PRACTICAL

AGRICULTURAL CHEMISTRY

FOR ELEMENTARY STUDENTS

ADAPTED *FOR USE IN AGRICULTURAL CLASSES AND* ***COLLEGES***

BY

J. BERNARD COLEMAN, A.R.C.Sc., F.I.C.
FORMERLY SENIOR DEMONSTRATOR OF CHEMISTRY AND LECTURER ON THE
PRINCIPLES OF AGRICULTURE IN THE UNIVERSITY COLLEGE, NOTTINGHAM

AND

FRANK T. ADDYMAN, B.Sc. (Lond.), F.I.C.
FORMERLY ASSISTANT IN THE LABORATORY OF
THE ROYAL AGRICULTURAL SOCIETY OF ENGLAND

NEW IMPRESSION

LONGMANS, GREEN, AND CO.
39 PATERNOSTER ROW, LONDON
NEW YORK AND BOMBAY

1905

PREFACE

THE course of instruction described in this book has been in use for some years at University College, Nottingham.

It is suited to the requirements of those commencing the study of Agriculture.

The experiments are so arranged as to give a scientific acquaintance with the substances commonly met with on the farm.

It is hoped that this elementary manual may be of assistance to the teachers and students of the numerous agricultural classes recently instituted throughout the country.

The matter is divided into the following sections :—

Section I. treats of simple chemical manipulation and the preparation of apparatus.

Section II. describes the preparation and properties of the constituents of air and water.

Section III. contains a number of experiments illustrating the properties of soils, manures, feeding materials, and dairy produce.

Section IV. gives the chemical tests for the bodies commonly occurring in soils, manures, and ashes of plants, and describes the qualitative analysis of these bodies.

It will be seen that only those substances are treated of that enter into the composition of the various agricultural products. For the analyses of minerals and other occasional constituents found in the earth, works on qualitative analysis should be consulted.

Section V. contains a list of apparatus and chemicals required for performing the experiments described in this book, together with instructions for preparing the various solutions.

After working through this course, students are recommended to consult Addyman's 'Agricultural Analysis.'

Our acknowledgments are due to Professor F. CLOWES, D.Sc. (Lond.), for permission to use woodcuts and other material from his text-book on Qualitative Analysis.

J. B. C.
F. T. A.

UNIVERSITY COLLEGE, NOTTINGHAM:
August 1893.

CONTENTS

SECTION I

CHEMICAL MANIPULATION AND APPARATUS

SECTION II

THE CONSTITUENTS OF AIR AND WATER

SECTION III

EXPERIMENTS ON SOILS, MANURES, FEEDING MATERIALS, AND DAIRY PRODUCE

SECTION IV

QUALITATIVE ANALYSIS OF SOILS AND MANURES

REACTIONS FOR THE METALS

REACTIONS FOR THE ACID-RADICALS

TABLES FOR QUALITATIVE ANALYSIS

WET EXAMINATION FOR THE METALS

SECTION V

APPARATUS, CHEMICALS, AND REAGENTS

PRACTICAL AGRICULTURAL CHEMISTRY

SECTION I

CHEMICAL MANIPULATION AND APPARATUS

The student whose time is very limited, on working through the experiments described in this book, may omit those paragraphs marked with an asterisk.

1. **The Bunsen Burner.**—Where gas can be obtained the Bunsen burner (fig. 1) will be found the most convenient lamp for heating purposes. Before use the coal-gas is mixed with air, and when ignited burns with a feebly luminous flame, which deposits no soot when a solid object is held in the flame. For this reason the Bunsen or some other *atmospheric* burner is nearly always employed for chemical work in place of the luminous flame-burner. The Bunsen burner (fig. 1) consists essentially of a gas-jet (*a*), which is surrounded by an outer tube (*c*), in which the air passing through two inlets (*b*) mixes with the gas. The mixture of air and gas is burnt at the top of the outer tube (*c*). Over the air-holes fits a ring, which by turning round will cut off either wholly or partially the supply

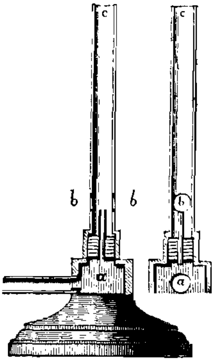

FIG. 1

of gas. When the flame is turned down it is necessary to reduce the supply of air, or the gas will take fire below, which then gives off unpleasant-smelling products, and may melt the rubber tubing attached to the burner. If the burner should thus take fire below, at once turn off the gas, reduce the air supply by turning the ring, and relight.

For heating a large surface a 'rose-top' may be used. It consists of a metal cap perforated with holes to distribute the gas. The cap is slipped on to the top of the burner when it is required for use.

2. **The Spirit-lamp.**—Where gas is not available the spirit-lamp (fig. 2) forms a convenient heating-lamp. Like the Bunsen burner the flame is non-luminous, and does not smoke; but the temperature is not so high, and the flame cannot be so conveniently regulated. It consists of a reservoir containing methylated spirit, into the neck of which passes a wick-holder which supports the cotton-wick. When not in use the spirit-lamp should be covered with the ground-glass cap (*a*) to prevent evaporation of the spirit.

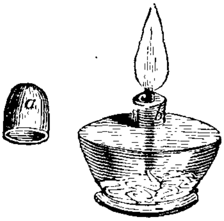

FIG. 2

3. **The Blowpipe.**—The mouth blowpipe shown in fig. 3 is useful for obtaining a high temperature. On blowing a stream of air by means of this apparatus through an ordinary luminous flame a small hot flame is obtained. In order to produce this effect turn off the air supply in the Bunsen burner (fig. 1), so as to obtain the luminous flame. Next turn down the gas supply until the flame is nearly two inches in height. Now place the jet of the blowpipe just over the orifice of the burner and blow a gentle current of air into the flame. The flame will then lose its luminosity and appear as a finely pointed tongue of flame (fig. 4). In the use of the blowpipe the student should practise so as

to produce a continuous blast. This is acquired by first inflating the cheeks with air from the lungs, keeping them inflated until the lungs are exhausted of air; then when inhaling—*i.e.* refilling the lungs—the air in the cheeks should be expelled gradually, and thus keep the blast continuous. After a little practice the student will be able to breathe through the nose during blowpipe-work, whilst he is employing his cheeks and lungs to keep up a steady blast.

4. For heating large vessels to a high temperature the *table blowpipe* is usually used. In this blowpipe the air is forced through the flame by means of a *foot-bellows*. Since both hands are at liberty it is usually used in glass-working (paragraphs 5, 6, and 7).

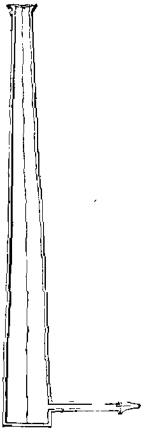

FIG. 3

5. Cutting and Bending Glass Tube and Rod.—Glass tube (or rod) may readily be cut by first making a deep cut with a sharp triangular file, then holding the tube on either side of the cut, and finally applying a strain partly between a pull and a break. The rough edges should either be filed or held for a short time in the Bunsen burner, so as to fuse the edges, and thus prevent the jagged edges from cutting the hands.

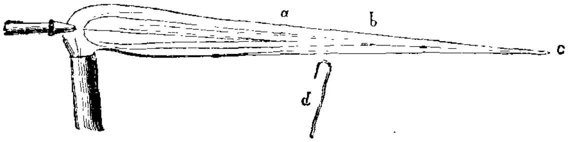

FIG. 4

Glass tube (or rod) is readily bent by holding the tube in the upper part of a fish-tail burner (fig. 5), constantly rotating the tube so as to heat it uniformly. When the glass becomes soft it may be bent at any desired angle

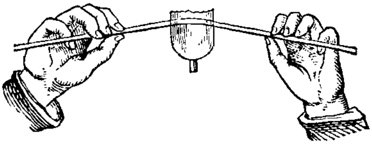

FIG. 5

When cold the soot may be wiped off with a duster. If bent as described the bend will be rounded and of uniform bore throughout. If bent in a Bunsen flame the tube is usually flattened out at the bend and very liable to break.

6. Making Closed Tubes.—Select a piece of glass tube about 6 in. long and $\frac{3}{16}$ in. internal diameter. Heat it in the middle portion by means of the blowpipe flame. When quite soft draw it out, as shown, fig. 6. Next heat the portion (*a*) in the tip of the flame, so that on drawing

FIG. 6

FIG. 7

out again a tube closed at one end (fig. 7) is formed. The closed end of the tube may then be rounded by heating it strongly and blowing gently into the open end, so as to slightly expand the softened portion. Or, if required, a bulb may be formed by again heating the closed end and blowing into the tube more strongly.

7. Mounting Platinum Wire.—For a number of purposes (paragraphs 26 and 27) a piece of platinum wire, about two inches long, and fused into a piece of glass tube to act as a holder, will be required. Draw out a piece of glass tube, as described above, break off the tube at *a* (fig. 6), place one end of the wire in the thin tube so left, and heat until the glass fuses round the end of the wire. Allow to

FIG. 8

cool. The glass tube will form a convenient handle for holding the wire during heating. Bend the free end of the wire into a loop, when it will be ready for use (fig. 8).

8. Boring Corks.—Corks are readily bored by means of sharpened brass tubes. Select a borer slightly less in diameter than the size of the glass tube to be inserted. Press the cork against a wooden surface and gently rotate the borer until a clean hole is cut (fig. 9). To make the hole smooth a round file should be used, which will also increase the diameter of the hole.

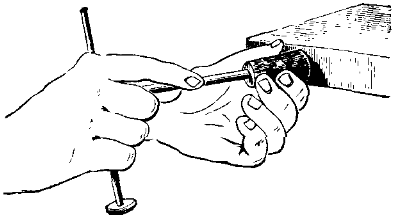

FIG. 9

9. In boring *rubber corks* a very sharp borer should be used, and the borer should be moistened with glycerine.

The cork borers can readily be sharpened by a special kind of knife sold for the purpose, or they may be filed in the interior by a round file, and on the exterior by a triangular file.

10. Fitting up Wash-bottle.—Select a thin 18 oz. conical flask (fig. 10). Procure a good, sound cork, free from flaws or cracks, slightly larger than the inner diameter of the neck. Soften the cork by rolling it backwards and forwards under the sole of the foot on the floor: this will somewhat lessen the diameter of the cork and ensure a good fit.

Bore two holes through the cork, as described in paragraph 8. Next bend a piece of glass tube at an angle of 120°, as shown in fig. 10 (*b*), taking care that the ends of the tube are rounded (paragraph 5). Force one end just through the cork. Now bend another piece of glass tube at an angle of 60° (*a*) and pass it through the second hole in the cork, so as to nearly touch the bottom of the flask. If the tubes have been carefully adjusted they will fit *tightly* into the cork, so that when the cork is placed in the neck of the flask, and one tube is closed with the finger, no air should escape when air is blown into the flask from the mouth by means of the other tube.

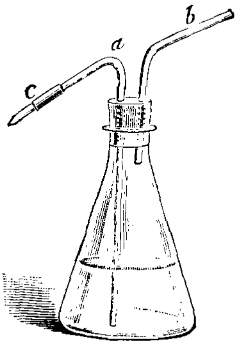

FIG. 10

Upon the end of the larger tube (*a*) a small piece of rubber tubing is placed, into which is pushed a short piece of glass tube drawn out into a jet (*c*).

Now fill the flask with *distilled* water. It may either be used for propelling a fine jet of water through the jet (*c*) by blowing into the larger tube (*b*), or a larger stream may be obtained by inverting the bottle and pouring *out* of the tube (*b*). If hot water is required the flask may be placed on wire gauze on a tripod stand, and the contents of the flask heated over the Bunsen flame.

A rubber cork may be substituted for the wooden one, and will be found to last much longer.

11. Solution.—Most solid substances dissolve in some kind of liquid. Water is the most common *solvent*. The amount dissolved varies according to circumstances; hence some substances are very soluble, others less so, and some only slightly soluble.

Solution usually takes place most rapidly when the substance is in a *fine powder.* Heating and shaking also promote solution.

Solution may be of two kinds : (1) simple, when the body dissolved does not change in its chemical composition, and is therefore left behind on evaporating off the liquid ; (2) chemical, when a body of different composition is left on evaporating off the liquid.

a. Simple Solution.—Place a little alum in a 3-in. evaporating-dish, nearly fill the dish with water. Heat over the Bunsen burner until the solid dissolves. Reserve the solution for future use.

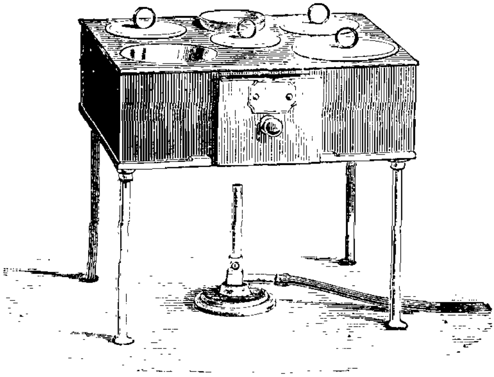

FIG. 11

b. Chemical Solution.—Place a few pieces of marble in a test-tube, add a little dilute hydrochloric acid (HCl). The marble, which is insoluble in water, will gradually dissolve, carbon dioxide gas being given off (paragraph 39).

12. Evaporation.—On heating a solution of a substance the liquid portion is driven off—*evaporated*—the solid being left behind.

Experiment.—Heat the liquid from paragraph 11 *b*, in a small evaporating dish until the liquid is all expelled ; white solid calcium chloride ($CaCl_2$) will be left behind.

Care must be taken that the flame is lessened, as the liquid in the dish becomes reduced, or the liquid will spirt, *i.e.* jump out of the dish.

13. A very convenient form of apparatus is the *steam-bath* shown in fig. 11. It consists of a copper bath, on the upper side of which are cut a number of holes to fit various-sized evaporating-dishes. The bath is three parts filled with water, and heated until the water just boils. The dishes containing the liquids to be evaporated can thus be kept nearly at a temperature of 100° C., and loss of the liquid by spirting is avoided. The water which is driven off from the bath when in use should be replaced from time to time, so as to keep the level of the water constant.

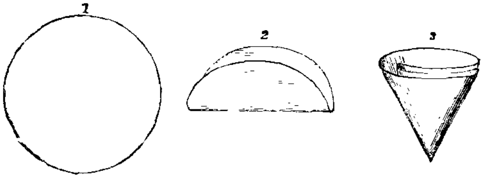

FIG. 12

14. **Crystallisation.**—Take the solution (paragraph 11*a*) and heat over the Bunsen flame until about one-quarter of the liquid is left, allow to cool, when crystals of alum will form. If the solution is too dilute, and no crystals form, further evaporation will be requisite. Most salts are more soluble in hot than in cold water; hence the salt usually *crystallises* out on cooling.

15. **Precipitation.**—Two clear solutions when added together frequently give rise to an insoluble solid, which gives a turbid appearance to the mixture. A body so formed is termed a *precipitate.*

Experiment.—To a little calcium chloride solution in a test-tube add a little ammonium carbonate solution; a white precipitate of calcium carbonate will be formed. Reserve the test-tube and contents for use in paragraph 17.

16. **Filtration.**—Very often it is necessary to separate a precipitate from a liquid in which it is suspended. This operation is performed by filtration or decantation (paragraph 19). In the former case the liquid and solid are thrown upon porous paper, the liquid passes through the paper, the solid being retained. Unsized paper, known as filter-paper, is used for this purpose. It is usually supplied cut into circular pieces.

17. Fit a filter-paper into a funnel (fig. 13) by folding it across twice at right angles (fig. 12), so as to form a conical bag as shown at 3. Press this bag into the dry funnel, and then moisten the paper with distilled water. The precipitate and liquid from paragraph 15 may then be poured into the funnel, when the liquid passing through will be quite clear, the solid remaining on the filter-paper.

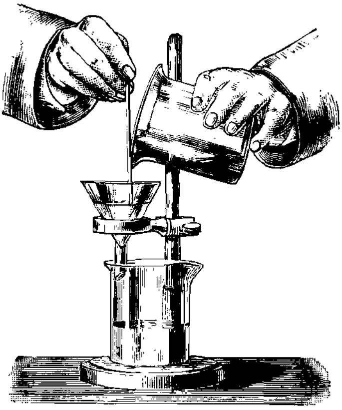
Fig. 13

18. **Washing Precipitates.**—Precipitates may be washed free from adhering solutions either by decantation or on the filter-paper, or by a combination of the two processes.

19. **Washing by Decantation.**—Prepare a little more precipitate, as described in paragraph 15; allow it to stand until the precipitate subsides, then pour off the *clear* supernatant liquid. Add a little distilled water, shake up, allow the solid to again subside, and pour off the clear liquid. Repeat this operation four or five times, when all the soluble matter will be washed out.

20. Washing on the Filter-paper.—The precipitate on the filter-paper (17) can be readily washed by pouring into the filter distilled water, allowing it to drain away, and repeating the operation four or five times. Hot water is best for this purpose, since it filters more rapidly than cold. The stream of water from the jet of the wash-bottle should be used for this purpose.

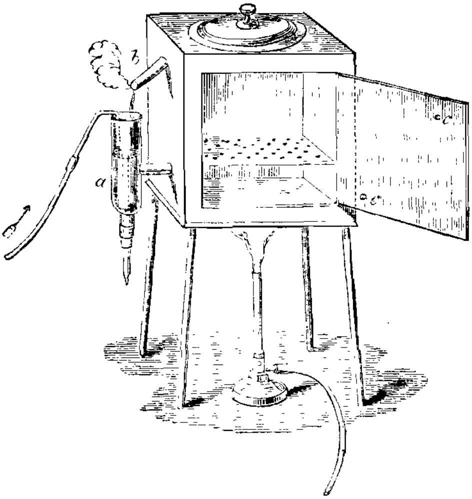

FIG. 14

21. In order to ascertain whether a precipitate is thoroughly washed, it is necessary either to evaporate a few drops of the water which has passed through the filter, or to test for some constituent present in the liquid which is to be separated. In the present case, since the liquid will be alkaline, the washing should therefore be continued until the wash-water ceases to turn turmeric paper brown (paragraph 28).

22. Drying Precipitates.—Precipitates are usually dried in a *steam-oven* (fig. 14), *i.e.* a copper oven hollowcased so as to contain water. The latter on being boiled keeps the interior of the oven approximately at a temperature of 100° C.

A more rapid way of drying precipitates is to open out the filter-paper containing the precipitate on a piece of wire gauze, and hold it some distance above the Bunsen flame.

23. **Ignition.**—Frequently substances require to be heated strongly or ignited. This is best performed in a small test-tube called an ignition-tube (6) or on a piece of platinum foil 2 in. × 1 in., the latter being held in the flame by means of crucible tongs.

Experiment.—Heat a little solid manganese sulphate in an ignition-tube; the substance will turn black, due to the production of the oxide.

24. **Fusion.**—On ignition some substances melt or fuse; occasionally other substances are added before fusion.

Experiment.—Heat a mixture of sodium carbonate and potassium nitrate with a trace of manganese dioxide on platinum foil; a green mass will be produced.

25. **Sublimation.**—On heating, some substances go off in vapour, but condense again on a cool surface.

Experiment.—Heat a little ammonium chloride in an ignition-tube held in a horizontal position. The salt will totally *sublime* and condense again as a white solid in the cold part of the tube.

26. **Flame Colorations.**—Certain substances when heated in a colourless flame, such as the Bunsen or blowpipe flame, give a distinct coloration to the flame.

Experiment.—Clean a piece of mounted platinum wire (7) by heating it in the blowpipe flame, moistening it with hydrochloric acid, reheating, and repeating the operation if necessary. Take up a little calcium chloride by means of the loop and hold in the flame. A red coloration will be given to the flame.

27. Borax Bead.—Fuse a little borax on the loop of a platinum wire until it becomes like a bead of colourless transparent glass. Now take a *very little* manganese dioxide, and heat in the *outer* blowpipe flame; a port-wine tint will be imparted to the bead. Next heat in the inner flame; the bead will become colourless. It will thus be seen that the two flames may give rise to different coloured beads.

28. Use of Test-papers.—Certain vegetable colours are affected by the addition of certain chemicals. The test-papers in common use are made by soaking paper in litmus or turmeric solutions. They are usually purchased in little books.

Litmus occurs normally as a blue substance. Its solution in water or alcohol is at once turned red by acid bodies. This *reddened* litmus is then sensitive to alkalies, which give the original blue colour again.

Turmeric is normally of a yellow colour. Its solution is turned brown by alkalies, the yellow colour being restored by acids.

29. *Experiment.*—Try the effect of solutions of hydrochloric acid, ammonium hydrate, and ammonium chloride on blue and red litmus and turmeric papers. It will be found the first gives an acid, the second an alkaline, and the third a neutral reaction.

Thus by means of test-papers we have the means of ascertaining when a reagent is added in excess, provided that reagent give a different reaction to the liquid to which it is added.

SECTION II

THE CONSTITUENTS OF AIR AND WATER

PREPARATION AND PROPERTIES OF OXYGEN

30. Place a few crystals of potassium chlorate in a perfectly dry test-tube and heat in the Bunsen flame. The substance first crackles, then melts and gives off bubbles of oxygen gas. When this appearance is noticed light a splinter of wood, and when it is fairly alight blow it out again, then whilst the end still glows introduce it into the mouth of the test-tube. The splinter will burst into flame. This behaviour of the glowing splinter is a test for the oxygen which is given off from the heated potassium chlorate.

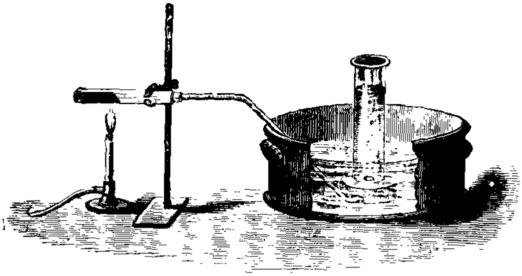

FIG. 15

The following equation represents the chemical action that takes place: $KClO_3 = KCl + O_3$.

31. In order to investigate the properties of oxygen gas a much larger quantity of the gas is required than can be prepared by the above method.

Choose a dry test-tube and fit a sound cork into the mouth of the tube. Bore the cork, and fit it with a bent tube of the shape shown in fig. 15. Next powder in a mortar about as much potassium chlorate as will fill a small watch-glass, together with about one-fifth as much manganese dioxide. One-third fill the test-tube with the mixture and place it in a retort-stand, as shown in the figure. Next place a beehive cell in a larger vessel and add water until it reaches about one inch higher than the top of the beehive cell. Before commencing to heat the tube, fill one of the jars in which the gas is to be collected with water, cover its mouth with a ground-glass plate. Invert it and place it on the beehive cell, as shown in the figure, removing the glass plate when the mouth of the jar is under the water See that the end of the delivery-tube is directly beneath the opening of the jar. Now heat the part of the oxygen mixture (potassium chlorate and manganese dioxide) nearest the cork with a Bunsen flame. Oxygen will come off more readily than in the former case (30), and, passing through the delivery-tube, will be collected in the jar. As soon as one jar is filled with the gas, close it with a glass plate and remove it from the earthenware dish, replacing it by another filled with water and inverted in the same manner. When three jars have been filled in this way remove the delivery-tube from the water and discontinue heating.

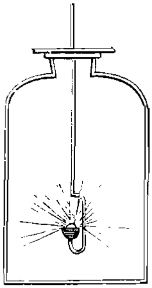
FIG. 16

32. One of the properties of oxygen has already been shown, *i.e.* its power of rekindling a glowing splinter of wood. All substances which burn in air burn still more readily in oxygen.

33. Burning Sulphur in Oxygen.—Place a small piece of sulphur on a deflagrating spoon. Heat it in a Bunsen burner until it ignites, then plunge it into a cylinder of the gas, as shown in fig. 16. It will burn brilliantly. When the sulphur has ceased burning withdraw the deflagrating spoon and pour a little water coloured with a few drops of blue litmus solution into the bottle. The sulphur dioxide formed by the combination of the sulphur with the oxygen will be dissolved, and the litmus will be turned red, showing that an acid body has been formed.

34. **Burning Charcoal in Oxygen.**—Burn a piece of charcoal in a jar of oxygen, just as the sulphur was burned in the last experiment. It will glow brightly but will give no flame. After all burning has ceased pour lime-water into the jar and shake up. The lime-water will turn milky owing to the presence of carbon dioxide, which is formed when charcoal is burned in oxygen. The action of carbon dioxide on lime-water is more fully explained in paragraph 42.

PREPARATION AND PROPERTIES OF NITROGEN

35. The most convenient source of nitrogen is the air, which consists chiefly of a mixture of the two gases oxygen and nitrogen in the proportion of four volumes of the latter to one of the former. To prepare nitrogen it is only necessary, then, to remove the oxygen from a portion of the air.

36. *Experiment.*—Half fill a stoneware dish with water and float on its surface a small evaporating dish. In the dish place a piece of phosphorus about the size of a pea. Care must be taken not to ignite the phosphorus. It should be cut under water and dried as rapidly as possible by means of filter-paper. Next place a stoppered bell-jar over the basin, as shown in figure 17. Ignite the phosphorus by touching it with a hot wire. Quickly withdraw

FIG. 17

the wire and stopper the bell-jar. The interior will first fill with white fumes, then the phosphorus will go out, and finally the white fumes will disappear, leaving the interior clear again. As the fumes disappear the water will rise in the bell-jar, showing that the volume of gas inside has contracted.

37. The explanation of this is as follows: As the phosphorus burns it combines with the oxygen of the air to form phosphorus pentoxide, which is a white solid body, and hence appears as a white cloud. When all the oxygen has been used up the phosphorus goes out. Next the phosphorus pentoxide dissolves in the water, and so nothing is left in the bell-jar except the nitrogen, which only occupies four-fifths the original volume of the oxygen and nitrogen together.

38. *Experiment.*—Nitrogen neither burns nor does it support combustion. To test this add water until the level is the same outside as it is inside the bell-jar, open the stopper and plunge the lighted taper into the gas; the taper will at once be extinguished.

PREPARATION AND PROPERTIES OF CARBON DIOXIDE

39. Fit a Woulffe's bottle with thistle-funnel and delivery tube as in fig. 18. Place in the bottle a few pieces of marble. Pour down the thistle-funnel enough water to cover the marble, then add a little strong hydrochloric acid. A brisk effervescence will take place, and carbon dioxide will be evolved.

40. Place a cylinder under the end of the delivery tube. Since the gas is so much heavier than air it will fall to the bottom. After the apparatus has been working for about half a minute hold a lighted taper just over the mouth of the jar. When the jar is full the gas will come in contact with the taper and put it out.

41. Carbon dioxide gas resembles nitrogen in that it will extinguish a flame as shown in the last experiment, but it differs from it in several ways. To show that it is much heavier than air pour the gas from one jar into another, as shown in figure 19. As the gas is invisible, nothing will be seen to pass. Now plunge a lighted taper into each of the jars. In the one which originally contained the gas, the taper will go on burning, showing that no carbon dioxide remains, whilst in the other the taper will be extinguished, showing that the gas has been poured out from the first jar into the second.

42. Another property by which carbon dioxide may be recognised is its *action on lime-water.* Half fill a small beaker with lime-water and place it so that the delivery-tube of the apparatus (fig. 18) dips into the liquid. Allow the gas to pass through the lime-water for a few minutes. First the liquid becomes milky, because the lime has combined with the carbon dioxide to form carbonate of lime or chalk, which is not soluble in water. In a short time, however, the liquid becomes clear again : this is because the chalk, although insoluble in pure water, is soluble in water which contains carbon dioxide gas dissolved in it.

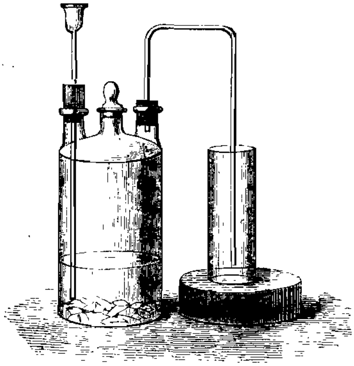

FIG. 18

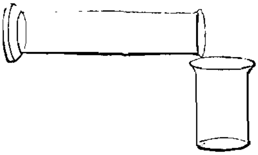

FIG. 19

PREPARATION AND PROPERTIES OF AMMONIA

43. Ammonia is generally prepared by heating together slaked lime and ammonium chloride. Grind together in a mortar equal parts of ammonium chloride and slaked lime, place a little of the mixture in a test-tube and heat it. Notice the strong smell of the ammonia which is formed.

44. To obtain larger quantities of the gas it is much more convenient to prepare it from its solution in water. If strong ammonia solution is warmed the gas comes off in a rapid stream.

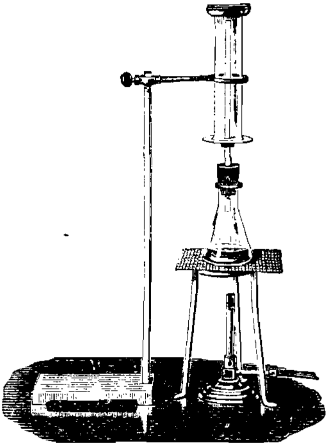
FIG. 20

Set up the apparatus shown in fig. 20, placing a small quantity of the strongest ammonia in the flask. Since ammonia is lighter than air it may be collected by upward displacement. To do this place a jar *over* the evolution-tube and warm the flask cautiously. The gas will ascend into the jar. Now dip a glass rod into strong hydrochloric acid and hold it near the mouth of the jar. When the jar is full the ammonia gas coming in contact with the hydrochloric acid will form dense white fumes around the moist part of the rod. Discontinue heating and remove the jar.

45. One of the most striking properties of ammonia gas is its extreme solubility in water. Place a ground-glass plate over the mouth of a jar filled with the gas as in the last experiment. Then hold the jar so that its mouth dips under the surface of the water contained in an earthenware dish. Remove the glass plate. The water will rush up into the jar.

46. Another property of ammonia is its action on turmeric paper, which it turns brown. Take a few drops of strong ammonia in a test-tube. Moisten a strip of turmeric paper and hold it over the mouth of the test-tube. It will probably become brown at once from the ammonia which escapes from the solution. If it does not alter its colour warm the liquid slightly; the paper will immediately become dark brown.

EXPERIMENTS ON AIR

47. It has already been stated that atmospheric air consists chiefly of oxygen and nitrogen. Besides these two gases it also contains several others in small quantities, viz. carbon dioxide, water-vapour, and traces of nitric acid and ammonia.

48. Carbon Dioxide in Air.—Pour a little clear lime-water into a saucer or shallow evaporating-basin and allow it to stand for an hour. At the end of that time it will be covered by a thin film of carbonate of lime or chalk. This is produced by the action of carbon dioxide, as explained in paragraph 42, and shows the presence of that gas in the air.

49. Water-vapour in Air.—Place on a dry porcelain tile a few lumps of dry calcium chloride and allow them to stand for an hour. At the end of that time the lumps will have become quite wet. The moisture which has been thus attracted can only have come from the air. This experiment, therefore, shows that the air contains water-vapour.

EXPERIMENTS ON WATER

50. Distillation of Water.—The water obtained from the general supply of a town is seldom sufficiently pure for use in a laboratory, as it contains several substances in solution. It may be freed from these impurities by the process known as distillation. The apparatus required for this operation is shown in fig. 21, and consists of a retort whose neck leads into a flask which is kept as cool as possible by being immersed in a vessel of water. Half fill the retort with water and heat it with a Bunsen flame, preferably with the flame from a rose burner. The water will boil, and the steam will pass over until it comes into the cool flask, where it will condense. In this manner pure water will be collected in the flask, whilst the impurities are left behind in the retort.

51. For the tests described in the next eight experiments three kinds of water should be used, *i.e.* distilled water, ordinary water as supplied to the laboratory, and some sample of really impure water, such as drainage water.

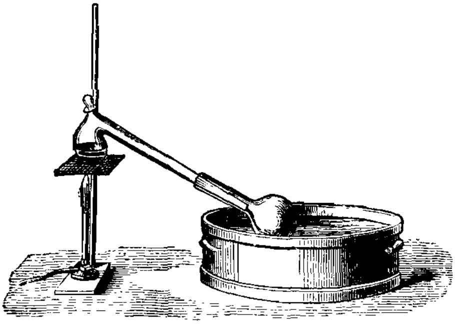

FIG. 21

52. Solid Matter in Water.—Half fill three evaporating-basins with the different waters under consideration and evaporate each to dryness. Notice the residue, if any, left in each case. When the residue is quite dry hold the dish in a Bunsen flame for a minute or so. Should there be any organic impurities in the water, such as are derived from decomposing animal or vegetable matter, the residue in the dish will become discoloured and blackened. The distilled water will be found to leave no residue. The laboratory water will leave a residue which will probably remain white on further heating. The drainage water will leave a residue which blackens on heating.

53. **Lime in Water.**—Half fill three clean test-tubes with the three samples of water. Place them side by side in the test-tube rack and add to each a few drops of ammonia and a little ammonium oxalate solution; allow to stand a few minutes. The distilled water will suffer no change, whilst the other two will become cloudy. Notice which gives the thickest cloud, as that one will contain most lime, and will probably be the hardest water.

54. **Salt in Water.**—Half fill three test-tubes with the waters as directed in the last experiment and add a drop of dilute nitric acid and ten drops of silver nitrate to each. The distilled water will not change in appearance. That water which gives most cloudiness contains most salt.

55. **Sulphates in Water.**—It is very seldom that a natural water contains sulphuric acid in the free state, but most spring waters contain it in combination with lime or magnesia. Add to portions of the different kinds of water in three test-tubes a drop of hydrochloric acid and ten drops of barium chloride. A cloudiness, which may require a few minutes to form, shows presence of sulphuric acid. The distilled water contains no sulphuric acid, whilst the other two contain it in varying quantities, as shown by the milkiness.

56. **Ammonia in Water.**—Take three test-tubes half filled with the different kinds of water as before, and to each add ten drops of Nessler's Solution. This is one of the most delicate tests known to chemists, and should the smallest trace of ammonia be present, the water to which the Nessler's Solution (265) has been added will become coloured yellow or brown, according to the amount of ammonia present. So delicate is the test that distilled water, unless it has been specially prepared, will contain sufficient ammonia to show it. After the test-tubes have stood two or three

minutes notice their colour by holding them over a sheet of white paper and looking down through the length of the tube. The drainage water will be much more coloured than the other two. As the most probable source of ammonia in a natural water is decaying animal matter it will be seen that it is very necessary that drinking water shall contain as little of this substance as possible.

PREPARATION AND PROPERTIES OF HYDROGEN

57. Fit up the apparatus for this experiment as shown in fig. 22. Place a handful of granulated zinc at the bottom of the Woulffe's bottle and pour sufficient water down the thistle-funnel to cover the zinc. Now add some strong hydrochloric acid, when a brisk effervescence will ensue. Do not collect the first portion of gas, but after it has been in action for two or three minutes fill a test-tube with water, invert it in the water, and allow the gas to pass into it. When it is full of gas close it with your thumb and bring it close to a lighted burner. Remove your thumb and apply the light to the tube. If the gas be pure it will burn steadily ; if it contain air it will explode with a sharp squeak. Continue testing until it is quite free from air, then collect a few cylinders as described in paragraph 31.

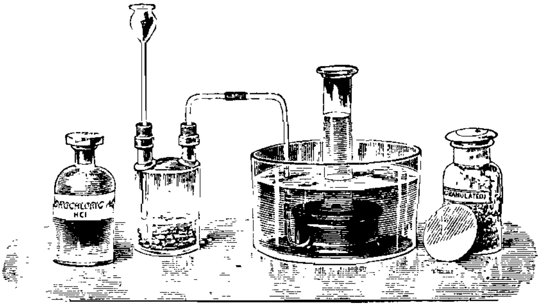

FIG. 22

58. Hydrogen burns but does not support combustion. As soon as a cylinder is full of hydrogen remove it from the trough, keeping its open end downwards, and thrust a lighted taper into it. The taper will be extinguished, but the hydrogen itself will burn with a flame which is scarcely visible.

59. Hydrogen is the lightest substance known. Fill another cylinder with hydrogen and pour the gas *upwards* into a cylinder which contains nothing but air. Then test each cylinder with a lighted taper. The one which formerly contained the gas will have no effect on the taper, whilst the one which formerly contained no hydrogen will give a sharp explosion, showing that hydrogen is lighter than air.

60. Fill a short thick cylinder with water, then invert it in a dish of water. Displace about two-thirds of the water with hydrogen and the rest with oxygen. Allow the gases to stand for a few minutes to mix thoroughly, then apply a lighted taper ; a loud explosion will take place.

SECTION III

EXPERIMENTS ON SOILS, MANURES, FEEDING MATERIALS, AND DAIRY PRODUCE

EXPERIMENTS ON SOILS

61. Arable soils consist principally of four substances—sand, clay, limestone, and humus or organic matter—and the varieties of soil are named according to the proportions in which the above constituents are present. Thus, certain soils are known as sandy soils, clay soils, limestone soils, and peat soils. Besides these are loams, which contain both sand and clay in large quantities; marls, which consist principally of limestone and clay; and calcareous soils, in which sand and limestone occur together.

62. Separation of Sand and Clay.—Place in a 3-in. evaporating-basin about as much dried *loam* as will cover a penny. Half fill the basin with distilled water, and boil it for a few minutes. Stir up and pour out the *whole* of the contents into a small beaker. Allow the beaker to stand for a few minutes, then pour off the cloudy liquid into another beaker, leaving the sediment behind. Now hold the beaker containing the sediment over a sink and allow water to run into it for a few minutes. The fine particles of clay will be washed away, and very soon the water will run off quite clear. The residue in the beaker is sand.

63. Action of Lime on Clay.—Frequently lime is added to a clay soil to make it more open and sandlike in its properties. To illustrate this action pour into two test-tubes a little of the clay-water prepared in the last experiment. To one of these add a thimbleful of lime-water and allow them to stand for an hour or so. The clay will scarcely have settled at all in the one to which no lime-water has been added, whilst the other will have become almost clear owing to the clay having fallen to the bottom of the liquid as though it were fine sand.

64. Limestone in Soil.—In paragraph 39 it was shown that when hydrochloric acid is added to marble (which is a form of limestone) effervescence takes place, and carbonic acid gas is evolved. Take a small quantity of soil in a test-tube and moisten it with water. Fill the test-tube about half full of dilute hydrochloric acid. If the soil contains considerable quantities of limestone the effervescence will be seen at once. Should only traces be present the effervescence may be detected by holding the mouth of the test-tube close to the ear, when the sound caused by the gas coming off will be distinctly heard.

65. Test for Lime.—Lime is oxide of calcium ; for a full set of tests for that metal see paragraphs 178–181. To test for lime in a soil : boil the mixture of soil and acid described in paragraph 64 for a minute, then add ammonia to it until it is alkaline, and filter. To the clear liquid so obtained add a little ammonium oxalate and allow the liquid to stand for a few minutes. A white precipitate or cloudiness shows that the soil contained lime.

66. Test for Organic Matter (Humus).—Place a little soil on a piece of platinum foil and hold it with a pair of crucible tongs just over the top of a Bunsen flame. The soil will first of all darken in colour until nearly black, then it will become lighter again until it is of much the same colour as it was before heating. The reason of these changes is that the organic matter (which always contains carbon) becomes charred, and the carbon so formed gives a dark colour to the substance. After a while the carbon itself burns, and leaves the soil as it was before the experiment, except that the organic matter has been burned away.

* **67. The Nature of Humus.**—The organic matter or humus in a soil consists principally of certain acids, which, like all other acids, combine with caustic potash to form salts. The soil acids themselves are not soluble in water, but the compounds which they form with caustic potash are soluble. To show this, place a small quantity of peat soil at the bottom of a test-tube and fill the tube about one-third full of caustic potash solution. Warm for a few minutes, then fill up the test-tube with water, shake well, and filter. The liquid which comes through will be coloured brown by the potash compounds in solution. Take a little of the solution in a test-tube and add an excess of dilute hydrochloric acid. The liquid will become cloudy because the soil acids will be again set free from the potash, and, as they are not soluble in water, they will form a precipitate.

EXPERIMENTS ON MANURES

68. The most important constituents of manures are lime (CaO), potash (K_2O), phosphoric acid (P_2O_5), and nitrogen (N). Most natural manures, such as farmyard manure and guano, contain all these substances. Artificial manures are generally made by mixing substances which contain one or more of the above constituents in a concentrated form. The experiments described in paragraphs 69, 70 are to show the properties of the various simple manures before mixing.

LIME MANURES

69. Slaking Lime.—Place a lump of freshly prepared lime, about the size of a small nut, on a tile and pour a few drops of water on to it. When this water is soaked up, pour a few more drops, and continue this process as long as the lime will continue to absorb it and still remain dry. The lime will become hot and fall into a fine powder, showing that chemical action has taken place, and the quicklime has combined with the water to form slaked lime.

70. Solubility of Lime.—Although limestone (carbonate of lime) is not soluble in pure water, slaked lime (hydrate of lime) is. Place a little powdered marble in a test-tube, and in another place a little of the slaked lime obtained in the last experiment. Add to each half a test-tube full of water and shake up. Allow both to settle and pour off the clear liquid into two other test-tubes. Filter if necessary. To each of these two clear liquids add a few drops of ammonium oxalate. The one in which the marble has been shaken will remain clear, showing that none has been dissolved; whilst the other will give a white precipitate, showing that some of the slaked lime has entered into solution.[1]

71. Action of Air on Lime.—When lime is exposed to the air it absorbs carbonic acid and gets converted again into carbonate of lime, which is known as *mild lime*. Pour a little lime-water (a solution of slaked lime in water) into an evaporating-dish and leave it exposed to the air for an hour or two. At the end of that time it will be covered with a thin scum. This is because the lime in the solution has been turned into carbonate of lime, which, being insoluble in the water, forms a scum over the surface.

72. Action of Lime on Acids.—Lime is not only useful as a food for plants, but it improves the soil in many other ways. One of these has already been pointed out in paragraph 63. Another use of lime is to add it to 'sour' soils, or soils which contain such quantities of acid that they will not grow good crops. To show this action, one-third fill

---

[1] Distilled water is seldom perfectly free from carbon dioxide; hence a trace of the marble is often dissolved, giving a faint precipitate with ammonium oxalate. When this is the case the student should notice the great difference between the precipitate obtained after using lime and that obtained by using marble.

a test-tube with distilled water, then add a few drops of hydrochloric acid and a few drops of litmus solution. The acid will colour the litmus red. Now add a few drops of lime-water and shake up. If the liquid be still red (*i.e.* if it be still acid) add a few more drops of lime-water and shake up again. Continue doing so until the colour changes to blue. When this takes place all the acid will have been neutralised.

* 73. **Action of Lime on Salts of Iron.**—Soluble salts of iron are often injurious to crops. Lime has the property of rendering these salts insoluble. Dissolve a crystal of ferrous sulphate (copperas) in half a test-tube of cold water. Add a little lime-water. The iron in the solution will be rendered insoluble and a dark-coloured precipitate of ferrous hydrate will be formed.

74. **Sulphur in Gas-lime.**—Lime which has been used in the purification of coal-gas, called gas-lime, is sometimes used as a manure and insecticide, but unless it is exposed to the action of the air for a considerable time it acts as a *plant poison*, as it contains calcic sulphide. To show the presence of a sulphide, place a little gas-lime in a test-tube and add a little dilute hydrochloric acid. Effervescence takes place and the calcic sulphide is decomposed, forming sulphuretted hydrogen, which may be recognised by its offensive smell.

* 75. **Sulphur in Gypsum.**—Gypsum (sulphate of lime) contains sulphur, but as a *plant-food.* Treat a little gypsum as in the last experiment. No sulphuretted hydrogen will be given off. Mix a little gypsum in a mortar with twice its weight of powdered charcoal. Place a little of this mixture on a piece of platinum-foil and heat over a Bunsen flame until all the charcoal is burned off. Allow to cool, then place the mass in a test-tube and add a little dilute hydrochloric acid. Sulphuretted hydrogen will now be evolved, showing that sulphur was present in the gypsum. The action of the

air on gas-lime is to turn the calcic sulphide (CaS) to gypsum ($CaSO_4$). The heating with charcoal brings about the opposite effect, *i.e.* reduces the gypsum to calcic sulphide.

POTASH MANURE

76. Potash in Kainit.—Kainit is the most common potash manure. To show that it contains potassium, place a little kainit on a watch-glass and moisten it with dilute hydrochloric acid. Test this substance in the flame as directed on page 11. The flame will appear yellow, due to sodium present as an impurity. Now observe the flame through an indigo prism or a piece of cobalt-blue glass. It will appear crimson. This is a distinctive test for potash (189).

PHOSPHATIC MANURES

77. Phosphoric Acid.—This generally occurs in artificial manures as a phosphate of lime. These phosphates are four in number, and each has its own distinctive properties. Their chemical names and formulæ are as follows:—

a. Monocalcic phosphate	$CaO.(H_2O)_2.P_2O_5$
b. Bicalcic phosphate	$(CaO)_2.H_2O.P_2O_5$
c. Tricalcic phosphate	$(CaO)_3.P_2O_5$
d. Tetracalcic phosphate	$(CaO)_4.P_2O_5$

Their commercial names are—

a. Superphosphate of lime. *b.* Reverted phosphate.
c. Bone or mineral phosphate. *d.* Slag phosphate.

The properties of slag phosphate are very similar to those of reverted phosphate, so in the next three experiments reverted phosphate is not considered, but it is referred to in paragraph 81.

78. Action of Water on Phosphates.—Into three test-tubes introduce equal quantities respectively of coprolite powder (which contains bone phosphate), basic slag (which contains slag phosphate), and superphosphate. About as much as can be held on a sixpence will be sufficient. Half fill each test-tube with distilled water and shake up. Filter each one into a clean test-tube through separate filters. If the solutions do not come through clear, pass them through the filters again. Now test each solution for phosphoric acid. This is done by adding an excess of ammonium molybdate solution and boiling ; a yellow precipitate shows that phosphoric acid is present. It will be found that the liquid from the superphosphate contains phosphoric acid, but that the others do not, showing that superphosphate of lime is the only one of the three substances that is soluble in water.

* 79. **Action of Ammonium Citrate on Phosphates.**—Place small quantities of superphosphate, slag and coprolite powder in separate test-tubes, as in paragraph 78. Shake up with ammonium citrate solution. Filter and test with ammonium molybdate as before. This time the liquids from both the slag and the superphosphate will be found to contain phosphoric acid, whilst that from the bone phosphate will not, showing that both superphosphate and slag phosphate are soluble in ammonium citrate, whilst bone phosphate is not.

80. **Action of Dilute Nitric Acid on Phosphates.** Proceed exactly as in the two previous experiments, treating the different phosphates with dilute nitric acid. Filter and test as before. All three phosphates will be found to be soluble in nitric acid, and will therefore give the molybdate test.

81. **Reversion of Superphosphate.**—When a superphosphate is placed on the soil the rain dissolves the soluble substance and thoroughly impregnates the soil with it. If it were to remain soluble, a quantity would eventually be

washed away into the drains. This, however, does not occur, as several substances in the soil cause it to 'revert,' or turn into reverted phosphate, which, like slag phosphate, is insoluble in water. The principal substances which bring about this reversion are lime, oxide of iron, and alumina. This reversion is shown in the next experiment.

82. **Action of Lime on Superphosphate**.—Mix a little superphosphate in a mortar with twice its weight of freshly slaked lime. Grind them well together and introduce a small quantity into a test-tube. Add distilled water and shake well, then allow to settle. When the liquid has become nearly clear, filter and test the clear liquid with ammonium molybdate. No phosphoric acid will be found. The lime has reverted the superphosphate and rendered it insoluble.

* 83. **Action of Ammonium Citrate on Reverted Phosphate.**—Take a little more of the mixture of lime and superphosphate made in the last experiment in a test-tube and treat it with ammonium citrate solution. Filter, and test with ammonium molybdate. The reverted phosphate will be found to resemble slag phosphate in that it dissolves in ammonium citrate.

The vegetable acids in soil act very much in the same way as ammonium citrate, so that the reverted phosphate, which has been formed and thoroughly mixed with the soil by the action of rain, lime, &c., on superphosphate, is slowly redissolved and given up to the plants as food.

NITROGENOUS MANURES

84. The nitrogen in manures occurs in one or more of three forms known chemically as *organic* nitrogen, *ammoniacal* nitrogen, and *nitric* nitrogen. In whatever form it may occur, the action of the organisms in the soil is to turn it into the last of the three, as this is the only form in which

it is fit for plant-food. The following three experiments show how the different forms may be recognised.

85. Test for Organic Nitrogen.—Mix together in a mortar about as much shoddy (which has been cut up very fine with a pair of scissors) as can be heaped up on a shilling with about four times its weight of soda lime. Heat a little of this mixture strongly in an ignition-tube (6). Ammonia gas will be given off, which may be recognised by its smell, and also by the fact that it turns moist turmeric paper brown.

Treat a little sulphate of ammonia in exactly the same way as the shoddy. Ammonia will be given off more readily than in the former case.

Treat a little nitrate of soda in the same way. No ammonia will be given off.

Shoddy contains organic nitrogen, sulphate of ammonia contains ammoniacal nitrogen, and nitrate of soda contains nitric nitrogen. From the experiment just performed it will be seen that the organic and ammoniacal forms are similar in that they both give off ammonia when heated with soda lime. They are distinguished from each other by the experiment described in paragraph 86.

86. Test for Ammoniacal Nitrogen.—Take three test-tubes: in the first, place a little shoddy, cut up fine; in the second, a little sulphate of ammonia; and in the third, a little nitrate of soda. Half fill each test-tube with potassic hydrate solution, and boil each in turn. The one containing sulphate of ammonia will give off ammonia, which may be recognised as before, whilst the other two will not. Ammoniacal nitrogen may always be recognised in this way.

87. Test for Nitric Nitrogen.—Take separate small portions of sulphate of ammonia, shoddy, and nitrate of soda in test-tubes and add water. Filter each and to the clear liquid add a few drops of indigo solution; then pour in strong sulphuric acid until the volume of liquid is about doubled. In the case of shoddy and sulphate of ammonia no change will take place. With nitrate of soda the indigo will be bleached. This operation may be used as a test for nitrates in manures.

The Mixing of Manures

88. In mixing manures care must be taken not to mix two substances which act chemically upon each other. Attention has already been called to the fact that lime acts upon superphosphate (82), rendering the phosphoric acid insoluble in water ; and since basic slag contains a certain quantity of lime it should not be mixed with superphosphate. Other substances which should not be mixed are shown in paragraphs 89 and 90.

89. Action of Superphosphate on Nitrate of Soda.—Mix equal quantities of superphosphate and nitrate of soda in a mortar. Notice the peculiar smell of the mixture. Heat a small quantity in an ignition-tube. It will give off *brown fumes.* The reason is that superphosphate contains a certain amount of free sulphuric acid which is used in its manufacture, and this acts upon the nitrate of soda, setting free nitric acid, which is recognised by its smell and the brown fumes formed when it is heated. Now since nitric acid contains nitrogen, and is volatile, it will pass off into the air, and so nitrogen will be lost. Further, nitric acid is a very corrosive substance, and will attack the bags in which manure is stored. Hence superphosphate and nitrate should never be mixed before applying them to the land.

90. Action of Slag on Sulphate of Ammonia.—Mix a small quantity of sulphate of ammonia with about six times its bulk of basic slag in a mortar. Notice the smell of ammonia. Heat a little of the mixture in an ignition-tube, and hold a piece of moist turmeric-paper over the end of the tube. The paper will become brown. This experiment teaches that when these two substances are mixed ammonia passes off into the air and is lost; and since ammonia contains nitrogen this loss is a serious one.

TESTING MANURES

91. To find the exact value of a manure it is necessary to make a full quantitative analysis. There are, however, a few simple tests by which the purity of a manure or the composition of a mixed manure may be recognised. These are detailed in paragraphs 92–106.

92. Ammonia in Guano.—No single test can be applied which will guarantee the purity of a Peruvian guano, but the one described in this paragraph, together with those in the next two experiments, will give a fair idea of its genuineness. Take a little guano in a test-tube, and treat it with potash exactly as was described in the case of nitrogenous manures (86). A genuine guano contains ammoniacal nitrogen, and hence ammonia will be evolved, which will turn turmeric-paper brown.

93. The Ash of Guano.—Place a little guano on a piece of platinum foil, and hold it by means of a pair of crucible tongs in the flame of a Bunsen burner. The guano will first darken in colour, then catch fire and flare up. When it ceases burning a black mass of charcoal will be left. Continue heating until all the charcoal is burned off. The mass now left on the foil is known as the ash of the guano, and should be quite white. If it is brown the guano has been adulterated.

94. Soluble Phosphoric Acid in Guano.—Treat a small quantity of guano with water in a test-tube as described in paragraph 78. Filter and heat the liquid with excess of ammonium molybdate solution. A yellow precipitate will be formed, showing that the guano contained phosphoric acid in a soluble state. The guano may be distinguished from superphosphate by moistening a small quantity on a tile and laying a piece of blue litmus over it. The litmus will not change. If this be tried with superphosphate the litmus-paper will be reddened.

95. **Volatility of Sulphate of Ammonia.**—Place a few crystals of pure sulphate of ammonia on a piece of platinum foil, and heat over a Bunsen flame. The crystals will first of all melt, then white fumes will rise from the substance, and finally it will vanish entirely, leaving no trace whatever on the foil. Repeat the experiment with a few crystals of *commercial* sulphate of ammonia. Exactly the same series of changes will take place, except that a slight film of impurity will be left on the foil. The smaller this film, the purer the sulphate will be.

96. **Thiocyanates in Sulphate of Ammonia.**—Occasionally sulphate of ammonia contains a powerful plant poison, known as thiocyanate of ammonia, which should always be tested for. Add to a solution of ammonium thiocyanate a few drops of ferric chloride solution ; a blood-red liquid will be formed. Now make a solution of commercial sulphate of ammonia in water and treat in the same way by adding a drop of ferric chloride. Should the least red coloration occur, the sulphate is unfit for use.

97. **Action of Heat on Bones.**—Samples of bones can usually be recognised by their appearance, except when in the state of bone-flour. Bone-flour may be recognised by the following test. Heat a little of the substance on platinum foil as in paragraph 93. The bones will give off an offensive smell, which is easily recognisable. The substance will next blacken from the formation of carbon, and finally become quite white again, owing to the organic matter being burnt away and only ash left.

98. **Action of Acid on Bones.**—Place a small quantity of bone-flour at the bottom of a test-tube and add

a small quantity of dilute hydrochloric acid. The liquid will effervesce, owing to the fact that bones contain carbonate of lime.

COMPOUND MANURES[1]

* 99. The following set of experiments (paragraphs 100–106) should be performed on several mixed manures. The object of the experiments is to find out what are the principal constituents of the manures.

* 100. **Test for Acidity.**—Place a little of the mixed manure on a watch-glass, moisten it thoroughly with water, and lay a piece of moist blue litmus-paper upon it. Should the litmus-paper *immediately* become red, the manure contains some acid, and most probably contains superphosphate of lime.

* 101. **Test for Soluble Phosphate.**—Place about as much of the manure as could be held on a penny in a mortar, cover with cold distilled water, and grind into a paste with the pestle. Allow the liquid to settle for two or three minutes, then filter it, washing the mud into the filter-paper with hot water. Save the residue for the next experiment. Divide the filtrate into two portions in test-tubes. Test one portion for phosphoric acid by boiling with excess of ammonium molybdate solution.

Should a yellow precipitate occur, then the manure contains soluble phosphoric acid, and should the manure have been proved by the last experiment to be acid then we may consider that it contains either superphosphate or dissolved bones.

To the second portion of the filtrate add ammonia ; a white precipitate of phosphate will be formed. Allow this to settle and notice the colour of the liquid. If it be quite colourless, then the soluble phosphate was mineral super-

---

[1] Two or three mixtures of the more important manures should be provided and the student allowed to discover their constituents.

phosphate; if the *liquid* be at all brown then the soluble phosphate was most probably dissolved bones. From this experiment, therefore, we learn first, whether the manure contains soluble phosphate, and secondly, whether that phosphate was prepared from bones or from a mineral phosphate.

* 102. **Test for Insoluble Phosphate.**—Should soluble phosphate have been found in paragraph 101, we are pretty certain to find insoluble phosphate also. This is tested for in the substance saved on the filter-paper from the last experiment. Scrape the mud off the filter-paper and place in a 3-inch evaporating-dish; just cover the substance with strong hydrochloric acid and warm for a few minutes. When as much has dissolved as is possible fill the dish nearly full of distilled water and stir well. Filter. The residue will be the sand which was present in the manure. Divide the liquid which comes through into two portions. Boil one portion with ammonium molybdate. Should a yellow precipitate form, then insoluble phosphate was present. To the other portion add ammonia, and notice the colour of the *precipitate*. If the insoluble phosphate has been derived from bones the precipitate will be quite white. If it has been derived from mineral phosphate the precipitate will probably contain phosphate of iron, and be more or less brown. From this experiment we learn whether the manure contains insoluble phosphate, and, if so, whether it is made from bones or mineral.

* 103. **Test for Organic Nitrogen.**—Boil up a small quantity of the manure with water in a 3-inch evaporating-basin. Filter and wash with the spray from a wash-bottle; keep the liquid for paragraph 105. When the liquid and washings have all run through, take the filter and its contents out of the funnel and place them in a dry evaporating-basin, and put this to dry in a steam-oven. (Whilst the substance is drying proceed with the next experiment.)

When quite dry, remove the substance from the filter-paper to a mortar, and there mix it with about three times its weight of soda-lime. Heat some of this mixture in an ignition-tube and test the evolved gases with turmeric-paper. A brown coloration given to the paper indicates organic nitrogen. The reason for the preliminary washing with water is to remove any sulphate of ammonia or other substance which might contain ammoniacal nitrogen.

* 104. **Test for Ammoniacal Nitrogen.**—Warm a little of the manure in a test-tube with caustic-potash solution; test the vapour which comes off with turmeric-paper as directed in paragraph 86. Should the paper turn brown, ammonical nitrogen is present in the manure; and since sulphate of ammonia is the principal substance in manures which contain nitrogen in this form, we may usually assume that the brown coloration indicates that sulphate of ammonia was present in the manure.

* 105. **Test for Nitric Nitrogen.**—Nitric nitrogen is generally added to manures in the form of nitrate of soda, but many natural manures contain nitrate of lime. This is especially the case with bat's guano. For this test use the clear liquid saved from paragraph 103. Follow out exactly the test described in paragraph 87. Should the indigo be bleached the manure contains nitric nitrogen.

* 106. **Test for Potash.**—Heat a little of the manure on platinum foil in the Bunsen flame until all the carbonaceous matter is burned off. Remove the ash which is left to a watch-glass and moisten it with hydrochloric acid. Test the substance in the flame on a loop of platinum wire, viewing the colour through an indigo-prism or a piece of cobalt-blue glass. Should the flame, when viewed thus, appear crimson, the manure contains potash. The most usual forms in which potash is added to mixed manures are sulphate of potash, muriate of potash, and kainit, which is a double sulphate of potash and magnesia.

EXPERIMENTS ON FEEDING MATERIALS

107. The experiments here described as showing some of the properties of feeding materials are divided into four sets, viz. experiments on oil-cakes, experiments on grass, experiments on turnips, and experiments on flour.

OIL-CAKES

108. The principal kinds of oil-cake are *linseed* cake and *cotton* cake, but many other substances are used in the form of cake, such as rape, palm-nut, and compound cakes. The chemical constituents which affect the feeding value of oil-cakes are much the same, whatever the seed used. The constituents are water, oil, albuminoids, carbohydrates, woody fibre, and sand, the last two forming the indigestible part of the cake. The meaning of the above chemical terms is explained as far as possible in the following experiments.

109. Water in Oil-cakes.—Grind up a piece of linseed-cake in a mortar and place a little of the powder in a bulb-tube with a neck about eight inches long. Boil some water in a small beaker standing on a wire gauze. Now hold the bulb containing the cake just beneath the surface of the boiling water in a slanting position, so that the bulb and cake may be heated up to the boiling-point of water, whilst the rest of the tube is kept cool. In a very short time water-vapour will come off from the apparently dry cake and condense in the cooler part of the tube, where it may be seen to dim the inner surface of the glass tube.

110. Oil in Oil-cakes.—Spread out a little linseed-cake, which has been ground up in a mortar, on a piece of filter-paper. Lay the paper on a clean white tile and just moisten the cake with ether. After it has stood for a minute exposed to the air, the greater part of the ether will have evaporated. Place the paper for five minutes in the steam-oven; after this time brush the dry linseed-powder from its surface. Grease-marks will be found on the paper, showing that the cake contained oil. This oil not only helps in forming the fat of the animal feeding on it, but it also helps in the development of animal heat.

111. Albuminoids in Oil-cakes.—Albuminoids are essentially the flesh-forming compounds in the cake, and they are distinguished from other constituents by the fact that they contain nitrogen. Mix a little powdered linseed-cake with soda-lime and heat some of the mixture in an ignition-tube. Ammonia will be given off, and may be tested for with moist yellow turmeric-paper as described in paragraph 85. This ammonia is formed by the action of soda-lime on the nitrogen of the albuminoids.

* **112. Carbohydrates in Oil-cakes.**—The name 'carbohydrate' is given to a large class of bodies containing the three elements, carbon, hydrogen, and oxygen. Starch, sugar, and dextrin are examples of carbohydrates. Most of these bodies, on being heated for some time with dilute sulphuric acid, are converted into grape-sugar. Half fill an evaporating-basin with dilute sulphuric acid (the ordinary dilute acid used in the laboratory must be mixed with twice its volume of water for this experiment). Throw on to the surface of the acid liquid as much powdered linseed-cake as can be held on a penny. Boil gently over a Bunsen flame, supporting the basin on a tripod and pipeclay triangle. Add a little hot water from time to time as the liquid evaporates, to prevent the acid becoming too strong. When it has boiled for five minutes remove from the flame, allow to cool, and filter. Grape-sugar must now be tested for in the clear solution. This is done by adding potash to the acid solution until it is slightly alkaline, then a few drops of Fehling's Solution (266), and heating. The blue colour of the Fehling's Solution will be destroyed, and a light-red or yellow precipitate of cuprous oxide will be formed.

* 113. **Woody Fibre in Oil-cakes.**—The woody fibre and the sand are the indigestible portions of oil-cakes. Woody fibre may be shown to be present in oil-cake in the following way.

Take as much ground linseed-cake as can be held on a sixpence, place in a test-tube, and fill the test-tube about one-third full of glycerine. Now heat very cautiously in the Bunsen flame until the glycerine just boils. Keep it hot for about a minute, then allow it to cool. Nearly fill the test-tube with water, warm again, and filter. The substance left on the filter will be nearly pure woody fibre.

* 114. **Sand in Oil-cake.**—Burn a little oil-cake powder on platinum foil over the Bunsen flame, in the same way as was described with bones in paragraph 97, until the ash is quite light-coloured. Empty the ash into a clean test-tube and fill it about an inch deep with dilute hydrochloric acid. Boil for a minute or so, then filter. Spread out the filter on a glass plate; grains of sand, if present, will be seen on the paper. This experiment may not always succeed on the first attempt owing to the small amount which can be burnt at once on a piece of foil. Two or three attempts will usually give some sand, especially if the same filter be used for all the experiments.

115. **Linseed-cake.**—All the above tests are applicable to any kind of oil-cake, but some few tests may be performed with special kinds of cake. A pure linseed-cake may generally be recognised from two of its properties. It is highly mucilaginous, and it does not contain starch.

116. **Mucilage in Linseed-cake.**—Place about a teaspoonful of ground linseed-cake in a 4-ounce beaker and half-fill the beaker with boiling water. Stir vigorously with a glass rod; allow to cool. It will be found that the linseed has swollen up into a gummy mass. The better the cake, the more mucilaginous the mass will be; whilst a very poor cake will not swell up at all, but settle quickly to the bottom of the liquid.

* **117. Testing Linseed-cake for Starch.**—Pour a little of the gummy substance prepared in the last experiment into a test-tube and boil it. As soon as it has boiled cool it down by allowing the cold water from a tap to run over the outside of the tube. When quite cool add a few drops of a solution of iodine in potassium iodide and shake up. If the cake assume a greenish colour it is pure and free from starch; if it turn deep blue or black it shows the presence of starch, and therefore it has been adulterated.

118. Cotton-wool in Cotton-cake.—In the preparation of cotton-cake it is necessary to free the seed from cotton-wool. If this be badly done the value of the cake will be much impaired.

Break up a piece of undecorticated cotton-cake, weighing about two ounces, as finely as possible in a mortar, then place it in a wire sieve having from twenty to thirty meshes to the linear inch. Shake the sieve until all the finer portion has passed through, and examine the husk which is left. Should the cake be an inferior one a small quantity of cotton-wool will usually be found adhering to it. The wool may often be seen without this preliminary sifting.

GRASS AND HAY

119. Grass and Hay.—All the substances which have been shown to occur in oil-cakes may be found in grass. Some of these, however, such as oil, occur in such small quantities that it would require far more delicate experiments than those detailed in these pages to show their presence. The following experiments, however, are instructive and should be performed.

120. Albuminoids in Grass.—Cut up a little grass (or hay) as finely as possible with a pair of scissors and grind it up in a mortar with a little *sharp* sand. This will render it sufficiently fine to mix readily with soda-lime. Mix it with an equal quantity of soda-lime and heat a little of the mixture in an ignition-tube. The albuminoids will give off ammonia. See paragraph 85.

121. Chlorophyll in Grass.—Chlorophyll is the green colouring matter which occurs in grass. Cut up a handful of grass with scissors and place it in a mortar; just cover the grass with methylated spirit and grind it gently with the pestle for a few minutes. Now filter the substance through a piece of linen stretched loosely over the top of a beaker and tied. The liquid which comes through will be quite green. Pour a little of this liquid into an evaporating-basin and leave it on a steam-bath to evaporate. Do not evaporate over a Bunsen flame, or it will catch fire. When all the spirit has evaporated a film of green chlorophyll will be found at the bottom of the dish. Now squeeze all the spirit out of the substance left in the linen and wash it with a little ether. The residue left in the linen will be found to be light-coloured, and if the washing be continued will eventually become colourless.

122. Ash in Grass.—Place a handful of hay, or grass, dried in the steam-oven, on a porcelain tile and light it with a match. When it has stopped burning gather all the ash on to a piece of platinum foil and heat it until it loses its black colour. Sometimes the ash thus left will be green: this is due to the presence of manganese, but more often it will be white or light-brown. Keep the ash for the next experiment.

* **123. Alkalies in Grass.**—The ash of grass contains both potash and soda, which will probably fuse in the Bunsen flame, and so cause the ash to adhere to the platinum foil. Roll up the foil, with the ash adhering to it, and place in a test-tube. Just cover it with distilled water and boil. Now take a drop of the solution thus prepared, on the end of a glass rod, and touch a piece of red litmus-paper with it. Where the liquid touches the paper the red will be turned to blue, showing the presence of an alkali.

Keep the test-tube containing the platinum foil and liquid for the next experiment.

* **124. Phosphates in Grass.**—To the water in the test-tube (paragraph 123) add an equal volume of dilute nitric acid and warm. Decant the liquid into another clean test-tube, leaving the platinum foil behind. To the clear liquid so obtained add an excess of ammonium molybdate solution and boil; a yellow precipitate will appear, showing that the grass contained phosphates.

ROOTS

125. Turnips.—Roots, such as turnips, swedes, and mangels, differ from the foods which have been considered, in that they contain a very much larger proportion of water and a greater quantity of sugar. When the water is squeezed out of the roots it brings the sugar and other soluble substances with it. Hence the components of a turnip may be divided into two kinds: the soluble, which with the water constitute juice, and the insoluble, which go by the name of crude fibre. The crude fibre is very much like hay in its constitution; therefore the experiments here described are intended only to show the properties of the juice.

126. Juice in Turnips.—Cut a turnip up into six sections with a large knife. Grate up one or two of these sections on a bread-grater, allowing the pulp to fall on to a piece of linen stretched over a porcelain tile. When a good handful of pulp has been thus prepared, fold it up in the cloth and squeeze out the juice into a beaker. Throw away the fibre left in the cloth and with the juice perform the experiments described in paragraphs 127 and 130.

127. Sugar in Turnips.—Taste a little of the juice. It has the flavour of raw turnip, but is nevertheless very sweet. Pour sufficient juice into a clean test-tube to fill about half an inch of the tube. Dilute this with about four times its volume of water, then add about an equal volume of strong lead acetate solution. Shake up well and allow to stand for quarter of an hour to settle. Whilst it is settling go on with the next experiment. At the end of the quarter of an hour the liquid in the test-tube will have become quite clear, except for a thick deposit of white material at the bottom. Pour off a little of the clear liquid into another test-tube and add caustic potash solution; a white precipitate will be caused. Add more caustic potash until the precipitate is redissolved; then add a little Fehling's Solution, and boil. A yellow or bright red precipitate will be formed, which shows the presence of sugar.

* 128. **Cane Sugar and Grape Sugar.**—The sugar found in swedes and turnips is a different substance from the sugar which we use for sweetening purposes. The former is glucose or grape sugar, the latter is cane sugar. The properties of these two kinds of sugar are best studied by using the pure substances. Dissolve a little cane sugar in water in a test-tube. In another test-tube make a solution of glucose; to each of these add a little Fehling's Solution and boil. The glucose will give a reddish precipitate, whilst the cane sugar will not.

* 129. **Inversion of Cane Sugar.**—Make a solution of cane sugar in a test-tube half full of water; add a few drops of strong hydrochloric acid and boil well. After boiling add a little potash to neutralise the acid, then a little Fehling's Solution, and boil again. A precipitate will now be formed, showing that the cane sugar has been changed to glucose by boiling with the acid.

* 130. **Albuminoids in Turnip Juice.**—One of the properties of albuminoids is that they are rendered insoluble by carbolic acid. Pour a tablespoonful of turnip juice into a beaker and add two drops of strong carbolic acid solution (80 per cent.) Allow the beaker to stand overnight. The albuminoids will settle, leaving the liquid clear.

FLOUR

131. The principal food constituent of wheat flour is starch, but its peculiar property of kneading with water depends upon another constituent, which is called gluten.

132. Starch in Flour.—The test for starch has already been given (117). Wet a little flour with water so as to make a thin cream. Boil a little water in a test-tube, and when it is boiling briskly add a drop of the cream, then boil for a few seconds. Cool the liquid by allowing a current of cold water to flow from a tap round the outside of the test-tube, and when quite cold add a drop of iodine solution. An immediate deep-blue coloration indicates the presence of starch. The colour will appear almost black, but if a drop of the dark liquid be mixed with a large quantity of water it will be seen that it really is of a dark-blue colour.

133. Gluten in Flour.—Mix a handful of flour with enough water to form a stiff paste. Knead it well in the fingers, then wrap it up in a small piece of muslin and hold it in a gentle stream of water from a tap, kneading it all the time. The starch will be gradually washed away through the muslin, leaving a dark-coloured indiarubber-like mass. This is gluten, which gives a mixture of flour and water its peculiar adhesiveness.

DAIRY PRODUCE

MILK

134. Action of Acid on Milk.—Half fill a test-tube with milk. Add about six drops of dilute sulphuric acid and shake. Allow the tube with its contents to stand for five minutes. At the end of that time the milk will be seen to have curdled. The acid has coagulated the soluble albuminoids, rendering them insoluble, and thus forming clots which separate out from the milk.

135. Fat in Milk.—Filter the curdled milk and save the clear filtrate (137). Spread out the filter-paper which contains the 'curd' on a glass plate and place it in the steam-oven to dry. When it has got quite dry the fat will melt out of the curd, and form grease stains on the filter-paper.

136. Albuminoids in Milk.—The residue left on the filter-paper, after the fat has been melted out as described in the last experiment, is principally albumen and casein. Both these substances contain nitrogen, which may be tested for by scraping this residue off the filter, mixing with soda-lime, and heating in an ignition-tube as described in paragraph 85 ; ammonia will be given off.

137. Sugar in Milk.—The clear liquid which has been saved (135) contains sugar. This sugar is different from either cane sugar or glucose, and goes by the name of lactose, or milk sugar. It has an action, however, on Fehling's Solution similar to that of glucose. Add to the clear liquid in the test-tube (135) a little potassium hydrate solution until the liquid is no longer acid, then add Fehling's Solution and boil ; a yellow precipitate will be formed, indicating the presence of sugar.

BUTTER

138. Butter consists principally of the fat of the milk, but it also contains portions of curd, salt, and water.

139. Water in Butter.—Place as much butter as you conveniently can in a test-tube. Then hold the tube in hot water until the butter is completely melted. Note the appearance of the tube. The pure butter-fat will form a clear top layer. Beneath this will come a cloudy layer containing the curd and salt, and beneath this, again, will be seen drops of water.

140. Curd in Butter.—Whilst the butter is still hot pour it on to a dry filter-paper in a funnel. Place the funnel in the neck of a 4-oz. conical flask and place the whole arrangement in the steam-oven (22). This will serve to keep the butter melted whilst it is filtering. In a few minutes nothing will be left on the paper but the curd and salt with a little water. The curd may be shown to contain *nitrogen* by heating with soda-lime as described in paragraph 85.

141. **Salt in Butter.**—Hold the greasy filter-paper prepared in the last experiment, together with its contents, by means of a pair of crucible tongs over a porcelain tile, then light it with the flame of a Bunsen. When it has quite burned, and the ash has fallen on to the tile, sweep it up into a test-tube. Half fill the test-tube with water and boil for a minute or two, then filter. The clear liquid which comes through will contain any salt which was present in the original butter. To test for salt add a drop of dilute nitric acid and a few drops of silver nitrate solution. A white precipitate will be formed (see paragraph 201).

CHEESE

142. Cheese contains exactly the same constituents as butter, but in different proportions. Thus whilst the butter consists principally of fat the cheese consists chiefly of curd.

143. **Fat in Cheese.**—Place a few cheese-parings on a piece of filter-paper and heat in the steam-oven (22). The fat in the cheese will melt and stain the paper.

144. **Albuminoids in Cheese.**—Heat a little of the cheese with soda-lime as described in paragraph 85. The presence of nitrogen is shown by the evolution of ammonia.

SECTION IV

QUALITATIVE ANALYSIS OF THE BODIES COMMONLY OCCURRING IN SOILS AND MANURES

INTRODUCTORY REMARKS

145. This section treats only of those bodies which occur in soils, manures, and agricultural products, namely, the carbonates, sulphates, chlorides, nitrates, nitrites, silicates, and phosphates of the metals aluminium, iron, manganese, calcium, magnesium, potassium, sodium, and ammonium, together with organic carbon, nitrogen, chlorine, and sulphur.

Chemical formulæ are freely used, but not unless the name of the compound has already been mentioned in the same paragraph.

In some instances the chemical changes are expressed by equations.

146. In naming a substance the usual nomenclature is adopted, *i.e.* each salt has a double name, the metal forming one portion, and the acid (called the acid-radical) the other portion of the name. Thus sodium on being added to sulphuric acid would form sodium sulphate :—

$$\underset{\text{Sodium}}{Na_2} + \underset{\substack{\text{Sulphuric}\\\text{acid}}}{H_2SO_4} = \underset{\substack{\text{Sodium}\\\text{sulphate}}}{Na_2SO_4} + \underset{\text{Hydrogen}}{H_2}$$

Hence in naming that body both names, or some modification of them, are included in the compound. In analysis it is found convenient to test for the metal and the acid radical separately. In the above case of sodium sulphate, the sodium (Na) would first be tested for by the sodium test (186), and then the acid radical (SO_4) would be tested for by the sulphate test (194).

147. It will be noticed that the name of a suitable substance for performing the tests upon is given at the head of each series of reactions. Thus, when testing for sodium, the most suitable substance to use is sodium chloride (NaCl). The reagent to be added is given immediately after the paragraph number.

148. **Entry in Note-book.**—A note-book of quarto size should be used. A concise account of each experiment or test should be entered *directly* it is made. Neat pencil entry will suffice. The entry should not be considered complete until after it has been examined and initialled by the teacher.

The following tests for sodium will serve for an example of entry :—

Sodium (Na). Used NaCl.

Dipped a platinum wire into the solution and held in Bunsen flame : golden-yellow flame-coloration ; not seen through prism.

Heated the solid in ignition-tube : decrepitated and finally fused ; no sublimate formed.

GENERAL RULES TO BE OBSERVED WHILST WORKING

149. Before commencing work see that the reagent-bottles are full ; filter any liquids that require it. Clean the apparatus if necessary. It is far better to put everything away clean. Keep the bench scrupulously clean during work.

150. In cleaning apparatus, glass and porcelain can usually be cleansed by washing with a brush. If this fails caustic alkalies or acid may be requisite. Failing these, rubbing or shaking with a little sea-sand will usually suffice.

Metal vessels are best cleaned with a little moistened sea-sand.

151. When using a reagent bottle the bottle should be grasped by the right hand, and the stopper taken out by the left hand. After use replace the stopper and put back the bottle on the shelf. In this way the bottle is *not* placed on the bench at all, and much time saved.

152. Brass crucible tongs must not be used for holding vessels containing acid liquids, or the brass may be dissolved and introduced into the liquid. Platinum crucibles must not be handled by brass tongs when red-hot.

153. When heating liquids in porcelain or glass the flame should never reach higher than the level of the liquid, or the vessel will break.

154. Liquids only are to be poured down the sink; solids and filter-papers should be placed in boxes or baskets.

155. Crucibles or vessels containing solids are best heated on pipeclay supports, flasks containing liquids on wire gauze.

156. When an operation is unfinished the vessels containing the substances should be labelled before putting them away. *Never trust* to memory in these matters.

157. Before commencing any operation read carefully through the *whole* of the description.

REACTIONS FOR THE METALS

ALUMINIUM (Al).—Use alum, $AlK(SO_4)_2.12H_2O$, or ammonia-alum, $AlNH_4(SO_4)_2.12H_2O$, solution.

158. Ammonium Hydrate (NH_4OH) gives a white gelatinous precipitate of aluminium hydrate, $Al_2(OH)_6$. This precipitate is somewhat soluble in a larger excess of

NH_4OH ; hence this reagent should only be added in slight excess. $Al_2(OH)_6$ is readily soluble in hydrochloric acid (HCl) and in acetic acid ($H\bar{A}$).

159. **Potassium Hydrate (KHO)** or **Sodium Hydrate (NaHO)** when added drop by drop gives the same precipitate as NH_4OH, but it is readily soluble in excess of these reagents. By adding ammonium chloride (NH_4Cl) in large excess to this solution, and boiling, the precipitate will be thrown down again.

160. **Ammonium Sulphide, $(NH_4)_2S$,** gives the same precipitate as NH_4OH with evolution of sulphuretted-hydrogen gas. This precipitate is insoluble in excess of the reagent.

IRON (Fe).—Use ferrous sulphate ($FeSO_4.7H_2O$) and ferric chloride (Fe_2Cl_6) solutions.

161. NOTE.—Iron forms two classes of compounds, known respectively as ferrous and ferric compounds. It is often necessary that the analyst should ascertain whether one or both of these two classes are present in a substance containing iron. Tests are here given for both classes.

FERROUS SALTS.—Use ferrous sulphate ($FeSO_4.7H_2O$).

162. **Ammonium Hydrate (NH_4OH)** or potassium hydrate (KHO) gives a dingy green precipitate of ferrous hydrate, $Fe(OH)_2$, which becomes brown on exposure to the air. It is soluble in hydrochloric acid (HCl), and insoluble in excess of KHO.

163. **Ammonium Sulphide, $(NH_4)_2S$,** gives a black precipitate of ferrous sulphide (FeS), soluble in hydrochloric acid (HCl).

164. **Potassium Ferrocyanide, $K_4Fe(CN)_6$,** gives a light-blue precipitate, becoming dark on exposure to the air.

165. **Potassium Ferricyanide, $K_3Fe(CN)_6$,** gives a dark-blue precipitate, soluble in HCl.

166. **Potassium Sulphocyanide (KCNS)** produces no change in ferrous solutions if free from ferric salts.

FERRIC SALTS.—*Use ferric chloride (Fe_2Cl_6).*

167. **Ammonium Hydrate (NH_4OH)** or **Potassium Hydrate (KHO)** gives a reddish-brown flocculent precipitate of ferric hydrate, $Fe_2(OH)_6$, soluble in hydrochloric acid (HCl), insoluble in excess of AmHO and KHO.

168. **Ammonium Sulphide, $(NH_4)_2S$,** gives a black precipitate of ferrous sulphide (FeS), which contains white sulphur (S). The black FeS hides the white S from view.

169. **Potassium Ferrocyanide, $K_4Fe(CN)_6$,** gives a dark-blue precipitate of Prussian blue, soluble in oxalic acid, turned brown by potassium hydrate (KHO).

170. **Potassium Ferricyanide, $K_3Fe(CN)_6$,** gives no precipitate, but the liquid darkens in colour.

171. **Potassium Sulphocyanide (KCNS)** gives a blood-red coloration, which may be destroyed by the addition of mercuric chloride ($HgCl_2$).

172. By heating a small portion of solid ferric or ferrous salt on the borax bead (27) in the outer blowpipe flame a reddish-brown colour is obtained whilst the bead is hot, which fades on cooling. The inner flame gives an olive-green bead both hot and cold.

MANGANESE (Mn).—Use manganous sulphate ($MnSO_4$) solution.

173. **Ammonium Hydrate (NH_4OH)** gives a white precipitate of manganous hydrate, $Mn(OH)_2$, which quickly

turns brown in the air. This is best seen by pouring the precipitate on to a filter-paper. If, however, ammonium chloride (NH_4Cl) has been added before the NH_4OH, the precipitate will not be formed.

174. **Potassium Hydrate (KHO)** gives the same precipitate as ammonium hydrate, even in the presence of AmCl.

175. **Ammonium Sulphide, $(NH_4)_2S$,** gives a flesh-coloured precipitate of manganous sulphide (MnS). This precipitate often appears yellow from the excess of the $(NH_4)_2S$, which has been added. On filtering off this liquid the true colour may be seen. The colour of the precipitate darkens on standing in the air.

176. If a solid substance containing manganese be mixed with three times its weight of sodium carbonate (Na_2CO_3), and a third as much potassium nitrate (KNO_3), and the mixture fused on platinum foil, a bluish-green mass is obtained on cooling.

177. **Borax Bead** (27).—In the outer flame violet whilst hot, amethyst when cold. In the inner flame colourless both hot and cold.

CALCIUM (Ca).—Use calcium chloride ($CaCl_2 \cdot 6H_2O$) solution.

178. **Ammonium Carbonate, $(NH_4)_2CO_3$,** added after ammonium chloride (NH_4Cl) gives a white precipitate of calcium carbonate ($CaCO_3$), soluble in acetic acid.

179. **Ammonium Oxalate, $(NH_4)_2C_2O_4$,** gives a white precipitate of calcium oxalate (CaC_2O_4) soluble in hydrochloric acid (HCl), and insoluble in acetic acid (HA).

180. **Sulphuric Acid (H_2SO_4)** gives a white precipitate of calcium sulphate ($CaSO_4$), which forms at once in strong solutions, but only on being boiled, in dilute solutions.

This precipitate is slightly soluble in water, but less so in alcohol. If the precipitate is not formed on boiling, it will come down on cooling and adding excess of alcohol.

181. **Flame Coloration** (26).—If a clean piece of platinum wire is dipped into the liquid, and then held in the Bunsen flame, a bright reddish-yellow colour will appear.

MAGNESIUM (Mg).—Use magnesium sulphate ($MgSO_4.7H_2O$) solution.

182. **Sodium Phosphate (Na_2HPO_4)** added after ammonium chloride (NH_4Cl) and ammonium hydrate (NH_4OH) gives a white crystalline precipitate of magnesium-ammonium phosphate ($MgNH_4PO_4.6H_2O$), soluble in acids.

183. **Potassium Hydrate (KHO)** gives a white precipitate of magnesium hydrate, $Mg(OH)_2$, soluble in acids.

184. **Ammonium Hydrate (NH_4OH)** gives the same precipitate as potassium hydrate; but if ammonium chloride (NH_4Cl) be added previously, this precipitate will not form.

185. **Ammonium Carbonate $(NH_4)_2CO_3$** gives a white precipitate of magnesium carbonate ($MgCO_3$) in *strong* solutions. Ammonium chloride (NH_4Cl) prevents the formation of this precipitate.

SODIUM (Na).—Use sodium chloride (NaCl) solution.

186. **Flame Coloration** (26).—Intense yellow. This colour is almost invisible when viewed through the indigo prism or a piece of cobalt-blue glass.

187. Solid sodium chloride heated in an ignition-tube

generally decrepitates and flies out of the tube ; but if it is perfectly dry it will fuse, giving off no fumes.

POTASSIUM (K).—Use potassium chloride (KCl) solution.

188. **Platinum Chloride ($PtCl_4$)** added to some of the potassium chloride in a watch-glass and stirred with a glass rod, gives a yellow crystalline precipitate of potassium platinum chloride (K_2PtCl_6). The precipitate forms only in moderately strong solutions, and is hastened by the addition of alcohol.

189. ***Flame Coloration*** *(26).—Pale violet.* When viewed through the indigo prism or cobalt-blue glass the colour appears crimson. This colour is seen through the prism in the presence of sodium salts.

190. Potassium chloride heated on platinum foil behaves exactly like sodium chloride.

AMMONIUM (NH_4).—Use ammonium chloride (NH_4Cl) solution.

191. **Potassium Hydrate (KHO)** poured either into the solution or on to some solid ammonium chloride in a test-tube and heated, gives off ammonia gas (NH_3), which may be recognised by its smell, or by holding a piece of moistened yellow turmeric-paper over the mouth of the test-tube, when it will be turned brown.

192. **Platinum Chloride ($PtCl_4$)** stirred in a watch-glass with the solution gives a yellow crystalline precipitate.

193. Solid ammonium chloride, if heated in an ignition-tube, volatilises, and forms a white sublimate on the cold part of the tube.

REACTIONS FOR THE ACIDS

SULPHATE ($''SO_4$).—Use sodium sulphate ($Na_2SO_4.12H_2O$) solution.

194. **Barium Chloride** ($BaCl_2$) gives a white precipitate of barium sulphate ($BaSO_4$), insoluble in acids.

CARBONATE ($''CO_3$).—Use sodium carbonate ($Na_2CO_3.10H_2O$) solution.

195. **Hydrochloric Acid** (HCl) causes carbon dioxide gas (CO_2) to come off with effervescence. This gas may be recognised either by dipping a glass rod into lime-water and holding the wet end of it just inside the test-tube; the adhering lime-water will be rendered milky from the formation of calcium carbonate ($CaCO_3$); or better by pouring the CO_2 gas into another test-tube containing a little lime-water (fig. 23), and then shaking up, when the lime-water will become milky.

FIG. 23

NITRITES ($'NO_2$).—Use potassium nitrite (KNO_2) solution.

196. **Dilute Sulphuric Acid** (H_2SO_4) on warming gives off brown nitrous fumes.

197. **Potassium Iodide** (KI) **Solution** and several drops of starch solution on addition to the liquid made acid with acetic acid gives a deep-blue coloration.

NITRATE ('NO_3).—Use potassium nitrate (KNO_3).

198. **Ferrous Sulphate ($FeSO_4$) Solution** when added to the above solution, and then strong sulphuric acid poured slowly down the side of the test-tube, so as to form a separate layer at the bottom of the tube, will form a brown ring where the two layers join (fig. 24). This brown colour is destroyed by heat; hence the tube must be kept quite cold during this test.

199. **Copper Turnings (Cu)** added, after acidifying with strong sulphuric acid (H_2SO_4), gives off brown fumes either at once or on warming the tube.

200. Heated with indigo and sulphuric acid the indigo is bleached. The most accurate method of applying this test is described in paragraph 87.

FIG. 24

CHLORIDE ('Cl).—Use sodium chloride (NaCl) solution.

201. **Silver Nitrate ($AgNO_3$)** gives a pure white precipitate of silver chloride (AgCl), soluble in ammonium hydrate (NH_4OH), insoluble in nitric acid (HNO_3).

Filter off a little of the precipitate and expose the filter-paper containing the precipitate near a window: it will be darkened by the action of the light.

202. **Strong Sulphuric Acid (H_2SO_4)** warmed with solid sodium chloride gives off fumes of hydrochloric acid (HCl), which redden blue litmus-paper.

203. The solid mixed with maganese dioxide (MnO_2) and strong sulphuric acid gives off a green gas, chlorine (Cl), which bleaches moist litmus-paper.

PHOSPHATE ($'''PO_4$).—Use sodium-hydrogen-phosphate ($Na_2HPO_4.12H_2O$) solution.

204. **Magnesium Sulphate** (Mg_2SO_4) to which has been added ammonium chloride (NH_4Cl) and a little ammonium hydrate (NH_4OH), gives a white crystalline precipitate of magnesium-ammonium phosphate ($MgNH_4PO_4.6H_2O$), soluble in acids.

205. **Ferric Chloride** (Fe_2Cl_6) added after acetic acid and sodium acetate gives a pale yellow precipitate of ferric phosphate ($FePO_4$), soluble in hydrochloric acid.

206. **Ammonium Molybdate** (NH_4HMoO_4) when warmed with a *little* phosphate solution gives a yellow precipitate. The ammonium molybdate should be in large excess, and the solution should be acidulated with nitric acid.

207. **Silver Nitrate** ($AgNO_3$) gives a yellow precipitate, soluble in ammonium hydrate (NH_4OH) or in nitric acid (HNO_3).

SILICATE ($''''SiO_4$).—Use sodium silicate (Na_2SiO_3) solution for liquid, and finely ground sand (SiO_2) for solid.

208. **Hydrochloric Acid** (HCl) gives a gelatinous precipitate of silicic acid (H_4SiO_4). This, however, sometimes remains in solution, in which case the liquid should be evaporated to dryness in a basin, moistened with strong hydrochloric acid, and boiled with water. An insoluble residue of silica (SiO_2) will remain.

209. If solid silica (SiO_2) be fused into a bead of sodium carbonate it causes the melted bead to froth, from the liberation of carbon dioxide.

210. If solid silica be fused into a bead of microcosmic salt ($NaNH_4HPO_4$) it is not dissolved, but floats about in semi-transparent particles.

TESTS FOR CARBON, NITROGEN, CHLORINE, AND SULPHUR IN ORGANIC COMPOUNDS

CARBON (C).—Use sugar.

211. Heated on platinum foil, carbonaceous substances generally blacken, from the separation of carbon. On continued heating the black substance burns away.

212. Copper Oxide (CuO), when heated with any substance containing carbon, sets free carbon dioxide. To perform this experiment mix a little sugar with three times its bulk of copper oxide and place at the bottom of a dry test-tube; cover with a little CuO. Fit a tube bent twice at right angles through the cork; let this tube dip into another test-tube containing lime-water, and heat the mixture. The lime-water will become milky.

NITROGEN (N).—Use urea, $CO(NH_2)_2$.

213. Soda-lime, on heating with most nitrogenous substances, liberates ammonia, which may be recognised by its smell and its action on turmeric-paper.

214. Sodium (Na) forms sodium cyanide when heated in a test-tube with most organic nitrogenous substances. On extracting with water, filtering, and adding a solution of ferrous sulphate containing a drop of ferric chloride and finally hydrochloric acid in excess, a precipitate of Prussian blue is left.

CHLORINE (Cl).—Use chloral hydrate.

215. Lime (CaO) when heated in a test-tube with an organic-chlorine compound forms calcic chloride ($CaCl_2$).

On dissolving in dilute nitric acid (HNO_3), filtering, and adding silver nitrate ($AgNO_3$), a white precipitate is formed.

SULPHUR (S).—Use albumen.

216. Boiled with dilute hydrochloric acid (HCl) and potassic chlorate ($KClO_3$) until the solution is colourless, sulphuric acid is formed, which may be tested for by barium chloride, when a white precipitate will be formed (194).

TABLES FOR QUALITATIVE ANALYSIS

The following Tables give the order in which the tests should be applied for the metals and acid-radicals treated of in the preceding pages

TABLE I.—PRELIMINARY EXAMINATION OF SOLID SUBSTANCES FOR METALS

217. Carefully note the appearance of the solid, such as *shape*, *colour*, *smell*, *hardness*, &c.

218. If a *solution* is being analysed it will be necessary, before proceeding with this examination, to evaporate a portion of the liquid to dryness and to use the dry residue.

219. Before applying the following tests finely powder some of the substance, using an agate mortar if it should be very hard.

Experiment	Observation	Inference
220. *Expt.* **1.**—Heat in a small test-tube or ignition-tube	1. The substance fuses and solidifies on cooling	Salts of K and Na or certain salts of Ca and Mg
	2. It sublimes . .	Ammonium salts
221.—Confirm by heating with potassium hydrate solution	Ammonia gas is given off which turns moistened turmeric-paper brown	Ammonium present
	3. Water is given off .	Presence of combined water
	4. It blackens . .	Presence of organic matter

Experiment	Observation		Inference
222. *Expt.* 2.—Take up a little of the substance on a loop of platinum wire, moisten with strong HCl, and hold in the Bunsen flame	1. Intense yellow coloration A crimson flame is seen when viewed through cobalt glass or indigo prism		Sodium Potassium also present
	2. Pale violet, crimson through indigo prism		Potassium
	3. Orange-red coloration		Calcium
223. *Expt.* 3.—Heat a small quantity of the substance in a borax bead first in the outer then in the inner blowpipe flame	*Colour of Beads*		
	Inner	Outer	
	1. Brown, hot and yellow cold	Olive green, hot and cold	Iron
	2. Reddish purple, hot and cold	Colourless, hot and cold	Manganese

If organic matter is present the following additional tests should be performed :—

224. **Carbon.**—Heat with CuO (212). Evolution of CO_2 shows presence of *carbon.*

225. **Chlorine.**—Heat with lime (215), dissolve in dilute HNO_3, and test with $AgNO_3$ solution ; a white precipitate indicates presence of *chlorine.*

226. **Sulphur.**—Heat with dilute hydrochloric acid and $KClO_3$ (216) ; filter, and add $BaCl_2$ solution ; a white precipitate shows presence of *sulphur.*

227. **Nitrogen.**—If ammonium salts are absent (221) heat the substance with soda-lime ; the evolution of ammonia gas (213) indicates organic nitrogen.

If ammonium salts are present heat the substance with KHO solution until ammonia gas ceases to be evolved ; filter, mix the residue with soda-lime, and heat in an ignition-tube; evolution of ammonia indicates presence of organic nitrogen.

WET EXAMINATION FOR METALS

228. If the substance be a solid it is first of all necessary to bring it into solution.

Finely powder the substance in a mortar. If the substance is very hard an agate mortar must be used.

229. Process of Solution.—Boil up as much of the powdered solid with distilled water as will cover a shilling. If the substance dissolves proceed with the analysis. If some remains undissolved heat another portion of the solid with dilute hydrochloric acid for several minutes. If all dissolves proceed with the analysis. If all does not dissolve heat a fresh portion with strong hydrochloric acid to which has been added a little strong HNO_3; dilute, filter if necessary, and proceed with the analysis. If any residue is left it will require treating as an insoluble substance by paragraph 250.

NOTES TO TABLE II.

230.—If the temperature of ignition be too high, insoluble Al_2O_3 and Fe_2O_3 will be formed which will not redissolve when treated with HCl. If organic matter is present the dish should be gently heated with a small flame until the black carbonaceous matter is burnt away.

231.—If AmCl is added in insufficient quantity Mn and Mg may be precipitated with AmHO. If AmCl is added in very large quantity MnS is prevented from precipitating when Am_2S is added.

232.—Since traces of Mn may be precipitated with AmHO, it is as well to test a portion of this residue for Mn by fusion on platinum foil with Na_2CO_3 and KNO_3, when a green mass will be formed.

233.—Since HNO_3 has been added in an earlier part of the analysis, the iron at this stage will be in the ferric state. A small quantity of the original substance dissolved in HCl should be tested for ferrous and ferric iron by paragraphs 165 and 171.

234.—Commercial KHO and NaHO frequently contain Al. These reagents should be tested by acidulating and adding AmHO.

235.—Potassium may also be detected at this stage by adding a small quantity of strong platinum chloride solution and stirring with a glass rod; a yellow precipitate of K_2PtCl_6 will be formed if K is present.

236.—TABLE II. FOR THE

Test for **ammonium** by heating the original solid with KHO solution,
original solution (229) if not already acid add HCl in excess. Add a few
ignite over the Bunsen flame (230). Treat with a little strong HCl, warm,

<table>
<tr>
<td rowspan="3">Residue is SiO_2
This residue should be quite white</td>
<td colspan="2">The filtrate may contain Al,
Add a few drops of this solution to some ammonium-
are present; <i>if not, phosphates are absent.</i>
To the rest of the solution add AmCl in moderate quantity
phate is present, examine this precipitate by Table III.; if
examined as below.</td>
</tr>
<tr>
<td colspan="2">Precipitate may contain $Fe_2(HO)_6$, $Al_2(HO)_6$ (232)
If the precipitate is quite white, aluminium only will be present; if coloured, iron will probably be present. Dissolve the residue in hot dilute HCl, add pure KHO or NaHO in excess, then add more KHO so as to have considerable excess. Warm and filter</td>
</tr>
<tr>
<td>Residue will be $Fe_2(OH)_6$
Dissolve in hot dilute HCl and add <i>KCNS</i>, a blood-red coloration shows
Presence of Fe (233)</td>
<td>Filtrate will contain $Al_2(OH)_6$ dissolved in excess of <i>KHO</i>
Add strong HCl until the solution is distinctly acid, then add <i>AmHO</i> very cautiously until the solution is faintly alkaline. A white gelatinous precipitate shows
Presence of Al (234)</td>
</tr>
</table>

SEPARATION OF THE METALS

ammonia gas will be evolved which turns turmeric-paper brown. To the
drops of strong HNO_3, evaporate to dryness in a porcelain dish, and very gently
add water and filter.

Fe, Mn, Ca, Mg, K, Na

molybdate solution and warm; if a yellow precipitate forms, phosphates

(231), heat to boiling, and then add AmHO in excess; filter. If a phos-
absent, examine the precipitate as below. In any case the *filtrate* must be

Filtrate may contain Mn, Ca, Mg, K, Na

Add Am_2S until the solution has a distinct yellow tinge. Warm and filter

<table>
<tr>
<td rowspan="3">**Buff precipitate will be MnS**
Confirm by heating on platinum foil with Na_2CO_3 and KNO_3; a green mass shows
Presence of Mn</td>
<td colspan="3">**Filtrate may contain Ca, Mg, K, Na**
Add ammonium oxalate ($Am_2C_2O_4$) *solution in fair* excess, filter</td>
</tr>
<tr>
<td rowspan="2">**White precipitate will be CaC_2O_4 *showing* presence of Ca**</td>
<td colspan="2">**Filtrate may contain Mg, K, Na**
Evaporate the filtrate to dryness in a porcelain dish, scrape out the residue on to a piece of platinum foil, ignite until all fumes *cease to be evolved. Boil the foil in a* ***very*** **small quantity** of water containing a few drops of HCl. Divide into two portions.</td>
</tr>
<tr>
<td>**Examination for Mg**
Add AmCl, AmHO *in* excess, and Na_2HPO_4 and shake well; a white crystalline precipitate shows
Presence of Mg</td>
<td>**Examination for K and Na**
Take up a little of the *solution* on the loop of platinum wire and hold in the Bunsen flame.
(1) A pale violet flame shows
Presence of K and absence of Na
(2) A bright yellow flame shows **presence of Na.** Examine this flame through the indigo prism or cobalt glass; a crimson *flame shows*
Presence of K (235)</td>
</tr>
</table>

237. TABLE III.—FOR THE EXAMINATION OF THE PHOSPHATE PRECIPITATE

The AmHO precipitate may contain $FePO_4$, $AlPO_4$, $Ca_3P_2O_8$, $MgNH_4P_2O_8$

Dissolve the precipitate in hot dilute HCl. To the solution add Am_2CO_3 solution, drop by drop, until the precipitate first formed redissolves with difficulty (238). Add a fair quantity of a mixture of acetic acid and ammonium acetate solution, and then add Fe_2Cl_6 until the liquid becomes reddish ; warm and filter.

<table>
<tr>
<td colspan="2">Filtrate may contain Ca and Mg
Add AmHO in excess, filter and add $Am_2C_2O_4$ solution ; warm and filter</td>
<td colspan="2">Precipitate may contain $FePO_4$ and $AlPO_4$
<i>Heat precipitate with KHO solution</i> ; filter</td>
</tr>
<tr>
<td>Precipitate will be CaC_2O_4 showing <i>presence</i> of Ca</td>
<td>Filtrate may contain Mg
Add Na_2HPO_4 solution and shake ; a white crystalline precipitate shows Presence of Mg</td>
<td>Filtrate may contain $AlPO_4$ dissolved in KHO
Add HCl in excess, then AmHO in very slight excess ; a white gelatinous precipitate shows Presence of Al</td>
<td>Precipitate will contain $FePO_4$, which reject, since iron will always be found at this stage owing to Fe_2Cl_6 having been added (239)</td>
</tr>
</table>

EXPLANATION OF THE PHOSPHATE TABLE

238.—The separation of the above phosphates depends on the following facts :—

The phosphates of iron and aluminium are insoluble in acetic acid, whereas those of calcium and magnesium are soluble. Hence the HCl solution of the phosphates is altered by the addition of HĀ and AmĀ into an acetic acid solution, when $AlPO_4$ and $FePO_4$ precipitate. The Fe_2Cl_6 is added for the purpose of precipitating the remainder (if any) of the phosphoric acid as $FePO_4$, and so leaves the Ca and Mg as acetates, which are then tested for by the usual reagents.

239.—This precipitate of $FePO_4$ is neglected here, since F_2Cl_6 has been added. Iron should be tested for in the original solution by tests (165 and 171). It should be noted that the metals Ca and Mg may also be present 'not as phosphate,' and of course will be found in Table II.

The four metals, Fe, Al, Ca, and Mg, should be returned 'as phosphate' or 'not as phosphate,' exactly as they are found.

TABLE IV.—PRELIMINARY EXAMINATION FOR ACID-RADICALS

In the following tests either the solid or a **strong** solution may be used :—

Test	Observation	Inference
240. *Expt.* I.—Treat a little of the substance with dilute HCl and heat gently	1. A colourless gas is given off which turns lime-water milky	CO_2 from a carbonate
	2. Red fumes	N_2O_3 from a nitrite
241. *Expt.* II.—Heat a little of the substance with strong H_2SO_4	1. A gas with a pungent acid smell is given off which fumes in the air and turns a drop of silver nitrate solution milky	HCl from a chloride
242.—Confirm by heating another portion with MnO_2, free from chloride, and strong sulphuric acid	A pale yellow gas is given off with choking smell, and which bleaches test-papers	Cl from a chloride
	2. An acid gas is given off, occasionally reddish in colour	Presence of a nitrate
243.—Confirm by dropping a few Cu turnings into the liquid and heat again	Red fumes given off	NO from a nitrate

TABLE V.—FURTHER EXAMINATION FOR ACID-RADICALS

244. **Sulphate.**—Boil a little of the original substance with dilute HCl, filter, and add barium chloride solution ; a white precipitate of $BaSO_4$ shows *presence of a sulphate.*

245. **Chloride.**—Boil a portion of the original substance with dilute HNO_3, filter, and add $AgNO_3$ solution ; a white precipitate denotes *presence of a chloride.*

246. Nitrite.—Boil with water, filter, and test with KI solution, starch, and $\bar{HA}$ (197); a blue coloration will appear.

247. Nitrate.—Boil the original substance with water; filter, cool under the tap, and add very cautiously an equal bulk of strong sulphuric acid; cool in water. When quite cold add slowly down the sides of the tube a little of a cold solution of $FeSO_4$. Where the liquids come in contact a brown ring will be formed.

248. Phosphate.—A phosphate, if present, will usually have been detected in Table II. (236). It is readily detected by boiling the original substance with dilute HNO_3 and then adding a few drops of this solution to ammonium molybdate solution; a yellow precipitate forms on warming.

249. Silicate.—A silicate will usually be found in Table II. (236). It may be readily detected if a little of the finely powdered substance is fused with Na_2CO_3 on platinum foil, and then treated with HCl. On evaporating to dryness the SiO_2 will be rendered insoluble, so that on treating with HCl and water the SiO_2 will be left as a white powder (208).

ANALYSIS OF SUBSTANCES INSOLUBLE IN WATER AND ACIDS

250. The insoluble substances usually associated with agricultural products are silica, silicates, and phosphates.

251. Mix the finely powdered substance with six times its weight of fusion mixture (268). Place in a porcelain or, preferably, a platinum crucible. Heat gently at first, then strongly over the blowpipe. Continue the heating until all effervescence ceases. Allow to cool and place the crucible and contents in a beaker, and gently heat with dilute HCl until the residue is all dissolved, or only gelatinous silica is left. Transfer to a porcelain dish, cautiously evaporate to dryness, and ignite gently. Now cover with strong HCl, warm, and dilute with water. The silica will be left in an insoluble form, and may be filtered off.

252. The solution is then examined for metals by Tables II. and III. (236 and 237), and for acid-radicals by Tables IV. and V. (240-249).

253. Since HCl has been added, a portion of the original powder should be boiled with sodium carbonate solution, the solution filtered, and then tested for chloride by adding dilute HNO_3 in excess, and afterwards $AgNO_3$ solution, when a white precipitate of silver chloride will form if chloride is present.

254. Nitrates are not found in insoluble bodies, as all nitrates are soluble in water.

255. Since Na and K cannot be tested for in the solution obtained after fusion, owing to the fusion mixture consisting of Na_2CO_3 and K_2CO_3, it is necessary to use a separate portion for the detection of these metals.

256. The most convenient method is that of Lawrence Smith. Mix the powdered substance with six times its weight of a mixture of one part pure solid AmCl and six parts pure precipitated $CaCO_3$. Place in a crucible, and heat to redness for twenty minutes. Allow to cool, boil up with water, and filter. The filtrate will contain the alkalies together with excess of calcium hydrate. Precipitate the calcium by adding AmHO, Am_2CO_3, and a few drops of $Am_2C_2O_4$ solution; filter, evaporate to dryness, and ignite.

257. Dissolve in a very small quantity of water; test for sodium by holding a little of the solution in the Bunsen flame on a platinum wire, when the golden flame coloration will be seen if Na is present.

258. Potassium may be detected by viewing the flame through an indigo prism or cobalt glass, when the crimson *coloration will be seen if K is present.* Potassium may also be detected by platinum chloride (188).

259.—EXAMPLE OF METHOD OF ENTERING THE RESULTS OF AN ANALYSIS IN THE NOTE-BOOK

Examination of pale brown earthy substance

Preliminary Examination for Metals

Experiment	Observation	Inference
1. Heated in an ignition-tube	Little water given off; no charring	H_2O present, organic matter absent
2. Heated on Pt wire *in Bunsen flame after* moistening with HCl	Yellowish - red *flame*	Trace Na; Ca *present*
3. Heated in borax bead	No result	Fe, Mn probably absent

Wet Examination

Boiled substance with water; did not dissolve. Treated with dilute HCl, all dissolved. Evaporated to dryness, moistened with HCl, added water, filtered off trace of SiO_2, and tested filtrate for metals.

Heated a few drops of solution with ammonium molybdate, obtained no precipitate; hence phosphates were absent. To bulk of solution added AmCl and AmHO.

	To solution added $Am_2C_2O_4$, filtered		
No precipitate; ∴ Fe and Al absent	White precipitate Ca present	Evaporated to dryness, ignited, dissolved residue in dilute HCl, divided into two portions	
		1. Added AmHO and Na_2HPO_4, white crystalline precipitate Mg present	2. Tested on Pt wire in Bunsen flame, faint yellow flame, no crimson colour through prism ∴ Trace Na present

Preliminary Examination for Acid-radicals

1. Heated with dilute HCl	Gas given off with effervescence, which turned lime-water milky; no red fumes evolved	Presence of carbonate Nitrite absent
2. Heated with strong H_2SO_4	Ditto	Probable absence of chloride and nitrate

Wet Examination for Acid-radicals

1. Heated substance with dilute HCl, filtered, added $BaCl_2$ and warmed	Faint white precipitate	Trace of sulphate
2. Heated substance with dilute HNO_3, filtered, and added $AgNO_3$	Faint milkiness	Trace of chloride
3. Heated substance with water, filtered, added strong H_2SO_4, *cooled, and then* added cold $FeSO_4$ solution	No brown ring	Nitrate absent

Phosphate was shown to be absent in the wet examination for the metals.

Found: Ca, Mg, water, carbonate, traces of sodium chloride, silicate, and sulphate

SECTION V

APPARATUS, CHEMICALS AND REAGENTS

List of Bench Apparatus for each Student

260. A list of the apparatus which should be kept in each bench-locker is given here. The Bunsen burner, with its indiarubber tube, may be left attached to the gas-tap on the bench. All the other apparatus should be locked up in the bench-locker when not in use.

1 Bunsen burner about $5\frac{1}{2}$ inches high, with $\frac{3}{8}$-inch tube, and means of closing the air-holes.

1 Rose-top to fit burner.

1 Piece of black indiarubber tubing, $\frac{5}{16}$ inch internal diameter and 16 inches long, to supply gas to the burner.

1 Test-tube stand with twelve holes, two of which are at least an inch across.

1 Test-tube brush.

12 Test-tubes, 5 inches long by $\frac{5}{8}$ inch diameter.

2 Boiling-tubes, 6 inches long by 1 inch diameter.

2 Round glass plates, ground on one side, 3 inches across.

2 Berlin porcelain evaporating-dishes with spouts, glazed inside and out, and 3 inches in diameter.

2 Watch-glasses, 2 inches across.

Conical flask, 4 oz. capacity.

1 Wedgwood mortar, 4 inches across, and pestle with wooden handle.

1 Iron tripod stand, 7 inches high, with round top 4 inches across.

1 Piece of coarse iron wire gauze, 5 inches square.

3 Glass funnels, two of them $2\frac{1}{2}$ inches across, one 2 inches across.

3 Beakers, wide form of 1, 2, and 3 oz. capacity.

3 Glass rods, rounded at the ends, 7, 6, and 3 inches in length.

1 Piece of platinum foil, $1 \times 1\frac{1}{2}$ inch.

2 Pieces of platinum wire, mounted (7).

1 Black's blowpipe, japanned tin.

1 Pipe-clay triangle, 2 inches along the side.

1 Wash bottle, to be made from 18 oz. flask (10).

1 Retort stand. Upright rod 17 inches, foot 6×3 inches, with three brass rings, the largest 3 inches across.

1 Wooden filter-stand, 12 inches high, with two rings.

1 Pair polished brass crucible tongs, 6 inches long.

1 Small horn spatula, $3\frac{1}{2}$ inches long.

1 Oval wicker draining basket, $10 \times 8 \times 4$ inches.

Cut filter-papers, $4\frac{1}{2}$, $3\frac{1}{2}$, and $2\frac{3}{4}$ inches across.

1 White porcelain tile, $4\frac{1}{2}$ inches square.

LIST OF SPECIAL APARATUS FOR SECTIONS I., II., AND III.

261. This apparatus need not be supplied to each student, but several sets should be kept.

1 Nest of three or four small brass cork-borers.

1 Triangular file.

1 Thin round file.

Several lengths and pieces of hard glass-tubing, about $\frac{1}{8}$ inch internal diameter.

1 Gross ignition-tubes, 3 inches long, $\frac{1}{2}$ inch across.

1 Gross corks, as free as possible from holes or cracks, varying from $\frac{3}{8}$ to $\frac{3}{4}$ inch across.

1 Small metal clamp in a boss fitting the retort stand (*fig.* 15).

1 Stoppered bell-jar, 30 oz. capacity.

4 Glass cylinders on feet with ground edge at top, 8 inches high, $1\frac{3}{4}$ inch across.

4 Similar cylinders, 6 inches high, $1\frac{1}{2}$ inch across.

1 Round brown stoneware trough, 12 inches across. 5 inches deep.

1 Metal deflagrating-spoon.

2 Two-necked Woulffe's bottles, 8 oz. capacity.

1 Tubulated retort, 6 oz. capacity.

2 Thistle funnels, 8 inches long.

4 Pieces of black indiarubber tubing, $\frac{3}{16}$ inch in internal diameter, $1\frac{1}{2}$ inch long.

Wooden spills.

Wax tapers.

1 Pair of scissors.

1 Brass wire sieve, 20 meshes to the inch.

List of Apparatus for General Use in Analysis

262. The following apparatus should be kept in the laboratory for the general use of students. One set will suffice for about twelve students.

1 Spirit-lamp, 4 oz. capacity, with earthenware wick-holder and ground glass cap.

If gas is not available a set of these lamps will be required in place of Bunsen burners (260).

4 Berlin porcelain crucibles, $1\frac{1}{2}$ inch across, with covers.

1 Iron mortar, 8 inches across, with pestle.

1 Fletcher's foot-bellows and blowpipe table covered with sheet zinc or lead.

1 Fletcher's blowpipe with central blast and 2 taps.

1 Indigo prism, stoppered, nearly filled with solution of indigo in strong sulphuric acid. The indigo solution is made by mixing commercial sulphindigotic acid with ten times its measure of strong sulphuric acid, leaving to settle for several days and decanting into the prism.

N.B.—Cobalt-blue glass may be substituted for the above.

1 Agate mortar, 3 inches across, and pestle.

1 Copper water-bath, with several openings (fig. 11). When in use it should be two-thirds filled with water, and

more water added from time to time to make up for evaporation.

1 Steam-oven (fig. 14), made of copper. The water should two-thirds fill the oven, and should be kept just below boiling. The loss by evaporation should be made good from time to time.

CHEMICALS AND REAGENTS

263. In the following lists will be found the reagents and test substances required in the course. In the first column stands the name; in the second the chemical formula of the substance. The subsequent columns give directions for their preparation for laboratory use.

264.—Reagents required for each Bench

Name	Formula	Weight of solid in grams to be dissolved in one winchester of water	Proportion of solid by weight (w) or liquid by measure (m) to water
Sulphuric acid	H_2SO_4	—	1 : 5 m
Hydrochloric acid . .	HCl	—	1 : 3 m
Nitric acid	HNO_3	—	1 : 3 m
Acetic acid	$HC_2H_3O_2$ or HA.	—	2 : 1 m
Ammonium chloride . .	NH_4Cl	300	1 : 8 w
Ammonium hydrate . .	NH_4HO . . .	—	1 : 3 m
Ammonium sulphide . .	$(NH_4)_2S$ . . .	—	1 : 1 m
Ammonium carbonate (*note* 1)	$(NH_4)_2CO_3$ . .	400	1 : 6 w
Ammonium oxalate . .	$(NH_4)_2C_2O_4.H_2O$.	100	1 : 24 w
Potassium hydrate . .	KHO	300	1 : 8 w
Potassium ferrocyanide .	$K_4Fe(CN)_6.3H_2O$.	200	1 : 12 w
Potassium ferricyanide .	$K_3Fe(CN)_6$ (*note* 2)	200	1 : 12 w
Sodium phosphate . .	$Na_2HPO_4.12H_2O$	200	1 : 12 w
Sodium carbonate . .	$Na_2CO_3.10H_2O$.	600	1 : 4 w
Calcium sulphate . . .	$CaSO_4$	Saturated solution	
Barium chloride . . .	$BaCl_2.2H_2O$ . .	200	1 : 12 w
Sodium carbonate . .	Na_2CO_3 . . .	Solid	
Borax	$Na_2B_4O_7.10H_2O$.	Solid	
Potassium chlorate . .	$KClO_3$	Solid	
Test-papers		Blue and red litmus and yellow turmeric-papers in small strips	

Note 1.—The solid $(NH_4)_2CO_3$ is dissolved in cold water, but in diluting, one-fourth of the 'winchester' must be *filled with* strong NH_4HO.

Note 2.—This reagent undergoes decomposition by exposure to light, and must not be kept near a window: it is better to dissolve a fragment of the solid each time it is required.

265.—CHEMICALS REQUIRED FOR SECTIONS I. AND II.

With the exception of the bench reagents the whole of the substances required for these sections are enumerated below :—

Name	Formula	Remarks
Alum	$AlK(SO_4)_2 \cdot 12H_2O$	Solid
Ammonium *chloride*	NH_4Cl	Solid
Calcium chloride	$CaCl_2$	Solid and solution
Manganese sulphate	$MnSO_4$	Solid
Potassium nitrate	KNO_3	Solid
Marble	$CaCO_3$	In lumps
Manganese dioxide	MnO_2	Solid
Wood charcoal	C	In pieces the size of a hazel-nut
Lime-water	$Ca(OH)_2$	Solution
Sulphur	S	Pieces of roll sulphur the size of a pea
Phosphorus	P	Kept under water
Granulated zinc	Zn	*Not necessarily* pure
Hydrochloric acid	HCl	Strong
Sulphuric acid	H_2SO_4	Strong
Nitric acid	HNO_3	Strong
Potassium iodide	KI	Solid
Starch powder		—
Slaked lime	$Ca(OH)_2$	Solid
Ammonia	$NH_4(OH)$	Strong
Silver nitrate	$AgNO_3$	Solution
Methylated spirit	C_2H_6O	Free from coal-oil
Mercuric chloride	$HgCl_2$	Solid
Potassium hydrate	KHO	Solid
Nessler's Solution (*note* 1)	—	—

Note 1.—Dissolve 33 grams of KI and 13 grams of $HgCl_2$ in 800 c.c. of water, add strong $HgCl_2$ solution *until a faint permanent* precipitate is formed, then *add 160 grams of solid* KHO. Allow *to* cool *and make up to one* litre *with water.* Use the clear supernatant liquid.

266.—SUBSTANCES USED FOR SECTION III.

Name	Formula	Remarks
Loam	—	—
Lime-water	$Ca(OH)_2$	Solution
Clay	—	Air-dried
Marble	$CaCO_3$	Ground fine
Peat soil	—	Air-dried
Quicklime	CaO	Freshly burned
Litmus solution	—	—
Ferrous sulphate	$FeSO_4.7H_2O$	Solid
Gas-lime	—	Fresh
Gypsum	$CaSO_4.2H_2O$	Solid
Charcoal	C	Powder
Kainit	$K_2Mg(SO_4)_2.6H_2O$	Commercial
Coprolite powder	—	—
Basic slag	—	—
Superphosphate of lime	$CaH_4(PO_4)_2$	Commercial
Citrate of ammonium (*note* 1)	$(NH_4)_3\overline{Ci}$	Solution
Sulphate of ammonia	$(NH_4)_2SO_4$	Commercial
Nitrate of soda	$NaNO_3$	Commercial
Shoddy	—	—
Soda-lime	—	Granulated
Indigo carmine	—	Solution
Sulphuric acid	H_2SO_4	Strong
Peruvian guano	—	—
Ammonium molybdate (*note* 2)	NH_4HMoO_4	Solution
Ferric chloride	Fe_2Cl_6	Solution
Potassium sulphocyanide	$KCNS$	Solution
Bone-meal	—	—
Linseed cake	—	Ground fine
Cotton cake, decorticated	—	Ground fine
Cotton cake, undecorticated	—	Ground fine
Glycerine	$C_3H_5(OH)_3$	—
Ether	$C_4H_{10}O$	—
Fehling's Solution (*note* 3)	—	—
Solution of iodine in potassium iodide	I and KI	—
Alcohol	C_2H_6O	Free from coal-oil
Hay	—	—
Turnips	—	Provided fresh when wanted
Cane sugar	—	Crystallised
Glucose	—	—
Carbolic acid	—	80 % solution B.P.
Flour	—	Wheaten
Milk	—	Fresh
Butter	—	Fresh
Cheese	—	Fresh

Note 1.—Made by rendering a strong solution of citric acid distinctly alkaline with ammonia.

Note 2.—Measure 100 c.c. water into a large flask, add 50 grams molybdic acid or 70 grams of ammonium molybdate, then 100 c.c. of strong ammonia ; stir until dissolved. Pour the solution into 720 c.c. cold nitric acid, sp. g. 1·20, stirring whilst adding.

Note 3.—Best kept as two solutions, A and B : A contains about 35 grams of copper sulphate dissolved in 500 c.c. of water, B contains 173 grams of Rochelle salt (sodium potassium tartrate) and 160 grams of potassium hydrate in 500 c.c. of water. For immediate use equal quantities of each are mixed.

267.—REAGENTS FOR GENERAL USE FOR THE DETECTION OF METALS

Name	Formula	Proportion by weight of solid to water
Sulphuric acid . . .	H_2SO_4 . .	Strong pure
Hydrochloric acid . .	HCl . .	Strong pure
Nitric acid . . .	HNO_3 . .	Strong pure
Platinum chloride . .	$PtCl_4$ . .	1 : 30
Methylated spirit . .	C_2H_6O . .	Strong
Slaked lime . . .	$Ca(HO)_2$.	Solid
Potassium sulphocyanide.	KCNS . .	1 : 100
Potassium nitrate . .	KNO_3 . .	Solid
Silver nitrate . . .	$AgNO_3$.	1 : 100
Magnesium sulphate .	$MgSO_4.7H_2O$	1 : 12

268.—REAGENTS FOR GENERAL USE FOR THE DETECTION OF ACID-RADICALS

Name	Formula	Proportion by weight of solid to water
Lime-water	$Ca(OH)_2$	Saturated
Ferric chloride (*note* 1)	Fe_2Cl_6	1 : 24
*Ferrous sulphate	$FeSO_4.7H_2O$	Solid
Potassium iodide	KI	1 : 60
*Starch	—	—
Indigo carmine solution	—	—
Manganese dioxide (*note* 2).	MnO_2	Solid
Ether (methylated)	—	—
*Potassium nitrite	KNO_2	Solid
Ammonium molybdate (*n.* 3)	NH_4HMoO_4	—
Microcosmic salt	$NaNH_4HPO_4.4H_2O$	Solid
Wax or paraffin	—	Solid
Distilled water	H_2O	—
Pure sodium hydrate	$NaHO$	1 : 10
Fusion mixture (*note* 4)	$K_2CO_3 + Na_2CO_3$	—
Solution of sodium acetate in dilute acetic acid (*note* 5).	NaA and $H\bar{A}$	—
Calcium carbonate, pure	$CaCO_3$	Powder
Ammonium chloride, pure	NH_4Cl	Powder
*Potassium ferricyanide	$K_3Fe(CN)_6$	Solid

* These solids do not keep in solution.

Note 1.—The solution should not contain any free acid. To remove this AmHO is added until the further addition of a single drop gives a reddish-brown precipitate. Filter off this precipitate, and the solution is ready for use.

Note 2.—Should be kept in fine powder; it must not evolve Cl or CO_2 when warmed with strong H_2SO_4.

Note 3.—See *note* 2, paragraph 266.

Note 4.—Dry finely powdered Na_2CO_3 and K_2CO_3 are mixed in proportions of 53 : 69 by weight and kept in a stoppered bottle.

Note 5.—Dissolve 20 grams $Na\bar{A}$ in 60 c.c. of distilled water and add to the solution 40 c.c. of strong $H\bar{A}$.

269.—Solutions for the Reactions of the Metals

Name	Formula	Weight of solid in grams to be dissolved in one winchester of water	Proportion by weight of solid to water
Potassium chloride	KCl	100	1 : 25
Ammonium chloride	NH_4Cl	200	1 : 12
Sodium chloride	NaCl	50	1 : 50
Magnesium sulphate	$MgSO_4.7H_2O$	50	1 : 50
Calcium chloride	$CaCl_2.6H_2O$	200 (in crystals)	1 : 12
Alum	$AlK(SO_4)_2 . 12H_2O$	200	1 : 12
Ferric chloride	Fe_2Cl_6	25	1 : 100
Ferrous sulphate	$FeSO_4.7H_2O$	25	1 : 100
Manganese sulphate	$MnSO_4$	25	1 : 100

270.—Solutions for the Reactions of the Acid-radicals

Name	Formula	*Weight of solid* in grams to be dissolved in one winchester of water	Proportion by weight of solid to water
Sodium sulphate	$Na_2SO_4.10H_2O$	25	1 : 100
Sodium carbonate	Na_2CO_3	—	Solid
Potassium nitrite	KNO_2	100	1 : 25
Potassium nitrate	KNO_3	100	1 : 25
Sodium chloride	NaCl	50	1 : 50
Sodium phosphate	$Na_2HPO_4.12H_2O$	50	1 : 50
Sodium silicate	Na_2SiO_3	100	1 : 25
Silica (white sand)	SiO_2	—	Solid

Note.—The above substances (269, 270) will also be required in the solid form for many of the tests.

271.—LIST OF CHEMICAL ELEMENTS, WITH THEIR SYMBOLS AND ATOMIC WEIGHTS

The words in brackets are the Latin names of the elements from which the symbols have been derived.

Name	Symbol	Atomic Weight	Name	Symbol	Atomic Weight
Aluminium	Al	27	Molybdenum	Mo	96
Antimony (stibium)	Sb	120	Nickel	Ni	59
Arsenic	As	75	Niobium	Nb	94
Barium	Ba	137	Nitrogen	N	14
Beryllium	Be	9	Osmium	Os	190
Bismuth	Bi	209	Oxygen	O	16
Boron	B	11	Palladium	Pd	107
Bromine	Br	80	Phosphorus	P	31
Cadmium	Cd	112	Platinum	Pt	196
Cæsium	Cs	133	Potassium (kalium)	K	39
Calcium	Ca	40	Rhodium	Rh	104
Carbon	C	12	Rubidium	Rb	85
Cerium	Ce	140	Ruthenium	Ru	102
Chlorine	Cl	35·5	Selenion	Se	79
Chromium	Cr	52	Silicon	Si	28
Cobalt	Co	59	Silver (argentum)	Ag	108
Copper (cuprum)	Cu	63·5	Sodium (natrium)	Na	23
Didymium	D	142	Strontium	Sr	87·5
Erbium	E	166	Sulphur	S	32
Fluorine	F	19	Tantalum	Ta	183
Gold (*aurum*)	Au	197	*Tellurion*	Te	125
Hydrogen	H	1	Thallium	Tl	204
Indium	In	113·4	Thorinum	Th	232
Iodine	I	127	Tin (stannum)	Sn	119
Iridium	Ir	193	Titanium	Ti	48
Iron (ferrum)	Fe	56	Tungsten (wolframium)	W	184
Lanthanum	La	138	Uranium	U	240
Lead (plumbum)	Pb	207	Vanadium	V	51
Lithium	L	7	Yttrium	Y	89
Magnesium	Mg	24	Zinc	Zn	65
Manganese	Mn	55	Zirconium	Zr	91
Mercury (hydrargyrum)	Hg	200			

272.—THERMOMETRIC SCALES

There are two different thermometric scales in use in this country, the Centigrade and Fahrenheit; the former of these is rapidly becoming universal for scientific purposes. The two scales are mutually convertible by the following formulæ, in which F.° represents a temperature on the Fahrenheit scale, C.° a temperature on the Centigrade scale:—

$$\tfrac{5}{9}\,(\text{F.}^\circ - 32) = \text{C.}^\circ$$
$$\tfrac{9}{5}\,\text{C.}^\circ + 32 = \text{F.}^\circ$$

The temperatures occasionally referred to in this book are given on the Centigrade scale.

273.—English Weights and Measures

APOTHECARIES' WEIGHT

lb.		oz.		drms.		scruples		grains
1	=	12	=	96	=	288	=	5760
		1	=	8	=	24	=	480
				1		3	=	60
						1	=	20

AVOIRDUPOIS WEIGHT

lb.		oz.		drms.		grains
1	=	16	=	256	=	7000
		1	=	16	=	437·5
				1	=	27·343

IMPERIAL MEASURE

gallon		pints		fluid oz.		fluid drms.
1	=	8	=	160	=	1280
		1	=	20	=	160
				1	=	8

1 gallon = 70,000 grains of water at 16·7°C

1 fluid ounce = $\frac{1}{20}$ pint = 437·5 " "

1 gallon = 277·280 cubic inches

1 fluid ounce = 1·733 "

274.—Decimal Weights and Measures

MEASURES OF LENGTH — ENGLISH

		metre		inches		mile	furlong	yards	feet	inches
Millimetre	=	0·001	=	0·03937	=	.	.	.	.	0·03937
Centimetre	=	0·01	=	0·39371	=	.	.	.	.	0·39371
Decimetre	=	0·1	=	3·93708	=	.	.	.	.	3·9371
Metre	=	1·0	=	39·37079	=	.	.	.	3	3·371
Decametre	=	10·0	=	393·70790	=	.	.	10	2	9·7
Hectometre	=	100·0	=	3937·07900	=	.	.	109	1	1
Kilometre	=	1000·0	=	39370·79000	=	.	4	213	4	10·2
Myriometre	=	10000·0	=	393707·90000	=	6	1	156	0	6

1 inch = ·0254 metre.

1 foot = ·3048 "

MEASURES OF CAPACITY

1 litre = 1 cubic decimetre

		litre		cubic inches		pints
Millilitre, or Cubic centimetre (c.c.)	=	0·001	=	0·06103	=	0·00176
Centilitre	=	0·01	=	0·61027	=	0·01761
Decilitre	=	0·1	=	6·1027	=	0·17608
Litre	=	1·0	=	61·027	=	1·76077
Decalitre	=	10·0	=	610·27	=	17·60773
Hectolitre	=	100·0	=	6102·7	=	176·07734
Kilolitre	=	1000·0	=	61027·0	=	1760·77341
Myriolitre	=	10000·0	=	610270·0	=	17607·73414

1 cubic inch = 0·01639 litre.

1 cubic foot = 28·31531 litres.

1 gallon = 4·54336 "

MEASURES OF WEIGHT

1 gram = the weight of 1 cubic centimetre (c.c.) of water at 4° C.

		grammes		grains		Avoirdupois		
Milligram	=	0·001	=	0·01543				
Centigram	=	0·01	=	0·15432				
Decigram	=	0·1	=	1·54323				
Gram	=	1·0	=	15·43235		lb.	oz.	drms.
Decagram	=	10·0	=	154·32349	=	0	0	5·65
Hectogram	=	100·0	=	1543·23488	=	0	3	8·5
Kilogram	=	1000·0	=	15432·34880	=	2	3	5
Myriogram	=	10000·0	=	154323·48800	=	22	1	2

1 grain = 0·0649 gram.
1 oz. (Troy) = 31·1035 grams.
1 lb. (Avoirdupois) = 452·593 „

INDEX

PRINTED BY
SPOTTISWOODE AND CO. LTD., NEW-STREET SQUARE
LONDON