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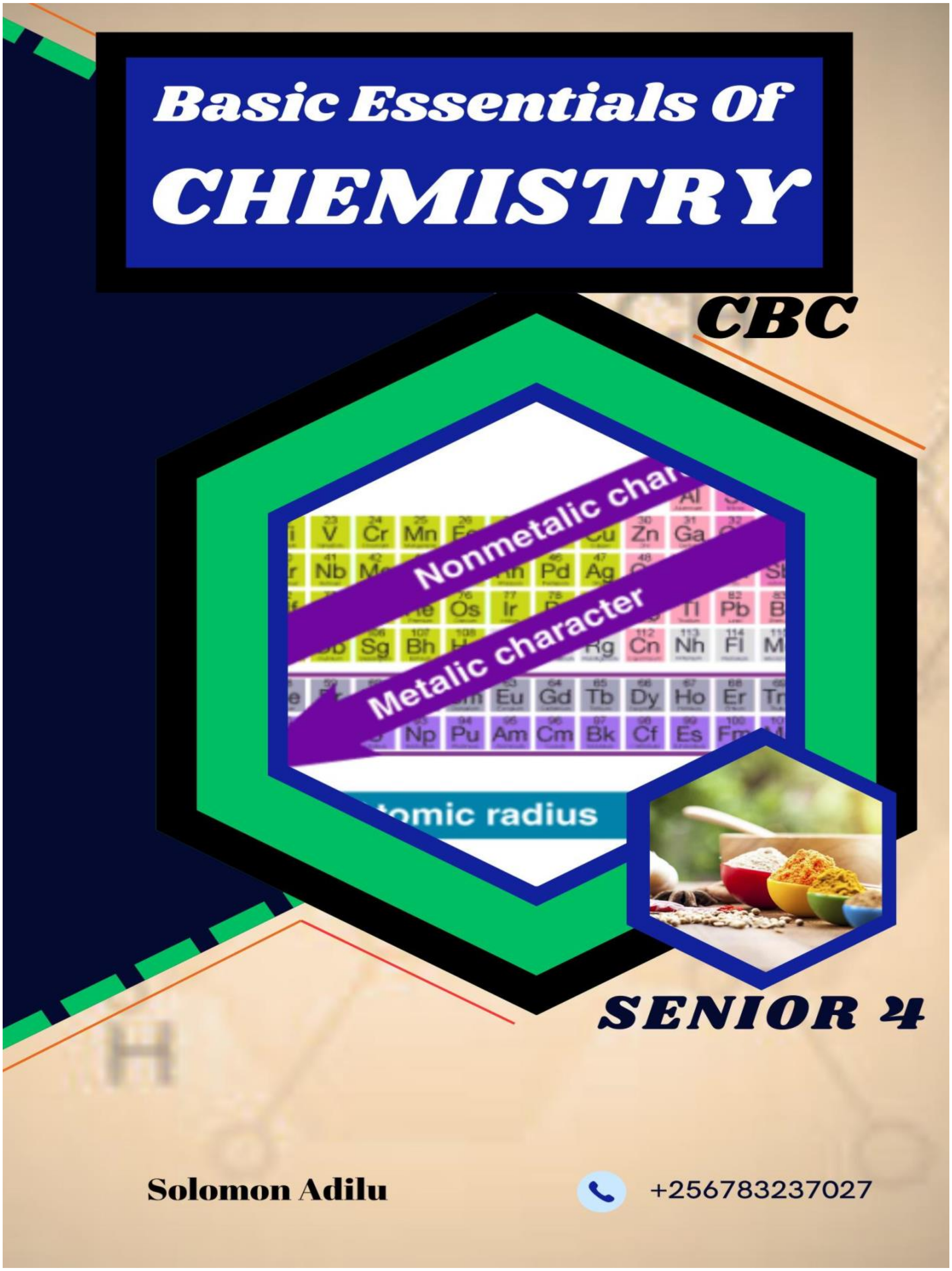

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How to Use This Book

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.

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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.

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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

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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

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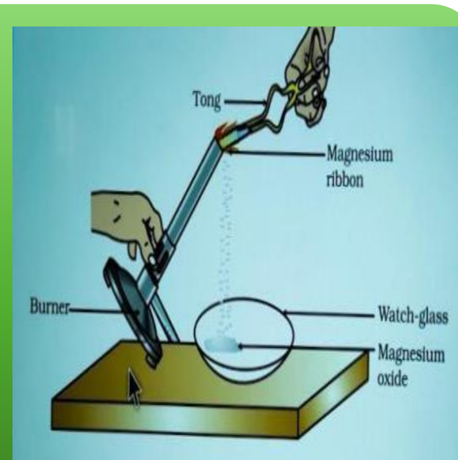
- Test tube
- Water
- Litmus paper

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**

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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.

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

<u>**Food for thoughts**</u>

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.

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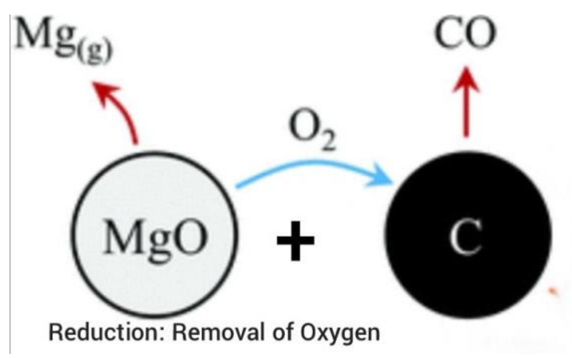
1.2. Reduction reactions

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

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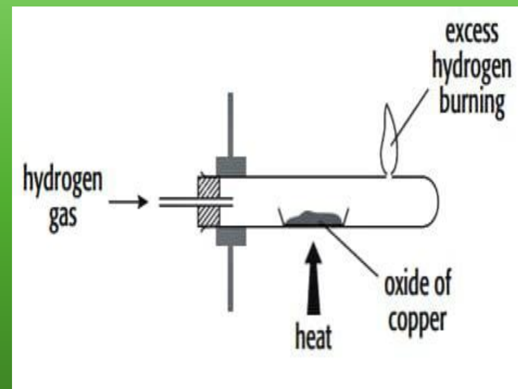
Procedure:

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

$$\overbrace{CuO\ (s) + H_2\ (g) \longrightarrow Cu}^{\text{Reduction}}\ (s) + H_2O\ (g)$$

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

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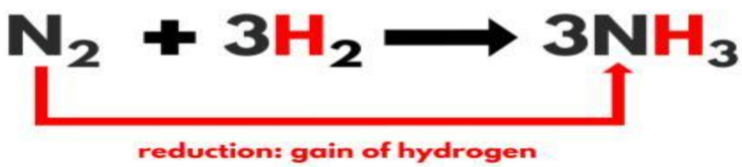
Reduction in the Haber Process: The Formation of Ammonia

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).

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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)**

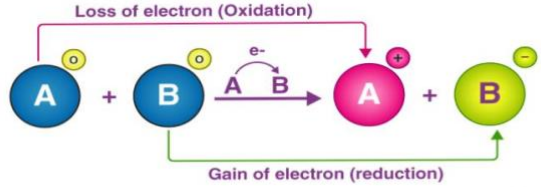
Oxidizing agents are substances that cause oxidation by the gain of one or more than one electron in a chemical reaction.

- 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.



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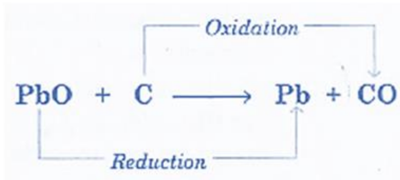
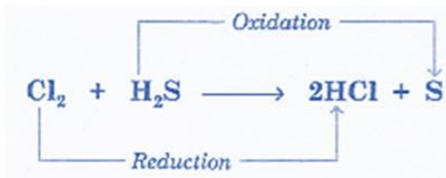
For Example:

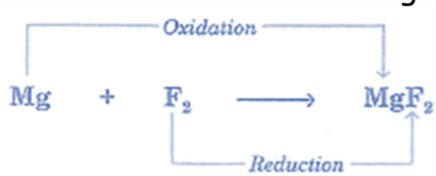
- **Reaction of PbO and carbon**: During the process, carbon (C) gains oxygen while lead oxide (PbO) loses oxygen. PbO undergoes reduction while C undergoes oxidation.



- **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.

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

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

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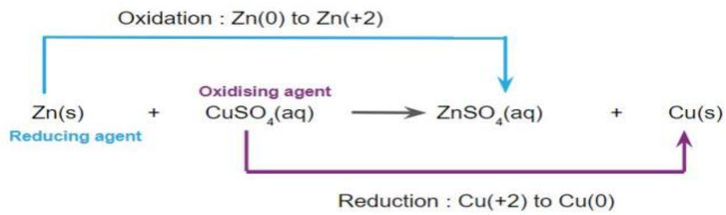
Copper ions (Cu^{2+}) from the copper sulphate solution gain electrons (are reduced) to become copper metal (Cu)



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.

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- 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.

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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:

$$3\,(Ag^{+} + e^{-} \rightarrow Ag)\ldots\ldots\ldots\ldots\ldots1)$$

$$Al \rightarrow Al^{+} + 3e^{-}\ \ldots\ldots\ldots\ldots\ldots2)$$

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.

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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

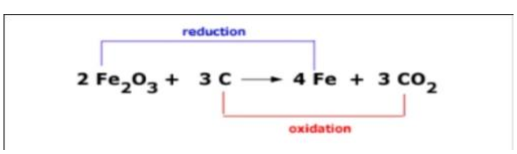
Environmental Remediation

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.

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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:

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- **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.

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