CHAPTER

6

p-BLOCK ELEMENTS

Syllabus

- *Group 16 Elements : General introduction, electronic configuration, oxidation states, occurrence, trends in physical and chemical properties, dioxygen: Preparation, Properties and uses, classification of Oxides, Ozone, Sulphur-allotropic forms; compounds of Sulphur : Preparation, Properties and uses of Sulphur-dioxide; Sulphuric Acid : industrial process of manufacture, properties and uses; Oxoacids of Sulphur (Structures only).*
- *Group 17 Elements : General introduction, electronic configuration, oxidation states, occurrence, trends in physical and chemical properties; compounds of halogens, Preparation, properties and uses of Chlorine and Hydrochloric acid, interhalogen compounds, Oxoacids of halogens (structures only).*
- *Group 18 Elements : General introduction, electronic configuration, occurrence, trends in physical and chemical properties, uses.*

Chapter Analysis

List of Topics	2016		2017		2018
	D	OD	D	OD	D/OD
Draw the structure		1Q (2 marks)*		1Q (2 marks)	1Q (2 marks)
What happens when		1Q (2 marks)*	1Q (2 marks)*		
Give reason		1Q (1 mark)	1Q (1 mark)	1Q (1 mark)	1Q (2 marks)
Complete the reactions			1Q (2 marks)*		

- * One question of 2 marks with two choices was asked.

On the basis of above analysis, it can be said that from exam point of view, Draw the Structure of Compounds, What Happens When and Give Reason are the most important type of questions asked from different topics of the chapter.

TOPIC-1

Group-16 Elements, Properties and Some Important Compounds

Revision Notes

- **Oxygen family : $_8$O, $_{16}$S, $_{34}$Se, $_{52}$Te, $_{84}$Po**
- **Physical properties :**
  - **(i) Atomic and ionic radii :** Smaller than the corresponding elements of group 15 due to increase in nuclear charge. Down the group they increase due to addition of a new shell.
  - **(ii) Ionisation enthalpy :** I.E.$_1$ is lower than those of corresponding elements of group 15 due to increase in nuclear charge. I.E.$_2$ is higher than those of group 15 due to smaller size of the ions and greater effective nuclear charge. Down the group I.E. decreases.
  - **(iii) Electron gain enthalpy :** Oxygen has less electron gain enthalpy than sulphur. From sulphur, the value again become less negative upto polonium.

TOPIC - 1
Group-16 Elements, Properties and Some Important Compounds .... **P. 115**

TOPIC - 2
Group-17 Elements, Properties and Some Important Compounds .... **P. 121**

TOPIC - 3
Group-18 Elements, Properties and Some Important Compounds .... **P. 128**

(iv) **Electronegativity :** More electronegative than group 15 elements. It decreases down the group due to increase in atomic size.

(v) Oxygen and sulphur are non-metals, selenium and tellurium are metalloids and polonium is a metal.

(vi) **Melting and boiling points :** Increases regularly from O to Te due to increase in size and hence greater van der Waals force. Po has lesser melting and boiling point than Te due to maximum inert pair effect.

(vii) **Density :** Increases down the group.

(viii) **Oxidation state :** Oxygen shows an oxidation state of –2 only (except OF_2 and H_2O_2). All other elements show +2, +4 and +6 oxidation states.

- **Chemical properties :**

(i) With hydrogen : Form hydroxide of type H_2E (E = O, S, Se, Te and Po).

Properties of hydrides :

(i) Thermal stability : Decreases down the group.

(ii) Acidic character : Increases down the group.

(iii) Reducing nature : All are reducing agents except H_2O.

(iv) Boiling point : From H_2O to H_2S there is a sudden drop which increases from H_2S to H_2Te.

(v) With halogens : Form halides of type EX_2, EX_4 and EX_6 where E is an element of group and X is a halogen.

Properties of halides :

(i) Only hexafluorides are the only stable halides.

(ii) All elements except selenium form dichlorides and dibromides. These dihalides are sp^3 hybridised and have tetrahedral structure.

$$2Se_2Cl_2 \rightarrow SeCl_4 + 3Se$$

(a) Preparation of SF_4 and SF_6 :

$$3SCl_2 + 4NaF \rightarrow SF_4 + S_2Cl_2 + 4NaCl$$

$$S + 3F_2 \xrightarrow{\text{Burn}} SF_6$$

(b) Properties of SF_4 : SF_4 is readily hydrolysed.

$$SF_4 + 2H_2O \rightarrow 4HF + SO_2$$

(c) SF_6 is sp^3d^2 hybridised and octahedral whereas SF_4 is sp^3d hybridised and is trigonal bipyramidal with one position occupied by a lone pair of electrons.

(iii) With oxygen : Form oxides of EO_2 and EO_3.

- **Dioxygen (O_2)**

Preparation :

In laboratory, $2KClO_3 \xrightarrow{MnO_2} 2KCl + 3O_2$

Properties :

(i) Slightly soluble in water and appreciably soluble in alkaline pyrogallol solution.

(ii) Paramagnetic.

(iii) Forms oxides with metals and non-metals.

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

$$4Al + 3O_2 \rightarrow 2Al_2O_3$$

$$P_4 + 5O_2 \rightarrow P_4O_{10}$$

$$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$$

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

$$4HCl + O_2 \rightarrow 2Cl_2 + 2H_2O$$

- **Classification of oxides :** On the basis of chemical nature.

(i) **Basic :** Na_2O, CaO, etc. metallic oxides.

(ii) **Acidic :** CO_2, SO_2, etc. non-metallic oxides.

(iii) **Amphoteric :** SnO_2, Al_2O_3, etc. are amphoteric oxides.

(iv) **Neutral :** H_2O, CO, etc. are neutral oxides.

(v) **Poly-oxide :** Oxides having oxygen more than required oxygen such as peroxide (Na_2O_2), super oxide (KO_2), dioxide (PbO_2), higher oxide (Mn_2O_7).

(vi) **Sub-oxide :** Oxides having oxygen less than required, *e.g.*, C_3O_2.

- **Ozone (O_3)**

Preparation : By subjecting pure and dry oxygen to silent electric discharge.

$$3O_2(g) \xrightarrow{\text{Discharge}} 2O_3(g),\ \Delta H = +\ 284\ \text{kJ}$$

Properties :

(i) Poisonous in nature.

(ii) Powerful oxidising agent. It is a stronger oxidising agent than O_2.

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

$$2I^- + H_2O + O_3 \rightarrow 2OH^- + I_2 + O_2$$

Uses :

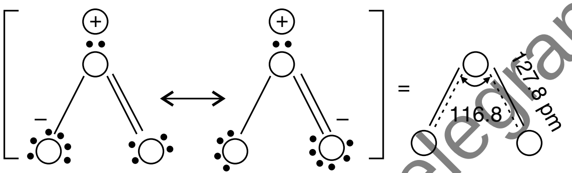
(i) As bleaching agent.

(ii) As disinfectant and germicide.

(iii) For purification of air in hospitals, railway tunnels, cinema house.

(iv) For bleaching oils, ivory flour, starch etc.

Structure :



- **Allotropes of Sulphur :**

(a) Rhombic Sulphur (α-Sulphur) :

(i) Yellow in colour, melting point 385.8 K and specific gravity 2.06.

(ii) Formed by evaporating the solution of roll sulphur in CS_2.

(iii) Insoluble in water but dissolves to some extent in benzene, alcohol and ether.

(iv) Readily soluble in CS_2.

(b) Monoclinic Sulphur (β-Sulphur) :

(i) Melting point is 393 K and specific gravity 1.98.

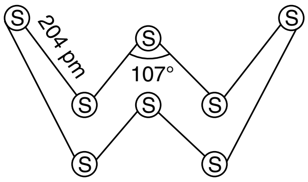
(ii) Soluble in CS_2.

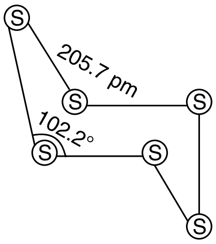
(iii) Prepared by melting rhombic sulphur in a dish and cooling.

(iv) Stable above 369 K and transforms into α-sulphur below it.

Both rhombic and monoclinic sulphur have S_8 molecules.

Shape of S_8 and S_6 molecules :





- **Sulphur dioxide (SO_2) :**

Preparation :

$$\underset{\text{(conc.)}}{S + 2H_2SO_4} \rightarrow 3SO_2 + 2H_2O$$

$$\underset{\text{(conc.)}}{Cu + 2H_2SO_4} \rightarrow CuSO_4 + SO_2 + 2H_2O$$

$$\underset{\text{(dil.)}}{Na_2SO_3 + 2HCl} \rightarrow 2NaCl + SO_2 + H_2O$$

Properties :

(i) Colourless gas with pungent, suffocating odour.

(ii) Highly soluble in water.

(iii) $$SO_2 + H_2O \rightleftharpoons \underset{\text{(Sulphurous acid)}}{H_2SO_3}$$

$$\begin{aligned} 2NaOH + SO_2 &\rightarrow Na_2SO_3 + H_2O \\ Na_2SO_3 + H_2O + SO_2 &\rightarrow 2NaHSO_3 \\ Cl_2 + SO_2 &\rightarrow SO_2Cl_2 \\ O_2 + 2SO_2 &\rightarrow 2SO_3 \end{aligned}$$

(iv) SO_2 act as reducing agent.

$$\begin{aligned} 2Fe^{3+} + SO_2 + 2H_2O &\rightarrow 2Fe^{2+} + SO_4^{2-} + 4H^+ \\ 5SO_2 + 2MnO_4^- + 2H_2O &\rightarrow 5SO_4^{2-} + 4H^+ + 2Mn^{2+} \end{aligned}$$

Uses :

(i) Used in refining petroleum and sugar.

(ii) As bleaching agent for wool and silk.

(iii) As anti-chlor, disinfectant and preservative.

- **Sulphuric acid (H_2SO_4)**

Preparation : By contact process which involves 3 steps :

(i) Burning of sulphur or sulphide ores in air :

$$S + O_2 \rightarrow SO_2$$

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

$$2SO_2 + O_2 \xrightarrow{V_2O_5} 2SO_3$$

(iii) Absorption of SO_3 in H_2SO_4 to give oleum. Oleum is diluted with water to get H_2SO_4 of desired concentration.

$$\begin{aligned} SO_3 + H_2SO_4 &\rightarrow \underset{\text{(Oleum)}}{H_2S_2O_7} \\ H_2S_2O_7 + H_2O &\rightarrow 2H_2SO_4 \end{aligned}$$

Properties :

(i) Colourless, dense, oily liquid with a specific gravity of 1.84 at 298 K.

(ii) Low volatility.

(iii) Strong acidic character.

(iv) Strong affinity for water.

(v) Acts as an oxidising agent.

$$\begin{aligned} Cu + \underset{\text{(conc.)}}{2H_2SO_4} &\rightarrow CuSO_4 + SO_2 + 2H_2O \\ S + \underset{\text{(conc.)}}{2H_2SO_4} &\rightarrow 3SO_2 + 2H_2O \\ C + \underset{\text{(conc.)}}{2H_2SO_4} &\rightarrow CO_2 + 2SO_2 + 2H_2O \end{aligned}$$

(vi) Acts as a dehydrating agent.

$$C_{12}H_{22}O_{11} \xrightarrow{H_2SO_4} 12C + 11H_2O$$

Uses :

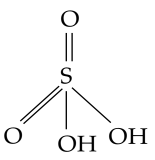
(i) In petroleum refining.

(ii) Manufacture of pigments, paints and dye stuff.

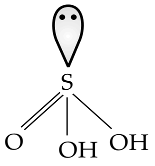
(iii) Detergent industry.

(iv) In storage batteries.

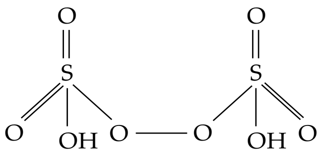
- **Oxoacids of Sulphur :**



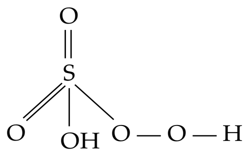
(H_2SO_4)
Sulphuric
acid



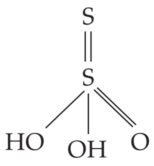
(H_2SO_3)
Sulphurous
acid

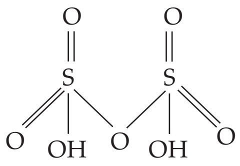


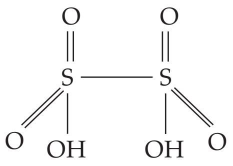
($H_2S_2O_8$)
Marshall's acid
Peroxodisulphuric
acid

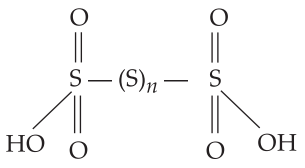


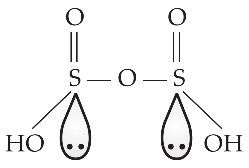
(H_2SO_5)
Caro's acid
Peroxomonosulphuric
acid

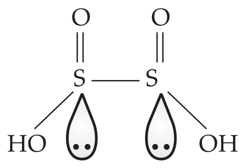

($H_2S_2O_3$)
Thiosulphuric acid


($H_2S_2O_7$)
Pyrosulphuric acid
(Oleum)


($H_2S_2O_6$)
Dithionic acid


($H_2S_nO_6$)
Polythionic acid


($H_2S_2O_5$)
Disulphurous acid


($H_2S_2O_4$)
Dithionous acid

Know the Terms

- **Chalcogens :** Group-16 elements are also known as chalcogens which means ore forming elements.
- **Oil of vitriol :** Pure sulphuric acid is highly viscous due to the presence of intermolecular hydrogen bonding. It is known as oil of vitriol.
- **Oxide :** A binary compound of oxygen with another element.

Objective Type Questions

(1 mark each)

A. Multiple choice Questions:

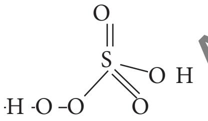
Q. 1. Which of the following are peroxoacids of sulphur?

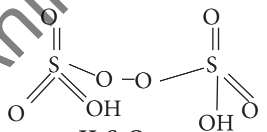
(a) H_2SO_5 and $H_2S_2O_8$ (b) H_2SO_5 and $H_2S_2O_7$
(c) $H_2S_2O_7$ and $H_2S_2O_8$ (d) $H_2S_2O_6$ and $H_2S_2O_7$

R [NCERT Exemp. Q. 21, Page 93]

Ans. Correct option : (a)

Explanation : Peroxoacids of sulphur must contain one O—O bond as shown below :


H_2SO_5


$H_2S_2O_8$

Q. 2. Hot conc. H_2SO_4 acts as moderately strong oxidising agent. It oxidises both metals and non-metals. Which of the following element is oxidised by conc. H_2SO_4 into two gaseous products?

(a) Cu (b) S
(c) C (d) Zn

A&E [NCERT Exemp. Q. 22, Page 93]

Ans. Correct option : (c)

Explanation : $[H_2SO_4 \rightarrow H_2O + SO_2 + O] \times 2$

$C + 2O \rightarrow CO_2$

$C + 2H_2SO_4 \rightarrow CO_2 + 2SO_2 + 2H_2O$

Carbon dioxide and sulphur dioxide are two gaseous products formed by oxidation of carbon by sulphuric acid.

B. Answer the following:

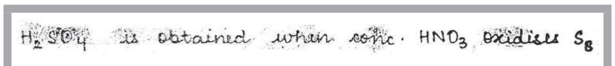
Q. 1. Write the formula of the compound of sulphur which is obtained when conc. HNO_3 oxidises S_8.

R [CBSE OD Set-2 2017]

Ans. H_2SO_4 1

[CBSE Marking Scheme 2017]

OR


H_2SO_4 is obtained when conc. HNO_3 oxidises S_8

1

[Topper's Answer 2017]

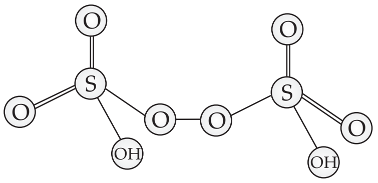
Q. 2. Write the formulae of any two oxoacids of sulphur. R [CBSE Comptt. OD 2015]

Ans. H_2SO_3 (Sulphurous acid) and H_2SO_4 (Sulphuric acid). ½ + ½

Q. 3. Draw the structure of $H_2S_2O_8$.

R [CBSE Delhi/Foreign 2012; KVS]

Ans.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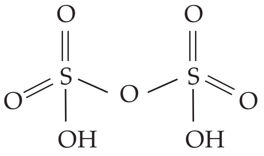
AI Q. 4. Draw the structure of $H_2S_2O_7$.

R [CBSE Delhi 2012]

Ans. Pyrosulphuric acid (oleum) :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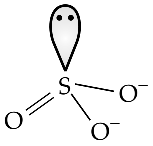
Q. 5. Predict the shape and the asked angle (90° or more or less) in the following case SO_3^{2-} and the angle O—S—O. U [CBSE Delhi 2012]

Ans. Pyramidal :



½

Angle : O—S—O more than 90° ½

Answering Tip

- Draw the structures with lone pair of electrons (if present). Avoid over-writing.

Q. 6. Arrange the following hydrides of Group-16 elements in the increasing order of their thermal stability : H_2O, H_2S, H_2Se, H_2Te.

A **[CBSE Foreign Set-1, 2, 3 2017]**

Ans. $H_2Te < H_2Se < H_2S < H_2O$ 1

[CBSE Marking Scheme 2017]

Q. 7. Account for the following:

Oxygen shows catenation behaviour less than sulphur. A&E **[CBSE Delhi 2013]**

Ans. Bond energy of S—S bond (213 kJ mol^{-1}) is greater than O – O bond (138 kJ mol^{-1}). Due to small size of oxygen atom there is greater lp–bp repulsion in O – O, resulting in weakening of O – O bond more than in S–S bond. Therefore, the tendency of catenation in oxygen is lower than sulphur. 1

AI **Q. 8. Oxygen is a gas but sulphur a solid. Explain.**

A&E **[CBSE OD 2012; KVS]**

Ans. Oxygen being smallest in size is capable of forming $p\pi - p\pi$ bond and exists as O=O(O_2 molecule) while sulphur being larger in size is not able to form $p\pi - p\pi$ bond. 1

Short Answer Type Questions

(2 marks each)

AI **Q. 1. What happens when :**

(i) conc. H_2SO_4 is added to Cu ?

(ii) SO_3 is passed through water ?

Write the equations. R **[CBSE Delhi Set-2 2017]**

Ans.(i) $Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$ 1

(ii) $SO_3 + H_2O \rightarrow H_2SO_4$ 1

[CBSE Marking Scheme 2017]

Answering Tip

- Give balanced chemical equation.

Q. 2. What happens when :

(i) Concentrated H_2SO_4 is added to calcium fluoride ?

(ii) SO_3 is passed through water ?

R **[CBSE Comptt. Delhi 2016]**

Ans. (i) $\underset{\text{(conc.)}}{H_2SO_4} + CaF_2 \rightarrow 2HF + CaSO_4$ 1

(ii) $SO_3 + H_2O \rightarrow H_2SO_4$ 1

[CBSE Marking Scheme 2016]

Answering Tip

- Give balanced chemical equation.

Q. 3. How is O_3 estimated quantitatively?

C **[NCERT]**

Ans. When ozone reacts with potassium iodide (KI) solution buffered with a borate buffer (pH = 9.2) then iodine (I_2) is liberated that can be titrated against a standard solution of sodium thiosulphate using starch as indicator. 2

Q. 4. Write the conditions to maximise the yield of H_2SO_4 by contact process. U **[NCERT]**

Ans. The conditions used to maximise the yield of H_2SO_4 by contact process :

(i) High pressure

(ii) Low temperature

(iii) V_2O_5 is used as catalyst **(any two) 2**

Long Answer Type Questions-I

(3 marks each)

Q. 1. Give reasons for the following :

(i) $(CH_3)_3 P = O$ exists but $(CH_3)_3 N = O$ does not.

(ii) Oxygen has less electron gain enthalpy with negative sign than sulphur.

(iii) H_3PO_2 is a stronger reducing agent than H_3PO_3.

A&E **[CBSE OD Set-1, 2, 3 2014]**

Ans. (i) Because as N can't form 5 covalent bonds as its maximum covalency is three. The octet cannot be extended as it doesn't have *d* orbital, while P can extend its octet as it has empty *d* orbital. 1

(ii) This is due to very small size of oxygen atom, repulsion between electrons is large in relatively small 2*p* sub-shell. 1

(iii) In H_3PO_2 there are 2P – H bonds, whereas in H_3PO_3 there is 1 P-H bond. 1

[CBSE Marking Scheme 2014]

Q. 2. How is SO_2 an air pollutant? U **[NCERT]**

Ans. Sulphur dioxide causes harm to the environment in many ways :

(i) When it combines with water vapour it forms sulphuric acid (H_2SO_4). This causes acid rain. Acid rain damages soil, plants, and buildings, especially those made of marble. 1

(ii) Even in very low concentrations, SO_2 causes irritation in the respiratory tract. It causes throat and eye irritation and can also affect the larynx to cause breathlessness. **1**

(iii) It is extremely harmful to plants. Plants exposed to sulphur dioxide for a long time lose colour from their leaves. This condition is known as chlorosis. This happens because the formation of chlorophyll is affected by the presence of sulphur dioxide. **1**

TOPIC-2

Group-17 Elements, Properties and Some Important Compounds

Quick Review

- **Halogen family :** $_9F$, $_{17}Cl$, $_{35}Br$, $_{53}I$, $_{85}At$.
- **Physical Properties :**
  - (i) **Atomic and ionic radii :** They are the smallest in their respective periods due to increase in nuclear charge. Down the group, they increase.
  - (ii) **Oxidation state :** Fluorine shows –1 only. Other elements show oxidation states +1, +3, +5 and +7.
  - (iii) **Ionisation enthalpy :** Higher than the corresponding members of group 16. Down the group, it decreases.
  - (iv) **Electron gain enthalpy :** Have maximum negative electron gain enthalpy in the corresponding periods.
  - (v) **Metallic character** : Due to very high ionisation enthalpies they are non-metals. The last element I, shows some metallic character as it can form I^+ by loss of electrons.
  - (vi) **Electronegativity :** These are the most electronegative elements in their respective periods. Down the group, electronegativity decreases.
  - (vii) F_2 and Cl_2 are gases, Br_2 is a liquid while I_2 is solid.
  - (viii) All halogens are coloured.
  - (ix) **Melting points and boiling points :** Increases down the group due to increase in size and nuclear charge causing greater van der Waals forces of attraction.
  - (x) **Bond dissociation enthalpy :** Bond dissociation enthalpy decreases from Cl_2 to I_2 *i.e.*, $Cl_2 > Br_2 > F_2 > I_2$.
- **Chemical Properties :**

(a) Highly reactive : The reactivity decreases down the group. Fluorine is the strongest oxidising halogen. A halogen oxidise halide ions of higher atomic number.

$$F_2 + 2X^- \rightarrow 2F^- + X_2 \qquad (X = Cl, Br \text{ or } I)$$
$$Cl_2 + 2X^- \rightarrow 2Cl^- + X_2 \qquad (X = Br \text{ or } I)$$
$$Br_2 + 2I^- \rightarrow 2Br^- + I_2$$

Fluorine oxidises water to oxygen whereas chlorine and bromine react with water to form corresponding hypothalic and hypohalous acids.

$$2F_2(g) + 2H_2O(l) \rightarrow 4H^+(aq) + 4F^-(aq) + O_2(g)$$
$$X_2(g) + H_2O(l) \rightarrow HX(aq) + HOX(aq) \qquad (X = Cl \text{ or } Br)$$

(b) Towards hydrogen : All elements form hydrides of the type HX (X = F, Cl, Br, I).

- (i) **Physical state :** Except HF which is a liquid because of H-bonding, all are gases.
- (ii) **Thermal stability :** It decreases down the group due to increase in bond length.
- (iii) **Reducing character :** It increases from HF to HI due to decrease of stability.
- (iv) **Acidic strength :** HF < HCl < HBr < HI.

(c) Towards halogens : They react with all elements except He, Ne and Ar to form binary halides.

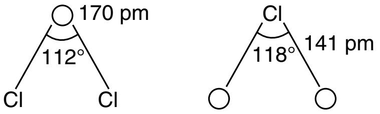
(d) Towards metal :

- (i) With particular metal, ionic character is
  M-F > M-Cl > M-Br > M–I.
- (ii) With metals having low I.E., halides are ionic.
- (iii) With metals having high I.E., halides are covalent.

(iv) With metals showing more than one oxidation states, halides with higher oxidation states are more covalent.

(v) Metals show highest oxidation state in fluorides.

(e) Towards oxygen : Halogens form many binary compounds with oxygen, but most of them are unstable. Cl, Br and I form oxides in their oxidation state +1 to +7. Their stability decreases in the order I > Cl > Br.



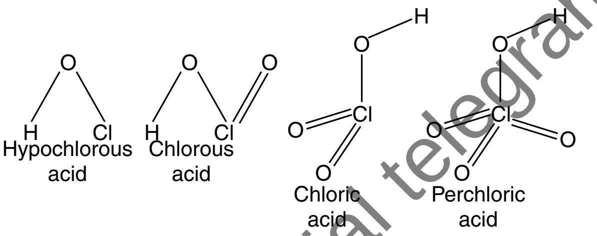
(f) Oxoacids : Because of high electronegativity and small size, fluorine forms only one oxoacid, HOF (hypofluorous acid). The other halogens form acid of the type HOX—hypohalous acid, HOXO–halous acid, $HOXO_2$ – halic acid and $HOXO_3$ – perhalic acid.

Acidic strength : HClO > HBrO > HIO

Acidic strength of oxoacids containing the same halogen :

$HOCl > HClO_2 < HClO_3 < HClO_4$

(g) Structure of oxoacids of Chlorine :



- **Chlorine (Cl_2)**

Preparation :

$$MnO_2 + 4HCl \xrightarrow{\Delta} MnCl_2 + Cl_2 + 2H_2O$$

$$2KMnO_4 + 16HCl \xrightarrow{\Delta} 2KCl + 2MnCl_2 + 8H_2O + 5Cl_2$$

In laboratory,

(i) $4HCl + O_2 \xrightarrow{CuCl_2} 2Cl_2 + 2H_2O$ (Deacon's process)

(ii) $4NaCl + MnO_2 + 4H_2SO_4 \rightarrow MnCl_2 + 4NaHSO_4 + 2H_2O + Cl_2$

(iii) Electrolytic process : By electrolysis of brine.

At cathode : $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$; $Na^+ + OH^- \rightarrow NaOH$

At anode : $Cl^- \rightarrow Cl + e^-$; $Cl + Cl \rightarrow Cl_2$

Properties :

(i) It is a greenish yellow gas with a pungent suffocating smell.

(ii) Soluble in water.

(iii) About 2.5 times heavier than air.

(iv) With metals and non-metals form chlorides.

$$2Al + 3Cl_2 \rightarrow 2AlCl_3;\ 2Na + Cl_2 \rightarrow 2NaCl$$
$$2Fe + 3Cl_2 \rightarrow 2FeCl_3;\ S_8 + 4Cl_2 \rightarrow 4S_2Cl_2$$
$$P_4 + 6Cl_2 \rightarrow 4PCl_3;\ H_2 + Cl_2 \rightarrow 2HCl$$

(v) Reacts with compounds containing hydrogen to form HCl

$$H_2S + Cl_2 \rightarrow 2HCl + S;\ C_{10}H_{16} + 8Cl_2 \rightarrow 16HCl + 10C$$
$$\underset{\text{(excess)}}{NH_3} + 3Cl_2 \rightarrow \underset{\text{(explosive)}}{NCl_3} + 3HCl;\ \underset{\text{(excess)}}{8NH_3} + 3Cl_2 \rightarrow 6NH_4Cl + N_2$$

(vi) With cold and dilute alkalies

$$\underset{\text{(cold and dilute)}}{2NaOH} + Cl_2 \rightarrow NaCl + NaOCl + H_2O$$

(vii) With hot and concentrated alkalies

$$\underset{\text{(hot and conc.)}}{6NaOH} + 3Cl_2 \rightarrow 5NaCl + NaClO_3 + 3H_2O$$

(viii) With dry slaked lime, it gives bleaching powder.

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

(ix) Chlorine water on standing loses its yellow colour. HOCl formed gives nascent oxygen.

$$Cl_2 + H_2O \rightarrow HCl + HOCl$$

$$HOCl \rightarrow HCl + O$$

(x) It oxidises ferrous to ferric, sulphite to sulphate, sulphur dioxide to sulphuric acid and iodine to iodic acid.

$$2FeSO_4 + H_2SO_4 + Cl_2 \rightarrow Fe_2(SO_4)_3 + 2HCl$$

$$Na_2SO_3 + Cl_2 + H_2O \rightarrow Na_2SO_4 + 2HCl$$

$$SO_2 + 2H_2O + Cl_2 \rightarrow H_2SO_4 + 2HCl$$

$$I_2 + 6H_2O + 5Cl_2 \rightarrow 2HIO_3 + 10HCl$$

Uses :

(i) For bleaching cotton and textiles.

(ii) In sterilising drinking water.

(iii) In the extraction of gold and platinum.

(iv) Manufacture of dyes, drugs, refrigerant and other organic compounds like $CHCl_3$, DDT, CCl_4, etc.

- **Hydrogen Chloride (HCl) :**

Preparation : In laboratory

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

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

HCl gas can be dried by passing conc. H_2SO_4 through it.

Properties :

(i) Colourless and pungent smelling gas.

(ii) Extremely soluble in water.

(iii) When three parts of conc. HCl and one part of conc. HNO_3 are mixed aqua-regia is formed which is used for dissolving noble metals *e.g.*, gold, platinum.

$$Au + 4H^+ + NO_3^- + 4Cl^- \rightarrow AuCl_4^- + NO + 2H_2O$$

$$3Pt + 16H^+ + 4NO_3^- + 18Cl^- \rightarrow 3PtCl_6^{2-} + 4NO + 8H_2O$$

(iv) Reacts with NH_3 giving white fumes of NH_4Cl.

$$NH_3 + HCl \rightarrow NH_4Cl$$

(v) Decomposes salts of weaker acids.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$$

$$Na_2SO_3 + 2HCl \rightarrow 2NaCl + H_2O + SO_2$$

Uses :

(i) In the manufacture of chlorine, glucose and NH_4Cl.

(ii) For extracting glue from bones and purifying bone black.

- **Interhalogen Compounds :** Halogen combines amongst themselves to form a number of compounds known as interhalogen compounds. Their general formula are XX', XX_3', XX_5' and XX_7' where X is halogen of larger size and higher electropositivity and X' of smaller size.

Preparation :

$$\underset{\text{(Equal volume)}}{Cl_2 + F_2} \xrightarrow{437\text{ K}} 2ClF; \qquad I_2 + \underset{\text{(excess)}}{3Cl_2} \rightarrow 2ICl_3$$

$$Cl_2 + \underset{\text{(excess)}}{3F_2} \xrightarrow{573\text{ K}} 2ClF_3; \qquad Br_2 + \underset{\text{(Diluted with water)}}{3F_2} \rightarrow 2BrF_3$$

$$\underset{\text{(Equimolar)}}{I_2 + Cl_2} \rightarrow 2ICl; \qquad Br_2 + \underset{\text{(excess)}}{5F_2} \rightarrow 2BrF_5$$

Properties :

(i) Covalent compounds.

(ii) Diamagnetic in nature.

(iii) More reactive than halogens.

(iv) Undergo hydrolysis.

$$XX' + H_2O \rightarrow HX' + HOX$$

- **Structure :** On the basis of VSEPR theory, XX_3' compounds have bent 'T' shape, XX_5' compounds have square pyramidal and IF_7 has pentagonal bipyramidal shape.

Uses :

(i) As non-aqueous solvents.

(ii) As fluorinating agents.

(iii) ClF_3 and BrF_3 are used for the production of UF_6 in the enrichment of ^{235}U.

Know the Terms

- **Pseudohalide ions :** CN^-, SCN^- and OCN^- ions are called pseudohalide ions while $(CN)_2$, $(SCN)_2$ and $(OCN)_2$ are known as pseudohalogens.
- **Bleaching powder :** $Ca(ON)_2 + Cl_2 \rightarrow CaOCl_2 + H_2O$
  Bleaching
  Powder

Objective Type Questions

(1 mark each)

A. Multiple choice Questions:

Q. 1. Affinity for hydrogen decreases in the group from fluorine to iodine. Which of the halogen acids should have highest bond dissociation enthalpy?

(a) HF **(b) HCl**

(c) HBr **(d) HI**

U **[NCERT Exemp. Q. 6, Page 91]**

Ans. Correct option : (a)

Explanation : F being smallest has the shortest HF bond and therefore HF has the highest bond dissociation energy.

Q. 2. Reduction potentials of some ions are given below. Arrange them in decreasing order of oxidising power.

Ion	ClO_4^-	IO_4^-	BrO_4^-
Reduction potential $E^\ominus$/V	$E^\ominus$=1.19V	$E^\ominus$=1.65V	$E^\ominus$=1.74V

(a) $ClO_4^- > IO_4^- > BrO_4^-$

(b) $IO_4^- > BrO_4^- > ClO_4^-$

(c) $BrO_4^- > IO_4^- > ClO_4^-$

(d) $BrO_4^- > ClO_4^- > IO_4^-$

A **[NCERT Exemp. Q. 26, Page 94]**

Ans. Correct option : (c)

Explanation : The higher the reduction potential, the higher is its tendency to get reduced. Hence, the order of oxidising power is :

$BrO_4^- > IO_4^- > ClO_4^-$

Q. 3. Which of the following is iso-electronic pair?

(a) ICl_2, ClO_2 **(b)** BrO_2^-, BrF_2^+

(c) ClO_2, BrF **(d)** CN^-, O_3

A **[NCERT Exemp. Q. 27, Page 94]**

Ans. Correct option : (b)

Explanation :

(a) $ICl_2 = 53 + 2 \times 17 = 87$
$ClO_2 = 17 + 16 = 33$
(b) $BrO_2^- = 35 + 2 \times 8 + 1 = 52$
$BrF_2^+ = 35 + 9 \times 2 - 1 = 52$
(c) $ClO_2 = 17 + 16 = 33$
$BrF = 35 + 9 = 44$
(d) $CN^- = 6 + 7 + 1 = 14$
$O_3 = 8 \times 3 = 24$

Q. 4. A black compound of manganese reacts with a halogen acid to give greenish yellow gas. When excess of this gas reacts with NH_3 an unstable tri-halide is formed. In this process the oxidation state of nitrogen changes from :

(a) – 3 to +3. **(b) – 3 to 0.**

(c) – 3 to +5. **(d) 0 to – 3.**

A&E **[NCERT Exemp. Q. 23, Page 93]**

Ans. Correct option : (a)

Explanation :

$MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl$
(Greenish yellow gas)

$NH_3 + 3Cl_2 \rightarrow NCl_3 + 3HCl$

When excess of chlorine tense with ammonia then NCl_3 and HCl will form. In this reaction on left-hand side chlorine have (−3) oxidation state and on the right-hand chlorine have (+3) oxidation state.

B. Answer the following:

Q. 1. Write the formula of the compound of iodine which is obtained when conc. HNO_3 oxidises I_2.

R **[CBSE OD Set-3 2017]**

Ans. HIO_3 1

[CBSE Marking Scheme 2017]

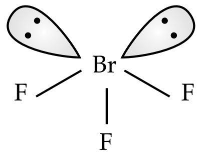
Q. 2. Name two poisonous gases which can be prepared from chlorine gas. R **[CBSE Delhi 2013]**

Ans. Phosgene ($COCl_2$), tear gas (CCl_3NO_2), mustard gas [$C_4H_8Cl_2S$]. **(Any two)** ½ + ½

Q. 3. Draw the structure of BrF_3 molecule.

R **[CBSE Delhi 2013]**

Ans.



1

[T-shape]

Answering Tip

- Draw the structure with lone pair of electrons (if present). Avoid over-writing.

AI **Q. 4. Fluorine exhibits only –1 oxidation state whereas other halogens exhibit +1, +3, +5 and +7 oxidation states also. Why is it so ?**

A&E **[CBSE Comptt. Delhi 2013]**

Ans. Fluorine has no *d*-orbital for excitation of electrons and it is most electronegative element. Hence, it shows oxidation state of –1 only. 1

AI **Q. 5. Bond enthalpy of fluorine is lower than that of chlorine why ?** A&E **[CBSE Comptt. OD 2013]**

OR

Bond enthalpy of F_2 is less than of Cl_2.

A&E **[CBSE Delhi 2013]**

Ans. Bond enthalpy of F—F is smaller due to greater repulsive interactions between the lone pair of one F atom with those of other. The repulsive interaction arise due to greater concentration of electron density on each F atom because of its extremely small size. 1

Q. 6. HF is a weaker acid than HCl why ?

A&E [CBSE Comptt. OD 2013]

Ans. Since H—F bond is strongest with higher bond dissociation energy than HCl, hence it is weakest acid among all the halogen acids. 1

Answering Tip

- Be specific about the key word in the answer. Avoid unnecessary explanation.

Q. 7. Give reason for the following :

F_2 is more reactive than ClF_3 but ClF_3 is more reactive than Cl_2. **A&E [CBSE Comptt. Delhi 2013]**

Ans. Interhalogen compounds are more reactive than halogen compounds. But in case of fluorine due to the small size of fluorine, it has high electronegativity and low bond energy so it is more reactive than ClF_3. Therefore ClF_3 is more reactive than Cl_2. 1

Q. 8. Give reason for the following :

$PbCl_4$ is more covalent than $PbCl_2$.

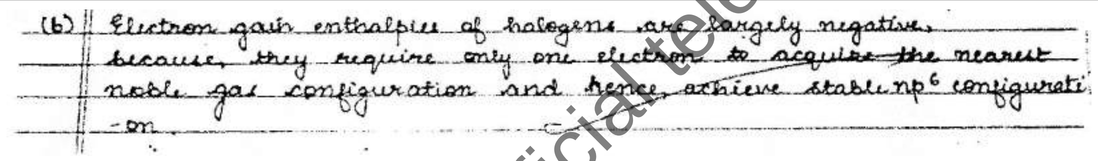
A&E [CBSE OD 2013]

Ans. Due to high oxidising power, halogens combine directly with most metals to form their corresponding halides. But if the metal exhibit more than one oxidation state, the halide in higher oxidation state will be more covalent than the one in lower oxidation state. Therefore $PbCl_4$ is more covalent than $PbCl_2$ as Pb exhibits more than one oxidation states. 1

Q. 9. Give reason for the following:

Electron gain enthalpies of halogens are largely negative. **A&E [CBSE O.D. Set-2, 2017]**

Ans.



(b) Electron gain enthalpies of halogens are largely negative because they require only one electron to acquire the nearest noble gas configuration and hence achieve stable np^6 configuration.

[Topper's Answer 2017]

Detailed Answer:

Halogens are smallest in size in their respective periods resulting in high effective nuclear charge. They accept one electron to attain noble gas electronic configuration. Hence, they have negative electron gain enthalpy. 1

Q. 10. Give reasons: Fluoride ion has higher hydration enthalpy than chloride ion.

A&E [CBSE Delhi Set-1, 2, 3, 2017]

Ans. Due to small size of fluoride ion/high charge density of fluoride ion/high charge size ratio of fluoride ion. 1

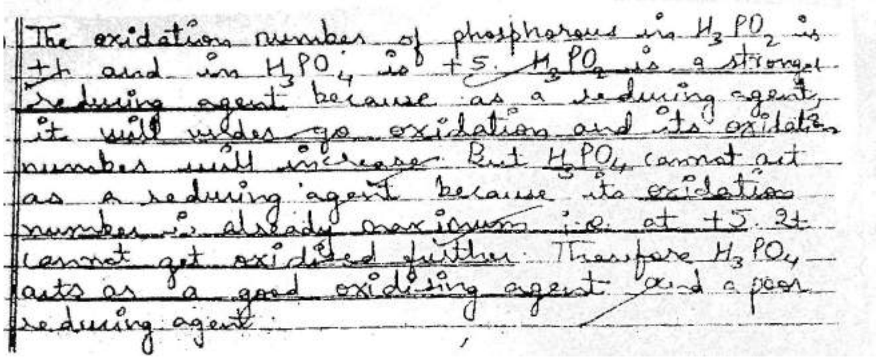
[CBSE Marking Scheme 2017]

Detailed Answer :

The size of fluoride ion is smaller to the chloride ion. So, on dissolving in water, the hydration energy released in the case of fluoride ion is higher than chloride ion because of stronger interactions between the water and ion molecules.

Q. 11. Assign reason for the following: Reducing character increase from HF to HI. **A&E [CBSE O.D. Set-2, 2016]**

Ans.



The oxidation number of phosphorous in H_3PO_2 is +1 and in H_3PO_4 is +5. H_3PO_2 is a stronger reducing agent because as a reducing agent, it will under go oxidation and its oxidation number will increase. But H_3PO_4 cannot act as a reducing agent because its oxidation number is already maximum i.e. at +5. It cannot get oxidised further. Therefore H_3PO_4 acts as a good oxidising agent and a poor reducing agent.

[Topper's Answer 2016] 1

Detailed Answer:

As we move from HF to HI, the thermal stability of these hydrides decreases as bond dissociation enthalpy of HX bond decreases. So, on moving from HF to HI, the hydrogen is available for reduction.

Therefore, reducing character increases. 1

Answering Tip

- While stating the reason, write the cause and the consequence.

Q. 12. Give reasons: ICl is more reactive than I_2.

A&E **[CBSE OD (Central) 2016]**

Ans. Inter halogen compound ICl are more reactive than halogens Cl_2 because X–X (I–Cl) bond in inter halogens is weaker than Cl–Cl bond in halogens except F–F bond. **1**

Answering Tip

- Briefly explain the reason.

Q. 13. Account for the following: Iron on reaction with HCl forms $FeCl_2$ and not $FeCl_3$.

A&E **[CBSE Delhi 2014]**

Ans. Because HCl is a mild oxidising agent and formation of hydrogen gas prevents the formation of $FeCl_3$. **1**

Answering Tip

- While stating the reason, write the cause and the consequence.

Short Answer Type Questions

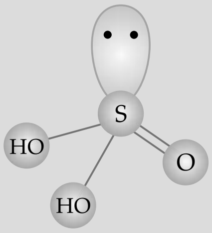
(2 marks each)

Q. 1. Draw the structures of the following:

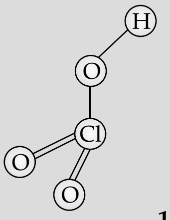
(i) H_2SO_3

(ii) $HClO_3$ R **[CBSE OD Set-1 2017]**

Ans. (i)



(ii)



1+1

[CBSE Marking Scheme 2017]

Answering Tip

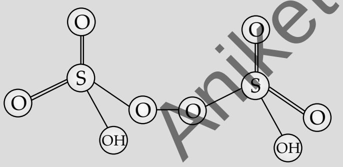
- Draw the correct shape with lone pair of electrons (if present). Avoid over-writing.

Q. 2. Draw the structures of the following:

(i) $H_2S_2O_8$

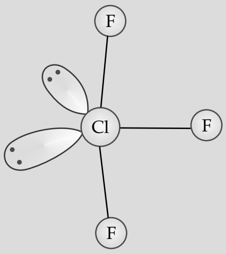
(ii) ClF_3 R **[CBSE OD Set-2 2017]**

Ans. (i)



1

(ii)



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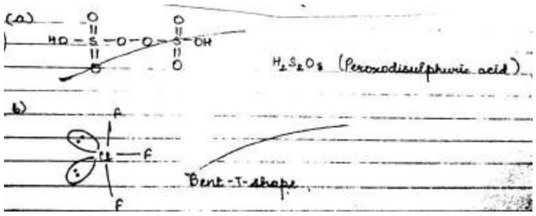
[CBSE Marking Scheme 2017]

OR



2

[Topper's Answer 2017]

Answering Tip

- Draw the structures with lone pair of electrons (if present). Avoid over-writing.

Q. 3. Complete the following chemical equations :

(i) $Ca_3P_2 + H_2O \rightarrow$

(ii) $3Cu + H_2SO_4$ (conc.) $\rightarrow$ R

OR

Arrange the following in the order of property indicated against each set :

(i) HF, HCl, HBr, HI – increasing bond dissociation enthalpy.

(ii) H_2O, H_2S, H_2Se, H_2Te – increasing acidic character. U **[CBSE Delhi 2014]**

Ans. (i) $Ca_3P_2 + 6H_2O \rightarrow 3Ca(OH)_2 + 2PH_3$ **1**

(ii) $Cu + 2H_2SO_4$ (conc.) $\rightarrow CuSO_4 + 2H_2O + SO_2$ **1**

Answering Tip

- Balance the chemical equation.

OR

(i) H—I < H—Br < H—Cl < H—F **1**

(ii) $H_2O < H_2S < H_2Se < H_2Te$ **1**

[CBSE Marking Scheme 2014]

Q. 4. Arrange the following in order of property indicated for each set :

(i) F_2, Cl_2, Br_2, I_2 – increasing bond dissociation enthalpy.

(ii) PH_3, AsH_3, BiH_3, SbH_3, NH_3 – increasing base strength. U **[CBSE SQP 2016; DDE]**

Ans. (i) $I_2 < F_2 < Br_2 < Cl_2$ **1**

(ii) $BiH_3 < SbH_3 < AsH_3 < PH_3 < NH_3$ **1**

Answering Tip

- Clear your concept on bond dissociation enthalpy of halogen.

AI **Q. 5. What happens when**

(i) HCl is added to MnO_2?

(ii) PCl_5 is heated ?

Write the equation involved.

R **[CBSE Delhi Set-3 2017]**

Ans. (i) $MnO_2 + 4HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O$ **1**

(ii) $PCl_5 \xrightarrow{\Delta} PCl_3 + Cl_2$ **1**

[CBSE Marking Scheme 2017]

Answering Tip

- Balance the chemical equation.

Q. 6. Account for the following:

(i) The two oxygen-oxygen bond lengths in ozone molecule are identical.

(ii) Most of the reactions of fluorine are exothermic.

A&E **[CBSE Comptt. Delhi Set-1 2017]**

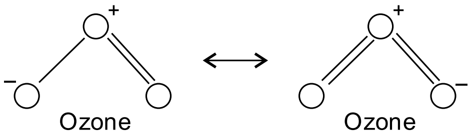
Ans. (i) Due to resonance the two O-O bond lengths are identical. 1

(ii) Due to strong bond formed by it with other elements. 1

[CBSE Marking Scheme 2017]

Detailed Answer:

(i) In ozone, the central oxygen atom forms one single bond with a terminal oxygen atom and double bond with other terminal oxygen atom. The π electrons of double bond are delocalised over the three oxygen atoms. This results into resonance hybrids with the average bond distance of the single and double bond.



1

Q. 7. Account for the following:

(i) Two S-O bond lengths in SO_2 are equal.

(ii) Fluorine shows only −1 oxidation state in its compounds. A&E **[CBSE Comptt. Delhi Set-2 2017]**

Ans. (i) Due to resonance the two S-O bond lengths are identical. 1

(ii) Absence of d-orbitals and most electronegative element. 1

[CBSE Marking Scheme 2017]

Q. 8. Account for the following:

(i) Bond angle in NH_4^+ is higher than that in NH_3.

(ii) ICl is more reactive than I_2.

A&E **[CBSE Comptt. Delhi Set-3 2017]**

Ans. (i) In NH_4^+, all are bond pairs whereas in ammonia the lone pair of electron on nitrogen repels the bond pairs and reduces the bond angle. 1

(ii) I-Cl bond is weaker than I-I bond / low bond dissociation enthalpy in I-Cl. 1

[CBSE Marking Scheme 2017]

Q. 9. Arrange the following in the order of property indicated against each set:

(a) F_2, Cl_2, Br_2, I_2 (increasing bond dissociation enthalpy)

(b) H_2O, H_2S, H_2Se, H_2Te (increasing acidic character) U

OR

Answer the following questions :

(i) Write the formula of the neutral molecule which is isoelectronic with ClO.

(ii) Draw the shape of $H_2S_2O_7$.

U + R **[CBSE SQP 2017]**

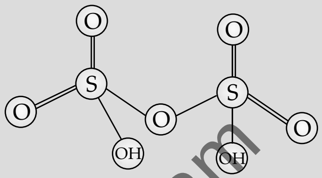
Ans. (a) $I_2 < F_2 < Br_2 < Cl_2$

(b) $H_2O < H_2S < H_2Se < H_2Te$

OR

(i) ClF 1

(ii)



Pyrosulphuric acid (Oleum)
($H_2S_2O_7$)

1

Q. 10. Give reasons :

(i) When Cl_2 reacts with excess of F_2, ClF_3 is formed and not FCl_3.

(ii) Dioxygen is a gas while Sulphur is a solid at room temperature.

A&E **[CBSE Delhi OD 2018]**

Ans. (ii) F cannot show positive oxidation state as it has highest electronegativity/Because Fluorine cannot expand its covalency / As Fluorine is a small sized atom, it cannot pack three large sized Cl atoms around it. 1

(iii) Oxygen has multiple bonding whereas sulphur shows catenation / Due to pπ-pπ bonding in oxygen whereas sulphur does not / Oxygen is diatomic therefore held by weak intermolecular force while sulphur is polyatomic held by strong intermolecular forces. 1

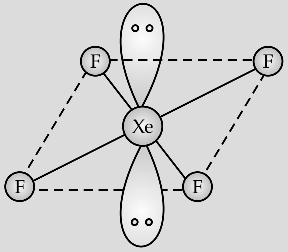
[CBSE Marking Scheme 2018]

Q. 11. Draw the structures of the following :

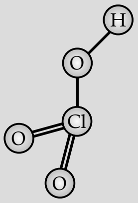
(i) XeF_4

(ii) $HClO_3$ R **[CBSE Delhi OD 2018]**

Ans. **(i)**



(ii)



1+1

[CBSE Marking Scheme 2018]

Long Answer Type Questions-I

(3 marks each)

Q. 1. Considering the parameters such as bond dissociation enthalpy, electron gain enthalpy and hydration enthalpy, compare the oxidizing power of F_2 and Cl_2. U **[NCERT]**

Ans. F_2 is a stronger agent than Cl_2 because

(i) Bond dissociation enthalpy of fluorine is less than that of chlorine. **1**

(ii) Electron gain enthalpy of fluorine is less than that of chlorine. **1**

(iii) F– has high hydration enthalpy. **1**

Q. 2. Explain why the stability of oxoacids of chlorine increases in the order given below : HClO < $HClO_2$ < $HClO_3$ < $HClO_4$ A&E **[NCERT Exemp. Q. 49, Page 97]**

Ans. Oxygen is more electronegative than chlorine; therefore, dispersal of negative charge present on chlorine increases from ClO to ClO_4 ion because numbers of oxygen atoms are attached to chlorine increases. Therefore, stability of ions will increase in the order given below :

$ClO < ClO_2 < ClO_3 < ClO_5$ **1½**

Thus due to increase in stability of conjugate base, acidic strength of corresponding acid increases in the following order :

$HClO < HClO_2 < HClO_5 < HClO_4$ **1½**

TOPIC-3
Group-18 Elements, Properties and Some Important Compounds

Revision Notes

- **Noble gases :** $_2He$, $_{10}Ne$, $_{18}Ar$, $_{36}Kr$, $_{54}Xe$, $_{86}Ra$.
- Also known as rare gases as they are present in very small amounts in the air. Or as inert gases as they were considered chemically unreactive.
- **Electronic configuration :** ns^2np^6 (except He which has $1s^2$)
- **Physical Properties :**
  (i) Gases
  (ii) Atomic radii increases down the group and highest in their respective periods.
  (iii) Highest ionisation enthalpy in their respective periods. Down the group, it decreases due to increase in atomic size.
  (iv) Large positive values of electron gain enthalpy as noble gases have stable electronic configuration and no tendency to accept electron.
  (v) Low melting points and boiling points due to weak dispersion forces. Down the group they increase because of increase in van der Waals forces.
  (vi) **Liquefaction :** They are difficult to liquify. Down the group, the ease of liquefaction increases.
- In 1962, Bartlett studied the given reaction :

$$O_2 + PtF_6 \rightarrow \underset{\text{Dioxygenyl hexafluoro platinate}}{O_2^+[PtF_6]^-}$$

As ionisation enthalpy of molecular oxygen was almost similar to xenon, below reaction was also found to occur :

$$Xe + PtF_6 \xrightarrow{289\text{ K}} Xe^+[PtF_6]^-$$

- **Preparation of Xenon fluorides :** Xenon forms three binary fluorides, XeF_2, XeF_4 and XeF_6.

$$\underset{\text{(excess)}}{Xe(g)} + F_2(g) \xrightarrow{673\text{ K, 1 bar}} XeF_2(s)$$

$$Xe(g) + 2F_2(g) \xrightarrow{873\text{ K, 7 bar}} XeF_4(s)$$

$$\underset{(1:20\text{ ratio})}{Xe(g) + 3F_2} \xrightarrow{573\text{ K, 60-70 bar}} XeF_6(s)$$

$$XeF_4 + O_2F_2 \xrightarrow{143\,K} XeF_6 + O_2$$

- **Preparation of Xenon trioxide (XeO_3) :**

$$6XeF_4 + 12H_2O \rightarrow 2XeO_3 + 4Xe + 3O_2 + 24HF$$
$$XeF_6 + 3H_2O \rightarrow XeO_3 + 6HF$$

- **Preparation of Xenon oxyfluorides :**

$$XeF_4 + H_2O \rightarrow XeOF_2 + 2HF$$

Xenon
oxydifluoride

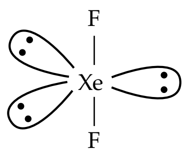
$$XeF_6 + H_2O \xrightarrow[\text{Hydrolysis}]{\text{Partial}} XeOF_4 + 2HF$$

Xenon
oxytetrafluoride

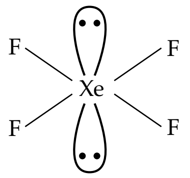
$$XeF_6 + 2H_2O \xrightarrow[\text{Hydrolysis}]{\text{Complete}} XeO_2F_2 + 4HF$$

Xenon
dioxydifluoride

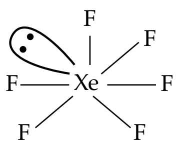
- **Structures of Xenon-fluorine compounds :**



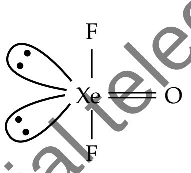
$XeF_2(sp^3d)$
[Linear]



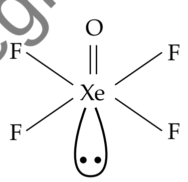
$XeF_4\ (sp^3d^2)$
[Square Planar]



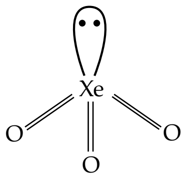
$XeF_6\ (sp^3d^3)$
[Distorted
Octahedral]



$XeOF_2\ (sp^3d)$
[T-Shaped]



$XeOF_4\ (sp^3d^2)$
[Square
Pyramidal]



$XeO_3(sp^3)$
[Trigonal
Pyramidal]

- **Uses :**

Helium	Neon	Argon	Krypton	Xenon
(i) To lift weather balloons and air ships.	For advertising.	To create an inert atmosphere.	For runway and approach lights in airports.	In electric flash bulbs for high speed photography.
(ii) As breathing mixture.	For filling sodium vapour lamps.	In geiger counters.	In high efficiency miner's cap lamps.	In gas filled lamps.
(iii) For inflating the tyres of aeroplanes.	In beacon light.	To date the age of rocks.		

Very Short Answer-Objective Type Questions (1 mark each)

A. Multiple choice Questions:

Q. 1. In the preparation of compounds of Xe, Bartlett had taken $O_2^+PtF_6^-$ as a base compound. This is because

(a) both O_2 and Xe have same size.

(b) both O_2 and Xe have same electron gain enthalpy.

(c) both O_2 and Xe have same ionisation enthalpy.

(d) both Xe and O_2 are gases.

U [NCERT Exemp. Q. 24, Page 94]

Ans. Correct option : (c)

Explanation : Bartlett had taken $O_2^+PtF_6^-$ as a base compound because O_2 and Xe both have almost same ionisation enthalpy. The ionisation enthalpies of noble gases are the highest in their respective periods due to their stable electronic configurations.

Q. 2. Which one of the following does not exist?

(a) $XeOF_4$	**(b) NeF_2**
(c) XeF_2	**(d) XeF_6**

R [NCERT Ex. Q. 7.37, Page 214]

Ans. Correct option : (b)

B. Match the following :

Q. 1. Match the species given in Column I with those mentioned in Column II.

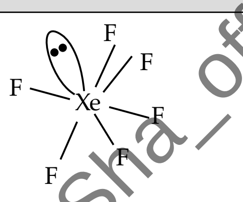
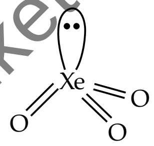
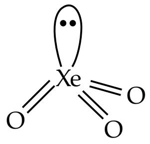
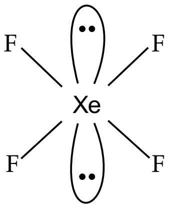
S. No.	Column I	S. No.	Column II
(A)	XeF_6	(1)	sp^3d^3 – distorted octahedral
(B)	XeO_3	(2)	sp^3d^2 – square planar
(C)	$XeOF_4$	(3)	sp^3 – pyramidal
(D)	XeF_4	(4)	sp^3d^2 – square pyramidal

Codes :

(a)	A (1)	B (3)	C (4)	D (2)
(b)	A (1)	B (2)	C (4)	D (3)
(c)	A (4)	B (3)	C (1)	D (2)
(d)	A (4)	B (1)	C (2)	D (3)

[NCERT Exemp. Q. 59, Page 97]

Ans. Correct Code : (a)

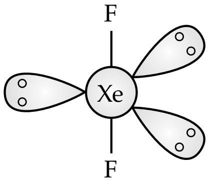
Column I	Column II	Explanation
(A)	(1)	 sp^3d^3 – distorted octahedral
(B)	(3)	 sp^3 – pyramidal
(C)	(4)	 sp^3d^2 – square pyramidal
(D)	(2)	 sp^3d^2 – square planar

C. Answer the following:

Q. 1. Draw the structure of XeF_2 molecule.

R [CBSE Comptt. Delhi/OD 2013]

Ans. XeF_2 :



1

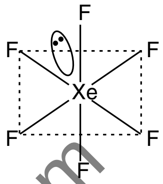
Answering Tip

- Draw the structures showing the lone pairs.

Q. 2. Draw the molecular structure of XeF_6.

R [CBSE Comptt. OD 2013; Delhi 2012]

Ans. XeF_6 :



1

Answering Tip

- Draw the structures showing the lone pairs.

Q. 3. Complete the following chemical equation :

$XeF_4 + SbF_5 \rightarrow$ **A [CBSE Delhi 2012]**

Ans. $XeF_4 + SbF_5 \rightarrow [XeF_3]^+[SbF_6]^-$ 1

Q. 4. Helium is used in diving equipment.

A [CBSE Delhi 2013]

Ans. Helium is used as a diluent for oxygen in modern diving apparatus because of its very low solubility in blood. 1

Q. 5. What inspired N. Bartlett for carrying out reaction between Xe and PtF_6 ?

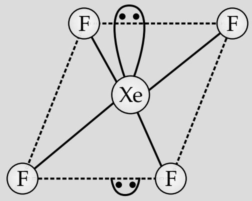
U [CBSE Delhi 2013; DDE]

Ans. First ionisation enthalpy of molecular oxygen was almost similar with that of Xenon. Thus, after preparing red coloured compound $O_2^+[PtF_6]^-$, Bartlett got inspired for carrying out reaction between Xe and PtF_6 and made efforts to prepare $Xe^+[PtF_6]^-$ by mixing Xe and PtF_6. 1

Q. 6. Draw the structures of the following :

XeF_4 **R [CBSE OD Set-2 2016; Delhi 2014]**

Ans.



Square Planar 1

[CBSE Marking Scheme 2017]

Answering Tip

- Draw the structures showing the lone pairs.

Q. 7. XeF_6 undergoes complete hydrolysis?

R [CBSE SQP 2017]

Ans. When XeF_6 undergoes complete hydrolysis, it forms

$XeF_6 + 3H_2O \rightarrow 6HF + XeO_3$ 1

[CBSE Marking Scheme 2017]

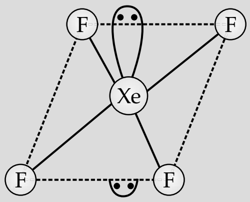
Short Answer Type Questions (2 marks each)

Q. 1. Draw the structures of the following :

(i) XeF_4 (ii) BrF_5

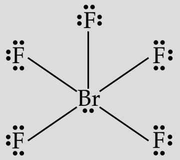
R **[CBSE OD Set-3 2017]**

Ans. (i)



Square Planar

(ii)



Square Pyramidal

1+1

[CBSE Marking Scheme 2017]

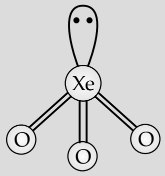
Answering Tip

- Draw the structures showing the lone pairs.

Q. 2. Draw the structures of the following :

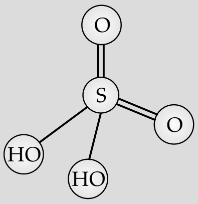
(i) XeO_3 (ii) H_2SO_4 R **[CBSE OD 2014]**

Ans. (i) XeO_3 :



1

(ii) H_2SO_4 :



1

[CBSE Marking Scheme 2014]

AI Q. 3. Write the structures of the following :

(i) BrF_3 (ii) XeF_4 R

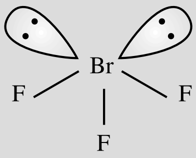
OR

What happens when :

(i) SO_2 gas is passed through an aqueous solution Fe^{3+} salt ?

(ii) XeF_4 reacts with SbF_5 ? R **[CBSE OD 2016]**

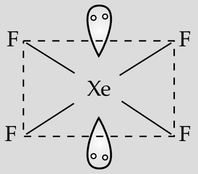
Ans. (i) BrF_3



Trigonal bipyramidal or Bent T-shaped

1

(ii) XeF_4



Square planar

1

Answering Tip

- Draw the structures with lone pair of electrons (if present). Avoid over-writing.

OR

(i) When SO_2 gas is passed through an aqueous solution of Fe^{3+} salt, SO_2 acts as a reducing agent and reduces Fe^{3+} to Fe^{2+}. The brown colour of iron (III) solution turns into green. 1

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

(ii) When XeF_4 reacts with strong Lewis acids like SbF_5 it forms complexes (addition compounds).

$$XeF_4 + SbF_5 \rightarrow [XeF_3]^+[SbF_6]^- \quad 1$$

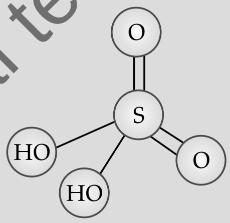
[CBSE Marking Scheme 2016]

Q. 4. Draw the structures of the following :

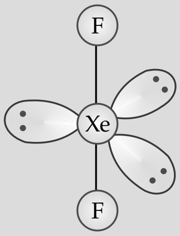
(i) H_2SO_4 (ii) XeF_2 R **[CBSE Delhi 2015]**

Ans.

(i)



(ii)



1 + 1

[CBSE Marking Scheme 2015]

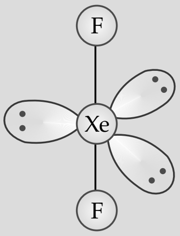
Answering Tip

- Draw the structures with lone pair of electrons (if present). Avoid over-writing.

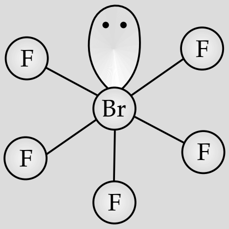
Q. 5. Draw the structures of the following:

(i) XeF_2 (ii) BrF_5 R **[CBSE Comptt. Delhi/OD 2018]**

Ans. (i)



(ii)



1+1

[CBSE Marking Scheme 2018]

Answering Tip

- Draw the structures with lone pair of electrons (if present). Avoid over-writing.

Q. 6. Complete the following equations :

(i) $P_4 + H_2O \rightarrow$

(ii) $XeF_4 + O_2F_2 \rightarrow$ R **[CBSE OD 2014]**

Ans. (i) $P_4 + H_2O \rightarrow$ no reaction or if attempted in any form, award one mark. 1

(ii) $XeF_4 + O_2F_2 \rightarrow XeF_6 + O_2$ 1

[CBSE Marking Scheme 2014]

Q. 7. Complete the following reactions:

(i) $NH_3 + 3Cl_2$ **(excess)** $\rightarrow$

(ii) $XeF_6 + 2H_2O \rightarrow$ R **[CBSE Delhi Set-1 2017]**

Ans. (i) $NH_3 + 3Cl_2 \text{ (excess)} \rightarrow NCl_3 + 3HCl$ **1**

(ii) $XeF_6 + 2H_2O \rightarrow XeO_2F_2$ **1**

[CBSE Marking Scheme 2017]

Commonly Made Error

- Students forget to balance the equation

Q. 8. Complete the following reactions:

(i) $Cl_2 + H_2O \rightarrow$

(ii) $XeF_6 + 3H_2O \rightarrow$ R **[CBSE Delhi Set-2 2017]**

Ans. (i) $Cl_2 + H_2O \rightarrow 2HCl + [O] / HCl + HOCl$ **1**

(ii) $XeF_6 + 3H_2O \rightarrow XeO_3 + 6HF$ **1**

[CBSE Marking Scheme 2017]

Commonly Made Error

- A number of students give unbalanced equations. In some cases, all the products were not mentioned. Some students write wrong products.

Q. 9. Complete the following chemical equation :

(i) $F_2 + 2Cl^- \rightarrow$

(ii) $2XeF_2 + 2H_2O \rightarrow$ R **[CBSE Delhi Set-3 2017]**

Ans. (i) $F_2 + 2Cl^- \rightarrow 2F^- + Cl_2$ **1**

(ii) $2XeF_2 + 2H_2O \rightarrow 2Xe + 4HF + O_2$ **1**

[CBSE Marking Scheme 2017]

Commonly Made Error

- Students don't write the correct products or mention only main product leading to errors in balancing.

Q. 10. Complete the following equations :

(i) C **+ conc.** $H_2SO_4 \rightarrow$

(ii) $XeF_2 + H_2O \rightarrow$ R **[CBSE OD 2014]**

Ans. (i) $C + 2H_2SO_4\text{(conc.)} \rightarrow CO_2 + 2SO_2 + 2H_2O$ **1**

(ii) $2XeF_2 + 2H_2O \rightarrow 2Xe + 4HF + O_2$ **1**

[CBSE Marking Scheme 2014]

Commonly Made Error

- Students mostly write wrong products.

Q. 11. Explain the following giving an appropriate reason in each case :

(i) O_2 **and** F_2 **both stabilize higher oxidation states of metals but** O_2 **exceeds** F_2 **in doing so.**

(ii) Structures of Xenon fluoride cannot be explained by Valence Bond approach.

A&E **[CBSE Delhi 2012]**

Ans. (i) This is due to the ability of oxygen to form multiple bonds with metals. Oxygen has -2 charge for each atom while F_2 bears -1 for each atoms. Thus the force of attraction between the metal atom and O^{2-} ion is greater than the force between same metal atom and F^-. Hence O_2 gets higher oxidation state of metals. **1**

(ii) This is because the energy required for the promotion of electrons in Xenon is very high./ Energy factor does not favour VB approach. **1**

[CBSE Marking Scheme 2012]

Q. 12. (i) Complete the following chemical equations :

(a) $NaOH + Cl_2 \rightarrow$

(hot and conc.)

(b) $XeF_4 + O_2F_2 \rightarrow$ R **[CBSE Delhi 2012]**

Ans. (i) (a) $6NaOH + 3Cl_2 \rightarrow 5NaCl + NaClO_3 + 3H_2O$ **1**

(b) $XeF_4 + O_2F_2 \xrightarrow{143\text{ K}} XeF_6 + O_2.$ **1**

Answering Tip

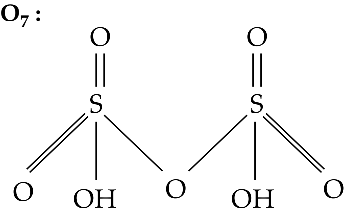
- Balance the chemical equations.

Q. 13. Draw the structures of the following molecules :

(a) $H_2S_2O_7$

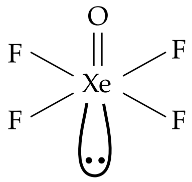
(b) $XeOF_4$ R **[CBSE Delhi 2012]**

Ans. (a) $H_2S_2O_7$ **:**



1

(b) $XeOF_4$ **:**



1

Answering Tip

- Balance the chemical equations. Draw the structures with lone pair of electrons (if present). Avoid over-writing.

AI **Q. 14 Account for the following :**

(i) Acidic character increases from HF to HI.

(ii) There is a large difference between the melting and boiling points of oxygen and sulphur.

A&E **[CBSE Delhi 2015]**

Ans. (a) Acidic character increases from HF to HI due to increase in size as a result attraction force decreases and acidity increase.

$$\xrightarrow[\text{Increasing order of acidity size increase}]{HF < HCl < HBr < HI}$$

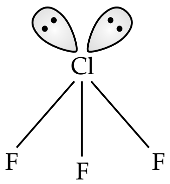
(ii) There is large difference between the melting point and boiling point of oxygen and sulphur due to small size and high electronegativity of oxygen. 2

AI **Q. 15. Draw the structures of the following :**

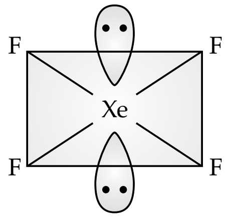
(i) ClF_3

(ii) XeF_4 R **[CBSE Delhi 2015]**

Ans. (i) ClF_3 :



(ii) XeF_4 : **1 + 1**



Answering Tip

- Ensure that the structure is drawn neatly with lone pairs and correct angles.

Q. 16. Account for the following :

(a) Cl_2 acts as a bleaching agent.

(b) Noble gases have very low boiling points. A&E

OR

(a) What happens when F_2 reacts with water ?

(b) Write the formula of a noble gas species which is isostructural with IBr_2.

U **[CBSE Foreign Set-1 2017]**

Ans. (a) Because Cl_2 in presence of moisture liberates nascent oxygen. **1**

(b) Interatomic interactions are weak. **1**

Answering Tip

- While stating the reason, be specific. Avoid unnecessary explanations.

OR

(a) $2F_2 + 2H_2O \rightarrow 4HF + O_2$
HF and O_2 are produced. **1**

(b) XeF_2 **1**

[CBSE Marking Scheme 2017]

Long Answer Type Questions-I (3 marks each)

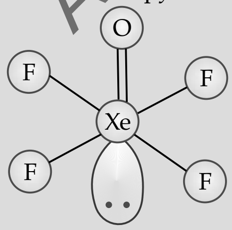
AI **Q. 1. (i) Arrange the hybrids of group 16 in increasing order of their acidic character. Justify your answer.**

(ii) Draw structure of $XeOF_4$.

U + R **[CBSE Comptt. Delhi Set-1, 2, 3 2017]**

Ans. (i) $H_2O < H_2S < H_2Se < H_2Te$, because of decrease in bond dissociation enthalpy. **1+1**

(ii)



1

Square pyramidal

[CBSE Marking Scheme 2017]

Answering Tip

- Draw the structures with lone pair of electrons (if present). Avoid over-writing.

Q. 2. (i) F_2 has lower bond dissociation enthalpy than Cl_2. Why ?

(ii) Which noble gas is used in filling balloons for meteorological observations ?

(ii) Complete the following equation :

$XeF_2 + PF_5 \rightarrow$ A&E **[CBSE Delhi 2015]**

Ans. (i) F_2 has lower bond dissociation energy than Cl_2 because the size of F_2 is much smaller than Cl_2 as a result interelectronic repulsion works and make F_2 weak. **1**

(ii) Helium is used in filling balloons for meteorological observations. **1**

(iii) $XeF_2 + PF_5 \rightarrow [XeF]^+ [PF_6]^-$ **1**

Answering Tip

- While stating the reason, write the cause and the consequence.

Q. 3. (i) Compare the oxidizing action of F_2 and Cl_2 by considering parameters such as bond dissociation enthalpy, electron gain enthalpy and hydration enthalpy.

(ii) Write the conditions to maximize the yield of H_2SO_4 by contact process. U **[CBSE 2015]**

Ans. (i) F_2 is the stronger oxidising agent than chlorine :

(a) Low enthalpy of dissociation of F-F bond.

(b) Less negative electron gain enthalpy of F.

(c) High hydration enthalpy of F^- ion. **1½**

(ii) The main reaction in contact process is

$2SO_2 + O_2 \rightleftharpoons 2SO_3 \uparrow$

This reaction is reversible and conditions to increase the yield of SO_3 are :

(a) High pressure

(b) Low temperature (optimum temperature 720 K) should be maintained and

(c) V_2O_5 as catalyst. 1½

Q. 4. (i) Draw the structure of a noble gas species which is isostructural with BrO_3^-.

(ii) Considering the parameters such as bond dissociation enthalpy, electron gain enthalpy and hydration enthalpy, compare the oxidising power of F_2 and Cl_2.

(iii) Why is $K_{a_2} << K_{a_1}$ for H_2SO_4 in water ?

OR

Explain the following :

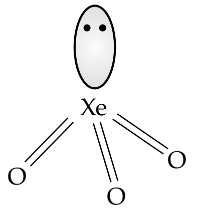
(i) Hydrogen fluoride is a weaker acid than hydrogen chloride in aqueous solution.

(ii) SF_6 is inert towards hydrolysis.

(iii) Out of noble gases only Xenon is known to form established chemical compounds.

A&E **[CBSE SQP 2016]**

Ans. (i) XeO_3 is isostructural with BrO_3^-. (pyramidal structure)



XeO_3

Pyramidal 1

(ii) The bond dissociation enthalpy of F—F bond is lower than that of Cl—Cl bond and hydration enthalpy of F^- ion is much higher than that of Cl^- ion.

These two factors more than compensate the less negative electron gain enthalpy of F_2. Thus, F_2 is a stronger oxidizing agent than Cl_2. 1

(iii) H_2SO_4 ionises in two stages and hence has two dissociation constants. $K_{a_2} << K_{a_1}$.

This is because the negatively charged HSO_4^- ion resonance stabilized which has much less tendency to donate a proton to H_2O as compared to neutral H_2SO_4. 1

OR

(i) Due to stronger H-F bond than HCl bond, HF ionises less readily than HCl in aqueous solution to give H^+ ions. Therefore, HF is a weaker acid than HCl. 1

(ii) In SF_6, S is sterically protected by six F atoms and hence does not allow H_2O molecules to attack the S molecule. Also, F does not have d-orbitals to accept the electrons donated by H_2O molecules. 1

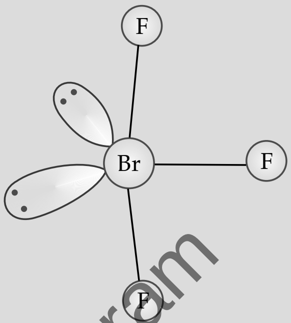
(iii) Except radon which is radioactive, Xenon has least ionisation energy among noble gases and hence it readily forms chemical compounds particularly with O_2 and F_2. 1

Q. 5. (i) Draw the structure of the following

(a) BrF_3 **(b) XeO_3**

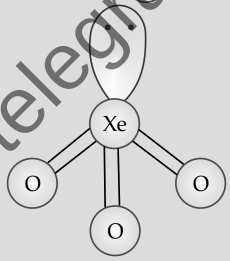
(c) $XeOF_4$ R **[CBSE Delhi Set-1 2015]**

Ans. (a)



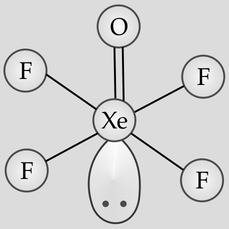
1

(b)



1

(c)



1

[CBSE Marking Scheme 2015]

Q. 6. (i) What happens when :

(a) chlorine gas reacts with cold and dilute solution of NaOH ?

(b) XeF_2 undergoes hydrolysis ?

(ii) Assign suitable reasons for the following :

(a) Out of noble gases only Xenon is known to form established chemical compounds.

U + A & E **[CBSE Comptt. Delhi/OD 2018]**

Ans. (i) (a) $2NaOH + Cl_2 \rightarrow NaCl + NaOCl + H_2O$ **1**

(b) $2XeF_2(s) + 2H_2O(l) \rightarrow 2Xe(g) + 4HF(aq) + O_2(g)$ **1**

(ii) Xe has least ionization energy among the noble gases and hence it forms chemical compounds particularly with O_2 and F_2. **1**

[CBSE Marking Scheme 2018]

Long Answer Type Questions-II

(5 marks each)

Q. 1. (i) Complete the following chemical reaction equations :

(a) $P_4 + SO_2Cl_2 \rightarrow$

(b) $XeF_6 + H_2O \rightarrow$

(ii) Predict the shape and the asked angle (90° or more or less) in each of the following cases :

(a) SO_3^{2-} and the angle O—S—O

(b) ClF_3 and the angle F—Cl—F

(c) XeF_2 and the angle F—Xe—F

A **[CBSE Delhi 2012]**

Ans. (i) (a) $P_4 + 10SO_2Cl_2 \rightarrow 4PCl_5 + 10SO_2$. 1

(b) $XeF_6 + H_2O \rightarrow XeOF_4 + 2HF$

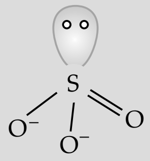
OR

$XeF_6 + 2H_2O \rightarrow XeO_2F_2 + 4HF$

OR

$XeF_6 + 3H_2O \rightarrow XeO_3 + 6HF$ 1

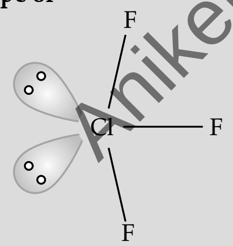
(ii) (a) Pyramidal or



½

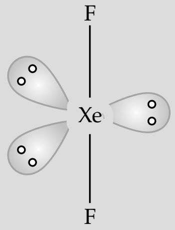
The angle O—S—O more than 90°. ½

(b) Bent T-shape or



The angle F—Cl—F is lesser than 90°. 1

(c) Linear shape or



The angle F—Xe—F is greater than 90°. 1

[CBSE Marking Scheme 2012]

Answering Tip

- Balance the chemical equations. Draw the structures with lone pair of electrons (if present). Avoid over-writing.

Q. 2. (i) Write balanced equations for the following reactions :

(a) Chlorine reacts with dry slaked lime.

(b) Carbon reacts with concentrated H_2SO_4.

(ii) Describe the contact process for the manufacture of sulphuric acid with special reference to the reaction conditions, catalysts used and the yield in the process. R + U **[CBSE Comptt. Delhi 2015]**

Ans. (i) (a) $2Ca(OH)_2 + 2Cl_2 \rightarrow Ca(OCl)_2 + CaCl_2 + 2H_2O$ 1

(b) $C + 2H_2SO_4(conc.) \rightarrow CO_2 + 2SO_2 + 2H_2O$ 1

(ii) It is manufactured by Contact Process which involves following steps :

(a) burning of sulphur or sulphide ores in air to generate SO_2.

(b) conversion of SO_2 to SO_3 by the reaction with oxygen in the presence of a catalyst (V_2O_5).

(c) absorption of SO_3 in H_2SO_4 to give Oleum ($H_2S_2O_7$). The oleum obtained is diluted to give sulphuric acid. 1

$2SO_2(g) + O_2(g) \xrightarrow{V_2O_5} 2SO_3(g)$ 1

Reaction condition – pressure of 2 bar and temperature of 720 K.

Catalyst used is V_2O_5.

Yield – 96 – 98% pure. 1

[CBSE Marking Scheme 2015]

Q. 3. (i) Account for the following:

(a) Reducing character decreases from SO_2 to TeO_2.

(b) $HClO_3$ is a stronger acid than HClO.

(c) Xenon forms compounds with fluorine and oxygen only.

(ii) Complete the following equations:

(a) $4NaCl + MnO_2 + 4H_2SO_4 \rightarrow$

(b) $6XeF_4 + 12H_2O \rightarrow$

A & E + R **[CBSE Comptt. OD Set-1, 2, 3 2017]**

Ans. (i) (a) Stability of higher oxidation state decreases down the group from S to Te/Stability of lower oxidation state increases down the group from S to Te. 1

(b) ClO_3 is more stable than ClO^-/ClO_3^- is a weak conjugate base than ClO^-/Due to higher oxidation state of chlorine in $HClO_3$ 1

(c) Fluorine and oxygen are most electronegative and very reactive. 1

(ii)

(a) $4NaCl + MnO_2 + 4H_2SO_4 \rightarrow MnCl_2 + 4NaHSO_4 + 2H_2O + Cl_2$ 1

(b) $6XeF_4 + 12H_2O \rightarrow 4Xe + 2XeO_3 + 24HF + 3O_2$ **1**

[CBSE Marking Scheme 2017]

Answering Tip

- **(ii)** Given balanced chemical reactions. Write all the products formed.

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