TOPIC

7 CHEMICAL CHANGES

7.1 STUDY NOTES

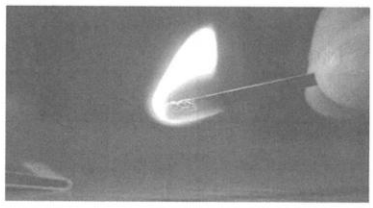
LEARNING OUTCOME

(a) Identify a change which leads to formation of new substance(s) as a chemical change.

- A **physical change** involves a change of state (see Book A Topic 2 Physical Properties of Matter). Examples of physical changes include ice melting or a puddle of water evaporating. These are physical changes as **no new substance is** formed. It is still water. The change is also easy to reverse. If we cool the water, it can be changed back to ice. If we condense the water vapour formed from evaporation, it will be changed back to liquid water.

Physical change	Chemical change
• No new chemical substance is formed. • The change is reversible. • Examples are melting, freezing, evaporation, condensation, boiling, sublimation, dissolving, expansion.	• A new chemical substance is formed. • The change is normally difficult to reverse. • Examples are combustion, oxidation, chemical decomposition, chemical combination.

A physical change occurs when ice cream melts.



A chemical change occurs when a matchstick burns.

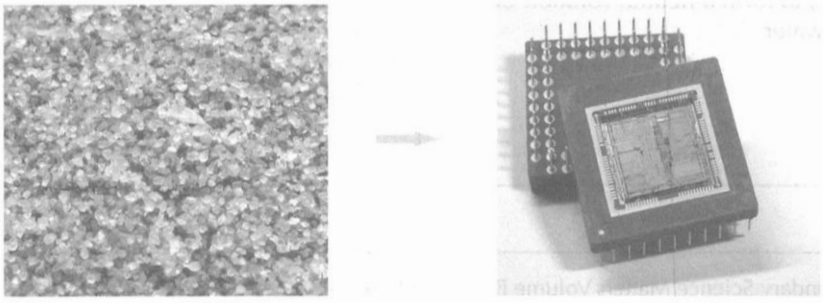
- A **chemical change** is called a **chemical reaction** as **new substances are made**. Chemical reactions can be represented by **word equations**. For example, when green copper carbonate is heated, it decomposes into black copper oxide and gives off carbon dioxide gas.

The word equation for this chemical decomposition is:

$$\underbrace{\text{Copper carbonate}}_{\text{Reactant}} \xrightarrow{\text{heat}} \underbrace{\text{Copper oxide} + \text{Carbon dioxide}}_{\text{Products}}$$

- The chemicals you start with in a chemical reaction are called **reactants**. These are always found on the left-hand side of the word equation. The chemicals you end up with in a chemical reaction are called **products**. These are always found on the right-hand side of the word equation. The **arrow** represents the direction of the chemical reaction.
- Chemical reactions can be used to convert materials into new and useful products, as shown in the table:

Source of raw materials	Raw materials	Useful products
Rocks	Sand Clay Limestone	Glass, silicon chips Cement Lime, cement
Mineral ores	Iron ore (haematite) Aluminium ore (bauxite)	Iron/steel objects Aluminium objects
Fossil fuels	Petroleum (crude oil) Natural gas Coal	Petrol, diesel, plastics, bitumen Cooking/heating oil Solid fuel (coke), drugs, dyes, detergents



The composition of sand varies greatly depending on its location. Some of its uses include the production of silicon chips.

Link

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LEARNING OUTCOME

(b) Show an awareness that there are different types of chemical reactions.

- The common types of chemical reactions are **combustion, thermal decomposition, oxidation** and **neutralisation**.

Chemical Reaction	Examples
Combustion–When substances combine with oxygen in the air to form new products; heat and light are also produced.	• Charcoal burns to produce carbon dioxide gas and grey ash. • Magnesium burns with a brilliant white light to form a white ash of magnesium oxide.
Thermal decomposition–When a substance is broken down on heating to form simpler substances.	• When limestone (calcium carbonate) is heated, it decomposes to form lime (calcium oxide) and carbon dioxide. • When sugar is heated, it chars and forms carbon and water vapour.
Oxidation–This is a chemical reaction with oxygen.	• All combustion reactions involve oxidation. • Respiration involves the chemical reaction of sugars (glucose) with oxygen to produce carbon dioxide and water.
Neutralisation–This is the chemical reaction between an acid and an alkali (base) to form a neutral solution of salt and water.	• Hydrochloric acid is neutralised by the alkali sodium hydroxide to form sodium chloride (common salt) and water. • Sulfuric acid is neutralised by the base magnesium oxide to form magnesium sulfate (Epsom salt) and water.

Link

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LEARNING OUTCOME

(c) Show an awareness that chemical reactions involve rearrangement of atoms and word equations are used to represent such chemical reactions.

- **Mass** is always **conserved** during chemical reactions **as atoms are rearranged** to change reactants into products.
- In any chemical reaction, because the atoms are just rearranged, the **total mass of reactants always equals the total mass of products**. No atoms are ever lost in chemical reactions.
- All **chemical reactions** can be represented by **word equations**.
  - **Combustion** of charcoal:
    carbon + oxygen → carbon dioxide
  - **Burning** of magnesium
    magnesium + oxygen → magnesium oxide
  - **Thermal decomposition** of limestone
    calcium carbonate → calcium oxide + carbon dioxide
  - **Thermal decomposition** of sugar
    glucose → carbon + water
  - **Respiration**
    glucose + oxygen → carbon dioxide + water
  - **Neutralisation** of an acid and an alkali
    hydrochloric acid + sodium hydroxide → sodium chloride + water
  - **Neutralisation** of an acid and a base
    sulfuric acid + magnesium oxide → magnesium sulfate + water

Link

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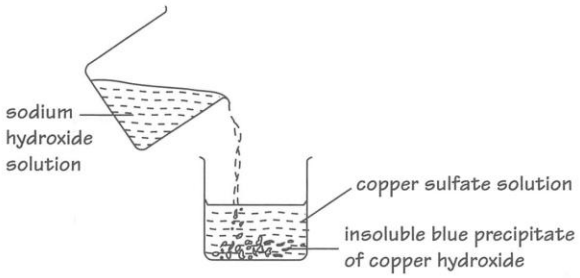
Exam Tip

A chemical change always leads to new products and an energy change. However, the mass is always conserved in a chemical reaction so that the total number of atoms before and after the chemical reaction is always the same.

LEARNING OUTCOME

(d) Investigate changes that matter undergo through mixing chemicals.

- When certain chemicals are mixed together, new substances can be produced. This means a **chemical reaction** has taken place and that new substances (**products**) are produced. Consider mixing copper sulfate solution with sodium hydroxide solution. Immediately after you pour the two solutions together, a blue precipitate (insoluble solid) appears. This chemical change is called **precipitation** and the word equation is:

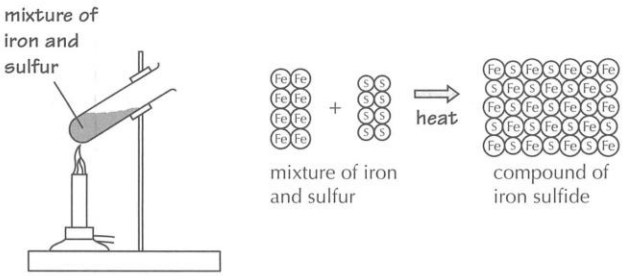


Copper sulfate + Sodium hydroxide → Copper hydroxide + Sodium sulfate

LEARNING OUTCOME

(e) Investigate changes that matter undergo through heating.

- **Heating matter** (element, compound or mixture) can cause **chemical change.**
- The chemical changes that take place on heating include **thermal decomposition, combustion (burning)** and **chemical combination**.
- **Chemical combination** takes place when two or more substances join together to form a new substance. For example when the elements iron and sulfur are heated together a new compound called iron sulfide is formed.



Heating Matter: Formation of iron sulfide

iron + sulfur → iron sulfide

Exam Tip

Whenever a non-metal joins with a metal, the ending of the non-metal changes to –ide. When oxygen joins with metals, oxides are formed. When sulfur joins with metals, sulfides are formed.

LEARNING OUTCOME

(f) Investigate changes that matter undergo by exposure to light.

- Light enables us to see but also interacts with matter around us to cause change. The most important light changes are **photosynthesis** in plants, **photographic change** in film and obtaining energy from **solar cells**.

- **Photosynthesis** is an important process which only occurs in green plants. During the process, carbon dioxide and water are converted into a simple plant food called glucose. The word equation for this chemical change is:

$$\text{Carbon dioxide} + \text{Water} \xrightarrow{\text{light}} \text{Glucose} + \text{Oxygen}$$

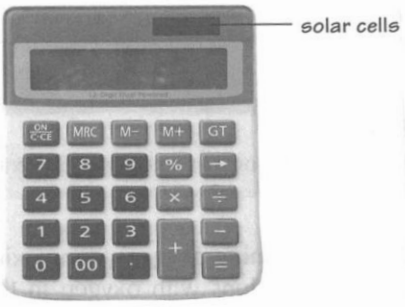
  For this process to occur, a green colouring called chlorophyll is needed to absorb light energy. Photosynthesis can only occur in green plants during the day. It is a very important process as it releases oxygen gas into the air. This helps to replace the oxygen used up during respiration by living organisms.

- **Photographic changes** occur when light causes certain chemicals on the photographic film, like silver bromide, to change into silver (dark areas). The word equation for this chemical change is:

$$\text{Silver bromide} \xrightarrow{\text{light}} \text{Silver} + \text{Bromine}$$

  The dark areas of silver are called the 'negative' and with the help of other chemicals these areas are developed to produce photographs. The light needed in photography can be sunlight (outdoor photography) or light from a flash bulb (indoor photography).

- **Solar cells** (also called **photovoltaic cells**) are common on electronic calculators. They are made of elements such as silicon or selenium which can convert light energy directly into electricity. They can be used in places where electricity is not readily available.

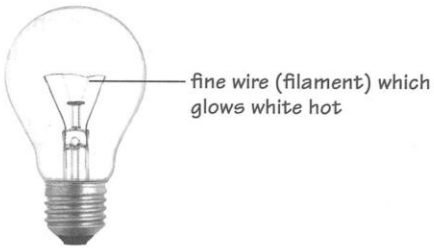


Solar cells found on calculators convert light energy directly into electricity.

LEARNING OUTCOME

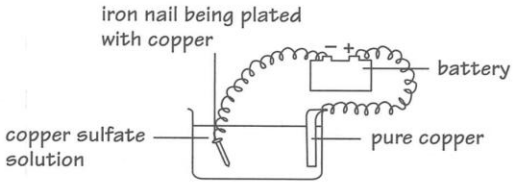
(g) Investigate changes that matter undergo by passing an electric current.

- The changes that take place when electricity is passed through matter include:
  - ➢ Heating effect
  - ➢ Production of light
  - ➢ Chemical effect
- **Electricity**, when passed through a fine wire, causes the wire to become white hot and thereby, produces **light** and **heat**.



Light bulb

- **Electricity**, when passed through copper sulfate solution, splits up the solution (**electrolysis**) and deposits copper metal on one of the electrodes (**electroplating**). This is the **chemical effect** of electricity causing a permanent chemical change.



Electroplating

Exam Tip

A chemical change involves an energy change. Therefore forms of energy like heat, light and electricity can result in chemical change.

LEARNING OUTCOME

(h) Investigate changes that matter undergo by oxidation.

- **Oxidation reactions** involve **gaining oxygen**. Many oxidation reactions, like **combustion** or **burning**, involve chemical reactions with oxygen in the air. These chemical reactions are often violent, giving off lots of energy in the form of heat and light.

Burning of charcoal

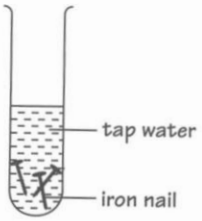
- A much slower oxidation reaction is **rusting**. This is the **chemical reaction** by which **iron is changed** through its reaction with oxygen (air) and water into the common flaky reddish-brown coating. Chemically, rust is **hydrated iron oxide**.

iron + oxygen + water → hydrated iron oxide

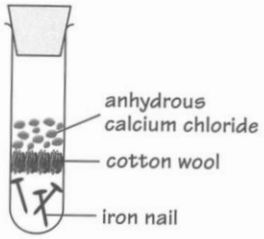
Experiment **Investigating Rusting**

1 Place clean iron nails in four different test tubes.

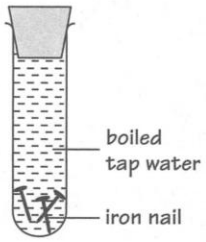
2 Add a little tap water to the first test tube.



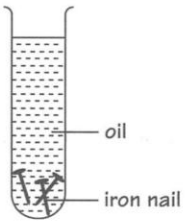
3 Place anhydrous calcium chloride in the second test tube. This keeps the air dry. Close the test tube with a rubber bung.



4 Fill the third test tube with boiled tap water. This contains no air. Close the tube with a rubber bung.



5 Fill the fourth test tube with oil. This prevents both air and water from reaching the iron nails.



6 Leave the test tubes in a test tube rack for several days. Which iron nails rusted? For rusting to take place, **both oxygen and water are necessary**. These are both present in the air.

- Many other metals like aluminium, zinc and chromium undergo oxidation reactions with the oxygen in the air. These are called **corrosion reactions**. However, unlike iron, they form a protective oxide coat on their surface. Iron forms a flaky coating which peels off. This then allows the iron underneath to rust as well. In this way, the iron is gradually rusted away.

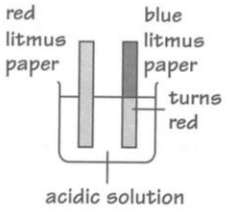
Exam Tip

All oxidation reactions involve a gain of oxygen, which comes from the surrounding air. Sometimes the reaction is violent, producing lots of heat, like combustion or burning. Other oxidation reactions are much slower, like rusting and other corrosion type reactions. All oxidation reactions form oxides as products.

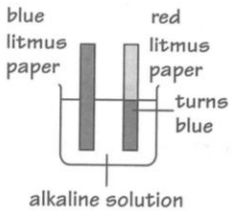
LEARNING OUTCOME

(i) Describe indicators as substances that change colour when an acid or alkali is added to them.

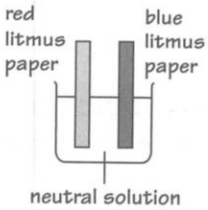
- **Indicators** are special chemicals which indicate if a substance is **acidic** or **alkaline**. An example of an indicator is litmus paper.



An acidic solution will turn blue litmus paper red but leaves red litmus paper unchanged.



An alkaline solution will turn red litmus paper blue but leaves blue litmus paper unchanged.



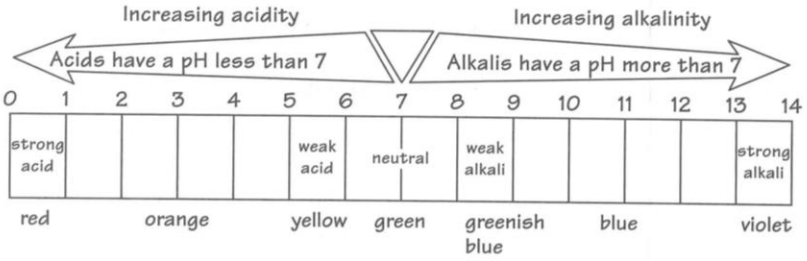
A neutral solution, e.g. pure water, does not change the colour of red or blue litmus paper.

- The colours of some common indicators in acid or alkali are shown in the table below.

Indicator	Colour in acid	Colour in alkali
Litmus	Red	Blue
Methyl orange	Red	Yellow
Phenolphthalein	Colourless	Pink
Universal indicator	Red, orange, yellow	Greenish–blue, blue, violet

- **Universal indicator** is a mixture of indicators and it can show a variety of colours, depending on how strong or weak the acid or alkali is. The scale that shows the strength of acids and alkalis is called the **pH scale**.
  - ➢ This is a scale of numbers usually from 0 to 14.
  - ➢ Strong acids have a low pH value. The lower the pH value, the stronger the acid is.
  - ➢ Strong alkalis have a high pH value. The higher the pH value, the stronger the alkali is.
  - ➢ A pH value of 7 is neutral.

Besides indicators, pH meters can also be used to measure the pH of a liquid.



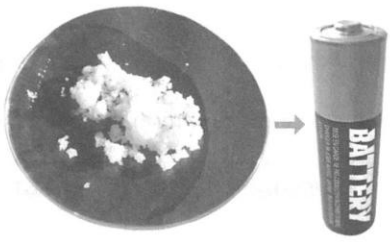
- pH values can change because when acids are added to alkalis (or vice versa) they cancel each other's effect. The pH of an acidic solution increases if an alkali is slowly added to it. The pH of an alkaline solution decreases if an acid is slowly added to it. Adding acids to alkalis, or vice versa, causes the pH to move towards the neutral value of pH 7 and is called **neutralisation**.

LEARNING OUTCOME

(j) Describe acids as a class of important chemicals which have certain properties.

Containers of strong acids have hazard symbols on them.

Hydrochloric acid is used in the manufacture of zinc chloride.



Zinc chloride is used in the manufacture of batteries.

- Acids are a **class of chemicals** which contain the element **hydrogen**.
- The following describe the properties of acids.
  - ➢ Acids have a **sour taste**.
  - ➢ Acids turn moist blue **litmus** paper **red**.
  - ➢ Acids 'corrode' or 'eat away' **metals** and produce **hydrogen gas**.

    For example, magnesium metal reacts with dilute sulfuric acid as shown by the word equation:

    Magnesium + Dilute sulfuric acid → Magnesium sulfate + Hydrogen

    If dilute hydrochloric acid is used, the word equation is:

    Magnesium + Dilute hydrochloric acid → Magnesium chloride + Hydrogen

    In general, the equation for a reaction of an acid with a metal is:

    Metal + Dilute acid → Salt + Hydrogen

  - ➢ Acids react with **carbonates** to produce **carbon dioxide gas**.

    For example, calcium carbonate reacts with dilute sulfuric acid as shown by the word equation:

    Calcium carbonate + Dilute sulfuric acid → Calcium sulfate + Carbon dioxide + Water

If dilute hydrochloric acid is used, the word equation is:

Calcium carbonate + Dilute hydrochloric acid → Calcium chloride + Carbon dioxide + Water

In general, the equation for a reaction of an acid with a carbonate is:

Carbonate + Dilute acid → Salt + Carbon dioxide + Water

Exam Tip

The element that is always present in all acids is hydrogen. This element is displaced from the acid when the acid reacts with a reactive metal like magnesium to form a salt and hydrogen gas.

LEARNING OUTCOME

(k) Describe neutralisation as the reaction between an acid and an alkali and show an awareness of some applications of neutralisation in everyday life.

- When **acids** and **alkalis** are mixed together, a chemical reaction called neutralisation occurs. For example, when sodium hydroxide and hydrochloric acid are mixed together, the two new substances that are formed are sodium chloride and water. Both of these new substances are neutral and have a pH of 7.

Sodium hydroxide + Hydrochloric acid → Sodium chloride + Water

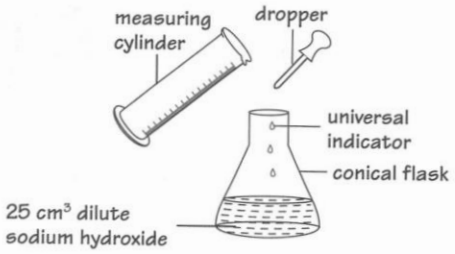
The general equation for the neutralisation reaction of an acid and alkali is:

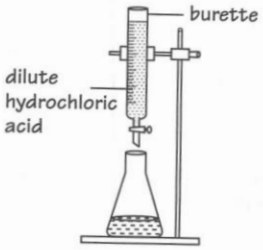
Acid + Alkali → Salt + Water

Experiment **Making Common Salt by Neutralisation**

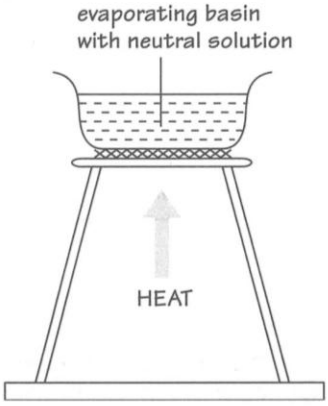
Using a measuring cylinder, place 25 cm^3 of dilute sodium hydroxide into a conical flask. Add 2 or 3 drops of universal indicator.

Using a burette, slowly run dilute hydrochloric acid into the flask until the indicator turns green. Record the volume of acid needed to neutralise the alkali.



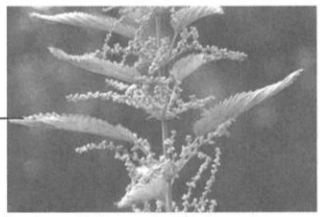


Repeat the experiment a second time but do not add any indicator. There is no need as we know how much acid to add to neutralise the alkali. Pour the neutral solution into an evaporating basin and carefully evaporate the solution using a water bath. Crystals of common salt (sodium chloride) will form in the basin.



There are many **everyday applications of neutralisation**. Here are a few examples:

- **Indigestion tablets** are alkaline to neutralise excess acid in the stomach.
- **Shampoos** contain mild alkalis. This causes small scales on the hair to open and make your hair unmanageable. **Hair conditioners** contains mild acids to neutralise the alkalis so that the scales close up.
- **Toothpaste** is alkaline to neutralise acids found in the mouth. Bacteria in the mouth converts sugars into acids which attack our teeth, causing decay.
- **Face cleaners** are weak alkalis and may cause your skin to become dry. **Toners** are weak acids to neutralise the effect of the cleaner and restore the normal pH of 5 to the skin. **Face peels** contain weak acids to remove old skin cells.
- **Nettle stings** are acidic. Such stings are neutralised by calamine lotion, which is alkaline.



- **Insect stings,** like a wasp sting, inject an alkali beneath the skin. The sting can be neutralised by applying a mild acid like vinegar. However, be careful as some insect stings are acidic. They need to be neutralised by a mild alkali, like calamine lotion or bicarbonate of soda.

- **Pollutants** from burning fossil fuels are often acidic gases and cause **acid rain**. This can be neutralised by adding lime to the affected water and soil.

Link

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LEARNING OUTCOME

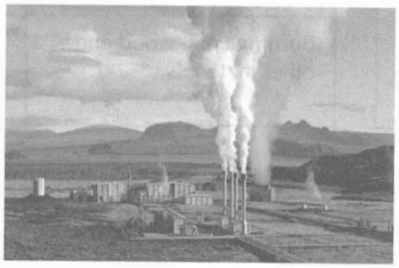
(l) Show an awareness of how chemical reactions can benefit our lives but can also cause harm to our health and environment.

- Examples of chemical reactions that **benefit our lives** are **cooking** and **respiration**.

Most of the chemical changes that take place during cooking involve thermal decomposition or oxidation type reactions.

- With many chemical reactions, energy is converted from one form into another. Burning **fossil fuels** (coal, oil, natural gas) releases stored chemical energy to produce heat and light energy.

- Energy released from chemical reactions can be used to produce other more useful forms of energy. Heat energy released from fuels in power stations is used to change water into steam, which drives the turbines in the generators to produce **electricity**.



Power station

- During combustion of fuels in vehicles and power stations, harmful substances are released into the surrounding air. These substances are called **air pollutants**. The table shows how air pollution can affect the environment.

Air pollutant	Source	Effects
Carbon dioxide	Burning of fuels	Causes greenhouse effect of the atmosphere which results in global warming
Carbon monoxide	Exhaust fumes of motor vehicles caused by incomplete combustion of carbon containing substances like petrol	Extremely poisonous and can cause suffocation and death
Oxides of nitrogen	Exhaust fumes from motor vehicles; also lightning activity	Can cause acid rain, breathing problems and lung cancer
Lead compounds	Exhaust fumes from motor vehicles because of various lead additives in petrol	High levels can cause brain damage in young children
Sulfur dioxide	Burning of fossil fuels like coal, oil or natural gas; also from volcanic activity	Causes acid rain which corrodes buildings, statues and damages aquatic life and plant growth; also irritates lungs and causes bronchitis and lung related diseases
Smoke (the carbon particles)	Burning coal, wood and other materials	Irritates lungs and causes bronchitis and lung related diseases

- Various air pollutants, especially carbon dioxide and oxides of nitrogen, trap the heat from the Sun and prevent it from escaping. This is called the **greenhouse effect** and it makes the Earth warmer, resulting in **global warming**. If we do not reduce the emission of **greenhouse gases**, scientists predict the Earth's temperature could rise by 1°C–3°C. The possible effects would include the following.
  - ➢ Large quantities of ice at the poles would melt, causing flooding of low-lying areas of the world.
  - ➢ Areas that are covered by vegetation may dry out and become deserts.
  - ➢ The frequency of drought in some areas may rise.

7.4 TEST YOURSELF

SECTION A Multiple-choice Questions (Total 12 marks)

Select the correct response and write the corresponding letter (A, B, C or D) in the brackets provided.

1. Which of these agents would help to achieve a chemical change?

   I Electricity II Heat III Magnetism IV Light

   A. I, II and III **B.** I, II and IV **C.** I, III and IV **D.** All of these ( )

2. During which of these changes does a chemical reaction occur?

   A. An electric current is passed through copper wire.
   B. Crude oil (petroleum) is distilled at 400°C.
   C. Magnesium ribbon is dissolved in hydrochloric acid.
   D. Salt water is heated and made less concentrated. ( )

3. Combustion is described as an oxidation type of chemical reaction. This means that oxygen gas _____.

   A. catches alight and is used up
   B. combines with other elements
   C. decomposes to produce other elements
   D. is given off during the chemical reaction ( )

4. Which of these would **not** cause a chemical change to sugar?

   A. Adding concentrated sulfuric acid to sugar
   B. Burning sugar in a flame
   C. Decomposing sugar by heating
   D. Dissolving sugar in a solvent ( )

5. Which of these useful products does **not** require a chemical process in its manufacture?

   A. Cement **B.** Diamond **C.** Glass **D.** Steel ( )

6. In most chemical reactions, _____.

   I energy is changed from one form to another
   II it is easy to reverse the reaction and change products back to original reactants
   III new chemical substances are formed

   A. I and II **B.** I and III **C.** II and III **D.** All of these ( )