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CHAPTER NOTES

General Principles of Isolation of Elements Class 12 Notes — CBSE Chemistry Chapter 6

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General Principles of Isolation of Elements Class 12 Notes — CBSE Chemistry Chapter 6

Chapter 6 — **General Principles and Processes of Isolation of Elements** — covers the metallurgy of extracting metals from their ores. From mining to refining, this chapter explains every step of how we get pure metals. It carries **3-5 marks** in Board exams and is mostly conceptual with important reactions to learn.

Key Concepts

Important Ores

Metal	Ore	Formula
Aluminium	Bauxite	$Al_2O_3 \cdot 2H_2O$
Iron	Haematite	Fe_2O_3
Iron	Magnetite	Fe_3O_4
Copper	Copper pyrite	$CuFeS_2$
Copper	Malachite	$Cu(OH)_2 \cdot CuCO_3$
Zinc	Zinc blende / Sphalerite	ZnS
Zinc	Calamine	$ZnCO_3$
Tin	Cassiterite	SnO_2

Steps of Metallurgy

The overall process follows this flow:

Mining → Concentration of Ore → Extraction of Metal → Refining

Step 1: Concentration of Ore (Beneficiation)

Method	Principle	Used For
Hydraulic Washing (Gravity Separation)	Difference in density — lighter gangue washed away	Oxide ores (tin, iron)
Magnetic Separation	Difference in magnetic properties	Magnetic ores (magnetite from non-magnetic gangue)
Froth Flotation	Difference in wetting properties	Sulphide ores (Cu, Pb, Zn)
Chemical Leaching	Selective dissolution in chemical	Bauxite (Bayer's process), Ag, Au

Froth Flotation — How it works: Ore is mixed with water + pine oil. Air is blown in. Sulphide particles (hydrophobic) attach to oil froth and float. Gangue (hydrophilic) sinks. Collectors (xanthates) enhance hydrophobicity. Depressants (NaCN) selectively separate mixed ores.

Leaching Reactions

Bayer's Process (for bauxite):

$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2Na[Al(OH)_4]$ (aluminate — dissolves)

SiO_2, TiO_2, Fe_2O_3 — left as red mud (don't dissolve)

$Na[Al(OH)_4] + CO_2 \rightarrow Al(OH)_3\downarrow + NaHCO_3$

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

Gold/Silver Leaching (MacArthur-Forrest/Cyanide Process):

$4Au + 8NaCN + 2H_2O + O_2 \rightarrow 4Na[Au(CN)_2] + 4NaOH$

$2Na[Au(CN)_2] + Zn \rightarrow Na_2[Zn(CN)_4] + 2Au\downarrow$

Step 2: Extraction of Metal

Method depends on the metal's reactivity:

Metal Type	Method	Examples
Highly reactive (K, Na, Ca, Mg, Al)	Electrolytic reduction	Hall-Héroult (Al), Downs process (Na)
Moderately reactive (Zn, Fe, Pb, Sn)	Carbon reduction (smelting)	Blast furnace (Fe), $ZnO + C \rightarrow Zn + CO$
Less reactive (Cu, Hg, Ag)	Self-reduction / roasting	$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$

Thermodynamics of Metallurgy — Ellingham Diagram

$\Delta G = \Delta H - T\Delta S$

Key principles from Ellingham diagram:

1. Metal whose oxide line is LOWER can reduce the oxide above it
2. A metal can reduce oxide of another metal that lies above it in the diagram
3. C line goes DOWN with temperature (entropy favours $C + O_2 \rightarrow CO_2$ at high T), so carbon becomes a better reducing agent at high temperatures
4. Al line is always below Fe line → Al can reduce Fe_2O_3 (thermite reaction!)

Thermite Reaction: $Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3$ + Heat. Used to weld railway tracks! This works because Al has a more negative ΔG for oxide formation than Fe.

Extraction of Iron — Blast Furnace

Zone of Combustion (bottom, ~2000°C): $C + O_2 \rightarrow CO_2$

Zone of Reducing (middle, ~700-1200°C):

$CO_2 + C \rightarrow 2CO$

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ (main reaction!)

Zone of Slag Formation: $CaO + SiO_2 \rightarrow CaSiO_3$ (calcium silicate slag)

Zone of Charge (top, ~500°C): $3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$

Extraction of Aluminium — Hall-Héroult Process

- Electrolysis of Al_2O_3 dissolved in molten cryolite (Na_3AlF_6)
- Cryolite lowers melting point from 2050°C to ~950°C
- CaF_2 (fluorspar) added to further lower melting point
- Cathode: $Al^{3+} + 3e^- \rightarrow Al$ (liquid, collected at bottom)
- Anode: $C + O^{2-} \rightarrow CO_2$ (carbon anode consumed — needs replacement)

Extraction of Copper — From Copper Pyrite ($CuFeS_2$)

Step 1 — Roasting: $2CuFeS_2 + O_2 \rightarrow Cu_2S + 2FeS + SO_2$

Step 2 — Smelting with SiO_2: $FeS + SiO_2 \rightarrow FeSiO_3$ (slag) $+ SO_2$

Step 3 — Self-reduction (Bessemer converter):

$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$

$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$ ← **Self-reduction!**
(Copper obtained is 99% pure — "blister copper")

Step 3: Refining

Method	Principle	Used For
Distillation	Difference in boiling points	Zn, Hg
Liquation	Low melting point metal flows out	Sn, Pb, Bi
Electrolytic Refining	Impure metal = anode, pure = cathode	Cu, Ag, Zn, Ni
Zone Refining	Impurities more soluble in melt	Si, Ge, Ga (semiconductors)
Van Arkel Method	Decomposition of volatile compound	Zr, Ti, Hf
Mond Process	Formation/decomposition of $Ni(CO)_4$	Ni

Mond Process: $Ni + 4CO \rightarrow(330\ K)\ Ni(CO)_4 \rightarrow(450\ K)\ Ni + 4CO$
Van Arkel: $Zr + 2I_2 \rightarrow(870\ K)\ ZrI_4 \rightarrow(1800\ K)\ Zr + 2I_2$

Important Definitions

Term	Definition
Ore	Mineral from which metal can be economically extracted
Gangue	Unwanted rocky/earthy material associated with ore
Flux	Substance added to remove gangue as fusible slag
Slag	Fusible product of flux + gangue
Roasting	Heating ore strongly in air (sulphide → oxide)
Calcination	Heating ore in absence/limited air (carbonate → oxide)
Smelting	Reduction of oxide to metal using carbon/CO at high temperature

Solved Examples — NCERT Based

Example 1: Why Carbon Cannot Reduce Al_2O_3

Q: Why is carbon reduction not used for extracting aluminium?

Solution: In the Ellingham diagram, the line for Al_2O_3 lies below the line for CO at all temperatures. This means ΔG for Al_2O_3 formation is more negative than for CO/CO_2. Therefore, carbon cannot reduce Al_2O_3 — the reverse reaction is thermodynamically unfavourable. That's why **electrolytic reduction** (Hall-Héroult process) is used instead.

Example 2: Choosing Concentration Method

Q: Which concentration method would you use for: (a) ZnS (b) Fe_3O_4 mixed with SiO_2 (c) $Al_2O_3{\cdot}2H_2O$

Solution:

(a) ZnS is a sulphide ore → **Froth flotation**

(b) Fe_3O_4 is magnetic, SiO_2 is not → **Magnetic separation**

(c) $Al_2O_3{\cdot}2H_2O$ (bauxite) → **Chemical leaching (Bayer's process)**

Example 3: Depressants in Froth Flotation

Q: How can you separate a mixture of ZnS and PbS using froth flotation?

Solution: Add **NaCN as depressant**. NaCN forms a layer of zinc cyanide [$Na_2[Zn(CN)_4]$] on ZnS, making it hydrophilic (sinks). PbS remains hydrophobic (floats with froth). Thus PbS is collected first, then ZnS is collected separately without the depressant.

Example 4: Electrolytic Refining

Q: In electrolytic refining of copper, what happens at each electrode? What is anode mud?

Solution:

Anode (impure Cu): $Cu \rightarrow Cu^{2+} + 2e^-$ (copper dissolves)

Cathode (pure Cu): $Cu^{2+} + 2e^- \rightarrow Cu$ (pure copper deposits)

Electrolyte: Acidified $CuSO_4$ solution

Anode mud: Insoluble impurities (Ag, Au, Pt) that settle below the anode — these are valuable and recovered separately!

Important Questions for Board Exams

1 Mark Questions

1. What is the role of cryolite in Hall-Héroult process?
2. Name the reducing agent used in thermite reaction.
3. What is the difference between roasting and calcination?
4. What is anode mud?

2 Mark Questions

1. Explain froth flotation process for concentration of sulphide ores.
2. Describe the role of depressant in froth flotation.
3. What is zone refining? Name the metals refined by this method.
4. How is copper extracted from low-grade ores?

3 Mark Questions

1. Describe the extraction of aluminium from bauxite by Hall-Héroult process.
2. Explain the significance of Ellingham diagram in metallurgy.
3. Describe the extraction of copper from copper pyrite with equations.
4. Explain Mond process and Van Arkel method with equations.

5 Mark Questions

1. Draw a neat Ellingham diagram. Explain how it helps predict the choice of reducing agent. Why can carbon reduce FeO but not Al_2O_3?
2. Describe the extraction of iron from haematite in a blast furnace. Write reactions occurring in different zones.

Quick Revision Points

- Concentration methods: gravity, magnetic, froth flotation (sulphides), leaching (bauxite/gold)
- Froth flotation: sulphide ore + water + pine oil + air; collectors enhance, depressants separate
- Bayer's process: bauxite + NaOH → aluminate → $Al(OH)_3$ → Al_2O_3
- Ellingham diagram: lower line reduces upper; C becomes better reducer at high T
- Highly reactive metals → electrolysis; moderate → carbon reduction; low → self-reduction
- Iron: blast furnace, CO is the main reducing agent
- Al: Hall-Héroult, electrolysis of Al_2O_3 in cryolite
- Cu: roasting → smelting → self-reduction → blister copper → electrolytic refining
- Refining: electrolytic (Cu), zone (Si/Ge), Mond (Ni), Van Arkel (Zr/Ti)
- Thermite: $Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3$ (welding railway tracks)

← Previous: Surface Chemistry **Next: p-Block Elements →**