An element is a pure substance that cannot be broken down into anything simpler. Everything on Earth is made from about one hundred different elements. An ATOM is the smallest particle of an element. They are much too small to be seen even with the most powerful microscope. Each element contains only one type of atom. Atoms have a NUCLEUS in the centre with ELECTRONS moving around it.

Different elements have different numbers of protons in their atoms. The ATOMIC NUMBER is the number of protons that an atom contains. The smallest atom is hydrogen with an atomic number of one. Lead is one of the largest atoms with an atomic number of eighty two.

**Exercise** - Complete the missing words in the sentences below.

1) An __________ cannot be broken down into anything simpler.

2) The smallest particle of an element is called an __________

3) The __________ is in the centre of an atom.

4) Electrons have a __________ charge.

5) Protons have a __________ charge.

6) The atomic number is the number of __________ in an atom.
W.S.41. **The periodic table.**

All of the elements have been arranged into the PERIODIC TABLE. This contains seven rows of elements called PERIODS. These are arranged so that each column contains elements with similar properties. The table shows the symbol and ATOMIC NUMBER (number of protons) for every element.

<table>
<thead>
<tr>
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<th>Group</th>
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<th>3</th>
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<td>Fr</td>
<td>Ra</td>
<td>Ac</td>
<td>Th</td>
<td>Pa</td>
<td>U</td>
<td>Np</td>
</tr>
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</table>

The most reactive metals.

<table>
<thead>
<tr>
<th>Group</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
<td>2</td>
<td>Ne</td>
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<tr>
<td>3</td>
<td>Na</td>
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<td>5</td>
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<td>14</td>
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<td>Te</td>
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<td>Po</td>
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<tr>
<td>64</td>
<td>At</td>
</tr>
<tr>
<td>65</td>
<td>Rn</td>
</tr>
</tbody>
</table>

Exercise - Complete the missing words in the passage below.

Each group in the periodic table contains elements that have similar .................. The atomic number gives the number of .................. that an element contains. The lightest element is .................. (H) which has an atomic number of one. The atomic number of .................. is eight. Sodium (Na) and potassium (K) are two very .................. metals. Iron (Fe) and nickel (Ni) are two of the .................. metals. The most reactive non-metals are called the .................. The .................. gases are very unreactive. Magnesium (Mg) and calcium (Ca) are both in group .................. of the periodic table. Nitrogen (N) and phosphorus (P) are both in group .................. of the periodic table.

magnetic noble two hydrogen reactive five halogens properties oxygen protons
Elements join together by chemical reactions to form compounds. Compounds have different properties to the elements that formed them. In a chemical reaction new substances are formed and energy is taken in or given out. It is also difficult to make a reaction go backwards.

**Exercise 1** - Fill in the missing words or symbols for the chemical reactions below.

**Coal burning**

\[
\text{CARBON} + \text{OXYGEN} \iff \text{CARBON DIOXIDE} + \text{HEAT} \\
\text{.........} + \text{O}_2 \iff \text{CO}_2 + \text{HEAT}
\]

**Hydrogen exploding**

\[
\text{HYDROGEN} + \text{...............} \iff \text{WATER} + \text{HEAT} \\
2\text{H}_2 + \text{O}_2 \iff 2\text{H}_2\text{O} + \text{HEAT}
\]

**Making salt**

\[
\text{SODIUM} + \text{CHLORINE} \iff \text{SODIUM CHLORIDE (salt)} \\
\text{Na} + \text{Cl} \iff \text{...............}
\]

**Exercise 2** - For each of the changes below write down if it is a physical or chemical change.

When a firework explodes it is a ____________ change.

When salt dissolves in water it is a ____________ change.

When a cake is baked in an oven it is a ____________ change.

When ice melts it is a ____________ change.
W.S.44. Metals and non-metals.

The elements can be divided into two main groups which are METALS and NON-METALS. The table below shows the properties of each group.

<table>
<thead>
<tr>
<th>Metals</th>
<th>Non-metals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most are shiny solids at room temperature</td>
<td>They vary in their properties. They usually</td>
</tr>
<tr>
<td>although mercury is a liquid. They usually</td>
<td>have low melting points and many are gases at room temperature.</td>
</tr>
<tr>
<td>have high melting points.</td>
<td>Most are poor conductors of heat.</td>
</tr>
<tr>
<td>Good conductors of heat.</td>
<td>Poor conductors of electricity except for graphite which is a form of</td>
</tr>
<tr>
<td>Good conductors of electricity.</td>
<td>carbon.</td>
</tr>
<tr>
<td>A few are magnetic (iron, cobalt and nickel).</td>
<td>None are magnetic.</td>
</tr>
<tr>
<td>They are often flexible (bendy) and can be</td>
<td>They are often brittle (hard but break easily).</td>
</tr>
<tr>
<td>hammered into shape.</td>
<td></td>
</tr>
</tbody>
</table>

Exercise 1 - For each diagram below write down if the element is a metal or a non-metal.

Iron is a ____________

Bromine is a ____________

Copper is a ____________

Sulphur is a ____________

Exercise 2 - Complete the sentences below.

1) M __________ is the only metal that is a liquid at room temperature.

2) G __________ is the only non-metal that is a good conductor of electricity.

3) The M __________ metals are iron, cobalt and nickel.

4) M __________ can be hammered into shape.
W.S.46. **Solubility.**

The diagrams below show how sugar can be dissolved in water.

<table>
<thead>
<tr>
<th>sugar - the SOLUTE</th>
<th>stir</th>
<th>water - the SOLVENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Sugar has **DISSOLVED** in the water to form sugar **SOLUTION.**

**Exercise 1** - Fill in the missing words in the passage below.

If a solid ................ in water we say that it is **SOLUBLE**. The substance that dissolves is called the **SOLUTE** and the liquid that it dissolves in is called the **SOLVENT**. Water is a good ................ because many substances will dissolve in it. If you have been using ................ paint you can not wash your brush in ................ because the paint will not dissolve. The correct solvent for gloss paint is white ................

**spirit**  **solvent**  **dissolves**  **gloss**  **water**

**The effect of temperature on solubility.**

Keep adding sugar.

| The cold water is fully **SATURATED** with sugar when no more will dissolve. | heat | The excess sugar now dissolves because it is more soluble in hot water. |
|                                                                               |      |                                                                        |
|                                                                               |      |                                                                        |
|                                                                               |      |                                                                        |
|                                                                               |      |                                                                        |
|                                                                               |      |                                                                        |
|                                                                               |      |                                                                        |

**Exercise 2** - Complete the sentences below.

1) If you keep adding sugar to cold water you reach a point where no more sugar will ___________

2) A solution that cannot dissolve any more solute is fully ___________

3) Solids are __________ soluble in water as the temperature rises.
W.S.47. **Expansion.**

If a metal bar is heated up it EXPANDS (gets bigger) slightly. This happens because the metal particles gain more energy and vibrate more.

Most materials expand slightly when they are heated.

**Problems caused by expansion.**

In hot weather a bridge could expand and buckle.

Overhead wires shorten in cold weather and could snap.

**Uses of expansion.**

As the mercury warms up it expands and moves up the thermometer scale.

Rivets hold metal plates tightly together.

**Exercise** - Fill in the missing words in the passage below.

Most materials ............... when they are heated and ............... when they are cooled. This is because their particles ............... more when hot and so move further ............... In hot weather a metal bridge could expand and ............... To stop this from happening it is held on rollers. Overhead wires could contract and ............... in cold weather. To stop this from happening they are given slack when they are put up. Mercury is a liquid metal that is used inside a ............... When it is put in a warmer place the mercury expands and moves up the ...............
All of the different materials around us have been formed by chemical reactions from about one hundred simple elements. The diagram below shows a chemical reaction between the elements iron and sulphur.

This reaction can be shown as a word equation:

IRON + SULPHUR → IRON SULPHIDE
(Reactants) (Product)

The new substance formed is a compound called iron sulphide. It has different properties to the iron and sulphur that it is made from.

Exercise 1 - fill in the missing words in the sentences below.

1. The mass of the reactants (starting chemicals) is E _ _ _ _ to the mass of the products (the chemicals that are made).
2. The products have different P _ _ _ _ _ _ _ _ to the reactants.
3. During a chemical reaction H _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ is either taken in or given out.
4. A chemical change is difficult to R _ _ _ _ _ _ (go backwards).

Exercise 2 - Join up each word in the left hand column with its meaning on the right.

ELEMENTS            The chemicals that are made.
PRODUCTS            The simplest substances.
COMPOUND            Starting chemicals.
REACTANTS            Elements joined together.
Types of chemical reaction. Name ..........................................................

There are several different types of chemical reaction.

Synthesis
Two or more substances join together to make a single new substance. For example when iron and sulphur are heated together:

$$\text{IRON} + \text{SULPHUR} \xrightarrow{\text{heat}} \text{IRON SULPHIDE}$$

Decomposition
A substance breaks down into simpler substances. For example, if calcium carbonate (limestone) is heated to a very high temperature:

$$\text{CALCIUM CARBONATE} \xrightarrow{\text{heat}} \text{CALCIUM OXIDE} + \text{CARBON DIOXIDE}$$

Oxidation
A substance gains oxygen during a chemical reaction. The substance that gains the oxygen is OXIDISED. For example, if copper is heated in air:

$$\text{COPPER} + \text{OXYGEN} \xrightarrow{\text{heat}} \text{COPPER OXIDE}$$

Exercise 1 - Complete the sentences below.

1) Synthesis means when substances __ __ __ together.
2) Decomposition means when a substance __ __ __ __ __ down.
3) Oxidation is when a substance gains __ __ __ __ __ in a chemical reaction.

Exercise 2 - For each diagram below write down the type of chemical reaction it shows.

1) Burning sodium metal in chlorine gas to form sodium chloride (salt). This type of reaction is:

2) Heating white lead nitrate crystals to produce a yellow powder and a brown gas. This type of reaction is:

3) If an iron nail is exposed to air it forms orange iron oxide (rust). This type of reaction is:
W.S.53. **Burning.**

Burning is a type of oxidation reaction. It happens when a substance reacts with oxygen in the air to produce heat and light. The substance that burns is oxidised during the reaction. For example when carbon in the form of coke is burnt:

\[ \text{CARBON} + \text{OXYGEN} \rightarrow \text{CARBON DIOXIDE} + \text{heat and light.} \]

**FUELS** can be burnt to release useful energy. They burn more strongly in pure oxygen. If a smouldering wooden splint is placed into a jar that contains oxygen it will relight. This is a test for oxygen gas.

**The fire triangle.**
The fire triangle shows the three things that are needed for burning to happen. Removing any of them stops a fire.

---

**Exercise** - Complete the sentences below.

1) Burning is a chemical reaction between fuel and **O** __ __ __

2) When carbon burns **C** __ __ __ **D** __ __ __ __ gas is produced.

3) Burning can be useful because it releases **E** __ __ __

4) The test for oxygen is a smouldering **S** __ __ __

5) The three things needed for a fire are oxygen, **F** __ __ and heat.

6) A fire blanket is used to stop **A** __ getting to a fire.

7) Pouring water onto a fire takes away the **H** __ __
**W.S.54. Products from chemical reactions.** Name ........................................

Most of the materials that we use every day have been made by chemical reactions. Some of the most common products are made from two important raw materials, **METAL ORES** and **CRUDE OIL**.

**Metal ores.**
Most metals exist as compounds called ORES inside rocks. Ores must be reacted with other chemicals to extract the metals that they contain. The more reactive the metal is, the more difficult it is to release from its ore. If a metal is less reactive than carbon it can be extracted by heating its ore with coke in a furnace. For example **HAEMATITE** (iron ore) contains iron oxide:

\[
\text{IRON OXIDE} + \text{CARBON} \rightarrow \text{IRON}
\]

**Crude oil.**
Natural oil from the ground is called **CRUDE OIL**. It contains a mixture of substances that can be changed into many useful products.

![Diagram of oil products]

**Exercise** - Complete the sentences below.

1) Many useful materials are made by chemical R __ __ __ __ __ __

2) An ore contains a M __ __ __ joined to other elements.

3) If a metal is less reactive than C __ __ __ it can be extracted using coke in a furnace.

4) Crude oil is a M __ __ __ __ of useful substances.

5) N __ __ __ is a synthetic fibre.
Some chemical reactions are harmful because they destroy our products.

**Corrosion of metals.**
Metals may be attacked by air, water or other substances around them. Usually the more reactive the metal is, the faster it corrodes. The corrosion of iron and steel is called RUSTING. The experiment below shows that both air and water are needed for rusting to happen.

![Diagram of a rusting experiment](image)

- **In dry air the iron nail does not rust.**
- **In water without air the iron nail does not rust.**
- **In air and water the iron nail rusts.**

To stop rusting metals can be coated with a substance that keeps out air and water. Paint, grease, plastic, or a thin layer of tin or zinc can be used.

**Oxidation of foods.**
Some foods react with oxygen gas in the air. This makes them taste unpleasant. Fat can be oxidised quickly, therefore fatty foods such as butter should be kept in a fridge to slow down the rate of oxidation. Another way of stopping oxidation is to keep air away from the food by using sealed packets or tins.

**Exercise** - Fill in the missing words in the passage below.

The corrosion of iron and steel is called ................. Iron will only rust if it is exposed to both air and ................. We can stop rusting by ................. the metal with a substance that keeps out .......... and water. This is why motor cars are given several layers of ................. Some foods are ................. when exposed to air. This gives them an unpleasant ................. Keeping foods ................. will slow down the rate of oxidation. Another way of stopping ................. is to make sure that the food does not come into contact with air.

air rusting taste cool water oxidation coating oxidised paint
Heat may be taken in or given out during a reaction. Sound, light, movement or electrical energy may also be produced. When fuels are burnt they give out heat and light energy. Explosive fuels give out movement and sound energy as well. The chemical reaction that takes place inside a torch battery gives out electrical energy.

Energy from fuels.

Wood can be burnt as a fuel. Fossil fuels form over millions of years.

Burning of fuels makes carbon dioxide, water and heat energy:

\[
\text{FUEL} + \text{OXYGEN} \rightarrow \text{CARBON DIOXIDE} + \text{WATER} + \text{ENERGY}
\]

The heat energy can be used to keep our houses warm and to cook food. It can also be changed into movement energy to drive engines.

Effects on the environment.
Burning fuels release carbon dioxide into the air. This stops heat escaping from the surface of the Earth back into space. This is called the GREENHOUSE EFFECT and it may lead to GLOBAL WARMING.
Oil and coal release sulphur dioxide gas when they burn. This gas goes into the air and dissolves in rain droplets to form ACID RAIN. In some parts of Europe acid rain has destroyed plant and animal life in lakes and forests. Acid rain also causes corrosion of buildings and statues.

Exercise - Complete the sentences below.

1) Different types of E _ _ _ _ can be produced by chemical reactions.
2) When fuels are burnt they give out heat and L _ _ _ _ energy.
3) The reaction inside a battery produces E _ _ _ _ _ _ _ _ energy.
4) Extra carbon dioxide gas in the air may lead to G _ _ _ _ warming.
5) Burning of oil and C _ _ _ releases sulphur dioxide gas.
6) Sulphur dioxide gas forms A _ _ _ rain
**W.S.57. Reactivity of metals.**

We can arrange the metals in order of most to least reactive. The three tests below are used to judge how reactive different metals are:

**Reaction with oxygen.**

- Heat the metal.
- **Gas jar**
- **Oxygen**

**Reaction with water.**

- Drop the metal into cold water.
- **Water trough**

**Reaction with acid.**

- **Acid**
- **Hydrogen gas**

<table>
<thead>
<tr>
<th>Metal</th>
<th>Reaction with oxygen</th>
<th>Reaction with water</th>
<th>Reaction with acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium</td>
<td>Burns strongly with a lilac flame.</td>
<td>Very fierce and ignites (catches fire).</td>
<td>Too dangerous to perform.</td>
</tr>
<tr>
<td>Sodium</td>
<td>Burns strongly with a yellow flame.</td>
<td>Fierce but it does not ignite.</td>
<td>Too dangerous to perform.</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Burns with a blinding white flame.</td>
<td>Very slow reaction but it reacts with steam.</td>
<td>Very fast reaction that produces hydrogen gas.</td>
</tr>
<tr>
<td>Zinc</td>
<td>Burns slowly with a dull red flame.</td>
<td>Reacts slowly with steam.</td>
<td>Quite a slow reaction. Some hydrogen produced.</td>
</tr>
<tr>
<td>Iron</td>
<td>Does not burn but it glows brightly.</td>
<td>Very slow reaction with steam.</td>
<td>Very slow reaction.</td>
</tr>
<tr>
<td>Lead</td>
<td>Melts but does not burn.</td>
<td>No reaction.</td>
<td>Extremely slow.</td>
</tr>
<tr>
<td>Copper</td>
<td>Does not burn but it forms a black coating.</td>
<td>No reaction.</td>
<td>No reaction.</td>
</tr>
<tr>
<td>Gold</td>
<td>No reaction.</td>
<td>No reaction.</td>
<td>No reaction.</td>
</tr>
</tbody>
</table>

**Exercise** - Complete the sentences below.

1) ____ __ ___ ___ ___ is the most reactive metal.

2) ____ ___ is the least reactive metal.

3) Potassium and sodium are too reactive to add to ____ __ ___.

4) You should not look at ____ __ ___ ___ ___ when it burns in oxygen.

5) ____ __ ___ does not corrode because it is an unreactive metal.

6) Metals react faster with ____ __ ___ than they do with water.
W.S.58. Displacement reactions.

If two metals are put together the more reactive metal will 'win' any competition to form a compound. The experiment below shows a reaction between an iron nail and copper sulphate solution.

![Diagram of iron nail in blue copper sulphate solution, with A coating of copper forms over the nail, green iron sulphate solution]

Iron and copper compete to be the compound in the solution. Iron is more reactive and so it DISPLACES (pushes out) the copper in the solution.

**IRON + COPPER SULPHATE ➞ IRON SULPHATE + COPPER**
*(blue solution)  (green solution)*

A metal will always displace a less reactive metal from solutions of its compounds.

Exercise 1 - Study the experiment below and then try to complete the missing words.

![Diagram of copper coin in solution, with colourless silver nitrate, coin becomes silver, solution goes blue]

**COPPER + SILVER NITRATE ➞ COPPER _______ + SILVER**
*(colourless)  (blue)*

Copper is _______ reactive than silver so it displaces silver in the solution.

Displacement reactions with metal oxides. Two metals can also compete for oxygen. For example, if magnesium powder is heated with copper oxide there is an explosive reaction:

**MAGNESIUM + COPPER OXIDE ➞ MAGNESIUM OXIDE + COPPER**

Exercise 2 - Complete the missing words in the sentences below.

Magnesium 'wins' the competition for _______ because it is higher in the reactivity series than _______ When a metal is heated with the oxide of a _______ reactive metal it will remove the oxygen from it.
W.S.60. **Acids and metals.**

Metals that are more reactive than copper will react with acids to form hydrogen gas and a salt.

\[
\text{ACID} + \text{METAL} \rightarrow \text{HYDROGEN} + \text{SALT}
\]

The more reactive the metal is, the faster the reaction will be. The experiment below shows the reaction between hydrochloric acid and magnesium.

1) The magnesium reacts with the acid.
2) A solution of magnesium chloride has formed.
3) Magnesium chloride salt is left behind.

**Exercise** - Complete the missing words in the sentences and equations below.

1) A metal must be more reactive than \( C \) \( \_\_\_\_\_\_ \) to react with an acid.

2) \( \text{ACID} + \text{METAL} \rightarrow \text{HYDROGEN} + \text{SALT} \)

3) Reactive metals produce hydrogen \( F \) \( \_\_\_\_\_\_ \) than unreactive metals.

4) The test for \( H \) \( \_\_\_\_\_\_\_ \) is a lighted splint.

5) Hydrogen is an \( E \) \( \_\_\_\_\_\_\_ \) gas.

6) \( \text{hydrochloric acid} + \text{magnesium} \rightarrow \text{SALT} + \text{magnesium chloride} \)

7) All of the \( A \) \( \_\_\_ \) has reacted when there are no more hydrogen bubbles given off.

8) The \( S \) \( \_\_\_ \) that has been made is magnesium chloride.
W.S.61. **Acids and bases.**

Bases can neutralise (cancel out) acids. Bases that dissolve in water are called alkalis. A base reacts with an acid to form a salt and water:

\[
\text{ACID} + \text{BASE} \rightarrow \text{SALT} + \text{WATER}
\]

For example, if sodium hydroxide, which is a very strong alkali, is reacted with hydrochloric acid then sodium chloride (common salt) is formed.

**Reaction with carbonates.**
Carbonates are bases that contain the elements carbon and oxygen. They react with acids to form a salt, carbon dioxide gas and water. The reaction is fizzy due to the carbon dioxide gas given off:

\[
\text{ACID} + \text{CARBONATE} \rightarrow \text{SALT} + \text{CARBON DIOXIDE} + \text{WATER}
\]

The experiment below shows the reaction between calcium carbonate (marble chips) and hydrochloric acid.

1) The marble chips react with the acid.

2) A solution of calcium chloride has formed.

3) Calcium chloride salt is left behind.

\[
\text{calcium carbonate} + \text{hydrochloric acid} \rightarrow \text{calcium chloride} + \text{carbon dioxide} + \text{water}
\]

**Exercise** - Complete the missing words in the sentences and equations below.

1) A B _ _ _ is a chemical that can neutralise an acid.

2) Bases that dissolve in water are called A _ _ _ _ _ _ _

3) ACID + BASE \rightarrow _ _ _ _ _ _ + WATER

4) Sodium C _ _ _ _ _ _ _ _ is common salt.

5) Carbonates contain the elements carbon and O _ _ _ _ _ _

6) Carbonates react with acids to produce C _ _ _ _ D _ _ _ _ _ _

7) Marble chips will F _ _ _ in acid until it has all been neutralised.
W.S.63. Acid rain.

Oil and coal release sulphur dioxide gas when they burn. This gas goes into the air and dissolves in rain droplets to form ACID RAIN. In some parts of Europe acid rain has destroyed plant and animal life in lakes and forests. Acid rain also causes corrosion of metal and stonework.

Carried by weather systems.

SULPHUR
DIOXIDE

Power stations burn fossil fuels in order to make electricity. Some factories also burn fossil fuels.

Carried by weather systems.

Sulphur dioxide mixes with water droplets in the air to form acid rain which falls onto lakes and forests.

Acid washes minerals out of the soil and kills plant life.

Acid kills fish and other water life.

Acid rain corrodes metals and stonework. Limestone dissolves very quickly.

Exercise - Use the diagrams above to help you complete the sentences below.

1) The main waste gas that causes acid rain is S __ __ __ __ dioxide.

2) Sulphur dioxide is given off from burning oil and C __ __

3) Power stations burn fossil fuels to make E __ __ __ __ __ __

4) Sulphur dioxide gas mixes with R __ __ in the atmosphere.

5) If a lake becomes too acidic the fish and other water life will D __

6) Acid rain washes M __ __ __ __ out of the soil.

7) Acid rain corrodes M __ __ __ and stonework.