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Introduction to p-Block Elements

General Electronic Configuration

- Last electron enters outermost p-orbital.
- General configuration: ns^2np^{1-6} (except He).
- Maximum oxidation state = total valence electrons (s + p electrons).
- Inert pair effect causes oxidation states two less than max.
- First period elements show anomalous behavior due to smaller size and no d-orbitals.

Group 13 Elements: The Boron Family

- Elements: B, Al, Ga, In, Tl, Nh.
- Boron is a semi-metal, closer to non-metals; high ionization energy.
- Aluminium is a metal with similarities to boron.
- Ga, In, Tl, Nh are metallic.
- Aluminium is abundant; Boron, Ga, In, Tl less so; Nh is radioactive with short half-life.

Electronic Configuration

Element	Symbol	Electronic configuration [noble gas] ns^2np^1
Boron	${}_5\text{B}$	$[\text{He}]2s^22p^1$
Aluminium	${}_{13}\text{Al}$	$[\text{Ne}]3s^23p^1$
Gallium	${}_{31}\text{Ga}$	$[\text{Ar}]3d^{10}4s^24p^1$
Indium	${}_{49}\text{In}$	$[\text{Kr}]4d^{10}5s^25p^1$
Thallium	${}_{81}\text{Tl}$	$[\text{Xe}]4f^{14}5d^{10}6s^26p^1$
Nihonium	${}_{113}\text{Nh}$	$[\text{Rn}]5f^{14}6d^{10}7s^27p^1$

Solved Examples

- **Ex 1:** Write the general electronic configuration of p-block elements.
Answer: ns^2np^{1-6} (except He).
- **Ex 2:** Name the elements of group 13.
Answer: B, Al, Ga, In, Tl, Nh.

Practice Set

- Q1: Which element in group 13 is a semi-metal?
A. Aluminium
B. Boron
C. Gallium
D. Thallium
- Q2: The inert pair effect is responsible for which of the following?
A. Maximum oxidation state
B. Smaller size of first period elements
C. Oxidation states two less than group oxidation state
D. High ionization energy
- Q3: Which element in group 13 is radioactive with a short half-life?
A. Indium
B. Thallium

- C. Nihonium
- D. Gallium

Answer Key

- Q1: B - Boron is a semi-metal with high ionization energy.
- Q2: C - Inert pair effect causes oxidation states two less than max.
- Q3: C - Nihonium is radioactive with a half-life of 20 seconds.

Memory Aids

- Group 13 elements mnemonic: *BAG IT N* (Boron, Aluminium, Gallium, Indium, Thallium, Nihonium).
- Inert pair effect increases down the group, stabilizing +1 oxidation state.

Atomic and Ionic Radii

Size Trends

- Group 13 elements and ions smaller than group 2 due to higher nuclear charge.
- Atomic and ionic radii increase down the group except gallium.
- Gallium's atomic radius is less than aluminium due to poor d-electron shielding.

Element	Metallic radius (Å)	Ionic radius	
		M^{3+} (Å)	M^+ (Å)
B	0.885	0.270	–
Al	1.43	0.535	–
Ga	1.35	0.620	1.20
In	1.67	0.800	1.40
Tl	1.70	0.885	1.50

Solved Examples

- **Ex 1:** Why is Ga atomic radius less than Al?
Answer: Poor shielding by 10 d-electrons in Ga.
- **Ex 2:** Compare ionic radii of M^{3+} and metallic radii.
Answer: Ionic radii are smaller due to loss of electrons.

Practice Set

- Q1: Which element has the smallest atomic radius?
 - A. Boron
 - B. Aluminium
 - C. Gallium
 - D. Indium
- Q2: Why does gallium have a smaller atomic radius than aluminium?
 - A. Better shielding
 - B. Poor d-electron shielding

- C. More protons
- D. Less electrons
- Q3: Ionic radius of M^{3+} compared to metallic radius is:
 - A. Larger
 - B. Smaller
 - C. Same
 - D. Variable

Answer Key

- Q1: A - Boron has the smallest atomic radius in group 13.
- Q2: B - Poor shielding by d-electrons reduces atomic size in Ga.
- Q3: B - Ionic radius smaller due to electron loss and increased nuclear attraction.

Memory Aids

- Remember: Ga radius < Al radius due to d-electron poor shielding.
- Ionic radius decreases with increasing positive charge.

Ionisation Enthalpy

Trends and Exceptions

- Ionisation enthalpy (IE) does not decrease smoothly down the group.
- Irregularities in Ga and Tl due to poor d- and f-electron shielding.
- Order of first IE: $B > Tl > Ga > Al > In$.
- IE values less than corresponding alkaline earth metals due to p-electron shielding.
- IE order: $IE_1 < IE_2 < IE_3$; sum of first three IE very high for M^{3+} .

Solved Examples

- **Ex 1:** Arrange group 13 elements in order of first ionisation enthalpy.
Answer: $B > Tl > Ga > Al > In$.
- **Ex 2:** Why is IE of group 13 less than group 2?
Answer: Less penetrating p-electrons shield less than s-electrons.

Practice Set

- Q1: Which element has the highest first ionisation enthalpy?
 - A. Aluminium
 - B. Boron
 - C. Gallium
 - D. Thallium
- Q2: The irregularity in IE values of Ga and Tl is due to:
 - A. Better shielding
 - B. Poor d- and f-electron shielding
 - C. Smaller size
 - D. Higher nuclear charge
- Q3: Sum of first three ionisation enthalpies is very high because:
 - A. Formation of M^{3+} ions
 - B. Formation of M^+ ions

- C. Electron gain
- D. Electron shielding

Answer Key

- Q1: B - Boron has highest first IE due to small size and high nuclear charge.
- Q2: B - Poor shielding by d- and f-electrons causes irregularity.
- Q3: A - High energy needed to remove three electrons forming M^{3+} .

Memory Aids

- IE order mnemonic: *Boron's IE is Best, Tl and Ga show irregularity.*
- High IE sum for M^{3+} ions due to strong nuclear attraction.

Electronegativity

Trends

- Electronegativity decreases from B to Al, then increases down the group.
- Increase due to poor shielding by inner d- and f-electrons.
- Group 13 elements more electronegative than group 1 and 2 metals.

Element	B	Al	Ga	In	Tl
Pauling's electronegativity	2.0	1.5	1.6	1.7	1.8

Solved Examples

- **Ex 1:** Which element has the highest electronegativity?
Answer: Boron (2.0).
- **Ex 2:** Which element has the lowest electronegativity?
Answer: Aluminium (1.5).

Practice Set

- Q1: Electronegativity trend in group 13 is:
 - A. Increases down the group
 - B. Decreases then increases
 - C. Constant
 - D. Decreases only
- Q2: Which element has the highest electronegativity?
 - A. Aluminium
 - B. Gallium
 - C. Boron
 - D. Thallium
- Q3: Group 13 elements are more electronegative than:
 - A. Group 1 metals
 - B. Group 2 metals

- C. Both A and B
- D. None

Answer Key

- Q1: B - Electronegativity decreases from B to Al then increases due to poor shielding.
- Q2: C - Boron has highest electronegativity.
- Q3: C - More electronegative than both group 1 and 2 metals.

Memory Aids

- Electronegativity dip at Al due to d-electron poor shielding.
- Remember: B highest, Al lowest in group 13.

Physical Properties

Key Characteristics

- Boron: hard, black solid, many allotropes, very high melting point.
- Other members: soft metals, low melting points, high electrical conductivity.
- Gallium: low melting point (303 K), liquid near room temp, high boiling point (2676 K).
- Density increases down the group from B to Tl.

Solved Examples

- **Ex 1:** Why does boron have a high melting point?
Answer: Strong crystalline lattice.
- **Ex 2:** Which element can be liquid near room temperature?
Answer: Gallium.

Practice Set

- Q1: Boron is:
A. Soft metal
B. Semi-metal
C. Liquid at room temp
D. Gas
- Q2: Which element has the lowest melting point?
A. Boron
B. Aluminium
C. Gallium
D. Thallium
- Q3: Density trend down group 13 is:
A. Decreases
B. Increases
C. Constant
D. Irregular

Answer Key

- Q1: B - Boron is a semi-metal.

- Q2: C - Gallium has unusually low melting point.
- Q3: B - Density increases down the group.

Memory Aids

- Boron: hard and high melting point due to strong lattice.
- Gallium melts near room temp, remember "Gallium melts in your hand".

Chemical Properties

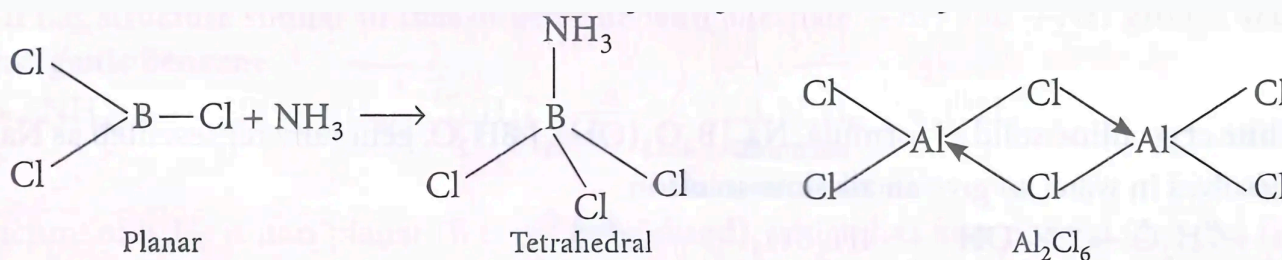
Oxidation States and Reactivity

- Valence configuration ns^2np^1 suggests +1 and +3 oxidation states.
- +1 state stability increases down the group (inert pair effect).
- Stability order: +3 state: $B^{3+} > Al^{3+} > Ga^{3+} > In^{3+} > Tl^{3+}$
- +1 state stability: $Tl^+ > In^+ > Ga^+ > Al^+ > B^+$
- +1 compounds more ionic than +3 compounds.
- Boron halides (BX_3) are electron deficient, act as Lewis acids.



Lewis Acid Strength

- Order: $BF_3 < BCl_3 < BBr_3 < BI_3$
- Lewis acid strength decreases down the group due to increasing size.
- BCl_3 and $AlCl_3$ are electron deficient and Lewis acids.
- BCl_3 forms adduct with NH_3 ; $AlCl_3$ forms dimer Al_2Cl_6 .

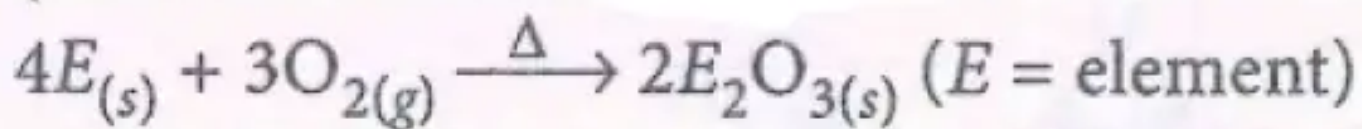


Hydrolysis and Hybridisation

- Trichlorides hydrolyse in water to form tetrahedral $[M(OH)_4]^-$ (sp^3 hybridisation).
- $AlCl_3$ in acidified water forms octahedral $[Al(H_2O)_6]^{3+}$ (sp^3d^2 hybridisation).

Reactivity Towards Air

- Group 13 elements form trioxides (E_2O_3) on heating in oxygen.
- Tl also forms Tl_2O .

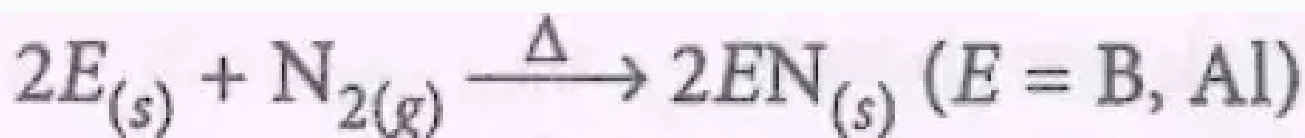


Oxide Nature

- B_2O_3 - acidic oxide.
- Al_2O_3 , Ga_2O_3 - amphoteric oxides.
- In_2O_3 , Tl_2O_3 , Tl_2O - basic oxides.
- B_2O_3 reacts with alkalis and metal oxides to form borates.

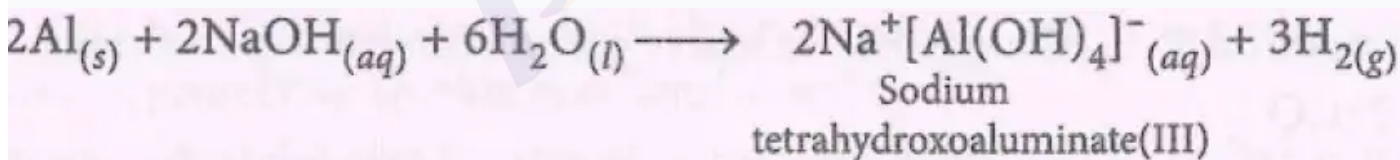
Nitrides Formation

- Boron and aluminium form nitrides on heating with nitrogen.



Reactivity Towards Acids and Alkalis

- Boron is inert to non-oxidising acids (dil. HCl , H_2SO_4).
- Other elements dissolve in acids forming M^{3+} salts and liberate H_2 .
- Oxidising acids react with all; conc. HNO_3 passivates aluminium.
- Boron, aluminium, gallium react with alkalis liberating H_2 .



Reactivity Towards Halogens

- Group 13 elements react with halogens to form trihalides (except TlI_3).
- Reaction: $2E(s) + 3X_2(g) \rightarrow 2EX_3(s)$ ($X = F, Cl, Br, I$).

Solved Examples

- **Ex 1:** Write the reaction of aluminium with oxygen.

Answer: $4Al + 3O_2 \xrightarrow{\Delta} 2Al_2O_3$.

- **Ex 2:** Write the reaction of aluminium with hydrochloric acid.

Answer: $2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$.

- **Ex 3:** Write the reaction of aluminium with sodium hydroxide.

Answer: $2Al + 2NaOH + 6H_2O \rightarrow 2Na[Al(OH)_4] + 3H_2$.

Practice Set

- Q1: Which oxidation states are common in group 13?
A. +1 and +3
B. +2 and +4
C. +3 and +5
D. +1 and +2
- Q2: Which oxide is amphoteric?
A. B_2O_3
B. Al_2O_3
C. Tl_2O
D. Tl_2O_3
- Q3: Aluminium reacts with NaOH to form:
A. $NaAlO_2$
B. $Na[Al(OH)_4]$
C. $Al(OH)_3$
D. AlO_3

Answer Key

- Q1: A - +1 and +3 are common oxidation states due to ns^2np^1 configuration.
- Q2: B - Al_2O_3 is amphoteric.
- Q3: B - Reaction produces sodium tetrahydroxoaluminate.

Memory Aids

- Inert pair effect stabilizes +1 state down the group.
- BCl_3 forms adducts; $AlCl_3$ forms dimers.
- Oxides: B_2O_3 acidic, Al_2O_3 amphoteric, Tl oxides basic.

Important Trends and Anomalous Properties of Boron

Key Characteristics

- Boron is the first element of group 13 and shows unique behaviour compared to aluminium and others.
- Smallest atomic size and highest ionisation energy in the group.
- Highest electronegativity among group 13 elements.
- Maximum covalency of 4 due to absence of d-orbitals; others have covalency up to 6.
- Exhibits only +3 oxidation state; others show +1 and +3.
- Boron halides are monomeric; others form dimeric halides.
- No inert pair effect observed in boron.
- Forms volatile, electron-deficient hydrides; others form polymeric hydrides; thallium does not form hydrides.
- Forms borides with metals; others form alloys instead.

Solved Examples

- **Ex 1:** Explain why boron shows only +3 oxidation state while thallium shows +1 and +3.
 - Boron lacks d-orbitals, so it cannot expand its octet; stable +3 state only.
 - Thallium exhibits inert pair effect stabilizing +1 state.
- **Ex 2:** Why are boron halides monomeric but aluminium halides dimeric?
 - Boron halides have small size and high charge density, favouring monomeric forms.
 - Aluminium halides form dimers due to larger size and availability of d-orbitals.

Practice Set

- **Q1:** Which property of boron is responsible for its anomalous behaviour?
 - A. Large atomic size
 - B. Low ionisation energy
 - C. Highest electronegativity in group 13
 - D. Presence of d-orbitals
- **Q2:** Boron forms volatile hydrides because:
 - A. They are electron-rich compounds
 - B. Boron has d-orbitals
 - C. They are electron-deficient compounds
 - D. Boron forms polymeric hydrides
- **Q3:** Which of the following is true about boron halides?
 - A. They are dimeric
 - B. They show inert pair effect
 - C. They are monomeric
 - D. They form alloys with metals

Answer Key

- **Q1:** C - Boron's highest electronegativity causes its unique properties.
- **Q2:** C - Boron's hydrides are electron-deficient, making them volatile.
- **Q3:** C - Boron halides exist as monomers, unlike other group 13 halides.

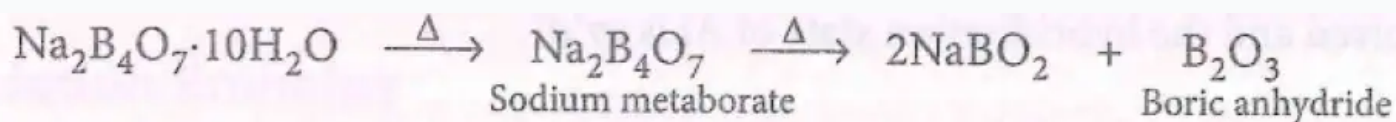
Memory Aids

- Boron: Small size + high electronegativity = unique +3 state only.
- No d-orbitals → max covalency 4, no inert pair effect.
- Boron halides monomeric; others dimeric.
- Volatile hydrides = electron-deficient; borides form, alloys do not.

Borax

Properties and Reactions

- Borax is a white crystalline solid with formula $\text{Na}_2[\text{B}_4\text{O}_5(\text{OH})_4] \cdot 8\text{H}_2\text{O}$, commonly written as $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$.
- Dissolves in water to give alkaline solution:
 $\text{Na}_2\text{B}_4\text{O}_7 + 7\text{H}_2\text{O} \rightarrow 2\text{NaOH} + 4\text{H}_3\text{BO}_3$
- On heating, loses water and swells, then melts to form a transparent liquid that solidifies into a glass-like borax bead.
- Borax bead test: Metaborates of transition metals give characteristic colors, useful for identification.



Solved Examples

- **Ex 1:** Heating borax ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$) leads to sodium metaborate and boric anhydride:
 $\text{Na}_2\text{B}_4\text{O}_7 \rightarrow 2\text{NaBO}_2 + \text{B}_2\text{O}_3$

Practice Set

- **Q1:** What is the formula of borax?
A. NaBO_2
B. $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$
C. B_2O_3
D. H_3BO_3
- **Q2:** Borax dissolves in water to give:
A. Acidic solution
B. Neutral solution
C. Alkaline solution
D. None
- **Q3:** Borax bead test is used to identify:
A. Alkali metals
B. Transition metals
C. Halogens
D. Noble gases

Answer Key

- **Q1:** B - Borax formula is $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$.
- **Q2:** C - Borax gives alkaline solution due to NaOH formation.
- **Q3:** B - Borax bead test identifies transition metals by color.

Memory Aids

- Borax = $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$, alkaline in water.
- Heating borax $\rightarrow$ borax bead (glass-like solid).
- Borax bead test detects transition metals by color.

Orthoboric Acid

Properties and Reactions

- Orthoboric acid (H_3BO_3) is a white crystalline solid with soapy touch.
- Sparingly soluble in cold water, highly soluble in hot water.
- Prepared by acidifying borax solution:
$$\text{Na}_2\text{B}_4\text{O}_7 + 2\text{HCl} + 5\text{H}_2\text{O} \rightarrow 2\text{NaCl} + 4\text{B}(\text{OH})_3$$
- Has layered structure with planar BO_3 units joined by hydrogen bonds.
- Acts as a weak monobasic Lewis acid, accepts electrons from OH^- :
$$\text{B}(\text{OH})_3 + 2\text{H}_2\text{O} \rightarrow [\text{B}(\text{OH})_4]^- + \text{H}_3\text{O}^+$$
- On heating above 370 K, forms metaboric acid (HBO_2) and then boric oxide (B_2O_3):
$$\text{H}_3\text{BO}_3 \rightarrow \text{HBO}_2 \rightarrow \text{B}_2\text{O}_3$$
- Borates detected by reaction with HF to form BF_3 gas, which colors Bunsen flame green:
$$\text{H}_3\text{BO}_3 + 3\text{HF} \rightarrow 2\text{BF}_3 + 3\text{H}_2\text{O}$$
- With conc. H_2SO_4 and methyl alcohol, gives green flame:
$$\text{B}(\text{OH})_3 + 3\text{CH}_3\text{OH} \rightarrow \text{B}(\text{OCH}_3)_3 + \text{H}_2\text{O}$$



Solved Examples

- **Ex 1:** Preparation of orthoboric acid from borax:
 $\text{Na}_2\text{B}_4\text{O}_7 + 2\text{HCl} + 5\text{H}_2\text{O} \rightarrow 2\text{NaCl} + 4\text{B}(\text{OH})_3$
- **Ex 2:** Heating orthoboric acid:
 $\text{H}_3\text{BO}_3 > 370\text{ K} \rightarrow \text{HBO}_2 > \text{further heating} \rightarrow \text{B}_2\text{O}_3$

Practice Set

- **Q1:** Orthoboric acid acts as:
 - Protonic acid
 - Lewis acid
 - Base
 - Neutral compound
- **Q2:** Boric acid on heating forms:
 - Borax
 - Metaboric acid
 - Boron hydride
 - Boron nitride
- **Q3:** BF_3 gas formed during borate test imparts what color to Bunsen flame?
 - Red
 - Blue
 - Green
 - Yellow

Answer Key

- **Q1:** B - Orthoboric acid is a Lewis acid, accepts electrons from OH^- .
- **Q2:** B - Heating boric acid forms metaboric acid (HBO_2).
- **Q3:** C - BF_3 colors Bunsen flame green.

Memory Aids

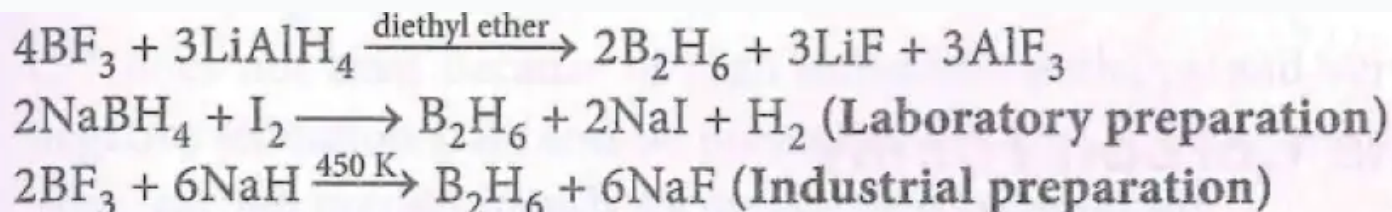
- Orthoboric acid = H_3BO_3 , weak Lewis acid.
- Heating sequence: $\text{H}_3\text{BO}_3 \rightarrow \text{HBO}_2 \rightarrow \text{B}_2\text{O}_3$.
- BF_3 gas gives green flame in borate test.

Diborane

Properties and Preparation

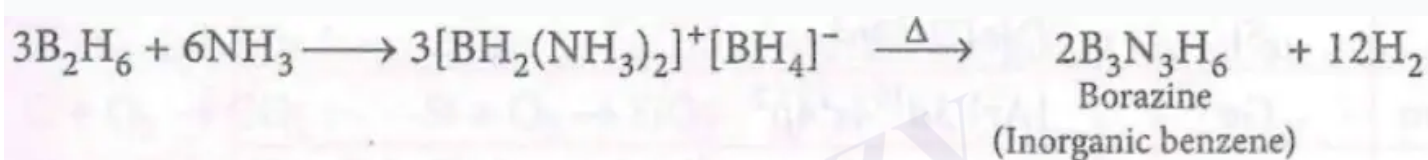
- Diborane (B_2H_6) is the simplest boron hydride, colorless and highly toxic gas.
- Boiling point: 180 K; catches fire spontaneously in air.
- Prepared by:
 - $\text{BF}_3 + \text{LiAlH}_4 \rightarrow \text{B}_2\text{H}_6 + \text{LiF} + \text{AlF}_3$

- $\text{NaBH}_4 + \text{I}_2 \rightarrow \text{B}_2\text{H}_6 + \text{NaI} + \text{H}_2$
- $\text{BF}_3 + \text{NaH (450 K)} \rightarrow \text{B}_2\text{H}_6 + \text{NaF}$
- Reacts with oxygen releasing heat:
 $\text{B}_2\text{H}_6 + 3\text{O}_2 \rightarrow \text{B}_2\text{O}_3 + 3\text{H}_2\text{O}; \Delta H^\circ = -1967 \text{ kJ/mol}$
- Hydrolyzed by water to form boric acid:
 $\text{B}_2\text{H}_6 + 6\text{H}_2\text{O} \rightarrow 2\text{H}_3\text{BO}_3 + 6\text{H}_2$
- Undergoes cleavage with Lewis bases to form borane adducts:
 $\text{B}_2\text{H}_6 + 2\text{NMe}_3 \rightarrow 2\text{BH}_3\text{NMe}_3$



Structure and Reaction with Ammonia

- B_2H_6 is non-planar; B is sp^3 hybridized.
- Has four normal (2c-2e) B-H bonds in plane and two bridge (3c-2e) B-H-B bonds (banana bonds) above and below plane.
- Reaction with NH_3 forms borazine ($\text{B}_3\text{N}_3\text{H}_6$), called inorganic benzene:



- $\text{B}_2\text{H}_6 + \text{NH}_3 \rightarrow \text{complex} \rightarrow (\text{heat}) \rightarrow \text{B}_3\text{N}_3\text{H}_6 + \text{H}_2$

Solved Examples

- **Ex 1:** Preparation from BF_3 and LiAlH_4 :
 $\text{BF}_3 + \text{LiAlH}_4 \rightarrow \text{B}_2\text{H}_6 + \text{LiF} + \text{AlF}_3$
- **Ex 2:** Reaction with water:
 $\text{B}_2\text{H}_6 + 6\text{H}_2\text{O} \rightarrow 2\text{H}_3\text{BO}_3 + 6\text{H}_2$

Practice Set

- **Q1:** Diborane is:
 - Colorless gas
 - Colored liquid
 - Solid
 - Colored gas
- **Q2:** Diborane reacts with water to form:
 - Borax
 - Boric acid
 - Borazine
 - Boron oxide
- **Q3:** Borazine is called inorganic benzene because:
 - It has benzene's formula
 - It has similar cyclic structure with alternating B and N
 - It is aromatic hydrocarbon
 - It is a metal complex

Answer Key

- **Q1:** A - Diborane is a colorless gas.
- **Q2:** B - Hydrolysis of diborane forms boric acid.
- **Q3:** B - Borazine has benzene-like cyclic structure with alternating B and N atoms.

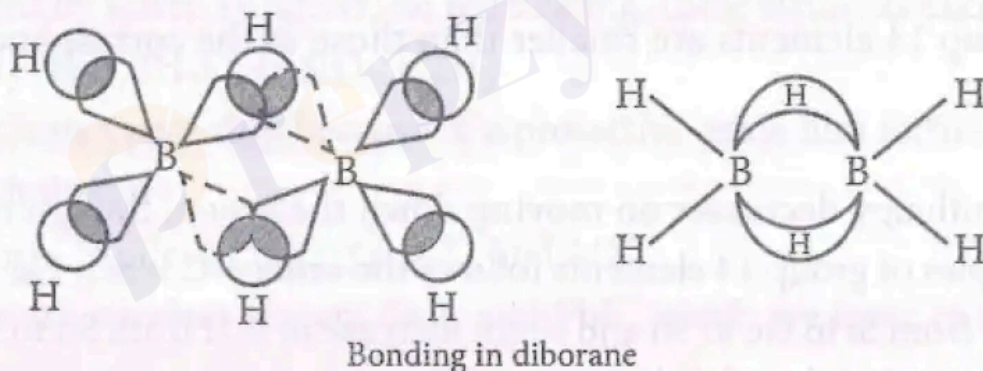
Memory Aids

- Diborane formula: B_2H_6 , sp^3 hybridized B atoms.
- Bridge bonds (banana bonds) explain unique structure.
- $Boron + NH_3 \rightarrow borazine$ (inorganic benzene).

Borohydrides

Properties and Preparation

- Borohydrides are metal tetrahydridoborates prepared by reacting metal hydrides with diborane in diethyl ether.
- Examples: $LiBH_4$, $NaBH_4$.
- Used as reducing agents in organic synthesis.
- Starting materials for other metal borohydrides.



Solved Examples

- **Ex 1:** Preparation reaction:
 $MH + B_2H_6 \rightarrow M^+[BH_4]^- + BH_3$

Practice Set

- **Q1:** Borohydrides are:
A. Metal oxides
B. Metal tetrahydridoborates
C. Metal halides
D. Metal hydrides
- **Q2:** $NaBH_4$ is used as:
A. Oxidizing agent
B. Reducing agent
C. Acid catalyst
D. Base catalyst

- **Q3:** Borohydrides are prepared by reaction of diborane with:
 - A. Metal oxides
 - B. Metal hydrides
 - C. Metal halides
 - D. Metal nitrates

Answer Key

- **Q1:** B - Borohydrides are metal tetrahydridoborates.
- **Q2:** B - NaBH_4 is a reducing agent.
- **Q3:** B - Prepared by reaction of diborane with metal hydrides.

Memory Aids

- Borohydrides = metal tetrahydridoborates (BH_4^-).
- LiBH_4 , NaBH_4 are common reducing agents.
- Prepared by $\text{MH} + \text{B}_2\text{H}_6$ reaction.

Uses of Boron

Applications of Boron and Its Compounds

- Boron fibres: Used in bullet-proof vests and lightweight composite materials for aircraft.
- Boron-10 isotope (^{10}B): High neutron absorption; metal borides used in nuclear reactors as protective shields and control rods.
- Borax and boric acid: Key in manufacturing heat-resistant glasses (e.g., Pyrex), glass-wool, and fibre glass.
- Borax: Acts as a flux in soldering metals and provides heat, scratch, and stain-resistant glazed coatings on earthenware.
- Orthoboric acid solution: Used as a mild antiseptic.

Solved Examples

- **Ex 1:** Identify the use of boron-10 isotope in nuclear reactors.
 - Step 1: Recognize ^{10}B absorbs neutrons.
 - Step 2: Used in control rods to regulate nuclear fission.

Practice Set

- Q1: Which boron compound is used in making heat-resistant glass?
 - A. Borax
 - B. Boric acid
 - C. Boron fibre
 - D. Orthoboric acid
- Q2: What is the primary use of boron-10 isotope?
 - A. Bullet-proof vests
 - B. Nuclear control rods
 - C. Glass manufacturing
 - D. Antiseptic
- Q3: Borax acts as a flux in which process?
 - A. Glass making
 - B. Soldering metals
 - C. Antiseptic preparation
 - D. Fibre glass production

Answer Key

- Q1: A - Borax is used in manufacturing heat-resistant glasses like Pyrex.
- Q2: B - Boron-10 absorbs neutrons, making it ideal for nuclear control rods.
- Q3: B - Borax is used as a flux in soldering metals.

Memory Aids

- "Boron-10 controls nuclear fission" - remember neutron absorption.
- "Borax in glass and solder" - flux and heat-resistant glass.
- Orthoboric acid = mild antiseptic.

Uses of Aluminium

Properties and Applications

- Aluminium: Bright silvery-white metal with high tensile strength.
- Electrical conductivity: Twice that of copper, making it excellent for electrical wiring.
- Thermal conductivity: High, used in heat exchangers and cooking utensils.
- Extensively used in industry and daily life due to light weight and corrosion resistance.

Solved Examples

- **Ex 1:** Why is aluminium preferred over copper in electrical wiring?
Step 1: Aluminium has twice the electrical conductivity of copper.
Step 2: It is lighter and cheaper, making it suitable for wiring.

Practice Set

- Q1: What is the colour of aluminium?
A. Dull grey
B. Bright silvery white
C. Yellowish
D. Reddish
- Q2: Aluminium's electrical conductivity compared to copper is:
A. Half
B. Equal
C. Twice
D. None
- Q3: Which property of aluminium makes it widely used in industry?
A. High density
B. High tensile strength and corrosion resistance
C. Low melting point
D. Poor conductivity

Answer Key

- Q1: B - Aluminium is bright silvery white.
- Q2: C - Aluminium has twice the electrical conductivity of copper.
- Q3: B - High tensile strength and corrosion resistance make aluminium industrially valuable.

Memory Aids

- "Aluminium shines bright and conducts right" - silvery white and high conductivity.
- "Light and strong aluminium" - key for industry and daily use.

Group 14 Elements

Overview

- Group 14 contains C, Si, Ge, Sn, Pb, and synthetic Fl (Flerovium).
- Carbon, silicon, tin, and lead are well-known; germanium is rare; flerovium is radioactive with short half-life.
- Silicon is the second most abundant element in Earth's crust after oxygen.

Electronic Configuration

Element	Symbol	Electronic configuration [noble gas] ns^2np^2
Carbon	${}_6\text{C}$	$[\text{He}] 2s^2 2p^2$
Silicon	${}_{14}\text{Si}$	$[\text{Ne}] 3s^2 3p^2$
Germanium	${}_{32}\text{Ge}$	$[\text{Ar}] 3d^{10} 4s^2 4p^2$
Tin	${}_{50}\text{Sn}$	$[\text{Kr}] 4d^{10} 5s^2 5p^2$
Lead	${}_{82}\text{Pb}$	$[\text{Xe}] 4f^{14} 5d^{10} 6s^2 6p^2$
Flerovium	${}_{114}\text{Fl}$	$[\text{Rn}] 5f^{14} 6d^{10} 7s^2 7p^2$

Electronic Configuration

- Elements have noble gas shorthand configurations showing valence electrons.
- Configurations explain chemical behavior and bonding.

Solved Examples

- **Ex 1:** Write the electronic configuration of Sn.

Answer: $[\text{Kr}] 4d^{10} 5s^2 5p^2$

Practice Set

- Q1: Which element is most abundant in Earth's crust?
A. Carbon B. Silicon C. Germanium D. Lead
- Q2: Which element is synthetic and radioactive?
A. Carbon B. Silicon C. Flerovium D. Tin
- Q3: What is the valence electron configuration of Carbon?
A. $2s^2 2p^2$ B. $3s^2 3p^2$ C. $4s^2 4p^2$ D. $5s^2 5p^2$

Answer Key

- Q1: B - Silicon is the second most abundant element in Earth's crust.

- Q2: C - Flerovium is synthetic and radioactive.
- Q3: A - Carbon has valence electrons $2s^2 2p^2$.

Memory Aids

- Remember: "C Si Ge Sn Pb Fl" for group 14 order.
- Silicon is abundant; Flerovium is synthetic and unstable.

Covalent Radius

Trends

- Covalent radius increases down the group.
- Increase from Si downwards is small due to poor shielding by d- and f-electrons.
- Group 14 elements have smaller covalent radii than group 13 elements.

Solved Examples

- **Ex 1:** Compare covalent radius of Si and Sn.
Answer: $\text{Sn} > \text{Si}$ due to larger atomic size.

Practice Set

- Q1: Which element has the smallest covalent radius?
A. Pb B. Ge C. C D. Sn
- Q2: Why is the increase in covalent radius from Si to Pb small?
A. Effective shielding B. Poor shielding by d- and f-electrons C. High nuclear charge D. Small atomic size
- Q3: Compared to group 13, group 14 elements have:
A. Larger radii B. Smaller radii C. Same radii D. No trend

Answer Key

- Q1: C - Carbon has the smallest covalent radius.
- Q2: B - Poor shielding by d- and f-electrons limits radius increase.
- Q3: B - Group 14 elements have smaller covalent radii than group 13.

Memory Aids

- Radius increases down group but less after Si due to d- and f-electron shielding.
- Group 14 radii < group 13 radii.

Ionisation Enthalpy

Trends

- Ionisation enthalpy decreases down the group, but not regularly.
- Order: $\text{C} > \text{Si} > \text{Ge} > \text{Sn} < \text{Pb}$ due to shielding and atomic size effects.
- Group 14 elements have higher ionisation enthalpy than group 13 due to higher nuclear charge and smaller size.

Solved Examples

- **Ex 1:** Arrange C, Sn, Pb in order of ionisation enthalpy.
Answer: $C > Sn < Pb$ (Pb slightly higher than Sn)

Practice Set

- Q1: Which element has the highest ionisation enthalpy?
A. Pb B. Ge C. C D. Sn
- Q2: Why does Pb have slightly higher ionisation enthalpy than Sn?
A. Better shielding B. Inert pair effect C. Smaller size D. Higher atomic number
- Q3: Ionisation enthalpy trend in group 14 is:
A. Increases down group B. Decreases regularly C. Decreases irregularly D. No change

Answer Key

- Q1: C - Carbon has the highest ionisation enthalpy.
- Q2: B - Inert pair effect causes Pb to have slightly higher ionisation enthalpy.
- Q3: C - Ionisation enthalpy decreases irregularly down the group.

Memory Aids

- Remember inert pair effect increases down group affecting ionisation enthalpy.
- Order: $C > Si > Ge > Sn < Pb$.

Electronegativity

Trends

- Group 14 elements are slightly more electronegative than group 13 due to smaller size.
- Electronegativity decreases from C to Si.
- From Si to Pb, electronegativity values are almost constant.

Solved Examples

- **Ex 1:** Compare electronegativity of C and Pb.
Answer: $C > Pb$; C is more electronegative.

Practice Set

- Q1: Which element is most electronegative?
A. Pb B. Si C. C D. Sn
- Q2: Electronegativity trend down group 14 is:
A. Increases B. Decreases C. Constant D. Irregular
- Q3: Why are group 14 elements more electronegative than group 13?
A. Larger size B. Smaller size C. Lower nuclear charge D. More shielding

Answer Key

- Q1: C - Carbon is most electronegative.
- Q2: B - Electronegativity decreases down the group.
- Q3: B - Smaller size leads to higher electronegativity.

Memory Aids

- Electronegativity decreases down group 14 except nearly constant from Si to Pb.
- Group 14 > Group 13 in electronegativity.

Physical Properties

Key Points

- Melting and boiling points of group 14 elements are higher than group 13 due to four covalent bonds.
- Melting and boiling points decrease down the group due to weaker M-M bonds from larger atomic size.

Solved Examples

- **Ex 1:** Explain why carbon has a high melting point.
Answer: Strong covalent bonds with four bonds per atom.

Practice Set

- Q1: Why do group 14 elements have higher melting points than group 13?
A. Ionic bonds B. Metallic bonds C. Four covalent bonds D. Van der Waals forces
- Q2: Melting point trend down group 14 is:
A. Increases B. Decreases C. Constant D. Irregular
- Q3: Which element has the lowest melting point?
A. C B. Si C. Pb D. Sn

Answer Key

- Q1: C - Four covalent bonds increase melting points.
- Q2: B - Melting points decrease down the group.
- Q3: C - Lead has the lowest melting point among these.

Memory Aids

- Four covalent bonds = high melting/boiling points.
- Melting/boiling points decrease down group 14.

Chemical Properties

Oxidation States and Reactivity

- Group 14 elements show +4 and +2 oxidation states.

- C^{4+} does not exist; carbon forms negative oxidation states in carbides.
- Silicon shows similar trends to carbon.
- Ge, Sn, Pb show +2 and +4; +2 stability increases down the group due to inert pair effect.
- Compounds in +4 state are covalent; in +2 state are ionic (e.g., $SnCl_2$ ionic, $SnCl_4$ covalent).
- Tendency to form covalent compounds decreases down the group; ionic compounds increase.

Reactivity Towards Oxygen

- Elements form oxides on strong heating with oxygen.
- Reactions: $C + O_2 \rightarrow CO_2$; $Si + O_2 \rightarrow SiO_2$.
- Monoxides CO, SiO, GeO exist; SiO is unstable.
- Higher oxidation state oxides are more acidic.
- PbO exists as red litharge and yellow massicot.
- Pb_3O_4 (red lead) is a mixed oxide: $2PbO \cdot PbO_2$.

Reactivity Towards Water

- C, Si, Ge unaffected by water; on red heating, they decompose steam.
- Reactions: $C + H_2O \rightarrow CO + H_2$; $Si + 2H_2O \rightarrow SiO_2 + 2H_2$.
- Lead is unaffected due to protective oxide film.

Reactivity Towards Halogens

- Group 14 forms halides MX_4 and MX_2 .
- Tetrahalides are covalent except SnF_4 and PbF_4 which are ionic.
- Heavier elements (Ge, Sn, Pb) form stable dihalides MX_2 due to inert pair effect.
- CCl_4 does not hydrolyze (no d-orbitals); $SiCl_4$ and heavier halides hydrolyze due to vacant d-orbitals.
- $SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$ (silicic acid formation).
- Thermal stability of tetrahalides decreases down group: $CX_4 > SiX_4 > GeX_4 > SnX_4 > PbX_4$.
- Thermal stability decreases with heavier halogen: $MF_4 > MCl_4 > MBr_4 > MI_4$.

Solved Examples

- **Ex 1:** Write the reaction of $SiCl_4$ with water.
Answer: $SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$

Practice Set

- Q1: Which oxidation states are common in group 14?
A. +1 and +3 B. +2 and +4 C. +3 and +5 D. +1 and +4
- Q2: Why does Pb show more stability in +2 state?
A. High ionisation energy B. Inert pair effect C. Small size D. High electronegativity
- Q3: Which halide does not hydrolyze?
A. CCl_4 B. $SiCl_4$ C. $SnCl_4$ D. $PbCl_4$

Answer Key

- Q1: B - +2 and +4 are common oxidation states.
- Q2: B - Inert pair effect stabilizes +2 state in Pb.
- Q3: A - CCl_4 does not hydrolyze due to lack of d-orbitals.

Memory Aids

- Inert pair effect increases down group, stabilizing +2 state.
- Carbon forms covalent compounds; heavier elements form ionic in +2 state.
- SiCl_4 hydrolyzes; CCl_4 does not.

Important Trends and Anomalous Behaviour of Carbon

Key Characteristics of Carbon

- Small atomic size compared to other group 14 elements.
- High electronegativity, leading to strong covalent bonding.
- Unique property of catenation: ability to form long chains of carbon atoms.
- Higher ionisation enthalpy than other group 14 members.
- Absence of d-orbitals restricts carbon's bonding capabilities.

Illustration of Anomalous Behaviour

- Melting and boiling points, ionisation energy, and electronegativity of carbon are significantly higher than other group 14 elements.
- Diamond form of carbon is one of the hardest known substances.
- Maximum tendency for catenation among group 14 elements.
- Strong tendency to form $\text{p}\pi\text{-p}\pi$ multiple bonds with elements like N, O, and S.
- CO_2 is a gas, whereas dioxides of other group 14 elements are solids.
- Maximum covalency of carbon is four due to lack of d-orbitals; others can expand covalency to six (e.g., $[\text{SiCl}_6]^{2-}$).

Solved Examples

- **Ex 1:** Explain why carbon shows maximum catenation.
 - Small size and strong C-C bond energy enable formation of long chains.
- **Ex 2:** Why is CO_2 a gas while SiO_2 is solid?
 - CO_2 has discrete molecules with double bonds; SiO_2 forms a giant covalent network.

Practice Set

- **Q1:** Which property is responsible for carbon's ability to form long chains?
 - A. High electronegativity
 - B. Catenation
 - C. High ionisation enthalpy
 - D. Absence of d-orbitals
- **Q2:** Why does carbon have a maximum covalency of four?
 - A. Presence of d-orbitals
 - B. Small atomic size
 - C. Absence of d-orbitals
 - D. High electronegativity
- **Q3:** Which of the following is a gas at room temperature?
 - A. CO_2
 - B. SiO_2
 - C. GeO_2
 - D. SnO_2

Answer Key

- **Q1:** B - Catenation allows carbon to form long chains due to strong C-C bonds.
- **Q2:** C - Carbon lacks d-orbitals, limiting its covalency to four.
- **Q3:** A - CO₂ is a gas; others are solids due to network structures.

Memory Aids

- "Catenation" = Carbon's chain-forming ability.
- CO₂ gas vs. SiO₂ solid: molecular vs. network structure.
- Max covalency 4 = no d-orbitals in carbon.

Allotropes of Carbon

Types of Allotropes

- Carbon exists in different structural forms called allotropes.
- Main allotropes: Diamond, Graphite, Fullerene (Crystalline); Carbon black, Coke, Charcoal (Amorphous).

Solved Examples

- **Ex 1:** Identify the allotrope used in jewellery.
Answer: Diamond due to its brilliant shine.

Practice Set

- Q1: Which allotrope of carbon is hardest?
A. Graphite
B. Diamond
C. Fullerene
D. Charcoal
- Q2: Which allotrope conducts electricity?
A. Diamond
B. Charcoal
C. Graphite
D. Coke
- Q3: Fullerene has a shape similar to:
A. Cube
B. Soccer ball
C. Pyramid
D. Sheet

Answer Key

- Q1: B - Diamond is hardest due to strong 3D covalent bonding.
- Q2: C - Graphite conducts electricity because of delocalized electrons in layers.
- Q3: B - Fullerene resembles a soccer ball (Buckminsterfullerene).

Memory Aids

- Diamond = 3D network, hardest.
- Graphite = layered, slippery, conducts electricity.
- Fullerene = soccer ball shape.

Crystalline Allotropes of Carbon

Properties and Structure

- **Diamond:** Carbon atoms in a strong 3D tetrahedral network; very hard, non-conductive.
- **Graphite:** Carbon atoms in layers; soft, slippery, conducts electricity.
- **Fullerene:** Carbon atoms arranged in rings forming a spherical shape (Buckminsterfullerene).

Allotrope	Properties
Diamond	A rigid three-dimensional network of sp^3 hybridised carbon atoms, hardest substance known and used as an abrasive.
Graphite	Most stable allotrope, having layered structure in which each layer has sp^2 hybridised carbon atoms in hexagonal rings and adjacent layers are held together by van der Waals' forces, soft, slippery, conductor of electricity and used as lubricant in machines.
Fullerene	Pure form of carbon, consists mainly of C_{60} , has shape like soccer ball, also called Buckminsterfullerene which contains 20 six-membered rings and 12 five-membered rings and all carbon atoms are sp^2 hybridised.

Solved Examples

- **Ex 1:** Explain why graphite is a good lubricant.
Answer: Layers slide over each other easily due to weak van der Waals forces.

Practice Set

- Q1: Which allotrope has a 3D network?
A. Graphite
B. Fullerene
C. Diamond
D. Carbon black
- Q2: Why does graphite conduct electricity?
A. Free electrons between layers
B. Ionic bonding
C. Metallic bonding
D. None
- Q3: Fullerene is also called:
A. Graphitic acid
B. Buckminsterfullerene
C. Carbon black
D. Coke

Answer Key

- Q1: C - Diamond has a 3D covalent network.
- Q2: A - Delocalized electrons between layers conduct electricity.

- Q3: B - Fullerene is Buckminsterfullerene.

Memory Aids

- Diamond = 3D network, hardest.
- Graphite = layers slide, conducts electricity.
- Fullerene = soccer ball shape.

Amorphous Allotropes of Carbon

Formation and Types

- Carbon black: Formed by burning hydrocarbons with limited air.
- Charcoal: Obtained by heating wood in absence of air.
- Coke: Obtained by heating coal in absence of air.
- All are impure forms of graphite or fullerenes.

Solved Examples

- **Ex 1:** How is carbon black produced?
Answer: By burning hydrocarbons in limited air supply.

Practice Set

- Q1: Charcoal is made by:
A. Burning coal
B. Heating wood without air
C. Burning hydrocarbons
D. Heating graphite
- Q2: Coke is used as:
A. Fuel
B. Lubricant
C. Reducing agent in metallurgy
D. Pigment
- Q3: Carbon black is used in:
A. Jewellery
B. Black ink and tyres
C. Fuel
D. Water gas production

Answer Key

- Q1: B - Charcoal is made by heating wood without air.
- Q2: C - Coke is a reducing agent in metallurgy.
- Q3: B - Carbon black is used as pigment and tyre filler.

Memory Aids

- Carbon black = limited air combustion.
- Charcoal = heated wood no air.
- Coke = heated coal no air, reducing agent.

Uses of Carbon

Applications of Different Forms

- Graphite: Lubricant at high temperature, refractory material for crucibles and electrodes.
- Carbon black: Black pigment in ink, filler in tyres.
- Coal and charcoal: Used as fuel.
- Coal: Used to manufacture producer gas and water gas.
- Coke: Reducing agent in metallurgy.
- Diamond: Precious stones in jewellery due to brilliant shine.

Solved Examples

- **Ex 1:** Why is graphite used as a lubricant?
Answer: Layers slide easily at high temperature.

Practice Set

- Q1: Which form of carbon is used in making crucibles?
A. Diamond
B. Graphite
C. Charcoal
D. Fullerene
- Q2: Carbon black is used in:
A. Jewellery
B. Black ink and tyres
C. Fuel
D. Producer gas
- Q3: Coke is mainly used as:
A. Fuel
B. Reducing agent
C. Lubricant
D. Pigment

Answer Key

- Q1: B - Graphite is refractory and used in crucibles.
- Q2: B - Carbon black is pigment and tyre filler.
- Q3: B - Coke is a reducing agent in metallurgy.

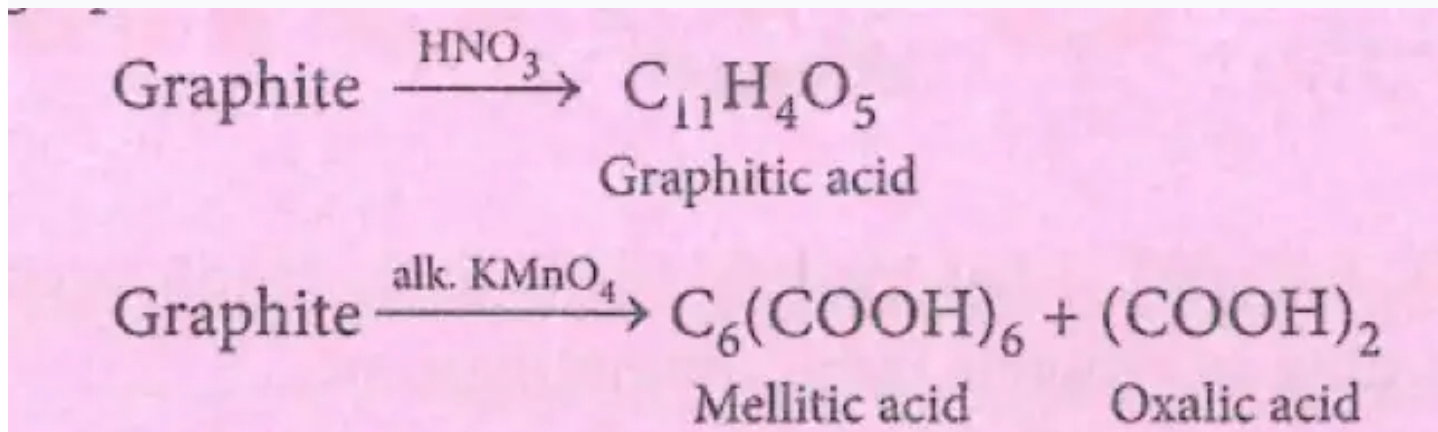
Memory Aids

- Graphite = lubricant, refractory.
- Carbon black = pigment, tyre filler.
- Coke = reducing agent.
- Diamond = jewellery.

Chemical Reactions of Graphite

Oxidation Reactions

- Graphite + conc. $\text{HNO}_3 \rightarrow$ Graphitic acid ($\text{C}_{11}\text{H}_4\text{O}_5$).
- Graphite + alkaline $\text{KMnO}_4 \rightarrow$ Mellitic acid ($\text{C}_6(\text{COOH})_6$) + Oxalic acid ($(\text{COOH})_2$).



Solved Examples

- Ex 1:** Write the product when graphite reacts with conc. HNO_3 .
Answer: Graphitic acid ($\text{C}_{11}\text{H}_4\text{O}_5$).
- Ex 2:** Name acids formed when graphite is oxidized with alkaline KMnO_4 .
Answer: Mellitic acid and oxalic acid.

Practice Set

- Q1: Graphite reacts with conc. HNO_3 to form:
A. Oxalic acid
B. Graphitic acid
C. Mellitic acid
D. Water
- Q2: Oxidation of graphite with alkaline KMnO_4 produces:
A. Graphitic acid
B. Oxalic acid and mellitic acid
C. Carbon black
D. Charcoal
- Q3: Which reagent is used to convert graphite to mellitic acid?
A. Conc. HNO_3
B. Alkaline KMnO_4
C. H_2SO_4
D. NaOH

Answer Key

- Q1: B - Graphitic acid is formed with conc. HNO_3 .
- Q2: B - Mellitic and oxalic acids form with alkaline KMnO_4 .
- Q3: B - Alkaline KMnO_4 oxidizes graphite to mellitic acid.

Memory Aids

- Conc. $\text{HNO}_3 \rightarrow$ Graphitic acid.
- Alkaline $\text{KMnO}_4 \rightarrow$ Mellite + Oxalic acids.

Carbon Monoxide

Properties and Preparation

- Colourless, odourless, poisonous, almost water insoluble gas.
- Prepared by:
 - $\text{C} + \text{limited O}_2 \rightarrow \text{CO}$
 - $\text{HCOOH} + \text{heat} + \text{H}_2\text{SO}_4 \rightarrow \text{CO} + \text{H}_2\text{O}$
 - $\text{C} + \text{H}_2\text{O (steam)} \rightarrow \text{CO} + \text{H}_2 \text{ (water gas)}$
 - $\text{C} + \text{O}_2 + \text{N}_2 \text{ (air)} \rightarrow \text{CO} + \text{N}_2 \text{ (producer gas)}$
- Powerful reducing agent; reduces many metal oxides except alkali, alkaline earth metals, Al, and some transition metals.
- Forms metal carbonyls by acting as a donor to metals.
- Toxic: forms stable complex with haemoglobin, preventing oxygen transport, causing death.

Solved Examples

- **Ex 1:** Write the reaction for preparation of CO from formic acid.
 - $\text{HCOOH} + \text{heat} + \text{H}_2\text{SO}_4 \rightarrow \text{CO} + \text{H}_2\text{O}$
- **Ex 2:** Reaction of carbon with steam.
 - $\text{C} + \text{H}_2\text{O} \rightarrow \text{CO} + \text{H}_2$

Practice Set

- Q1: Carbon monoxide is prepared by:
 - A. Complete combustion of carbon
 - B. Reaction of carbon with limited oxygen
 - C. Reaction of carbon with excess oxygen
 - D. Reaction of carbon with nitrogen
- Q2: Which of the following is NOT reduced by CO?
 - A. CuO
 - B. Fe_2O_3
 - C. Na_2O
 - D. PbO
- Q3: CO is toxic because it:
 - A. Is acidic
 - B. Forms stable complex with haemoglobin
 - C. Is water soluble
 - D. Reacts with oxygen

Answer Key

- Q1: B - CO forms when carbon reacts with limited oxygen, not complete combustion.
- Q2: C - CO does not reduce alkali metal oxides like Na_2O .
- Q3: B - CO forms a stable complex with haemoglobin, blocking oxygen transport.

Memory Aids

- CO reduces metal oxides except alkali, alkaline earth, Al oxides.
- $\text{CO} + \text{Hb} \rightarrow \text{carboxyhaemoglobin (toxic complex)}$.
- Preparation: $\text{Limited O}_2 + \text{C} \rightarrow \text{CO}$.

Carbon Dioxide

Properties and Preparation

- Colourless, odourless gas with molecular structure $\text{O}=\text{C}=\text{O}$ (linear, resonance forms).
- Prepared by:
 - Complete combustion of carbon or methane: $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$
 - Heating limestone: $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$
 - $\text{CaCO}_3 + \text{HCl} \rightarrow \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$ (lab method)
- Acidic oxide; reacts with bases to form salts.
- Solid CO_2 is dry ice, used for freezing foods and ice-cream.
- Not poisonous but excess causes greenhouse effect.
- Removed from air by photosynthesis: $6\text{CO}_2 + 12\text{H}_2\text{O} + \text{sunlight} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 + 6\text{H}_2\text{O}$

Solved Examples

- **Ex 1:** Write the reaction for lab preparation of CO_2 .
 - $\text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$
- **Ex 2:** Write the photosynthesis equation.
 - $6\text{CO}_2 + 12\text{H}_2\text{O} + \text{sunlight} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 + 6\text{H}_2\text{O}$

Practice Set

- Q1: Carbon dioxide is an example of:
 - A. Basic oxide
 - B. Acidic oxide
 - C. Neutral oxide
 - D. Amphoteric oxide
- Q2: Dry ice is:
 - A. Solid CO
 - B. Solid CO_2
 - C. Solid methane
 - D. Solid oxygen
- Q3: Photosynthesis removes CO_2 from air by producing:
 - A. Oxygen and glucose
 - B. Carbon monoxide
 - C. Methane
 - D. Water only

Answer Key

- Q1: B - CO_2 is an acidic oxide reacting with bases.
- Q2: B - Dry ice is solid carbon dioxide.
- Q3: A - Photosynthesis produces oxygen and glucose, removing CO_2 .

Memory Aids

- CO_2 = acidic oxide, reacts with bases.
- Dry ice = solid CO_2 , used as refrigerant.
- Photosynthesis: $6\text{CO}_2 + 12\text{H}_2\text{O} \rightarrow \text{glucose} + 6\text{O}_2$.

Silicon Dioxide

Properties and Reactions

- Also called silica; found as sand and quartz.
- Covalent, 3D network solid with high Si-O bond enthalpy.
- Almost non-reactive; attacked by HF and NaOH:
 - $\text{SiO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SiO}_3 + \text{H}_2\text{O}$
 - $\text{SiO}_2 + 4\text{HF} \rightarrow \text{SiF}_4 + 2\text{H}_2\text{O}$

Uses

- Quartz used as piezoelectric material in clocks, radios, TVs, mobile communications.
- Silica gel used as drying agent and support for chromatography and catalysts.
- Kieselghur (amorphous silica) used in filtration plants.

Solved Examples

- **Ex 1:** Write reaction of SiO_2 with NaOH.
 - $\text{SiO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SiO}_3 + \text{H}_2\text{O}$
- **Ex 2:** Write reaction of SiO_2 with HF.
 - $\text{SiO}_2 + 4\text{HF} \rightarrow \text{SiF}_4 + 2\text{H}_2\text{O}$

Practice Set

- Q1: Silicon dioxide is commonly found as:
 - A. Salt
 - B. Sand and quartz
 - C. Metal
 - D. Gas
- Q2: SiO_2 reacts with NaOH to form:
 - A. NaCl
 - B. Na_2SiO_3
 - C. NaOH
 - D. NaF
- Q3: Quartz is used in:
 - A. Electrical insulators
 - B. Piezoelectric devices
 - C. Fertilizers
 - D. Explosives

Answer Key

- Q1: B - Silicon dioxide is found as sand and quartz.
- Q2: B - Reaction with NaOH forms sodium silicate.

- Q3: B - Quartz is used as a piezoelectric material.

Memory Aids

- $\text{SiO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SiO}_3 + \text{H}_2\text{O}$
- $\text{SiO}_2 + 4\text{HF} \rightarrow \text{SiF}_4 + 2\text{H}_2\text{O}$
- Quartz = piezoelectric applications.

Silicones

Preparation and Properties

- Organosilicon polymers with repeating unit (R_2SiO).
- Prepared by hydrolysis of dialkyldichlorosilanes made from silicon and alkyl chlorides with copper catalyst at 300°C .
- Polymerization of silanols releases water, forming silicone polymers.
- Chain length controlled by adding $(\text{CH}_3)_3\text{SiCl}$ to block ends.
- Water repelling, high thermal stability, high dielectric strength, resistant to oxidation and chemicals.

Uses

- Sealants, greases, electrical insulators, waterproofing fabrics.
- Biocompatible: used in surgical and cosmetic implants.

Solved Examples

- **Ex 1:** Reaction of silicon with methyl chloride.
 - $\text{Si} + \text{CH}_3\text{Cl} \xrightarrow{\text{Cu catalyst, } 573\text{ K}} (\text{CH}_3)_2\text{SiCl}_2$
- **Ex 2:** Polymerization of silanols.
 - $2\text{R}_2\text{Si}(\text{OH})_2 \rightarrow \text{polymer} + \text{H}_2\text{O}$

Practice Set

- Q1: Silicones are polymers with repeating unit:
 - A. (RSiO_3)
 - B. (R_2SiO)
 - C. (SiO_2)
 - D. (SiCl_4)
- Q2: The polymerization of silanols releases:
 - A. H_2O
 - B. CO_2
 - C. H_2
 - D. O_2
- Q3: Silicones are used as:
 - A. Fertilizers
 - B. Sealants and greases
 - C. Explosives
 - D. Fuels

Answer Key

- Q1: B - Silicones have repeating unit (R_2SiO).
- Q2: A - Polymerization releases water.
- Q3: B - Used as sealants, greases, insulators.

Memory Aids

- Silicones = (R_2SiO) repeating unit.
- Polymerization releases H_2O .
- Used in waterproofing and implants.

Silicates

Structure and Types

- Compounds with SiO_4^{4-} tetrahedral units.
- Units may be discrete or linked by sharing oxygen atoms forming chains, rings, sheets, or 3D structures.

Uses and Applications

- Zeolites are aluminosilicates with some Si replaced by Al^{3+} , charge balanced by Na^+ , K^+ , Ca^{2+} , etc.
- Used as ion exchangers in water softening and catalysts in petrochemical industries.
- ZSM-5 zeolite converts alcohols directly into gasoline.

Solved Examples

- **Ex 1:** Describe the basic unit of silicates.
 - SiO_4^{4-} tetrahedral unit.
- **Ex 2:** Use of zeolites.
 - Ion exchangers and catalysts.

Practice Set

- Q1: The basic structural unit of silicates is:
 - A. SiO_2
 - B. SiO_4^{4-}
 - C. SiCl_4
 - D. SiH_4
- Q2: Zeolites are used as:
 - A. Fertilizers
 - B. Ion exchangers
 - C. Explosives
 - D. Fuels
- Q3: ZSM-5 is used to convert:
 - A. Alcohols to gasoline
 - B. Methane to alcohols
 - C. CO_2 to glucose
 - D. Silicon to silicates

Answer Key

- Q1: B - Silicates have SiO_4^{4-} tetrahedral units.
- Q2: B - Zeolites act as ion exchangers.
- Q3: A - ZSM-5 converts alcohols to gasoline.

Memory Aids

- Silicates = SiO_4^{4-} tetrahedra.
- Zeolites = aluminosilicates, ion exchangers.
- ZSM-5 = alcohol to gasoline catalyst.

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