

Revision Notes on p-Block Elements:

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Boron Family (Group 13 Elements)

- **Members:** B, Al, Ga, In & Tl
- **Melting Point:** Decreases from B to Ga and then increases up to Tl.
- **Ionization Energies:** $1^{\text{st}} \lll 2^{\text{nd}} < 3^{\text{rd}}$
- **Metallic Character:** Increases from B to Tl. B is non-metal

Boron

Preparation of Boron:

- From Boric Acid: $\text{B}_2\text{O}_3(\text{s}) + 3\text{Mg}(\text{s}) \rightarrow 2\text{B}(\text{s}) + 3\text{MgO}(\text{s})$
- From Boron Trichloride
 - (at 1270 K): $2\text{BCl}_3 + 3\text{H}_2(\text{g}) \rightarrow 2\text{B}(\text{s}) + 6\text{HCl}(\text{g})$
 - (at 900 °C): $2\text{BCl}_3(\text{g}) + 3\text{Zn}(\text{s}) \rightarrow 2\text{B}(\text{s}) + 3\text{ZnCl}_2(\text{s})$
- By electrolysis of fused mixture of boric anhydride (B_2O_3) and magnesium oxide (MgO) & Magnesium fluoride at 1100 °C
 - $2\text{MgO} \rightarrow 2\text{Mg} + \text{O}_2(\text{g})$
 - $\text{B}_2\text{O}_3 + 3\text{Mg} \rightarrow 2\text{B} + 3\text{MgO}$
- By thermal decomposition of Boron hydrides & halides:
 $\text{B}_2\text{H}_6(\text{g}) + \Delta \rightarrow 2\text{B}(\text{s}) + 3\text{H}_2(\text{g})$

Compounds of Boron:

Orthoboric acid (H_3BO_3)

Preparation of Orthoboric acid

- From borax : $\text{Na}_2\text{B}_4\text{O}_7 + \text{H}_2\text{SO}_4 + 5\text{H}_2\text{O} \rightarrow \text{Na}_2\text{SO}_4 + 4\text{H}_3\text{BO}_3$
- From colemanite : $\text{Ca}_2\text{B}_6\text{O}_{11} + 2\text{SO}_2 + 11\text{H}_2\text{O} \rightarrow 2\text{Ca}(\text{HSO}_3)_2 + 6\text{H}_3\text{BO}_3$

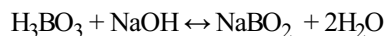
Properties of Orthoboric acid

- **Action of Heat:**

- **Weak monobasic acidic behavior:**



Thus on titration with NaOH, it gives sodium metaborate salt

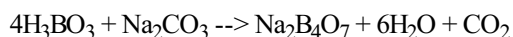


- **Reaction with Metaloxide:**

- **Reaction with Ammonium boro fluoride:**

Borax (sodium tetraborate) $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$

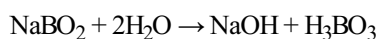
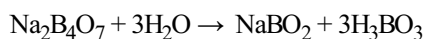
Preparation from Boric Acid



Properties of Borax

- **Basic Nature:-**

Aqueous solution of borax is alkaline in nature due to its hydrolysis

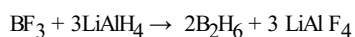


- **Action of heat:**

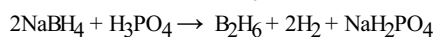
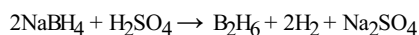
Diborane(B_2H_6)

Preparation of Diborane:

Reduction of Boron Trifluoride:



From NaBH_4 :

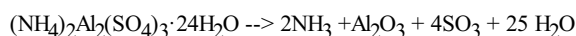
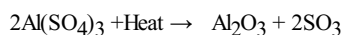
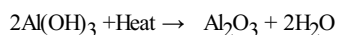


Properties of Diborane:

- **Reaction with water:** $\text{B}_2\text{H}_6 + \text{H}_2\text{O} \rightarrow 2\text{H}_3\text{BO}_3 + 6\text{H}_2$
- **Combustion:** $\text{B}_2\text{H}_6 + 2\text{O}_2 \rightarrow \text{B}_2\text{O}_3 + 3\text{H}_2\text{O} \quad \Delta H = -2615 \text{ kJ/mol}$

Compounds of Aluminium:

Aluminium Oxide or Alumina (Al_2O_3)



Aluminum Chloride AlCl_3 :

Structure of Aluminium Chloride:



Properties of Aluminium Chloride

- White, hygroscopic solid
- Sublimes at 183°C
- Forms addition compounds with NH_3 , PH_3 , COCl_2 etc.
- Hydrolysis: $\text{AlCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{Al}(\text{OH})_3 + 3\text{HCl} + 3\text{H}_2\text{O}$
- Action of Heat: $2\text{AlCl}_3 \cdot 6\text{H}_2\text{O} \rightarrow 2\text{Al}(\text{OH})_3 + \text{Al}_2\text{O}_3 + 6\text{HCl} + 3\text{H}_2\text{O}$

Carbon Family (Group 14 Elements):

- **Members:** C, Si, Ge, Sn, & Pb
- **Ionization Energies:** Decreases from C to Sn and then increases up to Pb.
- **Metallic Character:** C and Si are non metals, Ge is metalloid and Sn and Pb are metals
- **Catenation:** C and Si show a tendency to combine with its own atoms to form long chain polymers

Compounds of Carbon:

Carbon Monoxide

Preparation of Carbon Monoxide

- By heating carbon in limited supply of oxygen: $\text{C} + 1/2\text{O}_2 \rightarrow \text{CO}$.
- By heating oxides of heavy metals e.g. iron, zinc etc with carbon.
 - $\text{Fe}_2\text{O}_3 + 3\text{C} \rightarrow 2\text{Fe} + 3\text{CO}$

- $\text{ZnO} + \text{C} \rightarrow \text{Zn} + \text{CO}$
- By passing steam over hot coke: $\text{C} + \text{H}_2\text{O} \rightarrow \text{CO} + \text{H}_2$ (water gas)
- By passing air over hot coke: $2\text{C} + \text{O}_2 + 4\text{N}_2 \rightarrow 2\text{CO} + 4\text{N}_2$ (Producer gas)

Properties of Carbon Monoxide:

- A powerful reducing agent : $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$
 $\text{CuO} + \text{CO} \rightarrow \text{Cu} + \text{CO}_2$
- Burns in air to give heat and carbon dioxide: $\text{CO} + 1/2\text{O}_2 \rightarrow \text{CO}_2 + \text{heat}$.

Tests For Carbon Monoxide:

- Burns with blue flame
- Turns the filter paper soaked in platinum or palladium chloride to *pink or green*.

Carbon di-oxide

Preparation of Carbon di-oxide

- By action of acids on carbonates: $\text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$
- By combustion of carbon: $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$

Properties of Carbon di-oxide

- It turns lime water milky $\text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 \downarrow + \text{H}_2\text{O}$,
- Milkiness disappears when CO_2 is passed in excess
 $\text{CaCO}_3 + \text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{Ca(HCO}_3)_2$
- Solid carbon dioxide or *dry ice* is obtained by cooling CO_2 under pressure. It passes from the solid state straight to gaseous state without liquefying (hence dry ice).

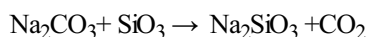
Carbides:

- **Salt like Carbides** : These are the ionic salts containing either C_2^{2-} (acetylide ion) or C^{4-} (methanide ion) e.g. CaC_2 , Al_4C_3 , Be_2C .
- **Covalent Carbides** : These are the carbides of non-metals such as silicon and boron. In such carbides, the atoms of two elements are bonded to each other through covalent bonds. SiC also known as *Carborundum*.
- **Interstitial Carbides** : They are formed by transition elements and consist of metallic lattices with carbon atoms in the interstices. e.g. tungsten carbide WC , vanadium carbide VC .

Compounds of Silicon:

Sodium Silicate (Na_2SiO_3):

?Prepared by fusing soda ash with pure sand at high temperature:



Silicones:

Silicon polymers containing $\text{Si}-\text{O}-\text{Si}$ linkages formed by the hydrolysis of alkyl or aryl substituted chlorosilanes and their

subsequent polymerisation.

Silicates:

Salts of silicic acid, H_4SiO_4 comprised of SiO_4^{4-} units having tetrahedral structure formed as result of sp^3 hybridization.

Nitrogen Family (Group 15 Elements)

- **Members:** N, P, As, Sb & Bi
- **Atomic Radii:** Increases down the group. Only a small increase from As to Bi.
- **Oxidation state:** +3, +4 & +5. Stability of +3 oxidation state increases down the group.
- **Ionization energy:** Increases from N to Bi.

Nitrogen

Preparation of Nitrogen:

- $3\text{CuO} + 2\text{NH}_3 + \text{Heat} \rightarrow \text{N}_2 + \text{Cu} + 3\text{H}_2\text{O}$
- $\text{CaOCl}_2 + 2\text{NH}_3 + \text{Heat} \rightarrow \text{CaCl}_2 + 3\text{H}_2\text{O} + \text{N}_2$
- $\text{NH}_4\text{NO}_2 + \text{Heat} \rightarrow 3\text{H}_2\text{O} + \text{N}_2 + \text{Cr}_2\text{O}_3$

Properties of Dinitrogen:

- Formation of Nitrides (with Li, Mg, Ca & Al): $\text{Ca} + \text{N}_2 + \text{Heat} \rightarrow \text{Ca}_3\text{N}_2$
- Oxidation: $\text{N}_2 + \text{O}_2 \rightarrow 2\text{NO}$
- Reaction with carbide (at 1273 K): $\text{CaC}_2 + \text{N}_2 \rightarrow \text{CaCN}_2 + \text{C}$

Oxides of Nitrogen

Oxy -Acids of Nitrogen :

Oxy Acids	Name of oxy – acid
1. $\text{H}_2\text{N}_2\text{O}_2$	Hyponitrous acid
2. H_2NO_2	Hydronitrous acid
3. HNO_2	Nitrous acid
4. HNO_3	Nitric acid
5. HNO_4	Per nitric acid

Ammonia (NH_3):

Preparation of Ammonia:

- By heating an ammonium salt with a strong alkali ; $\text{NH}_4\text{Cl} + \text{NaOH} \rightarrow \text{NH}_3 + \text{NaCl} + \text{H}_2\text{O}$
- By the hydrolysis of magnesium nitride: $\text{Mg}_3\text{N}_2 + 6\text{H}_2\text{O} \rightarrow 3\text{Mg}(\text{OH})_2 + 2\text{NH}_3$.
- Haber's process : $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$.

Properties of Ammonia:

- **Basic nature** : Its aq. solution is basic in nature and turns red litmus blue.
 $\text{NH}_3 + \text{H}_2\text{O} \leftrightarrow \text{NH}_4^+ + \text{OH}^-$
- **Reaction with halogens** :

- $8\text{NH}_3 + 3\text{Cl}_2 \rightarrow 6\text{NH}_4\text{Cl} + \text{N}_2$
- $\text{NH}_3 + 3\text{Cl}_2 \text{ (in excess)} \rightarrow \text{NCl}_3 + 3\text{HCl}$
- $8\text{NH}_3 + 3\text{Br}_2 \rightarrow 6\text{NH}_4\text{Br} + \text{N}_2$
- $\text{NH}_3 + 3\text{Br}_2 \text{ (in excess)} \rightarrow \text{NBr}_3 + 3\text{HBr}$
- $2\text{NH}_3 + 3\text{I}_2 \rightarrow \text{NH}_3 \cdot \text{NI}_3 + 3\text{HI}$
- $8\text{NH}_3 \cdot \text{NI}_3 \rightarrow 6\text{NH}_4\text{I} + 9\text{I}_2 + 6\text{N}_2$

• **Complex formation :**

- $\text{Ag}^+ + \text{NH}_3 \rightarrow [\text{Ag}(\text{NH}_3)_2]^+$
- $\text{Cu}^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4]^{2+}$
- $\text{Cd}^{2+} + 4\text{NH}_3 \rightarrow [\text{Cd}(\text{NH}_3)_4]^{2+}$

Precipitation of heavy metal ions from the aq. solution of their salts :

- $\text{FeCl}_3 + 3\text{NH}_4\text{OH} \rightarrow \text{Fe}(\text{OH})_3 + 3\text{NH}_4\text{Cl}$
Brown ppt.
- $\text{AlCl}_3 + 3\text{NH}_4\text{OH} \rightarrow \text{Al}(\text{OH})_3 + 3\text{NH}_4\text{Cl}$
White ppt.
- $\text{CrCl}_3 + 3\text{NH}_4\text{OH} \rightarrow \text{Cr}(\text{OH})_3 + 3\text{NH}_4\text{Cl}$
Green ppt.

Phosphorus:

Allotropy of Phosphorus:

a) White phosphorus:

- Translucent white waxy solid
- Extremely reactive
- Poisonous and insoluble in water

White phosphorus

b) Red Phosphorus:

- Formed by heating white phosphorus in absence of air.
- Does not burn spontaneously at room temperature.

Red Phosphorus

c) Black Phosphorus: Formed by further heating of red phosphorus.

Compounds of Phosphorus:

a) Phosphine, PH_3 :

Preparation of Phosphine

- $\text{Ca}_3\text{P}_2 + 6\text{H}_2\text{O} \rightarrow 2\text{PH}_3 + 3\text{Ca}(\text{OH})_2$

- $4\text{H}_3\text{PO}_3 + \text{Heat} \rightarrow \text{PH}_3 + 3 \text{H}_3\text{PO}_4$
- $\text{PH}_4\text{I} + \text{KOH} \rightarrow \text{PH}_3 + \text{KI} + \text{H}_2\text{O}$
- $\text{P}_4 + 3\text{KOH} + 3\text{H}_2\text{O} \rightarrow \text{PH}_3 + 3\text{KH}_2\text{PO}_2$

Properties of Phosphine:

- Formation of Phosphonic Iodide: $\text{PH}_3 + \text{HI} \rightarrow \text{PH}_4\text{I}$
- Combustion: $\text{PH}_3 + 2\text{O}_2 \rightarrow \text{H}_3\text{PO}_4$

b) Phosphorous Halides:

Preparation:

- $\text{P}_4 + 6\text{Cl}_2 \rightarrow 4\text{PCl}_3$
- $\text{P}_4 + 10\text{Cl}_2 \rightarrow 4\text{PCl}_5$
- $\text{P}_4 + 8\text{SOCl}_2 \rightarrow 4\text{PCl}_3 + 4\text{SO}_2 + 2\text{S}_2\text{Cl}_2$
- $\text{P}_4 + 10\text{SOCl}_2 \rightarrow 4\text{PCl}_5 + 10\text{SO}_2$

Properties:

- $\text{PCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_3 + 3\text{HCl}$
- $\text{PCl}_5 + 4\text{H}_2\text{O} \rightarrow \text{POCl}_3 + \text{H}_3\text{PO}_4 + 5\text{HCl}$
- $\text{PCl}_3 + 3\text{CH}_3\text{COOH} \rightarrow 3 \text{CH}_3\text{COCl} + \text{H}_3\text{PO}_3$
- $\text{PCl}_5 + \text{CH}_3\text{COOH} \rightarrow \text{CH}_3\text{COCl} + \text{POCl}_3 + \text{HCl}$
- $2\text{Ag} + \text{PCl}_5 \rightarrow 2\text{AgCl} + \text{PCl}_3$
- $2\text{Sn} + \text{PCl}_5 \rightarrow \text{SnCl}_4 + 2\text{PCl}_3$
- $\text{PCl}_5 + \text{Heat} \rightarrow \text{PCl}_3 + \text{Cl}_2$

?C) Oxides of Phosphorus:

d) Oxy – Acids of Phosphorus:

Oxo acid	Name
H_3PO_2	Hypophosphorus acid
H_3PO_3	Phosphorus acid
$\text{H}_4\text{P}_2\text{O}_6$	Hypophosphoric acid
H_3PO_4	Orthophosphoric acid
$\text{H}_4\text{P}_2\text{O}_7$	Pyrophosphoric acid
HPO_3	Metaphosphoric acid

Oxygen Family (Group 16 Elements) :

Sr. No.	Property	Oxygen	Sulfur	Selenium	Tellurium	Polonium
1.	Configuration	[He]2s ² 2p ⁴	[Ne]3s ² 3p ⁴	[Ar]4s ² 4p ⁴	[Kr]5s ² 5p ⁴	[Xe]6s ² 6p ⁴
2.	Common oxidation state	-2	-2, +4, +6	+4, +6	+4, +6	
3.	Atomic radius (pm)	66	104	116	143	167
4.	First ionization energy (KJ/mol)	1314	1000	941	869	812
5.	Electronegativity	3.5	2.5	2.4	2.1	2.0

Chemical Properties of Group 16:

Formation of volatile Hydrides:

□

Formation of Halides:

□

Formation of Oxide:

a) All elements (except Se) forms monoxide.

b) All elements form dioxide with formula MO₂, SO₂ is a gas, SeO₂ is volatile solid. While TeO₂ and PoO₂ are non – volatile crystalline solids.

c) **Ozone:** It is unstable and easily decomposes into oxygen. It acts as a strong oxidising agent due to the ease with which it can liberate nascent oxygen.

Oxyacids:

Sulphur	Selenium	Tellurium
Sulphurous acid H ₂ SO ₃ .	Selenious acid H ₂ SeO ₃	Tellurous acid H ₂ TeO ₃ .
Sulphuric acid H ₂ SO ₄	Selenic acid H ₂ SeO ₄	Telluric acid H ₂ TeO ₄ .
Peroxomonosulphuric acid H ₂ SO ₅ (Caro's acid)		
Peroxodisulphuric acid H ₂ S ₂ O ₈ (Marshall's acid)		
Thio sulphuric acid H ₂ S ₂ O ₃		
Dithionic acid H ₂ S ₂ O ₆		
Pyrosulphuric acid H ₂ S ₂ O ₇		

Allotropes of Sulphur :

Rhombic sulphur:

- It has bright yellow colour.

- It is insoluble in water and carbon disulphide. Its density is 2.07 gm cm^{-3} and exists as S_8 molecules. The 8 sulphur atoms in S_8 molecule forms a puckered ring.

Monoclinic Sulphur :

- Stable only above 369 K. It is dull yellow coloured solid, also called *b - sulphur*. It is soluble in CS_2 but insoluble in H_2O .
- It slowly changes into rhombic sulphur. It also exist as S_8 molecules which have puckered ring structure. It however, differs from the rhombic sulphur in the symmetry of the crystals

Plastic Sulphur:

- It is obtained by pouring molten sulphur to cold water.
- It is amorphous form of sulphur.
- It is insoluble in water as well as CS_2 .

Sulphuric Acid:

- Due to strong affinity for water, H_2SO_4 acts as a powerful dehydrating agent.
- Concentrated H_2SO_4 reacts with sugar, wood, paper etc to form black mass of carbon. This phenomenon is called charring.
- It is moderately strong oxidizing agent.
 -
- Decomposes carbonates, bicarbonates, sulphides, sulphites, thiosulphates and nitrites at room temperatures.
 -
- Salts like chlorides, fluorides, nitrates, acetates, oxalates are decomposed by hot conc. H_2SO_4 liberating their corresponding acids.
 - ? □

Halogen Family (Group 17 Elements)

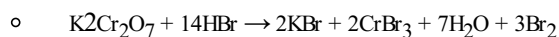
Inter halogen compounds:

Type XX'_1 ($n = 1$) (with linear shape)	Type XX'_3 ($n = 3$) (with T-shape)	XX'_5 ($n = 5$) (with square pyramidal shape)	XX'_7 ($n = 7$) with pentagonal bipyramidal shape)
ClF	ClF ₃	ClF ₅	
BrF BrCl	BrF ₃	BrF ₅	
ICl, IBr, IF	ICl ₃ , IF ₃	IF ₅	IF ₇

Hydrogen Halides:

Properties of Hydrogen Halides:

- All the three acids are reducing agents HCl is not attacked by H_2SO_4 .
 - $2\text{HBr} + \text{H}_2\text{SO}_4 \rightarrow 2\text{H}_2\text{O} + \text{SO}_2 + \text{Br}_2$
 - $2\text{HI} + \text{H}_2\text{SO}_4 \rightarrow 2\text{H}_2\text{O} + \text{SO}_2 + \text{I}_2$
- All the three react with KMnO_4 and $\text{K}_2\text{Cr}_2\text{O}_7$
 - $2\text{KMnO}_4 + 16\text{HCl} \rightarrow 2\text{KCl} + 2\text{MnCl}_2 + 8\text{H}_2\text{O} + 5\text{Cl}_2$



- Other reactions are similar.

- Dipole moment : $HI < HBr < HCl < HF$
- Bond length: $HF < HCl < HBr < HI$
- Bond strength: $HI < HBr < HCl < HF$
- Thermal stability: $HI < HBr < HCl < HF$
- Acid strength: $HF < HCl < HBr < HI$
- Reducing power: $HF < HCl < HBr < HI$

Pseudohalide ions and pseudohalogens:

Ions which consist of two or more atoms of which at least one is nitrogen and have properties similar to those of halide ions are called pseudohalide ions. Some of these pseudohalide ions can be oxidised to form covalent dimers comparable to halogens (X_2). Such covalent dimers of pseudohalide ions are called pseudohalogens.

The best known pseudohalide ion is CN^-

Pseudohalide ions	Name
CN^-	Cyanide ion
OCN^-	Cyanate ion
SCN^-	Thiocyanate ion
$SeCN^-$	Selenocyanate ion
NCN^{2-}	Cyanamide ion
N_3^-	Azide ion
OMC^-	Fulminate ion

Pseudohalogen

- $(CN)_2$ cyanogen
- $(SCN)_2$ thiocyanogen

Some important stable compound of Xenon

- XeO_3 Pyramidal
- XeO_4 Tetrahedral
- $XeOF_4$ Square pyramidal
- XeO_2F_2 Distorted octahedral

First rare gas compound discovered was $Xe^+ (PtF_6)^-$ by Bartlett.

Oxyacids of Chlorine

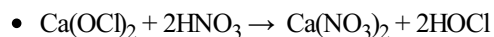
Formula	Name	Corresponding Salt
$HOCl$	Hypochlorous acid	Hypochlorites

HClO ₂	Chlorous acid	Chlorites
HClO ₃	Chloric acid	Chlorates
HClO ₄	Perchloric acid	Perchlorates

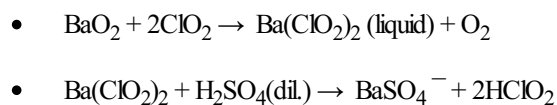
Acidic Character: Acidic character of the same halogen increases with the increase in oxidation number of the halogen: HClO₄ > HClO₃ > HClO₂ > HOCl

Preparation

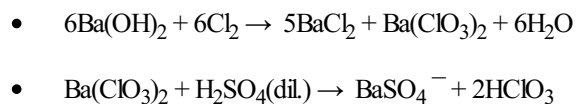
HOCl :



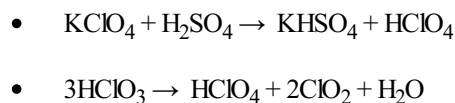
HClO₂ :



HClO₃ :



HClO₄ :



The Noble Gases (Group 18 Elements):

The noble gases are inert in nature. They do not participate in the reactions easily because they have

- stable electronic configuration i.e. complete octet.
- high ionization energies.
- low electron affinity.

Compounds of Xenon

□

Molecule	Total electron pairs (BP + LP)	Hybridisation	Shape
XeF ₂	5	Sp ³ d	Linear
XeF ₄	6	Sp ³ d ²	Square planar
XeF ₆	7	sp ³ d ³	Distorted octahedral

Uses of Nobles gas

The noble gases are used in following ways:

(A) Helium

- It is used to fill airships and observation balloons.
- In the oxygen mixture of deep sea divers.
- In treatment of asthma.
- Used in inflating aeroplane tyres.
- Used to provide inert atmosphere in melting and welding of easily oxidizable metals.

(B) Neon

- It is used for filling discharge tubes, which have different characteristic colours and are used in advertising purposes.
- Also used in beacon lights for safety of air navigators as the light possesses fog and steam penetrating power.

(C) Argon

Along with nitrogen it is used in gas – filled electric lamps because argon is more inert than nitrogen.