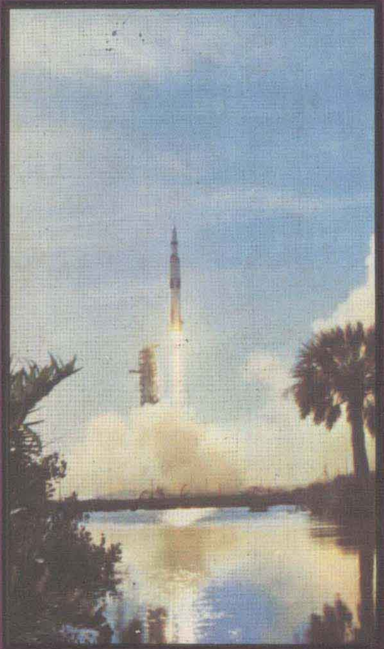
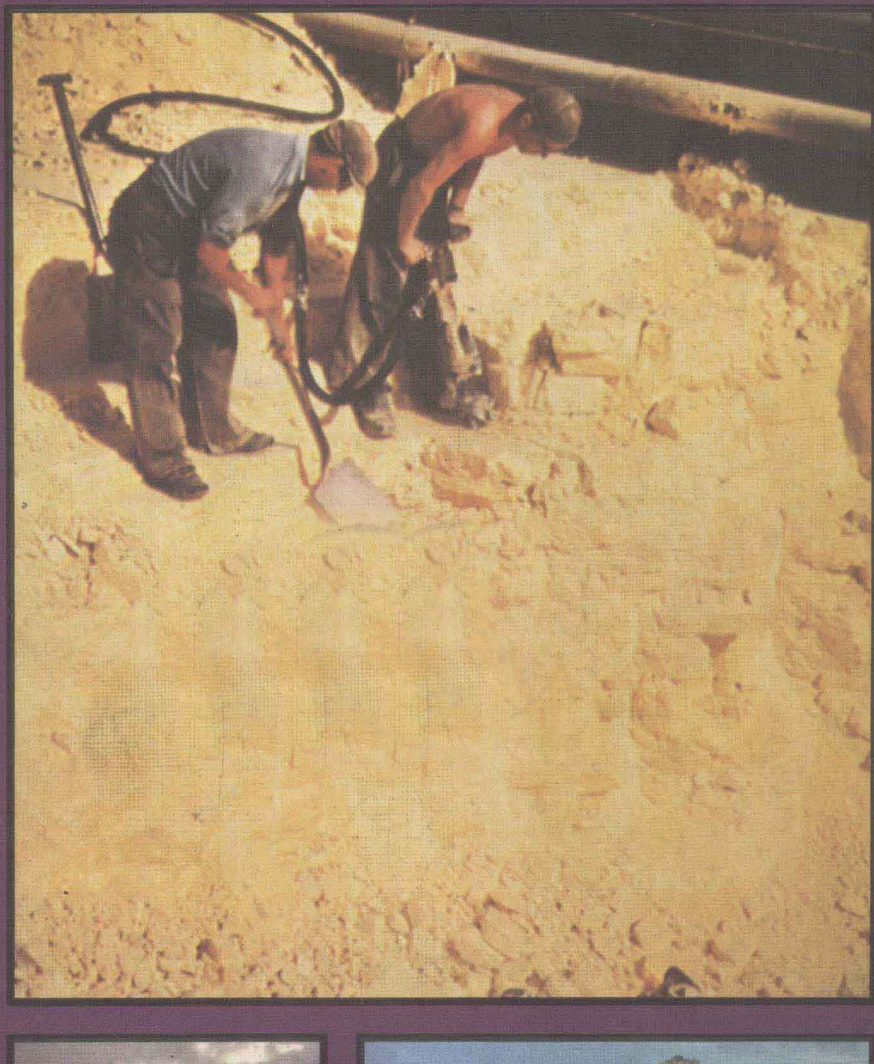
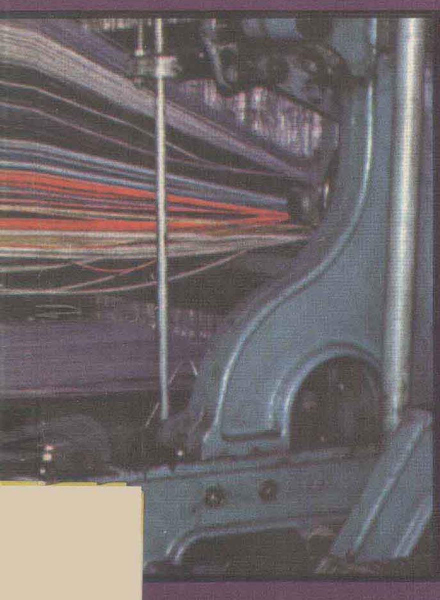
Keys to Chemistry Book 1

Graham Hill







Keys to Chemistry

Book 1

Graham Hill

The English Universities Press Ltd

ISBN 0 340 19072 8 Pupil's Book 1
0 340 18075 7 Teachers' book 1

The English Universities Press Ltd
St Paul's House, Warwick Lane, London EC4P 4AH

Designed and illustrated by Richard Lewis and Christine Malone
Phototypeset by Filmtype Services Limited, Scarborough, Yorkshire
Printed and Bound for the English Universities Press Ltd
by Butler and Tanner Ltd, Frome
and London

Preface

This book is about chemistry and chemists and the roles they play in science, industry and society. I hope you will find much to interest you as you begin your studies.

No doubt your teacher will ask you to read various sections, but I hope you will read it 'for fun' also. There are pictures or diagrams on almost every page. You will be interested to look at these, but it is important that you *read* the text which will tell you more about them.

You will benefit a great deal if you follow up the ideas and facts in the book by discussion amongst yourselves, by trying out some of the suggested experiments and by reading other books you have at home, at school or in your local library.

Try to answer as many as possible of the questions in the text of each chapter because they will help you to obtain a really firm knowledge and understanding of the topics covered. There is a great variety of study questions so you should find plenty to interest and entertain you.

At the end of each chapter you will find a summary of the more important facts and ideas.

The practical book which accompanies this textbook contains a series of experiments which cover most of the ideas dealt with in the following pages. You could try some of the experiments at home.

Graham Hill
Feb. 1974

To Clare, Alison and Nicola

Acknowledgments

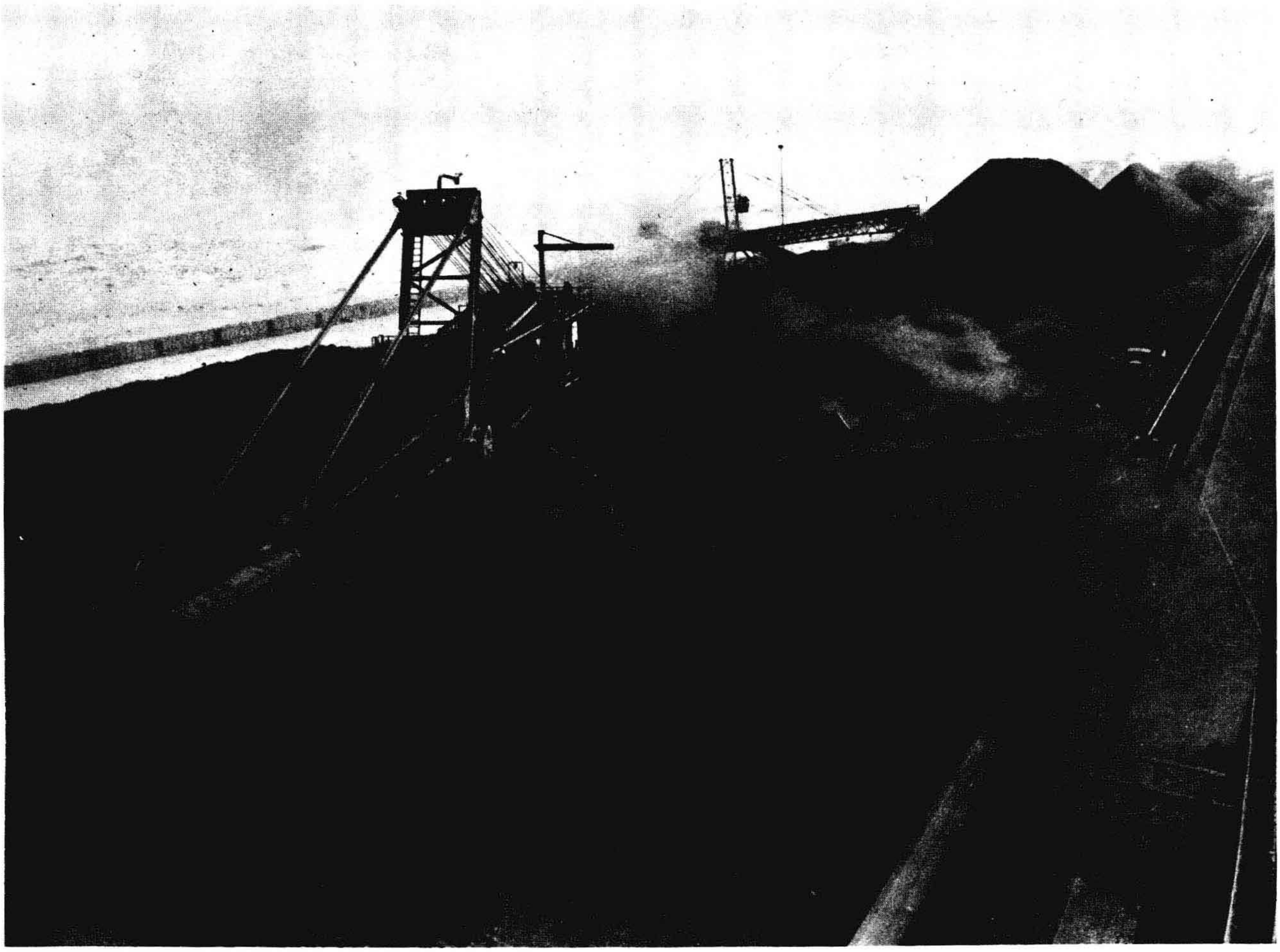
We are grateful for permission to reproduce photographs in this book as follows:

Cover:
Rocket: NASA
Breaking up solidified sulphur: Shell
Liming soil: Fisons Ltd
Chimney: Stewart Keating
Weaving: Hayward, Mitchell and Pavey Ltd
'The Alchemist', by David Teniers: Royal Picture Gallery, Mauritshuis, The Hague
Ink chromatogram: (Quink Permanent black – n-butanol: ethanol: 0·88 ammonia solution 3:1:1): Stewart Keating
Oil refinery: Petrofina (UK) Ltd

Page 6 British Steel Corporation 7 Turner & Newall Ltd 8 Tate & Lyle Ltd 9 (left) Crown Copyright Reserved – Geological Museum (right) Stewart Keating – courtesy of Prof R E O Williams, St Mary's Hospital Medical School, London 10 Trans Antarctic Association 11 (Figure 1.1) Reckitt & Colman Ltd 14 Thompson Newspapers Ltd 16 (left) Guiness (centre) Richard Lewis (right) Rowntree-Mackintosh Ltd 17 (Figure 2.4) Gallenkamp 18 United Nations 22 John Walker & Sons Ltd 23 (top) Roan Consolidated Mines (centre) Stewart Keating (bottom) British Steel Corporation 24 Dr J W Seakins, Institute of Child Health, Great Ormond Street Hospital for Sick Children, London 30 Richard Lewis 32 (top) Stewart Keating (bottom) Imperial Chemical Industries Ltd and Pfizer Ltd 36 Stewart Keating 40 British Lego Ltd 42 The British Museum 45 Richard Lewis 47 Maurice Nimmo 48 (top) Hallam Ashley (centre) British Aircraft Corporation (bottom) Upper Clyde Shipbuilders 49 (top) Richard Lewis (centre) Stewart Keating (bottom) Stewart Keating 54 Richard Lewis 55 British Insulated Callendars Cables Ltd 60 (left) Boots Pure Drug Co Ltd (right) Richard Lewis 61 Acheson Colloids Ltd 64 Sport & General Press Agency Ltd 65 (top) Radio Times Hulton Picture Library (bottom) Gas Council 67 (top) Mobil Oil Co Ltd (bottom) Barnaby's Picture Library 68 (top) South of Scotland Electricity Board (bottom) Stewart Keating 69 Evening Standard 70 United Kingdom Atomic Energy Authority 71 (top) Royal Institute of Chemistry (bottom) Radio Times Hulton Picture Library 72 Barnaby's Picture Library 73 Barnaby's Picture Library 74 Stewart Keating 75 Colchester Express 76 British Steel Corporation 77 British Rail Scottish Region 82 United Press International (UK) Ltd 83 The British Oxygen Co Ltd 84 Keystone 86 (first three) Stewart Keating (far right) Richard Lewis 88 Stewart Keating 91 Rothamsted Experimental Station 92 Sterling Health Products 94 Unilever 98 Ellard Educational Visuals 102 Thermit Welding (GB) Ltd 103 Griffin & George Ltd (Figure 8.8) Mount Wilson and Palomar Observatories 106 (top) British Steel Corporation (bottom) Dorset Natural History and Archaeological Society

Contents

Iron ore



1 What is chemistry?

1.1 Introduction

A heap of iron ore is useless as it stands. It looks like a dry dusty piece of earth: you can't eat it, you can't wear it, you can't even grow things in it. But if you heat it strongly with lime, coke and air, you can turn it into iron; and from iron you can get steel.

This is what chemistry is all about: finding out what the Earth is made of and changing useless things (like iron ore) into useful things (like iron and steel). More than that, chemistry is about knowing *how* and *why* you can make these changes happen.

Chemists call these different stuffs **substances.** Iron is a substance: so too are iron ore, lime, coke and air.

Substances that occur in Nature (those found on the Earth, in the sea, or in the atmosphere, and those dug out of the Earth's crust) are called *naturally occurring* substances. Substances which do not occur on the Earth but have to be made by chemical processes are called *man-made* substances. Iron and steel are man-made. Neither iron nor steel occurs on the Earth, but they can be made by chemical processes from iron ore. Asbestos occurs naturally on the Earth, but plastics like polythene and Perspex are man-made. Cotton and wool are naturally occurring fibres, but Terylene, Nylon and Acrilan are man-made fibres.

Try to answer these questions

1 Silver is a naturally occurring metal: it can be dug out of the Earth's crust (mined) as the metal. Name one other metal that can be mined as the metal.

2 Iron is a man-made metal: it has to be made and refined from iron ore. Name two other metals that have to be made from their ores.

3 Which of the following substances are man-made and which occur naturally?

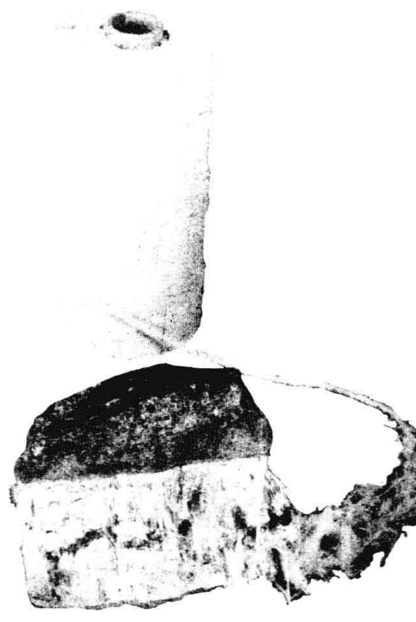
Aspirin	Bronze	Coal
Steel	Sand	Bakelite
PVC	Coke	Diamond

Natural (North Sea) gas

1.2 The chemist's source of useful raw material

Your mother is limited in what she cooks by the food she has in her kitchen. In the same way, chemists are limited in what they can produce by the raw materials they can get from the earth.

Asbestos is naturally occurring



The chemist's most important raw materials are:

Plants
Coal and crude oil
Rocks and mineral ores
The sea
The air

PLANTS provide the bulk of our food and much of our clothing. Flour, vegetables and sugar all come from plants, as do linen and cotton. Rubber comes from the rubber tree, and coconut and olive trees give us oils for cooking, cosmetics and soaps. Some drugs (quinine and cocaine) come from plants.

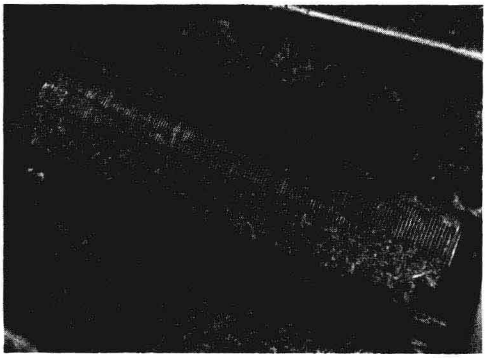
COAL AND CRUDE OIL contain hundreds of chemicals used as raw materials for other products. For example, man-made fibres are made from crude oil chemicals, and coal tar yields the raw materials for many dyes.

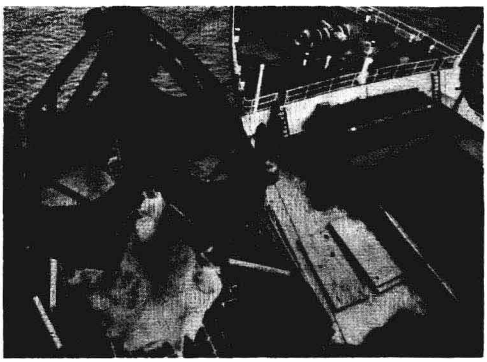
ROCKS AND MINERAL ORES give us metals and glass. Some metals, like gold and silver, are naturally occurring whereas others must be made by chemists from raw materials. Iron is made from red-brown iron ore (haematite) and aluminium is made from bauxite.

THE SEA contains in every kilogramme about 35 g of dissolved matter, 27 g of which is sodium chloride (common salt) and 4 g is magnesium chloride. Large quantities of sodium chloride are used for preparing and preserving foods, for curing leather and for making sodium and chlorine. Magnesium chloride is used to make magnesium, a metal widely used in alloys (see Section 4.8).

AIR is a mixture of gases. Chemists have extracted neon, argon, oxygen, nitrogen and other gases from the air. Most of the nitrogen is used to make ammonia, nitric acid and fertilizers. Neon and argon are used in filling electric light bulbs. Oxygen is used in oxy-acetylene cutting and welding, and in the manufacture of steel.

All the time, chemists are trying to find out what the different raw materials in the Universe are made of and how to change them into new and more useful materials. The work of





Sugar cane is harvested in the West Indies and then crushed in a local factory, to yield a sugar-containing liquid. Dried raw sugar is shipped to the UK for further refining chemists has led to the use of many new materials, such as plastics, detergents, fertilizers and medicines.

New substances are sometimes first made, or discovered, by accident. Well perhaps not entirely by accident . . . usually they were discovered because the chemist was very careful to *observe* and to *note down* everything he saw. It is very unlikely that you will discover anything new just yet, but if you study chemistry as a career you almost certainly will. You must learn to look very carefully at everything that happens and not to miss a thing.

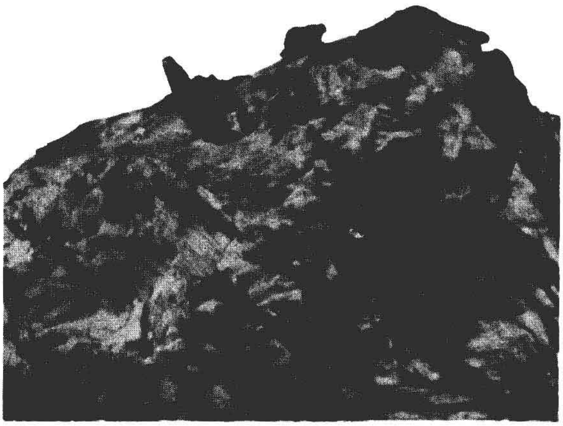
1.3 Describing different substances

Learn to describe the different substances you are looking at, in a way that other people can understand. In order to do this make a list of **properties** of the substances.

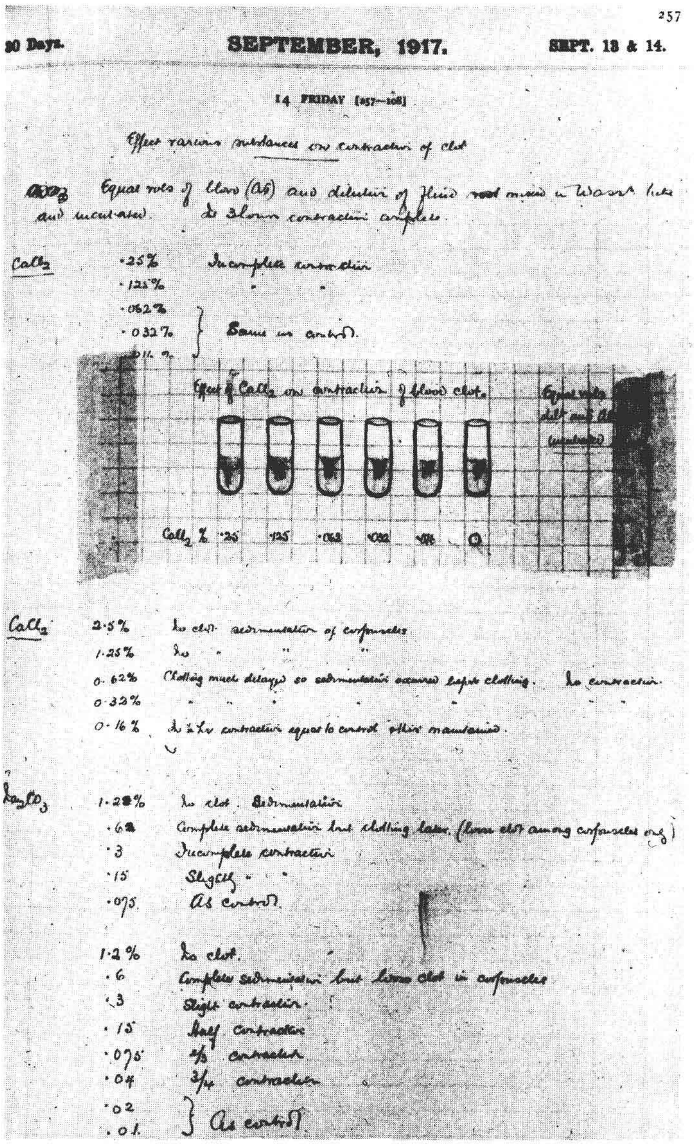
Chemists use the word 'property' in a special way. For instance, here is a list of some of the properties of wood:

1 It is brown in colour.
2 It is a solid substance.
3 It floats on water.
4 It can be made to burn.

'Native' silver in calcite (calcium carbonate)



Part of Sir Alexander Fleming's notebook for 1917



257

30 Days. SEPTEMBER, 1917. SEPT. 13 & 14.

14 FRIDAY [257—108]

Effect various substances on contraction of clot

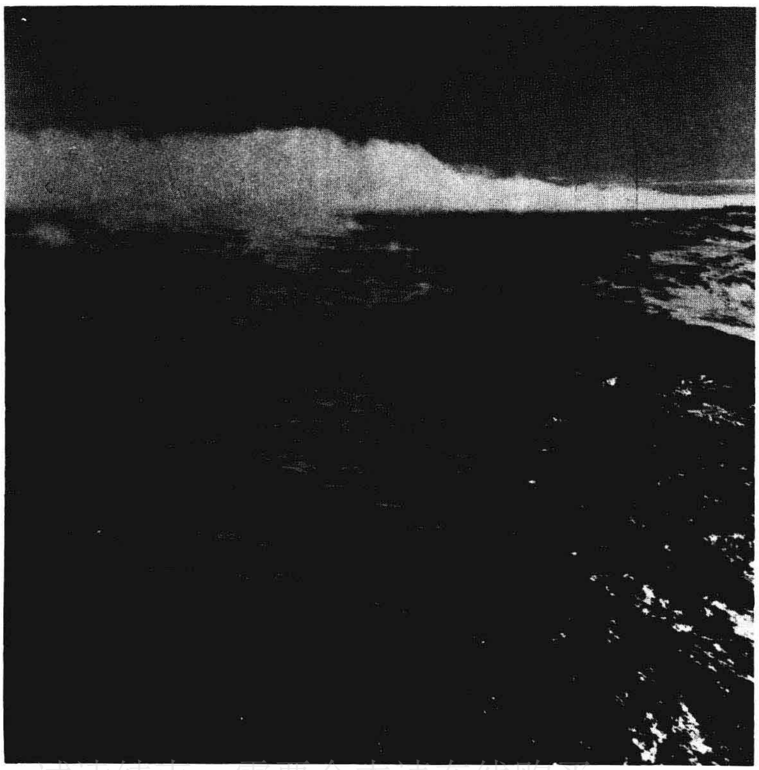
Effect of $CaCl_2$ on contraction of blood clot.

$CaCl_2$ % ·25 ·125 ·062 ·032 ·016 0

Clotting much delayed so sedimentation occurred before clotting.

As control.

How many states of water can you see?



Properties of other substances can be listed in the same way. The four properties listed above are:

Colour

State There are three states in which substances exist, **solid, liquid** and **gas.** Sand is a solid, petrol is a liquid, air is a gas.

Density By this we mean how 'heavy' the substance is compared to the same volume of water. For example, wood is less dense than water.

Burning Learning about how things burn and why they burn is an important part of chemistry.

Try answering this question

List the properties of the following substances under the headings Colour, State, Density and Burning:

Iron Salt Ice Oil

If there are any answers which you do not know try to find out for yourself by experiment.

Can you think of any properties of these substances which we have left out? . . . **Smell.** As chemists, learn to use your nose as much as your eyes: but ve **very** careful.

There are two other properties which may be of interest:

1 Whether the substance dissolves in water.

2 Whether the substance can carry an electric current.

1.4 Solids, liquids and gases

Scientists find it easier to study different substances if they can sort them out in some way. They call this **classifying** them. At school you are sorted out, along with many other children, into different classes. All the children in your class are about the same age.

We must sort out the different substances we are going to study and put them in different classes. Substances with similar properties are put into the same class. By classifying substances in this way we can see patterns in the vast number of facts; this makes them easier to remember and easier to understand. One simple way to classify substances is to divide them into solids, liquids and gases. These are sometimes called the three **states of matter.** We call a substance which is a gas, such as air, gaseous. The gas burnt in your cooker is gaseous, too.

Sometimes a gas is called a **vapour.** For example when water evaporates we call it water vapour. The difference in meaning between the words 'vapour' and gas is very little. We use the word 'vapour' to describe a gas which can also exist as a liquid at the same temperature.

Try to answer this question

Classify the following substances as solid, liquid or gas:

Petrol	Chlorine	Salt
Chalk	Moth-balls	Steam
Oil	Iron	Vinegar

Add two more solids, two more liquids and two more gases to each list.

Can you think of a substance which is difficult to classify? Mud, for example, seems to be half way between a solid and a liquid. If you look at it more closely you will see that it is not a single substance at all. It is made up of sandy specks of a solid mixed with water. You may think smoke is a gas, but the soot which forms in a chimney is a solid powder. In fact, smoke is very tiny specks of solid floating in the air.

1.5 Pure substances and mixtures

Mud and smoke are not single substances, they are **mixtures** of substances. We have another way of classifying different substances: pure substances and mixtures.

Figure 1.1

The label in Figure 1.1 shows that the honey is pure. This means that it has had nothing added to it (or taken from it). Pure honey contains dozens of different substances; the relative proportions of these substances gives each honey its own characteristic flavour. But when the chemist says something is **pure,** he means that it is a single substance, and not a mixture of substances.

Try to answer this question

Classify the following as pure substances or mixtures. Put those you are doubtful about into a third class labelled 'don't know'.

Sea water	Soil	Brick
Air	Paint	Petrol
Soap	Milk	Disinfectant

Did you put any substances in the class labelled 'pure substances'? If so, I'm afraid you are wrong. You may think that soap and disinfectant are 'pure' since they are used for cleaning and killing germs, but to a chemist they are not single substances, but mixtures. In fact, all the substances in the list are mixtures. Petrol, for instance, looks like a pure enough liquid, yet it is a mixture of octane and other liquids. Air is a mixture of gases, mainly nitrogen and oxygen.

1.6 Separating pure substances from mixtures

How can we tell whether a substance is pure or whether it is a mixture? One method is to try to separate it into a number of different pure substances. The different 'ingredients' in a mixture are called **components.**

Sea water has two main components, salt and water. Air has two main components, nitrogen and oxygen. Petrol has several different components. When we talk about a component in a mixture we always mean a pure substance.

Summary

1 Chemistry is the study of substances around us in the Universe.
2 Substances which are found naturally are

called naturally occurring substances. Substances made by chemical processes are called man-made substances.

3 The most important sources of raw material are plants, coal and crude oil, rocks, the sea and the air.

4 The properties of a substance describe how it behaves under certain conditions.

5 Chemists classify substances by sorting out those substances with the same properties into the same class. Substances may be classified as solid, liquid or gas. Another method is to classify them as pure substances or mixtures.

6 The different substances in a mixture are called components.

Study questions

1 Have a look in your mother's kitchen and larder. Make a list of 10 of the substances and materials there. Use the chemical name for substances if you can. Which of these substances are naturally occurring and which are man-made?

2 One of the most important substances extracted by chemists, for use in medicine, is penicillin. Find out what you can about:
(a) the discovery by chance of penicillin by Sir Alexander Fleming.
(b) its extraction for medical use.
(c) the importance of penicillin.
(d) why it is becoming less effective in medicine as an antibiotic?

3 Which branch of chemistry are each of the following particularly interested in?
The biochemist The pharmacist
The metallurgist The geologist
The chemical engineer

4 Chemistry has been described as a branch of science.
(a) How would you describe to someone of your age what science is?
(b) How would you describe to someone of your age what chemistry is?

5 Find out the names of the branches of science in which we study:
Living things The stars and planets
The weather Farming methods
Plants Metals
Rocks and minerals in the Earth

6 The chemical names of four substances we use at mealtimes are:
Sodium chloride Acetic acid
Hydrogen oxide Sucrose
What are their common names?

7 Coal is an important raw material. It is used as a fuel and many other materials can be made or extracted from it. Make a list of eight products made or extracted from coal.

8 Plants are a major source of raw material for the chemical industry. Make a list of six naturally occurring substances obtained from plants which are important in everyday life. Make a second list of six materials made from raw materials in plants.

9 Bloggs, a narrow minded young student was asked by his teacher to explain what

chemistry was about. 'The study of things out of bottles,' Bloggs replied. The teacher was shattered. Write 2 or 3 paragraphs to convince Bloggs that chemistry is concerned with everyday life.

10 (a) Find out which metals are obtained from the following ores. Give the chemical name for each ore:

Bauxite	Copper pyrites
Dolomite	Cinnabar
Haematite	Galena
Argentite	Calamine
Cassiterite (tinstone)	

(b) What do we mean by the word 'ore'?

11 All scientific discoveries can be used either for constructive or destructive purposes. For example, nitric acid is used in the manufacture of fertilizers and explosives. What other areas of chemistry present similar problems to modern chemists? Write two paragraphs on three of the following to show first their helpful and second their harmful uses:

Detergents	Atomic energy
Chemical warfare	Insecticides
The contraceptive 'pill'	

12 A French chemist and historian in the nineteenth century, C. A. Wurtz, Professor of Chemistry at the School of Medicine in Paris, began his book *The History of Chemistry* with the following words: 'Chemistry is a French science. It was founded by Lavoisier who will be remembered forever'.

(a) Find out what contribution Lavoisier made to chemistry in the eighteenth century.

(b) Write a letter to Professor Wurtz in reply to his claim. Give a list of six great chemists of various nationalities with a short description of their important achievements to show him that chemistry owes its success to men and women of all nations.

13 Have a good look at today's newspaper. What news or advertisements does it contain which are important to chemists and the chemical industry?

14 Write a short paragraph to explain each of the words below:

Substances	Property	State
Pure	Gaseous	Component
Classify	Mixture	

15 Make a list of some of the properties of:

Natural gas	Wool	Sand
Petrol	Chalk	Moth-balls

16 Write a few short sentences explaining to a friend who has not started to learn chemistry:

(a) why a chemist tries to classify substances.

(b) what a chemist means by a pure substance.

17 Apart from water, sodium chloride (salt) is the most abundant substance in the sea.

(a) How does it get into sea water?

(b) What is the simplest method of getting it from sea water in hot countries?

(c) Why is this method not used in this country?

(d) In this country most salt is obtained from inland beds beneath the surface of the land in Cheshire. How did the salt come to be there?

(e) More than 25 million tonnes of salt are mined each year in Britain. Many different substances can be obtained from salt. Most of the substances containing sodium or chlorine, which we use, are obtained from salt. Make a list of six substances which contain sodium or chlorine.

18 Set a candle burning. Describe carefully all you observe as it burns.

19 Have a look at some materials with a hand lens or under a microscope and describe carefully what you see. Try looking at:

A grain of sand	A grain of sugar
A human hair	A speck of dust

Crude oil

2 Separating mixtures

2.1 Introduction

Why do we separate petrol from thick black crude oil? Why do we separate pure water from sea water? Why are we interested in separating mixtures into pure substances?

Here are two important reasons:

1 We can get more, and more useful, materials. The pure substances can be put to uses for which the impure mixture was unsuitable. Just think what would happen if your father tried to run his car on crude oil rather than petrol!

2 Mixtures must be separated into pure substances before we can study the properties of the separated components and their principal uses. For example, only by doing experiments with pure water can we be sure that the reactions which occur are those of water and not some other substance it may contain. The properties of salty water are very different from those of pure water. Try drinking sea water.

The important question we ask in this chapter is 'How can we obtain pure substances from mixtures?'

Try to answer these questions

1 How can we obtain clear water from muddy water?

2 How can we obtain pure water from clear water which has solids mixed (dissolved) in it?

3 How are the various products (e.g., petrol, paraffin) separated from crude oil?

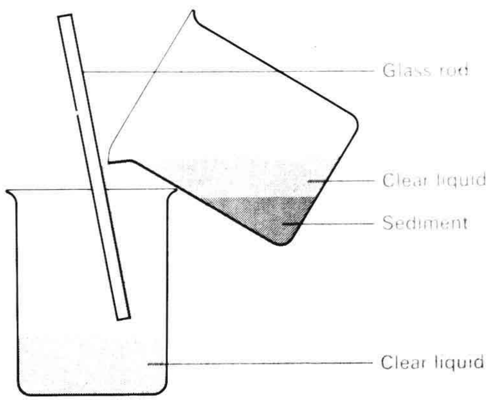
2.2 Decantation

Muddy water contains tiny particles of solid 'floating' in the water which makes it seem cloudy. If the water is left to stand for some time the heavier particles of solid sink to the bottom of the vessel and form a sediment. The clearer water can be separated easily from the solid sediment by pouring. This process, shown in Figure 2.1, is called **decantation.**

Decantation can be used to separate any liquid from heavier sediment. Have you watched your mother decanting water from vegetables after cooking?

Water obtained by decantation from its sediment of mud still appears cloudy due to very fine particles of solid 'floating' in it. We say that the particles are suspended in the water. 'Suspended' means 'hung up'. We call this mixture of fine solid particles suspended in water a **suspension.** In a suspension bridge, the road is 'hung up' with cables. Smoke is a suspension of fine solid particles in air. In a suspension there are two substances. The particles of the suspended substance are so small they do not sink even after a very long time. Have a look at some milk under a microscope. You will see tiny droplets of oil (cream) suspended in a watery liquid.

Figure 2.1



Try to answer these questions

Mist is a suspension.

1 What states of matter does it contain?

2 What are the suspended particles?

3 What are they suspended in?

What are the components of these suspensions?

How can we separate the suspension of minute solid particles from the cloudy water? How can we remove solid particles from smoke to obtain clean air? Think how your mother removes the water after boiling rice or peas. She strains off the water, trapping the solid rice or peas with a strainer. Can you think of other things used for straining off liquids?

Try putting muddy water through a strainer or sieve; you will not catch the solid particles because they are small enough to pass through the holes. You need a much finer sieve!

2.3 Filtration

We have a special word in chemistry which means 'to strain or sieve something'. We say that we **filter** it; and we call the process of filtering **filtration.**

In order to filter a suspension in which the particles are very small we must use something with even smaller holes to stop the solid particles from passing through. Filter paper, a special kind of thin white blotting paper usually made in the form of a circle, is made for this purpose. There are millions of fine holes in the paper through which water can flow, even though you cannot see them. Look at a piece of filter paper under a microscope – can you see the holes, or are they too small?

The simplest way of filtering is to use a glass funnel known as a filter funnel (Figure 2.2). The filter paper is folded so that it fits snugly in the funnel. The solid that remains in the filter paper is the **residue**, and the liquid that trickles through is the **filtrate**

Figure 2.2

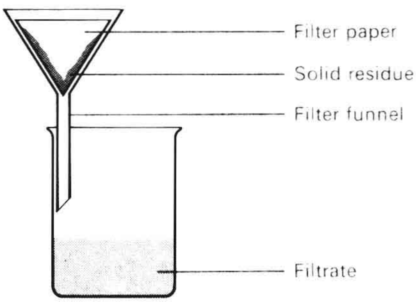
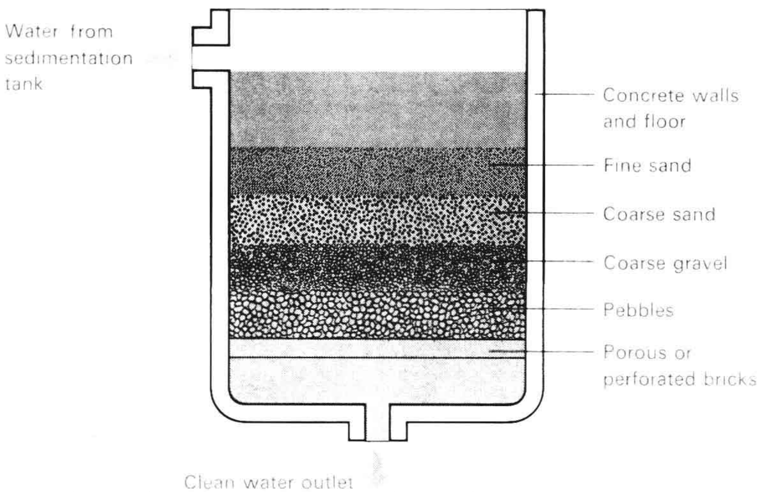


Figure 2.3 shows how river water is filtered before it is used for drinking and washing. First, the water goes through a sedimentation tank where the largest solid particles settle out; then it trickles through layers of gravel and sand in a filter bed.

Figure 2.3



Any solid can be separated from a liquid by filtration. The liquid does not have to be water. 'Gloss' paint, for instance, is a suspension of coloured particles in a special