and half its weight of concentrated ſulphuric acid is poured upon it, drop by drop, on account of the ſtrong heat that ariſes, and ſtirring the matters repeatedly. A receiver is next luted to the retort, and the diſtillation cautiouſly performed, on a ſand-bath previouſly warmed. Fumes, at firſt yellowiſh and then red, paſs over into the recipient, condenſing ſlowly to a ſour, reddiſh-yellow fluid. A part of them condenſes in the retort, and comes over in drops. The heat is kept up, until no more fumes or drops are perceived to come over.

§ 470.

The acid collected in the receivers has been formerly called, from the ſalt from which it is extracted, *acid of ſaltpetre (nitre)*; but in the new nomenclature its name is *nitric acid.* And the concentrated liquid, as deſcribed above, has obtained the appellation of *ſmoking ſpirit of*

nitre

nitre (acidum nitri fumans Glauberi). Its ſpecific gravity, when ſtrongly concentrated, is 1,583. On acceſs of air it ſends forth reddiſh yellow fumes, which, beſides, always fill the empty ſpace of the bottles wherein it is kept. It ſtrongly attracts moiſture; grows hot by mixing with water, in which caſe the reddiſh fumes are continually increaſing. When it is thus diluted with water, it firſt becomes green; but, on adding more water, it turns blue, and at laſt all colour diſappears.

§ 471.

We ſhall preſently ſee that the yellow or reddiſh colour, and the property of emitting reddiſh-yellow fumes, do not belong to *perfect nitric acid*, as ſuch, but preſuppoſe its having undergone ſome modification, and are the characteriſtic of another leſs perfect nitric acid.—If, therefore, ſmoking nitric acid be once more diſtilled in a glaſs retort, in a ſand-bath with a very gentle fire, the fuming part will riſe firſt, and the remainder will be deprived of all its colour, and its fuming quality. In like manner is the more volatile and ſmoking acid parted from the remaining perfect acid (§ 470) by dilution with water; and the reſidual colourleſs diluted acid muſt be conſidered as being the pure perfect nitric acid.

§ 472.

Sometimes, inſtead of ſulphuric acid, green vitriol calcined to redneſs is employed in large quantities to expel the nitric acid from nitre. Seven parts of vitriol, thus calcined, are diſtilled with eight parts of nitre, well dried, and reduced to fine powder, from large earthen and coated retorts, joined by luting with large recipients and adopters (§ 121), containing ſome water. This diſtillation is alſo performed in matraſſes (§ 79) of caſt-iron, provided with alembics or heads (§ 118) of clay or glaſs. The nitric acid of the ſhops, being weakened by water, is uſually colourleſs, and not ſmoking. In this ſtate it is called *aqua fortis*, or ſimply *ſpirit of nitre*. It is frequently much polluted with ſulphuric and muriatic acid.

§ 473.

To free the nitric acid from the ſulphuric, by which it is contaminated, the ſolution of barytes in nitric acid affords the moſt efficacious means. This ſolution is dropped into the nitric acid, to be purified, as long as any ſulphat of barytes is precipitated (§ 423); after which the acid is again rectified. The nitric acid is only then defiled by the muriatic, when unpurified nitre has been made uſe of for its preparation. Of the means to clear it from this laſt we can only treat hereafter, when ſpeaking of ſilver.

§ 474.

The reſidue in the retort, after diſtilling nitric acid from oil of vitriol and nitre (§ 470), is ſulphat of potaſh, uſually called vitriolated tartar. From this it is plain, that nitre is a neutral ſalt, conſiſting of vegetable alkali and its own peculiar acid; and that this laſt is leſs attracted by potaſh than ſulphuric acid. But when vitriol is employed for extricating nitric acid from nitre (§ 472), the ſulphat of potaſh is mingled with oxyd of iron; from which it may be ſeparated by lixiviating the ſalt with water, and filtering the lye.

§ 475.

Nitric acid is diſtinguiſhed from the ſulphuric by a peculiar odour, by its volatility, and by its highly corroſive action on organic bodies. It ſtains the ſkin, hair, ſilk, and other animal matters, with a permanent yellow colour. Its difference from other acids is beſt ſhewn by the neutral and middle ſalts *(Nitrats)* which it produces.

§ 476.

1. With pot-aſh, nitric acid forms the *common ſalt-petre*, or *nitre*; which in the new methodical nomenclature is called *nitrat of potaſh*; a ſalt ſhooting into priſmatic, ſix-ſided cryſtals of ſtriated lateral ſurfaces, terminating in pyramidal ſummits of ſix ſurfaces; having an acrid, bitteriſh, cooling taſte, and at a middle temperature ſoluble in ſeven

parts of water, but of boiling water requiring only a little more than its own weight for ſolution. Cryſtallized nitrat of pot-aſh contains, according to *Bergman*'s ſtatement, 0,49 of potaſh, 0,33 of nitric acid, and 0,18 of water of cryſtallization. The laſt, however, cannot be well aſcertained.

§ 477.

The cryſtals of nitre are permanent in the air. In heat this neutral ſalt liquefies and melts; and it not only loſes the water of its cryſtals, but is totally decompoſed by ignition, and its acid deſtroyed, as will be ſeen in the ſequel.

Of *ſalt-petre drops, or ſalt-prunellæ (nitrum tabulatum, ſal prunellæ).*

§ 478.

Nitrat of pot-aſh is found ready formed, in great quantities, in various parts of the globe: as in the *Eaſt-Indies*, in the territory of *Molfetta in Sicily*, and in *Lower-Hungary*. Neverthele*ſ*s a very conſiderable part of this article is artificially prepared by calcareous earth, impregnated with nitric acid, and vegetable alkali.

§ 479.

2. The *nitrat of ſoda* is uſually called *cubic* or *rhomboidal nitre.* It is a combination of nitric acid with mineral alkali. Its cryſtals are rhomboids, its taſte greatly reſembles that of common

nitre,

nitre, or nitrat of potaſh; it is ſomewhat diſpoſed to become moiſt, and is in a moderate warmth ſoluble in two parts of water. Its component principles are, according to *Bergman*, 0,32 parts of ſoda, 0,43 of nitric acid, and 0,25 of water. This neutral ſalt is ſeldom found native, and no uſe is made of it.

§ 480.

The vegetable alkali has an affinity with nitric acid, rather nearer than that of mineral alkali.

§ 481.

3. *Nitrat of ammoniac*, or the combination of nitric acid with pure volatile alkali, forms needled cryſtals, has a ſharp taſte, readily diſſolves in water, and does not decay in the air. In a red-heat, this neutral ſalt is totally decompoſed without addition; and at the ſame time not only the ammoniac, but alſo the nitric acid, its other conſtituent part, undergoes decompoſition, as will be proved hereafter.

Synonyma: *Nitric ſal-ammoniac (ſal ammoniacum nitroſum); flaming ſalt-petre (nitrum flammans).*

§ 482.

The nitrat of ammoniac is decompoſed by both the fixed alkalis, in conſequence of their poſſeſſing a greater affinity with nitric acid.

§ 483

4. Calcareous earth is eaſily diſſolved by nitric acid, and affords with it the *nitrat of lime*; a middle ſalt, of great deliqueſcence, of an acrid and bitter taſte. A red-heat decompoſes this ſalt, and the reſidual calcareous earth is poſſeſſed of the faculty of emitting light in the dark: in other words, it is the *phoſphorus* of *Baldwin*, but which ſoon loſes its phoſphoreſcent quality.

> Synonyma: *Calcareous ſalt-petre*, or *nitrous-lime (nitrum calcareum, calx nitrata)*.

§ 484.

The two fixed alkalis attract the nitric acid more ſtrongly than lime does; but calcareous earth has a greater affinity with that acid than pure or cauſtic ammoniac.

§ 485.

Nitrat of lime is found prepared by nature; and it is principally this native middle ſalt which is depoſited on nitre-beds, and old decaying walls in the vicinity of putrefying animal ſubſtances; and from which afterwards common nitre is artificially produced (§ 478) by the addition of pot-aſh.

§ 486.

5. *Nitrat of magneſia* affords likewiſe a very deliqueſcent middle ſalt, of a bitter and pungent taſte,

and

and decompoſable by fire. It has not yet been applied to any uſe.

Of the *magneſia nitri.*

§ 487.

Pot-aſh and ſoda completely decompoſe the ſolution of magneſian earth in perfect nitric acid; for they combine with the laſt, on account of their ſtronger affinity with it. Ammoniac, on the contrary, effects this decompoſition but incompletely, and rather forms with it a triple ſalt *(magneſia ammoniaco-nitrica).* Lime-water inſtantly precipitates the magneſian earth from its ſolvent nitric acid, as the calcareous earth has a ſtronger attraction than magneſia for this acid.

§ 488.

6. The ſolution of pure argil in nitric acid, or *nitrat of alumine*, is, by its tendency to deliqueſce, very difficultly cryſtallized, of a ſtyptic or aſtringent taſte, and decompoſed by a red-heat. It has been recommended as a *corroſive*, or means of ſtaining in the art of dying. All alkalis alſo, as well as lime and magneſia, decompoſe this middle ſalt.

§ 489.

7. *Nitrat of barytes*, or a combination of ponderous earth with nitric acid, admits of cryſtallization; and forms cryſtals, permanent in the air,

and

and of conſiderably difficult ſolubility, having a bitter and acrid taſte. Ignition decompoſes it.

Synonyma: *Nitrum baryticum, terra ponderoſa nitrata.*

§ 490.

Barytes exceeds, in its affinity with nitric acid, all alkaline ſubſtances.

§ 491.

8. Strontian earth is eaſily ſoluble in nitric acid, forming with it the middle ſalt, *Nitrat of Strontian*, whoſe cryſtals are not affected by the air, and are octahedral as to figure. If ſlips of paper are dipped into a ſolution of this ſalt, and dried again, on being lighted they burn with a beautiful purple-coloured flame.

§ 492.

The nitric-acid has a nearer affinity with all alkalis and earths than the carbonic.—As for the double affinities, we notice only, at firſt, the *decompoſition of nitrat of lime* by the carbonats of pot-aſh, of ſoda, of ammoniac; and, ſecondly, the *decompoſition of the nitrats of barytes* and *Strontian-earth* by the ſame carbonated neutral ſalts.

§ 493.

The *ſulphuric* precedes the nitric acid in the ſucceſſive gradations of affinities reſpecting alkalis and earths. On this principle depends the expulſion

ſion of nitric acid from nitre by the ſulphuric (§ 474), and the application of a diſſolved nitrat of barytes as a *re-agent*, to diſcover the preſence of ſulphuric acid in any fluid which it is ſuſpected to be united with; and, therefore, as a means to purify nitric acid from any ſulphuric (§ 473) with which it may be contaminated.

§ 494.

Of the double affinities between the *nitrats* and *ſulphats*, I mention in this place only the *decompoſition of common nitre* by Glauber's ſalt; the *decompoſition of nitrat of lime* by the ſulphats of pot-aſh, of ſoda, of ammoniac, of magneſia, of alumine; and the decompoſition of the *nitrat of barytes*, by all the ſulphats that are ſoluble in water, whether neutral or middle ſalts. For this reaſon the nitrat of barytes is a re-agent, not only for free ſulphuric acid (§ 493), but alſo for ſuch as is combined with other ſubſtances.

Nitrous Acid.

§ 495.

The acidifiable baſis of the nitric acid is capable of various degrees of oxygenation, or of receiving different portions of oxygen (§ 276); and on this account it appears in various ſtates. I have already mentioned (§ 271) that the fuming reddiſh ſpirit of nitre is not a perfect nitric acid; that by a gentle heat its ſmoking coloured portion may be driven out; in which caſe the *perfect* white and colourleſs nitric acid remains; and that by a ſimilar method its ſmoking part may be expelled by that degree of heat which is produced on mixing this acid with water (§ 471).

§ 496.

This fuming reddiſh part, which is but with difficulty condenſed into a liquid, which, beſides, is ſo volatile as to form reddiſh vapours and clouds even at the uſual temperature, and which does not poſſeſs the ſame degree of acidity as the perfect nitric acid, muſt be regarded as an *imperfect nitric acid*, and is called *nitrous acid.* A greater quantity of it is contained in the ſmoking ſpirit of nitre, in proportion as the oil of vitriol employed for its extraction from nitre has been itſelf more or leſs fuming.

§ 497.

That the acidifiable baſis of *nitrous acid* is combined with leſs oxygen than when forming the perfect or *nitric acid*, is evident from ſeveral facts.

For example: If nitrat of pot-aſh be made red-hot in a coated glaſs retort, and joined to the pneumatic apparatus, a great quantity of oxygen gas will come over; and, at laſt, if the retort be proof againſt melting, vapours of nitrous-acid will be extricated. The reſiduary maſs of ſalt in the retort has an alkaline taſte, but emits red fumes, and yields nitrous acid, if any of the weaker acids, as vinegar, be added, which in other circumſtances would not be powerful enough to diſengage the nitric acid.

It is obvious that, in this caſe, a portion of oxygen is expelled by the fire from the perfect nitric acid contained in nitre; and that this portion of oxygen flies off, combined with caloric, in the character of oxygen gas. Whence the acidifiable baſis of that acid remains behind with the alkali, but combined with a diminiſhed quantity of oxygen; and hence in the ſtate of nitrous acid, until, by the continuance of heat, more or leſs of the baſis itſelf is expelled.

§ 498.

From what has been ſaid, it plainly appears why all nitrats are decompoſed ſimply by being ignited.

§ 499.

When nitric acid is made to paſs through a red-hot glaſs tube, it produces oxygen gas and nitrous acid.

§ 500.

To conclude, when colourleſs concentrated nitric acid, incloſed in a very tranſparent retort, connected with the pneumatic apparatus, is expoſed to the

rays

rays of the ſun, it gives out oxygen gas, and the remaining nitric acid becomes again coloured. A dark heat, without light, does not produce theſe alterations.

§ 501.

Nitrous acid forms with alkalis and earths ſaline ſubſtances, different from thoſe which are generated by ſimilar combinations with nitric acid. Theſe are called *nitrites*. Will not theſe ſalts, by expoſure to open air, be again converted into nitrats? However, they are little known, and no uſe is made of them.

§ 502.

The nitrous acid has a much leſs affinity than the nitric with alkalis and earths.

Nitrous Gas.—Gaſeous Oxyd of Azot.

§ 503.

All bodies of the animal and vegetable kingdom decompoſe nitric acid, and deprive it, by means of the radical carbon which they contain, of moſt of its oxygen; ſo that the acid now appears of a different nature, and of different habitudes with other bodies. The ſame is effected by a great many metals, as by copper, mercury, and iron. If nitric acid be poured upon them, heat is produced, and air-bubbles extricated, which, on the acceſs of atmoſpheric air, immediately form a yellowiſh red cloud. The better to judge of the changes which happen in this caſe, we chooſe the following experiment.

§ 504.

Let a ſmall *proof-bottle* (§ 128) be filled with wire of copper or braſs; let ſome diluted nitric acid, prepared with one part of concentrated nitric acid and three parts of water, be poured upon the wire, in ſuch a manner that no atmoſpheric air remain in the veſſel; and let the bottle be duly connected with the pneumatic apparatus. The metal thus expoſed is diſſolved by the acid with ebullition; a great quantity of air eſcapes through the ſide-aperture of the glaſs, which is collected in the receivers, after the firſt portions have been ſuffered to fly off.

§ 505.

The kind of air obtained by this proceſs is called *nitrous gas.* It is colourleſs; ſhews no trace of an acid; does not redden by itſelf the tincture of litmus, nor render lime-water turbid; is inſoluble in water, utterly unfit for reſpiration, and extinguiſhes a light brought into it. When it meets with atmoſpheric air, it directly abandons the aerial form, and is transformed into reddiſh yellow acid vapours, like thoſe iſſuing from ſmoking ſpirit of nitre; and is finally converted into nitric acid, which is gradually imbibed by water. A Pariſian cubic inch of this nitrous gas weighs at 10° Reaum. and 28 inch. Barom. 0,54690 French grains.

§ 506.

If into a cylindrical glaſs-veſſel, holding nitrous gas confined by water, common air of the atmoſphere be introduced, reddiſh yellow fumes are inſtantaneouſly formed; heat is produced, and the volume of the two kinds of air, taken together, is diminiſhed; the water riſes in the cylinder, and becomes diluted nitric acid. When both airs have been mixed in a juſt proportion, nothing elſe remains at laſt than the azotic gas of the atmoſpheric air (§ 197).—Uſually 16 meaſures of this laſt are required to deſtroy completely $7\frac{1}{3}$ meaſures of nitrous gas.

§ 507.

If to atmoſpherical air, in the foregoing experiment (§ 506), pure oxygen gas be ſubſtituted, the redneſs and heat produced are much greater; and if both airs have been abſolutely pure, and mixed in due proportion, the whole of the air that was in the cylinder diſappears entirely. It is, however, difficult to obtain the nitrous and oxygen gaſes quite undefiled by the azotic which then remains behind.—About four meaſures of oxygen gas are required for $7\frac{1}{3}$ of nitrous gas.

§ 508.

The red miſts formed in theſe two experiments (§ 506, 507) are nitrous acid, which by degrees changes to nitric acid, and is abſorbed by water.

Hence,

Hence, by the combination of the oxygen and nitrous gaſes, nitric acid is generated, and both kinds of air diſappear.

§ 509.

The inference from all theſe experiments is, that nitrous gas contains the baſis of nitric acid, which is converted into this acid by imbibing oxygen; and hence, that the metal, during its ſolution in nitric acid (§ 504), decompoſes part of the acid by robbing it of oxygen, altering thereby its condition ſo much, that, at the uſual temperature of our atmoſphere, it no longer appears in the liquid ſtate, but ceaſes to act in the capacity of an acid, and exhibits different properties. But when nitrous and oxygen gas happen to come in contact, their baſes attract each other, and form again nitric acid, by diſmiſſing their caloric.

§ 510.

The baſis of nitrous gas contains, therefore, the radical of nitric acid. However, the following obſervations ſhew that it does not contain it quite pure, but always combined with a portion of oxygen, though inſufficient for making an acid with that radical. Whence it farther follows, that the nitric acid is not deprived by the metal (§ 504) of the whole of its oxygen, but only of the greater part; and, conſequently, that the baſis of nitrous gas conſiſts of the radical of the nitric acid, and ſome portion of oxygen.

§ 511.

But the formation of the baſis of nitrous gas does not conſtitute the firſt degree of oxygenation of the radical of nitric acid; there is yet another degree below this. For if nitrous gas be left for ſome time in contact with wetted iron filings, or moiſtened alkaline ſulphuret, a diminution of about two-thirds of its volume takes place, and the gas acquires properties different from its original ones. For the remaining third part of the gas is taken up by water; is neither decompoſed by, nor decompoſes, vital air; and produces no red fumes with it. Beſides, a lighted candle burns in it with increaſed brightneſs; and a ſparkling wick ſunk into it is ſpontaneouſly ignited to flame. Yet burning phoſphorus, ſulphur, and coals, are extinguiſhed in it, and animals are ſmothered. It is not affected by nitrous gas.

§ 512.

This gas, firſt mentioned by *Prieſtley* under the name of *dephlogiſticated nitrous air*, is called *gaſeous oxyd of azot*. During its production (§ 511) the baſis of nitrous gas (§ 509, 510) is deprived of part of its oxygen, but not of the whole quantity which it contains. The radical of nitric acid, therefore, forms, in combination with a ſtill ſmaller portion of oxygen, another ſpecies of gas different from the nitrous. This laſt may alſo be obtained by various other ways: for inſtance, by mingling nitrat of ammoniac with about three times as much ſand, and diſtilling it from a ſmall retort joined to the pneumatic apparatus. Towards the end of the operation a great quantity of azotic, or nitrogen gas, comes over.

§ 513.

Hence the radical of nitric acid is capable of various degrees of oxygenation. The firſt and loweſt degree forms the baſis of the gaſeous oxyd of azot (§ 512); the next conſtitutes the baſis of nitrous gas (§ 510); the third produces nitrous acid (§ 496); and the fourth and laſt generates the nitric acid (§ 470).

§ 514.

Azotic gas has no influence on nitrous gas, and neither of theſe airs act upon each other. The nitrous gas is likewiſe not affected by the carbonic, hydrogen, ſulphureous, and ammoniacal gaſes; it is, therefore, not decompoſed by any of the common non-reſpirable kinds of air. Oxygen gas alone is capable of decompoſing it; as, on the other hand, this laſt is itſelf decompoſed by the nitrous gas (§ 506, 507). For this reaſon nitrous gas has been propoſed and employed in *eudiometers*, to aſcertain what quantity of oxygen gas may be contained in any given portion of atmoſpherical air (§ 220). This method of examining the air does not, however, afford reſults ſo conſtant as to

be

be always depended on; though the inſtruments contrived by *Fontana* and *Ingenhouſz**, and the way of managing them, have arrived to very high perfection.

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* See *Experiments upon Vegetables*, &c. by *John Ingenhouſz*, 8vo. Lond. 1779. Part 2, ſect. 1, page 149; where the Doctor has fully explained the conſtruction and uſe of *Fontana's eudiometer*.—Ed.

§ 515.

Neither carbon (§ 230), nor ſulphur, decompoſe nitric acid in the cold; but they do it in heat, if the acid be very concentrated, though ſlowly and with difficulty. When combined with hydrogen, carbon, as well as ſulphur, decompoſe the nitric acid with much greater facility. As to carbon, this is proved by vegetable and animal ſubſtances, ſuch as ſugar, oil, &c. which, even in a moderate warmth, change the nitric acid to nitrous gas. As to ſulphur, this is ſhewn by the ſulphurated hydrogen gas (§ 447), which is decompoſed by concentrated nitric acid, and decompoſes it in its turn. Even the ſulphureous gas (§ 433) imbibes oxygen from nitric acid; and brown vitriolic acid may ſoon be rendered colourleſs by the addition of nitric acid, and by the heat ariſing from the mixture. Yet it would be improper to call this treatment a purification of ſulphuric acid.

Total Decompoſition of Nitric Acid.

Detonation.

§ 516.

Since charcoal, at the temperature of ignition, totally deprives the nitric acid of its oxygen, for which it exerts a ſtronger attraction, we can by ignited coals effect a complete decompoſition of that acid, and ſeparate its radical. But in order that nitric acid may be heated to redneſs, it ought to be in a fixed ſtate, as it exiſts in the nitrat of pot-aſh by means of the vegetable alkali.

§ 517.

Nitrat of pot-aſh, which by itſelf melts quietly in heat, is immediately ignited with noiſe, if it be brought into contact with burning charcoal, or if this laſt be added to it when in red-hot fuſion. This rapid inflammation, which is a decompoſition of the nitrat of pot-aſh expoſed to heat with combuſtible matters, is called *detonation* of nitre.

§ 518.

Beſides charcoal, ſulphur, and phoſphorus, nearly all the metals, and in general all inflammable matters, cauſe the nitrat of pot-aſh to detonate when in the ſtate of red-heat.

§ 519.

The combuſtion of inflammable bodies by detonation is performed more briſkly, more rapidly, and with a brighter light, than it commonly is in atmoſpheric air; and it entirely reſembles the combuſtion of theſe bodies in pure oxygen gas. The neutral ſalt is deſtroyed by it, and only the vegetable alkali remains; which may, indeed, be more or leſs altered by a new acid, the carbonic, which is generated in the proceſs, to the production of which the combuſtible body gave the radical, *viz.* the carbon, and the nitric acid afforded the oxygen.

Experiments: By detonating nitrat of pot-aſh with charcoal, and with ſulphur.

§ 520.

If, therefore, upon nitre melted in a red-hot crucible powdered charcoal be thrown till it ceaſes to detonate, the remaining vegetable alkali is but partially carbonated, becauſe part of the carbonic acid is again driven out by the ignition. That alkali is unneceſſarily diſtinguiſhed from pure pot-aſh by the name of *fixed nitre*, or *alkaline ſaltpetre (nitrum fixum)*, or by the name of *Glauber's alkaheſt (liquor nitri fixi)*, after it has deliqueſced in the air.

§ 521.

If, inſtead of charcoal, ſulphur be employed in this experiment, a lively detonation likewiſe takes place; and the remaining alkali becomes a ſulphat. By this it is plain, that in a red-heat ſulphur has a nearer affinity with oxygen than azot, the radical of nitric acid.

Baumé's quick-flux.

§ 522.

The inflammation of *gun-powder (pulvis pyrius)* is in like manner a true detonation of nitre, by means of its coaly and ſulphureous parts.

Its goodneſs depends on the purity of its ingredients, on their accurate and intimate incorporation, and on their due proportion to each other. Yet the proportion of theſe materials varies according to the uſe for which gun-powder is intended. Uſually it is made up of 75 parts of nitre, 16 of charcoal, and from 9 to 10 of ſulphur. Sulphur is neceſſary to cauſe the powder to catch fire more readily.

Theſe ingredients are, in *gun-powder-mills*, reduced to a pulverulent ſtate by ſtamping, and finely ground together, cautiouſly moiſtening the maſs from time to time, to impede its flying off in duſt; and, what is of the utmoſt conſequence, to prevent exploſion. Too much moiſture is hurtful, as it diſſolves and waſhes away the nitre. The *powder-paſte*, thus prepared, is afterwards *grained*; and laſtly, for nicer purpoſes, *glazed* or poliſhed.

§ 523.

Another remarkable compoſition of this kind is the *fulminating-powder*, which has this particular property, that without being confined, and even in ſmall quantity, it deflagrates with violent exploſion, if held in a ſpoon on ignited coals, and gradually heated, till the ſulphur is ſet on fire. Its ingredients are three parts of nitre, two parts of dry ſalt of tartar (pure vegetable alkali), and one part of ſulphur, very finely triturated, and well mingled together.

§ 524.

That we may be enabled to judge of what becomes of the nitric acid decompoſed on the detonation of nitre (§ 519, 520), it is neceſſary that the operation ſhould be performed in cloſed veſſels, connected with the pneumatic apparatus.

A maſs mingled of one part of powdered charcoal, and three parts of nitre, is the moſt proper for that purpoſe. The addition of ſulphur muſt be avoided, as otherwiſe the exploſion would be too violent. A portion of the above maſs, moderately moiſtened, is put into the cloſed end of a guna gun-barrel, and cloſely rammed in. This end of the barrel is laid upon ignited charcoal, while the whole barrel is much inclined, and its aperture placed beneath the funnel of the pneumatic trough, filled with hot water.

As ſoon as the end of the muſket, containing the materials to be detonated, becomes red-hot, the detonation begins, extending gradually throughout the whole maſs, and accompanied by a vehement and copious extrication of gas.—When, after the end of the experiment, the nitre remaining in the barrel is examined, it is found totally decompoſed, and in its place a carbonat of pot-aſh is left, together with a greater or ſmaller portion of unburnt coal.—The gas that paſſed over, is compoſed of carbonic and azotic gas.

§ 525.

Since the production of carbonic acid, in this inſtance, cannot be explained but on the hypotheſis that the carbon attracts oxygen from the nitric acid (eſpecially as all the nitric acid entirely diſappears, ſo much ſo that even the water of the trough contains no portion of it), and ſince a large quantity of nitrogen gas is extricated on this experiment, it follows that *azot*, or *nitrogen*, is the radical or acidifiable baſis of nitric acid.

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As the quantity of carbonic acid generated by this proceſs, and alſo the quantity of charcoal conſumed, may be aſcertained, it is poſſible to decide upon the proportion of oxygen to nitrogen in the very concentrated nitric acid contained in the nitrat of pot-aſh. For the proportion of carbon to oxygen in the carbonic acid being known (§ 225), it is, together with the quantity of the collected azotic gas, a datum from which to draw the concluſion.—According to *Lavoiſier*'s ſtatement, 0,205 parts of nitrogen, and 0,795 of oxygen, are combined in nitric acid, or nearly ſo.

§ 526.

Hence *azot* is the acidifiable baſis of nitric acid; and it aſſumes various forms, and is of a different nature, according as it is combined with various quantities of oxygen.—With about four parts of oxygen it conſtitutes the nitric acid; with about three the nitrous acid; with nearly two parts of oxygen it makes the baſis of nitrous gas; and with little more than an equal part it is the baſis of the gazeous oxyd of azot (§ 513).

In the *phlogiſtic ſyſtem*, azot, or *nitrogen*, is a compound of phlogiſton, and a peculiar baſis of its own.

§ 527.

The above theory is confirmed by the fact, that nitrous gas, when paſſing through a red-hot gun-barrel, is totally changed into azotic gas, becauſe the

the ignited metal takes up entirely that portion of oxygen, which ſtill remained as part of the nitrous gas.

§ 528.

By this doctrine is moreover explained: firſt, the total deſtruction, or rather decompoſition, of the nitrat of ammoniac, when expoſed by itſelf to red-heat (§ 481), and its transformation into water and nitrogen gas; as likewiſe the converſion of liquid ammoniac into nitrous gas, if it be made to paſs, by diſtillation, through a tube full of native oxyd of manganeſe ignited to redneſs.

§ 529.

A ſynthetical proof that nitric acid is really formed by the mixture ſtated above, is afforded by an experiment made by Mr. *Cavendiſh* *. This gentleman obſerved, that the volume of a mixture of ſeven parts of oxygen gas with three parts of the azotic, and confined by an alkaline lye in a glaſs-tube, was diminiſhed by frequently reiterated electric ſparks; and that the lye had become a nitrat. However, it is yet a matter of queſtion what ſhare the electric matter had in that event.

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* For farther particulars ſee Mr. *Cavendiſh's* papers in the Phil. Tranſ. vol. 75 and 78.—Ed.

§ 530.

Thus much, however, ſeems to be a decided, incontrovertible fact, that on the putrefaction of organic bodies, azot, one of their conſtituent parts, ſpontaneouſly unites with oxygen, which is yielded by water, or the atmoſphere, to form by this combination nitric acid; which, in this reſpect, might be called a product of putrefaction. But the reaſon why oxygen and azotic gas produce no nitric acid by ſimple mixture, conſiſts in the ſtrong affinity of their reſpective baſes to the caloric, with which they are united in theſe two gaſes.

§ 531.

Theſe premiſes being eſtabliſhed, it is eaſy to explain the theory of detonation according to the antiphlogiſtic ſyſtem.

The nitrat of pot-aſh diſengages in a red-heat oxygen gas (§ 497), which cauſes the briſk combuſtion of the inflammable ſubſtances. In the temperature, which then takes place, the combuſtible ſubſtance ſeizes all the oxygen of the nitric acid, whoſe radical, nitrogen, is ſet free, and flies off in the form of azotic gas. Thus the acid of this nitrat is completely decompoſed. To account for the ſtrong heat ariſing on detonation, we find a ſufficient cauſe in the great quantity of caloric, which the nitric acid of the nitrat of pot-aſh ſtill

contains

contains in a fixed ſtate, and which is not altogether employed for the formation of the gaſes which are then generated.

Yet the phenomena obſerved on detonation cannot ſtrictly be deduced from that portion of oxygen gas, which is extricated from the nitrat of potaſh; they rather depend on the nitric acid itſelf, which in a red-heat ignites the combuſtible ſubſtance by its oxygen, even before this radical is diſengaged in the aerial form. Laſtly, it is not difficult to explain, by theſe obſervations, why, by means of nitre, the combuſtion may be carried on in cloſed veſſels without any external air at all.

The cauſe of the dreadfully great power exerted by gun-powder, when inflamed in a confined ſpace, lies in the extreme rapidity with which the combuſtion ſpreads throughout its maſs; in the quantity of nitrogen and carbonic gaſes which are then ſo ſuddenly generated; in the elaſticity, great beyond all computation, which that gas muſt receive by the immenſe quantity of caloric becoming free at the ſame time; and, finally, in the expanſive power of the laſt in the moment of regaining its liberty.

§ 532.

In the deflagration of fulminating powder (§ 523) there is no doubt but that, on its gradual melting, ſulphurated hydrogen gas (§ 447) is produced from the

the alkaline ſulphuret (by virtue of the water contained in the nitrat of pot-aſh and in the alkali); or rather, that this gas, being then naſcent, and at the firſt period of its generation, produces a fulminating air by combining with the oxygen gas, diſengaged from the nitrat of pot-aſh.

Muriatic Acid.

§ 533.

If upon common *culinary ſalt* ſulphuric acid be poured, a conſiderable heat and ebullition inſtantly ariſe, and copious whitiſh fumes are extricated, of a peculiar acid and pungent taſte and ſmell.—If theſe fumes be collected by diſtillation, and condenſed with as little water as poſſible, an acid liquid is obtained, which is ſold in the ſhops by the name of *ſmoking ſpirit of ſalt (ſpiritus ſalis fumans Glauberi).*

§ 534.

This ſour fluid is an acid of a peculiar kind, which, from the ſalt from which it is procured, has received the name of *muriatic acid*, *marine acid*, or *acid of ſea-ſalt*. But becauſe the acid thus procured, is but an imperfect acid, as will be ſhewn hereafter, and becauſe its radical is ſuſceptible of an higher degree of ſaturation with oxygen, I call it

muriatous

*muriatous acid** (§ 276), and make uſe of the expreſſion, *muriatic acid*, to indicate that higher degree of oxygenation.

§ 535.

The beſt way of diſtilling the muriatic acid is from a tubulated glaſs-retort lodged in a warm ſand-bath, containing two parts of common ſalt, and connected with ſeveral collateral receivers, like the *middle bottles* of the pneumatic apparatus (§ 128), every one of them having a ſmall quantity of water introduced. All their junctures are well luted; but the tube of the laſt bottle muſt have communication with the outer air.

When every thing is thus prepared, a third part of ſulphuric acid is poured upon the two parts of ſalt through the tubular aperture of the retort, but very gradually, little by little; or ſtill better, if it be ſuffered to drop into the retort by means of a funnel faſtened to its tubular aperture, and whoſe inner opening may at pleaſure be cloſed wholly, or in part only. No ſtrong degree of heat is neceſſary to

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* Notwithſtanding this, the term *muriatous* has, in this tranſlation, been ſuppreſſed; and the expreſſion *muriatic acid*, as well as its correlative term, *oxygenated muriatic acid*, conſtantly uſed. For the motives of ſo doing, the reader is deſired to refer to the Preface.—Editor.

to drive this acid over. Water ſhould be put into the receivers, or elſe the vitriolic acid muſt be diluted with water, as without this precaution the muriatic acid could never be collected in the liquid form.

§ 536.

The reſiduum of this diſtillation, in the retort, is ſulphat of ſoda. By this it appears, that the culinary ſalt is a neutral ſalt, compoſed of ſoda, and the above peculiar acid.

§ 537.

The liquid acid obtained by this proceſs, can never, on account of the neceſſary addition of water, be ſo much concentrated as the nitric acid. It is properly colourleſs; and if ſufficiently concentrated, emits whitiſh fumes on expoſure to air. The yellow colour of the muriatic acid of the ſhops is owing to ferruginous particles. This laſt is prepared in a manner that cannot be approved of: viz. by diſtilling common ſalt with calcined green vitriol, and putting water into the recipients.

§ 538.

Strictly ſpeaking, this acid on being extricated from common ſalt by concentrated ſulphuric acid, comes over in the form of gas; which is again decompoſed by the water of the receivers imbibing its baſis.

This gas is obtained by expeditiouſly directing the aperture of the retort underneath the funnel of the quick-ſilver trough (§ 126); and duly collecting the riſing bubbles. It is called *muriatic acid gas*; is very ſour, its baſis being the muriatic acid. It is ſuffocating, and unfit for maintaining combuſtion. It is immediately imbibed by water, and this fluid becomes thereby liquid muriatic acid. Alkalis, lime-water, and the like, abſorb it rapidly, and loſe by this their alkaline qualities.

With atmoſpherical air and oxygen gas, it forms whitiſh clouds. If ammoniacal gas be mixed with it, and heat applied, both gaſes loſe in a moment their aerial form, and are transformed to a concrete ſalt. *(Sal ammoniac). Muriatic acid gas* is not acted upon by carbonic and nitrogen gas; nor by pure and ſulphurated hydrogen gas, nor by the ſulphureous and nitrous gaſes; provided they be not moiſt.

The expreſſion *muriatic acid gas* is taken from the New French Nomenclature:—The author calls it *muriatous gas*.—Edit.

§ 539.

The neutral and middle ſalts ariſing from muriatic acid are the following:

1. *Muriat of pot-aſh,* a ſalt of a pure ſaline taſte, forming cubic permanent cryſtals; which are ſoluble in three parts of cold water, contain, according to *Bergman,* 0,31 muriatic acid, 0,61 pot-aſh, and 0,08 of water, and decrepitate in fire; but melt only in a red heat.

Synonyma: *Digeſtive ſalt, febrifuge ſalt of Sylvius.*

§ 540.

2. Of all ſalts the moſt generally known, and moſt abounding in nature is *muriat of ſoda,* or *common ſalt.* The primitive figure of its cryſtals is a cube; but the ſmaller cubic cryſtals, on evaporating the ſolution, uſually aſſume the ſecondary form of hollow tetrahedrons. The taſte of this ſalt is purely ſaline. Its cryſtals, if completely pure, do not decay in the air, and contain, according to *Bergman,* 0,52 of muriatic acid, 0,42 of ſoda, and 0,06 of water of cryſtallization; though the quantity of the laſt is obviouſly ſtated too ſmall. At a moderate temperature theſe cryſtals require $2\frac{14}{17}$ of cold, and of boiling water $2\frac{13}{17}$ parts for ſolution. They cannot, therefore, be cryſtallized by cooling. When thrown on the fire, they decrepitate or crackle, becauſe their water is not ſufficient to diſſolve the ſalt. In a ſtrong red-heat this ſalt melts; its acid, however, cannot be expelled, nor can the ſoda be ſeparated from it, by this means alone, in its pure alkaline ſtate. In a white-

white-heat, this ſalt is entirely volatile, and on this property the manner of glazing ſtone-ware is founded (§336.)

§ 541.

Nature produces this neutral ſalt partly ready formed and undefiled as *rock-ſalt (ſal gemmae)* and offers it in the mines in ſolid lumps; ſeldom cryſtallized; more or leſs tranſparent, and of various colours. It is found in ſeveral countries, as in England, Gallicia, Hungary, Tranſylvania, Moldavia, &c. in ſtrata of conſiderable thickneſs. It is alſo found either embodied with earths, eſpecially gypſum, as *ſalt-ſtone*; or diſſolved as in *ſea-water*, or on land, in *brine-ſprings;* from which it is procured by evaporation; receiving thence various names of *ſea-ſalt*, *bay-ſalt*, &c.

§ 542.

From the degree of ſolubility of the muriat of ſoda (§ 540), it is plain, that no brine-ſpring can contain more of it, than 4,184½ ounces in the pound (of 16 ounces). The quantity of ſalt contained in the natural ſalt ſprings, or their *richneſs*, is expreſſed either by *loths*, viz. half-ounces of ſalt, which are contained in the pound, gallon, or any other fixed ſtandard meaſure, or better by ſo much *per cent.* and is aſcertained either hydroſtatically by *areometers*, or chemically.—None of the known brine-ſprings is a ſolution of pure muriat of ſoda;

but

but all of them contain, beſides, ſome extraneous ſalts, and other heterogenous ſubſtances, particularly gypſum, muriat of magneſia, muriat of lime, ſulphat of magneſia; all of which may contribute more or leſs to the impurities impairing the brine.

§ 543.

If ſalt-ſprings contain a ſufficient quantity of ſalt, it is directly ſeparated by evaporating the water; which proceſs is performed in large ſhallow iron pans or boilers, called *ſtoves*.

The brine is firſt clarified with bullock's blood and *ſcummed* off. When after farther evaporation the ſaline pellicle appears on the ſurface, or if the brine begins to *grain*, the heat is ſo regulated, that the vapours continually break the ſaline cruſt, and thus occaſion its ſinking to the bottom. The precipitating ſalt is next taken out with perforated ladles and put into baſkets, that the adhering brine may run off; and is laſtly dried in well heated chambers. If this firſt precipitating ſalt be impure, it is collected by itſelf.

The lye remaining laſt in the boiler *(mother-water)* contains the not-cryſtallizable ſalts of the ſpring; uſually ſome muriat of magneſia, or as is the caſe with ours (at *Halle* in Saxony) muriat of lime. Their accumulation in the boilers, when without cleaning them, freſh quantities of

brine

brine are continually boiled, always makes the ſalt that is obtained more and more deliqueſcent and bitter. And the cruſt (called *ſchlot* by the workmen), which is there formed, conſiſts of various ſubſtances; and may contain gypſum, carbonat of lime, ſulphat of magneſia, and a greater or ſmaller portion of muriated ſoda.

§ 544.

If the ſalt-ſprings be too poor, and require too great an expence of fuel to extract their ſalt, part of the ſuper-abundant water is evaporated by the aſſiſtance of atmoſpherical warmth, in particular buildings called *graduating houſes*. And in order to give to the water the greateſt poſſible ſurface, it is pumped up, and made to drop or trickle down through bruſh-wood in the form of rain; in which ſtate the air penetrating from all quarters, greatly accelerates the evaporation, while by particular contrivances the brine is ſheltered againſt winds and weather.

A dry and warm ſeaſon is choſen for this operation. When thus ſufficiently diminiſhed, the remaining water is finally evaporated in the boilers (§ 543). The incruſtations formed on the faggots and ſides of the wooden pans collecting the ſalt-water, trickling down from the top of the building, conſiſt chiefly of gypſum; but may alſo contain carbonat of lime, and carbonated oxyd of iron.—

However,

However, the ſalt obtained from a brine, thus graduated, is not always purer, than what is procured without that operation.

§ 545.

In ſome parts of Upper Germany, cavities or ditches are dug in the ſalt-mines, and ſweet water conveyed there, for the purpoſe of making, in that way, artificial brines; which afterwards are evaporated by boiling.

§ 546.

From the ſea-water common ſalt is moſtly obtained by ſpontaneous evaporation in warmer climates, and in a warm and dry ſeaſon. This is done in *ſalt-pits*, as they are called, or flat pieces of ground cloſe to the ſea-ſhore, banked round, to prevent their being overflowed at high-water, and divided into ſeveral compartments. When the cruſt is formed by evaporation, the workmen break it, rake it out occaſionally, and let it dry in heaps. In this ſtate it is called *bay-ſalt*; which is farther refined and cleared from impurities, by being again diſſolved, and evaporated upon the fire. The water of the ocean is not every where equally rich in ſalt; towards the equator and at a great depth, it contains more than at higher latitudes, and near the ſurface.

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* There are alſo ſome natural *ſalt-lakes*, as the *Feltonic* in the Ruſſian dominions near *Saratow* and *Dmitrewſk*.

Their ſalt is not different from bay-ſalt; except by the caſual intervention of ſome other ſubſtances.—Edit.

§ 547.

The muriats of ſoda, of whatever kind, whether obtained from rock-ſalt, ſea-ſalt, or from ſalt-ſprings, are not eſſentially different from each other; their difference conſiſts merely in the different adhering extraneous matters. The ſalt in the ſtate in which it is commonly ſold, is indeed hardly ever pure; being uſually contaminated with the muriats of lime or of magneſia; and under theſe circumſtances it is more or leſs diſpoſed to grow moiſt and to deliqueſce. Its ſolution is therefore rendered turbid by carbonated fixed alkali; which is never the caſe with pure muriat of ſoda.

§ 548.

Muriatic acid has a leſs affinity with ſoda, than with pot-aſh; hence the muriat of ſoda is decompoſed by the latter * *).—The proceſs ſucceeds beſt in winter. The alkaline part of the pot-aſh ſhould equal the weight of the dry culinary ſalt. If common pot-aſh is uſed, vitriolated tartar ſeparates firſt (§ 643). And as the ſoda cryſtallizes only after complete refrigeration, the lading over of the lye, while yet warm, from veſſel to veſſel, affords an expedient to part the digeſtive ſalt (§ 539) from the mineral alkali. Thoſe, who are aware of the quantities of carbonic acid and water contained in the carbonat of ſoda (§ 360), which is the reſult of the operation, cannot wonder that more of it is obtained, than the muriat, employed for that purpoſe, amounted to.

* What follows after *), the editor thought uſeful to transfer from the author's larger work.—Mr. *Weſtrumb* has likewiſe given an able diſſertation on that ſubject. —Edit.

§ 549.

3. Muriatic acid, when ſaturated with ammoniac, forms *muriat of ammoniac* or *common ſal-ammoniac*: a neutral ſalt, exciting a pungent, and in ſome manner urinous taſte, ſhooting into double plumous or feathered cryſtals, which are properly an aggregate of tetrahedrons. This ſalt is of eaſy ſolution in water, requiring at a moderate temperature of 50° Farenh. 2,727 parts of water, and on boiling, about equal parts. The cryſtals continue unaltered in the air.—This ſalt is volatile in the fire, and may be ſublimed, in looſe *flowers of ſal-ammoniac* if the fire be weak; but in compact cakes, if ſtronger.

§ 550.

Sal-ammoniac is certainly found native in various places, particularly as a volcanic product; but that of commerce is obtained by art. Till lately no no other factitious ſal-ammoniac was known, than that which came from Egypt; where, for many centuries paſt, it has been prepared by ſublimation from the ſoot of burnt camel's dung. The Egyptian muriat of ammoniac is brought to us in round convex and concave lumps or cakes, ſoiled in various degrees with particles of ſoot on their ſurface.—Of late it has been attempted in Europe, to combine the component principles of ſal-ammoniac in a ſecondary way (for example, ſulphat of ammoniac with muriat of ſoda), in ſuch a manner, that its price may not be too great.

§ 551.

Both the fixed alkalis immediately decompoſe the muriat of ammoniac, becauſe the muriatic acid has not ſo great an attraction for the volatile, as for the two other alkalis, ſoda and pot-aſh. Even ſimple trituration with either of them decompoſes it.

Engliſh ſmelling bottles, (ſel poignant d'Angleterre.)

§ 552.

Muriat of lime, or the combination of calcareous earth with muriatic acid, is a very deliqueſcent middle-ſalt; of a diſagreeable bitter taſte, not parting with its acid in the fire. It is found native in ſeveral waters and ſome brine-ſprings, as in that of *Halle*, and many render common ſalt deliqueſcent, if adhering to it (§547).

Synonyma:

Synonyma: *fixed ſal-ammoniac, oil of lime (oleum calcis)* and by ſome *marine ſelenite.*

§ 553.

As the two fixed alkalis, pot-aſh and ſoda, have a ſtronger attraction for the muriatic acid, than calcareous earth is poſſeſſed of; either of them decompoſes the muriat of lime.—Ammoniac, on the contrary, has a leſs affinity with that acid than lime; hence ſal-ammoniac is decompoſed by calcareous earth. On this principle depends the uſual method of preparing liquid ammoniac (§ 287), or *cauſtic ſpirit of ſal-ammoniac, (ſpiritus ſalis ammoniaci cum calce viva, alkali fluor.)*

To obtain it in the moſt commodious way, three parts of lime, juſt ſlacked in the air, are introduced into a glaſs retort, together with one part of ſal-ammoniac; a receiver, containing one part of water, is then luted to the retort, and the diſtillation is cautiouſly performed on a ſand bath. The reſidual maſs in the retort is muriat of lime, together with ſome unchanged calcareous earth. It melts in a red-heat, and yields, after congealing, *Homberg's phoſphorus*; which gives light in the dark, when violently ſtruck upon, or when ſcratched with an iron wire; but ſoon loſes this property in moiſt air.

§ 554.

5. The *muriat of magneſia* is likewiſe an extremely deliqueſcent middle-ſalt, of a very ſharp and bitteriſh taſte. In a red-heat it abandons its acid; but the laſt portions of it with greater difficulty.

Synonyma: *magneſian marine ſalt.*

§ 555.

Pot-aſh and ſoda ſeparate the magneſian earth from muriatic acid.—Ammoniac produces the ſame effect; but only imperfectly, forming rather with the magneſian muriat a triple ſalt (*ammoniacal muriat of magneſia*).—Lime-water precipitates the magneſia from the muriatic acid which held it in ſolution.

§ 556.

This middle ſalt abounds in nature, particularly in mineral waters, and ſalt-ſprings, having its ſhare in forming their mother water (§ 543). It is likewiſe contained in the waters of the ocean, and is the chief cauſe of the bitterneſs of ſea-water.

§ 557.

6. *Muriat of alumine*, or argil, is harſh and aſtringent to the taſte, cannot be cryſtallized, and is very deliqueſcent. Ignition decompoſes this middle-ſalt. All alkalis, lime-water and magneſia,

neſia, ſeparate the aluminous earth from its combination with muriatic acid.

Synonyma:—*Argillaceous marine ſalt.*

§ 558.

7. *Muriat of barytes* forms a middle-ſalt in tabular cryſtals, of a bitter taſte, ſoluble in ſix parts of water in a mean temperature, and not affected by the influence of the atmoſphere, either to deliqueſce or effloreſce. A red-heat drives out its acid.

Synonyma:—*Ponderous marine ſalt. (Terra ponderoſa ſalita.)*

§ 559.

Neither the fixed alkalis, nor the volatile, when pure, decompoſe the muriat of barytes; though the carbonated alkalis do it by means of double or intermediate affinity (§ 50). Thus alſo lime, magneſia and alumine, are unable to ſeparate the acid from the barytic muriat. Hence ponderous earth has of all alkaline or earthy ſubſtances (§ 279. 300) the greateſt affinity with muriatic acid; and is therefore placed directly under that acid, in the tables of elective attractions.

§ 560.

8. *Stontian-earth* is without difficulty diſſolved by muriatic acid. The *muriat of Strontian-earth*; produced by this combination, forms by ſlow imperceptible evaporation long permanent

cryſtals, taſting bitter, eaſily ſoluble in water, and conſtituting ſix-ſided priſms of alternate broad and narrow lateral ſurfaces, with three-ſided pyramidal terminations. Their acid is not ſeparated by fire. The place, which, in the liſt of affinities with muriatic acid, is due to Strontian-earth, is not yet exactly determined.

§ 561.

9. Circon-earth is ſoluble in muriatic acid; but the properties of the *muriat of circon-earth* are ſtill unknown.

§ 562.

10. According to *Wedgwood*, the muriatic is the only acid capable of diſſolving auſtral-earth, and requires for that purpoſe the aſſiſtance of boiling heat. The ſaturated ſolution of this *muriat of auſtral-earth* is not cryſtallizable, and is again decompoſed by mere affuſion of water; fire alſo expels the acid.

This ſection might have been ſpared.—See note to § 349.—Edit.

§ 563.

In the graduated arrangement of affinities, reſpecting alkalis and earths, the muriatic acid is by far ſuperior to the carbonic; and all carbonats, whether neutral or middle-ſalts, efferveſce with muriatic acid.

Of the decompoſitions of both kinds of neutral and middle-ſalts, by means of intervening double affinity, will be noticed in this place.—*Firſt*, the decompoſition of *muriat of ſoda* by carbonated pot-aſh, and the method thence derived of obtaining carbonat of ſoda, though it is not an eaſy taſk to ſeparate the muriat of pot-aſh from the latter.

Secondly, the decompoſition of *muriat of ammoniac* by carbonated poſt-aſh, and the method founded thereon of procuring carbonat of ammoniac, both in the liquid form (*ſpiritus ſalis ammoniaci tartariſatus*) and in the concrete or ſolid ſtate (*ſal volatile ſalis ammoniaci*), which is done by diſtilling one part of pulverized ſal-ammoniac with three parts of vegetable alkali in a glaſs retort: adding water, if the liquid ſtate, and omitting the water if the concrete ſtate of the carbonated ammoniac be intended; in which laſt caſe it is properly a ſublimation.

Thirdly, the decompoſition of *muriat of lime* by alkine carbonats; of the *muriat of magneſia* by the carbonats of pot-aſh and of ſoda; and the method, which depends on it, of obtaining, in a profitable way, the carbonated magneſia from the mother-lye of various ſalt-ſprings.

Laſtly, the decompoſition of the *muriat of barytes*, and *muriat of Strontian-earth* by carbonated alkalis, and the preparation of artificial car-

bonats

bonats of barytes and Strontian-earth, by this decompoſition of their muriats.

[*] *The chemical wonder.*—If the ſolutions of muriat of lime, and of carbonat of pot-aſh be made with as little water as poſſible, and added in due proportion, theſe two fluids coagulate to a jelly-like ſubſtance, becoming more and more ſolid, and at laſt quite hard. This is the chemical wonder mentioned by the author.—Edit.

§ 564.

As to affinity with alkalis and earths, the muriatic acid is inferior to *ſulphuric acid*; as the expulſion of muriatic acid from common ſalt, effected by the ſulphuric, ſufficiently proves (§ 535) The muriat of barytes is for this reaſon a *re-agent*, ſerving to diſcover the preſence of ſulphuric acid in any fluid *.

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[*] Hence the barytic muriat is a re-agent, of great uſe for purifying the muriatic acid itſelf from the ſulphuric, which it often contains.—Edit.

Of the reciprocal decompoſitions of neutral and middle-ſalts formed by the ſulphuric and muriatic acids, we mention the following: 1. The decompoſition of *muriat of ſoda* by ſulphat of ammoniac, and the preparation of ſal-ammoniac and Glauber's ſalt thereon eſtabliſhed (§ 550). 2. The decompoſition of *muriat of ſoda*, by ſulphat of magneſia in a freezing cold, and the cheap extraction of Glauber's ſalt from the incruſtations formed in the boilers by ſuch brine-ſprings as contain ſulphat of magneſia (§ 403); and alſo the formation of Glauber's ſalt, or ſulphat of ſoda in thoſe ſalt-ſprings in time of froſt. 3. The decompoſition of *muriat of lime* by ſulphat of ſoda, or of magneſia; and 4. The decompoſition of the *muriat of barytes* by all ſulphats, either of the neutral or middle kind.

§ 565.

The *nitric acid* poſſeſſes likewiſe a nearer affinity with alkalis and earths, than the muriatic acid. Its ſuperiority in this reſpect is, however, not very great.

§ 566.

From analogy it might be concluded, that muriatic acid, like the ſulphuric and nitric, is compoſed of a peculiar baſis of its own, and oxygen. But chemiſts have not as yet ſucceeded in exhibiting the firſt by itſelf, and ſeparating the laſt from it. Hence the *radical of muriatic acid* remains ſtill unknown (§ 271). *Girtanner* thinks he has diſcovered, that this radical is hydrogen, and *Armet* even ſuppoſes it to be the metal zinc.

Oxygenated Muriatic Acid.

§ 567.

The radical of the muriatic acid may be combined with a ſtill greater portion of oxygen, and appears

appears then in a different condition, of different qualities and diſpoſitions towards other ſubſtances. It thus becomes a perfect acid, and has therefore been called *oxygenated muriatic acid**.

Synonym.—*Dephlogiſticated marine acid.*

* The author does not approve of this appellation; he calls it ſimply *muriatic acid*, to diſtinguiſh it from its imperfect ſtate, wherein he calls it *muriatous acid* (§ 534). He appeals to (277) where he aſſerted it to be a falſe ſuppoſition, that any acidifiable baſis may be over-ſaturated with oxygen; and is in the opinion of the tranſlator quite right in this idea. The tranſlator, however, not preſuming to command or alter the uſe of language, keeps to the expreſſion of *oxygenated muriatic acid*, as adopted in this country, from the modern Nomenclature, and leaves it to the Engliſh chemiſts to decide upon this matter.—Ed.

§ 568.

To obtain oxygenated muriatic acid, the black oxyd of mangaueſe is employed; which, we know, (§ 201) contains a vaſt quantity of oxygen, and readily gives it up to the muriatic acid.—One part of it in a pulverulent ſtate, is put into a retort together with three parts of concentrated muriatic acid; the retort is next laid in a ſand-bath, and connected with the pneumatic trough, filled with hot water; upon which a gentle heat is applied. A kind of effervеſcence enſues, and after the atmoſpheric air of the veſſel has come over, an elaſtic fluid of a pale yellow colour is ex-

extricated; which is caught and preſerved in bottles, cloſed with glaſs ſtoppers fitted by grinding.

§ 569.

The expanſible fluid thus obtained is not a gas, but a *vapour*, which at a temperature ſcarcely higher than the freezing point congeals to a concrete ſubſtance, in a pointed ſpicular form, and aſſumes again the aerial ſtate at a raiſed temperature.—The elaſtic oxygenated muriatic acid poſſeſſes an uncommonly pungent, ſuffocating ſmell; kills in a moment all animals that are immerſed in it; is abſolutely and in every reſpect non-reſpirable; is gradually abſorbed by water, forming with it liquid oxygenated muriatic acid. It beſides does not admit of being confined by mercury; becauſe it diſſolves this metal, and can only be kept for uſe in bottles with ſtoppers of glaſs, well ground to fit the aperture as tightly as poſſible.

§ 570.

Blue vegetable pigments are not only reddened by oxygenated muriatic acid; but their colour, as well as that of every other of vegetable origin, of whatever deſcription, is totally deſtroyed by it. All flowers of variegated colours, and green leaves of plants are, in time, rendered white, and diſcoloured by this acid. No alkali is capable

of

of reſtoring their colour when loſt. Upon this property depends the uſe made of oxygenated muriatic acid for bleaching linen and cotton.

Berthollet has the merit of this diſcovery, and *Chaptal* has ſkillfully applied it to the reſtoring of old papers and ſullied prints to their former whiteneſs. Vide his memoir on that ſubject, in the *Mem. of the Paris Acad.* for the year 1787—Edit.

§ 571.

A lighted wax candle continues to burn in the elaſtic oxygenated muriatic acid; though with a diminiſhed and duller flame. Phoſphorus, charcoal, cinnabar, grey antimonial ore, antimony, biſmuth, zinc, and ſeveral other combuſtible bodies reduced to powder, are even ſpontaneouſly inflamed, when thrown into this elaſtic and warmed acid.—Theſe inflammable ſubſtances deprive it of a part of its oxygen, and convert it into the imperfect, or muriatic acid.

§ 572.

Hydrogen gas affords with oxygenated muriatic acid, when in the elaſtic ſtate, a mixture that may be ſet on fire. The product of the combuſtion is liquid muriatic acid.

§ 573.

Sulphur likewiſe decompoſes the oxygenated muriatic acid, converting it into the ſimple muriatic. For the ſulphur robs the acid of part of its oxygen, and is itſelf converted into ſulphuric acid.—Sulphurated hydrogen-gas is affected in the ſame manner by that elaſtic acid, as by vital air (§ 447, 449); ſulphur is precipitated, and the perfect muriatic acid, united with the hepatic water, at the ſame time produced, is transformed to common muriatic acid.

§ 574.

Nitrous gas directly produces with the elaſtic oxygenated muriatic acid reddiſh fumes; and two acids, the nitrous, and the common muriatic, are formed.

§ 575.

Azotic gas ſeems not to act on perfect muriatic acid.—But ammoniacal gas, if that acid be warm and in an elaſtic ſtate, produces with it a kind of combuſtion, whereby the ammoniac is decompoſed, and nitrogen gas, water, and ſimple muriatic acid, are generated.

§ 576.

The neutral and middle-ſalts, or *oxygenated muriats*, which ariſe from the combination of alkalis and earths with perfect muriatic acid, are eſſentially different from the ſimple muriats, formed by thoſe alkaline ſubſtances, and the common muriatic acid.

1. *Oxygenated muriat of pot-aſh* forms permanent, flat cryſtals, aſſuming the ſhape of ſix-ſided priſms, obliquely truncated at their ends; of a cooling ſaline taſte; more ſoluble in hot, than in cold water; poſſeſſing likewiſe the power of oxygenated muriatic acid in being deſtructive of all vegetable pigments; and emitting when heated pure oxygen gas, while at the ſame time it is converted into common muriat of pot-aſh. This neutral ſalt, when mingled with charcoal duſt, and projected into a red hot crucible, cauſes a violent detonation. It does the ſame with ſulphur. Triturated together with phoſphorus, the exploſion becomes very dangerous.

The experiment, made in France, for ſubſtituting this oxygenated muriat of pot-aſh for nitre as an ingredient in gun-powder, has coſt ſeveral lives. The ſtrongeſt preparation of this kind which the tranſlator has ever ſeen, was prepared by Mr. *Sandman*, who, beſides the great works he carries on in partnerſhip with Mr. *Jones* and *Alder* of Ratcliff-highway, prepares, in the moſt ſcientific manner, and greateſt perfection, all the nicer and finer articles of modern chemiſtry, and who, though not yet ſufficiently known according to his merit, yet by his genius, application, and ardent zeal for the ſcience, fairly promiſes to enrich it with important diſcoveries: ſome inſtances of which might even now be given.—Ed.

Conſult *Experiments and Obſervations on the Preparation, and ſome remarkable Properties of the Oxygenated Muriat of Pot-aſh.* By Thom. *Hoyle*, jun. in the *Memoirs of the Mancheſter Society*, &c. vol. 5.—Ed.

2. *The oxygenated muriat of ſoda is*, as to its qualities and habitudes, much alike with the former. 3. *The oxygenated muriat of ammoniac* cannot exiſt, according to the arguments given § 575; though *Van Mons* of Bruſſels pretends to have made ſuch a combination. 4. The oxygenated muriats, 4, of *lime*; 5, of *magneſia*; 6, of *alumine*; 7, of *barytes*; 8, of *Strontian-earth*; are not yet ſufficiently known.

> The reader need not be reminded, that the author calls theſe compounds ſimply *muriats*, to diſtinguiſh them from thoſe made with common muriatic acid, which he calls *muriatous, pot-aſh, ſoda,* &c.—Edit.

§ 577.

If liquid oxygenated muriatic acid, contained in a retort made of white or cryſtal-glaſs, and connected with the pneumatic apparatus, be expoſed to the ſun's rays, oxygen gas is diſengaged, and the reſidue is common muriatic acid.

§ 578.

Oxygen and muriatic acid gas (§ 538) mixed together do not produce oxygenated muriatic acid, becauſe their union is prevented by the combination of their reſpective baſes with the caloric.

§ 579.

The acid of the oxygenated muriat of pot-aſh is driven off from its combination with the alkali, by means of ſulphuric acid.

§ 580.

By the proceſs for obtaining oxygenated muriatic acid (§ 568), only a part of the common muriatic acid employed is oxygenated, or converted into perfect acid: for the native oxyd of manganeſe gives up a part of its oxygen to that acid, which thereby is rendered elaſtic, and eſcapes in vapours; while the metal, having thus been more diſoxyded, is diſſolved in the remaining part of the imperfect or ſimple muriatic acid.

Nitro-muriatic Acid, (Aqua regia).

§ 581.

Nitric acid is likewiſe deprived of part of its oxygen by common muriatic acid; which laſt is thereby oxygenated.—If, therefore, one or two parts of ſtrong colourleſs nitric acid be mixed with four parts of concentrated marine acid, a great heat and efferveſcence take place, and an elaſtic oxygenated muriatic acid is extricated. The mixture exhales alſo the odour peculiar to that acid, and aſſumes a yellow colour. In this ſtate it contains nitrous acid, combined with oxygenated muriatic acid.

This combination has by former chemiſts received the name of *aqua regis*, or *regia*, and is to be conſidered as *nitro-muriatic acid.* It derives its efficacy from that portion of perfect muriatic acid which it contains; and on that account it exerts ſolvent powers different from thoſe poſſeſſed by the common marine acid alone, or the nitric acid; namely, it has the power of diſſolving gold.—This menſtruum is alſo prepared by diſſolving ſal-ammoniac, or, in its ſtead, common culinary ſalt, in nitric acid.

Fluoric Acid, perfect and imperfect.

§ 582.

When ſulphuric acid is poured upon finely levigated *fluor-ſpar*, a quantity of whitiſh fumes, poſſeſſed of a ſour taſte and ſmell, eſcapes; and if a plate of glaſs be held above theſe clouds, its ſurface is rapidly attacked by them; the glaſs loſes its poliſh, becomes untranſparent, and has really ſuffered corroſion.

§ 583.

This effect upon glaſs and ſiliceous earth is produced by no other acid, which we are at preſent acquainted with; and for this reaſon, the acid extracted from the ſparry fluor by means of the ſulphuric, is entitled to be conſidered as a diſtinct, peculiar acid, named *fluoric acid.*

Synonyma: *Fluorous acid* by the author, becauſe he takes it for an imperfect acid (§ 590); alſo *ſparry acid*; *acid of fluor-ſpar* (*acidum fluoris mineralis*).

§ 584.

The fluoric acid may be collected by expoſing fluor ſpar and vitriolic acid together to diſtillation; but it appears, from the property juſt mentioned, that the operation ought not to be performed in glaſs veſſels, ſince the acid obtained would be contaminated with ſiliceous earth.

For when upon finely pulverized fluor ſpar an equal quantity of ſulphuric acid is poured in a glaſs-retort, to the neck of which a receiver with water is afterwards luted, and the whole ſubjected to diſtillation on a ſand-bath, the fluoric acid comes over, and is abſorbed by the water. But it depoſits on the ſides of the receiver a pulverulent ſiliceous cruſt, which has been taken up by the acid from the glaſs of the retort and volatilized, but ſeparates again as ſoon as the acid is abſorbed and diluted by the water.

The water of the receiver, therefore, contains the abſorbed fluoric acid, yet ſtill holding a portion of ſiliceous earth diſſolved; which is proved by ſaturating it with an alkali, with which the acid combines, throwing down the earth.—The reſiduum in the retort is gypſum, formed by the combination

of

of the ſulphuric acid with the calcareous earth of the fluor-ſpar.

> *Marggraf* was the firſt who took notice of this acid. *Scheele* explained its nature, and demonſtrated its difference from all other acids. *Wiegleb* proved that the earthy reſidue, when the proceſs was performed in glaſs veſſels, is of the ſiliceous kind. And all doubts about his opinion have been ſilenced; ſince *Scopoli* has employed gilt-ſilver, *Wenzel* leaden, and *Meyer* pewter-veſſels, for the extraction of fluoric acid from fluor-ſpar.—Edit.

§ 585.

Hence, to obtain this fluoric acid in its pure ſtate, the diſtillation of the experiment above deſcribed muſt be performed in a leaden retort and receiver.

§ 586.

With regard to ſmell, taſte, and volatility, the fluoric acid greatly reſembles the common muriatic. By diſtillation it cannot be obtained in a ſolid form without putting water in the receiver.—Unmixed with water, this acid poſſeſſes the form of gas, and is in this ſtate expelled from the fluor-ſpar by the ſulphuric acid; but the gas coming over is decompoſed by the water of the receiver, which imbibes its baſis, forming with it liquid fluoric acid.

§ 587.

If, therefore, on diſtilling fluor-ſpar with ſulphuric acid (§ 584), the orifice of the retort be placed under the funnel of the pneumatic quickſilver-trough, the fluoric acid paſſes over as a permanent elaſtic fluid, and conſtitutes the *fluoric-acid gas.* This gas meeting with atmoſpherical air is changed to white fumes, is immediately abſorbed, or rather decompoſed, by water, and combines with it to form liquid fluoric acid. Its ſpecific gravity is greater than that of common air; it is improper for reſpiration, and extinguiſhes a light brought within it. It is very ſour, directly clouds lime-water, and is decompoſed by it, as alſo by alkalis. With ammoniacal gas it unites, and forms a concrete body.

§ 588.

When this gas is diſtilled from a glaſs retort, and afterwards decompoſed by the addition of water, it depoſits ſiliceous earth. From this it is evident that the fluoric acid is capable of volatilizing, and giving the aerial form to ſilex.

§ 589.

From analogy with other acids, the fluoric muſt of courſe be made up of a diſtinct acidifiable baſis and oxygen. But hitherto it has been beyond the reach of art to decompoſe it, or to ſeparate its radical;

radical; which, conſequently, muſt be ranked among the unknown ſubſtances (§ 271).

§ 590.

Various phenomena make it probable to me, that the radical of fluoric acid, as far as we are acquainted with this laſt, is not quite ſaturated with oxygen; and, conſequently, that this acid muſt, like the muriatic, be looked upon as an *imperfect acid.* Its production in the perfect ſtate, or completely ſaturated with oxygen, by means of the native manganeſian oxyd, when it might be called *oxygenated fluoric acid*[*], deſerves a farther inveſtigation.

§ 591.

The neutral *fluats*, or ſalts proceeding from the combination of fluoric acid with alkalis and earths, have never been applied to any uſe. It will, therefore, be ſufficient to give their names:—1. *Fluat of pot-aſh.* 2. *Fluat of ſoda.* 3. *Fluat of ammoniac.*

§ 592.

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[*] The author ſtyles it ſimply *fluoric acid.* The phenomena alluded to are relative to its aerial ſtate. It does not ſeem that this gas is decompoſed by atmoſpherical air, merely by attracting its moiſture. There rather appears to happen in this caſe, though in a leſs degree, ſomething ſimilar to the alteration of nitrous gas effected by vital air (§ 508), *viz.* an increaſed oxygenation.—Edit.

§ 592.

4. With calcareous earth the fluoric acid produces a compound quite inſoluble in water; and if the acid be poured upon lime-water, a precipitate immediately falls down, being *fluat of lime.* Such is the natural *fluor-ſpar*, or ſimply *fluor*; which, for its entire inſolubility in water, does not belong to ſalts, but to earths. It is found in fine cubic cryſtals, of various degrees of tranſparency, and of the moſt beautiful and varying colours. This ſpar is fuſible in fire, yet without parting with its acid. While melting it diſſolves other kinds of earth, and is for this property made uſe of as a flux in *ſmelting-works*, to facilitate the fuſion of other matters (§ 93); whence alſo it has received its name. It is luminous in the dark, when heated.

§ 593.

None of the combinations of other earths with the fluoric acid is at preſent uſed either in arts or trades. Such are, 5. *Fluat of magneſia.* 6. *Fluat of barytes.* 7. *Fluat of alumine.* 8. *Fluat of Strontian-earth.*

§ 594.

The fluoric is, of all acids, the only one capable of diſſolving, and even volatilizing, *ſiliceous earth.*—If a plate of glaſs be held over the vapours or ſmoke ariſing from a warmed mixture of powdered

powdered fluor-ſpar and ſulphuric acid, its ſurface is ſhortly after attacked and corroded by them (§ 582). Hence this acid is of uſe for etching upon glaſs, and removing decayed or injured enamels from metals ornamented therewith: as watch-caſes, ſnuff-boxes, rings, &c.

The liquid fluoric acid acts alſo on glaſs, but not ſo effectually as the fluoric-acid vapours. *Marggraf* firſt perceived this property; it was reſerved to *Puymaurin* and *Klaproth* to apply it to etching upon glaſs.—*Beckmann* continued to improve upon this proceſs; and *Yelin* ſhewed the method of etching, by this means, the glaſs-micrometers.—Edit.

§ 595.

Fluoric acid effervеſces with and drives out the *carbonic acid* from carbonated alkalis and earths; but its affinity with thoſe ſubſtances is not ſo ſtrong as that of the *ſulphuric*, *nitric*, and *muriatic acids.*

Boracic Acid.—Borax.

§ 596.

The mineral acids ſeparate from *borax*, in the humid way, an acid ſalt, which in every reſpect is characterized as a peculiar acid, and goes by the name of *boracic acid.*

Synonym: *Sedative ſalt (ſal ſedativum Hombergii).*

§ 597.

§ 597.

If ſulphuric acid, for inſtance, be gradually dropped into a ſolution of borax in hot water till the ſolution acquires an acidulous taſte; if the fluid be then ſlowly evaporated in a glaſs-bowl, till ſhining ſcales appear; and if, after this, it is ſuffered to cool, white, reſplendent, ſaline flakes will ſhoot out, which, by filtering through paper, are ſeparated from the lixivium, well waſhed with cold water, and dried. Theſe are the boracic acid. When the remaining lye is farther evaporated, and treated in the ſame way, more ſuch flakes are obtained. At laſt, *ſulphat of ſoda* cryſtallizes; and for this reaſon the firſt evaporation ſhould not be carried too far, leſt that ſalt enter into the cryſtals of the boracic acid.

§ 598.

Boracic acid forms a white, ſcaly, glittering ſalt; ſoft to the touch; of a taſte hardly acidulous, yet reddening the tincture of litmus; and of difficult ſolubility in cold water, requiring for ſolution at 50° *Farenh.* 20 parts of it; but eaſily diſſolved by boiling water. This ſalt endures expoſure to air; is not volatilized by fire, though by aqueous vapours it may be mechanically raiſed up. By a red heat it is fuſed into a tranſparent glaſſy maſs, which is much diſpoſed to diſſolve the argillaceous earth of the crucible. By this melting it undergoes no farther change, than the loſs of its water of cryſtallization.

lization. The boracic acid is, therefore, by its fixity in fire, greatly diſtinguiſhed from all other mineral acids hitherto treated of.

§ 599.

From analogy with other acids, I am inclined to think that the boracic acid is formed by an acidifiable baſis peculiar to itſelf, and oxygen. Yet the production of its baſis, in a ſeparate ſtate, has hitherto fruſtrated all attempts; whence it is to be claſſed among the undiſcovered principles (§ 271).

§ 600.

Immerſe ſlips of paper into a ſaturated hot ſolution of that acid ſalt in water, and dry them again, they will then burn with a light yellow flame. But ſpirit of wine, wherein this ſalt has been diſſolved, burns with a yellowiſh-green flame. This laſt circumſtance does by no means prove, that copper is contained in boracic acid.

§ 601.

Since on preparing boracic acid, by the method ſtated above (§ 597) from borax by ſulphuric acid, we likewiſe obtain ſulphat of ſoda, it follows that the *borax* is a compound of its own acid and of ſoda. This ſubſtance is a ſalt of a bitteriſh alkaline taſte; changing the blue ſyrup of violets to green; not effervеſcing with acids; and uſually forming

forming ſix-ſided priſmatic cryſtals, two ſides of which exceed the others in breadth, and which are terminated by three-ſided pyramids. Of cold water it requires at 50° Farenh. 12 parts of its weight, of boiling water only 6, for ſolution. Its cryſtals are permanent in the air, and their glittering ſurface is but ſlowly dimmed by it. Expoſed to moderate heat, it liquefies in its own water of cryſtallization, ſwells up very ſtrongly, and becomes a white, ſolid, looſe maſs, of the name of *calcined borax*; no other way differing from the *cryſtallized*, than by the loſs of the water of cryſtallization.—Calcined borax readily melts, as ſoon as it has reached the ſtate of ignition, into a pellucid glaſs, which may be totally re-diſſolved in water, and again cryſtallized.

§ 602.

The borax of commerce, with regard to its compoſition (§ 601), is not the produce of art, but of nature. This *native*, or *crude borax*, is called *tincal (tincor*, *borech*, *pounxa)*, and is partly dug up in India, Thibet, and Perſia; partly obtained by evaporation from the waters of ſome ſalt lakes. It was formerly at Venice, but now chiefly in Holland, refined from its adhering impurities by ſolution in hot water, filtration, and careful cryſtallization. It is then called *refined*, or *Venetian borax*.

§ 603.

§ 603.

The acid of borax has alſo been found native* in ſome parts of the Grand Dukedom of Tuſcany; and, combined with calcareous and magneſian earths, in the gypſum of Luneburg.

§ 604.

*Common borax** conſiſts, according to *Bergman*, of 0,34 of boracic acid, 0,17 of ſoda, and 0,49 of water. It is, however, not a perfect neutral ſalt (§ 293) not being quite ſaturated with the acid, but having an exceſs of alkali. On this circumſtance depend its alkaline properties (§ 601), of which it may be deprived, and completely neutralized, if to a hot ſolution of it more boracic acid be added. 1. This *borat of ſoda* does not again cryſtallize; but exhibits, on evaporation, a clammy adheſive maſs. No uſe is made of it.

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* This diſcovery was made in 1777 by Hoefer, on analyſing the waters of the Lake *Cerchaio*, near *Monte Rotondo*; he alſo made borax by uniting that acid with ſoda. It was, beſides, found in ſome other ſtagnant waters in the territory of *Sienna*; and *Maſcagni* found it cryſtallized in the mud of thoſe lakes.—Edit.

* As the ſedative ſalt, or *boracic acid*, has been, and is ſtill, employed in medicine, ſo is the common *borax* much uſed in arts, to promote fuſion on ſoldering metals, and for other purpoſes.—Edit.

§ 605.

2. The *borat of pot-aſh*, like common borax, takes up a ſurplus of alkali, and may be cryſtallized in four-ſided columns, or paralellepipedons.—3. The *borat of ammoniac* ſhoots into ſmall rhomboidal cryſtals, which are decompoſed by fire, and give up their alkaline part, the ammoniac.

§ 606

4. With calcareous earth the boracic acid affords a middle ſalt, inſoluble in water, and hence without taſte. This *borat of lime*, or *boracite* (combined with the next-mentioned ſubſtance), has been found native in the gypſum dug at Luneburg* in Lower Saxony, preſenting cubic cryſtals, ſeveral or all of whoſe edges and corners are truncated. It is fuſible in a red-heat. Lime has a ſtronger attraction for boracic acid, than the alkalis have.

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[*] Of this Luneburg gypſum, or rather *borat of lime*, Dr. *Crichton* poſſeſſes in his exquiſite collection of minerals a very fine ſpecimen. Being himſelf very fond of mineralogy, he gratified his pupils with a ſight of this curioſity in his *Chemical Lecture-rooms*, (now of Clifford-ſtreet). It contains magneſia, ſome argil and ſilex, and the primitive form of its cryſtals is doubtleſs a cube, not a polyhedron of 24 ſurfaces, as was by ſome imagined. When the corners and edges are truncated all around, it may receive 24 ſurfaces, which make it very beautiful. Theſe cryſtals are ſo hard as to cut glaſs like a diamond, and ſtrike fire plentifully with ſteel.—Edit.

§ 607.

5. The *borat of magneſia* is of very difficult ſolution in water; an exceſs of acid renders it ſoluble with greater eaſe. By evaporation this earthy ſalt yields cryſtalline grains, and is decompoſed by lime-water.

§ 608.

6. *Borat of alumine* is, contrary to the preceding ſalt (§ 607), very ſoluble in water, and forming with it a gummy, tenacious maſs, of a very ſtyptic taſte. In fire it melts into a glaſs. Lime, magneſia, and the alkalis, decompoſe the aluminous borat by depriving it of its acid, for which they have a ſtronger attraction.

§ 609.

7. Neither *borat of barytes*, nor, 8, *borat of Strontian-earth*, have as yet been cloſely examined. *Bergman* conjectures that the boracic acid poſſeſſes leſs affinity with barytes, than with lime.

§ 610.

Silex, or ſiliceous earth, is not acted upon in the humid way, not even in a boiling heat, by boracic acid. But in the dry way, if urged by fire to the degree of fuſion, it is diſſolved by that acid, and flows into a vitreous ſubſtance; which may be more or leſs decompoſed by alkalis, aſſiſted by boiling, in proportion to the quantity of boracic acid that has entered into the combination.

§ 611.

The place belonging to boracic acid, in the ſucceſſive affinities of the acids with alkalis and earths, is very low. In that reſpect the boracic exceeds the *carbonic acid* very little; and is, therefore, inferior to all the other acids, which hitherto have been the ſubject of our reſearches.

§ 612.

Of the mutual decompoſitions of the borats, whether neutral or middle ſalts, by thoſe of which we have before treated, I will only notice, *firſt*, that of ſoda (§ 604), or the *borax* itſelf, by alum, taking place in the ſolution of both ſalts together in water, forming two new compounds, namely, ſulphat of ſoda, and borat of alumine; *ſecondly*, that of borax by ſulphat of magneſia, or Epſom ſalt, from which ſulphat of ſoda and borat of magneſia proceed; and, *thirdly*, that of borax by ſal-ammoniac, forming muriat of ſoda, and borat of ammoniac.

CHAPTER

CHAPTER VI.

Conſtituent Parts of Vegetables.

General Examination of Vegetables.

§ 613.

THE organic bodies offer to our view a far greater variety, with regard to their compoſitions, than unorganized ſubſtances. Notwithſtanding this, they conſiſt of but a ſmall number of principles (§ 3), which, merely on account of the different reciprocal proportions in which they are combined, generate thoſe ſtriking and numerous variations in the nature and ſenſible properties of the various products.

§ 614.

It will be ſhewn hereafter, that by the analyſis of vegetable and animal bodies, as far as it has been hitherto performed, we have as yet diſcovered no other radicals than thoſe heretofore treated of.—*Carbon*, *hydrogen*, and *oxygen*, are contained in all of them; many contain alſo *azot* and *phoſphorus*; and theſe conſtitute in moſt of thoſe bodies all their ponderable part.—*Sulphur*, *fixed alkalis*, *lime*, and *iron*, are, indeed, pretty often met with in the organic products of nature, but not in every one of them.

§ 615.

Becauſe the proportions of theſe principles to each other are, from the influence of heat, air, and water, ſo greatly variable, we may, no doubt, eaſily tranſform into one another ſuch of their compoſitions, as we chemically ſeparate from bodies of both the vegetable and animal kingdoms. Yet we cannot produce them ourſelves by combining their radicals. This can only be done by *living organs*.

§ 616.

The bodies of plants and animals are not *chemical mixtures*, but only *mechanical combinations* of other heterogeneous compounds (§ 4); and to obtain a perfect knowledge of their nature, it is required that theſe various mingled parts ſhould be firſt ſingly conſidered, and their own compoſition accurately enquired into.

§ 617.

Theſe mingled parts, whereof vegetable and animal matters conſiſt, may be conſidered as their *proximate* or *immediate conſtituent parts* (§ 7).

They

They are ſeparated by ſimple and almoſt mechanical operations, which cannot alter their compoſition; and thus prove that theſe compounds have, before the proceſs, pre-exiſted as ſuch in theſe bodies. —Theſe proximate conſtituent parts have their own peculiar places aſſigned in organic bodies; and by this they characterize the different organization in the parts, are thus ſeparated from each other, and ſhew, beſides, the efficient cauſe of the difference in their nature. It is alſo obvious, that it is not every organic body that contains all thoſe conſtituent parts, but each has its peculiar ones.

§ 618.

The bodies of the vegetable kingdom preſent the following eſſential proximate conſtituent parts (§ 617):

1. *Mucus.*
2. *Sugar.*
3. *Starch.*
4. *Gluten.*
5. *Albumen.*
6. *Tartar.*
7. *Tartareous acid.*
8. *Salt of ſorrel.*
9. *Oxalic acid.*
10. *Citric acid.*
11. *Malic acid.*
12. *Benzoic acid.*
13. *Gallic acid.*
14. *Reſin.*
15. *Gum-reſin.*
16. *Gum-elaſtic.*
17. *Fat-oil.*
18. *Ethereal-oil.*
19. *Camphor.*
20. *Acrid matter.*
21. *Narcotic matter.*
22. *Fibrous part.*

§ 619.

But, before we examine each of theſe principles in particular, we ſhall firſt take a general ſurvey of the habitudes and diſpoſitions common to all plants, by analyſing them in the dry way, *viz.* by fire.

§ 620.

If plants, freſhly gathered, are expoſed to heat not reaching the point of boiling water, they are by this freed from moiſture, or *dried.*—They give out, by this proceſs, their eſſential *water*, which, undoubtedly, made before one of their conſtituent parts; but they may alſo, at this temperature, be deprived of ſome other eſſential principles; as for inſtance, the etherial oil, the acrid and narcotic radical; and on that account they undergo ſome important changes reſpecting their powers and properties.

§ 621.

In heat, above the boiling point, vegetable ſubſtances ſuffer an alteration by far more remarkable. They are torrefied, or *roaſted*; their mixture is conſpicuouſly altered, and their radicals combine by the influx of caloric in different proportions, forming thus new products; as may be at once concluded from the particular ſmell and taſte, called *empyreumatic (empyreuma)*, which they receive by the roaſting, and of which they ſhewed no ſign before.

§ 622.

At a ſtill greater heat, with proper acceſs of air, all vegetable matters are at laſt ignited, and *burn* with a *flame*; leaving, after thorough *incineration*, a reſiduum that reſiſts the fire, or is fixed, and always amounts to but a ſmall quantity, in proportion to their whole maſs.

§ 623.

The *ſoot (fuligo)* depoſited from the flame of burning vegetables, is carbon, which, for want of a complete ingreſs of air into the inner part of the flame, could not be conſumed; and is partly carried off mechanically along with the ſmoke, partly precipitated from the laſt. Other heterogeneous particles may, however, more or leſs, adhere to it, by which, conſequently, its nature may be variable.

> The *fluttering* and the *gloſſy* concrete ſoot of chimneys, where wood is burnt, the *ſoot* of *oil*, and that of *pine-wood*, or *lamp-black*, belong to this ſubject. The former kind is uſed by the name of *biſtre* as a brown water-colour; the lamp-black is alſo employed in oil and crayon-painting.—Ed.

§ 624.

All ſuch parts as by roaſting, or combuſtion of vegetable bodies, are diſſipated, may be collected, and hence farther analyſed. With this view the vegetables muſt be expoſed to a heat of ſufficient intenſity,

intenſity, *viz.* of ignition, in a retort joined with the requiſite apparatus.

§ 625.

For inſtance: take ſhavings of beech-wood, introduce them into a coated earthen retort, ſo as to fill two-thirds of its capacity; lute to its neck a crooked glaſs-pipe, together with one or more intermediate bottles; taking care that all the joinings be air-tight; and direct the laſt conveying-tube (§ 128) beneath the funnel of the pneumatic-trough filled with hot water, or quickſilver. This done, begin with a gentle heat, increaſing it gradually till the retort be red hot. At firſt the atmoſpherical air of the apparatus eſcapes; it is ſucceeded by peculiar kinds of gaſes and fumes, of which the firſt riſe in the recipient placed on the ſhelf, at the ſame time that the laſt condenſe in the middle bottles by cooling.

§ 626.

An extraordinary great quantity of gas is obtained by this proceſs. Great part of it is *carbonic acid gas*, that may be ſeparated by lime-water, by *cream of lime* (quick-lime diffuſed in water to the conſiſtence of cream), or by a ſolution of cauſtic alkali.—The remaining gas is inflammable, of a diſagreeable empyreumatic ſmell, and poſſeſſing properties belonging to hydrogen gas; but diſtinguiſhed from pure hydrogen gas by a greater ſpecific gravity, by burning with a ſteadier flame, and by the particular circumſtance, that on being mixed and burnt with oxygen gas, it not only yields water, but alſo carbonic acid; and this laſt, even after it had been moſt carefully freed from all admixture of carbonic acid gas.—It conſtitutes, therefore, a particular ſpecies of gas, called *carbonated hydrogen gas* *.

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* Or, *heavy inflammable air*.

§ 627.

Conſequently the phenomena preſented by this gas evince, that hydrogen and carbon had made up its baſis; and of courſe, alſo, that both theſe principles muſt have been conſtituent parts of the wood from which this gas was obtained.

The carbonic acid gas, which at the ſame time is generated, proves that, beſides carbon, the wood likewiſe had poſſeſſed a ſhare of oxygen.—However, the carbonic acid was not pre-exiſtent in the wood ready formed; but its radicals, before the operation, were combined in other proportions, and with other conſtituent parts, forming compounds of a different kind. Only, when the intenſity of heat has reached a certain degree, a part of the carbon unites with part of the oxygen to produce carbonic acid; and forms, by combining with caloric, the carbonic acid gas; while, at the ſame time, a part of the hydrogen of the wood combines with ſome portion of carbon and caloric, and eſcapes in the form of carbonated hydrogen gas.

It is this inflammable gas which, on applying heat to wood in open air, forms the flame (§ 214) attending its combuſtion.

§ 628.

All plants, all their parts, and all their immediate principles or component parts, when ſubjected to dry diſtillation, afford carbonated hydrogen—and carbonic acid gas.

§ 629.

All other volatile parts that are expelled from wood by dry diſtillation (§ 625) are condenſed into liquids by refrigeration in the middle bottles. They conſtitute partly an aqueous fluid, of a yellow-red colour, of an empyreumatic odour, and manifeſtly *ſour*, which was formerly called a *ſpiritus;* partly they form an *oil*, of a ſtrong empyreumatic ſmell, and a ſharp taſte. This oil floats on the aqueous ſour fluid, and at firſt comes over thinner and clearer; but, towards the end, in an increaſed heat, it is of a darker colour, thicker conſiſtence, more tenaceous and pitchy. Both the fluids are ſeparable from each other by wetted filtering-paper.

§ 630.

The ſour fluid, obtained from wood, may be depurated from the adhering oleaginous particles by rectification (§ 115), on a ſand-bath, from a glaſs-retort with a receiver. It may alſo be deprived of its ſuperfluous water, and be thus concentrated, by other means to be mentioned hereafter, when treating of the acetic acid.—This fluid has been received in chemiſtry as a diſtinct acid, with the name of *pyro-ligneous acid*; but, if properly purified, it is not different from *acetic acid.* Its baſis is a compound of carbon and hydrogen; it did not exiſt in wood in the ſtate of an acid; but its conſtituent parts were, before the proceſs, combined in other proportions; and even its aqueous part is the mere product of fire, being generated from the hydrogen and oxygen of the wood.

§ 631.

The *empyreumatic oil* procured by the dry diſtillation of wood (§ 629) may be rendered thinner by rectification, as alſo of a clearer colour, and more volatile; and it leaves a coaly part behind. This oil is, like the acid, a *product*, not an educt (§ 10); and did not pre-exiſt in wood. If it be burnt in oxygen gas, water and carbonic acid are formed; and the radicals of this oil are hydrogen, carbon, and ſome oxygen.—The quantity of carbon contained in the ſucceſſive portions of this oil is the greater the later they come over into the receiver; and alſo in proportion to the intenſity of the heat applied.

§ 632.

This is the place to ſpeak of the preparation or *eliquation of tar (pix liquida, cedria)*, performed by a kind of diſtillation *per deſcenſum* (§ 124). Logs or roots of pine and Scotch fir, abounding in reſin, are heated in the *tar-furnaces*; whereby the reſin is partly melted, and collected by a channel contrived in the lower part of the furnace. But the reſin undergoes alſo a partial decompoſition; for which reaſon the wood not only gives firſt an attenuated clear reſin, but ſomewhat later an acidulous water *(acid phlegm*, or *tar-gall)*; and, finally, an empyreumatic pitchy oil, which is the *tar*, and is of a darker hue; and when inſpiſſated upon fire becomes *black pitch*.

§ 633.

Some plants, when diſtilled by themſelves in the dry ſtate, afford no acid fluid; but they rather yield *carbonat of ammoniac*, partly in the concrete, partly in the fluid ſtate; which, after being cleaned from the particles of empyreumatic oil, are quite of the ſame nature with any other kind of carbonated ammoniac. Such plants are *muſtard-ſeed, onions, garlic, tobacco, atropa belladonna*, or deadly nightſhade, and the *fungi*. But even the ſour liquor afforded

afforded by moſt other plants contains ammoniac, as is evinced by the addition of fixed alkali. The ſoot of wood likewiſe yields ammoniac by diſtillation.

§ 634.

This ammoniac could not pre-exiſt ready formed in theſe plants; nor can it in any way be diſcovered in them. It is likewiſe only in the courſe of the operation, in a ſtronger heat, that the combination of its principles takes place (§ 291); which proves, that *azot* is likewiſe an ingredient in the compoſition of plants, and in their proximate conſtituent parts.

§ 635.

The reſiduum, after the diſtillation of wood (§ 625), is *charcoal,* a black, ſolid, friable, infuſible matter, totally inſoluble in water, without taſte or ſmell, and ſtill exhibiting the fibrous ſtructure of the wood, from which it proceeded.—It is nothing elſe than that portion of carbon contained in wood, which did not meet with a ſufficient quantity of oxygen to fly off with it in the form of carbonic acid, nor a ſufficient portion of hydrogen to form with it carbonated hydrogen gas (§ 626); nor both together to generate, by combining with them, either empyreumatic acid, or empyreumatic oil.—It would be pure carbon, if there did not remain ſome other extraneous, fixed, ſaline, and earthy particles, that were contained in the wood, moſt intimately mingled with it.

§ 636.

Of this coal, or carbon, as a *ſimple* and *combuſtible ſubſtance*, I have already ſpoken above (§ 224, ſeq.); and likewiſe ſtated its habitudes with other ſubſtances examined before.

§ 637.

There is a conſiderable difference between different kinds of charcoal as to their texture, denſity, and capacity for burning, which ariſes partly from the nature and mixture of the bodies from which they are obtained, and alſo partly from the freer or more impeded acceſs of air, that was allowed on their combuſtion.—Theſe variations are the ground of the various applicability of coals for mechanical and economical purpoſes.

Thus *China ink* may be imitated by working up the coal of the kernels of peaches and apricots with parchment-ſize or iſing-glaſs.—The *Franckfort black*, uſed in printing and painting, is the coal of the vine, and more frequently of the ſtalks and huſks of grapes, and wine-lees.—The coal from the branches of the lime and hazel-trees is employed by artiſts to ſketch their drawings.—Ed.

§ 638.

The application of charcoal, as diſcovered by *Lowitz*, to the purifying of ſaline lyes from colouring matter, (whether mucilaginous, empyreumatic, oily, reſinous, gelatinous, &c.) reſts on the poroſity * of their ſtructure, by which thoſe parts are mechanically retained.

[*] By *Lowitz*, and others, this faculty has been wrongly aſcribed to a ſuppoſed dephlogiſticating property of charcoal.—Edit.

§ 639.

The preparation of charcoal, or the *charring of coals*, is a kind of dry diſtillation of wood. The deſign of this proceſs is to ſeparate from it, without converting the wood into aſhes, thoſe parts which, on combuſtion in open air, form the ſmoke, ſoot, and flame. Hence the chief management conſiſts in admitting no more air to the lighted wood to be charred, than what is requiſite to ignite it, and to keep it in a ſmothering heat without being ſufficient to effect a thorough combuſtion and incineration.

In the large way it is done in piles *upright*, or *horizontal*, by covering the pile with turf, moſs, and earth, and leaving at the bottom a hole to light it up. See, among others, *L'Art du Charbonnier par du Hamel du Monceau*, fol. Paris, 1761.—Charcoal, to be good, ought to be heavy, ſolid, and ſonorous, neither to ſmoke nor crackle in the fire. The beſt woods afford the beſt coal.—Edit.

§ 640.

If, on the combuſtion of wood, and of every other vegetable body, the free acceſs of air be no ways checked, then that portion of radical carbon which in dry diſtillation remains behind, is, by taking up oxygen from the atmoſphere, converted into carbonic acid, eſcaping in the aerial form; and there is nothing left but mere *aſhes (cinis)*; a greyiſh powder unfit for maintaining the fire; and containing, yet without coheſion, the fixed parts of the vegetable.

§ 641.

If thoſe aſhes of plants be lixiviated, or drenched with water, the lye will exhibit all the characteriſtic marks of the fixed alkali, which remains after the evaporation of the fluid.—Moſt of the plants thus treated give the *vegetable alkali*, which from them has received its name. But vegetables do not all afford it in equal quantity, and in the ſame purity; they, beſides, give leſs in proportion as they have mouldered or paſſed into the putreſcent ſtate before incineration.—All the alkali, which by lixiviation can be procured from the aſhes of plants, is impregnated, though not ſaturated, with carbonic acid. There may likewiſe, over and above the empyreumatic oleaginous particles, which give it a browniſh or yellowiſh caſt, be mingled with it other extraneous ſalts, or earthy matters (as ſulphat and muriat of pot-aſh, or ſiliceous and aluminous earth). This, indeed, is uſually the caſe.

§ 642.

In order to deſtroy the empyreumatic oily parts contained in this ſalt, calcination is the beſt means; and to effect a complete ſeparation of other matters (§ 641) nothing will be effectual but ſaturating it with carbonic acid (§ 355), and cryſtallizing.

§ 643.

Pot-aſh (cineres clavellati) (§ 357) is the vegetable alkali procured from the aſhes of plants, eſpecially of the hard ſpecies of wood, by lixiviation, and ſubſequent evaporation of the lye.

It is not a pure vegetable alkali, but ſuppoſed to be in part only combined with carbonic acid, and hence deliqueſcent; for it always contains a conſiderable portion of ſulphated vegetable alkali. While calcining, ſand is now and then fraudulently added, which fuſes with it, and becomes thereby ſoluble in water. Such ſiliceous pot-aſh may be very ſharp to the taſte; but a clear ſolution of it in a ſmall quantity of water will, on the addition of any acid, give a precipitate like that of the liquor of flints (§ 312), and thus diſcover the fraud.—Sometimes the aſhes from the hearths and ſtoves, where wood is the fuel, are employed to procure pot-aſh.

A purer vegetable alkali is obtained from the aſhes of calcined *wine-lees (cendres gravelées)*; and a ſtill purer one from tartar, which from its origin is called *ſalt of tartar (ſal tartari)* *.

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* This vegetable alkali, however pure, ought not to be confounded with the cauſtic vegetable alkali, deprived even of the carbonic acid, which in the new nomenclature is termed ſimply *pot-aſh* (§ 283).—Edit.

§ 644.

Every ſpecies of vegetable alkali, if duly purified from whatever plant it might have been obtained, is of the very ſame nature without exception. For this reaſon the *ſalts of particular plants (ſalia herbarum)*, as for example, the *ſalt of wormwood (ſal abſynthii)*, have no preference.

Of the *Tachenic ſalts.*

§ 645.

The aſhes which are obtained by the combuſtion of plants growing on ſhores moiſtened by ſea-water, yield *mineral alkali* by lixiviation. The term *ſoda* is frequently employed to denote ſuch kind of aſhes (§ 361).—Soda, taken in this ſenſe, is brought to Germany in maſſes as hard as ſtone, full of holes or large pores, of a blackiſh or grey-blue colour, intermingled with white grains, and covered with a whitiſh cruſt.

It is prepared in ſouthern Europe, particularly on the coaſts of Spain and France, from ſeveral plants, partly cultivated, partly growing ſpontaneouſly on the ſea-ſhore; and chiefly from the ſpecies, *ſalſola* and *ſalicornia.* Thoſe plants are dried, and then burnt in pits dug for that purpoſe. In theſe the hot embers are continually accumulated, ſtirring them often, as the quantity increaſes. At length they begin to melt, upon which they are ſuffered to cool. Laſtly, when cold, they are broken into lumps, and taken out.—The better ſort of ſoda is the *ſoude de barille*, from Alicante in Spain. An inferior kind is the *ſoude de varech* in Britanny, which is procured by the burning of *ſea-graſſes* and of *ſea-tang*; both analogous to the *kelp of* Scotland.

§ 646.

The mineral alkali contained in the ſoda (§ 645) may be ſeparated from earthy and other adhering parts by boiling and lixiviating thoſe aſhes; and, becauſe it is carbonated, it admits of being cryſtallized. This *ſalt of ſoda (ſal ſodae, Rochettae)* is, therefore, a carbonat of mineral alkali.—There are, beſides, ſome other extraneous ſalts, as Glauber's ſalt, and common ſalt, contained in the ſoda.

> The reader will again recollect, that in the new nomenclature (adopted in this tranſlation) by *ſoda*, without addition, it is not the above-mentioned aſhes of ſea-plants, but the mineral alkali itſelf, in its pureſt and cauſtic ſtate, that is meant (§ 285).—Edit.

§ 647.

According to *Vauquelin's* lateſt analytical reſearches, the mineral alkali exiſts in the ſoda plant ready formed by nature, and alſo a portion of ſea-ſalt. *Macquer* and *Poulletier de la Salle* have found in it ſulphat of ſoda.

§ 648.

Since the ſulphat of pot-aſh, ſo frequently met with in the aſhes of ſome ſpecies of wood (§ 643), cannot be ſeparated from theſe woods before their incineration, and conſequently did not pre-exiſt in them before combuſtion, it is, in my opinion, very probable that the ſulphuric acid is a product (§ 10), in theſe aſhes, and that *ſulphur* is one of the conſtituent parts of wood, which in its combuſtion combines with oxygen, and is thus transformed into ſulphuric acid, which uniting with the alkali forms its ſulphat.

§ 649.

Yet it becomes now more and more probable, that the fixed alkalis are not ſimple ſubſtances; but, on the contrary, a product of vegetation. We are ſo much the more entitled to doubt of the ſimplicity of their nature, as they are no longer to be found in the reſidue of plants, that have undergone complete putrefaction.

§ 650.

The earthy *parts*, left after the complete lixiviation of ſuch aſhes, are of a very ſmall amount with reſpect to the whole weight of the plant. Their nature is different according to the different nature of the ſoil, whereupon the plant grew. Yet they are as little an eſſential ingredient in the compoſition of the plant as the *iron*, that is found in thoſe aſhes.

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They are certainly rather accidental.—To believe that the earthy parts are the chief alimentary matter of plants, was pardonable in thoſe times only, when earth was thought to be the only principle of ſolidity.

> The late Dr. *Ingenhouſs* has added to his ingenious reſearches on plants an excellent *Eſſay on the food of plants, and renovation of ſoils*, 4to. inſerted in the papers of the London *Board of Agriculture*, 1796. That treatiſe is a valuable ſpecimen of *applied Chemiſtry* and *comparative Phyſiology*. The Doctor intended to prove again that plants chiefly live by reſpirable air, and cannot live without it; that they decompoſe that air, keeping to themſelves the carbon and azot, and giving out the oxygen combined with caloric as oxygen gas; which they do, eſpecially about noon in ſunſhine, and as pure as oxygen gas obtained from the oxyd of mangaueſe. But at night they digeſt more of carbon, and give out chiefly carbonic acid gas. Hence the unwholeſomeneſs of nightly air in large thick plantations, where there is no current of air: and though, in ſome manner, plants feed upon azot, yet they live more upon carbon.—Dr. *Ingenhouſs* endeavoured, beſides, to ſhew, 1. againſt Mr. *Haſſenfratz*, that it is not ſo much *carbon* as *carbonic acid* which conſtitutes the aliment of plants, and whoſe ſuperabundant portion they emit in the night; and, 2. that the *leaves*, and not the roots, are the principal organs by which plants imbibe the matters, requiſite to the digeſtion of their food.—Edit.

§ 651.

Since the plants, according to what has been ſaid before, (§ 616), are compoſed of heterogeneous mat-

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ters mechanically united, it is neceſſary to conſider ſingly every one of their mingled conſtituent principles, with which experience has made us acquainted, and by which the fluid and ſolid parts are formed, if we wiſh to obtain a complete chemical knowledge of vegetable ſubſtances. A liſt, together with the names of theſe principles, has already been given (§ 618).

Eſſential Salts of Plants.

§ 652.

We call thoſe ſalts *eſſential ſalts of plants* which excluſively belong to the vegetable kingdom, have as ſuch pre-exiſted in the plants, and may be extracted from them by operations that do not forcibly alter their mixture.

§ 653.

Theſe may be divided into *ſour* and *ſweet ſalts.* Of the laſt kind there is only one, *ſugar (ſaccharum)*; but of the firſt there exiſt ſeveral ſpecies. Some are *pure vegetable acids*, of which we know at preſent *ſix* eſſentially different: the *tartareous*, *oxalic*, *citric*, *malic*, *benzoic*, and *gallic.*—Others are a compound of pot-aſh or vegetable alkali, with an exceſs of acid *(acidula plantarum*, *acidules* in French). *Tartar* and *ſalt of wood-ſorrel* belong to this ſpecies.

§ 654.

All theſe vegetable acids have a compound baſis. The component parts of every one are carbon and hydrogen. The variety in their habitudes and properties is cauſed merely by the different proportion of theſe principles to each other, and to oxygen in each particular acid.—There is none of them which we cannot decompoſe; yet we cannot compound any one.

Tartar. Tartareous Acid.

§ 655.

In caſks wherein wine made of grape-juice ferments, eſpecially of the acerb and ſour kind, a ſolid matter is depoſited all around their ſides, incruſting them with coherent cryſtals, either red or whitiſh-grey, according as the wine which depoſited them was red or white.—This ſubſtance is called *crude tartar.*

§ 656.

This crude tartar is to be looked upon as an impure acid, and eſſential ſalt of the juice of vine-grapes, which is not originally produced by fermentation, but only ſeparated; and is, excluſively of water, likewiſe contained in the juices of various other fruits. It has a ſouriſh taſte, and all the diſtinguiſhing marks of an acid ſalt; but is of difficult ſolution in water.

§ 657.

It may, by repeated ſolution, filtration, and cryſtallization, be freed from the feculent and colouring parts which defile it. As procured in commerce it is already purified; and this purification, in large quantities, is chiefly done at *Montpellier* in France, and at *Venice*. Such depurated tartar is ſold by the name of *cryſtals of tartar*; and when the cryſtals are ſmall, and as it were in a pulverulent ſtate, they are called *cream of tartar*.

§ 658.

The cryſtals of purified tartar have no regular form. To be diſſolved by water they require, according to *Spielmann*, at 50° Farenh. 160 parts of cold, but only 28 of boiling water. They are permanent in the air.

§ 659.

Tartar is, like all the proximate component parts of plants, a combuſtible matter. When thrown upon burning coals, it diſengages an acidulous ſmoke of an empyreumatic ſmell; and, when thoroughly incinerated, it leaves the vegetable alkali *(pot-aſh)* behind.

Tartar is alſo made uſe of for obtaining a very pure vegetable alkali, that has received the name of

ſalt

ſalt of tartar (§ 643). For this purpoſe crude tartar is wrapt up in cornets of paper, which are twined round with pack-thread, and ſomewhat moiſtened. After this the parcels are put in a wind-furnace, in alternate layers with charcoal, and ignited throughout without diſturbing them. Theſe paper-caſes, with their contents, are, after cooling, pounded and lixiviated with boiling water; which being done, the ſtrained or better filtrated lixivium is evaporated to dryneſs in iron pans. The pot-aſh hereby obtained is only in part carbonated.

§ 660.

From this it is plain, that *tartar* is not a pure vegetable acid, but the vegetable alkali over-ſaturated with its acid (§ 653). For this reaſon it has in the new nomenclature been called *acidulous tartrite of pot aſh.*

§ 661.

The acid of tartar is deſtructible by fire. If tartar be ſubjected alone to dry diſtillation, a great quantity of carbonated hydrogen gas (§ 626) and of carbonic acid gas (§ 226), is extricated; and, beſides theſe, an acid fluid *(ſpirit of tartar)*, and an empyreumatic oil *(oleum tartari fœtidum)*, is obtained. The remaining coal ſhews, even before incineration, its alkaline nature.

§ 662.

It would be erroneous to imagine the acid fluid, obtained by this proceſs, to be the tartareous acid in the ſame ſtate, in which it was before contained in the tartar. It was merely generated by the alteration, which the fire cauſed in the proportion of its principles to each other.—Beſides, if duly purified, it does not preſent itſelf in the character of a diſtinct acid, belonging to the vegetable kingdom; notwithſtanding that it has been diſtinguiſhed by the name of *pyrotartareous acid.* Its relations to other bodies are the ſame as thoſe of acetic acid.—The empyreumatic oil of tartar is alſo, like all other oils of this kind (§ 631), a new product.

§ 663.

Like other inflammable bodies, tartar detonates with ignited nitrat of pot-aſh.—Equal quantities of powdered nitre and crude tartar, mingled, and put into a red hot crucible, yield pot-aſh after detonation. This pot-aſh owes its exiſtence to both bodies employed; has by former chemiſts been called *white flux*; and differs in no manner from any other good, and but partially carbonated vegetable alkali.—If to one part of nitrat of pot-aſh, three parts of crude tartar be added, a portion of the coal afforded by the later, remains united with the alkali, giving it a black

colour,

colour, and both together conſtitute the *black flux*.

> The name *flux* is given to this combination; becauſe it is added to promote the fuſion of earths and metals.—Edit.

§ 664.

The ſuperabundant acid of purified tartar may be fully ſaturated with pot-aſh in the humid way; if to a hot ſolution of vegetable alkali as much of pulverized tartar be added, as is neceſſary, ſo that neither the acid nor the alkali predominates.

By this combination a neutral ſalt, the *tartrite of pot-aſh* is obtained, which, in the ſhops, is barbarouſly termed *tartarized tartar (tartarus tartarizatus)**. This ſalt may be cryſtallized; but for common uſe, the lye, thus combined, is totally evaporated to dryneſs. It is much more ſoluble in water than cryſtals or cream of tartar (§ 657), requiring at 50° Farenh. only 2,264 parts, and at the temperature of boiling, ſcarcely equal parts of water to be diſſolved. By fire this neutral ſalt is decompoſed. It burns firſt to a ſpongy coal; but when calcined to whitneſs, it leaves the pot-aſh behind.

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* Alſo called *ſal vegetabile*; and moſt improperly *tartarus ſolubilis*, becauſe this appellation likewiſe ſuits the combination of tartar with other alkalis.—Edit.

§ 665.

Purified tartar, ſaturated with ſoda, forms a triple ſalt, called in the ſhops *ſeignette-ſalt** *(ſal polychreſtum de Seignette, ſal Rupellenſe* or *Rochelle)*; which ſhoots into well-ſhaped cryſtals, whoſe figure is very variable. This ſalt is entirely, and with eaſe, ſoluble in water. Its cryſtals are permanent. A calcining heat deſtroys it.

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* This combination has in the London Pharmacopœia obtained the name of *natron tartarizatum*. It is uſed as an addition to cathartics of the reſinous kind, &c. —Edit.

§ 666.

With ammoniac the purified tartar affords likewiſe a triple ſalt, which has been called *ſoluble tartar*; alſo *tartareous ſal-ammoniac (tartarus ſolubilis, ammoniacalis)*. It forms cryſtals of four-ſided columns with terminations obliquely truncated, and in oppoſite directions. It eaſily diſſolves in water. Fixed alkalis decompoſe it in the humid way; and by fire it is likewiſe deſtroyed in ſuch a manner, that merely the pot-aſh of the tartar is left.

§ 667.

If purified tartar and quick-lime be boiled together in water, the reſult is a cauſtic lye of pot-aſh. All the acid of the tartar combines with the calcareous earth, and produces with it the *tartrite of lime*, which is almoſt inſoluble in water. If, inſtead of burnt lime, crude calcareous earth, *viz.* carbonat of lime, be boiled with tartar and water, the whole of the tartareous acid is not ſeparated from the alkali; but only its predominating and redundant part unites with the chalk. The lixivium yields tartrite of pot-aſh (§ 664), and ſome tartrite of lime.

§ 668.

Sulphuric acid has a ſtronger affinity with calcareous earth than the acid of tartar; this laſt, therefore, may be ſeparated from the tartrite of lime, by the ſulphuric acid in the humid way. This has induced chemiſts to attempt the producing of *tartareous acid* itſelf in a ſtate of purity.

> This vegetable acid has alſo been called *eſſential ſalt of tartar.*

§ 669.

To prepare this acid, 10 parts of pulverized and purified acidulous tartrite of pot-aſh (§ 660) are boiled with a ſufficient quantity of water in a pewter veſſel. Dry, finely powdered, and elutriated chalk is then put in by ſmall quantities at a time, until no more effervescence enſues. Tartrite of lime or *tartareous ſelenite* will precipitate; and the lye ſtanding upon the ſediment is tartrite of pot-aſh. This lixivium muſt be decanted,

canted, and may be cryſtallized after filtration, or ſimply evaporated (§ 664).

The earthy ſalt, which formed the precipitate, is firſt carefully lixiviated with water, and put into a matraſs. Thirty parts of diluted ſulphuric acid, made by mixing 3 parts of the concentrated acid with 27 of water, are then poured upon it. The whole is left in digeſtion for at leaſt 12 hours, with a gentle heat. After which the clear liquid is decanted, and the reſiduum, which, by the union of the ſulphuric acid with lime, forms gypſum (§ 407), is preſſed and waſhed with *cold* water, to get out the adhering acid, which is added to the clear liquor of the preceding decantation, and is the tartareous acid. It is next filtered, and gently evaporated in flat porcelain or glaſs veſſels; during which operation it depoſites gypſum, which, from time to time, muſt be ſeparated.

The evaporation is to be carried on to the conſiſtence of a thin ſyrup. And when the clear tartareous acid is then left to a continued, ſlow, and imperceptible evaporation, it cryſtallizes.

Chemiſtry is indebted to *Scheele* for this method. To be aſſured that no vitriolic acid is contained in the liquor, a ſolution of ſugar of lead is added to a ſmall portion of it. The white precipitate, formed by this, will be diſſolved on the addition of nitric acid, if it be merely tartarite of lead, and there be be no ſulphat of lead formed by the vitriolic acid.— The tranſlator cannot recommend Schiller's method in the Chemical Annals of Crell, 1787, which conſiſts in ſimply boiling 1 ℔ of cream of tartar, with 6 ℔ of water, and adding ¼ ℔ of concentrated ſulphuric acid. It ſeems more ſimple indeed, and is apparently true in theory; yet the tranſlator has, on ſeveral attempts, as little ſucceeded as others. Inſtead of vitriolated tartar, and tartareous acid, there is always only ſimple tartar produced, though ſomewhat ſulphated.—Edit.

§ 670.

This eſſential ſalt of tartar forms tabular, and ſometimes ſpear-ſhaped cryſtals, bundled together in glandular groups. Their taſte is exceedingly ſour; they are not altered by the air; but they are eaſily diſſolved in water, and not volatilized by boiling heat.

§ 671.

Tartareous acid is deſtroyed by fire, and conſumed. By dry diſtillation it gives the ſame products as tartar: namely, carbonated hydrogen gas, carbonic acid gas, a ſour phlegm which is analogous to acetic acid, and an empyreumatic oil. There remains ſome coal in the retort.

§ 672.

Hence the radical of tartareous acid conſiſts of hydrogen and carbon. Both together, united with a certain portion of oxygen, form this acid; which on account of its peculiar properties is to be conſidered as a diſtinct acid. It is doubtleſs capable of receiving a greater ſhare of oxygen, and of different proportions, in the component parts of its baſis.—But it is then no longer tartareous acid; but is converted into another ſpecies of vegetable acid, as is proved even by dry diſtillation (§ 671).

§ 673.

Tartareous acid boiled with the ſulphuric, is, for the moſt part, converted into acetic acid. The ſulphuric is changed into ſulphureous acid by this proceſs; and carbonic acid gas is generated at the ſame time.

§ 674.

Concentrated nitric acid is likewiſe decompoſed in heat by the acid of tartar; nitrous gas, acetic and carbonic acids are then produced.

§ 675.

1. If tartareous acid be completely ſaturated with pot-aſh, the ſame neutral ſalt is obtained, as by combining tartar with pot-aſh, *viz. tartrite of pot-aſh*, or the officinal *tartarus tartarizatus* (§ 664). If leſs of the vegetable alkali be added to tartareous acid diſſolved in water, it produces tartar, called *regenerated tartar*, which in conſequence of its difficult ſolution precipitates, and this proves, that the tartareous

acid pre-exiſted as ſuch in the tartar. Tartrite of pot-aſh may be again converted into tartar, by adding tartareous acid to a ſolution of the former.

§ 676.

No uſe is made of the combinations of pure tartareous acid with other alkalis, and alkaline earths. Such are, 2. *Tartrite of ſoda.* 3. *Tartrite of ammoniac.* 4. *Tartrite of lime*; the uſe of which laſt in the preparation of tartareous acid has been mentioned before (§ 668); and beſides, the *tartrites* 5. of *magneſia*, 6. of *alumine*, 7. of *barytes*, and 8. of *Strontian-earth.*

§ 677.

The ſucceſſive ſeries of affinities of alkalis and earths with tartareous acid, is as follows: lime, to which it has the ſtrongeſt affinity, then barytes, magneſia, pot-aſh, ſoda, ammoniac, and laſtly, alumine.

§ 678.

The lixivium remaining from the decompoſition of tartar, or of the tartareous neutral-ſalts by quick-lime, has the particular property of continuing clear and bright, while cold; but growing milky on being heated, whether in open or cloſed veſſels. It alſo acquires this turbidneſs by being largely diluted with water; and becomes clear and pellucid by cooling.

§ 679.

With regard to affinity with alkalis and earths, the tartareous acid is by far ſuperior to the *carbonic*; but is greatly exceeded by the *ſulphuric*. Of the mutual decompoſitions of the ſulphats and tartrites, we only take notice, in this place, of the tartrite of pot-aſh decompoſed by ſulphat of ſoda. In order to make the experiment, let ſix parts of purified tartar be ſaturated with vegetable alkali, and add to the ſolution of the tartrite of pot-aſh, thus formed, five parts of ſulphat of ſoda. It will be found, that after evaporation, ſome ſulphat of pot-aſh firſt cryſtallizes, and afterwards ſeignette-ſalt (§ 665).

§ 680.

The *nitric*, *muriatic*, and *fluoric acids* precede the tartareous in their affinities with alkalis and earths: the calcareous earth excepted, whoſe attraction for the tartareous is greater than for the other acids juſt mentioned. The *boracic acid* has a weaker affinity with all alkalis and earths, than the tartareous.

Of the ſoluble cream of tartar (Cremor tartari ſolubilis).

§ 681.

The great tendency of tartareous acid to unite with a certain definite portion of vegetable alkali, and to form by this combination tartar of ſo difficult ſolubility (§ 658), produces a ſeeming exception from the general laws of affinities. Even ſuch acids, the acetic for inſtance, as are not ſo ſtrongly attracted by pot-aſh as the tartareous, decompoſe the neutral tartrite of pot-aſh, and ſeparate from it—not the tartareous acid, but tartar.—And thus alſo, whenever tartareous acid is added to the ſolution of any neutral ſalt, whoſe baſis is *pot-aſh*, as muriat of pot-aſh (§ 539), tartar is again generated.

Salt of Wood-Sorrel.—Oxalic Acid.

§ 682.

If the freſh leaves of *wood-ſorrel (oxalis acetoſella, oxal. corniculata)* or of *garden-ſorrel (rumex acetoſa)* be bruiſed or pounded in a *wooden* mortar; if their juice be then expreſſed, and after purification by reſt and filtration, it be further clarified by boiling with the white of eggs; and laſtly, evaporated, and left in glaſs bowls for ſpontaneous imperceptible exhalation, the eſſential ſalt of theſe plants will ſhoot into cryſtals round the ſides of the veſſel. This is what is called *ſalt of wood-ſorrel (ſal acetoſellæ).* Its cryſtals require a repeated ſolution in water, filtration, evaporation, and cryſtallization, to render them white and pure. This ſalt is chiefly and in large

large quantities prepared in the *Schwarzwald* (Black-Foreſt in Germany).

> It is obvious that this ſalt cannot be prepared with any proſpect of profit, unleſs in ſuch territories where there is an abundance of the plant, and at the ſame time plenty and cheapneſs of fuel: when it is conſidered, that according to *Hermbſtädt*, from 50 pounds of the freſh plant, 25 pounds of juice, and from theſe hardly more than 2 *ounces* of ſalt are obtained.—Edit.

§ 683.

The cryſtals of the ſalt of ſorrel are minute, of an undetermined figure, permanent in the air, and with difficulty diſſolved by cold water. Of boiling water they require 6 parts for ſolution. The acid contained in this ſalt is much ſtronger than that which is obtained from tartar. It is not volatilized by the heat of boiling water.

§ 684.

Salt of ſorrel is as little a pure vegetable acid as tartar. It is, on the contrary, the vegetable alkali over-charged with a peculiar acid belonging to this ſalt. Expoſed to fire, it melts after ſome decrepitation; gives out a very pungent ſour vapour, and leaves pot-aſh behind. When ſubjected to dry diſtillation, it emits carbonated hydrogen and carbonic acid gas; and beſides, an acid fluid, together with ſome ſublimed concrete acid. But it yields no empyreumatic oil, nor is there any coaly reſiduum left, but mere vegetable alkali.

§ 685.

Conſequently, the acid of the ſalt of ſorrel is decompoſed in heat, like the tartareous (§ 684). And for this reaſon, the dry diſtillation of this ſalt is not a ſuitable expedient for producing its acid in the ſame ſtate in which it exiſted in the ſalt. This purpoſe can only be accompliſhed by ſeparating the acid in the humid way, and in the following manner:

The ſalt of ſorrel is firſt ſaturated with ammoniac, whereby a triple ſalt is obtained; conſiſting of the acid peculiar to that ſalt, of pot-aſh, and of ammoniac. To the ſolution of this triple ſalt a ſolution of barytes in nitric acid is gradually added by drops, and as long as any precipitate takes place. By ſo doing, the acid of the ſalt of ſorrel combines with the barytes into a middle ſalt of very difficult ſolution, which precipitates; while on the other ſide, the nitric acid, pot-aſh, and ammoniac unite, and form together a new, and very ſoluble triple ſalt. The oxalat of barytes, which is the above precipitate, is edulcorated with cold diſtilled water; put into a matraſs, and again decompoſed by affuſing upon it diluted ſulphuric acid; which, from its ſtronger affinity, ſeizes the barytes, forming with it ſulphat of barytes (§ 423), and ſets free the acid of the ſalt of ſorrel.—This acid

acid mixes now with the diluting water, by which it is held in ſolution.

Nothing then remains, but to filter the ſolution, and to ſuffer it gently to evaporate; upon which the acid cryſtallizes. The ſulphat of barytes remaining on the filter ought alſo to be edulcorated.

§ 686.

This acid, thus obtained, is called *oxalic acid*, and we cannot help conſidering it as a diſtinct peculiar acid of the vegetable kingdom. Its cryſtals have at times the form of rhomboidal tables with truncated lateral edges; but are uſually ſpear-ſhaped. The taſte of this acid is extremely ſour. The oxalic acid itſelf is much more ſoluble in water than the ſalt of ſorrel; and it is not volatile in the heat of boiling water.

> The oxalic acid goes alſo by the name of *acid of ſugar*. Indeed it may be obtained from that ſubſtance in a cheaper, and ſpeedier way; as will be ſhewn § 728. —Edit.

§ 687.

The baſis of oxalic acid is a compound. If that acid be diſtilled by itſelf, we obtain from it carbonated hydrogen gas, carbonic acid gas, a little ſour phlegm, and ſome ſublimed concrete acid ſalt, which ſtill retains the properties of oxalic acid. Nothing remains in the retort, but a ſmall quantity of a grey or brown reſidue, which almoſt totally diſappears in open fire. The ſalt, that was ſublimed, is farther deſtroyed by diſtilling it a ſecond time.

§ 688.

Hence it follows, that the radical of oxalic acid is, like that of the tartareous, compoſed of hydrogen and carbon.—The oxalic is diſtinguiſhed from the tartareous acid by nothing elſe than by a different proportion of oxygen, and of the principles of its baſis. The tartareous acid may, for this reaſon, be transformed into oxalic, by diſtilling weakened nitric acid upon the former in a low heat; by which management nitrous and carbonic acid gaſes are generated. By concentrated nitric acid, and ſtronger heat, the tartareous is converted into acetic acid (§ 674); and the ſame happens to the oxalic, when treated in the ſame manner.—Thus alſo the concentrated ſulphuric acid is decompoſed in heat by the oxalic; and acetic, ſulphureous and carbonic acids, are produced, and volatilized.

§ 689.

If into oxalic acid, diſſolved in water, a ſolution of pot-aſh be dropped, and the quantity of water be not too great, a ſour ſaline powder will immediately precipitate, whoſe properties are in every reſpect like thoſe of the ſalt of ſorrel.

1. If the pot-aſh be fully ſaturated with oxalic acid, the product of this combination is the *oxalat of pot-aſh*: a neutral ſalt by far more ſoluble, than ſalt of ſorrel. However, neither this, nor 2. the *oxalat of ſoda*, nor 3. the *oxalat of ammoniac*, are in any way employed in arts or medicine. They are all of them deſtroyed by fire.

§ 690.

4. Calcareous earth has a very powerful attraction for oxalic acid, and conſtitutes with it a mixture inſoluble in water. If a little of a ſolution of oxalic acid be dropped into lime-water, the acid and the earth will inſtantaneouſly combine, and as readily precipitate: forming a middle ſalt, the *oxalat of lime*. This ſalt is deſtitute of taſte; it is deſtroyed by fire, without leaving a coaly reſidue; and is by this property diſtinguiſhed from tartrite of lime.

§ 691.

5. Another earthy ſaline combination of this acid, 6. the *oxalat of magneſia* is likewiſe inſoluble in water. 7. The *oxalat of barytes* is of very ſparing ſolubility; 8. the *oxalat of alumine*, or argil, on the contrary, is deliqueſcent.

§ 692.

The ſucceſſive order of affinities of the oxalic acid with alkalis and earths, is as follows.—Lime, barytes,

barytes, magneſia, pot-aſh, ſoda, ammoniac, alumine.

§ 693.

As to affinities with alkalis and earths, comparatively with other acids, the oxalic acid by far exceeds the *carbonic.* It is inferior to the *ſulphuric,* with regard to barytes and alumine; but ſuperior to it with lime and magneſia. Both the *nitric* and *muriatic acids* exceed the oxalic in their affinities with alkalis and alumine; but are inferior to it with lime, magneſia, and barytes.— By the *fluoric acid* the neutral oxalats (§ 689) are decompoſed; but not the oxalats of the middle, or earthy ſaline kind (§ 690, 91). And the *boracic acid,* through the whole liſt of alkalis and earths, has a more remote affinity than the oxalic.

§ 694.

From the very ſtrong attraction which the *oxalic acid* has for lime, even ſuperior to that of the ſulphuric (§ 693), it proves an *excellent reagent* for diſcovering calcareous earth in any fluid; even when this earth is united to an acid. Thus, for inſtance, the addition of oxalic acid to common water, impregnated with gypſum, or ſulphat of lime, immediately deſtroys its limpidity, and oxalat of lime is precipitated. This purpoſe is beſt anſwered by the oxalat of ammoniac.

§ 695.

Like the tartareous acid, the oxalic has a ſtrong tendency to combine with a certain quantity of pot-aſh; thus forming common ſalt of ſorrel. This phenomenon is in appearance another anomaly, or deviation from the laws of attraction, exerted by pot-aſh on acids.

Citric Acid.

§ 696.

The juice of *lemons*, or limes *(ſuccus citri)*, contains alſo a peculiar acid of its own; but united with foreign, eſpecially mucilaginous parts, from which it muſt be ſeparated in order to produce pure *citric acid.*

§ 697.

For this purpoſe, the juice of lemons, procured by preſſure, is heated; then refined by ſtraining and filtering, and ſaturated with powdered chalk, until all effervеſcence ceaſes.—The precipitate formed is calcareous earth, ſaturated with acid of lemon, or *citrat of lime:* of difficult ſolubility, and ſeparable from the fluid by ſubſequent filtration. It ought alſo to be edulcorated with cold water. As the ſulphuric acid has a ſtronger attraction for lime than the citric, this laſt is diſengaged from the citrat, by means of diluted ſulphuric acid, affuſed upon it it in a ſufficient quantity*, and with which, after proper ſtirring, it is boiled for a few minutes. After refrigeration, the contents of the matraſs are filtered; the remainder on the filter being gypſum, and the filtered lye being pure citric acid, which by evaporation of the diluting water is rendered capable of cryſtallizing; at the ſame time, that the gypſum, formed by the union of ſulphuric acid with lime, and of which ſtill a part remains diſſolved in the liquid, is ſeparated, and ſubſides.

§ 698.

The cryſtals of citric acid have an octahedral ſhape, truncated on their ſolid angles or points. They are permanent in the air; are with eaſe diſſolved by water, and excite a very ſour taſte.

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* The requiſite quantity of ſulphuric acid is that which is required to ſaturate the lime. Hence the portions of chalk added to the juice of lemons muſt be noted down, and the quantity of ſulphuric acid required for its ſaturation regulated accordingly. This proportion, if not known by other facts, or by the tables that have been given of ſuch proceſſes, may be found out by a ſeparate trial in ſmall quantities. For inſtance, half an ounce of chalk may be ſaturated, adding the ſulphuric acid by ſmall portions, and taking notice what quantity of it is required to effect the ſaturation. The ſame method holds good as a general rule in all other ſuch operations.—Edit.

§ 699.

Citric acid is, like all the other acids peculiar to vegetables, deſtructible by fire; and it yields by dry diſtillation, carbonated hydrogen gas, carbonic acid gas, an empyreumatic ſour phlegm, and leaves ſome coal behind.

§ 700.

By this fact it appears, that hydrogen and carbon likewiſe conſtitute the radical of citric acid; but, doubtleſs, in proportions of theſe component parts to oxygen, different from thoſe by which the tartareous and oxalic acids are formed. On a ſimilar treatment with theſe laſt (§ 673, 688), the citric acid likewiſe in heat robs the ſulphuric acid of part of its oxygen, is itſelf converted partly into acetic, and partly into carbonic acid; and the ſulphuric acid aſſumes the ſtate of the ſulphureous.

§ 701.

The citric is diſtinguiſhed from other vegetable acids by particular neutral and middle ſalts, denominated *citrats*, which it forms with alkalis and earths. 1. The *citrat of pot-aſh*, and 2. the *citrat of ſoda*, are cryſtallizable; but, 3. the *citrat of ammoniac* is not ſo. Of the middle ſalts of this kind, 4. the *citrat of lime* * is earthy and taſteleſs; 5. the *citrat of magneſia* deliqueſcent;

6. the

6. the *citrat of barytes*, and laſtly, 7. the *citrat of alumine*, both of difficult ſolution.

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* Synonyma: *Oculi cancrorum citrati, conchae citratae.*

§ 702.

We have ſeen that the citric acid is decomposable or deſtructible by fire (§ 699), and for this reaſon, all citrats, whether earthy or alkaline, are deſtroyed by heat; yet it ſeems to be worth while to inveſtigate farther the nature and properties of theſe ſalts.

§ 703.

The following is the order in which alkalis and earths ſucceed each other, with regard to the degree of affinity with citric acid.—Ponderous earth, lime, magneſia, pot-aſh, ſoda, ammoniac.

§ 704.

In the humid way, both the carbonic and boracic acids are expelled from alkalis by the citric; which, however, has a weaker affinity for the alkalis, than all the other acids hitherto treated of. The *citric acid* is, beſides, diſtinguiſhed from the two preceding vegetable acids: firſt, from the *tartareous*, by not decompoſing, like this (§ 681), the muriat of pot-aſh; and, ſecondly, from the *oxalic acid*, by its not decompoſing gypſum, which is decompoſed by this laſt (§ 693).

Malic Acid.

§ 705.

Verjuice or the juice of all ſorts of unripe or ſour apples contains an acid of a peculiar kind, which has been denominated *malic acid.*

After the unfermented juice preſſed out from apples has been clarified, it is ſaturated with chalk; this ſolution is in the next place ſtrained and mixed with alkohol, or rectified ardent ſpirit. The alkohol unites with the watery parts of the juice; and the acid uniting with the calcareous earth, forms malat of lime, which precipitates, and is ſeparated from the ſupernatant liquid, by means of a filter. Laſtly, the malic acid is diſengaged from the waſhed malat by diluted ſulphuric acid; which, by virtue of its ſtronger attraction, lays hold of the lime, forming with it gypſum, and thus ſets the malic acid at liberty.

§ 706.

The malic acid never cryſtallizes, but continues liquid. Of its neutral combinations, 1. the *malat of pot-aſh*, 2. the *malat of ſoda*, and, 3. the *malat of ammoniac* are all deliqueſcent. Of its combinations with earths, 4. the *malat of lime* admits of being cryſtallized, and alſo, 5. the

the *malat of barytes*; 6. the *malat of magneſia* is again deliqueſcent; but, on the contrary, 7. *malat of alumine* is of difficult ſolution.

§ 707.

Fire decompoſes the malic acid, and likewiſe all its neutral and middle-ſalts. By diſtilling dry malat of lime, carbonated hydrogen gas, and carbonic acid gas are produced, as from the foregoing vegetable acids; and the calcareous earth, together with a coaly reſidue, remains in the retort. It follows from this, that the radical of malic acid likewiſe conſiſts of hydrogen and carbon. By a ſmall portion of the nitric acid, the malic acid may be converted into the oxalic.

Concerning other ſour Juices of Plants.

§ 708.

The acids afforded by other plants have been found not to differ from thoſe which we have before examined.

Thus from *tamarinds (tamarindus indica)* tartareous acid, and tartar, are alſo obtained; and citric acid, according to *Vauquelin.*

The juice of *ſour cherries (ceraſum apronianum)* contains citric and malic acid.

The *berries of ſumac (rhus coriaria)* contain tartareous acid and tartar.

Common cranberries (vaccinium oxycoccos), red bilberries (vaccinium vitis idæa), the bird cherry (prunus padus), the berries of bitter-ſweet (ſolanum dulcamara), and *hips (cynoſbatus)* contain more citric than malic acid.

Berberries (berberis vulgaris), elder-berries (ſambucus nigra), ſloes (prunus ſpinoſa), berries of the wild ſervice-tree (ſorbus aucuparia) and the *common plum (prunus domeſtica)*, contain more malic than citric acid.

Gooſeberries (ribes groſſularia), white and red currants (ribes album et rubrum), whortle-berries (vaccinium myrtillus), ſtrawberries (fragaria veſca), and *raſpberries (rubus idæus)*, contain almoſt equal portions of citric and malic acid.

Unripe grapes (uva immatura) contain merely citric acid.

Benzoic Acid.

§ 709.

In the fragrant reſin called *Benzoin* there exiſts a ſalt, which on account of its properties cannot but be conſidered as a diſtinct vegetable acid, known by the appellation of *Benzoic Acid.*—The method of pro-

procuring it is this.—Benzoin is expoſed in a crucible to a gentle heat; a cornet of paper, conically twiſted, with the open baſe turned downwards, is placed on the aperture of the crucible. A ſtrong, white, very pungent ſmoke ſublimes from the reſin, ſettling around the inſide of the paper in white glittering needles, whoſe officinal name is *flowers of benzoin*, and which are the benzoic acid.

§ 710.

The benzoic acid may be procured more copiouſly, and in a leſs troubleſome way, by boiling four parts of finely pulverized benzoin with one part of burnt lime, and four parts of water.

The operation ſhould be performed in a pewter veſſel, and with conſtant ſtirring. The acid contained in the reſin unites with the calcareous-earth to a middle ſalt, which remains diſſolved in the lixivium, and muſt be filtered. The reſiduum is again boiled, but with a double quantity of water; and, when boiled, filtered and mixed with the firſt lye. Both lyes together are now in part evaporated; and, after they have cooled, muriatic acid is dropped in till no more precipitate ſubſides.

This precipitate, carefully lixiviated with *cold* water and dried, is the benzoic acid, which is purified by repeated ſolutions in boiling water and filtration; and may, by ſlow refrigeration, be cauſed to ſhoot into beautiful cryſtals in the ſhape of needles, or ſhort ſilky threads.

> The muriatic acid, by its ſtronger affinity, ſeizes the lime, and forms with it a ſoluble ſalt. But as the benzoic acid is leſs ſoluble, and the quantity of water neceſſary for its ſolution is diminiſhed by evaporation, it falls down; and ſtill more ſo, as the ſolvent power of water decreaſes by cooling. The precipitate, in the firſt part of the operation, is of a powdery form.—Edit.

§ 711.

The acidity of benzoic acid is not predominant; its taſte is, however, of a very irritating and acrid kind. In cold water it is of very difficult ſolution; boiling water has a much greater power upon it. Its cryſtals are not affected by the influence of air; but they are volatile in moderate heat (§ 709). They are combuſtible; but, to be burnt, they muſt be placed in immediate contact with red-hot charcoal. They alſo detonate with ignited nitrat of pot-aſh.

§ 712.

The baſis of this acid appears likewiſe to be a compound of hydrogen and carbon. Yet theſe principles muſt in this acid bear proportions to each other, as well as to oxygen, different from thoſe by which the vegetable acids mentioned before are formed.—This acid ſalt being volatile in

fire,

fire, its decompoſition is not an eaſy matter. Yet, by being diſtilled with ſulphuric acid and the native black oxyd of manganeſe, it is decompoſed, and becomes acetic acid.—The concentrated ſulphuric and nitric acids are not decompoſed by it in the humid way; and both diſſolve it eaſily, but drop it again unaltered on the addition of water.

§ 713.

The benzoic acid combines with all alkalis, and with alkaline earths, forming by this union cryſtallizable, neutral, and middle ſalts, of which till now no uſe has been made.

1, *Benzoat* of *pot-aſh*; 2, *benzoat* of *ſoda*; 3, *benzoat* of *ammoniac*; and

The *benzoats*, 4, of *lime*; 5, of *magneſia*; 6, of *alumine*; 7, of *barytes*; 8, of *Strontian-earth.*

§ 714.

The affinities of alkaline ſubſtances with the benzoic acid are in this order: Firſt, lime; then barytes, pot-aſh, ſoda, ammoniac, magneſia, and laſt of all alumine.

§ 715.

By the benzoic acid the *carbonic* and *boracic acids* are expelled from alkalis and earths. The benzoic is, on the other hand, itſelf expelled from theſe ſubſtances by the ſulphuric, nitric, nitrous, fluoric,

fluoric, tartareous, oxalic, citric, and malic acids. The explanation of theſe phenomena is, as in all other caſes of this kind, to be found in the laws of attractions.

Gallic Acid.

§ 716.

Various plants, entirely or in part, manifeſt an aſtringent taſte; and are alſo poſſeſſed of the characteriſtic property, that their aqueous or ſpirituous infuſion precipitates the ſulphat of iron (green vitriol) from its ſolution, of a black or black-blue colour.

§ 717.

Theſe qualities are poſſeſſed in an eminent degree by the *nut-galls*; and, beſides, by the *bark of oak*, *ſumach*, the *rinds of pomegranate*, *tormentil-root*, *biſtort* or ſnake-weed, and ſeveral others.

§ 718.

From nut-galls ſubjected to dry diſtillation carbonated hydrogen gas, and carbonic acid gas, are extricated; beſides theſe, a ſour phlegm and empyreumatic oil comes over; and at the ſame time ſublimes a light reſplendent ſalt, evidently ſour, which may be purified by ſubliming it a ſecond time with a gentle heat in two glaſs-cups faſtened together, and may be thus brought to the form of rather long ſhining cryſtals, radiating from a common centre, and croſſing one another. Part of this ſalt is alſo contained in a diſſolved ſtate in the above acid fluid, which is collected in the receiver when dry nut-galls are diſtilled.

§ 719.

Beſides this method, the above acid ſalt may be obtained from nut-galls in various other ways.—It conſtitutes a peculiar acid belonging to the vegetable kingdom, and is diſtinguiſhed by the name of *gallic acid* *. Iron is precipitated of a black hue from its ſaturated ſolution in acids by this ſalt, even without any addition. From this, therefore, we muſt explain that property, which the nut-galls poſſeſs in common with other aſtringent plants. But the extracts of nut-galls, the ſpirituous as well as the aqueous, contain, beſides this gallic acid, ſome mucilaginous, reſinous, extractive matter; which, in the opinion of *Dejeux*, conſtitutes in theſe nuts, together with the acid, a compound which, by theſe ingredients, is rendered ſoluble in water as well as in ſpirit of wine.

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* It is alſo called *aſtringent principle.*

According to *Chaptal*, *Elements de Chymie*, 1795, Tome II. page 331, the ſolution of *gold* is by this acid rendered of a dark green, and the metal is reduced and precipitated as a brown powder. The ſolution of ſilver is turned brown by it, and the *ſilver* falls down as a grey powder in the metallic ſtate.—*Mercury* is by this ſalt precipitated of an orange-yellow, *copper* of a brown, and *ſugar of lead* of a white colour.—Edit.

§ 720.

By nitric acid the gallic may be converted into oxalic acid. By this circumſtance it ſeems to me unqueſtionable, that the gallic acid has alſo a baſis compoſed of hydrogen and carbon; but which, of courſe, muſt be ſuppoſed to contain theſe principles in proportions different from thoſe other vegetable acids, as well relatively to each other as to the ſhare of oxygen. *Dejeux*, nevertheleſs, aſſerts, that its radical is ſimply carbon; and that the difference of gallic from carbonic acid conſiſts merely in the different quantities of their oxygen.

§ 721.

The neutral and middle ſalts, or *gallats*, formed by the gallic acid in combination with alkaline ſubſtances, have not yet been ſufficiently examined. All of them have the property of precipitating iron of a black colour.

1. *Gallat of pot-aſh;* 2. *of ſoda;* 3. *of ammoniac.*

4. *Gallat of lime;* 5. *of magneſia;* 6. *of alumine;* 7. *of barytes;* 8. *of Strontian-earth.*

Sugar.

§ 722.

Sugar (ſaccharum) is a true eſſential ſalt of the vegetable kingdom, contained in all plants of a ſweet taſte, and in their parts; though it can only be extracted from a few in a ſtate of purity and with profit. It is a product of nature, and art can do nothing elſe than ſeparate and purify it.

§ 723.

Common ſugar is prepared, particularly in the *Weſt-Indies*, from the juice of the *ſugar-cane (ſaccharum officinarum).* This juice being greatly diſpoſed to ferment, it is indiſpenſably neceſſary to ſeparate the ſugar as ſoon as the juice has been preſſed out of the cane. This is effected by evaporation and coagulation; but to ſucceed in it, the ſaccharine acid contained in the liquor, and which would prevent the ſugar from coagulating, muſt be firſt parted by adding lime, and the liquor be well ſkimmed.—The ſugar is made to coagulate by properly inſpiſſating the ſaccharine liquor and by cooling; after which the mother-water (*melaſſes* or *treacle*) is drained off.—Sugar thus procured is called *raw ſugar*, or *moſcovade*; is of a yellow colour, and is ſent

ſent to Europe in this ſtate for farther refining. Sugar farther purified from melaſſes, is called *powder ſugar*, and alſo *caſſonade*.

The laſt and complete purification, or *refining of ſugar*, is done in the following manner:—Raw ſugar is boiled again in copper-kettles with lime-water and bullock's blood, carefully deſpumated and ſtrained through woollen-cloth, and once more boiled down to a proper degree of conſiſtence. This ſaccharine decoction is now ready for cooling, which is performed by lading it firſt into a large copper cooler, and by transferring it from this into flat pans well moiſtened before hand, where it is repeatedly ſtirred to prevent its coaleſcing into larger cryſtals.—When completely cold it is put into unglazed conical moulds made of clay, the lower ſmall aperture of which is ſtopped up. In theſe it is ſuffered fully to coagulate. But the ſuperfluous ſyrup is cauſed to trickle off, by opening the lower points of the moulds.

Sugar thus prepared is called *loaf-ſugar*. An ingenious way of freeing it from the adhering particles of ſyrup, and of making it perfectly white, has been contrived, by covering the baſe of the inverted conical form with clay, previouſly ſoftened by maceration in water, of the thickneſs of ſeveral inches, and which is now and then moiſtened with a little water. By this excellent contrivance the

ſmall

ſmall cryſtals of ſugar, though of ſo deliqueſcent a nature, are waſhed and cleanſed from adhering foul water; and, beſides, the colouring particles and other impurities are diſſolved and carried off.—The operations here mentioned are ſeveral times repeated until the ſugar has obtained the whiteneſs and fineneſs required.—At laſt the ſugar-loaves are thoroughly dried in heated rooms.

§ 724.

The *ſyrup* collected on the inſpiſſation of the juice preſſed from the cane, as well as that which is obtained at the refining of ſugar, is only produced and generated by the operation. It is ſugar which, at a heat exceeding the degree of boiling water, has already ſuffered a beginning decompoſition.

§ 725.

Sugar is neither an acid nor an alkaline ſalt; it is neither a neutral nor a middle ſalt; it is in every reſpect to be conſidered as a ſalt of a peculiar nature. Sugar is very ſoluble in water, and requires at 50° Farenh. no more than 1,333 parts of it.—Sugar may be cryſtallized, as is obvious from *ſugar-candy*, which is prepared by leaving a purified ſolution of ſugar not yet boiled down to a very thick conſiſtence, to quiet exhalation in ſtrongly heated chambers, in copper or braſs veſſels, containing a number of threads croſſing each other, and faſtened to the ſides in various directions. The ſugar thus circumſtanced ſettles and cryſtallizes round the threads and ſides of the veſſel.

Accordingly, as the ſugar employed for this purpoſe has been purified in various degrees, the ſugar-candy will be *brown*, *yellow*, or *white*.—The cryſtals of ſugar form a quadrangular, flattened, oblique column, with terminations truncated on two ſides. Each of the ſmaller lateral ſurfaces of the column, however, is uſually compoſed of two, joining in a very obtuſe angle. The cryſtals of pure white ſugar-candy do not deliqueſce in air.

§ 726.

Sugar is a combuſtible ſubſtance, and is deſtroyed by fire. Expoſed to heat it gives out a ſtrong acidulous ſmoke; it intumeſces, and burns to a coal, which being incinerated ſcarcely leaves a reſidue behind. A large quantity of carbonic acid gas, and of carbonated hydrogen gas, is obtained from it by diſtillation; and, beſides theſe, an empyreumatic acid ſpirit, but only a ſmall portion of empyreumatic oil; and there remains a very ſpongy coal.—The acid ſpirit obtained in this proceſs ought to be taken for a mixture of acetic with oxalic acid; and does not deſerve to be received in the ſyſtem as a peculiar acid with the name of *pyromucous acid*.

§ 727.

Hence the component parts of ſugar are carbon, hydrogen, and oxygen; but it does not contain a ſufficient portion of the laſt to form an acid with the firſt. Notwithſtanding this, if the proportion of oxygen be indirectly augmented by taking off a part of its carbon, ſugar becomes then a true acid, and may be converted into oxalic acid by the nitric; and, by fermentation, into acetic acid.

§ 728.

To effect this pour ſix parts of nitric acid upon one part of pulverized white ſugar. A frothing takes place, and nitrous mixed with carbonic acid gas is diſcharged. Keep the whole in a gentle warmth until no more yellow-reddiſh vapours ariſe, and let the reſidual lixivium quietly cool.—Cryſtals of oxalic acid will ſhoot out. When theſe have been taken out, the remaining lye may be totally changed into oxalic acid, if a freſh portion of diluted nitric be added, and the fluid be evaporated and cooled, after the efferveſcence has ceaſed.

Bergman, and many others, took this for a particular acid, diſtinguiſhed from others; and it was called *acid of ſugar*. But *Scheele*, the diſcoverer of the method (§ 685) of preparing oxalic acid, has proved, beyond doubt, that the acid obtained from ſorrel is identically the ſame as that obtained from ſugar. This was confirmed by the experiments of *Weſtrumb* and *Hermſtaedt*.—Edit.

§ 729.

Sugar is widely diffuſed in the vegetable kingdom; all ſweet-taſted fruits and plants contain it: only, becauſe it is ſo often united with mucilaginous and extractive matters, it cannot be obtained from them all, eſpecially in a profitable way. The juice that flows in the ſpring from the *ſugar-maple (acer ſaccharinum)*, by an inciſion made in its ſtem, yields a true ſugar, if properly purified and boiled down. It is at preſent advantageouſly employed for that purpoſe in North-America.—Sugar has likewiſe been obtained from *parſnip-roots* (*paſtinaca ſativa*); from *ſkirrets* (*ſium ſiſarum*); from *white and red beet-roots* (*beta cicla*); from *carrots* (*daucus carota*); and from the ſtalks of *India corn* (*zea mays*)[*].

[*] The lateſt experiments made with theſe plants for the purpoſe of preparing ſugar from them are thoſe of *Hermſtaedt*. His paper on that head, tranſlated from the *Neue Schriften naturforſchender Freunde zu Berlin*, has been given in *Nicholſon's Journal*, Vol. III. for the month of October, 1799.—Edit.

The *ſugar-maple*, however, ſeems to anſwer that purpoſe with the greateſt profit.—As there are not yet ſufficient plantations of that tree in Germany, *Klaproth*, *Achard*, and *Hermſtaedt*, of Berlin, attempted to prepare it from a beet called *runkelrübe* by the Germans *(beta cicla altiſſima yaquin)*, and ſucceeded beyond expectation. The ſugar which it yields is as good as raw Liſbon ſugar, and the pound of it will hardly coſt three-pence. In all appearance it promiſes fair to be, within a few years, a ſubſtitute for the Weſt-India ſugar. Thoſe chemiſts are now about diſcovering a cheap method of refining it. Of the very ſimple proceſs of preparing that ſugar by the mere evaporation of the liquor preſſed out from the maſhed root, a ſhort account is given in the *Philoſophical Journal*, April, 1799, page 291; and *Nicholſon* has inſerted *Achard's circumſtantial deſcription of the method of cultivating the runkelrübe* in his Journal for September, 1799, page 237, ſeq.—Editor.

§ 730.

Among the ſweet eſſential ſalts of the vegetable kingdom manna and honey are alſo to be reckoned. *Manna* exudes from various ſpecies of *aſh*, particularly the *fraxinus rotundifolia* and *ornus*, either naturally, or by inciſions purpoſely made on the trunk of the tree.—*Honey* is the work of bees; but its origin, and the materials collected for it by theſe uſeful inſects, is vegetable. Of theſe two honey is, perhaps, moſt profitably employed, as it contains ſo much ſugar that its ſmall cryſtals are viſible, after it has ſtood for ſome time.

Mucilage of Plants.

§ 731.

Various parts of vegetables, for example the roots of *marſh-mallows*, the kernels of *quinces*, impart to water, if boiled with them, a certain toughneſs and glutinoſity, yet without much ſenſible ſapidity. The ſubſtance which, in this caſe, is diſſolved by water, is called *ſlime*, *mucus*, *mucilage*, and remains behind, when the decoction, previouſly ſtrained, is totally evaporated by a low heat.—The mucilage, when in this ſtate, forms a body devoid of taſte and ſmell, not ſoluble in ardent ſpirit, but which is diſſolved by cold as well as hot water.

§ 732.

This mucilage exiſts in all plants and their parts, with this difference only, that it cannot be procured in a pure ſtate from every one of them. It is alſo found in ſome plants, and in ſome of their parts, more plentifully than in others.

§ 733.

Some trees ſuffer their mucilage to tranſude either ſpontaneouſly, or by inciſions made in them. When it has become concrete by drying in the air, it is called *gum*.

Examples are afforded by *gum-arabic* from the *mimoſa nilotica* and *mim. ſenegal*; the *gum from the plum— and cherry-tree (gummi ceraſorum)*; and *gum tragacanth* from the *aſtragalus tragacantha*.

§ 734.

Mucilage is ſuſceptible of combuſtion. It yields, by dry diſtillation, carbonic acid and carbonated hydrogen

hydrogen gas, an acid empyreumatic fluid like ſugar, and an empyreumatic oil. The remaining coal is very pure; and whatever is left behind, after its incineration, proceeds from ſome adhering extraneous matters.

§ 735.

The mucilage may be changed into oxalic acid by the nitric; and *Vauquelin* has converted it, by muriatic acid, into the citric.

§ 736.

The conſtituent parts of vegetable mucilage and gum are, therefore, carbon, hydrogen, and ſome portion of oxygen (§ 734), and conſequently the ſame as thoſe of ſugar (§ 727).—There is, therefore, no other difference between them, than a variety in the proportions of their radicals to each other; and hence their tranſition from one into another is eaſy while the plant is growing.

Of Reſin.

§ 737.

Reſin (reſina) is inſoluble in water, but ſoluble in ſpirit of wine. It liquefies by heat, may be eaſily ſet on fire by applying a flame, and is poſſeſſed of an odour more or leſs ſtrong.

§ 738.

Reſin is a proximate conſtituent ingredient in ſeveral parts of vegetables. It is particularly found in the wood, roots, and buds. It may be extracted from them by ardent ſpirit; but there are ſome trees that ſuffer it to exude ſpontaneouſly.

To this claſs of bodies belong *pitch* (§ 632); *colophony*, made by the farther refining of Burgundy pitch; *maſtic*, from the *piſtacia lentiſcus*; *ſandarac*, from the *juniperus communis*; *elemi*, from the *amyris elemifera*; *tacamahac*, from the *populus balſamifera*; (?) *benzoin*, from the *ſtyrax benzoin*; *frankincenſe (olibanum)*, from the *juniperus lycia*; *guaiacum*, from the *guaiacum officinale*; *dragon's-blood*, from the *calamus rotang*, *dracæna draco*, and *pterocarpus draco*; *copal*, from the *rhus copallinum*; *ladanum*, from the *cyſtus creticus*, and *ſhell-lac (lacca in tabulis)*.

§ 739.

Such reſins as ſpontaneouſly iſſue from their plants, owe their fluidity to an ethereal oil combined with them, which itſelf is a conſtituent part of vegetables; and the reſins harden after its exhalation. It is from this oil that the fragrant ſmell of reſins orginates. Reſins, which have not yet aſſumed the concrete form, but ſtill continue in a fluid ſtate, are called *natural balſams**; and they may be conſidered as reſins diſſolved by ethereal oils.

Examples: *Common turpentine (terebinthina vulgaris)*, obtained from firs and pines; *Venetian turpentine*, from the *pinus larix*; *Cyprian turpentine*, from the *piſtacia terebinthus*; *Canada balſam*, from the *pinus balſamea* and *canadenſis*; *Copaiva balſam*, from the *copaifera officinalis*; *balſam of Peru*, from the *myroxylon peruifera*; *balſam of Tolu*, from the *toluifera balſamum*; *balſam of Mecca*, or *Gilead (opobalſamum liquidum)*, from the *amyris opobalſamum*.

* Fluidity and fragrancy ſeem to be eſſential requiſites to the nature of a balſam. Yet *Chaptal*, with ſome others, aſſerts, that ſeveral balſams are always in a concrete ſtate; and, according to him, they are reſins united to an acid ſalt. *Elem. de Chymie*, Tome III. ſect. 3, article 4.—Edit.

§ 740.

Pure reſins, when burned in oxygen gas, generate carbonic acid gas and water. Beſides, if diſtilled by themſelves without other addition, except a large quantity of ſand (which is neceſſary on account of their great intumeſcence), they afford carbonated hydrogen gas, carbonic acid gas, a ſouriſh fluid, and much empyreumatic oil, which at the end becomes quite pitchy. The remaining coal is very pure.

§ 741.

The radicals of reſins are conſequently carbon, hydrogen, and ſome oxygen. They may alſo be produced artificially from ethereal oils, as will be ſhewn hereafter. Acids affect them but little.

Gum-Reſin.

§ 742.

That juice, for the moſt part milky, which iſſues from plants wounded by inciſion, if ſpontaneouſly exhaled, or artificially evaporated, leaves a reſidual ſubſtance, which is not completely diſſolved either by water or by ſpirit of wine; and is, from this circumſtance, called *gum-reſin.* It cannot, with propriety, be conſidered as a blended maſs conſiſting of reſin and gum; it is rather to be taken for a peculiar mixture. Many gum-reſins are poſſeſſed of a ſtrong ſmell, and contain various other component parts united with them.

Such gum-reſins are: *Gum-ammoniac*; *galbanum*, from the *bubon galbanum*; *myrrh*; *euphorbium*, from the *euphorbia officinarum*; *gamboge*, from the *gambogia gutta*; *aſa-fœtida*, from the *ferula aſa-fœtida*; *opium*, from the ſeed-veſſels of the *papaver ſomniferum*.

Naturaliſts well know the difficulties that occur in arranging the products of nature; hence the reader will not be ſurprized at finding, in different books, different liſts of gums, reſins, balſams, and gum-reſins. That of our author ſeems, however, in every reſpect, to be very rational.—Edit.

Of Gluten.

§ 743.

If wheaten flour be firſt kneaded with cold water to a firm dough, and if this paſte be waſhed between the hands with cold water conſtantly flowing upon it, until the water is no longer rendered milky and turbid, but comes off clear and tranſparent, there will remain in the hands a tenacious *contractile* matter, which, on being forcibly enlarged by pulling while moiſt, looks gloſſy, and in ſome manner like a membrane, and which cannot be diſſolved either by water or by ſpirit of wine.

§ 744.

This peculiar ſubſtance has obtained the name of *gluten.* It hardens in heat to a brown horny matter; is diſſolved by acids; is conſumed by fire, ſending forth a ſmell like that of ſcorched hairs; and yields, by diſtillation, carbonic acid— and hydrogen gaſes, beſides ſome ammoniac, and an empyreumatic oil.—This gluten is tinged by nitric acid of a yellow colour, is decompoſed by it, and transformed into oxalic acid.

§ 745.

All experiments made with gluten prove, that it is compoſed of carbon, hydrogen, azot, phoſphorus, and oxygen.

§ 746.

The flour of other ſpecies of corn, different from wheat, contains a leſs quantity of gluten.—This, however, is a conſtituent principle of many other plants or their parts; of their leaves, for inſtance, and particularly of the *fungi*. There is no doubt but that the ammoniac, yielded by plants on dry diſtillation (§ 633), chiefly ariſes from their gluten.

Concerning Starch.

§ 747.

If the rinſing-water collected from the foregoing experiment (§ 743) be ſuffered to ſtand quietly for ſome time, it lets fall a white powdery ſediment. This is the *ſtarch (amylum)*, which, when dry, is pulverulent, taſteleſs, without odour, inſoluble both in cold water and ardent ſpirit; but is diſſolved by boiling water, making with it *paſte*, a well known ſubſtance.

This rinſing-water (§ 743) ſeparated from the ſtarch, and filtered, yields, if evaporated before it turns ſour, an extract which proves to be of a *mucilaginous ſaccharine* nature.

§ 748.

§ 748.

On account of theſe properties we are entitled to ſay, that ſtarch is eſſentially different from both mucilage and gluten. By diſtillation it gives the products yielded by mucilage (§ 734), and conſequently conſiſts of the ſame principles; but in the ſtarch they are united in other proportions than in mucilage.—Nitric acid converts ſtarch into oxalic and malic acid.

§ 749.

Starch is one of the conſtituent parts in all mealy, farinaceous ſeeds, fruits, roots, and other parts of plants. Of theſe the *fæculæ* of the ancients for medicinal uſe are an example. They are mere ſtarch; as for inſtance, the fecula of *wake-robin* (*radix ari, aronis*); of *bryony* (*bryonia alba*); the *ſtarch* of *potatoes* (*ſolanum tuberoſum*); of *ſago*, from the pith of the palm *landanum*; the *caſſava* of the Americans, from the *manioc-root* (*jatropha manihot*). The *ſalep* roots, from a ſpecies of *orchis*, conſiſt for the greateſt part of ſtarch.

§ 750.

Our common ſtarch is made from wheat. It is not neceſſary that the grain be firſt bruiſed in mills. The entire corn, well cleanſed, is ſoaked in cold water until the huſk ſeparates; and the grains, having become quite ſoft, give out by preſſure a milky fluid.

fluid. The grains are then taken out of the water by means of a ſieve, put into a coarſe linen ſack, and transferred into the *treading-tub*; where they are trodden, after cold water has been poured upon them.

By this operation the ſtarchy part is waſhed out, and mingling with the water makes it milky. The water is now drawn off, running through a ſieve into the *ſettling-tub*. Freſh water is again affuſed upon the grains, and the ſame operations continued, till the water in the treading-tub is no longer rendered milky. The ſtarch here precipitates by repoſe from the water that held it ſuſpended; during which, eſpecially in a warm ſeaſon, the *mucilaginous ſaccharine* matter of the flour (§ 747, note), that was diſſolved by the water, goes into the acetous fermentation. From this cauſe the ſtarch grows ſtill purer and whiter.

The water is next let off from the ſtarch, which is ſeveral times more waſhed with clear freſh water; the remaining part of which is ſuffered to drip through linen cloths ſupported by hurdles, upon which the wet ſtarch is placed. When the ſtarch has fully ſubſided, it is wrapt in and wrung between theſe cloths, or preſſed, to extort ſtill more of the remaining liquid. It is afterwards cut into pieces, which are laid in airy places on ſlightly burnt bricks to be completely dried, partly by the free currency

of

of air, and partly by the bricks imbibing their moiſture. Laſtly, the outer cruſt is ſcraped off, and they are broken into ſmaller pieces.

In the ſacks wherein the corn was trodden there remain its huſks and glutinous parts; and this reſiduum is employed as food for cattle.

Albuminous Matter of Plants.

§ 751.

Take ſome juice recently preſſed from young creſſes, or from white cabbage; let it ſtand quiet for ſeveral hours, and then paſs it cold through filtering-paper. If a glaſs bottle filled with this clear and tranſparent liquor be placed in boiling water, the liquor will depoſite a flocculent matter; which being ſeparated by filtering, and waſhed, reſembles the coagulated white of eggs, and for this reaſon has rightly been called the *albuminous matter (albumen)* of the vegetable kingdom.—This albumen, before it coagulates, is ſoluble in cold water, and of an inſipid taſte. In heat it coagulates, and this coagulum is inſoluble in hot as well as cold water. In ſpirit of wine it alſo coagulates, and is likewiſe inſoluble. Alkalis and liquid ammoniac diſſolve it.

§ 752.

Fourcroy found, by analyſing this ſubſtance, every poſſible agreement, as to nature and properties, between it and the albuminous matter of the animal kingdom; which laſt will be examined in its proper place.

753.

This albumen has been met with in the juice of a great many plants; and it is this matter, principally, that contributes to the formation of ſcum, when vegetable juices recently preſſed, and clearly ſtrained, are reduced to a ſmaller bulk by boiling.

Of Fat Oil.

§ 754.

A fluid matter, inſoluble in water, and capable of feeding flame if conveyed to it by means of a wick, may be expreſſed from the ſeeds and kernels of various plants. This liquid is, therefore, an *oil (oleum)*. It is, beſides, an oil of that kind which is not diſſolved by ardent ſpirit; it ſoils paper when dropped upon it, leaving a ſpot which is not made to diſappear by warming the paper; and poſſeſſes, when freſh and pure, a mild taſte, and uſually gives no very perceptible ſmell.---To diſtinguiſh it from other oils not having thoſe characters, it is called *fat oil (oleum unguinoſum).*

Synonyma: *Mild oil, fixed oil, expreſſed oil (oleum dulce, fixum, expreſſum).*

§ 755.

In order to obtain pure oil of a good quality the ſeeds and kernels are ſeparated from their hard ſhells and huſks, and all other extraneous matters; they are then bruiſed, and put into ſacks or cloths woven from hemp or horſe-hair; and in theſe they are preſſed between metallic plates, firſt ſlowly and gently, and afterwards more ſtrongly.—But, to promote the expreſſion of the oil, the bruiſed ſeeds are firſt expoſed to the ſteam of boiling water; or they are placed upon a low fire in a kettle ſprinkled with water, and thus carefully warmed, with diligent ſtirring, to prevent their being ſcorched, and then preſſed between warm metallic plates. By mere cold preſſing the oil can by no means be totally got out; yet too great a heat, which would cauſe a commencement of roaſting in the ſeeds and kernels, is highly detrimental to the oil.

§ 756.

Fat oils are, in the beſt way (by repoſe), ſpontaneouſly purified from the mucilaginous parts that were preſſed out along with them. Reſinous and ethereal oily particles which may be contained either in the huſk or in the grain of the ſeeds, impart to ſome fat oils, by being diſſolved in them, colour, taſte, and ſmell.

§ 757.

Several fat oils become dry of themſelves in the air, and paſs into the concrete ſtate, more eſpecially if they have been boiled beforehand. Others always remain greaſy, and ſome are ſolid in the common temperature of our atmoſphere.—Theſe laſt are ſtyled *vegetable butters (butyra plantarum)*.

To *drying fat oils* belong *linſeed-oil*, from the ſeed of the *linum uſitatiſſimum* and *perenne*; *poppy-oil*, from the ſeed of the *papaver ſomniferum*; and *hemp-oil*, from the ſeed of the *cannabis ſativa*.

To the *oils always continuing fluid* belong *olive-oil (oleum olivarum)*, from the fruit of the *olea europæa*; *oil of almonds*, from the kernels of the *amygdalus communis*; *rape-oil*, from the ſeeds of the *braſſica napus* and *campeſtris*; *oil of ricinum*, or *caſtor-oil*, from the kernels of the *ricinus communis*.

The kernels of *gourds*, *beech-maſt*, *walnuts*, *hazel-nuts*; the ſeeds of *muſtard*, of the *ſun-flower*; the kernels of *plums*, and of *grapes*, &c. afford alſo fat oils of economical uſe.

Among *vegetable butters* are reckoned *butter of cacao*, from the kernels of the *theobroma cacao*; *oil of laurels*, from the kernels of the *laurus nobilis*; and *oil of nutmegs*, from the nuts of that name.

§ 758.

Fat oils do not boil unleſs in a ſtrong heat, which is eſtimated at 600° Farenh. They undergo thereby a decompoſition. They are inflamed only at a heat ſufficient to volatilize them.

§ 759.

Fat oils burn with a flame. If oxygen gas has no ſufficient acceſs to this flame, it throws out a ſoot (*lamp-black*), which is the unconſumed coal of the oil. Hence, in Argand's lamp, the oil continues to burn away without ſoot or ſmoke as long as the air can ſtrike, unimpeded, through the axis or cavity of the flame; and aqueous vapours and carbonic acid gas are generated.—According to *Lavoiſier*'s ſtatement, 321 parts of oxygen gas are extricated from 100 parts of olive-oil on combuſtion, and 140 parts of water, and 281 of carbonic acid gas are produced. He infers from this, that this fat oil conſiſts very nearly of 79 parts of carbon, and of 21 of hydrogen.

§ 760.

Notwithſtanding this, the fat oils contain alſo ſome oxygen; for, if they be diſtilled by themſelves, they yield, beſides carbonated hydrogen gas and much empyreumatic oil, likewiſe carbonic acid gas, and a ſmall portion of empyreumatic acidulous phlegm, neither of which can be formed except by a ſhare of oxygen.

Of the *oil of bricks (oleum philoſophorum).*
Of *Scheele's ſweet ſubſtance* in fat oils.

§ 761.

By age, and careleſs keeping in warmth, even the very mildeſt fat oils grow *rancid*, and are tainted with a ſharp taſte and bad ſmell. Thoſe are peculiarly liable to this depravation which have been preſſed with too great a heat, or have been in ſome manner roaſted. The uſual condition of our oil-mills, and of the apparatus made uſe of for the expreſſion, is the cauſe that many ſeeds and kernels, which otherwiſe would yield an oil of good flavour, afford ſuch as at their very production is rancid, and of a diſagreeable ſmell and taſte.

§ 762.

The principle of rancidity in oils lies in the acceſs of oxygen from the atmoſphere to their hydrogen and carbon (§ 759); whereby an acid begins to be formed, and the nature and mixture of the oil is altered.

§ 763.

Fat oils and water have no chemical affinity with each other; and oil is never diſſolved by water. But an oil may be intimately mingled with it; and then a milky-white, untranſparent fluid is formed, which is called an *emulſion*. This vegetable milk, as it were, is prepared by triturating ſuch ſeeds as contain a fat oil with water, and ſqueezing the latter again out from the maſs.—Agreeably to the different

nature

nature of the ſeeds, the water may alſo diſſolve various other extractive matters preſent in them.

§ 764.

Reſins and natural balſams are diſſolved by fat oils with the aſſiſtance of heat. On mucilage, ſugar, gluten, albumen, and ſtarch, theſe oils ſhew no ſolvent power.

§ 765.

The fixed alkalis are a very active menſtruum for fat oils, and make up with them a new product, called *ſoap* (*ſapo*), and capable of ſolution in water and ſpirit of wine. Soap is made by boiling a cauſtic lixivium of fixed alkali with a fat oil, or tallow, or ſuet, and ſtirring continually, till both ſubſtances are completely incorporated.—*Soda* yields, with a congealing or drying oil (§ 757), a firm and hard ſoap. *Pot-aſh* affords a ſoap of much leſs ſolidity, and more greaſy, unleſs muriat of ſoda be added towards the end of the operation; but then the ſoap is, in fact, produced by the ſoda.

> Of the uſual ſoaps are: *Common ſoap*, made of tallow; *Venetian* or *Alicant*, or *Spaniſh ſoap*, made of olive-oil; *black ſoap*, made of train-oil; and *green ſoap*, made of hemp-, linſeed-, or rape-oil.

§ 766.

All acids decompoſe ſoap, and ſeparate again its oil. If, therefore, into a clear ſolution of ſoap in water,

water, or ardent ſpirit, an acid be dropped, a turbidneſs takes place, and the oil is ſeparated. But this laſt no longer exhibits its former properties: for inſtance, it diſſolves now, totally or in part, in ſpirit of wine. Whence it follows, that the action of the alkali upon the oil has altered its mixture (§ 759, ſeq.)

§ 767.

All ammoniacal neutral ſalts, and likewiſe the middle earthy and metallic ſalts, decompoſe ſoap.

§ 768.

Various waters obtained from *ſprings*, or from *wells*, for this reaſon diſſolve ſoap only imperfectly, or rather they decompoſe it. Such are called *hard waters*; but, on the contrary, thoſe are called *ſoft waters* which are free from all earthy middle ſalts, and diſſolve ſoap completely. On this account *ſpirit of ſoap*, or a ſolution of ſoap in ſpirit of wine, is employed as a *re-agent* to diſcover, whether a water be of the hard or of the ſoft kind.

§ 769.

Though *liquid ammoniac*, by agitation and trituration, unites with fat oils to a ſoap, yet this combination is not ſo perfect as that with fixed alkalis. This *ammoniacal ſoap* may, nevertheleſs, by means of double affinity, be procured in greater perfection, if to a ſolution of a ſoap made with fixed alkali, muriat of ammoniac be added, and the flocculent matter that falls down be ſeparated by filtering.

§ 770.

The preceding ſoaps are comprized under the name *alkaline*, and are thus diſtinguiſhed from *earthy ſoaps*; inaſmuch as ſeveral earths are capable of a chemical combination with fat oils. Lime-water, for example, decompoſes the ſolution of common ſoap, and forms a flocculent precipitate; which is a combination of fat oil with lime, and hence a calcareous or *lime-ſoap*. When dried, this earthy ſoap is friable; fuſible in heat; not ſoluble in water, but diſſolved by ſpirit of wine if aſſiſted by heat. Acids decompoſe it.—This calcareous ſoap is alſo obtained by combining the ſolution of common ſoap with an acid ſolution of lime.

§ 771.

In a ſimilar way *magneſian*, *argillaceous*, and *barytic-ſoap*, are prepared according to *Berthollet*; namely, by mixing the ſolution of common ſoap with the reſpective aqueous ſolutions of the ſulphats of magneſia or of alumine, or of muriated barytes.

§ 772.

Sulphuric acid, as before obſerved (§ 431), is decompoſed, and converted into ſulphureous acid, by fat oils; becauſe a portion of hydrogen and carbon, which are the radicals of ſuch oils (§ 759), deprive

deprive the acid of part of its oxygen, and take poſſeſſion of it. The fat oil is by this decompoſition likewiſe changed with regard to its conſtituent mixture; it becomes a reſin, obtains a firm conſiſtence, aſſumes a dark colour, and is rendered ſoluble in alkohol.—Such kind of reſin has alſo been denominated an *acid ſoap*.

§ 773.

With equal facility is the nitric acid decompoſed, and transformed into nitrous gas, by fat oils (§ 515). Here again, as in the foregoing caſe (§ 772), the hydrogen and carbon of the oil rob the acid of a part of its oxygen. The oil is alſo changed into a true reſin. By very concentrated nitric acid the fat oils, eſpecially thoſe of the drying kind (§ 757), may be brought even to ſpontaneous inflammation, as will be mentioned hereafter, on treating of ethereal oils.

§ 774.

Muriatic acid acts but little on fat oils; but by oxygenated muriatic acid they are thickened.

§ 775.

Sulphur is perfectly diſſolved by fat oils with the aſſiſtance of heat. This ſolution of ſulphur in oils is called *balſam of ſulphur* (*balſamum ſulphuris*). It is thus prepared:—A fat oil is heated in a pan, and powdered ſulphur is then put into it by degrees,

grees, and with unintermitted ſtirring. The mixture is very apt to inflame ſpontaneouſly. The colour of this ſulphureous balſam is browniſh or reddiſh; its odour is diſagreeable; its taſte rancid and ſharp. If the oil has been completely ſaturated with ſulphur while hot, the mixture is afterwards tenacious and firm when cold.

§ 776.

Balſam of ſulphur acted upon by heat developes ſulphurated hydrogen gas (§ 449) mixed with carbon. That balſam is obviouſly a combination of three ſimple inflammable ſubſtances, of ſulphur, hydrogen, and carbon; which, in this union, attract oxygen more ſtrongly than when ſingly each by itſelf. For this reaſon the oil grows rancid, even whilſt the balſam of ſulphur is preparing.

Elaſtic Reſin.

§ 777.

The *elaſtic reſin, caoutchouc (reſina elaſtica)*, is a leather-like, contractile, and, in moderate warmth, very diſtenſible matter, which is not diſſolved by water, nor by ſpirit of wine. It iſſues from a tree of South America (the *caoutchoua elaſtica*), by inciſions made on it; is a viſcid, milky-white liquor, which, by abſorbing oxygen from the atmoſphere, gradually paſſes into the ſtate of ſolidity.

Moulds

Moulds of clay, in the form of balls, are bruſhed over by layers with this juice till the cover has obtained a certain thickneſs. In this ſtate it is ſuffered to dry in ſolar heat, and ſmoke; after which the moulds are broken, and their earthy matter ſhaken out of the reſinous bottle thus formed.—This matter ſeems to exiſt in various, even indigenous plants.

§ 778.

The elaſtic reſin is ſoftened by heat; it melts at laſt, ſwelling up, and ſpreading an unpleaſant odour. On congealing again by cold it remains ſticky or adheſive, and never recovers its former elaſticity. It may be ſet on fire, and burns with flame.

§ 779.

When diſtilled, this reſin yields carbonic acid gas, hydrogen gas, an empyreumatic oil, and ammoniac. There remains but a trifling quantity of coaly matter, which affords no alkali by being burnt to aſhes.—Hence the radicals of this ſubſtance are carbon, hydrogen, azot, and oxygen.

§. 780.

By fat oils the elaſtic reſin is diſſolved in heat; and in this ſtate wax alſo combines with it. According to *Berniard* and *Achard*, the cauſtic alkalis have no ſolvent power on it in the humid way.

§ 781.

To give the elaſtic reſin any ſhape deſired, its ſolution in vitriolic ether has been found very convenient; as, after the evaporation of that fluid, the reſin is left with all its original elaſticity.—For the ſame purpoſe the rectified petroleum has alſo been employed by *Fabroni*, as equally effectual, and much cheaper.—Another ſtill more convenient method, without diſſolving the reſin, has been recommended by *Groſſart**.

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* A bottle of this reſin is cut in narrow ſlips, which are ſoftened in ether or in warm water; they are wrapt round the mould, preſſing the edges together, and ſecuring them with ribbons and pack-thread twiſted round. When dry, the mould is taken out, which is facilitated by ſoftening in warm water. Annal. de Chym. Tome XI. page 143, ſeq.—Edit.

Ethereal Oil.

§ 782.

If from a vegetable body that poſſeſſes a ſtrong ſmell, not eaſily paſſing away by rubbing the plant between the finger, a ſufficient quantity of water be diſtilled, the water is impregnated with that odour, and the vegetable matter loſes it. Such water is called *diſtilled water (aqua abſtractitia, deſtillata)*.

§ 783.

Beſides, if for this operation a ſufficient quantity of the vegetable ſubſtance is employed, together with the diſtilled water, there will riſe an oil eſſentially different from fat oils.—The difference of this oil from any fat one is evident from its volatility, ſhewn by its coming over into the receiver; from its leaving no trace or greaſy ſpot on paper upon which it is dropped, and afterwards warmed; from its penetrating ſmell, agreeing in every reſpect with that of the plant from which it has been abſtracted by diſtillation; and laſtly, from its being ſoluble in ſpirit of wine.—This kind of oil is called *ethereal oil* (*oleum æthereum*).

> Synonyma: *Volatile oil (oleum volatile)*; *ſcented oil (oleum odorum)*; *diſtilled oil (oleum deſtillatum)*; *eſſential oil (oleum eſſentiale)*.

§ 784.

Ethereal oils are obtained ſometimes from all the parts, ſometimes only from ſome particular parts of the plant; as the roots, bark, leaves, flowers, petals, flower-buds, peels of fruits, ſeeds, the native balſams and gum-reſins; and they are in theſe various parts ſometimes of a different nature in one and the ſame plant. The quantity of ethereal oil obtained from different plants, or their parts, is variable, and always ſmall in regard to the vegetable matter

matter employed. This accounts for the high price of ſeveral of theſe oils.

> In *Wiegleb's Chemiſtry*, tranſlated by Hopſon, or in the *New Edinburgh Diſpenſary*, 1797, the reader will find tables ſtating the quantity of ethereal oils, obtained by different chemiſts from a determinate quantity of certain plants.—Edit.

§ 785.

The ſmell of ethereal oils is penetrating and ſtrong. Yet it is not every highly odorous plant that affords much oil; even from ſome, as lilies, May-flower, and violets, no ethereal oil can be obtained, notwithſtanding that they give a perfumed diſtilled water. The taſte of ethereal oils is commonly ſharp and irritating.

§ 786.

Moſt ethereal oils are ſpecifically lighter than water, and float upon it. But ſome are heavier, and ſink to the bottom; ſuch as ſeveral procured from aromatic plants of hot regions: for inſtance, the oil of cloves, of cinnamon, of ſaſſafraſs-root.—Again, ſome ethereal oils are very thin and fluid, and do not aſſume the ſolid form at the freezing-point of water; others thicken much ſooner, of which the oil of fennel and aniſe-ſeed are an example; and others, as the oil of roſes, have, even at the common temperature, the conſiſtence of tallow.

§ 787.

The colour of ethereal oils is various. Some are *colourleſs*, as thoſe of turpentine, fennel, aniſe, and roſemary; ſome are *yellowiſh*, as the oils of caraway-ſeed, of cloves, of cinnamon, of lavender; ſome are of a *browniſh* hue, as thoſe of wormwood, origanum, and thyme; ſome few are *greeniſh*, as cajeput oil, and that of milfoil; or *blue*, as that of camomile.

§ 788.

Water actually diſſolves a part of the ethereal oil on being diſtilled from the plant, and receives thereby both taſte and ſmell. Only that portion of oil which the water is not able to diſſolve ſeparates by itſelf. Therefore, if every other circumſtance be alike, leſs oil is obtained in proportion as water is more copiouſly employed in the diſtillation. The ſolubility of ethereal oils in water ſeems, however, to admit of various degrees; and ſeveral fragrant plants yield no ſeparate oil, becauſe it is all diſſolved by the diſtilling-water.

§ 789.

The diſtillation of ethereal oils, and diſtilled waters, in great quantities, is performed in the common ſtill (§ 116).

Freſhly-gathered tender plants, herbs, and flowers, of a looſe texture, are uſed entire. Hard and ſolid bodies,

bodies, as wood, roots, bark or rinds, are prepared by a proper conciſion. Previous ſoaking in water, or maceration is neceſſary, only when by it ſuch parts can be made to ſink, as otherwiſe, by their levity, would ſwim on the top, and are apt to ſwell and riſe into the head of the ſtill.

The quantity of additional water cannot be well fixed by a general rule; it muſt, for every particular caſe, be found out by experience. In the diſtillation care is taken that the fluid do not paſs overwarm, or too hot, leſt the oil evaporate. The water in the refrigeratory is kept leſs cold only when thoſe oils are diſtilled, which eaſily grow ſtiff or coagulate in the cold. The operation is diſcontinued when the water coming over is no longer milky, or when it no longer exhibits the taſte and ſmell of the body ſubjected to diſtillation.

The water diſtilled, together with the oil, is poured into narrow-necked bottles, which are well ſtopped, and where it is left ſtanding to give the oil time for ſeparating; and this ſeparation of the oily particles adhering to the ſides of the veſſel is promoted by gentle agitation. Laſtly, the oil is taken off by a ſyringe; or, by means of a cotton wick, it is drawn over into the bottle appointed for preſerving it. By dipping the ſhorter end into the oil, and inſerting the longer one into the bottle, this

this wick acts as a ſyphon. Oils that ſink in water are parted by a ſeparatory funnel (§ 135).

> Some ethereal oils, as the *oleum bergamotte,* and *oleum de cedro,* are obtained by expreſſion; the firſt from the freſh peels of *oranges,* the ſecond from *lemons.*—In Italy, and ſuch countries where theſe fruits abound, and where thoſe oils are procured in this way, they are in general better.
>
> Another method of parting the oil from the water is by the ſeparatory glaſs *(recipient Italien)* (§ 135).—Editor.

§ 790.

Waters recently diſtilled are uſually infected with a burnt and herbaceous ſmell and flavour, but become more pleaſant by time only, if kept in a cool place. To procure them in the moſt perfect ſtate, the vegetable matters ſhould not be brought into immediate contact with water, but they ſhould be incloſed in a linen bag hung up in the ſtill, in ſuch a manner that they are penetrated merely by the vapours of the boiling water.—By this method the diſtilled waters are not in the leaſt expoſed to become empyreumatic.

§ 791.

The component parts of the ethereal, like thoſe of fat oils (§ 759), are carbon, hydrogen, and probably ſomewhat of oxygen. But, of courſe, theſe radicals do not bear in the ethereal oils the ſame proportion to each other, by which they are united in fat oils.—On combuſtion in oxygen gas they give more water than the laſt; and they are alſo eaſier inflamed. The coal, which is left behind in only a very ſmall quantity, is the ſoot of their flame, and is a very pure coal, without any trace of fixed alkali.

§ 792.

The nitric, the ſulphuric, and oxygenated muriatic acids, are with great rapidity deprived of part of their oxygen by the ethereal oils; and theſe oils themſelves are thereby converted into reſins.

§ 793.

If, to half an ounce of oil of turpentine contained in a crucible, two drachms of ſtrong ſulphuric acid be mixed, the mixture quickly ſtirred with a glaſs-rod, and then ſome concentrated nitric acid be immediately affuſed, a ſpontaneous, very lively, and ſudden inflammation takes place; and that part of the oil which has grown reſinous, burns with a blazing flame.—The experiment ſucceeds alſo with empyreumatic and drying fat oils (§ 773).

Conſult § 174, note 9.

§ 794.

Ethereal oils likewiſe take up oxygen from the atmoſphere; and for this reaſon they will be depraved, if not preſerved in well-cloſed veſſels.—They loſe, in time, by that abſorption, their peculiar

liar odour more and more; they become tenacious and thick; and are finally transformed into a true, firm reſin; and it is at laſt impoſſible to diſtinguiſh ethereal oils from one another, after they have been ſpoiled by age.

§ 795.

From this it has been erroneouſly concluded, that the ethereal oils conſiſt of two proximate conſtituent parts; of a peculiar, volatile, ſubtile matter, which has been called *ſpiritus rector*, *principle of odour*; *aroma*; and of another groſſer, reſinous part, ſerving as a receptacle to the former.—It was alſo inferred, that upon the firſt of theſe two the odour of plants and ethereal oils depends; that the odorous principle is by itſelf ſoluble in water; that the depravation of any ethereal oil conſiſts in the loſs of that principle; and that many fragrant plants cannot yield an ethereal oil in the ſeparate ſtate, but only an odorous water, becauſe they do not contain this reſinous part, which is the abode, as it were, of the ſpiritus rector.

But whatever may be imputed to this odorous principle is rather the excluſive property of the ethereal oil itſelf, conſidered as ſuch; and the reſin, into which ſuch oils are changed on their ſpoiling, is a product (§ 794), and did in no manner exiſt in them before.—The generation of this reſin reſts on a principle ſimilar to that of the rancеſcence of fat oils; namely, the alteration in their mixture by the acceſſion of oxygen; which is alſo placed beyond doubt, by the paſſing of ethereal oils into the reſinous ſtate, cauſed by nitric acid (§ 792).

§ 796.

The ethereal oils diſſolve fat oils, reſins, natural balſams, and elaſtic reſin.—All the reſins, however, are not with equal eaſe diſſolved by theſe oils. *Copal*, for inſtance, is beſt diſſolved by *oil of roſemary*.

Lac-varniſhes with ethereal oils.

Falſification of ethereal by fat oils.

§ 797.

With fixed alkalis the ethereal oils combine into a ſoap, but with much greater difficulty than fat oils. To theſe *ethereal oily ſoaps* (*ſavonules*, by the French) belongs *Starkey's ſoap*, made of pot-aſh and oil of turpentine.—The beſt way of preparing it is by digeſting in a matraſs (§ 78) *one* part of cauſtic vegetable alkali, with *four* parts of oil of turpentine; and then diſtilling the oil from it with a low heat, and cohobating it (§ 115) as often as may be neceſſary, till the ſalt has completely acquired the ſaponaceous nature.

§ 798.

Liquid ammoniac diſſolves, in diſtillation, the ethereal oils, though but ſparingly.

§ 799.

Sulphur may be diſſolved by ethereal oils with the aſſiſtance of heat. The product of this combination is a kind of *ſulphureous balſam* (§ 775), of a ſtrong offenſive ſmell and taſte.—Great precaution is neceſſary during the digeſtion, on account of the inflammable vapour thence ariſing. From its ſolution, ſaturated in heat, a part of ſulphur ſeparates after cooling in tranſparent cryſtals *(ſulphureous ruby)*.

Of Camphor.

§ 800.

Camphor (*camphora*) is a concrete, ſolid, white, tranſparent ſubſtance, poſſeſſing a ſtrong, penetrating ſmell and taſte, and ſo volatile as to exhale entirely even in moderate or ſummer heat. It may eaſily be ignited, and burns with a flame; but depoſits, on combuſtion, a vaſt quantity of ſoot, yet without leaving any reſidue. It melts in heat, but hardens again by cooling. Water has no ſolvent power on camphor, though it receives from it its ſtrong ſmell. Spirit of wine, on the contrary, diſſolves it. The ſpecific gravity of camphor is 0,996.

§ 801.

Camphor, as uſually ſold, is brought to us from Japan, obtained from a tree *(laurus camphora)* growing there; from the roots, leaves, bark, wood, and branches of which it is extracted by diſtillation, on boiling theſe parts with water in a kind of ſtill. Camphor thus obtained (*raw camphor*) is impure; and is farther refined in Europe, particularly in Holland, by ſublimation, in which it receives the ſhape of convex cakes.—This purification might alſo be done by ſolution in ſpirit of wine, its ſubſequent precipitation by water, and by fuſion in glaſs veſſels.

§ 802.

Many other plants contain true camphor; and it abounds more than was formerly believed in the vegetable kingdom. Such is the *camphor of Sumatra* (*baros*) from the *laurus Sumatrenſis*; the camphor of the roots of galangal (*marantha galanga*), *zedoary (amomum zedoaria)*, *ginger (amomum zingiber)*; of the ſeeds of cardamom *(amomum cardamomum)*, and *cubebs (piper cubeba*, or *caudatum*).—Beſides, many European vegetables contain real camphor in their ethereal or volatile oils, as *thyme (thymus vulgaris)*; the roots of ſweet-flag (*acorus calamus*), of *meadow-anemone (anemone pulſatilla*, or *pratenſis)*, of *ſage (ſalvia officinalis)*, of *hyſop (hyſopus officin)*, of *mother of thyme (thymus ſerpyllum)*, of *peppermint* (*mentha piperitia*),

peritia), of *roſmary* (*roſmarinus officin*), and others.—*Prouſt* has extracted it plentifully, by inſenſible exhalation, from the oils of *lavender*, *roſemary*, *origanum* or pot-marjoram, and *ſage*, at Murcia in Spain.

§ 803.

In all probability camphor conſiſts merely of carbon and hydrogen. But experiments are yet wanting, with reſpect to its combuſtion in vital air, to aſcertain with accuracy the quantities of theſe radicals, as contained in this inflammable ſubſtance.

§ 804.

Camphor is copiouſly diſſolved in the cold by concentrated ſulphuric acid, without effecting a perceivable decompoſition of that acid; only, when heated, ſulphureous gas is raiſed, together with the vapours of camphor. Water ſeparates again the camphor unaltered from the ſolution.—If the oxyd of manganeſe be added to the mixture, the camphor is converted into the acetic acid, and the ſulphuric acid is changed to the ſulphureous, as was obſerved by *Doerffurt*.

§ 805.

Concentrated nitric acid diſſolves the camphor plentifully and with eaſe, and quietly without production of heat, and without being decompoſed. By repoſe a fluid ſeparates on the upper part of the clear and limpid ſolution, which has the colour and conſiſtence of oil of almonds, and is called *oil of camphor (oleum camphoræ acidum).* This fluid is ſoluble in alkohol; but by adding water it grows turbid, and the camphor is precipitated.

§ 806.

Koſegarten has ſucceeded in decompoſing camphor, by repeatedly diſtilling perfect nitric acid from this ſubſtance.—He has by this proceeding extracted from it an acidulous ſalt, which after him was received into the ſyſtem as a peculiar acid of the vegetable kingdom, ſtyled *camphoric-acid.*—However, *Doerffurd* has proved that this pretended camphoric acid is perfectly the ſame with the benzoic.—Nor is this acid an educt obtained or ſeparated from the camphor by the proceſs, but a product at that time generated.

§ 807.

Camphor is diſſolvable by fixed or fat oils, as well as by the volatile or ethereal. It alſo combines with reſins and balſams, making them adheſive and glutinous.

§ 808.

Alkalis do not unite with camphor; they have no affinity with it; and at preſent no genuine *camphoraceous ſoap*, procured by direct immediate combination, is known.

§ 809.

By fuſion in gentle heat camphor unites with ſulphur, and produces with it a ſubſtance brittle and friable in the cold, but tough and tenacious in warmth. Camphor is likewiſe diſſolved in the humid way, by alkaline ſulphuret (§ 442), if aſſiſted by heat.

Acrid Vegetable Matter.

§ 810.

Several vegetables, or their parts, which are otherwiſe inodorous, or emit but a weak ſmell, excite a local inflammation, if applied for a while, in their freſh ſtate, to the ſkin; but loſe this faculty by drying. When recently gathered, and inwardly taken, they produce poiſonous effects. Of this kind are the freſh roots of *ſquills (ſcilla maritima)*; the leaves of *fox-glove* (*digitalis purpurea*); of *wild anemone* (*anemone nemoroſa*); of *virgin's bower* (*clematis erecta*); of *wolfsbane*, or *monk's hood* (*aconitum cammarum*); the roots of *blue orris* (*iris germanica*); of *aſphodel*, or *king's ſpear* (*aſphodelus ramoſus*); of *meadow ſaffron* (*colchicum autumnale*); of *white bryony*, or *wild vine* (*bryonia alba*); of *wake robin* (*arum maculatum*); and the fruits of *wild cucumber* (*momordica elaterium*).

§ 811.

Since theſe plants, by having been, during a ſufficient time, well dried, loſe their ſharpneſs or acrimony, and the effects on the living body thereon depending, it appears that the ſubſtance, which gives riſe to the violent irritation cauſed by them, is of a volatile nature; as is confirmed by its being communicated to water and ſpirit of wine, abſtracted from them by diſtillation. As, therefore, thoſe plants contain no eſſential oil, no camphor, and in general none of the volatile principles that have hitherto been the object of our enquiries, we cannot with propriety heſitate, to acknowledge this volatile matter to be a particular proximate conſtituent part belonging to the vegetable kingdom, and to diſtinguiſh it from other principles of that kind by the name, *acrid matter of plants* (*materia acris plantarum*).—Its action is not deſtroyed by acids nor by alkalis, and is not ammoniac, in any form.

§ 812.

In plants which are called *antiſcorbutic*, for inſtance, in ſcurvy-graſs, water-creſſes, garlic, onions, horſe-radiſh, common radiſh, and the ſeeds of muſtard, this acrid principle is combined with oleaginous particles of the ethereal kind, and its effects, it ſeems, are weakened by this union.

§ 813.

From plants furniſhed with this matter, we muſt diſcriminate thoſe which, outwardly applied on the living body, cauſe, in fact, a local inflammation, but are not deprived, by exſiccation, of this power, which rather originates from their reſinous parts.—Such are, *euphorbium*, or *wart-wort* (*euphorbia helioſcopia*); various parts of ſeveral ſpecies of the *daphne*, of the *guinea-pepper* (*capſicum annuum*), of the *pellitory of Spain* (*anthemis pyrethrum*), &c.

Narcotic Matter of Plants.

§ 814.

The *narcotic*, *ſoporific*, or *ſtupefying matter of plants*, is, by its action on the living body, eſſentially different from their acrid principle; and the venomous properties of ſeveral plants which depend on it, manifeſt themſelves in quite a different way. Examples of ſuch plants are, *opium* (*papaver ſomniferum*); the leaves of the *cherry-laurel* (*prunus lauro-cerafus*); of the *deadly night-ſhade* (*atropa belladonna*); of the *thorn-apple* (*datura ſtramonium*); of the *common black henbane* (*hyoſcyamus niger*); of the *wild roſemary, or marſh andromeda* (*ledum paluſtre*), &c.

§ 815.

§ 815.

The narcotic principle of plants is volatile, and is diſſipated by the decoction of vegetables that poſſeſs it. In ſome of them it is united with an ethereal oil.—In other reſpects we are as yet very little acquainted with its nature, and the mixture of its radicals.

Fibrous Part of Vegetables.

§ 816.

After all the immediate component parts of plants, related under the preceding heads, are ſeparated, there ſtill remains a reſiduum, which repreſents in a certain way the ſkeleton of the plant, and is diſtinguiſhed from the others by the name of *fibrous* or *ligneous part (materia fibroſa plantarum).* This matter has hitherto been too much neglected, but deſerves to be ſtudied more attentively, as one of the proximate conſtituent parts of the vegetable kingdom.

The fibrous vegetable matter is inſoluble in water, in ſpirit of wine, in oils and alkalis; but it is deſtructible by concentrated ſulphuric, nitric, and oxygenated muriatic acids. It is moreover combuſtible, and may be decompoſed by heat; giving then hydrogen gas, and carbonic acid gas, beſides an acid ſpirit, and an empyreumatic oil. It alſo contains

contains a large quantity of carbon. The denſity, or quantity of matter, contained in a certain volume of this fibrous part, is variable in different plants and their parts. It is moſt abundant in all the ſeveral ſpecies of wood; leſs in herbs.—Flax and hemp, after all other principles capable of extraction have been removed, are fit ſubjects for undertaking an experimental enquiry into its nature.

Extracts from Plants.

§ 817.

If certain parts are ſeparated from the plants by a proper menſtruum, and brought within a ſmaller compaſs by evaporating the ſolvent, the remaining ſubſtance is then called an *extract (extractum)*, (§ 77.)

§ 818.

The extracts of the ſame plant differ from each other according to the various nature of the extracting medium. For this purpoſe either water or alkohol, or both, are made uſe of. *Water diſſolves* acid-ſaline, ſweet, bitter, mucilaginous, aſtringent, ethereal-oily, acrid, and narcotic parts. *Spirit of wine diſſolves* reſinous, ſweet, aſtringent, ethereal-oily, camphoraceous, acrid, and narcotic parts. There are, however, ſeveral principles, which by themſelves are inſoluble in water, and ſpirit of wine,

wine, yet may be diſſolved in either menſtruum, when combined with other matters.

§ 819.

In conſequence of theſe phenomena, extracts are divided into *aqueous* or *gummy (extracta aquoſa, gummoſa)*; *ſpirituous* or *reſinous (extracta ſpirituoſa, reſinoſa)*; and, laſtly, *mixed*, or of both kinds together *(extracta mixta)*.—In this place we can only treat of the firſt ſpecies.

§ 820.

Since the ethereal oils, the camphoraceous, acrid, and narcotic principles fly off, and are loſt by decoction with water, and ſubſequent evaporation of the ſolution; which proceſs, in the preſent point of view, is called extraction, it is obvious that vegetable matters, whoſe efficacy is owing to thoſe matters, are unfit for making extracts from them. Under ſuch circumſtances it is better to employ the infuſion itſelf (§ 78.), without evaporating it.

§ 821.

The way of proceeding, in the preparation of common extracts, is to reduce the vegetable body to ſmall pieces; to boil it with water; to repeat this boiling ſeveral times with freſh water; to ſtrain the decoction; to let it grow clear by ſtanding; and laſtly to evaporate it with a moderate heat, until it it is of due conſiſtence. Towards the end of the evaporation particular care is to be taken, that the extract be not tainted with empyreuma.

Of the extracts of *La Garaye.*

§ 822.

Another method of making extracts is, by inſpiſſating the juices expreſſed from plants recently collected: in other words, by reducing them, by a gentle heat, to the thickneſs required. From what we have ſaid of the proximate conſtituent parts of plants before treated of, there can be no doubt but that extracts, prepared in this manner, may often conſiſt of parts quite different from thoſe that are contained in extracts made by the decoction of dry plants (§ 821).—The inſpiſſated juices of fruits, and of ſome ſweet roots, are denoted by the term *rob.*

Vegetable Pigments.

General Principles of the Art of Dyeing.

§ 823.

A great number of plants, or their parts, communicate their colour to water, employed for their extraction by infuſion or decoction, and alſo to any other ſuitable extracting medium. The extractive principle which imparts the colour, is named *colouring* *matter*, or *pigment*, to diſtinguiſh it from that perception which we call *colour*.

§ 824.

The *art of dyeing* *, or the art of imbuing ſtuffs with various pigments afforded by the vegetable, mineral, and animal kingdoms, is a particular branch of the technical or applied chemiſtry, and is wholly dependent on chemical principles.

§ 825.

The *pigments* of the *vegetable kingdom* are not particular component parts of a peculiar kind, requiring to be diſtinguiſhed from thoſe which we have already examined; but they belong to one or the other, or they are a mixture of ſeveral. They are diſtinguiſhed from the others by nothing elſe but by having colour; this, however, does not juſtify the conſidering them as diſtinct radicals.

§ 826.

The manner and cauſe by which pigments excite the perception of colour is an object, the inveſtigation

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* This branch, ſo eſſential in manufactures, has been, after *Hellot*, *Macquer*, and *Poerner*, treated of in a maſterly manner, according to the principles of modern chemiſtry, by *Berthollet*, in *Elements de l'Art de la Teinture*, Paris, 1791, 2 vols.; and lately in England by *Dr. Bancroft*.—Ed.

gation of which properly belongs to *phyſics*, or natural philoſophy. I only obſerve in this place, that by adopting a chemical compoſition of light (§ 189. 190.), and its decompoſition by the pigment, it may be ſatisfactorily explained why the latter exhibits a colour.—But from the change of colour produced in any body by its abſorbing oxygen, or by the eſcaping of this from it, we are not entitled to conſider oxygen as the general colouring or diſcolouring principle.

§ 827.

Such pigments as, either diſſolved by water alone, or by its combination with other menſtrua, are contained in the *colour-baths* or decoctions, inſinuate themſelves into the ſurface, or even into the ſubſtance of the ſtuffs, tinged by them, and are conſequently thus ſeparated from the water. It muſt therefore be granted that there ſubſiſts an attractive power among ſuch ſtuffs and the pigment, greater than that, which the ſolvent medium has for the pigment.

§ 828.

But the nature of the ſtuffs to be dyed cauſes a great difference in their attraction for pigments.—Thus it is known by experience, that wool takes the colour, or may be dyed with moſt eaſe, ſilk with more difficulty, ſtill more ſo linen cloth, and cotton. Hence various preparations and treatments of the ſtuffs become neceſſary, to make them fit for receiving the tinge. A colour, for inſtance, which is laſting on wool, is not, on this account, likewiſe permanent on cotton; and therefore the very ſame pigment demands various proceſſes, according to the various kinds of ſtuffs.

§ 829.

Thoſe pigments, whoſe colour is ſo durable as not to fade by waſhing, or in the air, or the ſun's rays, or after a great length of time is but little faded, are ſaid to be *true*, ſolid, fixed, or *permanent dyes*. By the term *falſe*, ſpurious *dyes*, pigments are denoted which give but little reſiſtance, if at all, to the actions of air, ſun, and water, and fade by their influence, or diſappear entirely.

§ 830.

Moſt of the uſual pigments may, indeed, be extracted or diſſolved by ſimple water, yet ſome are quite incapable of ſuch ſolution, and require the aſſiſtance of other ſolvents to afford a colour-bath. For this reaſon pigments have been divided into mucilaginous, reſinous, glutinous, &c. But this claſſification is uſeleſs; becauſe, in the preſent ſtate of knowledge, the nature of few pigments only is well aſcertained, and ſeveral of them are *mixed extractive matters*.

§ 831.

Yet the diviſion into *ſubſtantive* and *adjective pigments*, lately propoſed by Dr. Bancroft, ſeems to be of practical utility. The firſt are ſuch as are taken up from the bath, by the ſtuffs not previouſly prepared or macerated. The ſecond are thoſe which do not adhere of their own accord, or are not abſorbed by the ſtuffs out of the baths, unleſs they be firſt ſoaked in another ſubſtance called a *corroſive*, *mordant*, or macerating medium, which ſerves as a bond of union between the pigment and the ſtuff. The number of the laſt kind of pigments is far the greateſt.

§ 832.

The adjective pigments (§ 831.) may moſt frequently be extracted by mere water, which they readily impregnate with their colour, and afford clear ſolutions. They appear by this to be moſtly of a mucilaginous nature.

§ 833.

The ſubſtances uſed to macerate the ſtuffs, for making them capable of imbibing adjective pigments, are almoſt all of an acid-ſaline matter. Of this claſs are, ſulphat of alumine (§ 416.); acidulous tartrite of pot-aſh (§ 660.); the ſolution of tin in nitro-muriatic (§ 581.), and oxygenated muriatic acid (§ 567.); the vegetable aſtringent principle

principle (§ 719.); acetite of alumine; ſulphat of copper, or blue vitriol; ſulphat of zinc, or white vitriol; acetite of copper, or verdigris; and arſenic.

§ 832.

The way in which theſe *mordants* exert their efficacy, conſiſts *partly* in their ſurrendering a portion of their oxygen, whereby the ſubſtance of the ſtuffs is altered, and hence their attractive power for the pigment increaſed; *partly* in their changing, in like manner, the nature of the pigment itſelf, and making it coagulate.—On this account, the colours of the pigments ſuffer various alterations by theſe intermedia, and receive various *ſhades*, or degrees of brightneſs, or darker hue.—Which of the mordants may be beſt for any particular pigment, or deſired ſhade of colour, and for a particular kind of ſtuff, can be pointed out by experience only.

§ 835.

Blue, *red*, and *yellow*, are conſidered as the fundamental or principal colours.—By combining theſe with each other in various proportions (*chiefly* on the *ſtuffs* themſelves, *rarely* in the *bath*), as alſo by uſing mordants, and of theſe, either acid or alkaline ſubſtances, the ſtuffs are tinged, not only with all the intermediate, but alſo with various ſhades of the chief colours; and a wonderful variety of tints is produced.

Liſt of the principal *dyes*, or colouring ſubſtances, afforded by the *vegetable kingdom*:

I. *Subſtantive Pigments.*

1. *Blue dyes:—Indigo* and *woad*, of which hereafter in particular: the juice preſſed from the fruits of the *geniſta americana*, which by itſelf is colourleſs, but tinges the ſtuff that it is brought upon, after ſome time, with a fixed and laſting blue colour, the *baſtard ricinus (croton tinctorium)*, a tranſient *(ſpurious)* blue.

2. *Red dyes:—Safflower*, or *baſtard ſaffron (carthamus tinctorius)*, after it has been freed from its yellow pigment by ſcalding with water. The red pigment which remains requires the addition of alkali to be ſoluble in water; but the alkali muſt again be precipitated from the ſolution by an acid. Its colour is fading.—The leaves of the *lawſonia inermis* (not yet employed); the *archil* or *orchal (lichen rocella)*; the *dyers* or *crawfiſh-eye-lichen (lichen parellus)*.

3. *Yellow dyes:—Arnatto (bixa orellana)*, which will be treated of hereafter. The roots and bark of the *berberry-ſhrub (berberis vulgaris)*: very fading.

Beſides, *logwood* or *campeachy wood (haematoxylon campechianum)*; *braſil-wood (caeſalpinia ſappan)*, giving a brown red; *nut-galls (cynipidis nidus)*; the *green huſks of wallnuts (juglans regia)*; *ſumac (rhus coriaria)*; *alder-tree (betula alnus)*; *tormentil-root (tormentilla erecta)*: giving brown and ſallow colours.

II. *Adjec-*

II. *Adjective Pigments.*

1. *Blue* colours:—*Logwood and braſil-wood* (*haematox. campech. & cæſalp. ſapp.*) with pot-aſh; *elder-berries* (*ſambucus ebula*); *whortle-berries* (*vaccinium myrtillus*); *privet* (*liguſtrum vulgare*); the roots of *dyer's bugloſs* (*anchuſa tinctoria*): all with pot-aſh.

2. *Red* colours:—*Madder* (*rubia tinctorum*); *fernambouc* (*lignum fernambuci*), the fineſt and deareſt ſpecies of braſil-wood; *red Saunder's-wood* (*pterocarpus ſantalinus*); the *grey-blue ſpotted lichen* (*lichen ſaxatilis*); the roots of *dyer's bugloſs* (*anchuſa tinctoria*).

3. *Yellow* colours:—The bark of *quercitron* (*quercus nigra*); *fuſtic wood* (*morus tinctoria*); *dyer's weed* (*reſeda luteola*); *common ſaw-wort* (*ſerratula tinctoria*); *turmeric root* (*curcuma longa*); *French berries*, or *graines d'Avignon*, (*rhamnus infectorius*); *dyer's green weed*, *woad-waxen*, or *dyer's-broom* (*geniſta tinctoria*); *fenugreck ſeed* (*trigonella fænum græcum*); *camomile with ſerrated winged leaves* (*anthemis tinctoria*); *peels of onions* (*allium cepa*); *ſafflower* (*carthamus tinctorius*); narrow leaved Canada golden rod (*ſolidago Canadenſis*); *French marigold* (*tagetes patula*), with an open ſubdivided ſtalk; *the ſeeds of meadow-trefoil* (*trifolium pratenſe*); and the ſeeds of *ſnail trefoil*, or lucerne ſeed (*medicago ſativa*).

Of Indigo.

§ 836.

Indigo (pigmentum indicum) is a blue pigment, which is obtained as a fecula from *anil*, or indigo plant, in the Eaſt and Weſt-Indies.—Three ſpecies of this plant are cultivated in America; *indigofera tinctoria*, *ind. diſperma*, and *ind. argentea.* The two laſt yield leſs, but better indigo; the firſt is cultivated in the greateſt quantity.—Before it bloſſoms, the ſtalks along with the leaves are cut off ſeveral inches above the ground; and as ſoon as they have been cleanſed from adhering ſand and earth by rinſing, they are put in the *ſoaking vat*, kept down with wooden croſs-pieces, covered with water, and left ſtanding in the ſhade.

After a ſhort time, a kind of fermentation takes place, attended with ſenſible heat; air-bubbles ariſe, and on the ſurface of the water a pellicle appears, of a colour inclining to that of copper. Particular attention is to be paid, that the fermentation be not carried on too far, and paſs into putreſcence; elſe all the indigo would be loſt. Yet at the ſame time it ſhould not be interrupted too early, as otherwiſe too little indigo is obtained.

For

For this reaſon a handful of the plant is every five minutes taken out of this firſt vat; and if it be found that the points are ſoft and pale, or that the larger leaves become faint, the greeniſh liquor is immediately drawn off from the herb into the *ſtirring vat*, where it is inceſſantly ſtirred with wooden crutches and ſhovels to put it into ſtrong motion. During this operation the liquor lets fall a blue flocculent ſediment, and its green tinge is changed to yellow. The ſeparation of this fecula, which is the indigo, is promoted by adding more freſh, cold, clear, and limpid water, to the fluid contained in this ſecond vat; and a greater quantity of indigo is alſo produced by this management.

If then a portion of the liquid be taken out for trial, and no ſediment formed, after lime-water has been added to and ſhaked with it, it is a ſign that all the indigo is ſeparated.—The indigo is then ſuffered completely to ſubſide in the ſtirring-vat, and the clear incumbent fluid is drained off as cloſely to the fecula as poſſible, by cocks placed in holes bored at different heights. After this the ſediment is laded into conical linen bags, and waſhed with cold water, which is ſuffered to drip off, by hanging them in the ſhade, in wooden caſes; and thus the indigo is completely dried.

§ 837.

The various ſorts of indigo met with in trade are not all of equal goodneſs.—It may be divided into three aſſortments; the *blue*, the *violet*, and the *copper-coloured*. It is better, the purer and lighter it is. The beſt, coming from *Guatamala*, is blue, not covered on the outer ſurface, or when broken, with a white cruſt; and ſo light, that it ſwims on water.

§ 838.

Beſides the *anil*, other different ſpecies of plants alſo yield, by a ſimilar treatment, a blue fecula or ſediment, entirely reſembling indigo.—One of theſe is *woad (iſatis tinctoria)*, which in Germany, long before the indigo was known, was uſed for dying blue, and is even at preſent employed, with the addition of indigo.—For this purpoſe freſh leaves of woad are collected in a dry ſeaſon, waſhed, ſuffered to wither in the air, bruiſed, formed in roundiſh lumps, dried, and thus ſold by the name of *woad*. By this proceſs the leaves undergo a kind of fermentation, whereby the indigo which they contain is ſeparated, remaining ſimply mingled with their pulp. The want of uniformity in the fermentation, throughout the whole maſs, and the uncertainty with reſpect to its proper limits, are the reaſon that the effects of this dyeing material are neither

ther of a determined hue, nor can be relied on for durability.

§ 839.

A true indigo may likewiſe be prepared from woad, by the ſame method as preſcribed for the indigo plant (§ 836).

§ 840.

A new plant, from which, according to *Roxburgh's* diſcovery, an indigo may be extracted, is an Eaſt-Indian tree, which he calls *nerium tinctorium (roſe-bay)*, and whoſe leaves contain this pigment. But the manner of preparing it varies from the uſual procedure.—The indigo is extracted from it by hot water, and without fermentation.—A copper boiler is filled with the leaves, without preſſing them down, and water affuſed upon them, to fill the veſſel to within a few inches below its brim. The matter is next quickly heated to about 150 or 160° Farenh. at which temperature it is kept, with unabated ſtirring. When the fluid in the boiler exhibits a dark green colour, it is ſtrained through a ſieve into the ſtirring-vat; and while yet warm, agitated for ſome minutes, with the addition of $\frac{1}{75}$ of clear lime-water. The indigo then ſeparates, and is farther treated like common indigo.

§ 841.

Of all the proximate conſtituent parts peculiar to vegetable ſubſtances, that we have at preſent examined,

amined, indigo appears, with reſpect to its mixture, to come neareſt to gluten (§ 744), or to the albuminous matter (§ 751); though in ſome points it plainly ſhews its difference from both.

§ 842.

Pure indigo, if diſtilled by itſelf, emits carbonic acid and hydrogen-gas, and yields ammoniac and empyreumatic oil. The reſiduum of the diſtillation is a coal, of difficult icineration, which affords but a ſmall quantity of aſhes, and contains ſome iron.—According to *Berthollet*, indigo conſiſts of much carbon and hydrogen, ſome azot, ſome oxygen, and a little iron, which he eſtimates at $\frac{1}{30}$ of the weight of the indigo.

§ 843.

Neither water nor ſpirit of wine diſſolve indigo; both take up from it merely an extractive matter, foreign to it, and thus leave it the purer. Nor is indigo diſſolved by fat or by ethereal oils, by the muriatic and by vegetable acids.

§ 844.

Concentrated ſulphuric acid diſſolves indigo. It attacks this pigment with heat and ebullition, and ſulphureous gas is extricated. The mixture has a blackiſh appearance, but becomes a beautiful blue by dilution with water. This diluted ſolution is in time deprived of all its colour, and in general it may be remarked, that the addition of oxygen renders the colour of it leſs durable, and makes it at laſt entirely diſappear.

§ 845.

Both the nitric and the oxygenated muriatic acids deſtroy the colour of indigo. According to *Woulf's* experiment it is inflamed by the firſt, if concentrated; but if weakened, the ſolution is blue, loſes ſoon its colour, turns browniſh, and depoſites a flocculent browniſh matter.

§ 846.

The dyers uſe various methods of precipitating the indigo on the ſtuffs.

The moſt important of theſe is the *woad-vat*, as it is called. Woad (§ 839) is made diſpoſed to fermentation in water, at a convenient temperature, and by adding wheaten bran and madder. Indigo and burnt lime are next added.—In this way the indigo is, by the fermenting vegetable matters, deprived of part of its oxygen, and diſſolved by the aſſiſtance of lime. The liquid is green, but is covered on the ſurface by a pellicle of a blue or cupreous colour. The cauſe of this laſt is, that the diſſolved indigo, by attracting again oxygen, is rendered blue, and loſes its ſolubility in the fluid.—The ſtuffs ſteeped in the vat come out greeniſh, but are changed to blue in the air. This vat is em-

ployed

ployed for *woollen ſtuffs;* and it may be kept working for a conſiderable time, if after each dyeing ſome freſh quicklime and indigo be added.—Yet, if the fermentation be not moſt carefully regulated, it may eaſily be overdone, and begin to putrefy, in which caſe all the pigment is deſtroyed.

Silk is dyed in a vat, where indigo (without addition of woad) is diſſolved, with the aſſiſtance of a proper degree of warmth, along with pot-aſh, vegetable ferments, bran, and madder. The ſolution looks green, and a ſcum, of a blueiſh coppery tinge, floats on its top.

A cold blue vat, or bath for *cotton*, is made from indigo finely levigated with water, or an alkaline lixivium, to which burnt lime, previouſly ſlaked and diluted with water, and ſome ſulphat of iron, are added. On this mixture a part of the calcareous earth unites with the ſulphuric acid of the vitriol, while the calx or oxyd of iron is precipitated. This oxyd robs the indigo of its oxygen, by virtue of its ſtronger attraction for this acidifying principle; and the indigo is thus, and by the aſſiſtance of the reſidual diſengaged calcareous earth, rendered ſoluble. The fluid becomes alſo green, like the preceding, yet inclines gradually to yellow, and is covered with a film or pellicle of a blueiſh coppery tinge.—The ſtuffs are dyed in this vat, after the coarſer particles have ſubſided. They are taken out of a yellowiſh colour, which on expoſure to air, owing to the indigo abſorbing again oxygen, changes through various ſhades from green to blue. It is proper to acidulate the laſt water, in which the ſtuff is rinſed, with a little ſulphuric acid.

For *linen goods* a vat is prepared, with a lye of cauſtic pot-aſh, wherein the indigo is boiled with orpiment (ſulphurated arſenical oxyd), till the bath be green, exhibiting at the top a copper-coloured pellicle.

Finally the *Saxon-blue*, uſed for dyeing *ſilk* and *woollen ſtuffs*, belongs to this place. The method of operating is indeed very commodious, and ſaving of expence, yet attended with the great diſadvantage of becoming thereby leſs permanent, and fading much ſooner. For dyeing in this manner, from 5 to 8 parts of ſulphuric acid are gradually poured on one part of finely pulverized indigo. Heat is produced by the mixture; the indigo decompoſes a part of the acid, which on that account eſcapes as ſulphureous acid; while the carbon of the pigment likewiſe abſorbs a portion of oxygen from the ſulphuric acid, and flies off in the form of carbonic acid gas.—The mixture is left ſtanding for 24 hours; the ſolution is then largely diluted with water, and uſed for dyeing.

Concerning Litmus.

§ 847.

Litmus is another blue pigment, which, according to *Ferber*, is moſt probably prepared from the moſs called *archil* or *orchal* (*lichen roccella*, *orſeille*), and from the *dyer's lichen* (*lichen parellus*)*. The moſs is ſteeped in wooden ciſterns, in urine, lime-water, ſlaked lime, and ſome pot-aſh, or ſoda, where it is kept under ſhelter. Now and then it is agitated, and ſuffered to macerate, till it begins to ferment in ſome degree. This fermentation, which muſt not be permitted to paſs into putrefaction, is kept on, until the moſs be converted into a blue and ſoft pulp, which is attenuated by grinding, forced through a hair-cloth, formed into ſquare lumps, and dried in the ſhade.

§ 848.

Litmus is, ſtrictly ſpeaking, only ſo far blue, as it is combined with an alkaline ſubſtance. Its natural colour is red, and this native tinge is again reſtored by acids, by which the alkaline matter is neutralized.

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* It is not ſo well known whether litmus be alſo made of the *baſtard ricinus*, or *turnſole plant* (*croton tinctorium*). However, the blue turnſole rags (*tourneſol en draps*), are, according to *Montet*, prepared of that plant, at *Grand-Galargues*, in Languedoc.—Ed.

neutralized.—On this account the *tincture of litmus* is qualified to ſerve as a *reagent.*

Of Arnatto.

§ 849.

The *rocou*, or *arnatto* (§ 835), is alſo to be mentioned here. It is prepared from the pulp of the ſeed-capſules of a tree growing in Guiana, *Urucu* (*Bixa Orellana*). The ſeeds, together with the red tough matter ſurrounding them, are ſoftened in a wooden trough with water, until, by a kind of fermentation, which ſpreads a very nauſeous ſmell, and by diligent ſtirring and pounding, the kernels are ſeparated from the pulp. This maſs is then ſtrained through a ſieve, and boiled; whereupon a thin reddiſh ſcum, which is the pigment, ſeparates. When ſkimmed off, it is carefully inſpiſſated in another kettle, and after being completely cool, is moulded in roundiſh lumps, wrapt round with leaves of trees, and packed for ſale.—Arnatto is not diſſolvable by water, nor by ſpirit of wine; to be fit for dyeing, it requires an alkaline menſtruum. It ſeems to partake of the nature of the vegetable albuminous matter.

Sap-Colours.

§ 850.

Sap-colours are either inſpiſſated juices of plants, or extracts from them; ſuppoſing, however, that theſe juices are impregnated with a certain colour. Of this kind are, *gamboge* (§ 742); *ſap-green*, from the *buckthorn-berries* (*rhamnus catharticus*), not perfectly ripe; the *extracts* of *fernambouc* wood, of *ſaffron* (*crocus ſativus*, or *orientalis*); of *green walnut-huſks* (*nux juglans*); the juice of *whortle-berries*, thickened by boiling; the inſpiſſated juices of *honeyſuckle* (*lonicera xyloſteum*); of the American *night-ſhade* (*phytolacca decandra*), and others. The tints of theſe pigments may be greatly varied by adding acids, alkalis, and other ſalts.

Lake-Colours.

§ 851.

Freſhly precipitated argillaceous earth readily abſorbs the mucilaginous colouring parts of plants; or it retains them, and is by them coloured. On this fact the preparation of ſeveral *lakes*, or *lake-colours*, is founded. Of lakes of a baſer and coarſer ſort, the calcareous earth is the baſis.

§ 852.

The *counterfeit florentine lake* may ſerve as an example to ſhew in what manner lake-colours are made. Equal parts of fernambouc, or the fineſt braſil-wood, and ſulphat of alumine, are boiled in a ſufficient quantity of water. The decoction is then ſtrained, and a lye of pot-aſh added, till the alum is duly decompoſed; taking care, however, that the quantity of the alkali be not in exceſs. Laſtly, the precipitate is ſeparated from the fluid by filtration; is laid on paper in the form of ſmall cones, by means of a funnel, and dried with haſte.

> The genuine *florentine lake* is obtained, as well as *carmine*, from an animal pigment, the *cochineal*. Of this we ſhall ſpeak hereafter.

§ 853.

By the ſame method other ſorts of lakes may be manufactured from various tinging vegetable bodies; *viz.* by precipitating their ſtrained decoction, made with alum and water; the precipitant is again a fixed alkali. Or by inverting the proceſs, the decoction is made with alkali and water, and the lake-colour precipitated by an aqueous ſolution of ſulphat of alumine; beſt, while warm. To this claſs belong, *madder-lake* of *Marggraf; Neri's yellow lake*, from the *dyer's-broom (geniſta tinctoria)*; another *yellow lake*, from the *quercitron-bark*; the *lakes* after the manner of *Scopoli*; the *Dutch-pink* *(ſtile de grain)*, from the decoction of turmeric with alum, and decompoſed by chalk; and others.

Of Bleaching.

§ 854.

The *bleaching* of ſtuffs and other bodies reſts on this circumſtance, that vegetable colours are deſtructible by the joint actions of air, moiſture, and light; or rather on the alterations which the mixture of pigments undergoes by the influence of theſe cauſes. The ſtuffs are for that purpoſe firſt liberated from the adhering groſſer and extractible particles, by which they are coloured. This is effected by boiling them in an alkaline lye; after which they are expoſed, with the greateſt poſſible ſurface, to the action of the ſun's rays, keeping them continually moiſt.—It agrees pretty well with the theory, that beſides this proceſs, weakly ſour liquids, as *whey*, and *very much diluted ſulphuric acid*, may be ſerviceable to promote the bleaching.

§ 855.

For it ſeems to be at preſent placed beyond any doubt, that the pigment with which the ſtuffs are impregnated, or the fibrous ligneous part itſelf, is deprived of its colour by abſorbing oxygen. And in this circumſtance the efficacy of bleaching is to be ſought for, as is abundantly confirmed by the analogous

analogous action of oxygenated muriatic acid; which, by ceding part of its oxygen to coloured vegetable ſubſtances, deprives them of their colour (§ 570).

§ 856.

This remarkable property of oxygenated muriatic acid has been already reſorted to, with the greateſt advantage, in the bleaching of linen and cotton yarns in great quantities; as they may be reſtored by it to whiteneſs in a much ſhorter time, and at any ſeaſon. *Berthollet* * has deſcribed the proceeding and the apparatus to be employed in the large way.—In my opinion it would be an advantageous alteration in this method of bleaching, if, inſtead of oxygenated muriatic acid itſelf, an alkaline lye, completely ſaturated with that acid, were employed; it being much eaſier to impregnate this lixivium with it than ſimple water.

“ To perform the bleaching upon this principle, “ *Chaptal* propoſes to ſteep the linen, or cotton, in “ a weak alkaline lye, and to boil it with it. After “ this proceſs they are taken out and wrung. When “ thus freed from the ſuperfluous moiſture, they are “ either expoſed for a little while, and with the “ greateſt poſſible ſurface, to the vapours of the “ elaſtic oxygenated muriatic acid (§ 569); or,

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* See *Annales de Chimie*, tom. II. p. 251, ſeq. and tom. VI. p. 204, ſeq.—Ed.

" better, they are immerſed in a liquor compoſed " of that acid in a condenſed ſtate, and diluted " with water. During this they ſhould be ſtirred " and wrung. Laſtly, the unpleaſant odour with " which they become impregnated, is removed by " waſhing them in large quantities of water. The " addition of alkali in the lye has been thought neceſſary to neutralize the acid, and prevent its corroſive effects, by which the ſtuffs themſelves might " be deſtroyed.—As Dr. *Gren* juſtly remarks, it is " deſirable that the health of the workmen were " leſs endangered in this proceſs; and the advantageous alteration which he propoſes, by impregnating the alkaline lye itſelf with the acid, is the " contrivance of *Pickel.*"—Ed.

In this country *Theophilus Rupp* has given a ſimple apparatus, and method of bleaching with oxygenated muriatic acid, without the addition of alkali; and *William Higgins*, chemiſt to the linen-board of Dublin, recommends to ſubſtitute ſulphuret of lime for potaſh in this proceſs.—See *Nicholſon's Journal*, vol. II. p. 268; vol. III. p. 253.—Ed.

END OF VOL. I.

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