BEGINNING SCIENCE

CHEMISTRY

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OXFORD

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Introduction

Chemistry is all around you

The clothes that you are wearing, the food that you eat, and the air that you breathe are all part of chemistry. As scientists carry out research, they make new discoveries that affect your daily lives. You can read about just a few of them in the extracts that follow. These discoveries are being made now, while you are learning your chemistry. But remember that you may well be the scientists of tomorrow, making important discoveries of your own, so learn your chemistry well.

'Chemical engineers at Pennsylvania State University have been trying to solve a problem that has arisen with modern concrete bridges. It seems that concrete is about 15% air, and salty water from salt that has been put onto roads to clear ice, gets into the tiny holes, taking with it oxygen. This rusts the reinforcing iron that is inside the concrete. The engineers have been doing experiments to dry the holes out and then fill them with liquid plastic, which sets and keeps the salt out.'

'Carbon fibres – thin whiskers of pure graphite – are fifty times stronger than steel, but lighter than aluminium. Experiments have been going on for a number of years, mixing carbon fibres with more common materials like fabric and plastics to make new, super strong materials.'

'Protein extracted from certain jellyfishes have strange and very valuable properties. It seems that they can be made to glow when calcium and strontium compounds get near them. Doctors are researching these materials to see if they are of use as an early warning of heart disease. Sharks' livers also contain chemicals that can be used in anti-cancer drugs.'

'Polyethene terephthalate (polyester to you and me) has brought the fizzy drink manufacturers out of the Glass Age into the Plastic Age. Early plastics like polythene and PVC couldn't keep the carbon dioxide in drinks. It leaked out and glass bottle had to be used. Now, Terylene (one of the brand names of polyester) does the job.'

'Scientists in West Wales are going to pour two tonnes of lime into a lake to try to neutralise the ever increasing effects of acid rain.'

'Scientists reckoned that bacteria, cardboard, and even water used in manufacturing processes might be partly responsible for causing garments kept in polythene bags to go yellow. It is now thought that nitrogen oxide fumes in the air (mainly from car exhaust fumes) react with certain plastics to make a yellowing agent. The solution? Dip the finished fabrics in citric acid first of all before packing them and this seems to do the trick.'

'Dental scientists are developing a new white plastic that will soon replace metal amalgams used to fill holes in teeth. The plastic is put in in a soft form, but when specially coloured light is shone onto it, it hardens quickly and forms a hard substance that can do the chewing just as well as proper teeth.'

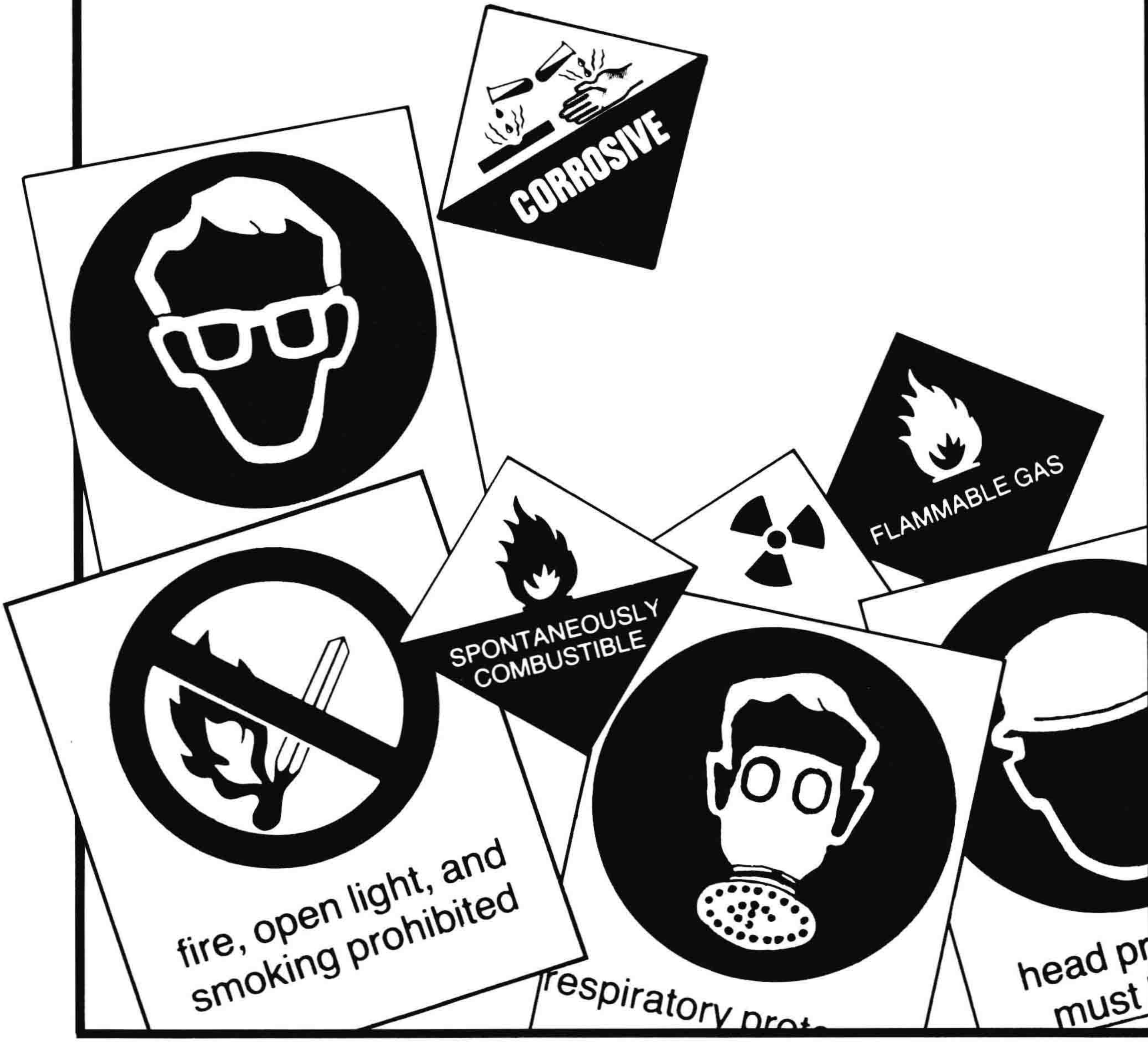
'"Dirty" industries like mining, smelting, and electroplating are pleased to hear that new bacteria are being bred that can withstand high concentrations of lethal cadmium and lead compounds in water, and which can be used to remove these impurities before they get into our drinking water.'

'Scientists have found ways of making superglue safe to use in surgery. They are using it to join delicate bone, blood vessels, and even nerves. They have had to remove dangerous cyanide groups from the superglue molecules but leave the bits that do the gluing.'

'Anorexia Nervosa – the slimming disease – could be caused by a zinc deficiency, scientists think. Zinc, like iron, is essential in our diet because it is necessary for the growth and repair of cells. Absence of zinc in our bodies can also depress our sense of taste and smell. Foods that contain good supplies of zinc are milk, meat, fish, and wholemeal bread.'

TOPIC 1

Methods



Useful information about chemicals, rules, and possible dangers is presented in these symbols.

1.1 Safety first

There are dangers all around you, but most of them you take for granted. You can't afford to do this in a laboratory.

Danger

First of all, let's look on the black side. If you were careless in the laboratory, you could poison yourself or even blow yourself up!

Now let's be realistic. These things could happen, but they could just as easily happen in other places. In fact laboratories are pretty safe when compared with other places in schools.

Figure 1 shows some statistics about accidents that happened in schools all over the country, during one school year. The Accident Scale in the second column compares how often accidents happened in different parts of the school. The higher the number, the more accidents there were. You can see that the most dangerous place appears to be the playground, and the safest place, the toilets!

place of accident	accident scale
playground	20.0
playing field	10.2
gymnasium	9.2
classroom	3.8
corridor	2.1
cloakroom	2.0
handicraft room	1.6
laboratory	1.3
swimming pool	1.1
domestic science room	1.0
stairs	0.8
toilets	0.4

Figure 1 This table compares how often accidents occurred in different parts of schools in one year. Accidents happened in the playground far more often than in the laboratory.

Laboratory rules

But wait a minute. This doesn't mean that accidents will not happen in the laboratory. It means that science teachers and science pupils are generally careful people who try not to *let* accidents happen. They have rules about working and behaving in the laboratory.

Here are some rules for you to think about:

1 When you are in the laboratory:
do not run,
put your satchels, bags, and coats safely out of the way,
if you have long hair, tie it up.

2 Always:
wear safety specs, goggles, or a face mask when you are heating anything, or when you are doing any experiment that may be dangerous.

3 Never:
eat or drink anything in the laboratory,
look down into a test tube that contains chemicals,
point a test tube at anyone while it is being heated,
play with electrical switches,
play with fire.

4 Always:
ask your teacher if you are not sure how to do something,
follow instructions carefully.

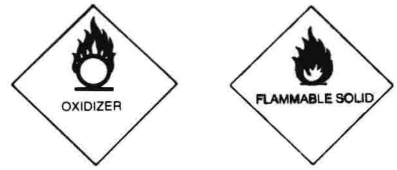
5 Never, ever:
play around,
make up your own experiments without first checking with your teacher.

6 Before you leave the laboratory:
wipe the bench and tidy up,
put your stool under the bench or out of the way.

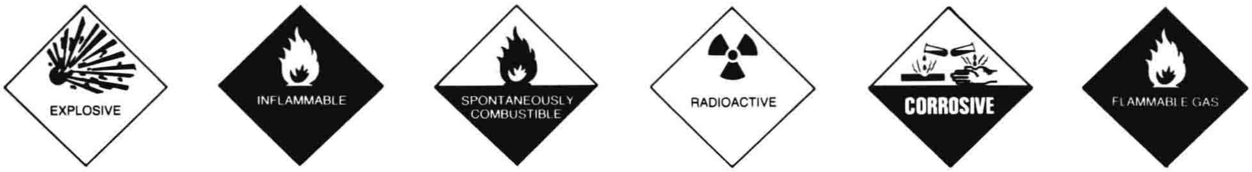
When working in a laboratory, you should always tie back your hair if it is long and wear goggles when you are heating anything.

Symbols

Many of the jars and bottles in the laboratory have safety symbols on them. Here are the more common ones, and some others you may also meet:



These symbols tell you about chemicals:



These symbols tell you what you must not do. They always have red circles and red diagonal lines:


laboratory coats must not be worn in this room


smoking, drinking, and eating prohibited


do not drink this water


fire, open light, and smoking prohibited

And these show what you must do. They have blue circles:


respiratory protection must be worn


head protection must be worn


eye protection must be worn

Exercises

1 Read this passage and see how many broken rules you can find:

Fred ran up the stairs and staggered through the door of the science laboratory. Falling over a stool that was in the middle of the floor, he threw his bag onto the bench and collapsed in a heap.

The teacher hadn't arrived for the lesson yet, so Fred got out his lunch and ate a sandwich. After this, he decided to start the lesson on his own. He had a recipe for gunpowder that he wanted to try out. So he looked around for the chemicals and mixed them in a heap on the bench. Nothing happened, so he decided they needed heating. He put them into a test tube, but couldn't find any matches to light the Bunsen burner. So he tore a page from his exercise book and lit it from the gas water heater. Being a tidy person, he then made a bonfire of all his rubbish in the sink.

The gunpowder didn't seem to be doing much. Fred gave it a poke with his pencil, and peered down the tube so as not to miss anything important. . . .

2 What do you think happened to Fred?

1.2 Apparatus

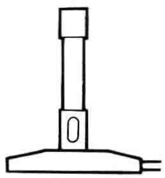
Chemists use special pieces of apparatus for special jobs.

Naming apparatus

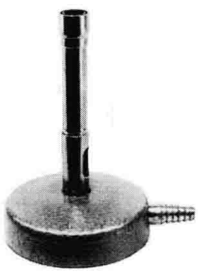
You will use many different pieces of apparatus in your science lessons. You must learn to call them all by their correct names. You must also learn to spell their names correctly.

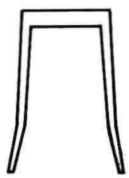
Most of the apparatus is made of borosilicate glass, often called ***Pyrex***. Pyrex is expensive and although it is quite tough, it will break if dropped or mistreated. Take care.

Here are some of the pieces you will meet.

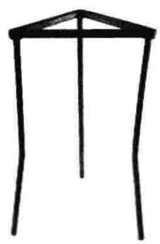


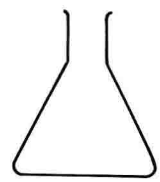
Bunsen burner



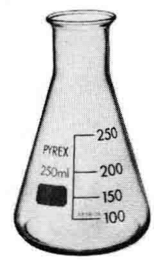


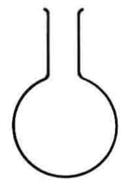
tripod



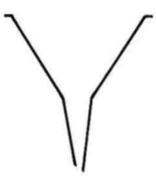


conical flask

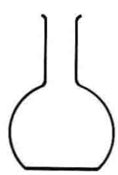




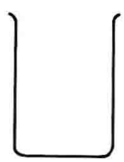
round-bottomed flask



filter funnel

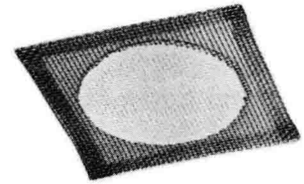


flat-bottomed flask



beaker

gauze



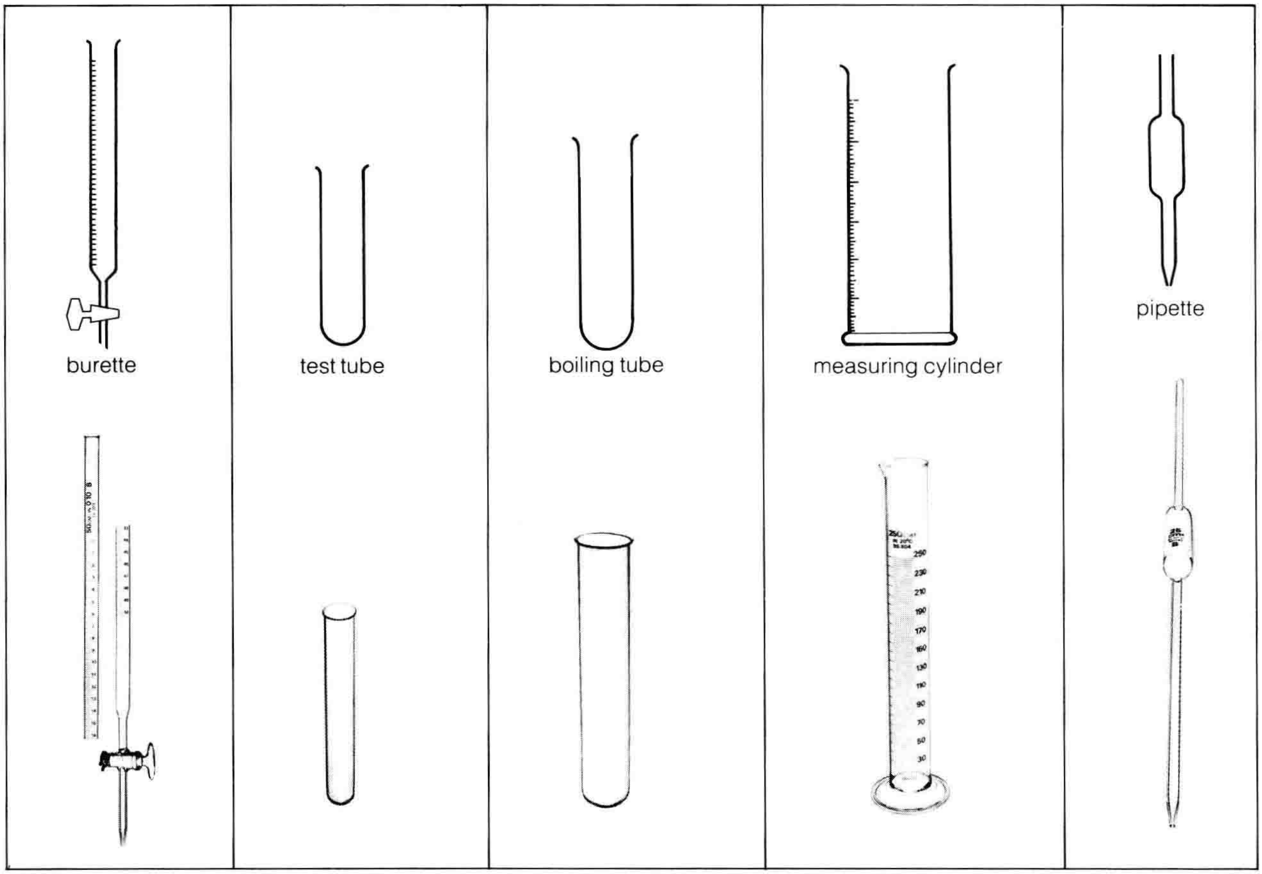
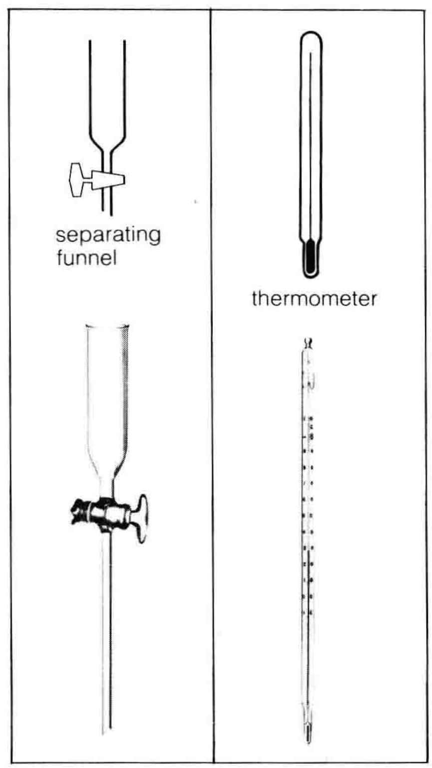


Figure 1 Some common pieces of laboratory apparatus



Drawing apparatus

Chemists use diagrams instead of true drawings, to show apparatus. A diagram is shown above each photograph in Figure 1. Diagrams are simpler, and easier to draw. They look neater too. Remember these rules for drawing diagrams:

1 Use a pencil.
2 Use a ruler for all straight lines.
3 Label any piece of apparatus that is not easily recognised.
4 Label the substances in the apparatus.

Exercises

1 Learn to spell the names of the pieces of apparatus you have met. Your teacher may give you a test.
2 Practise drawing diagrams of these pieces of apparatus, for yourself.

1.3 Techniques (1)

Many pieces of apparatus are used for measuring.

Volume

The glassware you use will often have units of volume marked on it. These are the same units that are used to measure the volumes of everyday things like washing-up liquid, medicines, and soft drinks.

The units usually used are:

the ***litre***, which has the symbol **l**
the ***millilitre***, which has the symbol **ml**.

The container of washing-up liquid in Figure 1 has its volume marked in ml.

'Milli' means 'one-thousandth of', so you need 1000 millilitres to make one litre:

1000 ml = 1 l

Most countries sell petrol by the litre instead of by the gallon.

Two other units that are often used in chemistry are:

the ***cubic decimetre***, which has the symbol **dm^3**
the ***cubic centimetre***, which has the symbol **cm^3**.

Just like millilitres and litres:

$1000\ cm^3 = 1\ dm^3 = 1\ l$

Don't be confused by these different units. Remember that:

a cubic centimetre is the same as a millilitre
a cubic decimetre is the same as a litre.

Beakers and conical flasks may have either cubic centimetres or millilitres printed on them. The beakers in Figure 2 both hold the same volume.

Figure 1 This container holds 750 ml of washing-up liquid.

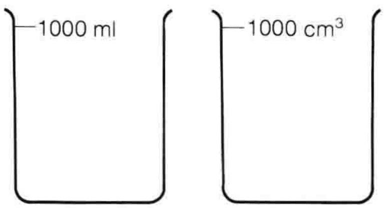


Figure 2 Each beaker will hold 1 litre of liquid.

Measuring volume

You can measure the volume of a liquid using a ***measuring cylinder***. This is a glass container marked or ***graduated*** in either cm^3 or ml. But there is a problem. When a liquid is poured into a narrow tube, its surface is not flat, but curved. This curve is called a ***meniscus***. Look at Figure 3.

When you read the volume of a liquid in a measuring cylinder you must follow three rules:

1 Put the measuring cylinder on a flat surface.
2 Have your eyes at the same level as the surface of the liquid.
3 Take the reading from the bottom part of the meniscus.

The volume of the liquid in Figure 3 is 55 cm^3.

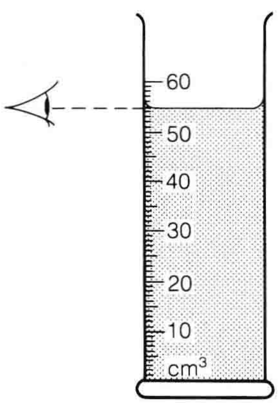


Figure 3 The surface of the liquid is curved. This curve is called a meniscus.

The burette and pipette

You can measure out a liquid more exactly, using a burette or a pipette. Figure 4A shows a ***burette***. When the tap at the bottom is opened, the liquid will run out slowly. By noting the change in level of the liquid, you can tell how much has run out.

Figure 4B shows a ***pipette***. Liquid is sucked into the pipette, using a safety filler, until the bottom of the meniscus just touches the line. You then know the exact volume of the liquid. For example, the pipette in Figure 4B holds exactly 25 cm³ when it is filled. The liquid is then run out into a beaker or flask.

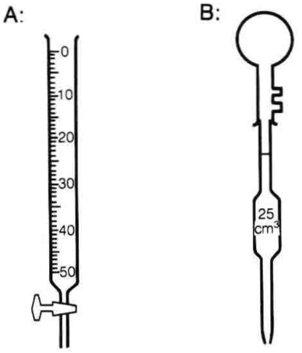


Figure 4 **A:** A burette. **B:** A pipette.

The thermometer

The thermometer is an instrument that measures temperature. Scientific thermometers are marked or graduated using the *Celsius scale.*

At normal atmospheric pressure, the freezing point of pure water is 0 °C (nought degrees Celsius) on this scale. Its boiling point is 100 °C. These are the two ***fixed points*** of the scale and there are 100 degrees in between. The thermometer in Figure 5 shows a temperature of 45 °C.

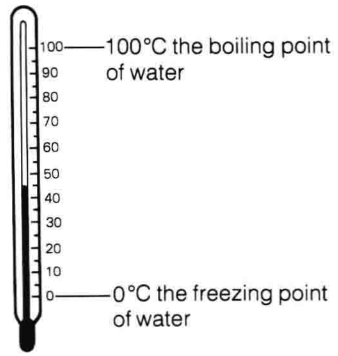


Figure 5 This thermometer shows a reading of 45°C.

When you use a thermometer, remember to follow these rules:

1. Handle the thermometer carefully. It can easily roll off the bench and break.
2. Look at the scale first and make sure that you can read and understand it.
3. Keep the bulb of the thermometer in the substance while you are reading the temperature.
4. The mercury level will fall on its own, when the thermometer is removed from the substance. Do not cool it under the tap.

Exercises

1. What is a meniscus? Draw a measuring cylinder with water in it, to help your explanation.
2. Write down the three rules for using a measuring cylinder. How much liquid is there in the measuring cylinder in Figure 6?

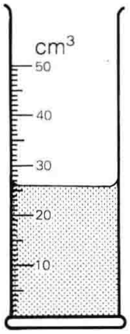


Figure 6

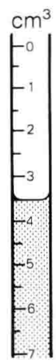


Figure 7

3. The burette in Figure 7 was full to begin with. How much liquid has been run out of it?
4. Has the pipette in Figure 8 been filled correctly? Explain your answer.

Figure 8

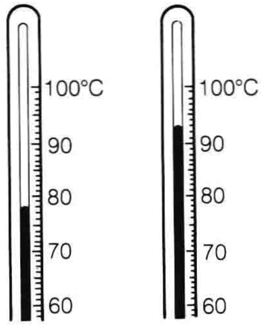


Figure 9

5. What temperature is shown on each thermometer in Figure 9?
6. How many cm³ are there in:
   a) 1 dm³? **b)** 1 l? **c)** 0.5 dm³? **d)** 0.25 l?

1.4 Techniques (2)

Chemists usually need to know how much of a chemical they have used.

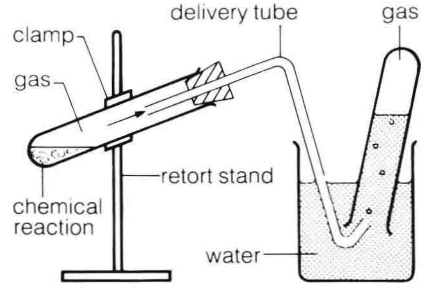


Figure 1 This is the apparatus used to collect a gas.

Collecting gases

Quite often, you may need to collect a gas that is being made in a chemical reaction. Figure 1 shows apparatus for collecting the gas in a test tube.

The reaction takes place in a test tube or boiling tube. This is held in place by a ***clamp*** and a ***retort stand***. The gas from the reaction travels along a ***delivery tube***. It bubbles through the water and rises into a test tube. As it collects in the test tube, it pushes the water down until the test tube is full of gas. This is called ***downward displacement of water***. If you think about it, you will see that this method would not work for a gas that dissolves in water.

The mass of this sugar is 1 kg.

Weighing

The amount of a substance is called its ***mass***. Mass is measured in these units:

the ***kilogram***, which has the symbol **kg**
the ***gram***, which has the symbol **g**.

'Kilo' means '1000', so there are 1000 grams in a kilogram:

1000 g = 1 kg

At the supermarket, you can buy sugar in kilogram bags (see photo).

The mass of an object is usually measured on an instrument called a ***top-loading balance***. Look at Figure 2. The number in the little window shows the mass of the beaker, to one decimal place. It is 48.5 g. Now look at the black bar beside the number. Its top edge meets the diagonal scale at 6, so 6 is the second place of decimals. The full reading is 48.56 g.

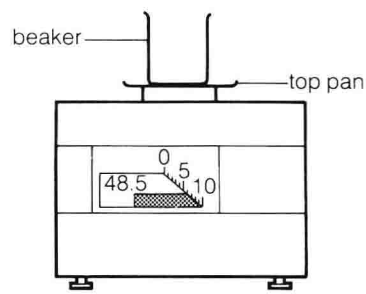


Figure 2 A top-loading balance measures the mass of an object.

Top-loading balances are very sensitive and must be placed on a firm bench away from draughts.

Weighing out a powder

This sounds easy, but make sure you do it properly. First you must weigh the test tube or beaker that will hold the powder. Next, you must take the powder from the bottle carefully, without spilling any. Figure 3 shows the correct way to hold the bottle and spatula. Do not take too much powder at a time. Then, when the powder is in the test tube or beaker, you must weigh both together, and find the mass of the powder by subtraction. Set your results out neatly, as in this example.

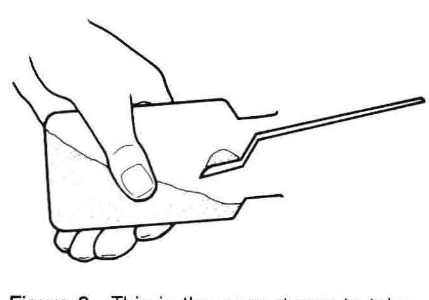


Figure 3 This is the correct way to take powder from a bottle.

Example

Mass of beaker	= 48.56 g
Mass of beaker + powder	= 72.06 g
Mass of powder	= 72.06 g − 48.56 g
	= 23.50 g

The Bunsen burner

In 1852, Robert Wilhelm Bunsen became Professor of Chemistry at the University of Heidelberg, in Germany. One of the many important things he did there was to invent an apparatus that would mix gas and air in just the right amounts to give a hot, clean flame. The result was the ***Bunsen burner***. See Figure 4.

When you use a Bunsen burner, remember these points:

1 Before you light it, close the air hole.

2 Get a lighted match or splint ready. Next turn on the gas and light it. Then open the air hole.

3 When the air hole is fully open, the flame is very hot and noisy, and nearly invisible. It is called a roaring flame.

4 The blue cone in the middle of the roaring flame is gas that has not yet burned. The hottest part of the flame is just above the blue cone.

5 When the air hole is closed, the flame is luminous and sooty. So always have the air hole open or half open when you are heating something.

6 If you are not using the Bunsen burner for a time, close the air hole so that the flame is luminous and can be easily seen. This may prevent an accident.

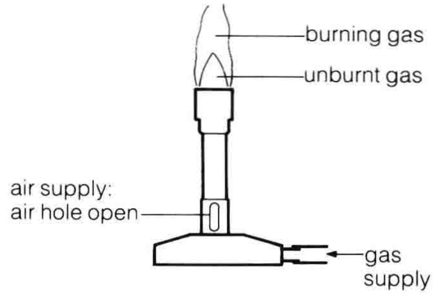


Figure 4 A Bunsen burner

Heating things in a test tube

When you are heating a solid in a test tube, remember:

1 Always use a test tube holder.

2 Always wear safety specs.

3 Always hold the test tube at an angle, as shown in Figure 5.

4 Never look down the test tube or point it at anyone.

When you heat a liquid in a boiling tube:

1 Don't put too much liquid in, or it will boil over.

2 Add a few anti-bumping chips to make it boil smoothly.

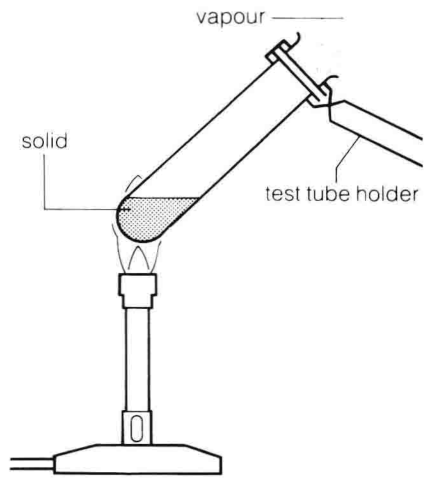


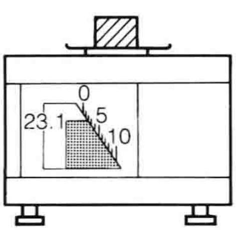
Figure 5 When heating a solid in a test tube, always hold the tube at an angle.

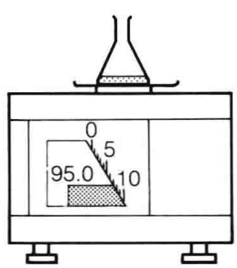
Exercises

1 a) Explain what is meant by the 'downward displacement of water'.

b) Why is downward displacement of water unsuitable for collecting a gas that dissolves in water?

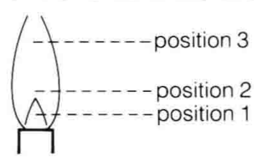
2 Write down the mass of each object shown below:





3 These results were obtained when a powder was weighed out into a test tube:
Mass of test tube = 25.43 g
Mass of test tube + powder = 48.30 g
What mass of powder was put into the test tube?

4 Here is an experiment to try in the laboratory. Light a Bunsen burner and open the air hole to obtain a roaring flame. Hold a piece of wire in a pair of tongs, and put it into the flame in each of the positions shown. What can you tell about the temperature of the flame in the three positions?

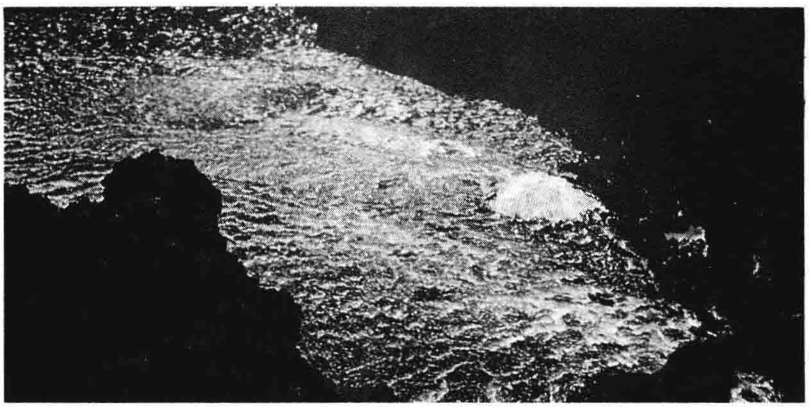


1.5 Separating mixtures (1)

When a chemist does an experiment, he often ends up with a mixture of substances instead of just one. He must know how to separate the substances.

Pure substances and mixtures

Every substance that exists is either a solid, a liquid, or a gas. For example, iron, cement, wood, and plastic are solids. Water, sulphuric acid, and petrol are liquids. The air, carbon dioxide, and hydrogen are gases. Solid, liquid, and gas are called the three ***states of matter***.



Can you identify the three states of matter in this photo of a volcanic eruption?

A single substance that has nothing else mixed with it is called a ***pure substance***. If there is anything else mixed with it, then it is a ***mixture***. Figure 1 shows some everyday mixtures and the table below tells you what some mixtures are made of.

mixture	states of matter involved	contents
the air	gases	mainly oxygen and nitrogen
the sea	solids, liquids, and gases	The sea is not pure water. It has salt, oxygen and all sorts of other substances dissolved in it.
fizzy drink	solid, liquid, and gas	sugar, flavouring, colouring, and carbon dioxide all dissolved in water.
brass	solids	copper and zinc
salad dressing	liquids	oil and vinegar. These liquids do not dissolve in each other and have to be shaken up

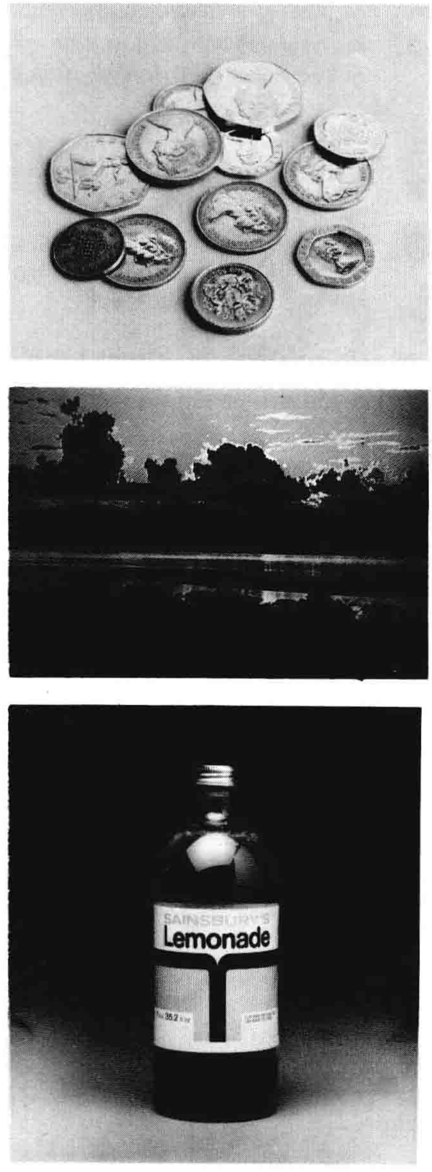


Figure 1 Coins, rivers, the sky, and soft drinks are all mixtures of substances.

Chemists use different methods to separate different types of mixtures. Read on, and you will learn about them.

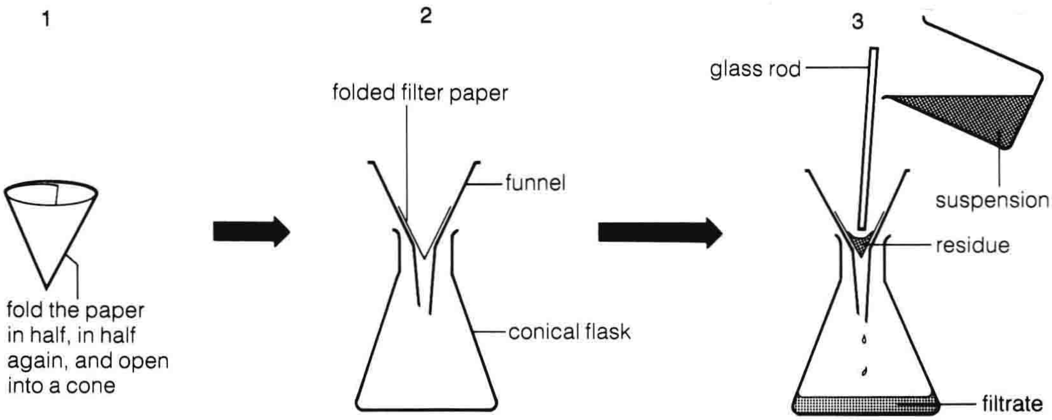


Figure 2 Filtering a suspension

Filtering

This method is used for separating a solid from a liquid in which it hasn't dissolved. For example, tea contains tea leaves. To separate them, you pour the tea through a strainer. The liquid passes through the holes in the strainer, but the leaves don't.

Dirty water contains tiny particles of dirt that have not dissolved. They just float about in the water. This type of mixture is called a ***suspension***. The dirt is removed by pouring the water through a laboratory strainer called ***filter paper***. Like a tea strainer, filter paper has holes in it, but they are too small to see without a microscope.

Figure 2 shows how to filter a suspension:

1 Fold the paper in half, and in half again. Open it out into a cone.

2 Put the cone into a filter funnel, and set this in a conical flask.

3 Using a glass rod as a guide, pour the dirty water into the paper cone. Do not overfill it.

The dirt that remains in the paper is called the ***residue***. The clean water that filters through is called the ***filtrate***.

Figure 3 **A centrifuge is used to** separate the solid from the liquid in a suspension. When the centrifuge is switched on, it spins at high speed; the buckets containing the test tubes swing out, and the solid is flung to the bottom of the test tube.

The centrifuge

Filtering is a good method for separating the liquid and solid in a suspension. Sometimes, however, it is too slow, or the amount of solid is so small that it would get lost in the filter paper. In this case, a ***centrifuge*** is used instead. Look at Figure 3. The suspension is put into a small test tube which is then placed in one of the buckets. The opposite bucket is counter-balanced, using a test tube of water. When the centrifuge is switched on, it spins at high speed, the bottoms of the buckets swing out, and the solid in the suspension is flung to the bottom of the test tube. The liquid can then be drawn off with a dropper, as shown in Figure 4.

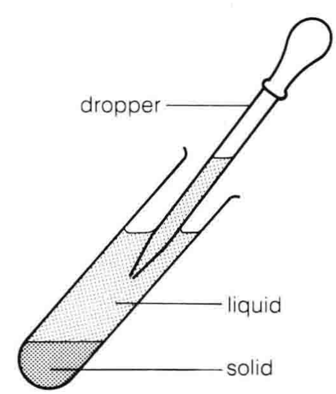


Figure 4 Draw the filtrate off with a dropper to separate the solid residue.