

- 7.1 Group 15 Elements
- 7.2 Dinitrogen
- 7.3 Ammonia
- 7.4 Oxides of Nitrogen

Phosphine

7.5 Nitric Acid

7.7

- 7.6 Phosphorus Allotropic Forms
- 7.12 Simple Oxides 7.13 Ozone 7.14 Sulphur - Allotropic Forms

7.11 Dioxygen

7.10 Group 16 Elements

7.8

7.9

7.15 Sulphur Dioxide

**Phosphorus Halides** 

**Oxoacids of Phosphorus** 

- 7.16 Oxoacids of Sulphur
- 7.17 Sulphuric Acid
- 7.18 Group 17 Elements
- 7.19 Chlorine
- 7.20 Hydrogen Chloride
- 7.21 Oxoacids of Halogens
- 7.22 Interhalogen Compounds
- 7.23 Group 18 Elements



# QUICK RECAP

Elements in which the last electron enters any one of the three *p*-orbitals of their respective outermost shell are called *p*-block elements.

### **GROUP 15 ELEMENTS (NITROGEN FAMILY)**

Group 15 elements are collectively called *pnictogens*.

D General characteristics :			
Electronic configuration	$n ns^2 np^3$		
Elements	$_{7}$ N, $_{15}$ P, $_{33}$ As, $_{51}$ Sb, $_{83}$ Bi		
Physical state and	$\mathrm{N}_2$ (unreactive gas), $\mathrm{P}_4$ (solid non-metal), $\mathrm{As}_4$ and $\mathrm{Sb}_4$ (Solid metalloids),		
metallic character	Bi (metal)		
Atomic radii	Increase down the group, smaller than that of group 14 elements due to increased		
	nuclear charge.		
Melting and	M.pt. increases from N to As and then decreases whereas b. pt. increases from		
boiling points	N to Sb and decreases very slightly.		
Ionisation enthalpy	Decreases regularly down the group due to increase in size.		
Electronegativity	Decreases down the group.		
Allotropy	Nitrogen ( $\alpha$ and $\beta$ -Nitrogen), phosphorus (white, red, scarlet, violet, $\alpha$ - black,		
	$\beta$ -black), arsenic (grey, yellow, black), antimony (metallic, yellow, explosive)		

### Chemical properties :

- Stability of +3 oxidation state increases and that of +5 decreases down the group due to *inert pair effect*.
- ▶ **Halides :** All the elements form trihalides of the type *MX*<sub>3</sub> and except nitrogen, all form pentahalides of the type *MX*<sub>5</sub>.
  - **Stability** :  $NF_3 > NCl_3 > NBr_3$
  - Lewis acid strength: PCl<sub>3</sub> > AsCl<sub>3</sub> > SbCl<sub>3</sub> and PF<sub>3</sub> > PBr<sub>3</sub> > PI<sub>3</sub>
  - Lewis base strength :  $NI_3 > NBr_3 > NCl_3 > NF_3$
  - Bond angle : PF<sub>3</sub> < PCl<sub>3</sub> < PBr<sub>3</sub> < PI<sub>3</sub> (increasing *b.p. - b.p.* repulsions)
- ► Hydrides : All the elements form hydrides of the type *M*H<sub>3</sub> which are covalent and pyramidal in shape. Their general trends are :



► Oxides : All these elements form oxides of the



Compound	Preparation	Properties	Uses
N <sub>2</sub>	$NH_4Cl + NaNO_2 \rightarrow N_2^{\uparrow} + 2H_2O + NaCl$	$6Li + N_2 \xrightarrow{\text{Heat}} 2Li_2N$	Used in manufacture of nitric
	$(NH_{1})_{a}Cr_{a}O_{a} \xrightarrow{\Delta} N_{a}\uparrow +4H_{a}O + Cr_{a}O_{a}$	Heat.	acid, ammonia, calcium
	$ \begin{array}{c} (1114) \\ (211$	$3Mg + N_2 \longrightarrow Mg_3N_2$	cyanamide and other nitrogen
	$Da(1N_3)_2 \rightarrow Da + 51N_2$	773 K	compounds.
$\mathbf{N} \equiv \mathbf{N}$		$N_{2(g)} + 3H_{2(g)} \sim 2NH_{3(g)}$	Liquid dinitrogen is used
		$N_{2(2)} + O_{2(2)} \xrightarrow{Heat} 2NO_{(2)}$	as a refrigerant to preserve
		2100(g)	biological materials, food
			items and in cryosurgery.

D Preparation, properties and uses of some important compounds :

NH3	$\begin{array}{l} \mathrm{NH}_{2}\mathrm{CONH}_{2}+2\mathrm{H}_{2}\mathrm{O} \longrightarrow \\ (\mathrm{NH}_{4})_{2}\mathrm{CO}_{3} \rightleftharpoons 2\mathrm{NH}_{3}+\mathrm{H}_{2}\mathrm{O}+\mathrm{CO}_{2} \\ 2\mathrm{NH}_{4}\mathrm{Cl}+\mathrm{Ca}(\mathrm{OH})_{2} \longrightarrow 2\mathrm{NH}_{3} \\ &+2\mathrm{H}_{2}\mathrm{O}+\mathrm{Ca}\mathrm{Cl}_{2} \\ (\mathrm{NH}_{4})_{2}\mathrm{SO}_{4}+2\mathrm{Na}\mathrm{OH} \longrightarrow 2\mathrm{NH}_{3} \\ &+2\mathrm{H}_{2}\mathrm{O}+\mathrm{Na}_{2}\mathrm{SO}_{4} \\ Haber's \ process: \\ \mathrm{N}_{2(g)}+3\mathrm{H}_{2(g)} \overbrace{\overset{773}{\leftarrow}}{\overset{773}{\leftarrow}} 2\mathrm{NH}_{3(g)}; \\ \Delta H_{f}^{\circ}=-46.1 \ \mathrm{kJ/mol} \end{array}$	$\begin{array}{c} \operatorname{NH}_{3(g)} + \operatorname{H}_2\operatorname{O}_{(l)} & \longrightarrow \operatorname{NH}_{4(aq)}^+ + \operatorname{OH}_{(aq)}^-\\ \operatorname{ZnSO}_{4(aq)} + 2\operatorname{NH}_4\operatorname{OH}_{(aq)} & \longrightarrow \\ & \operatorname{Zn}(\operatorname{OH})_{2(s)} + (\operatorname{NH}_4)_2\operatorname{SO}_{4(aq)}\\ & (\operatorname{white ppt.}) & \end{array}$ $\begin{array}{c} \operatorname{FeCl}_{3(aq)} + \operatorname{NH}_4\operatorname{OH}_{(aq)} & \longrightarrow \\ & \operatorname{FecO}_3 \cdot x\operatorname{H}_2\operatorname{O}_{(s)} + \operatorname{NH}_4\operatorname{Cl}_{(aq)}\\ & (\operatorname{brown ppt.}) & \end{array}$ $\begin{array}{c} \operatorname{Cu}_{(aq)}^2 + 4\operatorname{NH}_{3(aq)} & \longrightarrow & [\operatorname{Cu}(\operatorname{NH}_3)_4]_{(aq)}^{2+}\\ & (\operatorname{blue}) & (\operatorname{deep blue}) & \\ \operatorname{Ag}_{(aq)}^+ + \operatorname{Cl}_{(aq)}^- & \rightarrow & \operatorname{AgCl}_{(s)}\\ & (\operatorname{colourless}) & (\operatorname{white ppt.}) & \\ \operatorname{AgCl}_{(s)} + 2\operatorname{NH}_{3(aq)} & \longrightarrow & [\operatorname{Ag}(\operatorname{NH}_3)_2]\operatorname{Cl}_{(aq)}\\ & (\operatorname{white ppt.}) & (\operatorname{colourless}) & \end{array}$	Used in refrigerators, manufacturing of rayon, HNO <sub>3</sub> , NaHCO <sub>3</sub> , nitrogenous fertilizers.
н <sub>0</sub> -N 20	NaNO <sub>3</sub> + H <sub>2</sub> SO <sub>4</sub> $\longrightarrow$ NaHSO <sub>4</sub> + HNO <sub>3</sub> Ostwald's Process : $4NH_3 + 5O_2 \xrightarrow{Pt/Rh gauge}{500 \text{ K}, 9 \text{ bar}} \rightarrow$ $4NO + 6H_2O$ $2NO + O_2  2NO_2$ $3NO_2 + H_2O \longrightarrow 2HNO_3 + NO$	$\begin{array}{c} HNO_{3(aq)} + H_2O_{(l)} \longrightarrow H_3O_{(aq)}^+ + NO_{3(aq)}^- \\ 3Cu + 8HNO_3(dilute) \longrightarrow 3Cu(NO_3)_2 \\ + 2NO + 4H_2O \\ Cu + 4HNO_3(conc.) \longrightarrow Cu(NO_3)_2 \\ + 2NO_2 + 2H_2O \\ 4Zn + 10HNO_3(dilute) \longrightarrow \\ 4Zn(NO_3)_2 + 5H_2O + N_2O \\ Zn + 4HNO_3(conc.) \longrightarrow Zn(NO_3)_2 \\ + 2H_2O + 2NO_2 \\ I_2 + 10HNO_3 \longrightarrow 2HIO_3 + 10NO_2 + 4H_2O \\ C + 4HNO_3 \longrightarrow CO_2 + 2H_2O + 4NO_2 \\ S_8 + 48HNO_3 \longrightarrow 8H_2SO_4 + 48NO_2 \\ + 16H_2O \\ P_4 + 20HNO_3 \longrightarrow 4H_3PO_4 + 20NO_2 \\ + 4H_2O \\ NO_3^- + 3Fe^{2+} + 4H^+ \longrightarrow NO + 3Fe^{3+} \\ [Fe(H_2O)_6]^{2+} + NO \\ \hline \end{array}$	Used as fertilizers, explosives, perfumes and dyes.
PH <sub>3</sub>	$Ca_{3}P_{2} + 6H_{2}O \longrightarrow 3Ca(OH)_{2} + 2PH_{3}$ $Ca_{3}P_{2} + 6HCl \longrightarrow 3CaCl_{2} + 2PH_{3}$ $P_{4} + 3NaOH + 3H_{2}O \longrightarrow PH_{3}$ $+ 3NaH_{2}PO_{2}$ (sodium hypophosphite) $PH_{4}I + KOH \longrightarrow KI + H_{2}O + PH_{3}$	$3CuSO_4 + 2PH_3 \longrightarrow Cu_3P_2 + 3H_2SO_4$ $3HgCl_2 + 2PH_3 \longrightarrow Hg_3P_2 + 6HCl$ $PH_3 + HBr \longrightarrow PH_4Br$	The spontaneous combustion of phosphine is technically used in <i>Holme's</i> <i>signals.</i> It is also used in <i>smoke</i> <i>screens.</i>
$\begin{array}{c} PCl_{5} \\ Cl \\ Cl \\ P' \\ Cl \\ Cl \\ Cl \\ Cl \end{array}$	$P_4 + 10Cl_2 \longrightarrow 4PCl_5$ (white or red)	PCl <sub>5</sub> $\xrightarrow{H_2O}$ $H_3PO_4 + HCl$ PCl <sub>5</sub> $\xrightarrow{P_4S_{10}}$ PSCl <sub>3</sub> PCl <sub>5</sub> $\xrightarrow{SO_2}$ SOCl <sub>2</sub> + POCl <sub>3</sub> PCl <sub>5</sub> $\xrightarrow{P_4O_{10}}$ POCl <sub>3</sub>	Used as chlorinating and dehydrating agent.



• Prepa	Preparation and properties of oxides of introgen :			
Formula	O.S.	Preparation	Properties	
N <sub>2</sub> O	+1	$NH_4NO_3 \xrightarrow{\Delta} N_2O + 2H_2O$	colourless gas, neutral	
NO	+2	$2NaNO_2 + 2FeSO_4 + 3H_2SO_4 \longrightarrow Fe_2(SO_4)_3 + 2NaHSO_4$	colourless gas, neutral	
		+ 2H <sub>2</sub> O + 2NO		
N <sub>2</sub> O <sub>3</sub>	+3	$2NO + N_2O_4 \xrightarrow{250 \text{ K}} 2N_2O_3$	blue solid, acidic	
NO <sub>2</sub>	+4	$2Pb(NO_3)_2 \xrightarrow{673 \text{ K}} 2PbO + 4NO_2 + O_2$	brown gas, acidic	
N <sub>2</sub> O <sub>4</sub>	+4	$2NO_2 \xrightarrow{cool} N_2O_4$	colourless solid/liquid, acidic	
$N_2O_5$	+5	$4HNO_3 + P_4O_{10} \longrightarrow 4HPO_3 + 2N_2O_5$	colourless solid, acidic	

### Allotropes of phosphorus :

Property	White phosphorus	Red Phosphorus	Black phosphorus
Colour	White, but turns yellow on exposure	Dark red	Black
State	Waxy solid, can be cut with knife	Brittle powder	Crystalline with greasy touch
Smell	Garlic smell	Odourless	—
Density	1.84	2.1	2.69
Ignition temperature	307 K	543 K	673 K
Melting point	317 K	Sublimes in absence of air at 560 K	860 K

► White phosphorus consists of discrete tetrahedral P<sub>4</sub> molecule.



- Structure of white phosphorus
- Red phosphorus is polymeric and consists of inter linked P<sub>4</sub> tetrahedra.



Structure of red phosphorus

Black phosphorus is thermodynamically most stable at room temperature and has two forms : α-black phosphorus and β-black phosphorus.

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### **Oxoacids of phosphorus :** $\bigcirc$ HC HC OH OH OH H<sub>3</sub>PO<sub>4</sub> $H_4P_2O_7$ Pyrophosphoric Orthophosphoric acid acid ОH H<sub>2</sub>PO<sub>2</sub> H<sub>3</sub>PO<sub>2</sub> Orthophosphorous Hypophosphorous acid HO OH $(HPO_3)_n$ $(HPO_3)_3$ Cyclotrimetaphosphoric Polymetaphosphoric acid acid

### **GROUP 16 ELEMENTS (OXYGEN FAMILY)**

Group 16 elements are collectively called *chalcogens*.

Electronic configuration	ns <sup>2</sup> np <sup>4</sup>
Elements	<sub>8</sub> O, <sub>16</sub> S, <sub>34</sub> Se, <sub>52</sub> Te, <sub>84</sub> Po
Physical state and metallic characters	O <sub>2</sub> (gas), S <sub>8</sub> (solid non-metal), Se and Te (solid metalloid), Po (radioactive)
Atomic radii Increase down the group	
Ionisation enthalpy	Decreases down the group
Electronegativity	Decreases down the group
Electron gain enthalpy	Increases from oxygen to sulphur and then decreases.
Melting and boiling points	Increase down the group upto Te and then decreases.
Allotropy	All elements show allotropy

### General characteristics :

### **Chemical properties :**

 $\mathbf{D}$ 

- Stability of -2 oxidation state decreases down the group, stability of +4 oxidation state increases and that of +6 oxidation state decreases down the group due to *inert pair effect*.
- ► Hydrides : All the elements form stable hydrides of the type H<sub>2</sub>M. Their general trends are :
  - Boiling point :  $H_2O > H_2Te > H_2Se > H_2S$
  - Volatility :  $H_2S > H_2Se > H_2Te > H_2O$
  - **Bond angle :**  $H_2O > H_2S > H_2Se > H_2Te$

- Acidic character :  $H_2O < H_2S < H_2Se < H_2Te$ 

- $\label{eq:reducing power: H_2Te} \textbf{Reducing power: } H_2Te > H_2Se > H_2S > H_2O$
- **Halides :** All elements form halides of the type  $EX_{6}$ ,  $EX_4$  and  $EX_2$ .
- Oxides :

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Simple oxides	MgO, Al <sub>2</sub> O <sub>3</sub>
Mixed oxides	Pb <sub>3</sub> O <sub>4</sub> , Fe <sub>3</sub> O <sub>4</sub>
Acidic oxides	SO <sub>2</sub> , Cl <sub>2</sub> O <sub>7</sub> , CO <sub>2</sub> , N <sub>2</sub> O <sub>5</sub>
Basic oxides	Na <sub>2</sub> O, CaO, BaO
Amphoteric oxides	Al <sub>2</sub> O <sub>3</sub>
Neutral oxides	CO, NO, N <sub>2</sub> O

**Dioxygen**  $(O_2)$ :

Preparation :  $2\text{KClO}_{3} \xrightarrow{\Delta} 2\text{KCl} + 3\text{O}_{2}$   $2\text{Ag}_{2}\text{O}_{(s)} \xrightarrow{\Delta} 4\text{Ag}_{(s)} + \text{O}_{2(g)}$   $2\text{Pb}_{3}\text{O}_{4(s)} \xrightarrow{\Delta} 6\text{PbO}_{(s)} + \text{O}_{2(g)}$   $2\text{HgO}_{(s)} \longrightarrow 2\text{Hg}_{(l)} + \text{O}_{2(g)}$   $2\text{PbO}_{2(s)} \longrightarrow 2\text{PbO}_{(s)} + \text{O}_{2(g)}$   $2\text{H}_{2}\text{O}_{2(aq)} \longrightarrow 2\text{H}_{2}\text{O}_{(l)} + \text{O}_{2(g)}$ 

### Properties :

- Dioxygen is colourless and odourless gas, soluble in water and paramagnetic in nature.
- Dioxygen directly reacts with all metals (except noble metals like Au, Pt ), nonmetals (except noble gases).

$2Ca + O_2 \longrightarrow 2CaO$	(Basic oxide)
$4Al + 3O_2 \longrightarrow 2Al_2O_3$ (Amp	photeric oxide)
$P_4 + 5O_2 \longrightarrow P_4O_{10}$	(Acidic oxide)
$C + O_2 \longrightarrow CO_2$	(Acidic oxide)
$2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$	(Roasting)

122

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$
 (Combustion)  
 $2SO_2 + O_2 \xrightarrow{V_2O_5} 2SO_3$  (Catalytic oxidation)

 $4\text{HCl} + \text{O}_2 \xrightarrow{\text{CuCl}_2} 2\text{Cl}_2 + 2\text{H}_2\text{O}$ 

(Catalytic oxidation)

- ► Uses :
  - For artificial respiration in hospitals and by mountaineers, pilots and divers.
  - In oxy-hydrogen and oxy-acetylene torches which are used for cutting and welding of metals.
  - Liquid dioxygen is used as a rocket fuel.
- $\bigcirc$  Ozone (O<sub>3</sub>) :
- **Preparation** :  $3O_2 \xrightarrow{\text{electric discharge}} 2O_3$
- Properties : It is a pale blue gas, dark blue liquid and violet black solid.
- Oxidising action :

 $O_3 \longrightarrow O_2 + O$ 

 $PbS + 4O_3 \longrightarrow PbSO_4 + 4O_2$ 

 $2I_{(aq)} + H_2O_{(l)} + O_{3(g)} \longrightarrow 2OH_{(aq)}^- + I_{2(g)} + O_{2(g)}$ (used for estimation of O<sub>3</sub> by reacting I<sub>2</sub> with hypo.)

- ► Reducing action :  $H_2O_2 + O_3 \longrightarrow H_2O + 2O_2$  $BaO_2 + O_3 \longrightarrow BaO + 2O_2$
- Structure :

Oxidation state of O is +1 and -1.

- Uses :
  - Used for bleaching ivory, flour, delicate fabrics, etc.
  - As germicide and disinfectant for sterilising water.
  - Manufacture of KMnO<sub>4</sub> and artificial silk.

### Allotropes of sulphur :

- Rhombic sulphur (α-sulphur) : Has S<sub>8</sub> molecules, yellow in colour, m.pt. 385.8 K, specific gravity 2.06 g cm<sup>-3</sup>, insoluble in water, soluble in CS<sub>2</sub>.
- Monoclinic sulphur (β-sulphur) : Has S<sub>8</sub> molecules, colourless, needle-shaped crystals, m.pt. 393 K, specific gravity 1.98 g cm<sup>-3</sup>, soluble in CS<sub>2</sub>.

Sulphur dioxide (SO<sub>2</sub>) :

- Preparation :
  - By heating sulphur in air : S + O<sub>2</sub>  $\xrightarrow{\Delta}$  SO<sub>2</sub>
  - Lab method : By heating Cu with conc. H<sub>2</sub>SO<sub>4</sub>.

 $Cu + 2H_2SO_4 \longrightarrow CuSO_4 + SO_2 + 2H_2O$ It is also prepared by treating a sulphite with dilute  $H_2SO_4$ .

$$SO_3^{2-}_{(aq)} + 2H'_{(aq)} \longrightarrow H_2O_{(l)} + SO_{2(g)}$$

- Properties :
  - As reducing agent :  $SO_2 + Cl_2 + 2H_2O \longrightarrow H_2SO_4 + 2HCl$   $2KMnO_4 + 5SO_2 + 2H_2O \longrightarrow K_2SO_4$  $+ 2MnSO_4 + 2H_2SO_4$
  - As oxidising agent :  $2H_2S + SO_2 \longrightarrow 2H_2O + 3S \downarrow$
  - Bleaching action : Its bleaching action is due to reduction and is temporary.
     SO<sub>2</sub> + 2H<sub>2</sub>O → H<sub>2</sub>SO<sub>4</sub> + 2[H]
     Coloured matter + [H] → Colourless matter.
- Structure : SO<sub>2</sub> is a gas having sp<sup>2</sup> hybridisation and V-shape.

• Uses :

- In the manufacture of sulphuric acid, sulphites and hydrogen sulphide.
- As a disinfectant, fumigant and preservative.
- For bleaching delicate articles.

### Oxoacids of sulphur :





H<sub>2</sub>SO<sub>4</sub>

Sulphuric acid

HO

 $H_2SO_3$ Sulphurous acid



 $H_2S_2O_8$ Peroxodisulphuric acid

 $H_2S_2O_7$ Pyrosulphuric acid (Oleum)

HO

# Sulphuric Acid $(H_2SO_4)$ :

Preparation : Contact process :



### **GROUP 17 ELEMENTS (HALOGEN FAMILY)**

Group 17 elements are collectively called *halogens*.

General characteristics :

Electronic configuration	ns²np <sup>5</sup>
Elements	<sub>9</sub> F, <sub>17</sub> Cl, <sub>35</sub> Br, <sub>85</sub> At
Colour and physical state	$F_2$ (pale yellow gas), $Cl_2$
	(greenish yellow gas),
	Br <sub>2</sub> (reddish brown
	liquid), I <sub>2</sub> (purple solid)
Atomic radii	Increase down the group
Ionisation enthalpy	Very high and
	decreases down the
	group.
Electronegativity	Decreases down the
	group.
Electron gain enthalpy	Cl > F > Br > I
Melting and boiling points	Increase down the group
Bond energy	$Cl_2 > Br_2 > F_2 > I_2$
Heat of hydration	$F^- > CI^- > Br^- > I^-$

### Chemical properties :

F shows only – 1 oxidation state while other elements show –1, +1, +3, +5 and +7 oxidation states also.

- General trends :
  - **Reactivity**:  $F_2 > Cl_2 > Br_2 > I_2$
  - **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 two oxides OF<sub>2</sub> and O<sub>2</sub>F<sub>2</sub> called *oxygen fluorides*, other halogens form oxides in which oxidation states of these halogens range from +1 to +7.
  - The higher oxides of halogens are more stable than the lower ones.

### Metal halides :

- Ionic character : MF > MCl > MBr > MI
- For metals exhibiting more than one oxidation states, the halides in higher oxidation states will be more covalent than the one in lower oxidation states.

# $\bigcirc \quad Chlorine (Cl_2):$

Preparation :  $PbO_2 + 4HCl \longrightarrow PbCl_2 + 2H_2O + Cl_2$   $2KMnO_4 + 16HCl \longrightarrow 2KCl + 2MnCl_2$  $+ 8H_2O + 5Cl_2$ 

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

### Manufacture :

 Deacon's process: By oxidation of hydrogen chloride gas by atmospheric oxygen in the presence of CuCl<sub>2</sub> at 723 K.

 $4\text{HCl} + \text{O}_2 \xrightarrow{\text{CuCl}_2} 2\text{Cl}_2 + 2\text{H}_2\text{O}$ 

- Electrolytic process : By the electrolysis of brine solution.
- Down's process : Obtained as by-product during manufacture of sodium by electrolysis of fused NaCl.
- Properties: It is a yellowish green gas, poisonous in nature, soluble in water. Its aqueous solution is known as *chlorine water*.

# Hydrochloric acid (HCl) :

Bleaching action and oxidising property :  $Cl_a + H_aO \longrightarrow HOCl + HCl$ 

$$HOCl \longrightarrow HCl + [O]$$

Coloured matter +  $[O] \longrightarrow$  Colourless

matter The bleaching action of chlorine is permanent

and is due to its oxidising nature. – Action of hydrogen :

- $H_2 + Cl_2 \frac{U.V. \text{ light}}{Charcoal catalyst} > 2HCl$
- Displacement reactions :  $2KBr + Cl_2 \longrightarrow 2KCl + Br_2$  $2KI + Cl_2 \longrightarrow 2KCl + I_2$
- Action of NaOH :  $2NaOH + Cl_2 \longrightarrow NaCl + NaOCl + H_2O$ (cold)  $6NaOH + 3Cl_2 \longrightarrow 5NaCl + NaClO_3 + 3H_2O$ (hot and conc.)
- Addition reactions :  $SO_2 + Cl_2 \longrightarrow SO_2Cl_2;$  $CO + Cl_2 \longrightarrow COCl_2$
- ► Uses: It is used as a bleaching agent, disinfectant and in the manufacture of CHCl<sub>3</sub>, CCl<sub>4</sub>, DDT, bleaching powder, poisonous gas phosgene (COCl<sub>2</sub>), tear gas (CCl<sub>3</sub>NO<sub>2</sub>) and mustard gas (ClC<sub>2</sub>H<sub>4</sub>SC<sub>2</sub>H<sub>4</sub>Cl).

Preparation	Properties	Uses
$NaCl + H_2SO_4 \xrightarrow{420 \text{ K}} NaHSO_4 + HCl$ $NaHSO_4 + NaCl \xrightarrow{823 \text{ K}} Na_2SO_4 + HCl$	Colourless and pungent smelling gas, easily liquifiable, extremely soluble in water. NH <sub>3</sub> + HCl $\longrightarrow$ NH <sub>4</sub> Cl Na <sub>2</sub> CO <sub>3</sub> + 2HCl $\longrightarrow$ 2NaCl + H <sub>2</sub> O + CO <sub>2</sub> ; Na <sub>2</sub> SO <sub>3</sub> + 2HCl $\longrightarrow$ 2NaCl + H <sub>2</sub> O + SO <sub>2</sub> 3 parts of conc. HCl and 1 part of conc. HNO <sub>3</sub> is used for dissolving noble metals <i>e.g.</i> , gold, platinum Au + 4H <sup>+</sup> + NO <sub>3</sub> <sup>-</sup> + 4Cl <sup>-</sup> $\longrightarrow$ AuCl <sub>4</sub> <sup>-</sup> + NO + 2H <sub>2</sub> O; 3Pt + 16H <sup>+</sup> + 4NO <sub>3</sub> <sup>-</sup> + 18Cl <sup>-</sup> $\longrightarrow$ 3PtCl <sub>6</sub> <sup>2-</sup> + 4NO + 8H <sub>2</sub> O	In manufacture of Cl <sub>2</sub> , NH <sub>4</sub> Cl and glucose in medicine and as a laboratory reagent. For extracting glue from bones and purifying bone black.
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Variation of the general properties of oxyacids 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	_	_	_	eases eases eases ases
Cl	HClO	HClO <sub>2</sub>	HClO <sub>3</sub>	$HClO_4$	decr decr decr
Br	HBrO	—	HBrO <sub>3</sub>	$\mathrm{HBrO}_4$	ivity oility ower gth c
Ι	HIO	_	HIO <sub>3</sub>	$HIO_4$	legat l stab ng pc stren
<ul> <li>Oxidation number of the central atom increases (+1, +3, +5, +7) →</li> <li>Thermal stability increases →</li> <li>Covalent character of X—O bond increases →</li> <li>Oxidising power decreases →</li> <li>Acidity increases →</li> <li>Electronegativity of the central atoms remains the same —</li> </ul>					<ul> <li>← Electron</li> <li>← Thermai</li> <li>← Oxidisii</li> <li>← Acidic</li> </ul>

### Oxyacids of halogens :

● Interhalogens compounds: Halogens combine amongst themselves to form a number of interhalogens of the type XX', XX'<sub>3</sub>, XX'<sub>5</sub> and XX'<sub>7</sub>, where X is a larger size halogen (more electropositive) and X' is smaller size halogen.

### **Preparation :**

 $\begin{array}{ll} \text{Cl}_2 + \text{F}_2 \xrightarrow{437 \text{ K}} 2\text{ClF}; & \text{I}_2 + 3\text{Cl}_2 \longrightarrow 2\text{ICl}_3 \\ (\text{equal volume}) & (\text{excess}) \\ \text{Cl}_2 + 3\text{F}_2 \xrightarrow{573 \text{ K}} 2\text{ClF}_3; & \text{Br}_2 + 3\text{F}_2 \longrightarrow 2\text{BrF}_3 \\ (\text{excess}) & (\text{diluted with water}) \\ \text{I}_2 + \text{Cl}_2 \longrightarrow 2\text{ICl}; & \text{Br}_2 + 5\text{F}_2 \longrightarrow 2\text{BrF}_5 \\ (\text{equimolar}) & (\text{excess}) \end{array}$ 

Structures :

Туре	Hybridi- sation	Shape	Structure
XX	sp <sup>3</sup>	Linear	
<i>XX</i> <sub>3</sub> '	sp³d	T-shaped	$ \begin{array}{c} \overset{X'}{{\underset{X'}{\bigcirc}}}_{X}^{X'} \\ \overset{X'}{{\underset{X'}{\bigcirc}}}_{X'} \end{array} $

XX'5	sp <sup>3</sup> d <sup>2</sup>	Square pyramidal	$\begin{array}{c} X' \\ X' \\ X' \\ X' \\ \vdots \\ X' \\ \vdots \\ X' \\ X'$
XX'7	sp³d³	Pentagonal bipyramidal	$\begin{array}{c} X' \\ X' $

### **GROUP 18 ELEMENTS (NOBLE GASES)**



These are monoatomic gases and are also known as *rare gases* or *aerogens*.

General characteristics :

Electronic	ns <sup>2</sup> np <sup>6</sup>
configuration	
Elements	<sub>2</sub> He, <sub>10</sub> Ne, <sub>18</sub> Ar, <sub>36</sub> Kr, <sub>54</sub> Xe, <sub>86</sub> Rn
Physical state	Gases
Atomic radii	Increase down the group.
Electron gain	Positive
enthalpy	
Melting and	Very low due to weak dispersion
boiling points	forces

- Chemical properties : Noble gases are least reactive due to high ionization enthalpy and more positive electron gain enthalpy.
  - Xenon-fluorine compounds :  $\begin{array}{c} Xe \\ (excess) \end{array} + F_2 \xrightarrow{673 \text{ K}, 1 \text{ bar}} XeF_2 \\ \hline Xe \\ (1:5 \text{ ratio}) \end{array} + 2F_2 \xrightarrow{873 \text{ K}, 7 \text{ bar}} XeF_4 \\ \hline Xe \\ (1:20 \text{ ratio}) \end{array} + 3F_2 \xrightarrow{573 \text{ K}, 60-70 \text{ bar}} XeF_6 \end{array}$
- ► Xenon-oxygen compounds :  $6XeF_4 + 12H_2O \longrightarrow 4Xe + 2XeO_3 + 24HF + 3O_2$



### Uses :



Structures of some compounds of xenon :

F



 ${
m XeF}_6$ Distorted octahedral,  $sp^3d^3$ 

F

Helium	Neon	Argon	Krypton	Xenon
<ul> <li>To lift weather balloons and air ships.</li> <li>As breathing mixture.</li> <li>For inflating the tyres of aeroplanes</li> </ul>	<ul> <li>For advertising.</li> <li>For filling sodium vapour lamps.</li> <li>In becon light</li> </ul>	<ul> <li>To create an inert atmosphere.</li> <li>In geiger counters.</li> <li>To date the age of rocks</li> </ul>	<ul> <li>For runway and approach lights in airports.</li> <li>In high efficiency miners' cap lamps.</li> </ul>	<ul> <li>In electric flash bulbs for high speed photography.</li> <li>Krypton and xenon are more efficient than argon in gas filled lamps.</li> </ul>

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# **Previous Years' CBSE Board Questions**

# 7.1 Group 15 Elements

### VSA (1 mark)

- Arrange the following in the increasing order of property mentioned : NH<sub>3</sub>, PH<sub>3</sub>, AsH<sub>3</sub>, SbH<sub>3</sub>, BiH<sub>3</sub> (Base strength) (1/5, Delhi 2016, 2010)
- 2. Give reason : Nitrogen does not form pentahalide. (1/3, Delhi, AI 2016, 1/3, AI 2011C)
- Account for the following : BiH<sub>3</sub> is the strongest reducing agent amongst all the hydrides of group 15.

(1/5, Foreign 2015)

(1/5, Foreign 2014)

- 4. Why does  $R_3P = O$  exist but  $R_3N=O$  does not? (R = alkyl group) (1/5, Delhi 2015C)
- 5. Why is  $NH_3$  more basic than  $PH_3$ ? (1/5, AI 2015C, 2014C)
- 6. Give reasons for the following :  $(CH_3)_3P = O$  exists but  $(CH_3)_3N = O$  does not. (1/3, AI 2014)
- Why is the single N—N bond weaker than the single P—P bond? (Foreign 2014)
- Account for the following : Bi is a strong oxidizing agent in the +5 state. (1/5, Foreign 2014)
- Account for the following : PCl<sub>5</sub> is known but NCl<sub>5</sub> is not known.
- Arrange the following in the increasing order of their basic character :

 $NH_3$ ,  $PH_3$ ,  $AsH_3$ ,  $SbH_3$ ,  $BiH_3$  (Foreign 2014)

- Arrange the following group of substances in the order of the property indicated against each group : NH<sub>3</sub>, PH<sub>3</sub>, AsH<sub>3</sub>, SbH<sub>3</sub> - increasing order of boiling points. (1/5, Delhi 2014C)
- Assign reasons for the following : NF<sub>3</sub> is an exothermic compound whereas NCl<sub>3</sub> is not.
  - (1/5, AI 2014C, 2013C, 2012, 2011, 2010, 1/3, Delhi 2011, 2010)

**13.** Why is nitrogen gas very unreactive?

(AI 2014C)

- **14.** Give reasons for the following : PH<sub>3</sub> has lower boiling point than NH<sub>3</sub>. (1/5, Delhi 2013)
- Explain the following : BiCl<sub>3</sub> is more stable than BiCl<sub>5</sub>.
   (1/2, Delhi 2013C)
- 16. Account for the following : Nitrogen is found in gaseous state. (1/5, Delhi 2013C)
- Though nitrogen exhibits +5 oxidation state, it does not form pentahalide. Why?
   (1/2, AI 2013C, Delhi 2012C)
- 18. Account for the following :  $NF_3$  is an exothermic compound but  $NCl_3$  is an endothermic compound. (1/3, AI 2013C, 2012, 2011, 2010,

1/5, Delhi 2011, 2010)

- 19. Bismuth is a strong oxidising agent in the pentavalent state. Explain.
   (1/3, AI 2013C, 1/5, Delhi 2012C)
- 20. Explain the following observations : The molecules NH<sub>3</sub> and NF<sub>3</sub> have dipole moments which are of opposite direction. (1/5, Delhi 2012)
- **21.** Explain the following observation : Phosphorus has greater tendency for catenation than nitrogen. (*1/5, AI 2012, 2010, 2009, 2008*)
- **22.** Why is BiH<sub>3</sub> the strongest reducing agent amongst all the hydrides of group 15 elements?
  - (1/5, AI 2012C)
- **23.** Account for the following : Tendency to form pentahalides decreases down the group in group 15 of the periodic table.

(1/5, Delhi 2011)

- 24. Draw the structure of the following molecule :  $NF_3$  (1/3, Foreign 2011)
- 25. Explain the following :+3 oxidation state becomes more and more stable from As to Bi in the group.

(1/5, Delhi 2011C)

- Account for the following : BiCl<sub>3</sub> is less covalent that PCl<sub>3</sub>.
   (1/5, Delhi 2011C)
- 27. Explain the following observations giving appropriate reasons : The stability of +5 oxidation state decreases down the group in group 15 of the periodic table. (1/5, Delhi 2010)
- **28.** Why are pentahalides of a metal more covalent than its trihalides? (*AI 2010C*)
- Account for the following : NH<sub>3</sub> is clearly basic while PH<sub>3</sub> is only feebly basic. (1/3, AI 2010C)
- **30.** Why is Bi(V) stronger oxidant than Sb(V)? (*Delhi, AI 2009*)
- **31.** Account for the following : NH<sub>3</sub> is a stronger base than PH<sub>3</sub>. (1/3, Delhi 2009, 2009C)
- Explain the following observation : Phosphorus is much more reactive than nitrogen. (1/3, Delhi 2009)
- **33.** Why is red phosphorus, less reactive than white phosphorus? (*AI 2009*)
- **34.** Explain the following observation : Ammonia has a higher boiling point than phosphine. (1/5, AI 2009)
- 35. Give reasons for the following observation : The basic character of the hydrides of group 15 elements decreases with increasing atomic numbers. (1/5, AI 2009C)
- **36.** Why is the bond angle in  $PH_3$  molecule lesser than that in NH<sub>3</sub> molecule? (1/3, AI 2008)
- 37. Answer the following.Of Bi (V) and Sb(V) which may be a stronger oxidising agent and why? (1/2, AI 2008)
- **38.** Assign reasons for the following : Ammonia  $(NH_3)$  has greater affinity for protons than phosphine  $(PH_3)$ . (1/5, AI 2008)
- **39.** Nitrogen does not form any pentahalide like phosphorus. Why? (*AI 2008C*)
- **40.** Why is dinitrogen very unreactive as compared to phosphorus? (*AI 2008C*)
- **41.** PH<sub>3</sub> has lower boiling point than NH<sub>3</sub>. Why? (1/3, Delhi 2008C)

# 7.2 Dinitrogen

### VSA (1 mark)

**42.** Give reasons for the following :  $N_2$  is less reactive at room temperature.

(1/3, AI 2015)

**43.** Write the reaction of thermal decomposition of sodium azide. (1/3, Delhi 2007)

# 7.3 Ammonia

### VSA (1 mark)

- 44. On adding NaOH to ammonium sulphate, a colourless gas with pungent odour is evolved which forms a blue coloured complex with Cu<sup>2+</sup> ion. Identify the gas. (Delhi 2016)
- **45.** Account for the following : Bond angle in  $NH_4^+$  is higher than  $NH_3$ . (1/5, Foreign 2015)
- **46.** What happens when ammonium chloride is treated with Ca(OH)<sub>2</sub>? (1/5, AI 2015C)
- **47.** Why does  $NH_3$  act as a Lewis base? (AI 2014)
- Mention the optimum conditions for the industrial manufacture of ammonia by Haber's process. (1/3, Foreign 2011)
- **49.** Complete the following reactions : NH<sub>3</sub> + NaOCl  $\longrightarrow$  (1/3, AI 2009C)
- **50.** Complete the following chemical equation :  $Cu_{(aq)}^{2+} + NH_{3(aq)} \longrightarrow \dots \dots \dots$ (excess) (1/3, Delhi 2008)
- **51.** Describe the favourable conditions for the manufacture of ammonia by Haber's process.

(1/5, AI 2008)

- 52. How does ammonia react with a solution of Cu<sup>2+</sup>? (Delhi 2007)
- **53.** Write balanced equation when ammonia is dissolved in water. (1/2, Delhi 2007)

SAI (2 marks)

54. How is ammonia prepared on the large scale? Name the process and mention the optimum conditions for the production of ammonia by this process. (2/5, AI 2014C)

### LA (5 marks)

**55.** How is ammonia manufactured industrially? Draw flow chart for the manufacture of ammonia. Give any two uses. (*AI 2007*)

# 7.4 Oxides of Nitrogen

### VSA (1 mark)

- 56.  $Pb(NO_3)_2$  on heating gives a brown gas which undergoes dimerisation on cooling? Identify the gas. (AI 2016)
- 57. Draw the structures of the following compounds: N<sub>2</sub>O<sub>5</sub> (1/3, Delhi 2014, AI 2012)
- **58.** Why does  $NO_2$  dimerise? (AI 2014, 2012C)
- **59.** Using VSEPR theory predict the probable structure of the following :  $N_2O_3$

(1/5, Delhi 2014C)

- **60.** What is the covalency of nitrogen in  $N_2O_5$ ? (Delhi 2013)
- **61.** Explain the following : NO<sub>2</sub> readily forms a dimer. (*1/2, Delhi 2013C, 2010*)
- **62.** Explain the following : The bond angles (O–N–O) are not of the same value in NO<sub>2</sub><sup>-</sup> and NO<sub>2</sub><sup>+</sup>. (1/5, Delhi 2012)
- **63.** Give reason : Nitric oxide becomes brown when released in air (1/5, *Delhi*, *AI 2012C*)
- 64. State reasons for the following : The N-O bond in  $NO_2^-$  is shorter than the N-O bond in  $NO_3^-$ .

(1/2, AI, Delhi 2011)

**65.** Draw structures of the following species:  $NO_3^-$ 

(1/5, AI 2008)

### VBQ (3 marks)

- **66.** Mr. Rakesh, a chemistry teacher, observed some suspicious movements in his neighbourhood people and one day he saw packets of ammonium nitrate in their hand. As a chemistry teacher he knew that ammonium nitrate is used in explosives. He immediately informed the police about this. Police immediately took the required action and caught them with 3 kg of ammonium nitrate which they were using in explosives. Comment in brief :
  - (a) About the value/s displayed by Mr. Rakesh.
  - (b) Name of gas evolved on heating ammonium nitrate. Write the chemical reaction.
  - (c) Write two uses of ammonium nitrate. (AI 2013C)

# 7.5 Nitric Acid

### VSA (1 mark)

67. Complete the following chemical reaction equations;
 Cu + HNO<sub>3(dilute)</sub> →

(1/5, Delhi 2015C, AI 2012)

- **68.** Complete the following chemical equations :  $I_2 + HNO_3 \longrightarrow (1/5, Delhi \ 2011)$ (Conc.)
- **69.** Explain the following situations : In the structure of  $HNO_3$  molecule, the N—O bond (121 pm) is shorter than N—OH bond (140 pm). (1/3, Delhi 2009)
- 70. Explain the following observations : In the structure of HNO<sub>3</sub>, the N—O bond (121 pm) is shorter than N—OH bond (140 pm). (1/5, AI 2009)

# **7.6** Phosphorus – Allotropic Forms

### VSA (1 mark)

- **71.** Which allotrope of phosphorus is more reactive and why? (1/5, *Delhi 2015*)
- **72.** Write the structural difference between white phosphorus and red phosphorus.

(1/3, Delhi 2014)

- 73. Complete the following equations :  $P_4 + H_2O \longrightarrow (1/2, AI 2014)$
- **74.** Draw the structure of the following : Red  $P_4$  (1/5, Foreign 2014)
- 75. White phosphorus is more reactive than red phosphorus. (1/5, Delhi 2012C)
- 76. Explain the following giving appropriate reasons :Red phosphorus is less reactive than white phosphorus. (1/3, Foreign 2011)

# 7.7 Phosphine

### VSA (1 mark)

77. Complete the following chemical reaction equation :

 $P_4$  + NaOH +  $H_2O$  →

(1/5, Delhi 2015C, 2014C, 2009)

- **78.** Complete the following chemical equations :  $Ca_3P_2 + H_2O \longrightarrow (1/3, Delhi 2014, 2008)$
- **79.** Complete the following equation : HgCl<sub>2</sub> + PH<sub>3</sub>  $\longrightarrow$  (1/3, AI 2011, 2009)

# **7.8** Phosphorus Halides

### VSA (1 mark)

- 80. Account for the following : Solid PCl<sub>5</sub> is ionic in nature. (1/5, Delhi 2016)
- **81.** Account for the following : PCl<sub>5</sub> is more covalent than PCl<sub>3</sub>. (1/2, Delhi 2014)
- 82. Complete the following equation : Ag + PCl<sub>5</sub>  $\longrightarrow$  (1/2, AI 2014)
- **83.** Draw the structure of each of the following : Solid PCl<sub>5</sub> (1/2, Delhi 2014C)
- **84.** Draw the structure of PCl<sub>5(s)</sub> molecule. (*AI 2014C, 2009, 2008*)
- **85.** Complete the following chemical equations :  $P_4 + SOCl_2 \longrightarrow (1/2, AI 2014C, 1/5, Delhi 2012, 1/3, Foreign 2011)$
- **86.** What happens when PCl<sub>5</sub> is heated? *(1/2, Delhi 2013, 2007)*
- **87.** Why does PCl<sub>3</sub> fume in moisture? (*Delhi 2013C, 2012C*)
- **88.** Which one of  $PCl_4^+$  and  $PCl_4^-$  is not likely to exist and why? (*Delhi 2012*)
- 89. Explain the following observations : All the bonds in PCl<sub>5</sub> molecule are not equivalent. (Delhi 2012)
- **90.** Account for the following : PCl<sub>5</sub> acts as an oxidising agent. (1/5, AI 2012C)
- **91.** Explain the following observations : All the P—Cl bonds in PCl<sub>5</sub> are not equivalent. (1/5, AI 2009)
- 92. Suggest a possible reason for the following observations:
  In the solid state, PCl<sub>5</sub> behaves as an ionic species. (1/3, AI 2009C)
- 93. Assign a reason for each of the following statements : All the bonds in PCl<sub>5</sub> are not equal in length.

(1/5, AI 2008)

**94.** Why does  $PCl_5$  fume in moisture? Give reaction. (AI 2007)

# 7.9 Oxoacids of Phosphorus

### VSA (1 mark)

- 95. Arrange the following in the increasing order of property mentioned : H<sub>3</sub>PO<sub>3</sub>, H<sub>3</sub>PO<sub>4</sub>, H<sub>3</sub>PO<sub>2</sub> (Reducing character) (1/5, Delhi 2016)
- **96.** What is the basicity of  $H_3PO_4$ ? (*Delhi 2015*)
- **97.** Draw the structure of the following :  $H_4P_2O_7$  (Pyrophosphoric acid) (1/5, Foreign 2015)
- **98.**  $H_3PO_2$  is a stronger reducing agent than  $H_3PO_3$ . (1/3, Delhi, 1/3, AI, 1/5, Foreign 2014)
- **99.** What is the basicity of  $H_3PO_3$ ? (1/3, AI 2014)
- **100.** What happens when  $H_3PO_3$  is heated? Write the reactions involved.

(Delhi 2013, 1/3, AI 2010C)

- **101.** Draw the structure of the following molecules : (HPO<sub>3</sub>)<sub>3</sub> (*Delhi 2013*)
- **102.** Draw the structure of the following molecule : H<sub>3</sub>PO<sub>3</sub> (1/2, Delhi 2013)
- **103.** Account for the following : H<sub>3</sub>PO<sub>2</sub> has reducing nature. (1/5, Delhi 2013C)
- **104.** Draw the structure of  $H_3PO_2$  molecule.

(Delhi 2013C, 2012, AI 2013C)

- **105.** What is the basicity of  $H_3PO_2$  acid and why? (1/5, AI, 2011, 2012)
- **106.** Write a reaction to show the reducing behaviour of  $H_3PO_2$ . (*Delhi 2012C*)
- **107.** Write chemical equations for the following processes : orthophosphorous acid is heated. (1/3, Delhi 2008)

# 7.10 Group 16 Elements

### VSA (1 mark)

- **108.** Give reasons : SO<sub>2</sub> is reducing while TeO<sub>2</sub> is an oxidising agent. (1/3, AI 2016)
- **109.** Account for the following : There is large difference between the melting and boiling points of oxygen and sulphur. (1/5, Delhi 2015)
- **110.** Give reasons for the following :  $H_2$ Te is the strongest reducing agent amongst all the hydrides of group 16 elements.

(1/3, AI 2015)

### CBSE Chapterwise-Topicwise Chemistry

- 111. Why is dioxygen a gas but sulphur a solid? (1/5, Delhi 2015C)
- **112.** Elements of group 16 generally show lower value of first ionization enthalpy compared to the corresponding elements of group 15 Why? (1/5, AI 2015C)
- **113.** Arrange the following in the order of property indicated against each set :

 $H_2O, H_2S, H_2Se, H_2Te$  – increasing acidic character (1/3, Delhi 2014)

- 114. Give reasons for the following : Oxygen has less electron gain enthalpy with negative sign than sulphur. (1/3, AI 2014)
- 115. Arrange the following group of substances in the order of the property indicated against the group :O, S, Se, Te increasing order of electron gain

enthalpy with negative sign. (1/5, Delhi 2014C)

- **116.** Assign reasons for the following : SF<sub>6</sub> is kinetically inert. (1/5, AI 2014C)
- 117. Assign reasons for the following :  $H_2S$  is more acidic than  $H_2O$ (1/5, AI 2014C, 2011, 2009)
- 118. Assign reasons for the following : Sulphur has a greater tendency for catenation than oxygen. (1/5, AI 2014C, 2012, 2009, 1/3, Delhi 2009)
- **119.** Account for the following :Oxygen shows catenation behaviour less than<br/>sulphur.(1/5, Delhi 2013)
- 120. Account for the following :  $H_2S$  is less acidic than  $H_2Te$ . (1/5, Delhi 2013C, 1/3, AI 2010C)
- **121.** Account for the following : SF<sub>6</sub> in inert towards hydrolysis. (1/5, *Delhi 2013C*)
- **122.** Account for the following : Boiling point of water is much higher than that of hydrogen sulphide. (1/3, AI 2013C)
- 123. Explain the following observation : Oxygen is a gas but sulphur is a solid. (1/5, AI 2012)
- **124.** Account for the following : Thermal stability of water is much higher than that of  $H_2S$ . (1/5, Delhi 2012C)

- **125.** State reason for the following : SF<sub>6</sub> is kinetically an inert substance. (1/2, Delhi, AI 2011)
- 126. Account for the following : Elements of group 16 generally show lower value of first ionisation enthalpy compared to the elements in the corresponding periods of group 15. (1/3, AI 2011C)
- 127. How would you account for the following? The value. of electron gain enthalpy with negative sign for sulphur is higher than that for oxygen. (1/5, Delhi 2010)
- **128.** Explain the following situations : $SF_4$  is easily hydrolysed whereas  $SF_6$  is not easily hydrolysed.(1/3, Delhi 2009)
- **129.** Give reasons for the following :  $OF_6$  compound is not known.

(1/3, Delhi 2009C)

- **130.** Give reason for the following observations : Sulphur exhibits tendency for catenation but oxygen does not do so. (1/3, AI 2009C)
- **131.** Draw the structures of the following molecule : SF<sub>4</sub> (*Delhi 2008*)
- **132.** Assign reasons for the following :  $SF_6$  is much less reactive than  $SF_4$ .

(1/5, AI 2008)

133. Assign a reason for each of the following statements :The electron gain enthalpy with negative sign

for oxygen  $(-141 \text{ kJ mol}^{-1})$  is less than that for sulphur  $(-200 \text{ kJ mol}^{-1})$  (1/2, AI 2008)

SAI (2 marks)

134. Account for the following :

- (i)  $H_2S$  has lower boiling point than  $H_2O$ .
- (ii) Reducing character decreases from SO<sub>2</sub> to TeO<sub>2</sub>. (2/3, Foreign 2015)
- 135. Give reasons for the following :
  - (a) Oxygen molecule has the formula  $O_2$  while sulphur is  $S_8$ .
  - (b)  $H_2S$  is less acidic than  $H_2$ Te. (*Delhi 2008C*)

# 7.11 Dioxygen

### VSA (1 mark)

- 136. Complete the following reactions :
  - (i)  $C_2H_4 + O_2 \rightarrow$ (ii)  $4Al + 3O_2 \rightarrow$  (iii)
    - (Delhi 2008C)

# **7.13** Ozone

### VSA (1 mark)

**137.** Ozone is thermodynamically unstable?

**138.** How the supersonic jet aeroplanes are responsible for the depletion of ozone layers?

(1/5, Delhi 2015)

(1/5, Delhi 2016)

- **139.** Account for the following : The two O—O bond lengths in the ozone molecule are equal. (1/3, Delhi 2014)
- 140. Account for the following :  $O_3$  acts as a powerful oxidising agent. (1/5, AI 2011C)
- 141. Account for the following :The two oxygen-oxygen bond lengths in ozone(O3) molecule are same.(1/3, AI 2011C)
- **142.** Draw the structure of  $O_3$  molecule.
  - (Delhi 2010)

(1/5, AI 2008)

**143.** Complete the following chemical reaction equations :

 $I^{-}_{(aq)} + H_2O_{(l)} + O_{3(g)} \longrightarrow (1/2, Delhi \ 2009)$ 

# **7.14** Sulphur – Allotropic Forms

### VSA (1 mark)

- **144.** Which allotrope of sulphur is thermally stable at room temperature? (*Foreign 2015*)
- 145. Account for the following : Sulphur in vapour form exhibits paramagnetic behaviour. (1/3, AI 2014, 2008, 1/5, Foreign, 2014, 2011)

1/5, Delhi 2012, 2011C, 2008)

**146.** Draw the structure of the following :  $S_8$ 

### SAI (2 marks)

147. Name the two most important allotropes of sulphur. Which one of the two is stable at room temperature? What happens when the stable form is heated about 370 K? (Foreign 2014)

# 7.15 Sulphur Dioxide

### VSA (1 mark)

148. What happens when :

 $SO_2$  gas is passed through an aqueous solution  $Fe^{3+}$  salt? (1/2, AI 2016)

**150.** Predict the shape and the asked angle (90° or more or less) in the following case :  $SO_3^{2-}$  and the angle O — S — O

(1/5, Delhi 2012)

**151.** What happens when Sulphur dioxide gas is passed through an aqueous solution of a Fe (III) salt?

(1/3, AI 2011)

- **152.** Complete the following chemical equation :  $Fe^{3+} + SO_2 + H_2O \longrightarrow$ (1/5, Foreign 2011, Delhi 2011C)
- **153.** Why are the two S O bonds in SO<sub>2</sub> molecule of equal strength? (1/5, AI 2010C)
- **154.** Excess of SO<sub>2</sub> reacts with sodium hydroxide solution. (1/5, *Delhi 2009C*)

### LA (5 marks)

- 155. (a) How is sulphur dioxide prepared in :
  - (i) Laboratory
  - (ii) Industrially?
  - (b) What happens when sulphur dioxide is passed through water and reacts with sodium hydroxide? Write balanced equation.
  - (c) Write its any two uses. (Delhi 2007)

# 7.16 Oxoacids of Sulphur

### VSA (1 mark)

- **156.** Write the structure of the following molecule :  $H_2SO_3$  (1/2, AI 2015)
- 157. Draw the structure of the following : $H_2SO_4$ (1/5, Delhi 2015C, 2014)
- **158.** Draw the structure of the following :  $H_2S_2O_8$ (1/5, Foreign 2014, 2011,
  - 1/3, Delhi 2013, 2012, 1/3, AI 2009C)
- **159.** Draw the structure of the following molecule :  $H_2S_2O_7$  (1/3, AI 2013, 2009, 1/5, Delhi 2012)
- 160. Write the structure of the following species :  $H_2SO_5$ . (1/2, Delhi 2007)

### SAII (3 marks)

- **161.** Draw the structure of
  - (i)  $H_2SO_3$  (ii)  $H_2SO_4$ (iii)  $H_2S_2O_7$  (Delhi 2007)

# 7.17 Sulphuric Acid

### VSA (1 mark)

- 162. Write the conditions to maximize the yield of H<sub>2</sub>SO<sub>4</sub> by Contact process. (1/5, Delhi 2016) **163.** Complete the following equation :  $Cu + conc. H_2SO_4 \longrightarrow$ (1/3, AI 2014) 164. Complete the following equation :  $CaF_2 + H_2SO_4 \longrightarrow$ (1/2, AI 2014) 165. Complete the following equation :  $C + conc. H_2SO_4 \longrightarrow$ (1/2, AI 2014, Delhi, Foreign 2011) **166.** Why is  $K_{a_2} \ll K_{a_1}$  for H<sub>2</sub>SO<sub>4</sub> in water? (1/2, Foreign 2014) **167.** Account for the following : Concentrated sulphuric acid has charring action on carbohydrates. (1/3, AI 2013C,)
- **168.** Complete the following equation :  $SO_3 + H_2SO_4 \longrightarrow (1/5, AI 2011)$
- SAI (2 marks)
- 169. With the help of chemical equation explain the principle of Contact process in brief for the manufacture of sulphuric acid by Contact process. (2/3, AI 2013C)

### SAII (3 marks)

**170.** Describe the Contact process for the manufacture of sulphuric acid with special reference to the reaction conditions, catalysts used and yield in the process.

(3/5, Delhi 2015C)

- 171. Describe the conditions and the steps involved in the manufacture of sulphuric acid by Contact process. Write the necessary reactions. (No diagram is required.) (3/5, Delhi 2012C)
- 172. With the help of chemical equations explain the principle of contact process in brief for the manufacture of sulphuric acid. (No diagram).(AI 2012C)

# 7.18 Group 17 Elements

### VSA (1 mark)

**173.** Account for the following : Acidic character increases from HF to HI.

(1/5, Delhi 2015)

- 174. F2 has lower bond dissociation enthalpy than<br/>Cl2. Why?(1/5, Delhi 2015, 2013)
- 175. Why are halogens coloured? (1/5, Delhi 2015C, AI 2012)176. Answer the following :
- Why are halogens strong oxidising agents? (1/5, AI 2015C)
- 177. Arrange the following in the order of property indicated against each set :
  HF, HCl, HBr, HI increasing bond dissociation enthalpy (1/2, Delhi 2014)
- **178.** Arrange the following groups of substances in the order of the property indicated against each group :

 $F_2$ ,  $Cl_2$ ,  $Br_2$ ,  $I_2$  – increasing order of bond dissociation enthalpy.

(1/5, Delhi 2014C, 2011C)

- **179.** Why is  $F_2$  a stronger oxidising agent than  $Cl_2$ ? (*AI 2014C*, 2009)
- **180.** Assign reasons for the following : HCl is a stronger acid than HF though fluorine is more electronegative than chlorine.

(1/5, AI 2014C)

- 181. Account for the following : Fluorine does not exhibit positive oxidation state. (1/5, Delhi 2013, 2011C, 2009, 1/5, AI 2012, 2010)
- **182.** Fluorine exhibits only -1 oxidation state whereas other halogens exhibit +1, +3, +5 and +7 oxidation state also. Why is it so?

(Delhi 2013C)

- **183.** HF is a weaker acid than HCl. Why? (*AI 2013C*)
- 184. Account for the following : HF is not stored in glass bottles but is kept in wax-coated bottles. (1/3, AI 2013C)
- 185. Explain the following observations. Despite lower value of its electron gain enthalpy with negative sign, fluorine (F<sub>2</sub>) is a stronger oxidising agent than Cl<sub>2</sub>. (1/5, AI 2012)
- 186. Despite having greater polarity, hydrogen fluoride boils at a lower temperature than water. (1/5, AI 2012)
- 187. Give reason : Bond dissociation energy of F<sub>2</sub> is less than that of Cl<sub>2</sub>. (1/5, Delhi 2012C, 2009, 1/5, AI 2012C)

- 188. Explain giving reason for the following situation. In aqueous medium HCl is stronger acid than HF. (1/2, Foreign 2011)
- **189.** Account for the following :  $F_2$  is a stronger oxidising agent than  $Cl_2$ . (1/3, AI 2011C)
- **190.** Arrange HF, HCl, HBr and HI in the order of increasing acid strength.
  - (AI 2011C, Delhi 2009C)
- 191. Account for the following : Electron gain enthalpy with negative sign for fluorine is less than that for chlorine. (1/3, AI 2011C, 1/3, AI 2010)
- **192.** How would you account for the following? Halogens are strong oxidizing agents
  - (1/5, Delhi 2010, 1/3, AI 2010C)
- 193. Explain the following : The electron gain enthalpy with negative sign for fluorine is less than that for chlorine, still fluorine is a stronger oxidising agent than chlorine. (1/3, AI 2010)
- 194. Account for the following : Fluorine always exhibits an oxidation state of -1 only in its compounds. (1/5, Delhi 2010C)
- **195.** Explain the following observation : Hydrogen fluoride has a much higher boiling point than hydrogen chloride. (*1/5, AI 2009*)
- **196.** Suggest a possible reason for the following observations :

Fluorine forms the largest number of interhalogen compounds amongst the halogens. (Delhi 2011C, 1/3, AI 2009C)

**197.** Give reasons for the following observation : Hydrogen iodide is a stronger acid than hydrogen fluoride in aqueous solution.

(1/3, AI 2009C)

- **198.** Complete the following chemical equation :  $F_{2(g)} + H_2O_{(l)} \longrightarrow \dots \dots \dots (1/3, Delhi 2008)$
- **199.** Assign reasons for the following : The negative value of electron gain enthalpy of fluorine is less than that of chlorine.

(1/5, AI 2008)

**200.** Fluorine exhibits only – 1 oxidation state in its compounds whereas other halogens exhibit many other oxidation states. Why?

(AI 2008C)

### SAI (2 marks)

- **201.** Compare the oxidizing action of  $F_2$  and  $Cl_2$  by considering parameters such as bond dissociation enthalpy, electron gain enthalpy and hydration enthalpy. (2/5, Delhi 2016)
- **202.** Arrange the following in order property indicated for each set.
  - (i) F<sub>2</sub>, Cl<sub>2</sub>, Br<sub>2</sub>, I<sub>2</sub> increasing bond dissociation enthalpy.
  - (iii) HF, HCl, HBr, HI increasing acid strength (2/3, Delhi 2010)
- **203.** Describe the following about halogens (Group 17 elements):
  - (i) Relative oxidising power of halogens.
  - (ii) Relative acidic strength of the hydrogen halides. (2/3, Delhi 2010C)

# 7.19 Chlorine

### VSA (1 mark)

**204.** Write balanced equation for the following reactions :

Chlorine reacts with dry slaked lime.

(1/3, Delhi 2015C)

- **205.** Name two poisonous gases which can be prepared from chlorine gas. (AI 2013)
- **206.** Account for the following : Bleaching of flowers by Cl<sub>2</sub> is permanent while that of SO<sub>2</sub> is temporary? (1/3, AI 2013C)
- 207. Complete the following chemical equation : NaOH + Cl<sub>2</sub> → (hot and conc.) (1/5, Delhi 2012, 2010, 2008,
  - 1/3, AI 2009C)
- **208.** Account for the following :

   Chlorine water loses its yellow colour on standing.

   (1/5, AI 2012C)
- 209. Complete the following reaction equation : NaOH (cold & dilute) + Cl<sub>2</sub> → (1/3, Delhi 2011C, AI 2010)
- **210.** Complete this reaction : 6NaOH + 3Cl<sub>2</sub>  $\longrightarrow$  (1/3, AI 2011C)
- **211.** Complete the following reaction equation :

 $I_2 + H_2O + Cl_2 \longrightarrow$ (AI 2011C, 1/5, Delhi 2010C)

**212.** Write the balanced chemical equation for the reaction of  $Cl_2$  with hot and conc. NaOH solution. Justify that this reaction is a disproportionation reaction.

(1/5, Delhi 2008C)

# 7.20 Hydrogen Chloride

### VSA (1 mark)

**213.** Iron dissolves in HCl to form FeCl<sub>2</sub> and not FeCl<sub>3</sub>. (1/5, Foreign 2015, 2014)

# 7.21 Oxoacids of Halogens

### VSA (1 mark)

- 214. Account for the following : Fluorine forms only one oxoacid HOF. (1/5, Delhi 2016)
- **215.** Account for the following  $HClO_4$  is stronger acid than HClO. (1/5, Foreign 2015)
- **216.** Draw the structures of the following : HClO<sub>4</sub> (1/2, AI 2014, 2011, 2009, 1/5 Foreign 2014)
- 217. Account for the following : Fluorine does not form oxoacids. (1/5 AI 2012C)
- **218.** How would you account for the following : The oxidising power of oxoacids of chlorine follows the order :

 $HClO_4 < HClO_3 < HClO_2 < HClO$ (1/2, Foreign 2011)

- **219.** Draw the structure of the following :  $HClO_3$  (1/5, AI 2009)
- **220.** Answer the following : Which neutral molecule would be isoelectronic with ClO<sup>-</sup>? (1/2, AI 2008, 1/3, AI 2008C)
- 221. Arrange HClO<sub>3</sub>, HClO<sub>2</sub>, HOCl and HClO<sub>4</sub> in order of increasing acid strength. Give reason for your answer. (1/5, Delhi 2008C)

# SAI (2 marks)

- **222.** Draw the structure of
  - (i) Hypochlorous acid.
  - (ii) Chlorous acid. (AI 2007)

# 7.22 Interhalogen Compounds

### VSA (1 mark)

- **223.** Draw the structure of :  $BrF_5$  (1/5, Delhi 2016)
- **224.** Give reasons : ICl is more reactive than  $I_2$ .
- (*1/3*, *AI* 2016, 2012, 2011C, 2009) **225.** Draw the structure of the following : CIF<sub>3</sub>
- (Delhi 2015, AI 2008, 2012)
- **226.** Draw the structures of the following : BrF<sub>3</sub> (1/5, Delhi 2015C, 2014, 2014C, 2013,2011, 2009 1/5, AI 2014, 2011, 2008)
- **227.** Write the formula and describe the structure of noble gas species which is isostructural with  $BrO_3^-$  (1/5, Delhi 2014C)
- **228.** Complete the following chemical equation :  $F_2(Excess) + Cl_2 \xrightarrow{300^{\circ}C} (1/5, AI 2014C)$
- **229.**  $F_2$  is more reactive than  $ClF_3$  but  $ClF_3$  is more reactive than  $Cl_2$ . (1/5, Delhi 2013C)
- **230.** Predict the shape and the asked angle (90° or more or less) in each of the following cases.  $ClF_3$  and the angle F Cl F
  - (1/5, Delhi 2012)
- **231.** Account for the following : BrCl<sub>3</sub> is more stable than  $BrCl_5$ . (1/5, AI 2012C)
- **232.** Why is ICl more reactive than I<sub>2</sub>? (*AI 2012C, 2010C*)
- **233.** Answer the following : Why does fluorine not play the role of a central atom in interhalogen compounds? (*AI 2011*)
- **234.** Complete the following chemical equations:  $Br_2 + F_2 \longrightarrow (Foreign \ 2011)$
- **235.** ClF<sub>3</sub> molecule has a *T*-shaped structure and not a trigonal planar one. (1/3, Delhi 2010)
- **236.** Flourine never acts as the central atom in polyatomic interhalogen compounds.

(1/5, AI 2010)

- **237.** Give one use of ClF<sub>3</sub>. (1/5, *Delhi 2008C*)
- **238.** How are interhalogen compounds formulated and how are they prepared? (1/3, AI 2008C)

### SAI (2 marks)

**239.** How are interhalogen compounds formed? What general compositions can be assigned to them? (*AI 2013*)

### 136

# 7.23 Group 18 Elements

### VSA (1 mark)

- **240.** Draw the structure of XeF<sub>4</sub>. (1/5, *Delhi 2016, 2014,2009C, 2008, 1/2, AI 2016, 2014, 2010*)
- **241.** What happens when  $XeF_4$  reacts with  $SbF_5$ ? (AI 2016)
- **242.** Write the structures of the following molecule : XeOF<sub>4</sub>. (1/5, AI 2015, 2015C, 2013, 2012, Foreign 2014)
- **243.** Give reasons for the following : Helium is used in diving apparatus as a diluent for oxygen. (1/3, AI 2015)
- **244.** Draw the structures of the following : XeF<sub>2</sub> (1/5, *Foreign 2015*, *Delhi 2014*, *2012*, *2013*, *2011*, *AI 2014*, *2008*)
- **245.** Draw the structure of the following : XeO<sub>3</sub> (1/5, AI 2015C, 2014)
- **246.** Complete the following equation :  $XeF_4 + O_2F_2 \longrightarrow (1/2, Delhi 2014C, 2012, 1/2 AI 2014, 2012)$
- **247.** Complete the following equation :  $XeF_2 + H_2O \longrightarrow (1/2, AI 2014, 2009, 1/5, Delhi 2011, 2011C)$
- **248.** Account for the following : Unlike xenon, no distinct chemical compound of helium is known. (1/5, Foreign 2014)
- **249.** Complete the following chemical reaction equation :  $XeF_4 + H_2O \longrightarrow$ 
  - (1/2, AI 2014C, 2012, 2011, 2011C, 2008, 1/5, Delhi 2012)
- **250.** What inspired N. Bartlett for carrying out reaction between Xe and PtF<sub>6</sub>? (*Delhi 2013*)
- **251.** Draw the structures of the following molecules:  $XeF_6$  (1/2, AI 2013, 1/5, Delhi 2012)
- **252.** Account for the following : Helium is used in diving apparatus.

(1/3, AI 2013C)

- **253.** Complete the following chemical reactions equations :
  - $XeF_6 + H_2O \longrightarrow$  (1/5, Delhi 2012, 1/3, Foreign 2011, 1/2, AI 2010, 2010C)

254.	Predict the shape and asked angle (90° or more or less) in each of the following case.
	(1/5, Delhi 2012)
255.	Explain the following observations: Helium forms no real chemical compound. (1/5, AI 2012)
256.	Noble gases have low boiling points. Why? (Delhi 2012C, AI 2011)
257.	Complete the following reaction equation : XeF <sub>2</sub> + PF <sub>5</sub> $\longrightarrow$
	(1/5, Delhi 2011C, 1/2, AI 2011C)
258.	Explain the following : XeF <sub>2</sub> is linear molecule without a bend. (1/3, AI 2010)
259.	Explain the following situations : $XeF_2$ has a straight linear structure and not a bent angular structure. (1/3, Delhi 2009)
260.	Explain the following observations : The majority of known noble gas compounds are those of Xenon. (1/3, Delhi 2009)
261.	Write balanced chemical equations for the following reaction : $XeF_6$ is hydrolysed (1/3, Delhi 2009C)
262.	Complete the following reaction : XeF <sub>6</sub> + KF $\longrightarrow$ (1/3, AI 2009C)
263.	Draw the structures of $XeF_4$ and predict their shapes. (1/2, AI 2009C)
264.	Write the chemical equation for the following process : $PtF_6$ and xenon are mixed together (1/3, Delhi 2008)
265.	Assign reasons for the following :
	Of the noble gases only xenon is known to form well-established chemical compounds.
	(1/5, AI 2008)
266.	Why do some noble gases form compounds with fluorine and oxygen only? ( <i>Delhi 2008C</i> )
267.	List the uses of neon and argon gases.
	(2/5, AI 2007)
S/	(2 marks)
268.	(i) Which noble gas is used in filling balloons

for meteorological observations? (ii) Complete the equation :  $XeF_2 + PF_5 \longrightarrow$  (2/5, Delhi 2015) **269.** Write the balanced chemical equations for obtaining  $XeO_3$  and  $XeOF_4$  from  $XeF_6$ . (1/5, Delhi 2013C)

### **270.** Explain the following :

- (i) Xenon does not form such fluorides as XeF<sub>3</sub> and XeF<sub>5</sub>.
- (ii) Out of noble gases, only Xenon is known to form real chemical compounds

(Delhi 2012C)

- 271. How is XeO<sub>3</sub> obtained? Write the related chemical equations. Draw the structure of XeO<sub>3</sub>. (AI 2012C)
- 272. Write the formulae and the structure of noble gas species which are isostructural with
  (i) ICl<sub>4</sub>
  (ii) BrO<sub>3</sub>

(Delhi 2009C)

(i) 
$$XeF_4 + O_2F_2 \longrightarrow$$

(ii)  $XeF_4 + SbF_5 \longrightarrow$  (2/3, AI 2009C)

**274.** Draw structure of (i) XeOF<sub>4</sub> (ii) XeO<sub>3</sub>.

(Delhi 2007)

### SAII (3 marks)

- 275. (i) How does xenon atom form compounds even though the xenon atom has a closed shell electronic configuration?
  - (ii) Draw the structure of  $XeOF_4$ .
  - (iii) Complete and balance the following equation :  $XeF_4 + H_2O \longrightarrow$

(AI 2008C)

### **Detailed Solutions**

1. Increasing (Lewis) base strength order is : BiH<sub>3</sub> < SbH<sub>3</sub> < AsH<sub>3</sub> < PH<sub>3</sub> < NH<sub>3</sub>

The reason for this order is that as we move from  $NH_3$  to  $BiH_3$ , the size of the central atom increases. Hence lone pair is not easily available for donation. The electron density on the central atom decreases on moving from  $NH_3$  to  $BiH_3$  and so the basic strength also decreases.

2. Nitrogen can not expand its octet due to absence of *d*-orbitals.

**3.** Among hydrides of group-15 elements, the bond length increases from N – H to Bi – H with increasing size of element. Bi – H bond is longest and weakest, it can break more easily and evolve  $H_2$  gas which acts as the reducing agent.

4.  $R_3$ N = O molecule has five covalent bonds with N atom. The octet in N cannot be extended as it does not have *d* orbitals for the formation of  $p\pi$ - $d\pi$  bond.

In the case of  $R_3P = O$ , P can extend its octet since it has empty *d*-orbitals in its valence shell and form  $p\pi$ - $d\pi$  bond.

5. Lewis basic nature of  $NH_3$  and  $PH_3$  molecules is due to the presence of lone pairs on N and Bi atoms, respectively. P atom is much larger than N atom and also has empty *d* orbitals. Electron density due to lone pair on P gets diffused because of the presence of *d*-orbitals and so the lone pair is not easily available for donation. Hence  $PH_3$  is less basic than  $NH_3$ .

6. Refer to answer 4.

7. The single N—N bond is weaker than the single P—P bond because of high interelectronic repulsion of the non-bonding electrons, occurring due to the small bond length.

**8.** On moving down the group, the stability of +5 oxidation state decreases while +3 oxidation state increases due to inert pair effect.

Thus +5 oxidation state of Bi is less stable and Bi(V) is a stronger oxidising agent.

**9.** Nitrogen cannot expand its valency beyond 4 due to absence of *d*-orbitals whereas phosphorus show pentavalency due to presence of *d*-orbitals.

**10.** *Refer to answer 1.* 

**11.**  $PH_3 < AsH_3 < NH_3 < SbH_3 < BiH_3$ 

The abnormally high boiling point of  $NH_3$  is due to the intramolecular H-bonding. Further as we move from  $PH_3$  to  $BiH_3$  the molecular mass increasing. As a result, the van der walls forces of attraction increase and the boiling points increase regularly from  $PH_3$  to  $BiH_3$ .

**12.** In case of nitrogen, only  $NF_3$  is known to be stable. N–F bond strength is greater than F–F bond strength, therefore, formation of  $NF_3$  is spontaneous. In case of  $NCl_3$ , N—Cl bond strength is lesser than Cl—Cl bond strength. Thus, energy has to be supplied during the formation of  $NCl_3$ .

**13.** The bond dissociation enthalpy of triple bond in  $N \equiv N$  is very high due to  $p\pi - p\pi$  overlap. Hence, N<sub>2</sub> is less reactive at room temperature.

14. Unlike  $NH_3$ ,  $PH_3$  molecules are not associated through hydrogen bonding in liquid state. Therefore, the boiling point of  $PH_3$  is lower than  $NH_3$ .

**15.** BiCl<sub>3</sub> is more stable than BiCl<sub>5</sub>. On moving down the group, the stability of + 5 oxidation state decreases while + 3 oxidation state increases due to inert pair effect.

**16.** Nitrogen exists as a diatomic moleucle with a triple bond between two atoms. These  $N_2$  molecules are held together by weak van der Waals force of attraction which can be easily broken by the collision of the molecules at room temperature. Therefore  $N_2$  is a gas at room temperature.

- **17.** *Refer to answer 2.*
- **18.** *Refer to answer 12.*
- 19. Refer to answer 8.

20.

In  $NH_3$  the bond moment and lone pair moment work in same direction. Hence, net dipole moment is higher.



In  $NF_3$  the bond moment and lone pair moment work in opposite direction. Hence, net dipole moment is lower.

**21.** The property of catenation depends upon the strength of the element - element bond. Since,

 $P - P (213 \text{ kJ mol}^{-1})$  bond strength is much more than  $N - N (159 \text{ kJ mol}^{-1})$  bond strength so, phosphorus shows marked catenation properties than nitrogen.

22. Refer to answer 3.

**23.** Due to inert pair effect the stability of +5 oxidation state decreases down the group in group 15. Hence tendency to form pentahalide decreases down the group 15 of the periodic table.

**24.** Total no. of electrons around the central N atom = 5

No. of bond pairs = 3

No. of lone pairs = 1

Hybridisation =  $sp^3$ 

Therefore, according to VSEPR theory;  $NF_3$  should be pyramidal.



**25.** On moving down the group, the stability of + 5 oxidation state decreases while that of + 3 oxidation state increases due to inert pair effect.

**26.**  $BiCl_3$  is less covalent than  $PCl_3$  because the size of  $Bi^{3+}$  is much larger than  $P^{3+}$  (According to Fajan's rule)

27. Refer to answer 23.

**28.** In + 5 oxidation state charge/radius ratio is higher than that in + 3 oxidation state. Hence, +5 oxidation state has more polarising power than that of + 3 oxidation state and pentahalides (in O.S. + 5) are more covalent than trihalides.

**29.** *Refer to answer 5.* 

**30.** On moving down the group, the stability of +5 oxidation state decreases while +3 oxidation state increases due to inert pair effect. Thus +5 oxidation state of Bi is less stable than +5 oxidation state of Sb. Therefore, Bi(V) is a stronger oxidising agent than Sb(V).

**31**. Due to presence of a lone pair of electrons on N and P, both  $NH_3$  and  $PH_3$  act as Lewis bases and accept a proton to form an additional N—H and P—H bonds respectively

$$H_3N: + H^+ \rightarrow NH_4^+ ; H_3P: + H^+ \rightarrow PH_4^+$$

However, due to smaller size of N over P, N—H bond thus formed is much stronger than the P—H bond. Therefore,  $NH_3$  has higher proton affinity than  $PH_3$ . In other words,  $NH_3$  is more basic than  $PH_3$ .

**32.** Since nitrogen forms triple bond between the two N-atoms and the phosphorus forms single bond between two P-atoms, bond dissociation energy of nitrogen (941.4 kJ mol<sup>-1</sup>) is larger than the bond dissociation energy of phosphorus (213 kJ mol<sup>-1</sup>). Hence, phosphorus is much more reactive than nitrogen.

**33.** White phosphorus is more reactive than red phosphorus under normal conditions because of angular strain in the  $P_4$  molecule where the angles are only 60°.

**34.**  $NH_3$  molecules are held together by strong inter molecular hydrogen bonds whereas  $PH_3$  molecules are held together by weak van der Waals bonds. Thus,  $NH_3$  has a higher boiling point than  $PH_3$ .

35. Refer to answer 1.

**36.** The bond angle in  $PH_3$  is much lower [93.6°] than that in  $NH_3$  [107.8°] due to less repulsion between bond pairs.

**37.** *Refer to answer 30.* 

**38.**  $PH_3$  and  $NH_3$  both are Lewis bases, since they have a lone pair of electrons on 'N' and 'P' atom respectively.



Because size of P is larger than N atom, therefore N atom carries more negative charge density than carried by P. Hence  $NH_3$  has more proton affinity than  $PH_3$ .

**39.** *Refer to answer 9.* 

**40.** Bond dissociation enthalpy of  $N_2$  molecule is very high (941.4 kJ mol<sup>-1</sup>) and so is least reactive at normal temperature and remains inert even in atmosphere.

Yellow phosphorus exists as  $P_4$  molecule with a tetrahedral shape. The P – P – P bond angle is about 60° because of which the molecule is under tremendous strain and so phosphorus is reactive.

### **41.** *Refer to answer 34.*

**42.** In  $N_2$  molecule N atoms are held by triple bonds. It has very high bond dissociation energy (941.4 kJ mol<sup>-1</sup>). Therefore  $N_2$  is inert at room temperature.

**43.** Thermal decomposition of sodium azide gives nitrogen gas.

$$2\text{NaN}_{3} \longrightarrow 2\text{Na} + 3\text{N}_{2}$$
44.  $(\text{NH}_{4})_{2}\text{SO}_{4} + 2\text{NaOH} \xrightarrow{\Delta}$ 

$$2\text{NH}_{3} + \text{Na}_{2}\text{SO}_{4} + 2\text{H}_{2}\text{O}$$
(colourless and
pungent odoured gas)
$$Cu^{2+} + 4\text{NH}_{3} \longrightarrow [Cu(\text{NH}_{3})_{4}]^{2+}$$
(Blue colour)

**45.** N in NH<sub>3</sub> in  $sp^3$ -hybridized. It has three bond pairs and one lone pair around N. Due to stronger lone pair-bond pair repulsions than bond pair-bond pair replusions. the tetrahedral angle decreases from 109° – 28′ to 107.8°. As a result, NH<sub>3</sub> is pyramidal. However, when it reacts with a proton, it forms NH<sup>4</sup><sub>4</sub> ion which has four bond pairs and no lone pair. Due to the absence of lone pair-bond pair repulsions and presence of four identical bond pair-bond pair interaction, NH<sup>4</sup><sub>4</sub> assumes tetrahedral geometry with a bond angle of 109° – 28′. This explains why the bond angle in NH<sup>4</sup><sub>4</sub> is higher than in NH<sub>3</sub>.



**46.** 
$$2NH_4Cl + Ca(OH)_2 \longrightarrow 2NH_3 + 2H_2O + CaCl_2$$

**47.**  $NH_3$  has a lone pair of electrons on the N-atom which it can donate to an electron acceptor. Hence,  $NH_3$  acts as a Lewis base.

**48.** Optimum conditions for the production of ammonia are :

Temperature =  $\sim 700 \text{ K}$ 

Pressure = about 200 atm  $(200 \times 10^5 \text{ Pa})$ 

Catalyst = iron oxide with small amounts of  $K_2O$  and  $Al_2O_3$  (as promoters).

**49.** 
$$NH_3 + NaOCl \longrightarrow NaNH_2 + HClO$$

50. 
$$\operatorname{Cu}_{(aq)}^{2+} + 4\operatorname{NH}_{3(aq)} \longrightarrow [\operatorname{Cu}(\operatorname{NH}_{3})_{4}]_{(aq)}^{2+}$$
  
Blue (excess) Deep blue

- **51.** *Refer to answer 48.*
- 52. Refer to answer 50.
- 53.  $NH_{3(g)} + H_2O_{(l)} \rightleftharpoons NH_{4(aq)}^+ + OH_{(aq)}^-$

**54.** Ammonia is manufactured industrially by Haber's process.

 $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}; \Delta_r H^\circ = -46.1 \text{ kJ mol}^{-1}$ This is a reversible exothermic reaction. High pressure about 200 atm, low temperature about 700 K and use of catalyst such as iron oxide with small amounts of Al<sub>2</sub>O<sub>3</sub> and K<sub>2</sub>O would favour the formation of ammonia according to Le-Chatelier's principle.

**55.** *Refer to answer 54.* 

The flow chart for the production of ammonia is shown below :



Uses of ammonia : (i) Ammonia is used to produce various nitrogenous fertilizers - for example : urea, ammonium nitrate, ammonium phosphate etc.

(ii) Liquid ammonia is used as a refrigerant.

56.  $2Pb(NO_3)_2 \xrightarrow{673 \text{ K}} 4 \text{ NO}_2 + 2PbO + O_2$ NO<sub>2</sub> is the brown gas

**57.** The structure of  $N_2O_5$  is

Covalence of nitrogen in  $N_2O_5 = 4$ 

**58.** Because  $NO_2$  contains odd number of valence electrons and on dimerisation, it is converted to stable N<sub>2</sub>O<sub>4</sub> molecule with even number of electrons.



**60.** In  $N_2O_5$  covalence of nitrogen is four.

61. Refer to answer 58.

**62.** In NO<sub>2</sub><sup>-</sup> 'N' atom has  $sp^2$ -hybridisation whereas in NO<sub>2</sub><sup>+</sup>, 'N' atom has *sp*-hybridisation.

$$\bigcup_{0 \neq N \searrow 0^{-}}^{(1)} \qquad O = \overset{\oplus}{N = 0}$$

Hence, bond angles are not of the same value.

63. Nitric oxide forms brown fumes of nitrogen dioxide (NO<sub>2</sub>) instantaneously in the presence of air.  $2NO + O_2 \longrightarrow 2NO_2$ 

64. In  $NO_2^-$ , the average N-O bond order is 1.5 due to two resonating structures whereas in NO<sub>3</sub>, the average N-O bond order is 1.33 due to three resonating structures. Higher the bond order, shorter is the bond length.



66. (a) Mr. Rakesh displayed values like awareness care, concern alertness.

(b) Nitrous oxide  $(N_2O)$ 

$$NH_4NO_3 \xrightarrow{\Delta} N_2O + H_2O$$

- (c) (i) It is used as a fertiliser.
- (ii) It is used to modify the detonation rate.
- 67.  $3 \text{ Cu} + 8 \text{HNO}_{3 (dilute)} \longrightarrow$  $3 \text{Cu}(\text{NO}_{2})_{2} + 2 \text{NO} + 4 \text{H}_{2} \text{O}$

$$5Cu(10O_3)_2 + 2100 + 411_20$$

**68.**  $I_2 + 10HNO_{3(conc.)} \rightarrow 2HIO_3 + 10NO_2 + 4H_2O_3$ 

69. HNO<sub>3</sub> is supposed to exist in two resonating forms. Due to two resonating structures, N - O bond is shorter than N—OH bond.

$$HO-N \longleftrightarrow HO-N$$

70. Refer to answer 69.

71. White phosphorus is most reactive of all the allotropes because it is unstable due to the angular strain on P<sub>4</sub> molecule with bond angle of 60°.

72. White phosphorus consists of discrete tetrahedral P<sub>4</sub> molecule.

Red phosphorus is polymeric, consisting of chains of P<sub>4</sub> tetrahedra linked together.

73. 
$$P_4 + H_2O \longrightarrow$$
 No reaction

White phosphorus is more reactive due to its discrete tetrahedral structure and angular strain.

75. White phosphorus consists of discrete  $P_4$ molecules in which each phosphorus atom is tetrahedrally bonded to other three phosphorus atoms. So, white phosphorus is highly reactive. In red phosphorus, P4 molecules are linked in an extended chain structure. So, red phosphorus is much less reactive.



- 76. Refer to answer 75.
- 77.  $P_4 + 3NaOH + 3H_2O \longrightarrow PH_3 + 3NaH_2PO_2$
- 78.  $Ca_3P_2 + 6H_2O \longrightarrow 3Ca(OH)_2 + 2PH_3$
- **79.**  $3 \text{HgCl}_2 + 2 \text{PH}_3 \longrightarrow \text{Hg}_3 \text{P}_2 + 6 \text{HCl}$

80. Phosphorus pentachloride is a salt containing the tetrahedral cation  $[PCl_4]^+$  and the octahedral anion  $[PCl_6]^-$  therefore, it is ionic in solid state.



**81.** *Refer to answer 28.* 

82. 
$$2Ag + PCl_5 \longrightarrow 2AgCl + PCl_3$$
  
83. Cl  
 $a = Cl$   
 $Cl$   
 $cl$   

In PCl<sub>5</sub>, there are three equatorial and two axial bonds present. Since, three equatorial bonds are repelled by two bond pairs and two axial bonds are repelled by three bond pairs so, axial bonds are weaker and longer than the equatorial bonds.

- 84. Refer to answer 83.
- **85.**  $P_4 + 10SO_2Cl_2 \longrightarrow 4 PCl_5 + 10SO_2$
- **86.**  $PCl_5 \xrightarrow{Heat} PCl_3 + Cl_2$

**87.** PCl<sub>5</sub> hydrolyses in the presence of moisture giving fumes of HCl.

 $PCl_5 + H_2O \rightarrow POCl_3 + 2HCl$ 

**88.**  $PCl_4^-$  because  $PCl_3$  cannot form bond with  $Cl^-$  ions.

89. Refer to answer 83.

**90.** The oxidation state of phosphorus in  $PCl_5$  is +5. As P has five electrons in its valence shell, it cannot increase its oxidation state beyond +5 by donating electrons. It can decrease its oxidation number from +5 to +3 or some lower value. So,  $PCl_5$  acts as an oxidising agent.

- **91.** *Refer to answer 83.*
- 92. Refer to answer 80.
- 93. Refer to answer 83.
- 94. Refer to answer 87.

**95.** Reducing character of oxyacids of phosphorus depends on the number of P–H bonds. More the number of P–H bonds in oxyacid, more is the reducing character.  $H_3PO_2$  has two P–H bonds,  $H_3PO_3$  has one P–H bond and  $H_3PO_4$  has no P–H bond. Thus, order of reducing character is  $H_3PO_2 > H_3PO_3 > H_3PO_4$ 

**96.** Basicity of oxoacids of P is equal to the number of P—OH bonds in the molecule.



97.

It is tribasic due to the presence of three replaceable hydrogen atoms.

$$\begin{array}{c} O & O \\ \parallel & \parallel \\ HO \stackrel{P}{\mid} O \stackrel{P}{\mid} OH \\ OH & OH \end{array}$$

Structure of pyrophosphoric acid

**98.** The acids which contain P—H bond, have strong reducing properties. Hypophosphorus acid  $(H_3PO_2)$  contains two P—H bonds, whereas orthophosphorus acid  $(H_3PO_3)$  has one P—H bond. Hence,  $H_3PO_2$  is stronger reducing agent than  $H_3PO_3$ .



It is dibasic due to the presence of two replaceable hydrogen atoms.

100. 
$$4H_3PO_3 \xrightarrow{\Delta} 3H_3PO_4 + PH_3$$

102. Refer to answer 99.

103. Refer to answer 98.

**104.** *Refer to answer* 98.

It is monobasic acid due to the presence of one replaceable hydrogen.

**106.**  $4\text{AgNO}_3 + 2\text{H}_2\text{O} + \text{H}_3\text{PO}_2 \longrightarrow$  $4\text{Ag} + 4\text{HNO}_3 + \text{H}_3\text{PO}_4$ 

**107.** *Refer to answer 100.* 

**108.** The +6 oxidation state of S is more stable than +4 therefore,  $SO_2$  acts as a reducing agent. Further, since the stability of +6 oxidation decreases from S to Te therefore, the reducing character of the dioxides decreases while their oxidising character increases. Thus, TeO<sub>2</sub> acts as an oxidising agent.

**109.** Oxygen molecules are held together by weak van der Waals' forces because of the small size and high electronegativity of oxygen. Sulphur shows catenation and the molecule is made up of 8 atoms with strong intermolecular forces. Hence, there is large difference in the melting and boiling points of oxygen and sulphur.

**110.** Bond dissociation enthalpy and hence thermal stability of hydrides decreases from  $H_2O$  to  $H_2Te$ . Therefore,  $H_2Te$  releases hydrogen readily. Hence,  $H_2Te$  is the strongest reducing agent amongst all the hydrides of group 16.

**111.**  $O_2$  molecules are held together by weak van der Waal's forces because of the small size and high electronegativity of oxygen.

Sulphur shows catenation and the molecule is made up of eight atoms,  $(S_8)$  with strong intermolecular attractive forces. Hence, sulphur exists as solid at room temperature.

**112.** The first ionization enthalpy of group 16 elements is lower than those of group 15 elements despite their smaller atomic radii and higher nuclear charge. This is due to the relatively symmetrical and more stable configuration of the elements of group15 as compared to those of the elements of group 16.

**113.**  $H_2O < H_2S < H_2Se < H_2Te$ 

As the atomic size increases down the group, the bond length increases and hence, the bond strength decreases. Consequently, the cleavage of E —H bond (E= O, S, Se, Te, etc.) becomes easier. As a result, the tendency to release hydrogen as proton increases *i.e.*, acidic strength increases down the group.

**114.** The electron gain enthalpy of oxygen is less negative than sulphur. This is due to its small size. As a result of which the electron-electron repulsion in the relatively small 2*p*-subshell are comparatively

larger and hence the incoming electrons are not accepted with same ease as in case of other (sulphur) elements of this group.

**115.** Electron gain enthalpy of oxygen is less negative than sulphur due to compact size of oxygen atom (inter-electronic repulsion is more in O). From sulphur onwards enthalpy again becomes less negative upto Po.

O < S > Se > Te > Po

**116.** In SF<sub>6</sub>, S atom is sterically protected by six F atoms and does not allow any reagent to attack on the S atom. Due to these reasons,  $SF_6$  is kinetically an inert substance.

**117.** *Refer to answer 113.* 

**118.** The property of catenation depends upon E - E bond strength of the element. As S – S bond is much stronger (213 kJ mol<sup>-1</sup>) than O – O bond (138 kJ mol<sup>-1</sup>), sulphur has greater tendency for catenation than oxygen.

119. Refer to answer 118.

**120.** *Refer to answer 113.* 

**121.** *Refer to answer 116.* 

122.  $H_2O$   $H_2S$ Boiling point 373 K > 213 K

The abnormally high boiling point of  $H_2O$  is due to strong intermolecular H-bonding. Since, all other elements have much lower electronegativity than oxygen, they do not undergo H-bonding.

123. Refer to answer 111.

**124.** The thermal stability of the hydrides decrease from  $H_2O$  to  $H_2Te$ . This is because as the size of central element increases, the bond *E*—H become weaker and thus breaks on heating.

$$E$$
 These bonds break on heating.

144

**125.** *Refer to answer 116.* 

**126.** *Refer to answer 112.* 

**127.** *Refer to answer 114.* 

**128.** In SF<sub>6</sub>, six F atoms protect the sulphur atom from attack by the reagent to such an extent that even thermodynamically most favourable reactions like hydrolysis do not occur. But in SF<sub>4</sub>, S is not sterically protected as it is surrounded by only four F atoms hence, SF<sub>4</sub> is reactive.

**129.**  $OF_6$  compound is not known because oxygen cannot expand its octet due to unavailability of *d*-orbital.

**130.** *Refer to answer 118.* 

 $SF_4$  is a gas with  $sp^3d$ -hybridisation and have trigonal bipyramidal geometry and see-saw structure due to the presence of lone pair of electrons in equatorial positions.

132. Refer to answer 128.

133. Refer to answer 114.

**134.** (i) Refer to answer 122.

(ii) Refer to answer 108.

**135.** (a) Due to small size oxygen forms  $p\pi - p\pi$  multiple bonds. As a result, oxygen exists as diatomic (O<sub>2</sub>) molecule. Due to its bigger size sulphur does not form  $p\pi - p\pi$  multiple bonds. Consequently, sulphur because of its higher tendency of catenation and lower tendency for  $p\pi - p\pi$  multiple bonds forms octa-atomic (S<sub>8</sub>) molecules having eight membered puckered ring structure.



- (b) Refer to answer 113.
- **136.** (i)  $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O_2$

(ii)  $4Al + 3O_2 \rightarrow 2Al_2O_3$ 

**137.** Ozone is thermodynamically unstable and decomposes into oxygen.

$$2O_3 \xrightarrow{\Delta} 3O_2; \Delta H = -ve$$

The above conversion is exothermic *i.e.*,  $\Delta H$  is negative. Also, entropy increases *i.e.*,  $\Delta S = +$  ve.

Thus,  $\Delta G$  for the decomposition of ozone is negative. Hence, it is thermodynamically unstable.

**138.** Nitrogen oxide emitted from the exhausts of supersonic jet aeroplanes readily combines with ozone to form nitrogen dioxide and diatomic oxygen. Since supersonic jets fly in the stratosphere near the ozone layer, they are responsible for the depletion of ozone layer.

**139.** The two O — O bond lengths in the ozone molecule are equal as it is a resonance hybrid of two main forms :



**140.** Ozone is a powerful oxidising agent because ozone has higher energy content than dioxygen hence, decomposes to give dioxygen and atomic oxygen.

$$O_{3(g)} \longrightarrow O_{2(g)} + O_{(g)}$$
  
Ozone Dioxygen Atomic oxygen

The atomic oxygen thus liberated brings about the oxidation while molecular oxygen is set free.

**141.** *Refer to answer 139.* 



**143.**  $2I_{(aq)}^- + H_2O_{(l)} + O_{3(g)} \rightarrow 2OH_{(aq)}^- + I_{2(s)} + O_{2(g)}$ **144.** Rhombic sulphur

**145.** At elevated temperature, sulphur vapour exists as  $S_2$  molecules which are paramagnetic like  $O_2$ .



147. Sulphur exists in numerous allotropes of which yellow rhombic ( $\alpha$ -sulphur) and monoclinic ( $\beta$ -sulphur) is most important. The stable form is rhombic, which transform to monoclinic sulphur, when heated above 369 K.

**148.**  $2Fe^{3+} + SO_2 + 2H_2O \rightarrow 2Fe^{2+} + SO_4^{2-} + 4H^+$ 

149. 
$$SO_{2(g)} + Cl_{2(g)} \rightarrow SO_2Cl_{2(l)}$$

sp<sup>3</sup> Hybridisation

Shape : pyramidal O—S —O angle > 90°

151. Refer to answer 148.

152. Refer to answer 148.

Due to resonance, the two  $\pi$ -bonds are equal (143 pm) and are of equal strength.

154.  $2NaOH + SO_2 \rightarrow Na_2SO_3 + H_2O$ 

**155.** (a) (i) It is prepared in laboratory by treating a sulphite with dil.  $H_2SO_4$ .

 $SO_{3(aq)}^{2-} + 2H_{(aq)}^{+} \longrightarrow H_2O_{(l)} + SO_{2(g)}$ 

(ii) It is produced industrially as a by - product of the roasting of sulphide ores.

 $4\text{FeS}_{2(s)} + 11\text{O}_{2(g)} \longrightarrow 2\text{Fe}_2\text{O}_{3(s)} + 8\text{SO}_{2(g)}$ 

(b) When sulphur dioxide is passed through water, it forms a solution of sulphurous acid.

 $SO_{2(g)} + H_2O_{(l)} \rightleftharpoons H_2SO_{3(aq)}$ Sulphurous acid

When sulphur dioxide reacts with sodium hydroxide solution sodium, sulphite is formed.  $2NaOH + SO_2 \longrightarrow Na_2SO_3 + H_2O$ Sod. sulphite

- (c) Uses : (i) In refining sugar and petroleum.
- (ii) In bleaching wool and silk.
- (iii) As an anti chlor, disinfectant and preservative.
- (iv) In the manufacture of sulphuric acid, sodium hydrogen sulphite and calcium hydrogen sulphite.





157.

H<sub>2</sub>SO<sub>5</sub>

161. (i) Refer to answer 156.(ii) Refer to answer 157.(iii) Refer to answer 159.

**162.** In Contact process, the rate determining step is  $2SO_2 + O_2 \xrightarrow{V_2O_5} 2SO_3$ ,  $\Delta_f H^\circ = -196.6 \text{ kJ mol}^{-1}$  This reaction is reversible and exothermic *i.e.*,  $\Delta H$  is negative. Thus, according to Le-Chatelier's principle, the conditions to maximise the yield are as follows : (a) At lower temperature : As heat is evolved in the reaction so, at lower temperature the reaction proceeds more in forward direction.

(b) At higher pressure : As three moles of gaseous reactants give two moles of gaseous products thus, at higher pressure reaction moves in forward direction.

**163.** 
$$\operatorname{Cu} + 2\operatorname{H}_2\operatorname{SO}_4 \longrightarrow \operatorname{CuSO}_4 + \operatorname{SO}_2 + 2\operatorname{H}_2\operatorname{O}_{(\operatorname{conc.})}$$

**164.**  $CaF_2 + H_2SO_4 \longrightarrow CaSO_4 + 2HF$ 

146

165. C + 2H<sub>2</sub>SO<sub>4</sub> (conc.) 
$$\longrightarrow$$
 CO<sub>2(g)</sub> + 2H<sub>2</sub>O<sub>(l)</sub> +  
2SO<sub>2(g)</sub>  
166. H<sub>2</sub>SO<sub>4(g2)</sub> + H<sub>2</sub>O<sub>(b</sub>  $\rightarrow$  H<sub>2</sub>O<sup>+</sup><sub>(g2)</sub> + HSO<sup>-</sup><sub>4(g2)</sub>

$$K_{a_1} > 10, \text{ very large}$$

$$HSO_{4(aq)}^{-} + H_2O_{(l)} \rightarrow H_3O_{(aq)}^{+} + SO_{4(aq)}^{2-}$$

$$K_{a_2} = 1.2 \times 10^{-2}$$

 $K_{a_2}$  is smaller than  $K_{a_1}$  because dissociation of HSO<sub>4</sub><sup>-</sup> is less probable due to presence of negative charge on the ion.

**167.** Concentrated  $H_2SO_4$  removes water from organic compounds hence, it has charring action on carbohydrates.

$$C_{12}H_{22}O_{11} \xrightarrow{\text{conc. } H_2SO_4} 12C + H_2O$$
  
Sugar Sugar charcoal

168.  $SO_3 + H_2SO_4 \longrightarrow H_2S_2O_7$ 

- 169. (a) Contact process : It involves three stages :
- Burning of sulphur or sulphide ore in air to generate SO<sub>2</sub>.

 $S + O_2 \rightarrow SO_2$ 

 $4\text{FeS}_2 + 11\text{O}_2 \rightarrow 8\text{SO}_2 + 2\text{Fe}_2\text{O}_3$ 

(ii) Conversion of  $SO_2$  to  $SO_3$  by reaction with oxygen in the presence of  $V_2O_5$  catalyst.

$$2SO_{2(g)} + O_{2(g)} \xleftarrow{V_2O_5}{2SO_{3(g)}} 2SO_{3(g)};$$
$$\Delta_r H^\circ = -196 \text{ kJ mol}^{-1}$$

(iii) The SO<sub>3</sub> gas from the catalytic converter is absorbed in conc.  $H_2SO_4$  to form oleum  $(H_2S_2O_7)$ . Dilution of oleum with water gives  $H_2SO_4$  of desired concentration.

$$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7 \text{ (Oleum)}$$
$$H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$$

**170.** *Refer to answers 162 and 169.* 

171. Refer to answer 169.

**172.** *Refer to answer 169.* 

**173.** The acidic strength of the hydrohalic acids in the order :

 $\mathrm{HF} < \mathrm{HCl} < \mathrm{HBr} < \mathrm{HI}$ 

This order is a result of bond dissociation enthalpies of H - X bond decreases from H - F to H - I as the size of halogen atom increases

**174.**  $F_2$  has lower bond dissociation enthalpy than  $Cl_2$  because F atom is very small and hence the electron-electron repulsions between the lone pairs of electrons are very large.

**175.** Halogens absorb radiations in visible region which results in excitation of outer electrons to higher level resulting in different colours.

**176.** General electronic configuration of halogens is  $ns^2np^5$ . They easily accept one electron to complete their octet. This makes them a good oxidising agent.

178. Increasing bond dissociation enthalpy order is

 $I_2 < F_2 < Br_2 < Cl_2$ 

Bond dissociation enthalpy of  $F_2$  is less than that of  $Br_2$  and  $Cl_2$  due to the lone pair - lone pair repulsions.

**179.** Fluorine is the strongest oxidising agent as it accept electron easily. It oxidise other halide ions in solution or even in solid phase.

$$F_2 + 2X^- \longrightarrow 2F^- + X_2 (X = Cl, Br \text{ or } I)$$
  

$$Cl_2 + 2X^- \longrightarrow 2Cl^- + X_2 (X = Br \text{ or } I)$$
  

$$Br_2 + 2I^- \longrightarrow 2Br^- + I_2$$

**180.** HF is the weakest acid because of its high bond dissociation energy due to small size of fluorine atom.

**181.** Since, fluorine is the most electronegative element, it shows only a negative oxidation state of -1, and does not show any positive oxidation state.

**182.** This is due to non-availability of *d*-orbitals in valence shell of fluorine.

183. Refer to answer 180.

**184.** HF acid attacks glass with the formation of fluoro silicate ions. Thus it is stored in wax-coated glass bottles to prevent the reaction.

185. Refer to answer 179.

**186.** Higher boiling point of  $H_2O$  is due to the extensive H-bonding than HF.

**187.** *Refer to answer 174.* 

**188.** In aqueous medium HCl is stronger acid than HF because bond dissociation enthalpy of H—Cl is lower than that of HF

189. Refer to answer 179.

**190.** *Refer to answer 173.* 

**191.** The electron gain enthalpy of fluorine is less negative than that of chlorine due to the small size of fluorine atom.

### CBSE Chapterwise-Topicwise Chemistry

- **192.** *Refer to answer 176.*
- **193.** Refer to answer 179.
- 194. Refer to answer 182.

**195.** Hydrogen fluoride has much higher boiling point (b.p. 293 K) than hydrogen chloride (b.p. 189 K) due to strong hydrogen bonding.

**196.** Fuorine is the most electronegative element among halogens and it cannot exhibit any positive oxidation state. Therefore, it form largest number of interhalogen compounds.

**197.** Refer to answer 173.

**198.** 
$$2F_{2(g)} + 2H_2O_{(l)} \rightarrow 4H_{(aq.)} + 4F_{(aq.)} + O_{2(g)}$$

199. Refer to answer 191.

200. Refer to answer 182.

**201.** Oxidising power of a substance depends on the factors like bond dissociation enthalpy, electron gain enthalpy and hydration enthalpy. Due to small size of fluorine, its electron gain enthalpy is less than that of chlorine. However, its low bond dissociation enthalpy and high hydration enthalpy compensate the low electron gain enthalpy. Fluorine because of its small size has higher hydration enthalpy than chlorine. Also, due to repulsion between electrons it has lower bond dissociation energy. Thus, fluorine has better oxidising action than chlorine.

- 202. (i) Refer to answer 178.(ii) Refer to answer 173.
- **203.** (i) From top to bottom in group 17 oxidising power of halogens decreases

**204.** 
$$2Cl_2 + 2Ca(OH)_{2(dil)} \xrightarrow{Cold} CaCl_2 + Ca(OCl)_2 + 2H_2O$$
  
Calcium hypochlorite

**206.** The bleaching action of  $Cl_2$  is due to oxidation of coloured substances to colourless substances by nascent oxygen. Since, the bleaching action of  $Cl_2$  is due to oxidation and that of  $SO_2$  is due to reduction, therefore, bleaching effect of  $Cl_2$  is permanent while that of  $SO_2$  is temporary.

**207.** 6NaOH +  $3Cl_2 \rightarrow 5NaCl + NaClO_3 + H_2O$ (hot and conc.) **208.** Chlorine water on standing loses its yellow colour due to the formation of HCl and HClO.

$$NaCl_{(aq)} + NaClO_{(aq.)} + H_2O_{(l)}$$

210. Refer of answer 207.

**211.** 
$$I_2 + 6H_2O + 5Cl_2 \rightarrow 2HIO_3 + 10HCl$$
  
Iodic acid

**212.**  $3Cl_2 + 6NaOH \rightarrow 5NaCl + NaClO_3 + 3H_2O$ This reaction is a disproportionation reaction as chlorine from zero oxidation state is changed to – 1 and + 5 oxidation states.

**213.** Its reaction with iron produces H<sub>2</sub>.

$$Fe + 2HCl \rightarrow FeCl_2 + H_2$$

Liberation of hydrogen prevents the formation of ferric chloride.

**214.** Fluorine forms only one oxoacid HOF. Because for the formation of other oxoacids *d* orbitals are required for the multiple  $p\pi - d\pi$  bonding between extra oxygen atoms and fluorine.

High electronegativity and small size of fluorine also favours only the formation of one oxoacid.

**215.** As the number of oxygen bonded to the central atom increases, the oxidation number of the oxidation atom increases causing a weakening of the O—H bond strength and an increase in the acidity. Hence,  $HClO_4$  is stronger acid than HClO.



**217.** *Refer to answer 214.* 

**218.** As the stability of the oxoanion increases, its tendency to decompose to give  $O_2$  decreases and hence its oxidising power decreases. Since the stability of the oxoanion decreases in the order :

 $ClO_4^- > ClO_3^- > ClO_2^- > ClO^-$  therefore oxidising power of their oxoacids increases in the reverse order :



H

**220.**  $\text{ClO}^-$  has 17 + 8 + 1 = 26 electrons. A neutral molecule with 26 electrons is  $\text{OF}_2(8 + 2 \times 9) = 18 + 8 = 26$  electrons.

**221.** Acid strength of oxoacids of the same halogen increases with increase in oxidation number of the halogen.

Thus the increasing order of acid strength is

$$OCl < HClO_2 < HClO_3 < HClO_3$$

(ii) HOClO: Chlorous acid

**223.** Geometry – Octahedral Shape – Square pyramidal Hybridisation –  $sp^3d^2$ 

 $F \xrightarrow{|}_{Br}$ 

**224.** Interhalogen compounds are more reactive than halogens (except flourine) because X - X' bond (I-Cl bond) in interhalogens is weaker than X-X bond (I-I bond) in halogens except F - F bond. In other words I - Cl bond is weaker than I - I bond. That's why ICl is more reactive than I<sub>2</sub>.

**225.** Hybridisation 
$$-sp^3d$$
  
Structure – Trigonal bipyramidal  
Shape – Bent (*T*-shaped)  
Angle F–Cl–F : less than 90°  
**226.** Hybridisation –  $sp^3d$ 

**226.** Hybridisation – *sp*<sup>3</sup>*d* Structure – Trigonal bipyramidal Shape – Bent -*T* 

**227.** The central atom Br has seven electrons. Four of these electrons form two double bonds or coordinate bonds with two oxygen atoms while the fifth electron forms a single bond with  $O^-$  ion. The remaining two electrons form one lone pair. Hence, in all there are three bond pairs and one lone pair around Br atom in  $BrO_3^-$ . Therefore, according to VSEPR theory,  $BrO_3^-$  should be pyramidal.

Here,  $BrO_3^-$  has  $26(7 + 3 \times 6 + 1 = 26)$  valence electrons. A noble gas species having 26 valence electrons is  $XeO_3(8 + 3 \times 6 = 26)$ . Thus, like  $BrO_3^-$ ,  $XeO_3$  is also pyramidal.

**228.** 
$$3F_2$$
 (excess) +  $Cl_2 \xrightarrow{300^{\circ}C} 2ClF_3$ 

**229.** Interhalogen compounds are more reactive than halogen because the X' - X bond in interhalogens is weaker than X-X bond in halogens. But in case of flourine, the F—F bond is weaker. This is because of the small size of fluorine atoms, the F—F bond distance is very small due to which there is appreciable inter-electronic repulsion. This repulsion weakens the bond between two fluorine atoms. Hence,  $F_2$  is more reactive than ClF<sub>3</sub> but ClF<sub>3</sub> is more reactive than Chlorine.

230. Refer to answer 225.

Angle F — Cl — F : Less than 90°

**231.** O.S. of Br in  $BrCl_5$  is +5, whereas in case of  $BrCl_3$  is +3. As Br is more stable in +3 oxidation state than +5, due to inert pair effect. Therefore, it is unstable and readily reduces from +5 to +3 oxidation state.

232. Refer to answer 224.

**233.** Fluorine does not have *d*-orbitals and its cannot show higher oxidation state. Therefore it does not play the role of a central atom in inter halogen compounds.

**234.**  $Br_2 + 5F_2$  (excess)  $\longrightarrow 2BrF_5$ 

**235.** In ClF<sub>3</sub>, central atom Cl has three bond pairs and two lone pairs. According to VSEPR theory, the two lone pairs will occupy the equatorial position to mimimise lp-lp and lp - bp repulsion. In addition, the axial fluorine atoms will be bent towards the equatorial fluorine in order to minimise the lp-lp repulsions. That's why ClF<sub>3</sub> has a bent T shaped structure. For figure *refer to answer 226*.

236. Refer to answer 233.

**237.**  $\text{ClF}_3$  is used for the production of  $\text{UF}_6$  in enrichment of  $\text{U}^{235}$ .

$$U_{(s)} + 3\operatorname{ClF}_{3(l)} \to \operatorname{UF}_{6(g)} + 3\operatorname{ClF}_{(g)}$$

**238.** Interhalogen compounds are formulated as XX',  $XX'_3$ ,  $XX'_5$  and  $XX'_7$  where X is halogen of larger size and X' of smaller size.

The interhalogen compounds can be prepared by direct combination or by the action of halogen on lower interhalogen compounds. The product formed depends upon some specific conditions, for example,

$$Cl_2 + F_2 \xrightarrow{437 \text{ K}} 2ClF$$
  
(Equal volume)

 $Cl_2 + 3F_2 \xrightarrow{573 \text{ K}} 2ClF_3$ (Excess)  $\begin{array}{c} I_2 + Cl_2 \longrightarrow 2ICl \\ (equimolar) \end{array}$  $I_2 + 3Cl_2 \rightarrow 2ICl_3$ Excess  $Br_2 + 3F_2 \rightarrow 2BrF_3$ (diluted with water)  $Br_2 + 5F_2 \rightarrow 2BrF_5$ (excess)

239. Refer to answer 238.



XeF<sub>4</sub> Shape : Square planar Hybridisation :  $sp^3d^2$ 

**241.**  $\operatorname{XeF}_4 + \operatorname{SbF}_5 \rightarrow [\operatorname{XeF}_3]^+ [\operatorname{SbF}_6]^-$ **242.**  $XeOF_4$  is square pyramidal.



243. Helium is used in diving apparatus as diluent for oxygen because of its low solubility (as compared to  $N_2$ ) in blood, a mixture of oxygen and helium is used in diving apparatus used by deep sea divers

**244.** XeF<sub>2</sub>: Total valence electron pair  $=\frac{8+2}{2}=5$ Bond pairs = 2Lone pairs = 5 - 2 = 3Hybridisation =  $sp^3d$ Geometry = Trigonal bipyramidal Shape = Linear 245. XeO<sub>3</sub>:  $O = \frac{\bigvee_{Xe}}{\|} O$ Hybridisation =  $sp^3$ Geometry = Tetrahedral Shape = Pyramidal

**246.**  $\operatorname{XeF}_4 + \operatorname{O}_2\operatorname{F}_2 \xrightarrow{143 \text{ K}} \operatorname{XeF}_6 + \operatorname{O}_2$ 

**247.**  $2 \text{XeF}_{2(s)} + 2 \text{H}_2 \text{O}_{(l)} \longrightarrow 2 \text{Xe}_{(g)} + 4 \text{HF}_{(aq)} + \text{O}_{2(g)}$ 248. Extremely small size and fully filled outer orbital makes helium very stable and reistant to chemical reaction and hence, it does not form compounds unlike bigger atoms of other elements of noble gas family.

**249.**  $6XeF_4 + 12H_2O \longrightarrow 2XeO_3 + 24HF + 3O_2 + 4Xe$ 250. Neil Bartlett first prepared a red compound which is formulated as O<sub>2</sub><sup>+</sup>PtF<sub>6</sub><sup>-</sup>. He then realised that the first ionisation enthalpy of molecular oxygen (1175 kJ/mol) is almost identical with Xe (1170 kJ/mol). He made efforts to prepare same type of compound with Xe and was successful in preparing another red compound  $Xe^+PtF_6^-$ .

Total valence electron pairs  $=\frac{8+6}{2}=7$ Bond pair =6Lone pair = 7 - 6 = 1Hybridisation =  $sp^3d^3$ Shape = Distorted octahedral Geometry = Pentagonal bipyramidal **252.** *Refer to answer 243.* 

**253.**  $XeF_6 + H_2O \longrightarrow XeOF_4 + 2HF$ 

254. Refer to answer 244.

 $F - Xe - F : 180^{\circ}$ 

**255.** Helium has completely filled  $ns^2$  electronic configurations in its valence shell. Due to its small size and high IE, helium is chemically unreactive. That's why it forms no real chemical compound.

256. Noble gases being monoatomic gases are held together by weak London dispersion forces, therefore they have low boiling points.

**257.**  $\operatorname{XeF}_2 + \operatorname{PF}_5 \longrightarrow [\operatorname{XeF}]^+ [\operatorname{PF}_6]^-$ 

258. Since there are two Xe-F covalent bonds and three one pairs in XeF<sub>2</sub>. According to VSEPR theory, the shape of XeF<sub>2</sub> is linear.

259. Refer to answer 258.

260. Since, xenon (Xe) has least ionization energy among noble gases hence it readily forms chemical compounds particularly with  $O_2$  and  $F_2$ .

**262.**  $XeF_6 + KF \longrightarrow K^+ [XeF_7]^-$ 

150

**263.** *Refer to answer 240.* 

**264.**  $PtF_6 + Xe \longrightarrow Xe^+ [PtF_6]^-$ 

**265.** Except radon which is radioactive, Xe has least ionisation energy among noble gases and hence it readily forms chemical compounds particularly with oxygen and fluorine.

**266.** Fluorine and oxygen are the most electronegative elements and hence are very reactive. Therefore, they form compounds with noble gases particularly with xenon.

**267.** Neon is used in discharge tubes and fluorescent bulbs for advertisement display purposes.

Argon is used to provide an inert atmosphere in high temperature metallurgical processes and for filling electric bulbs.

**268.** (i) Helium is used for filling balloons for meteorological observations because it is non-inflammable.

(ii) Refer to answer 257.

All the orbital of Xe have paired electrons. The promotion of one, two or three electrons from 5p-filled orbitals to the 5d-vacant orbitals will give rise to two, four and six-half filled orbitals. Therefore, xenon can combine with even number of fluorine atoms, not add. Thus, it cannot form XeF<sub>3</sub> and XeF<sub>5</sub>. (ii) *Refer to answer 265.* 

**271.**  $XeO_3$  can be obtained by hydrolysis of  $XeF_4$  and  $XeF_6$ .

$$6XeF_4 + 12H_2O \longrightarrow 4Xe + 2XeO_3 + 24 \text{ HF} + 3O_2.$$
  

$$XeF_6 + 3H_2O \longrightarrow XeO_3 + 6\text{HF}$$



**272.** (i) Structure of  $ICl_4^-$ : I in  $ICl_4^-$  has four bond pairs and two lone pairs. Therefore, according to VSEPR theory, it should be square planar as shown. Here,  $ICl_4^-$  has  $(7 + 4 \times 7 + 1) = 36$  valence electrons. A noble gas species having 36 valence electrons is  $XeF_4(8 + 4 \times 7 = 36)$ . Therefore, like  $ICl_4^-$ ,  $XeF_4$  is also square planar.



(ii) Structure of  $\text{BrO}_3^-$ : The central atom Br has seven electrons. Four of these electrons form two double bonds or coordinate bonds with two oxygen atoms while the fifth electron forms a single bond with O<sup>-</sup> ion. The remaining two electrons form one lone pair. Hence, in all there are three bond pairs and one lone pair around Br atom in  $\text{BrO}_3^-$ . Therefore, according to VSEPR theory,  $\text{BrO}_3^-$  should be pyramidal.



Here,  $BrO_3^-$  has  $26(7 + 3 \times 6 + 1 = 26)$  valence electrons. A noble gas species having 26 valence electrons is  $XeO_3(8 + 3 \times 6 = 26)$ . Thus, like  $BrO_3^-$ ,  $XeO_3$  is also pyramidal

- **273.** (i) *Refer to answer 246.* 
  - (ii) Refer to answer 241.
- **274.** (i) *Refer to answer 242.* 
  - (ii) Refer to answer 245.
- **275.** (i) *Refer to answer 265.* 
  - (ii) Refer to answer 242.
  - (iii) Refer to answer 249.