(Chapter 7)(The p – Block Elements)

XII

Intext Questions

Question 7.1:

Why are pentahalides more covalent than trihalides?

Answer

In pentahalides, the oxidation state is +5 and in trihalides, the oxidation state is +3. Since the metal ion with a high charge has more polarizing power, pentahalides are more covalent than trihalides.

Question 7.2:

Why is BiH_3 the strongest reducing agent amongst all the hydrides of Group 15 elements?

Answer

As we move down a group, the atomic size increases and the stability of the hydrides of group 15 elements decreases. Since the stability of hydrides decreases on moving from NH_3 to BiH_3, the reducing character of the hydrides increases on moving from NH_3 to BiH_3.

Question 7.3:

Why is N_2 less reactive at room temperature?

Answer

The two N atoms in N_2 are bonded to each other by very strong triple covalent bonds. The bond dissociation energy of this bond is very high. As a result, N_2 is less reactive at room temperature.

Question 7.4:

Mention the conditions required to maximise the yield of ammonia.

Answer

Ammonia is prepared using the Haber's process. The yield of ammonia can be maximized under the following conditions: **(i)** High pressure (~ 200 atm)

(ii) A temperature of ~700 K

(iii) Use of a catalyst such as iron oxide mixed with small amounts of K_2O and Al_2O_3

Question 7.5:

How does ammonia react with a solution of Cu^{2+}? Answer

NH_3 acts as a Lewis base. It donates its electron pair and forms a linkage with metal ion.

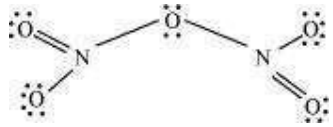
$$Cu^{2+}_{(aq)} + 4\,NH_{3(aq)} \leftrightarrow \left[Cu(NH_3)_4\right]^{2+}_{(aq)}$$

Blue Deep blue

Question 7.6:

What is the covalence of nitrogen in N_2O_5?

Answer



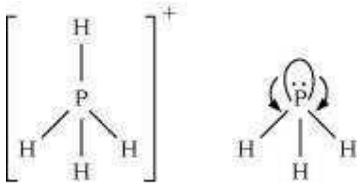
From the structure of N_2O_5, it is evident that the covalence of nitrogen is 4.

Question 7.7:

Bond angle in PH_4^+ is higher than that in PH_3. Why?

Answer

In PH_3, P is sp^3 hybridized. Three orbitals are involved in bonding with three hydrogen atoms and the fourth one contains a lone pair. As lone pair-bond pair repulsion is stronger than bond pair-bond pair repulsion, the tetrahedral shape associated with sp^3 bonding is changed to pyramidal. PH_3 combines with a proton to form PH_4^+ in which the lone pair is absent. Due to the absence of lone pair in PH_4^+, there is no lone pair-bond pair repulsion. Hence, the bond angle in PH_4^+ is higher than the bond angle in PH_3.



PH_4^+ PH_3

Question 7.8:

What happens when white phosphorus is heated with concentrated NaOH solution in an inert atmosphere of CO_2?

Answer

White phosphorous dissolves in boiling NaOH solution (in a CO_2 atmosphere) to give phosphine, PH_3.

$$P_4 + 3NaOH + 3H_2O \longrightarrow \underset{\text{Phosphine}}{PH_3} + \underset{\text{Sodium hypophosphite}}{3NaH_2PO_2}$$

Question 7.9:

What happens when PCl_5 is heated?

Answer

All the bonds that are present in PCl_5 are not similar. It has three equatorial and two axial bonds. The equatorial bonds are stronger than the axial ones. Therefore, when PCl_5 is heated strongly, it decomposes to form PCl_3.

$$PCl_5 \xrightarrow{\text{heat}} PCl_3 + Cl_2$$

Question 7.10:

Write a balanced equation for the hydrolytic reaction of PCl_5 in heavy water. Answer

$$PCl_5 + D_2O \longrightarrow POCl_3 + 2DCl_2$$

$$POCl_3 + 3D_2O \longrightarrow D_3PO_4 + 3DCl$$

Therefore, the net reaction can be written as

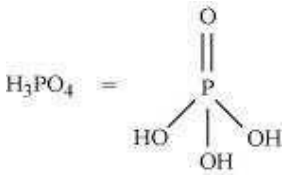
$$PCl_5 + 4D_2O \longrightarrow D_3PO_4 + 5DCl$$

Question 7.11:

What is the basicity of H_3PO_4?

Answer

H_3PO_4



Since there are three OH groups present in H_3PO_4, its basicity is three i.e., it is a tribasic acid.

Question 7.12:

What happens when H_3PO_3 is heated?

Answer

H_3PO_3, on heating, undergoes disproportionation reaction to form PH_3 and H_3PO_4. The oxidation numbers of P in H_3PO_3, PH_3, and H_3PO_4 are +3, −3, and +5 respectively. As the oxidation number of the same element is decreasing and increasing during a particular reaction, the reaction is a disproportionation reaction.

$$\underset{\text{Orthophosphorous acid}}{\underset{(+3)}{4H_3PO_3}} \xrightarrow{\Delta} \underset{\text{Orthophosphoric acid}}{\underset{(+5)}{3H_3PO_4}} + \underset{\text{Phosphine}}{\underset{(-3)}{PH_3}}$$

Question 7.13:

List the important sources of sulphur.

Answer

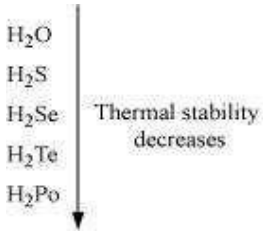
Sulphur mainly exists in combined form in the earth's crust primarily as sulphates [gypsum ($CaSO_4.2H_2O$), Epsom salt ($MgSO_4.7H_2O$), baryte ($BaSO_4$)] and sulphides [(galena (PbS), zinc blends (ZnS), copper pyrites ($CuFeS_2$)].

Question 7.14:

Write the order of thermal stability of the hydrides of Group 16 elements.

Answer

The thermal stability of hydrides decreases on moving down the group. This is due to a decrease in the bond dissociation enthalpy (H−E) of hydrides on moving down the group. Therefore,



Question 7.15:

Why is H_2O a liquid and H_2S a gas?

Answer

H_2O has oxygen as the central atom. Oxygen has smaller size and higher electronegativity as compared to sulphur. Therefore, there is extensive hydrogen bonding in H_2O, which is absent in H_2S. Molecules of H_2S are held together only by weak van der Waal's forces of attraction.

Hence, H_2O exists as a liquid while H_2S as a solid.

Question 7.16:

Which of the following does not react with oxygen directly?

Zn, Ti, Pt, Fe

Answer

Pt is a noble metal and does not react very easily. All other elements, Zn, Ti, Fe, are quite reactive. Hence, oxygen does not react with platinum (Pt) directly.

Question 7.17:

Complete the following reactions:

(i) $C_2H_4 + O_2 \rightarrow$

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

Answer

$$\underset{\text{Ethene}}{C_2H_4} + \underset{\text{Oxygen}}{3O_2} \longrightarrow \underset{\text{Carbon dioxide}}{2CO_2} + \underset{\text{Water}}{2H_2O}$$

$$\underset{\text{Aluminium}}{4Al} + \underset{\text{Oxygen}}{3O_2} \longrightarrow \underset{\text{Alumina}}{2Al_2O_3}$$

(i)

(ii)

Question 7.18:

Why does O_3 act as a powerful oxidising agent?

Answer

Ozone is not a very stable compound under normal conditions and decomposes readily on heating to give a molecule of oxygen and nascent oxygen. Nascent oxygen, being a free radical, is very reactive.

$$\underset{\text{Ozone}}{O_3} \xrightarrow{\Delta} \underset{\text{Oxygen}}{O_2} + \underset{\text{Nascent oxygen}}{[O]}$$

Therefore, ozone acts as a powerful oxidising agent.

Question 7.19:

How is O_3 estimated quantitatively?

Answer

Quantitatively, ozone can be estimated with the help of potassium iodide. When ozone is made to react with potassium iodide solution buffered with a borate buffer (pH 9.2), iodine is liberated. This liberated iodine can be titrated against a standard solution of sodium thiosulphate using starch as an indicator. The reactions involved in the process are given below.

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

Iodide Ozone Iodine

$$I_2 + 2\,Na_2S_2O_3 \longrightarrow Na_2S_4O_6 + 2\,NaI$$

Sodium thiosulphate Sodium tetrathionate

Question 7.20:

What happens when sulphur dioxide is passed through an aqueous solution of Fe(III) salt?

Answer

SO_2 acts as a reducing agent when passed through an aqueous solution containing Fe(III) salt. It reduces Fe(III) to Fe(II) i.e., ferric ions to ferrous ions.

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

Question 7.21:

Comment on the nature of two S−O bonds formed in SO_2 molecule. Are the two S−O bonds in this molecule equal?

Answer

The electronic configuration of S is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$.

During the formation of SO_2, one electron from 3*p* orbital goes to the 3*d* orbital and S undergoes sp^2 hybridization. Two of these orbitals form sigma bonds with two oxygen atoms and the third contains a lone pair. *p*-orbital and *d*-orbital contain an unpaired electron each. One of these electrons forms *p*π- *p*π bond with one oxygen atom and the other forms *p*π- *d*π bond with the other molecule. This is the reason SO_2 has a bent structure. Also, it is a resonance hybrid of structures **I** and **II**.

Both S−O bonds are equal in length (143 pm) and have a multiple bond character.

Question 7.22:

How is the presence of SO_2 detected?

Answer

SO_2 is a colourless and pungent smelling gas.

It can be detected with the help of potassium permanganate solution. When SO_2 is passed through an acidified potassium permanganate solution, it decolonizes the solution as it reduces MnO_4^- ions to Mn^{2+} ions.

$$5SO_2 + 2MnO_4^- + 2H_2O \longrightarrow 5SO_4^{2-} + 4H^+ + 2Mn^{2+}$$

Question 7.23:

Mention three areas in which H_2SO_4 plays an important role.

Answer

Sulphuric acid is an important industrial chemical and is used for a lot of purposes. Some important uses of sulphuric acid are given below.

(i) It is used in fertilizer industry. It is used to make various fertilizers such as ammonium sulphate and calcium super phosphate.

(ii) It is used in the manufacture of pigments, paints, and detergents.

(iii) It is used in the manufacture of storage batteries.

Question 7.24:

Write the conditions to maximize the yield of H_2SO_4 by Contact process.

Answer

Manufacture of sulphuric acid by Contact process involves three steps.

1. Burning of ores to form SO_2

2. Conversion of SO_2 to SO_3 by the reaction of the former with O_2

(V_2O_5 is used in this process as a catalyst.)

3. Absorption of SO_3 in H_2SO_4 to give oleum ($H_2S_2O_7$)

The key step in this process is the second step. In this step, two moles of gaseous reactants combine to give one mole of gaseous product. Also, this reaction is exothermic. Thus, in accordance with Le Chatelier's principle, to obtain the maximum amount of SO_3 gas, temperature should be low and pressure should be high.

Question 7.25:

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

Answer

$$H_2SO_{4(aq)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + HSO^-_{4(aq)}; \quad K_{a_1} > 10$$

$$HSO^-_{4(aq)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + SO^-_{4(aq)}; \quad K_{a_2} = 1.2 \times 10^{-2}$$

It can be noticed that $K_{a_1} >> K_{a_2}$

This is because a neutral H_2SO_4 has a much higher tendency to lose a proton than the negatively charged HSO_4^-. Thus, the former is a much stronger acid than the latter.

Question 7.26:

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

Answer

Fluorine is a much stronger oxidizing agent than chlorine. The oxidizing power depends on three factors.

1. Bond dissociation energy

2. Electron gain enthalpy

3. Hydration enthalpy

The electron gain enthalpy of chlorine is more negative than that of fluorine. However, the bond dissociation energy of fluorine is much lesser than that of chlorine. Also, because of its small size, the hydration energy of fluorine is much higher than that of chlorine. Therefore, the latter two factors more than compensate for the less negative electron gain enthalpy of fluorine. Thus, fluorine is a much stronger oxidizing agent than chlorine.

Question 7.27:

Give two examples to show the anomalous behaviour of fluorine.

Answer

Anomalous behaviour of fluorine

(i) It forms only one oxoacid as compared to other halogens that form a number of oxoacids.

(ii) Ionisation enthalpy, electronegativity, and electrode potential of fluorine are much higher than expected.

Question 7.28:

Sea is the greatest source of some halogens. Comment.

Answer

Sea water contains chlorides, bromides, and iodides of Na, K, Mg, and Ca. However, it primarily contains NaCl. The deposits of dried up sea beds contain sodium chloride and carnallite, $KCl.MgCl_2.6H_2O$. Marine life also contains iodine in their systems. For example, sea weeds contain upto 0.5% iodine as sodium iodide. Thus, sea is the greatest source of halogens.

Question 7.29:

Give the reason for bleaching action of Cl_2.

Answer

When chlorine reacts with water, it produces nascent oxygen. This nascent oxygen then combines with the coloured substances present in the organic matter to oxide them into colourless substances.

$$Cl_2 + H_2O \longrightarrow 2HCl + [O]$$

Coloured substances + [O] → Oxidized colourless substance

Question 7.30:

Name two poisonous gases which can be prepared from chlorine gas.

Answer

Two poisonous gases that can be prepared from chlorine gas are

(i) Phosgene ($COCl_2$)

(ii) Mustard gas ($ClCH_2CH_2SCH_2CH_2Cl$)

Question 7.31:

Why is ICl more reactive than I_2?

Answer

ICl is more reactive than I_2 because I−Cl bond in ICl is weaker than I−I bond in I_2.

Question 7.32:

Why is helium used in diving apparatus?

Answer

Air contains a large amount of nitrogen and the solubility of gases in liquids increases with increase in pressure. When sea divers dive deep into the sea, large amount of nitrogen dissolves in their blood. When they come back to the surface, solubility of nitrogen decreases and it separates from the blood and forms small air bubbles. This leads to a dangerous medical condition called bends. Therefore, air in oxygen cylinders used for diving is diluted with helium gas. This is done as He is sparingly less soluble in blood.

Question 7.33:

Balance the following equation: $XeF_6 + H_2O \rightarrow XeO_2F_2 + HF$

Answer

Balanced equation

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

Question 7.34:

Why has it been difficult to study the chemistry of radon?

Answer

It is difficult to study the chemistry of radon because it is a radioactive substance having a half-life of only 3.82 days. Also, compounds of radon such as RnF_2 have not been isolated. They have only been identified.