First Reactions

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OUTLINE

'First Reactions', is an introductory course of basic chemistry. It is designed as a 2-year course for pupils and is written in two parts.

Part I introduces chemistry very simply, using only very straightforward concepts. The use of diagrams, photographs, simple experiments and references to the applications of chemistry in everyday life make the text interesting to pupils of widely differing abilities.

Part II develops the concepts from Part I in more detail and introduces, still quite simply, more chemistry suitable as a basis for further study, although it is still a complete course in itself. The course will certainly interest and stimulate boys and girls and give them the confidence to want to continue to study the subject further up the school.

Quantitative work is developed throughout the course to include experiments involving weighing, volume, measuring and timing.

There are sections for further reading for pupils who need more background material and a range of questions at the end of each section.

T H McCormack

CONTENTS

Part I Introduction

What is chemistry?

Have you ever wondered why a firework goes off, why a cake rises in the oven or how petrol can drive a car? Well, it is all to do with chemistry—a part of Science which deals with changes taking place to form new things.

In this book we will set out to find out what a chemical change is and then to try as many as possible in the laboratory. To do this you will have to do many tests (or experiments) with chemicals and be able to work carefully and safely in the laboratory.

What will we use?

You will be using chemicals and apparatus. The chemicals are all the substances—powders, crystals, liquids and gases—which your teacher will give you and which you must handle exactly as you are told to. To help you to do experiments you will work with a lot of useful objects called apparatus, most of which is made of glass. We have used diagrams to help to explain how you should do the experiments. By a 'diagram' we mean a simple picture of the apparatus and when you write your experiments in your book you will have to draw diagrams of the apparatus used. It is important that you learn to recognise and draw diagrams of all the pieces of apparatus shown. You will meet new pieces as you do more chemistry.

Is it safe to do chemistry?

The answer to this question is 'Yes, as long as you do just what you are told and act sensibly.' Your teacher will talk to you about safety in the laboratory and how to behave, so always listen to, and do exactly what you are told. **Do not try out your own experiments.** All of the chemicals which you will use are perfectly safe if used properly. If you are ever uncertain about anything, ask before going on with it.

What are experiments?

This is simply a word for tests carried out in a laboratory. You do them to find out things which you do not know about. You could look up the answers in a book but even they can sometimes be wrong so you should always try to find out by doing it yourself.

How to record an experiment

It is very important to write down what you do in an experiment and what you find out so that other people can read it if they are interested. The best way of doing this is set out below and you should practise it.

Date of Experiment *Title of Experiment*
Diagram (draw the apparatus you used)
Method (say what you did)
Results (what you noticed happening)
Conclusion (what you have found out)

Experiment **2.2** on page 6 is a good example of this.

Will we do any measuring?

You do not measure as much in chemistry as in other parts of science until you get further up the school but you will do some measuring.

Below is set out a table of some measurements you may do and the units you will use.

Measurement	Units
volume of liquid or gas	cubic centimetres (cm^3) $1000cm^3 = 1dm^3$ ($1dm^3$ is called a cubic decimetre)
mass of a chemical	grammes (g) or tonnes (t)
time for something to happen	seconds (s)

Now you are ready to start 'doing chemistry'. It is a subject from which you should get a lot of enjoyment and which you should find very interesting.

Topic 1 The Elements

ELEMENTS are the simplest chemicals and all other substances are made up of elements joined together in different ways.

One way to tell the elements apart from each other is by being able to recognise them by their appearances . . . that is, what they look like. The table below lists some of the more important elements and describes what they look like at room temperature.

Element	Appearance
hydrogen	colourless gas
nitrogen	colourless gas
oxygen	colourless gas
sulphur	yellow solid
magnesium	shiny grey solid
zinc	shiny grey solid
aluminium	shiny silvery solid
calcium	shiny dark grey solid
lead	dark grey solid
copper	shiny brown solid
mercury	silvery liquid
bromine	deep red liquid
chlorine	yellow/green gas
sodium	shiny grey solid
carbon	black solid
iron	dull grey solid

You should try to learn these appearances and also learn to spell the names of the elements correctly.

As you can see from the table, three are shiny grey solids and three are colourless gases. This means that, while this table helps to name many elements, others need to be tested somehow to find out what they are. You will learn how to do this later.

The symbols of the elements

As more and more new chemicals were discovered it became obvious to scientists many years ago that they were going to need some kind of 'shorthand' code for each new chemical. This would help them to record their experiments quickly and to exchange results with scientists from other countries.

Here are some of Dalton's symbols. Would you find them easy to remember?

One was tried by Dalton around 1808 using circles with different signs inside them, but this became very confusing. Eventually Berzelius (in 1818) suggested using initial letters of the names of the elements and so our present day system of chemical shorthand was devised. Some of the symbols now used look nothing like the names of the elements, this is because they are based on old Latin, Greek or Arabic names. For example, lead was once called *p*lum*b*um, iron was called *fe*rrum, copper was *cu*prum and mercury was *h*ydrar*g*yrum.

The list below should be learnt as soon as possible.

Element	Symbol
hydrogen	H
nitrogen	N
oxygen	O
sulphur	S
magnesium	Mg
zinc	Zn
aluminium	Al
calcium	Ca
lead	Pb
copper	Cu
mercury	Hg
bromine	Br
chlorine	Cl
sodium	Na
carbon	C
iron	Fe

Questions for you

1. Draw a neat diagram of each of the following pieces of apparatus and write a few iines to say what you think it is used for: a beaker, a filter funnel, a test-tube holder, a tripod.
2. In the list of letters below are hidden the names of 10 elements. The letters of the names are in the correct order and you can use each letter more than once.
   SOLTHUMCXEYDAOILZRGPION
   PHCEGREBSIDONUMR
   Try to find the 10 names and write them in your book.
3. In your book make a list of the elements which have the first letter of their name as their symbol. Do the same for these with the first and second letter. Finally do the same for those whose symbols look nothing like the names.
4. Choose one or two elements and find out all you can about them—for instance, where they are found, what they are used for, how they are obtained and any other interesting facts.
   The Appendix on page 105 will help you with this.
5. Unscramble the letters below to find the names of the elements. Write down their symbols alongside.
   (i) eprocp, (ii) uiasmengm, (iii) ruphuls, (iv) nabroc, (v) mluinauim.

Topic 2 Compounds

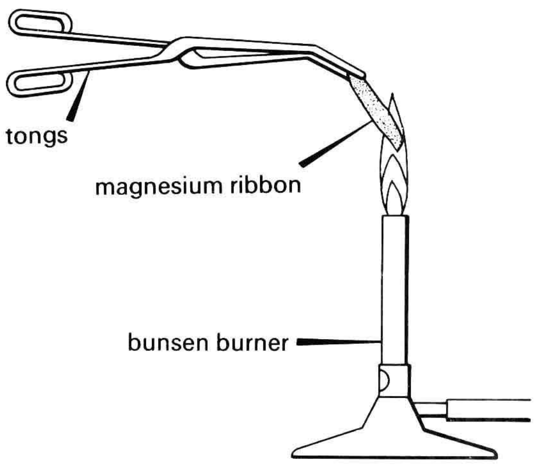
Elements combine together to form chemical *compounds*. Two compounds which can be made by simply joining two elements together are magnesium oxide and iron sulphide. Experiment **2.1.** below explains how to do this.

Experiment 2.1 Making compounds from elements

1. Magnesium oxide from magnesium and oxygen

Apparatus: pair of tongs, bunsen burner, tile (fireproof), safety glasses.

Diagram:



Method:

Hold a piece of magnesium ribbon about 5cm long in the tongs then put it into the bunsen flame. When it has lit up take it out of the flame but **do not stare at it** as the light from it is very bright.

2. Iron sulphide from iron and sulphur

Apparatus: test-tube, test-tube holder, fireproof tile, safety glasses.

Method:

Put a mixture of 1 part iron filings and 4 parts sulphur powder into the test-tube and heat it strongly. When it has started to glow inside take it away from the bunsen flame.

Results: For both of these experiments write down what you see happening.

Conclusion:

For the conclusion you must decide whether a new chemical has been formed and whether it looks anything like the elements with which you started.

Magnesium oxide

This is made by heating magnesium ribbon, held in tongs, in a bunsen flame. The ribbon starts to burn with a bright, white light. **You should not stare at this light.** A white ash or powder is left behind which is the magnesium oxide. The magnesium has combined with the oxygen from the air (see page 37).

We can write down what has happened like this:

$$\text{magnesium} + \text{oxygen} \xrightarrow{\text{heat}} \text{magnesium oxide}$$

This is called an equation and means: magnesium <u>combined with</u> oxygen <u>when heated formed</u> magnesium oxide. You can see that the + means 'combined with', the word 'heat' means that you had to heat it and the arrow ⟶ means 'and formed' or 'changed into'. You will meet these signs a lot in chemistry.

Iron sulphide

This is made by heating together sulphur powder and iron filings. The mixture will turn from a yellow/grey colour to a black solid and will glow orange like a furnace. The iron and the sulphur have joined together. You may see some yellow fumes as sulphur vapour escapes from the test-tube. You may also smell something like fireworks. This is the sulphur burning. The black solid left behind is iron sulphide.

Again we can write an equation in words for what has happened:

$$\text{iron} + \text{sulphur} \xrightarrow{\text{heat}} \text{iron sulphide}$$

As in the last reaction, this equation means: iron combined with sulphur when heated formed iron sulphide.

In chemistry most of the substances which you will use will be compounds.

You also use them at home. The most common is salt, sodium chloride, which contains the elements sodium and chlorine joined together. Vinegar and sugar are both compounds of carbon, hydrogen and oxygen.

Do compounds look anything like the elements from which they are made?

To answer this question, let us look at the compounds which we have just made and compare them with the elements from which they have been formed.

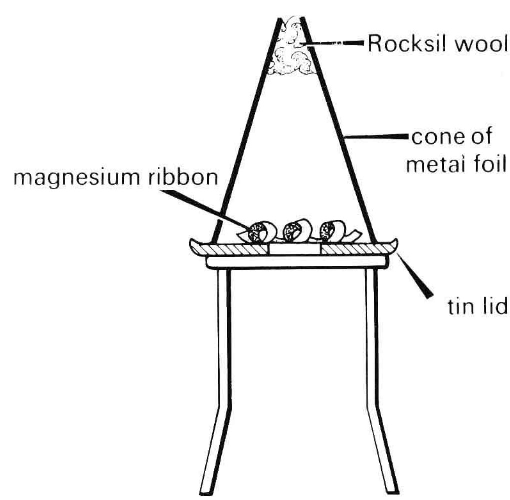
Compound	Element **1.**	Element **2.**
magnesium oxide a white ash-like powder	*magnesium* a shiny grey solid	*oxygen* a colourless gas
iron sulphide a black solid	*iron* a shiny, dark grey solid	*sulphur* a yellow powder

Well, do the compounds look like the elements from which they are made? From our observations it seems that they do not, and indeed, you will find this is so with most compounds. You might like to look at some other compounds and their elements and check this result. For example copper sulphate crystals which contain the elements copper, sulphur and oxygen joined together, or zinc carbonate powder which contains the elements zinc, carbon and oxygen joined together.

We can also see if there is any change in mass when elements make compounds, by the following Experiment (**2.2**).

Experiment 2.2 Is the mass of magnesium oxide more or less than the magnesium from which it was made? (Demonstration)

Diagram:



Method:

The apparatus is set up as shown in the diagram. The magnesium ribbon is weighed carefully, then placed on the tin lid over the small hole in it. This is then put under the metal foil cone and the whole apparatus is carefully weighed again. By holding the bunsen burner under the hole in the tin lid the magnesium ribbon can be lit and heated strongly until all of the ribbon has been burnt.

The apparatus is then left to cool and the whole apparatus reweighed.

Results:

A set of results like those below should be neatly copied into your book.

1. mass of magnesium ribbon alone = g

2. mass of magnesium ribbon + apparatus before heating = g

3. mass of magnesium ribbon + apparatus after heating = g

By taking **2.** from **3.** we get:

4. change in mass caused by the reaction = g

Conclusion:

In your conclusion you should say whether the magnesium oxide has more or less mass than the magnesium did.

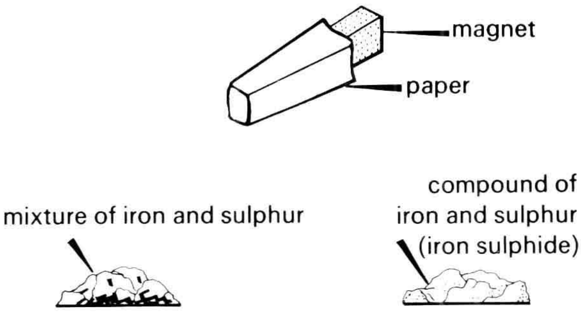
Question: Would the experiment have worked as well without the cone? . . . If not, why not?

From experiments like the one above we find that the **compounds always weigh more than either of the elements did at the beginning**. This means that, even though magnesium oxide looks light and powdery, it is still heavier than the magnesium from which it has been made. The reason is that you are adding things together (in this case magnesium and oxygen) and so their mass is bound to be more than the magnesium alone. Experiment **2.2** can be used to prove this point. The cone is needed in this experiment to trap the magnesium oxide fumes.

Finally, once elements are joined together in a compound, it is very difficult to separate them again. It is *not* like a mixture. This can be easily proved by trying to separate the iron from a mixture of iron filings and sulphur. Now try to separate the iron in the same way from the compound of iron and sulphur (the iron sulphide).

Experiment 2.3 Comparing a mixture of iron and sulphur with a compound of iron and sulphur

Diagram:



Method:

Wrap a piece of paper around your magnet and rub it slowly through the mixture of iron filings and sulphur. What do you see happen?

Now do the same with the compound of iron and sulphur (iron sulphide). Do you find the same sort of thing happening?

Next put a small amount of your mixture in a clean test-tube half full of water and shake it gently. Do the same with a small amount of the iron sulphide.

Results: You should write down everything you have seen that happens in these experiments.

Conclusion:

You should say whether you have managed to separate the iron from the sulphur in any of the experiments.

From your experiment you should find that **iron and sulphur are easily separated in the mixture but in the compound they have joined together in a way that makes them difficult to separate**.

This is always true for mixtures of elements and compounds of elements.

Questions for you

1. For each of the following compounds write down what they look like and also what the elements in them look like:

   copper oxide which contains copper and oxygen
   sodium carbonate which contains sodium, carbon and oxygen
   iron sulphide which contains iron and sulphur.

2. What do you think the names of the compounds formed would be when:
   (i) calcium is heated in air or oxygen (compare magnesium)
   (ii) lead is heated in air or oxygen
   (iii) magnesium is heated with sulphur

3. Copy and complete the following word equations:

   $$\text{copper} + \text{oxygen} \xrightarrow{\text{heat}}$$

   $$\text{sodium} + \text{oxygen} \xrightarrow{\text{heat}}$$

   $$\text{iron} + \text{sulphur} \xrightarrow{\text{heat}}$$

   $$\text{calcium} + \text{sulphur} \xrightarrow{\text{heat}}$$

4. Below are the results of an experiment in which calcium was burnt in oxygen in a container and the container was weighed before and after the experiment.

   mass of empty container = 25.0g
   mass of container + calcium = 45.0g
   mass of container + calcium after burning = 53.0g

   What mass of calcium was used in the experiment?
   What mass of product was left at the end?
   By how much has the mass of the calcium gone up?
   Why has the mass of the calcium gone up?

5. Two pupils burnt a 10cm length of magnesium ribbon each, then weighed the ash which was left at the end. They got different results. Why do you think this was so? How could they do the experiment to make sure the results would be the same?

6. Write down as many ways as you can in which a mixture of iron and sulphur will be different from a compound of iron and sulphur.

7. Try to describe what it is like to be a piece of iron in a mixture of iron and sulphur. Say what happens to you when the mixture is heated strongly.

Topic 3 What is a Chemical Reaction?

There are two different types of changes which substances can undergo. One is the type of change that will return the substance to its original condition without any help. For example, if you melt wax by heating it gently, then leave it to cool down, it will go back to solid wax. Also if you boil water near a window and then leave it, the steam will turn back to water as it cools on the window. These changes are called *physical changes*.

On the other hand, once you have baked a cake mixture in the oven or burnt a piece of coal on the fire, no matter how long you leave the mixture or ashes afterwards, they will never go back to what they were. These changes are called *chemical changes* and this is the type that we shall spend most of our time dealing with.

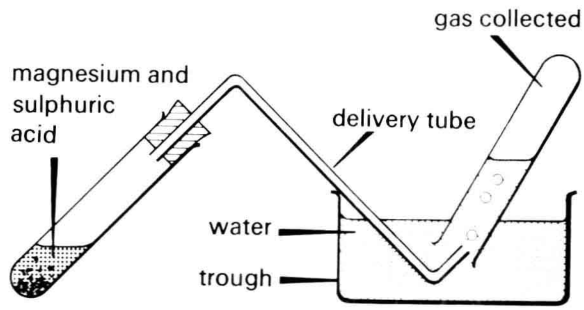
Most of your chemistry at school involves looking at chemical reactions. When a chemical reaction takes place, the *products* (the substances present at the end of reaction) are different from *the reactants* (the materials you started with) and even if you leave them for a long time the products will not change back again.

Try the following chemical reactions and write down everything you see happen.

Experiment 3.1 Looking at chemical reactions

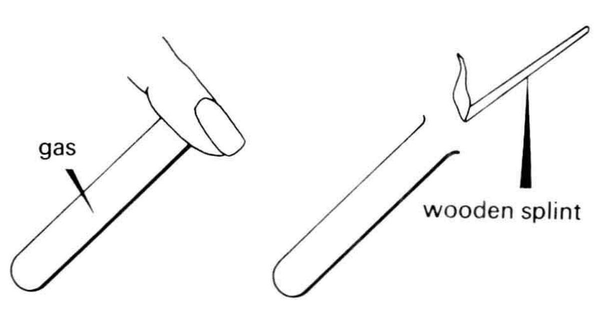
1. Magnesium and sulphuric acid

Diagram:



Method:

Set up the apparatus as shown above. Drop the magnesium ribbon into the dilute sulphuric acid and replace the bung and delivery tube. The reaction will start straight away and bubbles of gas come off which collect in the second test-tube pushing the water out of it as shown. We say that the gas is being collected over water. When one test-tube is full of gas replace it with another until the reaction stops. Now try to light the gas in the test-tubes using a lighted wooden splint as shown below.



Results: Here you should write down exactly what you saw happening in the reaction and also what happened when you tried to light the test-tubes of gas.

Conclusion:

Try to find out what the gas collected was and also the name of any other product which might have been formed.

Further Experiment: Add 2 or 3 more small pieces of magnesium ribbon to the sulphuric acid until 1 piece does not react. All the acid is 'used up' or reacted. Pour the liquid only into an evaporating basin and gently boil it until half the liquid has gone. What do you see? Can you explain what has happened?

2. Calcium carbonate and hydrochloric acid

Diagram and Method:

These are exactly the same as in the above reaction but when you test the gas this time, test one test-tubeful with a lighted splint and add limewater to the other, then shake it up with your thumb over the top.

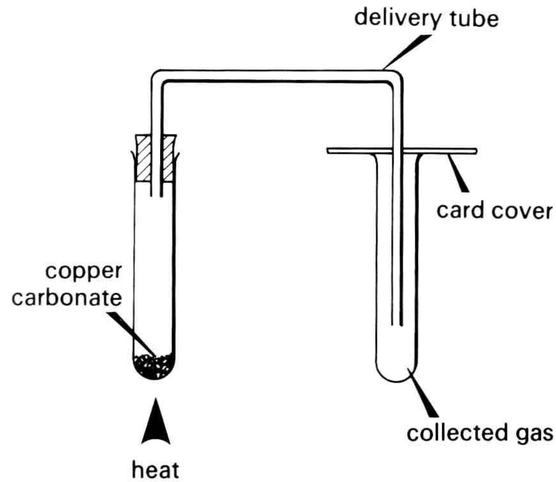
Results and Conclusion: Treat these the same way as you did in Experiment **1.**

3. Magnesium and oxygen

Repeat this experiment as explained on page 5.

4. Heating copper carbonate

Diagram:



Method:

Set up the apparatus as shown in the diagram and start heating the copper carbonate. If any gas comes from the green powder it will collect in the test-tube on the right and the card cover will stop most of it escaping. After about 30 seconds remove the collecting test-tube and cork it. Replace it with another one. At the end of the experiment, the two test-tubes used for collecting can be tested for any gas by trying to light one and adding limewater (calcium hydroxide solution) to the other.

Results: Here you should write down what you see happen and also what happened when you tested the two test-tubes of gas.

Conclusion:

What do you think has happened in this reaction?

Looking at our findings:

1. Magnesium and sulphuric acid

If a small piece of magnesium ribbon is dropped into a test-tube containing dilute sulphuric acid several things start to happen at once. The magnesium fizzes and starts to *dissolve* (that is, starts to disappear into the acid). The test-tube also starts to get warm. Eventually all of the magnesium disappears and the fizzing stops.

Explanations: A reaction has taken place between the magnesium and the acid because the magnesium has disappeared completely and so must have changed into something else. The fizzing was caused by a gas that was quickly produced. The test-tube gets warm because the reaction produces heat. We say it is an *exothermic reaction.* The reactions in Experiment **2.1** in Topic 2 are also exothermic.

It is possible to collect the gas coming off (see Experiment **3.1**) and test it by holding a lighted splint to it. You should find that it 'pops'. This 'pop' is a small explosion and proves that the gas is hydrogen. This is the TEST FOR HYDROGEN—it 'pops' when ignited.

The magnesium has dissolved in the sulphuric acid forming magnesium sulphate which you cannot see because it is dissolved in the solution. You might be able to think of a way of proving that it is in the solution at the end, perhaps by somehow getting rid of some of the liquid.

An equation for this reaction may be written using words in the same way as we did for earlier reactions:

Equation:

$$\underset{}{\text{magnesium}} + \underset{\text{acid}}{\text{sulphuric}} \longrightarrow \underset{\text{sulphate}}{\text{magnesium}} + \underset{\text{(gas)}}{\text{hydrogen}}$$

2. Calcium carbonate and hydrochloric acid

When a piece of calcium carbonate (marble) chipping is dropped into a test-tube of dilute hydrochloric acid it starts to fizz rapidly and the chipping gets smaller as it slowly reacts. The test-tube does not get warm.

Explanations: Again, a reaction has taken place because the calcium carbonate disappears and so must change into something else. The rapid fizzing is caused by bubbles of gas and if this gas is collected (see Experiment **3.1**.) and limewater is added to it, the limewater turns milky. This proves that the gas is carbon dioxide. This is the TEST FOR CARBON DIOXIDE—if it is shaken with limewater it turns the limewater milky.

Equation:

$$\underset{\text{carbonate}}{\text{calcium}} + \underset{\text{acid}}{\text{hydrochloric}} \longrightarrow \underset{\text{chloride}}{\text{calcium}} + \text{water} + \underset{\text{dioxide (gas)}}{\text{carbon}}$$

Where do you think the calcium chloride was at the end of the Experiment? Where was the magnesium sulphate at the end of the last Experiment?

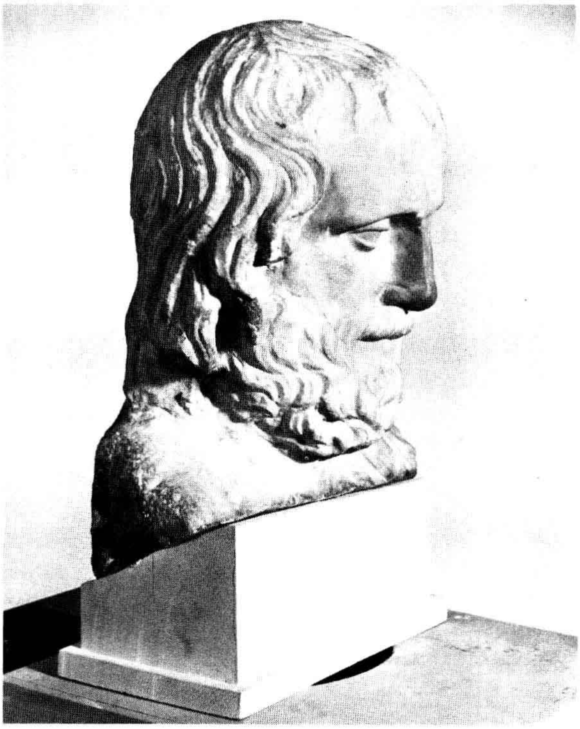
Notes from Experiments 1. and 2.

(a) Both reactions use a 'dilute' acid. This comes from a concentrated acid which has had water added to it to make it safer to use.

(b) In both reactions a rapid fizzing is observed. This type of fizzing is called *effervescence.*

(c) In Experiment **2.** you use calcium carbonate. This is a very common substance. It is found in different forms and given different

These are the white cliffs of Dover. They are made of calcium carbonate.



This carved piece of marble is another form of calcium carbonate.

non-chemical names such as marble, limestone and chalk (not blackboard chalk but the white substance which makes the white cliffs of Dover). You will meet it again later.

(d) In both reactions a chemical is formed which stays dissolved in the solution. These chemicals are magnesium sulphate and calcium chloride.

3. Magnesium and oxygen

If a piece of magnesium ribbon is held with tongs in a bunsen flame it soon starts to burn with a bright, white light and continues to burn without further heating until all of the magnesium has burnt. A white ash or powder is left at the end.

Explanations: An exothermic reaction has taken place between the magnesium and oxygen from the air producing white magnesium oxide. We say the magnesium has been *oxidised* to magnesium oxide (*oxidised* means 'has had oxygen added to it').

The same reaction is used to produce the 'flash' in a flash bulb and has been used in the past for flash photography. To make the flash, magnesium powder was used but it proved very dangerous! The photographer had to make sure that he clicked the camera at the same time as the flash went off. Nowadays it is timed electrically so that the timing is correct. The startled look on the faces in some old photographs is easily understood when you realise how they were taken.