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Introduction

Overview

- Group 13-18 elements form the p-block of the periodic table.
- Properties influenced by atomic size, ionisation enthalpy, electron gain enthalpy, and electronegativity.
- Second period elements lack d-orbitals; heavier elements have d- and/or f-orbitals affecting properties.

Solved Examples

- Ex 1: Explain why ionisation enthalpy decreases down the group.
  Step 1: Atomic size increases down the group.
  Step 2: Outer electrons are farther from nucleus.
  Step 3: Less energy required to remove electron.

Practice Set

- Q1: Which factor primarily influences p-block element properties?
  A. Atomic size
  B. Nuclear spin
  C. Magnetic moment
  D. Isotopic mass
- Q2: Why do second period p-block elements differ from heavier ones?
  A. Presence of f-orbitals
  B. Absence of d-orbitals
  C. Higher electronegativity
  D. Larger atomic radius
- Q3: Which property decreases down the p-block group?
  A. Atomic size
  B. Ionisation enthalpy
  C. Electron gain enthalpy
  D. Electronegativity

Answer Key

- Q1: A - Atomic size affects ionisation energy and electronegativity, key to p-block properties.
- Q2: B - Second period elements lack d-orbitals, affecting their chemical behavior.
- Q3: D - Electronegativity decreases down the group due to increased atomic size.

Memory Aids

- Remember: "No d-orbitals in 2nd period" for unique properties.
- Properties trend: Size ↑, Ionisation energy ↓, Electronegativity ↓ down the group.

Group 15 Elements

General Characteristics

- Elements: N, P, As, Sb, Bi, Moscovium (synthetic, short half-life).
- Known as pnictogens.

- General electronic configuration: ns^2np^3.
- Atomic radii increase down the group; smaller than group 14 due to higher nuclear charge.
- Melting point increases N to As, then decreases due to inert pair effect.
- Metallic character increases down the group.
- Ionisation enthalpy decreases down the group; higher than group 14 due to half-filled p-orbital stability.
- Electronegativity decreases down the group.
- Allotropy present in all except nitrogen.

Chemical Properties

- Oxidation states: +3 stability increases down the group; +5 decreases due to inert pair effect.
- Halides: General formula EX_3 or EX_5.
- Halide stability: $NF_3 > NCl_3 > NBr_3$ (due to size differences).
- Lewis acid strength: $PCl_3 > NBr_3 > NCl_3 > NF_3$ (decreasing electron density on N with increasing halogen electronegativity).
- Halide bond angle: $PF_3 < PCl_3 < PBr_3 < PI_3$ (due to decreasing bond pair-bond pair repulsions).
- Hydrides (EH_3): Bond angle decreases $NH_3 > PH_3 > AsH_3 > SbH_3 > BiH_3$.
- Basicity: $NH_3 > PH_3$; AsH_3, SbH_3, BiH_3 are not basic.
- Boiling point order: $PH_3 < AsH_3 < NH_3 < SbH_3 < BiH_3$.
- Melting point order: $PH_3 < AsH_3 < SbH_3 < NH_3$.
- Thermal stability: $NH_3 > PH_3 > AsH_3 > SbH_3 > BiH_3$.
- Reducing character: $NH_3 < PH_3 < AsH_3 < SbH_3 < BiH_3$.
- Solubility in water: NH_3, PH_3 soluble; AsH_3, SbH_3, BiH_3 insoluble.
- Oxides: General formula E_2O_3 or E_2O_5.
- Acidic strength of trioxides: $N_2O_3 > P_4O_6 > As_4O_6 > Sb_4O_6$ (due to decreasing electronegativity).
- Nitrogen oxides sequence: N_2O, NO (neutral), N_2O_3, N_2O_4, N_2O_5 (increasing oxidation state).
- Reactivity with metals: Forms binary compounds with -3 oxidation state (e.g., Ca_3N_2, Ca_3P_2, Na_3As).

Element	Symbol	At. No.	Electronic configuration
Nitrogen	N	7	[He] $2s^2\,2p^3$
Phosphorus	P	15	[Ne] $3s^2\,3p^3$
Arsenic	As	33	[Ar] $3d^{10}\,4s^2\,4p^3$
Antimony	Sb	51	[Kr] $4d^{10}\,5s^2\,5p^3$
Bismuth	Bi	83	[Xe] $4f^{14}\,5d^{10}\,6s^2\,6p^3$
Moscovium	Mc	115	[Rn] $5f^{14}\,6d^{10}\,7s^2\,7p^3$

Solubility : $\underbrace{NH_3}_{\text{(Soluble)}}, \underbrace{PH_3, AsH_3, SbH_3, BiH_3}_{\text{(Insoluble)}}$

$\underbrace{N_2O}_{\text{Neutral}} < NO < N_2O_3 < N_2O_4 < N_2O_5$ [Oxidation number of central atom increases]

Solved Examples

- Ex 1: Predict the bond angle trend in group 15 hydrides.
  Step 1: NH_3 has highest bond angle due to lone pair repulsion.
  Step 2: Bond angle decreases down the group due to increasing atomic size.
- Ex 2: Explain the stability trend of +3 and +5 oxidation states.
  Step 1: +3 state stability increases down the group due to inert pair effect.
  Step 2: +5 state stability decreases down the group.

Practice Set

- Q1: Which element is not a pnictogen?
  A. Nitrogen
  B. Phosphorus
  C. Sulfur
  D. Bismuth
- Q2: Which halide is most stable?
  A. NBr_3
  B. NCl_3
  C. NF_3
  D. PCl_3
- Q3: Which hydride has the highest basicity?
  A. PH_3
  B. NH_3
  C. AsH_3
  D. SbH_3

Answer Key

- Q1: C - Sulfur belongs to group 16, not group 15.
- Q2: C - NF_3 is most stable due to size and electronegativity differences.
- Q3: B - NH_3 is the most basic hydride in group 15.

Memory Aids

- Pnictogens: "N P As Sb Bi" - remember Moscovium is synthetic.
- Oxidation state trend: +3 ↑, +5 ↓ down the group.
- Hydrides: Basicity and bond angle decrease down the group.
- Halide stability: $NF_3 > NCl_3 > NBr_3$.

Dinitrogen

Preparation of Nitrogen Gas

- Ammonium chloride reacts with sodium nitrite:
  $NH_4Cl + NaNO_2 \rightarrow N_2 + 2H_2O + NaCl$
- Thermal decomposition of ammonium dichromate:
  $(NH_4)_2Cr_2O_7 \rightarrow Cr_2O_3 + N_2 + 4H_2O$
- Thermal decomposition of barium azide:
  $Ba(N_3)_2 \rightarrow Ba + 3N_2$

Chemical Properties

- Reaction with lithium:
  $N_2 + 6Li \rightarrow 2Li_3N$ (lithium nitride)
- Reaction with magnesium:
  $N_2 + Mg \rightarrow Mg_3N_2$ (magnesium nitride)
- Reaction with oxygen at high temperature:
  $N_2 + O_2 \rightarrow 2NO$ (nitric oxide)
- Haber process (ammonia synthesis):
  $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (high pressure, temperature, catalyst; exothermic)

Preparation : $NH_4Cl + NaNO_2 \longrightarrow N_2\uparrow + 2H_2O + NaCl$; $(NH_4)_2Cr_2O_7 \xrightarrow{\Delta} N_2\uparrow + 4H_2O + Cr_2O_3$

$Ba(N_3)_2 \xrightarrow{\Delta} Ba + 3N_2\uparrow$

Chemical properties : $6Li + N_2 \xrightarrow{\Delta} 2Li_3N$; $3Mg + N_2 \xrightarrow{\Delta} Mg_3N_2$

$N_{2(g)} + O_{2(g)} \overset{\Delta,\ 2000\ K}{\rightleftharpoons} 2NO_{(g)}$; $N_2 + 3H_2 \overset{773\ K,\ 200\ atm}{\rightleftharpoons} 2NH_3;\ \Delta_f H^\circ = -46.1\ kJ\ mol^{-1}$ (Haber's process)

Solved Examples

- **Ex 1:** Calculate moles of N_2 produced from 1 mole NH_4Cl and $NaNO_2$.
  Step 1: Reaction: $NH_4Cl + NaNO_2 \rightarrow N_2 + 2H_2O + NaCl$
  Step 2: 1 mole NH_4Cl produces 1 mole N_2.
- **Ex 2:** Write balanced equation for ammonia synthesis.
  Step 1: $N_2 + 3H_2 \rightleftharpoons 2NH_3$

Practice Set

- **Q1:** Which reagent is used with ammonium chloride to prepare nitrogen gas?
  A. Sodium hydroxide
  B. Sodium nitrite
  C. Sodium carbonate
  D. Sodium sulfate
- **Q2:** What is the product when nitrogen reacts with lithium?
  A. $LiNO_3$
  B. Li_3N
  C. $LiNO_2$
  D. LiOH
- **Q3:** In the Haber process, what is the stoichiometric ratio of N_2 to H_2?
  A. 1:1
  B. 1:2
  C. 1:3
  D. 3:1

Answer Key

- **Q1:** B - Sodium nitrite reacts with ammonium chloride to produce nitrogen gas.
- **Q2:** B - Lithium reacts with nitrogen to form lithium nitride (Li_3N).
- **Q3:** C - The Haber process uses 1 mole N_2 and 3 moles H_2.

Memory Aids

- Remember: "$NaNO_2 + NH_4Cl \rightarrow N_2$" for nitrogen preparation.

- Haber process ratio: $N_2 : H_2 = 1 : 3$.
- Nitrogen forms nitrides with active metals like Li and Mg.

Ammonia Preparation

Laboratory Preparation

- Ammonium salts react with alkali to release NH_3.
- Reactions:
  - $2NH_4Cl + Ca(OH)_2 \rightarrow 2NH_3 + CaCl_2 + 2H_2O$
  - $(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 2H_2O$
  - $Mg_3N_2 + 6HCl \rightarrow 3MgCl_2 + 2NH_3$
- Urea hydrolyses in water to form ammonium carbonate, which decomposes to NH_3, CO_2, and H_2O (reversible reaction).

$$\underset{\text{Urea}}{NH_2CONH_2} + 2H_2O \rightarrow \underset{\text{Ammonium carbonate}}{(NH_4)_2CO_3} \rightleftharpoons 2NH_{3(g)} + CO_{2(g)} + H_2O_{(l)}$$

Manufacture

- Haber's process: $N_2 + 3H_2 \rightleftharpoons 2NH_3$ ($\Delta H° = -46.1$ kJ/mol, exothermic)
- Conditions: 773 K, 200 atm, iron oxide catalyst with K_2O and Al_2O_3 promoters.

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} \; ; \Delta_f H° = -46.1 \text{ kJ/mol}$$

Solved Examples

- **Ex 1:** Calculate moles of NH_3 produced from 1 mole N_2 in Haber's process.
  - $1\ N_2 + 3\ H_2 \rightarrow 2\ NH_3$
  - So, 1 mole N_2 produces 2 moles NH_3.

Practice Set

- Q1: Which reagent is used in laboratory preparation of NH_3?
  - A. $NH_4Cl + Ca(OH)_2$
  - B. $NH_3 + H_2O$
  - C. $N_2 + H_2$
  - D. $NH_4OH + ZnCl_2$
- Q2: What is the enthalpy change in Haber's process?
  - A. +46.1 kJ/mol
  - B. -46.1 kJ/mol
  - C. 0 kJ/mol
  - D. -100 kJ/mol
- Q3: Which catalyst is used in Haber's process?
  - A. Copper oxide
  - B. Iron oxide
  - C. Zinc oxide
  - D. Aluminium oxide alone

Answer Key

- Q1: A - Ammonia is prepared in lab by reacting ammonium salts with alkali like $Ca(OH)_2$.
- Q2: B - The reaction is exothermic with $\Delta H° = -46.1$ kJ/mol.
- Q3: B - Iron oxide catalyst is used with promoters K_2O and Al_2O_3.

Memory Aids

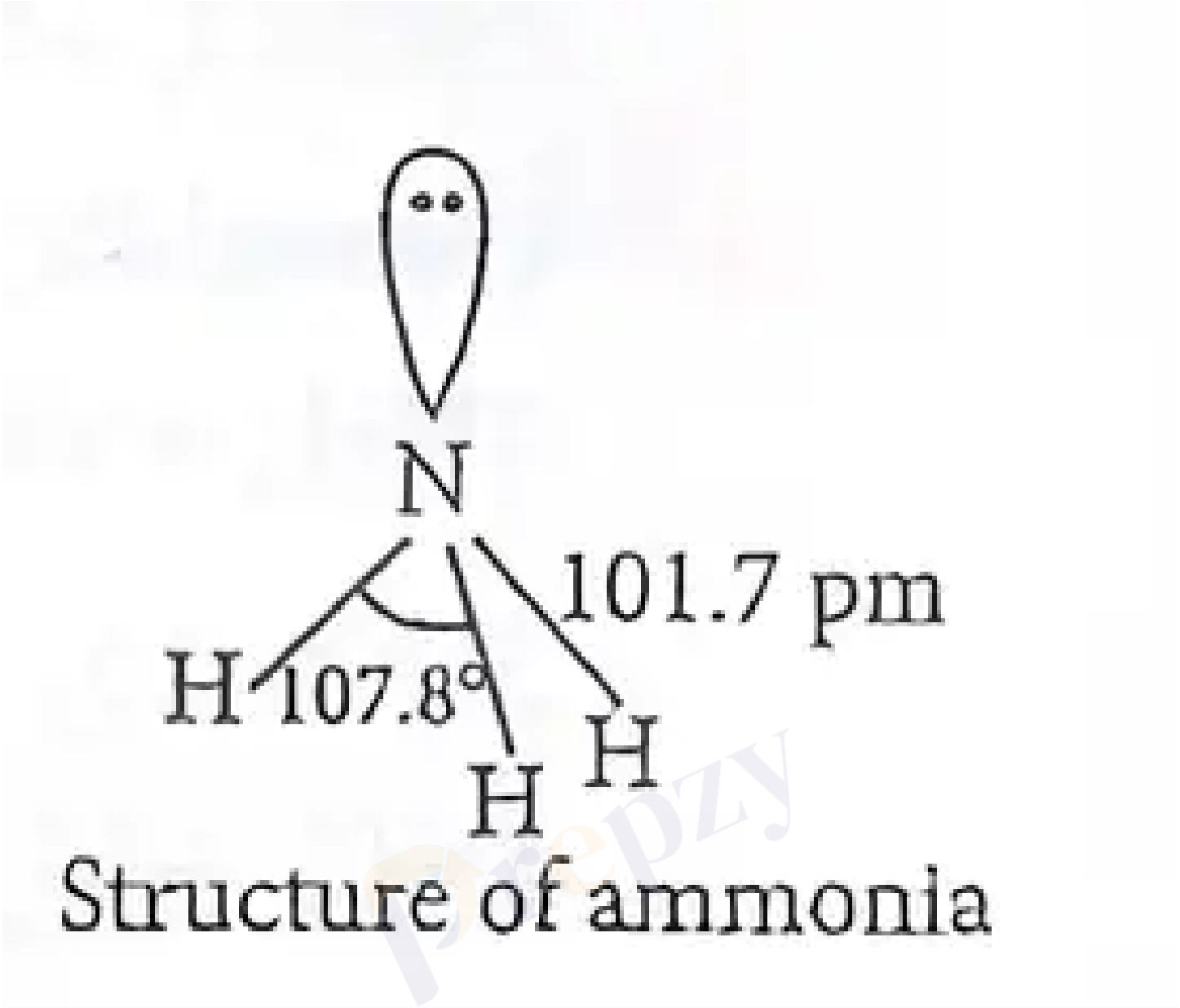
- Lab prep: Ammonium salt + alkali → NH_3
- Haber's process: $N_2 + 3H_2 \rightleftharpoons 2NH_3$, exothermic
- Catalyst: Iron oxide + K_2O + Al_2O_3

Ammonia Structure

Molecular Structure

- NH_3 is covalent with nitrogen using three sp^3 hybrid orbitals overlapping with hydrogen 1s orbitals.
- One sp^3 orbital holds a lone pair.
- Shape: Trigonal pyramidal, bond angle ≈ 107.8°.
- In liquid/solid, NH_3 molecules are hydrogen bonded.

Prepzy



Structure of ammonia

Solved Examples

- **Ex 1:** Identify bond angle in NH_3.
  - Answer: 107.8° due to lone pair repulsion.

Practice Set

- Q1: What is the shape of NH_3 molecule?
  - A. Linear
  - B. Trigonal planar
  - C. Trigonal pyramidal
  - D. Tetrahedral
- Q2: Which orbital hybridization is present in nitrogen of NH_3?
  - A. sp
  - B. sp^2
  - C. sp^3
  - D. sp^3d
- Q3: What causes the bond angle in NH_3 to be less than 109.5°?
  - A. Lone pair repulsion
  - B. Hydrogen bonding

- C. Double bonds
- D. Ionic character

Answer Key

- Q1: C - NH_3 is trigonal pyramidal due to lone pair on nitrogen.
- Q2: C - Nitrogen is sp^3 hybridized in NH_3.
- Q3: A - Lone pair repulsion reduces bond angle from 109.5° to 107.8°.

Memory Aids

- Shape: Trigonal pyramidal = 3 bonds + 1 lone pair
- Hybridization: sp^3 for nitrogen
- Lone pair repulsion lowers bond angle

Ammonia Basic Character

Basic Nature

- NH_3 donates lone pair, acts as Lewis base.
- In water: $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
- Produces alkaline solution due to OH^- ions.

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

Reaction with Heavy Metal Ions

- Forms insoluble metal hydroxide precipitates:
  - $FeCl_3 + 3NH_4OH \rightarrow 3NH_4Cl + Fe(OH)_3$ (brown ppt.)
  - $ZnCl_2 + 2NH_4OH \rightarrow 2NH_4Cl + Zn(OH)_2$ (white ppt.)

Formation of Complex Compounds

- NH_3 forms stable soluble complexes with Ag^+, Cu^{2+}, Hg^{2+}.
  - $AgOH + 2NH_4OH \rightarrow [Ag(NH_3)_2]OH + 2H_2O$
  - $AgCl + 2NH_4OH \rightarrow [Ag(NH_3)_2]Cl + 2H_2O$
  - $Cu(OH)_2 + (NH_4)_2SO_4 + NH_4OH \rightarrow [Cu(NH_3)_4]SO_4 + 4H_2O$ (deep blue solution)

Solved Examples

- **Ex 1:** Write the reaction of NH_3 with water.
  - $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

Practice Set

- Q1: What ion is formed when NH_3 dissolves in water?
  - A. NH_4^+
  - B. OH^-
  - C. NH_3
  - D. H_3O^+
- Q2: What is the color of $Fe(OH)_3$ precipitate formed with NH_4OH?
  - A. White
  - B. Brown
  - C. Blue
  - D. Green
- Q3: Which complex is formed by NH_3 with Cu^{2+}?
  - A. $[Cu(NH_3)_2]^{2+}$
  - B. $[Cu(NH_3)_4]^{2+}$
  - C. $[Cu(NH_3)_3]^{2+}$
  - D. $[Cu(NH_3)]^{2+}$

Answer Key

- Q1: A - NH_3 accepts H^+ to form NH_4^+ in water.
- Q2: B - $Fe(OH)_3$ forms brown precipitate.
- Q3: B - Tetraamminecopper (II) complex $[Cu(NH_3)_4]^{2+}$ is deep blue.

Memory Aids

- $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$ (basic solution)
- $Fe(OH)_3$ brown ppt., $Zn(OH)_2$ white ppt.
- Cu complex deep blue, Ag complex soluble

Nitrogen Hydrides

Types and Nature

- Three hydrides: NH_3 (ammonia), N_2H_4 (hydrazine), N_3H (hydrazoic acid).
- NH_3 and N_2H_4 are basic; N_3H is acidic.

Solved Examples

- **Ex 1:** Identify acidic hydride among nitrogen hydrides.
  - Answer: N_3H (hydrazoic acid) is acidic.

Practice Set

- Q1: Which nitrogen hydride is acidic?
  - A. NH_3
  - B. N_2H_4
  - C. N_3H

    - D. None
- Q2: Hydrazine formula is?
    - A. NH_3
    - B. N_2H_4
    - C. N_3H
    - D. NH_2OH
- Q3: Which hydride is basic?
    - A. N_3H
    - B. NH_3
    - C. Both NH_3 and N_2H_4
    - D. None

Answer Key

- Q1: C - N_3H is acidic hydride.
- Q2: B - Hydrazine is N_2H_4.
- Q3: C - NH_3 and N_2H_4 are basic.

Memory Aids

- Acidic: N_3H; Basic: NH_3, N_2H_4
- Hydrazine = N_2H_4

Oxides of Nitrogen

Preparation and Properties

- Nitrogen oxides are compounds of nitrogen and oxygen with varying oxidation states.
- Common oxides include N_2O, NO, N_2O_3, NO_2, and N_2O_5.
- Preparation methods vary: thermal decomposition, direct combination, and oxidation reactions.
- Physical states differ: gases (N_2O, NO, NO_2), liquids, or solids.
- Acidic or neutral nature depends on the oxide; e.g., N_2O is neutral, NO_2 is acidic.

Name	Formula	O.S.	Preparation	Properties
Dinitrogen oxide [Nitrogen(I) oxide]	N_2O	+1	$NH_4NO_3 \xrightarrow{\Delta} N_2O + 2H_2O$	colourless gas, neutral
Nitrogen monoxide [Nitrogen(II) oxide]	NO	+2	$2NaNO_2 + 2FeSO_4 + 3H_2SO_4 \longrightarrow Fe_2(SO_4)_3 + 2NaHSO_4 + 2H_2O + 2NO$	colourless gas, neutral
Dinitrogen trioxide [Nitrogen(III) oxide]	N_2O_3	+3	$2NO + N_2O_4 \xrightarrow{250\ K} 2N_2O_3$	blue solid, acidic
Nitrogen dioxide [Nitrogen(IV) oxide]	NO_2	+4	$2Pb(NO_3)_2 \xrightarrow{673\ K} 2PbO + 4NO_2 + O_2$	brown gas, acidic
Dinitrogen tetroxide [Nitrogen(IV) oxide]	N_2O_4	+4	$2NO_2 \underset{heat}{\overset{cool}{\rightleftharpoons}} N_2O_4$	colourless solid/ liquid, acidic
Dinitrogen pentoxide [Nitrogen(V) oxide]	N_2O_5	+5	$4HNO_3 + P_4O_{10} \longrightarrow 4HPO_3 + 2N_2O_5$	colourless solid, acidic

Solved Examples

- **Ex 1:** Preparation of Nitric Oxide (NO)
  Step 1: React NH_4NO_3 (ammonium nitrate) by heating.
  Step 2: $NH_4NO_3 \rightarrow N_2O + 2H_2O$ (decomposition reaction)
- **Ex 2:** Formation of Nitrogen Dioxide (NO_2)
  Step 1: Oxidize NO in air.
  Step 2: $2NO + O_2 \rightarrow 2NO_2$

Practice Set

- **Q1:** Which oxide of nitrogen is a colorless, neutral gas?
  A. NO_2
  B. N_2O
  C. NO
  D. N_2O_5
- **Q2:** What is the oxidation state of nitrogen in N_2O?
  A. +1
  B. +2
  C. +3
  D. +4
- **Q3:** Which reaction correctly represents the preparation of NO?
  A. $NH_4NO_3 \rightarrow N_2O + 2H_2O$
  B. $2NO + O_2 \rightarrow 2NO_2$
  C. $NH_4NO_3 \rightarrow NO + 2H_2O$
  D. $N_2 + O_2 \rightarrow 2NO$

Answer Key

- **Q1:** B - N_2O is a colorless, neutral gas.
- **Q2:** A - Nitrogen has +1 oxidation state in N_2O.
- **Q3:** D - Direct combination of N_2 and O_2 forms NO.

Memory Aids

- Remember: N_2O is "laughing gas" (neutral, colorless).
- NO is formed by direct combination of N_2 and O_2 at high temperature.
- NO_2 is brown and acidic; formed by oxidation of NO.

Nitric Acid Preparation

Laboratory Preparation

- React sodium nitrate ($NaNO_3$) with concentrated sulfuric acid (H_2SO_4):
- $NaNO_3 + 5H_2SO_4 \rightarrow NaHSO_4 + HNO_3$

Ostwald's Process

- Ammonia (NH_3) oxidized to nitric acid using platinum/rhodium catalyst.
- Step 1: $NH_3 + O_2 \rightarrow NO + H_2O$ (catalyst, high T & P)

- Step 2: $NO + O_2 \rightarrow NO_2$
- Step 3: $NO_2 + H_2O \rightarrow HNO_3 + NO$
- NO is recycled; HNO_3 concentrated by distillation (~68%) and dehydration (up to 98%).

$$4NH_3 + 5O_2 \xrightarrow[500\ K,\ 9\ bar]{Pt/Rh\ gauge\ catalyst} 4NO + 6H_2O$$

$$2NO + O_2 \rightleftharpoons 2NO_2$$

$$3NO_2 + H_2O \longrightarrow 2HNO_3 + NO$$

Solved Examples

- **Ex 1:** Write the reaction for laboratory preparation of HNO_3.
- Answer: $NaNO_3 + 5H_2SO_4 \rightarrow NaHSO_4 + HNO_3$
- **Ex 2:** Outline the first step of Ostwald's process.
- Answer: $NH_3 + O_2 \rightarrow NO + H_2O$ (with catalyst, high temperature and pressure)

Practice Set

- Q1: Which catalyst is used in Ostwald's process?
- A. Iron B. Platinum/Rhodium C. Copper D. Nickel
- Q2: What is the product when $NaNO_3$ reacts with H_2SO_4?
- A. $NaHSO_4$ and HNO_3 B. Na_2SO_4 and HNO_3 C. $NaNO_2$ and H_2SO_4 D. NaOH and HNO_3
- Q3: What is the maximum concentration of HNO_3 achievable by distillation before dehydration?
- A. 50% B. 68% C. 85% D. 98%

Answer Key

- Q1: B - Platinum/Rhodium catalyst is used for oxidation of NH_3 in Ostwald's process.
- Q2: A - Reaction produces $NaHSO_4$ and HNO_3 in laboratory preparation.
- Q3: B - Distillation concentrates HNO_3 up to ~68%; further dehydration needed for 98%.

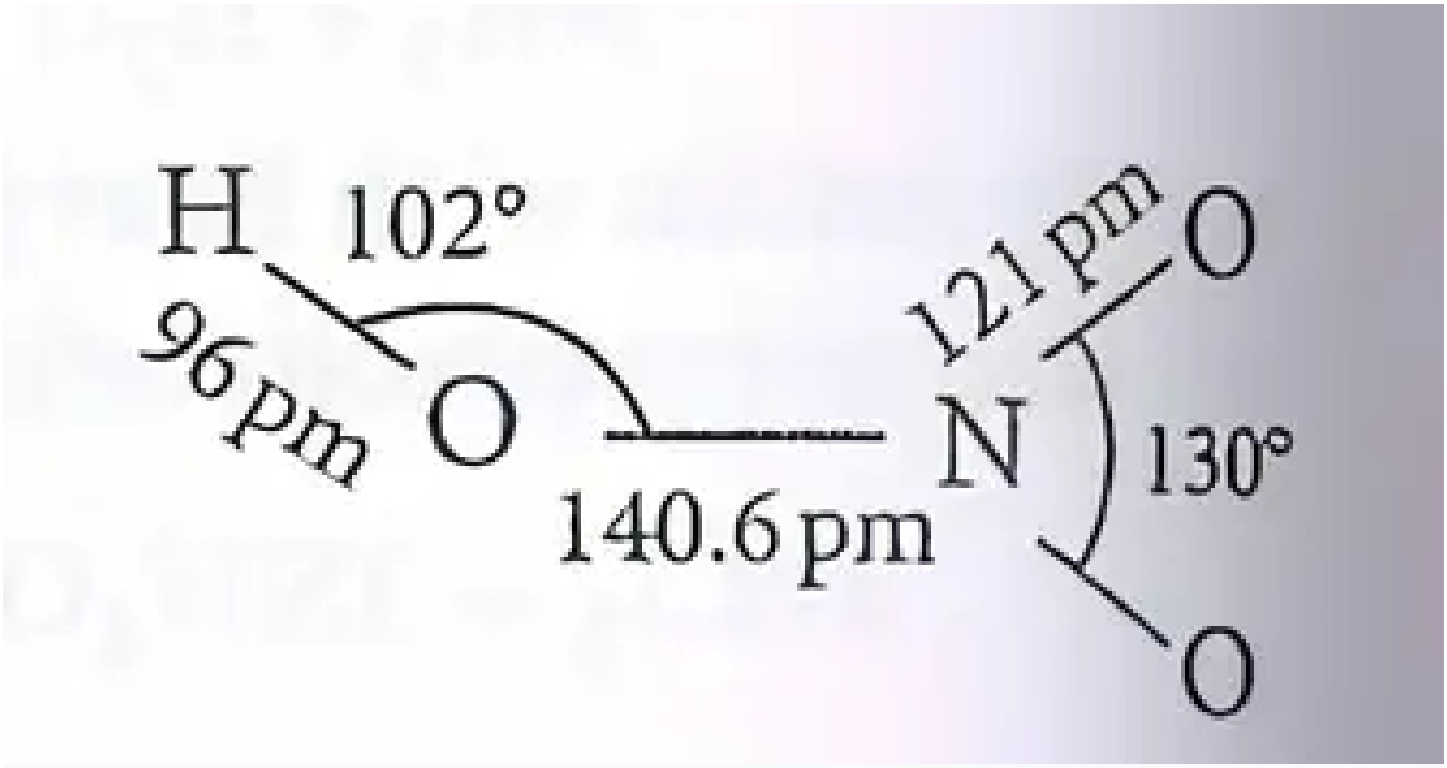
Memory Aids

- Ostwald's catalyst: Platinum/Rhodium = "Pt/Rh"
- Lab prep: $NaNO_3 + H_2SO_4 \rightarrow HNO_3 + NaHSO_4$
- Distillation max ~68%, dehydration for 98%

Nitric Acid Properties

Physical Properties

- Pure HNO_3 is colourless; impure appears yellow due to nitrogen oxides.
- Gaseous HNO_3 is planar molecule.
- Molecular structure: bond lengths and angles important for shape.



Chemical Properties

- Strong oxidising agent.
- Non-metals oxidised to highest oxyacids; NO_2 gas evolved.
- Examples:
- $I_2 + 10HNO_3 \rightarrow 2HIO_3 + 10NO_2 + 4H_2O$
- $C + 4HNO_3 \rightarrow CO_2 + 2H_2O + NO_2$
- $S_8 + 48HNO_3 \rightarrow 8H_2SO_4 + 48NO_2 + 16H_2O$
- $P_4 + 20HNO_3 \rightarrow 4H_3PO_4 + 20NO_2 + 4H_2O$
- Reacts with metals as acid and oxidising agent.

Concentration of nitric acid	Metal	Main products
Very dilute HNO_3	Mg, Mn	H_2 + metal nitrate
	Fe, Zn, Sn	NH_4NO_3 + metal nitrate
Dilute HNO_3	Pb, Cu, Ag, Hg	NO + metal nitrate
	Fe, Zn	N_2O + metal nitrate
	Sn	$NH_4NO_3 + Sn(NO_3)_2$
Conc. HNO_3	Zn, Fe, Pb, Cu, Ag	NO_2 + metal nitrate
	Sn	$NO_2 + H_2SnO_3$ (Metastannic acid)

Solved Examples

- **Ex 1:** Write the reaction of iodine with hot concentrated HNO_3.
- Answer: $I_2 + 10HNO_3 \rightarrow 2HIO_3 + 10NO_2 + 4H_2O$
- **Ex 2:** What gas is evolved when carbon reacts with HNO_3?
- Answer: NO_2 gas

Practice Set

- Q1: What colour is pure nitric acid?
- A. Yellow B. Colourless C. Blue D. Green
- Q2: Which gas is evolved when non-metals react with hot concentrated HNO_3?
- A. NO B. NO_2 C. N_2 D. NH_3
- Q3: Which product forms when sulfur reacts with hot concentrated nitric acid?
- A. H_2SO_4 B. SO_2 C. H_2SO_3 D. S_8

Answer Key

- Q1: B - Pure HNO_3 is colourless; yellow indicates impurities.
- Q2: B - NO_2 gas evolves during oxidation of non-metals.
- Q3: A - Sulfur oxidised to H_2SO_4 by hot concentrated HNO_3.

Memory Aids

- Pure HNO_3 = Colourless; Yellow = NOx impurities
- Non-metals + hot conc. HNO_3 → highest oxyacids + NO_2
- Common gases: NO_2 evolved in oxidation

Nitric Acid Reactions with Metals

Reaction Patterns

- Acts as acid and strong oxidising agent.
- Reactions depend on nitric acid concentration: very dilute, dilute, concentrated.
- Very dilute HNO_3:
- Mg, Mn → H_2 + metal nitrate
- Fe, Zn, Sn → NH_4NO_3 + metal nitrate
- Dilute HNO_3:
- Pb, Cu, Ag, Hg → NO + metal nitrate
- Fe, Zn → N_2O + metal nitrate
- Sn → NH_4NO_3 + Sn nitrate
- Concentrated HNO_3:
- Zn, Fe, Pb, Cu, Ag → NO_2 + metal nitrate
- Sn → NO_2 + H_2SnO_3 (metastannic acid)

Concentration of nitric acid	Metal	Main products
Very dilute HNO_3	Mg, Mn	H_2 + metal nitrate
	Fe, Zn, Sn	NH_4NO_3 + metal nitrate
Dilute HNO_3	Pb, Cu, Ag, Hg	NO + metal nitrate
	Fe, Zn	N_2O + metal nitrate
	Sn	NH_4NO_3 + $Sn(NO_3)_2$
Conc. HNO_3	Zn, Fe, Pb, Cu, Ag	NO_2 + metal nitrate
	Sn	NO_2 + H_2SnO_3 Metastannic acid

Solved Examples

- **Ex 1:** What gas is evolved when copper reacts with dilute nitric acid?
- Answer: NO gas
- **Ex 2:** Write the product when tin reacts with concentrated nitric acid.
- Answer: NO_2 and H_2SnO_3 (metastannic acid)

Practice Set

- Q1: Which gas is evolved when iron reacts with dilute nitric acid?
- A. H_2 B. NO C. N_2O D. NO_2
- Q2: What is the product when tin reacts with concentrated nitric acid?
- A. NH_4NO_3 B. $NO_2 + H_2SnO_3$ C. NO + Sn nitrate D. N_2O
- Q3: Which metal produces hydrogen gas with very dilute nitric acid?
- A. Fe B. Pb C. Mg D. Cu

Answer Key

- Q1: C - Iron with dilute HNO_3 produces N_2O gas.
- Q2: B - Tin with concentrated HNO_3 forms NO_2 and metastannic acid.
- Q3: C - Magnesium produces H_2 with very dilute nitric acid.

Memory Aids

- Very dilute: Mg, Mn → H_2; Fe, Zn, Sn → NH_4NO_3
- Dilute: Pb, Cu, Ag, Hg → NO; Fe, Zn → N_2O; Sn → NH_4NO_3
- Concentrated: Zn, Fe, Pb, Cu, Ag → NO_2; Sn → $NO_2 + H_2SnO_3$

Brown Ring Test

Test Explanation

- Detects nitrate ion (NO_3^-).
- Reaction: $NO_3^- + 3Fe^{2+} + 4H^+ \rightarrow NO + 3Fe^{3+} + 2H_2O$
- Complex formation: $[Fe(H_2O)_6]^{2+} + NO \rightarrow [Fe(H_2O)_5(NO)]^{2+}$ (brown ring)

Solved Examples

- **Ex 1:** Write the brown ring test reaction.
- Answer: $NO_3^- + 3Fe^{2+} + 4H^+ \rightarrow NO + 3Fe^{3+} + 2H_2O$; $[Fe(H_2O)_6]^{2+} + NO \rightarrow [Fe(H_2O)_5(NO)]^{2+}$

Practice Set

- Q1: What ion does the brown ring test detect?
- A. NO_2^- B. NO_3^- C. NH_4^+ D. NO^+
- Q2: What is the colour of the brown ring?
- A. Blue B. Green C. Brown D. Yellow
- Q3: Which ion reacts with Fe^{2+} in the brown ring test?

- A. NO_3^- B. NO^+ C. NO_2^- D. NH_4^+

Answer Key

- Q1: B - Brown ring test detects nitrate ion (NO_3^-).
- Q2: C - The ring formed is brown in colour.
- Q3: A - NO_3^- ion reacts with Fe^{2+} to form the complex.

Memory Aids

- Brown ring = Nitrate detection
- $Fe^{2+} + NO_3^- + H^+ \rightarrow$ brown complex

Nitrous Acid

Basic Facts

- Formula: HNO_2
- Unstable; exists only in solution.

Solved Examples

- **Ex 1:** State the stability of nitrous acid.
- Answer: Nitrous acid is unstable and exists only in solution.

Practice Set

- Q1: What is the formula of nitrous acid?
- A. HNO_3 B. HNO_2 C. H_2SO_4 D. HCl
- Q2: Nitrous acid is stable in which state?
- A. Solid B. Gas C. Solution D. None
- Q3: Which acid is unstable and exists only in solution?
- A. Nitric acid B. Sulfuric acid C. Nitrous acid D. Hydrochloric acid

Answer Key

- Q1: B - Nitrous acid formula is HNO_2.
- Q2: C - Nitrous acid exists only in solution.
- Q3: C - Nitrous acid is unstable and exists only in solution.

Memory Aids

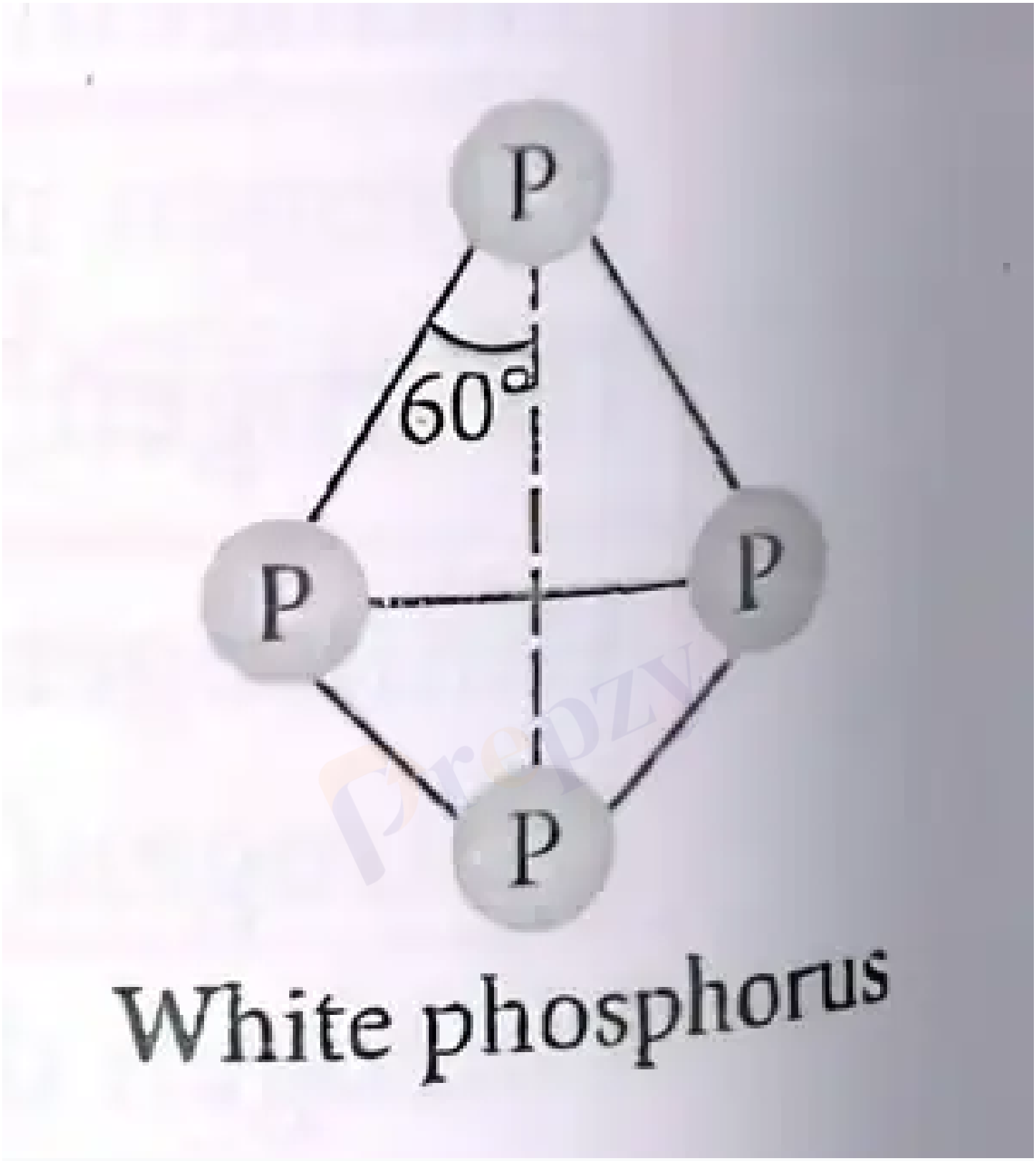
- HNO_2 = Nitrous acid, unstable, solution only

Phosphorus Allotropic Forms

White Phosphorus

- White phosphorus is a white translucent waxy solid, poisonous and insoluble in water but soluble in CS_2.
- It glows in the dark due to chemiluminescence.
- Consists of discrete tetrahedral P_4 molecules with bond angles of 60°, causing angular strain.
- Highly reactive and less stable due to strain in P_4 molecule.
- Reacts with boiling NaOH in inert atmosphere to produce PH_3 and sodium hypophosphite (NaH_2PO_2):
  $P_4 + 3NaOH + 3H_2O \rightarrow PH_3 + 3NaH_2PO_2$
- Catches fire in air forming dense white fumes of P_4O_{10}:
  $P_4 + 5O_2 \rightarrow P_4O_{10}$

Prepzy



Solved Examples

- **Ex 1:** Write the reaction of white phosphorus with boiling NaOH.
  Solution: $P_4 + 3NaOH + 3H_2O \rightarrow PH_3 + 3NaH_2PO_2$

Practice Set

- Q1: What is the molecular shape of white phosphorus?
  A. Linear

B. Tetrahedral
C. Octahedral
D. Planar

- Q2: Which gas is produced when white phosphorus reacts with boiling NaOH?
  A. PH_3
  B. NH_3
  C. H_2S
  D. CO_2
- Q3: What is the product when white phosphorus burns in air?
  A. P_4O_6
  B. P_4O_{10}
  C. P_2O_5
  D. P_2O_3

Answer Key

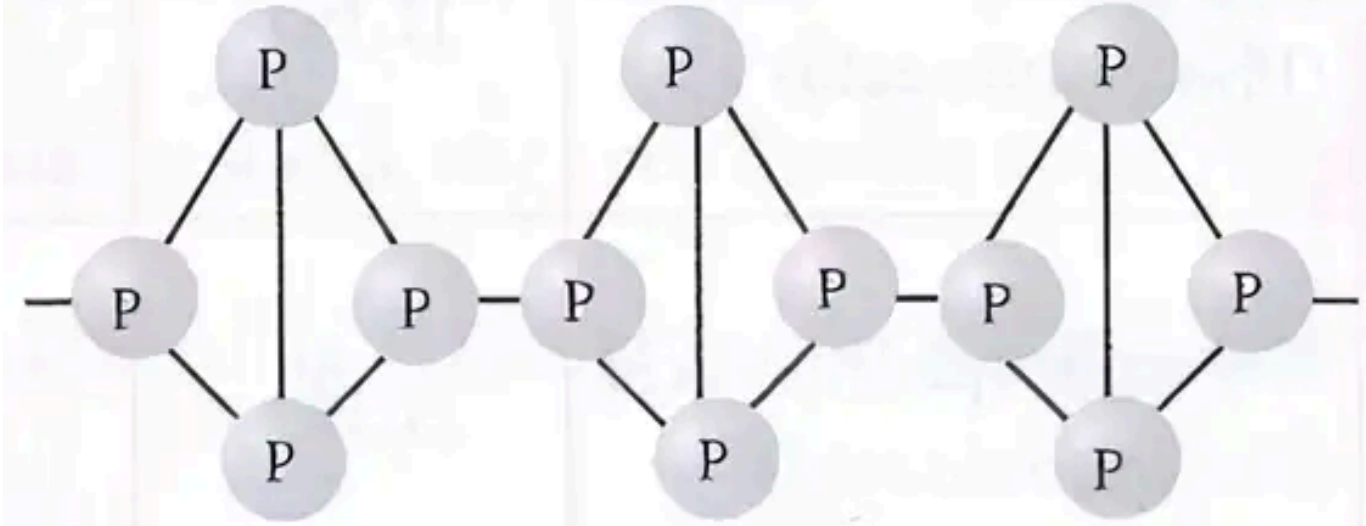
- Q1: B - White phosphorus has a tetrahedral P_4 molecular structure.
- Q2: A - PH_3 (phosphine) is formed when white phosphorus reacts with boiling NaOH.
- Q3: B - Burning white phosphorus produces P_4O_{10} fumes.

Memory Aids

- White phosphorus = P_4 tetrahedron, 60° bond angle, reactive due to strain.
- Burns in air → P_4O_{10} (dense white fumes).
- Reacts with NaOH → PH_3 + sodium hypophosphite.

Red Phosphorus

- Obtained by heating white phosphorus at 573 K in an inert atmosphere for several days.
- Has iron grey lustre, odourless, non-poisonous, insoluble in water and CS_2.
- Less reactive than white phosphorus and does not glow in the dark.
- Polymeric structure consisting of chains of P_4 tetrahedra.
- Heating red phosphorus under high pressure forms black phosphorus phases.



Red phosphorus

Solved Examples

- **Ex 1:** How is red phosphorus prepared?
  Solution: By heating white phosphorus at 573 K in an inert atmosphere for several days.

Practice Set

- Q1: What is the colour of red phosphorus?
  A. White
  B. Iron grey
  C. Black
  D. Yellow
- Q2: Which property distinguishes red phosphorus from white phosphorus?
  A. Poisonous nature
  B. Glows in dark
  C. Odourless and non-poisonous
  D. Soluble in water
- Q3: What happens when red phosphorus is heated under high pressure?
  A. Converts to white phosphorus
  B. Converts to black phosphorus phases
  C. Burns to P_4O_{10}
  D. Dissolves in CS_2

Answer Key

- Q1: B - Red phosphorus has an iron grey lustre.
- Q2: C - Red phosphorus is odourless and non-poisonous unlike white phosphorus.
- Q3: B - Heating red phosphorus under high pressure forms black phosphorus phases.

Memory Aids

- Red phosphorus = polymeric chains, less reactive, no glow.
- Heated white P at 573 K → red P.
- High pressure + heat on red P → black P phases.

Black Phosphorus

- Exists in two forms: α-black and β-black phosphorus.
- α-black phosphorus: formed by heating red phosphorus at 803 K in a sealed tube.
- Has opaque monoclinic or rhombohedral crystals, can sublime in air, and does not oxidise in air.
- β-black phosphorus: prepared by heating white phosphorus at 473 K under high pressure.
- Does not burn in air up to 673 K and has a layered structure.

Solved Examples

- **Ex 1:** How is α-black phosphorus prepared?
  Solution: By heating red phosphorus at 803 K in a sealed tube.
- **Ex 2:** How is β-black phosphorus prepared?
  Solution: By heating white phosphorus at 473 K under high pressure.

Practice Set

- Q1: Which form of black phosphorus is formed by heating red phosphorus at 803 K?
  A. α-black phosphorus
  B. β-black phosphorus
  C. White phosphorus
  D. Red phosphorus
- Q2: What is a key property of β-black phosphorus?
  A. Burns easily in air
  B. Layered structure and does not burn up to 673 K
  C. Glows in dark
  D. Soluble in water
- Q3: Which statement is true about α-black phosphorus?
  A. It oxidises easily in air
  B. It has rhombohedral crystals and can sublime in air
  C. It is highly reactive
  D. It is soluble in CS_2

Answer Key

- Q1: A - α-black phosphorus is formed by heating red phosphorus at 803 K.
- Q2: B - β-black phosphorus has a layered structure and does not burn up to 673 K.
- Q3: B - α-black phosphorus has rhombohedral crystals and can sublime in air without oxidising.

Memory Aids

- α-black P: from red P at 803 K, rhombohedral, stable in air.
- β-black P: from white P at 473 K + high pressure, layered, non-flammable up to 673 K.

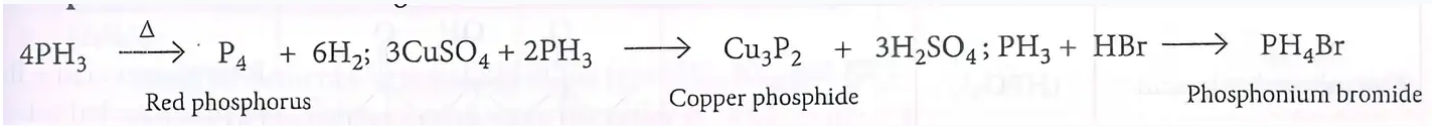
Phosphine

Preparation

- $Ca_3P_2 + 6H_2O \rightarrow 3Ca(OH)_2 + 2PH_3$
- $Ca_3P_2 + 6HCl \rightarrow 3CaCl_2 + 2PH_3$
- $PH_4I + KOH \rightarrow KI + H_2O + PH_3$
- $P_4 + 3NaOH + 3H_2O \rightarrow 3NaH_2PO_2 + PH_3$

Properties

- Colourless gas with a rotten fish smell
- Highly poisonous
- Reacts with anhydrous HX (HCl, HBr, HI) but not with aqueous HX
- Phosphonium halides formed with aqueous HX decompose to give back PH_3



Reactions

- On heating (Δ), PH_3 decomposes to red phosphorus (P_4) and hydrogen gas (H_2)
- $PH_3 + CuSO_4 \rightarrow Cu_3P_2 + H_2SO_4$
- $PH_3 + HBr \rightarrow PH_4Br$ (phosphonium bromide)

Solved Examples

- **Ex 1:** Write the reaction of Ca_3P_2 with water.
  - $Ca_3P_2 + 6H_2O \rightarrow 3Ca(OH)_2 + 2PH_3$
- **Ex 2:** What happens when PH_3 is heated?
  - $PH_3 \rightarrow P_4 + H_2$ (on heating)

Practice Set

- **Q1:** Which gas is produced when Ca_3P_2 reacts with water?
  - A. NH_3
  - B. PH_3
  - C. H_2S
  - D. CO_2
- **Q2:** Phosphine reacts with which of the following to form phosphonium halide?
  - A. Aqueous HCl
  - B. Anhydrous HBr
  - C. Water
  - D. NaOH
- **Q3:** On heating, phosphine decomposes to form:
  - A. White phosphorus and oxygen
  - B. Red phosphorus and hydrogen
  - C. Phosphorus pentoxide and water
  - D. Phosphoric acid and hydrogen

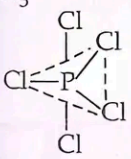
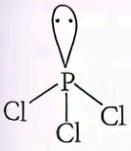
Answer Key

- **Q1:** B. PH_3 - Ca_3P_2 reacts with water to produce phosphine gas.
- **Q2:** B. Anhydrous HBr - Phosphine reacts with anhydrous HX to form phosphonium halides.
- **Q3:** B. Red phosphorus and hydrogen - PH_3 decomposes on heating to red phosphorus and hydrogen gas.

Memory Aids

- PH_3 smells like rotten fish and is highly poisonous.
- Phosphine reacts only with anhydrous HX, not aqueous HX.
- Heating PH_3 gives red phosphorus + H_2.

Phosphorus Halides

Compound	Preparation	Properties	Uses
PCl_5 	$P_4 + 10Cl_2 \rightarrow 4PCl_5$ (white or red) $P_4 + 10\ SO_2Cl_2 \rightarrow 4PCl_5 + 10SO_2$	$PCl_5 + 4H_2O$ (excess) $\rightarrow H_3PO_4 + 5HCl$ $PCl_5 + SO_2 \rightarrow SOCl_2 + POCl_3$ $6PCl_5 + P_4O_{10} \rightarrow 10POCl_3$ $PCl_5 + Zn \rightarrow ZnCl_2 + PCl_3$	Used as chlorinating and dehydrating agent.
PCl_3 	$P_4 + 6Cl_2 \rightarrow 4PCl_3$ $P_4 + 8SOCl_2 \rightarrow 4PCl_3 + 4SO_2 + 2S_2Cl_2$	$PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3HCl$ $3CH_3COOH + PCl_3 \rightarrow 3CH_3COCl + H_3PO_3$ $3C_2H_5OH + PCl_3 \rightarrow 3C_2H_5Cl + H_3PO_3$	Used as reagent in organic synthesis and as a precursor of PCl_5, $POCl_3$ and $PSCl_3$.

Chemical Structures

- PCl_3: Phosphorus bonded to three chlorine atoms, trigonal pyramidal shape.
- PCl_5: Phosphorus bonded to five chlorine atoms, trigonal bipyramidal shape.

Preparation

- PCl_3: Prepared by direct reaction of white phosphorus (P_4) with chlorine gas (Cl_2) in limited amount.
  - $P_4 + 6Cl_2 \rightarrow 4PCl_3$
- PCl_5: Prepared by chlorination of PCl_3 or direct reaction of P_4 with excess chlorine.
  - $PCl_3 + Cl_2 \rightarrow PCl_5$
  - $P_4 + 10Cl_2 \rightarrow 4PCl_5$

Chemical Properties

- Hydrolysis:
  - $PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3HCl$
  - $PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$
- Reaction with SO_2:
  - $PCl_5 + SO_2 \rightarrow POCl_3 + SOCl_2$
- Reaction with Zn:

- $PCl_5 + 2Zn \rightarrow 2ZnCl_2 + P$
- Organic reactions:
  - PCl_3 used to prepare organophosphorus compounds.

Uses

- PCl_5: Chlorinating and dehydrating agent.
- PCl_3: Used in organic synthesis and preparation of other phosphorus compounds.

Solved Examples

Ex 1: Write the reaction for preparation of PCl_3 from phosphorus and chlorine.

- Step 1: React P_4 with Cl_2 in limited amount.
- Step 2: $P_4 + 6Cl_2 \rightarrow 4PCl_3$

Ex 2: Show hydrolysis of PCl_5.

- Step 1: Add water to PCl_5.
- Step 2: $PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

Practice Set

- **Q1:** What is the shape of PCl_5 molecule?
  - A. Tetrahedral
  - B. Trigonal bipyramidal
  - C. Octahedral
  - D. Trigonal pyramidal
- **Q2:** Which reagent is used to prepare PCl_3 from white phosphorus?
  - A. Cl_2 (limited)
  - B. Cl_2 (excess)
  - C. SO_2
  - D. Zn
- **Q3:** What is the product when PCl_5 reacts with SO_2?
  - A. H_3PO_4
  - B. $POCl_3$ and $SOCl_2$
  - C. PCl_3 and Cl_2
  - D. $ZnCl_2$

Answer Key

- **Q1:** B - PCl_5 has trigonal bipyramidal shape due to five bonded chlorine atoms.
- **Q2:** A - Limited Cl_2 reacts with P_4 to form PCl_3.
- **Q3:** B - PCl_5 reacts with SO_2 to give $POCl_3$ and $SOCl_2$.

Memory Aids

- PCl_3 = 3 Cl atoms, trigonal pyramidal shape.

- PCl_5 = 5 Cl atoms, trigonal bipyramidal shape.
- $PCl_3 + Cl_2 \rightarrow PCl_5$ (chlorination step).
- PCl_5 hydrolyzes to H_3PO_4, PCl_3 hydrolyzes to H_3PO_3.

Oxoacids of Phosphorus

Overview

- Oxoacids of phosphorus contain phosphorus, oxygen, and hydrogen.
- Phosphorus exhibits different oxidation states in these acids: +3 and +5.
- Common oxoacids include phosphorous acid (H_3PO_3), phosphoric acid (H_3PO_4), and others.
- Structures vary: some have P=O bonds, others have P–OH groups.
- Preparation methods include hydrolysis of phosphorus halides and oxidation of phosphorus compounds.

Solved Examples

- **Ex 1:** Write the formula and oxidation state of phosphorus in phosphorous acid.
  - Formula: H_3PO_3
  - Oxidation state of P: +3
- **Ex 2:** How is phosphoric acid prepared from P_4O_{10}?
  - $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$

Practice Set

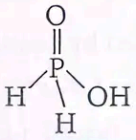
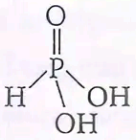
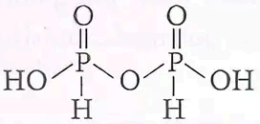
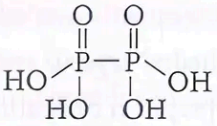
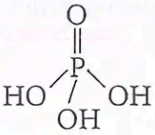
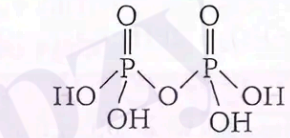
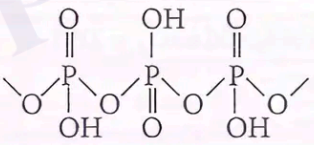
- **Q1:** What is the oxidation state of phosphorus in H_3PO_4?
  - A. +3
  - B. +4
  - C. +5
  - D. +2
- **Q2:** Which acid is prepared by hydrolysis of PCl_3?
  - A. H_3PO_4
  - B. H_3PO_3
  - C. H_3PO_2
  - D. $H_4P_2O_7$
- **Q3:** Which of the following has phosphorus in +3 oxidation state?
  - A. H_3PO_4
  - B. H_3PO_3
  - C. H_3PO_2
  - D. $H_4P_2O_7$

Answer Key

- **Q1:** C. +5 — Phosphorus in phosphoric acid is in +5 oxidation state.
- **Q2:** B. H_3PO_3 — Hydrolysis of PCl_3 gives phosphorous acid.
- **Q3:** B. H_3PO_3 — Phosphorous acid has P in +3 oxidation state.

Memory Aids

- Phosphorous acid (H_3PO_3) has P in +3 state; phosphoric acid (H_3PO_4) has P in +5 state.
- Hydrolysis of $PCl_3 \rightarrow H_3PO_3$; $PCl_5 \rightarrow H_3PO_4$.
- Remember: "-ous" acids have lower oxidation state than "-ic" acids.

Name	Formula	Oxidation state of phosphorus	Structure	Preparation
Hypophosphorous acid (Phosphinic acid)	H_3PO_2	+1		White P_4 + alkali
Orthophosphorous acid (Phosphonic acid)	H_3PO_3	+3		$P_2O_3 + H_2O$
Pyrophosphorous acid	$H_4P_2O_5$	+3		$PCl_3 + H_3PO_3$
Hypophosphoric acid	$H_4P_2O_6$	+4		Red P_4 + alkali
Orthophosphoric acid	H_3PO_4	+5		$P_4O_{10} + H_2O$
Pyrophosphoric acid	$H_4P_2O_7$	+5		Phosphoric acid + heat
Metaphosphoric acid	$(HPO_3)_n$	+5		Phosphorus acid + Br_2, heat in a sealed tube

Group 16 Elements

Overview

- Elements: Oxygen (O), Sulphur (S), Selenium (Se), Tellurium (Te), Polonium (Po), Livermorium (Lv).
- Also called chalcogens.
- Livermorium is synthetic, radioactive, very short half-life, limited study.
- General electronic configuration: ns^2np^4.

Element	Symbol	At. No.	Electronic configuration
Oxygen	O	8	$[He]\ 2s^2\ 2p^4$
Sulphur	S	16	$[Ne]\ 3s^2\ 3p^4$
Selenium	Se	34	$[Ar]\ 3d^{10}\ 4s^2\ 4p^4$
Tellurium	Te	52	$[Kr]\ 4d^{10}\ 5s^2\ 5p^4$
Polonium	Po	84	$[Xe]\ 4f^{14}\ 5d^{10}\ 6s^2\ 6p^4$
Livermorium	Lv	116	$[Rn]\ 5f^{14}6d^{10}7s^27p^4$

Physical Properties

- Atomic and ionic radii increase down the group.
- Ionization enthalpy decreases down the group; lower than group 15 due to half-filled p-subshell stability in group 15.
- Electronegativity decreases down the group.
- Electron gain enthalpy: O less negative than S due to small size; from S to Po, becomes less negative.
- Melting and boiling points increase down to Te; Po has lower m.pt. and b.pt. than Te.
- Elemental states: O_2 is diatomic (pπ-pπ multiple bonding); S, Se, Te are octa-atomic due to absence of pπ-pπ bonding.
- All elements exhibit allotropy.

Chemical Properties

- Oxidation states: O shows -2, -1, -1/2, 0, +1, +2; others show -2, +2, +4, +6.
- Stability of -2 state decreases down the group (decreasing electronegativity).
- +4 state stability increases; +6 state stability decreases due to inert pair effect.

Hydrides

- General formula: H_2E.
- Physical state: H_2O is liquid; others are gases.
- Boiling points: $H_2S < H_2Se < H_2Te < H_2O$.
- Bond angles: $H_2O > H_2S > H_2Se > H_2Te$.
- Reducing power: $H_2Te > H_2Se > H_2S > H_2O$.
- Acidic character: $H_2O < H_2S < H_2Se < H_2Te$.
- Thermal stability: $H_2O > H_2S > H_2Se > H_2Te$.

Oxides

- Form EO_2 and EO_3 types.
- Both types are acidic.
- Reducing property decreases from SO_2 to TeO_2.

Halides

- Form EX_6, EX_4, and EX_2 types.

- Halide stability order: $F^- > Cl^- > Br^- > I^-$.
- Only hexafluorides are stable with octahedral geometry.
- Tetrafluorides: SF_4 (gas), SeF_4 (liquid), TeF_4 (solid); trigonal bipyramidal structure.
- Dihalides have tetrahedral structure.
- Monohalides exist as dimers.

Solved Examples

- **Ex 1:** Write electronic configuration of Se.
  Solution: [Ar] $3d^{10}\ 4s^2\ 4p^4$.
- **Ex 2:** Arrange H_2S, H_2O, H_2Se in order of increasing boiling point.
  Solution: $H_2S < H_2Se < H_2O$.
- **Ex 3:** Identify oxidation states of oxygen in H_2O_2 and O_2.
  Solution: H_2O_2: -1; O_2: 0.

Practice Set

- **Q1:** Which element is not a chalcogen?
  A. Oxygen
  B. Sulphur
  C. Nitrogen
  D. Selenium
- **Q2:** Which hydride has the highest boiling point?
  A. H_2S
  B. H_2Se
  C. H_2Te
  D. H_2O
- **Q3:** Which halide of group 16 elements is most stable?
  A. EX_2
  B. EX_4
  C. EX_6 (hexafluoride)
  D. Monohalide

Answer Key

- **Q1:** C. Nitrogen is in group 15, not group 16.
- **Q2:** D. H_2O has highest boiling point due to hydrogen bonding.
- **Q3:** C. Hexafluorides (EX_6) are most stable with octahedral structure.

Memory Aids

- Chalcogens: O, S, Se, Te, Po, Lv (Livermorium synthetic).
- Hydrides boiling point: $H_2S < H_2Se < H_2Te < H_2O$.
- Halide stability: $F^- > Cl^- > Br^- > I^-$.
- Oxidation states: O (-2 to +2), others (-2, +2, +4, +6).

Dioxygen Preparation

Methods of Preparation

- Heating oxo salts like chlorates, nitrates, and permanganates in the lab.

- Example: Decomposition of potassium chlorate ($KClO_3$) with MnO_2 catalyst:
  - $KClO_3$ □123 K □12B MnO_2 □12B heat □12B $KCl + O_2$
  - MnO_2 lowers melting point and speeds reaction (ratio 1:4 with $KClO_3$).
  - MnO_2 must be carbon-free to avoid explosion with $KClO_3$.
- Thermal decomposition of heavy metal oxides:
  - Metal oxides decompose on heating to metal + O_2 (e.g., HgO, Ag_2O, PbO_2).
- Decomposition of hydrogen peroxide (H_2O_2) using MnO_2 catalyst:
  - $2H_2O_2$ □12B MnO_2 □12B $2H_2O + O_2$
- Large scale: Electrolysis of water:
  - $2H_2O$ □12B $2H^+ + 2OH^-$
  - Cathode: $2H^+ + 2e^-$ □12B H_2 (byproduct)
  - Anode: $4OH^-$ □12B $2H_2O + O_2 + 4e^-$

$$2KClO_3 \xrightarrow[\Delta]{MnO_2} 2KCl + 3O_{2(g)}$$

$$2HgO_{(s)} \xrightarrow{\Delta} 2Hg_{(l)} + O_{2(g)} \quad ; \quad 2Pb_3O_{4(s)} \xrightarrow{\Delta} 6PbO_{(s)} + O_{2(g)} \quad ; \quad 2PbO_{2(s)} \longrightarrow 2PbO_{(s)} + O_{2(g)} \quad ;$$
$$2Ag_2O_{(s)} \xrightarrow{\Delta} 4Ag_{(s)} + O_{2(g)}$$

$$2H_2O_{2(aq)} \xrightarrow{MnO_2} 2H_2O_{(l)} + O_{2(g)}$$

Solved Examples

- **Ex 1:** Write the reaction for oxygen preparation from potassium chlorate.
  - $KClO_3$ □12B MnO_2 □12B heat □12B $KCl + O_2$
- **Ex 2:** Write the reaction for oxygen preparation by decomposition of mercury oxide.
  - 2HgO □12B heat □12B $2Hg + O_2$
- **Ex 3:** Write the reaction for oxygen preparation from hydrogen peroxide using MnO_2.
  - $2H_2O_2$ □12B MnO_2 □12B $2H_2O + O_2$

Practice Set

- Q1: Which catalyst is used in the decomposition of potassium chlorate to produce oxygen?
  - A. MnO_2
  - B. Fe_2O_3
  - C. CuO
  - D. ZnO
- Q2: What is the product formed when mercury oxide decomposes on heating?
  - A. HgO and O_2
  - B. Hg and O_2
  - C. Hg and H_2O
  - D. HgO and H_2O
- Q3: In the electrolysis of water, what gas is produced at the cathode?
  - A. O_2
  - B. H_2
  - C. CO_2
  - D. Cl_2

Answer Key

- Q1: A. MnO_2 - It acts as a catalyst in $KClO_3$ decomposition.
- Q2: B. Hg and O_2 - Mercury oxide decomposes to mercury metal and oxygen gas.
- Q3: B. H_2 - Hydrogen gas is produced at the cathode during water electrolysis.

Memory Aids

- MnO_2 lowers $KClO_3$ melting point and speeds oxygen release.
- Heavy metal oxides decompose to metal + O_2 on heating.
- H_2O_2 decomposes faster with MnO_2 catalyst.
- Electrolysis: Cathode produces H_2, Anode produces O_2.

Dioxygen Physical Properties

Key Physical Properties

- Colourless, odourless, tasteless gas.
- Paramagnetic due to 2 unpaired electrons in antibonding molecular orbitals.

Solved Examples

- **Ex 1:** Why is O_2 paramagnetic?
  - Because it has 2 unpaired electrons in antibonding orbitals.

Practice Set

- Q1: What is the colour of dioxygen gas?
  - A. Colourless
  - B. Blue
  - C. Green
  - D. Yellow
- Q2: Why is dioxygen paramagnetic?
  - A. No unpaired electrons
  - B. 2 unpaired electrons in antibonding orbitals
  - C. Paired electrons only
  - D. It is diamagnetic
- Q3: Which property is NOT true for dioxygen?
  - A. Odourless
  - B. Tasteless
  - C. Colored
  - D. Paramagnetic

Answer Key

- Q1: A. Colourless - Dioxygen is colourless gas.
- Q2: B. 2 unpaired electrons in antibonding orbitals - This causes paramagnetism.
- Q3: C. Colored - Dioxygen is colourless, so this is false.

Memory Aids

- O_2 is paramagnetic due to 2 unpaired electrons.
- Colourless, odourless, tasteless gas.

Dioxygen Chemical Properties

Reactions and Behavior

- Reacts with all metals except noble metals (Au, Pt).
- Reacts with non-metals and some noble gases.
- Forms oxides:
  - Ca + O_2 □ CaO (basic oxide)
  - Al + O_2 □ Al_2O_3 (amphoteric oxide)
  - P + O_2 □ P_4O_{10} (acidic oxide)
  - C + O_2 □ CO_2 (acidic oxide)
- Roasting of zinc sulfide:
  - $2ZnS + 3O_2$ □ $2ZnO + 2SO_2$
- Combustion of methane:
  - $CH_4 + 2O_2$ □ $CO_2 + 2H_2O$
- Catalytic oxidation:
  - $2SO_2 + O_2$ □ $2SO_3$ (V_2O_5 catalyst)
  - $4HCl + O_2$ □ $2Cl_2 + 2H_2O$ ($CuCl_2$ catalyst)

$$2Ca + O_2 \longrightarrow 2CaO \quad \text{(Basic oxide)}$$
$$4Al + 3O_2 \longrightarrow 2Al_2O_3 \quad \text{(Amphoteric oxide)}$$
$$P_4 + 5O_2 \longrightarrow P_4O_{10} \quad \text{(Acidic oxide)}$$
$$C + O_2 \longrightarrow CO_2 \quad \text{(Acidic oxide)}$$
$$2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2 \quad \text{(Roasting)}$$
$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O \quad \text{(Combustion)}$$
$$2SO_2 + O_2 \xrightarrow{V_2O_5} 2SO_3 \quad \text{(Catalytic oxidation)}$$
$$4HCl + O_2 \xrightarrow{CuCl_2} 2Cl_2 + 2H_2O \quad \text{(Catalytic oxidation)}$$

Solved Examples

- **Ex 1:** Write the reaction of calcium with oxygen.
  - $2Ca + O_2$ □ $2CaO$
- **Ex 2:** Write the catalytic oxidation of sulfur dioxide.
  - $2SO_2 + O_2$ □ $2SO_3$ (V_2O_5 catalyst)

Practice Set

- Q1: Which metal does NOT react with oxygen?
  - A. Calcium
  - B. Gold

    - C. Aluminum
    - D. Zinc
- Q2: What type of oxide is Al_2O_3?
    - A. Basic
    - B. Acidic
    - C. Amphoteric
    - D. Neutral
- Q3: Which catalyst is used in the oxidation of SO_2 to SO_3?
    - A. $CuCl_2$
    - B. V_2O_5
    - C. MnO_2
    - D. Fe_2O_3

Answer Key

- Q1: B. Gold - Noble metals like Au do not react with oxygen.
- Q2: C. Amphoteric - Al_2O_3 reacts with acids and bases.
- Q3: B. V_2O_5 - Catalyst for SO_2 oxidation to SO_3.

Memory Aids

- Oxygen reacts with all metals except Au, Pt.
- Al_2O_3 is amphoteric oxide.
- V_2O_5 catalyzes SO_2 oxidation.

Simple Oxides

Classification of Oxides (Based on Chemical Behaviour)

- Oxides are compounds of oxygen with another element.
- Simple oxides contain one metal + oxygen (e.g., MgO).
- Mixed oxides contain two or more metals + oxygen (e.g., Pb_3O_4).
- Acidic oxides react with water to form acids (e.g., SO_2).
- Basic oxides react with acids to form salts (e.g., Na_2O).
- Amphoteric oxides react with both acids and bases (e.g., Al_2O_3).
- Neutral oxides do not react with acids or bases (e.g., CO).

Simple oxides	MgO, Al_2O_3
Mixed oxides	Pb_3O_4, Fe_3O_4
Acidic oxides	SO_2, Cl_2O_7, CO_2, N_2O_5
Basic oxides	Na_2O, CaO, BaO
Amphoteric oxides	Al_2O_3
Neutral oxides	CO, NO, N_2O

Acidic Oxides

- Dissolve in water forming acids.
- Examples:
  - $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$
  - $N_2O_5 + H_2O \rightarrow 2HNO_3$
  - $2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$
  - $P_4O_6 + 6H_2O \rightarrow 4H_3PO_3$
- Acidic strength order:
  - Dioxides: $SO_2 > SeO_2 > TeO_2 > PoO_2$
  - Trioxides: $SO_3 > SeO_3 > TeO_3$

Basic Oxides

- Dissolve in water forming bases.
- Examples:
  - $Na_2O + H_2O \rightarrow 2NaOH$
  - $K_2O + H_2O \rightarrow 2KOH$
  - $CaO + H_2O \rightarrow Ca(OH)_2$

Amphoteric Oxides

- React with both acids and bases.
- Examples:
  - $Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$
  - $Al_2O_3 + 6NaOH + 3H_2O \rightarrow 2Na_3[Al(OH)_6]$
  - $Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$ (Sodium aluminate)

Solved Examples

- **Ex 1:** Write the reaction of P_4O_{10} with water.
  - $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$
- **Ex 2:** Reaction of Al_2O_3 with NaOH.
  - $Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$

Practice Set

- **Q1:** Which oxide is amphoteric?
  - A. SO_2
  - B. Al_2O_3
  - C. Na_2O
  - D. CO
- **Q2:** What is the product when Na_2O reacts with water?
  - A. NaOH
  - B. NaCl
  - C. Na_2CO_3
  - D. $NaAlO_2$
- **Q3:** Which oxide forms HNO_3 on reaction with water?
  - A. N_2O_5
  - B. CO
  - C. CaO

- D. Pb_3O_4

Answer Key

- **Q1:** B - Al_2O_3 is amphoteric, reacting with both acids and bases.
- **Q2:** A - $Na_2O + H_2O$ forms NaOH, a base.
- **Q3:** A - N_2O_5 reacts with water to form nitric acid (HNO_3).

Memory Aids

- Acidic oxides form acids with water; basic oxides form bases.
- Amphoteric oxides react with both acids and bases (e.g., Al_2O_3).
- Order of acidic strength: $SO_2 > SeO_2 > TeO_2$.
- Remember sodium aluminate: $Al_2O_3 + NaOH \rightarrow NaAlO_2$.

Ozone

Preparation

- Ozone (O_3) is prepared by electric discharge through oxygen gas (O_2).
- Electric discharge breaks O_2 molecules into oxygen atoms.
- Oxygen atoms recombine to form ozone molecules.
- Chemical equation: $3O_2 \xrightarrow{electric discharge} 2O_3$

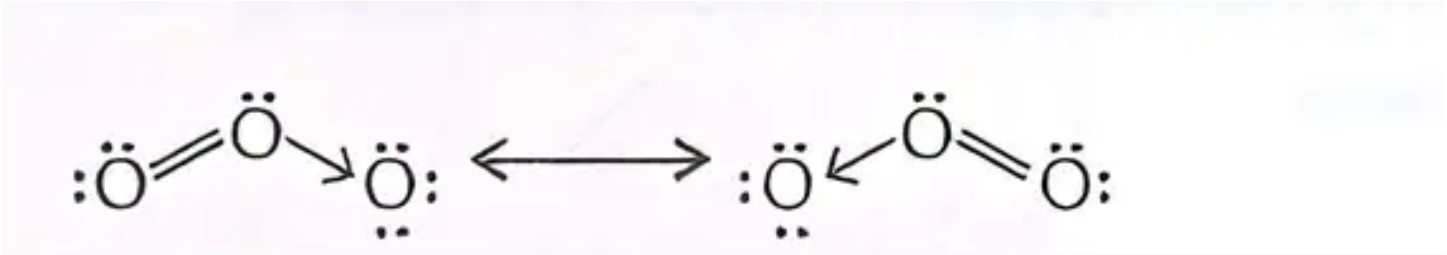


Properties

- Ozone is pale blue gas, dark blue liquid, and violet-black solid.
- Decomposes to oxygen: $O_3 \rightarrow O_2 + O$
- Acts as a strong oxidizing agent: $PbS + 4O_3 \rightarrow PbSO_4 + 4O_2$
- Acts as a reducing agent: $2I^- + H_2O + O_3 \rightarrow 2OH^- + I_2 + O_2$
- Used for estimation of ozone by titrating I_2 with sodium thiosulphate.
- Reacts with nitric oxide: $NO + O_3 \rightarrow NO_2 + O_2$

Structure

- Central oxygen atom in ozone has sp^2 hybridisation.
- Ozone molecule has an angular shape.
- Ozone is a resonance hybrid of two structures with equal O–O bond lengths (128 pm).



Solved Examples

- **Ex 1:** Write the reaction for ozone preparation by electric discharge.
  - $3O_2 \xrightarrow{\text{electric discharge}} 2O_3$
- **Ex 2:** Show ozone acting as an oxidizing agent with PbS.
  - $PbS + 4O_3 \rightarrow PbSO_4 + 4O_2$

Practice Set

- **Q1:** What is the hybridisation of the central oxygen atom in ozone?
  - A. sp
  - B. sp^2
  - C. sp^3
  - D. sp^3d
- **Q2:** Which of the following reactions shows ozone acting as a reducing agent?
  - A. $PbS + 4O_3 \rightarrow PbSO_4 + 4O_2$
  - B. $2I^- + H_2O + O_3 \rightarrow 2OH^- + I_2 + O_2$
  - C. $NO + O_3 \rightarrow NO_2 + O_2$
  - D. $O_3 \rightarrow O_2 + O$
- **Q3:** How many ozone molecules are formed when 3 molecules of oxygen gas undergo electric discharge?
  - A. 1
  - B. 2
  - C. 3
  - D. 6

Answer Key

- **Q1:** B. sp^2 — Central oxygen in ozone is sp^2 hybridised.
- **Q2:** B. $2I^- + H_2O + O_3 \rightarrow 2OH^- + I_2 + O_2$ — Ozone acts as reducing agent here.
- **Q3:** B. 2 — 3 O_2 molecules produce 2 O_3 molecules by electric discharge.

Memory Aids

- Ozone preparation: "3 O_2 to 2 O_3" by electric discharge.
- Ozone is both oxidizing and reducing agent.
- Ozone structure: Resonance hybrid with equal bond lengths, angular shape, sp^2 hybridisation.

Sulphur Allotropic Forms

Rhombic Sulphur (α-sulphur)

- Consists of S_8 molecules, yellow in color.
- Melting point: 385.8 K; Specific gravity: 2.06.

- Crystals formed by evaporating solution of roll sulphur in CS_2.
- Insoluble in water; slightly soluble in benzene, alcohol, and ether.
- Readily soluble in CS_2.

Monoclinic Sulphur (β-sulphur)

- Also consists of S_8 molecules, colorless needle-shaped crystals.
- Melting point: 393 K; Specific gravity: 1.98.
- Soluble in CS_2.

Structural Details

- S_8 ring in both rhombic and monoclinic sulphur is puckered and crown-shaped.
- Cyclo S_6 ring has a chair form.

Hydrogen Sulphide (H_2S)

- Also called sulphurated hydrogen.
- Poisonous and fatal in large amounts.
- Antidote: Dilute chlorine oxidizes H_2S to sulphur.
- Reaction: $H_2S + Cl_2 \rightarrow 2HCl + S$

Solved Examples

- **Ex 1:** Identify the allotrope of sulphur with melting point 385.8 K.
  Answer: Rhombic sulphur (α-sulphur).
- **Ex 2:** Write the reaction of H_2S with chlorine.
  Answer: $H_2S + Cl_2 \rightarrow 2HCl + S$.

Practice Set

- **Q1:** Which allotrope of sulphur has yellow color and S_8 molecules?
  A. Monoclinic sulphur
  B. Rhombic sulphur
  C. Cyclo S_6
  D. None of these
- **Q2:** What is the melting point of monoclinic sulphur?
  A. 385.8 K
  B. 393 K
  C. 400 K
  D. 350 K
- **Q3:** What is the product formed when H_2S reacts with chlorine?
  A. HCl and S
  B. H_2SO_4
  C. SO_2 and H_2O
  D. H_2SO_3

Answer Key

- **Q1:** B - Rhombic sulphur is yellow and contains S_8 molecules.

- **Q2:** B - Monoclinic sulphur melts at 393 K.
- **Q3:** A - H_2S reacts with Cl_2 to form HCl and sulphur.

Memory Aids

- Rhombic sulphur = Yellow, S_8, melts at 385.8 K.
- Monoclinic sulphur = Colorless needles, melts at 393 K.
- $H_2S + Cl_2 \rightarrow 2HCl + S$ (Dilute chlorine antidote reaction).

Sulphur Dioxide

Preparation

- Direct combination: $S + O_2 \rightarrow SO_2$
- Lab method: $SO_3^{2-} + 2H^+ \rightarrow H_2O + SO_2$
- Roasting of sulphide ores: $4FeS_2 + 11O_2 \rightarrow 2Fe_2O_3 + 8SO_2$

Physical Properties

- Colourless gas with pungent smell
- Highly soluble in water
- Liquefies at room temperature at 2 atm pressure
- Boiling point: 263 K

Chemical Properties

- Reacts with water to form sulfurous acid: $SO_2 + H_2O \rightarrow H_2SO_3$
- Reacts with NaOH to form sodium sulfite: $SO_2 + 2NaOH \rightarrow Na_2SO_3 + H_2O$
- Sodium sulfite reacts with SO_2 and water to form sodium bisulfite: $Na_2SO_3 + SO_2 + H_2O \rightarrow 2NaHSO_3$
- Reacts with chlorine to form sulfuryl chloride: $SO_2 + Cl_2 \rightarrow SO_2Cl_2$
- Oxidation to sulfur trioxide in presence of V_2O_5 catalyst: $2SO_2 + O_2 \rightarrow 2SO_3$

$$SO_2 + H_2O \rightleftharpoons H_2SO_3 \quad ; \quad 2NaOH + SO_2 \longrightarrow Na_2SO_3 + H_2O$$
$$Na_2SO_3 + H_2O + SO_2 \longrightarrow 2NaHSO_3 \quad ; \quad SO_2 + Cl_2 \longrightarrow SO_2Cl_2 \quad ; \quad 2SO_2 + O_2 \xrightarrow{V_2O_5} 2SO_3$$

Bleaching Action

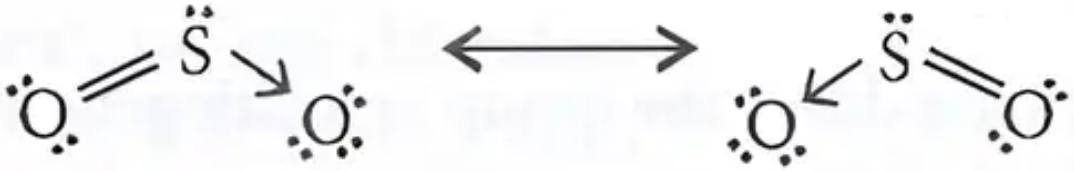
- $SO_2 + 2H_2O \rightarrow H_2SO_4 + 2[H]$
- Coloured matter + [H] → Colourless matter (reduction of dyes)

Reducing Nature

- $2Fe^{3+} + SO_2 + 2H_2O \rightarrow 2Fe^{2+} + SO_3^{2-} + 4H^+$
- $5SO_2 + 2MnO_4^- + 2H_2O \rightarrow 5SO_4^{2-} + 4H^+ + 2Mn^{2+}$

Structure

- SO_2 molecule is angular (bent shape)
- Resonance hybrid of two canonical forms with alternating double and single bonds
- Lone pairs on sulfur and oxygen atoms contribute to resonance



Solved Examples

- **Ex 1:** Write the reaction for lab preparation of SO_2.
  Solution: $SO_3^{2-} + 2H^+ \rightarrow H_2O + SO_2$
- **Ex 2:** Show the reaction of SO_2 with NaOH.
  Solution: $SO_2 + 2NaOH \rightarrow Na_2SO_3 + H_2O$

Practice Set

- **Q1:** Which of the following is a method to prepare SO_2?
  A. $S + O_2 \rightarrow SO_2$
  B. $H_2 + O_2 \rightarrow H_2O$
  C. $CO + O_2 \rightarrow CO_2$
  D. $N_2 + O_2 \rightarrow NO$
- **Q2:** SO_2 reacts with NaOH to form:
  A. $NaHSO_3$
  B. Na_2SO_3
  C. Na_2SO_4
  D. Na_2SO_2
- **Q3:** Which catalyst is used for oxidation of SO_2 to SO_3?
  A. V_2O_5
  B. Fe_2O_3
  C. MnO_2
  D. Al_2O_3

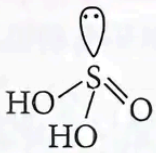
Answer Key

- **Q1:** A - Direct combination of sulfur and oxygen forms SO_2.
- **Q2:** B - SO_2 reacts with NaOH to form sodium sulfite (Na_2SO_3).
- **Q3:** A - Vanadium pentoxide (V_2O_5) is the catalyst for SO_2 oxidation.

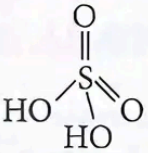
Memory Aids

- SO_2 preparation: $S + O_2$ direct combination
- Bleaching action due to reduction by SO_2
- SO_2 is a reducing agent in acidic medium
- Structure: Angular molecule with resonance forms

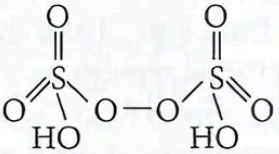
Oxoacids of Sulphur



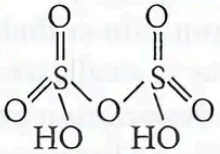
H_2SO_3
Sulphurous acid



H_2SO_4
Sulphuric acid



$H_2S_2O_8$
Peroxodisulphuric acid



$H_2S_2O_7$
Pyrosulphuric acid (Oleum)

Overview

- Oxoacids contain sulfur (S) bonded to oxygen (O) and hydrogen (H).
- Four main oxoacids: Sulphurous acid (H_2SO_3), Sulphuric acid (H_2SO_4), Peroxodisulphuric acid ($H_2S_2O_8$), Pyrosulphuric acid (Oleum, $H_2S_2O_7$).
- Sulphurous acid: S bonded to 3 O and 2 H atoms.
- Sulphuric acid: S bonded to 4 O and 2 H atoms.
- Peroxodisulphuric acid: Two S atoms connected by O-O bond, with extra O and H.
- Pyrosulphuric acid: Two S atoms connected by one O atom, plus more O and H.

Solved Examples

- **Ex 1:** Identify the number of oxygen atoms in H_2SO_4.
  - Count oxygen atoms bonded to S: 4
- **Ex 2:** Write the formula for Peroxodisulphuric acid.
  - Two S atoms, O-O bond, total 8 O and 2 H: $H_2S_2O_8$

Practice Set

- Q1: Which acid has sulfur bonded to three oxygen atoms?
  - A. Sulphuric acid
  - B. Sulphurous acid
  - C. Peroxodisulphuric acid
  - D. Pyrosulphuric acid
- Q2: What type of bond connects the two sulfur atoms in Peroxodisulphuric acid?
  - A. Single S-S bond
  - B. Oxygen-oxygen (O-O) bond
  - C. Double S=O bond
  - D. Hydrogen bond
- Q3: Which acid is also known as Oleum?
  - A. Sulphurous acid
  - B. Sulphuric acid
  - C. Pyrosulphuric acid
  - D. Peroxodisulphuric acid

Answer Key

- Q1: B - Sulphurous acid has sulfur bonded to three oxygen atoms.
- Q2: B - Peroxodisulphuric acid has two sulfur atoms connected by an oxygen-oxygen bond.
- Q3: C - Pyrosulphuric acid is also called Oleum.

Memory Aids

- Remember: Sulphurous acid = fewer oxygens (3), Sulphuric acid = more oxygens (4).
- Peroxodisulphuric acid has O-O bond linking two S atoms.
- Oleum = Pyrosulphuric acid with two S atoms linked by one O atom.

Sulphuric Acid

Overview

- Also called **oil of vitriol** and **king of chemicals**.
- Strong mineral acid widely used in industry.

Preparation by Contact Process

- Step 1: Sulfur (S) burns in oxygen (O_2) forming sulfur dioxide (SO_2).
- Step 2: SO_2 oxidized to sulfur trioxide (SO_3) using V_2O_5 catalyst.
- Step 3: SO_3 reacts with H_2SO_4 to form oleum ($H_2S_2O_7$).
- Step 4: Oleum mixed with water to produce concentrated H_2SO_4.

$$S + O_2 \longrightarrow SO_2; \quad 2SO_2 + O_2 \xrightarrow{V_2O_5} 2SO_3$$

$$SO_3 + H_2SO_4 \longrightarrow \underset{\text{Oleum}}{H_2S_2O_7}; \quad H_2S_2O_7 + H_2O \longrightarrow 2H_2SO_4$$

Physical Properties

- Colorless, dense, oily liquid.
- Specific gravity ~1.8 at 298 K.
- Dissolution in water is highly exothermic; always add acid to water with stirring.

Chemical Properties

- Strong diprotic acid: loses two protons stepwise forming H_3O^+, HSO_4^-, and SO_4^{2-}.
- Reacts with bases like NaOH forming sodium bisulfate or sodium sulfate depending on base amount.
- Reacts with metal halides (MX) producing hydrogen halides (HX) and metal sulfates (M_2SO_4).
- Strong dehydrating agent: removes water from sugars ($C_{12}H_{22}O_{11}$) leaving carbon.
- Reacts with metals like Cu producing $CuSO_4$, SO_2, and H_2O.
- Reacts with sulfur producing SO_2 and H_2O.
- Reacts with carbon producing CO_2, SO_2, and H_2O.

$$\left.\begin{aligned} H_2SO_4 + H_2O &\longrightarrow H_3O^+ + HSO_4^- \\ HSO_4^- + H_2O &\longrightarrow H_3O^+ + SO_4^{2-} \end{aligned}\right] \text{Strong dibasic acid}$$

$$NaOH + H_2SO_4 \longrightarrow NaHSO_4 + H_2O \quad \text{(Acid sulphate)}$$

$$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O \quad \text{(Normal sulphate)}$$

$$2MX + \underset{\text{(Less volatile acid)}}{H_2SO_4} \longrightarrow \underset{\text{(More volatile acid)}}{2HX} + M_2SO_4 \quad (X = F, Cl, NO_3)\ (M = \text{Metal})$$

$$C_{12}H_{22}O_{11} \xrightarrow{H_2SO_4} 12C + 11H_2O \text{ (Strong dehydrating agent)}$$

$$Cu + 2H_2SO_{4(Conc.)} \longrightarrow CuSO_4 + SO_2 + 2H_2O$$

$$S + 2H_2SO_{4(Conc.)} \longrightarrow 3SO_2 + 2H_2O \quad ; \quad C + 2H_2SO_{4(Conc.)} \longrightarrow CO_2 + 2SO_2 + 2H_2O$$

Solved Examples

- **Ex 1:** Write the reaction for SO_2 oxidation in contact process.
  Answer: $SO_2 + \frac{1}{2}O_2 \xrightarrow{V_2O_5} SO_3$
- **Ex 2:** Reaction of H_2SO_4 with NaOH (1 mole).
  Answer: $H_2SO_4 + NaOH \rightarrow NaHSO_4 + H_2O$
- **Ex 3:** Reaction of concentrated H_2SO_4 with sugar.
  Answer: $C_{12}H_{22}O_{11} \xrightarrow{conc.H_2SO_4} 12C + 11H_2O$

Practice Set

- Q1: What is the catalyst used in the contact process?
  A. Fe_2O_3 B. V_2O_5 C. MnO_2 D. CuO
- Q2: Which product forms when SO_3 reacts with H_2SO_4 in contact process?
  A. Sulfuric acid B. Oleum C. Sulfur dioxide D. Sulfur trioxide
- Q3: What happens when concentrated H_2SO_4 reacts with sugar?
  A. Forms CO_2 B. Forms carbon and water C. Forms sulfur dioxide D. Forms copper sulfate

Answer Key

- Q1: B - V_2O_5 is the catalyst for SO_2 oxidation in contact process.
- Q2: B - SO_3 reacts with H_2SO_4 to form oleum ($H_2S_2O_7$).
- Q3: B - Concentrated H_2SO_4 dehydrates sugar forming carbon and water.

Memory Aids

- Contact Process Steps: S → SO_2 → SO_3 → Oleum → H_2SO_4.
- Always add acid to water to avoid heat splashes.
- H_2SO_4 is diprotic: loses 2 protons stepwise.
- Dehydration of sugar by conc. H_2SO_4 leaves black carbon.

Group 17 Elements

General Information

- Members: Fluorine (F), Chlorine (Cl), Bromine (Br), Iodine (I), Astatine (At), Tennessine (Ts).
- Known as halogens (Greek: halo = salt, genes = born).
- Highly reactive non-metallic elements.
- Astatine and Tennessine are radioactive.
- General electronic configuration: ns^2np^5.

Element	Symbol	At. No.	Electronic configuration
Fluorine	F	9	$[He]\ 2s^2\ 2p^5$
Chlorine	Cl	17	$[Ne]\ 3s^2\ 3p^5$
Bromine	Br	35	$[Ar]\ 3d^{10}\ 4s^2\ 4p^5$
Iodine	I	53	$[Kr]\ 4d^{10}\ 5s^2\ 5p^5$
Astatine	At	85	$[Xe]\ 4f^{14}\ 5d^{10}\ 6s^2\ 6p^5$
Tennessine	Ts	117	$[Rn]\ 5f^{14}\ 6d^{10}\ 7s^2\ 7p^5$

Physical Properties

- Atomic and ionic radii increase down the group; halogens are smallest atoms in a period.
- Ionisation enthalpy is very high but decreases down the group.
- Electronegativity: Fluorine is the most electronegative; decreases down the group.
- Electron gain enthalpy increases from F to Cl, then decreases to I; F has smaller value due to small size and repulsions.
- Bond dissociation enthalpy increases from F_2 to Cl_2, then decreases for Br_2 and I_2; F–F bond weaker due to lone pair repulsions.
- Melting and boiling points increase down the group.

Chemical Properties

- Oxidation states: F only -1; others show -1, +1, +3, +5, +7.
- Higher oxidation states of Cl, Br, I seen in fluorides, oxides, oxoacids.
- Oxidising power decreases down the group: $F_2 > Cl_2 > Br_2 > I_2$.

Hydrogen Halides

- Reactivity order to form HX: $F_2 > Cl_2 > Br_2 > I_2$.
- Boiling points: HF > HI > HBr > HCl.
- Melting points: HI > HF > HBr > HCl.
- Bond lengths: HI > HBr > HCl > HF.
- Bond dissociation enthalpy: HF > HCl > HBr > HI.
- Acidic strength: HI > HBr > HCl > HF.
- Thermal stability: HF > HCl > HBr > HI.
- Reducing power: HI > HBr > HCl > HF.

Oxides

- Fluorine forms OF_2 and O_2F_2 (oxygen fluorides).
- Other halogens form oxides with oxidation states from +1 to +7.

Metal Halides

- Ionic character order: MF > MCl > MBr > MI.
- Halides in higher oxidation states are more covalent than in lower states.
- Iodine does not displace Cl or Br from their halides but displaces them from their oxysalts.
- Example reaction: $2KCO_3 + I_2 \rightarrow 2KIO_3 + Cl_2$.

Solved Examples

Ex 1: Write the electronic configuration of Bromine.
Step 1: Bromine atomic number = 35.
Step 2: Configuration = [Ar] $3d^{10}\ 4s^2\ 4p^5$.

Ex 2: Arrange halogens in order of oxidising power.
Answer: $F_2 > Cl_2 > Br_2 > I_2$.

Practice Set

- Q1: Which halogen has the highest electronegativity?
  A. Chlorine
  B. Fluorine
  C. Bromine
  D. Iodine
- Q2: Which hydrogen halide has the highest boiling point?
  A. HCl
  B. HI
  C. HF
  D. HBr
- Q3: What is the oxidation state of fluorine in its compounds?
  A. +1
  B. -1
  C. 0
  D. +7

Answer Key

- Q1: B. Fluorine is the most electronegative element in group 17.
- Q2: C. HF has the highest boiling point due to strong hydrogen bonding.
- Q3: B. Fluorine shows only -1 oxidation state due to its high electronegativity.

Memory Aids

- Halogen order by oxidising power: F > Cl > Br > I.
- Boiling point order of HX: HF > HI > HBr > HCl.
- Fluorine always -1 oxidation state.
- Bond dissociation enthalpy: $F_2 < Cl_2$ due to lone pair repulsions.

Chlorine Preparation

Industrial Methods

- MnO_2 or $KMnO_4$ + HCl → $MnCl_2$ + H_2O + Cl_2
- NaCl + H_2SO_4 + MnO_2 → Cl_2 + other products
- $KMnO_4$ + HCl → KCl + $MnCl_2$ + H_2O + Cl_2
- Deacon's process: O_2 + HCl ($CuCl_2$ catalyst) → Cl_2 + H_2O

$$MnO_2 + 4HCl \longrightarrow MnCl_2 + 2H_2O + Cl_2$$

$$4NaCl + MnO_2 + 4H_2SO_4 \longrightarrow MnCl_2 + 4NaHSO_4 + 2H_2O + Cl_2$$

$$2KMnO_4 + 16HCl \longrightarrow 2KCl + 2MnCl_2 + 8H_2O + 5Cl_2$$

$$4HCl + O_2 \xrightarrow{CuCl_2} 2Cl_2 + 2H_2O$$ [Deacon's process for manufacture of Cl_2]

Electrolytic Process

- Electrolysis of brine (concentrated NaCl solution)
- Chlorine gas is liberated at the anode

Solved Examples

- **Ex 1:** Write the reaction of MnO_2 with HCl to produce chlorine.
  Answer: MnO_2 + 4HCl → $MnCl_2$ + $2H_2O$ + Cl_2

Practice Set

- Q1: Which catalyst is used in Deacon's process?
  A. $CuCl_2$
  B. $FeCl_3$
  C. MnO_2
  D. $KMnO_4$
- Q2: Chlorine is obtained at which electrode during electrolysis of brine?
  A. Cathode
  B. Anode
  C. Both electrodes
  D. None
- Q3: Which of the following is NOT a method to prepare chlorine?
  A. Reaction of $KMnO_4$ with HCl
  B. Electrolysis of brine
  C. Reaction of NaCl with H_2SO_4 and MnO_2
  D. Reaction of NaCl with NaOH

Answer Key

- Q1: A - $CuCl_2$ catalyzes oxygen and HCl to form Cl_2 in Deacon's process.
- Q2: B - Chlorine is liberated at the anode during brine electrolysis.
- Q3: D - NaCl reacts with H_2SO_4 and MnO_2, not NaOH, to produce chlorine.

Memory Aids

- Deacon's process uses $CuCl_2$ catalyst.
- Electrolysis of brine liberates Cl_2 at anode.
- MnO_2 + HCl is a common lab method.

Chlorine Physical Properties

Key Characteristics

- Greenish-yellow gas with pungent, suffocating odor
- 2.5 times heavier than air
- Liquefies to greenish-yellow liquid, boiling point 239 K
- Soluble in water

Solved Examples

- **Ex 1:** What is the color and odor of chlorine gas?
  Answer: Greenish-yellow with pungent odor.

Practice Set

- Q1: Chlorine gas is:
  A. Colorless
  B. Greenish-yellow
  C. Blue
  D. Red
- Q2: Chlorine is heavier than air by a factor of:
  A. 1.5
  B. 2.5
  C. 3.5
  D. 4.5
- Q3: Boiling point of chlorine is:
  A. 239 K
  B. 273 K
  C. 300 K
  D. 200 K

Answer Key

- Q1: B - Chlorine is greenish-yellow gas.
- Q2: B - Chlorine is about 2.5 times heavier than air.
- Q3: A - Chlorine boils at 239 K.

Memory Aids

- Greenish-yellow gas, pungent smell = Chlorine
- Boils below room temperature (239 K)

Chlorine Chemical Properties

Reactions with Metals and Non-metals

- $2Al + 3Cl_2 \rightarrow 2AlCl_3$
- $P_4 + 6Cl_2 \rightarrow 4PCl_3$
- $2Na + Cl_2 \rightarrow 2NaCl$
- $S_8 + 4Cl_2 \rightarrow 4S_2Cl_2$
- $2Fe + 3Cl_2 \rightarrow 2FeCl_3$

Reactions with Hydrogen Compounds

- $H_2S + Cl_2 \rightarrow 2HCl + S$
- $C_{10}H_{16} + 8Cl_2 \rightarrow 16HCl + 10C$

Reaction with Ammonia

- $8NH_3 + 3Cl_2 \rightarrow 6NH_4Cl + N_2$ (excess NH_3)
- $NH_3 + 3Cl_2 \rightarrow NCl_3 + 3HCl$ (excess Cl_2)

Reaction with Alkalies

- $2NaOH + Cl_2 \rightarrow NaCl + NaOCl + H_2O$ (cold, dilute)
- $6NaOH + 3Cl_2 \rightarrow 5NaCl + NaClO_3 + 3H_2O$ (hot, concentrated)

Reaction with Slaked Lime

- $2Ca(OH)_2 + 2Cl_2 \rightarrow Ca(OCl)_2 + CaCl_2 + 2H_2O$

As an Oxidising Agent

- $2FeSO_4 + H_2SO_4 + Cl_2 \rightarrow Fe_2(SO_4)_3 + 2HCl$
- $SO_2 + 2H_2O + Cl_2 \rightarrow H_2SO_4 + 2HCl$
- $I_2 + 6H_2O + 5Cl_2 \rightarrow 2HIO_3 + 10HCl$

As a Bleaching Agent

- $Cl_2 + H_2O \rightarrow 2HCl + [O]$
- Coloured substance + [O] → Colourless substance

Solved Examples

- **Ex 1:** Write the reaction of chlorine with sodium hydroxide (cold and dilute).
  Answer: $2NaOH + Cl_2 \rightarrow NaCl + NaOCl + H_2O$

Practice Set

- Q1: Which product is formed when chlorine reacts with hot concentrated NaOH?
  A. NaClO
  B. $NaClO_3$
  C. NaCl
  D. $NaClO_4$
- Q2: Reaction of chlorine with ammonia in excess ammonia produces:
  A. NH_4Cl
  B. NCl_3
  C. N_2
  D. NH_3
- Q3: Chlorine acts as an oxidising agent in reaction with:
  A. $FeSO_4$
  B. NaCl
  C. H_2O
  D. NH_3

Answer Key

- Q1: B - Hot concentrated NaOH with Cl_2 forms $NaClO_3$.
- Q2: A - Excess NH_3 with Cl_2 forms NH_4Cl and N_2.
- Q3: A - Cl_2 oxidises $FeSO_4$ to $Fe_2(SO_4)_3$.

Memory Aids

- Cold dilute NaOH + Cl_2 → NaOCl (bleach)
- Hot concentrated NaOH + Cl_2 → $NaClO_3$ (chlorate)
- Excess NH_3 + Cl_2 → NH_4Cl + N_2

Hydrogen Chloride

Lab preparation

- Industrial Mannheim process involves two steps:
- At 420 K: NaCl + H_2SO_4 → $NaHSO_4$ + HCl
- At 823 K: $NaHSO_4$ + NaCl → Na_2SO_4 + HCl
- HCl gas is dried by passing through concentrated H_2SO_4

$$NaCl + H_2SO_4 \xrightarrow{420\ K} NaHSO_4 + HCl$$

$$NaHSO_4 + NaCl \xrightarrow{823\ K} Na_2SO_4 + HCl$$

Physical properties

- Colourless, pungent smelling gas
- Easily liquefied

- Extremely soluble in water

Chemical properties

- Decomposes salts of weaker acids:
- $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$
- $Na_2SO_3 + 2HCl \rightarrow 2NaCl + H_2O + SO_2$
- Aqua regia (3 parts conc. HCl + 1 part conc. HNO_3) dissolves noble metals:
- $Au + 4H^+ + NO_3^- + 4Cl^- \rightarrow AuCl_4^- + NO + 2H_2O$
- $Pt + 16H^+ + 4NO_3^- + 18Cl^- \rightarrow 3PtCl_6^{2-} + 4NO + 8H_2O$

Solved Examples

- **Ex 1:** Write the reaction for HCl preparation at 420 K in Mannheim process.
  Answer: $NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$
- **Ex 2:** Write the reaction of aqua regia with gold.
  Answer: $Au + 4H^+ + NO_3^- + 4Cl^- \rightarrow AuCl_4^- + NO + 2H_2O$

Practice Set

- **Q1:** Which gas is produced when NaCl reacts with concentrated H_2SO_4 at 420 K?
  A. Cl_2 B. HCl C. SO_2 D. $NaHSO_4$
- **Q2:** What is the product formed when $NaHSO_4$ reacts with NaCl at 823 K?
  A. NaCl B. Na_2SO_4 C. HCl D. SO_2
- **Q3:** Aqua regia is a mixture of:
  A. 3 parts conc. HCl + 1 part conc. HNO_3
  B. 1 part conc. HCl + 3 parts conc. HNO_3
  C. 2 parts conc. HCl + 2 parts conc. HNO_3
  D. 4 parts conc. HCl + 1 part conc. HNO_3

Answer Key

- **Q1:** B. HCl - Produced by reaction of NaCl with H_2SO_4 at 420 K.
- **Q2:** B. Na_2SO_4 - Formed by reaction of $NaHSO_4$ with NaCl at 823 K.
- **Q3:** A. 3 parts conc. HCl + 1 part conc. HNO_3 - Correct composition of aqua regia.

Memory Aids

- Mannheim process: $NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$ (420 K), then $NaHSO_4 + NaCl \rightarrow Na_2SO_4 + HCl$ (823 K)
- Aqua regia = 3 parts HCl + 1 part HNO_3, dissolves Au and Pt
- HCl decomposes salts of weaker acids releasing CO_2 and SO_2

Oxoacids of Halogens

Properties and Trends

- Halogens form oxoacids with oxidation states +1, +3, +5, and +7.
- Thermal stability increases with higher oxidation state.
- Halogen-oxygen bond becomes more covalent as oxidation state increases.

- Oxidizing power decreases with increasing oxidation number.
- Acidity increases with higher oxidation states.
- Electronegativity of halogen atoms remains constant across these acids.
- Opposite trends observed: electronegativity vs. thermal stability, oxidizing power, and acid strength.

Variation of the general properties of oxoacids of halogens

Halogen	Hypohalous acids (O.S. of halogen = +1)	Halous acids (O.S. of halogen = +3)	Halic acids (O.S. of halogen = +5)	Perhalic acid (O.S. of halogen = +7)
F	HOF	—	—	—
Cl	$HClO$	$HClO_2$	$HClO_3$	$HClO_4$
Br	$HBrO$	—	$HBrO_3$	$HBrO_4$
I	HIO	—	HIO_3	HIO_4

—— Oxidation number of the central atom increases (+1, +3, +5, +7) ⟶
—— Thermal stability increases ⟶
—— Covalent character of X—O bond increases ⟶
—— Oxidising power decreases ⟶
—— Acidity increases ⟶
—— Electronegativity of the central atoms remains the same ⟶

← Electronegativity decreases —
← Thermal stability decreases —
← Oxidising power decreases —
← Acidic strength decreases —

Solved Examples

- **Ex 1:** Identify the oxidation state of chlorine in $HClO_3$.
  - Cl in $HClO_3$: Let oxidation state = x
  - Oxygen = -2, Hydrogen = +1
  - Equation: x + 3(-2) + 1 = 0 → x - 6 + 1 = 0 → x = +5
- **Ex 2:** Compare acidity of HClO and $HClO_4$.
  - HClO (Cl +1) is less acidic than $HClO_4$ (Cl +7).
  - Higher oxidation state increases acid strength.

Practice Set

- **Q1:** Which oxoacid of chlorine has the highest thermal stability?
  - A. HClO
  - B. $HClO_2$
  - C. $HClO_3$
  - D. $HClO_4$
- **Q2:** In oxoacids of halogens, acidity increases with:
  - A. Decreasing oxidation state
  - B. Increasing oxidation state
  - C. Constant oxidation state
  - D. None of the above
- **Q3:** Which property decreases as the oxidation state of halogen increases in oxoacids?
  - A. Thermal stability
  - B. Acidity
  - C. Oxidizing power
  - D. Electronegativity

Answer Key

- **Q1:** D. $HClO_4$ - Highest oxidation state (+7) gives highest thermal stability.

- **Q2:** B. Increasing oxidation state - Acidity increases with higher oxidation states.
- **Q3:** C. Oxidizing power - It decreases as oxidation state increases.

Memory Aids

- Higher oxidation state → Stronger acid, more stable, less oxidizing.
- Remember: $HClO < HClO_2 < HClO_3 < HClO_4$ in acidity and stability.
- Electronegativity of halogen remains unchanged across oxoacids.

Interhalogen Compounds

General Characteristics

- Formed by combination of two different halogens.
- Types: XX, XX_3, XX_5, XX_7.
- X = larger halogen (more electropositive), X' = smaller halogen.

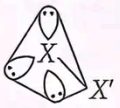
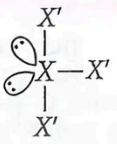
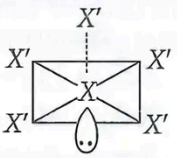
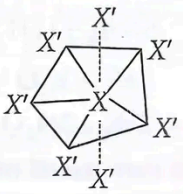
Preparation

$$\underset{\text{(equal volume)}}{Cl_2 + F_2} \xrightarrow{437\ K} 2ClF \quad ; \quad \underset{\text{(excess)}}{I_2 + 3Cl_2} \longrightarrow 2ICl_3 \quad ; \quad \underset{\text{(excess)}}{Cl_2 + 3F_2} \xrightarrow{573\ K} 2ClF_3 \quad ;$$

$$BrF_3 + F_2 \xrightarrow{473\ K} BrF_5 \quad ; \quad IF_5 + F_2 \xrightarrow{543\ K} IF_7$$

- $Cl_2 + F_2$ (437 K) → ClF
- I_2 + excess Cl_2 → ICl_3
- Cl_2 + excess F_2 (573 K) → ClF_3
- $BrF_3 + F_2$ (473 K) → BrF_5
- $IF_5 + F_2$ (543 K) → IF_7

Structures

Type	Hybridisation	Shape	Structure
XX'	sp^3	Linear	
XX'_3	sp^3d	T-shaped	
XX'_5	sp^3d^2	Square pyramidal	
XX'_7	sp^3d^3	Pentagonal bipyramidal	

- XX' (2 groups): Linear, sp^3 hybridization.
- XX'_3 (3 groups): T-shape, sp^3d hybridization.
- XX'_5 (5 groups): Square pyramidal, sp^3d^2 hybridization.
- XX'_7 (7 groups): Pentagonal bipyramidal, sp^3d^3 hybridization.

Pseudohalogens

- Ions with two or more electronegative atoms including nitrogen, similar to halide ions.
- Examples: CN^-, SCN^-, OCN^-.
- Dimeric molecules: $(CN)_2$, $(SCN)_2$, $(OCN)_2$.

Solved Examples

Ex 1: Write the product when Cl_2 reacts with F_2 at 437 K.

Step 1: $Cl_2 + F_2 \rightarrow ClF$ (Chlorine monofluoride)

Ex 2: Identify the shape and hybridization of ClF_3.

Step 1: ClF_3 has 3 bonded atoms and 2 lone pairs.

Step 2: Shape is T-shaped, hybridization sp^3d.

Practice Set

- Q1: Which interhalogen compound is formed by I_2 and excess Cl_2?
  - A. ICl
  - B. ICl_3
  - C. ICl_5
  - D. ICl_7
- Q2: What is the shape of BrF_5 molecule?
  - A. Linear
  - B. T-shaped
  - C. Square pyramidal
  - D. Pentagonal bipyramidal
- Q3: Which hybridization corresponds to XX'_7 interhalogen compounds?
  - A. sp^3
  - B. sp^3d
  - C. sp^3d^2
  - D. sp^3d^3

Answer Key

- Q1: B - ICl_3 is formed by I_2 and excess Cl_2.
- Q2: C - BrF_5 has square pyramidal shape.
- Q3: D - XX'_7 compounds have sp^3d^3 hybridization.

Memory Aids

- Interhalogen types: 2 (linear), 3 (T-shape), 5 (square pyramidal), 7 (pentagonal bipyramidal).
- Hybridization order: sp^3, sp^3d, sp^3d^2, sp^3d^3.
- Preparation temperatures increase with higher fluorine content.
- Pseudohalogens mimic halide ions; remember CN^-, SCN^-, OCN^-.

Group 18 Elements

General Characteristics

- Elements: He, Ne, Ar, Kr, Xe, Rn, Og
- All are monoatomic gases and chemically inert, called noble gases
- General electronic configuration: $ns^2\ np^6$
- High ionization enthalpy, decreases down the group
- Atomic radii increase down the group
- Electron gain enthalpy is positive (no tendency to gain electrons)
- Low melting and boiling points due to weak dispersion forces
- Least reactive due to stable electronic configuration

Element	Symbol	At. No.	Electronic configuration
Helium	He	2	$1s^2$
Neon	Ne	10	[He] $2s^2\ 2p^6$
Argon	Ar	18	[Ne] $3s^2\ 3p^6$
Krypton	Kr	36	[Ar] $3d^{10}\ 4s^2\ 4p^6$
Xenon	Xe	54	[Kr] $4d^{10}\ 5s^2\ 5p^6$
Radon	Rn	86	[Xe] $4f^{14}\ 5d^{10}\ 6s^2\ 6p^6$
Oganesson	Og	118	[Rn] $5f^{14}\ 6d^{10}\ 7s^2\ 7p^6$

Solved Examples

- **Ex 1:** Write the electronic configuration of Argon.
  Answer: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

Practice Set

- Q1: Which noble gas has the smallest atomic radius?
  A. Helium
  B. Neon
  C. Argon
  D. Krypton
- Q2: What is the general electronic configuration of noble gases?
  A. $ns^2\ np^5$
  B. $ns^2\ np^6$
  C. $ns^1\ np^6$
  D. $ns^2\ np^4$
- Q3: Ionization enthalpy trend in noble gases is:
  A. Increases down the group
  B. Decreases down the group
  C. Remains constant
  D. Random

Answer Key

- Q1: A - Helium has the smallest atomic radius due to least number of electron shells.
- Q2: B - Noble gases have completely filled $ns^2\ np^6$ configuration.
- Q3: B - Ionization enthalpy decreases down the group as atomic size increases.

Memory Aids

- "He Never Argues, Krypton Xenon Radon Oganesson" for element order
- General config: $ns^2\ np^6$ (except He: $1s^2$)
- High ionization enthalpy = inertness

Prepzy

Xenon Fluorine Compounds

Reactions and Properties

- $Xe + F_2$ (excess, 673 K, 1 bar) → XeF_2
- $Xe + 5F_2$ (873 K, 7 bar) → XeF_4
- $Xe + 20F_2$ (573 K, 60-70 bar) → XeF_6
- $XeF_4 + O_2F_2$ (143 K) → $XeF_6 + O_2$
- XeF_2, XeF_4, XeF_6 are colorless crystalline solids, sublime at 298 K
- Powerful fluorinating agents, hydrolyzed by water:
  $2XeF_2 + 2H_2O \rightarrow 2Xe + 4HF + O_2$
- React with fluoride ion acceptors/donors to form cations and fluoroanions:
  $XeF_2 + PF_5 \rightarrow [XeF]^+[PF_6]^-$
  $XeF_4 + SbF_5 \rightarrow [XeF_3]^+[SbF_6]^-$
  $XeF_6 + MF \rightarrow M^+[XeF_7]^-$ (M = Na, K, Rb, Cs)

$$\underset{\text{(excess)}}{Xe} + F_2 \xrightarrow{673\ K,\ 1\ bar} XeF_2; \quad \underset{(1:5\ \text{ratio})}{Xe} + 2F_2 \xrightarrow{873\ K,\ 7\ bar} XeF_4; \quad \underset{(1:20\ \text{ratio})}{Xe} + 3F_2 \xrightarrow{573\ K,\ 60-70\ bar} XeF_6$$

Solved Examples

- **Ex 1:** Write the reaction to prepare XeF_6 from XeF_4.
  Answer: $XeF_4 + O_2F_2 \rightarrow XeF_6 + O_2$

Practice Set

- Q1: Which xenon fluoride is formed at 673 K and 1 bar?
  A. XeF_2
  B. XeF_4
  C. XeF_6
  D. XeO_3
- Q2: What is the product when XeF_2 reacts with water?
  A. XeF_4
  B. $Xe + HF + O_2$
  C. XeO_3
  D. XeF_6
- Q3: Which ion is formed when XeF_6 reacts with fluoride ion donors?
  A. $[XeF]^+$
  B. $[XeF_3]^+$
  C. $[XeF_7]^-$
  D. $[XeF_5]^-$

Answer Key

- Q1: A - XeF_2 forms at 673 K and 1 bar with excess fluorine.
- Q2: B - XeF_2 hydrolyzes to Xe, HF, and O_2.
- Q3: C - XeF_6 reacts with fluoride donors to form $[XeF_7]^-$.

Memory Aids

- XeF_2: linear, formed at low pressure and moderate temperature
- XeF_4: square planar, formed at higher pressure and temperature
- XeF_6: distorted octahedral, formed at very high pressure

Xenon Oxygen Compounds

Reactions and Properties

- $6XeF_4 + 12H_2O \rightarrow 4Xe + 2XeO_3 + 24HF + 3O_2$
- $XeF_6 + 3H_2O \rightarrow XeO_3 + 6HF$
- $XeF_6 + H_2O \rightarrow XeOF_4 + 2HF$
- $XeF_6 + 2H_2O \rightarrow XeO_2F_2 + 4HF$ (partial hydrolysis)

Solved Examples

- **Ex 1:** Write the reaction of XeF_6 with water to form XeO_3.
  Answer: $XeF_6 + 3H_2O \rightarrow XeO_3 + 6HF$

Practice Set

- Q1: What is the product when XeF_6 reacts with 3 moles of water?
  A. XeO_3
  B. $XeOF_4$
  C. XeO_2F_2
  D. XeF_4
- Q2: Partial hydrolysis of XeF_6 produces:
  A. XeO_3
  B. $XeOF_4$
  C. XeO_2F_2
  D. XeF_2
- Q3: Which compound is formed by complete hydrolysis of XeF_4 with water?
  A. XeO_3
  B. XeF_6
  C. $XeOF_4$
  D. XeO_2F_2

Answer Key

- Q1: A - $XeF_6 + 3H_2O$ forms XeO_3.
- Q2: C - Partial hydrolysis yields XeO_2F_2.
- Q3: A - Complete hydrolysis of XeF_4 forms XeO_3.

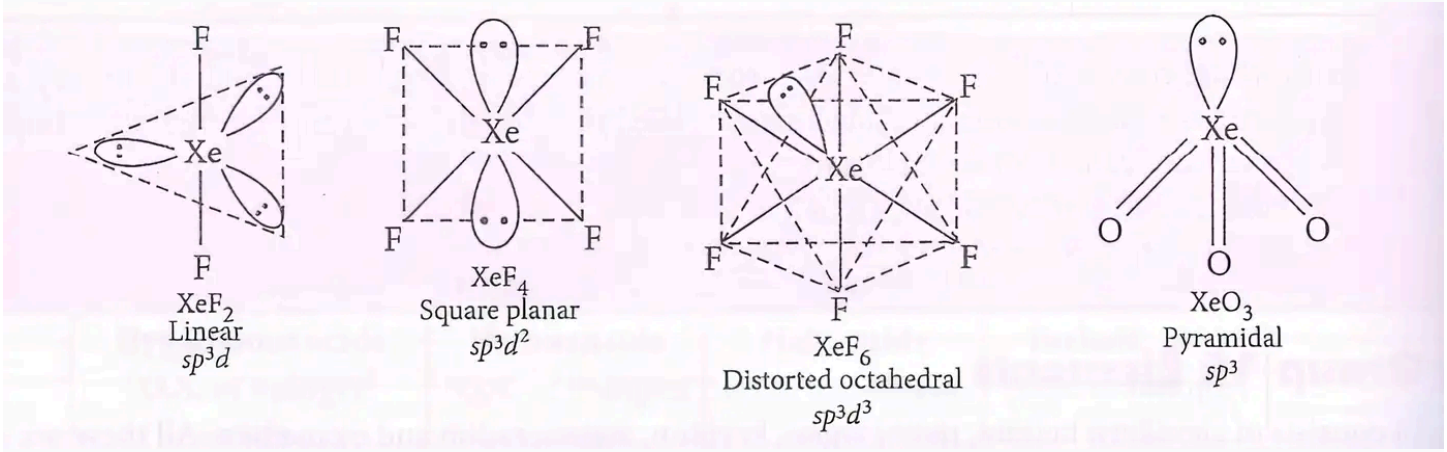
Memory Aids

- Complete hydrolysis → XeO_3
- Partial hydrolysis → XeO_2F_2
- $XeOF_4$ formed by limited water reaction

Structures of Xenon Compounds

Molecular Shapes and Hybridization

- XeF_2: Linear shape, sp^3d hybridization
- XeF_4: Square planar, sp^3d^2 hybridization
- XeF_6: Distorted octahedral, sp^3d^3 hybridization
- XeO_3: Pyramidal, sp^3 hybridization



Solved Examples

- **Ex 1:** Identify the shape of XeF_4.
  Answer: Square planar

Practice Set

- Q1: What is the hybridization of XeF_2?
  A. sp^3d
  B. sp^3d^2
  C. sp^3d^3
  D. sp^2
- Q2: XeF_6 has which molecular geometry?
  A. Octahedral
  B. Distorted octahedral
  C. Square planar
  D. Linear
- Q3: XeO_3 molecule shape is:
  A. Linear
  B. Tetrahedral
  C. Pyramidal
  D. Trigonal planar

Answer Key

- Q1: A - XeF_2 is sp^3d hybridized.
- Q2: B - XeF_6 is distorted octahedral.
- Q3: C - XeO_3 is pyramidal.

Memory Aids

- Remember shapes by number of bonded atoms and lone pairs
- XeF_2: linear, XeF_4: square planar, XeF_6: distorted octahedral
- XeO_3 pyramidal due to lone pair on Xe