Basic Essentials Of CHEMISTRY

CBC

SENIOR 4

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How to Use This Book

Welcome to your Chemistry Journey! This textbook is designed to make your learning experience engaging and informative. Here are some tips on how to make the most of it:

Read Actively:

Skim: Quickly go through the chapter headings, subheadings, and visuals to get an overview.

Read Carefully: Pay attention to key concepts, definitions, and examples.

Highlight and Annotate: Mark important points, ask questions, and write down your thoughts.

Engage with the Text:

Solve Problems: Practice the exercises and problems to solidify your understanding.

Conduct Experiments: Perform the suggested experiments to observe chemical phenomena firsthand.

Discuss with Peers: Share your ideas and ask questions to deepen your knowledge.

Use the Visuals: Diagrams and Graphs: Analyze the visual aids to understand complex concepts.

Tables and Charts: Use these to organize information and identify patterns.

Photographs: Observe real-world applications of chemistry.

Review Regularly:

Summarize: Write brief summaries of each chapter to reinforce key points.

Create Mind Maps: Visualize the connections between concepts.

Quiz Yourself: Test your knowledge with practice questions and quizzes.

Seek Help When Needed:

Consult Your Teacher: Ask questions and seek clarification.

Study Groups: Collaborate with classmates to discuss and solve problems.

Online Resources: Explore additional resources like educational websites and videos. By following these tips, you can enhance your learning experience and achieve academic success.

Introduction to Chemistry

Chemistry: The Science of Change
Chemistry is the science that explores the composition, structure, properties, and interactions of matter. It is the study of substances, atoms, molecules, and how they combine to form everything around us. From the air we breathe to the food we eat, chemistry plays a vital role in our daily lives.

Why Study Chemistry?

Understanding chemistry helps us:
Make Informed Decisions: By understanding the properties and effects of chemicals, we can make informed choices about the products we use.
Solve Real-World Problems: Chemists develop new materials, medicines, and technologies to address global challenges.
Appreciate the Natural World: Chemistry explains the beauty and complexity of the natural world, from the smallest atom to the largest galaxy.

Key Concepts in Chemistry

Matter and Its Properties: Learn about the different states of matter, their properties, and how they change.
Atoms and Elements: Explore the building blocks of matter, atoms, and how they combine to form elements.
Chemical Reactions: Discover the fascinating world of chemical reactions, how substances change, and the energy involved.
The Periodic Table: Understand the organization of elements and their periodic trends.
Acids and Bases: Learn about the properties of acids and bases and their applications.
Organic Chemistry: Explore the chemistry of carbon compounds, the basis of life.
As you delve into the world of chemistry, you will develop essential skills such as critical thinking, problem-solving, and experimental design. You will also gain a deeper appreciation for the interconnectedness of science and society.

Preface

Welcome to the World of Chemistry! This textbook is designed to introduce you to the fascinating world of chemistry, a science that explores the composition, structure, properties, and interactions of matter. As you journey through these pages, you will discover how chemistry is essential to our daily lives, from the food we eat to the technology we use. This book is aligned with the New Lower Secondary Curriculum, providing you with a solid foundation in key chemical concepts. Through engaging explanations, practical examples, and stimulating activities, you will develop a deep understanding of chemistry and its applications.

Key Features of This Book

Clear and Concise Explanations: Complex topics are broken down into simple, easy-to-understand concepts.
Real-World Applications: Numerous examples illustrate how chemistry is relevant to everyday life.
Engaging Activities: Hands-on experiments and projects encourage active learning and critical thinking.
Stunning Visuals: Colorful diagrams and photographs enhance understanding and make learning enjoyable.
Review Questions and Practice Problems: Reinforce learning and prepare for assessments.
We hope that this book inspires you to explore the wonders of chemistry and fosters a lifelong love of learning.

Happy exploring

1. OXIDATION AND REDUCTION

 

Competency: The learner understands oxidation and reduction in terms of gain or loss of oxygen and in terms of electron transfer, and he/she appreciates that the two processes always occur together.

Key words

- Oxidation
- Reduction
- Redox Reactions
- Oxidizing Agent
- Reducing Agent
- Electrolysis
- Electrolyte
- Electrode
- Oxidation Number
- Oxidation State

By the end of this topic, the learner should be able to;

- Understand the processes of oxidation and reduction and their importance in the chemical industry (u, s)
- Explain redox reactions in terms of electron transfer(u)
- Understand the changes that take place during the electrolysis of some compounds (u, s)

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Oxidation and **reduction** reactions are as common and well-known as fire, the oxidation and dissolution of metals, the discoloration of fruit, and respiration and photosynthesis—fundamental life processes.
Chemical reactions come in a variety of forms. Some of these reactions, like the burning of petrol and the rusting of iron, are things seen in our everyday life. The foundation for the creation of various compounds is a variety of crucial industrial reactions.
Chemical reactions involve the **transfer** of **electrons** from one chemical substance to another. These electron-transfer reactions are termed as **"oxidation-reduction reactions"** or **"redox reactions."** Energy changes in form of heat, light, electricity, accompany these reactions. The oxidation and reduction reactions also involve the addition of **oxygen** or **hydrogen** to different substances.

1.1. Oxidation Reactions

What is Oxidation?

Oxidation is the loss of electrons or loss of hydrogen or gain of oxygen. A chemical reaction that involves the combination of an element with oxygen is commonly referred to as oxidation.

The chemical reaction between magnesium metal and oxygen results in the formation of magnesium oxide, which is known as the oxidation of magnesium. An oxidizing agent function is to introduce oxygen to another substance.

Studying the process of burning Magnesium metal in air

Experiment: Oxidation of Magnesium

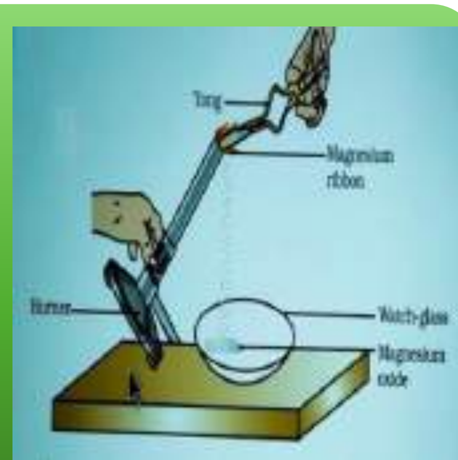
Question: What happens to magnesium metal when it reacts with oxygen in the air?
Hypothesis: When magnesium metal is heated in the presence of air (which contains oxygen), it will undergo oxidation, forming magnesium oxide. This reaction will be accompanied by the release of heat and light.

Materials

- Magnesium ribbon
- Bunsen burner
- Test tube holder

- Test tube
- Water
- Litmus paper

Procedure



- Extract 2cm of a piece of magnesium ribbon and clean it using sand paper.
- Hold the ribbon with a test tube holder and ignite it using a Bunsen burner flame.
- Observe the change as the magnesium burns.
- Use a watch glass to collect the substance formed after burning the ribbon.
- Add a few drops of water to the cooled substance and test with a litmus paper

Discussion questions

1) What did you observe during the burning?
2) Explain the reason for cleaning Magnesium ribbon with a sand paper.
3) Explain what happened to Magnesium metal.
4) Write an equation for the combustion of Magnesium.

Expected observation

The grey Magnesium metal burns with a bright sparkling white flame and produces a white powdery substance.

When a few drops of water is added to the cooled white substance, the resulting substance turns red litmus paper blue.

Explanation

During combustion, magnesium reacts with oxygen in the air to form magnesium oxide (white ash). This process is called **oxidation**

Equation

$$2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$$

Gain oxygen: Oxidation

Magnesium gains oxygen (oxidized).
The bright white light and the formation of white magnesium oxide powder indicate the oxidation of magnesium. The presence of oxygen in the water confirms that magnesium has gained oxygen.
This experiment demonstrates the concept of oxidation in terms of oxygen gain.
When an atom loses electrons, it becomes oxidized. E.g in the above reaction, magnesium loses electrons to oxygen.

Magnesium is oxidized.

$$Mg \longrightarrow Mg^{2+} + 2e^-$$

Food for thoughts

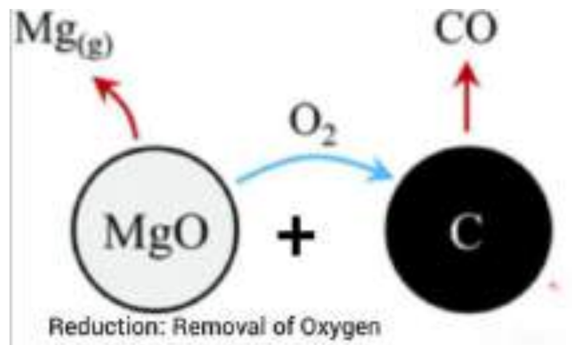
1) I).State the kind of Oxidation that occurs when dry ammonia is passed over heated copper (II) oxide.
   II).State what is observed and write the equation of reaction.

1.2. Reduction reactions

What is Reduction?

Reduction is the process of gaining electrons or gain of hydrogen or loss of oxygen.

The origin of the term reduction is from the Latin language, where it means "**to lead back**". At a temperature of 2000°C, magnesium oxide reacts with carbon to produce magnesium metal and carbon monoxide, which is an instance of magnesium oxide being **reduced** to magnesium metal. Reducing agents are responsible for eliminating oxygen from other substances.



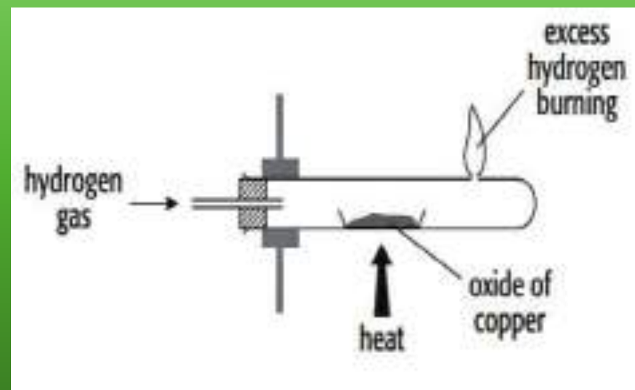
Experiment: Reduction of Copper(II) Oxide by Hydrogen

Materials:

- Copper(II) oxide (CuO)
- Hydrogen gas (H_2)
- Test tube
- Bunsen burner
- Delivery tube
- Clamp

Procedure:

1. Place a small amount of copper(II) oxide in a test tube.
2. Connect the test tube to a delivery tube and clamp.
3. Pass hydrogen gas through the test tube using a Bunsen burner to heat the gas.
4. Observe the reaction and note any changes.
5. Once the reaction is complete, carefully remove the test tube from the delivery tube and clamp.
6. Observe the resulting product and compare it to the original copper(II) oxide.



Observations:

- The copper(II) oxide will turn from black to reddish-brown as it reacts with the hydrogen gas.
- The resulting product will be copper metal.

Conclusion:

The experiment demonstrates the reduction of copper(II) oxide by hydrogen gas. The copper(II) oxide gains hydrogen to form copper metal, which is a reduction reaction.

Equation

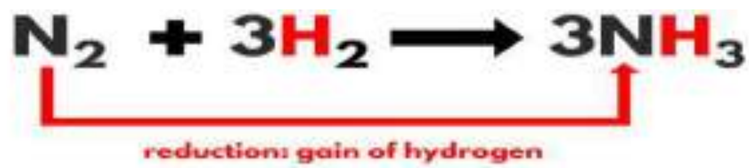
Reduction

$$CuO\,(s) + H_2\,(g) \longrightarrow Cu\,(s) + H_2O\,(g)$$

This experiment illustrates the concept of reduction by gain of hydrogen, where a substance gains hydrogen to form a new compound.

Reduction in the Haber Process: The Formation of Ammonia

A classic example of reduction involving hydrogen gain is the Haber Process, where nitrogen gas (N_2) reacts with hydrogen gas (H_2) to form ammonia (NH_3):



In this reaction:
Each nitrogen atom gains three hydrogen atoms to form ammonia (NH_3).
By gaining hydrogen atoms, the nitrogen atoms in N_2 are reduced to form NH_3.
This reaction is crucial for industrial processes, as ammonia is used in the production of fertilizers and other chemicals.

1.3. Classical Concept Of Oxidation and Reduction (Redox Reactions)

Redox reactions, short for **reduction-oxidation** reactions, are chemical reactions that involve the transfer of electrons between two species.
The addition of oxygen or the removal of hydrogen is classically referred to as **oxidation**, and the addition of hydrogen or the removal of **oxygen** is referred to as reduction. It demonstrates that oxidation and reduction are opposing processes. Two different types of reagents are required to carry out the oxidation-reduction reaction.

a. **Reducing Agents (Reductants)**

Reducing agents are substances that cause reduction by donating electrons.

- They readily lose electrons.
- When a reducing agent donates electrons, it itself undergoes oxidation (loss of electrons).

Reducing agents

- Hydrogen (H_2)
- Carbon (C)
- Hydrogen Sulphide (H_2S)
- Metals such as zinc (Zn), magnesium (Mg), and iron (Fe)
- Ammonia (NH_3)
- Sulphur dioxide (SO_2)

b. **Oxidizing Agents (Oxidants)**

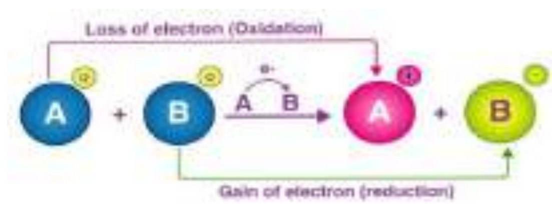
Oxidizing agents are substances that cause oxidation by the gain of one or more than one electron in a chemical reaction.

- They readily accept electrons
- When an oxidizing agent gains electrons, it itself undergoes reduction (gain of electrons).

Oxidizing agents

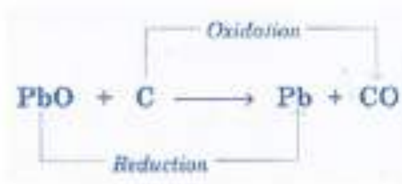
- Oxygen (O_2)
- Chlorine (Cl_2)
- Bromine (Br_2)
- Nitric acid (HNO_3)
- Concentrated Sulphuric acid (H_2SO_4)
- Hydrogen peroxide (H_2O_2)
- Potassium permanganate ($KMnO_4$)
- Potassium dichromate ($K_2Cr_2O_7$)

That is, the reducing agent (reductant) and the oxidizing agent (oxidant) are oxidized and reduced, respectively, in the provided oxidation-reduction reaction.

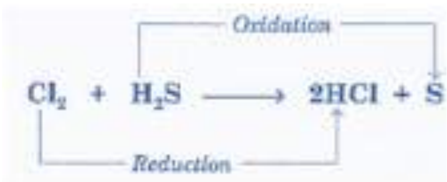


For Example:

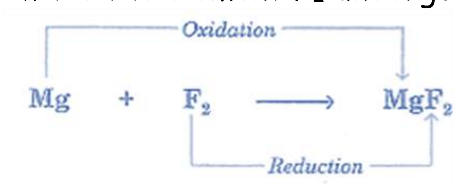
- **Reaction of PbO and carbon**: During the process, carbon (C) gains oxygen while lead oxide (PbO) loses oxygen. PbO undergoes reduction while C undergoes oxidation.



- **Reaction of H_2S and Cl_2**: Here, hydrogen is being removed from hydrogen sulphide (H_2S) and is being added to chlorine (HCl). Thus, H_2S is oxidized and Cl_2 is reduced.



- **Reaction between Mg and F_2**: The electronegative radical fluoride ion (F^-) is introduced to magnesium, while the electropositive radical Mg^{2+} is introduced to fluorine. Consequently, the element Mg undergoes oxidation while the element F_2 undergoes reduction.



Electronic Concept of Oxidation and Reduction

The electronic concept of a redox reaction is based on the electron transfer process.

A helpful mnemonic to remember is **"OIL RIG"**:

Oxidation Is Loss of electrons

Reduction Is Gain of electrons

Oxidation: The phenomenon of oxidation involves the loss of one or more electrons by an atom or a group of atoms participating in a chemical reaction. The loss of electrons causes the positive or negative charge of a species to increase or decrease, respectively.

$Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$ (loss of electron)
$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq + e^-$ (increase in positive charge)
$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$(decrease in negative charge)

Reduction: It is a chemical process whereby an atom or a group of atoms involved in a chemical reaction undergoes a gain of one or more electrons. The gaining of electrons leads to a reduction in the positive charge or an increase in the negative charge of the entity.

$O + 2e^- \rightarrow O^{2-}$ (gain of electron)
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$ (decrease in positive charge)
$S(s) + 2e^- \rightarrow S^{2-}(aq)$ (increase in negative charge)

Experiment: Demonstrating Redox Reactions

Materials

- Copper sulphate solution
- Zinc metal strip
- Test tube
- Beaker

Procedure

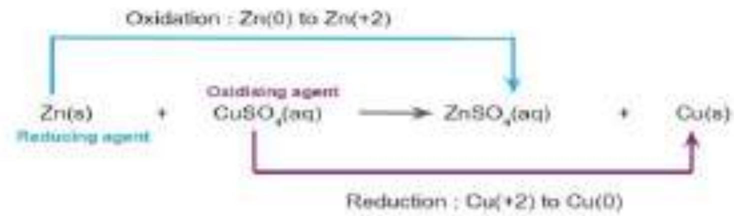
- Dissolve copper sulphate crystals in water to form a blue solution.
- Place zinc metal strip in the test tube, Ensure the zinc strip is clean and free of any coating.
- Add copper sulphate solution to the test tube
- Observe the reaction

Observation

The blue copper sulphate solution will react with the zinc metal.
You will notice that the zinc metal will start to dissolve, and a reddish-brown coating of copper metal will form on its surface. The blue color of the copper sulphate solution will fade as the copper ions are reduced to copper metal.

Zinc metal loses electrons (is oxidized) to become zinc ions (Zn^{2+}).

Copper ions (Cu^{2+}) from the copper sulphate solution gain electrons (are reduced) to become copper metal (Cu)



The overall reaction is a redox reaction, where both oxidation and reduction occur simultaneously.

Equation

$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$

This experiment clearly demonstrates the transfer of electrons between zinc and copper ions, highlighting the essence of redox reactions.

Oxidation and Reduction in Terms of Oxidation number

According to this concept, the **increase** in oxidation number means **Oxidation** (loss of the electron) whereas the **decrease** in oxidation number means **Reduction** (gain of electron).

Therefore, **Oxidation number** is the total number of **electrons gained/lost** by an atom or ion in a chemical reaction.

Oxidation state is the measure of the degree of oxidation or reduction of an atom in a compound.

The oxidation state of an atom can be determined using a set of rules, which vary depending on the specific element and the compound it is in.

Rules for assigning oxidation numbers

- The oxidation number of an uncombined element(when it is in its atomic or molecular state i.e Zn, Cl_2)is0.
- The oxidation number of a monatomic ion is equal to its charge i.e the Oxidation number of Zinc ion (Zn^{2+})is^{+}2.

- The sum of the oxidation numbers in a neutral compound is 0 i.e for sodium carbonate, Na_2CO_3,
  $2Na=2(^{+}1)$, $C=^{+}4$, $3O= 3\times(^{-}2)=^{-}6$
  $^{+}2+ ^{+}4+ ^{-}6= 0$.
- The sum of the oxidation numbers in a polyatomic ion is equal to the charge of the ion i.e for nitrate ions, NO_3^{-} the Oxidation number is $^{-}1$.
  I.e $N=^{+}5$, $3O= 3\times(^{-}2)=^{-}6$
  $^{+}5 + ^{-}6 =^{-}1$
- The oxidation state of hydrogen when bonded to a non-metal is $^{+}1$ but when it's bonded to a metal, the Oxidation number is $^{-}1$.
- The Oxidation number of Oxygen in compounds is $^{-}2$, except in peroxides where it has an Oxidation number of $^{-}1$.

The oxidation state of water (H_2O) is 0.
This is because the sum of the oxidation numbers of all the atoms in a neutral molecule must equal zero. In water, hydrogen has an oxidation number of +1 and oxygen has an oxidation number of -2. Therefore, 2(+1) + (-2) = 0.
For the reaction between Zinc and Sulphuric acid,
$$\mathbf{Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2}$$
The O.N of Zn increased from 0 to 2 i.e Zn got oxidized.
The O.N of H_2 decreased from 2 to 0 i.e H_2 got reduced.

Food for thoughts

a. Calculate the Oxidation number of the elements stated in the following substances.

i. Nitrogen in Nitrogen dioxide
ii. Carbon in the Carbonate ions.
iii. Lead in Lead (II) Oxide
iv. Magnesium in Magnesium Hydride
v. State how the Oxidation numbers of copper and Zinc changed in the reaction between Zinc and Copper (II) sulphate.

Half Equations

Half-equations are mathematical expressions that represent one of the two half-reactions involved in a redox reaction.

Redox reactions comprise of two distinct processes, namely oxidation and reduction. Half-equations delineate individual processes in relation to the movement of electrons. One of the equations illustrates the oxidation process, which involves the loss of electrons, while the other equation depicts the reduction process, which entails the acquisition of electrons.

Example:

$$Ag^{+} + Al \rightarrow Ag + Al^{3+}$$

Reduction half-reaction:

$$Ag^{+} + e^{-} \rightarrow Ag$$

Aluminum is oxidized, losing three electrons to change from Al to Al^{3+}:

Oxidation half-reaction:

$$Al \rightarrow Al^{3+} + 3e^{-}$$

To combine these two half reactions and cancel out all the electrons, we need to multiply the silver reduction reaction by 3:

$$3\ (Ag^{+} + e^{-} \rightarrow Ag)\ldots\ldots\ldots\ldots\ldots\ldots 1)$$

$$Al \rightarrow Al^{+} + 3e^{-}\ \ldots\ldots\ldots\ldots\ldots\ldots 2)$$

From eqn 1 and 2,

$$3Ag^{+} + Al \rightarrow 3Ag + Al^{3+}$$

- The equation has achieved balance not only in regard to the elements but also with respect to the electrical charge.
- The substance that has undergone oxidation is referred to as the oxidized substance, Al
- The substance that has undergone reduction is referred to as the reduced substance, Ag^{+}
- Aluminum serves as the reducing agent and the oxidized substance.
- The oxidizing agent is the same as the reduced substance: Ag^{+}

Reduction and Oxidation Processes in Chemical Industries

Redox reactions are fundamental to various chemical industries. They involve the transfer of electrons between species:

Oxidation: Loss of electrons.

Reduction: Gain of electrons.

Various ores exists on the earths' crust, such as

Element	Ore	Formula
Aluminum (Al)	Bauxite	$Al_2O_3 \cdot 2H_2O$
Iron (Fe)	Hematite, Magnetite	Fe_2O_3, Fe_3O_4
Copper (Cu)	Copper Pyrite, Malachite	$CuFeS_2$, $CuCO_3 \cdot Cu(OH)_2$
Calcium (Ca)	Limestone, Gypsum	$CaCO_3$, $CaSO_4 \cdot 2H_2O$
Zinc (Zn)	Zinc Blende, Calamine	ZnS, $ZnCO_3$

These reactions (Redox reactions) are essential for processes such as:

Metallurgy

Battery Technology

Organic Synthesis

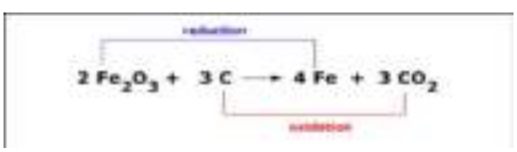
Environmental Remediation

Applications of Redox Processes in Chemical Industries

- **Metallurgy**

Redox reactions are fundamental to the process of metal extraction. These reactions involve the transfer of electrons between chemical species. In the context of metal extraction, redox reactions are used to reduce metal ions in ores to their elemental form.

Extraction of Metals: Many metals, like iron, copper, and aluminum, are extracted from their ores through redox reactions. For instance, in the blast furnace, iron ore (Fe_2O_3) is reduced to iron metal using carbon(in the form of coke) as a reducing agent:



Electrolytic Refining: Impure metals are refined using electrolysis, a process that involves oxidation and reduction reactions. For example, copper is refined by electrolyzing a solution of copper sulphate.

Why Redox Reactions are Crucial

Metal Recovery: Redox reactions allow for the efficient recovery of metals from their ores, which are often metal compounds.
Purity of Metals: By carefully controlling the redox conditions, it's possible to obtain high-purity metals.
Energy Efficiency: Redox reactions can be optimized to minimize energy consumption and maximize metal yield.

- **Battery Technology**

Primary Batteries: These batteries undergo irreversible redox reactions. For instance, in a zinc-carbon battery, zinc is oxidized, and manganese dioxide is reduced.

Secondary Batteries: These batteries can be recharged, involving reversible redox reactions. In a lithium-ion battery, lithium ions move between the anode and cathode during charging and discharging, leading to oxidation and reduction reactions.

- **Environmental Remediation**

Water Treatment: Redox reactions are used to remove pollutants from water. For example, chlorine is used to oxidize organic contaminants, while iron(II) sulphate is used to reduce contaminants like chromium(VI).

Soil Remediation: Redox reactions can be employed to clean up contaminated soil. For instance, zero-valent iron can be used to reduce contaminants like chlorinated solvents.

Contributions of Metal Extraction to the Ugandan Economy

Uganda's mining sector, though relatively young, has the potential to significantly contribute to the country's economic growth. Here are some of the key contributions:

- **Foreign Direct Investment (FDI)**

Attracting Investment: The discovery of valuable mineral resources, such as gold, copper, and cobalt, attracts significant foreign investment. This influx of capital can stimulate economic growth and create jobs. Technology Transfer: Foreign investors often bring advanced mining technologies and expertise, which can benefit the local mining industry and contribute to technological advancement.

- **Revenue Generation**

Export Earnings: The export of minerals, particularly gold and copper, generates foreign exchange earnings for the country.
Tax Revenue: Mining companies pay taxes and royalties to the government, contributing to public revenue.
Licensing Fees: The government earns revenue from licensing fees for mining operations.

- **Job Creation**

Direct Employment: The mining sector directly employs a significant number of people, both skilled and unskilled, in various roles such as mining, processing, and administration.
Indirect Employment: The mining sector also generates indirect employment in supporting industries like transportation, logistics, and hospitality.

- Infrastructure Development

Road and Rail Networks: Mining operations often require the construction of roads and railways to transport minerals to processing facilities and ports. This infrastructure development can benefit the broader economy.
Power Generation: Increased demand for electricity to power mining operations can stimulate the development of power infrastructure.

- **Local Economic Development**

Community Development: Mining companies often implement community development programs to improve the living standards of local communities. These programs may include building schools, hospitals, and providing clean water.

Local Procurement: Mining companies can source goods and services locally, boosting local businesses and economies.

Experiment: Investigating Redox Reactions

Aim: To investigate redox reactions and identify the oxidizing and reducing agents involved.

Materials:

- Test tubes
- Test tube rack
- Droppers
- Solutions of:
  - Potassium permanganate ($KMnO_4$)
  - Iron(II) sulphate ($FeSO_4$)
  - Potassium iodide (KI)
  - Chlorine water
  - Dilute Sulphuric acid (H_2SO_4)

Procedure:

Experiment 1: Reaction between Potassium Permanganate and Iron(II) sulphate

- Add a few drops of dilute Sulphuric acid to a solution of iron(II) sulphate in a test tube.
- Slowly add a few drops of potassium permanganate solution to the iron(II) Sulphate solution.
- Note the color change.

Experiment 2: Reaction between Potassium Iodide and Chlorine Water

- Add a few drops of potassium iodide solution to a test tube.
- Slowly add a few drops of chlorine water to the potassium iodide solution.
- Note the color change.

Observations and Explanations:

Experiment 1

Observation: The purple color of potassium permanganate fades, and the solution turns yellowish-brown.

Explanation:

Oxidation: Iron(II) ions are oxidized to iron(III) ions:

$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$

Reduction: Manganese(VII) ions in potassium permanganate are reduced to manganese(II) ions:

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$

Overall Reaction:

$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$

In this reaction, iron(II) Sulphate acts as a reducing agent, while potassium permanganate acts as an oxidizing agent.

Experiment 2:

Observation: The colorless solution turns brown.

Explanation

Oxidation: Iodide ions are oxidized to iodine:

$2I^-(aq) \rightarrow I_2(aq) + 2e^-$

Reduction: Chlorine is reduced to chloride ions:

$Cl_2(aq) + 2e^- \rightarrow 2Cl^-(aq)$

Overall Reaction:

$Cl_2(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2Cl^-(aq)$

In this reaction, potassium iodide acts as a reducing agent, while chlorine water acts as an oxidizing agent.

Distinguishing Redox and Non-Redox Reactions

Redox reactions involve the transfer of electrons between chemical species. They involve,

- Oxidation: Loss of electrons
- Reduction: Gain of electrons

Identifying Redox Reactions:

- Change in Oxidation States

A change in oxidation number of an element indicates a redox reaction.

- Presence of Oxidizing and Reducing Agents

An oxidizing agent gains electrons (is reduced).
A reducing agent loses electrons (is oxidized).

Non-redox reactions do not involve the transfer of electrons. They typically involve acid-base reactions, precipitation reactions, or complex formation.

Examples of Non-Redox Reactions

Acid-Base Reactions

$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

No change in oxidation states of any element.

Precipitation Reactions

$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

No change in oxidation states of any element.

Key Differences Between Redox and Non-Redox Reactions

Feature	Redox Reactions	Non-Redox Reactions
Electron Transfer	Occurs	Does not occur
Oxidation States	Change	Remain constant
Examples	Rusting, combustion, electrolysis	Acid-base reactions, precipitation, complex formation

1.4. Electrolysis

Electrolysis is a chemical process that can be used to **separate ionic compounds** into their constituent ions, when in **solution** or **molten state**, by using an **electrical current(electricity)** to drive **chemical reactions**. Electrolysis makes use of electrostatic attractions to pull the ions in a solution in opposite directions. This is what gives rise to the word electrolysis, which means to **split using electricity**. Substances **must be in solution or molten state** to undergo electrolysis as the ions of the substance need to be able to **move freely**. If the substances were solid then the ions within them would be bound in place and unable to separate.

What is Electrolysis?

Electrolysis is a process by which an electric current is passed through a solution or molten substance, causing chemical changes to occur at the electrodes. This process involves the oxidation of anions at the anode and the reduction of cations at the cathode in an electrolyte solution.

Key concepts

- **Electrolyte**: A substance that **conducts electricity** when dissolved in water. Examples include copper(II) sulphate, sodium chloride, and Sulphuric acid.
- **Electrodes**: Conductors that allow the passage of **electric current**. The **anode** (positive electrode) and **cathode** (negative electrode) is where the **chemical reactions** take place. The electrodes commonly used are carbon and platinum since they are generally inert and do not participate in the reaction.

- **Ion**: A **charged** particle that moves through the electrolyte solution.
- **Power source**: A device that provides the **electric current** for electrolysis.
- **Electrolytic cells** are devices that use electrical energy to drive non-spontaneous chemical reactions. They consist of:
  Electrodes, Electrolyte and Power source

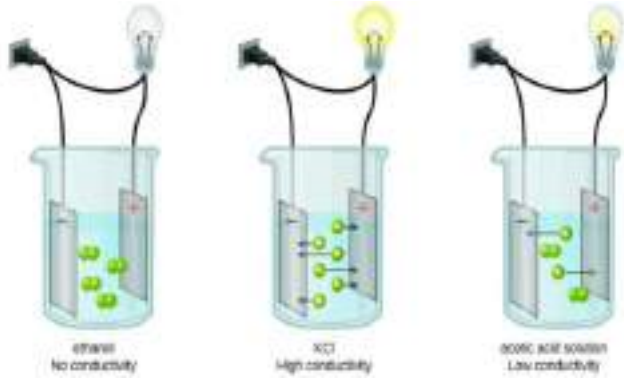
- **Electron transfer**: The transfer of electrons between **ions** and **electrodes** during electrolysis. In an electrolytic cell, **electrons flow** from the **external power source**, through the **electrolyte**, and between the **electrodes**. The **anode** is where **oxidation** occurs, meaning **electrons** are **released**. The released electrons **flow out** of the **anode** and into the **external circuit**.
- The electrons flow through the external circuit, driven by the **potential difference (voltage)** provided by the **power source.**
- The **cathode** is where **reduction** occurs, meaning **electrons** are **gained**. The electrons from the external circuit **flow into** the **cathode**, where they are used to **reduce the ions** in the **electrolyte**.
- As the electrons flow through the external circuit, **ions** in the **electrolyte move** to **balance** the charge. The combination of electron flow and ion movement allows the **electrolyte** to be **broken down** into its **constituent elements**, hence electrolysis process.

Electrolyte, Moving Ions, and Electrical Conductivity

Electrolyte: An electrolyte is a substance that, when dissolved in water, produces a solution that can conduct electricity. This is because electrolytes dissociate into ions when dissolved in water.

Strong electrolytes	**Weak electrolytes**
<u>Strong Acids:</u> Hydrochloric acid (HCl) Nitric acid (HNO_3) Sulphuric acid (H_2SO_4) <u>Strong Bases:</u> Sodium hydroxide ($NaOH$) Potassium hydroxide (KOH) Calcium hydroxide ($Ca(OH)_2$) <u>Salt solutions:</u> Sodium chloride ($NaCl$) Potassium chloride (KCl) Magnesium sulphate ($MgSO_4$)	<u>Weak Acids:</u> Acetic acid (CH_3COOH) Carbonic acid (H_2CO_3) <u>Weak Bases:</u> Ammonia (NH_3)

Moving Ions:



Cations: Positively charged ions.
Anions: Negatively charged ions.
When an electrolyte dissolves in water, it breaks apart into its constituent ions. These ions are free to move around in the solution.

Electrical Conductivity:

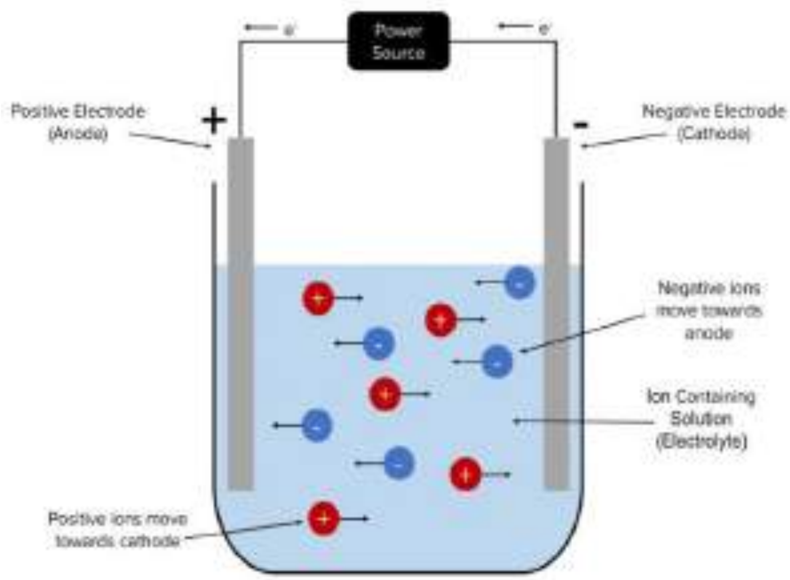
Current Flow: When electrodes are placed in an electrolyte solution and connected to a battery, an electric current flows through the solution.

Ion Movement: The cations in the solution are attracted to the negative electrode (cathode), and the anions are attracted to the positive electrode (anode).
Charge Transfer: As the ions move towards the electrodes, they carry electric charge, allowing the current to flow.
Electrolytes conduct electricity due to the presence of free ions that can move and carry electric charge. This movement of ions enables the flow of electric current through the solution.

Note: The conductivity of an electrolyte solution depends on factors such as the concentration of ions, the type of ions, and the temperature of the solution.

The Electrolysis Process

The electrodes (**Cathode** and **Anode**) are dipped in a solution of the compound(**electrolyte**). The **cathode** is negatively charged and the **anode** is positively charged. The substance must be ionic, meaning it must be made up of ions that are free to move. This can be achieved by dissolving the substance in water or melting it until it becomes a liquid.



The electrodes are then connected to an electrical power source, allowing a circuit to be set up. In most cases these electrodes are **inert** (meaning that they do not react). This prevents the **electrolyte** from **reacting with the electrodes**. An **electric current** is made to flow from the power source to the electrodes, with the **electrolyte carrying charge between them** to complete the circuit. This causes the ions of the electrolyte to **move** towards them, causing the compound to **decompose**.
The **positive ions** of the electrolyte will be **attracted to the negative charge of the cathode**. This causes the ions to move through the solution towards the **cathode**. At the **Cathode,** reduction occurs as the electrons flow in from the external circuit.
The **negative ions** of the electrolyte will be **attracted to the positive charge of the anode**. This causes the ions to move through the solution towards the **anode**. At the **anode**, Oxidation of ions occur. The electrons that are released by this process will then be collected by the cathode to flow into the external circuit.
Once an ion has been oxidized or reduced it is **discharged** from the solution. Discharged species will often leave the solution either as **solid** sediments or as **gasses**.

Experiment: investigating Electrical Conductivity of Solid and Molten Substances

Materials

- Conductivity tester
- Solid substances (e.g., salt, sugar, copper sulfate, graphite)
- Crucible
- Bunsen burner
- Heat-resistant gloves

Procedure

- Test solid substances
- Connect the conductivity tester to the solid substance.
- Observe if the light bulb on the conductivity tester lights up.
- Record your observations.
- Test molten substances
- Place a small amount of the solid substance in the crucible.
- Heat the crucible using a Bunsen burner until the substance melts.
- Carefully dip the conductivity tester into the molten substance.
- Observe if the light bulb on the conductivity tester lights up.
- Record your observations.

Observations and Conclusions

Solid substances

Ionic solids (e.g., salt, copper sulphate): Generally do not conduct electricity in their solid state due to the fixed position of ions.

Metallic solids (e.g., copper, iron): Good conductors of electricity due to the presence of free electrons.

Covalent solids (e.g., sugar, graphite): Poor conductors of electricity, except for graphite, which has a layered structure with free electrons.

Molten substances

Ionic solids: Conduct electricity when melted due to the movement of ions.

Metallic solids: Remain good conductors of electricity in their molten state.

Covalent solids: Generally do not conduct electricity in their molten state.

Conclusion

Electrical conductivity depends on the presence of charged particles that can move freely

Ionic solids conduct electricity when melted due to the mobility of ions

Metallic solids conduct electricity both in solid and molten states due to the presence of free electrons

Covalent solids generally do not conduct electricity, except for those with a layered structure like graphite

Experiment: Electrical Conductivity of an Aqueous Solution

Materials

- Conductivity tester
- Various aqueous solutions (e.g., salt water, sugar water, distilled water, vinegar)
- Beaker

Procedure

- Dissolve the desired amount of solute in water to form various solutions.
- Dip the conductivity tester into the solution.
- Observe if the light bulb on the conductivity tester lights up.
- Record your observations.

Observations and Conclusions

Aqueous solutions of ionic compounds (e.g., salt water, vinegar): Good conductors of electricity due to the presence of ions.

Aqueous solutions of covalent compounds (e.g., sugar water): Poor conductors of electricity due to the absence of ions.

Distilled water: A poor conductor of electricity due to its low ion concentration.

Conclusion

The electrical conductivity of an aqueous solution depends on the presence of ions

Ionic compounds dissociate into ions when dissolved in water, making their solutions good conductors

Covalent compounds do not dissociate into ions, resulting in poor conductivity of their aqueous solutions

Distilled water, with a very low ion concentration, is a poor conductor of electricity

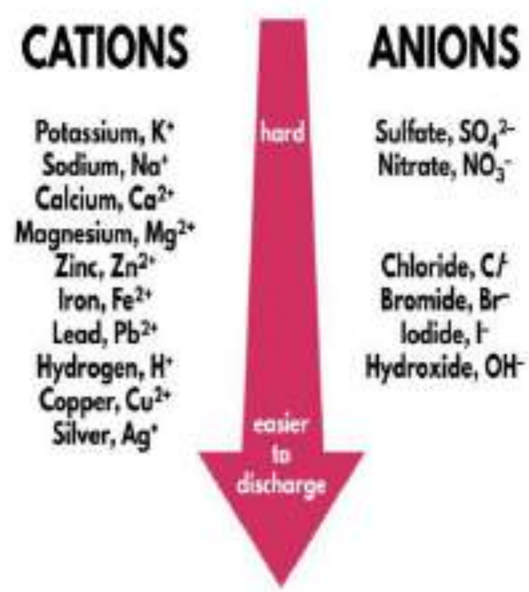
Selective Discharge of Ions at Electrodes

Selective discharge is the phenomenon where, during electrolysis, specific ions are preferentially discharged at the electrodes over others. This selectivity is influenced by several factors:

Factors Affecting Selective Discharge

1. **Position in the Electrochemical Series**:

Ions of metals lower in the reactivity series are more easily discharged. For example, in an aqueous solution containing both copper ions (Cu^{2+}) and sodium ions(Na^{+}), copper ions will be preferentially discharged at the cathode because copper is less reactive than sodium.



2. **Concentration of Ions:**

Ions with higher concentrations are more likely to be discharged. If a solution contains both concentrated copper ions and dilute sodium ions, copper ions will be discharged first.

3. **Nature of the Electrode:**

The nature of the electrode can influence the discharge of ions. For example, if a mercury cathode is used in the electrolysis of sodium chloride solution, sodium ions are preferentially discharged to form a sodium amalgam, even though hydrogen ions are usually discharged at the cathode.

Examples of Selective Discharge

- Electrolysis of Aqueous Copper(II) sulphate Solution:

At the cathode: Cu^{2+} ions are preferentially discharged over H^+ ions, as copper is less reactive than hydrogen.

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

At the anode: OH^- ions are preferentially discharged over SO_4^{2-} ions, as they are more readily oxidized.

$4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$

- Electrolysis of Aqueous Sodium Chloride Solution

At the cathode: H^+ ions are preferentially discharged over Na^+ ions, as hydrogen is less reactive than sodium.

$2H^+(aq) + 2e^- \rightarrow H_2(g)$

At the anode: Cl^- ions are preferentially discharged over OH^- ions.

$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

Electrolysis of Copper(II) Sulphate Solution

Electrolysis Setup:

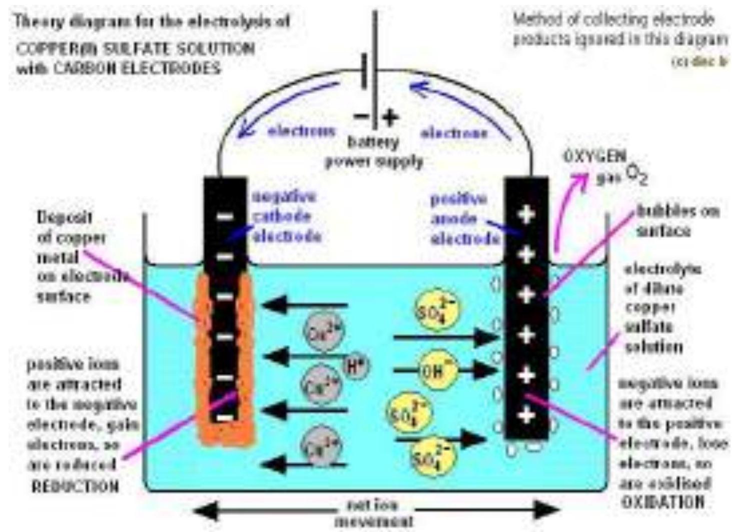
- Electrolyte: Copper sulphate solution ($CuSO_4(aq)$)
- Electrodes: Carbon rods (anode and cathode)
- Power Source: Direct Current (DC) power supply

Process

- Prepare a copper sulphate solution ($CuSO_4$) by dissolving copper sulphate crystals in distilled water.
- Sharpen two pencils to expose the lids, this act as carbon electrodes.
- Set up the electrolytic cell by placing the electrodes in the copper sulphate solution.
- Connect a DC power source (e.g., battery) to the electrodes.
- Pass an electric current through the solution, causing the copper ions to move towards the electrodes.

When copper sulphate dissolves in water, it dissociates into copper ions (Cu^{2+}) and sulphate ions (SO_4^{2-}).

Ion movement: Cu^{2+} (cations) move towards the cathode, while SO_4^{2-} (anions) move towards the anode



Electrode Reactions

Cathode(Negative Electrode):

Copper ions (Cu^{2+}) gain two electrons and are reduced to copper metal, which is deposited on the cathode:

$Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)$

You'll observe a reddish-brown coating of copper metal forming on the cathode.

Anode (Positive Electrode):

At the anode, water molecules (H_2O) lose electrons and are oxidized to form oxygen gas (O_2) and hydrogen ions (H^+).

$2H_2O\ (l) \rightarrow O_2\ (g) + 4H^+\ (aq) + 4e^-$

You'll observe bubbles of oxygen gas being released at the anode.

Overall Reaction:

$2CuSO_4(aq) + 2H_2O(l) \rightarrow 2Cu(s) + O_2(g) + 2H_2SO_4(aq)$

Observations:

Anode: Bubbles of oxygen gas are observed at the anode.

Cathode: A reddish-brown deposit of copper metal forms on the cathode.

Why Water is Oxidized at the Anode:

While both water molecules and sulphate ions are present at the anode, water is more readily oxidized than sulphate ions. This is due to the higher oxidation potential of water compared to sulphate ions.

Key Points:

- The use of carbon electrodes is suitable for this electrolysis as they are inert and do not react with the electrolyte.
- The blue color of the copper(II) sulphate solution fades as the copper ions are reduced and deposited on the cathode.
- This process can be used for electroplating, where a thin layer of copper is deposited onto another metal.

Electrolysis of Dilute Sulphuric Acid Using Carbon Electrodes

Electrolysis Setup:

- Electrolyte: Dilute Sulphuric acid ($H_2SO_4(aq)$)
- Electrodes: Carbon rods (anode and cathode)
- Power Source: Direct Current (DC) power supply

Process

- Prepare a Sulphuric acid solution (H_2SO_4) by diluting concentrated Sulphuric acid with distilled water.
- Use two carbon electrodes (e.g., graphite rods) made by sharpening the pencils to expose the lids
- Set up the electrolytic cell by placing the electrodes in the Sulphuric acid solution.
- Connect a DC power source (e.g., battery) to the electrodes.
- Pass an electric current through the solution, causing the ions to move towards the electrodes.

Electrode Reactions

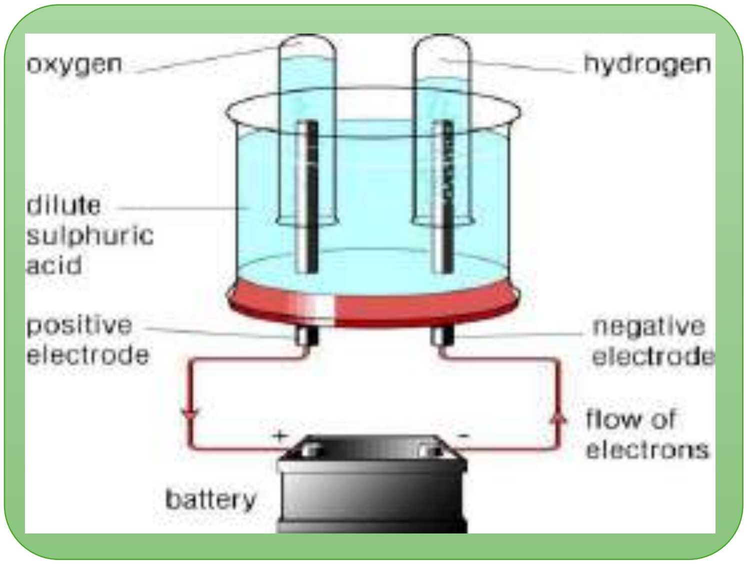
Anode (positive electrode): At the anode, sulphate ions (SO_4^{2-}) do not react, but water molecules (H_2O) lose electrons and are oxidized to form oxygen gas (O_2) and hydrogen ions (H^+).

$2H_2O\ (l) \rightarrow O_2\ (g) + 4H^+\ (aq) + 4e$

Cathode (negative electrode):

At the cathode, hydrogen ions (H^+) gain electrons and are reduced to form hydrogen gas (H_2), the gas can be identified by passing a burning splint through the Cathode, hydrogen gas burns with a pop sound.

$2H^+ (aq) + 2e^- \rightarrow H_2 (g)$



Observations and Results

- Hydrogen gas evolution: Observe the evolution of hydrogen gas at the cathode. Bubbles of hydrogen gas are observed at the cathode.
- Oxygen gas evolution: Observe the evolution of oxygen gas at the anode. Bubbles of oxygen gas are observed at the anode.
- Electrolyte color change: Note the absence of a significant color change in the electrolyte.

Why Water is Oxidized at the Anode:

While both water molecules and sulphate ions are present at the anode, water is more readily oxidized than sulphate ions. This is due to the higher oxidation potential of water compared to sulphate ions.

Key Points:

The electrolysis of dilute sulphuric acid produces hydrogen gas and oxygen gas, which are both useful products.

This process can be used to produce hydrogen gas for various applications, including fuel cells.

Applications of electrolysis

Experiment: Electroplating Copper onto a Metal Object

Aim: To demonstrate the process of electroplating by coating a metal object with copper metal.

Hypothesis: If a metal object is connected as the cathode in a copper sulphate solution, it will be coated with copper metal due to the reduction of copper ions.

Variables:

Independent Variables:

- Voltage applied
- Electrolyte concentration
- Electrolysis time

Dependent Variable:

- Amount of copper deposited on the metal object

Controlled Variables:

- Temperature of the electrolyte
- Distance between the electrodes
- Type of metal object

Risks and Mitigation:

Electric Shock.

- Use low voltage DC power sources.
- Ensure all connections are secure.
- Avoid touching the exposed electrical parts.

Chemical Burns:

- Wear gloves and goggles when handling the copper sulfate solution.
- Avoid skin contact with the solution.
- Rinse any spills immediately with water.

Metal Toxicity:

- Handle copper sulphate solution with care.
- Dispose of the solution and metal waste responsibly.

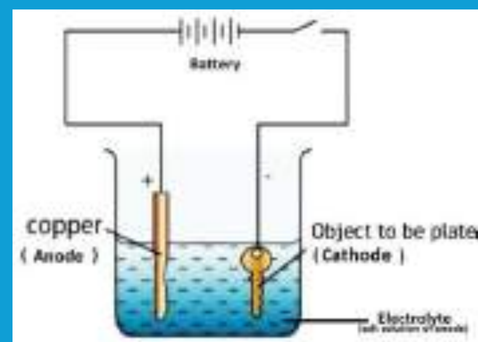
Materials:

- A 250 mL beaker
- Copper(II) sulphate solution

- Carbon rod/ copper rod
- A metal object to be plated (e.g., a metal key)
- A 9-volt battery
- Connecting wires
- Crocodile clips

Procedure:

- Dissolve copper(II) sulphate crystals in distilled water to create a saturated solution.
- Clean the metal object to be plated. Connect the carbon electrode to the positive terminal of the battery (anode).Connect the metal object to the negative terminal of the battery (cathode).Immerse both electrodes in the copper(II) sulphate solution.



- Turn on the power supply.
- Observe the reactions at both electrodes:
- Allow the electrolysis to continue for a specific time (e.g., 30 minutes).
- Turn off the power supply and remove the metal object from the solution and rinse it with water.

Expected observations and discussions

- A reddish-brown copper coating will form on the metal object (cathode).
- The copper anode will gradually erode as copper ions dissolve into the solution.

The metal object should gradually acquire a copper coating.

Explanation:

At the Anode (Oxidation):

$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$

Copper metal loses electrons to form copper ions.

At the Cathode (Reduction):

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

Copper ions gain electrons from the cathode and deposit as solid copper on the metal object.

Task: Discuss the applications of electrolysis.

Responses

Electrolysis, a process involving the passage of an electric current through a substance to effect a chemical change, has numerous applications across various industries. Here are some of the most significant ones:

Metallurgy

- Electroplating: This process involves coating a metal object with a thin layer of another metal. It's used to improve the appearance, corrosion resistance, or conductivity of the object.
- Electro-refining: Impure metals can be refined into pure metals through electrolysis. The impure metal is used as the anode, and pure metal is deposited on the cathode.
- Electrometallurgy: Metals like aluminum, sodium, and potassium are extracted from their ores using electrolysis.

Chemical Industry

- Chlor-alkali Process: This process involves the electrolysis of brine (sodium chloride solution) to produce chlorine gas, sodium hydroxide, and hydrogen gas. These products are essential for various industries, including plastics, paper, and textiles.
- Production of Hydrogen and Oxygen: Electrolysis of water can be used to produce hydrogen and oxygen gas, which have numerous applications, such as fuel cells and rocket propulsion.

Other Applications

Battery Technology: Electrolysis is used in the charging and discharging of rechargeable batteries, such as lithium-ion batteries.

Water Treatment: Electrolysis can be used to remove impurities from water, such as heavy metals and organic pollutants.

Anodizing: This process involves the electrolytic oxidation of a metal surface to form a protective oxide layer. It's used to improve the corrosion resistance and appearance of metals like aluminum.

Task: Explain the role of electrolytes in the body.

End of chapter summary

Key Concepts

- Oxidation: Loss of electrons by an atom, molecule, or ion, gain of oxygen, loss of hydrogen, or increase in oxidation number. Reduction is the gain of electrons by an atom, molecule, or ion, removal of oxygen, addition of hydrogen or decrease in oxidation number.
- Redox Reaction: A chemical reaction that involves both oxidation and reduction.
- Oxidizing Agent: A substance that causes oxidation by accepting electrons. It gets reduced after the reaction. Reducing Agent is a substance that causes reduction by donating electrons. It gets oxidized during the reaction.
- Electrolytes: Substances that conduct electricity when dissolved in water.
- Electrical Conductivity: The ability of a substance to conduct electricity.
- Cations: Positively charged ions.
- Anions: Negatively charged ions.
- Electrolysis: The process of using electricity to drive redox reactions.
- Cathode: The negatively charged electrode where reduction occurs.
- Anode: The positively charged electrode where oxidation occurs.
- Electrolysis: The process of using electricity to drive redox reactions.
- Electroplating: The process of depositing a thin layer of a metal onto the surface of another metal using electrolysis.
- Metallurgy: The extraction of metals from their ores through redox reactions.
- Energy Storage: Redox reactions are used in batteries to store energy.
- Environmental Protection: Redox reactions are used to clean up pollutants in the environment.

2. INDUSTRIAL PROCESSES IN CHEMISTRY

Competency: The learner appreciates the principles behind some industrial processes and the importance of the products formed.

Key words

- Ore
- Fertilizer
- Nitrate
- Cement
- Calcination
- Electrolysis
- Crystallization
- Extraction
- Refining
- Casting
- Primary Industry
- Secondary Industry
- Tertiary Industry
- Roasting
- Limestone

The learner should be able to:

- Know about some of the main industries that produce useful chemicals, such as the oil industry for organic chemicals, the production of metals, the acid industry, the alkali industry, the fertilizer industry and the cement industry.
- Understand the processes for obtaining useful chemicals from rocks.
- Understand the processes involved in extracting and purifying metals, with particular reference to processes used in Uganda.
- Understand the importance of nitrates as fertilizers in food production and know how they are produced from the nitrogen in the air.
- Outline four industrial processes that make use of natural resources obtained in Uganda.
- Recognize the importance of industrial processes in utilizing natural resources to make useful chemicals, and appreciate that industrial processes have social benefits and cause problems of pollution and environmental destruction.
- Describe some of the dangers to the community arising from these industrial processes and the steps that may be taken to minimize these dangers.
- Understand the process in the manufacture of lime and cement.
- Understand the production of alkali and chlorine by the electrolysis of salt solution.

Industrial processes are large-scale chemical reactions carried out in factories to produce various products. These processes involve the use of raw materials, energy, and catalysts to convert substances into desired products.

Key Industrial Processes

Haber process

- Produces ammonia from nitrogen and hydrogen gases.
- Used to manufacture fertilizers and explosives.

Contact Process

- Produces sulphuric acid from sulphur, oxygen, and water.
- Used in the production of fertilizers, batteries, and other chemicals.

Chloralkali Process

- Produces chlorine, sodium hydroxide, and hydrogen gas from sodium chloride brine.
- Used in the production of paper, plastics, and disinfectants.

Cracking

- Breaks down large hydrocarbon molecules into smaller ones.
- Used to produce gasoline, diesel fuel, and other petroleum products.

Fermentation

- Converts sugars into ethanol and carbon dioxide using microorganisms.
- Used in the production of alcoholic beverages, biofuels, and pharmaceuticals.

Common Industries, their products and class.

Industry	Products	Use of the products	Class of industry
Sugar Industry (Kakira sugar works)	Sugar	Food, Beverages	Primary Industry
Coffee Industry (Uganda Coffee Development Authority)	Coffee Beans	Beverages	Primary Industry
Cotton Industry (Uganda Cotton Ginners Association)	Cotton Lint, Textiles	Clothing, Bedding	Secondary Industry

Tobacco Industry	Tobacco Products	Smoking	Secondary Industry
Cement Industry (Hima cement Ltd)	Cement	Construction	Secondary Industry
Steel Industry (Mukwano Steel Industry)	Steel Products	Construction, Manufacturing	Secondary Industry
Brewery Industry (Uganda Breweries Ltd)	Beer, Soft Drinks	Beverages	Secondary Industry
Food Processing Industry (British American Tobacco Uganda)	Processed Foods	Food	Secondary Industry
Leather Industry	Leather Products	Footwear, Clothing	Secondary Industry
Timber Industry	Timber Products	Construction, Furniture	Primary Industry
Electricity Generation Industry (Uganda Electricity Generation Company Ltd)	Electricity	Powering Homes, Industries	Tertiary Industry
Oil Refining Industry	Refined Petroleum Products	Transportation, Energy	Secondary Industry
Pharmaceutical Industry	Medicines	Healthcare	Secondary Industry
Textile Industry (Nytil Picfare Ltd)	Textiles, Clothing	Clothing, Bedding	Secondary Industry

Note:

- Primary Industry: Extraction and production of raw materials
- Secondary Industry: Processing and manufacturing of goods
- Tertiary Industry: Provision of services

Major Industries Producing Useful Chemicals

Industry	Chemicals produced	Uses
Petrochemical Industry	Ethylene, Propylene, Benzene, Toluene, Xylene	Plastics, synthetic fibers, detergents, solvents, pharmaceuticals
Chemical Industry	Sulphuric acid, Nitric acid, Chlorine, Sodium hydroxide	Fertilizers, batteries, paper, textiles, cleaning agents
Pharmaceutical Industry	Aspirin, Paracetamol, Antibiotics, Vaccines	Medicine, healthcare
Fertilizer Industry	Urea, Ammonia, Phosphoric acid, Potassium chloride	Agriculture
Food Processing Industry	Citric acid, Acetic acid, Sodium benzoate	Food preservatives, flavorings, acidity regulators
Cement Industry	Calcium oxide (lime), Calcium silicate	Cement production, construction
Metal Industry	Various metals and alloys	Construction, machinery, electronics

Useful Minerals, Their Chemical Formulas, and Uses

Mineral Name	Chemical Formula	Image	Use
Gold	Au		Jewelry, electronics, dentistry
Silver	Ag		Jewelry, photography, electronics

Copper	Cu		Electrical wiring, plumbing, alloys
Platinum	Pt		Jewelry, catalytic converters, laboratory equipment
Quartz	SiO_2		Glassmaking, electronics, jewelry
Feldspar	$KAlSi_3O_8$, $NaAlSi_3O_8$, $CaAl_2Si_2O_8$		Ceramics, glass, fertilizers
Mica	$KAl_2(AlSi_3O_{10})(OH)_2$		Insulation, lubricants, electronics
Calcite	$CaCO_3$		Cement production, construction materials, agriculture
Gypsum	$CaSO_4 \cdot 2H_2O$		Plaster, drywall, cement

Hematite	Fe_2O_3		Iron ore, pigment
Magnetite	Fe_3O_4		Iron ore, magnetic materials
Bauxite	AlO(OH)		Aluminum production
Halite (Rock Salt)	NaCl		Food seasoning, industrial use
Fluorite	CaF_2		Steelmaking, glassmaking, ceramics

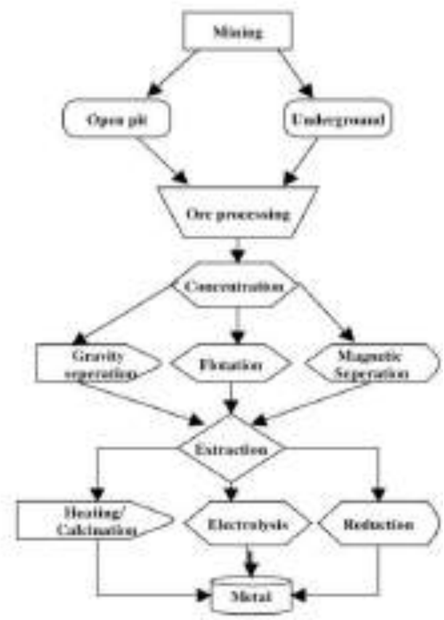
Obtaining Useful Chemicals from Rocks

The process of extracting useful chemicals from rocks involves a series of steps, from mining the raw material to refining it into valuable products.

Mining

Identification of Ore Deposits: Geological surveys and exploration techniques are used to locate mineral-rich deposits.

Rocks containing the desired minerals are extracted from the earth through mining or quarrying. Different mining methods are employed based on the type of deposit and its depth. Open-pit Mining for deposits near the surface and Underground Mining for deeper deposits.



Ore Processing

Crushing and Grinding: The mined ore is crushed and ground into smaller particles to increase the surface area for further processing.

Concentration

The crushed rocks are then separated into different minerals using various techniques such as:

- Gravity Separation: Separates minerals based on density differences.
- Froth Flotation: Uses surfactants to selectively attach to mineral particles, separating them from the gangue.
- Magnetic Separation: Separates magnetic minerals from non-magnetic ones.

Extraction of Useful Chemicals

The separated minerals are then processed to extract the useful chemicals. This can involve:

- Heating (calcination)
- Reaction with acids or bases
- Electrolysis

Purification

The extracted chemicals are then purified to remove impurities. This can involve:

- Crystallization
- Distillation

- Chromatography

The purified chemicals are then packaged and distributed to various industries for use.

Properties of Ore Considered Before Concentration

Before selecting a suitable concentration method, several properties of the ore are considered:

- Density: The difference in density between the ore mineral and the gangue minerals determines the suitability of methods like gravity separation.
- Magnetic Properties: Magnetic ores, like magnetite, can be separated from non-magnetic gangue using magnetic separation.
- Particle Size: The size of the ore particles influences the choice of crushing and grinding techniques.
- Reactivity: The chemical reactivity of the ore minerals determines the choice of leaching agents and other chemical treatments.
- Solubility: The solubility of the ore mineral in specific solvents can be exploited in hydrometallurgical processes.

Metallurgical Processes

Metallurgy: The science and technology of extracting metals from their ores and refining them.

Pyrometallurgy: Involves heating the ore to high temperatures to extract the metal.

- Roasting: Oxidizing the ore to remove impurities.
- Smelting: Reducing the metal oxide to the pure metal using a reducing agent like carbon.

Hydrometallurgy: Involves leaching the metal from the ore using chemical solvents.

Electrometallurgy: Uses electrolysis to extract pure metals from solutions.

Chemical Processing

Chemical Reactions: Various chemical reactions are used to extract and purify chemicals from minerals.

- Precipitation: Solutes are separated from a solution by forming a solid precipitate.
- Crystallization: Pure substances are obtained from solutions by forming crystals.
- Distillation: Separates liquids based on their boiling points.

Refining and Purification

Further Processing: The extracted chemicals are often further refined and purified to achieve the desired purity and quality.

Physical and Chemical Methods: Techniques like distillation, crystallization, and chemical reactions are used to remove impurities.

Extraction and purification of Metals

Food for thoughts

What is Metal Extraction?

Why is Metal Extraction Necessary?

Metal extraction is the process of separating metals from their **ores** and other impurities. This process involves various physical and chemical methods to isolate the metal in its pure form.

Metal extraction is necessary because metals are not found in their pure form in nature. They are often mixed with other elements and compounds, and extracting the metal from its ore is essential for its use in various industries.

Metal extraction and purification are crucial for the **production** of **high-quality metals**, which are used in various industries such as construction, transportation, electronics, and more.

Common methods used for extraction and purification of metals and examples of metals extracted by each method

Method of Extraction	Description	Examples of Metals Extracted
Electrolysis (Pr)	Uses electric current to extract metal from ore	Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg)
Reduction with Carbon	Uses carbon to reduce metal oxide to pure metal	Iron (Fe), Zinc (Zn), Tin (Sn)
Reduction with Hydrogen	Uses hydrogen to reduce metal oxide to pure metal	Tungsten (W), Molybdenum (Mo)
Flotation	Separates metal-bearing minerals from impurities based on differences in surface properties	Copper (Cu), Lead (Pb), Zinc (Zn)
Magnetic Separation	Separates metal-bearing minerals from impurities based on differences in magnetic properties	Iron (Fe), Titanium (Ti)
Hydrometallurgy	Uses aqueous solutions to extract metal from ore	Copper (Cu), Nickel (Ni), Gold (Au)
Distillation (Pr)	Separates metal from impurities based on differences in boiling points	Mercury (Hg), Zinc (Zn)
Crystallization (Pr)	Separates metal from impurities based on differences in solubility	Copper (Cu), Silver (Ag)

Extraction of Aluminum: The Hall-Héroult Process

Aluminum is a lightweight, durable, and versatile metal widely used in various industries. Its primary ore is bauxite, which contains aluminum oxide (Al_2O_3). However, due to the high melting point of aluminum oxide, it's not feasible to directly electrolyze it.

Aluminum is primarily extracted from bauxite, which is the main ore of aluminum. Bauxite contains aluminum oxides along with impurities like iron oxides, silica, and titanium dioxide.

Bauxite is crushed and then treated with a concentrated solution of sodium hydroxide ($NaOH$) under high pressure and temperature. This dissolves the aluminum oxides, forming sodium aluminate.

The impurities, being insoluble, remain as a solid residue called "red mud." The sodium aluminate solution is then cooled and seeded with crystals of aluminum hydroxide ($Al(OH)_3$). This causes the aluminum hydroxide to precipitate out of the solution.

The precipitated aluminum hydroxide is then filtered, washed, and dried. The dried aluminum hydroxide is heated strongly to drive off water, converting it into pure aluminum oxide (Al_2O_3).

$2Al(OH)_3(s) \rightarrow Al_2O_3(s) + 3H_2O(g)$

2. Electrolysis of Alumina:

* Hall-Héroult Process: This process is used to extract aluminum from pure aluminum oxide (alumina).
  * Electrolyte: Alumina has a very high melting point, making it difficult to electrolyze directly. Therefore, it is dissolved in molten cryolite (Na_3AlF_6), which significantly lowers the melting point.
  * Electrolysis Cell: The electrolysis cell consists of a steel tank lined with carbon, which acts as the cathode. Carbon anodes are immersed in the molten electrolyte.
  * Electrolysis: When a direct current is passed through the electrolyte, the following reactions occur:
    * At the Cathode (Reduction):
      * $Al^{3+} + 3e^- \rightarrow Al(l)$
      * Aluminum ions gain electrons and are reduced to molten aluminum, which collects at the bottom of the cell.
    * At the Anode (Oxidation):
      * $2O^{2-} \rightarrow O_2(g) + 4e^-$
      * Oxide ions lose electrons and are oxidized to oxygen gas. The oxygen reacts with the carbon anodes, forming carbon dioxide.

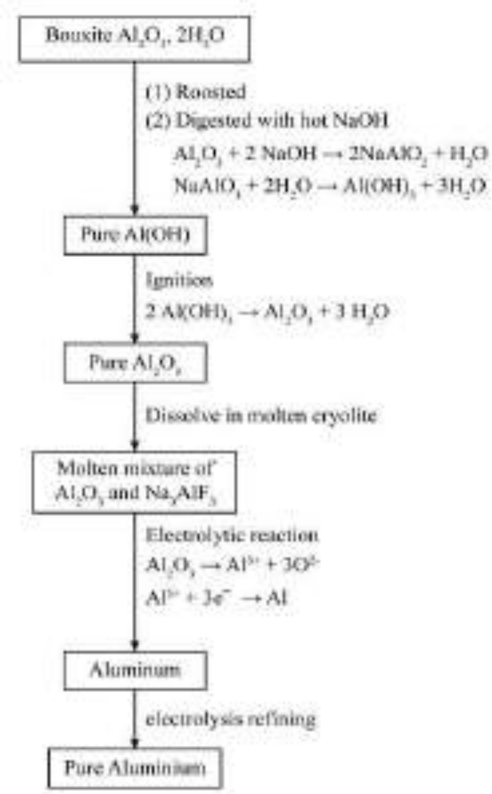
* Molten Aluminum: The molten aluminum is periodically tapped from the bottom of the cell.

Key Points:

* The extraction of aluminum is an energy-intensive process, primarily due to the high temperatures required for the Bayer and Hall-Héroult processes.
* The Bayer process generates a significant amount of red mud, which can be an environmental concern if not properly managed.
* Recycling aluminum is crucial to conserve energy and reduce environmental impact, as it requires significantly less energy than extracting aluminum from bauxite.

I hope this explanation is helpful!

The Hall-Héroult Process is the primary method for extracting aluminum from bauxite.



Bauxite, the primary ore of aluminum, is mined from open-pit or underground mines. The bauxite is crushed into smaller pieces to increase the surface area.

The crushed bauxite is mixed with a hot concentrated solution of sodium hydroxide (NaOH) in a process known as digestion. The NaOH dissolves the aluminum-bearing minerals, leaving behind impurities such as iron oxides and silicates.

$Al_2O_3 (s) + 2NaOH (aq) \rightarrow 2NaAlO_2 (aq) + H_2O (l)$

The resulting mixture is then clarified to remove any remaining impurities. This is done by adding flocculants, which cause the impurities to clump together and settle out of the solution.

The clarified solution is then seeded with small crystals of aluminum hydroxide ($Al(OH)_3$).The $Al(OH)_3$ precipitates out of the solution, leaving behind a solution of sodium aluminate ($NaAlO_2$).

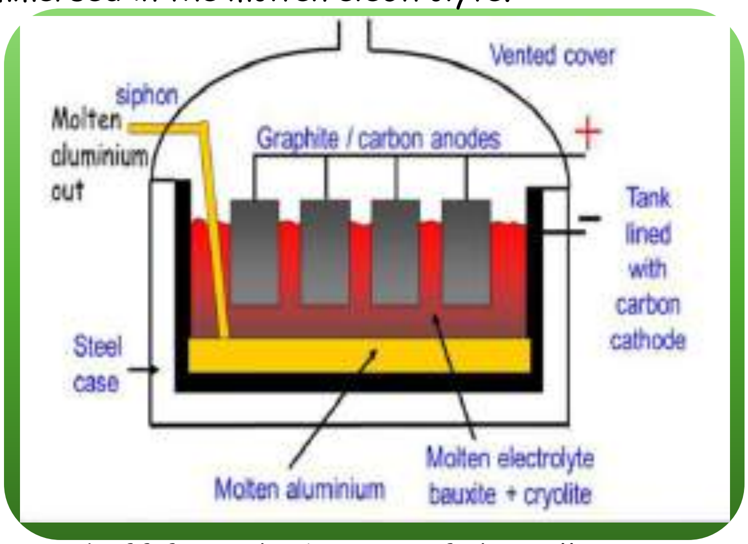
The precipitated $Al(OH)_3$ is then heated in a calciner to produce alumina (Al_2O_3).This process removes water and converts the $Al(OH)_3$ into a more reactive form.

$2Al(OH)_3 (s) \rightarrow Al_2O_3 (s) + 3H_2O (g)$

The alumina is then dissolved in a bath of molten cryolite (Na_3AlF_6) in electrolytic cell at a temperature of around 950°C to lower the melting point and improve conductivity.

$Al_2O_3 (s) + 2Na_3AlF_6 (l) \rightarrow 4NaF (l) + 2AlF_3 (l) + 3O^{2-} (l)$

Electrolysis Cell is designed with a large steel tank lined with graphite which acts as the cathode. Carbon anodes are immersed in the molten electrolyte.



An electric current is then passed through the bath, causing the aluminum to be reduced at the cathode (negative electrode) and deposited as pure aluminum.

At the cathode: Aluminum ions gain electrons and are reduced to molten aluminum, which collects at the bottom of the cell.

$Al^{3+} (aq) + 3e^- \rightarrow Al (s)$

The molten aluminum is periodically tapped off from the bottom of the cell.

The resulting aluminum is then cast into its desired shape using a mold. The casting process involves pouring the molten aluminum into the mold and allowing it to cool and solidify.

At the anode: Oxide ions lose electrons and form oxygen gas, which reacts with the carbon anode to form carbon dioxide.

$2O^{2-} (l) \rightarrow O_2 (g) + 4e^-$

Key Points

The Hall-Héroult process is energy-intensive due to the high temperatures required.
The carbon anodes are gradually consumed during the process and need to be replaced periodically.
The process produces significant amounts of carbon dioxide, contributing to greenhouse gas emissions.

Extraction of Copper

Copper is a widely used metal, essential for various applications such as electrical wiring, plumbing, and construction. Its extraction involves several steps, including mining, concentration, smelting, and refining.

Raw materials

The principle ores in the extraction of copper are;

- Copper pyrites
- Cuprite
- Copper (I) sulphide
- Malachite

Extraction of Copper from copper pyrite

Copper ore (copper pyrite) is extracted from open-pit or underground mines.
The ore is crushed into smaller pieces and then ground into a fine powder to increase the surface area for the next stage.
The powdered ore is mixed with water, oil, and a frothing agent. Air is blown through the mixture, creating a froth. This process of Froth Flotation separates the copper-containing minerals from the gangue (impurities). The copper-containing minerals, being hydrophobic, adhere to the air bubbles and rise to the surface with the froth, while the gangue sinks to the bottom. The froth is skimmed off, and the copper-rich concentrate is recovered.

The copper concentrate is heated strongly in the presence of air in a furnace. This process, called roasting, converts copper sulphides into oxides while removing some of the sulphur as sulphur dioxide gas.

$2CuFeS_2 + O_2 \rightarrow Cu_2S + 2FeS + SO_2$

$2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$

$Cu_2S + O_2 \rightarrow Cu_2O + SO_2$

The roasted ore is mixed with silica (SiO_2) and coke (carbon) and smelted in a blast furnace.

The silica reacts with iron(II) oxide (FeO) to form iron(II) silicate ($FeSiO_3$), which is a slag that floats on top of the molten copper.

$FeO + SiO_2 \rightarrow FeSiO_3$ (slag)

Some of the copper(I) oxide (Cu_2O) is reduced to metallic copper by carbon.

$Cu_2O + C \rightarrow 2Cu + CO$

The molten material from the blast furnace, called matte, contains copper(I) sulphide (Cu_2S) and some iron sulphides. It is transferred to a converter, where air is blown through the molten matte.

The remaining iron sulphides are oxidized to iron(II) oxide, which reacts with silica to form slag.

The copper(I) Sulphide is further oxidized to copper(I) oxide.

Finally, copper(I) oxide reacts with the remaining copper(I) sulphide to produce blister copper and sulfur dioxide.

$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$

Blister copper contains impurities like sulphur, oxygen, and other metals. It is further refined to produce pure copper.

Electrolytic Refining: In this process, impure copper is made the anode, and a thin sheet of pure copper is made the cathode. The electrolyte is a solution of copper sulphate and Sulphuric acid. On passing an electric current, pure copper dissolves from the anode and deposits on the cathode, while the impurities settle at the bottom as anode mud.

The refined copper is cast into various shapes like sheets, rods, or wires for further use.

Key Points:

- Copper mining and processing can have significant environmental impacts, including water pollution, soil erosion, and deforestation.
- Recycling copper is essential for sustainable resource management and reducing environmental impact.
- Copper is an essential component of many modern technologies, and its demand continues to grow.

Extraction of Iron

Iron is one of the most widely used metals, essential for construction, manufacturing, and transportation. It's primarily extracted from iron ore, which is a rock containing iron oxide minerals.

Uganda's iron ore deposits are primarily located in two main regions:

1. Southwestern Region:

Muko Area: This region, located in Kabale and Kisoro districts, is known for high-grade hematite iron ore deposits.

Kigezi Region: This region also contains significant iron ore reserves.

2. Eastern Region:

Tororo District: This region has deposits of magnetite iron ore in the Sukulu and Bukusu areas.

Principle iron ores

- Hematite - Fe_2O_3
- Magnetite - Fe_3O_4
- Iron Pyrite - FeS_2
- Siderite - $FeCO_3$

Process of iron extraction

Iron ore is mined from deposits using artisanal mining methods, which involves open pit mining.

The extracted ore is then crushed and ground into a fine powder. This increases the surface area of the ore and allows for more efficient extraction.

The ore is then roasted in air to remove moisture and other impurities

The crushed and ground ore is then smelted in a blast furnace at high temperatures (around 1200°C). The blast furnace is a large, vertical furnace that uses a combination of coal and air to smelt the iron.

The smelting process involves the reduction of iron oxides to iron using charcoal as a reducing agent.

Equation: $Fe2O3$ (s) + 3C (s) → 2Fe (l) + 3CO (g)

The molten iron is then tapped from the bottom of the blast furnace and cast into pig iron.

The pig iron is then further refined through various steelmaking processes, such as "finery forging", to produce pure iron or steel which can be used in a variety of applications, including construction, transportation, and consumer goods.

Key Points

- Iron ore is the primary source of iron, with hematite (Fe_2O_3) and magnetite (Fe_3O_4) being the most common minerals.
- The blast furnace is a crucial step in iron production, converting iron ore into molten iron.
- Steelmaking processes, such as the Basic Oxygen Process, refine pig iron into steel, which is a stronger and more versatile material.

- The iron and steel industry is a major contributor to global economies and infrastructure development.

The major environmental impacts of metal extraction

Air Pollution

Impact: Metal extraction and processing can release pollutants such as particulate matter, sulphur dioxide, and heavy metals into the air, contributing to poor air quality and negative health effects.

Mitigation

- Implementing air pollution control technologies, such as scrubbers and electrostatic precipitators.
- Using cleaner energy sources, such as solar or wind power, to reduce reliance on fossil fuels.
- Implementing dust suppression measures, such as sprinkler systems and dust collection systems.

Water Pollution

Impact: Metal extraction and processing can result in the release of pollutants such as heavy metals, acid mine drainage, and other chemicals into nearby water sources, posing risks to aquatic ecosystems and human health.

Mitigation

- Implementing wastewater treatment systems to remove pollutants and contaminants.
- Using containment systems, such as liners and leachate collection systems, to prevent pollution from tailings and waste rock.
- Implementing water conservation measures, such as water recycling and efficient use of water.

Soil and Land Degradation

Impact: Metal extraction and processing can result in soil and land degradation, including erosion, sedimentation, and loss of biodiversity.

Mitigation

- Implementing reclamation and rehabilitation plans to restore mined land to its original state or to a stable and productive ecosystem.
- Using soil conservation measures, such as mulching and terracing, to prevent erosion.
- Implementing biodiversity conservation measures, such as habitat restoration and species reintroduction.

Energy Consumption and Greenhouse Gas Emissions

Impact: Metal extraction and processing require significant amounts of energy, resulting in greenhouse gas emissions and contributing to climate change.

Mitigation

- Implementing energy-efficient technologies and practices, such as using LED lighting and optimizing processing equipment.
- Using renewable energy sources, such as solar or wind power, to reduce reliance on fossil fuels.
- Implementing carbon capture and storage technologies to reduce greenhouse gas emissions.

Waste Generation and Management

Impact: Metal extraction and processing generate significant amounts of waste, including tailings, waste rock, and hazardous waste.

Mitigation

- Implementing waste reduction and minimization strategies, such as reducing water usage and optimizing processing equipment.
- Using waste management practices, such as containment and disposal in accordance with regulatory requirements.
- Implementing recycling and reprocessing programs to recover valuable materials from waste.

Manufacture of Fertilizers

Fertilizers; are substances added to the soil to provide essential nutrients for plant growth. They are crucial for agriculture and food production.

Types of Fertilizers

- Organic Fertilizers: Derived from natural sources such as animal waste, compost, and green manure. Examples include cow dung, bone meal, and fish emulsion.
- Inorganic Fertilizers: Synthetically manufactured using chemical processes. Examples include ammonium nitrate, urea, and superphosphate.

Components of Fertilizers

- Nitrogen (N): Essential for plant growth, promotes leaf development and protein synthesis.
- Phosphorus (P): Important for root development, flower and fruit formation.
- Potassium (K): Helps with overall plant health, resistance to disease and water balance.

Chemical Composition of Common Nitrogen containing Fertilizers

Fertilizer	**Chemical Composition**
Ammonium Nitrate	NH_4NO_3
Urea	$NH_2-CO-NH_2$
Ammonium sulphate	$(NH_4)_2SO_4$
Diammonium Phosphate	$(NH_4)_2HPO_4$
Monoammonium Phosphate	$NH_4H_2PO_4$
Potassium Nitrate	KNO_3
Calcium Ammonium Nitrate	$Ca(NH_4)_2(NO_3)_4$

Manufacture of nitrate fertilizers from nitrogen

The atmospheric air is trapped and fed into air filters to remove impurities. Atmospheric air is compressed to a high pressure (around 5-10 atm) using a compressor. This increases the temperature and pressure of the air, making it more suitable for distillation.

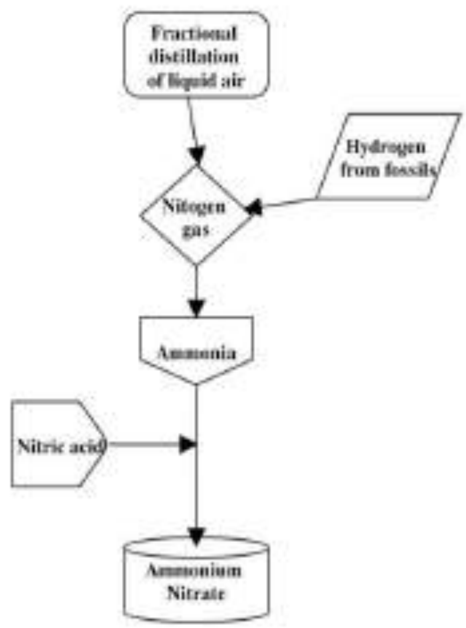
The compressed air is then cooled to a low temperature (around -150°C) using a heat exchanger or a refrigeration system. This causes the water vapor and other impurities to condense and separate from the air.

The cooled and purified air is then fed into a distillation column, where it is separated into its component gases based on their boiling points. The distillation column is typically a tall, vertical column with a series of trays or packing materials.

The nitrogen is separated based on its boiling point, which is around -196°C.

The separated nitrogen gas is then collected and stored in tanks or cylinders.

Nitrogen and hydrogen (from fossils) gases are mixed in a ratio of 3:1 (hydrogen: nitrogen) and then heated to a high temperature (around 450°C) using a heat exchanger.



The heated gas mixture is then passed over an iron-based catalyst, causing the nitrogen and hydrogen to react and form ammonia. It's then cooled and condensed using a heat exchanger and condenser causing the gas to liquefy, it's later purified by using a series of distillation columns to remove impurities.

Equation: $N_2 (g) + 3H_2 (g) \rightarrow 2NH_3 (g)$

The nitric acid from the Ostwald process is neutralized with ammonia to form ammonium nitrate.

Equation: $HNO_3 (aq) + NH_3 (g) \rightarrow NH_4NO_3 (s)$

The resulting solution is then cooled and allowed to crystallize, forming solid ammonium nitrate.

Production of Calcium Ammonium Nitrate

Calcium ammonium nitrate (CAN) is another common nitrate fertilizer that can be produced using a similar process.

The nitric acid is neutralized with ammonia and calcium carbonate to form calcium ammonium nitrate.

Equation: $2HNO_3 (aq) + (NH_4)_2CO_3 (aq) + CaCO_3 (s) \rightarrow Ca(NO_3)_2 (aq) + (NH_4)_2CO_3 (aq) + H_2O (l)$

The resulting solution is then cooled and allowed to crystallize, forming solid calcium ammonium nitrate.

The nitrate fertilizer is typically packaged in bags or bulk containers and transported to farms and agricultural suppliers. It is then applied to crops as needed, providing essential nutrients for plant growth.

Environmental Impacts of Fertilizer Production

Greenhouse Gas Emissions

Fertilizer production, particularly nitrogen-based fertilizers, requires large amounts of energy majorly derived from fossils, this leads to greenhouse gas emissions resulting into global warming hence seasonal changes, floods and drought.

Mitigation

- Use renewable energy sources, such as solar or wind power, to power fertilizer production.
- Implement carbon capture and storage technologies.

Water Pollution

Fertilizer production can result in water pollution through the release of nutrients, heavy metals, and other pollutants into the water harming aquatic life hence affecting the ecosystem.

Mitigation

- Implement wastewater treatment systems to remove pollutants from fertilizer production effluent.
- Use closed-loop systems to minimize water usage and prevent water pollution.

- Implement best management practices for fertilizer storage and handling.

Air Pollution

Fertilizer production can result in air pollution through the release of particulate matter, nitrogen oxides, and other pollutants, this may result into acid rain lowering soil pH hence affecting crop yields.

Mitigation

- Implement air pollution control technologies, such as scrubbers and electrostatic precipitators
- Use cleaner energy sources, such as natural gas or renewable energy, to power fertilizer production.
- Implement best management practices for fertilizer storage and handling.

Waste Generation

Fertilizer production generates large amounts of waste, including hazardous waste and solid non biodegradable waste, affecting water infiltration into the soil.

Mitigation

- Implement waste reduction and minimization strategies, such as reducing water usage and implementing recycling programs.
- Use environmentally friendly packaging materials and design.
- Implement proper waste disposal practices, including hazardous waste management.

Industrial Processes and Natural Resources

Food for thoughts

1._List some of the natural resources used in the production of materials and give the respective materials.

2._Discuss renewable and non renewable natural resources, giving examples anda comparison between them.

3._List the common chemical products and the industries that produce these chemicals.

Industrial processes play a pivotal role in transforming natural resources into valuable chemicals.
Industrial processes are large-scale operations that involve the transformation of raw materials into valuable products. These processes often rely on complex chemical reactions, physical changes, or a combination of both.

Key Aspects of Industrial Processes

1. Raw Materials:

These are the basic substances used as inputs in the process. They can be natural resources like minerals, plants, or petroleum, or synthetic materials derived from other processes.

2. Process Steps:

Industrial processes involve a series of steps, each designed to transform the raw materials into a desired product. These steps may include:
Physical processes: crushing, grinding, heating, cooling, filtration, distillation
Chemical processes: reactions, catalysis, oxidation, reduction

3. Equipment and Machinery

Industrial processes require specialized equipment and machinery to carry out the various steps efficiently and safely.

4. Energy Input

Energy, often in the form of heat, electricity, or fuel, is essential to drive industrial processes.

5. Product Output

The final products of industrial processes can be diverse, ranging from basic chemicals to complex manufactured goods.

6. By-products and Waste

Industrial processes often generate by-products and waste materials that need to be managed responsibly.

Industrial processes that make use of the natural resources in Uganda

Natural Resource	Industry that uses the resource	Industrial Process	Products

Forests	Forestry and Wood Processing	Logging, Sawmilling, Pulp and Paper	Timber, lumber, plywood, paper products
Water	Hydropower	Hydroelectric Power Generation	Electricity
Minerals (Gold, Copper, Iron Ore)	Mining and Metallurgy	Mining, Smelting, Refining	Gold, copper, iron, steel
Petroleum and Natural Gas	Petroleum and Gas	Exploration, Production, Refining	Petroleum products (petrol, diesel, kerosene), Liquefied Petroleum Gas (LPG)

Benefits of Industrial Processes in Utilizing Natural Resources

Industrial processes offer numerous benefits in the utilization of natural resources:

Economic Benefits

Job Creation: Industrial processes generate employment opportunities in various sectors, contributing to economic growth.

Revenue Generation: The sale of products and services derived from natural resources contributes to national income and foreign exchange earnings.

Value Addition: Raw materials are transformed into high-value products, increasing their economic worth.

Infrastructure Development: Industrial activities stimulate the development of infrastructure like roads, railways, and ports.

Social Benefits

Improved Living Standards: Industrialization leads to better living standards through increased access to goods and services.

Education and Skill Development: Industrial processes require skilled labor, promoting education and training.

Reduced Poverty: Economic growth fueled by industrialization can alleviate poverty and inequality.

Environmental Benefits

Sustainable Resource Utilization: Efficient industrial processes can minimize waste and reduce the depletion of natural resources.
Technological Advancements: Innovation in industrial processes can lead to cleaner and more sustainable technologies.
Waste Reduction and Recycling: Industrial processes can incorporate recycling and waste reduction practices to minimize environmental impact.

However, it's crucial to balance these benefits with potential negative impacts on the environment and society. Sustainable industrial practices are essential to ensure the long-term viability of natural resources and the well-being of future generations.

Environmental Impacts of Industrial Processes

Industrial processes, while essential for economic growth, can have significant environmental and social impacts.

1. Pollution

Air Pollution: Emission of pollutants like greenhouse gases, particulate matter, and toxic gases contribute to global warming affecting climate hence seasonal changes, drought and floods.

Mitigation

Install pollution control technologies like scrubbers, filters, and catalytic converters.
Promote cleaner energy sources like solar, wind, and hydro power.
Implement strict emission standards and regulations.
Water Pollution: Discharge of wastewater containing pollutants like heavy metals, organic matter, and chemicals can leach into water bodies harming the aquatic organisms.

Mitigation

Treat wastewater before discharge to remove pollutants.

Land Pollution: Generation of solid waste and land degradation from mining and industrial activities can deplete soil fertility affecting crop yields.

Mitigation

Implement waste management practices like recycling, composting, and landfill disposal.

Restore degraded land through reforestation and reclamation.

2. Resource Depletion

Overexploitation of natural resources like minerals, forests, and water, affecting the future generations

Mitigation

Promote sustainable resource management practices.

Develop alternative materials and technologies.

Implement efficient resource extraction and utilization techniques.

3. Health Issues

Exposure to pollutants can lead to respiratory diseases, cancer, and other health problems.

Mitigation

Implement strict occupational health and safety standards.

Provide regular health check-ups for workers.

Ensure safe working conditions and use of personal protective gears.

4. Social Disruption

Industrial activities can displace communities and disrupt social fabric.

Mitigation

Conduct proper environmental impact assessments.

Implement fair compensation and resettlement programs.

Engage with local communities to minimize social disruption.

Manufacture of Cement

Cement is a hydraulic material used as a binder in construction. It is produced by heating limestone (calcium carbonate) and clay in a kiln to form clinker, which is then ground with gypsum to produce cement.

Manufacturing Process

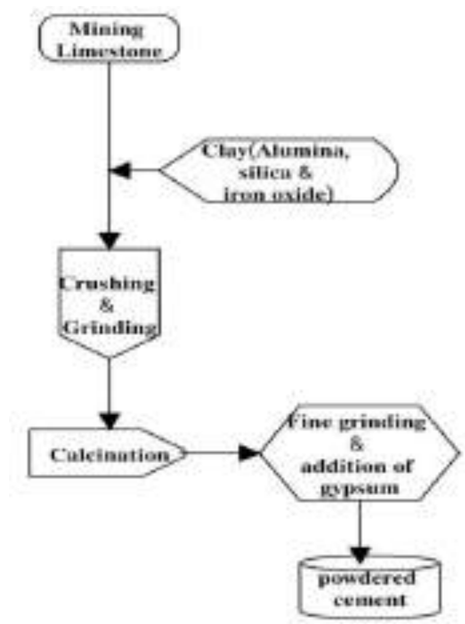
The raw materials used to manufacture cement are:

- Limestone ($CaCO_3$)
- Clay (SiO_2, Al_2O_3, Fe_2O_3)

Cement production in Uganda involves a series of processes, from raw material extraction to the final product.

Extraction: Limestone: The primary raw material, limestone, is extracted from quarries.

Clay: Clay, rich in alumina and silica, is also sourced from mines or quarries.



Crushing and Grinding: The extracted materials are crushed and ground into a fine powder known as raw meal.

Calcination: The raw meal is heated to a high temperature (around 1450°C) in a rotary kiln. At this high temperature, limestone decomposes to form **CaO**.

$$CaCO_3 \rightarrow CaO + CO_2$$

The CaO reacts with alumina and silica forming clinker, the primary ingredient of cement.

$$CaO + Al_2O_3 \cdot 2SiO_2 \rightarrow Ca_2Al_2SiO_7 \text{(Clinker)}$$

Fine Grinding: The clinker is ground into a very fine powder. Gypsum is added to control the setting time of the cement.

$$Ca_2Al_2SiO_7 + CaSO_4 \cdot 2H_2O \rightarrow \text{Cement.}$$

Packaging and Storage: The finely ground cement is packaged into bags or bulk containers for storage and transportation.

Social benefits of the process of production of cement

Economic Benefits:

Job Creation: Cement production generates employment opportunities in various sectors, including mining, manufacturing, transportation, and construction.
Economic Growth: The industry contributes to the overall economic growth of a nation by stimulating related industries and boosting GDP.
Tax Revenue: Cement companies contribute to government revenue through taxes, royalties, and other levies.

Infrastructure Development:

Housing and Shelter: Cement is a crucial component in the construction of homes, schools, hospitals, and other infrastructure.
Urbanization: Cement enables the expansion of cities and towns, accommodating population growth.
Transportation: It's used in the construction of roads, bridges, and other transportation infrastructure, facilitating connectivity and trade.

Improved Quality of Life:

Better Living Conditions: Cement-based construction improves living standards by providing durable and affordable housing.
Public Health: It contributes to the construction of hospitals, clinics, and sanitation facilities, improving public health.
Education: Cement is used in the construction of schools, enabling access to education for many.

Environmental Impacts of Cement Production

Cement production, while essential for infrastructure development, can pose certain risks to communities.

Environmental Dangers and Mitigation

Air Pollution:

Danger: Emission of particulate matter, nitrogen oxides (NOx), and sulphur dioxide (SO2) from burning of fossil fuels, clinker production can lead to respiratory problems and acid rain.

Mitigation

Electrostatic Precipitators: Capture particulate matter.

Selective Catalytic Reduction (SCR) Systems: Installing SCR systems can reduce NOx and sulphur dioxide emissions.

Wearing of personal protective equipments (PPEs)

Water Pollution:

Danger: Discharge of wastewater containing pollutants like suspended solids, heavy metals, and organic matter can contaminate water bodies, endangering the life of aquatic organisms.

Mitigation

Wastewater Treatment Plants: Treat wastewater before discharge.

Effluent Monitoring: Regularly monitor water quality.

Water Recycling: Reuse treated wastewater.

Noise Pollution:

Danger: Noise from machinery can disturb nearby communities, leading to sleep disturbances and hearing loss.

Mitigation

Noise Barriers: Construct barriers to reduce noise propagation.

Noise-Reducing Equipment: Use quieter machinery and equipment.

Regular Maintenance: Ensure proper maintenance of equipment to reduce noise levels.

Social and Health Risks

Occupational Health Risks:

Danger: Exposure to dust, noise, and hazardous chemicals can lead to respiratory diseases, hearing loss, and other health problems for workers.

Mitigation

Personal Protective Equipment (PPE): Provide workers with appropriate PPE, such as masks, earplugs, and safety goggles.

Regular Health Checkups: Conduct regular health checkups for workers.

Ventilation Systems: Improve ventilation in workplaces to reduce exposure to dust and fumes.

Land Degradation

Danger: Cement production requires large amounts of limestone, which is often quarried from natural habitats, leading to land degradation and loss of biodiversity.

Mitigation

Revegetation: Rehabilitate quarried land by revegetating with native plant species.

Waste Generation

Danger: Cement Kiln Dust, Cement production generates cement kiln dust, which can be hazardous if not disposed of properly and contaminate soil and water

Mitigation

2. Waste reduction and recycling: Implement waste reduction and recycling programs to minimize waste generation.

3. Proper disposal: Ensure proper disposal of hazardous waste, including cement kiln dust and other chemical waste.

Production of sodium hydroxide and chlorine by electrolysis of brine.

Food for thoughts

1._Discuss the raw materials used in the production of sodium hydroxide and chlorine.

2._Where are these raw materials obtained from in Uganda?

The production of sodium hydroxide (NaOH) and chlorine (Cl_2) by electrolysis is a widely used industrial process. The process involves the electrolysis of sodium chloride (NaCl) solution, also known as brine, to produce NaOH and Cl_2.

Principle behind the Process

The process is based on the principle of electrolysis, where an electric current is used to drive a chemical reaction. In this case, the reaction is the decomposition of NaCl into NaOH and Cl_2.

Experiment: Electrolysis of Sodium Chloride to Produce Sodium Hydroxide

Aim: To demonstrate the electrolysis of sodium chloride (NaCl) to produce sodium hydroxide (NaOH) and chlorine gas (Cl_2), and to test the properties of the products.

Hypothesis: Electrolysis of sodium chloride will produce sodium hydroxide at the cathode (negative electrode) and chlorine gas at the anode (positive electrode). The litmus paper will turn blue in the presence of sodium hydroxide, indicating its production.

Variables:

Independent Variable

- Electric current applied to the sodium chloride solution.

Dependent Variable

- Production of sodium hydroxide and chlorine gas.

Controlled Variables

- Concentration of sodium chloride solution

- Temperature of the solution
- Surface area of the electrodes
- Voltage and current of the power supply

Risks and Mitigation

Risks

- Electric shock: The experiment involves working with an electric current, which can cause electric shock if not handled properly.
- Chemical burns: The experiment involves working with sodium hydroxide, which can cause chemical burns if not handled properly.
- Chlorine gas exposure: The experiment involves the production of chlorine gas, which can be toxic if inhaled.

Mitigation

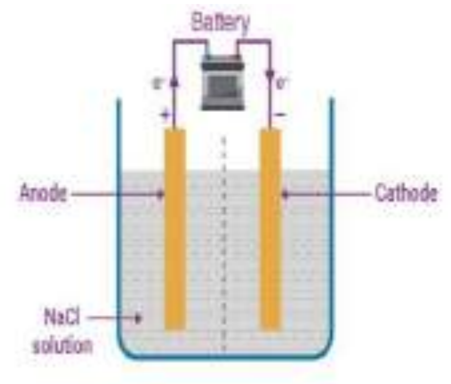
- Wear protective gloves, goggles, and a lab coat to prevent electric shock and chemical burns.
- Perform the experiment in a fume cupboard to prevent inhalation of chlorine gas.
- Ensure that the power supply is turned off before handling the electrodes or the solution.
- Neutralize the solution with acid after the experiment to prevent any further reactions.

Materials

- U-shaped glass tube
- Graphite electrodes(pencils)
- Concentrated sodium chloride solution
- DC power supply
- Litmus paper
- Test tubes

Procedure

- Fill the U-shaped tube with concentrated sodium chloride solution. Insert the graphite electrodes into the solution, ensuring they are submerged.
- Connect the positive terminal of the DC power supply to one electrode and the negative terminal to the other.
- Turn on the power supply and observe the reaction at the electrodes.
- Test the products



At the cathode: Collect the gas produced at the negative electrode in a test tube and test it with a lighted splint.
At the anode: Collect the gas produced at the positive electrode in a test tube and test it with moist litmus paper.
In the solution; Test the solution in the U-tube with litmus paper to determine its pH.

Expected Observations
At the cathode; Hydrogen gas will be produced. It will ignite with a pop sound when a lighted splint is brought near it.
At the anode; Chlorine gas will be produced. It will turn moist blue litmus paper red.
In the solution: The solution will become alkaline, turning red litmus paper blue.
Conclusion
The electrolysis of sodium chloride solution produces sodium hydroxide, hydrogen gas, and chlorine gas.
The sodium hydroxide is formed at the cathode, while the hydrogen gas and chlorine gas are formed at the anode.

At the Cathode (Negative Electrode):
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

At the Anode (Positive Electrode):

$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

Overall Reaction: $2NaCl(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g) + Cl_2(g)$

Industrial Manufacture of Sodium hydroxide and Chlorine Gas

The electrolysis of brine (a concentrated solution of sodium chloride) is a crucial industrial process for the production of sodium hydroxide (NaOH) and chlorine gas (Cl_2).

The production of sodium hydroxide (NaOH) and chlorine (Cl_2) through electrolysis is known as the **chlor-alkali** process.

Electrolysis Cell

The electrolysis cell used for the production of NaOH and Cl_2 is typically a diaphragm cell or a membrane cell. The cell consists of two electrodes, an anode and a cathode, separated by a diaphragm or membrane.

The electrolyte is concentrated sodium chloride which contains the following ions: Na^+, H^+, Cl^- and OH^-

Electrolytic Cell Setup:

Electrolyte: Concentrated brine solution (NaCl)
Anode: Typically made of graphite or titanium
Cathode: Usually made of steel or mercury

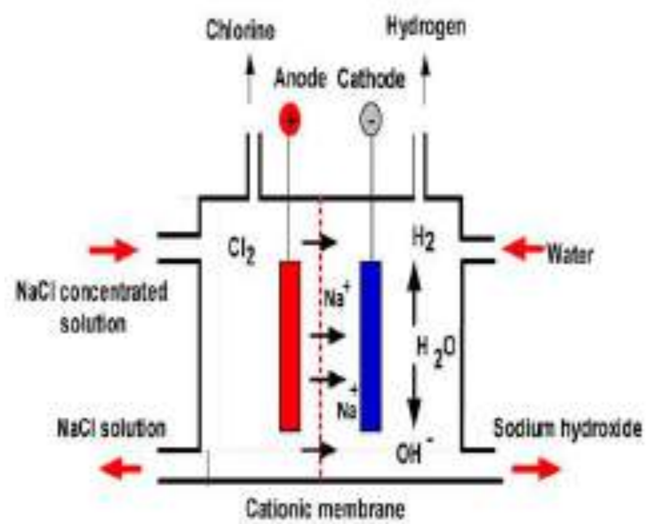
Electrolysis Process:

A sodium chloride (NaCl) solution, also known as brine, is prepared by dissolving in water and purified to remove impurities.

The purified brine solution is then fed into an electrolytic cell. The cell consists of a mercury cathode (negative electrode) and a graphite anode (positive electrode). Electricity is then passed through the cell.
At the cathode, sodium ions (Na^+) are reduced to form sodium metal, which dissolves in mercury to form a sodium amalgam (Na-Hg).
$2Na^+ (aq) + 2e^- \rightarrow 2Na (s)$
$Na (s) + Hg (l) \rightarrow Na\text{-}Hg$ (amalgam)

The sodium amalgam is then reacted with water to produce sodium hydroxide (NaOH) and hydrogen gas (H_2).
$2Na\text{-}Hg$ (amalgam) $+ 2H_2O (l) \rightarrow 2NaOH (aq) + H_2 (g) + Hg (l)$

The resulting sodium hydroxide solution is then separated and purified through a series of steps, including filtration and evaporation to produce a solid or liquid product.



At the anode, The Cl– ions are discharged. Chloride ions (Cl^-) lose electrons and are oxidized to form chlorine gas (Cl_2).
$2Cl^- (aq) \rightarrow Cl_2 (g) + 2e^-$
The chlorine gas (Cl_2) produced at the anode is collected and purified by liquefying under pressure for use in various industrial applications.

Note:
To extract sodium metal, the sodium amalgam is separated from the brine solution. The amalgam is heated to distill off the mercury, leaving behind sodium. The sodium metal is collected and cast into desired shapes. The metal is stored under oil or paraffin since its very reactive.

Applications of Sodium Hydroxide and Chlorine

Sodium hydroxide ($NaOH$) is used in a variety of applications, including:

- Production of paper and pulp
- Production of detergents and soaps
- Water treatment
- Textile industry

Chlorine (Cl_2) is used in a variety of applications, including:

- Water treatment
- Disinfection and sanitation
- Production of plastics and polymers (PVC)
- Production of pharmaceuticals and chemicals

Hydrogen; Used as a fuel, in the production of ammonia, and in the refining of metals.

Benefits of the process of electrolysis of brine

Job creation: The electrolysis of sodium chloride creates jobs in the chemical industry, both directly and indirectly, this generates income for individuals and communities improving standards of living of the people.

Economic growth: The electrolysis of sodium chloride contributes to the overall economic growth of a country by providing essential chemicals for various industries.

Quality life: The sodium hydroxide and chlorine produced are used in water treatment plants to produce clean drinking water, improving the quality of life for communities.

Social development: Companies involved in the electrolysis of sodium chloride often engage with local communities through corporate social responsibility initiatives, this leads to development of communities.

Side effects of the process of production of sodium hydroxide and chlorine

Side effects of sodium hydroxide (NaOH) production:

Caustic burns and eye damage: NaOH is highly corrosive and can cause severe burns and eye damage.

Mitigation: Use personal protective equipment (PPE) such as gloves, goggles, and face shields when handling NaOH. Ensure proper ventilation and emergency showers are available.

Environmental contamination: NaOH can contaminate soil and water if not disposed of properly.

Mitigation: Implement proper waste disposal and storage procedures. Use containment systems to prevent spills and leaks.

Air pollution: The production of NaOH can release air pollutants such as particulate matter, nitrogen oxides, and sulfur dioxide.

Mitigation: Implement air pollution control measures such as scrubbers, electrostatic precipitators, and fabric filters.

Side effects of chlorine (Cl_2) production:

Toxic gas release: Cl_2 is a toxic gas that can cause respiratory problems and other health issues.

Mitigation: Implement proper ventilation systems and use gas detectors to monitor Cl_2 levels. Ensure proper storage and handling procedures.

Chlorine gas explosions: Cl_2 is highly reactive and can explode if not handled properly.

Mitigation: Implement proper safety protocols when handling Cl_2, such as using explosion-proof equipment and following proper storage and handling procedures.

Environmental contamination: Cl_2 can contaminate soil and water if not disposed of properly.

Mitigation: Implement proper waste disposal and storage procedures. Use containment systems to prevent spills and leaks.

Shared side effects and mitigation strategies:

Energy consumption and greenhouse gas emissions: The production of NaOH and Cl_2 requires significant amounts of energy, which can lead to greenhouse gas emissions.

Mitigation: Implement energy-efficient technologies and processes. Consider using renewable energy sources or purchasing carbon offsets.

Water pollution: The production of NaOH and Cl_2 can result in water pollution if not properly managed.

Mitigation: Implement proper wastewater treatment and management procedures. Use containment systems to prevent spills and leaks.

Community impacts: The production of NaOH and Cl_2 can have negative impacts on local communities, such as noise pollution and odors.

Mitigation: Implement community engagement and outreach programs. Use noise-reducing and odor-control technologies to minimize impacts.

End of chapter summary

- Ore: a naturally occurring mineral from which a metal or other valuable substance can be extracted.
- Fertilizer: a substance added to soil to promote plant growth and fertility. Nitrate Fertilizers are fertilizers that contain nitrogen in the form of nitrate, such as ammonium nitrate and calcium nitrate. Processes used to produce nitrate fertilizers may include fractional distillation of liquid air to produce Nitrogen, the Haber process and the Ostwald process.
- Cement: a binding agent used in construction, made from a mixture of limestone, clay, and other minerals. Process involved in production of cement, include calcination and hydration.

Metals: elements that are typically hard, shiny, and conductive, such as copper, iron, and aluminum. Metals are extracted from their ores, which may include mining, crushing, and refining.

- Extraction of Copper: process used to extract copper from its ore (Malachite or Cuprite). It includes mining, crushing, and refining. It's then later refined by electrolysis.

- Iron is extracted from its primary ore(Hematite) mixed with limestone, coke in a blast furnace.
- Electrolysis of sodium chloride (brine) is used in production of sodium hydroxide and chlorine gas.
- Sodium Hydroxide: a strong base used in a variety of industrial processes, including the production of paper and soap. Chlorine: a yellow-green gas used in a variety of industrial processes, including the production of plastics and disinfectants.

End of chapter Scenarios

Item 1:

The government has licensed a new company to mine limestone in the Mbarara district where a new cement factory is to be built. The factory will use limestone as the main raw material.

However, the locals are concerned about the potential environmental impacts of the mining activities.

Task;

Prepare a presentation to educate the locals on the cement production process, and how the factory will contribute to the local economy.

Item 2:

The government has planned to revive the Kilembe Mines in the Kasese district. The mines will extract copper ore, which will then be processed into pure copper. The LC1 of one of the villages in Kasese wants you to educate his community members on how the process of production of pure copper will be done.

Task;

Design a presentation to educate the locals on the copper extraction process, and how the revived mines will benefit the local community.

Item 3:

A group of students from a local secondary school have visited a soap manufacturing factory in the Kampala district. They were then told that soap is produced by mixing vegetable oil with sodium hydroxide. They are curious to know how sodium hydroxide is produced. You are one of the student chosen to move with these students as one with good knowledge on production of sodium hydroxide.

Task;

Explain the sodium hydroxide production process in a way that is easy for the students to understand.

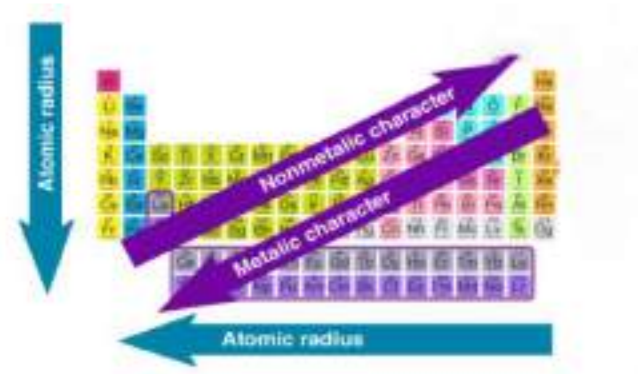
Item 4:

A new fertilizer manufacturing plant is being set up in the Mbarara district. The plant will produce ammonium nitrate fertilizer nitrogen in the air and hydrogen obtained from fossils as the raw materials. The locals are interested in knowing more about the fertilizer manufacturing process.

Task;

Design a chart that will explain to the locals the processes involved in manufacturing fertilizers.

3. TRENDS IN THE PERIODIC TABLE



Competency: The learner appreciates the diversity of properties of elements and how these properties change across the periods and groups of the Periodic Table.

Key words

- Periodic Table
- Periods
- Groups
- Metals
- Nonmetals
- Metalloids
- Atomic Radius
- Valency
- Periodic Trends
- Group Trends
- Atomic Size
- Atomic Number
- Electron Configuration
- Metallic Character
- Shielding Effect
- Nuclear Charge
- Periodicity

By the end of this topic, the learner should be able to;

- Know the trends in physical properties of the elements across the periods in the Periodic Table(k)
- Know the trends in typical, physical, and chemical properties of simple compounds of the elements of the third period (u, s)
- Predict physical and chemical properties of different elements in Group 1 (u, s)

Periodic trends are the systematic changes in the properties of elements as you move across a period or down a group in the periodic table.
The periodic table is a systematic arrangement of elements based on their atomic number and electronic configuration. It provides a visual representation of the relationships between different elements and helps us understand their properties and behaviors. It's organized in form of rows and columns.

Groups and Periods

Groups: These are the vertical columns in the periodic table. Elements within a group share similar chemical properties due to having the same number of valence electrons (electrons in the outermost shell).
As we move down a group in the periodic table, the atomic structure changes in a specific way. The most significant change is the addition of a new energy level or shell. This means that as we move down a group, atoms have more electron shells. With the addition of new shells, the atomic radius increases. This is because the outermost electrons are further away from the nucleus, leading to a larger atomic size.
Elements within the same group have the same number of valence electrons. This means they have the same electron configuration in their outermost shell.
For example, all alkali metals (Group 1) have one valence electron, and all alkaline earth metals (Group 2) have two valence electrons.

Electronic Configurations of Elements in the Same Group

Group 1 elements	Symbol	Atomic Number	Electronic configuration
Lithium	Li	3	2:1
Sodium	Na	11	2:8:1
Potassium	K	19	2:8:8:1

Periods: These are the horizontal rows in the periodic table. Elements within the same period have the same number of electron shells.

As you move across a Period, the number of valence electrons increases by one, leading to changes in their chemical properties. For example, as you move across period 3, sodium and magnesium are metals, while chlorine and argon are nonmetals.

Electronic Configurations of Elements in the Same period

Element	**Symbol**	**Atomic number**	**Electronic configuration**
Sodium	Na	11	2:8:1
Magnesium	Mg	12	2:8:2
Aluminum	Al	13	2:8:3
Silicon	Si	14	2:8:4
Phosphorus	P	15	2:8:5
Sulphur	S	16	2:8:6
Chlorine	Cl	17	2:8:7
Argon	Ar	18	2:8:8

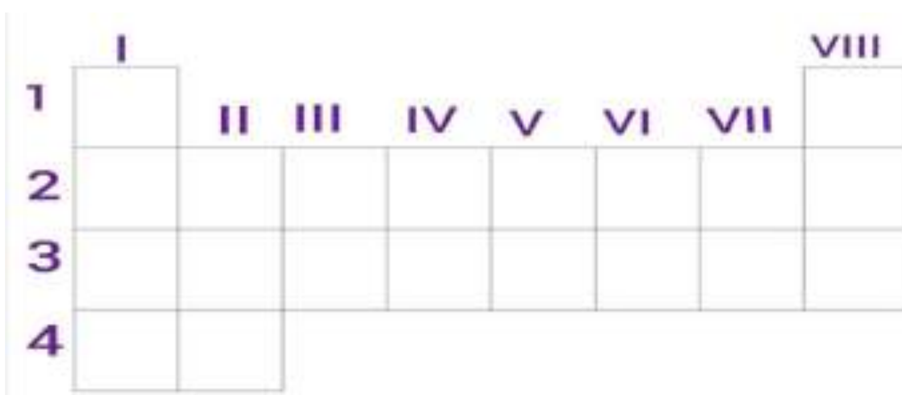
Food for thoughts

1. Element X is in Period 2 and Group IV of the Periodic Table.

a) What is the atomic number of X?

b) Write its electronic configuration.

2. The electronic configurations of elements V, W, X, Y, and Z are 2,2; 2,5; 2,8,3; 2,8,8,2; and 2,8,7, respectively. Place V, W, X, Y, and Z in the grid to show their positions in the Periodic Table indicating the atomic number for each element at the top left corner of each grid.



Remember, these are not the usual elements, they are just letters representing elements.

The Principle Underlying the Periodic Table: Electronic Configuration

The periodic table is organized based on the electronic configuration of elements. This means the arrangement of electrons in an atom's orbitals determines its position in the table.

Key principles

1. Atomic Number

Elements are arranged in increasing order of their atomic number, which represents the number of protons (and, in a neutral atom, the number of electrons) in the nucleus.

2. Electron Configuration

The specific arrangement of electrons in energy levels (shells) and orbitals determines an element's chemical properties.

Elements with similar electron configurations, especially in their outermost (valence) shells, exhibit similar chemical behaviors.

3. Periods and Groups

Periods: Horizontal rows. Elements in the same period have the same number of electron shells or energy levels. In moving from one element to the other in the same period, valence electrons increases by one.

Groups: Vertical columns. Elements in a group have the same number of valence electrons, leading to similar chemical properties. As you swipe from one element to the other down the same group, a new energy level is added.

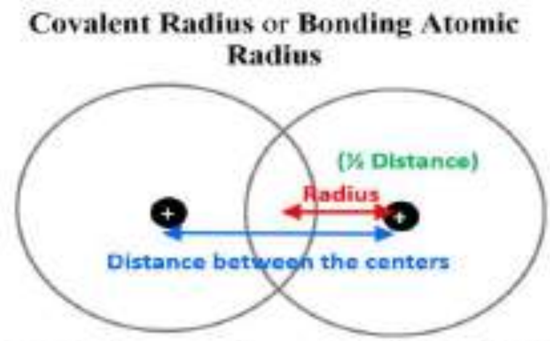
Trends in the periodic table

Periodic Trends are the regular patterns in the properties of elements that can be observed across a period or down a group in the periodic table. These trends are primarily due to changes in the electron configuration of elements.

Trends in Atomic Radii of Elements in the same period

The distance between the nucleus and the outermost electrons of an atom is the atomic radius.

The figure below illustrates the concept of atomic radius, which is half the distance between the nuclei of two identical atoms bonded together.



For bonding atoms, the atomic radius is half of the distance between the nuclei.

The figure shows two identical atoms bonded covalently. A covalent bond involves the sharing of electron pairs between atoms.

The distance between the nucleus of one atom and the nucleus of the other atom is measured. Half of this distance is considered the atomic radius of each atom.

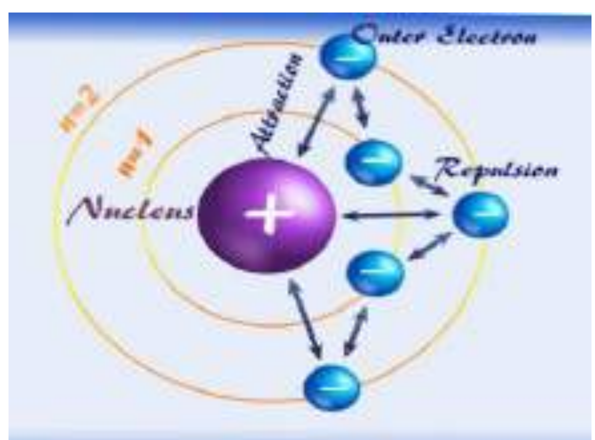
Understanding atomic radius helps explain various chemical and physical properties of elements, such as:

Reactivity: Atoms with larger atomic radii tend to be more reactive, as their outer electrons are further from the nucleus and easier to lose or gain.

Bonding: Atomic radius influences the bond length and bond strength between atoms.

Physical Properties: Atomic radius can affect properties like melting point, boiling point, and density.

Attractive and Repulsive Forces in an Atom



An atom is a delicate balance of opposing forces.

The positively charged protons in the nucleus attract the negatively charged electrons. This is the primary force (electrostatic force of attraction) holding the atom together. This Force acts to reduce the atomic radius of an atom.

Electrons, being negatively charged, repel(shield) each other. This force(shielding force) tends to push the electrons apart thereby acting to increase the atomic radius. This repulsion is particularly strong when electrons are in close proximity.

Trends in variation of atomic radii of elements in the same period in the periodic table

The atomic radius of the elements in moving from left to right decreases.

Why does this happen?

1. Increasing Nuclear Charge:
As we move across a period, the number of protons in the nucleus increases. This leads to a stronger positive charge in the nucleus.
2. Shielding Effect:
Electron shielding stays constant since the number of inner shell electrons stays the same as electrons are added to the same principal energy level over time, the increase in nuclear charge outweighs the net shielding effect.
3. Effective Nuclear Charge:
The increased positive charge attracts the electrons more strongly towards the nucleus. The electrons are pulled closer to the nucleus, reducing the atomic radius.

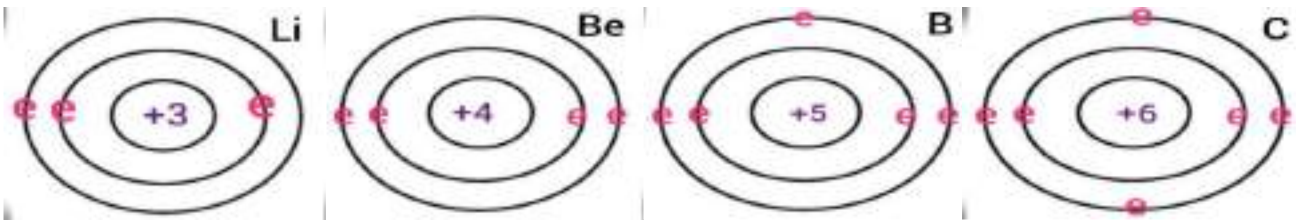
Electrostatic force of attraction plays a significant role in determining atomic radius. This force, which arises from the attraction between positively charged protons in the nucleus and negatively charged electrons, influences the size of an atom.

As you move across a period, the number of protons in the nucleus increases. This increased nuclear charge exerts a stronger electrostatic force on the electrons. Consequently, the electrons are pulled closer to the nucleus, resulting in a decrease in atomic radius.

In summary, the trend of decreasing atomic radius across the Period is primarily driven by the increasing nuclear charge, which overpowers the effect of increased electron shielding.

Food for thoughts

Consider the elements of period 2 whose Atomic structures are given below.



Explain with reasons, the atom with the,

I. Smallest atomic radius
II. Largest atomic radius
III. Explain the trend in atomic radii of period 2 elements.
IV. Write the electronic configuration of the elements.

Trends in variation of atomic radii of elements in the same group in the periodic table

As we move down a group in the periodic table, the atomic radius generally increases.

Why does this happen?

1. Addition of Electron Shells:

As we move down a group, each subsequent element adds a new electron shell. These additional shells increase the overall size of the atom.

2. Shielding Effect:

Inner electrons shield outer electrons from the full attractive force of the nucleus.

As we move down a group, the number of inner electrons increases, leading to greater shielding. This shielding effect reduces the effective nuclear charge felt by the outermost electrons.

3. Increased Nuclear Charge

While the nuclear charge increases down a group, its effect is outweighed by the increased shielding effect and the addition of new electron shells.

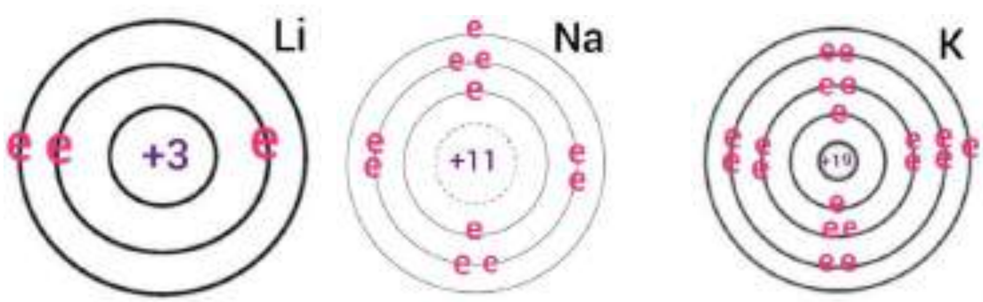
As you move down a group, the number of electron shells increases. This shielding effect, where inner electrons shield outer electrons from the full nuclear charge, reduces the effective nuclear charge felt by the outermost electrons. As a result, the outermost electrons are less tightly held by the nucleus, leading to an increase in atomic radius.

In summary

The combination of increased electron shells and increased shielding effect dominates the trend in atomic radii down a group, leading to an overall increase in size.

Food for thoughts

Study the atomic structures of group I elements given below.



Identify the atom with;

I. The largest atomic radius
II. The smallest atomic radius
III. Explain your choices in I and II above.
IV. Write the electronic configuration for each atom above

The Balance of Forces

Stable Atom: In a stable atom, the attractive forces between the nucleus and electrons are balanced by the repulsive forces between the electrons.

Energy Levels: Electrons occupy specific energy levels or orbitals around the nucleus. These energy levels represent regions where the balance between attractive and repulsive forces is optimal.

The balance between attractive and repulsive forces determines the stability and structure of an atom. If the repulsive forces become too strong, the atom may become unstable or undergo a chemical reaction.

Understanding these forces is crucial for explaining the behavior of atoms and molecules.

Trends in metallic character in the periodic table

Metallic character is a periodic trend that can be observed by analyzing the properties of elements.

Understanding the factors that influence metallic character, such as atomic size, nuclear charge, and electron configuration, helps explain these trends.

Metallic character refers to the degree to which an element exhibits metallic properties.

Metals typically have properties like, Luster, Malleability, Ductility, Conductivity (electrical and thermal).

Metal atoms typically have a tendency of losing their valence electrons so as to attain stability.

The more easier the atom loses electrons from the Nucleus, the more metallic character the atom exhibits.

Activity: Exploring Metallic Character Trends in the Periodic Table

Objectives

- Understand the concept of metallic character.
- Identify trends in metallic character across a period and down a group.
- Explain the reasons behind these trends.

Materials:

- Periodic table
- Pen and paper

Procedure:

Part 1: Understanding Metallic Character

1. Define Metallic Character

2. Identify Metals and Nonmetals

Using a periodic table, color-code the metals and nonmetals.

Discuss the general location of metals and nonmetals on the periodic table.

Part 2: Trends in Metallic Character

1. Trend Across a Period
2. Observe the trend in metallic character as you move from left to right across a period.

2. Trend Down a Group

Observe the trend in metallic character as you move down a group.

Expected observations

- Metallic character generally decreases across a period.

As you move across a period, the tendency of the atoms losing electrons reduces, atoms tend to gain electrons to achieve a stable electron configuration. This makes them less likely to lose electrons, which is a characteristic of metals.

- Metallic character generally increases down a group.

As you move down a group, the atomic size increases, and the valence electrons are farther from the nucleus. This makes it easier for atoms to lose electrons, increasing metallic character.

Therefore, elements at the bottom of a group tend to exhibit more metallic properties, such as:

- Conductivity of electricity and heat
- Malleability and Ductility
- Reactivity with nonmetals

These properties are characteristic of metals.

Part 3: Analyzing Specific Examples

1. Compare Sodium (Na) and Chlorine (Cl)

Discuss the differences in their metallic character.

Explain why sodium is more metallic than chlorine.

2. Compare Lithium (Li) and Potassium (K)

Discuss the differences in their metallic character.

Explain why potassium is more metallic than lithium.

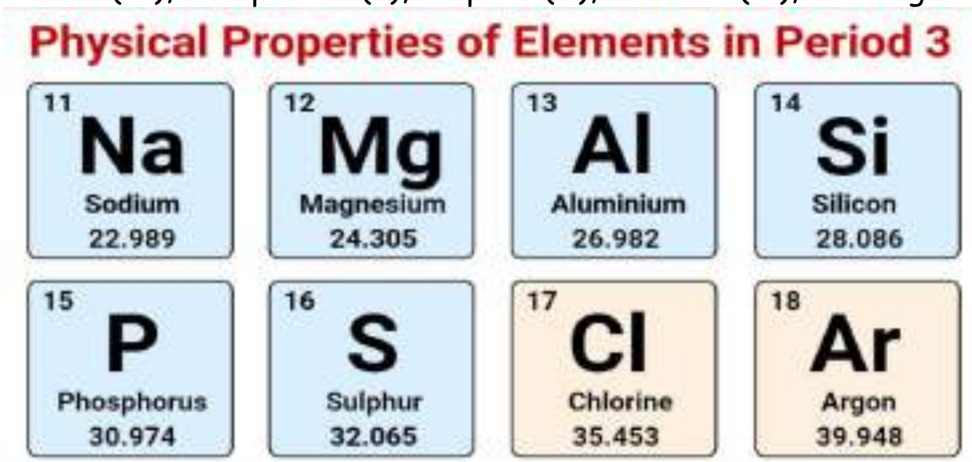
Extension Activity:

Research the reactivity of alkali metals and halogens. How does their metallic character relate to their reactivity?

Investigate the use of metals and nonmetals in everyday life. How do their properties influence their applications?

Period 3 elements

The elements of period 3 are placed in the third row of the periodic table. The elements positioned in period 3 are Sodium (Na), Magnesium (Mg), Aluminum (Al), Silicon (Si), Phosphorus (P), Sulphur (S), Chlorine (Cl), and Argon (Ar).



Firstly, we have well known for the periodicity the rows in the periodic table. The elements in the periodic table are arranged based on their properties and periodicity. Hence, the elements of period 3 are also related to different physical and chemical properties of each other.

Physical Properties of Elements in Period 3

The modern periodic law states- " The physical and the chemical properties of the elements are the periodic functions of their atomic numbers". Moreover, electrons, atomic numbers, and molecular structure help us to understand the trends of chemical bonding, chemical properties, and physical properties, respectively.

Physical State of Elements in Period 3

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Physical state	Solid	Solid	Solid	Solid	Solid	Solid	Gas	Gas

Na, Mg and Al adapt metallic bonding with strong forces of attraction between the cations and delocalized Mobile electrons. The strength of the metallic bond depends on the number of electrons each atom contributes to the electron cloud.
Si is a metalloid which has a giant molecular structure with strong covalent bonds between atoms of silicon.
P, S, Cl, Ar, are non metals which consist of molecules held together by Vander walls forces of attraction. The strength of these forces depends on the molecular size or molecular mass.

Trends in Melting and boiling Points of Elements in Period 3

The melting point is defined as the amount of energy required to break a bond(s) and change the phase of the substance from solid to liquid. Melting and boiling points of elements across any period depends on molecular weight and the strength of the forces that act between molecules (intermolecular forces) of a substance. The stronger these forces are, the higher the melting point.
Melting and boiling points of Period 3 elements show an interesting trend as we move across the period.
General Trend:
In the case of period 3 elements, there is a gradual increase in melting point from left to right from Sodium to Silicon and decreases further right from phosphorus to argon with exceptions of sulphur.

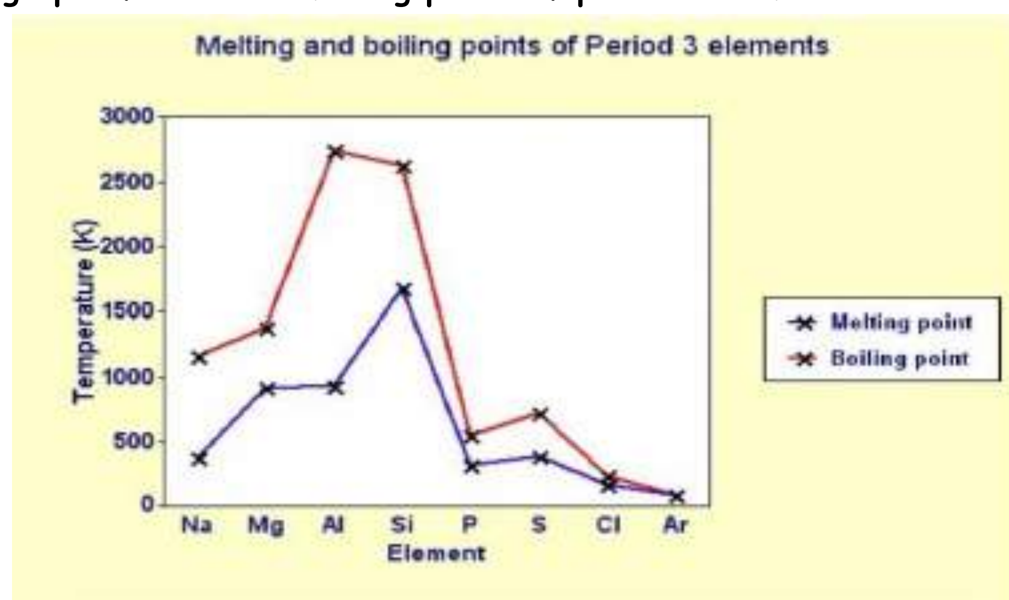
Here is a table of the melting and boiling points of period 3 elements for reference:

Element	**Na**	**Mg**	**Al**	**Si**	**P**	**S**	**Cl**	**Ar**
Atomic number	11	12	13	14	15	16	17	18
Melting Point (°C/K)	97.8°C 371K	650°C 923K	660°C 932K	1414°C 1683K	44.2°C 317K	115.2°C 392K	-101°C 172K	-189.3°C 84K
Boiling Point (°C/K)	883°C 1156K	1090°C 1363K	2467°C 2740K	3265°C 3538K	280°C 553K	444.6°C 717.6K	-34°C 239K	-185.7°C 87.3K

As you can see, the melting and boiling points generally increase from sodium to silicon, then decrease from phosphorus to argon. The exceptions to this trend is Sulphur, which has a higher melting and boiling points due to the formation of covalent network structures.

Sulphur (S) exists as a polymeric solid, specifically as S_8 molecules, which are arranged in a ring structure. These molecules have stronger intermolecular forces, which require more energy to break apart. Additionally, sulphur also exhibits some covalent character in its solid state, which further contributes to its higher melting and boiling points.

A graph of trends in melting points of period 3 elements



Reasons for the Trends:

1. Metallic Bonding (Sodium, Magnesium, Aluminum):

Stronger Metallic Bonds: As we move from sodium to aluminum, the number of delocalized electrons increases. This leads to stronger metallic bonds.
Stronger metallic bonds require more energy to break, resulting in higher melting and boiling points.

2. Covalent Network Structure (Silicon):

Giant Covalent Structure: Silicon has a giant covalent structure, where each silicon atom is covalently bonded strongly to four other silicon atoms forming a network structure. These strong covalent bonds require a significant amount of energy to break, leading to a high melting and boiling point.

3. Simple Molecular Structures (Phosphorus, Chlorine):

Weak Intermolecular Forces: These elements exist as simple molecules held together by weak intermolecular forces (van der Waals forces).These weak forces require relatively little energy to overcome, resulting in lower melting and boiling points.

4. Noble Gas (Argon):

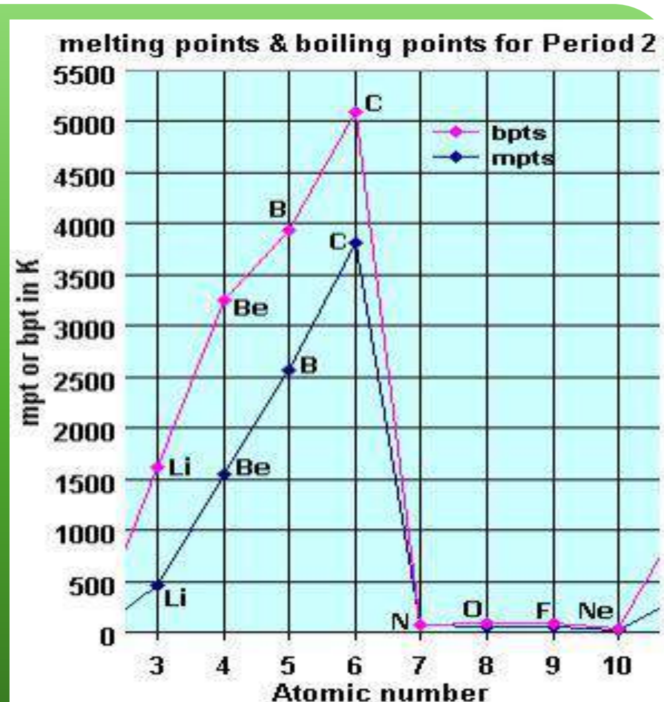
Weak van der Waals Forces: Argon exists as individual atoms held together by weak van der Waals forces. Due to the weak interatomic forces, argon has very low melting and boiling points.

In summary:

The trend in melting and boiling points across Period 3 is influenced by the type of bonding present in the elements. Metallic bonding results in high melting and boiling points, while weak intermolecular forces lead to low melting and boiling points. Silicon, with its giant covalent structure, has exceptionally high melting and boiling points.

Food for thoughts

Study the graph below showing the trend in melting and boiling points for period 2 elements.



Questions

a. How does melting and boiling point vary across the period (period 2)?

b. Explain the variation in Melting and boiling points across the period.

c. Draw a conclusion based on the trend above.

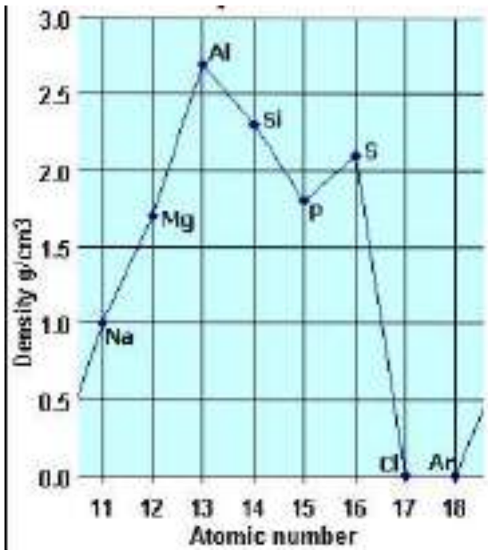
Trends in densities across the period

Densities of period 3 elements generally increase from left to right across the period, then decrease for the last two elements.

Here is a table of the densities of period 3 elements for reference:

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Atomic number	11	12	13	14	15	16	17	18
Density (g/cm^3)	0.97	1.74	2.70	2.33	1.82	2.07	1.56	1.40

In moving from left to right, the densities generally increase among metals i.e from sodium to aluminum, then decrease from silicon to argon. The exceptions to this trend is sulphur, which has slightly higher density than expected due to their covalent network structures.



General Trend

Increasing Density: From sodium to aluminum, the density generally increases due to the increasing atomic mass.

Decreasing Density: From silicon to chlorine, the density decreases due to the change to covalent structures with weaker intermolecular forces.

Exceptions:

Sulphur has a relatively high density compared to other non-metallic elements in the period, such as phosphorus and chlorine.

The reason for sulphur's higher density lies in its molecular structure and packing efficiency. Sulphur exists as S8 rings, which are relatively compact structures. These S8 rings pack efficiently in the solid state, leading to a higher density.

In contrast, phosphorus exists as P4 molecules, which have a more open structure. This less efficient packing results in a lower density compared to sulphur.

Variation in Densities of Period 3 Elements

The density of an element is influenced by several factors, including atomic mass and atomic structure. As we move across Period 3, the density generally increases, with some exceptions.

1. Atomic Mass: As we move across a period, the atomic mass generally increases. This means that there are more particles packed into a given volume, leading to an increase in density.

2. Atomic Structure: Metallic Elements (Na, Mg, Al):These elements have a metallic lattice structure, where atoms are closely packed together. As the atomic mass increases, the packing efficiency also increases, leading to higher density.

Giant Covalent Network (Si): Silicon has a giant covalent network structure, with strong covalent bonds between atoms. This results in a high density.

Simple Molecular Structures (P, S, Cl):These elements exist as discrete molecules with weaker intermolecular forces. This leads to lower densities compared to metallic and giant covalent structures.

In summary:

The variation in densities of Period 3 elements is influenced by a combination of factors, including atomic mass, atomic structure, and the strength of interatomic forces. Understanding these factors helps explain the observed trends in density across the period.

Chemical properties across Period 3

Period 3 elements are basically grouped into metals (Na, Mg, and Al), metalloids (Si) and non-metals (P, S, Cl, Ar).

The reaction of these elements with other substances (Chemical properties) very across the period from left to right.

i. Experiment: Reactions of Period 3 Elements with water

Aim: Comparing the reactions of period 3 metal elements with water.

Hypothesis: The reaction of period 3 metal elements with water varies from element to element.

Variables.

Independent variable – type of the metal

Dependent variable-reactivity of the metal with water

Controlled variable -size and surface area of the metal

What you need:

- Sodium metal
- Steel wool
- Water

- Magnesium ribbon
- Aluminum foil
- Three glass beakers

Risks:

1. The reaction of sodium with moisture or water can be explosive
2. Chemical Burns: The reaction products, especially sodium hydroxide, can cause severe chemical burns.

Mitigation Strategies:

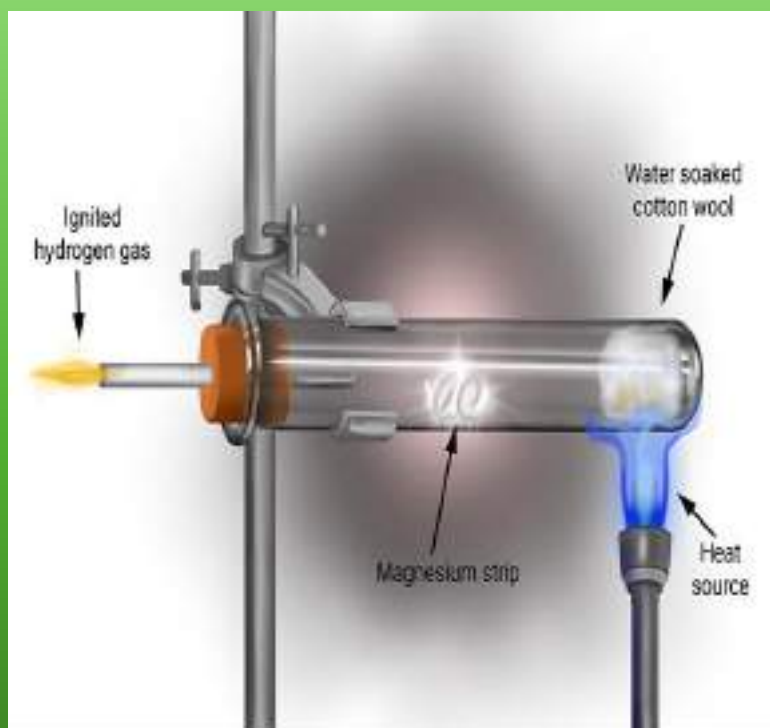
Use small quantities of sodium to minimize the risk of violent reactions.

Handle sodium metal with extreme caution, using tongs or tweezers.

Always keep sodium metal under oil or kerosene to prevent exposure to air and moisture.

Know how to handle chemical burns and eye injuries.

Procedure



1. Half-fill each beaker with water.
2. Using steel wool, clean (scrub) the aluminum and magnesium ribbons.
3. Cut a small piece of sodium, aluminum, and magnesium ribbons.
4. Drop the pieces into separate beakers with water.
5. Observe carefully and write your observation in a notebook.
6. Put a clean piece of magnesium ribbon and aluminum foil in separate test tubes and heat using a Bunsen burner to react it with steam.

Discussion questions

a. Explain how the reaction of the elements with water varies.

b. Write equations for the reaction of each Metal with water.

Expected Responses

The reactivity of Period 3 metals with water generally decreases across the period

Reactions with water: summary

Element	Description	Equation
Na	vigorous	$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$
Mg	slow with cold water; vigorous with steam	$Mg_{(s)} + 2H_2O_{(l)} \rightarrow Mg(OH)_{2(aq)} + H_{2(g)}$ $Mg_{(s)} + H_2O_{(g)} \rightarrow MgO_{(s)} + H_{2(g)}$
Al	no reaction	–
Si	no reaction	–
P	no reaction	–
S	no reaction	–
Cl	dissolves to form chlorine water	$Cl_{2(aq)} + H_2O_{(l)} \rightleftharpoons HClO_{(aq)} + HCl_{(aq)}$
Ar	no reaction	–

Sodium (Na)

Vigorous Reaction: Reacts violently with cold water, producing hydrogen gas and a strongly alkaline solution of sodium hydroxide. A lot of heat is liberated, the heat causes sodium to melt into a silvery ball that darts on the surface of water but doesn't burn in a flame.

Equation: $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

Magnesium (Mg)

Reacts slowly with cold water, forming magnesium hydroxide and hydrogen gas. The reaction is often aided by the presence of impurities.

Equation: $Mg(s) + 2H_2O(l) \rightarrow Mg(OH)_2(s) + H_2(g)$

Reacts more vigorously with hot water or steam, burns in steam with a bright flame forming a white solid of magnesium oxide and hydrogen gas liberated.

Equation: $Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$

Aluminum (Al)

Does not react with cold water due to the formation of a protective layer which stops further reaction.

Reaction with Steam: Reacts slowly with steam, forming aluminum oxide and hydrogen gas.

Equation: $2Al(s) + 6H_2O(g) \rightarrow Al_2O_3(s) + 3H_2(g)$

Chlorine (Cl)

Reacts with water to form a mixture of hydrochloric acid and hypochlorous acid.

Equation: $Cl_2(g) + H_2O(l) \rightarrow HCl(aq) + HOCl(aq)$

Why the Decrease in Reactivity?

As we move across Period 3, the metallic character of the elements decreases. This is due to:

1. Increasing Nuclear Charge: The number of protons in the nucleus increases, pulling the electrons closer and making it more difficult to lose electrons.
2. Decreasing Atomic Radius: The atomic size decreases, making it harder for the outer electrons to be lost.

These factors make it increasingly difficult for the metals to donate electrons to water molecules and form metal hydroxides and hydrogen gas.

Reactions of the elements with oxygen

The elements except chlorine and argon generally react directly with oxygen to produce oxides. The reactivity of period 3 elements with air varies depending on their electronic configuration and metallic or nonmetallic nature.

Activity

a. Using equations, show the reactions of period 3 elements with oxygen.
b. Research and find out the general trend in the reaction of the elements with oxygen.

Sodium (Na)

Reaction: $4Na + O_2 \rightarrow 2Na_2O$ (in limited air)

$2Na + O_2 \rightarrow Na_2O_2$ (in excess air)

Condition: Heat

Observations: Burns vigorously in limited air to form a white solid (sodium oxide).
Burns in excess air to form a yellow-white solid

Uses: Sodium oxide is used in the manufacture of ceramics, glass, bowls and paper.

Magnesium (Mg)

Reaction: $2Mg + O_2 \rightarrow 2MgO$

Conditions: Heat

Observations: Burns brightly in air to form a white solid (magnesium oxide).

Uses: Magnesium oxide is used in the manufacture of cement and as an antacid.

Aluminum (Al)

Reaction: $4Al + 3O_2 \rightarrow 2Al_2O_3$

Conditions: powdered aluminum, heat.

Observations: Burns slowly in air to form a white solid (aluminum oxide).

Uses: Aluminum oxide is used in the manufacture of ceramics and as an abrasive.

Silicon (Si)

Reaction: $Si + O_2 \rightarrow SiO_2$

Conditions: powdered silicon, heat

Observations: Burns slowly in air to form a white solid (silicon dioxide).

Uses: Silicon dioxide is used in the manufacture of glass and concrete.

Phosphorus (P)

Reaction: $4P + 3O_2 \rightarrow 2P_2O_3$ (white phosphorus)

$4P + 5O_2 \rightarrow 2P_2O_5$ (red phosphorus)

Conditions: heat

Observations: Burns in air with a bright white flame and smoke to form a white or yellowish solid (phosphorus oxide).

Uses: Phosphorus oxides are used in the manufacture of fertilizers and matches.

Sulphur (S)

Reaction: $S + O2 \rightarrow SO2$

Conditions: heat

Observations: Burns in air with a blue flame when heated to form a colorless gas (sulphur dioxide).

Uses: Sulphur dioxide is used in the manufacture of sulphuric acid and as a preservative.

Chlorine (Cl) and Argon (Ar)

Reaction: No reaction with oxygen.

Observations: Chlorine is a highly reactive gas that does not react with oxygen.

Uses: Chlorine is used in the manufacture of plastics, disinfectants, and pharmaceuticals.

Physical and Chemical Properties of Period 3 Oxides and Chlorides

Oxides

Physical properties

Ionic character; Oxides of sodium, magnesium and aluminum are ionic, while oxides of silicon, phosphorus, sulphur, and chlorine are covalent.

Melting and boiling points; Ionic oxides generally have higher melting and boiling points than covalent oxides due to the strong electrostatic attraction between ions.

Solubility; Ionic oxides are generally soluble in water, while covalent oxides are generally insoluble.

Aluminum oxide (Al_2O_3) is not soluble in water.

This is due to its strong ionic bonds and crystal lattice structure, which make it difficult for water molecules to break apart the compound. While it may react with strong acids and bases, it does not dissolve in water to any significant extent.

Oxides	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_6 P_4O_{10}	SO_2 SO_3
Structure	giant ionic lattice			giant molecular	simple molecular	
Bonding	strong electrostatic forces of attraction between ions			covalent bonds between atoms	weak Van der Waals' forces of attraction between molecules	
Melting point / °C	1280	2900	2040	1610	24 580	-75 17
Acid / base nature	basic		amphoteric	acidic		
Reaction with water	alkaline solution (pH ≈ 13)	weakly alkaline solution (pH ≈ 9)	Insoluble (pH = 7)		acidic solution (pH < 2)	acidic solution (pH < 2) acidic solution (pH = 1)

Chemical properties

Acidity; Oxides of nonmetals are acidic, while oxides of metals are basic.

Amphoteric nature; Aluminum oxide is both acidic and basic.

Chlorides

Physical properties

Ionic character; Chlorides of sodium, magnesium, and aluminum are ionic, while chlorides of silicon, phosphorus, sulphur, and chlorine are covalent.

Melting and boiling points; Ionic chlorides generally have higher melting and boiling points than covalent chlorides.

Solubility; Ionic chlorides are generally soluble in water, while covalent chlorides are generally insoluble.

Chemical properties

Acidity; Chlorides of nonmetals are acidic, while chlorides of metals are neutral.

Reasons for the trends

Melting and boiling points; The strong electrostatic attraction between ions in ionic compounds leads to higher melting and boiling points compared to covalent compounds, where the intermolecular forces are weaker.

Solubility; Ionic compounds are generally soluble in water due to their ability to form ion-dipole interactions with water molecules. Covalent compounds are generally insoluble in water due to their lack of polarity.

Chloride	$NaCl$	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3	PCl_5
Structure	giant ionic lattice		simple molecular			
Bonding	strong electrostatic forces of attraction between the ions		weak van der Waals' forces of attraction between molecules			
Melting point / °C	808	714	sublimes at 180	– 70	-112	sublimes at 162
Reaction with water	dissolves to form neutral solution	hydrolyses to a small extent to form a slightly acidic solution	hydrolyses to give acidic solution			
Approximate pH of solution	pH ≈ 7	pH ≈ 6.5	pH ≈ 3	pH = 1	pH = 1	pH = 1

Experiment: Reactions of Period 3 Elements with Chlorine

Safety Precautions:

- Wear safety goggles and gloves throughout the experiment.
- Handle chlorine gas or chlorine water with care, as they are toxic and corrosive.
- Conduct the experiment in a well-ventilated area.

Materials:

- Small samples of Period 3 elements (Na, Mg, Al, Si, P, S)
- Chlorine gas (Cl_2) or chlorine water (Cl_2 solution)
- Glass containers or test tubes
- Bunsen burner or heat source
- Safety goggles and gloves

Procedure:

1. Prepare the samples: Cut small pieces of the Period 3 elements and place them in separate glass containers or test tubes.
2. Fill separate containers with dry chlorine gas.
3. Hold the container with the metal sample near the chlorine gas container.
4. Observe the reaction.

Expected Observations:

- Sodium (Na): Reacts vigorously with chlorine, producing a yellow flame and sodium chloride.

Equation $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$

- Magnesium (Mg): When heated, reacts with dry chlorine, producing a bright white flame and magnesium chloride.

Equation $Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$

- Aluminum (Al): Reacts with chlorine when heated, producing a white smoke and aluminum chloride. Aluminum chloride is partially Covalent

Equation $2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$

- Silicon (Si): Reacts with chlorine when heated, producing silicon tetrachloride.

Equation $Si(s) + 2Cl_2(g) \rightarrow SiCl_4(l)$

- Phosphorus (P): When heated, reacts with limited chlorine, producing phosphorus trichloride.

Equation $2P(s) + 3Cl_2(g) \rightarrow 2PCl_3(l)$

In excess chlorine it burns to produce phosphorus Penta chloride.

Equation $2P(s) + 5Cl_2(g) \rightarrow 2PCl_5(s)$

- Sulphur (S): Molten sulphur reacts with chlorine, producing sulphur dichloride.

Equation $S(l) + Cl_2(g) \rightarrow SCl_2(l)$

The order of the reactivity of the elements is **Na>Mg>Al>Si>S**

Activity

1. Write molecular equations to show the reactions of the elements with chlorine.

Conclusion:

This experiment demonstrates the varying reactivity of Period 3 elements with chlorine. The reactions range from vigorous and explosive (sodium and magnesium) to moderate (aluminum and silicon) and relatively slow (phosphorus and sulphur).

The reactivity of period 3 elements with chlorine varies depending on their metallic or nonmetallic nature and their position in the periodic table.

Metals generally react with chlorine to form ionic chlorides, which are solid compounds.

Nonmetals generally react with chlorine to form covalent chlorides, which can be gases or liquids.

Noble gases, such as argon, are unreactive due to their stable electron configurations.

Physical and chemical properties of group 1 elements

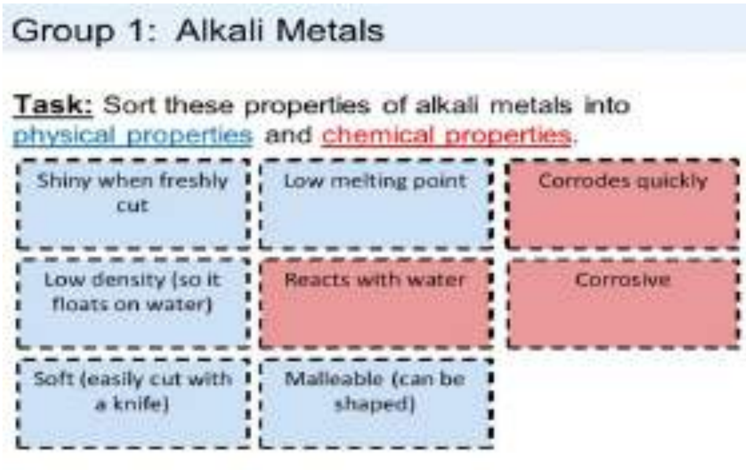
Group 1 elements include;

And others like Rubidium, Caesium, and Francium.

Group 1 elements are:

- also known as ***alkali metals***
- located at the left end of the periodic table, in the first column.
- ***shiny when cut***, but ***quickly tarnished*** upon exposure to air
- ***soft*** and can be cut with a knife
- are ***very reactive*** (they have to be stored in ***paraffin oil*** to prevent contact with oxygen and water in the air)
- Good conductors of electricity and heat since alkali metals are indeed metals.
- Soluble in water.

Due to their high reactivity, alkali metals are typically stored in mineral oil to prevent reaction with air and moisture. They have various applications, including in batteries, pharmaceuticals, and chemical industries.



Trends in Melting and boiling points of group 1 elements down the group

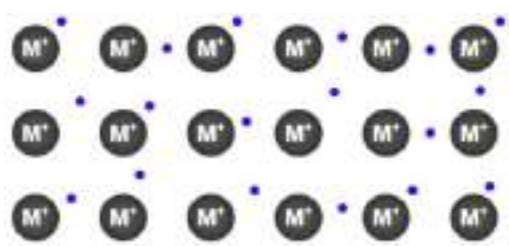
As we move down Group 1, the melting and boiling points of the alkali metals decrease.

Table

Element	Lithium (Li)	Sodium (Na)	Potassium (K)
Melting Point (°C)	180.5	97.8	63.5
Boiling Point (°C)	1342	883	758.8

Why does this happen?

This is due to the strength of metallic bonding which involves the electrostatic attraction between positively charged metal ions and delocalized electrons. Atoms of alkali metals are held together by **metallic bonds.**



The distance between the positive nucleus (M^+) and the delocalized electron (blue circles) increases down the group. This is due to an increase in the number of electron shells down the group. This causes the strength of the electrostatic force of attraction between the positive nucleus and the delocalized electron to decrease down the group resulting in weaker metallic bonds.

As a result, less heat energy is required to break the bonds between atoms.

Therefore, the melting and boiling points of the elements decrease down the group.

In summary:

- Larger atomic size leads to weaker metallic bonds.
- Weaker metallic bonds require less energy to break.
- Less energy required results in lower melting and boiling points.

Trends in Hardness of group 1 elements

Experiment: Investigating the Variation in Hardness of Group 1 Metals

Aim: To investigate the trend in hardness of Group 1 metals: lithium, sodium, and potassium.

Hypothesis: The hardness of Metals decreases as you move down the group.

Materials:

- Lithium metal (small piece)
- Sodium metal (small piece)
- Potassium metal (small piece)
- Mineral oil
- Forceps
- Knife
- Gloves

Safety First:

- Alkali metals are highly reactive, so handle them with care. Avoid touching the metals with bare hands
- Keep the metals under mineral oil to prevent reaction with air and moisture.

Procedure:

1. Observation:

- Visual Inspection: Observe the appearance of each metal. Note their color and luster.
- Cutting Test: Using forceps, carefully remove a small piece of each metal from the mineral oil. Attempt to cut each piece with a knife. Record your observations.

2. **Hardness Comparison:**

- **Qualitative Comparison: Compare the ease with which you could cut each metal. Rank them from hardest to softest based on your observations.**

Data Collection and Analysis:

- Record your observations on the appearance, cutting ease, and relative hardness of each metal.
- Analyze the data to identify the trend in hardness as you move down Group 1.
- Discuss the reasons for this trend, relating it to the structure of the metals and the strength of metallic bonding.

Note: Due to the high reactivity of alkali metals, it is advisable to conduct this experiment under the guidance of a qualified chemistry teacher in a well-equipped laboratory.

Expected Observations

Alkali metals become softer as we move down the group.

This trend is directly linked to the strength of metallic bonding. As we move down Group 1:

1. Atomic Size Increases: The atomic radius of the elements increases, meaning the distance between the positively charged nuclei and the delocalized electrons also increases.

2. Weaker Metallic Bonds: This increased distance weakens the electrostatic attraction between the nuclei and the delocalized electrons, resulting in weaker metallic bonds.
3. Decreased Hardness: Weaker metallic bonds make the metals softer and easier to cut.

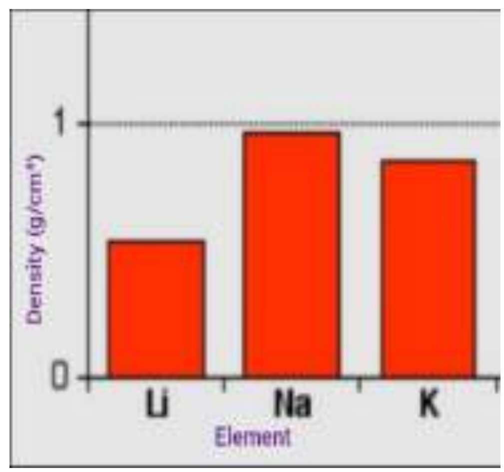
In summary:

- Larger atomic size leads to weaker metallic bonds.
- Weaker metallic bonds result in decreased hardness.

Therefore, elements at the bottom of the group are generally softer than those at the top.

Trends in Densities of alkali metals (group 1)

Explain using the graph below the trend in variation of densities down the group.



As the atomic mass increases down the group, the density increases (density = mass/volume). However, alkali metals have relatively low densities – lithium, sodium and potassium float on water.

Why does this happen?

1. Atomic Size: As we move down the group, the atomic size increases. This means that the atoms become larger.
2. Atomic Mass: With increasing atomic size, the atomic mass also increases.
3. Metallic Structure: All alkali metals have a similar metallic structure, where metal ions are surrounded by a sea of delocalized electrons.
4. Packing Efficiency: The packing efficiency of atoms in the metallic lattice remains relatively constant down the group.

The slight abnormality in the density trend of Group 1 elements, where sodium has a higher density than expected compared to potassium, can be attributed to:
Sodium: Adopts a crystal lattice structure, which is a relatively efficient packing arrangement.

The more efficient packing in sodium's structure leads to a higher density, even though potassium has a larger atomic mass.

In summary:
As we move down Group 1, the increasing atomic mass and constant packing efficiency lead to an increase in density.

Chemical properties of group 1 (alkali metals)

Reactivity of Group 1 Elements

The reactivity of Group 1 elements ***increases*** down the group. This is because: Group 1 elements react by ***donating 1 electron*** from the outermost shell (valence electron).

$M \rightarrow M^+ + e^-$

This makes alkali metals ***electropositive*** (they have a tendency to ***donate electrons***).The valence electron is held in place by the ***electrostatic force of attraction*** with the positively charged nucleus.
The ***atomic radius*** of elements ***increases*** down the group because a new electron shell is added.
The ***distance*** between the ***nucleus*** and the ***valence electron increases*** making the ***electrostatic force of attraction*** between the nucleus and the valence electron ***weak.***
Therefore, it gets ***easier*** for the atom to ***donate*** the valence electron going down the group. (The ***electropositivity*** of alkali metals ***increases*** down the group)

Experiment: Reactions of Group 1 Elements with Oxygen
Safety Note: Alkali metals are highly reactive, especially with water and oxygen. This experiment should only be conducted under the supervision of a qualified chemistry teacher in a well-equipped laboratory. Always wear safety goggles and gloves when handling these metals.

It's important to note that the alkali metals are highly reactive and must be stored in oil to prevent them from reacting with oxygen and water in the air.

Additional Considerations:

- Always handle alkali metals with extreme caution. Never touch them with bare hands.
- Use very small pieces of metal to minimize the intensity of the reaction.
- Conduct the experiment in a well-ventilated area to dissipate any fumes.
- Dispose of the reaction products according to local regulations.

Materials:

- Small pieces of lithium, sodium, and potassium metal (stored in mineral oil)
- Forceps
- Filter paper
- Bunsen burner
- Tongs
- Watch glass
- Oxygen gas jar

Procedure:

- Clean the surface of each metal piece using filter paper to remove the mineral oil.
- Set up a Bunsen burner and a gas jar filled with oxygen gas.
- Ignite a small piece of lithium metal using a Bunsen burner flame and quickly place the burning metal into the oxygen gas jar.
- Observe the reaction.
- Repeat the above step using sodium metal.
- Carefully cut a small piece of potassium metal and place it on a watch glass and quickly ignite the metal using a hot glass rod. Observe the reaction.

Expected observations

All the metals burn in air forming white metal oxides. The metal oxides react with water to form an alkaline solution of metal hydroxide.

Lithium burns with a red flame in air, forming a white solid (lithium oxide).
$4Li\ (s) + O_2\ (g) \rightarrow 2Li_2O\ (s)$

Sodium burns with a bright yellow flame in air, forming a white solid (sodium oxide).
$4Na\ (s) + O_2\ (g) \rightarrow 2Na_2O\ (s)$
When the air is in excess, it forms a yellow solid of sodium peroxide.
Potassium reacts vigorously with oxygen, often igniting spontaneously in air with a lilac flame, forming a white solid (potassium oxide).
$4K\ (s) + O_2\ (g) \rightarrow 2K_2O\ (s)$

Conclusions:
Reactivity: As you move down Group 1, the reactivity of the metals with oxygen increases. Potassium is the most reactive, followed by sodium, and then lithium. This is because, the atomic size of the alkali metals increases as you move down the group. This means that the outermost electron is further away from the nucleus and is held less tightly making the metal easier to lose the electron and react with oxygen
Flame Color: The color of the flame produced during the reaction can be used to identify the metal. Lithium produces a red flame, sodium produces a yellow flame, and potassium produces a lilac flame.

Experiment: Reactions of Group 1 Elements with Cold Water

Key Points to Remember:
- Always handle alkali metals with extreme caution, as they are highly reactive.
- Store alkali metals in mineral oil to prevent reaction with air and moisture.
- Conduct experiments with alkali metals under the supervision of a qualified chemistry teacher.

Materials:
- Small pieces of lithium, sodium, and potassium metal (stored in mineral oil)

- Forceps
- Trough
- Water
- Phenolphthalein indicator

Procedure:

- Fill a trough with water and add a few drops of phenolphthalein indicator.
- Clean the surface of each metal piece using filter paper to remove the mineral oil.
- Carefully drop a small piece of lithium metal into the trough of water. Observe the reaction
- Repeat the steps above using sodium and potassium metals.

Observations

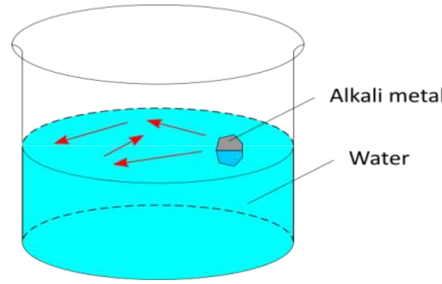
As you move down Group 1, the reactivity of the metals with water increases.
Potassium is the most reactive, followed by sodium, and then lithium.
The metals float, fizz, and move around on the water's surface. The reaction is more violent and faster as you move down the group.
The reaction is exothermic, meaning it releases heat. The heat can ignite the hydrogen gas, causing the reaction to be violent or explosive.

All alkali metals react with water to produce hydrogen gas. The rate of hydrogen gas production increases down the group. The hydrogen gas produced can sometimes ignite, producing a characteristic flame color for each metal.
The reaction produces an alkaline solution, which turns the phenolphthalein indicator pink/purple.

Why does this happen?

As you move down the group, the atomic size of the alkali metals increases. This means that the outermost electron is further away from the nucleus and is held less tightly. Making it easier to be lost during a reaction.

Alkali metals react with water to form hydrogen gas and colourless alkaline solutions of metal hydroxides that turn red litmus paper blue (alkaline solutions).
This is why Group 1 elements are called alkali metals.



The more reactive the alkali metal, the more volume of hydrogen produced, and the faster it moves on the surface of the water.

General equation

Alkali metal + Water → Metal hydroxide + Hydrogen gas

Lithium floats on water because it's less dense than water. It fizzes and gradually disappears, forming a colorless solution of lithium hydroxide. .

Lithium + Water → Lithium hydroxide + Hydrogen gas

$$2Li\ (s) + 2H_2O\ (l) \rightarrow 2LiOH\ (aq) + H_2\ (g)$$

Sodium metal floats, darts on the surface of the water and melts into a silvery ball, fizzing rapidly, and disappears producing a hissing sound. The reaction of sodium with water is vigorous, producing a colorless solution of sodium hydroxide and hydrogen gas.

Sodium + Water → Sodium hydroxide + Hydrogen gas

$$2Na\ (s) + 2H_2O\ (l) \rightarrow 2NaOH\ (aq) + H_2\ (g)$$

Potassium moves very rapidly on the surface of the water and melts into a silvery ball, producing a hissing sound. The metal reacts violently with water, producing a lot of heat, forming a colorless solution of potassium hydroxide and hydrogen gas. The reaction is often explosive, and the hydrogen gas produced ignites immediately with a lilac flame.

Potassium + Water → Potassium hydroxide + Hydrogen gas

$$2K\ (s) + 2H_2O\ (l) \rightarrow 2KOH\ (aq) + H_2\ (g)$$

Reactivity of Group 1 Metals with Chlorine

The reactivity of group 1 elements with chlorine increases as you move down the group. This means that lithium is the least reactive, and potassium is the most reactive.

Group 1 elements react vigorously with chlorine gas to produce metal chlorides.

The chlorides are white solids at room temperature, and dissolve in water to make a neutral solution.

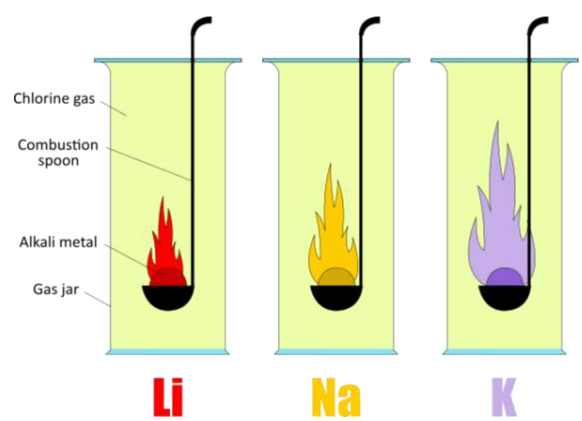
The reaction becomes more vigorous as you move down the group. For example, the reaction of potassium with chlorine is more vigorous than the reaction of lithium with chlorine.

Why does this happen?

As you move down the group:

The atomic size of the alkali metals increases. This means that the outermost electron is further away from the nucleus and is held less tightly.

Alkali metal + chlorine → Metal chloride



Lithium burns vigorously in chlorine with a red flame since it's a strong reducing agent, forming lithium chloride (LiCl).

$2Li\ (s) + Cl_2\ (g) \rightarrow 2LiCl\ (s)$

Sodium burns vigorously in chlorine with a bright yellow flame forming sodium chloride (NaCl)..

$2Na\ (s) + Cl_2\ (g) \rightarrow 2NaCl\ (s)$

Potassium burns vigorously in chlorine with a very bright lilac flame forming potassium chloride (KCl).

$2K\ (s) + Cl_2\ (g) \rightarrow 2KCl\ (s)$

Uses of Group 1 Elements

Sodium: Used in sodium lamps, sodium hydroxide production, and organic chemistry.
Potassium: Used in fertilizers, potassium hydroxide production, and batteries.
Lithium, Used in batteries, lithium carbonate production, and psychiatric medications.

End of chapter summary

Key concepts

- Periodic Table is a tabular arrangement of elements, organized by their atomic number (number of protons in the nucleus), electron configuration, and recurring chemical properties.
- Elements are arranged in the periodic table in order of increasing atomic number (number of protons in the nucleus) and recurring chemical properties.
- Elements are grouped into vertical columns (groups) and horizontal rows (periods) based on their chemical properties and electron configuration.
- Elements in the same period have the same number of electron shells/energy levels. Elements in the same group have the same number of Valence electrons.
- Atomic radius increases in moving down the group and decrease in moving across the period.
- Period 3 elements exhibit varying levels of reactivity, with metals (Na, Mg, Al) being highly reactive and nonmetals (P, S, Cl) being less reactive. Metallic character decreases across the period, with Na and Mg being highly metallic and Cl and Ar being nonmetallic.
- Reactivity of period 3 elements increases across the period, with Na and Mg being highly reactive and Cl and Ar being less reactive.
- Magnesium is used in the manufacture of fireworks, flares, and sparklers, Aluminum is used in the manufacture of aircraft, automobiles, and packaging materials.

- Atomic radius increases down the group because of addition of a new electron shell.
- Group 1 elements are highly reactive metals that readily lose one electron to form a positive ion (M^+).
- The single outer electron in Group 1 elements makes it easy for them to lose an electron and form a positive ion. This makes group 1 elements highly reactive.
- The reactivity increases down the group, with Francium being the most reactive. Group 1 elements exhibit various applications including Sodium being used in the manufacture of paper, dyes, and textiles, Potassium in the manufacture of fertilizers, soaps, and glass, Caesium used in atomic clocks and photoelectric cells.

End of chapter Scenarios

<u>Item 1:</u>

Abel, a chemistry learner, is investigating the reactions of elements A and B with water. The observations are summarized in a table:

Element A: Reacts violently with cold water, floating on the surface and forming an alkaline solution with hydrogen gas.

Element B: Reacts slowly with cold water, forming an alkaline solution and hydrogen gas. Reacts more vigorously with steam, forming a white solid and hydrogen gas.

Task;

As a chemistry learner;

a) Give the category of elements A and B.

b) Predict the reaction of other elements in period 3 with water.

c) Advise Abel about the dangers associated with the reaction of these elements with water.

Item 2:

A friend in S.1 is curious about the writing she found in Lab as she was one time cleaning the lab, she also wants to know the relevance of the element in the writing and applications in daily life.

Task;

As a student of Chemistry,

a) Explain the category of the element.

b) Explain the properties of the element.

c) Give the uses of the element.

d) Help understand the impact of the element on the environment.

Item 3:

The alkali metals are a group of elements in the periodic table that include lithium (Li), sodium (Na), potassium (K), rubidium (Rb), Caesium (Cs), and francium (Fr). These elements are highly reactive and exhibit some interesting trends in their properties.

Melting Points of Alkali Metals

Element	Lithium	Sodium	Potassium	Rubidium	Caesium	Francium
Melting point (^oC)	180.54	97.82	63.38	39.30	28.44	27

Task;

1. What are the physical properties exhibited by alkali metals.
2. Discuss the trend in the density of the alkali metals as you move down the group.
3. Describe the reactions of the alkali metals with:
   - Water
   - Chlorine
   - Oxygen
4. Explain why the reactivity of the alkali metals increases as you move down the group.

Item 4:

The period 3 elements are a group of elements in the third row of the periodic table. These elements exhibit some interesting trends in their properties.

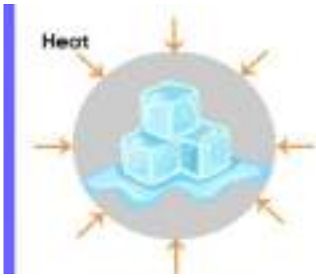
Densities of Period 3 Elements

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Density (g/cm^3)	0.97	1.74	2.70	2.33	1.82	2.07	0.003	0.002

Task;

1. Explain the trend in the densities of the period 3 elements as you move from left to right across the period.
2. Discuss the trend in the tendency of the period 3 elements to lose electrons as you move from left to right across the period.
3. Describe the reactions of the period 3 elements with:
   - Water
   - Chlorine
   - Oxygen
4. Explain why the reactivity of the period 3 elements with water decreases as you move from left to right across the period.

4. ENERGY CHANGES DURING CHEMICAL REACTIONS




Competency: The learner appreciates that in any chemical reaction, energy usually in the form of heat is usually lost or gained.

Key Words

- Exothermic
- Energy
- Endothermic
- Enthalpy
- Bonds
- Absorption and Release

By the end of this topic, the learner should be able to;

- Recognize and appreciates the difference between endothermic and exothermic reactions and understands that substances store chemical energy in their bonds (k,u)
- Understand and appreciate the importance of exothermic and endothermic reactions in our everyday lives (u, s)
- Recognize that the burning of fuels is an exothermic process producing useful energy (u, s)
- Understand the concept of heat of reaction and interpret energy profiles of chemical reactions (u,s)

The energy change in a chemical reaction is due to the difference in the amounts of stored chemical energy between the products and the reactants. This stored chemical energy, or heat content, of the system is known as its **enthalpy** and it's measured in **kj/mol.**

All chemical reactions involve an energy change. For example when Petrol burns, heat is given out and when ammonium nitrate dissolves in water, heat is taken in.

All chemical substances possess chemical energy stored in bonds. When a chemical reaction occurs, the atoms in the reactants rearrange their chemical bonds to make products. The new arrangement of bonds does not have the same total energy as the bonds in the reactants. Therefore, when chemical reactions occur, there will always be an accompanying energy change.

This energy can take many forms, such as:

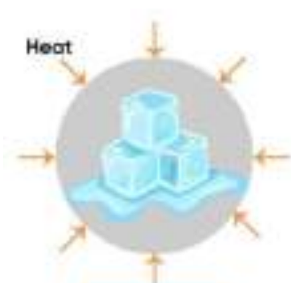
- Heat
- Light
- Sound
- Electrical energy

When a chemical reaction occurs and heat is transferred from the surrounding to the reacting molecules, it's called an **"endothermic reaction".** As the energy is taken from the surroundings, the temperature falls as the temperature of the reaction mixture increases.

When a chemical reaction occurs and heat is transferred from the reacting molecules to the surrounding, it's called an **"exothermic reaction".**

Processes in which Energy Absorption occurs

An endothermic process absorbs heat and cools the surroundings. The absorbed energy serves as the activation energy for the reaction to take place. As reactants break bonds, energy is released, and when products make new bonds, energy is released.



Endothermic processes require the addition of external energy, often in the form of heat, to continue. Since endothermic processes take heat from their surroundings, they tend to chill them.

What is Endothermic Reaction?

Endothermic reactions are chemical changes that occur when a system absorbs thermal energy from its surroundings, resulting in a rise in its total internal energy level, or Enthalpy. The absorbed energy is retained in the chemical bonds of the products.

By reducing the temperature of the surrounding environment, these processes produce a cooling effect. Endothermic processes occur when ice cubes absorb heat energy from their surroundings and melt to produce liquid water (no chemical bonds are broken or formed).
When a chemical bond is broken, energy is often released. The formation of chemical bonds requires an energy input as well. Energy may be given or released in a variety of ways (such as heat, light, and electricity). The formation of chemical bonds as a result of heat absorption from the environment characterizes endothermic processes.

Process	**Description**	**Energy Source**
Photosynthesis	Plants convert CO_2 & H_2O to glucose & O_2	Sunlight
Melting	Solid to liquid phase transition	Heat
Electrolysis	Decomposition of water into H_2 & O_2	Electrical energy
Cooking food	Transforming raw ingredients into edible food	Heat
Dissolving salt in water	Breaking down ionic bonds between sodium and chloride ions dispersing them in water to form homogeneous solution	Heat from surrounding

Processes in which Energy release occurs

Exothermic reactions are chemical reactions that generate heat. Exothermic reactions is often released as heat, making the surrounding environment hotter.

What is an Exothermic Reaction?

An exothermic reaction is a chemical process that involves the release of energy in the form of heat or light. For example, a lot of heat is created when carbon burns in oxygen to make carbon dioxide.
The concept that atomic bonds break and energy is released when the reactants in an exothermic reaction prepare to transform during a chemical reaction is included in the definition of an exothermic reaction.
The total energy of the products in an exothermic reaction is less than the total energy introduced into the system by the reactants. Heat is one of the results of an exothermic reaction.

Process	Description	Energy Release
Combustion	Burning fuels (e.g., wood, gasoline)	Heat & light
Oxidation reactions	Combination of substances with oxygen	Heat
Nuclear reactions	Nuclear fission or fusion	Heat & radiation
Respiration	Converting glucose onto energy through oxygen based breakdown	ATP
Fermentation	Converting glucose in to energy without oxygen	ATP

Importance of endothermic and exothermic Reactions

Process/Reaction	Classification	Importance
Combustion of Fuels	Exothermic	Provides heat and energy for various applications, including cooking, heating, and powering vehicles.
Photosynthesis	Endothermic	Converts sunlight energy into chemical energy stored in glucose, essential for life on Earth
Respiration	Exothermic	Releases energy for cellular functions, supports life on Earth
Ice Melting	Endothermic	Essential for various natural processes, including water cycle and climate regulation.
Instant Cold Packs	Endothermic	Used for first aid to reduce swelling and pain.
Water Vapor Condensation	Exothermic	Releases heat energy, influencing weather patterns and climate.
Evaporation of water	Endothermic	Crucial for water cycle, weather patterns, and temperature regulation
Oxidation of metals	Exothermic	Essential for corrosion protection, material durability, and manufacturing processes
Nuclear reactions	Exothermic	Source of nuclear energy, medical applications, and scientific research
Fermentation	Exothermic	Produces ethanol, bread, beer, and cheese; essential for food industry and biofuels

Temperature Changes in Dissolving Substances

The process of dissolving can be endothermic (temperature goes down) or exothermic (temperature goes up). When water dissolves a substance, the water molecules attract and "bond" to the particles (molecules or ions) of the substance causing the particles to separate from each other. The "bond" that a water molecule makes is not a covalent or ionic bond. It is a strong attraction caused by water's polarity. It takes energy to break the bonds between the molecules or ions of the solute.

Energy is released when water molecules bond the solute molecules or ions.

If it takes more energy to separate the particles of the solute than is released when the water molecules bond to the particles, then the temperature goes down (endothermic). If it takes less energy to separate the particles of the solute than is released when the water molecules bond to the particles, then the temperature goes up (exothermic).

Different substances dissolve to different extents because they are made from different atoms, ions, or molecules. For example, dissolving Epsom salt in water causes a decrease in temperature, while dissolving borax in water causes an increase in temperature.

There is always a temperature change when a cold pack and a hot pack are activated. These temperature changes are due to a solid substance dissolving in water. It takes energy to break bonds and energy is released when bonds are formed during the process of dissolving.

In the following experiment you will find out how much the temperature increases or decreases as each of four solutes dissolves in water and correctly classify the process of dissolving as either exothermic or endothermic for each solute.

Experiment on temperature changes in dissolving substances

Aim: To investigate the temperature changes that occur during the dissolution of various substances in water and classifying the reactions as endothermic or exothermic.

Hypothesis:

Exothermic Reactions: The dissolution of certain substances in water will release energy, causing the temperature of the solution to increase.

Endothermic Reactions: The dissolution of other substances in water will absorb energy from the surroundings, causing the temperature of the solution to decrease.

Variables:

<u>Independent Variable:</u> The type of substance dissolved.

<u>Dependent Variable:</u> The change in temperature of the solution.

<u>Controlled Variables:</u> The volume of water, the initial temperature of the water, and the mass of the substance.

Materials:

- Beaker
- Thermometer
- Distilled water
- Measuring cylinder
- Various substances (e.g., sodium hydroxide, sodium hydrogen carbonate, ammonium nitrate, sodium chloride)
- Stirring rod

Risks and Mitigation:

- Chemical Burns.

Wear gloves and goggles when handling substances, especially sodium hydroxide. Rinse any spills immediately with water.

- Eye Injury

Wear safety goggles to protect your eyes from splashes.

- Inaccurate Temperature Readings

Use a calibrated thermometer and ensure accurate readings.

Procedure:

- Measure 50 mL of water using a measuring cylinder.
- Record the initial temperature of the water using the thermometer.
- Add 5 grams of sodium chloride (NaCl) to the beaker and stir until the salt dissolves.

- Using a thermometer, record the temperature of the solution at regular intervals (e.g., every minute) for 7 minutes.
- Repeat the above steps using sodium hydroxide, ammonium nitrate and sodium hydrogen carbonate.
- Record your results in a suitable table.
- Plot the temperature changes against time for each substance.

Data Table:

	Time (min)	0	1	2	3	4	5	6	7
NaCl	**Temperature (^oC)**	22.0	21.8	21.6	21.5	21.4	21.3	21.2	21.1
NaOH	**Temperature (^oC)**	22.0	25.2	28.1	30.5	32.3	33.8	35.1	36.2
NH_4NO_3	**Temperature (^oC)**	22.0	20.3	19.2	18.5	18.0	17.6	17.3	17.1
$NaHCO_3$	**Temperature (^oC)**	22.0	22.5	23.0	23.3	23.6	23.8	24.0	24.1

Note: The specific temperature changes will depend on the exact conditions of the experiment and the quantities of substances used.
These values are sample data and may vary based on actual experimental conditions.

Analysis:
Sodium Chloride (NaCl): Slight decrease in temperature: This indicates a **mildly endothermic** reaction. The energy absorbed from the surroundings is used to break the ionic bonds in the solid NaCl and to hydrate the ions.
Sodium Hydroxide (NaOH): Significant increase in temperature: This indicates a **strongly exothermic** reaction. The energy released during the formation of strong ion-dipole interactions between the Na^+ and OH^- ions and water molecules exceeds the energy required to break the ionic bonds in solid NaOH.
Ammonium Nitrate (NH_4NO_3): Significant decrease in temperature: This indicates a **strongly endothermic** reaction. Energy is absorbed from the

surroundings to break the ionic bonds in the solid and form new bonds with water molecules.

Sodium Hydrogen Carbonate ($NaHCO_3$): Slight increase in temperature: This indicates a **mildly exothermic** reaction. The energy released during the formation of ion-dipole interactions with water molecules slightly exceeds the energy required to break the ionic bonds in the solid $NaHCO_3$.

Key Points to Remember:

The energy changes observed during dissolution are primarily due to the formation of ion-dipole interactions between the ions of the solute and the polar water molecules. The strength of these interactions and the lattice energy of the solid determine whether the dissolution process is exothermic or endothermic.

Experimentation and data analysis can provide valuable insights into the underlying chemical processes.

Energy Transformations in Combustion Reactions

The fuel (ethanol, paraffin, or wood) contains chemical energy in the form of molecular bonds. When the fuel is ignited, the chemical bonds break, releasing heat energy. This heat energy is what we feel when we get close to a fire.

A portion of the released energy is converted into light energy, which we see as a flame.

Experiment: Determining the Heat Energy Released by Burning Ethanol

Aim: To determine the amount of heat energy released when a specific amount of ethanol is burned completely.

Hypothesis: When ethanol is burned, a specific amount of heat energy will be released.

Variables:

<u>Independent Variable:</u> Mass of ethanol burned

<u>Dependent Variable:</u> Temperature change (ΔT) and Heat energy released (Q)

Controlled Variables: Initial temperature of water, volume of water, specific heat capacity of water, heat loss to the surroundings

Materials:

- Ethanol
- Spirit burner
- Water (100mL)
- Thermometer
- Measuring cylinder
- Heatproof mat
- Matches
- Balance
- Calorimeter (or a simple insulated container like a tin can or a glass beaker)

Risk Assessment and Mitigation:

- Fire Hazard

Use ethanol in small quantities.

Use ignition source cautiously.

Have a fire extinguisher ready.

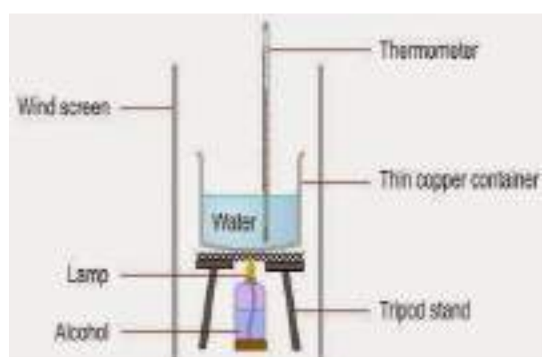
- Burns

Use tongs or heat-resistant gloves to handle hot equipment.

Be cautious when lighting the spirit burner.

Procedure

- Weigh the spirit burner with ethanol, record it's mass as W1 (g)
- Measure a specific volume of water (e.g., 100 mL) using a measuring cylinder and determine its mass.
- Measure and record the initial temperature T1 of the water in the calorimeter.



- Carefully light the spirit burner and place it under the calorimeter.
- Heat the water until the temperature has risen by 10°C.

- Measure and record the final temperature T2 of the water.
- Weigh the spirit burner with the remaining ethanol and note it's mass W2.
- Subtract the final mass of the spirit burner from the initial mass to determine the mass of ethanol

Results and Analysis

Record the mass of ethanol burned, the initial and final temperatures of water, and then calculate heat energy released.

Analyze the results and draw conclusions about the heat energy released by ethanol.

Consider potential sources of error, such as heat loss to the surroundings and incomplete combustion of ethanol.

Calculations:

1. Calculate the Heat Energy Gained by Water.

Density of water= 1 g/mL

$Q = mc\Delta T$

Where:

Q = heat energy gained by water (joules)

m = mass of water (g)

c = specific heat capacity of water (4.18 J/g°C)

ΔT = change in temperature of water (°C)

Mass of water=density × volume

=(1×100)

=100g

Trial Results

Mass of water (g)	Initial Temp (°C)	Final Temp (°C)	ΔT (°C)
100	20.0	25.5	5.5

$Q = 100g \times 4.184\ J/g^\circ C \times 5.5^\circ C = 2319\ J$

2. Calculate the Heat Energy Released by Ethanol

Assumption: The heat released by the ethanol is absorbed by the water.

Therefore, the heat energy released by ethanol is equal to the heat energy gained by water.

Conclusion

Burning ethanol releases a significant amount of heat energy, proportional to the mass of ethanol burned. This experiment demonstrates the application of thermodynamics principles to measure heat energy changes.

Task 1

A fuel with a mass of 2.5 g is burnt to heat 100 cm^3 of water. The temperature of the water increases from 25°C to 85°C. Calculate the energy released per gram of the fuel.

Response

Given values:

- Mass of water (m) = 100 cm^3 = 100 g (since density of water is approximately 1 g/cm^3)
- Specific heat capacity of water (c) = 4.184 J/g°C
- Initial temperature (T_1) = 25°C
- Final temperature (T_2) = 85°C
- Mass of fuel = 2.5 g

Temperature change (ΔT) = $T_2 - T_1$ = 85°C - 25°C = 60°C

Energy = m x c x ΔT

= 100 g x 4.184 J/g°C x 60°C

= 25104 J

Since 2.5 g of fuel released 25104 J of energy, the energy released per gram of fuel is:

Energy per gram = Total energy / Mass of fuel
= 25104 J / 2.5 g
= 10041.6 J/g

Task 2
A certain home uses 30g of biogas to heat 20 liters of water from 25°C to 60°C. The biogas plant produces 0.5 m^3 of biogas per day, which is used to heat the water. If the energy released per cubic meter of biogas is 20 MJ/m^3.

b. Calculate the amount of heat produced.
c. Determine the energy released by the biogas plant

Response
To calculate the heat produced, we'll use the formula:
Heat energy (Q) = mass (m) x specific heat capacity (c) x temperature change (ΔT)

Given values:
- Mass of water (m) = 20 liters = 20 kg (since density of water is approximately 1 kg/liter)
- Specific heat capacity of water (c) = 4.184 J/g°C = 4184 J/kg°C
- Initial temperature (T_1) = 25°C
- Final temperature (T_2) = 60°C

Temperature change (ΔT) = T_2 - T_1 = 60°C - 25°C = 35°C

Heat energy (Q) = m x c x ΔT
= 20 kg x 4184 J/kg°C x 35°C
= 2,927,600 J
= 2.928 MJ

Calculating the energy released by the biogas plant
Given that the biogas plant produces 0.5 m^3 of biogas per day, and the energy released per cubic meter of biogas is 20 MJ/m^3:

Energy released per day = Volume of biogas produced per day x Energy released per cubic meter

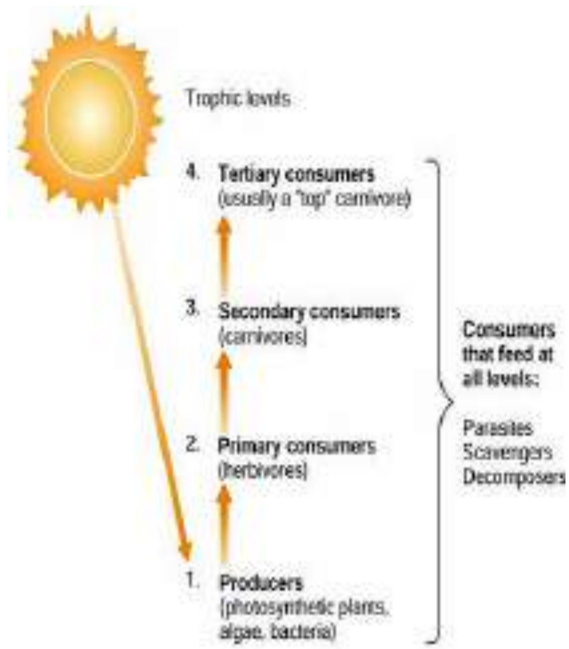
= 0.5 m^3/day x 20 MJ/m^3

= 10 MJ/day

Energy Flow in Ecosystems

Energy flow in an ecosystem refers to the transfer of energy from one trophic level to another.

Energy flows through ecosystems in a unidirectional manner, from the sun to producers (autotrophs) and then to consumers (heterotrophs). This energy flow is characterized by endothermic and exothermic reactions.



Energy Source

The primary energy source for most ecosystems is the sun. Solar energy is captured by plants, algae, and some bacteria through photosynthesis.

Producers (Autotrophs)

Producers, such as plants, algae, and some bacteria, convert light energy from the sun into chemical energy in the form of organic compounds like glucose. This process is called primary production and requires energy, therefore it's endothermic.

$6\ CO_2 + 6\ H_2O$ + light energy → $C_6H_{12}O_6$ (glucose) + $6\ O_2$

Consumers (Heterotrophs)

Consumers, such as animals, obtain energy by consuming producers or other consumers. There are different levels of consumers:

- Herbivores (primary consumers): Eat producers (plants).

- Carnivores (secondary consumers): Eat herbivores.
- Omnivores (tertiary consumers): Eat both plants and animals.
- Decomposers (detritivores): Break down dead organisms, releasing nutrients back into the ecosystem.

Energy is lost through respiration at producer level, decomposition and excretion at consumer level, this are exothermic processes as heat is released.

Respiration: Organisms break down glucose to release energy, which is then used to fuel metabolic processes. This process releases energy and is therefore exothermic.

$C_6H_{12}O_6$ (glucose) + 6 O_2 → 6 CO_2 + 6 H_2O + energy

Decomposition: Microorganisms break down dead organic matter, releasing energy in the process.

- Dead organic matter → CO_2 + H_2O + energy

Energy Transfer

Energy is transferred from one trophic level to the next through consumption. However, energy is lost at each trophic level due to:

- Heat loss: Energy is released as heat during metabolic processes.
- Energy expenditure: Energy is spent on activities like movement, growth, and reproduction.
- Inefficiencies: Energy is lost during the transfer process, such as through waste or indigestible materials.

On average, only about 10% of the energy is transferred from one trophic level to the next. This means that a significant amount of energy is lost at each level, ultimately limiting the number of trophic levels in an ecosystem.

Note:

- Energy flows through ecosystems from the sun to producers and then to consumers.

- Energy is lost at each trophic level due to heat loss, energy expenditure, and inefficiencies.
- Decomposers play a crucial role in releasing nutrients back into the ecosystem.

Heats of Reaction

What is a Heat of Reaction?

A heat of reaction also known as enthalpy change is a measure of the amount of heat energy released or absorbed during a chemical reaction. This energy change is often represented as "ΔH" (delta H).

It's a measure of the energy difference between the reactants and the products.

Types of Heats of Reaction

1. Enthalpy of Formation (ΔHf):

The heat change when one mole of a compound is formed from its constituent elements in their standard states.

2. Enthalpy of Combustion (ΔHc):

The heat released when one mole of a substance is completely burned in oxygen.

3. Enthalpy of Neutralization (ΔHn):

The heat change when one mole of water is formed from the neutralization of an acid by a base.

Exothermic Reactions and Energy Changes

The term exothermic implies "heating up." When an exothermic process progresses, energy, frequently in the form of heat, is released. When the energy created in an exothermic reaction is released as heat, the temperature rises. As a result, the products will almost certainly be hotter than the reactants. An exothermic reaction has the following general equation:

Reactants → Products + Energy

The products have less energy than the reactants.

ΔH is negative.

Examples are;

Combustion Reactions

Burning methane (natural gas): $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ (ΔH = -891 kJ/mol)

Oxidation Reactions

Rusting iron: $4Fe + 3O_2 \rightarrow 2Fe_2O_3$ (ΔH = -1650 kJ/mol)

Acid-Base Reactions

Neutralizing hydrochloric acid: $HCl + NaOH \rightarrow NaCl + H_2O$ (ΔH = -57 kJ/mol)

When a process absorbs or emits heat under constant pressure, enthalpy change happens. The enthalpy change (ΔH) may be calculated as the difference between the enthalpy of the products and the enthalpy of the reactants.

$\Delta H = H_{Products} - H_{Reactants}$

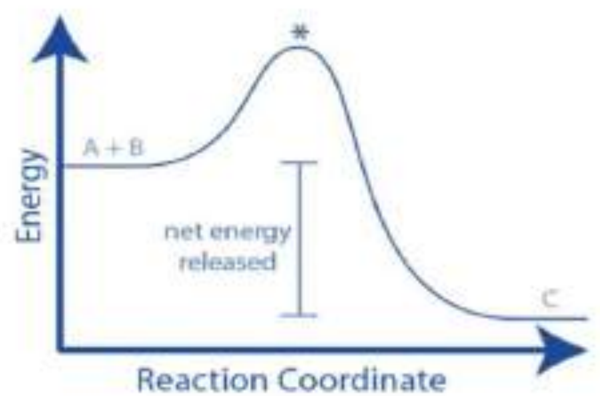
The energy profile diagram for an exothermic chemical process shows that the reactants have more energy than the products. As a result, **ΔH** is negative ($\Delta H < 0$), and the process is exothermic.

The difference in energy between the reactants and products is the overall change in energy in a reaction.

Energy Profile of Exothermic Reaction

The energy of the product is lower than the energy of the reactants, for an exothermic process (as thermal energy has been transferred to the surroundings)

Exothermic processes transmit thermal energy to the surroundings, raising the temperature of the surroundings. This energy is transferred from the chemical energy storage of the chemical system to the surroundings, causing the system's energy to decline – indicating a negative energy shift.



Endothermic Reactions and Energy Change

Endothermic is a word that literally means **"absorbing heat"** or **"taking in heat"**. Endothermic reactions require a steady input of energy, generally in the form of heat. In an endothermic reaction, not enough energy is released when the products develop to break additional bonds in the reactants, therefore, energy must be continually provided.

The products have more energy than the reactants.

ΔH is positive.

Here are examples of endothermic reactions, along with their equations:

Photosynthesis

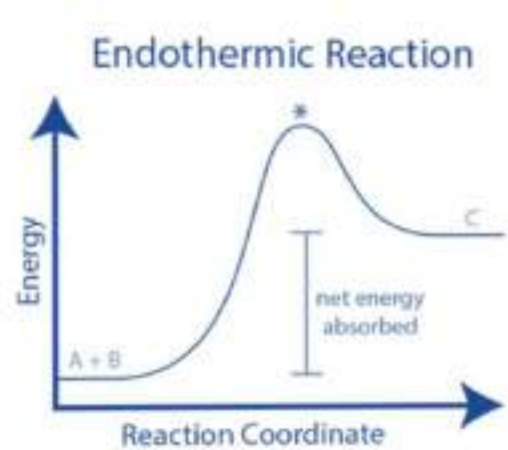
$6CO_2 + 6H_2O$ + light energy $\rightarrow C_6H_{12}O_6$ (glucose) $+ 6O_2$ ($\Delta H = +2805$ kJ/mol)

Chemical Reactions

Synthesis of ammonia: $N_2 + 3H_2 \rightarrow 2NH_3$ ($\Delta H = +92$ kJ/mol)

Decomposition of calcium carbonate: $CaCO_3 \rightarrow CaO + CO_2$ ($\Delta H = +178$ kJ/mol)

Energy Profile of Endothermic Reaction



Endothermic reactions absorb energy from their surroundings. This means that the products of an endothermic reaction have a higher energy state than the reactants. Therefore, the enthalpy change (heat change) for an endothermic reaction is always positive. The change in energy (also known as the enthalpy change) is denoted by the symbol ΔH.

To initiate a reaction, bonds in the reactant molecules must be broken. This process requires energy input.

The energy needed to break these bonds is absorbed from the surroundings.

New bonds form to create the product molecules. However, the energy released during bond formation is less than the energy absorbed during breaking of bonds for the reactants. As a result, the products end up with a higher energy state than the reactants.

As you can see from the diagram, the products are at a higher energy level than the reactants. This difference in energy is the energy that was absorbed from the surroundings during the reaction.

Key Points

Energy is Conserved: Energy cannot be created or destroyed, only transformed from one form to another.

Exothermic Reactions: Feel hot to the touch, like burning fuel.

Endothermic Reactions: Feel cold to the touch, like dissolving ammonium nitrate in water.

Energy Diagrams: Visual representations of energy changes in reactions.

End of chapter summary

Key Concepts

- Chemical Reactions are Processes in which one or more substances (reactants) are converted into new substances (products) and they are either endothermic or exothermic.
- Endothermic Reactions are reactions that absorb energy from the surroundings, often in the form of heat.
- Exothermic Reactions are reactions that release energy to the surroundings, often in the form of heat.
- Substances such as Fossil Fuels (Coal, oil, and natural gas), Biomass (Wood, crops, and waste materials), Food (Carbohydrates, proteins, and fats in food) contain chemical energy stored in their molecular bonds.
- Bond Breaking requires energy input to break existing chemical bonds. Bond Formation releases energy as new chemical bonds are formed.
- Heat energy is transferred between substances during a reaction.
- $Q = mc\Delta T$: The equation for heat energy transfer, where Q is the heat energy, m is the mass, c is the specific heat capacity, and ΔT is the temperature change.

- $\Delta H = \Sigma H(products) - \Sigma H(reactants)$: The equation for the enthalpy change (ΔH) of a reaction, where $\Sigma H(products)$ is the sum of the enthalpies of the products and $\Sigma H(reactants)$ is the sum of the enthalpies of the reactants.

End of chapter Scenarios

Critical Thinking Questions

1) Explain why some chemical reactions require energy input while others release energy.
2) Discuss the importance of energy changes during chemical reactions in everyday life.
3) How do energy changes during chemical reactions impact the environment?

Item 1

A car engine of 440kg burns 1 kg of gasoline. If the temperature of the engine increases by 200°C, and the specific heat capacity of the engine is 0.5 kJ/kg°C, calculate the heat released by the engine.

Item 2

A reaction between ammonia (NH_3) and oxygen (O_2) produces nitric oxide (NO) and water (H_2O). The reaction is represented by the equation:

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$

During the reaction, the temperature of 500g of water surrounding the reaction vessel increases from 20°C to 30°C. The specific heat capacity of water is 4.184 J/g°C.

Task;

1. Is the reaction exothermic or endothermic? Explain your answer.
2. Calculate the heat energy transferred to the water during the reaction.
3. Calculate the heat of reaction (ΔH) for the reaction.

Item 3

Hydrogen peroxide (H_2O_2) decomposes into water (H_2O) and oxygen (O_2), releasing 98 kJ/mol of energy. If 2 moles of hydrogen peroxide decompose, and the temperature of the solution increases by 5°C, calculate the heat capacity of the solution.

Item 4

A power plant burns 1000 kg of natural gas, releasing 53.6 GJ of energy. If the temperature of the boiler increases by 500°C, and the specific heat capacity of the boiler is 1.5 kJ/kg°C, calculate the mass of the boiler.

Item 5

Calcium (Ca) reacts with oxygen (O_2) to form calcium oxide (CaO). The reaction releases 1275 kJ/mol of energy. If 1 mole of calcium oxide is formed, and the temperature of the surroundings increases by 20°C, calculate the heat capacity of the surroundings.

Item 6

Tr. Solomons' wife always uses 3 g of gas to boil 400 cm^3 of pure water from 22°C to 100°C to prepare morning tea for her husband. The gas is 85% methane, 5% carbon dioxide, 5% nitrogen, and 5% hydrogen.

Task:

a) Calculate the amount of heat produced.

b) i) Deduce the mass of methane used.

ii) If she uses the same mass of methane every day, calculate the mass of methane used for one week.

iii) If a kilogram of the gas costs UGX 11,000, calculate her total expenditure on the gas for ninety days.

5. CHEMICALS FOR CONSUMERS

Competency: The earner appreciates that the products used in everyday life exists as chemicals and some of them can be prepared at home or in the laboratory.

Key words

- Chemicals
- Food Additives
- Preservatives
- Colorants
- Flavor Enhancers
- Emulsifiers
- Analgesics
- Antibiotics
- Detergents
- Surfactants

By the end of this topic, the learner should be able to;

- Analyze properties of soap and detergent and compare and contrast the effectiveness of their cleansing action (u, s)
- Evaluate the use of food additives (k, u, s)
- Understand the importance of chemicals in medicine (k,u)
- Appreciate the importance of the chemical industry and its contribution to our lives(u)

What are Chemicals?

Substances with a definite composition.

Can be natural or synthetic.

They are used in a wide variety of products that we consume daily.

Types of Chemicals for Consumers

1. **Household Chemicals**
    - Cleaning Agents: Detergents, disinfectants.
    - Personal Care Products: Shampoos, conditioners, lotions, toothpaste.
    - Food Additives: Preservatives, flavorings, colorings.
2. **Agricultural Chemicals**
    - Fertilizers: Provide essential nutrients to plants.
    - Pesticides: Control pests and diseases.
    - Herbicides: Kill weeds.
3. **Medicinal Chemicals**
    - Drugs: Treat illnesses and alleviate pain.
    - Vaccines: Prevent diseases.

Detergents

Detergents are a type of surfactant, or surface-active agent, that are designed to clean and remove dirt, grime, and stains from surfaces.

Reference to Carbon in life, Basic Essentials Of Chemistry by Solomon Adilu

Soapy detergents

Soap is typically made from a combination of oils, fats, and alkali, which are mixed together and heated to create a chemical reaction called saponification.

Soapless detergents have been used for centuries, with early versions made from soap and other natural ingredients. Modern soapless detergents were first developed in the early 20th century, using synthetic surfactants.

Detergents generally are typically composed of surfactants, which are molecules with both hydrophilic (water-loving) and lipophilic (oil-loving) parts.

Emulsification: Detergents break down dirt and grease into smaller particles and surround them with their hydrophilic heads.
Suspension: The emulsified particles are suspended in water.
Removal: The suspended particles are rinsed away with water.

Properties

- Soap: Made from animal fat or plant oil, alkaline in nature, effective in soft water.
- Soapless detergents: Made from synthetic materials, neutral or slightly alkaline in nature, effective in hard water.

HISTORY OF SOAP

The origins of soap date back to ancient Mesopotamia, some 4500 years ago, where the first written evidence was found on clay tablets. The ancient Sumerians mixed animal and vegetable fats with alkaline salts to produce a soap-like material used for washing wool and cotton and for medicinal purposes.
The ancient Egyptians, around 1550 BC, used a soap-like substance for cleansing the body, while **the ancient Romans used it for bathing and cleaning their homes**. After the fall of the Roman Empire, soap production declined in Europe, but continued to flourish in the Islamic world.
In the Middle Ages, soap production resumed in Europe, especially in Italy, Spain and France. **The cities of Venice, Marseille and Savona became famous for soap production, using local oils such as olive oil**. In the 18th century, soap production spread to England and other parts of Europe where they introduced using palm oil and coconut oil.

Additives in detergents

Detergents contain a variety of additives to enhance their cleaning power and overall performance, some are highlighted in the table below.

Additive	Examples	Function
Surfactants	Sodium lauryl sulphate (SLS)	Reduce surface tension, enabling water to penetrate fabrics and remove dirt.
Builders	Sodium carbonate (washing soda)	Enhance the cleaning power of surfactants, often by softening hard water, through binding to calcium and magnesium ions.
Bleaching agents	Sodium hypochlorite	Oxidize stains, making them colorless
Anti-redeposition Agents	Carboxymethyl cellulose	Prevent re-deposition of dirt onto fabrics
Enzymes	Protease: Breaks down protein stains (e.g., blood, grass) Amylase: Breaks down starch stains (e.g., food spills) Lipase: Breaks down grease and oil stains	Break down specific types of stains, such as protein, starch, or grease.
Fragrances		Add a pleasant scent
Dyes	Azo dyes Anthraquinone dyes	Give the detergent a specific color
Preservatives	Parabens Formaldehyde	Prevent bacterial growth and maintain product quality
Foam Stabilizers	Linear alkylbenzene sulphonates	Help to maintain the foam produced by the detergent, making it last longer
pH Adjusters	Sodium hydroxide	Adjust the pH of the detergent to ensure it is effective and gentle on clothes

Foam Boosters	Alkyl ethoxylates	Increase the amount of foam produced by the detergent, making it appear more effective
Fillers	Sodium Sulphate, Sodium chloride	Add bulk to the detergent and help to maintain its texture

Evaluation of detergents

Advantages of Detergents

- Effective cleaning: Detergents are effective at removing dirt, grime, and stains from surfaces.
- Convenient: Detergents are widely available and easy to use.
- Variety of options: There are many types of detergents available, including liquid, powder, and tablet forms.
- Cost-effective: Detergents are often less expensive than other cleaning methods.

Disadvantages of Detergents

- Many detergents contain harsh chemicals that can harm the environment and contaminate waterways.
- Some detergents can cause skin and eye irritation, especially if not used properly.
- Some detergents can leave behind a residue that can attract dirt and dust.
- Some detergents are not biodegradable and can persist in the environment.

Similarities between soapy and soapless detergents

- Both soapy and soapless detergents are designed to clean and remove dirt, grime, and stains from surfaces.
- Both types of detergents contain surfactants, which are molecules that reduce the surface tension of water, allowing it to penetrate and lift away dirt and grime.
- Both types of detergents can produce foam, which helps to lift and remove dirt and grime.

- Both types of detergents can have an environmental impact, including contributing to water pollution and harming aquatic life.

Differences

Soapy detergents	Soapless detergents
Forms soap scum with hard water, which can leave residue on surfaces	Does not form soap scum with hard water
Reduced cleaning ability due to formation of soap scum	Unaffected cleaning ability, as they do not form soap scum
Made from natural ingredients like plant oils or animal fats	Made from synthetic ingredients
Usually biodegradable since they are made from plant or animal products	Non biodegradable
Sodium salts of long chain Carboxylic acids	Sodium salts of long chain benzene sulphonic acids

Comparison of effectiveness

- Soaps: Effective for cleaning delicate surfaces, gentle on skin, biodegradable.
- Soapless detergents: Effective for cleaning tough surfaces, good for removing grease and oil, not biodegradable.

Analysis of cleansing action

- Soap: Works by emulsifying oils, allowing water to penetrate and lift away dirt.
- Soapless detergents: Works by reducing surface tension, allowing water to penetrate and lift away dirt.

How Detergents Impact the Environment

Water Pollution

Eutrophication: Phosphates in detergents can stimulate excessive plant growth in water bodies. The increased plant growth, or algal blooms, can deplete oxygen levels in the water. This lack of oxygen can harm aquatic organisms, leading to fish kills and ecosystem disruption.

Soil Contamination

Leaching: Detergents can leach into soil through runoff from lawns, roads, and other surfaces. This can disrupt soil microorganisms and reduce soil fertility. Reduced soil fertility can negatively impact plant growth and health.

Wildlife Harm

Aquatic toxicity: Detergents can be toxic to aquatic organisms, such as fish, invertebrates, and amphibians, this can contribute to the degradation of aquatic habitats, affecting biodiversity.

Climate Change

Greenhouse gas emissions: Some detergent ingredients, such as surfactants and fragrances, can contribute to greenhouse gas emissions. These emissions contribute to global warming and hence climate change, leading to rising sea levels, extreme weather events, and other environmental consequences.

Food Additives

Background

Some Additives have been used for centuries; for example, preserving food by pickling with Vinegar, salting, as with bacon, preserving sweets or using sulphur dioxide as in some wines.

Various labeling regulations have been put into effect to ensure that contents of processed foods are known to consumers, and to ensure that food is fresh-important in unprocessed foods and probably important even if preservatives are used. In addition, we also need to add some preservatives in order to prevent the food from spoiling. Direct additives are intentionally added to foods for a particular purpose. Indirect additives are added to the food during its processing, packaging and storage. Food Preservatives are the additives that are used to inhibit the growth of bacteria, molds and yeasts in the food. Some of the additives are manufactured from the natural sources such as corn, beet and soybean, while some are artificial, man-made additives. Most people tend to eat the ready-made food available in the market, rather than preparing it at home. Such foods contain some kind of additives and preservatives, so that their quality and flavor is maintained and they are not spoiled by bacteria and yeasts.

Salt and sugar are the most Commonly used additives.

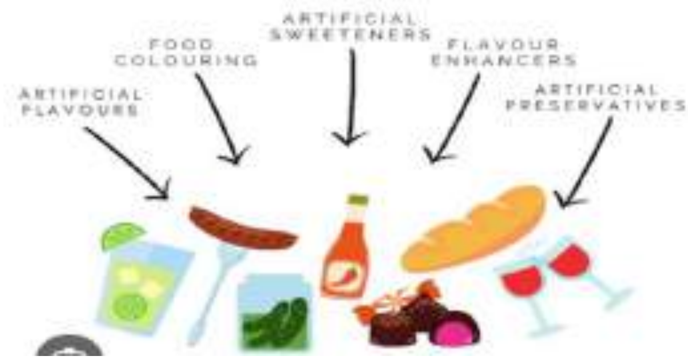
What are Food Additives?

Food additives are substances added to food to Enhance/improve its appearance, taste, texture, or shelf life. They are widely used in the food industry to enhance the quality and safety of food products. They are added to food at various stages of production, processing, packaging and storage.

Sources of Food Additives

1. _Natural Sources_: Derived from plants, animals, or microorganisms (e.g. beet juice, yeast extract).

2. _Synthetic Sources_: Manufactured through chemical synthesis (e.g. artificial colors, preservatives).



Types of food additives

Type of food additive	Function	Examples
Preservatives	Prevent food spoilage by inhibiting the growth of microorganisms like bacteria, yeast, and mold and extend self life of food	Natural (Salt, sugar, vinegar, lemon juice(ascorbic acid), lactic acid) Synthetic (nitrates, sulphites, Sodium benzoate, potassium sorbate)
Coloring Agents	Enhance the visual appeal of food. They work by interacting with light. They absorb specific wavelengths of light and reflect others, creating the colors we see	Natural (beet juice , turmeric) Synthetic colors (tartrazine, Allura Red AC)
Flavoring Agents	Improve the taste and aroma of food	Natural (vanilla extract, lemon extract)

		Synthetic (monosodium glutamate, yeast extract)
Thickeners and Stabilizers	Improve the texture and consistency of food. They work by forming a network of molecules that trap water molecules, slowing down their movement	Natural (Starch, gelatin, pectin) Synthetic (Methyl cellulose, Sodium and Calcium alginate)
Emulsifiers	Prevent the separation of oil and water in food products. They reduce the surface tension between oil and water, allowing them to mix	Natural (Lecithin, pectin). Synthetic (monoglycerides, diglycerides)
Antioxidants	Prevent food from spoiling by inhibiting oxidation. They Neutralize free radicals, which are unstable molecules that can cause oxidative damage to food components.	Natural (Vitamin C in fruit juice & cured meat, vitamin E in palm oil & sun flowers) Synthetic (BHA, BHT in margarine and cereal)
Sweeteners	Improve the taste of food and beverages Reduce calorie intake in low-calorie or diet products Enhance the shelf life of certain products	Natural sweeteners like sugar, honey). Synthetic (aspartame, sucralose, and stevia)

Chemicals in food additives

Chemical	**Function**	**Examples of foods that contain them**
Preservatives		
Sodium Benzoate	Prevents growth of bacteria and mold	Salad dressings, fruit juices, pickles
Sodium Nitrite	Prevents the growth of bacteria, particularly Clostridium botulinum,	Cured meats (bacon, ham, salami), Processed meats (hot

	and adds flavor and color to foods	dogs, sausages), Smoked fish, Canned meats
Ascorbic Acid(Vitamin C)	Prevents oxidation, browning, and spoilage of foods.	Fresh fruits (oranges, lemons, strawberries) - Fruit juices (orange, apple, grapefruit) - Canned fruits and vegetables - Frozen fruits and vegetables - Meat products (sausages, bacon) - Soft drinks and energy drinks
Colorants		
Azo Compounds	Synthetic food dyes that add yellow, orange, and red colors to foods	Soft drinks, candy, baked goods, fruit juices
Triphenylmethane Compounds	Synthetic food dyes that add blue and green colors to foods.	Ice cream, Candy, baked goods, fruit juices.
Flavor Enhancers		
Monosodium Glutamate (MSG)	Enhances umami flavor	Chinese food, Processed meats (hot dogs, sausages), Canned vegetables and soups, Instant noodles
Aspartame	Provides a sweet taste without the calories	Diet sodas - Sugar-free gum - Low-calorie desserts (ice cream, pudding) - Tabletop sweeteners (Equal, Nutrasweet) - Sugar-free energy drinks
Thickeners and Stabilizers		
Acacia Gum	Natural adhesive and emulsifier that is used as a thickening agent,	Confectionery (gums, jellies), Beverages (soft drinks, energy drinks), Dairy products (yogurt,

	stabilizer, and texture modifier in foods	ice cream), Baked goods (cakes, cookies)
Gelatin	Protein derived from animal collagen that is used as a gelling agent, thickener, and stabilizer in foods	Desserts (puddings, jellies, marshmallows), Confectionery (gummies, caramels), Dairy products (yogurt, ice cream), Meat products (sausages, canned meats)
Xanthan Gum	Thickens and stabilizes	Salad dressings, sauces, beverages
Antioxidants		
Butylated Hydroxytoluene (BHT)	Prevents oxidation and spoilage	Cereals, baked goods, snack foods
Butylated Hydroxyanisole (BHA)	Prevents oxidation and spoilage	Cereals, baked goods, snack foods
Tertiary Butylhydroquinone (TBHQ)	Prevents oxidation and spoilage	Fried foods, baked goods, snack foods

Rationale for the use of food additives

Technological Reasons

- Preservation: Food additives help prevent spoilage and extend shelf life.
- Texture and Stability: Additives improve texture, prevent separation, and maintain consistency.
- Flavor Enhancement: Additives enhance or restore flavors, aromas, and colors.

Safety Reasons

- Prevention of Foodborne Illnesses: Additives prevent the growth of harmful microorganisms.
- Protection against Oxidation: Antioxidants prevent oxidation, which can lead to spoilage and toxicity.

Nutritional Reasons

- Fortification: Additives enhance the nutritional value of foods, particularly for vulnerable populations.
- Replacement of Nutrients: Additives replace nutrients lost during processing, storage, or cooking.

Economic Reasons

- Cost Savings: Additives reduce production costs by extending shelf life, improving texture, and enhancing flavor.
- Increased Efficiency: Additives streamline food production, reducing waste and improving yields.

Consumer Demand

- Convenience: Additives help create convenient, ready-to-eat foods.
- Aesthetics: Additives enhance appearance, texture, and flavor, making foods more appealing.

Evaluation of the products

Similarities

- Both natural and synthetic food additives can be used to preserve food and extend its shelf life.
- Both types of additives can be used to enhance the flavor and texture of food products.
- Both natural and synthetic food additives are used in a wide range of food products, including beverages, baked goods, snacks, and processed meats.
- Both natural and synthetic food additives can cause adverse reactions in some individuals, such as allergic reactions or intolerances.
- Both natural and synthetic food additives can affect the nutritional content of food products, either by adding or removing nutrients.

Differences

Criteria	**Natural Food Additives**	**Synthetic Food Additives**
Safety	Generally considered safe	Potential health risks
Availability	Limited availability and consistency	Consistent quality and availability
Nutritional Value	Can provide health benefits	Lack nutritional value
Shelf Life	Limited shelf life	Longer shelf life
Environmental Impact	Minimal environmental impact	Potential environmental concerns
Regulatory Status	Often exempt from regulation	Strictly regulated by food authorities

Banned Food Additives

Food additives can be useful in enhancing the appearance, flavor, and texture of food products. However, some food additives have been linked to health problems and have been banned or restricted in various countries.
It is essential for consumers to be aware of the potential risks associated with food additives and to make informed choices about the foods they eat.
The following food additives have been banned or restricted in various countries due to concerns over their safety and potential health risks.

Food additive	**Reason for banning**
Saccharin	Linked to bladder cancer and other health problems
Potassium Bromate	Carcinogenic, linked to cancer
Bisphenol A (BPA) an industrial chemical used in the production of polycarbonate plastics and epoxy resins. It's found in a variety of products,	BPA is an endocrine disruptor, meaning it can interfere with the body's hormone system. Linked to reproductive problems, including infertility and birth defects. Affect brain development and behavior.

including food and beverage containers, water bottles, and baby bottles.	
Certain artificial sweeteners (e.g., cyclamate)	Potential health risks, including bladder cancer
Nitrates and Nitrites	When nitrates and nitrites react with amines in food, they can form nitrosamines, which are known to be carcinogenic. High intake of processed meats, which are often high in nitrates and nitrites, has been linked to an increased risk of certain types of cancer, particularly colorectal cancer

Impacts of food additives

Health Risks

Some food additives have been linked to health problems, such as cancer, allergies, and hyperactivity.

Mitigation

- Read food labels carefully and avoid products with additives that have raised health concerns.
- Choose organic or natural products when possible.
- Support regulatory efforts to ban or restrict the use of harmful additives.

Some food additives can alter the gut microbiome, leading to changes in digestive health and immune function.

Mitigation

- Eat a balanced diet rich in whole, unprocessed foods.
- Avoid or limit foods with additives that can disrupt gut health.
- Consider probiotics or prebiotics to support gut health.

Consuming high amounts of food additives has been linked to an increased risk of chronic diseases, such as obesity, diabetes, and heart disease.

Mitigation

- Limit or avoid foods with high amounts of additives.
- Choose whole, unprocessed foods whenever possible.
- Support public health initiatives aimed at reducing chronic disease rates.

Environmental Impacts

The production and disposal of food additives can have negative environmental impacts, such as water pollution and waste generation.

Mitigation

- Support sustainable and eco-friendly production practices.
- Encourage companies to adopt environmentally responsible packaging and disposal practices.
- Choose products with minimal or biodegradable packaging.

Impact on Food Quality

The overuse of food additives can lead to a decrease in food quality, making food products less nutritious and less flavorful.

Mitigation

- Support artisanal or small-scale food producers who prioritize quality and minimal processing.
- Choose products with fewer and more natural ingredients.
- Advocate for food labeling transparency and regulation.

Food for thoughts

In groups, Discuss Life Without Food Additives. Base on Increased Food Costs, Food Shelf Life, Changes in Food Texture and Taste, Increased Risk of Foodborne Illnesses, Improved Health, Food Quality, Environmental Benefits.

Medicines and Drugs

Medicines, also known as pharmaceuticals or drugs, are substances used to prevent, diagnose, treat, or alleviate symptoms of diseases or medical conditions.
Drugs are a broader term that includes both medicines and substances that are not intended for medical use.

What are Chemicals in Medicine?
Chemicals in medicine refer to the various substances used in the diagnosis, treatment, and prevention of diseases. These chemicals can be derived from natural sources, synthesized in laboratories, or produced through biotechnology.

Sources of Chemicals in Medicine

1. Natural Sources: Many medicines are derived from natural sources, such as plants, animals, and microorganisms.
2. Synthetic Chemistry: Many medicines are synthesized in laboratories using chemical reactions.
Drugs or medicines can be traditional(Derived from plants, often used in traditional medicine practices e.g Ginger, turmeric, Kola nuts) or modern (Synthetic, Created in laboratories e.g Aspirin, penicillin, ibuprofen)

Note: While traditional medicines have been used for centuries, many of them have not undergone rigorous scientific testing to prove their effectiveness and safety. It is important to consult with a healthcare professional before using any type of medicine

Traditional medicines

Here is a table of traditional medicines, their category, sources, and functions

Category	Traditional medicine	Source	Functions
Antibiotics	Garlic(antibacterial and anti-inflammatory)	Allium sativum plant	Prevents infection, reduces blood pressure. Treats colds and flu.
	Pawpaw Leaves and roots (antimicrobial, anti-inflammatory, antifungal)	Carica papaya plant	Treats and Relieves pain . Treats malaria, coughs and colds, skin conditions like eczema, wounds. Inhibits growth of Candida albicans.
	Guava Leaf and flower (Antimicrobial, antibacterial, anti-inflammatory)	Psidium guajava plant	Treats diarrhea, dysentery, relieves pain, reduces inflammation. Treats arthritis. Treats skin conditions like acne and eczema.
Analgesics	Salicin in Willow bark (its a compound similar to aspirin)	Salix alba tree	Relieves pain, reduces inflammation
	Moringa extract	Moringa Oleifera	Reduces pain and inflammation.
	Ginger extract contains compound gingerol		Inhibits pain pathways associated with headache, menstrual cramps, reduces inflammation, blocks pain receptors
	Turmeric extract (contains Curcumin)		Reduces inflammation, inhibits

			pain pathways, blocks pain receptors
Psychotherapeutics	Antidepressants Hypericum perforatum (St. John's Wort), Ekisanzi(Cassia occidentalis) Aloe Vera Omuboro (Rhus vulgaris)	Hypericum perforatum plant	Treat mild depression, anxiety, and insomnia The gel from the aloe Vera plant is used to treat depression, anxiety, and skin conditions Treat depression, anxiety, and stress
	Passionflower(passion fruit flower)	Passion fruit plant	Treat anxiety and insomnia.
	Kola nuts (stimulant)	Kola nitida plant	Increases alertness. Treats depression
	Antipsychotics Rauvolfia vomitoria (Devil Pepper) Solanum incanum (Sodom Apple) Cannabis sativa (Marijuana)		Treat psychosis by regulating the function of the brain that controls thinking, mood and perception.

Note

Some traditional medicines may interact with conventional medications or have side effects, so it's essential to consult with a healthcare professional before using them.

Modern Medicine

Here is a table of modern medicines, their category, sources, and functions

Category	Modern Medicine	Source	Function
Antibiotic	Amoxicillin	Synthetic	Treats bacterial infections
	Ciprofloxacin	Synthetic	Treats bacterial infections including UTIs
	Penicillin	Synthetic	Treats bacterial infections
	Azithromycin	Synthetic	Treats bacterial infections including skin infections and STIs
	Erythromycin	Synthetic	Treats bacterial infections including acne, pneumonia, Gonorrhea)
Analgesic	Paracetamol	Synthetic	Relieves pain, reduces fever
	Aspirin	Synthetic	Prevents blood clots, relieves pain
	Ibuprofen(Anti-inflammatory)	Synthetic	Relieves pain, reduces inflammation
Psychotherapeutic	Fluoxetine (Antidepressant)	Synthetic	Treats depression, anxiety
	Chlorpromazine (Antipsychotic)	Synthetic	Relieves anxiety disorders and delusions.
	Amphetamine (stimulant)		Treats ADHD and narcolepsy

Note:

Modern medicines can have side effects, interactions, and contraindications, so it's essential to consult with a healthcare professional before using them.

How Do Medicines Work?

Medicines work by interacting with the body's biological systems, such as cells, tissues, and organs. They can:

1. Relieve symptoms: Medicines can relieve symptoms such as pain, fever, and inflammation.
2. Cure diseases: Some medicines can cure diseases, such as antibiotics for bacterial infections.
3. Prevent diseases: Vaccines and some medicines can prevent diseases, such as flu vaccines and cholesterol-lowering medicines.

Medicines can block the action of enzymes and interfere with cell signaling pathways, which can help to alleviate symptoms or prevent disease progression.
Antibiotics and antiviral medicines work by killing or inhibiting the growth of microorganisms.

Categorizing Medicines

Medicines can be categorized according to their functions I.e

1. **Analgesics:** Relieve pain, e.g., acetaminophen, ibuprofen.

Analgesics can provide relief from acute and chronic pain and inflammation, which can help with conditions like arthritis.
Some analgesics, like acetaminophen, can help reduce fever.
Traditional examples: Aspirin, opium derivatives
Modern examples: Acetaminophen, ibuprofen, paracetamol.
Analgesics, also known as pain relievers, work by interacting with the body's pain pathways to reduce or eliminate pain.

Mechanisms of Action

Blocking pain signals: Analgesics can block pain signals from reaching the brain, either by binding to receptors or by inhibiting the production of pain-causing chemicals.

Site of Action

1. Peripheral nervous system: Analgesics can act on the peripheral nervous system, which includes nerves outside the brain and spinal cord.
2. Central nervous system: Analgesics can also act on the central nervous system, which includes the brain and spinal cord.

2. **Antibiotics:** these are medications that work by targeting and killing or inhibiting the growth of microorganisms, such as bacteria, fungi, and protozoa., e.g., penicillin, tetracycline.

Traditional: Some herbal remedies have antimicrobial properties.

Modern: Penicillin, cephalosporins, tetracyclines

Mechanisms of Action

1. Interfering with cell wall formation: Antibiotics like penicillin and ampicillin inhibit the synthesis of the bacterial cell wall, leading to cell lysis and death.
2. Inhibiting protein synthesis: Antibiotics like tetracycline and erythromycin bind to bacterial ribosomes, inhibiting protein synthesis and preventing bacterial growth.
3. Interfering with DNA replication: Antibiotics like ciprofloxacin and gentamicin inhibit bacterial DNA replication, preventing the bacteria from multiplying.
4. Disrupting membrane function: Antibiotics like polymyxin and daptomycin disrupt the bacterial cell membrane, leading to cell death.

Site of Action

1. Bacterial cell wall: Antibiotics like penicillin and ampicillin target the bacterial cell wall.
2. Bacterial ribosomes: Antibiotics like tetracycline and erythromycin target bacterial ribosomes.
3. Bacterial DNA: Antibiotics like ciprofloxacin and gentamicin target bacterial DNA.
4. Bacterial cell membrane: Antibiotics like polymyxin and daptomycin target the bacterial cell membrane.

Keep in mind that antibiotics only work against bacterial infections and are ineffective against viral infections like the common cold or flu.

3. **Psychotherapeutic Drugs:** Drugs used to treat mental health disorders.

Psychotherapeutic medicines, also known as psychotropic medications, work by influencing the brain's chemistry and function to treat various mental health conditions.

Traditional: Some herbal remedies, such as St. John's wort, have been used to treat depression.

Modern: Antidepressants, antipsychotics, anxiolytics

1. Antidepressants: Used to treat depression, anxiety, and some other conditions.
2. Antipsychotics: Used to treat psychotic disorders, such as schizophrenia and bipolar disorder.
3. Anxiolytics: Used to treat anxiety disorders.
4. Mood stabilizers: Used to treat bipolar disorder and other mood disorders.
5. Stimulants: Used to treat attention deficit hyperactivity disorder (ADHD) and narcolepsy.

Mechanisms of Action

Psychotherapeutic medicines can increase or decrease the levels of certain neurotransmitters, such as serotonin, dopamine, and norepinephrine, which play a crucial role in mood regulation and other psychological processes.

They bind to specific receptors in the brain, altering their activity and influencing various physiological and psychological processes.

They promote neuroplasticity, the brain's ability to adapt and change in response to new experiences and learning.

Effects on Mental Health Conditions

- Mood stabilizers like lithium can help regulate mood swings and reduce symptoms of bipolar disorder.
- Anxiolytics like alprazolam can help reduce anxiety symptoms and promote relaxation.
- Antipsychotics like haloperidol can help manage symptoms of psychosis, such as hallucinations and delusions.

Evaluation of modern and traditional medicines

Similarities

- Both modern and traditional medicines aim to prevent and treat diseases, improving human health and well-being.
- Many modern medicines are derived from natural products, such as plants, animals, and microorganisms, which is also a key component of traditional medicines.
- Both modern and traditional medicines require careful consideration of dosage and administration to ensure safety and efficacy.
- Both modern and traditional medicines can have side effects and interact with other medicines or health conditions.

Modern Medicines

Advantages

- Modern medicines are often highly effective in treating a wide range of diseases and conditions.
- Modern medicines can act quickly to relieve symptoms and improve health outcomes.
- Modern medicines are standardized, ensuring consistent quality and potency.
- Modern medicines are subject to rigorous testing and regulatory oversight, ensuring safety and efficacy.

Disadvantages

- Modern medicines can have unintended side effects, some of which can be severe.
- Some modern medicines can lead to dependence and addiction.
- Modern medicines can be expensive, making them inaccessible to some people.
- The production and disposal of modern medicines can have negative environmental impacts.

Traditional Medicines

Advantages

- Traditional medicines are often more accessible and affordable than modern medicines.
- Traditional medicines are often deeply rooted in cultural and traditional practices.
- Traditional medicines often take a holistic approach to health, considering physical, emotional, and spiritual well-being.
- Traditional medicines are often derived from natural sources and can be more sustainable than modern medicines.

Disadvantages

- Traditional medicines lack specific dosage
- Traditional medicines can vary in quality and potency, as they are often not standardized.
- Traditional medicines may not have undergone rigorous scientific testing, making it difficult to evaluate their efficacy and safety.
- Traditional medicines can interact with modern medicines or have adverse effects, especially if used in large quantities or for extended periods.
- Traditional medicines may not be regulated in the same way as modern medicines, making it difficult to ensure safety and efficacy.

End-of-chapter summary:

Key Concepts

- Soaps and Detergents: Chemicals used for cleaning, made from oils, fats, and alkalis.
- Saponification: The process of making soap from oils and fats.
- Food Additives: Chemicals added to food to preserve, flavor, or color it.
- Preservatives: Chemicals used to extend the shelf life of food by preventing spoilage.
- Colorants: Chemicals used to add color to food.
- Flavoring Agents: Chemicals used to add flavor to food.

- Thickeners: Chemicals used to thicken the texture of food.
- Antioxidants: Chemicals used to prevent oxidation and spoilage of food.
- Emulsifiers: Chemicals used to mix two or more liquids that don't normally mix.
- Sweeteners: Chemicals used to add sweetness to food.
- Pharmaceuticals: Chemicals used to prevent or treat diseases, such as medicines and vaccines.
- Analgesics: Medicines used to relieve pain, such as acetaminophen and ibuprofen.
- Psychotherapeutic Drugs: Medicines used to treat mental health conditions, such as antidepressants and antipsychotics.
- Antibiotics: Medicines that kill or inhibit the growth of microorganisms.
- Medical Imaging: Chemicals used to create images of the body.
- Toxicity: The potential of chemicals to harm humans or the environment.

End of chapter Scenarios

Item 1:

Maria owns a bakery, and her customers have been complaining that her cakes are too dense and dry. Maria wants to add an ingredient to improve the texture of her cakes but doesn't know which one to use. She has approached you for guidance.

Task;

As a chemistry learner,

(a) (i) Guide her on the categories of ingredient products Maria should use.
(ii) Explain to Maria how the ingredient product works.

(b) Explain the dangers associated with the long-term use of the ingredient product.

(c) Evaluate the products.

Item 2:

Akua owns a company that produces fruit juices. She is thinking of which ingredient to add to her pineapple juice to make it more appealing and attractive to customers but she doesn't know which ingredient to buy.

Task;

As a chemistry learner,

(a) (i) Explain the categories of ingredients Akua should use.

(ii) Explain to Akua how the ingredient works.

(b) Explain the dangers associated with the long-term use of the ingredient.

Item 3:

Madam Adjeley, who runs a restaurant at Kanapa trading center, once used lemons on her foods. She was surprised to see that her food spent a longer time without getting spoilt. She approached you to clearly explain to her the matter.

Task;

As a chemistry learner,

(a) (i) Explain the category of the ingredient she used.

(ii) Explain how the ingredient works.

(b) Evaluate the products.

Item 5:

A patient with depression was prescribed a medication. After taking the medication, the patient's mood improved, and they experienced a reduction in symptoms of depression.

As a chemistry student,

(a) (i) Classify the medication under the appropriate category of drugs.

(ii) Explain how the medication functions to alleviate symptoms of depression.

(b) Explain the challenges associated with the long term use of the product.

Item 6:

Atim, with a severe urinary tract infection (UTI) visited her Aunt who is a health personnel at Ongino health center IV. When she explained the situation to her, the Aunt quickly gave her a certain drug. After taking the drugs, Atim became well and she was completely fine.

Task;

As a chemistry student,

(a) (i) Give the Category of medication she was given.

(ii) Explain how the medication functions.

(b) Advise Atim on the challenges associated with the long term use of the product.

(c) Evaluate the product.

Item 7:

Opondo felt a severe headache on his way back home, when he reached home, his mother quickly prepared a plant extract and gave him. After some time , the pain subsided, and he was able to resume his daily activities.

Task;

As a chemistry student,

(a) (i) Give the appropriate category of drugs Opondos' Mother gave him.

(ii) Explain how the product functions.

(b) Evaluate the products..

Item 8:

Okitoi felt severe anxiety and panic attack. When he visited a doctor, he was prescribed a medication. After taking the medication, the symptoms improved, and he was able to manage their anxiety.

Task;

As a chemistry student,

(a) (i) Explain the category of drugs Okitoi was given.

(ii) Explain how the product works.

(b) Advise Okitoi on the long term use of the product.

6. NUCLEAR PROCESSES

Key words

- Atomic structure
- Radioactivity
- Nuclear decay
- Fission
- Fusion
- Radiation
- Electromagnetic waves
- Half-Life
- Chain Reactions
- Radioisotopes
- Nuclear Waste

By the end of this topic, the learner;

- Understands atomic structure, the processes of nuclear fission and fusion, the use we can make of them, and the dangers associated with them (k,u)
- Understands the spontaneous and random nature of nuclear decay and interpret decay data in terms of half life (u, s)
- Understands and appreciate that there are significant social, political, and environmental dimensions associated with use of unclear power(u)

Atomic Structure and Nuclear Reactions

Atomic Structure: Atoms are the building blocks of matter. They consist of protons, neutrons, and electrons.

Structure of an Atom

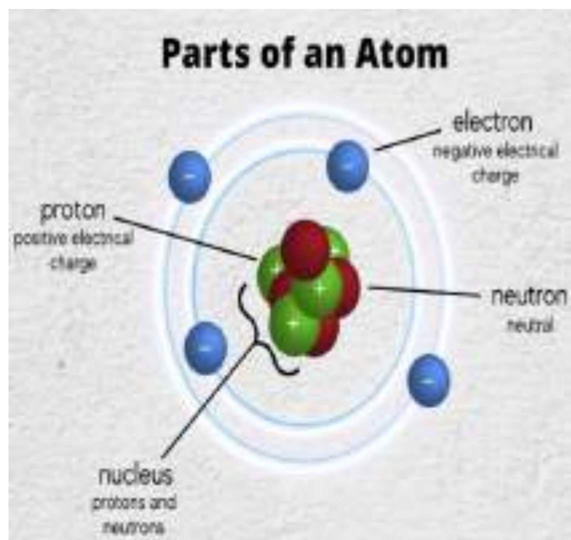
Atomic Model: The atomic model describes the structure of an atom. The most widely accepted model is the nuclear model, which states that an atom consists of a small, dense nucleus surrounded by electrons.

Nucleus: The nucleus is the central part of an atom and contains protons and neutrons. Protons have a positive charge, while neutrons have no charge.

Electron Cloud: The electron cloud is the region around the nucleus where electrons are found. Electrons have a negative charge and are attracted to the positive charge of the protons in the nucleus.

Composition of an Atom

An atom is composed of three main subatomic particles: protons, neutrons, and electrons.



- Protons: Protons are positively charged particles found in the nucleus of an atom. The number of protons in an atom determines the element of an atom.
- Neutrons: Neutrons are particles with no charge found in the nucleus of an atom. The number of neutrons in an atom determines the isotope of an element.
- Electrons: Electrons are negatively charged particles that orbit the nucleus of an atom. The number of electrons in an atom is equal to the number of protons.

Sub atomic particles

Protons	Neutrons	Electrons
- Have a positive charge, which attracts electrons. - Have a mass of approximately 1 atomic mass unit (amu). - Found in the nucleus of an atom.	- Have no charge, making them neutral particles. - Have a mass of approximately 1 amu. - Found in the nucleus of an atom.	- Have a negative charge, which attracts protons. - Have a very small mass, approximately 1/1836 that of a proton. - Orbit the nucleus of an atom in energy levels or electron shells.

The nucleus of an atom has the greatest mass. The nucleus is composed of protons and neutrons, which are collectively known as nucleons. These nucleons have a significant mass compared to the electrons, which orbit the nucleus.

Since the nucleus contains most of the atom's mass, it is often referred to as the "mass center" of the atom.

Atoms are neutral since they have an equal number of positively charged protons and negatively charged electrons.

When the number of protons (positive charges) is equal to the number of electrons (negative charges), the atom has no net charge and is therefore neutral.

For example

Hydrogen (H): 1 proton (+1) and 1 electron (-1) = neutral atom

Helium (He): 2 protons (+2) and 2 electrons (-2) = neutral atom

An element can have more than one atom, this occurs when an element experiences a change in the number of neutrons but the proton number (atomic number) stays the same. The two atoms are referred to as isotopes.

Therefore isotopes are atoms of the same element which have the same atomic number but different mass numbers.

Nuclear reactions

Nuclear reactions are processes in which the nucleus of an atom is altered, resulting in changes to the atomic number (number of protons) and/or mass number (number of protons and neutrons).

Nuclear Reactions Involve

- Changes to the Nucleus: Nuclear reactions involve changes to the nucleus, such as the addition or removal of protons and/or neutrons.
- High-Energy Particles: Nuclear reactions often involve high-energy particles, such as alpha particles, beta particles, and gamma radiation.
- Energy Release or Absorption: Nuclear reactions often involve the release or absorption of energy, which can take the form of radiation, heat, or light.

Examples of Nuclear Reactions

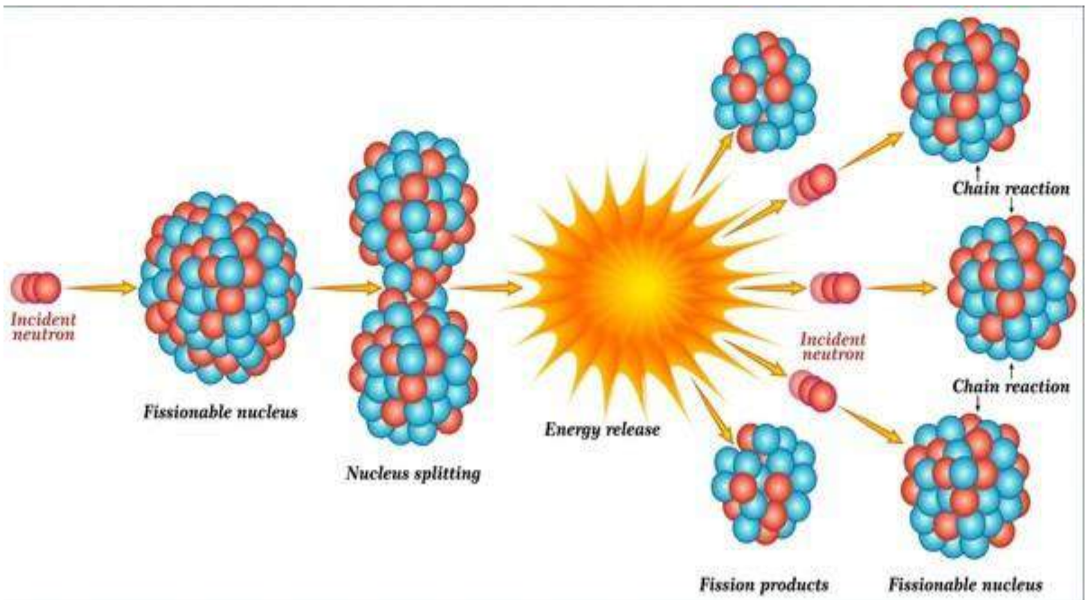
- Nuclear Fission
- Nuclear Fusion
- Radioactive Decay

Nuclear Fission

Nuclear fission is the process by which a heavy atomic nucleus disintegrates/splits into two or more smaller light nuclei.
This decay can be natural spontaneous splitting by radioactive decay, or can actually be simulated in a lab by achieving necessary conditions (bombarding/striking with slow moving neutrons). The resulting fragments(small nuclei) tend to have a combined mass which is less than the original. The missing mass is what is converted into nuclear energy.

Process of Nuclear Fission

During nuclear fission, a neutron collides with an atomic nucleus, causing it to split into two or more smaller nuclei, releasing more neutrons and energy. The released neutrons cause further fission reactions with other atoms, leading to a chain reaction and the process repeats itself. A tremendous amount of energy is released in the form of heat and radiation each time an atom splits.



Nuclear fission is used in nuclear power plants to generate electricity:

The energy released from the fission process heats water into steam. The steam spins a turbine to produce electricity.

Uranium and plutonium are the most common materials used in nuclear fission reactions because they are easy to control and initiate.

The elements that undergo nuclear fission reactions

- Uranium-235 (^{235}U) and Uranium-233 (^{233}U).
- Plutonium-239 (^{239}Pu)
- Thorium-232 (^{232}Th)
- Radium-226 (^{226}Ra)

These elements can undergo nuclear fission reactions, such as:

- Neutron-induced fission: A neutron collides with an atomic nucleus, causing it to split.
- Spontaneous fission: An atomic nucleus splits spontaneously without the need for a neutron collision i.e Occurs naturally in certain isotopes.

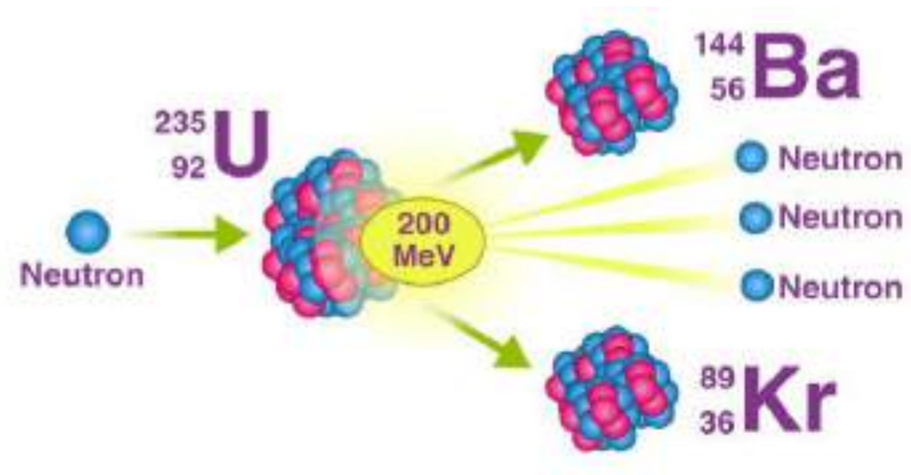
These elements are used in nuclear reactors, nuclear weapons, and other applications where nuclear fission is utilized.

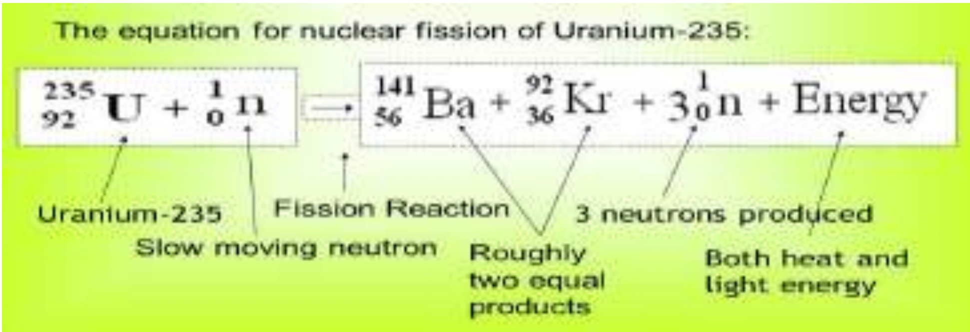
If the chain reaction is allowed to run unchecked, it can become a powerful and destructive force, as seen in the detonation of an atom bomb

Examples of Nuclear Fission

- Atomic bomb: An atomic bomb uses nuclear fission to release energy.
- Nuclear power plants: Nuclear power plants use nuclear fission to generate electricity i.e fission of uranium-235 in nuclear reactors.

For instance, uranium-235 becomes highly unstable and splits after absorbing a low-energy neutron, known as a thermal neutron. The resulting fragments tend to have a combined mass which is less than the original. The missing mass is what is converted into nuclear energy in the above reaction





The fission releases a large amount of energy, which can be harnessed to generate electricity. The energy released during fission reactions is significant because the resulting daughter nuclei have:

- A higher binding energy per nucleon, indicating greater stability
- A reduced overall mass

Applications of Nuclear Fission

- Electricity generation: Nuclear power plants use nuclear fission to generate electricity.
- Medical applications: Radioisotopes produced through nuclear fission are used in medicine for diagnosis and treatment.

One of the major applications of a fission reaction is the production of electricity via nuclear power plants. Nuclear fission is an advantageous method for producing power for several reasons.
We use nuclear reactors to generate electricity making use of the nuclear fission reaction. The heat from nuclear fission is passed to a working fluid, which in turn runs through steam turbines. These either drive a ship's propellers or turn electrical generators' shafts.

Nuclear Fusion

Nuclear fusion is the process by which two or more light atomic nuclei combine to form a single, heavier nucleus. This process releases a large amount of energy.

Examples of Nuclear Fusion

- The sun: The sun is a massive nuclear fusion reactor, where hydrogen nuclei fuse together to form helium isotope Nucleus, releasing vast amounts of energy in the process.
- Hydrogen bomb: A hydrogen bomb is a type of nuclear weapon that uses nuclear fusion to release energy.

The elements that undergo nuclear fusion reactions

Nuclear fusion typically involves the fusion of isotopes of hydrogen, which are:

- Deuterium (D or ^{2}H):A stable isotope of hydrogen with one proton and one neutron in its nucleus.
- Tritium (T or ^{3}H): A radioactive isotope of hydrogen with one proton and two neutrons in its nucleus.
- Protium (^{1}H): The lightest and most abundant isotope of hydrogen, with one proton and no neutrons in its nucleus.

These isotopes of hydrogen can undergo nuclear fusion reactions, such as:

- Deuterium-Tritium (D-T) reaction: D + T $\rightarrow$ ^{4}He + n + Energy

$$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n + \text{Energy}$$

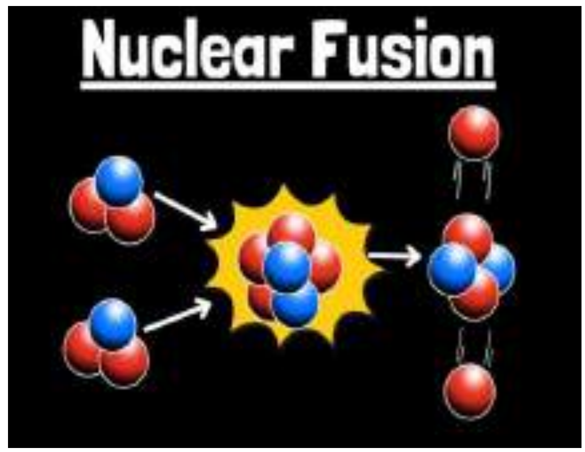
- Deuterium-Deuterium (D-D) reaction: D + D $\rightarrow$ ^{3}He + n + Energy
- Protium-Deuterium (P-D) reaction: ^{1}H + D $\rightarrow$ ^{2}He + Energy

Process of Nuclear Fusion

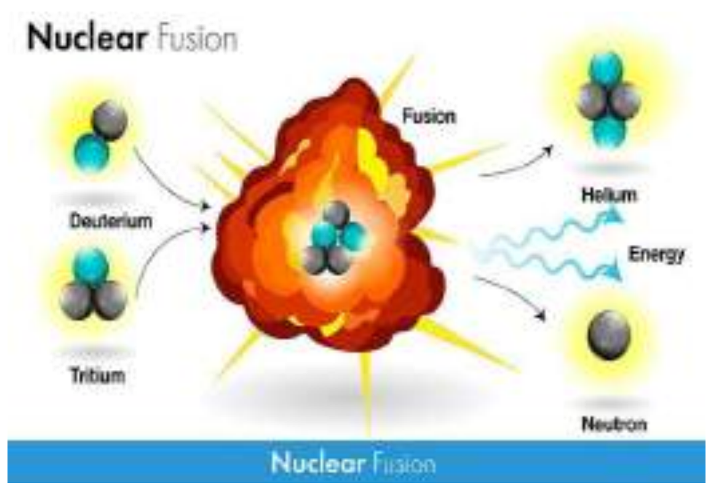
Conditions

Nuclear fusion takes place in a state of matter called plasma, which is a hot, charged gas of free-moving electrons and positive ions. The nuclei must collide at extremely high temperatures, around ten million degrees Celsius, to overcome their electrical repulsion.

- Two or more nuclei collide at high speeds in order to overcome their mutual repulsion. After collision with sufficient energy, they will fuse together to form a single, heavier nucleus. The total mass of the resulting nucleus is less than the mass of the two original nuclei, and the leftover mass is converted into energy making the reaction release a large amount of energy, which can be harnessed to generate electricity.



Nuclear fusion is the mechanism through which the Sun and other stars obtain their energy.
For instance: Atoms of Tritium and Deuterium (hydrogen isotopes Hydrogen-3 and Hydrogen-2, respectively) combine to generate a neutron and a helium isotope. Along with this, a massive quantity of energy is released.



Advantages of Nuclear Fusion

- Clean energy source: Nuclear fusion is a clean energy source, as it produces minimal radioactive waste and does not produce greenhouse gases or other pollutants.
- Abundant fuel supply: The fuel used in nuclear fusion (usually a form of hydrogen) is abundant and can be extracted from seawater.
- High energy yield: Nuclear fusion releases a large amount of energy per reaction, making it a promising source of electricity.

Challenges of Nuclear Fusion

Sustaining fusion reactions for long periods of time is difficult because of the extreme pressure and temperature required

- Achieving and sustaining high temperatures: Nuclear fusion requires the plasma (ionized gas) to be heated to incredibly high temperatures (about 150 million°C) in order to initiate and sustain the fusion reaction making them difficult to achieve on Earth
- Confining and stabilizing the plasma: The plasma must be confined and stabilized in order to achieve and sustain the high temperatures necessary for nuclear fusion.
- Developing materials that can withstand the conditions: The materials used in a nuclear fusion reactor must be able to withstand the incredibly high temperatures and radiation fluxes inside the reactor.

Evaluation of the processes

Similarities

Both fission and fusion are nuclear reactions that shift atoms to produce energy

Differences between Nuclear Fission and Nuclear Fusion

Parameter	Nuclear fission	Nuclear fusion
Definition	Fission is defined as the splitting of a nucleus into two daughter nuclei	Fusion is defined as the combining of two lighter nuclei into a heavier one
Generation of energy	The amount of energy produced is huge	The amount of energy produced is relatively huge
Fuel	Uranium is the primary fuel that is used in the power plants	Hydrogen isotopes are the primary fuel that is used in the power plants

Advantages of Nuclear reactions

- High Energy Density: Nuclear reactions release a large amount of energy per reaction, making them a highly efficient source of energy.
- Reliable Energy Source: Nuclear power plants can operate continuously, providing a reliable source of electricity.
- Zero Greenhouse Gas Emissions: Nuclear reactions do not produce greenhouse gas emissions, making them a cleaner source of energy.
- Air Pollution Reduction: Nuclear reactions can reduce air pollution by providing a cleaner alternative to fossil fuels.
- Waste Reduction: Nuclear reactions can reduce waste by providing a more efficient source of energy.

Applications of nuclear reactions

- Nuclear Power: Nuclear reactions are used to generate electricity in nuclear power plants.
- Cancer Treatment: Nuclear reactions are used in cancer treatment, such as in radiation therapy.
- Medical Imaging: Nuclear reactions are used in medical imaging, such as in positron emission tomography (PET) scans.
- Radioisotopes: Nuclear reactions are used to produce radioisotopes, which are used in medical research and treatment.
- Food Irradiation: Nuclear reactions are used to sterilize food, reducing the risk of foodborne illness.

- Nuclear accidents can release radioactive materials into the environment, contaminating soil, water, and air.

<u>Mitigation</u>

+ Implement robust safety measures and emergency preparedness plans.

+ Conduct regular maintenance and inspections of nuclear facilities.

- Radioactive waste remains hazardous for thousands of years and requires specialized storage and disposal.

<u>Mitigation</u>

+ Develop and implement safe and secure storage and disposal methods.

+ Invest in research and development of new technologies for radioactive waste management.

- Nuclear reactions can contaminate the environment with radioactive materials, affecting human health and ecosystems.

<u>Mitigation</u>

+ Implement robust environmental monitoring and surveillance programs.

+ Develop and implement effective remediation strategies for contaminated sites.

- Exposure to radioactive materials from nuclear reactions can increase the risk of cancer, genetic mutations, and other health problems.

<u>Mitigation</u>

+ Use of shielding, protective clothing, and radiation detectors to minimize exposure to radiation.

+ Develop and implement effective emergency response plans in case of radiation exposure.

- Nuclear reactions can pose security risks, as radioactive materials can be used to create nuclear weapons or "dirty bombs."

Mitigation

+ Implement robust security measures to prevent the theft or diversion of radioactive materials.

+ Enhance international cooperation and sharing of best practices on nuclear security.

- Nuclear reactions can have significant economic costs, including the cost of building and maintaining nuclear power plants, disposing of radioactive waste, and addressing nuclear accidents.

Mitigation

+ Develop and implement cost-effective technologies for nuclear power generation and radioactive waste management.

+ Enhance international cooperation and sharing of best practices on nuclear economics.

+ Develop and implement effective policies and regulations to manage nuclear risks and costs.

Questions

1. What Is nuclear fission?

Nuclear Fission is a type of nuclear reaction in which the splitting of a nucleus into two daughter nuclei takes place.

2. What are the types of nuclear reactions?

The following are the types of nuclear reactions:

1. Nuclear Fission
2. Nuclear Fusion
3. Nuclear Decay
4. Transmutation

3. What is nuclear energy?

Nuclear energy is the energy released during nuclear reactions like nuclear fission or nuclear fusion.

4. What is a nuclear fusion reaction?

Nuclear fusion is a type of nuclear reaction in which two lighter nuclei combine to form a heavier one.

5. Which type of reaction do Nuclear reactors use to generate electricity?

Nuclear reactors use nuclear fission reactions to generate electricity.

6. Write the reaction of the splitting of Plutonium-239.

Plutonium Fission Reaction

$$^{239}_{94}\mathrm{Pu} + {}^{1}_{0}n \rightarrow {}^{134}_{54}Xe + {}^{103}_{40}Zr + 3\,{}^{1}_{0}n$$

7. Which primary fuel is used in the power plants in nuclear fusion and fission reactions?

Nuclear fusion reactions use Hydrogen isotopes.

Nuclear fission reactions use Uranium as a primary fuel

8. What happens when uranium-235 atom is bombarded with a neutron?

When an atom of uranium-235 bombards with a neutron, it splits into two lighter nuclei krypton and barium releasing huge amounts of energy according to the following equation

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n} + \mathrm{Energy}$$

9. Write the equation of splitting of Uranium-233 in nuclear fission reaction.

Radioactivity

Radioactivity is the spontaneous emission of radiation from an unstable atomic nucleus. This radiation can take the form of alpha particles, beta particles, or gamma rays.

Radioactive Decay

Radioactive decay is the process by which unstable atomic nuclei lose energy and stability by emitting radiation in the form of particles or electromagnetic waves. This process involves the spontaneous transformation of one element into another, resulting in a more stable nucleus.

Key Characteristics of Radioactive Decay

- Spontaneous: Radioactive decay occurs spontaneously, without any external influence.
- Random: The decay process is random, and it is impossible to predict when a particular nucleus will decay.
- Irreversible: Radioactive decay is an irreversible process, meaning that the nucleus cannot revert to its original state.
- Energy Release: Radioactive decay involves the release of energy in the form of radiation.

Radiations

Radiation refers to the emission or transmission of energy in the form of electromagnetic waves or high-energy particles. Radiation can be classified into two main categories: ionizing and non-ionizing radiation.

Ionizing Radiation

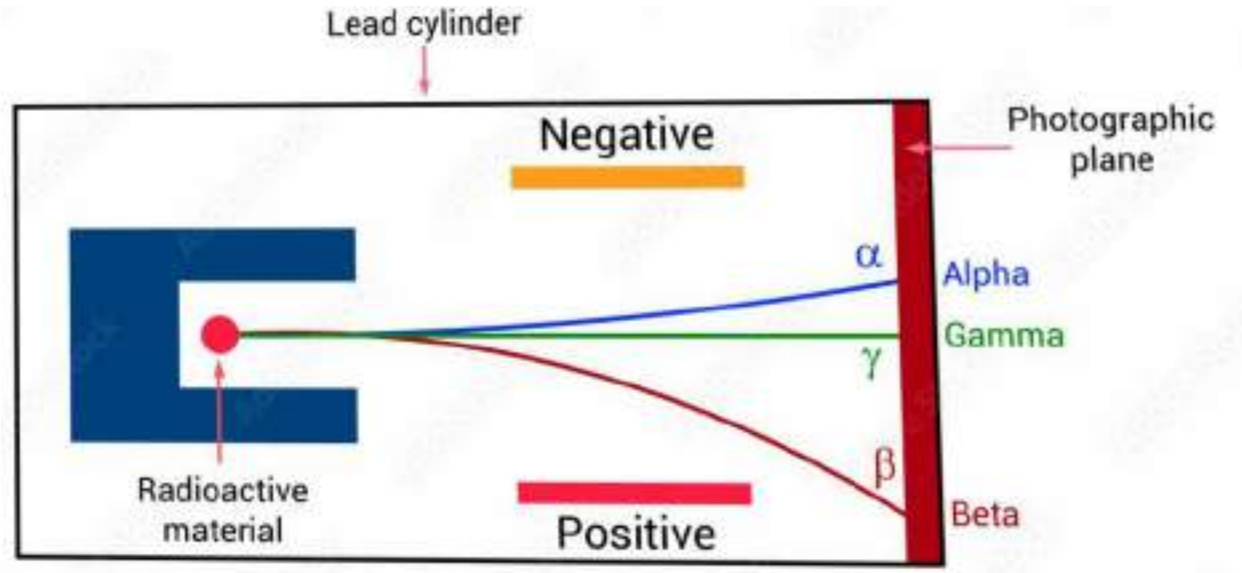
- Alpha Radiation (α) : A type of ionizing radiation consisting of high-energy helium nuclei.
- Beta Radiation (β): A type of ionizing radiation consisting of high-energy electrons.
- Gamma Radiation (γ): A type of ionizing radiation consisting of high-energy electromagnetic waves.

Non-Ionizing Radiation

- Ultraviolet (UV) Radiation: A type of non-ionizing radiation with wavelengths shorter than visible light.
- Infrared (IR) Radiation: A type of non-ionizing radiation with wavelengths longer than visible light.
- Microwaves: A type of non-ionizing radiation with wavelengths longer than IR radiation.
- Radio Waves: A type of non-ionizing radiation with wavelengths longer than microwaves.

Type of radiation	**Penetration power**	**Ionization power**	**Effect on electric and magnetic field**
Alpha (α)	Low	High	Deflected by electric and magnetic fields
Beta (β)	Medium	Medium	Deflected by electric and magnetic fields
Gamma (γ)	High	Low	No effect on electric and magnetic fields
Neutron (n)	High	High	No effect on electric and magnetic fields

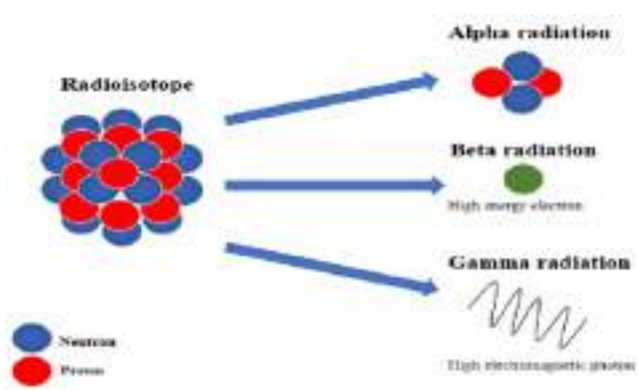
illustration of the effect of electric and magnetic plates on radiations.



Types of Radioactive Decay

- Alpha Decay: Emission of alpha particles (helium nuclei) from the Nucleus
- Beta Decay: Emission of beta particles (electrons or positrons) from the Nucleus.
- Gamma Decay: Emission of gamma radiation (high-energy electromagnetic radiation) from the Nucleus.
- Other Types: Other types of radioactive decay include electron capture, proton emission, and neutron emission.

Radioactive decay



Alpha Decay

This is where an **alpha particle (α)** is emitted from the nucleus.
An alpha Particle is a high-energy helium nucleus (2 protons and 2 neutrons) emitted from the nucleus of an atom during radioactive decay.
Alpha particles consist of two protons and two neutrons. It's represented as a helium atom since it has a mass of 4 atomic mass units.
Alpha particles are slow and heavy (in comparison to other radiations), which means they are **easily stopped by a few centimeters of air**, a piece of paper, or the skin. Because of their size and their +2 charge, they are **highly ionizing**. Alpha decay results in the **mass number decreasing by 4**, and the **atomic number decreasing by 2**.
Element changes to a different element, two positions to the left in the periodic table as seen in the example below:

Decay of Uranium-235

$$^{235}_{92}U \longrightarrow {}^{4}_{2}\alpha + {}^{231}_{90}Th$$

Example:

Parent element: Uranium (U) - Atomic number: 92, Mass number: 238

Uranium-238 decays into Thorium-234 by emitting an alpha particle as shown below.

Alpha (α) Radiation

$$^{238}_{92}U \longrightarrow\ ^{234}_{90}Th +\ ^{4}_{2}He$$

Mass number: 238 = 234 + 4

Atomic number: 92 = 90 + 2

Solving Nuclear Equations Involving Alpha Decay

General Equation

X → Y + α

Where X is the parent nucleus, Y is the daughter nucleus, and α is the alpha particle.

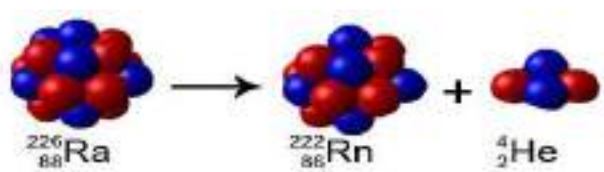
The proton number is normally considered when determining the new element formed since it always remains the same for all isotopes.

Balancing the Equation

To balance the equation, the mass numbers (A) and atomic numbers (Z) of the parent and daughter nuclei must be equal.

Example

1) Radium decays by emitting an alpha particle producing Radon. The equation can represented as below.



2) Complete the following nuclear equation

238U → ? + α

Solution:

238U → 234Th + α

Mass numbers: 238 = 234 + 4

Atomic numbers: 92 = 90 + 2

Food for thoughts.

Complete the following equations and identify the elements which every element given decays to. By emitting an alpha particle.

1. Polonium-210

$^{210}Po \rightarrow$

2. Thorium-232

$^{232}Th \rightarrow$

3. Americium-241

$^{241}Am \rightarrow$

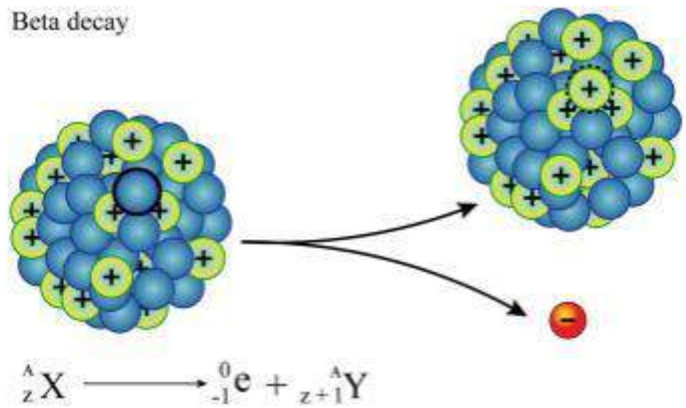
Beta Decay

This is where a **beta particle (β)** is emitted from the nucleus, after a **neutron changes into a proton** in the nucleus of an unstable atom.
Beta particles are high-energy electrons or positrons that are emitted from the nucleus of an atom during certain types of radioactive decay.

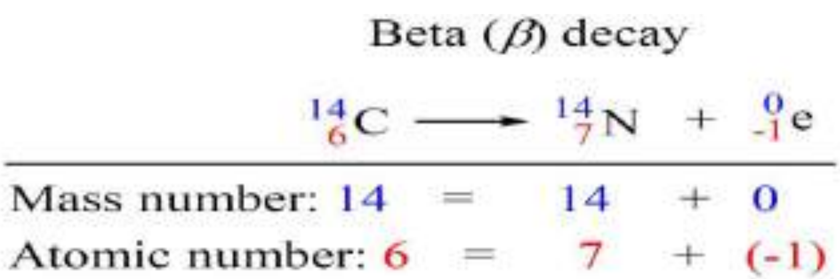
It is effectively an electron, with negligible mass and a -1 charge. Beta particles are much faster than alpha particles and more penetrating. They can pass through skin, air, and paper and are only **stopped by thin aluminum**. They have a **much lower ionizing power** than alpha particles. Beta decay **does not change the mass number** of the radioactive atom but does increase the **atomic number by 1**.

Beta decay is a mechanism through which unstable nuclei can achieve a more stable configuration.

Illustration of beta decay



Example, decay of carbon-14



Solving Nuclear Equations Involving Beta Decay

Example

Complete the following nuclear equation:

14C → ? + β-

Solution:

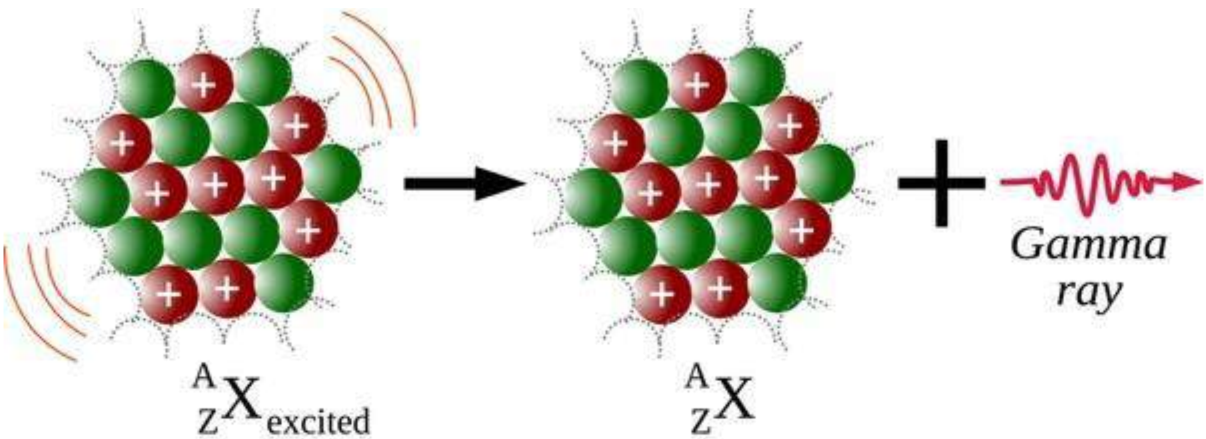
14C → 14N + β- + $\bar{\nu}$

Mass numbers: 14 = 14 + 0

Atomic numbers: 6 = 7 – 1

Gamma decay

This is the release of excess energy in the form of gamma radiation, usually when a nucleus transitions from a higher-energy state to a lower-energy state, in the form of electromagnetic **gamma waves (γ)**.
Gamma radiation is high-energy electromagnetic radiation emitted by the nucleus. Gamma waves travel at the speed of light, have no mass and no charge and are **weakly ionizing**. They have the highest penetration power, and are **only stopped by thick lead or concrete** (although even then some will pass through). Because they have zero mass and zero charge they do not change either the atomic mass or the atomic number of the radioactive atom.

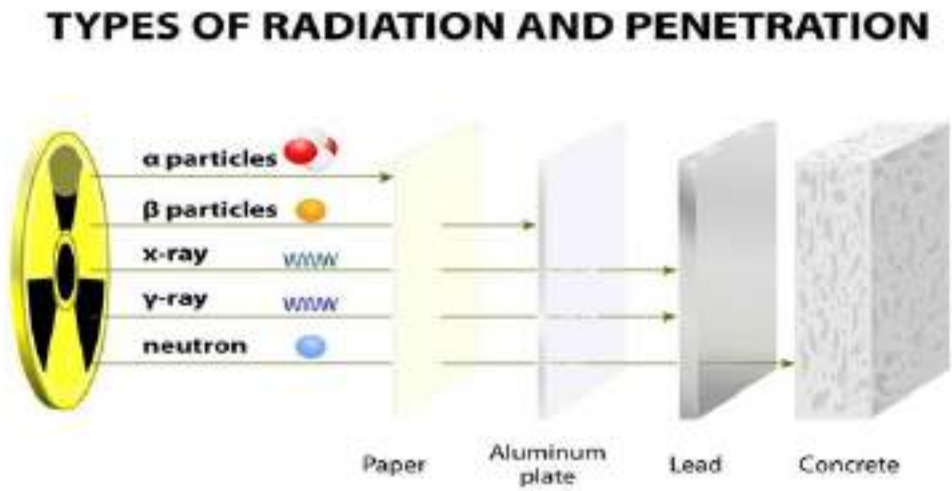


Gamma Decay of Helium-3

- Helium-3 has 2 protons and 1 neutron with a total atomic mass of 3.
- Helium-3 releases a gamma ray, releasing energy, as it undergoes gamma decay. The resulting element is remains Helium-3.

$$^{3}_{2}He \longrightarrow ^{3}_{2}He + ^{0}_{0}\gamma$$

Differences in the penetrating power of the three radiations discussed above.



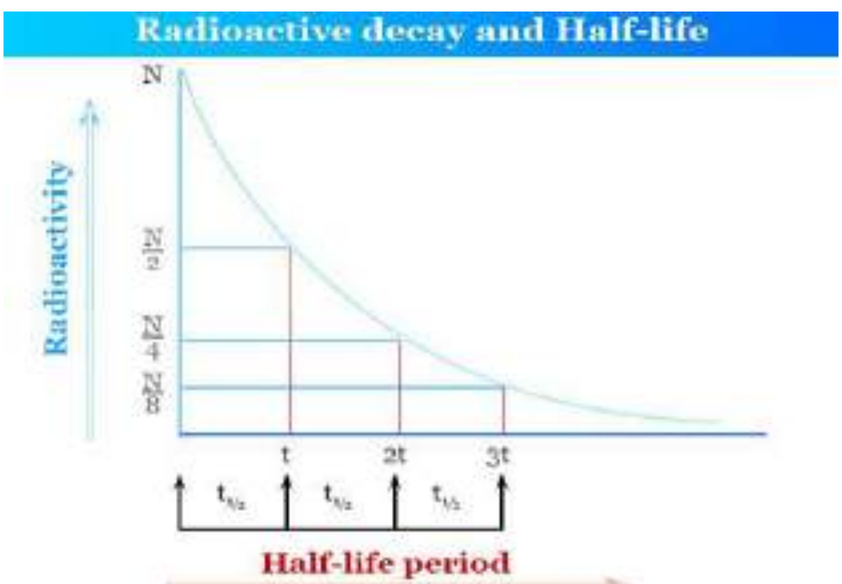
Differences between the 3 main types of radioactive decay

Decay	Structure	Charge	Stopped by	Ionizing power	Uses	Key points
Alpha	2 protons, 2 neutrons	+2	Skin, few cm of air, paper	High	Smoke alarms	Most dangerous radiation inside the body
Beta	1 electron	-1	Thin aluminum	Low	Manufacturing e g to check thickness of paper	Released when a neutron turns into a proton in the Nucleus of an atom.
Gamma	Electromagnetive wave	0	Thick lead, Very thick concrete	Very low	Medical imaging tracers, sterilization of medical equipment	Not a particle, generally released alongside beta and

						alpha particles.

Half-Life

Half-life is the time taken for half of the atoms in a sample of a radioactive substance to decayinto a more stable form.
Some isotopes are stable and do not decay. However, unstable radioactive isotopes undergo nuclear decay and emit radiation. Over time, the amount of the radioactive isotope decreases.
Different radioactive elements decay at different rates.E.g Carbon-14 has a half-life of about 5,730 years. This means that after 5,730 years, half of a sample of Carbon-14 will have decayed into Nitrogen-14. Whereas Sodium-25 has a much shorter half-life of only 1 minute.
After one half-life, half of the original amount remains. After two half-lives, one-quarter remains, and so on.



Activity

Exploring Half-Life

Aim: To understand the concept of half-life through a hands-on activity.

Materials

- A bag of tiles (Scrabble game tiles)
- A table or chart to record data

Procedure

1. Initial Setup: Start with a specific number of tiles (e.g., 100). This represents the initial amount of a radioactive substance.

2. Half-Life Simulation

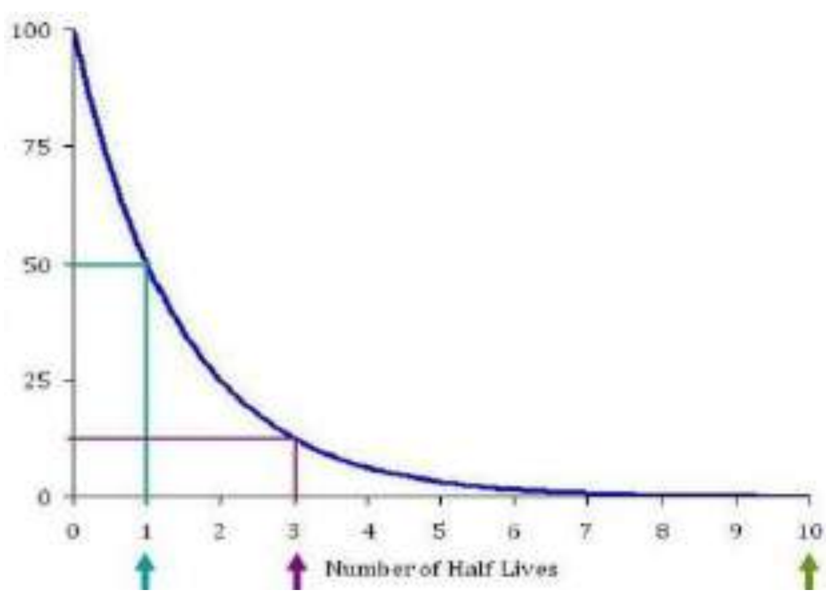
Round 1: Randomly remove half of the tiles. Record the number of tiles remaining. This represents one half-life.

Round 2: Randomly remove half of the remaining tiles. Record the number of tiles. This represents two half-lives.

Continue: Repeat until you have a very small number of tiles or until it's no longer practical to remove half.

Data Recording

- Record the number of tiles remaining after each round.
- Plot a graph of the number of tiles remaining versus the number of half-lives.



Discussion Questions

1. What is the half-life of the tiles in this simulation?

The half-life is the number of rounds it took to reduce the initial number of tiles by half. For example, if it took 2 rounds to halve the initial number, the half-life is 2 rounds.

2. How does the number of tiles decrease over time?

The number of tiles decreases exponentially over time. This means that in each half-life, the number of tiles is reduced by half.

3. What happens to the rate of decay as time goes on?

The rate of decay decreases over time. Initially, a large number of tiles decay in each round. However, as the number of tiles decreases, the rate of decay also decreases.

4. How does this simulation relate to the concept of radioactive decay and half-life?

This simulation models the random nature of radioactive decay. Each tile represents a radioactive atom. As the candies are randomly removed, it simulates the random decay of atoms. The half-life of the tiles is analogous to the half-life of a radioactive substance. Both involve a constant rate of decay, where a fixed proportion of the substance decays in a given time period.

Extension Activity

1. Use different initial number of tiles to see if the half-life changes.
2. Simulate the decay of different radioactive isotopes with varying half-lives.
3. Research real-world examples of radioactive decay and their half-lives.

Example

If a radioactive substance has a half-life of 10 years and we start with 100 grams, after 10 years, 50 grams will remain. After another 10 years (20 years total), 25 grams will remain.

Note

- Constant for a Given Isotope: The half-life of a specific radioactive isotope is constant, regardless of the initial amount of the substance.
- Exponential Decay: Radioactive decay follows an exponential decay pattern. This means that the amount of radioactive material decreases by half in each successive half-life period.
- Random Process: Radioactive decay is a random process at the atomic level. We cannot predict exactly when a specific atom will decay, however, for large numbers of atoms, the decay rate is predictable.

Half-life is a crucial concept in understanding radioactive decay. It helps us to predict the rate of decay, the amount of radioactive material remaining, and the potential applications of radioactive isotopes.

Determining half-life from the graph

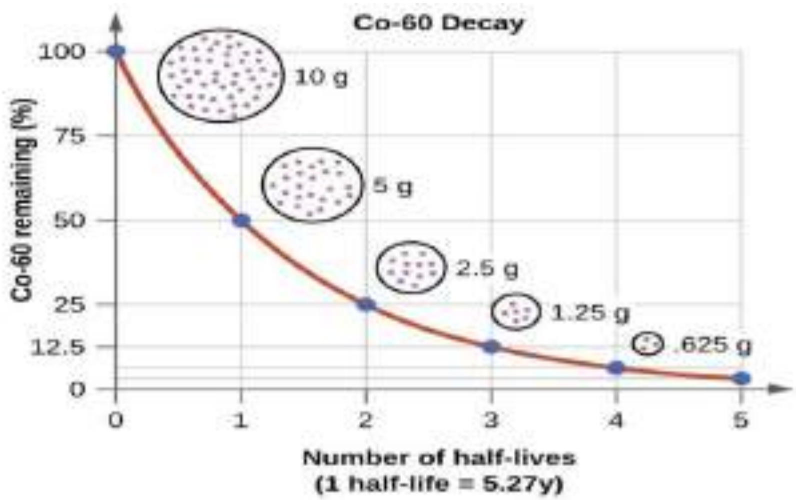
A graph of radioactive decay typically shows the number of radioactive atoms (or the activity) on the y-axis and time on the x-axis. The graph is characterized by an exponential decay curve.

Steps

1. Identify the Initial Activity. This is the starting point on the y-axis.
2. Divide the initial activity by 2 to find the half-activity.
3. Draw a horizontal line from the half-activity point on the y-axis to the curve.
4. From the intersection point on the curve, draw a vertical line down to the x-axis.
Read the time value at this point on the x-axis. This is the half-life.
5. Repeat the process for different points on the curve to confirm the half-life.

Example

Let's say we have a graph showing the decay of a radioactive isotope. The initial activity is 100 counts per minute (cpm).



1. Half the initial activity: 100 cpm / 2 = 50 cpm.
2. Find the corresponding time: Locate the point on the graph where the activity is 50 cpm.
3. Read the time: The time corresponding to 50 cpm is 1 half-life (=5.27years)

Therefore, the half-life of this isotope is 5.27years

Calculating half-life

Example

1. A radioactive substance decays to one-sixteenth of its original mass in 24 days. What is its half-life?

Response

To reach one-sixteenth, the substance has gone through four half-lives (1/2 * 1/2 * 1/2 * 1/2 = 1/16)

So, 4 half-lives = 24 days

Therefore, 1 half-life = 24 days / 4 = 6 days

The half-life of the isotope is 6 days.

2. A radioactive isotope has a half-life of 5 years. If you start with 200 grams of this isotope, how much will remain after 15 years?

Response

Determine the number of half-lives: 15 years / 5 years/half-life = 3 half-lives

Calculate the remaining mass

After 1 half-life: 200g / 2 = 100g

After 2 half-lives: 100g / 2 = 50g

After 3 half-lives: 50g / 2 = 25g

So, 25 grams of the isotope will remain after 15 years.

3. A radioactive substance has a half-life of 20 days. If 16 grams of the substance is present initially, how much will remain after 80 days?

Response

Determine the number of half-lives: 80 days / 20 days/half-life = 4 half-lives

Calculate the remaining mass

After 1 half-life: 16g / 2 = 8g

After 2 half-lives: 8g / 2 = 4g

After 3 half-lives: 4g / 2 = 2g

After 4 half-lives: 2g / 2 = 1g

So, 1 gram of the substance will remain after 80 days.

4. A radioactive isotope has a half-life of 14 days. If its initial activity is 2000 counts per minute (cpm), what will its activity be after 56 days?

Response

Determine the number of half-lives: 56 days / 14 days/half-life = 4 half-lives

Calculate the remaining activity

After 1 half-life: 2000 cpm / 2 = 1000 cpm

After 2 half-lives: 1000 cpm / 2 = 500 cpm

After 3 half-lives: 500 cpm / 2 = 250 cpm

After 4 half-lives: 250 cpm / 2 = 125 cpm

So, the activity after 56 days will be 125 cpm.

Food for thoughts

1. A radioactive isotope has a half-life of 10 years. If you start with 160 grams of this isotope, how much will remain after 40 years?
2. A radioactive substance has a half-life of 25 days. If 32 grams of the substance is present initially, how much will remain after 100 days?

Applications of Radioactivity

Radioactivity, while potentially dangerous, has numerous beneficial applications across various fields. Here are some key applications and their associated risks and mitigation strategies

- Medical Applications

1. Cancer Treatment: Radiotherapy uses ionizing radiation to kill cancer cells.
Risk: Exposure to radiation can damage healthy cells.
Mitigation: Precise targeting techniques, such as radiation therapy, minimize damage to healthy tissue.
2. Medical Imaging: Techniques like X-rays, CT scans, and PET scans use radiation to produce images of the body's internal structures.
Risk: Exposure to radiation, especially frequent or high-dose exposure.
Mitigation: Limiting exposure times, using shielding, and optimizing imaging techniques.
3. Sterilization of Medical Equipment: Radiation is used to sterilize medical equipment, ensuring it is free from harmful microorganisms.
Risk: Potential for accidental exposure to radiation.
Mitigation: Strict protocols for handling and storing radioactive materials.

- Industrial Applications

1. Food Preservation: Radiation is used to kill bacteria and other microorganisms, extending the shelf life of food products.

Risk: Potential for food contamination if not properly handled.

Mitigation: Strict regulations and quality control measures to ensure food safety.

2. Material Analysis: Radioactive isotopes are used in techniques like radiocarbon dating to determine the age of objects.

Risk: Exposure to radiation during sample preparation and analysis.

Mitigation: Proper handling and disposal of radioactive materials, as well as shielding to protect workers.

3. Industrial Gauging: Radioactive isotopes are used to measure thickness, density, and level of materials in various industries.

Risk: Exposure to radiation from radioactive sources.

Mitigation: Regular maintenance and shielding of radioactive sources, as well as strict safety protocols.

- Energy Production

1. Nuclear Power: Nuclear power plants use nuclear fission to generate electricity.

Risk: Potential for accidents, such as nuclear meltdowns, and the generation of radioactive waste.

Mitigation: Robust safety measures, including multiple layers of containment, emergency response plans, and careful waste management.

General Mitigation Strategies for Radioactivity

Shielding: Using materials like lead or concrete to absorb radiation.

Distance: Increasing the distance from the radiation source reduces exposure.

Time: Limiting exposure time minimizes the risk of harm.

Proper Handling and Disposal: Following strict guidelines for handling and disposing of radioactive materials.

Regular Monitoring: Monitoring radiation levels to ensure safety.

Nuclear Power

What is Nuclear Power?

Nuclear power is a type of energy that comes from splitting atoms, a process called nuclear fission. This process releases a huge amount of energy, which can be harnessed to generate electricity.

How does it work?

Uranium atoms are split, releasing energy in the form of heat. This heat energy is used to boil water, producing steam. The steam turns a turbine, which spins a generator to produce electricity.

Advantages of Nuclear Power

- Low Greenhouse Gas Emissions: Nuclear power plants produce very little greenhouse gas emissions, making them a cleaner energy source compared to fossil fuels.
- Reliable Energy Source: Nuclear power plants can operate continuously, providing a reliable source of electricity.
- High Energy Density: Nuclear fuel is highly concentrated, meaning a small amount can generate a large amount of energy.

Impacts of Nuclear Power

Nuclear power, while a powerful energy source, comes with both benefits and drawbacks. Here are some of the key impacts and mitigation strategies:

1. **Radioactive Waste**

Impact: Nuclear power plants generate radioactive waste that can remain hazardous for thousands of years if not properly handled.
Mitigation: Safe storage and disposal of nuclear waste in secure facilities. Advanced technologies like deep geological repositories are being explored to isolate waste from the environment.

2. **Thermal Pollution**

Impact: Discharging heated water into water bodies can harm aquatic ecosystems.
Mitigation: Using cooling towers or other cooling technologies to reduce the temperature of the water before it is released.

3. **Accident Risk**

Impact: Nuclear accidents, such as those at Chernobyl and Fukushima, can have devastating consequences, including loss of life, environmental damage, and economic disruption.
Mitigation: Rigorous safety standards, regular inspections, and emergency response plans to minimize the risk of accidents.

4. **High Initial Costs**

Impact: Building nuclear power plants requires significant upfront investment.
Mitigation: Government subsidies, international cooperation, and innovative financing models can help reduce costs.

5. **Nuclear Proliferation**

Impact: The technology used in nuclear power plants can be diverted for military purposes.
Mitigation: International safeguards and non-proliferation treaties to ensure that nuclear technology is used for peaceful purposes.

End of chapter summary

Key Concepts

- Radioactivity: The process by which unstable atomic nuclei lose energy and stability.
- Nuclear Reactions: Reactions that involve changes to the nucleus of an atom.
- Nuclear Fission: A type of nuclear reaction in which an atomic nucleus splits into two or more smaller nuclei.
- Nuclear Fusion: A type of nuclear reaction in which two or more atomic nuclei combine to form a single, heavier nucleus.
- Alpha, Beta, and Gamma Radiation: Types of radiation emitted by radioactive substances.
- Radiation: Energy that travels in the form of electromagnetic waves or high-speed particles.
- Ionizing Power: The ability of radiation to remove tightly bound electrons from atoms, resulting in the formation of ions.
- Half-Life: The time it takes for half of the atoms in a sample of a radioactive substance to decay.
- Alpha Radiation: High ionizing power, but can be stopped by a sheet of paper. Deflected by electric and magnetic fields due to its positive charge.
- Beta Radiation: Medium ionizing power, can be stopped by a thin layer of metal. Deflected by electric and magnetic fields due to its negative charge.
- Gamma Radiation: Low ionizing power, but can penetrate thick layers of material. Not deflected by electric or magnetic fields due to its zero charge.
- Radioactive Decay: The process by which unstable atomic nuclei lose energy and stability.
- Nuclear Chain Reactions: Reactions in which the products of one reaction cause subsequent reactions.
- Nuclear Power Generation: The process of generating electricity using nuclear energy from nuclear reactions. Nuclear energy is used to generate electricity in power plants.

- Medicine: Radioisotopes are used in medicine for diagnosis and treatment, in the industry for a variety of applications, including food irradiation and sterilization of medical instruments.
- Scientific Research: Nuclear processes are used in scientific research, including the study of the structure of atoms and the properties of materials.
- Radiation Protection: Measures taken to protect people and the environment from the harmful effects of radiation.
- Nuclear Waste Management: The safe disposal of radioactive waste.
- Nuclear Accidents: Measures taken to prevent and respond to nuclear accidents.

End of chapter Scenarios

Item 1

Due to increasing demand for power in Uganda, there are discussions about building a nuclear power plant. the government is considering building a nuclear power plant. This would provide a reliable and low-carbon source of energy, helping to meet the growing energy needs of the country. The government is considering building a nuclear power plant, this would provide a reliable and low-carbon source of energy, helping to meet the growing energy needs of the country. However, there is little public knowledge about the use of nuclear energy and concerns about its potential dangers.

Task:

As a student who has studied nuclear processes, you are invited to the Ministry of Energy and Mineral Development to help inform the public about:

a) Category of the processes involved. **Hint** This involves explaining the basic principles of nuclear fission and fusion.

b) How the processes will help to solve the problem. Hint This involves discussing how nuclear power can provide a reliable and low-carbon source of electricity.
c) Impact of the processes on the environment. Hint This involves addressing concerns about nuclear waste, radiation, and potential accidents.
d) Evaluation of the processes.

Item 2

Residents of a village in Jinja District are concerned about the disposal of waste from a factory into a nearby pond. The image shows two pipes discharging wastewater into the pond which is used by a community for their animals. This waste always causes water temperature to increase each time it's disposed. A scientist was tasked to investigate the nature of the water and he gave the following results.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{138}_{56}Ba + ^{95}_{36}Kr + 3^{1}_{0}n + \text{energy}$$

You have been contacted to provide relevant information about the results given by the scientist.

Task:

As a learner of chemistry;

a) Explain the category of the product.
b) Give guidance on the use of the product.
c) Advise on the dangers associates with the long term use of the product.

Item 3

During World War II, the cities of Hiroshima and Nagasaki were devastated by atomic bombs which released immense destructive energy. However, this energy can also be harnessed for beneficial purposes, such as treating cancer.

Task;

As a chemist;

a) Identify the type of nuclear reaction used in the atomic bomb.
b) Describe other applications of nuclear energy.
c) Evaluate the risks associated with nuclear energy.

Item 4

A nuclear power plant has been decommissioned, leaving behind a significant amount of radioactive waste. This waste must be safely stored and managed for thousands of years. 200g of the isotope in the waste was analyzed and it was found to be having half-life of 5years.

Task;

As a learner of chemistry;

a) Explain the category of the nuclear processes that were being carried out in the power plant.
b) Determine how much of the radioactive waste will remain after 15years.
c) Advise on the uses of the radioactive waste
d) Discuss the long-term environmental impacts of radioactive waste disposal.

All the best from Tr.solomon

This book is still under review

In case of any errors, contact the author

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Thanks