MATERIALS

Extraction of Metals from Ores and Alloying

How Does Reactivity Affect Extraction?

The **reactivity of a metal** determines the method used for its extraction from ores.

- **Highly reactive** metals such as potassium, sodium, calcium, magnesium, and aluminium (placed above carbon in the reactivity series) cannot be extracted by reduction with carbon. These metals are extracted by electrolysis of their molten compounds.
- **Metals less reactive** than carbon, such as iron, zinc, lead, and tin, are extracted from their ores by reduction using carbon, coke, or carbon monoxide.
- **Very unreactive metals** such as gold, silver, platinum, and copper may occur in the native (free) state and often do not require chemical extraction.
- Electrolysis can also be used for purification, for example, in the refining of copper.

Steps Involved in the Extraction of Metals

1. Extraction

(a) Crushing and Grinding

The ore obtained from the earth is first **crushed into small fragments** and then **ground into a fine powder**. This increases the surface area for further processing.

(b) Concentration of Ore

The powdered ore is concentrated to remove unwanted impurities (gangue). Common methods include:

- Froth flotation process
- Magnetic separation
- Gravitational separation

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2. Roasting

Roasting is the process in which the **concentrated ore is heated in the presence of air below its melting point** to convert it into its **oxide form**.

Examples:

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- Zinc blende (ZnS)
- Cinnabar (HgS)
- Copper pyrites ($CuFeS_2$)

1. Roasting of Zinc Blende (ZnS):

$$2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$$

2. Roasting of Cinnabar (HgS):

$$HgS(s) + O_2(g) \rightarrow Hg(l) + SO_2(g)$$

3. Roasting of Copper Pyrites ($CuFeS_2$):

$$2CuFeS_2(s) + 4O_2(g) \rightarrow Cu_2S(s) + 2FeO(s) + 3SO_2(g)$$

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3. Smelting

Smelting is the process of **reducing metal oxides to free metals** by heating them with a **reducing agent**.

Common reducing agents:

- Carbon
- Carbon monoxide
- Hydrogen

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Examples:

1. Reduction of Iron (III) oxide by Carbon Monoxide:

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$$

2. Reduction of Tungsten (VI) oxide by Hydrogen:

$$WO_3(s) + 3H_2(g) \rightarrow W(s) + 3H_2O(l)$$

3. Reduction of Zinc Oxide by Carbon:

$$ZnO(s) + C(s) \rightarrow Zn(s) + CO(g)$$

Smelting of Copper Ore (Two-Step Process)

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(a) Formation of Copper Matte

The roasted copper ore is heated with **coke and sand** at about **1100°C**. Two layers are formed:

- **Lower layer:** Copper matte (mixture of Cu_2S and FeS)
- **Upper layer:** Slag (iron silicate)

1. Oxidation of Iron(II) Sulphide

$$2FeS(s) + 3O_2(g) \rightarrow 2FeO(s) + 2SO_2(g)$$

2. Formation of Slag

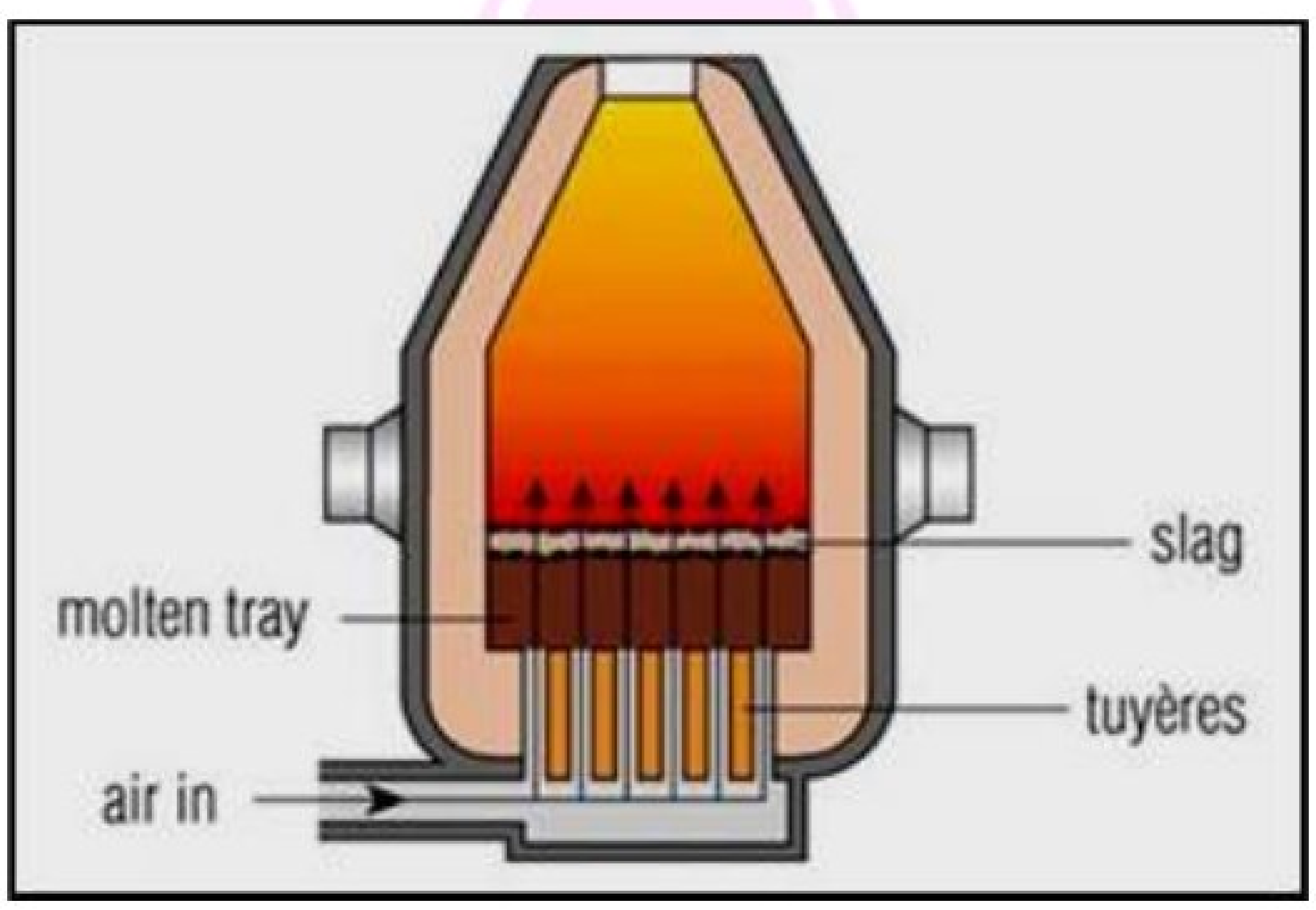
$$FeO(s) + SiO_2(s) \rightarrow FeSiO_3(s)$$

(b) Bessemerisation

Air is blown through molten copper matte in a **Bessemer converter**.

- Iron sulphide is oxidized and removed as slag.
- Cu_2S is partially oxidized to Cu_2O.
- Cu_2O reacts with remaining Cu_2S to form **metallic copper**.

The copper obtained is about **97–99% pure** and is known as **blister copper** due to trapped SO_2 gas bubbles.



1. Oxidation of Cuprous Sulphide

$$2Cu_2S(l) + 3O_2(g) \rightarrow 2Cu_2O(l) + 2SO_2(g)$$

2. Self-Reduction (Auto-reduction) Reaction

$$Cu_2S(l) + 2Cu_2O(l) \rightarrow 6Cu(l) + SO_2(g)$$

4. Refining (Purification) of Metals

The metal obtained after smelting contains impurities and must be refined.

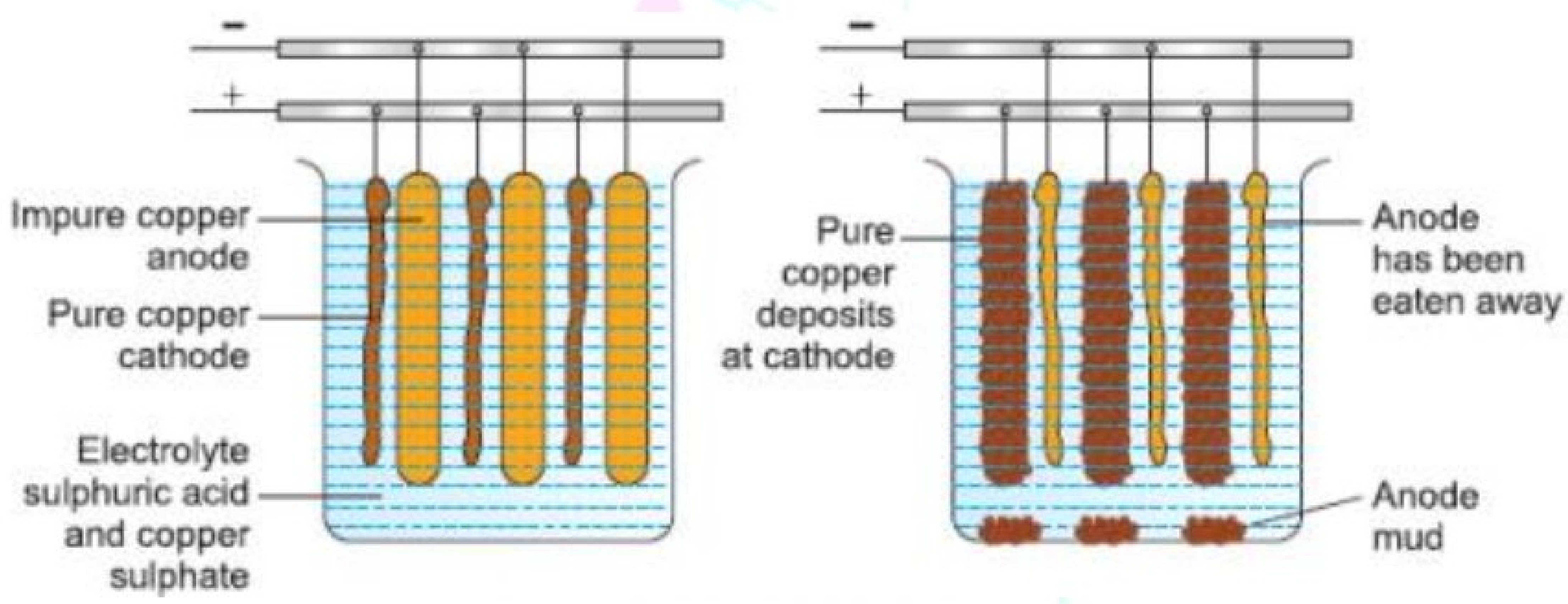
(a) Electrolytic Refining

Used for metals like **copper**.

- **Anode:** Impure copper
- **Cathode:** Pure copper sheet
- **Electrolyte:** Acidified copper sulphate solution

Process:

- Copper dissolves from the anode as Cu^{2+} ions.
- These ions gain electrons at the cathode and deposit as pure copper.
- Impurities such as gold and silver settle at the bottom as **anode mud**.



Reactions:

- At anode:

$$Cu \rightarrow Cu^{2+} + 2e^{-}$$

- At cathode:

$$Cu^{2+} + 2e^{-} \rightarrow Cu$$

(b) Distillation

Metals with **low boiling points** such as **mercury and arsenic** are purified by distillation.

5. Alloying

Alloying is the process of **mixing a metal with one or more other elements** (metals or non-metals) to improve properties such as:

- Strength
- Hardness
- Corrosion resistance
- Ductility

Methods of Alloying

1. **Melting and Mixing:**
   The base metal is melted, and alloying elements are added and mixed thoroughly.
   - *Example:* Steel (iron + carbon)
2. **Powder Metallurgy:**
   Finely powdered metals are mixed, pressed into shape, and heated.
3. **Mechanical Alloying:**
   Powder particles are repeatedly fractured and welded to form advanced alloys.

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6. Shaping of Metals and Alloys

- **Casting:** Pouring molten metal into moulds
- **Forging:** Hammering or pressing hot metal
- **Rolling:** Passing metal through rollers to form sheets
- **Machining:** Cutting and shaping using tools

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7. Heat Treatment

- **Annealing:** Heating followed by slow cooling to reduce internal stress and increase ductility
- **Quenching:** Rapid cooling in water or oil to increase hardness
- **Tempering:** Reheating quenched metal to balance hardness and toughness

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Examples of Alloys

Alloy	Composition
Steel	Iron + Carbon
Bronze	Copper + Tin
Brass	Copper + Zinc
Stainless Steel	Iron + Chromium + Carbon

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Interesting Fact

Bronze (90% copper, 10% tin) is resistant to corrosion, which is why bronze statues last for centuries. Stainless steel does not rust due to the presence of chromium, which forms a protective oxide layer.

Importance of Alloy Making

1. Increases hardness and strength of metals
2. Reduces melting point range
3. Improves resistance to corrosion and chemicals
4. Changes colour and appearance
5. Improves casting properties and dimensional stability

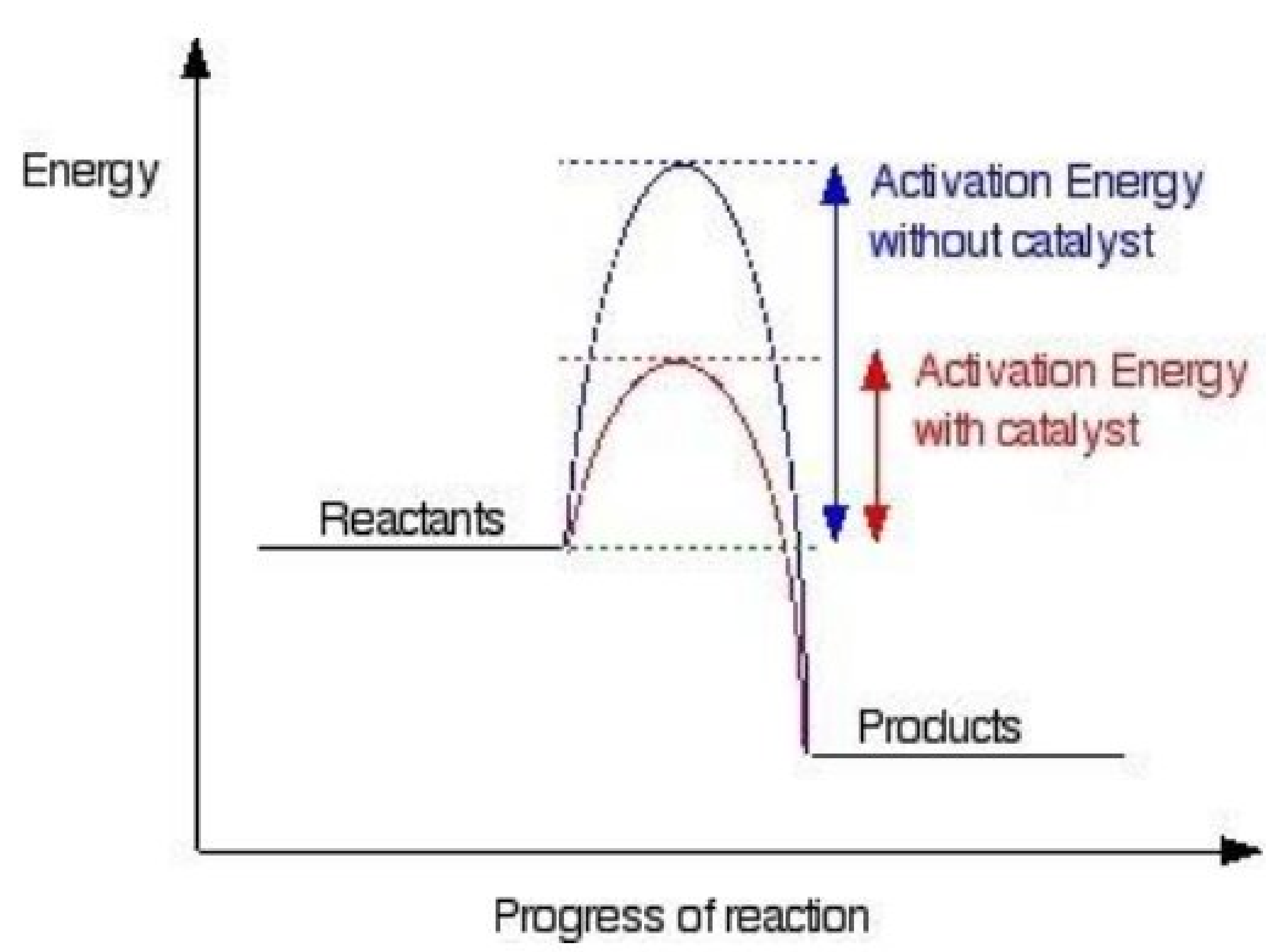
Mechanism of Catalysts

What is Catalysis?

Catalysis is the process in which the rate of a chemical reaction is changed by the presence of a substance called a **catalyst**.

Key Points:

- A catalyst increases or decreases the speed of a chemical reaction.
- The *catalyst is not consumed during the reaction* and *remains chemically unchanged at the end.*
- Even a small quantity of catalyst can affect a large amount of reactants.
- During the reaction, the catalyst forms a temporary intermediate with reactants and is regenerated afterward.
- In the presence of a catalyst, less activation energy is required to start the reaction.
- The overall energy change (ΔH) of the reaction remains unchanged.
- A single catalyst may catalyze more than one reaction.



Effect of Other Substances:

- **Inhibitors (poisons):** Reduce or stop the activity of a catalyst.
- **Promoters:** Increase the efficiency of a catalyst and may alter the operating temperature.

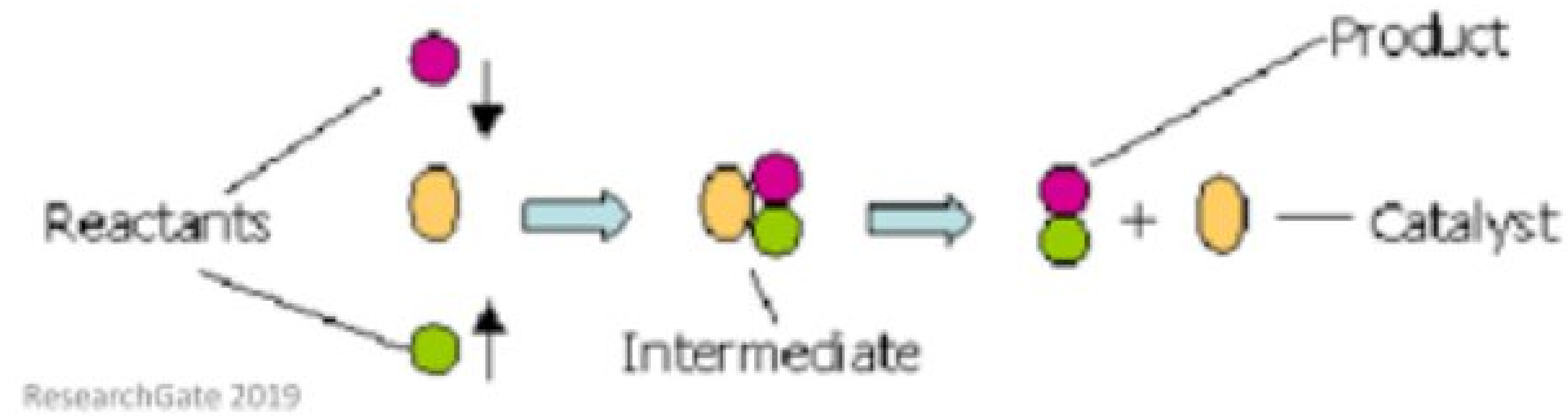
Activation Energy:

- Catalyzed reactions have lower activation energy than uncatalyzed reactions.
- Due to lower activation energy, more reactant molecules can react at the same temperature.
- Reaction rate depends on the frequency of effective collisions, especially during the rate-determining step.
- Increasing the amount of catalyst generally increases the reaction rate.
- Although catalysts are not used up, they may be deactivated, poisoned, or destroyed.

Mechanism of Catalysis

Definition:

The mechanism of catalysis explains how a catalyst increases the rate of a chemical reaction by providing an alternative reaction pathway with lower activation energy.



Role of Transition Metals:

- Transition metals are excellent catalysts because they have partially filled d-orbitals.
- These orbitals allow them to donate and accept electrons easily.
- They readily form temporary bonds with reactant molecules.

How a Catalyst Works:

1. Catalyst provides an alternative pathway with lower activation energy.
2. Reactants form a temporary intermediate with the catalyst.
3. The intermediate breaks down to form products.
4. Catalyst is regenerated at the end of the reaction.

Energy Profile:

- Activation energy without catalyst is high.

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- Activation energy with catalyst is lower.
- Lower activation energy means a faster reaction.

Example 1: Catalytic Decomposition of Hydrogen Peroxide

Reaction:

$$H_2O_2 \rightarrow 2H_2O + O_2$$

Catalyst: Manganese dioxide (MnO_2)

Mechanism:

- Hydrogen peroxide molecules are **adsorbed** on the surface of MnO_2.
- MnO_2 provides a surface for reaction with **lower activation energy**.
- Temporary **intermediate species** form on the MnO_2 surface.
- Water and oxygen molecules **desorb** from the surface.
- MnO_2 remains **unchanged** and can be reused.

Example 2: Contact Process (Oxidation of Sulfur Dioxide)

Reaction:

$$SO_2 + O_2 \rightleftharpoons 2SO_3$$

Catalyst: Vanadium(V) oxide (V_2O_5)

Conditions:

- Temperature: ~450°C
- Pressure: Atmospheric pressure

Role of Catalyst:

- V_2O_5 provides an alternative pathway with **lower activation energy**.
- Increases the rate of oxidation of SO_2 to SO_3.
- Catalyst remains unchanged after the reaction.

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For More Information:

Online and physical tuition is available

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