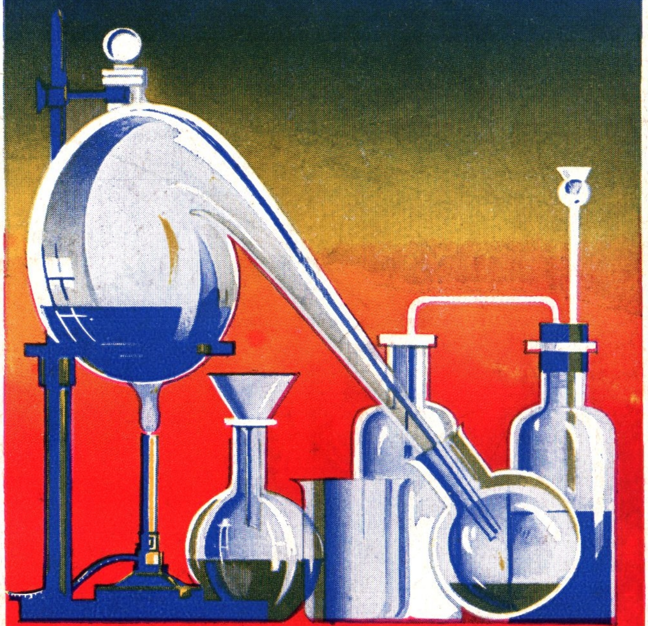
KEMEX

REGISTERED

CHEMICAL EXPERIMENTS



INSTRUCTIONS

FOR

No. O OUTFIT

MECCANO LIMITED
LIVERPOOL ENGLAND

PRICE - SIXPENCE

PRODUCT of MECCANO LIMITED LIVERPOOL

KEMEX

Reg. 538304

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CHEMICAL EXPERIMENTS

The Kemex Outfits have been introduced to provide apparatus, chemicals and instructions for carrying out a series of fascinating experiments in which the secrets of the wonderful science of chemistry are revealed.

This No. 0 contains everything necessary to perform 75 attractive experiments. In addition to making gases, preparing crystals and testing for acids and alkalies, there are fascinating amusements with a chemical garden that actually grows, and with mysterious inks that remain invisible until their secret is known.

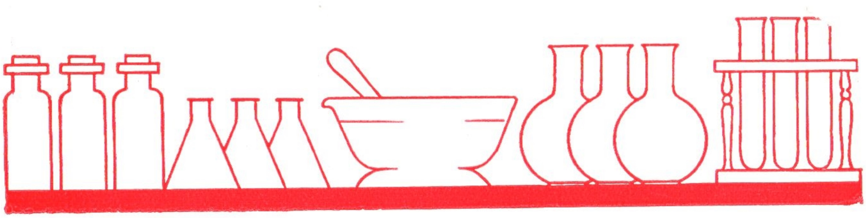
The No. 1 Outfit enables experiments to a total of 130 to be carried out. These include all that can be performed with the No. 0 Outfit, together with the extraction of an inflammable gas from water, fascinating experiments in diffusion, the production of smoke rings, and mystifying examples of chemical magic.

The No. 2 Outfit opens up a much wider range. Its contents enable all the No. 0 and No. 1 Outfit experiments to be performed. In addition, wool and silk can be dyed, soap can be made, and metals can be smelted from their compounds. With this Outfit 250 interesting experiments can be carried out.

The No. 3 Outfit completes the Kemex scheme, and with it from 350 to 400 experiments can be made. It covers the whole range of the No. 1 and No. 2 Outfits, and has additional apparatus and materials for a further series of experiments, showing how chemistry is applied in the home and in the factory.

To get the greatest fun from your Kemex Outfit you should read the "*Meccano Magazine*," in which special articles link up with the Outfits and describe new and interesting experiments in all branches of chemistry.

Kemex Outfits for Chemical Fun!



The Beginnings of Chemistry

The earliest chemical experiments date back to prehistoric times, and were concerned with the crude operations by which primitive Man produced metals from their ores. The first metals to be noticed by Man were probably gold and silver, which would attract his attention by reason of their bright colour, but are too soft to be made into satisfactory weapons or tools. Next came copper, which is more useful, especially when hardened by the addition of tin to form bronze.

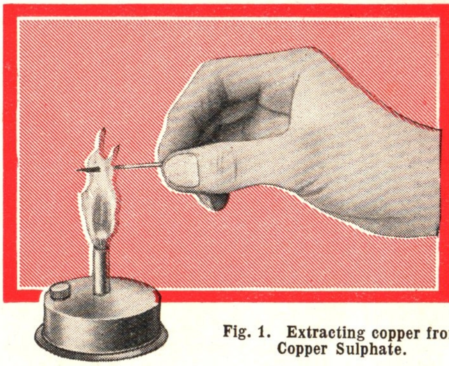


Fig. 1. Extracting copper from Copper Sulphate.

Experiment in Copper Smelting

In view of the great antiquity of copper smelting it will be interesting to commence our chemical experiments with one of this nature. For this we require a piece of wood about 4in. in length and about twice the thickness of a match. Hold the end in the flame of the Spirit Lamp (Part No. K22) until the wood begins to char, and then rub it with a large crystal of washing soda. Some of the soda is absorbed, and by repeating the action the end of the stick becomes transformed into a piece of charcoal thoroughly soaked in soda.

Crush a few small crystals of Copper Sulphate (No. K108); place as much as possible of the substance on the charred end of the stick, and hold this in the flame (Fig. 1). The blue powder becomes white, and further colour changes take place as the match continues to burn, the mass becoming black with a reddish tint in places. Stop the heating before the charred end of the wood burns away or falls off, and break the end off into a dish or small saucer half filled with water. With the point of a penknife, crush the charred end and stir it into the water, and then give the dish a circular movement in order to wash the remains. Add more water and continue the movement, tilting the dish slightly so that the water swirls out over the edge, a process similar to that used by gold prospectors when washing gold-bearing gravel in a pan. The light charcoal is washed away, the remaining soda is dissolved, and finally reddish-brown particles are left at the bottom of the dish. These particles are flakes of copper smelted out of the Copper Sulphate. Most of the water remaining on the copper may be removed by blotting paper, and the drying completed by leaving the dish in a warm place for a few minutes.

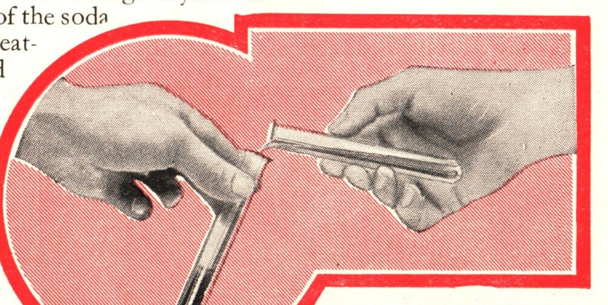


Fig. 2. Forming a precipitate by mixing solutions of different chemicals.

What is Chemical Change?

Chemistry shows that all things are built up of a certain number of elements, or simple substances that cannot themselves be split up, and to-day 91 chemical elements are recognised.

Substances that are not elements are known as compounds. They are built up from elements by combining these in various proportions, but they must be formed by what is known as a chemical change, in which is produced a substance that is entirely different from its components.

Fig. 3. Displacing copper from Copper Sulphate by means of Zinc.

The two following experiments will make clear the distinction between mere mixing and real chemical action. A Scoop (Part No. K36) is included in the Outfit for roughly measuring the quantities of chemicals required in experiments, and in this Manual one scoopful will be described as one measure. Add two measures of common salt to a Test Tube (Part No. K1) half full of water. Close the end of the test tube with the thumb and invert the tube rapidly several times so as to shake the salt and water together. The salt disappears, but its presence in the liquid may be shown by tasting it. The salt has not combined with the water to form a new substance. It has only dissolved to form a solution, and the change is not of the kind we have described as chemical.

Now mix two measures each of Sulphur (No. K131) and Iron Filings (No. K112) on the lid of a small tin. The particles of iron may readily be seen in this mixture, and may be extracted from it by means of a magnet. Thus no chemical change has taken place, for no new substance has been formed.

Heat the mixture by holding the tin in a pair of tongs over a fire or the flame of the spirit lamp. Some of the sulphur burns with a blue flame, but a black substance is formed in the tin. When this substance is cool, break it up and place part of it in a test tube. Add one measure of Sodium Bisulphate (No. K125) and cover with water. Bubbles are formed in the liquid, and a gas with the unpleasant smell of bad eggs is produced. This gas cannot be obtained by the action of Sodium Bisulphate on either Iron Filings or Sulphur. A new substance therefore has been formed, and the change has been chemical.

Burning of Magnesium

The burning of magnesium is another chemical change that is brought about by heating. Cut a piece of Magnesium Ribbon (No. K116) an inch in length, and hold one end of it in a flame by means of a pair of pliers or small tongs. The metal burns and a white ash that is a new substance is formed.

Many interesting chemical changes take place in solution in water. Dissolve one measure of Cobalt Chloride (No. K105) in a test tube one-third full of water, and add to it a solution of washing soda made by dissolving a few crystals in a test tube containing water to a depth of 1 in. A light blue solid is formed immediately the two liquids are mixed together (Fig. 2).

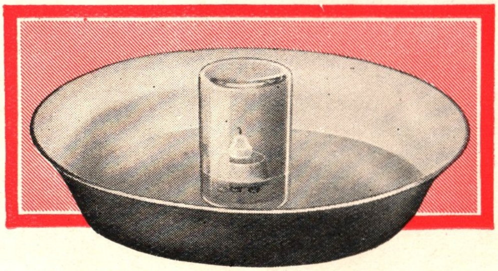


Fig. 4. Candle burning in a limited volume of air.

A solid formed in this manner is called a precipitate, for it is precipitated or thrown out of the liquid. In this case the solid is cobalt carbonate, an interchange taking place that gives also sodium nitrate, which is soluble in water and remains in solution.

In other interesting examples of chemical change, one metal may be made to displace another. Dissolve two measures of Copper

Sulphate (No. K108) in a test tube half full of water. Pour half of the solution into a second test tube, and dip in it the blade of your penknife, after cleaning the steel with emery paper. A reddish-brown coating is formed on the steel. This is copper, displaced from the solution of the chemical containing it, a little iron being dissolved in its stead.

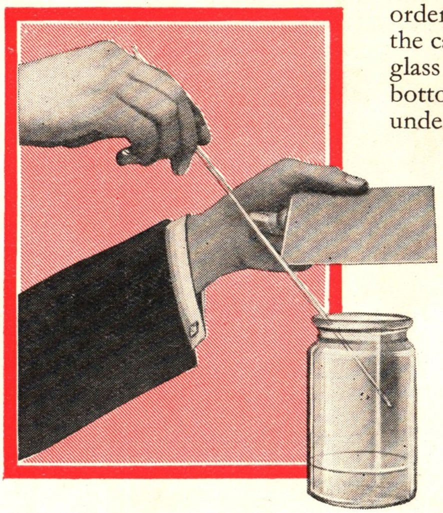


Fig. 5. Testing the gas left after a candle has burned.

To the remainder of the Copper Sulphate solution add three small pieces of Granulated Zinc (No. K134) and heat, holding the test tube in a holder made by folding a sheet of paper so as to form a four-fold strip about six inches in length and an inch in width. The mouth of the tube must point away from the face (Fig. 3). *This precaution should always be taken when heating a liquid in a test tube.* The Zinc acts on the hot Copper Sulphate solution and a reddish-brown powder is formed. This is copper, displaced by the zinc in the same manner as by the iron in the previous experiment. The solution becomes colourless and now contains zinc sulphate instead of Copper Sulphate.

Burning and Breathing

In one of the experiments already made we showed that the burning of magnesium is a chemical change. The burning of any combustible must be a change of this kind, for a new substance is always produced, and many striking experiments reveal the mysteries of burning and also of breathing.

For the first experiment fix a short piece of candle on a cork, and float this on water about 2 in. in depth in a shallow bowl or basin, screwing Meccano bolts into the underside of the cork if necessary in order to make it float upright. Light the candle and cover it with an inverted glass jar placed with its mouth at the bottom of the bowl, and of course under the surface of the water (Fig. 4).

The flame soon becomes paler and at last dies out altogether, and when the jar has become cold the level of the water in it is higher than at the beginning of the experiment. Thus some of the air has disappeared, although its escape was cut off. With the jar still upside down in the bowl extract the cork and candle. Then close the mouth of the jar with a sheet of paper or thin cardboard, and lift it out, placing it upright on the table. Test the remaining air by putting the lighted end of a taper in it, pulling the paper cover aside for this purpose (Fig. 5). The flame is immediately extinguished.

This experiment shows that air contains two gases, one of which is used up when the candle burns. The proportion removed in this manner is about one-fifth, and the remaining four-fifths is of no use for burning. The first of these gases is oxygen, formerly known as " fire air " because it is necessary

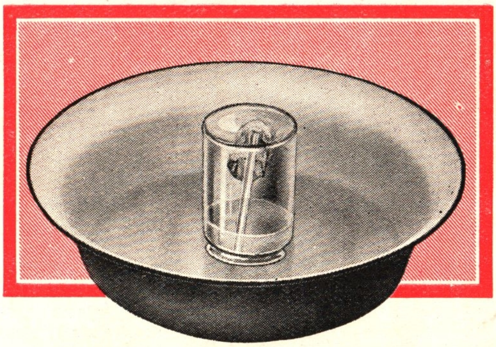


Fig. 6. Showing that the rusting of iron is slow burning.

in burning; and the second is called nitrogen. Both are elements.

The experiment may be repeated with sulphur instead of a candle. This substance is best placed on a small tin lid resting on the cork, and lighted by means of a match.

Rusting is Slow Burning

Now let us try a similar experiment with a metal that does not burn, but apparently undergoes a change of another kind when exposed to the air. This is iron, which rusts readily, especially in moist air, and the formation of the reddish-brown material is clearly a chemical change. Collect a number of small fragments of iron, such as tacks and small nuts and bolts. Wrap these in a piece of muslin and suspend them from the top of a short piece of wood inside a jar standing upside down in water (Fig. 6). Leave the jar undisturbed for a day or two and then examine the contents of the muslin bag; they will be found to have acquired a coating of rust. As the iron rusts the level of the water in the jar rises, showing that something is taken out of the air. No matter how much iron is enclosed in the muslin bag, however, or how long it stays in the jar, the proportion of air removed is never greater than one-fifth, and the gas remaining in the jar will not allow a taper to burn in it. It is, in fact, nitrogen, and the iron in rusting has removed the oxygen.

This experiment shows that rusting is a similar chemical change to burning, the only difference being that rusting takes place much more slowly than burning, and is not accompanied by a flame. Oxygen is necessary for both, and a candle will not burn, nor will iron rust, if this gas is absent.

Fig. 7. Breathing through lime water shows that breathing is a similar chemical change to burning.

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Place the cork with the piece of candle on it used in a previous experiment on the bottom of the jar and cover the jar with a piece of card. When the candle is lighted it burns for some time, but eventually is extinguished. Then lift out the cork and candle and pour part of the lime water into the jar. On shaking, the lime water becomes milky in appearance. This is a test for carbon dioxide, and the effect of the gas in the jar on the lime water is a proof that the burning of the candle has formation of this gas.

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extract it directly from the air, but fortunately it may be obtained by heating certain chemicals containing it. One of these is Potassium Chlorate (No. K122). Crush two measures of this to powder by means of a piece of hard wood and heat it in a test tube. It melts, and on further heating bubbles of oxygen rise to the surface.

In order to show that the gas produced is oxygen, put the glowing end of a half-burned chip of wood inside the tube. The wood will immediately burst into flame, for the glowing chip burns so furiously in the oxygen that the temperature rises to ignition point again. A glowing wood chip is an excellent means of testing for oxygen, and the wood spills sold by tobacconists are specially suitable for the purpose.

Making Oxygen

Making oxygen on a large scale and collecting it is one of the most interesting and attractive chemical experiments. The gas is best prepared by heating a mixture of powdered Potassium Chlorate (No. K122) and Manganese Dioxide (No. K118), a black substance that has the remarkable power of assisting the oxygen to escape from Potassium Chlorate at a lower temperature than would be required in its absence. Crush the Potassium Chlorate that still remains in the Outfit and mix it with about one-quarter of the amount of Manganese Dioxide. Put the mixture in a test tube that has been thoroughly dried by keeping it for some time in a warm place.

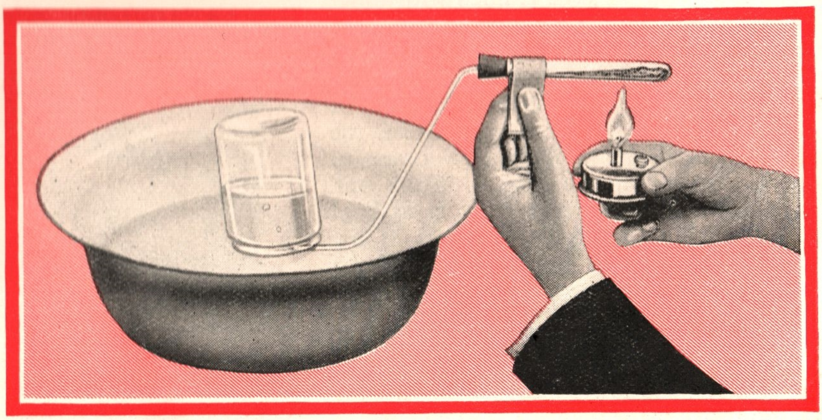

Fig. 8. Heating Potassium Chlorate and Manganese Dioxide and collecting the oxygen produced.

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These experiments give the solution to the problem of burning and rusting. What happens is that the substance concerned unites with the oxygen of the air, and for this reason the new compound formed is said to be an oxide. Thus iron rust is oxide of iron produced by the union of iron and oxygen ; the white ash formed when magnesium burns is magnesium oxide.

Detecting Invisible Gases

A candle and sulphur also form oxides when they burn in the air, but these are invisible because they are colourless gases. That formed when Sulphur burns is sulphur dioxide and may be detected by its choking smell. Carbon dioxide is formed when a candle burns, for carbon is the chief element present in the material of the candle. This gas has no smell, but is easily recognised, although colourless and invisible, as explained in the following experiment.

For this purpose lime water is required, and this is made by putting one measure of Calcium Oxide (No. K103) in a test tube containing water to a depth of about 2 in. Shake the test tube in order to dissolve as much lime as possible and allow the remainder to settle in the bottom of the tube. The clear liquid is a solution of lime and is usually known as lime water. Pour it carefully into a second test tube.

Place the cork with the piece of candle on it used in a previous experiment on the bottom of the jar and cover the jar with a piece of card. When the candle is lighted it burns for some time, but eventually is extinguished. Then lift out the cork and candle and pour part of the lime water into the jar. On shaking, the lime water becomes milky in appearance. This is a test for carbon dioxide, and the effect of the gas in the jar on the lime water is a proof that the burning of the candle has resulted in the formation of this gas.

IMPORTANT

CHANGE IN METHOD OF PREPARING OXYGEN.

In response to a suggestion from a Government authority, Potassium Chlorate (No. K122) has been withdrawn from Kemex Outfits. This chemical was used as a source of oxygen, and it is now replaced by Bleaching Powder (No. K135), which can be used with Cobalt Chloride (No. K105) for preparing this gas, in the following manner.

Fill a test tube with water, close it with the thumb, invert it with its mouth under water in a basin, and remove the thumb. The tube then remains full of water, and is allowed to rest with its upper end against the side of the basin. Deal similarly with two further test tubes.

Place six measures of Calcium Oxide (No. K103) with 12 measures of washing soda in a test tube half filled with water, and heat to boiling point. Allow the tube to cool and the solid material to settle, and then pour a few drops of the clear liquid into another tube containing a solution of six measures of Cobalt Chloride in about ½ in. of water in a separate tube. A blue precipitate that slowly changes to pink is obtained.

Place half the Bleaching Powder from the container in a test tube fitted with the Large Right Angle Delivery Tube (Part No. K13). Cover the chemical with water, and over it pour the precipitate from the Cobalt Chloride solution. The mixture immediately becomes black. Hold the test tube at an angle, so that the free end of the delivery tube dips below the water in the basin, and heat gently. Oxygen is then produced. Place each of the water-filled test tubes in turn over the end of the delivery tube, so that the gas bubbles into it, and leave the tubes under water until required for use.

With the gas thus collected experiments with oxygen described in the Manual can be carried out, a taper being used instead of a candle.

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to powder by means of a piece of hard wood and heat it in a test tube. It melts, and on further heating bubbles of oxygen rise to the surface.

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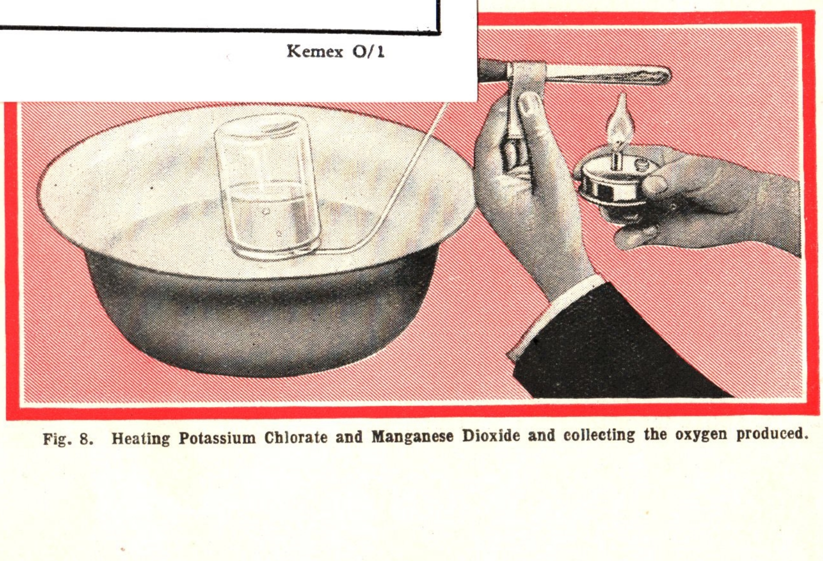


Fig. 8. Heating Potassium Chlorate and Manganese Dioxide and collecting the oxygen produced.

Next, carefully work one end of the Double Angle Delivery Tube (Part No. K14) through one of the small Bored Corks (Part No. K19)

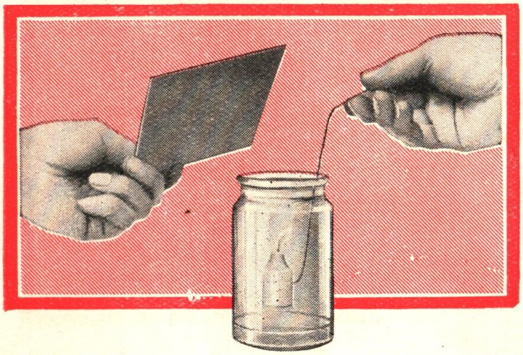


Fig. 9. A candle burns furiously and with a very brilliant flame in oxygen.

with a screwing motion, a direct push being avoided as this may cause breakage. Fit the cork thus equipped into the test tube containing the oxygen mixture.

Means of collecting the gas must be provided. Test tubes may be used as gasholders, but small glass jars are more suitable, and the quantity of Potassium Chlorate gives sufficient oxygen to fill three vessels of the size of 1-lb. jam jars. A further requirement is a small bowl containing water to a depth of about 2 in.

The first jar to be used is filled with water and its mouth closed by pressing on it a piece of paper. It is then placed upside down on the bottom of the bowl, and when the paper is removed the jar remains full of water, which is kept in position by the pressure of the atmosphere. In order to collect the gas to be given off in our experiment, all that is necessary is to hold the test tube so that the open end of the delivery tube is under the mouth of the inverted jar, when the gas will bubble up and displace the water (Fig. 8).

Tap the tube gently until the mixture forms a layer along the lower side, leaving a clear passage above it for the gas ; and commence to heat the mixture by moving the lighted spirit lamp backward and forward under the test tube. Bubbles of air driven out by the expansion due to heating first escape, but soon the stream becomes more rapid owing to the production of oxygen, and then the inverted jar must be placed above the end of the delivery tube. The spirit lamp may be put down for the brief time required for this, but a better plan is to call in the assistance of a friend, who can make himself useful by holding the jar in order to prevent it from toppling over, for it becomes unsteady when full of gas.

Stop the heating when all the water in the jar has been displaced by gas, and immediately lift the delivery tube away in order to avoid the inrush of cold water that would follow the cooling of the gas inside, for this would spoil the experiment and perhaps break the test tube. Then slip a sheet of paper over the mouth of the jar of oxygen and lift this out, keeping the paper tightly pressed down. To prevent the subsequent escape of the gas invert a saucer over the wet paper. The second jar may then be placed ready for use as a gasholder and the experiment continued until all three jars are full of oxygen.

Furious Burning in Oxygen

Pour water into the first jar to a depth of about half an inch, and then lower into it a lighted piece of candle impaled on a wire (Fig. 9). The candle burns so furiously that

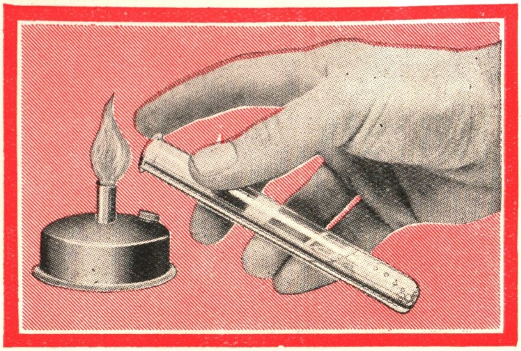


Fig. 10. Burning hydrogen at the mouth of the tube in which it is produced.

the tallow melts rapidly in the great heat that is developed in the chemical action.

The flame becomes duller and smokier when the oxygen in the jar has been used up. Remove the candle, cover the mouth of the jar, and shake the jar to bring the water into contact with the gas remaining in it. Then place the vessel and its contents on one side for use in a later experiment.

Similar experiments with Sulphur (No. K131) and Magnesium Ribbon (No. K116) are equally striking. In each case the bottom of the jar should be covered with water. One measure of Sulphur is sufficient and may be burned in a tiny spoon made by suspending a piece of tin from a stout wire. Ignite the Sulphur by means of the flame of the spirit lamp and lower it into the second jar of oxygen, when its pale blue flame becomes far more brilliant. As in the case of the candle, shake the jar in order to dissolve the gas produced and keep the solution for a further experiment.

Hold a piece of Magnesium Ribbon about 1½ in. in length in a small pair of pliers or tongs and ignite it before lowering into the third jar of oxygen. The Magnesium burns with a very brilliant flame in air, but the flame becomes dazzling in intensity the instant it is surrounded by pure oxygen. A white ash is formed and this may be allowed to drop into the water at the bottom of the jar, in which a little dissolves.

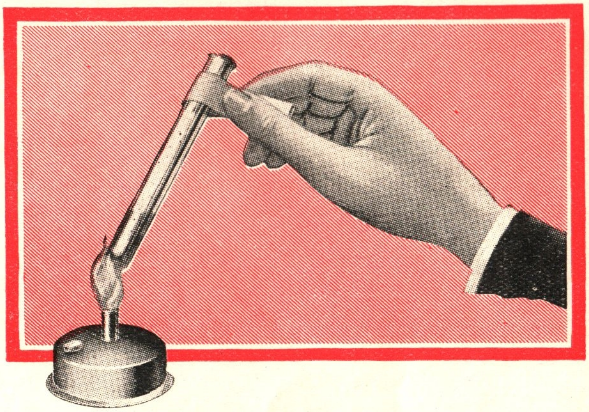


Fig. 11. Starch, sawdust, sugar and similar substances char when heated and give off inflammable gas.

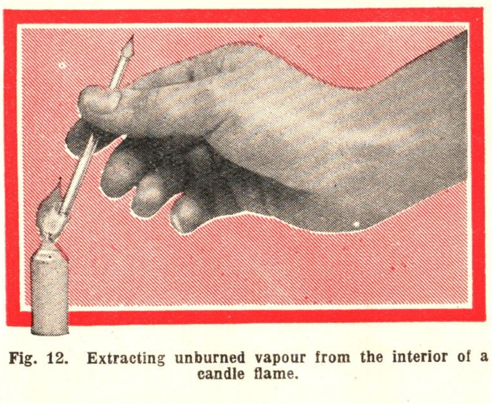


Fig. 12. Extracting unburned vapour from the interior of a candle flame.

Chemical Detectives

Heat a measure of powdered Litmus (No. K114) in a test tube half filled with water. The liquid is left to cool and any undissolved solid is allowed to settle before the clear liquid is poured off.

Pour a few drops of Litmus solution into the jars in which the candle and the sulphur were burned in oxygen. In the first jar the Litmus solution changes to a dull red and in the second to pink. The oxides of sulphur and carbon are said to be acid oxides, and the change of colour of the Litmus solution from blue to red is an indication of this.

It is not always convenient to use Litmus solution for tests of this kind, and Litmus papers are sometimes employed instead. These are easily made from the solution already prepared by dipping into it strips of fine-grained blotting paper and allowing them to dry. A convenient size for the strips is 2 in. by ¼ in.

There are substances that have the power of bringing about the reverse change, and the red Litmus solution obtained by the addition of a few drops of acid to the blue solution we have prepared is once more turned blue when one of them is added to it. These substances are called alkalies. Red Litmus papers to be used as tests for alkalies may be prepared by dipping the blue ones in a solution formed by adding a few drops of vinegar, or dilute hydrochloric acid obtained from a chemist, to a test tube almost full of water.

Use Litmus papers to test solutions of common substances such as washing soda, baking soda, and ammonia, and of Sodium Bisulphate (No. K125), Calcium Oxide (No. K103) and other chemicals included in the Outfit.

Other interesting indicators include the juices formed by crushing elderberries or dark coloured cherries, or by boiling shreds of fresh red cabbage with water. Test these also with substances known to be acids or alkalies.

Another chemical that can be used for detecting alkalies and acids is Logwood. Boil two measures of Logwood (No. K115) in a test tube half filled with water for about five minutes and pour off the clear solution left when the undissolved solid has settled to the bottom of the tube. Divide this red liquid into two portions. To one add a few small crystals of washing soda, and to the other a measure of Sodium Bisulphate (No. K125). The washing soda is alkaline and turns the Logwood solution blue; the Sodium Bisulphate, which is acid, changes the colour from red to yellow.

Hydrogen, Lightest of Gases

Dissolve two measures of Sodium Bisulphate (No. K125) in a test tube containing water to a depth of one inch and drop into the liquid a strip of Magnesium Ribbon (K116) half an inch in length. There is a violent action, and a gas is given off that burns with a blue flame when the mouth of the test tube is brought to the flame of the spirit lamp (Fig. 10). Similar results follow the use of Granulated Zinc (No. K134) or Iron Filings (No. K112) instead of Magnesium, but in these cases the action is less violent.

Hydrogen is colourless and has no smell. It is lighter than air, and may be collected in a test tube held above the mouth of the tube in which it is being produced. When collected in this manner the gas usually is mixed with a proportion of air, and there is a loud but harmless explosion when a light is applied to it.

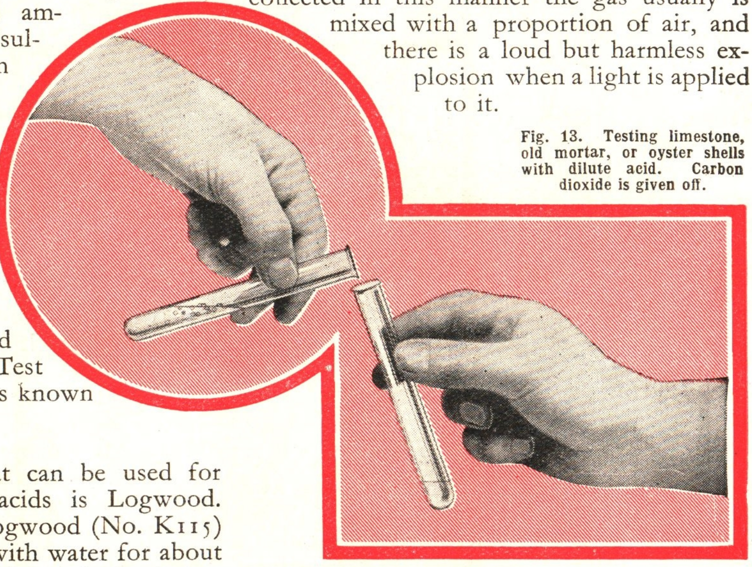


Fig. 13. Testing limestone, old mortar, or oyster shells with dilute acid. Carbon dioxide is given off.

Water, Nature's Solvent

Water is one of the most important chemicals, as well as being one of the most abundant, for it is as necessary to animal life as oxygen, and plants cannot grow without it. In nature this remarkable liquid occurs in the form of rain and in springs, rivers and oceans, but pure water is practically never met with, for the liquid is a wonderful solvent, being capable of dissolving a large number of substances. Even rain water contains dissolved carbon dioxide and other impurities derived from the air.

Pure water may be obtained by distillation, the name given to the double process of evaporation or change of liquid to vapour by heating, and condensation or the opposite change from vapour to liquid, brought about by cooling.

Place the large right-angle delivery tube in a small bored cork and fit this into a test tube. The delivery tube leads into a clean dry test tube, which stands in water in a basin. Water to a depth of about an inch is placed in the first test tube, and in order to show the effect of distillation a few crystals of common salt are added. Heat the salty water to boiling. Steam passes into the dry test tube, where it is cooled and condensed. The distilled water collected in this manner does not taste of salt, and also lacks the pleasant flavour of tap water.

How the Chemist uses Water

To the chemist water is of great importance because so many substances dissolve in it, and chemical changes readily take place in solution. In order to find whether a chemical is soluble in water, place one measure of it in a test tube containing water to a depth of an inch, close the end of the test tube with the thumb, slowly invert it, and restore it to its normal position in order to mix the substance with the water. Test common salt, soda and sugar in this manner. In each case the solid disappears from sight and therefore is soluble in water.

Add a second measure of salt to the solution already prepared and shake the tube. If the further quantity dissolves, add more. Eventually a stage is reached when the water in the tube will dissolve no more salt, and the solution is then said to be saturated. Different amounts of various soluble chemicals are required to saturate a given quantity of water. Repeat the experiment with Manganese Dioxide (No. K118). Shaking a measure of this substance with water makes no apparent difference to the quantity to be seen in the tube. Manganese Dioxide is insoluble in water.

Most chemicals are more soluble in hot water than in cold. Add one measure of common salt to the saturated solution already prepared and heat the liquid to boiling point. A little more salt dissolves.

Try the same experiment with Potassium Chlorate (No. K122). The extra measure dissolves as the temperature is raised, and further measures of Potassium Chlorate added to the hot liquid also readily dissolve. A given volume of water dissolves nearly 20 times as much Potassium Chlorate at boiling point as at freezing point.

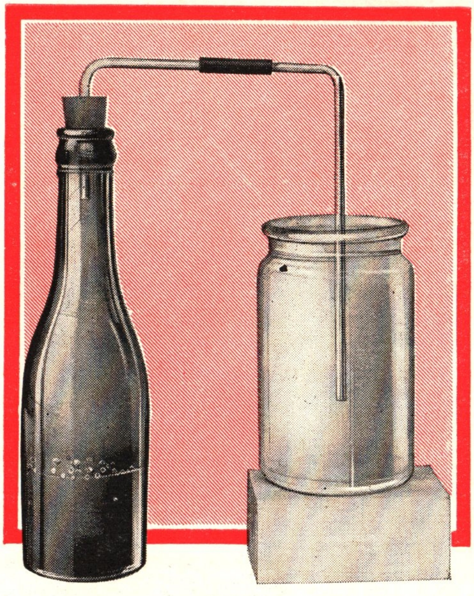


Fig. 14. Preparing carbon dioxide by the action of vinegar on washing soda.

Mysteries of Crystallisation

Allow the solution of Potassium Chlorate to cool and the extra quantity dissolved then separates out. Pour off the liquid and shake the solid on to a piece of blotting paper. Examine the residue when it is dry. It consists of a number of pieces of a definite shape. These are crystals of Potassium Chlorate.

When a chemical separates from its solution in water in this manner it usually

Fig. 15. Extinguishing a flame by pouring carbon dioxide over it.

does so in the form of crystals. These vary in shape—each substance having its own peculiar crystalline formation—and also in size. Larger crystals are best obtained by allowing the solution from which they separate to cool slowly, and small ones are produced by rapid cooling and stirring.

Prepare crystals of Copper Sulphate (No. K108), Iron Alum (No. K111), and other soluble chemicals contained in the Outfit. After drying them on clean blotting paper, compare their shapes, using a magnifying glass of low power if one is available.

Ink for Secret Writing

Cobalt Chloride crystals show an interesting change when heated, the red colour changing to blue. Addition of water after cooling then restores the original red colour.

Dissolve two measures of Cobalt Chloride (No. K105) in sufficient water to cover them at the bottom of a test tube. Using this solution as an ink, write on a sheet of glazed paper with a clean pen or a sharpened match stick. When the " ink " dries, the writing is practically invisible. Now hold the paper in front of a fire or over a flame, and the writing is revealed in strong blue lines. When the paper cools the colour fades away, and may be made to disappear more quickly by breathing on it.

The solution may be employed as a secret ink, for writing carried out with the pink solution is almost invisible, and cautious dilution with water gives a solution so weak that writing carried out with it would escape any but the most careful scrutiny.

Writing with Tea and Water

Mix together one measure of Tannic Acid (No. K132) and one of Iron Alum (No. K111) that has been crushed to a powder. Place the mixture on a sheet of writing paper and rub it into the paper thoroughly with the aid of a dry pad of cotton wool or paper. Shake off the powder that has not been absorbed, and write or draw on the paper with a pen dipped in water. The result is a great surprise to whose who have no knowledge of chemistry, for the water acts like a black ink, producing writing that is easily readable.

The explanation of this experiment is that in solution the two chemicals form a black precipitate of iron tannate. A very good ink may be made by dissolving one measure of each in separate test tubes one quarter filled with water and mixing the solutions. A little gum should be stirred into the black liquid formed.

This chemical change enables Tannic Acid to be used as a secret ink. Make a solution of this in the manner already described, write with it on white paper and allow the writing to dry. Moisten a strip of clean

Fig. 16. Passing ammonia gas into water in order to form a solution.

blotting paper with a solution of Iron Alum of the strength already given and press this on the paper. The invisible writing immediately shows up as strongly as if freshly written with black ink.

This effective trick will mystify most observers if the writing with Tannic Acid is secretly carried out beforehand. It may be reversed, the Iron Alum solution being used as the ink and the blotting paper dipped in a solution of Tannic Acid, or even strong tea.

Fig. 17. Reproducing a newspaper illustration on a sulphur medallion.

Inflammable Gases from Wood, Sugar and Paper

Heat small quantities of starch, sugar, paper, bread and wood, all of which are organic substances, in a small test tube, and ignite the gas given off by bringing the mouth of the tube to the flame of the lamp (Fig. 11). In all cases this gas burns with a yellow smoky flame, and drops of a tarry liquid collect on the inner surface of the tube. The gas and the tarry liquid are similar to the products of the heating of coal carried out in gasworks.

The smoky luminous flame of coal gas is now seldom used. Instead the gas is mixed with air before burning, the flame of the mixture being blue and not smoky. It is hollow, and unburned gas can be extracted from its interior. A similar experiment can be made with the unburned vapour in the interior of a candle flame (Fig. 12).

Experiments with Carbon Dioxide

One of the most important compounds of carbon is carbon dioxide, the heavy invisible gas we have already made by burning organic substances. It is more easily prepared by pouring vinegar on crystals of washing soda in a test tube. A vigorous effervescence occurs and the gas produced turns lime water milky when it is carefully poured downward into a second test tube containing this liquid (Fig. 13). Washing soda is known to chemists as sodium carbonate. Many other common substances are carbonates. Test oyster shells, whiting, chalk, limestone, old mortar and marble by adding a little vinegar to a small quantity of each in turn, warming slightly if necessary. In all cases carbon dioxide is given off. The chalk tested must be natural chalk, not prepared blackboard chalk.

A jar of carbon dioxide may be prepared by the action of vinegar on washing soda in a small bottle fitted with a small bored cork and a delivery tube to carry the gas downward (Fig. 14). When the apparatus is ready place a tablespoonful of washing soda in the bottle, cover it with water and pour in a test tube full of vinegar. Place the cork in the neck of the bottle immediately, and the gas given off is driven into the jar. If only one right-angle delivery tube is available, this is fitted directly into the cork and the bottle is tilted to allow the delivery tube to dip into the jar in which the gas is to be collected.

Pour the carbon dioxide that has been collected in this experiment over a lighted candle or spirit lamp (Fig. 15). The flame is extinguished immediately and without the fuss that would follow the use of water for similar purposes. The gas acts by blanketing out the air and thus choking the flame, for ordinary combustibles do not burn in the gas.

Changes of an interesting kind occur when carbon dioxide is passed through lime water contained in a test tube. The solution first turns milky, but becomes clear when more carbon dioxide is passed through. Boil the clear liquid and once more it becomes milky, bubbles of carbon dioxide being given off.

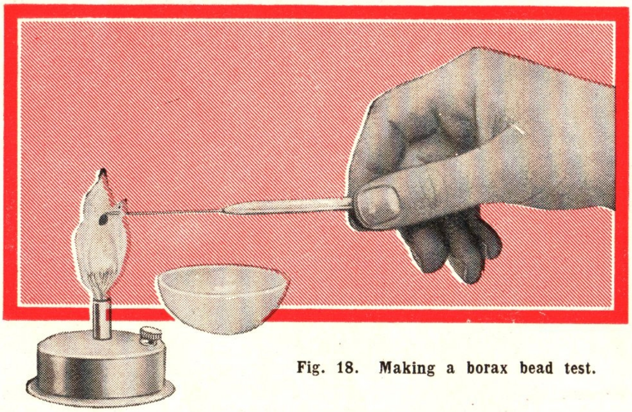


Fig. 18. Making a borax bead test.

Experiments with Ammonia

Add three measures of Calcium Oxide (No. K103) and a few drops of water to a small quantity of wool in a test tube. Place a piece of moist red Litmus paper over the mouth of the tube and heat the mixture gently. The Litmus paper becomes blue, and on cautiously smelling the vapours given off the odour of ammonia is recognised. Make similar tests with hair and cheese.

Place a mixture of five measures each of Ammonium Chloride (No. K101) and Calcium Oxide (No. K103) in a dry test tube fitted with a small bored cork and the large right-angle delivery tube. Hold the test tube in a horizontal position over the flame, with the delivery tube pointing upward into an inverted dry test tube. The ammonia given off collects in this tube, for it is lighter than air. When the tube seems to be full of the gas, place its mouth under water, still in an inverted position. When a little water has entered close the test tube with the thumb and shake the ammonia with the water. The gas dissolves, giving an alkaline liquid.

More ammonia solution may be prepared by turning the delivery tube downward to dip just below the surface of water to the depth of an inch in a test tube (Fig. 16). The delivery tube must be lifted out as soon as the stream of bubbles of gas ceases, in order to prevent water entering the test tube in which the mixture is being heated.

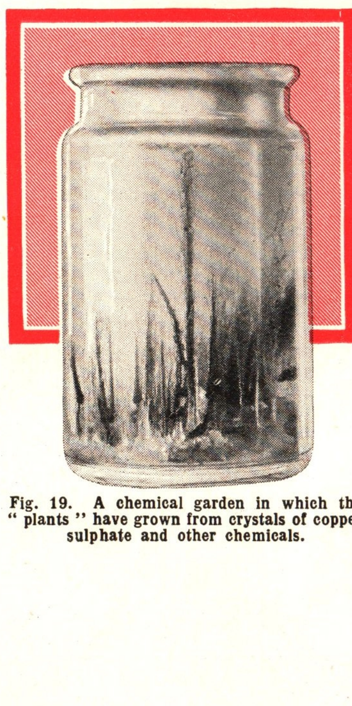


Fig. 19. A chemical garden in which the "plants" have grown from crystals of copper sulphate and other chemicals.

Sulphur—The Volcanic Element

Sulphur or brimstone is one of the most interesting of the elements. Its second name means the burning stone, and it is found in the craters of volcanoes. It burns with a pale blue flame, and the fumes produced have a choking smell.

Sulphur is a yellow solid, but readily melts when heated. Place six measures of Sulphur (No. K131) in a small dry test tube and heat slowly. The element melts to form a pale yellow mobile liquid, and on further heating become darker and darker in colour until eventually it is a deep reddish brown. At this stage it is syrupy, and does not fall out even when the tube is inverted. Continue to heat, and the liquid, still dark red in colour, again becomes mobile. Pour it into water in a saucer.

The form of sulphur obtained by pouring the hot liquid into cold water is very curious, for it may be pulled and stretched like a piece of indiarubber. It loses its elasticity in a few hours, changing automatically into a hard brittle mass that consists of tiny eight-sided crystals, which are readily seen by means of a powerful magnifying glass or microscope.

A Novel Printing Process

An interesting experiment with sulphur is in reproducing pictures and type from newspapers, for in certain conditions printers' ink adheres to it readily. Surround the portion of a picture that is to be reproduced with a ring of cardboard, which is best obtained by removing the bottom from a small cardboard box. Heat sulphur in a dry test tube until a pale yellow liquid is obtained, and pour this into the mould (Fig. 17). On cooling remove the cardboard, and the picture will be found to be transferred to the lower side of the Sulphur medallion formed within it. The picture is, of course, reversed.

Interesting Analytical Tests

Borax is a chemical of special interest because of its use by analysts, who make with it what are usually described as borax bead tests. The beads are made in a loop at the end of the Nickel Chrome Wire (Part No. K39) held in a small pair of tongs or fixed into a short piece of glass tube, one end of which has been drawn out to a jet after softening by heating in a flame. An alternative is to bind the wire by means of thread to a short piece of wood that serves as a handle.

Twist the end of the wire into a loop about $\frac{1}{4}$in. in diameter. Heat the loop in the flame and dip it into a small quantity of borax, placed on a sheet of paper in a convenient position. The borax adheres to the loop, and on heating first swells up as it loses water of crystallisation, and then melts down to form a clear glass bead within the loop (Fig. 18). Touch a minute crystal of Cobalt Chloride (No. K105) with the hot bead and reheat. The bead becomes deep blue in colour owing to the formation of blue cobalt borate.

Copper, iron and manganese compounds give greenish blue, yellow and pale rose beads respectively.

Fig. 20. Cobalt chloride growths in a chemical garden.

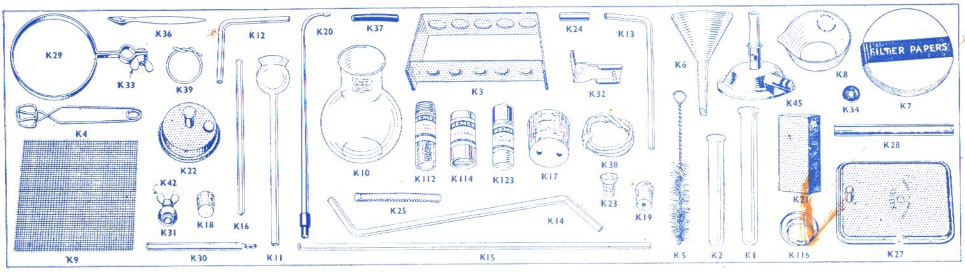
Chemical Gardens

Fascinating experiments can be made with the well-known thick glassy-looking syrup to which the name of water-glass is given. For this purpose sufficient solution of water-glass is prepared to fill a large glass jar, using the syrup in the proportion of one tablespoonful to a tumblerful of water. Place the jar in a position in which it will not be disturbed, and drop into the solution two or three small crystals of Cobalt Chloride (No. K105). A slender column of cobalt silicate then grows on each crystal, the growth becoming wider and taller until it reaches the surface of the solution.

Other chemicals give rise to growths of this kind, and Figs. 19 and 20 show "chemical gardens" produced by "planting" Copper Sulphate (No. K108) and other chemicals.

KEMEX

LIST OF PARTS AND CONTENTS OF OUTFITS



No.	Description	Quantities in Outfits No. 0	No. 1	No. 2	No. 3
K1	Test Tube, 5″ × ⅝″	4	4	4	6
K2	,, ,, Heat Resisting, 4″ × ½″	—	—	2	2
K3	,, ,, Stand...	—	—	1	1
K4	,, ,, Holder	—	1	1	1
K5	,, ,, Brush...	1	1	1	1
K6	Funnel	—	1	1	1
K7	Filter Paper, 3½″ diameter ...	—	12	50	100
K8	Evaporating Dish	—	—	1	1
K9	Gauze Square	—	—	1	1
K10	Flask, Wide-necked	—	—	—	1
K11	Thistle Funnel	—	—	—	1
K12	Right Angle Delivery Tube, Small	—	—	1	1
K13	,, ,, ,, ,, Large	1	1	1	1
K14	Double Angle Delivery Tube ...	1	1	1	1
K15	Glass Tube, 12″	—	—	—	2
K16	,, Rod	—	1	1	1
K17	Cork, Large, Double Bore ...	—	—	—	1
K18	,, Small	—	—	1	4
K19	,, ,, Bored	2	2	3	4
K20	Blowpipe	—	—	—	1
K21	Charcoal Block	—	—	—	1
K22	Spirit Lamp, Complete	1	1	1*	1*
K23	,, ,, Stopper	—	—	—	—
K24	,, ,, Wick Holder ...	—	—	—	—
K25	,, ,, Wick	—	—	—	—
K26	Universal Stand, Complete ...	—	—	—	1
K27	,, ,, Base	—	—	—	—
K28	,, ,, Pillar	—	—	—	—
K29	,, ,, Ring	—	—	—	—
K30	,, ,, Pillar Extension	—	—	—	—
K31	,, ,, Clamp	—	—	—	—
K32	,, ,, Top Bracket ...	—	—	—	—
K33	,, ,, Wing Nut ...	—	—	—	—
K34	,, ,, Washer... ...	—	—	—	—
K35	Evaporating Stand	—	—	1	—
K36	Scoop	1	1	1	1
K37	Rubber Connection Tube ...	—	1	1	1
K38	Asbestos Fibre	—	1	1	1
K39	Nickel Chrome Wire	1	1	1	1
K40	Instruction Manual, No. 1 ...	—	1	—	—
K41	Instruction Manual, No. 2-3 ...	—	—	1	1
K42	Universal Stand, Wing Screw ...	—	—	—	—
K45	Bunsen Burner, Complete ...	—	—	1†	1†
K46	Instruction Manual, No. 0 ...	1	—	—	—
K47	Rubber Tubing for Bunsen ...	—	—	—	—
K100	Aluminium Sulphate	—	—	—	1
K101	Ammonium Chloride	1	1	1	1
K102	Calcium Carbonate (Marble) ...	—	—	—	1
K103	Calcium Oxide (Lime)	1	1	1	1
K104	Charcoal	—	—	—	1
K105	Cobalt Chloride	1	1	1	1
K106	Congo Red	—	—	—	1
K107	Copper Oxide	—	1	1	1
K108	Copper Sulphate	1	1	1	1
K109	Copper Turnings	—	—	—	1
K110	Ferrous Ammonium Sulphate ...	—	—	—	1
K111	Iron Alum	1	1	1	1
K112	Iron Filings	1	1	1	1
K113	Lead Nitrate	—	1	1	1
K114	Litmus	1	1	1	1
K115	Logwood	1	1	1	1
K116	Magnesium Ribbon	1	1	1	1
K117	Magnesium Sulphate	—	1	1	1
K118	Manganese Dioxide	1	1	1	1
K119	Manganese Sulphate	—	—	—	1
K120	Nickel Ammonium Sulphate ...	—	—	—	1
K121	Phenolphthalein Solution ...	—	—	1	1
K122	Potassium Chlorate	1	1	1	1
K123	Potassium Iodide Solution ...	—	—	1	1
K124	Potassium Nitrate	—	1	1	1
K125	Sodium Bisulphate	1	1	1	1
K126	Sodium Bisulphite	—	—	—	1
K127	Sodium Borate (Borax)	—	—	—	1
K128	Sodium Ferrocyanide	—	—	—	1
K129	Sodium Thiocyanate	—	—	—	1
K130	Strontium Nitrate		—	1	1
K131	Sulphur	1	1	1	1
K132	Tannic Acid (Tannin)	1	1	1	1
K133	Tartaric Acid	—	—	1	1
K134	Zinc, Granulated...	1	1	1	1

* Or K45 Bunsen Burner.

† Or K22 Spirit Lamp:

HOW TO CONTINUE

Now that you have experienced the fun and excitement of carrying out chemical experiments you will be keen on proceeding further with this wonderful hobby. You may do this by purchasing a No. 1, a No. 2 or a No. 3 Kemex Outfit, all of which will enable you to perform a splendid series of entirely new experiments.

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