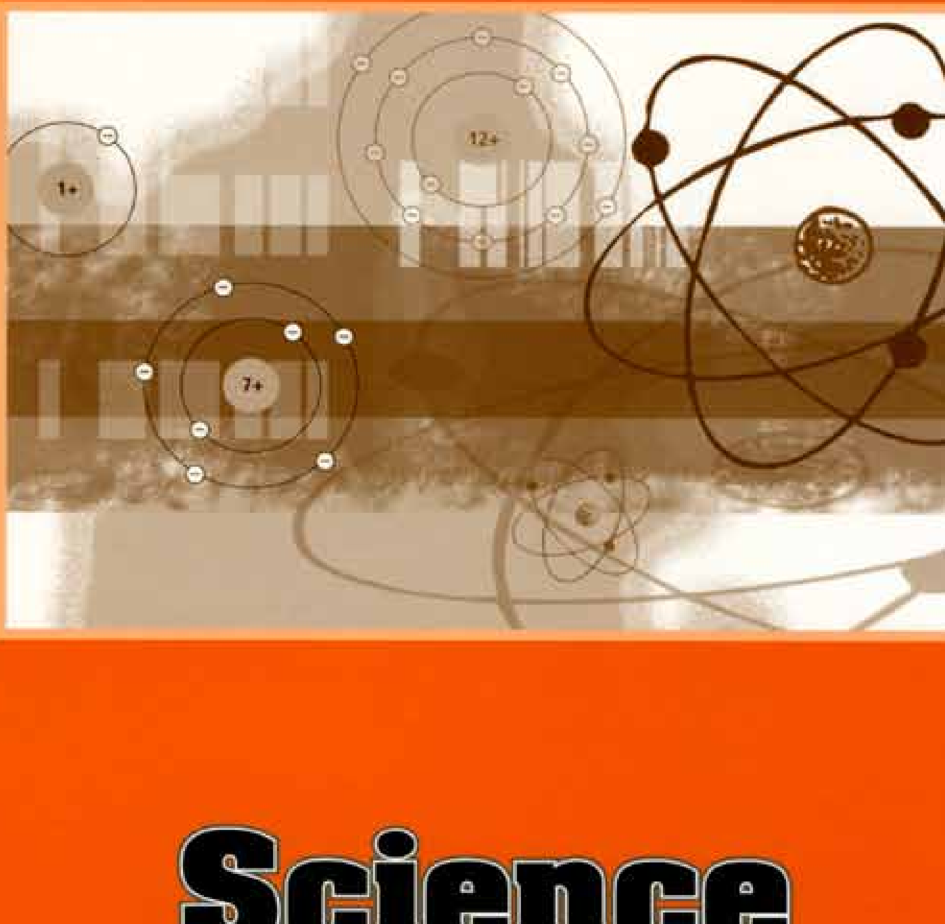
Book 2

Year 11



Science

Science

Year 11 Book Two

GOVERNMENT OF SĀMOA
MINISTRY OF EDUCATION, SPORTS AND CULTURE

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Unit 1: REVISION

This is a revision chapter. Use it to help you remember what was covered in Year 10 Science.

Energy

Heat energy moves from hot areas to cold areas. This means that heat energy becomes evenly spread throughout an object.

Heat energy can be transferred in three different ways. These ways are **conduction**, **convection** and **radiation**. Conduction usually occurs in solids. Convection occurs in liquids and gases and radiation can occur through air and through space where there are no particles. For example, when you stand in front of a fire, some heat is transferred to you through radiation. Convection currents draw the hot air from around the fire upwards, so they also carry heat to you.

Conduction occurs when heat energy is passed from one particle to the next. When a particle in a solid gains heat energy it vibrates quicker. That particle bumps into the next particle and passes some heat energy to it. This makes the second particle also vibrate faster so it bumps into the next particle and so on until the heat energy is evenly distributed through the solid.

Convection currents occur when particles in a liquid or gas gain heat energy. This makes them move apart and that part of the liquid or gas becomes less dense than the rest of the liquid or gas. This causes the warmer, less dense particles in the liquid or gas to rise up in a current. Colder, more dense material moves down to replace the warmer material. This method of heat transfer is called convection.

Radiation transfers heat energy as electromagnetic radiation. Radiation can travel through a vacuum. A vacuum is a space where there are no particles. Shiny objects reflect radiation and dull dark objects absorb radiation. When an object absorbs radiation its temperature rises.

People use equipment that is designed to take advantage of or slow down heat transfer. Fridges and freezers are designed to transfer heat from the inside to the outside which keeps food cold or frozen. Chilly bins are also designed to slow down heat transfer by insulating the ice and food inside from heat energy.

Sound travels as longitudinal waves through a medium that has particles such as solids, liquids and gases. The amplitude is the size of the wave. The larger the amplitude, the louder the sound. Wavelength is the length of the repeating pattern of the sound wave. Frequency is the number of wavelengths that pass a point in one second. High frequency waves have a high pitch.

Activity 1

Heat Energy

Aim To revise work on heat energy.

Answer the following questions:

1. Describe how heat energy is transferred by conduction, convection and radiation.
2. Explain how chilly bins stop conduction, convection and radiation of heat energy.
3. Copy the following statements and state the method of heat transfer being used for each one:
   a. The movement of air in a warm oven.
   b. The warmth of the Sun felt on Earth.
   c. Some objects make your hand feel hotter when you touch them.
   d. The air is hotter above a fire.
   e. The whole piece of metal gets hot when one end is put into a fire.
   f. Ice melting in the sun.

Speed And Pressure

The way an object is moving can be described using distance travelled (d) and time taken (t). The formula used to work out average speed is:

$$\textbf{Average speed} = \frac{\text{distance travelled}}{\text{time taken}} \qquad v_{av} = \frac{d}{t}$$

Distance can be calculated using the formula:

$$\textbf{Distance} = \text{average speed} \times \text{time} \qquad d = v_{av} \times t$$

Time can be calculated using the formula:

$$\textbf{Time} = \frac{\text{distance}}{\text{average speed}} \qquad t = \frac{d}{v_{av}}$$

Pressure is the force per area. The molecules in gases and liquids pushing on the sides of the container cause pressure. Bike and car tyres have been filled with a lot of air and the air pressure inside the tyres makes the ride smoother. Basketballs bounce because of the pressure inside the ball.

Activity 2 Speeding Objects And Pressure

Aim To revise work on speed and pressure.

Answer the following questions:

1. How fast is a car going if it travels 40 km in 1 hour?
2. How fast is a car going if it travels 15 km in 0.5 hours?
3. If a car travels at 12 kmph how far will it go in 1 hour? 2 hours? 0.5 hours? 0.25 hours?
4. If a bus travels at 30 kmph how long will it take to go 60 km?
5. Explain how pressure causes bus tyres to stay firm.

Uses Of Materials

People use different materials in different ways because they have different physical and chemical properties. The chemical properties of a material are related to the way it reacts or does not react with other materials. The physical properties of the material are those related to things such as: melting and boiling points, colour, density, lustre, strength, hardness or softness, texture, flexibility or brittleness, malleability or ductility, heat and electrical conduction, or whether it is transparent, opaque or translucent.

For example, water has lots of properties useful to people. People use water because it is not poisonous, it is a liquid at room temperature, it dissolves lots of other materials, evaporates at air temperature, can be frozen and boiled easily, does not burn, reacts with some metals and not others, and reacts with air and iron to form rust. Water also has adhesive and cohesive properties. Adhesive means how strongly attracted the water molecules are to other materials. Cohesive means how strongly the water molecules are attracted to each other.

Activity 3 Uses Of Materials

Aim To revise work on uses of materials.

Answer the following questions:

1. List all the physical properties mentioned above and give a meaning of each.
2. Name two physical properties and one chemical property you would consider when choosing a material for the following purposes:

   a. Jewellery.
   b. Building material.
   c. Cooking equipment.
   d. Tools: *e.g. A hammer.*
   e. Pipes for carrying water.

3. Explain why the properties of water listed above are useful to humans.

Atoms And Gases

All materials are made out of atoms. Scientists are still discovering new particles that are found in atoms. Therefore, the models used to represent atoms will continue to change.

The simplified model of atom structure states that an atom has a dense core called a nucleus. The protons and neutrons are found in the nucleus. The rest of the atom is mostly empty space. Inside an atom, electrons are located at certain distances away from the nucleus – these are referred to as electron shells.

The electron shell closest to the nucleus can hold two electrons and the second shell can hold up to eight. The third shell is able to hold more than eight electrons, however, for the elements up to calcium (atomic number 20) only eight electrons are found in the third shell. The arrangement of electrons written as 2, 8, 8, 1 means that the atom has electrons in the first three shells: i.e. 2, 8 and 8. It also has 1 electron in the fourth shell which gives a total number of 19 electrons. The number of electrons in an atom equals the number of protons. If the element has 19 electrons it must have an atomic number of 19. Potassium is the element with an atomic number of 19.

The **atomic number** of an element is the number of protons in the nucleus. The **mass number** is the number of protons and neutrons.

Protons are positively charged. A neutron has the same mass as a proton and has no charge. This means it is electrically neutral. Electrons are very small compared to protons and have a negative charge.

Two oxygen atoms join together to form a molecule of oxygen gas. It is a colourless gas in the air with no smell. It is used by living things in respiration and involved in burning. Materials burn in oxygen.

Carbon dioxide gas is used by plants to make sugars in the process called photosynthesis and is released by plants and animals as a waste product of respiration.

Carbon dioxide is made by reacting an acid with a carbonate compound. Carbon dioxide is a colourless gas with no smell that makes up a very small percentage of the gases in air. It is denser than air, so it will sink to the bottom of a container. It is used in fire extinguishers and fizzy drinks. Solid carbon dioxide (dry ice) is used to keep things cold.

Hydrogen atoms are found in water and a number of other compounds. Two hydrogen atoms join together to form a molecule of hydrogen. Hydrogen is a colourless gas with no smell. Hydrogen gas can be made by reacting a metal with an acid. When a burning stick is placed near it, it explodes making a popping noise. It is used to make a number of other compounds such as plastics, dyes and margarine.

Activity 4 Atoms And Gases

Aim To revise work on atoms and gases.

Answer the following questions:

1. Describe what atomic mass is.
2. Describe what a mass number is.
3. Copy and complete the following table into your exercise book:

Particle in atom	Found	Charge	Relative mass
Proton			1
Neutron			1
Electron			1/1840

4. Describe the properties of the gases oxygen, hydrogen and carbon dioxide.
5. Describe how to test for the gases oxygen, hydrogen and carbon dioxide.

Acids And Bases

Acids are a group of materials that react in water to release hydrogen ions. Acids can be solids, liquids or gases and when found in foods they create a sharp or sour taste. They turn litmus red and have a pH below seven. Organic acids, such as acetic acid, are made by living things. Mineral acids include sulfuric acid. Acids are corrosive on metals and skin. They should be washed off skin in running water immediately. Some acids are strong; others are weak. When dissolved in water strong acids react more with water and release more H^+ ions than weak acids do.

Bases are opposite to acids. This means that they produce hydroxide ions that react with the hydrogen ions from acids to form neutral water. Bases that can dissolve in water are called alkalis. Bases turn litmus blue and have a pH above seven. Some bases are stronger than others which means they release more OH^- ions than weaker bases.

Litmus and universal indicator are used to find out if a material is an acid, a base or neutral. Indicators are made from plant material. A number of different types of plant material, such as tea and the dyes from some flowers, can be used as indicators.

Reactions

Acids and bases react together to form a salt and water. This is called a neutralisation reaction because the reaction removes the acid particles (H^+ ions) and base particles (OH^- ion). Each acid forms a different family of salts. For example, hydrochloric acid forms chloride salts. Acids react with some metals to form a metal salt and hydrogen gas. Acids react with carbonates to form a metal salt, carbon dioxide gas and water.

Activity 5 Acids And Bases

Aim To revise work on acids and bases.

Answer the following questions:

1. Copy the table below and fill in the gaps:

Substance	pH	Taste	Litmus	Universal Indicator	Example
Acid			Red		
Base		No taste. It feels soapy.			
Neutral	7				Water

2. Write the general word equations for the following reactions.
   a. Acid and base. b. Acid and metal. c. Acid and a carbonate.
3. Name the ion that ALL acids release when dissolved in water.
4. Name the ion that is produced when alkalis dissolve in water.

Chemical Reactions

Chemical bonds are the forces that hold two or more atoms together. During a chemical reaction the chemical bonds holding the atoms together are broken and new bonds are formed.

Four things can happen when a material is heated: burning, decomposition, change of state, or the material gets hotter. Burning and decomposition are chemical reactions. Change of state is a physical change. Signs of a chemical reaction happening include colour change, bubbling and fizzing, precipitation (an insoluble solid [precipitate] may form when two solutions, i.e. aqueous mixtures of soluble ionic compounds, are mixed), light, smoke and heat, a new smell and coldness.

When water boils it bubbles but this is not a chemical reaction. When solid iron is heated it changes colour but this is not a chemical reaction, and is not a physical change until to melts. Careful observation, knowledge of the reactants, and testing are needed to identify a chemical reaction.

Chemical formulae show the number and difference type of atoms present in a compound. $CaCO_3$ (calcium carbonate) has one atom of carbon, one atom of calcium and three atoms of oxygen. $4CaCO_3$ means there are four molecules of calcium carbonate.

Symbol equations, such as the one below, are used to show the numbers of atoms and molecules involved in a chemical reaction, and the products that are formed.

$$H_2SO_4 + Mg \longrightarrow MgSO_4 + H_2$$

Activity 6 Chemical Reactions

Aim To revise work on chemical reactions.

Answer the following questions.

1. Describe what happens to chemical bonds when two materials react together.
2. Describe as many signs as possible that a chemical reaction is occurring.
3. Explain why water bubbling is not a chemical reaction.
4. Describe what a symbol equation is.
5. Explain what a chemical formulae shows.

Unit summary
Copy out each sentence and fill in the missing word(s). The capital letter is the first letter of the missing word.

Heat energy

1. The method of heat transfer in a solid is usually (C _ _ _ _ _ _ _ _ _).
2. The method of heat transfer in a liquid or gas is usually (C _ _ _ _ _ _ _ _ _).
3. The method of transfer that travels through a vacuum is (R _ _ _ _ _ _ _ _).
4. Shiny objects (R _ _ _ _ _ _) radiation and dull objects (A _ _ _ _ _) radiation.
5. High frequency waves have a high (P _ _ _ _).

Speed and pressure

1. How fast an object is going is called its (S _ _ _ _).
2. The speed of an object is related to (T _ _ _ T _ _ _ _) and (D _ _ _ _ _ _ _ T _ _ _ _ _ _ _ _).
3. An object travelling fast can cover a long distance in a (S _ _ _ _) time.

4. Pressure is caused by the force of (P _ _ _ _ _ _ _ _) against an object.

Uses of materials

1. The ability of a material to react with other materials is a (C _ _ _ _ _ _ _ P _ _ _ _ _ _ _).
2. Change of state, lustre and texture are (P _ _ _ _ _ _ _ P _ _ _ _ _ _ _ _ _).
3. A proton has a (P _ _ _ _ _ _ _) charge.
4. A (N _ _ _ _ _ _) has no charge.
5. When materials burn, they join with (O _ _ _ _ _) to form an oxide.

Atoms and gases

1. The number of protons in an atom is its (A _ _ _ _ _ N _ _ _ _ _).
2. Mass number is the number of (P _ _ _ _ _ _) plus (N _ _ _ _ _ _ _) in an atom.
3. Oxygen is used by plants and animals in (R _ _ _ _ _ _ _ _ _ _).
4. Carbon dioxide gas is use by plants in (P _ _ _ _ _ _ _ _ _ _ _ _ _ _).
5. Hydrogen gas burns with an explosion making a (P _ _ _ _ _ _) noise.

Acids and Bases

1. Acids have a pH (L _ _ _ _ _ _ _ _).
2. Bases have a pH (G _ _ _ _ _ _ _ _ _ _ _).
3. Acids release (H _ _ _ _ _ _ _) ions when they react.
4. Alkalis release (H _ _ _ _ _ _ _) ions when dissolved in water.
5. Things used to test if a substance is an acid, base or neutral are called (I _ _ _ _ _ _ _ _ _).

Chemical Reactions

1. Chemical bonds are the (F _ _ _ _ _) that hold two or more atoms together.
2. In a chemical reaction the chemical (B _ _ _) holding the atoms together are either formed or broken.
3. An insoluble solid that forms when two solutions are mixed is called a (P _ _ _ _ _ _ _ _ _ _).
4. Chemical formulae show the number and type of (A _ _ _ _) present in a compound.
5. Symbol equations are used to show the atoms and molecules involved in a chemical reaction and the (P _ _ _ _ _ _ _) that are formed.

Unit 2: STRUCTURE OF MATERIALS

Introduction
In this unit you will investigate the structure of atoms and ions.

Atoms

All materials are made up of small particles called atoms. Many different atoms have been discovered or made and new ones are still being made by scientists. Different atoms are called **elements**. For example oxygen, sulfur and carbon are elements. As well as a name, scientists have given each element a symbol that can be used instead of writing the name. The elements are listed on a chart called a **Periodic Table**. The Periodic Table has the elements listed in rows and arranged in groups so elements with similar chemical properties are together. Elements are listed on the Periodic Table in order of their atomic number. The **atomic number** of an element is the number of protons that the element has in its **nucleus**. The nucleus is a small dense part in the centre of the atom. Each element has a different number of protons in its nucleus. This results in differences in the chemical and physical properties between elements.

All Periodic Tables show the names or symbols of the elements. Some Periodic Tables also have other information about each element. A Periodic Table is printed on the inside front cover of this book. This Periodic Table shows the name, symbol, atomic number and the relative atomic mass of each element.

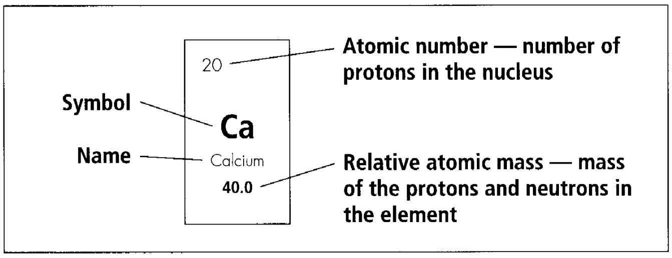


Diagram 2.1
Information on the Periodic Table.

Hydrogen is located on the Periodic Table where it is because it has the physical properties of a non-metal but chemical properties like a metal (*e.g. It reacts by giving up electrons*). All atoms have the same structure. Atoms of different elements are made up of different numbers of the smaller particles called protons, neutrons and electrons. For example, each carbon atom has a nucleus containing six protons: i.e. Atomic number six. Carbon is the only type of atom that has six protons. If an atom has more or less than six protons then the element is NOT carbon. Carbon atoms also have six electrons in the areas around the nucleus called **electron shells**. Atoms always have the same number of electrons and protons. For example, if an atom has nine protons it will have nine electrons. Protons have a positive electrical charge and electrons have a negative charge. Having the same number of positive and negative charges makes the overall electric charge of an atom neutral.

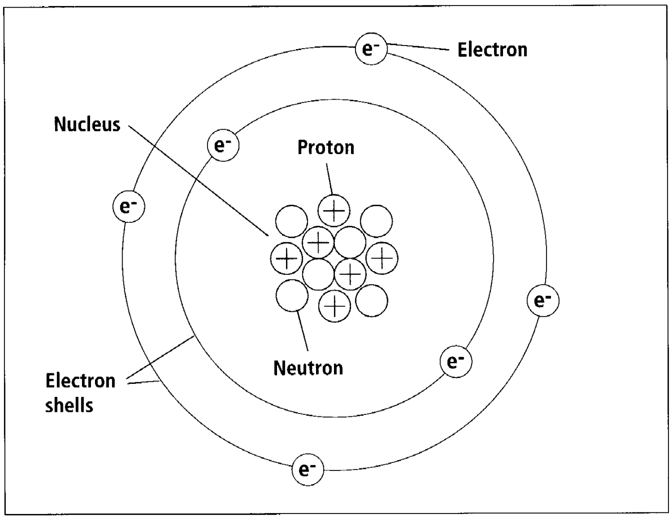


Diagram 2.2
Carbon atom.

Atoms also have neutrons in their nucleus. Neutrons have no electrical charge. The positively charged protons in the nucleus repel each other so the neutrons act as a 'glue' to hold the protons together in the nucleus. Atoms of the same type can have different numbers of neutrons in their nucleus. For example, carbon atoms can have six or seven neutrons in the nucleus. Oxygen atoms can have eight, nine or ten neutrons. Usually atoms have the same number of neutrons as protons. Ninety-nine percent of oxygen atoms have eight neutrons. The number of protons plus neutrons in an atom is known as the **mass number**.

The **relative atomic mass** is the mass of the protons plus the neutrons where each proton and neutron is given the mass of one atomic mass unit. Electrons are very small compared to protons and neutrons so they have very small mass and can be ignored in the calculation of mass. Diagram 2.2 shows that the relative atomic mass of carbon is 12.

Working out the relative atomic mass of different elements:

- Carbon has six protons and six neutrons.
- The mass of six protons plus the mass of six neutrons equals a relative atomic mass of 12.
- Helium has two protons and two neutrons.
- 2 + 2 = 4 so helium has a relative atomic mass of four.

Activity 1

The Periodic Table

Aim To use information on the Periodic Table to complete the following:

1. Write the symbols for the following elements: aluminium, fluorine, sodium, gold and krypton.
2. Write the names of the following elements: N, Ar, W, Mg and H.
3. What is the atomic number of the following elements? Helium, Calcium, Li, Iron and Br.
4. What is the relative atomic mass of the following elements? Copper, P, Cl, Beryllium and Ne.
5. Name the elements found in group 18.
6. Give the symbols for the elements found in row three.

Activity 2

About Atoms

Aim Use the information already given about atoms, to complete the following:

1. List the words written in bold and give their meaning.
2. Explain hydrogen's location on the Periodic Table.
3. What feature of atoms is used to put the elements in order on the Periodic Table?
4. How are the groups and rows of the Periodic Table worked out?
5. What makes an atom electrically neutral?

6. Copy and complete the following table:

Element	Symbol	Protons	Neutrons	Electrons	Atomic number	Mass number
Hydrogen						
Lithium						
Nitrogen						
Magnesium						
Aluminium						
Phosphorus						
Potassium						

Electron Arrangements

The electrons in atoms are arranged in shells. The first shell is small and close to the nucleus. It can only hold up to two electrons. The next shell can hold up to eight. Electron arrangements can be drawn or written in the format 2, 5. Which means two electrons in the first shell and five in the second. The third shell can hold up to 18 electrons but after 8, the fourth shell starts to fill.

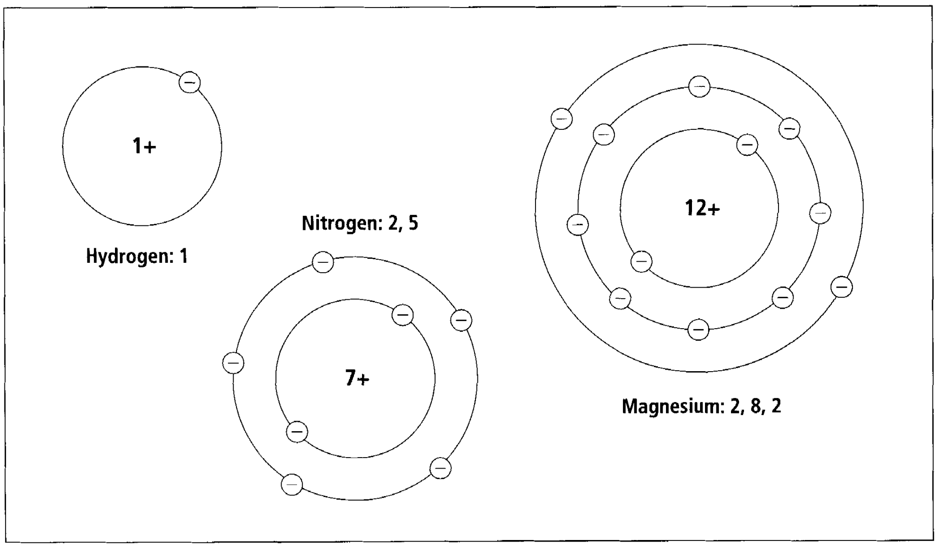


Diagram 2.3
Electron arrangement.

Reactivity Of Elements

Electron arrangements are important because they influence the chemical properties of the element. For example, the atoms in group 18 are called the noble gases because they don't react. They don't react with other elements because they have full electron shells. A full outside electron shell makes the atoms very stable. The elements in group 17 are very **reactive** because they only need one more electron to fill up their outside electron shell. Reactive means that the element takes part in chemical reactions. The electron arrangement of the element controls its reactivity.

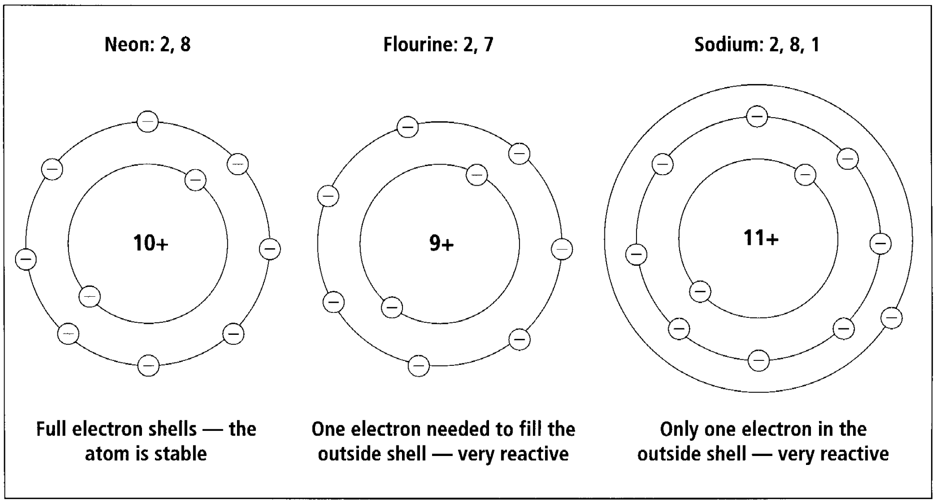


Diagram 2.4
Stable and reactive electron arrangements.

Activity 3 Electron Arrangements

Aim To investigate how electron arrangement influences reactivity.

Complete the table on the next page for the first twenty elements on the Periodic Table. Use the key below to work out the approximate reactivity of each element (note that other factors also influence reactivity). Parts of the table have been done for you.

Key Stable = full electron shells
Very reactive = one electron more or less than a full shell
Reactive = two electrons more or less than a full shell
Least reactive = over two electrons more or less than a full shell

Name	Electrons	Electron arrangement	Change needed to get a full outside electron shell	Stability
Hydrogen	1	1	One less electron (It is a special case)	Very reactive
Helium	2	2	None (already full)	Stable
Lithium	3	2, 1	One less	Very reactive
Beryllium	4	2, 2	Two less	
Boron	5			
Carbon	6		Four more or four less	
	7		Three more	

Ions

Atoms become more stable by getting a full outer electron shell. They can do this by losing, gaining or sharing electrons. Atoms can only react if other atoms are also able to lose, gain or share electrons. An atom that has lost or gained electrons is called an **ion**. Metal atoms react by losing electrons. For example, a lithium atom has three electrons but a lithium ion only has two. This is because the lithium atom reacted by losing an electron to another atom. The diagram below shows a lithium atom losing one electron to a chlorine atom. When this happens both the lithium and chlorine atoms form ions and they both have their outer shell full of electrons.

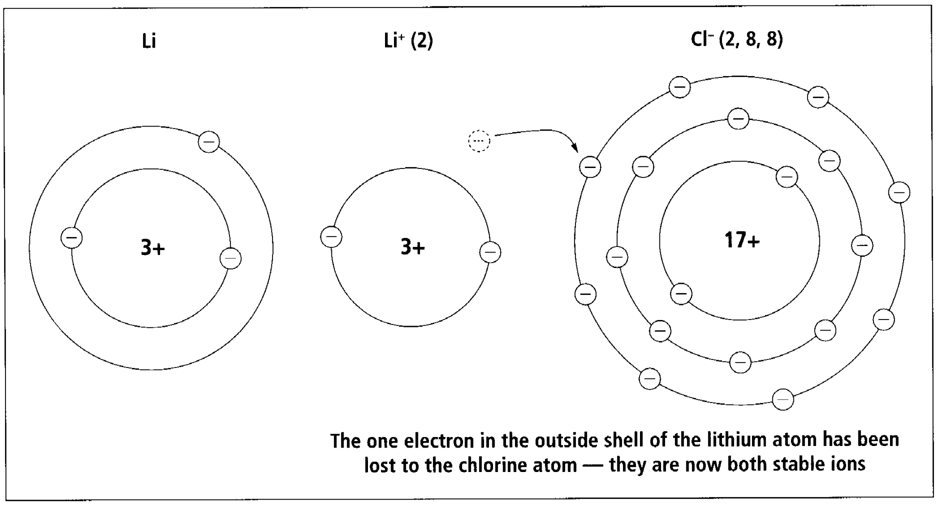


Diagram 2.5
Lithium atom reacting with a chlorine atom to become ions.

Diagram 2.5 shows a chlorine atom gaining an electron to become an ion. Non-metal atoms react by gaining electrons. When non-metal atoms gain electrons to form ions their name changes. For example:

Atom name	**Ion name**
Nitrogen	Nitride
Oxygen	Oxide
Fluorine	Fluoride
Sulfur	Sulfide
Chlorine	Chloride
Bromine	Bromide
Iodine	Iodide

The ion formed when an atom gains electrons now has more electrons than protons so has an electrical charge. For example, when magnesium and oxygen react together each magnesium atom loses two electrons and each oxygen atom gains the two electrons from the magnesium. The following diagram shows how the electrical charges in the magnesium and oxygen atoms change when they react and form ions.

Magnesium atom: Mg (2, 8, 2)

	1	2	3	4	5	6	7	8	9	10	11	12
Protons	+	+	+	+	+	+	+	+	+	+	+	+
Electrons	–	–	–	–	–	–	–	–	–	–	–	–

Magnesium ion: Mg^{2+} (2, 8)

	1	2	3	4	5	6	7	8	9	10	11	12
Protons	+	+	+	+	+	+	+	+	+	+	+	+
Electrons	–	–	–	–	–	–	–	–	–	–		

Oxygen atom: O (2, 6)

	1	2	3	4	5	6	7	8
Protons	+	+	+	+	+	+	+	+
Electrons	–	–	–	–	–	–	–	–

Oxygen ion: O^{2-} (2, 8)

	1	2	3	4	5	6	7	8	9	10
Protons	+	+	+	+	+	+	+	+		
Electrons	–	–	–	–	–	–	–	–	–	–

Diagram 2.6
Positive and negative charges in atoms and ions.

The number of protons doesn't change in a reaction. The magnesium atoms and ions both have 12 protons and the oxygen atoms and ions both have eight protons. Only the number of electrons has changed. The magnesium atom lost two electrons to become a magnesium ion. The ion now has two positive charges that are not balanced by negative charges. The extra positive charges in the magnesium ion are shown using the symbol Mg^{2+}. The two extra negative charges in the oxide ion are shown using the symbol O^{2-}.

Look at the electron arrangements that magnesium and oxygen have after reacting together. They both have the stable electron arrangement 2, 8. This means that both materials have a full outside electron shell. Metal and non-metal atoms react together to get complete outside electron shells which makes them stable.

Table of ions

Positive ions		Negative ions	
Sodium	Na^+	Chloride	Cl^-
Potassium	K^+	Hydroxide	OH^-
Hydrogen	H^+	Iodide	I^-
Ammonium	NH_4^+	Nitrate	NO_3^-
Silver	Ag^+	Carbonate	CO_3^{2-}
Magnesium	Mg^{2+}	Hydrogen carbonate	HCO_3^-
Calcium	Ca^{2+}	Sulfate	SO_4^{2-}
Zinc	Zn^{2+}	Oxide	O^{2-}
Iron II	Fe^{2+}	Phosphate	PO_4^{3-}
Copper	Cu^{2+}		
Barium	Ba^{2+}		
Iron III	Fe^{3+}		
Aluminium	Al^{3+}		

Activity 4

Materials needed:
Magnesium ribbon;
Tongs;
Burner;
Matches;
Sandpaper;
Safety glasses.

Forming Ions

Aim To investigate the formation of ions.

1. Gently remove the oxide layer from the magnesium ribbon using sandpaper.
2. Hold a small piece of magnesium in the tongs.
3. Heat the small piece of magnesium with a burner until it reacts with oxygen in the air: i.e. It burns.
4. Record your observations of the reactants, the reaction itself and the product (magnesium oxide) formed.

4. Use the following words to explain what has happened in the reaction: Atom, ion, electrons, magnesium, oxygen, magnesium oxide.
5. Explain the difference between an atom and an ion.
6. Sometimes two or three elements will join together to form an ion. Copy the table of ions on the previous page into the inside front cover of your exercise book.
7. The symbol NH_4^+ means one nitrogen atom (N)and four hydrogen atoms (H_4) have formed an ion that has lost one electron ($^+$). Explain what the following symbols mean: K^+, NH_4^+, Al^{3+}, OH^-, CO_3^{2-}, S^{2-}, PO_4^{3-}.
8. Some of the elements in groups three to 12 can lose different numbers of electrons. What is the example of this given in the table of ions?

Sharing Electrons

It is difficult for atoms, such as carbon and silicon, to lose or gain electrons to become stable because they have four electrons in their outside electron shell. Four is a large number of electrons to gain or lose. These atoms react by sharing electrons with other adjacent atoms. The atoms that are sharing the electrons form a **molecule**. Sharing electrons allows each atom to have a full outside electron shell.

Lewis diagrams are used to show the electron arrangement in atoms and molecules. Only the electrons in the outside shell are shown in Lewis diagrams because these are the only electrons that are lost, gained or shared in a reaction.

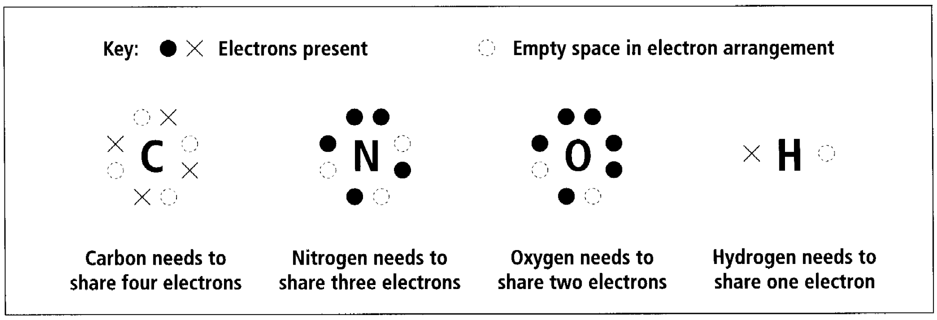


Diagram 2.7
Lewis diagram showing the electron arrangements in atoms.

The electrons can be shown as dots or crosses. Often the electrons in the atoms of one element are shown with crosses and the electrons in other atom are shown as dots. This allows you to see which electrons are being shared.

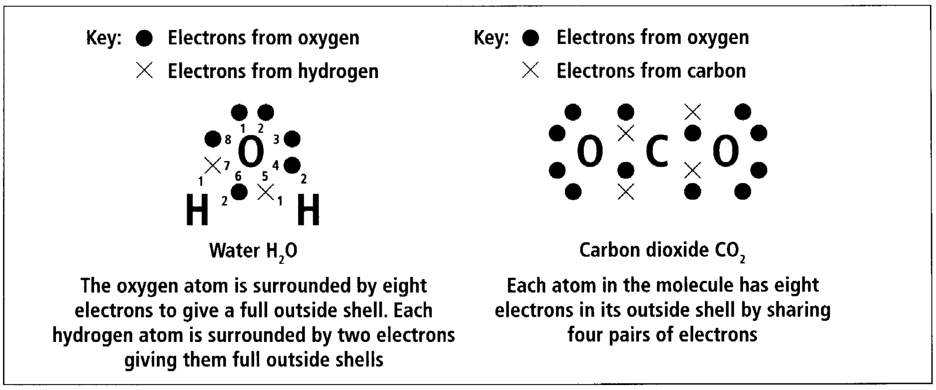


Diagram 2.8
Two common molecules formed by sharing electrons.

Chemical Bonds

When atoms react by losing, gaining or sharing electrons they are forming **chemical bonds**. The chemical bonds are forces of attraction that hold the ions in a crystal or the atoms in a molecule together. When a material contains ions **ionic bonds** hold the ions together. The chemical bonds formed inside a molecule when electrons are shared are called **covalent bonds**.

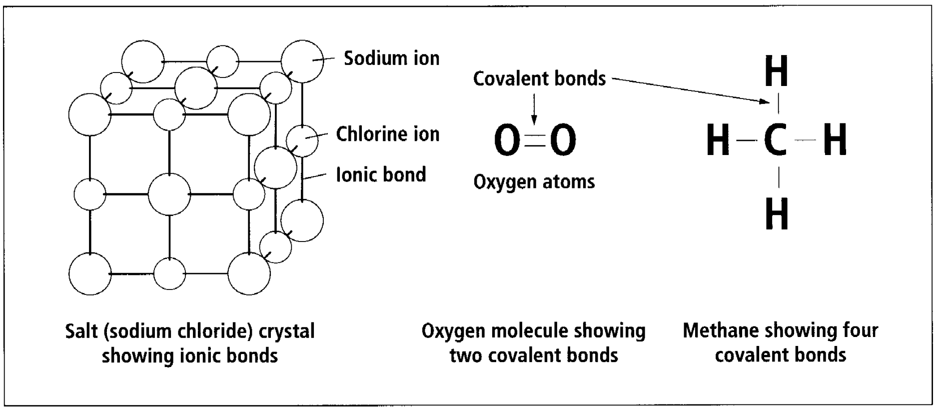


Diagram 2.9
Materials with ionic and covalent bonds.

Materials that are made up of ions (*e.g. Sodium chloride*) are called **ionic compounds**. The sodium ion is a positively charged ion and the chlorine ion is a negatively charged chloride ion. The forces of attraction between the negative and positive ions are the ionic bonds.

Covalent materials are molecules containing covalent bonds. The electrons in covalent substances are shared between adjacent atoms in the molecule. The sharing of electrons holds atoms in the molecule together.

Ions, such as carbonate ions CO_3^{2-}, are formed by atoms sharing electrons between themselves and by having extra electrons.

Activity 5 Chemical Bonds

Aim To record information on ionic and covalent chemical bonds.

1. Elements react by losing, gaining or sharing electrons. Rule four columns in your exercise book and head them up: **Lose electrons**, **Share electrons**, **Gain electrons** and **Stable**. Sort the first 20 elements of the Periodic Table into the four columns (note, some may appear in more than one list).
2. Describe the difference between ionic and covalent bonds. Draw some examples.
3. Describe the difference between ionic compounds and covalent molecules. Draw some examples.

Writing Chemical Formulae And Names

Chemical formulae are used as a shorthand way of writing the names of materials. The chemical formula also gives information about the number of atoms present in each molecule. For example, the formula for water is written as:

$$\mathbf{H_2O}$$

The *H* and the *O* are written on the line and the *2* is written smaller and through the line. The formula for water shows it is made up of two atoms of hydrogen shown as H_2 and one atom of oxygen shown as *O*.

Name	Formula	Information formula shows:
Oxygen gas	O_2	Two atoms of oxygen.
Carbon dioxide	CO_2	One atom of carbon (C) and two atoms of oxygen(O_2).
Sulfuric acid	H_2SO_4	Two atoms of hydrogen (H_2), one atom of sulfur (S) and four atoms of oxygen (O_4).
Calcium carbonate (coral)	$CaCO_3$	One atom of calcium (Ca), one atom of carbon (C), and three atoms of oxygen (O_3).
Zinc nitrate	$Zn(NO_3)_2$	One atom of zinc (Zn), and two lots of nitrate (NO_3). Two lots of nitrate include two nitrogen (N) and six oxygen (O_3) atoms. This information shows that zinc nitrate has one atom of zinc, two atoms of nitrogen and six atoms of oxygen.

The information on the table of ions can be used to help write the chemical formula of metal compounds. Two different methods are outlined below. Use the steps and points to write the formula. Write the formula showing the steps until you know the method and can do the steps in your head. Writing the formula for aluminium oxide (Al_2O_3).

Step 1:
Write the symbols of the two ions, with the metal first.
$\mathbf{Al^{3+}}$ and $\mathbf{O^{2-}}$
Aluminium ion and oxide ion.

Step 2:
The symbol for the oxide ion shows that it gains two electrons. Write the number of electrons gained by the non-metal after the symbol for the metal. Write the number through the line, not on the line.
$\mathbf{Al^{3+}{}_2\ O^{2-}}$

Step 3:
The symbol for the aluminium ion shows that it loses three electrons. Write the number of electrons lost by the metal after the symbol for the non-metal.
$\mathbf{Al^{3+}{}_2\ O^{2-}{}_3}$

Step 4:
Rewrite the formula leaving out the symbols for the ions.
$\mathbf{Al_2O_3}$
This formula shows that aluminium oxide has two atoms of aluminium and three atoms of oxygen bonded together.

Point 1:
When writing chemical formulae, ones are left out. For example, potassium chloride is written:

Step 1: $\mathbf{K^+Cl^-}$
Step 2: $\mathbf{K^+{}_1Cl^-}$
Step 3: $\mathbf{K^+{}_1Cl^-{}_1}$
Step 4: **KCl**

This means that sodium chloride is written NaCl, not Na_1Cl_1.

Point 2:
If there is the same number of each atom in the formula the numbers can be missed out. For example, copper oxide is written:

Step 1: $\mathbf{Cu^{2+}O^{2-}}$
Step 2: $\mathbf{Cu^{2+}{}_2O^{2-}}$
Step 3: $\mathbf{Cu^{2+}{}_2O^{2-}{}_2}$
Step 4: **CuO**

This means that the formula for calcium oxide is written CaO, not Ca_2O_2.

Point 3:

Sometimes brackets ( ) are needed when writing a formula with ions made up of more than one atom. The brackets are used when there is more than one of an ion. For example, magnesium hydroxide is written:

Step 1: **$Mg^{2+}OH^{-}$**

Step 2: **$Mg^{2+}{}_{1}OH^{-}$**

Step 3: **$Mg^{2+}{}_{1}OH^{-}{}_{2}$**

Step 4: **$Mg(OH)_2$**

This means that the formula for copper nitrate is written $Cu(NO_3)_2$ not $CuNO_{32}$.

The following information describes another way to learn to write formulae for metal compounds.

The following chart is **not** a Periodic Table but it has a similar shape to the Periodic Table. The bar across the top of the chart shows how many electrons the element loses or gains. An 'X' means that the element doesn't usually lose or gain electrons.

1	2	3	X	3	2	1	X
H	He						
Li	Be		C	N	O	F	Ne
Na	Mg	Al	Si	P	S	Cl	Ar
K	Ca						
Ag	Fe (II)	Fe (III)					
	Cu						
	Zn						
	Sn						
	Pb						
	Ba						

Writing the formula for aluminium oxide (Al_2O_3).

Step 1:
Write the symbols of the two elements, with the metal first.
Al and O

Step 2:
Using the table above, write the number for the **non-metal** after the **metal.**
Al_2O

Step 3:
Write the number for the **metal** after the **non-metal**.
Al_2O_3

Metal compounds are named for the ions they contain (*e.g.* $PbCl_2$). If you look on the Periodic Table you will find that Pb is the symbol for lead and Cl is the symbol for chlorine, so $PbCl_2$ is lead chloride. Remember, when chlorine becomes an ion it is called chloride. See the table of names of ions at the beginning of this unit. NH_4OH is ammonium hydroxide. Both parts to this name can be found in the table of ions given earlier in the unit. Names like carbon monoxide and carbon dioxide use prefixes to show how many atoms are present. The prefixes used are the ones used in maths.

- **Mono** for one.
- **Di** for two.
- **Tri** for three.
- **Tetra** for four.

Carbon monoxide becomes CO
Carbon dioxide becomes CO_2

Names ending in 'ate' or 'ite' mean that there are more than two elements in the compound and one of them is oxygen. For example, sodium sulfate has atoms of sodium, sulfur and oxygen. When naming ionic compounds, the cation from the metal is placed first in the name.

Activity 6 Chemical Formulae

Aim To write chemical formulae for a range of materials.

1. Copy and complete the following table to describe the information in the chemical formulae.

Name	Formula	Information formula shows
Hydrochloric acid	HCl	
Magnesium oxide	MgO	
Sucrose (sugar)	$C_{12}H_{22}O_{11}$	
Sodium sulfate	$NaSO_4$	
Calcium hydroxide	$Ca(OH)_2$	
Carbon dioxide	CO_2	
Glucose	$C_6H_{12}O_6$	
Ethanol	C_2H_5OH	
Ammonia	NH_3	
Vitamin B1	$C_{12}H_{17}ON_4SClHCl$	
Sodium bicarbonate	$NaHCO_3$	
Copper sulfate	$CuSO_4$	

Sometimes brackets ( ) are needed when writing a formula with ions made up of more than one atom. The brackets are used when there is more than one of an ion. For example, magnesium hydroxide is written:

Step 1: $\mathbf{Mg^{2+}OH^{-}}$

Step 2: $\mathbf{Mg^{2+}{}_{1}OH^{-}}$

Step 3: $\mathbf{Mg^{2+}{}_{1}OH^{-}{}_{2}}$

Step 4: $\mathbf{Mg(OH)_2}$

This means that the formula for copper nitrate is written $Cu(NO_3)_2$ not $CuNO_{32}$.

The following information describes another way to learn to write formulae for metal compounds.

The following chart is **not** a Periodic Table but it has a similar shape to the Periodic Table. The bar across the top of the chart shows how many electrons the element loses or gains. An 'X' means that the element doesn't usually lose or gain electrons.

1	**2**	**3**	**X**	**3**	**2**	**1**	**X**
H	He						
Li	Be		C	N	O	F	Ne
Na	Mg	Al	Si	P	S	Cl	Ar
K	Ca						
Ag	Fe (II)	Fe (III)					
	Cu						
	Zn						
	Sn						
	Pb						
	Ba						

Writing the formula for aluminium oxide (Al_2O_3).

Step 1:
Write the symbols of the two elements, with the metal first.
Al and O

Step 2:
Using the table above, write the number for the **non-metal** after the **metal.**
$\mathbf{Al_2O}$

Step 3:
Write the number for the **metal** after the **non-metal**.
$\mathbf{Al_2O_3}$

Metal compounds are named for the ions they contain (*e.g.* $PbCl_2$). If you look on the Periodic Table you will find that Pb is the symbol for lead and Cl is the symbol for chlorine, so $PbCl_2$ is lead chloride. Remember, when chlorine becomes an ion it is called chloride. See the table of names of ions at the beginning of this unit. NH_4OH is ammonium hydroxide. Both parts to this name can be found in the table of ions given earlier in the unit. Names like carbon monoxide and carbon dioxide use prefixes to show how many atoms are present. The prefixes used are the ones used in maths.

- **Mono** for one.
- **Di** for two.
- **Tri** for three.
- **Tetra** for four.

Carbon monoxide becomes CO
Carbon dioxide becomes CO_2

Names ending in 'ate' or 'ite' mean that there are more than two elements in the compound and one of them is oxygen. For example, sodium sulfate has atoms of sodium, sulfur and oxygen. When naming ionic compounds, the cation from the metal is placed first in the name.

Activity 6 Chemical Formulae

Aim To write chemical formulae for a range of materials.

1. Copy and complete the following table to describe the information in the chemical formulae.

Name	Formula	Information formula shows
Hydrochloric acid	HCl	
Magnesium oxide	MgO	
Sucrose (sugar)	$C_{12}H_{22}O_{11}$	
Sodium sulfate	$NaSO_4$	
Calcium hydroxide	$Ca(OH)_2$	
Carbon dioxide	CO_2	
Glucose	$C_6H_{12}O_6$	
Ethanol	C_2H_5OH	
Ammonia	NH_3	
Vitamin B1	$C_{12}H_{17}ON_4SClHCl$	
Sodium bicarbonate	$NaHCO_3$	
Copper sulfate	$CuSO_4$	

2. Name the following:

a. NaBr b. $ZnSO_4$ c. KOH d. $Ca(NO_3)_2$

e. Al_2S_3 f. $FePO_4$ g. $Al_2(SO_4)_3$ h. NH_4Cl

i. $Fe(NO_3)_2$ j. $Fe(NO_3)_3$ k. $Ca(HCO_3)_2$ l. NaOH

3. Write formulae for the following materials:

a. Potassium chloride. b. Sodium oxide.
c. Lead sulfate. d. Calcium nitrate.
e. Iron III oxide. f. Tin II sulfide.
g. Zinc carbonate. h. Iron III sulfate.
i. Calcium chloride. j. Sodium hydroxide.

4. Here are some ions: K^+, Ca^{2+}, Fe^{3+}, Cl^-, SO_4^{2-}. Using only these ions write the names and formulae of:

a. Three chlorides. b. Two iron III compounds. c. Three sulfates.

5. Match the following names with a formula from the formula list:

Name list	**Name list**	**Formula list**	**Formula list**
Sodium nitrate	Magnesium oxide	FeS	SO_2
Copper oxide	Potassium sulfate	CaC_2	$Mg(NO_3)_2$
Sodium iodide	Magnesium nitride	CO_2	$Mg_3(PO_4)_2$
Sulfur dioxide	Sodium nitrate	Na_2SO_4	$Mg(OH)_2$
Hydrogen sulfide	Carbon tetrachloride	$FeCl_3$	$NaHSO_4$
Magnesium posphate	Potassium sulfate	NaI	NaI
Potassium bicarbonate	Calcium carbide	CuO	Mg_3N_2
Iron II chloride	Sodium sulfide	K_2SO_3	SO_3
Sulfur trioxide	Sodium iodate	Na_2S	K_2CO_3
Iron II sulfide	Iron III chloride	MgH_2	H_2S
Magnesium hydroxide	Magnesium nitrate	MgO	CO
Sodium bisulfate	Sodium sulfate	$FeCl_2$	$KHCO_3$
Potassium carbonate	Sodium iodide	$NaNO_3$	$FeSO_4$
Carbon monoxide	Iron II sulfate	$NaIO_3$	$NaNO_2$
Magnesium hydride	Carbon dioxide	CCl_4	K_2SO_4

Activity 7 Study Notes

Aim To make study notes to use when revising this unit.

- Read through all the material you have covered in this unit.
- Read it again, this time highlighting the key science ideas.
- Rewrite the key science ideas into a different form so that you can use them as study notes. There are lots of different forms of study notes but they all have only the key words written down. Some people use diagrams.

Unit 3: METAL COMPOUNDS

Introduction

Metal compounds are ionic compounds in which the positive ion is a metal ion. Metal compounds are named by the negative ion they contain. For example, sodium carbonate and magnesium carbonate are metal compounds called **carbonates**. Sodium chloride and potassium chloride are metal compounds called chlorides. Other metal compounds include oxides and hydroxides.

Properties Of Metal Compounds

Colour

Most metal compounds are colourless. If the metal compound is coloured it may contain metal ions such as copper (II) ions, iron ions and lead ions.

Solubility

In some metal compounds the ions are not held very tightly together so they can be dissolved by water. The metal compound is said to be **soluble** because the water molecules can pull the crystals of the metal compound apart and the ions will move around in the water. When a metal compound is soluble it forms a transparent solution. This means that light can be seen through the solution.

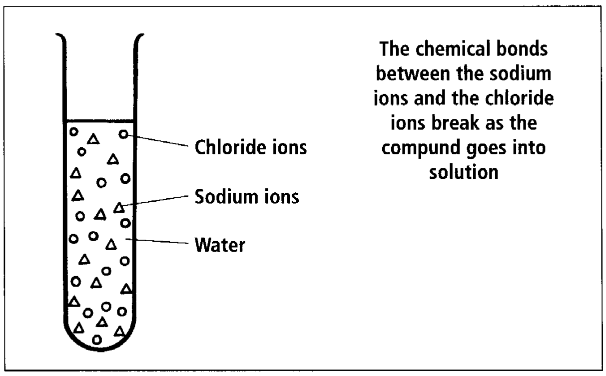


Diagram 3.1
Soluble sodium chloride in solution.

Ions Reacting Together

Sometimes when the solutions of two metal compounds are mixed a solid material forms. This solid material is called a **precipitate** because it has formed and come out of the solution as a solid. This type of reaction is called a precipitation reaction. Precipitates form because within the solutions of the two soluble compounds there are ions that join together tightly to form insoluble ionic compounds. When the solutions are mixed these ions join together and form a solid.

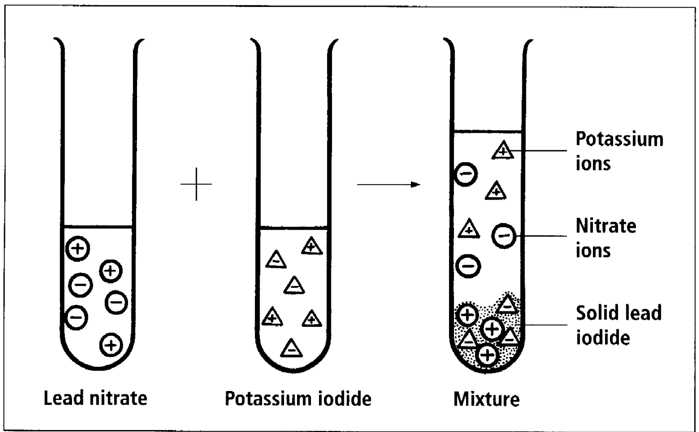


Diagram 3.4
Formation of a precipitate.

Activity 2

Materials needed:

Test tubes;

A range of soluble metal compounds: e.g. Sodium sulfate, barium chloride, silver nitrate, sodium chloride, sodium carbonate, zinc chloride, copper sulfate, sodium hydroxide, sodium nitrate, magnesium sulfate, iron III nitrate and potassium chloride.

Will A Precipitate Form?

Aim To use the solubility rules to predict if a precipitate will form.

1. Work with only one pair of solutions at a time, wash glassware carefully before starting the next pair.
2. Copy and complete the table on the next page by listing the ions present in the solutions, and predict any precipitate that might form. Write the name and formula of any predicted precipitate.
3. Check your prediction by mixing the two solutions together.
4. **Discussion:** Use information about soluble and insoluble metal compounds to explain why precipitates form when some solutions are mixed.
5. **Evaluation:** List the difficulties you had in carrying out this investigation. Discuss how you overcame these difficulties.

Solutions mixed	Ions present	Will a precipitate form?	Name of the precipitate	Precipitate formula	Observation when solutions mixed
Sodium sulfate and barium chloride	Na^+, SO_4^{2-}, Ba^{2+}, Cl^-	Yes	Barium sulfate	$BaSO_4$	White solid forms
Silver nitrate and sodium chloride					
Sodium carbonate and zinc chloride					
Copper sulfate and sodium hydroxide					
Sodium nitrate and magnesium sulfate					
Iron III nitrate and sodium hydroxide					
Potassium chloride and sodium sulfate					

Identifying Metal Ions And Non-metal Ions

Precipitation reactions and flame tests can be used to identify the ions in a metal compound.

Activity 3

Materials needed:
Beaker of clean water;
A dropper;
A spotting tile;
Burner;
Test tubes;
Litmus paper;
Sodium hydroxide;
Ammonium hydroxide;
Hydrochloric acid;
Silver nitrate;
Potassium iodide;
Barium chloride;
Solutions of a range of metal compounds to test;
Unknown metal compounds labelled A, B, C and D.

Using Precipitation Reactions To Identify Ions

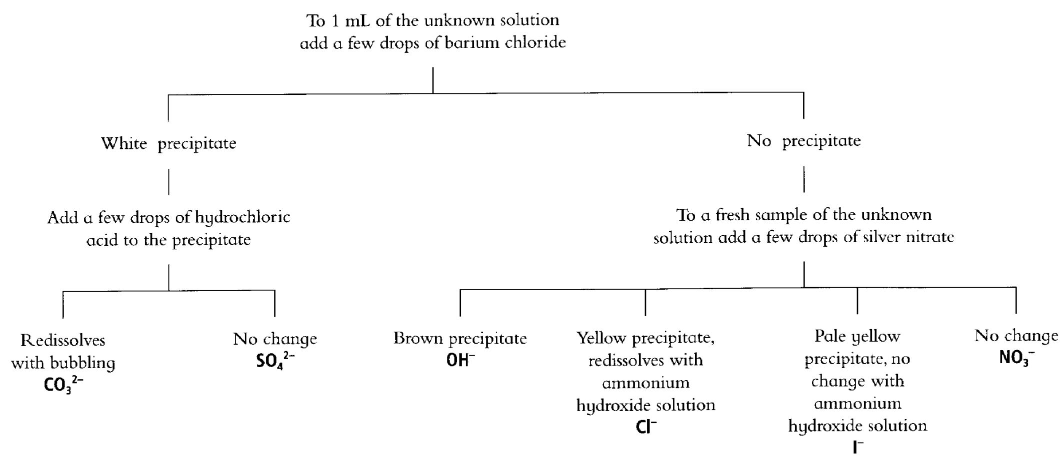
Aim To identify ions in metal compounds.

1. Choose a metal compound such as sodium carbonate. Follow the instructions on the charts on the next two pages to identify the positive and negative ions in the compound.
2. Record your results in a table.
3. Wash equipment carefully between each test.
4. Try out the tests on a range of metal compounds and identify the positive and negative ions in them.
5. Once you are familiar with the techniques needed to identify the positive and negative ions in solution, try to see if you can identify the unknown solutions A, B, C and D.

Identifying some positive ions

- Place one drop of the unknown solution onto a tile and add one drop of sodium hydroxide solution
  - Pale blue precipitate: Cu^{2+}
  - Dark green precipitate: Fe^{2+}
  - Brown precipitate
    - To a fresh drop of unknown solution, add one drop of potassium iodide solution
      - Pale yellow precipitate: Ag^{+}
      - Brown solution: Fe^{3+}
  - White precipitate
    - Add two extra drops of sodium hydroxide to the precipitate on the tile
      - No change: Mg^{2+}
      - Redissolves
        - To a fresh drop of the unknown solution add one drop of potassium iodide solution
          - Bright yellow precipitate: Pb^{2+}
          - No change
            - To a fresh drop of the unknown solution add one drop of ammonium hydroxide solution
              - White precipitate: no change with more ammonium hydroxide: Al^{3+}
              - White precipitate: redissolves with more ammonium hydroxide: Zn^{2+}
  - No change
    - Place 1 mL of unknown solution into a test tube with 1 mL of sodium hydroxide solution and warm with burner
      - No change: Na^{2+}
      - Smell of ammonia: turns red litmus paper to blue: NH_4^{+}

Identifying some negative ions



Flame Tests

When heated in a flame each metal element gives off a different coloured light. This colour can be used to identify the metal in a compound. The list below gives examples of elements and the colour of flame they produce.

Element	**Colour of flame**
Calcium	Orange-red
Copper	Green
Lithium	Red
Potassium	Violet
Sodium	Yellow
Strontium	Crimson

Activity 4

Materials needed:

Burner;

Nichrome wire loop;

Hydrochloric acid in a beaker;

A range of metal compounds: e.g. Sodium chloride, sodium carbonate, lithium chloride, copper chloride, copper sulfate, copper nitrate, potassium chloride potassium nitrate, strontium nitrate, strontium chloride;

Four containers of metal compound labelled A, B, C and D;

Safety glasses.

Flame Tests For Metal Ions

Aim To use flame tests to identify metal ions.

1. Light the burner and adjust the flame to hot.
2. Clean the wire loop by dipping it in hydrochloric acid and then putting it in the burner flame until it glows.
3. Dip the hot wire in a metal compound then place the loop in the flame again.
4. Record the name of the compound and the colour of the flame it gave.

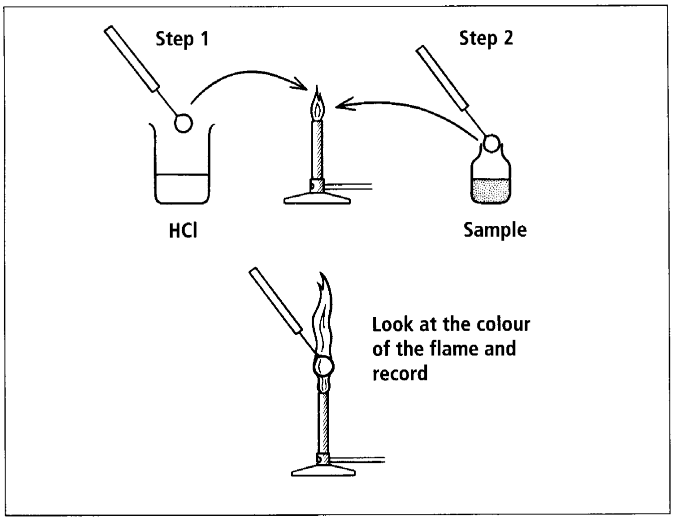


Diagram 3.5
Flame test method.

5. Clean the loop again (instruction two above) before testing the next metal compound.
6. When you have finished clean the loop again and test the sample labelled A. Record the colour of the flame.
7. Use the colour of the flame to work out which metal the compound contained.
8. Clean the loop and test sample B. Record the colour of the flame and the metal it contains.
9. Continue testing the samples labelled C and D.
10. Check that you have the correct answer for the metals in A, B, C and D.

Metal Oxides

Metal oxides are formed when metals react with oxygen. Some metals, such as sodium and lithium, react quickly with oxygen. Other metals, such as gold and copper, react slowly with oxygen.

Metal + oxygen $\longrightarrow$ metal oxide

Copper + oxygen $\longrightarrow$ Copper oxide

$2Cu + O_2 \longrightarrow 2CuO$

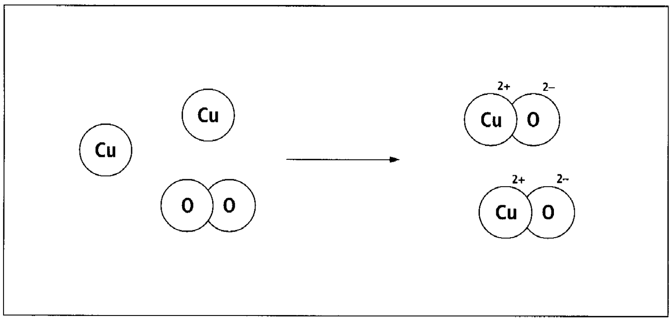


Diagram 3.6
Copper and oxygen reaction.

Activity 5

Metal Oxides

Materials needed:

Sodium or lithium metal;

Samples of metal: e.g. Magnesium, copper, zinc, lead;

Sandpaper or steel wool.

Aim To investigate the formation of metal oxides.

1. Warning: metallic sodium and lithium are extremely hazardous substances. Your teacher may demonstrate the reaction of sodium or lithium metal with air. Describe the colour of the freshly cut surface of the metal.
2. Watch the freshly cut surface closely. Describe the changes.
3. Choose a sample of metal. Describe the colour of the surface of the metal. What do you think the material on the outside of the metal is?
4. Clean the sample of metal with sandpaper. Describe the colour of the clean surface.
5. Leave the sample for three or more days and observe changes, if any, that occur. Record you observations in a table.
6. Record the observations of other groups looking at the same and different metals.
7. Compare the reaction between magnesium and oxygen when magnesium is left in the air or is heated (use the observations from the activity in a previous unit, or burn another piece of magnesium). Describe the differences between the two reactions.
8. Write a conclusion for your findings about the reaction of different metals with oxygen.

Activity 6

Metal Oxides With Acids And Bases

Materials needed:

Test tubes;

Beaker of hot water;

Dilute hydrochloric acid;

Dilute sodium hydroxide solution;

Metal oxides: e.g. Copper oxide, magnesium oxide, aluminium oxide.

Aim To investigate if metal oxides react with acids or bases.

1. Place a **very small amount** of each oxide in separate test tubes. If you put too much oxide in you will not be able to observe a reaction.
2. Add 1 cm depth of acid and shake gently. Does the oxide react with the acid? If a reaction occurs the oxide will disappear.
3. If any oxide is left, warm the test tubes in a beaker of very hot water for two to three minutes and watch to see if the oxide reacts.
4. Record your observations in a table.
5. Repeat the tests using sodium hydroxide (a base) in place of the acid. Do any of the oxides react with a base?
6. **Interpretation:** Make lists of the metal oxides that did react with the acid, those that reacted with the base, and those that reacted with both.
7. Make a conclusion.
8. **Discussion:** If a compound reacts with an acid, what kind of material must it be? Acid or base. Therefore, what kind of material are metal oxides?
9. What is different about aluminium oxide?

Activity 7 Word Equations

Aim Use the following information about the reactions of acids to complete the word equations.

Acid relatives

- Hydrochloric acid forms **chloride** compounds.
- Sulfuric acid forms **sulfate** compounds.
- Nitric acid forms **nitrate** compounds.
- Acetic acid forms **acetate** compounds.

The reaction can be written as:

Metal oxide + acid $\longrightarrow$ metal compound + water

Complete the following word equations:

1. Copper oxide + sulfuric acid $\longrightarrow$
2. Lead oxide + nitric acid $\longrightarrow$
3. Zinc oxide + hydrochloric acid $\longrightarrow$
4. Aluminium oxide + hydrochloric acid $\longrightarrow$

Metal Hydroxides

Metal hydroxides are formed when metals react with water.

Metal + water $\longrightarrow$ metal hydroxide + hydrogen

Sodium + water $\longrightarrow$ sodium hydroxide + hydrogen

$2Na + 2H_2O \longrightarrow 2NaOH + H_2$

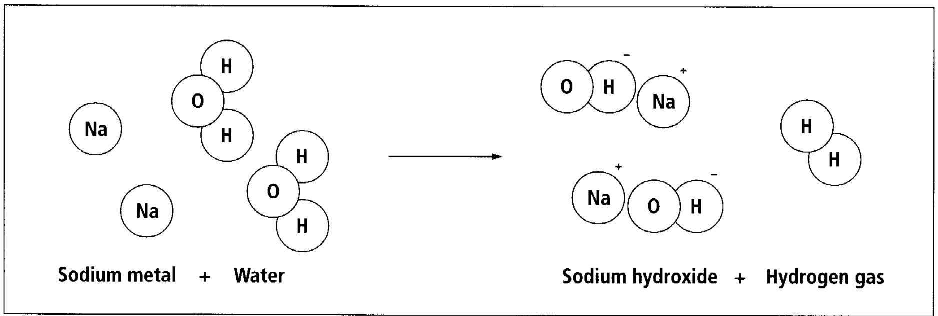


Diagram 3.7
Sodium and water reaction.

Activity 8

Materials needed:

Sodium metal or calcium metal;

Large container of water with a cover.

Metal Hydroxide

Aim To make a metal hydroxide.

1. Observe the warning maintained in Activity 5, number 1.
2. Your teacher may demonstrate the reaction of a metal with water. Record your observations of the reaction.
3. Write a word equation for the reaction.

Activity 9

Material needed:

Hydroxide samples, solutions or gels: e.g. Sodium hydroxide, calcium hydroxide (limewater), magnesium hydroxide, ammonium hydroxide;

Dilute hydrochloric acid;

Litmus paper or universal indicator paper;

Test tubes.

Metal Hydroxides With Acids And Bases

Aim To investigate if metal hydroxides react as acids or bases.

1. Test solutions of hydroxides with litmus paper or universal indicator solution to find out if they are acids or bases.
2. Place a small amount of hydroxide sample or gel in 1 cm of acid in a test tube. Shake gently and watch to see if it dissolves. This would show that the hydroxide is reacting with the acid.
3. Place a small amount of hydroxide sample or gel in 1 cm of sodium hydroxide solution. Shake gently and watch to see if it dissolves. This would show that the hydroxide is reacting with the sodium hydroxide.
4. **Interpretation:** Make lists of the metal hydroxides that reacted with the acid, those that reacted with the base, and those that reacted with both.
5. Make a conclusion.
6. **Discussion:** Are metal hydroxides acids or bases? Use information from your investigation to explain your answer.
7. The reaction between the hydroxide and acid can be written as:

   Metal hydroxide + acid $\longrightarrow$ Metal compound + water

   Complete the following word equations:

   a. Copper hydroxide + sulfuric acid $\longrightarrow$

   b. Sodium hydroxide + nitric acid $\longrightarrow$

   c. Lead hydroxide + acetic acid $\longrightarrow$

   d. Calcium hydroxide + hydrochloric acid $\longrightarrow$

Metal Carbonates

Marble, limestone rock and coral are made up of a material called calcium carbonate. The mineral calcite is also a form of calcium carbonate. Limestone rocks are often dissolved away to form natural caves and caverns.

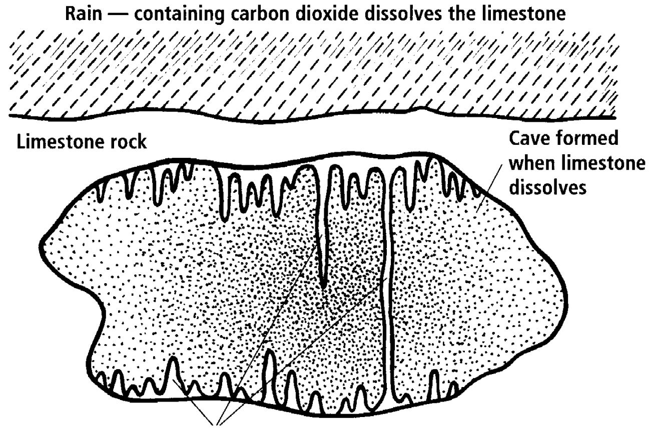


Diagram 3.8
Limestone cave.

Activity 10

Materials needed:

Range of metal carbonates: e.g. Calcium carbonate (egg shells, coral, shells), copper carbonate, sodium carbonate (washing soda), sodium hydrogen carbonate (baking soda);

Range of acids: e.g. Hydrochloric acid, sulfuric acid, nitric acid, acetic acid (vinegar).

Carbonate Acid Reactions

Aim To investigate the reaction between different carbonates and different acids.

1. Plan and carry out an investigation to find out about the reaction between carbonates and acids. Which gas will be given off in the reaction: oxygen, carbon dioxide or hydrogen? How will you test the gas to identify which gas it is? What equipment will you need.
2. Write up the results, discussion and conclusion of your investigation.
3. This is a pattern-seeking investigation. Explain how this is different from a fair-test investigation.
4. Write a general equation for the reaction between carbonates and acids.
5. Write a word equation for the reaction between a specific carbonate and a specific acid.
6. Complete the following word equations:
   a. Lead carbonate + nitric acid $\longrightarrow$
   b. Calcium carbonate + acetic acid $\longrightarrow$
   c. Zinc carbonate + sulfuric acid $\longrightarrow$
7. Describe how you could test a rock to see if it contained the mineral calcite.

Activity 11

Baking Soda

1. Write word equations for the two reactions described in the information below about baking soda.
2. Explain how baking soda works in baking.
3. Why is baking soda only used in some recipes?

Baking soda
Baking soda is sodium bicarbonate (or sodium hydrogen carbonate). It is sometimes used in baking instead of baking powder. When baking soda is heated it decomposes into sodium carbonate, carbon dioxide and water. The carbon dioxide makes the baking rise. The sodium carbonate that forms doesn't break down anymore in the heat. Sodium carbonate doesn't taste very nice so is only used in recipes that also have an acid such as vinegar or fruit. The acid reacts with the sodium carbonate to give a metal compound, carbon dioxide and water.

Activity 12

Materials needed:
Test tubes;
Burner;
Sample of carbonate: e.g. Copper carbonate, zinc carbonate, calcium carbonate (crushed egg shells, coral, shells), sodium carbonate;
Limewater.

Heating A Carbonate Compound

Aim To find out what is formed when a carbonate compound is heated.

1. Set up the equipment as shown in the diagram below.

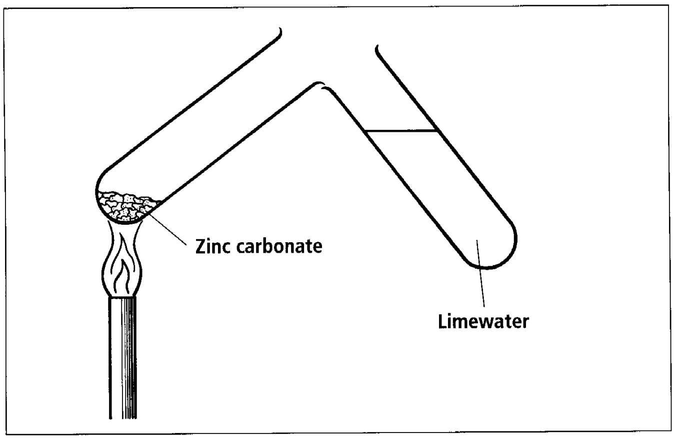


Diagram 3.9
Heating a carbonate.

2. Heat the carbonate. Look for evidence of changes in the carbonate and changes in the limewater.
3. Results: Describe what you saw happening. What gas was given off?
4. Repeat the reaction with another carbonate.

This type of reaction is called a **decomposition** reaction. During a decomposition reaction a larger compound is broken down into smaller compounds. No other chemical, for example oxygen from the air, takes part in the reaction. In this case the metal carbonate decomposes to give a metal oxide. Sodium and potassium carbonates are very stable and do not decompose when heated.

Heat is important in this reaction but it is not a chemical so the word equation has 'heat' written over the arrow like this:

$$\text{Metal carbonate} \xrightarrow{\text{Heat}} \text{Metal oxide} + \text{carbon dioxide}$$

5. **Conclusion:** Write a word equation for the decomposition of the carbonates you used in this activity.

$$\underline{\qquad\qquad}\ \text{carbonate} \xrightarrow{\text{Heat}} \underline{\qquad\qquad} + \underline{\qquad\qquad}$$

6. **Discussion:** What is a decomposition reaction? Explain what is happening to the carbonate in this reaction. Name two stable carbonates that do not decompose when heated.

Activity 13 Limestone Cycle

Aim To investigate the different types of lime.

1. Read the information below about the limestone cycle then copy and complete the diagram on the opposite page to show the *common* and **scientific** names of the different types of lime.

The limestone cycle

There are several substances which are sometimes called lime. Firstly, *limestone*, *marble* and *chalk* are all forms of the same chemical, **calcium carbonate**, $CaCO_3$. Sea shells and egg shells contain calcium carbonate. It is also called garden lime by gardeners who use it to reduce the acidity of the soil.

Then there is *quicklime*, **calcium oxide** CaO. This reacts violently with water to give *slakelime*, **calcium hydroxide**, $Ca(OH)_2$ and a lot of heat. It is not very soluble in water, but a little dissolves and the filtered solution is known as *limewater*. Limewater is used to test for carbon dioxide. When carbon dioxide is added to limewater they react to form a precipitate of **calcium carbonate**.

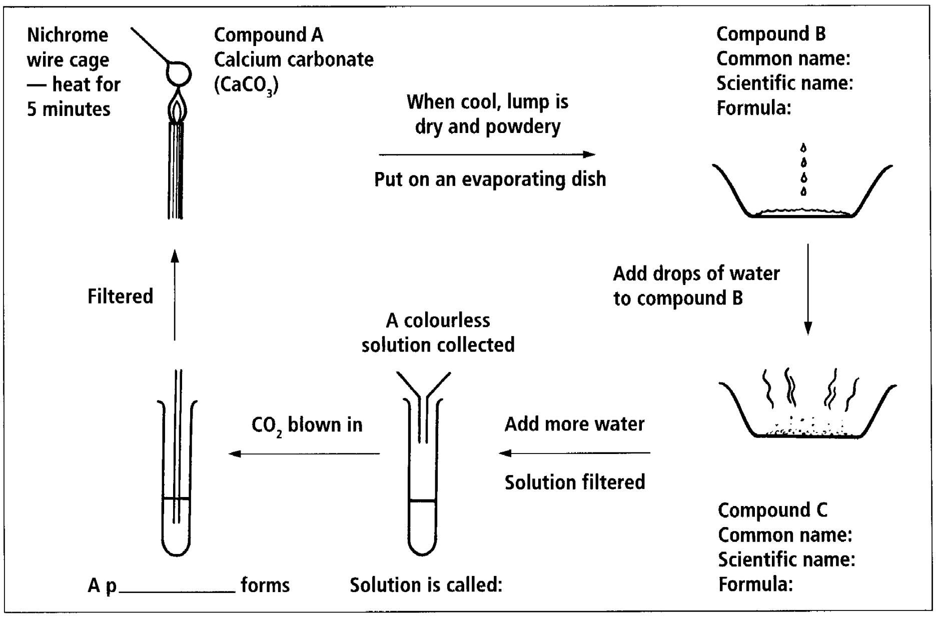


Diagram 3.10
The limestone cycle.

2. The diagram below shows another series of reactions that start from copper carbonate. Copy the diagram and complete the boxes to show the name and chemical formula of each compound.

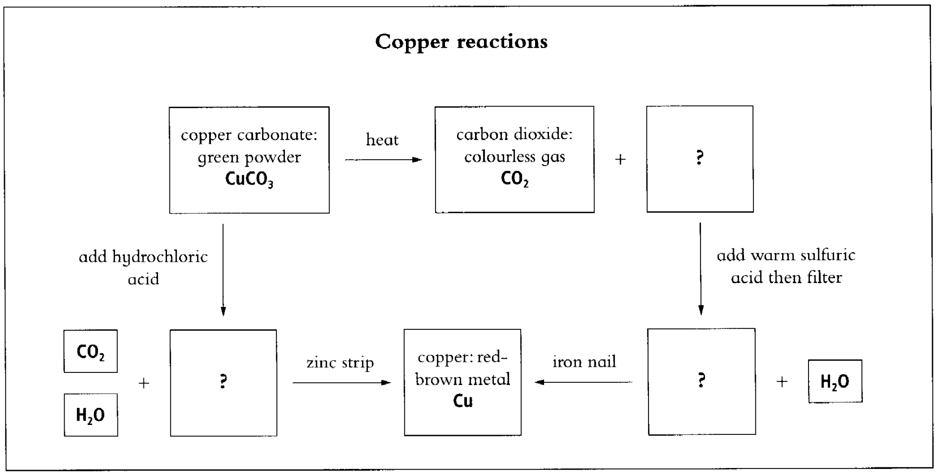


Diagram 3.11
Copper reactions.

Activity 14

Investigating Another Group Of Metal Compounds

Materials needed:

Range of metal compounds of one type: e.g. Chlorides, sulfates, nitrates;

Water;

Hydrochloric acid;

Sodium hydroxide;

Litmus or universal indicator.

Aim To investigate a group of metal compounds.

1. Plan and carry out an investigation into the properties of a group of metal compounds. Physical and chemical properties that could be investigated include: colour of compound, solubility in water, pH of solution, reaction with acids and bases, precipitate reactions, and how to test ions. What equipment will you need?
2. Write a report of your investigation that describes the physical and chemical properties of a group of metal compounds.
3. Research the uses of the materials in the group of metal compounds. For example, calcium sulfate is called plaster of Paris. It is used to make casts for broken bones and in plaster board used to line the walls of buildings. Sodium chloride (table salt) is used to flavour food.

Activity 15

Investigation Of A Metal And The Compounds Produced By That Metal

Materials needed:

Range of compounds of one type of metal: e.g. Sodium — sodium oxide, sodium hydroxide, sodium carbonate, sodium bicarbonate, sodium chloride, sodium sulfate, sodium nitrate.

Aim To investigate a metal and the compounds produced by that metal.

1. Plan and carry out an investigation into the properties of a metal and the compounds produced by that metal. Physical and chemical properties that could be investigated include: colour of compounds, solubility in water, reaction with acids and bases, precipitate reactions, how to test for the metal ion, comparison of the metal and the metal compounds.
2. Look at the table on the following page that summarises the reactions of different metals in order of how reactive the metal is. How reactive is the metal you are studying?
3. Write a report of your investigation that compares the physical and chemical properties of the compounds produced by a metal. Include information on the physical and chemical properties of the metal.

Metal	Reaction with air	Reaction with water	Reaction with acid
Sodium	Vigorous in cold air	Vigorous in cold water	Violent
Calcium			
Magnesium		Reacts in hot water	Vigorous in cold acid
Aluminium	Burns in air to form oxides	Reacts in steam	Vigorous in warm acid
Zinc			Vigorous in cold acid
Iron		Reacts slowly in steam	Slow in cold acid
Lead	Forms an oxide, but doesn't burn	Reacts very slowly in hot water	Slow with warm acid
Copper		Reaction not noticeable	No reaction

Activity 16 Study Notes

Aim To make study notes to use when revising this unit.

- Read through all the material you have covered in this unit.
- Read it again, this time highlighting the key science ideas.
- Rewrite the key science ideas into a different form so that you can use them as study notes. There are lots of different forms of study notes but they all have only the key words written down. Some people use diagrams.

Unit 4: CHEMICAL REACTIONS AND PROCESSES

Introduction

In this unit, you will investigate chemical reactions, the steps used in a chemical process to change one material into another, and the effects of materials on people and the environment.

Chemical Reactions

Chemical reactions is the name given to the chemical changes you learned about in Year 9. A chemical reaction occurs when the atoms in one, two or more chemicals join together in a different way. For example, when wood burns in a chemical reaction the carbon and hydrogen atoms in the wood join with oxygen atoms to form carbon (soot), carbon dioxide and water. The other atoms in the wood (*e.g. Sulfur*) form a powdery ash. Heat and light is given out during this reaction.

Wood + Oxygen ⟶ Carbon + Carbon dioxide + Water + Ash

Reactants **Products**

A chemical reaction always involves the breaking of chemical bonds between the atoms in the **reactants** and the forming of new bonds with different atoms to form the **products**. Reaction involves changes in the amount of energy in each of the materials involved in the reaction. In some reactions the products have less energy than the reactants. The energy is given out in the form of heat and light. Other reactions take in heat and the materials in the reaction feel cold. This means that the reactants have less energy than the products.

Activity 1 Chemical Reactions

Aim Revise information on chemical reactions.

1. What is a 'chemical reaction'?
2. List 10 examples of chemical reactions or chemical changes.

3. What is the meaning of the terms 'reactant' and 'product'?
4. Burning is a chemical reaction that people use when cooking food on an open fire.
   a. Describe the energy changes that occur during burning.
   b. Explain how these energy changes are used to cook food.
5. Energy changes are just one thing that shows a chemical reaction is taking place. Describe three other signs that show a chemical reaction is taking place.
6. Describe places where you see signs of chemical reactions in your everyday life.

The following types of chemical reactions are described in the Year 9 and Year 10 Science books and in units 2 and 3 in this book:

- Burning.
- Decomposition reactions.
- Precipitation.
- Rusting and corrosion.
- Neutralisation.

7. Write paragraphs to describe each of these types of reaction. Give examples.

Redox Reactions

The term 'redox' is the joining of the two words: *reduction* and *oxidation*. Reduction and oxidation are two processes that occur together in a chemical reaction. Redox reactions are very important in everyday life. The burning of fuel in a car engine, the rusting of iron, the production of electricity in a battery, the production of aluminium and many other elements and compounds are all redox reactions.

During redox reactions one material loses electrons and the other material gains electrons. The Lewis diagram below shows the loss and gain of electrons during the redox reaction: potassium burning in chlorine.

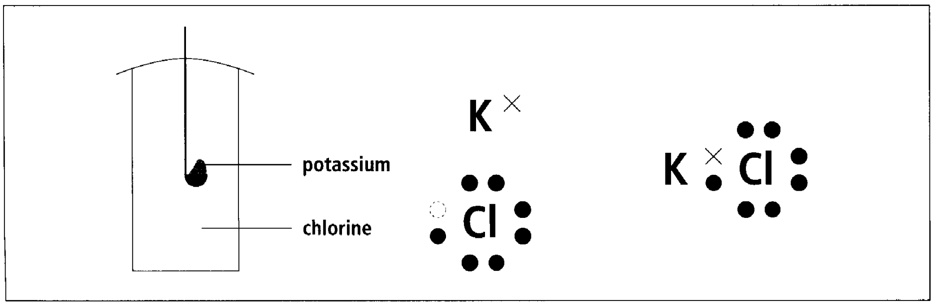


Diagram 4.1
A redox reaction.

Redox reactions also occur when a material reacts with oxygen. For example, when magnesium burns it loses electrons and joins with oxygen. When the magnesium reacts with the oxygen and loses electrons it is said to be **oxidised**. The oxygen gains electrons and is **reduced**. During rusting the iron is oxidised and the oxygen is reduced.

Electricity and carbon are used to make aluminium from aluminium oxide. In this redox reaction the aluminium ions gain electrons to become aluminium atoms and are reduced, and oxygen ions lose electrons and then react with carbon.

Aluminium oxide + carbon $\longrightarrow$ aluminium + carbon dioxide

$2Al_2O_3 + 3C \longrightarrow 4Al + 3CO_2$

Electrolysis

Early scientists discovered that an electric current could be used to split compounds into its elements. For example, water splits into the gases hydrogen and oxygen. This reaction is called **electrolysis**. Electrolysis of water is carried out in a special piece of glassware that has small electrodes that carry the electric current into the water.

The electrolysis reaction is the decomposition of water and it is a redox reaction. The oxidation reaction occurs at one electrode, and the reduction reaction at the other electrode.

The water is oxidised at one electrode through the reaction:

$2H_2O \longrightarrow O_2 + 4H^+ + 4e^-$

At the other electrode water is reduced through the reaction:

$4H_2O + 4e^- \longrightarrow 2H_2 + 4OH^-$

You can tell which electrode is which because in the decomposition reaction, the volume of H_2 produced is twice the volume of O_2. This means there is always twice as much gas on one side of the special glassware as there is on the other.

$2H_2O \longrightarrow 2H_2 + O_2$

In 1839 it was discovered that the reverse reaction could be carried out. Oxygen and hydrogen could be joined together to form water. The joining of hydrogen and oxygen to form water produced energy used to generate an electric current. This discovery lead to the development of a technology called the **fuel cell**. Although fuel cells were used to provide electrical power to the Apollo moon capsule and other spacecraft, they have not been used very widely. Much research has gone into production of fuel cells that can be used in cars.

Activity 2 Revising Redox Reactions

Aim To describe redox reactions.

1. List some redox reactions.
2. Carbon burns to give carbon dioxide.

   $C + O_2 \longrightarrow CO_2$

   a. Which element is oxidised?

   b. Which element is reduced?

3. When lead oxide is heated on a carbon block the following reaction occurs. Describe what happens in this reaction in terms of oxidation and reduction.

   Lead oxide + carbon $\longrightarrow$ lead + carbon monoxide

   $PbO + C \longrightarrow Pb + CO$

4. Sodium metal can be burned in chlorine gas to make sodium chloride. Describe this reaction in terms of oxidation and reduction.

   $Na + Cl \longrightarrow NaCl$

5. Describe what happens in the redox reaction called electrolysis.
6. Your teacher may demonstrate the electrolysis reaction. Record your observations.
7. If you can, visit the following website to see the special glassware that is used to carry out electrolysis:

   http://www.chem.uiuc.edu/clcwebsite/elec.html

8. What does a fuel cell do?
9. If you can, visit the following websites to find out more about fuel cells:

   http://www.vectorsite.net/ttfuelc2.html
   http://www.fuelcells.org/
   http://www.howstuffworks.com/fuel-cell.htm

Chemical Processes

A chemical process is a series of steps that are used to make a material. Many chemical processes have steps involving physical changes and steps involving chemical changes. For example, the production of Vailima beer and homebrew involves a series of steps that change some of the chemicals in plant material into a chemical called an alcohol. This chemical process uses micro-organisms to carry out chemical changes. Alcohols are a special group of chemicals that include methanol and ethanol. Only some alcohols can be used as a drink. Some alcohols are used to fuel car engines.

Methanol can be made from natural gas. The flow chart below shows the steps in the process used to make methanol.

Making Methanol

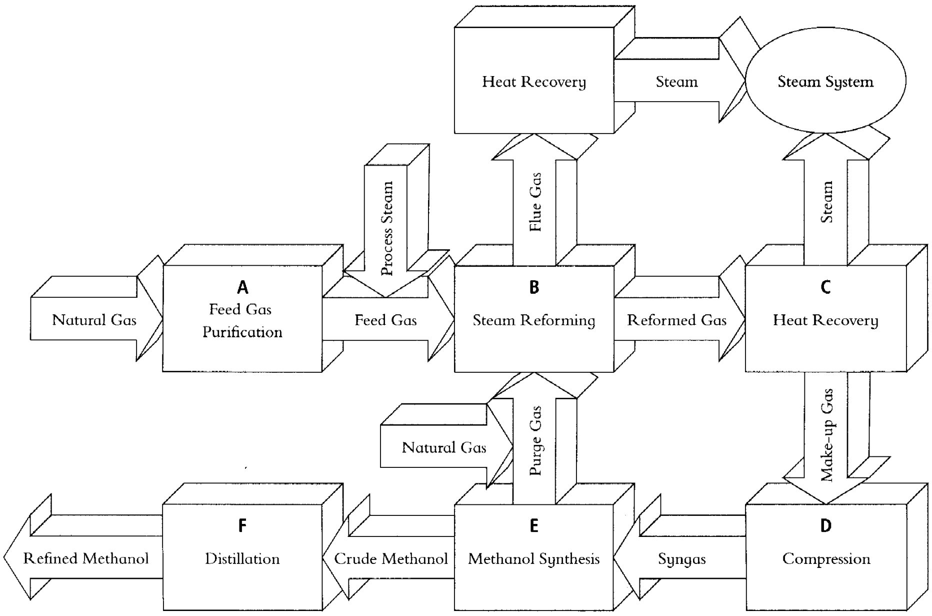


Diagram 4.2
Making methanol.

Step A (feed gas purification) involves physical and chemical changes that remove unwanted materials from the natural gas. The next steps involve chemical changes to the chemicals in the natural gas so that they will react in Step E to become methanol. Step F (distillation) is a physical change. Here the materials are separated by distillation so that pure (refined) methanol is produced. Year 9 Science, Book Two, unit 2, pages 21–32 discusses different types of physical and chemical changes.

The Crude Oil Refining Process

The World Petroleum Organisation describes an oil refinery as:

> An organised and co-ordinated arrangement of manufacturing processes designed to produce physical and chemical changes in crude oil to convert it into everyday products like petrol, diesel, lubricating oil, fuel oil and bitumen.

In an oil refinery petrol is produced in a chemical process that uses a technique called fractional distillation. Fractional distillation means that lots of different parts or fractions of a mixture can be separated out. The petrol making process begins with a raw material called crude oil. Crude oil is a mixture of carbon compounds with different numbers of carbon atoms. Fractional distillation uses the differences in boiling points of the different chemicals to separate them into groups.

Information about the different parts or fractions in crude oil

Fraction	Amount* (%)	Boiling point (°C)	Carbon atoms	Uses
LPG	5	Less than 40°	Less than C_6	Fuels
Petrol	35	40–180°	C_7–C_{10}	Petrol
Kerosene	10	160–250°	C_{10}–C_{16}	Jet fuel
Light gas oil	20	250–300°	C_{16}–C_{20}	Diesel
Heavy gas oil	2	300–350°	C_{20}–C_{25}	Fuel oils
Residues	28	More than 350°	C_{25}+	Heavy oils, asphalt/ bitumen on roads

* The amount of each part in crude oils is different. These percentages are included as an example only.

The following diagram shows the steps needed to take crude oil from the ground under the sea and refine it into the different fractions.

Step	Description of step	Physical or chemical change involved
1	Drilling – an oil rig on the ocean is used to drill down to the crude oil and pump it out of the ground.	None.
2–4	The oil is stored then pumped to where it is going to be refined and then stored again.	None.
5	The crude oil is heated until it becomes a gas.	Physical change from liquid to gas.

Diagram 4.3A
The oil refining process.

6	The crude oil gas rises up the fractionating tower. The temperature at the bottom of the tower is hotter than the top. As the crude oil goes up, it cools down. The parts of the crude oil having the highest boiling points become a liquid first. These are the materials with the largest molecules. For example, the black oil residue used to make bitumen has more than 35 carbon atoms in each molecule. It turns to a liquid at temperatures around 350°C. This happens at the bottom of the tower. The materials that have the fewest carbon atoms will rise to the top of the tower before they are separated out.	Physical change of separating materials in a mixture.
7	The chemical used depends on the products that are required at the time. Some of the materials with larger numbers of carbon atoms in their molecules are not needed as much so they are often 'cracked'. Cracking breaks the larger molecules into the smaller molecules such as petrol which people use lots of.	Cracking is a chemical change. The larger molecules are cracked into smaller molecules.
8	The blending and finishing also depends upon the type of product wanted by people. In the past, lead was added to petrol to help the engine run better.	Mixing lead into petrol is a physical change.

Diagram 4.3B
The oil re'uning process.

Activity 3 Oil Refining Process

Aim To process information relating to oil refining.

1. Describe an oil refinery in your own words.
2. Explain the difference between physical changes and chemical changes.
3. Describe the properties and uses of kerosene.
4. What is the relationship between boiling point and the number of carbon atoms in the molecule?
5. Re-draw Diagram 4.3A and B into a flow chart.
6. What is the raw material used to make diesel?
7. Explain why crude oil is heated until it is a liquid.
8. What happens during fractional distillation?
9. Cracking breaks large molecules into smaller ones. Why does the cracking process take place?
10. Explain why the adding of lead to petrol is a physical change and not a chemical change.

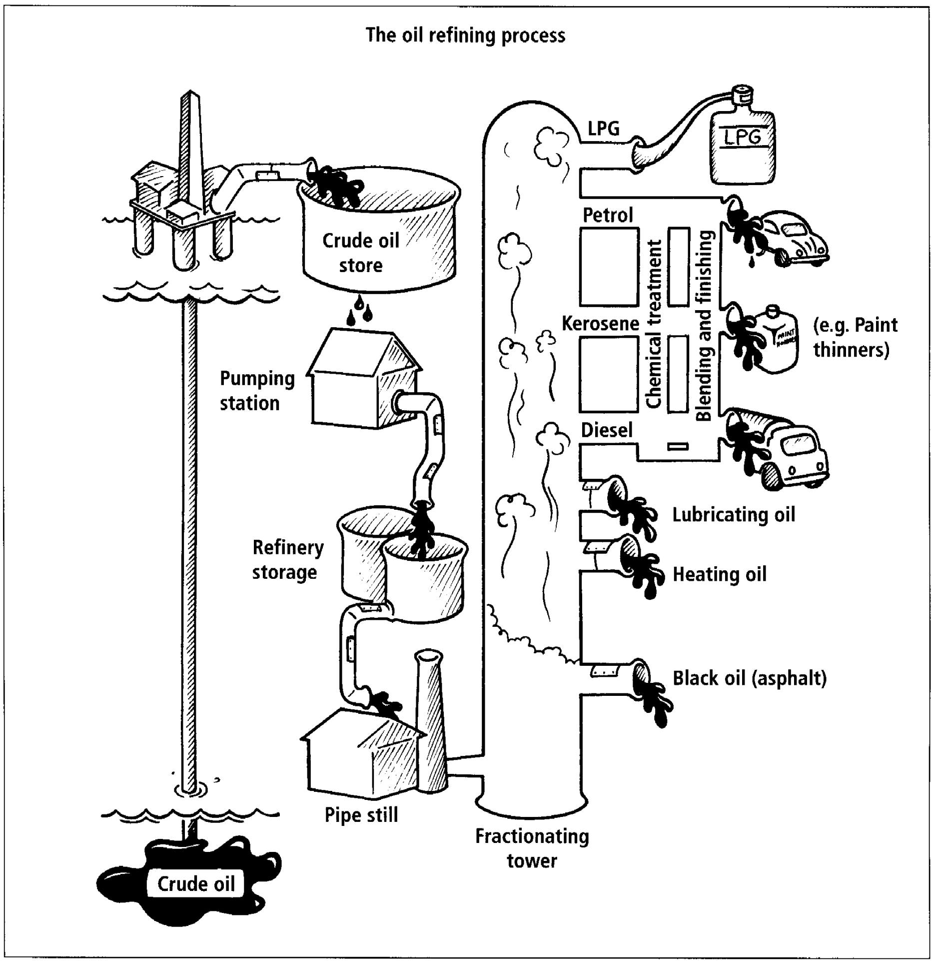


Diagram 4.4
The oil refining process.

11. Compare your flow chart of the oil refining process with the diagram above.
12. Explain why LPG (Liquid Petrolium Gas) is shown coming out of the fractioning tower at the top.
13. Find out the names of the carbon compounds in LPG.

Activity 4 Researching A Chemical Process

Aim To carry out research to identify the steps in a chemical process.

1. Select one of the topics listed below.
2. Carry out research using primary sources (*e.g. Interviews with people, 'ueld trips, your own observations*) and secondary sources (written material: *e.g. Books, posters, web sites*).
3. Produce a flow chart showing the key steps in the process.
4. Describe what happens in each key step.
5. Identify which steps involve chemical changes and which involve physical changes. Some steps may involve both.

Topics

- Paint production.
- Fertiliser or compost production.
- Carbide production.
- Aluminium or iron production.
- Making glass.
- Vailima beer production.
- Making homebrew from rice, breadfruit or potatoes.

Effects Of Materials On People And The Environment

People use a wide range of natural and manufactured materials in their everyday life. These materials can have positive and negative effects on people and the environment.

Activity 5 Survey Of Public Opinion

Aim To find out what people think about the effect of substances on people and environment.

1. Do the chemicals from car engines affect people and the environment? Read the following information:

> Chemicals released from car and bus engines are a source of air pollution in cities. Long-term exposure to high air pollution from traffic, industry and power plants can lead to increased risk of cancer and cardiovascular diseases in humans. Short-term exposure may lead to increased problems with bronchitis, asthma and other respiratory tract diseases.

2. Work in groups to write a questionnaire that can be used to survey people to find out their opinion on the increased use of motor vehicles in Samoa and the effects that petrol and exhaust fumes have on people and the environment. For example, one of your questions could ask people if they are aware of the effects of petrol and exhaust fumes on people and the environment. Another could ask about effects that they, or other people they know, have experienced.
3. Carry out your survey. Make sure your group asks as many people as possible to complete your questionnaire.
4. Write up the results of your survey.
5. Share the results of your survey with the rest of the class.
6. What do you think people should do to reduce the risk of illness from the effects of petrol and exhaust fumes?

Activity 6 The Positive Side

Aim To focus on the positive effects of a material on people or the environment.

1. Not all materials have a negative effect on people and the environment. Carry out a class brainstorm where every group suggests examples of materials that have positive effects on people or the environment.
2. Select one of the ideas and produce a group poster about the positive effects of the material on people or the environment. For example, your topic could be the making and use of organic fertilisers made from vegetable and other plant waste.

Activity 7 Waste Management

Aim To investigate an example of waste management.

1. Find out information about waste management in the local area by visiting sites, listening to a guest speaker, researching or surveying local people. You could investigate a waste management issue that occurs around your school.
2. The information you find might answer the following questions:
   - What materials are becoming wastes?
   - Where are these waste materials coming from?
   - Why are they wastes?
   - What effect does the waste have on people and the environment?
   - What system of waste management is in place to deal with the waste?

- Is the waste management effective or are the waste materials still causing problems?
- Are there any long-term problems with the method of waste management? What are they? How are they being overcome?

3. Make a poster or pamphlet explaining how to use a local waste management system or, why you should use a local waste management system.

Activity 8 Research

- Carry out an investigation into the positive and negative effects of a group of substances on people and the environment: *e.g. Fertilisers, CFC's, fuels, household cleaners, plastics, detergents.*
- Make a poster to promote the proper use of one of the above substances or a group of substances.
- Explain how to minimise the negative effects the substances represented on your poster have on people and the environment.

Activity 9 Study Notes

Aim To make study notes to use when revising this unit.

- Read through all the material you have covered in this unit.
- Read it again, this time highlighting the key science ideas.
- Rewrite the key science ideas into a different form so that you can use them as study notes.

Unit 5: LIGHT AND ELECTROMAGNETIC RADIATION

Introduction
In this unit, you will investigate the properties of light and the effect of other types of electromagnetic radiation.

Light

Light is very important to people. It enables us to see all the things around us. When we 'see' an object, light from a light source goes from the object into our eyes. Our eyes change the light into nerve impulses. The nerve impulses go to the brain where they are interpreted to give the shape, colour and position of the object.

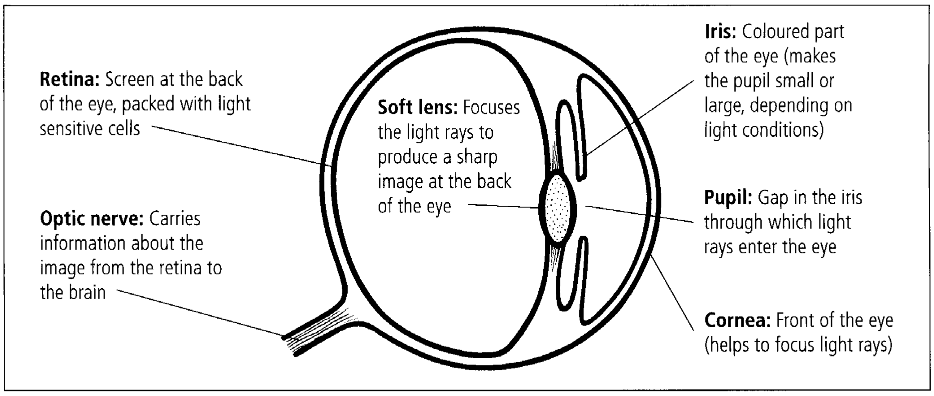


Diagram 5.1
Parts of an eye.

Light enters our eyes through a gap in the coloured iris of the eye. The gap is called the pupil. The pupil can get larger and smaller to control the amount of light going into the eye. In bright light the pupil gets smaller so that only a small amount of light goes into our eye. This stops the eye from being damaged by too much light.

The light goes through the lens where it is focused and then the image of the object lands on the light sensitive rod and cone cells on the retina of the eye. There is a diagram of rod and cone cells in the textbook Science Year 11, Book One, page 48. The rod and cone cells have light sensitive organelles that receive the light and cause nerve impulses to travel down the optic nerve to the brain. The image of the object on the eye is always upside down but the brain interprets it so that we see the object the correct way up.

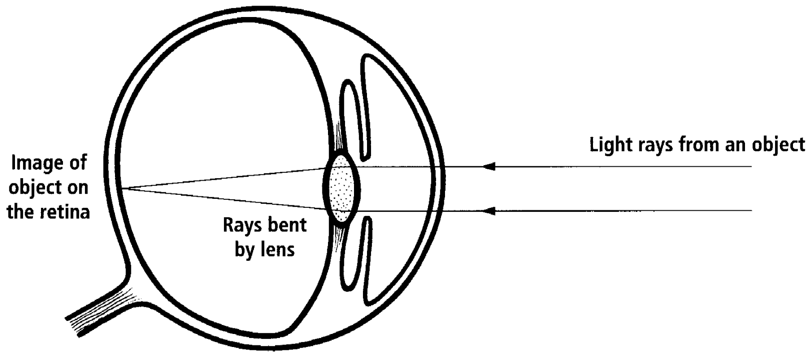


Diagram 5.2
Seeing an object.

Activity 1 The Eyes

Aim To record information about eyes.

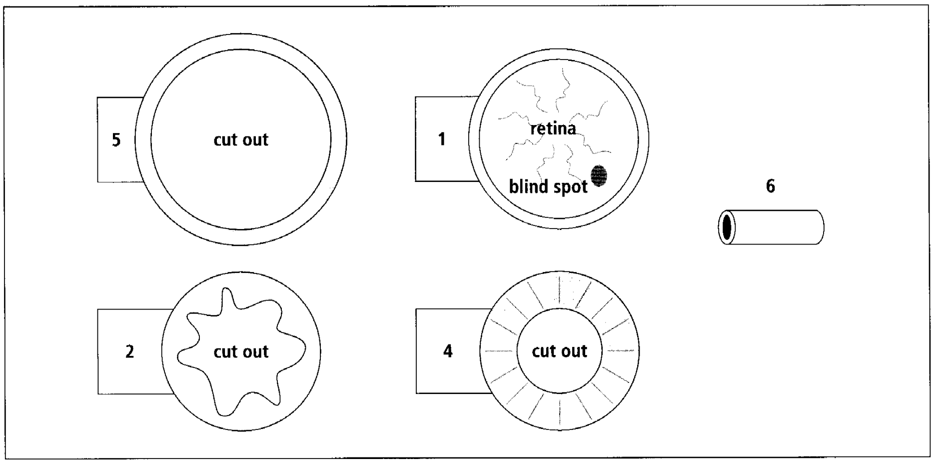
1. Match each part of the eye with the correct information about the structure and function of that part of the eye.

Part of the eye	Structure of the part	Function of the part
Cornea	Coloured part of the eye	Carries information from the cells in the retina to the brain
Iris	Made up of lots of nerve cells	Lets light into the eye and helps to focus the light
Pupil	Has light sensitive rod and cone cells	Bends the light so that it forms a sharp image on the retina
Lens	Clear covering over the front of the eye	Gets bigger or smaller to control the amount of light going into the eye
Retina	Clear solid oval shape	Makes the pupil large or small to let the correct amount of light into the eye
Optic nerve	Gap in the iris	Senses the light that has come into the eye and sends a nerve impulse to the brain

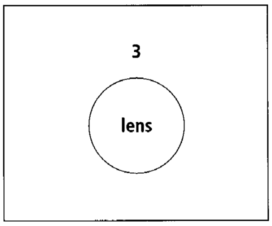
2. Describe the pathway light takes when it goes from an object into the back of your eye.
3. Make up one of the following model eyes.

Model 1

1. Draw the parts (1, 2, 4, 5 and 6) on paper. Draw them the same size as the diagrams.
2. Colour the part in as appropriate and cut them out.



3. Cut a piece of clear plastic the same size and shape as the lens diagram, part three (below).

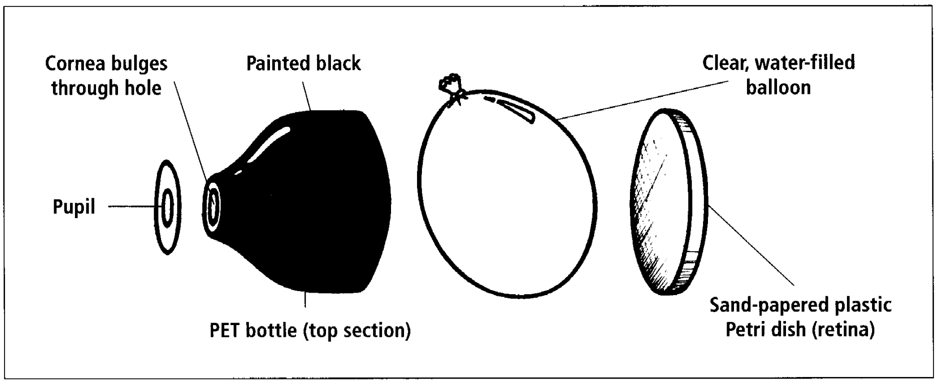


4. Cut a piece of clear plastic to fit over the hole in part five. This will be part seven, the cornea.
5. Stick the flap on part one, the retina, into your exercise book. Only the flap should be stuck down.
6. Stick the flap on part two, the muscles, on top of the flap for part one.
7. Stick part three, the lens, onto the centre of part two.

8. Stick the flap on part four, the iris and pupil, on top of the flap for part two.
9. Stick the flap of part five, the edge of the cornea, on top of the flap for part four.
10. Stick part seven, the cornea, over the hole in part five.
11. Stick part six, the optic nerve, on to the back of part one, the retina. Stick the end of part six to the back of the blind spot.

Model 2

1. Fill a clear plastic balloon with water and tie the top tightly.



2. Cut the screw top off a plastic bottle. Cut about 10 cm of the top off the bottle. Paint the top of the bottle black or cover it with black paper.
3. Rub the surface of a plastic Petri dish with fine sandpaper.
4. Put the parts of the model together as shown below.

5. Focus an image of an object on the 'retina' by pushing on the Petri dish to make the balloon bulge out the front to form a 'cornea'.
6. Describe the image you can see on the Petri dish retina.
7. Describe any changes in the image when a small 'pupil' is added in front of the 'cornea'.
8. Tape the Petri dish in place so that far away objects are focused on the Petri dish 'retina'. Focus near objects by adding reading glasses in front of the 'pupil'.

Light Sources

We are unable to see objects unless there is light. Light is a form of energy. Objects that change other forms of energy into light are called **light sources**. The Sun is our main light source. The nuclear reactions that take place inside the Sun and other stars change nuclear energy into light and heat energy. This energy travels through space to Earth.

Other light sources are fires and objects that turn electrical energy into light energy, for example, torches and light bulbs. Torches turn the chemical energy in a cell into electrical energy and then into light energy. Inside light bulbs the electrical energy travels through a thin wire filament. The resistance of the wire filament causes the electrical energy to turn into heat energy. This causes the filament to glow white hot and give out light. These bulbs are called incandescent light bulbs. Incandescent light bulbs waste a lot of energy.

Fluorescent tubes are more energy efficient sources of light. Fluorescent tubes are made of glass and have an electrode at each end. The inside of the glass is coated with a material called phosphor. The tubes are filled with argon gas and mercury vapour. When electricity reaches the fluorescent tube it causes electrons to flow through the gas from one electrode to the other. This causes the mercury atoms to give off ultraviolet light. When the ultraviolet light hits the phosphor it makes the phosphor give off light.

The objects we see are either light sources or reflectors of light. Light sources give out light but reflectors of light bounce light from a light source into our eyes.

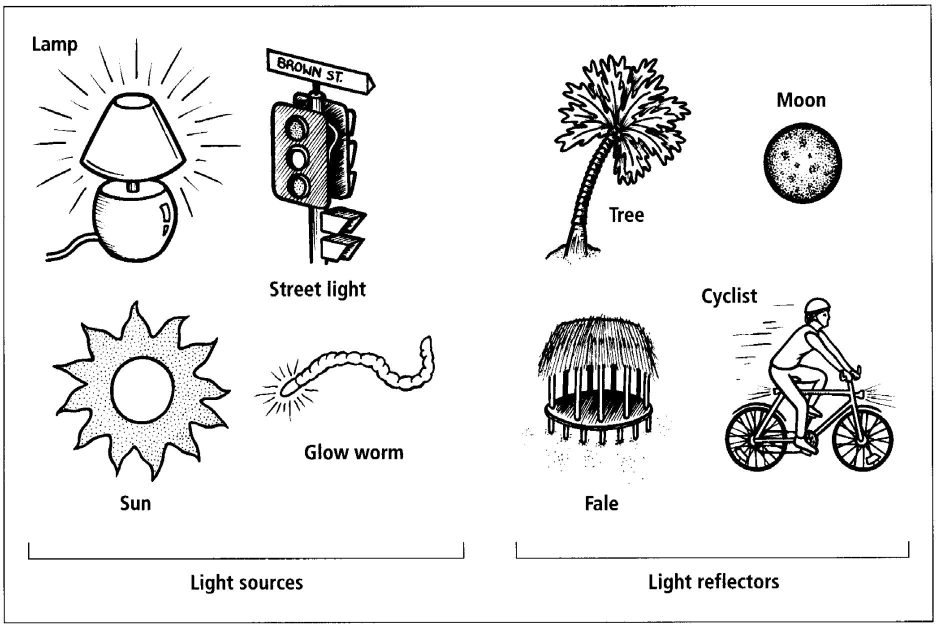


Diagram 5.3
Light sources and reflectors of light.

Some objects are good reflectors of light and others are poor reflectors of light. Mirrors are very good reflectors of light. So is the surface of a still pond but water is a poor reflector if the surface of the water is moving. Light coloured clothing is a better reflector of light than dark coloured clothing. People have developed special materials that reflect light well. These materials are used on clothing and vehicles so that they are easier to see.

Activity 2 Light Sources And Reflectors

Aim To record information about light sources and reflectors.

1. List as many different sources of light as you can. Beside each source write down the name of the form of energy it uses to make light energy.
2. The moon is not a light source because it does not make its own light. Where does moonlight come from?
3. Complete the following *True/False, Make it Right* activity by copying each true statement and rewriting incorrect statements.
   a. We can only see objects when light energy is present.
   b. Light sources change a form of energy into light energy.
   c. The Sun and other stars are reflectors not light sources.
   d. The planets, such as Mars and Venus, are light sources.
   e. Inside stars, nuclear energy is changed into heat and light energy.
   f. Light energy can travel through space.
   g. Torches turn electrical energy into light energy.
   h. Incandescent bulbs are more efficient than fluorescent tubes.
   i. The filament in a light bulb turns white hot and gives out light.
   j. We see light-reflecting objects when they bounce light to our eyes.
4. Write the name of each object in Diagram 5.5 (on the next page) into your exercise book. Say if the object is a light source or light reflector.
5. Explain why people should wear light coloured clothing when walking on the road at night.
6. Explain why car headlights have a shiny surface behind the bulb.

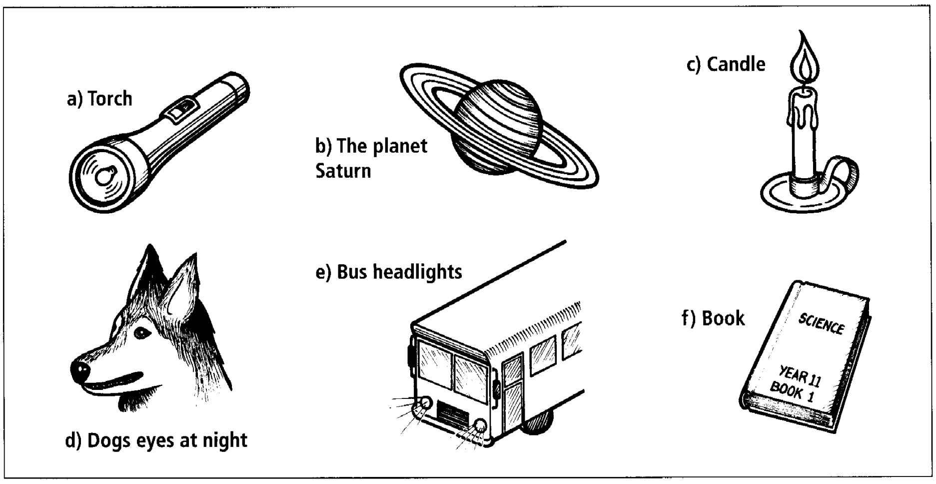


Diagram 5.4
Which are reflectors and which are light sources?

Properties Of Light — Straight Lines

Light travels in straight lines at the very fast speed of 300 000 km/second. It spreads out in all directions from the source. Objects like torches have reflectors behind the bulb. They reflect light so that all the light given off by the bulb will form a beam of light out the front of the torch. The beam of light from the torch spreads out as it moves away from the torch. This makes the beam get dimmer and dimmer the further it travels.

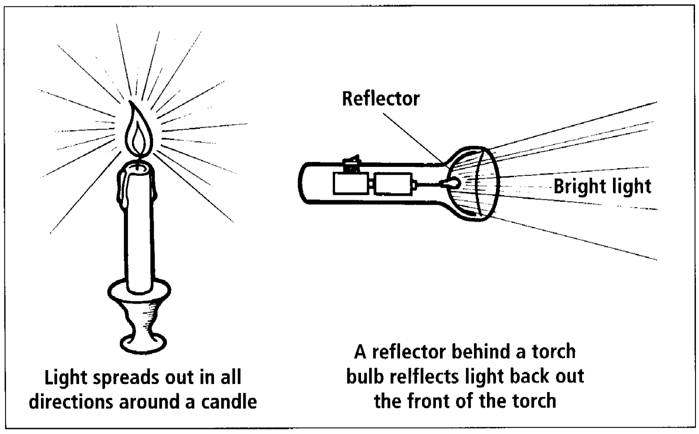


Diagram 5.5
Candle and torch light.

If you look at a candle through a cardboard tube the light from the candle travels in straight lines through the tube to your eye. If you raise, lower or bend the tube you can no longer see the candle because the straight rays of light will not go into and through the tube.

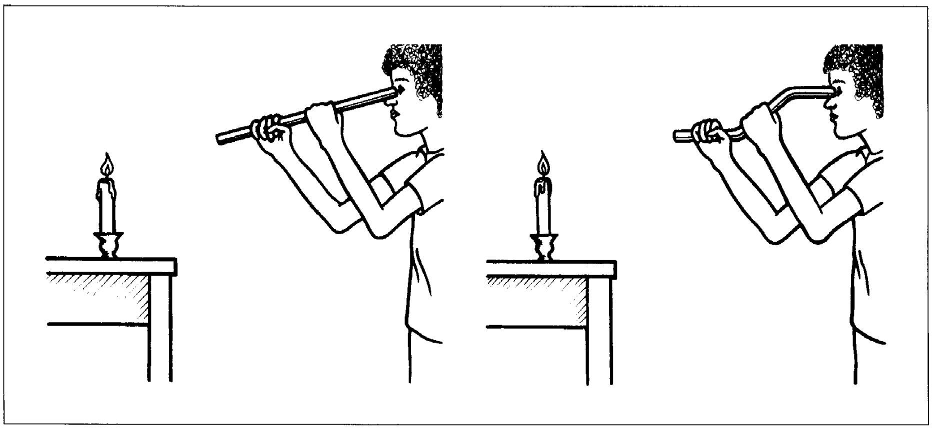


Diagram 5.6
Looking at a candle through a tube.

Shadows form because light travels in straight lines. A shadow is an area beside an object receiving less light. The object is blocking the light from the light source and stopping it from travelling straight to the area of shadow. The light travels past the sides of the object and cannot bend around behind it.

- Light travels large distances very quickly. How far will it travel in 10 seconds?

  speed = 300 000 km/s   time = 10 seconds

  $$\text{speed} = \frac{\text{distance}}{\text{time}}$$

  d = speed × time

  d = 300 000 × 10

  d = 3 000 000 km

- How long will it take light to travel 7 500 000 km?

speed = 300 000 km/s   distance = 7 500 000 km

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$\text{time} = \frac{\text{distance}}{\text{speed}}$$

$$t = \frac{7\,500\,000}{300\,000}$$

t = 25 seconds

Activity 3

Materials needed:
Torch or light bulb with tin foil behind the bulb and a short cardboard tube out the front;
Chalk dust.

Light Travels In Straight Lines

Aim To investigate light travelling in straight lines.

Task 1

1. Turn on a torch in a darkened room. Sprinkle chalk dust into the beam.
2. Use drawings or words to describe the shape of the beam.
3. Measure the width and length of the beam.
4. Investigate ways to make a beam go further. Record your observations and measurements.

Materials needed:
Torch;
Pencil;
Paper for a screen.

Task 2

1. Set up the equipment as shown below.

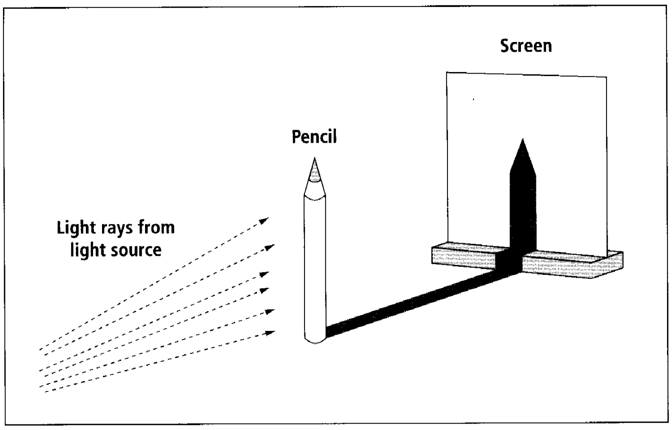


Diagram 5.7
Shadow set up.

2. Draw up a table to measure the distances between the torch and the pencil and the pencil and the screen. Also record the height of the shadow.
3. Write a statement about how the height of the shadow changes as the distance between the torch and the pencil changes.

Task 3

1. Draw a diagram to explain why we can't see around corners (because light travels in straight lines).
2. Shadows are also caused because light travels in straight lines. Draw a diagram of a light source, an object and its shadow. Rule straight light rays on the diagram to explain how the shadow forms.
3. When sports games, such as Rugby Super 12 games, are played under lights at night the players have more than one shadow but the shadows are not as dark as one shadow would be. Explain why.

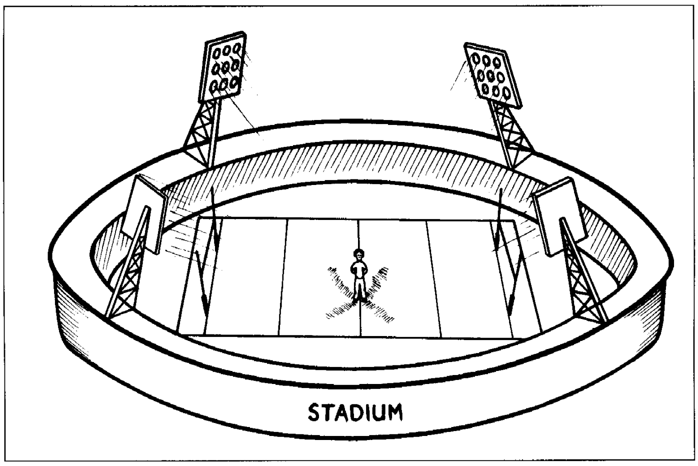


Diagram 5.8
Shadows at a rugby game.

Task 4
Complete each of the following calculations.

1. How far will light travel in 20 seconds?
2. How far will light travel in 60 seconds?
3. How far will light travel in 1 hour (3600 seconds)?
4. How long will it take light to travel 30 000 000 km?
5. How long will it take light to travel 600 000 km?
6. How long will it take light to travel 1 500 000 km?

Activity 4

Pin Hole Camera

Materials needed:

Two cardboard tubes that fit into each other;

Tissue paper;

Black card or aluminium foil.

Aim To make a pin hole camera and use it to investigate images.

1. Make a pin hole camera similar to the one in the diagram below.

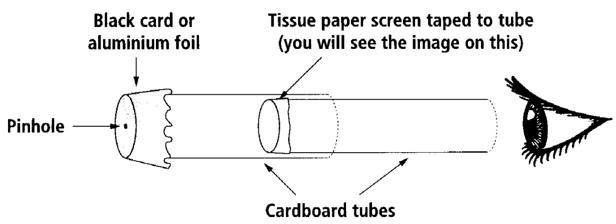


Diagram 5.9
Pinhole camera.

2. Point the camera at a bright object. Look down the camera with one eye. Close the other eye. Allow your eye time to adjust to the dim light. Look at the faint image that appears on the tissue paper screen.
3. Describe the image. Is it coloured? Large or small? Up the right way or upside down? Sharp or blurred? Bright or dim?
4. Draw a large diagram of your pinhole camera. Explain how the camera works by drawing two or three rays of light coming into the camera and forming an image. Use a ruler to draw thin single rays. Put arrowheads on the rays to show which direction they are travelling.
5. Copy and complete the following results table.

Camera set up	What the image looks like
Screen close to the pinhole	
Screen far away from the pinhole	
Two pinholes 1 cm apart	
A large pinhole 4–5 mm wide	

6. Look at a bright object. Slide the tubes of the camera in so that the screen is close to the pinhole. Observe the image and record what the image looks like. Is it coloured? Large or small? Up the right way or upside down? Sharp or blurred? Bright or dim?
7. Set the screen far way from the pinhole and then look at a bright object. Record what the image looks like.
8. Change the black card or aluminum foil on the front of the camera to one with two pinholes. Record what the image looks like.
9. Change the black card or aluminum foil on the front of the camera to one with one large pinhole. Record what the image looks like.
10. Copy and complete the following ray diagram to explain why the image through a smaller pinhole is sharper but dimmer than the image made through a larger pinhole.

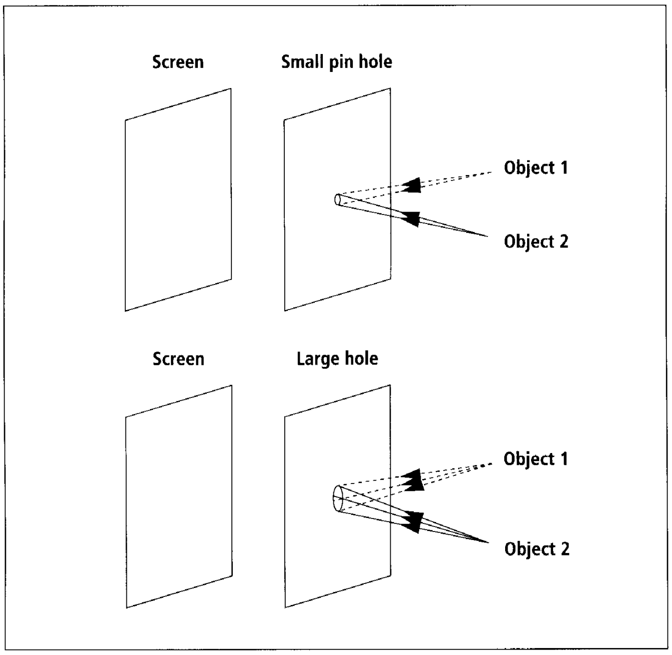


Diagram 5.10
Pinhole image.

Reflection Of Light

When light hits an object it could bounce back, be all or partly absorbed by the object, or go through the object. For example, light will bounce off the shiny surface of a pot but will go through a piece of glass. When light bounces back off an object it is said to have **reflected** off the surface. Light is reflected off shiny surfaces. A glass mirror has a thin layer of shiny silver on the back of the glass. Light is reflected off the silver surface.

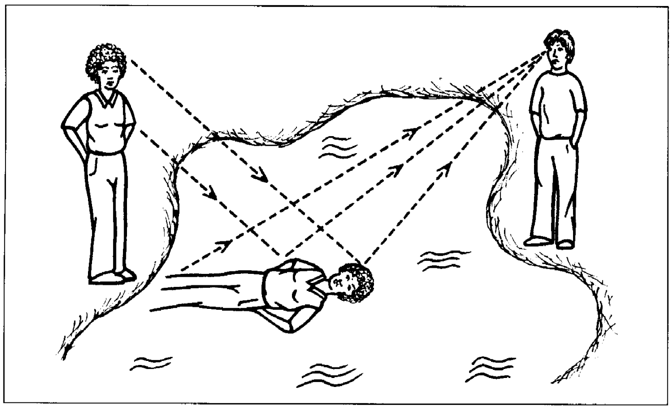


Diagram 5.11
Reflection on a pond.

Reflection of light from a smooth, shiny surface follows a particular rule. Complete the following activity to work out the rule.

Activity 5

Materials needed:
Plane (flat mirror);
Blue tac, sellotape or mirror stand to stand the mirror up on a page;
Single slit for the front of the ray box. It allows a single fine beam of light out;
Ray box and power pack or torch, cardboard and comb set up as shown.

Reflection Rule

Aim To work out the rule that describes how a ray of light will be reflected off a smooth, shiny surface.

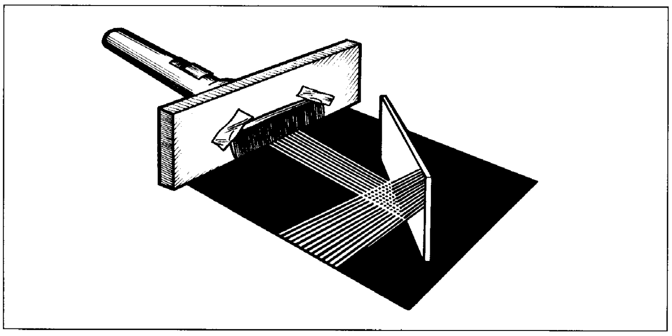


Diagram 5.12
Alternative set up will show multiple rays at the same time.

1. Stand the mirror up on a page of white paper.
2. Set up the ray box so that it shines a single ray of light onto the mirror. Move the ray box until you can see a single ray of light hitting the mirror and being reflected back again.
3. Rule a line on the page where the mirror is sitting.

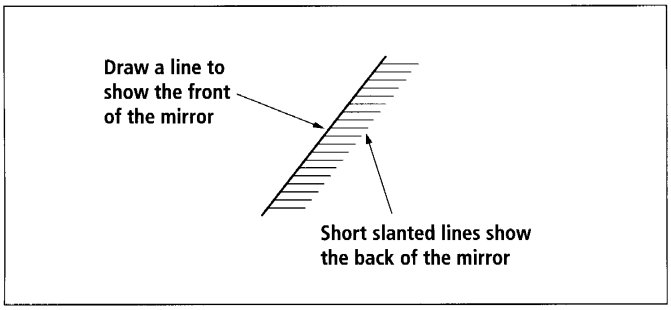


Diagram 5.13
Mirror line.

4. Mark the position of the incoming ray and the reflected ray by marking two dots on the page for each ray.

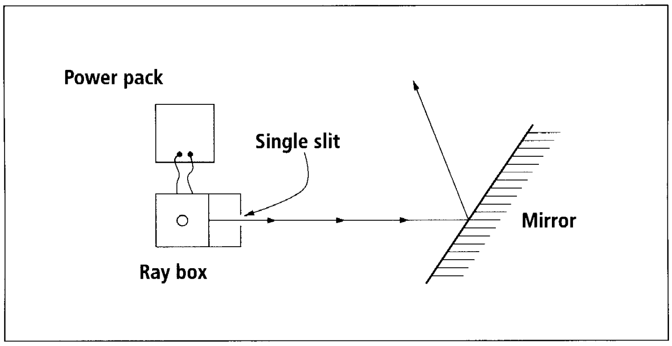


Diagram 5.14
Making rays.

5. Remove the ray box and mirror then rule a line through each set of dots to show the position of the two rays. Label the incoming ray and reflected ray. Put arrowheads on each ray to show the direction it is travelling.
6. Measure the angle between the mirror and the incoming ray. Measure the angle between the mirror and the reflected ray.

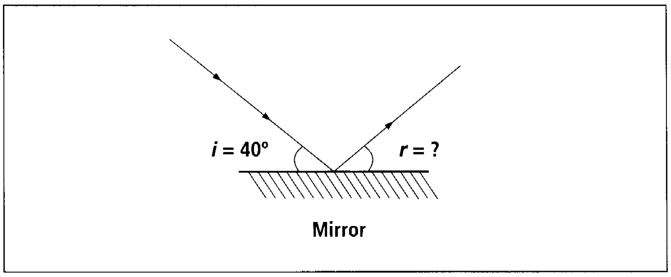


Diagram 5.15
Measuring angles.

7. Results. Record your results in a table. Make space on the table for four or five more measurements of the angle (i) between the incoming ray and the mirror and (r) between the reflected ray and mirror.
8. Test the following incoming rays and others of your own choice.

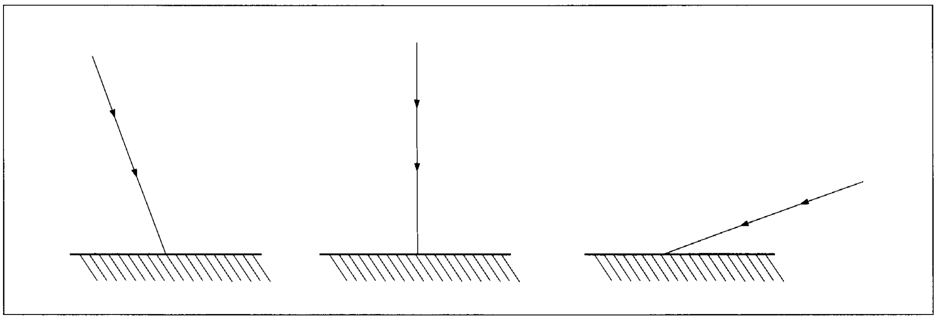


Diagram 5.16
More rays to test.

9. Conclusion. Write a conclusion that gives the rule for the size of angle i and angle r.

Images And Ray Diagrams

Mirrors are used for looking at reflections. We can use the equal angle rule you worked out in the last activity to find out about images formed in the mirror. In science, when working with light we use a special line called a **normal**. The normal is an imaginary line drawn at right angles to the reflecting surface. The equal angle rule says that the angle between the normal and the incoming rays is equal to the angle between the normal and the reflected ray.

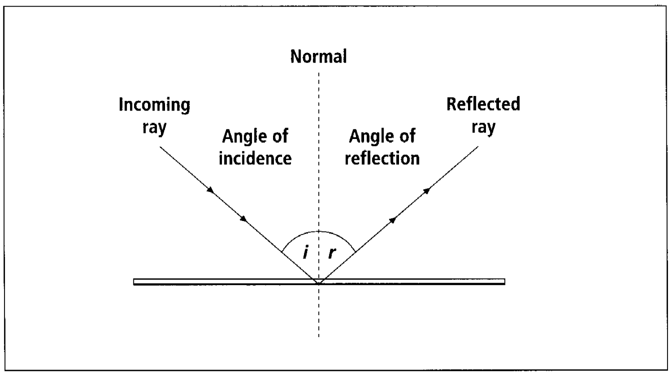


Diagram 5.17
The equal angle rule.

All reflections follow the equal angle and the straight line rules. Diagram a) below shows the light rays from a light source being reflected at equal angles. In Diagram b) the light rays being reflected from a pin also follow the equal angle rule.

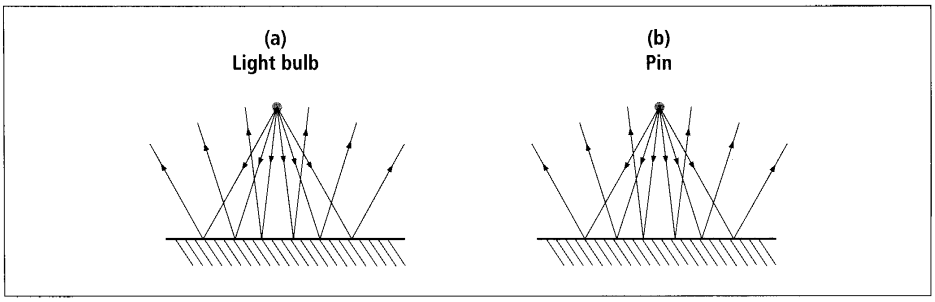


Diagram 5.18
Reflection of light rays (a and b).

Diagrams a) and b) are called ray diagrams. Ray diagrams are used to show what is happening to the light. They only show some of the rays from the light and only show the rays being reflected off the pin and on to the mirror. If too many rays are shown, the diagrams are confusing.

How do mirrors work to show an image of an object? Our brain knows that light travels in straight lines and our eyes can't see that the light has been reflected off the mirror. See Diagram 5.19 a) on the next page. Because our eyes can't see the reflection of light they 'see' the image of the object behind the mirror. See Diagram 5.19 b). Only two rays are needed to find the image.

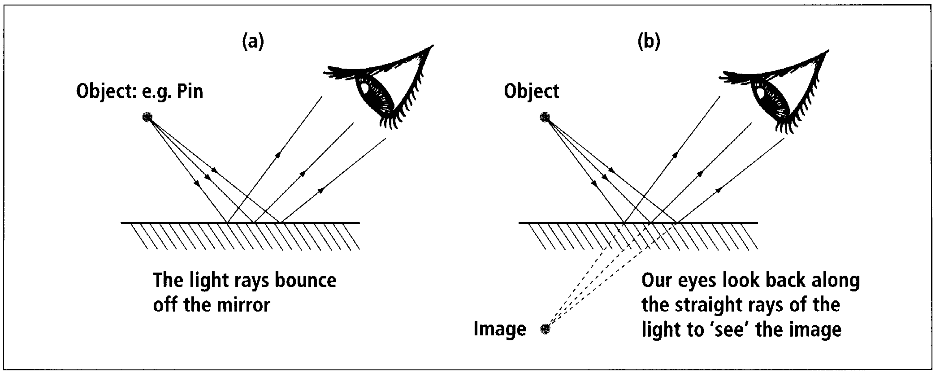


Diagram 5.19
Image in a mirror.

Rules for drawing ray diagrams:

- Use a ruler and a sharp pencil to draw the rays accurately.
- It is usual to only draw two incoming rays that start from the object.
- Use the rule appropriate to the mirror or lens. With plane mirrors use the equal angle rule.
- The image is always where the lines of the rays meet.

Activity 6

Materials needed:
Plane mirror;
Two pencils or pens;
Modelling clay: e.g. Blu tac or plasticine;
Pin or nail.

Images In A Plane Mirror

Aim To practice drawing ray diagrams.

Task 1

1. Work in groups of two or three.
2. Place a plane mirror on a sheet of white paper.
3. Hold the pencil or use modelling clay to stand it in front of the mirror (See Diagram 5.21 on the next page).
4. Hold a second pencil behind the mirror. Now look into the mirror and move the pencil behind the mirror so that it and the image sit exactly on top of each other. Move your head from side to side to check that the pencil and image stay together.
5. Measure the distance between the first pencil and the mirror.
6. Measure the distance between the pencil behind the mirror and the mirror.
7. Compare the distances. Write a rule to describe what you found out. The rule could start: 'The distance between the object and the mirror is . . .'

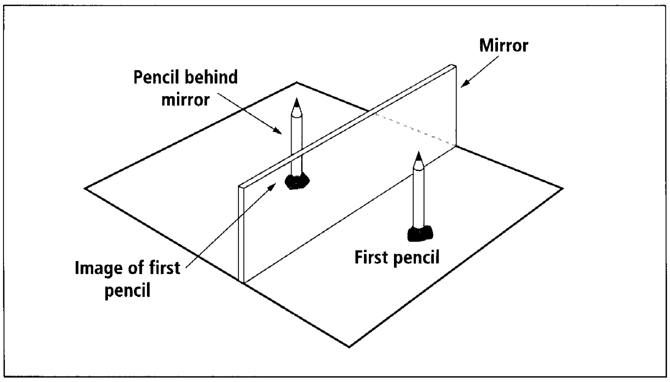


Diagram 5.20
Reflection of pencils.

Task 2

1. Copy the following diagrams, a), b), c) and d) into your exercise book.

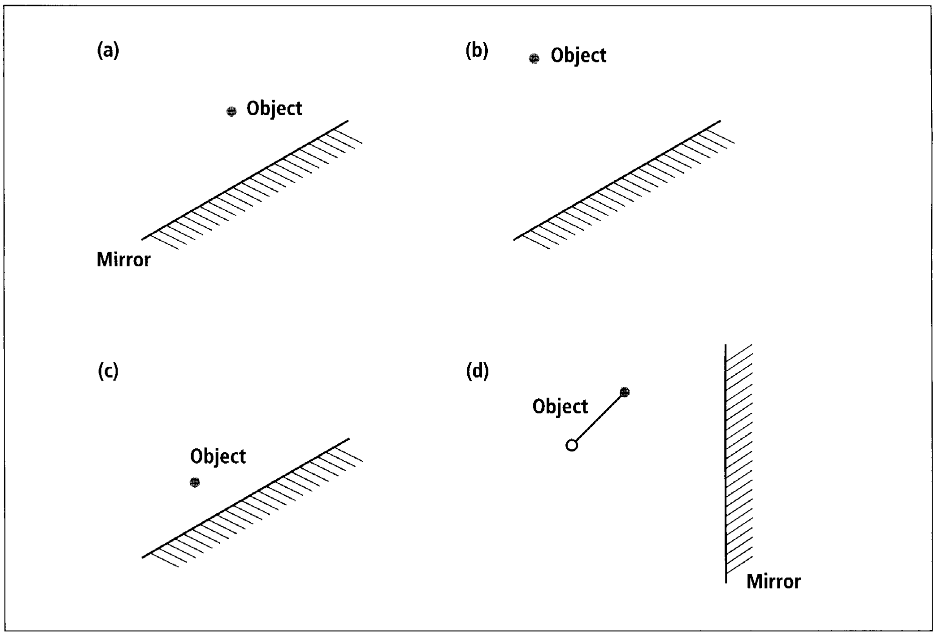


Diagram 5.21
Mirror and object diagrams.

2. Place a mirror on the page over the drawing. Place a pin on the object and look at the image.
3. Remove the mirror and pin then draw a ray diagram to show the position of the image.
4. Describe the position of the image compared to the object in each of a), b) and c). What is the rule about the position of the image? Does the ray diagram for d) support this rule?

Activity 7 Mirror Writing

1. Write a word in block capital letters.
2. Rule a line near the word.

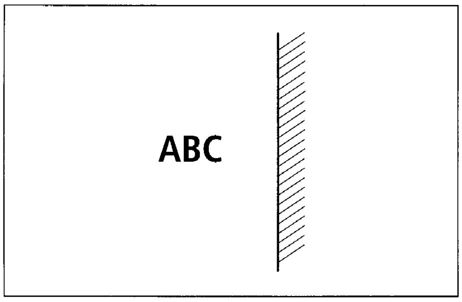


Diagram 5.22
Mirror writing.

3. Put the silver surface of the mirror on the line.
4. Draw the image of the word as accurately as possible, and in the right position.
5. Draw the images of other words or objects.
6. Trace Diagram 5.23 into your exercise book. Leave space for the images to be drawn in.

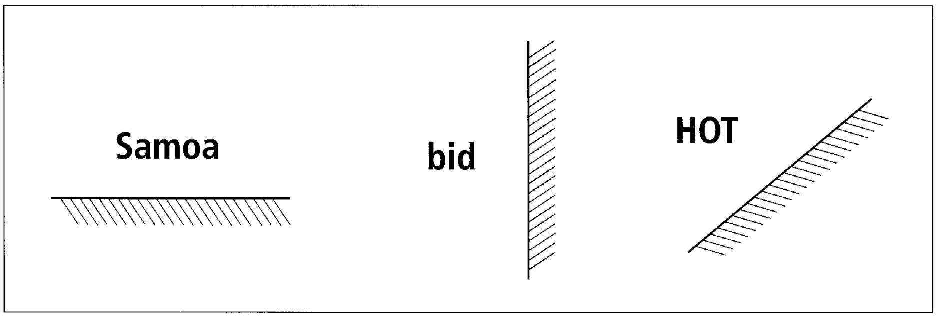


Diagram 5.23
Reflected words.

7. Draw the images of these words without using the mirror.
8. Use a mirror to check your answer.
9. Write your name and then show how it would look reflected by each of the three mirror positions shown in the diagram above.
10. Describe what the image of an object looks like when it is reflected in a mirror.

The scientific name for what you have just described is **lateral inversion**. It means that the image is turned around by the mirror. What we see as our image in the mirror is not exactly how others see us.

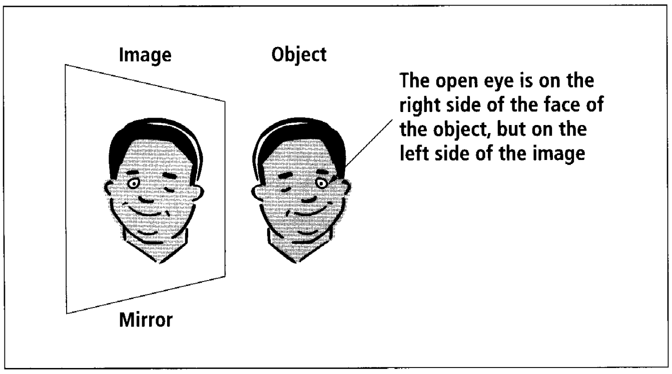


Diagram 5.24
Lateral inversion.

11. Write a summary for this activity that lists what the image of an object is like in a plane mirror. Is the image larger, smaller or the same size? Is the image the same distance behind the mirror as the object is in front or is it closer or further away? Is the image directly behind the image or at the other end of the mirror? Is the image the same way round or does it show lateral inversion?

Activity 8

Materials needed:
Two or three plane mirrors.

One And Two Mirrors

Aim To investigate the image produced by two mirrors together.

Task 1

1. Hold up one mirror in front of you.
2. Carry out a number of different activities to investigate what your image does as you carry out the activity. For example, what happens when you close your left eye? Move your right eyebrow?
3. Describe the difference between the activity carried out by yourself and your image.

4. Arrange two mirrors so that they join at 90°.

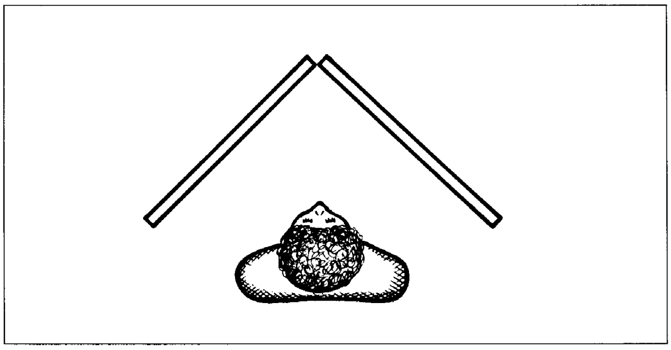


Diagram 5.25
Looking into 90'Ū mirrors.

5. Look into the mirrors in such a way that the image of your nose runs down the join between the two mirrors.
6. Repeat the activities you did in Task 1 with the single mirror. What do you notice about the image this time?
7. Describe the difference between the image in one mirror and two mirrors at 90° to each other.

Task 2

1. Place two mirrors on top of the lines in diagram (a).

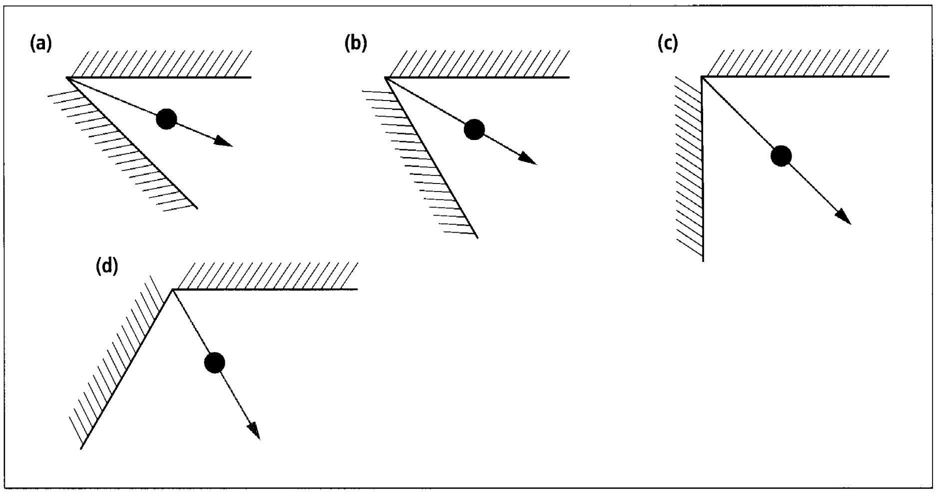


Diagram 5.26
Mirrors at different angles.

2. Look carefully at the images. Record how many you can see.
3. Do the same for diagrams b), c) and d).
4. Work out the rule for the number of images seen and the size of the angle between the mirrors. Write this rule down.
5. Use your rule to work out the angle you would need between the two mirrors to get four images. Draw a diagram to check if you are correct.
6. Tape three mirrors, facing inwards, into a triangle. Describe the image they produce.

Curved Mirrors

Shiny curved surfaces also act as mirrors by reflecting light and forming images. What the image looks like depends on the shape of the curved surface. Mirrors which have a surface that curves inwards are called **concave mirrors**. Those that curve outwards are called **convex mirrors**.

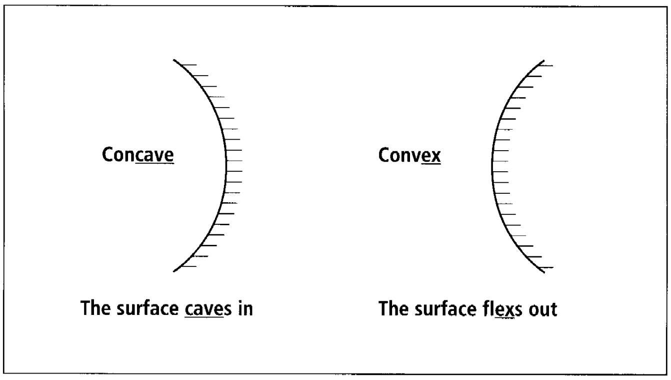


Diagram 5.27
Curved mirrors.

Three examples of mirrors that are slightly concave are make-up mirrors, shaving mirrors and the small round mirror on a long handle that dentists use to look at your teeth. Convex mirrors are used in supermarkets for security of the goods on the shelves and on corners on narrow roads where you can't see if a vehicle is coming the other way.

Curved mirrors can be slightly curved or very curved. Either way the curve is an arc (part of the circumference of a circle). From this arc you can form a complete circle, as shown in Diagram 5.28. Some concave mirrors are small enough to be placed on a page and a complete circle can be drawn starting and finishing with the mirror. The centre of the circle formed is called the **centre of curvature** and is labelled C. The **principal axis** goes from the centre of the mirror through the centre of curvature.

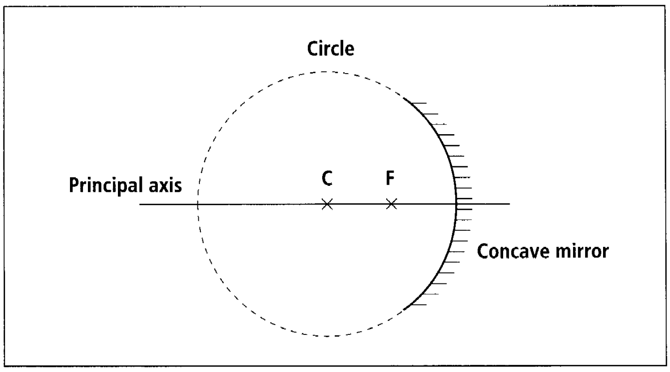


Diagram 5.28
The circle formed around a concave mirror.

Halfway between the centre of curvature and the mirror is a point called the **focal point**, labelled F. Some of the rays of light that are reflected from the mirror will travel through the focal point of the mirror.

Often bulbs in car headlights and torches are put at the focal point of the reflector behind them. That way the light reflected off the reflector forms a strong, bright, parallel beam of light.

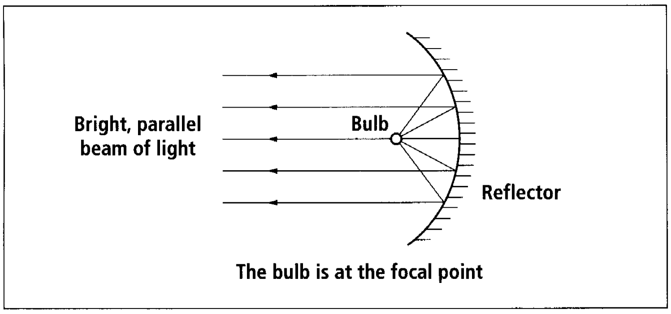


Diagram 5.29
Bulb and reflector in a car headlight.

Activity 9

Materials needed:
Concave mirror;
Convex mirror.

Curved Mirrors

Aim To investigate the image formed by curved mirrors.

1. Work in pairs.
2. Hold the convex mirror close to one of your eyes, and look at the image of your eye.
3. Keep looking at the image in the mirror as you slowly move it away. Your partner may have to move it further away for you.

4. Compare the image you can see in the convex mirror with the image formed in a plane mirror. What is different about this image? Is it the same size? Is it the same distance behind the mirror?
5. Record your observations in a table.

	Convex mirror	Concave mirror
Close to face		
Medium distance		
Far away		

6. Repeat using a concave mirror. Start with the mirror close to one eye and move it away.
7. Was the image clear at first? did it become blurred? Did it reappear again? Did you notice a double image?
8. These mirrors follow the equal angle rule. Copy and complete the following diagrams by showing the position and direction of the reflected rays.

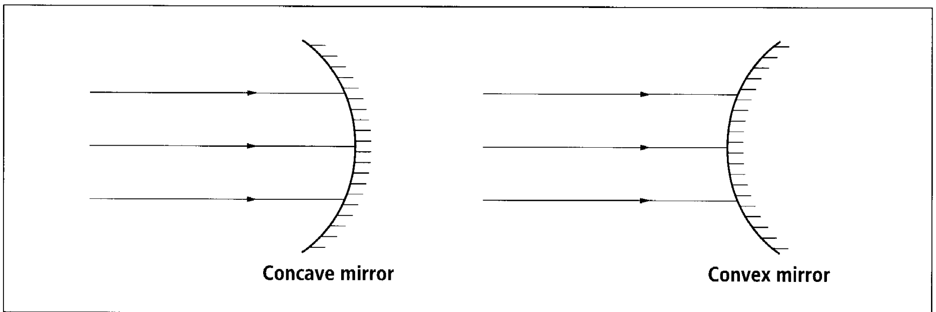


Diagram 5.30
Rays into curved mirrors.

9. What do you notice about the reflected rays from each mirror do the rays cross each other? Why or why not?
10. Place a concave mirror on a page and draw the circle formed by the mirror. Mark the centre of curvature in the centre of the circle. Mark the focal point half way between the centre of curvature and the focal point.
11. If possible, draw the circle formed by concave mirrors with different curves.

Activity 10

Materials needed:
Bright light source;
Concave mirror;
Modelling clay: e.g. Blu tac, plasticine or clay;
Sheet of paper.

Images On A Screen

Aim To project images from a concave mirror onto a screen.

1. Place a bright light on a bench.
2. Stand a concave mirror in modelling clay some distance away from the light. Tilt the mirror so that it points slightly upwards.
3. Hold a piece of paper up above the light and move it towards the mirror until the image is sharp and clear.

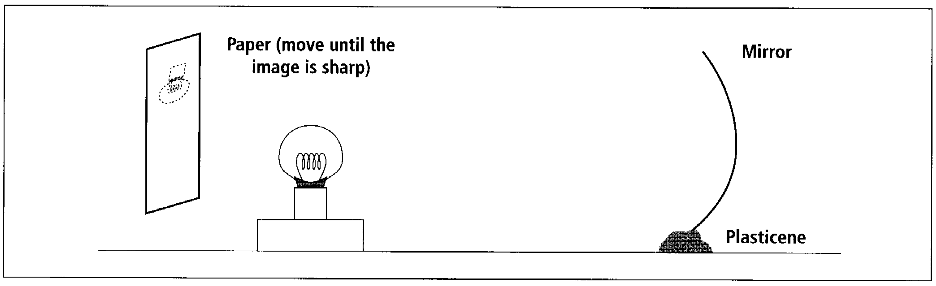
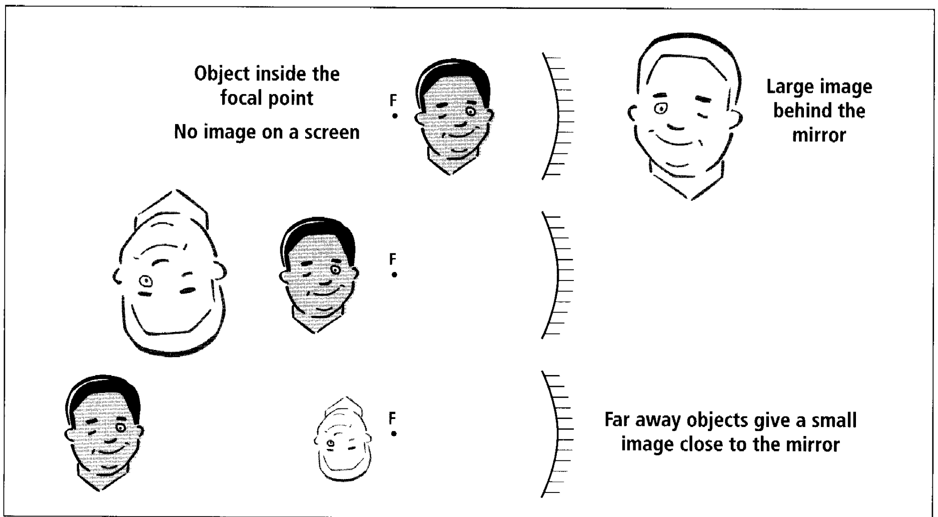


Diagram 5.31A
Mirror set up.

4. Move the light closer to the mirror. Move the paper until you find the new image.
5. Move the light closer and closer to the mirror. Check the location and size of the image at different points. Is the image upside down or the right way up? When you get very close to the mirror the image will be behind the mirror so it won't be able to be seen on a screen.

Diagram 5.31B (below)
Images in a concave mirror.



6. Compare the images you get with the ones in Diagram 5.31B. Were you surprised by what you found? Did you find the same images?
7. Begin with the light well away from the mirror again. Record the distance between the light and the mirror and the image and the mirror. Describe the image, if there is one. Move the light and repeat.
8. Write a summary about the images formed by concave and convex mirrors.

Activity 11

Materials needed:
Concave mirror;
Convex mirror;
Ray box set up to shine at least two parallel rays.

Finding The Focal Point

Aim To use light rays to investigate the position of the focal point of curved mirrors.

1. Place the concave mirror at the edge of the page so there is enough room for light to be shone on the mirror and a diagram drawn in front of it.
2. Draw a line along the reflecting surface of the mirror. This will show the shape of the mirror.
3. Remove the mirror. Add short slanted lines to show the back of the mirror.
4. Draw in the principal axis going at right angles to the centre of the mirror.
5. Replace the mirror. Use the ray box to shine light rays parallel to the axis.

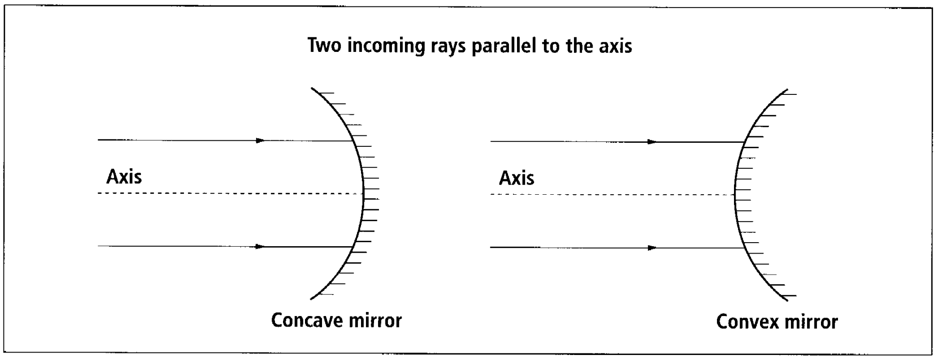


Diagram 5.32
Concave and convex mirror set up.

6. Look at the ways the rays are reflected. Move the ray box slightly to make sure the rays are parallel. If they are parallel they will cross on the axis at the focal point.
7. Mark in the reflected rays.

8. Mark in the focal point. Write a sentence to describe what the focal point is.
9. Draw the circle formed by the mirror. Mark in the centre of curvature. Is the focal point halfway between the centre of curvature and the mirror?
10. Place a convex mirror in the middle of the page. Mark the mirror and the axis.
11. Shine two rays of light parallel to the axis onto the mirror.
12. What happens to the rays this time? Describe why you can not see the focal point.
13. Mark in the reflected rays.
14. Draw dotted lines to show where our eyes think the reflected rays have come from behind the mirror. Do the rays cross?
15. Use the information you found out in this activity to write a discussion about the focal point of curved mirrors.

Ray Diagrams For Curved Mirrors

Ray diagrams can be used to show the size and position of the object and image. It is quite difficult to draw the incoming and reflected rays at equal angles so two or three special rays are used when drawing ray diagrams. The first ray hits the mirror at the axis so is reflected at equal angles. The second comes in parallel to the axis and is reflected through the focal point. The third ray comes in through the focal point and goes out parallel to the axis.

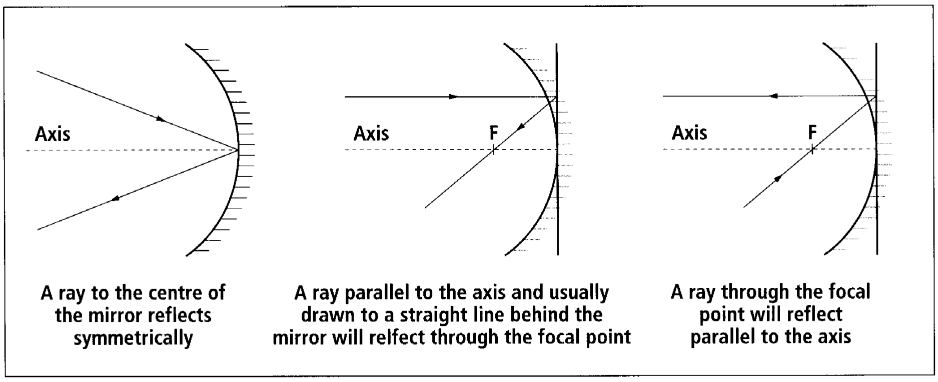


Diagram 5.33
Special rays used for drawing ray diagrams for curved mirrors.

Only two of these rays are needed to show the image. The image is formed where the two rays cross.

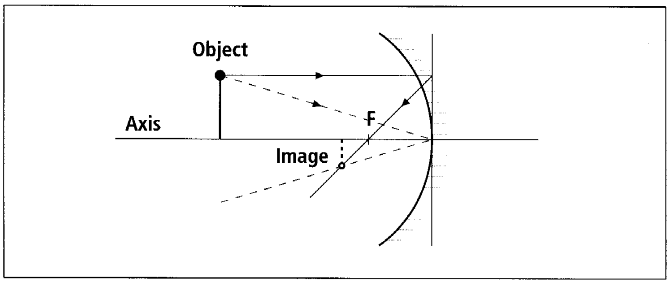


Diagram 5.34
Ray diagram for a concave mirror.

Steps for drawing a ray diagram for a curved mirror. Ray diagrams are usually drawn as scale diagrams.

Step 1 Draw the axis of the mirror and a line at right angles to it.

Step 2 Draw in the type of mirror being used and its focal point.

Step 3 Draw in the object. Make sure you draw it to scale.

Step 4 Draw in two of the special light rays from the top of the object to the mirror and then being reflected. The place where the two light rays cross is the top of the image. Draw in the image.

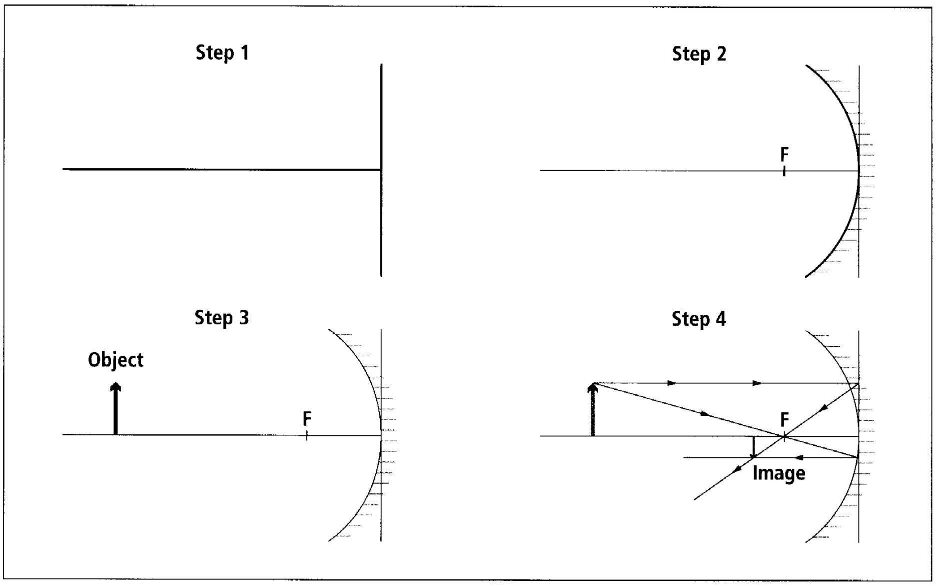


Diagram 5.35
Drawing a ray diagram.

The ray diagram on the previous page shows that the image of an object placed beyond the focal point of a concave mirror is upside down, smaller than the object and closer to the mirror. This is a real image and would be able to be seen on a screen.

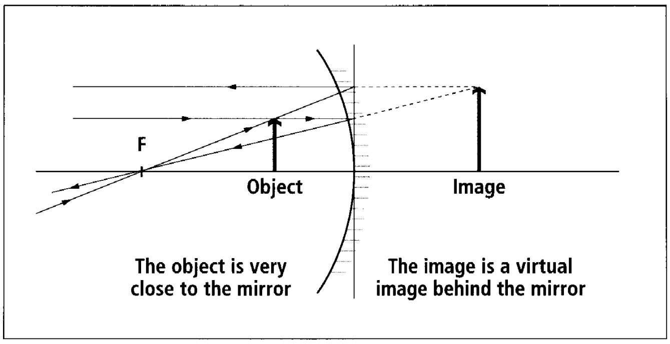


Diagram 5.36
Virtual image.

The image of an object placed between a concave mirror and its focal point, is up the right way, larger and further away from the mirror than the object. It is called a **virtual image**. This means it is behind the mirror and not real, so it can not be shown on a screen.

Activity 12

Drawing Ray Diagrams

Aim To draw ray diagrams to find the size and position of the image of an object in a concave mirror.

1. Copy Diagram 5.35 Step 2 five times.
2. On each diagram select a different place to draw an object 1 cm tall. Make sure the object is always standing up on the axis of the mirror.
3. Complete each of the five ray diagrams by drawing in two rays to locate the image.
4. Draw in the image and describe what it looks like compared to the object.

Materials That Let Light Through

Materials can be **transparent**, **translucent** or **opaque**. Transparent materials let all the light through. Glass is transparent. Some types of fabric let some light through. These fabrics are called translucent. Opaque materials don't let any light through. Wood is opaque. Materials that let light through are called a **medium** for the transfer of light.

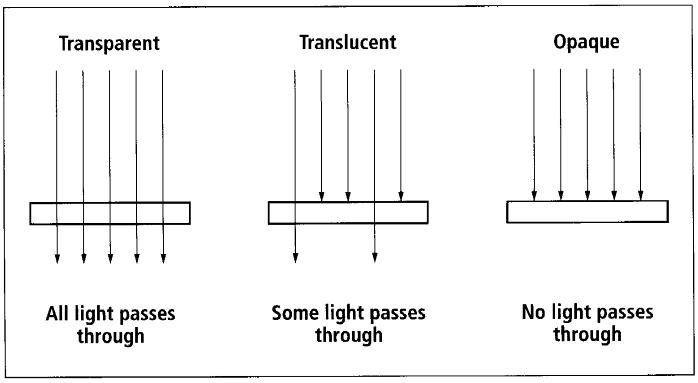


Diagram 5.37
Letting different amounts of light through.

Activity 13

Materials needed:
A torch or other light source;
Different materials: e.g. Plastic objects, glass objects, leaves, feathers, fabrics, paper, card.

Letting Light Through

Aim To investigate the amount of light different materials let through.

1. Draw a table to record the names of the materials tested, your predictions and your results.
2. Select a material. Predict if it is transparent, translucent or opaque. Record your prediction.
3. Place the material over the light source. Observe how much light passes through each material. Record this information on your table.
4. Group the materials on how much light they let through.
5. What do you notice about the materials in each group? Does the colour of the material make a difference? Does the thickness of the material make a difference? How many layers of a translucent material will stop letting light through?

Activity 14

Materials needed:
Coffee mug;
Coin;
Ruler;
Water.

The Appearing Coin

Aim To investigate a property of light.

1. Work in pairs.
2. Put a coin in a mug. Stand a ruler up on the bench next to the mug (see Diagram 5.38 on the next page).
3. Put your eye level with the zero mark on the ruler. Get your partner to move the mug until you see only the far edge of the coin.
4. Have your partner very slowly pour water into the mug until it is full.
5. Describe what happens to your view of the coin as the water is added.

6. Move your eye down the ruler until you see only the far edge of the coin again. How far down the ruler did you move your eye?
7. What do you think happened to make the coin appear when the water was added?

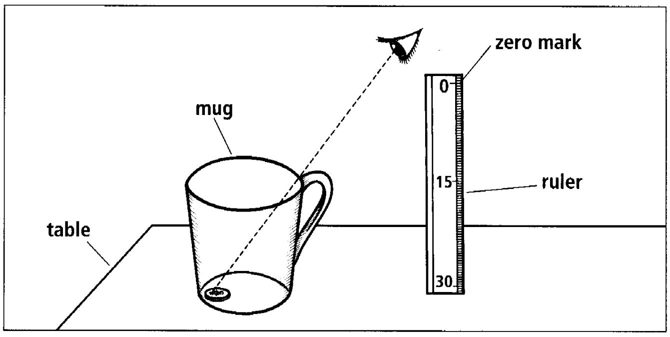


Diagram 5.38
Mug and coin set up.

Activity 15

Materials needed:
Glass or plastic blocks — rectangular and semicircular;
Power pack;
Ray box;
Single slit.

Bending Light

Aim To investigate how light bends when it travels from one material to another.

1. Set up the ray box so that it lets a single ray of light hit the side of a rectangular glass block. See A below.

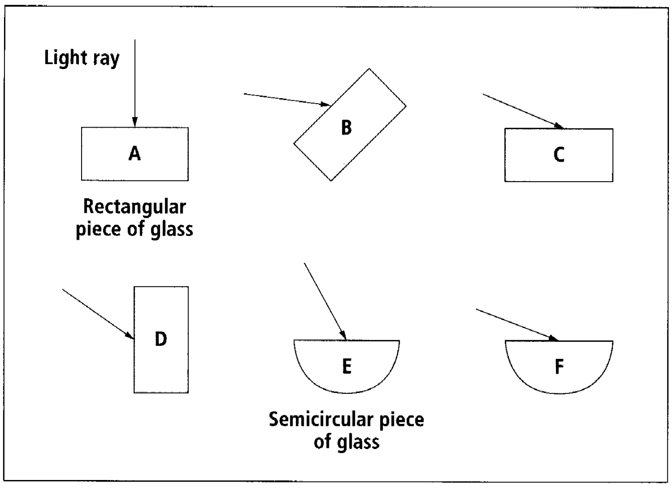


Diagram 5.39
Glass blocks.

2. Draw a diagram to show what happens to the direction of the light rays as it travels from the air into the glass and then from the glass back into the air again.
3. Set up each of B to F in turn. Try to get the angle the same as the diagram above.
4. Draw a diagram of your results.
5. Try other angles and shapes.
6. Describe what happens when light travels from one transparent material to another.

Refraction Of Light

When light hits the edge of a transparent material some light is always reflected. When light goes from one transparent material into another it changes direction slightly. This bending of the light ray is called **refraction.**

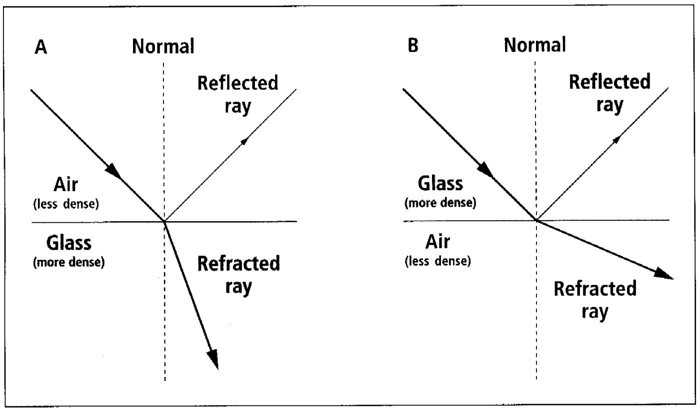


Diagram 5.40
Refraction of light.

In diagram A the light ray bends towards the normal. Glass is more dense than air so when the light ray passes from air into glass it will bend towards the normal. In diagram B the refracted ray bends away from the normal as it moves from a dense material to a less dense material.

Activity 16

Materials needed:
Power pack and ray box;
Glass or plastic semicircular block;
Single slit.

Trapping Light

Aim To investigate refraction of light in a semicircle.

1. Set up the ray box so that a single ray of light goes into the curved side of the semicircle. Place the ray box so that the light ray makes an angle a little bit bigger than 45° at the centre of the block.

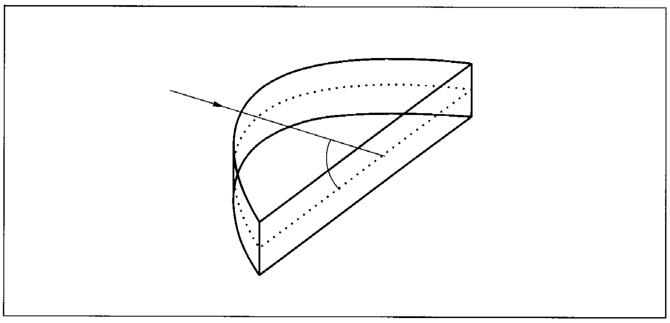


Diagram 5.41
Semicircular piece of glass.

2. You should see a refracted ray coming out the flat side, if you don't, make the angle a little bigger. Can you see a reflected ray as well?
3. Draw a diagram of what you see.
4. Move the ray box or semicircle so that the ray makes a smaller angle at the centre. Can you see a refracted ray? Can you see a reflected ray?
5. Draw a diagram of what you can see.
6. Make the angle at the centre smaller until you can see only one ray.
7. Draw a diagram of what you can see.

Total Internal Reflection

When light hits the join between two mediums at a very small angle all of the light is reflected and none is refracted. This is called **total internal reflection** because all of the light is reflected to stay in the material. In Activity 16 the light was able to escape out the curved side of the semicircle. Fibre optic cables use total internal reflection to keep bouncing the light off the internal surface as it travels down the fibre. These cables can be used by doctors to take photographs inside a person's body.

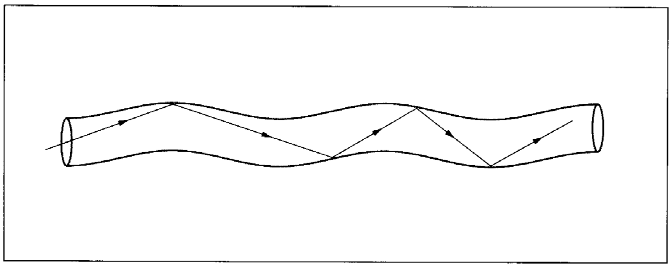


Diagram 5.42
Fibre optic cable.

Gem stones, such as diamonds, are cut into shapes so that total internal reflection makes them sparkle more.

Lenses

Lenses are pieces of glass or plastic curved on one or both surfaces. Lenses make use of the property of refraction or bending of light.

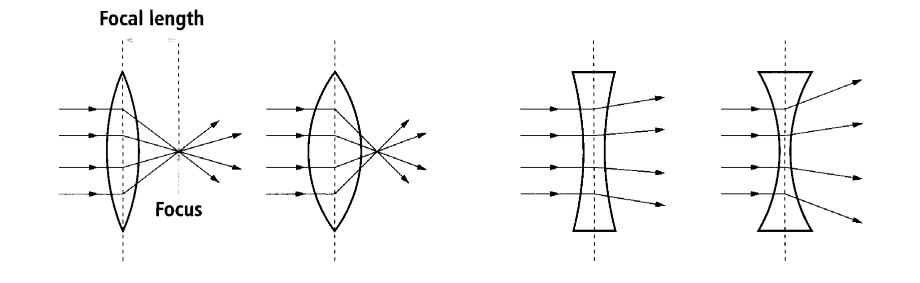
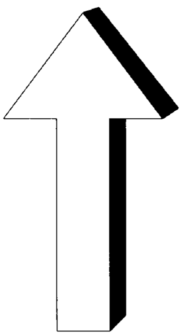


Diagram 5.43
Convex and concave lenses.

Activity 17

Materials needed:
Convex lens;
Concave lens.



Lenses

Aim To investigate the images formed by lenses.

1. Draw a large arrow, similar to the one below on the left.
2. Hold a convex lens 5 cm above the arrow you have drawn. Look at the arrow through the lens.
3. Describe the image. Record the following information in a table.
   Size – is the image larger, smaller or the same size as the object?
   Sharpness – is the image sharp or blurred?
   Way up – is the image upside down or the right way up?
   Position – is the image the same distance from your eye as the real arrow? Further away or closer? (Focus on the image then, without moving your head or the lens, focus on a bit of the real arrow just to the side of the lens. Your eyes will tell you which is closer).
4. Find out about the image when the lens is at 10 cm, 30 cm, 50 cm and 2 m from the object.
5. Repeat the observations with a concave lens.
6. Move the convex lens slowly up from the arrow on the page, looking at the image all the time. Describe what happens.
7. Use the lenses to look at other interesting things.

Activity 18 Using Glasses To Improve Sight

Aim To record information about how lenses are used to help people to see better.

- Read the following information and then draw diagrams to explain how lenses in glasses are used to help people to see better.

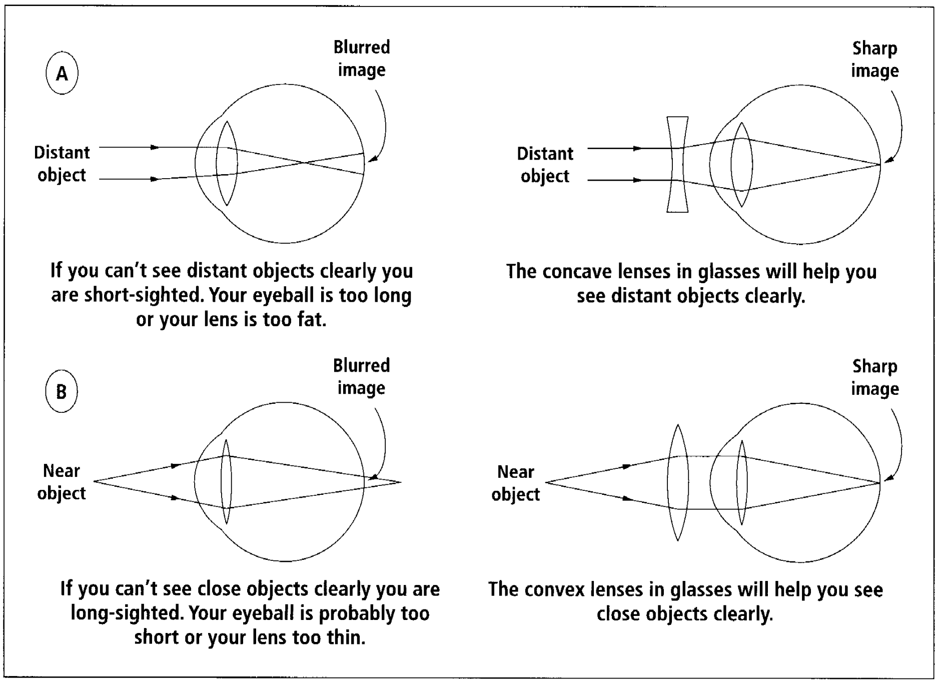


Diagram 5.44
Correcting faults with the lenses in your eyes.

Ray Diagrams For Lenses

There are two special rays that are used to draw ray diagrams for lenses. The first ray goes from the top of the object, parallel to the axis, through the lens and down through the focal point. The second ray goes through the centre of the lens.

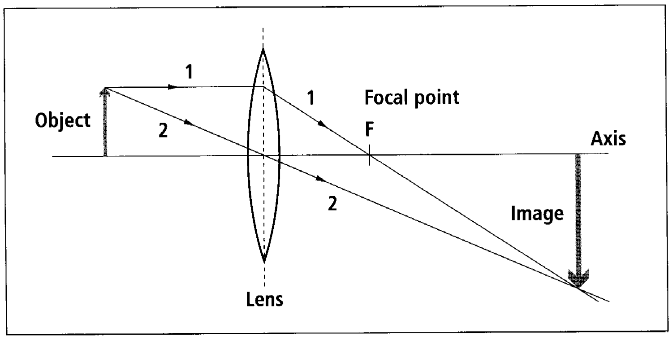


Diagram 5.45
Ray diagram for a lens.

Activity 19 Ray Diagrams For Lenses

Aim To draw ray diagrams for lenses

1. Copy the following diagrams.
2. Add the two special rays to show the position of the image. The image has been drawn in on the first one for you.

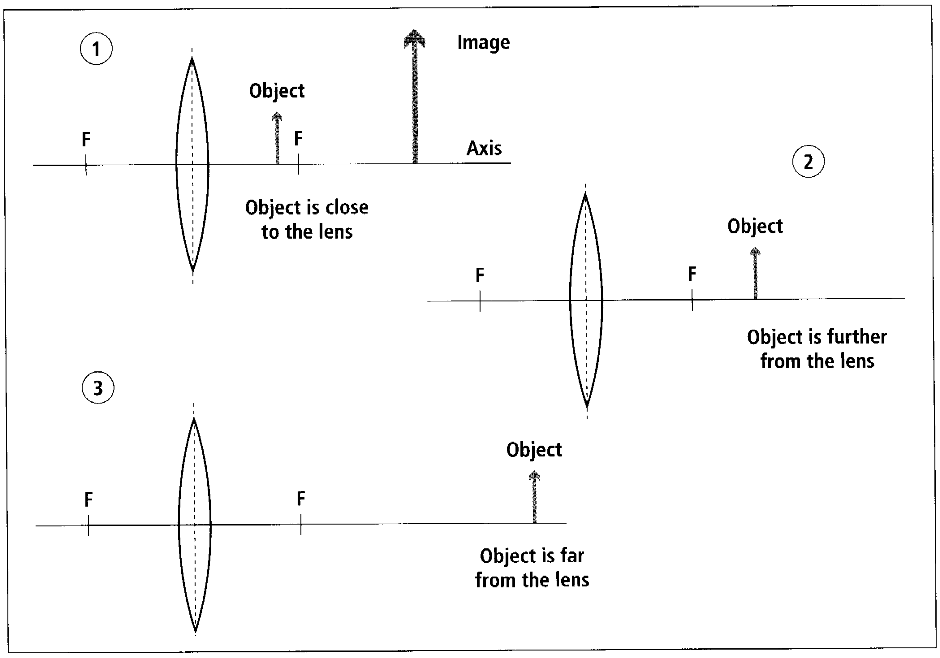


Diagram 5.46
Ray diagrams for lenses.

Activity 20

Refraction In lenses

Aim To find out about refraction of light by lenses.

- Produce a report about the way light is refracted by lenses. You could investigate the effect of the thickness of the lens on the way light is refracted or you could investigate the refraction of light by sending light rays towards the lens at different angles. For example:

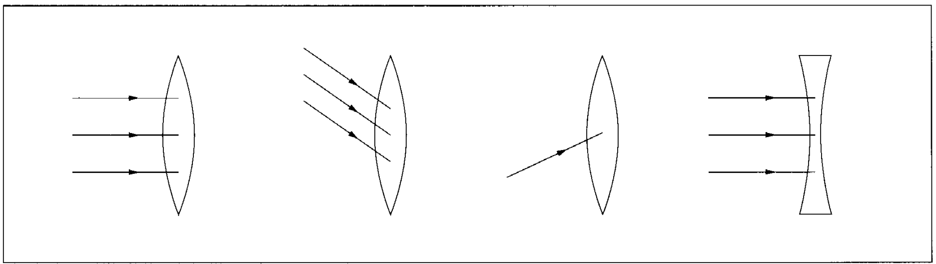


Diagram 5.47
Different angles.

Activity 21

Materials needed:
Ray box and power pack;
Convex lens in blu tac;
Metre ruler;
Paper screen.

Images On A Screen

Aim To investigate the images produced by a convex mirror.

1. Set up the equipment as shown below.
2. Record the distance from the bulb to the lens and the distance from the lens to the paper screen. Also record observations about the images on the screen. Are they large, small, the same size? Upside down or the right way up? Bright or dim? Sharp or blurry?
3. Write a discussion on what you found out about the images produced by a convex lens.

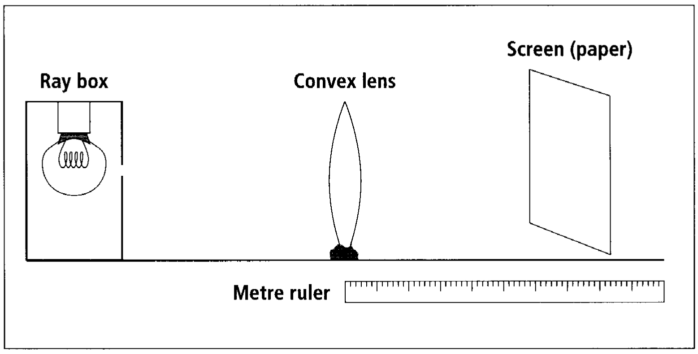


Diagram 5.48
Image set up.

White Light And Coloured Light

Remember the investigation in which you carried out flame tests on different material. You found that materials such as sodium chloride, copper sulfate and calcium carbonate all burn with different flame colours. In other words when burning they gave off different coloured light.

The light coming to us from the Sun is white light. White light is made up of light of seven different colours. The colours are red, orange, yellow, green, blue, indigo (blueish purple) and violet. These are the colours of the rainbow. A rainbow is formed in the sky when white sunlight hits droplets of water in the atmosphere. Some of the light refracts into some of the drops, reflects from the drops' inner surfaces, and then refracts out of the drops. This splits the white light into the colours and forms the rainbow.

Why does the sky appear blue? The white light coming into the Earth's atmosphere hits dust particles that scatter the blue light more than the red or yellow. This makes the Sun look yellow but the sky looks blue.

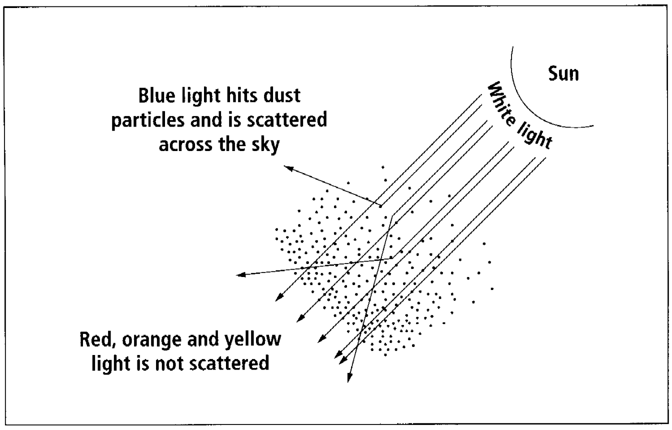


Diagram 5.49
Scattering of blue light to make the sky blue.

At sunrise and sunset the white light from the sun has to travel through much more of the atmosphere before it gets to land. If there is a lot of dust or smoke in the atmosphere at this time even more light from the blue end of the spectrum is scattered making the Sun and sky around it look orange or even red.

Activity 22

Materials needed:
Ray box and power pack;
Prism;
Single slit;
White paper.

Prism

Aim To investigate light through a prism.

1. Set up the equipment so that a single ray of light hits the prism. See below.
2. You should be able to see a spectrum or rainbow of colours as the white light splits into the individual colours.
3. Draw a diagram of what you can see. The spreading of white light into a spectrum is called **dispersion**.
4. Investigate dispersion of white light by shining a thin bright beam of light through a beaker of water.
5. Record your observations.

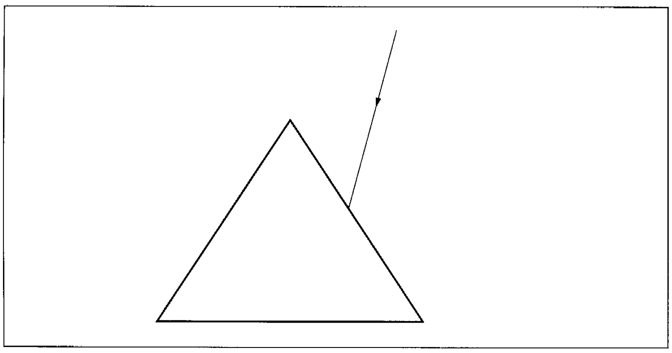


Diagram 5.50
Prism set up.

Laser Light

Lasers were first made in 1960. Since then people have used them in lots and lots of different ways. A laser is a narrow, high energy beam of light. The light in a laser doesn't spread out like the light from other light sources does.

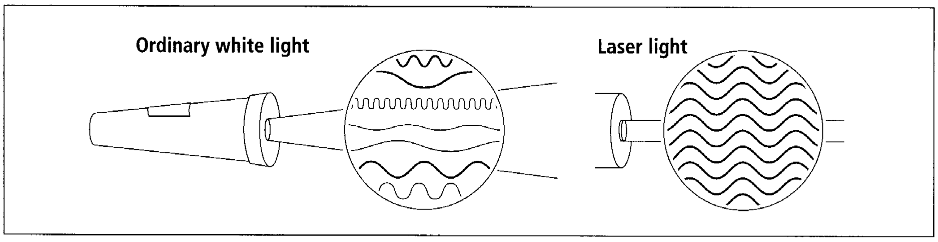


Diagram 5.51
Ordinary light and laser light.

Uses For Lasers

1. Cutting metals. Lasers are used to cut and drill holes in metals because they cut it quickly, easily and very accurately. The heat energy from the laser makes a cut by heating the metal so hot that it turns into a gas.

2. Surgery. The very thin laser beams can be used during surgery. The energy in the laser beam is pointed onto diseased tissue. The diseased tissue will vaporise leaving the healthy tissue untouched. Lasers are used in eye surgery and to remove birthmarks. They are also used to close broken blood vessels to stop bleeding during surgery.

3. Communication. Fibre optic cables use thin laser beams of light to carry telephone conversations and computer data. These cables are able to carry a lot more conversations and data than wire cables.

4. Distances in space. A ray of laser light is sent to the moon and it reflects back. The ray can be seen on Earth again because it is bright and it doesn't spread out as ordinary light does. The time the ray takes to travel to the moon and back is measured and used to work out the distance travelled.

5. Shopping. Shops such as supermarkets use lower power laser beams to read the bar codes on goods.

6. Entertainment. CD players have a laser inside them that is used to read the information on the CD.

Activity 23

Lasers

Aim To record information about lasers.

1. Describe, in your own words, three examples of how lasers are used.
2. A laser pulse travelling at 300 000 kilometres per second takes 2.54 seconds to travel to the moon and back. How far is it from Earth to the moon?

- Carry out research into laser technology. If you have access to the internet, a good place to start is:

  http://www.howstuffworks.com/laser.htm
  http://entertainment.howstuffworks.com/cd2.htm

Electromagnetic Radiation

Electromagnetic radiation is the name given to waves that carry electric and magnetic energy. There are lots of different types of electromagnetic radiation. These waves have different wavelengths and together are called the **electromagnetic spectrum**.

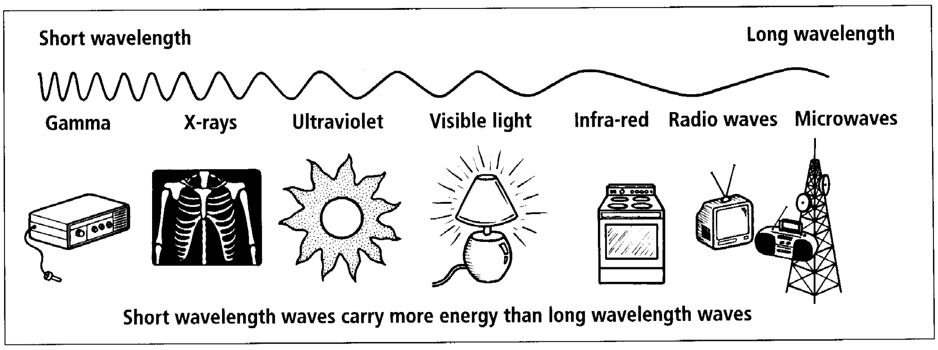


Diagram 5.52
Electromagnetic spectrum.

Light is the part of the electromagnetic spectrum that our eyes are adapted to see. Light forms only a very small part of the electromagnetic spectrum.

Effects of electromagnetic radiation
There has been lots of debate about the effects of electromagnetic radiation on the health of people. It is well known that gamma rays are harmful and that X-rays must be used with care because they cause damage to living cells. Cell phones give off electromagnetic radiation. Some people believe that the effects are minimal but there is a growing number who believe that electromagnetic radiation from cell phones is harmful.

Activity 24 Electromagnetic Radiation

Aim To investigate the uses and effects of electromagnetic radiation.

1. Select one of the types of electromagnetic radiation and carry out research into how people use that type of radiation.
2. Find out about the dangers of overexposure to electromagnetic radiation.

Activity 25 Study Notes

Aim To make study notes to use when revising this unit.

- Read through all the material you have covered in this unit.
- Read it again, this time highlighting the key science ideas.
- Rewrite the key science ideas into a different form so that you can use them as study notes. There are lots of different forms of study notes but they all have only the key words written down. Some people use diagrams.

Unit 6: ELECTRICITY

Introduction
In this unit you will investigate use of electricity, electrical circuits and the way electricity travels in series and parallel circuits.

Electricity

Street lights through some villages on Upolo, cell phone battery chargers in fales and the noise of electrical generators on Savaii show the use of electricity in Samoa. Electricity is becoming an increasingly important energy source with many many uses.

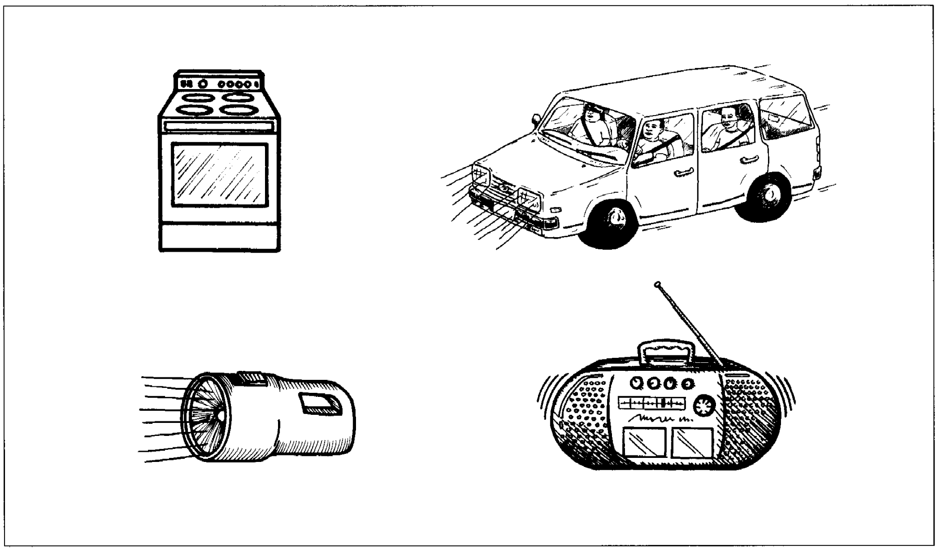


Diagram 6.1
Electrical energy being used.

Activity 1

What We Already Know About Electricity

Aim To find out what we know already about electricity.

Talk about each of the following questions with a friend or your group. Then write a sentence about each. Begin each sentence with 'I think that . . .' to make it clear that these are your ideas now, because you may have different ideas later.

1. What is an **electric current**?
2. What is a **battery**?
3. What does the term **high voltage** mean?
4. When electric lights are turned on what happens to make the bulb glow or light up?

Activity 2

Materials needed:
1.5 V cells (batteries);
2.5 V torch bulbs;
Wires.

Batteries, Bulbs And Wires

Aim To find out about electric circuits.

1. Work in pairs or groups
2. Make a torch bulb glow using a cell and two wires. You will have to try different ways to join the bulb, cell and the two wires together until you find a way that makes the bulb glow. Draw a diagram of the cell, bulb and wires to show how you got the bulb to glow.
3. Now make the bulb glow using a cell and only one wire. Draw a diagram to show how you got the bulb to glow.
4. This time use two cells and one or two wires to make the bulb glow. Draw a diagram to show how you got the bulb to glow.
5. Write an explanation of how the cell, wires and bulb must go together to make the bulb glow.

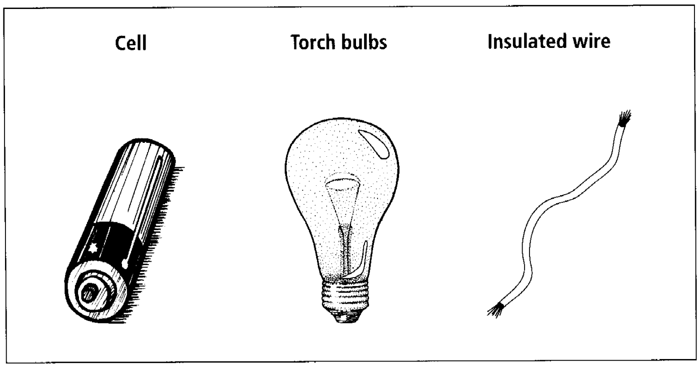


Diagram 6.2
Equipment set up.

Conductors And Insulators

In each of the previous examples you needed to have a complete circuit for the electricity to flow in, before you could get the bulb to glow. A complete circuit means that the electricity can move from the cell to the bulb and then back to the cell again.

In the previous activity the electricity moved from the cell to the bulb and back to the cell in wires made of metal. Not all materials will let electricity flow through them. Materials that let electricity flow through them are called **conductors**. Copper metal is a good conductor of electricity.

Materials that do not let electricity flow through them are called **insulators**. Power lines use insulating materials that stop the electricity from flowing to the ground.

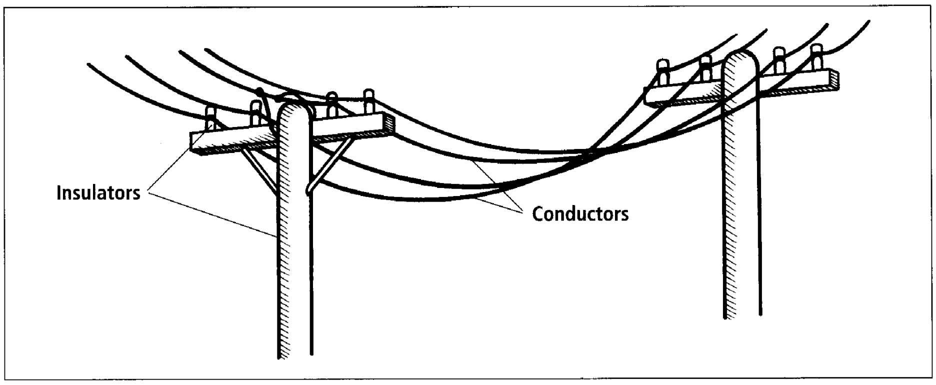


Diagram 6.3
Power lines.

Activity 3

Materials needed:
Power pack or cells;
Bulb;
Three wires;
Small pieces of lots of different materials;
Sandpaper or wire wool.

Conductors And Insulators

Aim To find out which materials let electricity flow through them.

1. Work in groups.
2. Join the wires and bulb to the power pack or cells as shown in the diagram on the next page.
3. Test each of the materials to see if they conduct electricity. Record your results in a table. If some materials are dirty they won't conduct electricity until they have been scratched clean with an abrasive material such as sandpaper.

Conductors	Insulators

4. Discuss your results and write a discussion that describes the types of material that are conductors and the types that are insulators.

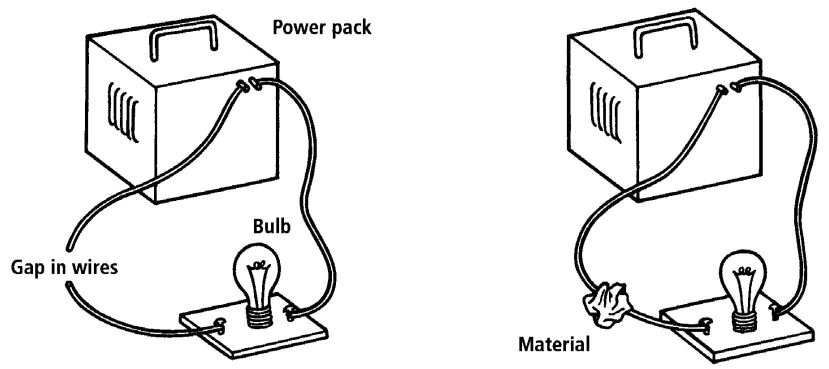


Diagram 6.4
Circuit for testing for conductors and insulators.

Electrical Circuits

The activity above used an electrical circuit to test if a material was a conductor or an insulator. When a conductor was placed between the ends of the wires the circuit was complete and the bulb glowed. When an insulator was placed between the ends of the wires the circuit was not complete so the bulb did not glow.

Each electrical circuit must have:

- A **source** of electricity or electrical energy: *e.g. Cells.*
- A **user** of electrical energy: *e.g. Bulb, element.* Electricity will flow without a user in the circuit but it could overheat and stop the circuit from working.
- **Conductors** that join the parts of the circuit: *e.g. Wires.*

Electrical circuits can also have:

- **Safety** devices that stop the electricity flowing if something goes wrong with the circuit: *e.g. Fuses, cut-out switches.*
- **Control** devices that control the electricity in the circuit: *e.g. Switches that turn the electricity on and off.*
- **Measuring** devices that measure different aspects of the electricity in the circuit: *e.g. Voltmeters, ammeters.*

Activity 4

Materials needed:
Torch;
Electric kettle or electric jug or toaster.

Electrical Circuits Inside Equipment

Aim To identify the parts of electrical circuits.

1. Work in groups.
2. Open the torch and look inside. Identify the following parts of the electrical circuit:
   a. Source of electrical energy.
   b. User of electrical energy.
   c. Control switch.
   d. Conductors that are completing the circuit. These could be wires, plates or even the outside case of the torch if it is metal.
3. Draw the torch showing each part of the circuit. Add labels naming each part and explaining its function.
4. Identify each part of the electrical circuit in an electric kettle, jug or toaster. Draw the circuit, labelling the parts.
5. Compare the sources and users in the two circuits. Describe the similarities and differences between the two circuits.

Circuit Symbols

Look back at the drawing you have made of the electrical circuits we have investigated. Look at the drawings done by others in your group and your class. Notice how everyone has used different styles and shapes for the parts. Scientists and other people drawing electrical circuits want everyone else to be able to easily understand their electrical circuit drawings so they use a set of symbols for each of the parts of a circuit. See Diagram 6.5.

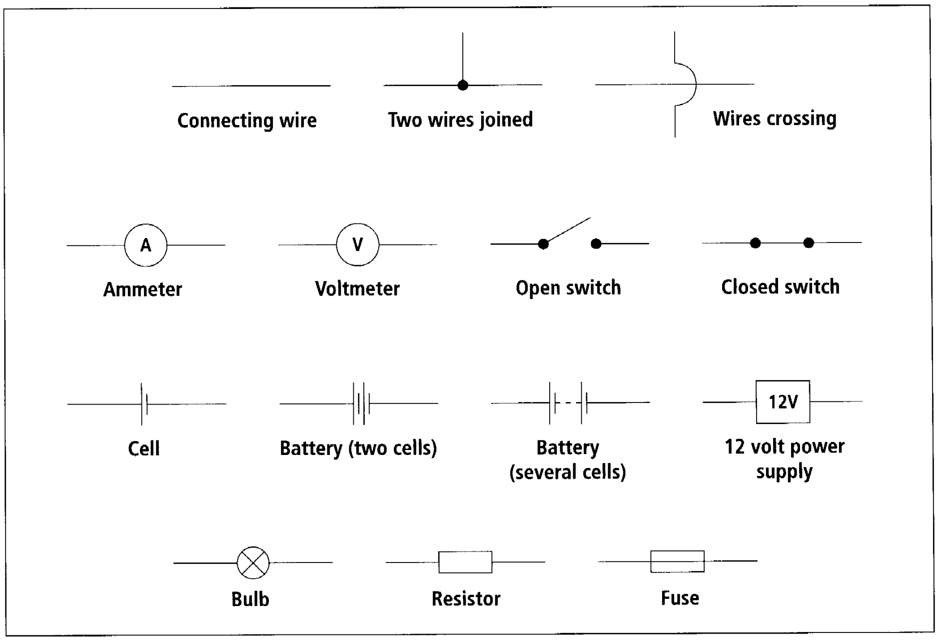


Diagram 6.5
Circuit symbols.

Here is an example of a drawing of an electrical circuit beside a diagram of the same circuit shown using circuit symbols.

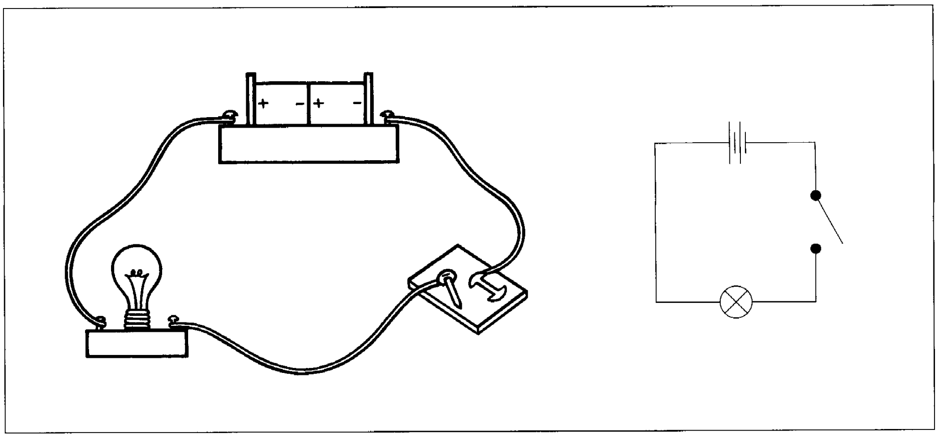


Diagram 6.6
Drawing and diagram of an electrical circuit.

Rules For Drawing Circuits

- Always use the correct symbol for each part.
- Draw the circuit in a square shape with the source at the top and the other parts placed around the sides of the square.
- Rule straight lines for parts such as wires and the symbol for cells.
- Make sure all the lines for the wires are joined and special parts such as voltmeters are placed in the circuit correctly.

Activity 5

Materials needed:
Cells;
Wires;
Switches;
Bulbs.

Drawing Circuits

Aim To use circuit symbols to draw electrical circuits.

1. Copy Diagram 6.4 into your exercise book and name each symbol.
2. Copy the rules for drawing circuits into your exercise book.
3. Redraw each of the circuits you drew in Activity 2 and Activity 4.
4. Draw the circuit used in Activity 3 correctly.
5. Draw a circuit showing a battery of three cells, a switch, a fuse and two bulbs.
6. What is wrong with the following drawing of a circuit?

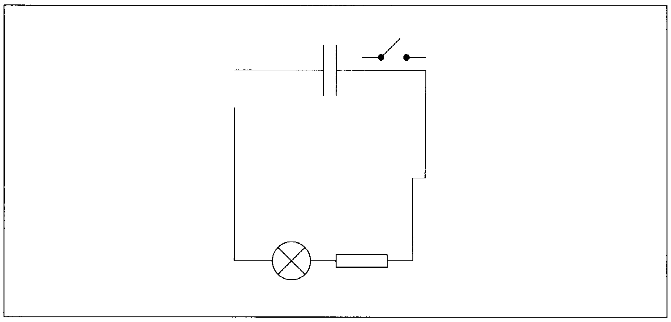


Diagram 6.7
An incorrect circuit.

7. Set up a circuit and then draw it.
8. Draw the circuits set up by other students.

Types Of Electricity

Materials have positive and negative electrical charges inside them. The positive charges are caused by the protons inside the nuclei of the atoms in the material and the electrons around the nuclei of these atoms cause the negative charges.

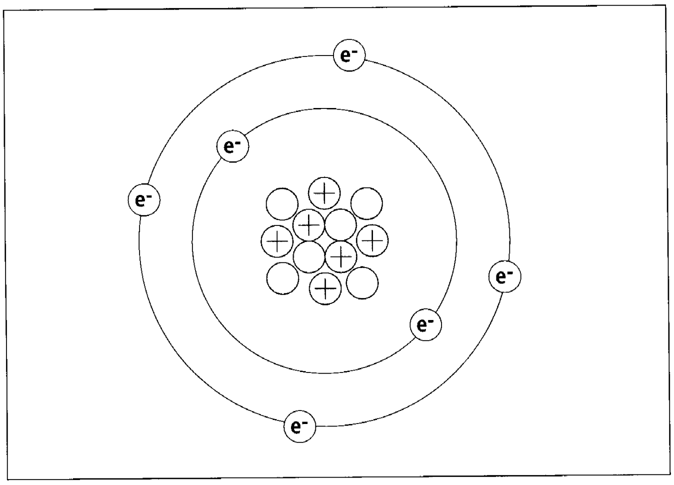


Diagram 6.8
Positive protons and negative electrons in a carbon atom.

In some insulating materials the negative charges are able to easily move from one material to another. When this happens **static electricity** is formed. Rubbing two insulating materials together can produce static electricity. For example rubbing a plastic pen on some clothing fabrics. When the negative charges move from one material to another the materials become charged. The material that lost the negative electrons becomes positively charged because it now has more positive charges than negative. The material that gains the negative electrons becomes negatively charged because it now has more negative charges than positive charges.

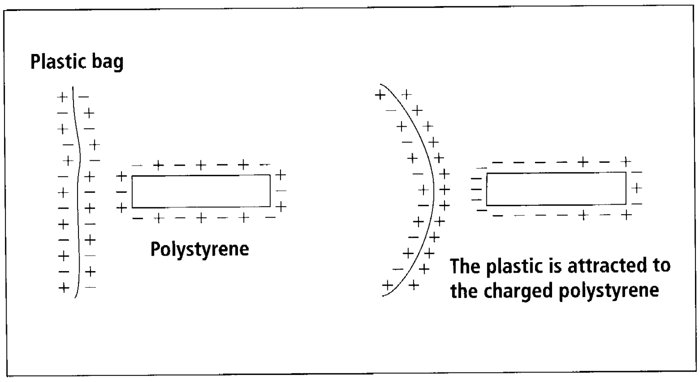


Diagram 6.9
Polystyrene rod and plastic bag showing static electricity.

Negatively- and positively-charged objects are attracted to each other.

Materials with the same charge (*e.g. Both positive or both negative*) repel or try to push each other away.

Thunder and lightning are the result of static electricity. As the particles inside clouds rub together some become positively charged and some become negatively charged. Warm air takes the positive charges higher leaving the bottom of the cloud negative. The negative charges in the clouds are attracted to the positive charges in the ground. When the attraction is strong enough a lightning bolt forms and carries the negative charges to the ground. The lightning moves at 100 000 kilometres per second and as it does it causes a shockwave we call thunder.

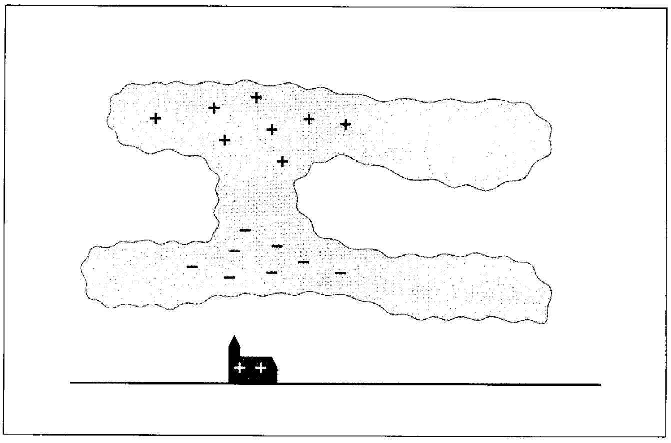


Diagram 6.10
Formation of lightning.

Source: http://www.exploratorium.edu/ronh/weather/weather.html

Activity 6

Materials needed:
Plastic objects;
Different types of cloth or fabric;
Very small pieces of paper 1 cm x 1 cm;
Water running from a tap or jug.

Static Electricity

Aim To investigate static electricity.

1. Rub a plastic object on a cloth for one minute to give it a charge.
2. Slowly lower the charged plastic object towards several very small pieces of paper on the desk. If nothing happens try rubbing a different object or different type of cloth.
3. Describe what happens when the charged object gets close to the paper. This is an effect of static electricity.
4. Choose a different object. Rub it against a piece of cloth and then lower it towards the paper. Does it have the same effect? Record the results for different objects in a table.

Object	What happens when lowered towards pieces of paper?

5. Rub a plastic object on a cloth for one minute. Then hold the object close to water running from a tap or jug. Describe what happens to the water.
6. Now try different objects and different cloths.
7. Write a discussion for this activity. Use the terms negative charge, positive charge, attract and repel to explain what happened in this activity.

Electrical Current

The other type of electricity is called electrical current because the electricity is moving from one place to another along a conductor. The atoms in metals have a special structure. Some of the electrons are able to move from one atom to another. In a piece of metal the electrons are randomly moving between atoms.

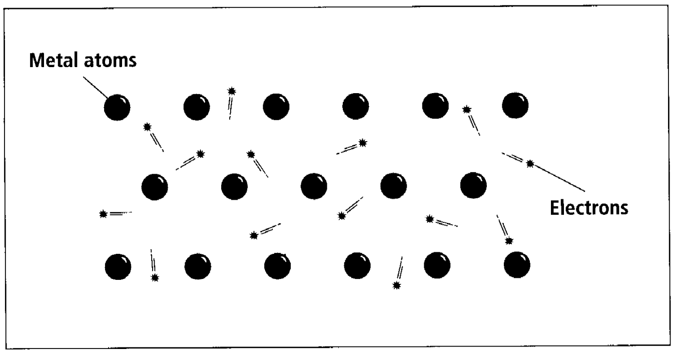


Diagram 6.11
Electrons moving between metal atoms in a wire.

When the metal is put into an electrical circuit the electrons that are moving between atoms stop moving randomly and, instead, all move in the same direction along the metal. The movement of the electrons in the same direction is called an **electric current**. The symbol **I** is used to stand for electrical current.

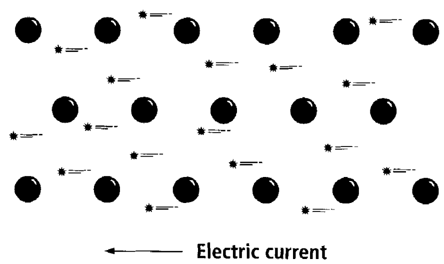


Diagram 6.12
Electrical current moving in a metal wire.

Activity 7

Materials needed:

One small container for each person in the class: e.g. Cups, bottom part from a plastic bottles;

A container of small stones.

Electric Current Model

Aim To understand what an electric current is.

1. Everyone in the class sits in a circle. Each person holds a container. In this model the people in the class are a wire and the container being held is a packet of electrons.
2. **Model an electric current flowing in the wire**. Each person hands their container to the person on their left and takes the container given to them by the person on the right. Continue passing on and receiving containers until the teacher says stop.
3. **Model a cell giving energy to a packet of electrons**. One person puts down their cup and holds a container of small stones. This person is the 'cell' that is supplying energy to the circuit. The stones are the energy that each packet of electrons gets when it passes through the cell. The class begins to pass their container from one person to another again. As each cup passes the 'cell' the person acting as the cell places a stone in the container. The cell continues adding one stone to each container. Continue passing on and receiving cups until half of the containers have stones in them.
4. **Model a circuit containing a cell and a user of electrical energy**: *e.g. A bulb.* The person holding the first container to have a stone in it becomes the bulb that is using electrical energy. The person tips the stone out of the container to represent the energy being used by the bulb and they pass on an empty container to the next person. The 'cell' continues adding one stone to each container and the 'bulb' continues to use the electrical energy. Continue passing on and receiving containers in this way until the teacher says stop.

5. In your exercise book describe how this model shows each of the following:
   a. Electric current.
   b. The cell supplying energy.
   c. The bulb using electrical energy.

Series And Parallel Circuits

The parts of a circuit can be joined in series or in parallel. When the parts in a circuit are in **series** all the electrical current flows through each part. In parallel circuits the electrical current splits and some goes in each wire.

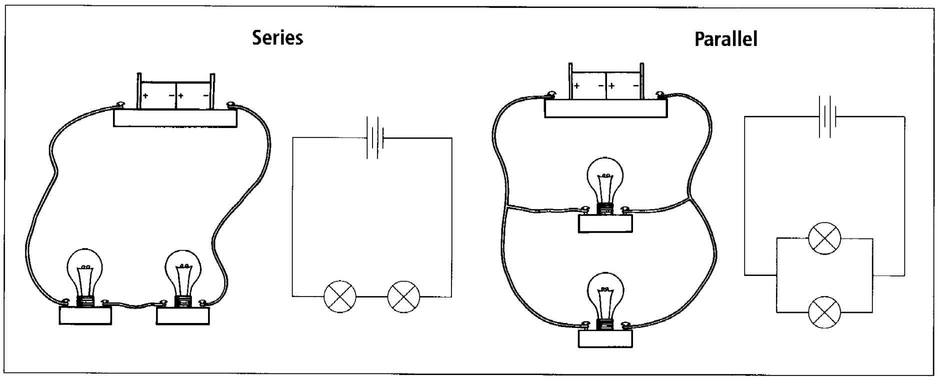


Diagram 6.13
Drawings and diagrams of two bulbs in series and parallel.

Activity 8

Materials needed:
Cells or power supplies;
Wires;
Bulbs.

Series And Parallel Circuits

Aim To set up series and parallel circuits.

- Copy the table below to record your observations.

	Series Circuit	Parallel circuit
Brightness of one bulb		
Brightness of two bulbs		
Brightness of three bulbs		
Description of path of current		
One bulb unscrewed		

Task 1 (series circuits)

1. Set up a circuit with one bulb.
2. Record the brightness of the bulb.
3. Add a bulb to your circuit so it becomes a series circuit the same as the one shown in Diagram 6.13 (on the previous page).
4. What do you notice about the brightness of the two bulbs in series? Record your observations.
5. Add a third bulb in series. What do you notice about the brightness of the three bulbs in series? Record your observations.
6. Describe the pathway of the current in a series circuit.
7. Unscrew one of the bulbs. What happens to the other two bulbs in the circuit? Record your answer.

Task 2 (parallel circuits)

1. Set up a circuit with one bulb.
2. Record the brightness of the bulb.
3. Add a bulb to your circuit so it becomes a parallel circuit the same as the one shown in Diagram 6.13 (on the previous page).
4. What do you notice about the brightness of the two bulbs in parallel? Record your observations.
5. Add a third bulb in parallel. What do you notice about the brightness of the three bulbs in parallel? Record your observations.
6. Describe the pathway of the current in a parallel circuit.
7. Unscrew one of the bulbs. What happens to the other two bulbs in the circuit? Record your answer.
8. Make statements comparing the ways series and parallel circuits work. Include brightness of bulbs, pathways and what happens when a bulb is removed.

Measuring Electrical Current And Energy

An electrical current will only flow if there is energy to move all the electrons in the same direction and an unbroken pathway for the electrons to move around. The amount of electrical current in a circuit is measured in a unit called **amps**. An amp is a measure of the number of electrons that go past a point in one second. The symbol **A** is used to stand for amps. An ammeter is used to measure the amount of electrical current in a circuit. An ammeter is joined in series with the other parts of the circuit.

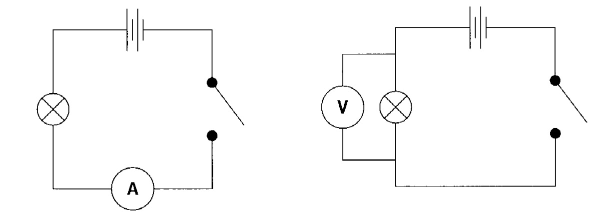


Diagram 6.14
Ammeter and voltmeter.

The energy around an electrical circuit drops as the electrons move through the parts of the circuit that use electrical energy. For example, when the electrical current moves through a bulb the bulb changes some of the electrical energy into heat and light. This drop of energy is measured using a **voltmeter**. The unit used to measure the difference in energy is a **volt** (V). A voltmeter is joined in parallel with the part across which the energy drop is being measured.

Activity 9

Materials needed:
Power supply or cells;
Wires;
Bulbs;
Ammeter.

Measuring Current In Series And Parallel Circuits

Aim To investigate the current in different parts of series and parallel circuits.

1. Copy the following table into your exercise book.

		Predicted current (A)	Actual current (A)
In Series	A		
(Circuit A)	B		
	C		
Parallel	A		
(Circuit B)	B		
	C		

2. Connect two bulbs in series with a power supply. Predict the current at points A, B and C. Record your predication in the table.
3. Use the ammeter to measure the current at the three points A, B and C shown on the circuit below. Record your results.
4. Make a statement about current in a series circuit.

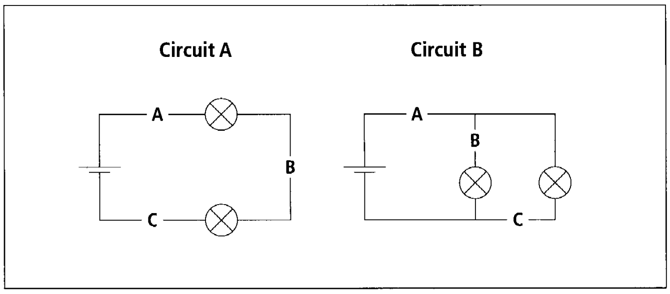


Diagram 6.15
Circuits in series and in parallel.

5. Connect two bulbs in parallel with a power supply. Predict the current at points A, B and C. Record your predication in the table.
6. Use the ammeter to measure the current at the three points A, B and C shown on the circuit above. Record your results.
7. Make a statement about current in a parallel circuit

Activity 10

Measuring Voltage

Materials needed:
Power supply or cells;
Wires;
Bulbs;
Voltmeter;

Aim To investigate the voltage in different parts of series and parallel circuits.

1. Connect two bulbs in series with a power supply.
2. Use the voltmeter to measure the voltage at the three points A, B and C shown on circuit C below.

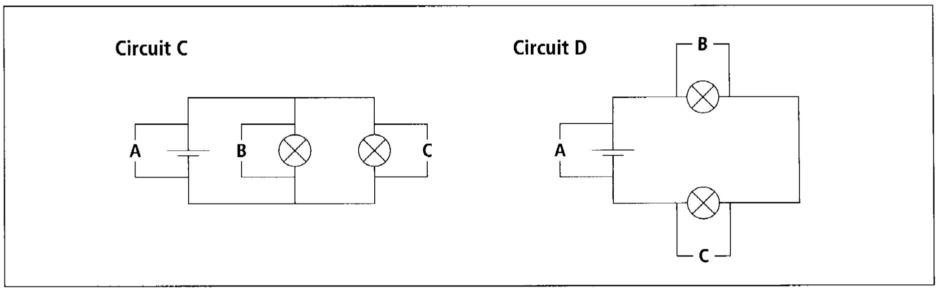


Diagram 6.16
Circuits C and D.

3. Make a statement about voltage around a series circuit.
4. Connect two bulbs in parallel with a power supply.
5. Use the voltmeter to measure the voltage at the three points A, B and C shown on circuit D.
6. Make a statement about voltage around a parallel circuit.

Activity 11

Materials needed:
Power supply or cells;
Wires;
Bulbs;
Ammeter;
Voltmeter.

Circuit Investigation

Aim To investigate current and voltage in a circuit.

1. Build a circuit that has both series and parallel connections. See the diagram below of circuits E and F for an example.
2. Measure the current at points A to G. Record the results.
3. Measure the voltage at points A to E on the diagram below. Record your results.

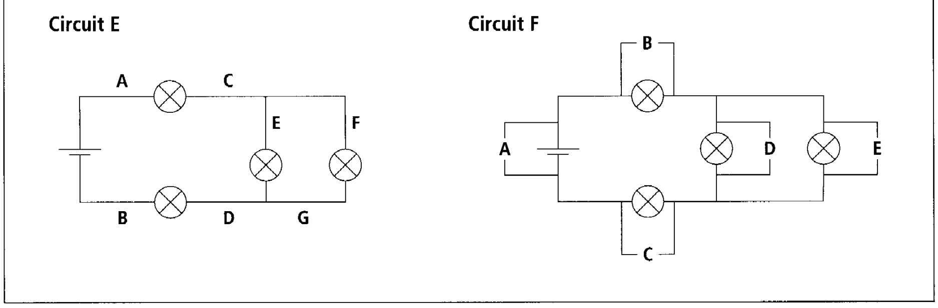


Diagram 6.17
Circuits E and F.

4. Build a different circuit and measure the current and voltage at different places in the circuit.
5. Make a statement about current in series and parallel circuits.
6. Make a statement about voltage in series and parallel circuits.
7. Read the following information and then check that your statements in questions 5 and 6 above are correct.

When two parts of a circuit are connected in series, the current moves from the first part of the circuit to the next. The current travelling through the two parts is the same.

$I_1 = I_2$

In a series circuit the current is the same all the way around the circuit.

When two parts of a circuit are connected in parallel, the current splits and some goes through each part.

$I_{total} = I_1 + I_2$

If the two parts have the same resistance then the current will split in half. When three or more parts are in parallel, each part will get a share of the current.

When two parts of a circuit are connected in series, the voltage is shared between the two parts.

$V_{total} = V_1 + V_2$

If the two parts have the same resistance then the voltage will split in half. When three or more parts are in series, each part will get a share of the voltage.

When two parts of a circuit are connected in parallel each part will get the full voltage produced by the cells or power supply.

8. Calculate the current readings for each of the following circuits.

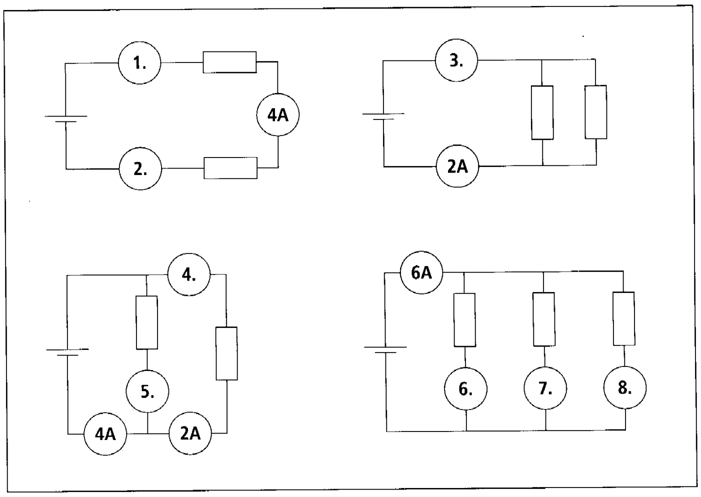


Diagram 6.18
The current in four circuits.

9. Are the lights in a fale or school connected in series or parallel? Explain your answer.
10. Calculate the voltage readings for each of the following circuits.

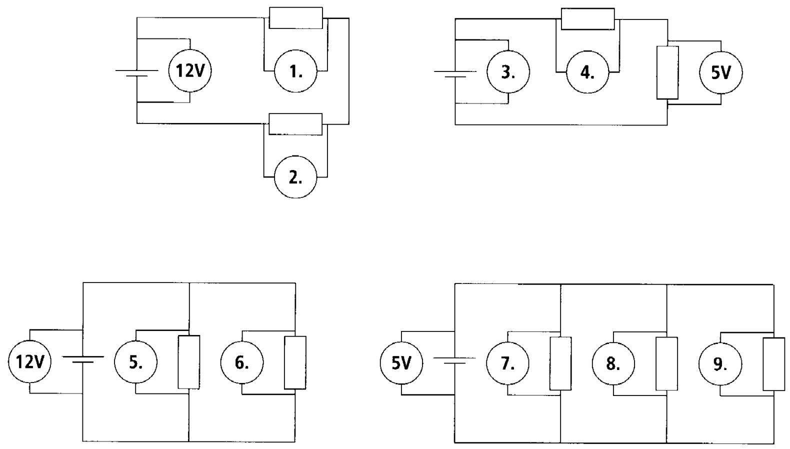


Diagram 6.19
Voltage in four circuits.

Activity 12 Study Notes

Aim To make study notes to use when revising this unit.

- Read through all the material you have covered in this unit.
- Read it again, this time highlighting the key science ideas.
- Rewrite the key science ideas into a different form so that you can use them as study notes. There are lots of different forms of study notes but they all have only the key words written down. Some people use diagrams.

Topic specific vocabulary for Year 11 Book 2 Science

Vocabulary	Useful words that go with the key word	Other words
to be attracted	attracted to	attraction
chemical	a chemical process, a chemical reaction, a chemical bond, chemical properties	
dense	less dense	density
devices	safety devices, control devices, measuring devices	
to be distributed	is evenly distributed	
element		elements
frequency	high frequency waves	
to interpret	are interpreted	
neutral	a neutralisation reaction	neutralisation
properties	the physical properties of the material, the chemical properties, adhesive and cohesive properties	
reactive		reactivity
reflection	the reflection rule, internal reflection, reflected off, the reflected rays, the reflecting surface, reflectors of light	reflections, reflected, reflecting, reflectors
refraction	a refracted ray	
	refracted	
to repel		
to sense	light sensitive	sensitivity
soluble	insoluble in water, solubility rules	insolubility
a source	a source of electricity, light sources	sources
term	long term exposure to, short term exposure, long term problems	
to vibrate		

Useful structures for Year 11 Book 2 Science

Expressing what happens during a process
During conduction heat energy is passed from one particle to the next.

Expressing the conditions for a process to occur
Convection currents occur when particles in a liquid or gas gain heat energy.
A chemical reaction occurs when the atoms in one, two or more chemicals join together in a different way.
Sometimes when the solutions of two metal compounds are mixed a solid material forms.
When carbon dioxide is added to limewater they react to form a precipitate of calcium carbonate.
When two parts of a circuit are connected in parallel, the current splits and some goes through each part.
If the two parts have the same resistance then the current will split in half.

Naming the outcome of a process
When a material is formed by atoms losing or gaining electrons the chemical bonds formed are called ionic bonds.
The chemical bonds formed inside a molecule where electrons are shared are called covalent bonds.

Explaining effects of things
Heat energy moves from hot areas to cold areas. *This means that* heat energy becomes evenly spread throughout an object.
The positively charged protons in the nucleus repel each other *so* the neutrons act as a 'glue' to hold the protons together in the nucleus.

Expressing comparison and contrast
Electrons are very small *compared to* protons and have a negative charge.
Light sources give out their own light *but* reflectors of light bounce light from a light source into our eyes.
Carbon dioxide is *denser* than air, so it will sink to the bottom of a container.
Incandescent bulbs are *more* efficient that fluorescent tubes.

Expressing the function of objects
Chilly bins are designed to slow down heat transfer by insulating the ice and food inside from heat energy.
Lasers are used to cut and drill holes in metals because they cut it quickly, easily and very accurately.
Fibre optic cables use thin laser beams of light to carry telephone conversations and computer data.

KEY VOCABULARY

Topic specific vocabulary for Year 11 Book Two Science

Related to chemical reactions and processes reactants corrosion neutralisation precipitation a redox reaction oxidised electrolysis a fuel cell micro-organisms methanol ethanol feed gas purification the refining process crude oil fractional distillation the fractionating tower cracking	**Related to the structure of materialsions** a molecule the atomic number the atomic mass electron clouds the mass number inert gases electron arrangement Lewis diagrams ionic bonds covalent bonds stable	**Related to metal compounds** metal compounds carbonates metal carbonates calcium carbonate chlorides oxides hydroxides a suspension a precipitate chloride compounds sulfate compounds nitrate compounds acetate compounds a decomposition reaction
Related to energy conduction convection radiation precipitation a particle protons neutrons the electron shell the atomic number the mass number convection currents electromagnetic radiation a vacuum heat transfer longitudinal waves the amplitudewavelength a positive charge a negative charge corrosiveuniversal indicator litmus	**Related to light and electromagnetic radiation** nerve impulses rod and cone cells organelles cornea iris pupil lens retina optic nerve a filament incandescent light bulbs fluorescent tubes electrodes ultraviolet light lateral inversion concave mirrors convex mirrors the centre of curvature the principal axis transparent translucent opaque fibre optic cables a prism a laser dispersion electromagnetic radiation carcinogenic	**Related to electricity** electric current electrical circuits series circuits parallel circuits a conductor an insulator static electricity amps an ammeter a volt a voltmeter high voltage