ENERGY AND MATTER

Chemical elements

Experiment 1: Common metallic elements demonstrated.

Experiment 2: Common non-metallic elements demonstrated.

Elements as the building blocks of matter

Matter is anything that has a mass and occupies space. An element is a pure substance which cannot be split up into other simpler units by any ordinary chemical process. It is a pure substance and constitutes the building units of all other known substances. An element is made up of its own types of atoms.

Chemical symbol

Elements have a name and a chemical symbol. A chemical symbol is a shorthand representation of the element. When we write the first letter in the symbol of an element, we use a capital letter. For example, the symbol of carbon is C.

The symbols of many elements also contain a second letter. In this case, the second letter is written as small letters, keeping its first letter a capital letter. For example, the symbol of chlorine is C*l*. Notice how the letter '*l*' is written so that the examiner does not think it is the capital letter 'I'.

The symbol of iodine should also be written as 'I' and not as 'l' to avoid confusion. The symbol of aluminium should be written as 'A*l*' and not as 'Al'.

Valency of an element

The valency of a chemical species is its combining power with other chemical species. It helps us to determine the chemical formula of a compound. A chemical formula is a shorthand representation of the compound.

Classifying elements as metals and non-metals

Elements can be classified as metals and non-metals. Examples of metals or metallic elements are iron, mercury, copper, gold, aluminium, etc. Examples of non-metals or non-metallic elements are carbon, sulfur (also written as ‘sulphur’), bromine, chlorine, oxygen, etc.

The table below gives the symbols and the valencies of selected elements:

Metal	Symbol	Valency	Non-Metal	Symbol	Valency
aluminium	*Al*	3	argon	Ar	0
barium	Ba	2	bromine	Br	1
calcium	Ca	2	carbon	C	2 or 4
copper	Cu	1 or 2	chlorine	*Cl*	1
gold	Au	1 or 3	fluorine	F	1
iron	Fe	2 or 3	helium	He	0
lead	Pb	2 or 4	hydrogen	H	1
magnesium	Mg	2	iodine	I	1
mercury	Hg	1 or 2	neon	Ne	0
potassium	K	1	nitrogen	N	3
silver	Ag	1	oxygen	O	2
sodium	Na	1	phosphorus	P	3 or 5
tin	Sn	2 or 4	silicon	Si	4
zinc	Zn	2	sulfur	S	2, 4 or 6

Distinguishing between metals and non-metals

Experiment 3: Some properties of metals demonstrated.

Experiment 4: Some properties of non-metals demonstrated.

The table below summarises the main differences between metals and non-metals, based on their properties:

Metals	Non-Metals
Shiny appearance when pure	Dull appearance (most non-metals)
Good conductors of heat	Poor conductors of heat
Good electrical conductors	Poor electrical conductors (except graphite)
They are malleable and ductile	They are usually brittle
They are solids under room conditions (except mercury)	They are solids or gases under room conditions (except bromine)
Bases and alkalis are obtained from metals	Acids and neutral compounds are obtained from non-metals

Compounds

Experiment 5: Common compounds used in the laboratory.

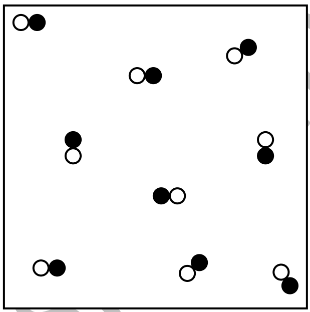
A compound is a pure substance, which contains two or more elements chemically combined together in a fixed proportion. Each compound has a name and a chemical formula, for example, water is a compound and has formula H_2O. Carbon dioxide is another compound of formula CO_2.

When compounds are formed, energy is either given out or absorbed.

A compound does not retain the properties of the elements it contains. Magnesium is a metallic element and it appears as a grey shiny solid. Oxygen is a non-metallic element and it appears as a colourless gas. When magnesium is burned in the oxygen of the air, a chemical reaction occurs and a new substance is formed. This new substance, which is different from magnesium and oxygen, appears as a white powder and is given the name magnesium oxide.

Compounds can be broken down into simpler substances using heat (thermal decomposition) or electricity (electrolysis). If we melt the white solid magnesium oxide and then pass an electric current through it, we can get back the magnesium and the oxygen gas.

The diagram below represents a compound in the gaseous state. It is made up of two different elements chemically combined together.



Determining chemical formulae of simple compounds

When two or more atoms combine, they form a molecule. Molecules consisting of atoms of two or more elements are called compounds.

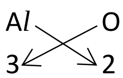
To write down the formula of a simple compound, containing only two elements, proceed as follows:

1. Recall and write down the symbols of the two elements it contains, side by side.
2. Recall and write down the valency of each element below the symbol of that element.
3. Cross-arrange the symbol of one element with the valency of the other element.
4. Simplify the formula of the compound to its lowest terms, if necessary.

Worked example:

Write down the formula of the compound aluminium oxide.

Aluminium has symbol A*l* and its valency is 3. Oxygen has symbol O and its valency is 2.



The formula of aluminium oxide is Al_2O_3.

The above formula contains 2 aluminium atoms and 3 oxygen atoms.

Mixtures

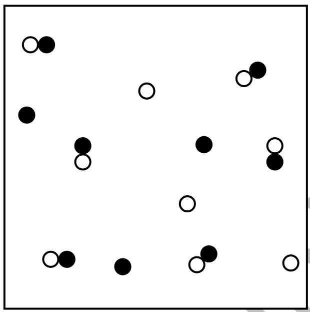
Experiment 6: Making and separating a mixture of sulfur powder and iron filings.

A mixture is an impure substance which contains two or more elements or compounds in proportions which may vary. The elements or compounds present in the mixture may vary in proportion, yet it will still be a mixture.

A mixture retains the original properties of each element or compound present in it. For example, air, which is a mixture of gases, will allow things to burn in it because it contains oxygen. Air will also turn limewater milky because it contains carbon dioxide.

When a mixture is prepared no heat or light energy is given out or absorbed.

Examples of common mixtures are sea water, petroleum, soap, beer, etc.



The above diagram shows a mixture in the gaseous state. This mixture contains two different elements and one compound.

Physical and chemical changes

Experiment 7: Observing some physical changes.

Experiment 8: Observing some chemical changes.

The following table summarises the main differences between a physical and a chemical change:

Physical change	Chemical change
Produces no new substance. For example, melting an ice cube will not change the mass of the water.	Always produces a new substance. For example, burning a piece of magnesium (grey, shiny solid) in oxygen (colourless gas) will produce magnesium oxide (white solid).
Is generally reversible. For example, the steam that we obtain from boiling water can be cooled down to obtain the liquid water back.	Is generally irreversible. When iron rusts in the presence of air and moisture, the rust formed cannot be easily converted back into iron. This is why rusting is considered as a wasteful process.
Is not accompanied by energy changes, except for those involving changes of states. When a piece of iron is magnetised it does not absorb or give out heat or light.	Is accompanied by considerable heat changes. If a small piece of sodium is dropped into water there is so much heat evolved that a flame is observed.
Produces no change in mass. Thus, if we heat a filament by passing an electric current through it, the filament does not become heavier or lighter.	Produces substances whose masses are different from those of the original substances. Magnesium oxide will be heavier than the piece of magnesium which originally produced it by burning.

THE ENVIRONMENT

Air pollution: causes, consequences and prevention

Most air pollution comes from burning substances called fossil fuels, such as coal and petrol. Air pollution may affect humans directly, causing diseases such as cancer, bronchitis, emphysema and asthma. More indirectly, the effects of air pollution are experienced through gradual change to climates all over the world. For example, the growing use of fossil fuels has led to a build-up of carbon dioxide in the atmosphere, causing global warming. Another serious effect of pollution is acid rain. This occurs when certain gases created by burning fossil fuels combine with particles of water in the atmosphere. When these particles fall to the ground as rain or snow, they damage forests, soils, bodies of water and buildings.

Air pollution can be prevented by:

1. changing to cleaner fuels and processes,
2. strictly checking pollution levels in automobiles' exhaust emission,
3. using devices for filtering smoke in chimneys of factories and powerhouses,
4. using smokeless sources of energy like smokeless stoves, which use biogas or solar energy.

Water pollution: causes, consequences and prevention

Water pollution is caused when people dump tonnes of rubbish of all kinds into the ocean, lakes, rivers and streams. Factories sometimes dump oils, poisonous chemicals and other harmful industrial waste into them. Some cities and towns pour waste-carrying water into them. When chemical fertilisers seep into the ground, they can make the groundwater unfit to drink. The chemicals also may drain into rivers and lakes, where they can harm fish and other forms of life.

Water pollution can be prevented by:

1. using environmentally friendly household products, and by trying not to overuse chemical fertilizers, pesticides, and herbicides,
2. recycling various products, instead of dumping them into rivers, e.g., biogas can be made from city waste,
3. treating sewage and industrial waste before throwing them into river bodies.

SUSTAINABLE LIVING—USE OF RESOURCES

Global warming

Global warming refers to the measurable increases in the average temperature of the Earth's atmosphere, oceans and landmasses. Gases like carbon dioxide, methane or nitrogen dioxide can trap too much of the Sun's heat and cause global warming.

Carbon dioxide and nitrogen dioxide come from the burning of fossil fuels like petroleum, coal and natural gas (methane).

Global warming will cause a rise in the sea level. It will also be responsible for destructive climatic conditions. This will eventually cause the extinction of many plant and animal species.

HEALTH AND SAFETY

Acids

An acid is a hydrogen containing compound which, when dissolved in water, can produce a solution of pH less than 7. We can also define an acid as a compound, which turns damp blue litmus paper red. Examples of acids are hydrochloric acid (formula HC*l*), sulfuric acid (H_2SO_4), nitric acid (HNO_3), ethanoic acid and carbonic acid.

Properties of acids

1. Acids turn litmus paper red. They will also turn phenolphthalein indicator colourless and turn methyl orange indicator red.

Experiment 9: To show the colours produced by a strong acid on litmus, phenolphthalein, methyl orange and Universal indicators.

2. Acids react with bases and alkalis to produce a salt and water only. This type of reaction is called a neutralisation.

   acid + base or alkali ⟶ salt + water

   For example, hydrochloric acid will react with sodium hydroxide to form sodium chloride and water. The word equation for this reaction is:

   hydrochloric acid + sodium hydroxide ⟶ sodium chloride + water

3. With reactive metals, acids produce a salt and hydrogen gas.

   acid + reactive metal → salt + hydrogen

   For example, zinc will react with sulfuric acid to produce zinc sulfate and hydrogen gas:

   zinc + sulfuric acid → zinc sulfate + hydrogen

   Note: If the hydrogen is collected in a test tube, it will pop with a lighted splint. This is the test for hydrogen gas.

Experiment 10: To show the reaction between zinc and hydrochloric acid.

4. Acids react with carbonates to produce a salt, water and carbon dioxide gas.

   acid + carbonate → salt + water + carbon dioxide

   For example, nitric acid will react with calcium carbonate to form calcium nitrate, water and carbon dioxide gas:

   nitric acid + calcium carbonate → calcium nitrate + water + carbon dioxide

Experiment 11: To show the reaction between calcium carbonate and nitric acid.

Importance of acids

Some acids are found in food. They include acetic acid in vinegar, lactic acid in milk and citric acid in lemons. They often have a sour taste. Others are found in animals. The stomach makes an acid that helps break down food. Amino acids are the building blocks of helpful chemicals called proteins. Sulfuric acid is used to make fertilisers, dyes, drugs, explosives, detergents and certain batteries.

Bases and alkalis

A base is a compound, which reacts with an acid to form a salt and water only. Examples of bases are magnesium oxide and copper (II) oxide, which are oxides of metals.

If a base is readily soluble in water, we call it an alkali. An alkali is defined as a compound, which produces a solution of pH greater than 7. We can also define an alkali as a compound, which turns red litmus paper blue. Examples of alkalis are potassium hydroxide (formula KOH), sodium hydroxide (NaOH), calcium hydroxide and aqueous ammonia.

Properties of alkalis

1. Alkalis turn litmus paper blue. They will also turn phenolphthalein indicator pink and methyl orange indicator yellow.

Experiment 12: To show the colours produced by a strong alkali on litmus, phenolphthalein, methyl orange and Universal indicators.

2. Alkalis feel like soap because they are corrosive and they react with the skin.
3. Alkalis react with acids to form a salt and water only. For example, potassium hydroxide will react with sulfuric acid to form potassium sulfate and water:

   potassium hydroxide + sulfuric acid → potassium sulfate + water

Importance of bases and alkalis

Some bases and alkalis are used in foods or medicines. These often have a bitter taste. Examples of such bases include baking soda and milk of magnesia. Other bases are used in manufacturing. Sodium hydroxide (caustic soda or lye), breaks down animal and plant tissues. It is used to make soap, paper and artificial fibres.

Salts

Salts are compounds formed when an acid neutralises a base or an alkali. The first name of a salt tells us from which metal or metallic compound they have been prepared: for example, sodium chloride (found in common salt or kitchen salt) contains sodium. The second name of a salt tells us from which acid it has been prepared: for example, calcium sulfate (found in 'plaster of Paris') has been prepared from sulfuric acid.

Importance of salts

1. Ammonium phosphate is used as a fertiliser that helps plants produce strong roots.
2. Ammonium sulfate is a salt used as a nitrogen fertiliser to help plants grow well.
3. Calcium sulfate is used in plaster of Paris which is used as a cast for setting broken bones.
4. Potassium chloride helps plants carry out the process of photosynthesis. (One problem that may arise with these salts is that they are washed by heavy rains and they pollute our rivers and lakes).
5. Sodium bicarbonate is used in baking and in the treatment of mild indigestion.
6. Sodium chloride is used for food preservation and to enhance the taste of foods.
7. Sodium fluoride is used in toothpaste to prevent cavities.

Indicators

An indicator is a substance which has one colour in very acidic solutions and another colour in very alkaline solutions.

Name of indicator	Colour in strongly acidic solution	Colour in neutral solution	Colour in strongly alkaline solution
litmus	red	purple	blue
phenolphthalein	colourless	colourless	pink
methyl orange	red	orange	yellow

Indicators are used in the laboratory to exactly neutralise acidic or alkaline solutions, so that there is no excess of neither acid nor alkali left in the reaction mixture. This technique is called titration.

Neutralisation

Neutralisation is the reaction between an acid and an alkali to produce a neutral solution (containing a salt and water only). Thus, nitric acid and sodium hydroxide will neutralise each other to produce sodium nitrate and water:

$$\text{nitric acid} + \text{sodium hydroxide} \rightarrow \text{sodium nitrate} + \text{water}$$

Hydrochloric acid and calcium hydroxide will also neutralise each other to produce calcium chloride and water:

$$\text{hydrochloric acid} + \text{calcium hydroxide} \rightarrow \text{calcium chloride} + \text{water}$$

If the pH of a soil is low, such acidic conditions do not allow certain plants to grow well. The excess acidity can be treated using calcium hydroxide, which will neutralise the acid in the soil.

Neutralisation is used in every life to:

1. neutralise bee stings with weak alkalis like sodium bicarbonate (baking soda),
2. neutralise wasp stings with weak acids like ethanoic acid (vinegar),
3. neutralise the acids released by bacteria in the mouth with toothpastes,
4. excess acidity in the digestive system with antacids like sodium bicarbonate, calcium carbonate or magnesium hydroxide.

The pH scale and the Universal Indicator

The pH scale, which measures the acidity or alkalinity of a solution, ranges from 0 (very acidic) to 14 (very alkaline). Thus, on this scale acids have pH values less than 7, alkalis have pH values greater than 7 and neutral solutions have pH value equal to 7.

The pH indicator, also known as the Universal Indicator, is a mixture of several indicators and it can be used to estimate the pH or acidity of a solution. It is normally red in strongly acidic solutions (pH=0 to 2), yellowish-green in neutral solutions (pH=7) and violet in strongly alkaline solutions (pH=12 to 14).

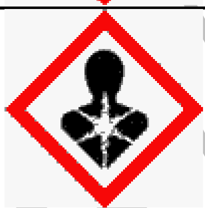
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
acidic							neutral	alkaline						
← more acidic														more alkaline →

Note: A pH meter, which is more accurate than the Universal Indicator, can also be used to measure the pH of a given solution.

Hazards associated with chemical substances

Many chemicals are useful to living organisms, but there are also many which are hazardous to them. A hazardous chemical substance is one which is toxic, harmful, corrosive or irritant. If not handled properly, it may cause death, poisoning, burns or irritations. Chemists use hazard symbols to indicate which danger is associated which a particular chemical, so that people handling them may take the necessary precautions.

Globally Harmonized System of Classification and Labelling of Chemicals (GHS) are now used to label chemical substances. Some examples are:

New international hazard symbol	Meaning	Examples
	Toxic, especially if swallowed	Pesticides, drain cleaners, laundry detergents, paints, bleach, mercury, etc.
	Corrosive	Acids (e.g. sulfuric acid), alkalis (e.g. caustic soda), etc.
	Flammable	Alcohols, cooking gas, petrol, etc.
	Longer term health hazards: may cause allergy, asthma symptoms or breathing difficulties if inhaled	Ammonia, chlorine, sulfur dioxide, some fragrance chemicals, etc.

SCIENCE AND TECHNOLOGY

Common applications of science and technology in our daily life

Deoxyribonucleic acid (DNA)

Experiment 13: To show a model of the structure of DNA.

In every living organism, all the information about how that organism will look and function is carried in a material called deoxyribonucleic acid, or DNA. In a human body, for instance, DNA tells the body what colour the eyes should be and how big the feet will grow. Each different piece of information is carried on a specific segment of the DNA. These segments are called genes. DNA is found tightly packed inside the nucleus of every cell of every living organism on Earth. This packaged form of the DNA is called a chromosome.

DNA is not visible to the naked eye. It can only be viewed with the most powerful microscopes. In 1953 scientists constructed a model of DNA using X-rays. The X-ray pattern showed that the structure of DNA had a shape a bit like two twisted ladders side by side. The discovery proved to be one of the most important scientific breakthroughs of the 1900s. It helped explain how evolution might work, and it has been used to develop greater understanding in all areas of genetic science. Genetics is the study of how traits are passed from one generation to the next through genes, which are made up of DNA.

When DNA is working correctly, it keeps the body functioning properly and allows it to reproduce. Mutations or changes of the DNA can cause diseases or other problems. In the late 20th century, scientists studying DNA learned how some mutations occur. Today they can identify the genes in the human body that control certain functions. Scientists working with plants can now alter their genes to make the plants resist certain pests. Experts now use DNA to identify people based on only a small sample of their cells.