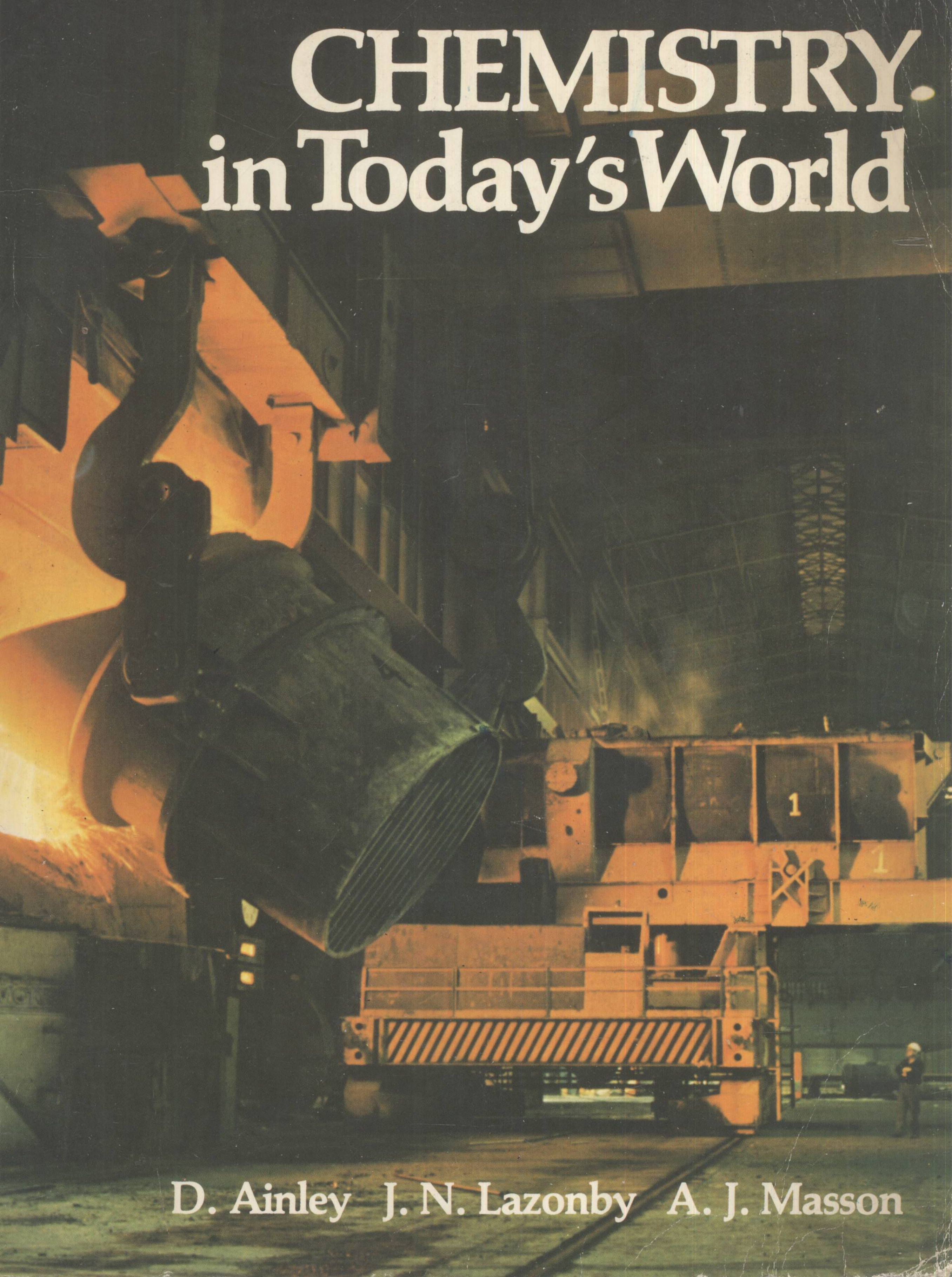
CHEMISTRY in Today's World



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CHEMISTRY in Today's World

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Preface

The book is designed for the last two or three years of chemistry courses which lead to examinations at 16+. Whereas the topics in the book are those which are required by the syllabuses of the various examination boards, we believe it is essential that the study of these topics should also be justified in other ways. This has been achieved by showing how certain lines of enquiry help to develop our understanding of the behaviour of substances and also by emphasising the parts played by individual scientists in the development of the subject. The other main reason for including topics is that they are important to our present and future lives. The applications of chemistry are considered, not only because of their economic importance, but also from the point of view of their effects on our environment and the need to conserve the world's resources. Many of the photographs in the text illustrate the part played by chemistry in Today's World.

While writing the book, we have assumed and indeed believe, that teachers prefer to devise their own courses and do not wish to provide a book for their students which places too many constraints on the teaching sequence or teaching methods employed. Thus we have written a single-volume book and divided each chapter into two distinct though related parts—investigations and text. This separation is intended to allow greater flexibility in use than is possible with a course book. It is not an attempt to divorce practical work from theoretical progress and thus within the text, wherever theories are outlined, they are presented as possible explanations of observable behaviour.

Instructions for investigations are given at the beginning of most chapters and those which are more appropriate as demonstrations are described in the text. The instructions are written in such a way that the investigations may be used as an integral part of a problem-solving type of approach. Each investigation is followed by questions which encourage the student to think about the observations before they are discussed more thoroughly in class. The investigations may be used at the discretion of the teacher, whereas students are able to work independently with the text without necessarily having carried out all of the investigations. The division of each chapter into numbered sections, the extensive use of cross-referencing within the text and the comprehensive index, facilitate the retrieval of information, and students will find the book easy to use for revision. The summaries at the end of each chapter provide the student with an overview of the topic rather than a condensed version of the content.

The book is supported by a data section and a set of questions. The data section includes tables of physical properties of selected elements and compounds. The questions cover the main topic areas in the book and each question in the second set of revision questions consists of several parts, with each successive part making increased demands on the students and so catering for the need to assess the knowledge and understanding of students who represent a wide range of ability.

A teachers' guide, which provides further details on the investigations and references to other sources of information and teaching aids may be obtained by sending a stamped addressed A5 envelope to J. N. Lazonby, Department of Education, University of York, Heslington, York Y01 5DD.

Acknowledgements

We thank Mr J. D. Haden for reading the manuscript and for his valuable advice, and Dr. J. McIntyre and Mr. D. J. M. Rowe for their helpful discussions on industrial chemistry. In particular we thank Professor D. J. Waddington for his encouragement, guidance and help at all stages in the production of the book.

Among the many sources of information consulted during the preparation of the book we particularly acknowledge the use we have made of the I.C.I. booklets, Fertilisers and Inorganic Chemicals.

The sources of photographs are acknowledged in the text. We thank the companies and organisations who have allowed us to use their photographs and we thank Mr. R. Edwards and Mr. J. Olive for those which were taken especially for the book.

We are grateful to the following examination boards for granting permission to use questions from past examination papers: East Midlands Regional Examinations Board, Joint Matriculation Board, Oxford and Cambridge Schools Examination Board, Oxford Delegacy of Local Examinations, South Western Examinations Board, University of Cambridge Local Examinations Syndicate, University of London University Entrance and Schools Examinations Council, Welsh Joint Education Committee, West Midlands Examinations Board and Yorkshire Regional Examinations Board.

Finally we thank our families for their patience and for their encouragement during the preparation of the book.

D.A.
J.N.L.
A.J.M.

Contents

Chapter 1

What are substances made of?

1.1 What does a chemist do?

St. Paul's Cathedral in London was designed by Sir Christopher Wren. On his tomb inside the cathedral is written 'If you seek my memorial, look about you'. In other words, the cathedral is evidence of his work.

Similarly, if we wish to see evidence of what a chemist does, we just have to look around us. Many of the materials which we use in our everyday lives involve the work of chemists at some stage in their production. The chemist's products include plastics, paints, textiles, dyes, medicines, fertilisers, insecticides and detergents. Most of these products are made from a small number of raw materials, such as coal, oil, air, salt and limestone, which are present in or around our Earth. It is the job of chemists to convert these raw materials into the substances we use.

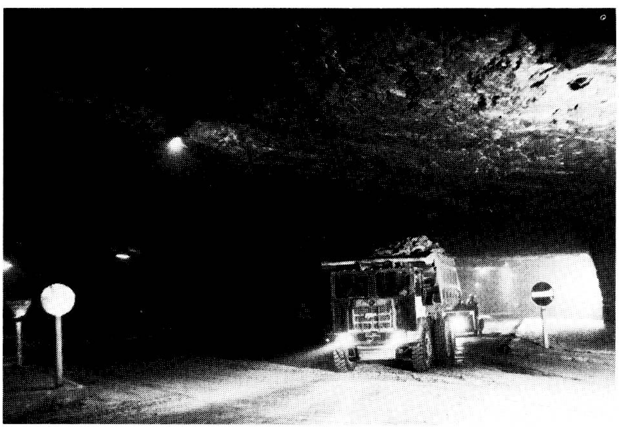
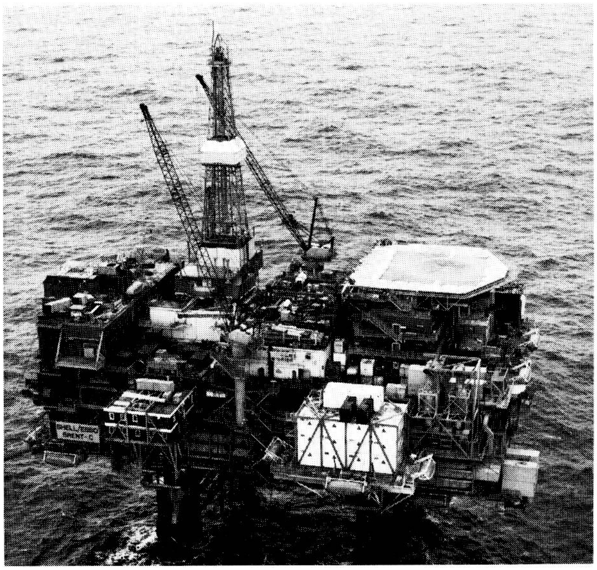


Fig. 1.1 Some of the main sources of raw material for the chemical industry (a) inside the salt mine at Winsford, Cheshire. A lorry load of rock salt is being transported to another section of the mine. (Courtesy I.C.I. Ltd, Mond Division. Photo: Photo Graphics, Merseyside)

(b) A general view of the Swindon Limestone Quarry in Yorkshire, showing the rock face and the lime-kilns. (Courtesy Tilling Construction Industries Ltd. Photo: J. Holmes)



(c) An oil production platform in the North Sea

Chemists are also employed in medical work where, for example, the results of chemical tests on a sample of blood or urine can help a doctor to diagnose a patient's illness. Chemical techniques are also important in forensic science (the use of science for investigating crimes), checking the purity of water and food supplies, and many other areas which influence our daily lives.

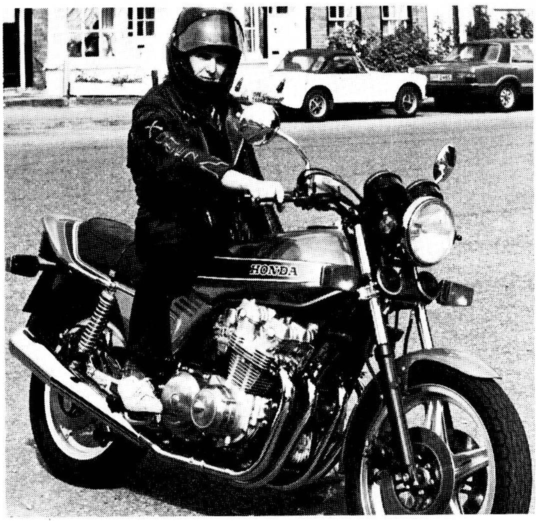


Fig. 1.2 The materials used to make this motorbike, such as the metals for the engine and frame, the plastic for the seat and cable covering, the rubber for the tyres and the glass for the lights, are all produced by chemical processes. (Photo: Russell Edwards, B.Sc)

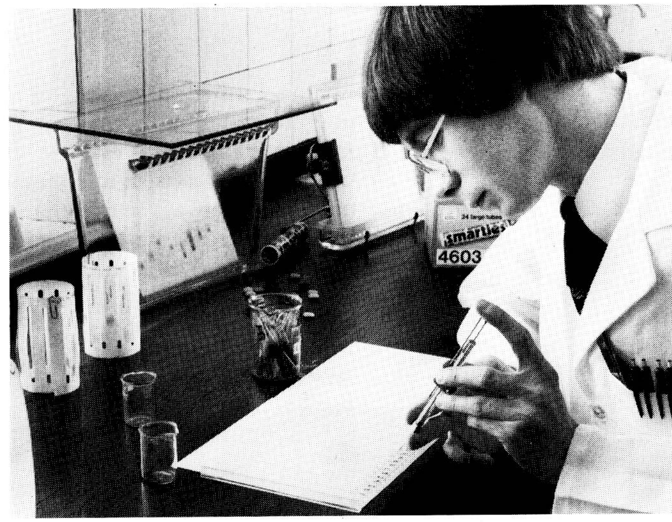


Fig. 1.3 A use of chemical techniques in the food industry—this photograph shows thin layer and paper chromatography being used to separate and identify the colouring materials in Smarties. (Courtesy Rowntree Mackintosh Ltd)

1.2 Chemical and physical changes

Most raw materials consist of mixtures of substances. The chemist must first find ways of separating the useful substances from these mixtures and then converting them into the materials which are required.

In order to carry out these steps, chemists perform two types of changes on substances. One type of change is more drastic than the other. The differences can be illustrated by thinking about the ways in which candle wax can be changed.

When candle wax is heated it melts to form a colourless liquid, but if the liquid is cooled, it changes back to solid wax again. The melting of candle wax has not changed it into a different substance. It is still candle wax even when it is a liquid.

On the other hand, if candle wax is held in a flame, it will burn with a yellow flame, giving off smoke and gases. In this example, the candle wax has been changed into different substances. It would be very difficult to change these substances back into candle wax.

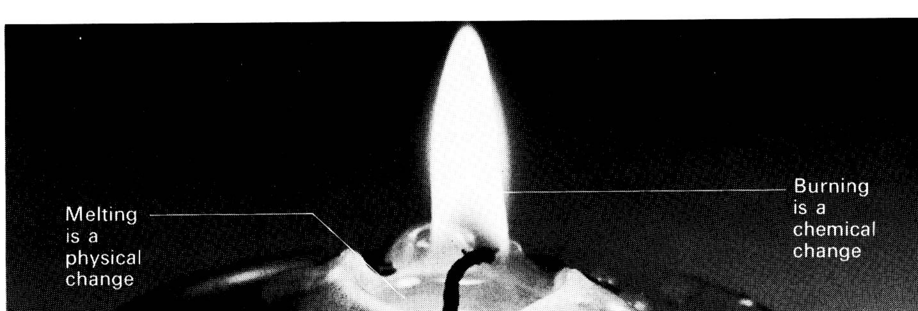


Fig. 1.4 A lighted candle involves both chemical and physical changes. (Photo: Russell Edwards, BSc)

A change in which different substances are not formed (e.g. melting wax) is called a **physical change**, as we have only changed the physical form of the substance.

A change in which different substances are formed (e.g. burning wax) is called a **chemical change**, as new chemical substances have been formed.

Chemical changes can be called chemical reactions. This name is particularly appropriate if the chemical change occurs when two substances are put together. Clearly, in this type of change the two substances can be thought of as reacting together to form different substances. For example, the change which occurs when a piece of wood is burned, can be thought of as a reaction between wood and air. Ash, smoke and gases are formed by this reaction.

This particular chemical reaction needs some heat to start it off, but once started, the wood burns and gives out more heat. Many reactions need heat to start them off, but some occur by simply mixing the substances. For example, a chemical reaction occurs between two components of health salts when they are dissolved in water. Some types of glue work by mixing two components together; a chemical reaction occurs while the glue is setting. The resin which is used with fibreglass to repair damaged motor cars is made by mixing two substances which spontaneously react together.

Sometimes it is obvious that new substances have been formed, but if it is not, what other indications might there be that a chemical change has occurred? One sign might be that there is an obvious energy change. For example, when a substance burns energy in the forms of heat and light is given out. When the components of a glue or resin are mixed no light is given out (i.e. there is not a flame) but the mixture does become hot which indicates that a chemical change is occurring.

During a chemical change different substances are formed and it is usually difficult to convert these substances back to the original substances. This means that a chemical change is not easily reversible. However, you must take care when using this indication of a chemical change. If, for example, you break a glass bottle, it is not easy to reverse the change, but this is not a chemical change as no new substances have been formed. The broken pieces of bottle are still made of glass. A physical change has occurred because you have changed the physical form of the bottle. To reverse the change, it would be necessary to melt the glass and reshape it. This would not be easy for most of us, but it would still be a physical change.

The differences between physical and chemical changes are summarised in Table 1.1.

TABLE 1.1. *Physical and chemical changes*

	PHYSICAL CHANGES	CHEMICAL CHANGES
Differences	No new substances are formed. The product is chemically identical to the starting material.	New substances are formed in the change.
Possible signs	1. The change can often be simply reversed.	Usually the product can only be converted back to the original material with great difficulty.
	2. The energy changes are usually small.	Often accompanied by obvious energy changes.

1.3 What substances consist of

Chemists have investigated materials by subjecting them to physical and chemical changes. They have found that every material can be broken down into one or more of about ninety substances which cannot themselves be broken down into anything simpler. These substances, from which everything is made, are called **elements**.

For example, if electricity is passed through molten salt, the salt is broken down into two substances. One of these substances is a silvery-grey metal called sodium and the other is a pale green gas called chlorine. Try as hard as we might, we cannot break down sodium and chlorine into anything simpler. Sodium and chlorine are therefore elements.

Water can be split up into hydrogen and oxygen, but hydrogen and oxygen cannot be broken down any further. Therefore, hydrogen and oxygen are elements, but water is not.

Other common elements which you are likely to have heard of are iron, aluminium and copper. If you have a piece of copper, then it is just copper—you cannot get anything else out of it. On the other hand blue copper sulphate is not an element. By carrying out chemical changes on the crystals it is possible (although not easy) to obtain from them four different elements: copper, sulphur, hydrogen and oxygen.

A list of elements is given in the Data Section. From what is known about the elements, we are able to say that nowhere in the whole Universe are we likely to find any more than the ninety or so elements which can be found in the Earth or its atmosphere.

1.4 The elements

There is considerable variety in the elements which exist. The most obvious way in which they differ is in their physical states. Many are solids, some are gases and two are liquids at room temperature and pressure.

Another way of classifying elements is to divide them into **metals** and **non-metals** as in Table 1.2. All of the gases, one of the liquids (bromine) and a small number of solids are non-metals. All of the other solids and the other liquid (mercury) are metals.

TABLE 1.2. *Some common elements*

SOLIDS AT ROOM TEMPERATURE		LIQUIDS AT ROOM TEMPERATURE		GASES AT ROOM TEMPERATURE	
METALS	NON-METALS	METALS	NON-METALS	METALS	NON-METALS
aluminium	carbon	mercury	bromine		chlorine
calcium	phosphorus				fluorine
chromium	sulphur				helium
copper					hydrogen
gold					neon
iron					nitrogen
lead					oxygen
magnesium					
platinum					
radium					
silver					
sodium					
tin					
uranium					
zinc					

If you were to obtain a sample of a solid element from a material, how would you know whether it was a metal or a non-metal? One possible way of deciding would be simply to look at it and to handle the solid. Metals are usually shiny and most are silvery-grey in colour (copper and gold are obvious exceptions). They are generally hard and strong, and they feel cold to the touch because they easily conduct heat away from your hand. Metals can usually be beaten or rolled into strips or sheets, and drawn into wires.

Solid non-metallic elements are not as uniform in their appearances and natures as metals. They show a variety of colours. Sulphur is yellow, phosphorus is either red or light yellow and carbon is black or grey. They are usually hard and brittle (although some forms of carbon and phosphorus are not). They are poor conductors of electricity (except carbon), and they are poor conductors of heat, so they do not feel as cold to the touch as metals. Generally non-metals are less dense than metals.

The physical differences between metallic and non-metallic elements are summarised in Table 1.3.

TABLE 1.3. *The physical properties of metallic and solid non-metallic elements*

METALLIC ELEMENTS	SOLID NON-METALLIC ELEMENTS
1. Shiny, silvery-grey colour	1. Variously coloured
2. Generally hard and strong	2. No uniformity in hardness and strength
3. Generally high densities	3. Generally low densities
4. Good conductors of heat and electricity	4. Generally poor conductors of heat and electricity

All this table does is to show the general properties of the two groups of elements. There are exceptions to most of these properties. A more definite way of deciding if an element is metallic or non-metallic is to examine the chemical properties of the elements. This is done in 11.19.

1.5 Putting elements together

Iron and sulphur are two solid elements and the effects of putting them together in different ways are easily studied. Iron, when alone, is attracted to a magnet and goes rusty when exposed to moist air. When dilute sulphuric acid is added to it, bubbles of gas are steadily given off and the gas can be shown to be hydrogen.

If powdered sulphur is stirred with iron filings, so that the two are thoroughly mixed, the iron filings in the mixture will still be attracted to a magnet, will still go rusty if the mixture is exposed to moist air and will still react with dilute sulphuric acid, causing hydrogen to be given off. The presence of the sulphur in the mixture has not changed the behaviour, or properties, of the iron.

If the mixture of iron filings and sulphur is heated it glows red-hot, and the glow persists for a while even when the flame is removed. This shows that heat is being given out by the elements and suggests that they are reacting with each other. The iron becomes joined to, or combined with, the sulphur to form a black **compound** called iron(II) sulphide.

If there was sufficient sulphur in the mixture to combine with all the iron, the product would not be attracted to a magnet and would show no sign of rusting when exposed to moist air. If dilute sulphuric acid is added to the black solid a gas is given off, but this time, instead of hydrogen, it is a foul-smelling gas called hydrogen sulphide. The properties of the iron, when it is joined to (combined with) the sulphur, are quite different to those which it shows when alone or when simply mixed with the sulphur.

Every substance in this world which contains more than one element is either a mixture of elements or a compound in which the elements have been joined together. In a mixture the elements are able to show the same properties as they do when alone, but a compound has its own properties which are usually different from those of the elements in it.

Air is a **mixture** of gases, the most abundant ones being oxygen and nitrogen and it will allow things to burn in it and animals to breathe in it, just as pure oxygen will. These processes are slower in air than in pure oxygen since the oxygen in air is diluted by the nitrogen and not so much of it is available in one place as would be the case in pure oxygen.