Chapter 7

The p-Block Elements

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1 Marks Questions

1. Write the elements of group 15?

Ans. The elements of group 15 are Nitrogen (N), Phosphorous (P) , Arsenic (As) , Antimony (Sb) and Bismuth (Bi).

2. Write chemical name & formulae of

a) Chile saltpetre

b) Indian saltpetre

Ans. (a) Chile saltpetre – Sodium nitrate – $NaNO_3$

(b) Indian saltpetre – Potasium nitrate – KNO_3

3. What is special about the valence configuration of Group 15?

Ans. The valence configuration of 15 group is ns^2np^3 the s-orbital is completely filled and p-orbital is half filled . This half filled orbital gives extra stability to elements of this group.

4. The atomic radii increases considerably from N to P but very little increase is observed from As to Bi. why?

Ans. There is a considerable increase in size from N to P as expected but due to the presence of completely filled d- orbitals which have very poor shielding effects, the increases in size is very little from As to Bi.

5. Give reason for the following- the first ionization enthalpy of 15^{th} group elements is higher than 16^{th} group elements ?

Ans. Due to extra stability of half filled configuration, the first Ionisation enthalpy of 15 group elements is higher than 16^{th}

6. How does metallic character vary down the 15 group & why?

group configuration ns^2np^3

Ans. The metallic character increases down the group due to decrease in ionization enthalpy and increase in size of atom.

7. What are the common oxidation states of this group?

Ans. The common oxidation states of the group are -3, +3 & +5.

8. What is the maximum covalence shown by N?

Ans. Nitrogen shows a maximum covalence of +4 because only four orbitals, one S and three P- orbitals are available for bonding in Nitrogen.

9. Bi (v) is a stronger oxidizing agent than Bi(III). Why?

Ans. Bi is more stable in +3 oxidation state in comparison to +5 due to inert pair effect therefore Bi (v) has a strong tendency to act as oxidizing agent.

10. Give an example showing disproportionation of oxidation state of nitrogen?

Ans. $\underset{+3}{3HNO_2} \rightarrow \underset{+5}{HNO_3} + H_2O + \underset{+2}{2NO}$

Here Nitrogen is getting oxidized to a higher oxidation state as well as reduced to a lower oxidation state.

11. Complete and balance -

(i) $(NH_4)_2SO_4 + 2NaOH \rightarrow$

(ii) $2FeCl_3(aq) + 3NH_4OH(aq) \rightarrow$

(iii) $AgCl(s) + 2NH_3(aq) \rightarrow$

(iv) $NaNO_3 + H_2SO_4 \rightarrow$

(v) $3NO_2(g) + H_2O(l) \rightarrow$

(vi) $Cu + 4HNO_3(conc) \rightarrow$

(vii) $4Zn + 10HNO_3(dil) \rightarrow$

(viii) $\left[Fe(H_2O)_6\right]_2 + \ + NO \rightarrow$

(ix) $I_2 + 10HNO_3 \rightarrow$

(x) $S_8 + 48HNO_3(conc) \rightarrow$

Ans. (i) $(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + 2H_2O + Na_2SO_4$

(ii) $2FeCl_3(aq) + 3NH_4OH(aq) \rightarrow Fe_2O_3.xH_2O_{(s)} + 3NH_4Cl(aq)$

(iii) $AgCl(s) + 2NH_3(aq) \rightarrow \left[Ag(NH_3)_2\right]Cl\ (aq)$

(iv) $NaNO_3 + H_2SO_4 \rightarrow NaHSO_4 + HNO_3$

(v) $3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$

(vi) $Cu + 4HNO_3(conc) \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$

(vii) $4Zn + 10HNO_3(dil) \rightarrow 4Zn(NO_3)_2 + 5H_2O + N_2O$

(viii) $\left[Fe(H_2O)_6\right]^{2+} + NO \rightarrow \left[Fe\ (H_2O)_5(NO)\right]^{2+} + H_2O$

(ix) $I_2 + 10HNO_3 \rightarrow 2HIO_3 + 10NO_2 + 4H_2O$

(x) $S_8 + 48HNO_3(conc) \rightarrow 8H_2SO_4 + 48NO_2 + 16H_2O$

12. What are the optimum conditions for maximum yield of ammonia?

Ans. The optimum conditions for the production of ammonia are – 200×10^5 Pa or 200 atm pressure, 700K temperature , and presence of catalyst such as iron oxide with K_2O and Al_2O_3 as promoters.

13. Ammonia is a Lewis base. Why?

Ans. Due to the presence of lone pairs on nitrogen atom of ammonia, it can donate electron pair and acts as a lewis base.

14. Ammonia has higher boiling and melting points than expected. Why?

Ans. In solid and liquid states, ammonia molecules are associated by intermolecular hydrogen bonding. There fore ammonia has higher boiling and melting points.

15. Give reasons-

a) Halogens have smallest atomic radii in their periods

b) The negative electron gain enthalpy of fluorine is less than that of chlorine.

c) All halogens are coloured.

d) The only possible oxidation state of fluorine -1.

e) Fluorine forms only one oxoacid.

f) The stability of hydrides follows the order HF>HCl>HBr>HI.

Ans. (a) Due to maximum effective nuclear charge, halogens have smallest atomic radii.

(b) Due to small size of fluorine atom, there are strong inter electronic repulsions in the small 2p orbital of fluorine and thus incoming electron does not experience much attraction and fluorine has less negative electron gain enthalpy than that of chlorine.

(c) Halogens absorb radiation in visible region which results in oxidation of electrons to higher energy level by absorbing different quanta of radiation, they show different colours.

(d) Since fluorine is most electronegative element and is short of only one electron for completing octet, it shows the only oxidation state of -1.

(e) Due to small size and high electro-negativity, Fluorine forms only one hypohalous acid.

(f) As the size of element increases down the group, the bond dissociation enthalpy for HX bond decreases making the bond weaker and weaker therefore the order of thermal stability is HI < HBr < HCl < HF.

16. Complete and balance-

(i) $2F_2(g)+2H_2O\ (l)\rightarrow$

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

(iii) $4HCl\ +\ O_2\xrightarrow{CuCl_2}$

(iv) $C_{10}H_{16} + 8Cl_2 \rightarrow$

(v) $6NaOH + 3Cl_2 \rightarrow$

Ans. (i) $2F_2(g) + 2H_2O(l) \rightarrow 4H^+(aq) + 4F^- + O_2(g)$

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

(iii) $4HCl + O_2 \xrightarrow{CuCl_2} 2Cl_2 + 2H_2O$

(iv) $C_{10}H_{16} + 8Cl_2 \rightarrow 16HCl + 10C$

(v) $6NaOH + 3Cl_2 \rightarrow 5NaCl + NaClO_3 + 3H_2O$

17. Chlorine water on standing loses its yellow colour. Why?

Ans. On standing chlorine water forms HCl and Hypochlorous acid (HOCl) due to which it loses its colour. $Cl_2 + H_2O \rightarrow HCl + HOCl$

18. Explain the bleaching action of chlorine?

Ans. The bleaching action of chlorine is due to its tendency to give nascent oxygen so that the substance gets oxidized. $Cl_2 + H_2O\ 2HCl + [O]$

Coloured substances + [O] $\rightarrow$ colourless substance.

19. Write two uses of chlorine?

Ans. Chlorine is used for

a) Bleaching wood pulp, cotton and textiles

b) Manufacturing dyes, drugs, refrigerants etc.

c) Sterilizing drinking water.

20. Give reasons for the following?

(a) Nitrogen does not show catenation.

(b) PCl_5 **exists but** NCl_5 **does not.**

(c) The stability of Hydrides follows the order-

$$NH_3 > PH_3 > Ar_3H_3 > SbH_3$$

(d) PH_3 **is a weaker base than** NH_3**.**

(e) Molecular nitrogen is chemically inert.

Ans. (a) Nitrogen being small in size has high electron density. Due to strong inter electronic repulsions, N-N single bond is weak & nitrogen does not undergo catenation.

(b) Due to absence of d-orbitals, nitrogen cannot expand its oxidation state to +5 and NCl_5 does not exist whereas in P due to presence of empty 3d orbital +5 oxidation state is attained.

(c) As we move down the group 15, atomic radii increases making the bond of element with Hydrogen weaker this decreases the stability of hydrides of heavier elements. Therefore the order of stability is.

$$NH_3 > PH_3 > AsH_3 > SbH_3$$

(d) As Phosphorous atom is larger than N- atom, the lone pair of electrons is distributed over a large surface area of P-atom than N-atom. Therefore the tendency of P to donate the lone pair of electrons is less.

(e) Molecular nitrogen (N_2) is inert because N≡ N bond energy is very high due to small size of N- atom and presence of multiple bond.

21. Complete and balance-

(a) $NH_4Cl(aq) + NaNO_2(aq) \rightarrow$

(b) $Ba(N_3)_2 \rightarrow$

(c) $3Mg + N_2 \rightarrow$

(d) $N_2 + O_2 \xrightarrow{Heat}$

(e) $2NaN_3 \rightarrow$

Ans. a. $NH_4Cl(aq) + NaNO_2(aq) \rightarrow N_2(g) + 2H_2O(\ell) + NaCl(aq)$

b. $Ba(N_3)_2 \rightarrow Ba + 3N_2$

c. $3Mg + N_2 \xrightarrow{heat} Mg_3N_2$

d. $N_2 + O_2 \xrightarrow{Heat} 2NO(g)$

e. $2NaN_3 \rightarrow 2Na + 3N_2$

22. What are the two isotopes of nitrogen? Write two uses of dinitrogen.

Ans. The two isotopes of nitrogen are ^{14}N and ^{15}N.

23. Write the characteristics of pure Ozone?

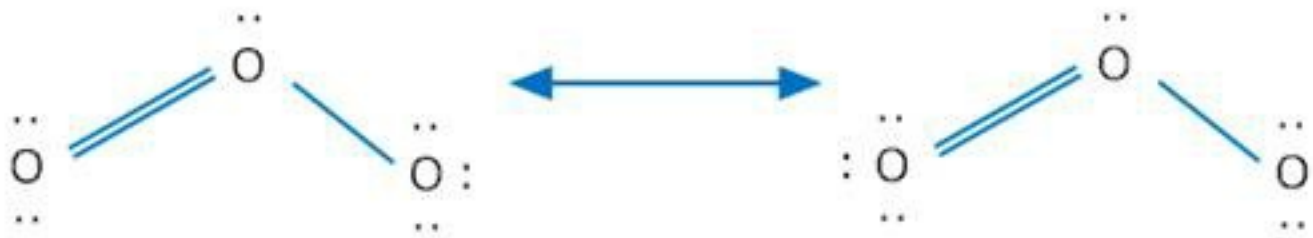
Ans. Pure ozone is pale blue gas, dark blue liquid and violet black solid.

24. At what concentration ozone is harmful?

Ans. If the concentration of ozone increases above 100 ppm, breathing becomes uncomfortable resulting in headache and nausea and it becomes harmful.

25. Draw the resonating structures of ozone?

Ans.



26. Explain the oxidizing action of ozone?

Ans. Ozone has a very strong tendency to liberate nascent oxygen according to the equation:- $O_3 \rightarrow O_2 + O$

Therefore it acts as a strong oxidizing agent.

27. How is ozone estimated quantitatively?

Ans. When ozone reacts with an excess of potassium iodide solution buffered with a borate buffer ($_{p}H = 9.2$) iodine is liberated. This iodine can be titrated against a standard solution of sodium thiosulphate to estimate the amount of ozone.

$$2I^{-}(aq) + H_2O + O_3 \rightarrow 2OH^{-}(aq) + I_2(s) + O_2(g)$$

28. Complete and balance:-

(i) $PbS\ (s)\ +\ 4O_3(g) \rightarrow$

(ii) $NO(g)\ +\ O_3(g) \rightarrow$

(iii) $4FeS_2(s)\ +\ 11O_2(g) \rightarrow$

(iv) $2NaOH\ +\ SO_2 \rightarrow$

(v) $2Fe^{3+} + SO_2 + 2H_2O \rightarrow$

(vi) $Cu\ +\ 2H_2SO_4(conc) \rightarrow$

Ans. (i) $PbS\ (s)\ +\ 4O_3(g) \rightarrow PbSO_4(s)\ +\ 4O_2(g)$

(ii) $NO(g)\ +\ O_3(g) \rightarrow NO_2(g)\ +\ O_2(g)$

(iii) $4FeS_2(s) + 11O_2(g) \rightarrow 2Fe_2O_3(s) + 8SO_2(g)$

(iv) $2NaOH\ +\ SO_2 \rightarrow Na_2SO_3 + H_2O$

(v) $2Fe^{3+} + SO_2 + 2H_2 \rightarrow O2Fe^{2+} + SO_4^{2-} + 4H^{+}$

(vi) $Cu + 2H_2SO_4(conc) \rightarrow CuSO_4 + SO_2 + 2H_2O.$

29. Give a test to detect the presence of SO_2 gas?

Ans. When SO_2 (g) is passed through a violet coloured acidified potassium permanganate solution, it gets decolourised.

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

30. Which aerosols and oxides deplete ozone layer

Ans. Freon used in aerosol sprays deplete the ozone layer. Nitrogen oxides emitted from the exhaust systems of supersonic jet aeroplanes deplete the ozone layer.

31. Write the members of 16 Group.

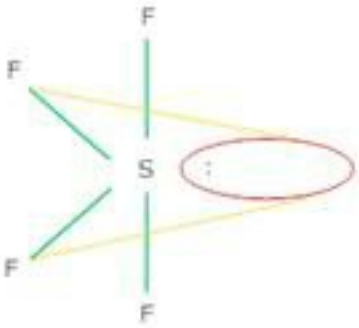
Ans. The elements of group 16 are: Oxygen(O), Sulphur (S), Selenium (Se), Tellurium (Te) and Polonium (Po)

32. Give the general electronic configuration of 16 Group.

Ans. The general electronic configuration of 16 group is ns^2np^4.

33. Discuss the geometry of SF_4.

Ans. In SF_4 the hybridisation of sulphur is sp^3d. The structure is trigonal bi-pyramidal in which one of the equatorial positions is occupied by a one pair of electrons. The geometry is called see-saw geometry.



34. Complete and balance-

(a) $2Ag_2O(s) \rightarrow$

(b) $2H_2O_2(aq) \rightarrow$

(c) $2Zns + 3O_2 \rightarrow$

(d) $4HCl + O_2 \xrightarrow{CuCl_2}$

(e) $Al_2O_3(s) + 6HCl(aq) + 9H_2O(l) \rightarrow$

(f) $Al_2O_3(s) + 6NaOH(aq) + 3H_2O(l) \rightarrow$

Ans. (a) $2Ag_2O(s) \rightarrow 4Ag(s) + O_2(g)$

(b) $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

(c) $2Zns + 3O_2 \rightarrow 2ZnO + 2SO_2$

(d) $4HCl + O_2 \xrightarrow{CuCl_2} 2Cl_2 + 2H_2O$

(e) $Al_2O_3(s) + 6HCl(aq) + 9H_2O(l) \rightarrow 2[Al(H_2O)_6]^{3+}(aq) + 6Cl^-$

(f) $Al_2O_3(s) + 6NaOH(aq) + 3H_2O(l) \rightarrow 2Na_3[Al(OH)_6](aq)$

35. Enlist some uses of dioxygen.

Ans. Oxygen is used-

(a) In oxyacetylene welding.

(b) In manufacture of steel.

(c) In hospitals and mountaineering as oxygen cylinders.

36. Write different isotopes of oxygen.

Ans. The isotopes of oxygen are ^{16}O, ^{17}O, ^{18}O .

37. Which of the following does not react with oxygen directly? Zn, Ti, Pt, Fe

Ans. 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.

38. Why is ICl more reactive than I_2?

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

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

Ans. Balanced equation: $XeF_6 + H_2O \rightarrow XeO_2F_2 + 4HF$

40. How is ammonia manufactured industrially?

Ans. Ammonia is prepared on a large-scale by the Haber's process.

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$

41. Why does $R_3P=O$ exist but $R_3N=O$ does not (R = alkyl group)?

Ans. N(unlike P) lacks the *d*-orbital. This restricts nitrogen to expand its coordination number beyond four. Hence, $R_3N=O$ does not exist.

42. Explain why fluorine forms only one oxoacid, HOF.

Ans. Fluorine forms only one oxoacid i.e., HOF because of its high electronegativity and small size.

43. Which one of the following does not exist?

(i) $XeOF_4$ **(ii)** NeF_2

(iii) XeF_2 **(iv)** XeF_6

Ans. NeF_2 does not exist.

2 Marks Questions

1. Complete and Balance-

a) $P_4 + 8SOCl_2 \rightarrow$

b) $3CH_3COOH + PCl_3 \rightarrow$

c) $P_4 + 10SO_2Cl_2 \rightarrow$

d) $POCl_3 + 3H_2O \rightarrow$

e) $Sn + PCl_5 \rightarrow$

f) $4AgNO_3 + 2H_2O + H_3PO_2 \rightarrow$

Ans. Complete and Balance-

a) $P_4 + 8SOCl_2 \rightarrow 4PCl_3 + 4SO_2 + 2S_2Cl_2$

b) $3CH_3COOH + PCl_3 \rightarrow 3CH_3COCl + H_3PO_3$

c) $P_4 + 10SO_2Cl_2 \rightarrow 4PCl_5 + 10SO_2$

d) $POCl_3 + 3H_2O \rightarrow H_3PO_4 + 3HCl$

e) $Sn + PCl_5 \rightarrow SnCl_4 + 2\ PCl_3$

f) $4AgNO_3 + 2H_2O + H_3PO_2 \rightarrow 4Ag + 4HNO_3 + H_3PO_4$

2. All five bonds in PCl_5 are not equal. Give an equation in support of this statement.

Ans. When heated, PCl_5 loses a chlorine molecule this shows that two P- CL bonds are weaker and hence longer than others.

$$PCl_5 \xrightarrow{Heat} PCl_3 + Cl_2$$

3. Draw the structure of following :-

(i) N_2O

(ii) N_2O_4

(iii) HNO_3

(iv) PCl_5

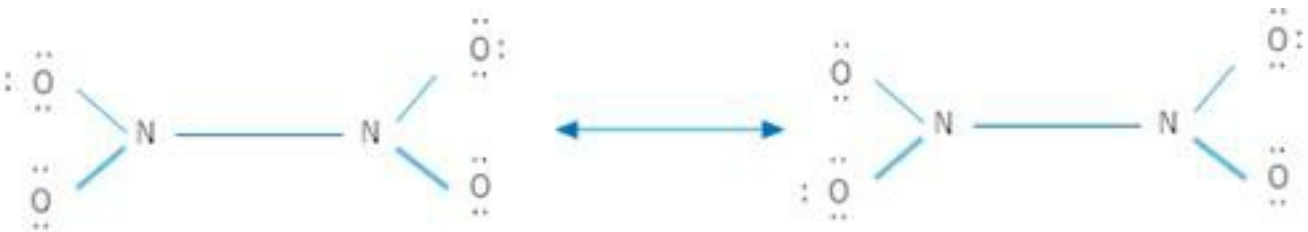
(v) $(HPO_3)_3$

(vi) H_3PO_2

(vii) H_3PO_3

Ans. (i)

(ii)



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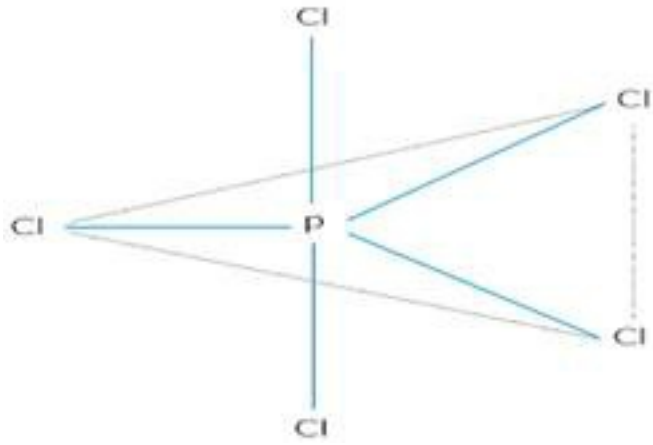

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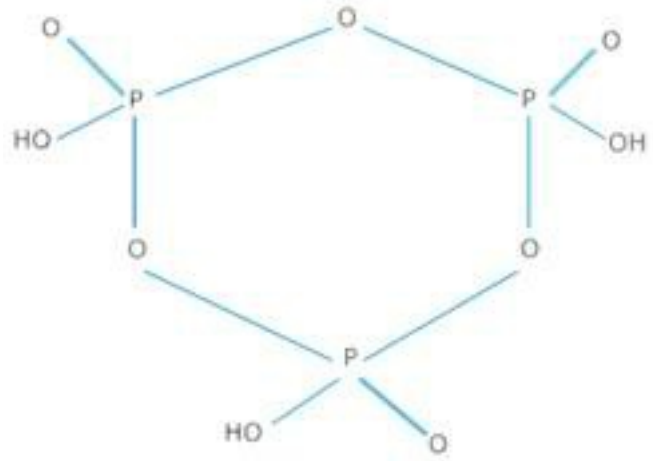

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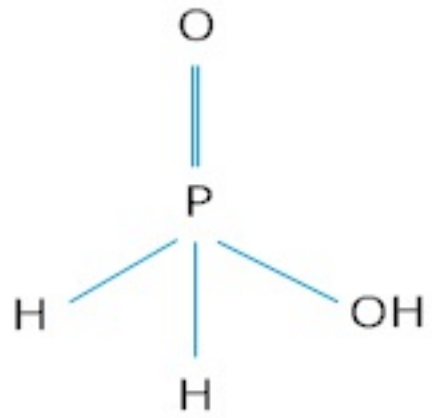

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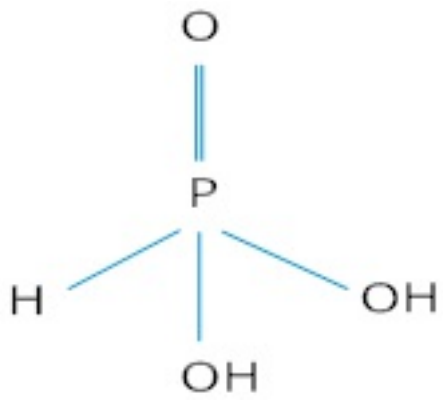


4. Write two uses of dinitrogen.

Ans. Dinitrogen is used

(a) In the manufacture of ammonia.

(b) As a refrigerant to preserve biological material, food items.

(c) In cryosurgery.

5. Explain the chemistry behind brown ring test for detection of nitrate ions.

Ans. The brown ring test for nitrate ions depends on the ability of Fe^{2+} to reduce nitrates to nitric oxide, which reacts with Fe^{2+} to form a brown coloured complex.

$$NO_3^- + 3Fe^{2+} + 4H^+ \rightarrow NO + 3Fe^{3+} + 2H_2O$$

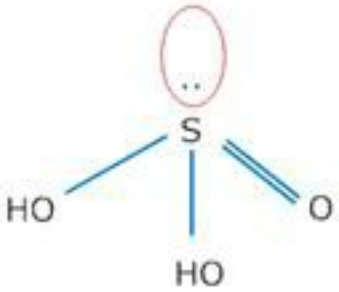
$$\left[Fe(H_2O)_6\right]^{2+} + NO \rightarrow \left[Fe(H_2O)_5 NO\right]^{2+} + H_2O$$

6. Give the structures of

(i) sulphurous acid and

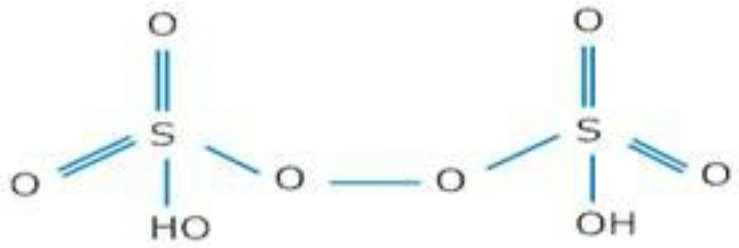
(ii) Peroxodisulphurous acid?

Ans. (i) Sulphurous acid



H_2SO_3

(ii) Peroxodisulphuric acid



H_2SO_8

7. Write the various steps for preparation of sulphuric acid by contact process?

Ans. Contact process for sulphuric acid:-

Step 1: Burning of sulphur in air to give SO_2 .

$S + O_2 SO_2$

Step 2: Conversion of SO_2 *to* SO_3 by reacting it with oxygen in presence of V_2O_5 .

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

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

$$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7\,(oleum)$$

Step 4: Dilution of oleum with water to get H_2SO_4 of desired concentration

$$H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$$

8. Name different sulphates formed by sulphuric acid?

Ans. The two type of sulphates are –

(i) Normal sulphate eg. Na_2SO_4, $CuSO_4$

(ii) acid sulphate eg. $NaHSO_4$.

9. Why are pentahalides more covalent than trihalides?

Ans. 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.

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

Ans. 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.

11. Why is N_2 less reactive at room temperature?

Ans. 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.

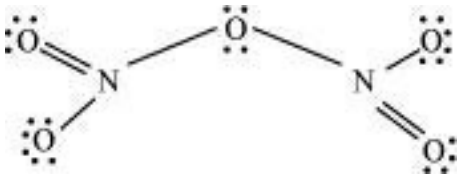
12. How does ammonia react with a solution of Cu^{2+}?

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

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

13. What is the covalence of nitrogen in N_2O_5 ?

Ans.



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

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

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

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

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

Ans. 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 are stronger than the axial ones. Therefore, when PCl_5 is heated strongly, it decomposes to form PCl_3.

16. What happens when PCl_5 is heated ?

Ans. $PCl_5 + D_2O \rightarrow POCl_3 + 2DCl_2$

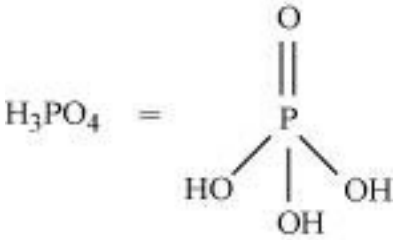
$POCl_3 + 3D_2O \rightarrow D_3PO_4 + 3DCl$

Therefore, the net reaction can be written as

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

17. What is the basicity of H_3PO_4?

Ans. 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.

Concept Insight: Basicity is the Number of hydrogen that are replacable.

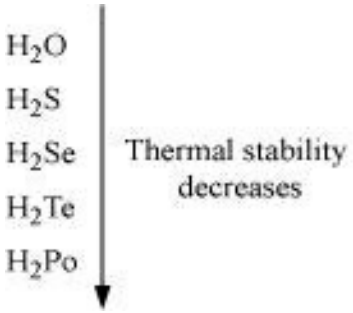
18. List the important sources of sulphur.

Ans. 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 $(CuFeS_2)$].

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

Ans. 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,



20. Why is H_2O a liquid and H_2S a gas?

Ans. 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 gas.

21. Complete the following reactions:

(i) $C_2H_4 + O_2 \rightarrow$

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

Ans. (i) $\underset{\text{Ethane}}{C_2H_4} + \underset{\text{Oxygen}}{3O_2} \rightarrow \underset{\text{Carbondioxide}}{2CO_2} + \underset{\text{Water}}{2H_2O}$

(ii) $\underset{\text{Aluminium}}{4Al} + \underset{\text{Oxygen}}{3O_2} \rightarrow \underset{\text{Alumina}}{2Al_2O_3}$

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

Therefore, ozone acts as a powerful oxidising agent.

22. Why does O_3 act as a powerful oxidizing agent?

Ans. 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 readical, 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 oxidizing agent.

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

Ans. 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.

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

24. Give two examples to show the anomalous behaviour of fluorine.

Ans. **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.

25. Sea is the greatest source of some halogens. Comment.

Ans. 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.

26. Give the reason for bleaching action of C_{12}.

Ans. 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.

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

Coloured substances + [O] $\rightarrow$ ' Oxidized colourless substance

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

Ans. Two poisonous gases that can be prepared from chlorine gas are

(i) Phosgene $(COCl_2)$

(ii) Mustard gas $(ClCH_2CH_2SCH_2CH_2Cl)$

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

Ans. 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.

29. Why is helium used in diving apparatus?

Ans. 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.

30. Why does the reactivity of nitrogen differ from phosphorus?

Ans. Nitrogen is chemically less reactive. This is because of the high stability of its molecule, N_2. In, N_2 the two nitrogen atoms form a triple bond. This triple bond has very high bond strength, which is very difficult to break. It is because of nitrogen's small size that it is able to form $p\pi - p\pi$ bonds with itself. This property is not exhibited by atoms such as phosphorus. Thus, phosphorus is more reactive than nitrogen.

31. Why does NX_3 form hydrogen bond but PH_3 does not?

Ans. Nitrogen is highly electronegative as compared to phosphorus. This causes a greater attraction of electrons towards nitrogen in NX_3 than towards phosphorus in PH_3. Hence, the extent of hydrogen bonding in PH_3 is very less as compared to NX_3.

32. How is nitrogen prepared in the laboratory? Write the chemical equations of the reactions involved.

Ans. An aqueous solution of ammonium chloride is treated with sodium nitrite.

$$NH_4Cl_{(aq)} + NaNO_{2(aq)} \rightarrow N_{2(g)} + 2H_2O_{(l)} + NaCl_{(aq)}$$

NO and HNO3are produced in small amounts. These are impurities that can be removed on passing nitrogen gas through aqueous sulphuric acid, containing potassium dichromate.

33. Why does nitrogen show catenation properties less than phosphorus?

Ans. Catenation is much more common in phosphorous compounds than in nitrogen compounds. This is because of the relative weakness of the N-N single bond as compared to the P-P single bond. Since nitrogen atom is smaller, there is greater repulsion of electron density of two nitrogen atoms, thereby weakening the N-N single bond.

34. Give the disproportionation reaction of H_3PO_3.

Ans. On heating, orthophosphorus acid (H_3PO_3) disproportionates to give orthophosphoric acid (H_3PO_3) and phosphine (PH_3). The oxidation states of P in various species involved in the reaction are mentioned below.

$$4\overset{+3}{H_3P}O_3 \rightarrow 3\overset{+5}{H_3P}O_4 + \overset{-3}{P}H_3$$

35. Which aerosols deplete ozone?

Ans. Freons or chlorofluorocarbons (CFCs) are aerosols that accelerate the depletion of ozone. In the presence of ultraviolet radiations, molecules of CFCs break down to form chlorine-free radicals that combine with ozone to form oxygen.

36. Explain why inspite of nearly the same electronegativity, oxygen forms hydrogen bonding while chlorine does not.

Ans. Both chlorine and oxygen have almost the same electronegativity values, but chlorine rarely forms hydrogen bonding. This is because in comparison to chlorine, oxygen has a smaller size and as a result, a higher electron density per unit volume.

37. Write two uses of ClO_2.

Ans. Uses of ClO_2:

(i) It is used for purifying water.

(ii) It is used as a bleaching agent.

38. Why are halogens coloured?

Ans. Almost all halogens are coloured. This is because halogens absorb radiations in the

visible region. This results in the excitation of valence electrons to a higher energy region. Since the amount of energy required for excitation differs for each halogen, each halogen displays a different colour.

39. Write the reactions of F_2 and Cl_2 with water.

Ans.(i) $Cl_2 + H_2O \rightarrow \underset{\text{Hydrochloric acid}}{HCl} + \underset{\text{Hypochlorous acid}}{HOCl}$

(ii) $2F_{2(g)} + 2H_2O_{(l)} \rightarrow 4H^+_{(aq)} + 4F^-_{(aq)} + O_2 + 4HF_{(aq)}$

40. How can you prepare Cl_2 from HCl and HCl from Cl_2? Write reactions only.

Ans.(i) Cl_2 can be prepared from HCl by Deacon's process.

$$4HCl + O_2 \xrightarrow{CuCl_2} 2Cl_2 + 2H_2O$$

(ii) HCl can be prepared from Cl2on treating it with water.

$$Cl_2 + H_2O \rightarrow \underset{\text{Hydrochloric acid}}{HCl} + \underset{\text{Hypochlorous acid}}{HOCl}$$

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

Ans. Neil Bartlett initially carried out a reaction between oxygen and PtF_6. This resulted in the formation of a red compound, $O_2^+[PtF_6]^-$.

Later, he realized that the first ionization energy of oxygen (1175 kJ/mol) and Xe (1170 kJ/mol) is almost the same. Thus, he tried to prepare a compound with Xe and PtF_6. He was successful and a red-coloured compound, $Xe^+[PtF_6]^-$ was formed.

42. Write balanced equations for the following:

(i) NaCl is heated with sulphuric acid in the presence of MnO_2.

(ii) Chlorine gas is passed into a solution of NaI in water.

Ans. (i) $4NaCl + MnO_2 + 4H_2SO_4 \rightarrow MnCl_2 + 4NaHSO_4 + 2H_2O + Cl_2$

(ii) $Cl_2 + NaI \rightarrow 2NaCl + I_2$

43. With what neutral molecule is ClO^- isoelectronic? Is that molecule a Lewis base?

Ans. ClO^- is isoelectronic to ClF. Also, both species contain 26 electrons in all as shown.

Total electrons ClO^- = 17 + 8 + 1 = 26

In ClF = 17 + 9 = 26

ClF acts like a Lewis base as it accepts electrons from F to form ClF_3.

44. How are XeO_3 and $XeOF_4$ prepared?

Ans. (i) XeO_3 can be prepared in two ways as shown.

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

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

(ii) $XeOF_4$ can be prepared using XeF_6.

$$XeF_6 + H_2O \rightarrow XeOF_4 + 2HF$$

45. Why do noble gases have comparatively large atomic sizes?

Ans. Noble gases do not form molecules. In case of noble gases, the atomic radii corresponds to van der Waal's radii. On the other hand, the atomic radii of other elements correspond to their covalent radii. By definition, van der Waal's radii are larger than covalent radii. It is for this reason that noble gases are very large in size as compared to other atoms belonging to the same period.

3 Marks Questions

1. Write three differences between white and red phosphorous.

Ans.

White phosphorous	Red phosphorous
1. It is translucent waxy solid	1. It has iron grey Lustre.
2. It is poisonous and glows in dark	2. It is non poisonous and does not glow in dark.
3. It is less stable and more reactive.	3. It is more stable and less reactive.

2. Why does NO_2 dimerise?

Ans. NO_2 contains odd number of valence electrons. It behaves as a typical odd molecule. On demerisation, it is converted to stable N_2O_4 molecule with even number of electrons.

3. Mention the conditions required to maximise the yield of ammonia.

Ans. Ammonia is prepared using the Haber's process. The yield of ammonia can be maximized under the following conditions:

(i) High pressure $\left(\propto \frac{1}{4} 200\ \text{atm}\right)$

(ii) A temperature of $\propto \frac{1}{4} 700\ \text{K}$

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

4. What happens when H_3PO_3 is heated?

Ans. H_3PO_4,on heating, undergoes disproportionation reaction to form PH_3 and H_3PO_4. The oxidation numbers of P in H_3PO_4, 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.

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

5. How is O_3 estimated quantitatively?

Ans. 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.

$$\underset{\text{Iodide}}{2I^-} + H_2O + \underset{\text{Ozone}}{O_3} \rightarrow 2OH^- + \underset{\text{Iodine}}{I_2} + O_2$$

$$I_2 + \underset{\substack{\text{Sodium}\\\text{thiosulphate}}}{2Na_2S_2O_3} \rightarrow \underset{\substack{\text{Sodium}\\\text{tetrathionate}}}{Na_2S_4O_6} + 2NaI$$

6. How is the presence of SO_2 detected?

Ans. 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.

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

7. Mention three areas in which H_2SO_4 plays an important role.

Ans. Sulphuric acid is an important industrial chemicaland 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.

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

Ans. 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.

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

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

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

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.

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

Ans. 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.

11. Illustrate how copper metal can give different products on reaction with HNO_3.

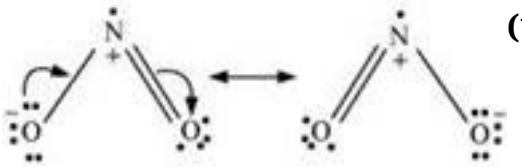
Ans. Concentrated nitric acid is a strong oxidizing agent. It is used for oxidizing most metals. The products of oxidation depend on the concentration of the acid, temperature, and also on the material undergoing oxidation.

$$3Cu + 8HNO_{3(dilute)} \rightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$$

$$Cu + 4HNO_{3(conc.)} \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$$

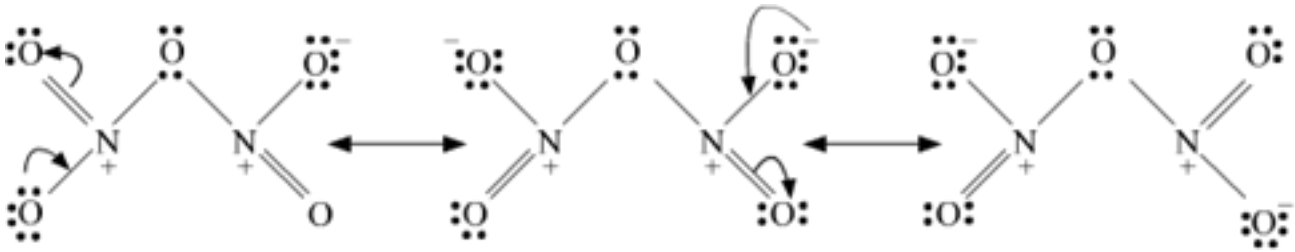
12. Give the resonating structures of NO_2 and N_2O_5.

Ans.



(1)

(2)



13. The HNH angle value is higher than HPH, HAsH and HSbH angles. Why? [Hint: Can be explained on the basis of sp^3 hybridisation in NH_3 and only *s-p* bonding between hydrogen and other elements of the group].

Ans. Hydride $NH_3\ PH_3\ AsH_3\ SbH_3$

H-M-H angle $107°92°91°90°$

The above trend in the H-M-H bond angle can be explained on the basis of the electronegativity of the central atom. Since nitrogen is highly electronegative, there is high electron density around nitrogen. This causes greater repulsion between the electron pairs around nitrogen, resulting in maximum bond angle. We know that electronegativity decreases on moving down a group. Consequently, the repulsive interactions between the electron pairs decrease, thereby decreasing the H-M-H bond angle.

14. Explain why NH_3 is basic while BiH_3 is only feebly basic.

Ans. NH_3 is distinctly basic while BiH_3 is feebly basic.

Nitrogen has a small size due to which the lone pair of electrons is concentrated in a small region. This means that the charge density per unit volume is high. On moving down a group, the size of the central atom increases and the charge gets distributed over a large area decreasing the electron density. Hence, the electron donating capacity of group 15 element hydrides decreases on moving down the group.

15. Nitrogen exists as diatomic molecule and phosphorus as P_4. Why?

Ans. Nitrogen owing to its small size has a tendency to form $p\pi - p\pi$ multiple bonds with itself. Nitrogen thus forms a very stable diatomic molecule, N_2. On moving down a group,

the tendency to form $p\pi - p\pi$ bonds decreases (because of the large size of heavier elements). Therefore, phosphorus (like other heavier metals) exists in the P_4 state.

16. Why is dioxygen a gas but sulphur a solid?

Ans. Oxygen is smaller in size as compared to sulphur. Due to its smaller size, it can effectively form $p\pi - p\pi$ bonds and form O_2 (O==O) molecule. Also, the intermolecular forces in oxygen are weak van der Wall's, which cause it to exist as gas. On the other hand, sulphur does not form M_2 molecule but exists as a puckered structure held together by strong covalent bonds. Hence, it is a solid.

17. Knowing the electron gain enthalpy values for $O \rightarrow O^-$ and $O \rightarrow O^{2-}$ as -141 and $702 kJ\,mol^{-1}$ respectively, how can you account for the formation of a large number of oxides having O^{2-} species and not O^-?

(Hint: Consider lattice energy factor in the formation of compounds).

Ans. Stability of an ionic compound depends on its lattice energy. More the lattice energy of a compound, more stable it will be.

Lattice energy is directly proportional to the charge carried by an ion. When a metal combines with oxygen, the lattice energy of the oxide involving O^{2-} ion is much more than the oxide involving O-ion. Hence, the oxide having O^{2-} ions are more stable than oxides having O^-. Hence, we can say that formation of O^{2-} is energetically more favourable than formation of O^-.

18. Why are halogens strong oxidising agents?

Ans. The general electronic configuration of halogens is np^5, where n = 2-6. Thus, halogens need only one more electron to complete their octet and to attain the stable noble gas configuration. Also, halogens are highly electronegative with low dissociation energies and high negative electron gain enthalpies. Therefore, they have a high tendency to gain an electron. Hence, they act as strong oxidizing agents.

19. How are xenon fluorides XeF_2, XeF_4 and XeF_6 obtained?

Ans. XeF_2, XeF_4 and XeF_6 are obtained by a direct reaction between Xe and F_2. The condition under which the reaction is carried out determines the product.

$$\underset{\text{(Excess)}}{Xe_{(g)}} + F_{2(g)} \xrightarrow{673K, 1bar} XeF_{2(s)}$$

$$\underset{\text{(1:5 ratio)}}{Xe_{(g)}} + 2F_{2(g)} \xrightarrow{873K, 7bar} XeF_{4(s)}$$

$$\underset{\text{(1:20 ration)}}{Xe_{(g)}} + 3F_{2(g)} \xrightarrow{573K, 60-70bar} XeF_{6(s)}$$

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

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

(ii) HF, HCl, HBr, HI - increasing acid strength.

(iii) $NH_3, PH_3, AsH_3, SbH_3, BiH_3$ **– increasing base strength.**

Ans. (i) Bond dissociation energy usually decreases on moving down a group as the atomic size increases. However, the bond dissociation energy of F_2 is lower than that of Cl_2 and Br_2. This is due to the small atomic size of fluorine. Thus, the increasing order for bond dissociation energy among halogens is as follows:

$$I_2 < F_2 < Br_2 < Cl_2$$

(ii) HF < HCl < HBr < HI

The bond dissociation energy of H-X molecules where X = F, Cl, Br, I, decreases with an increase in the atomic size. Since H-I bond is the weakest, HI is the strongest acid.

(iii) $BiH_3 \leq SbH_3 < AsH_3 < PH_3 < NH_3$

On moving from nitrogen to bismuth, the size of the atom increases while the electron density on the atom decreases. Thus, the basic strength decreases.

21. List the uses of Neon and argon gases.

Ans. Uses of neon gas:

(i) It is mixed with helium to protect electrical equipments from high voltage.

(ii) It is filled in discharge tubes with characteristic colours.

(iii) It is used in beacon lights.

Uses of Argon gas:

(i) Argon along with nitrogen is used in gas-filled electric lamps. This is because Ar is more inert than N.

(ii) It is usually used to provide an inert temperature in a high metallurgical process.

(iii) It is also used in laboratories to handle air-sensitive substances.

5 Marks Questions

1. Give reasons :-

(a) Oxygen molecule is diatomic where as sulphur molecule is polyatomic.

(b) The most common oxidation state of oxygen is -2.

(c) H_2O is liquid whereas H_2S is gas at room temperature.

(d) The increasing order of acidic character in 16th group hydrides is $H_2O < H_2Se < H_2Te$.

(e) SF_6 is exceptionally stable, SH_6 does not exist.

Ans. (a) Oxygen being small in size forms effective and strong Pπ-Pπ bonds with other oxygen atom. Therefore oxygen molecule is diatomic and discrete whereas Sulphur due to its larger size, its orbitals cannot overlap effectively to form Pπ-Pπ bonds & completes valency by forming σ bonds with many sulphur atom. Therefore sulphur molecule is polyatomic solid.

(b) Since oxygen is highly electronegative, it has little tendency to give electrons. Therefore its most common oxidation state is -2.

(c) H_2O is liquid at room temperature due to presence of intermolecular Hydrogen bonding which is absent in H_2S.

(d) As we move down the group, the size of atom increases this make the bond of the element with hydrogen weak. Due to weaker bonds, the bond dissociation enthalpy decreases making the molecule more acidic. Therefore the order of acidic strength is.

$$H_2O < H_2S < H_2Se < H_2Te$$

(e) SF_6 is exceptionally stable due to steric reasons. Hydrogen being electropositive or less electronegative than fluorine cannot make the s- electrons of sulphur to participate in bonding. Therefore SF_6 does not exist.

2. Discuss the different types of oxides.

Ans. A binary compound of oxygen with another element is called oxide. Oxides can be simple or mixed. Simple oxides can be classified as acidic, basic Amphoteric or neutral.

An oxide that combines with water to give an acid is termed acidic oxide e.g. CO_2, SO_2 etc.

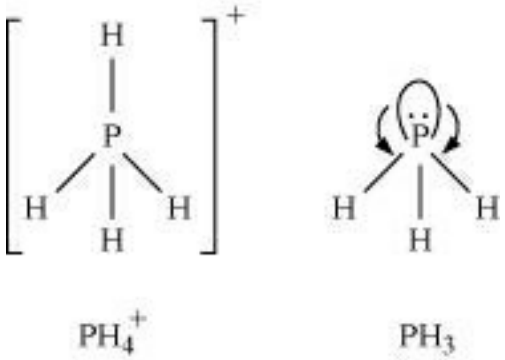
An oxide that combines with water to give a base is called basic oxide e.g. Na_2O , CaO, BaO etc.

An oxide that shows characteristics of both acids and bases is Amphoteric oxide e.g. Al_2O_3 .

An oxide that shows characteristic of neither acid nor base is called neutral oxide e.g. CO, NO and N_2O .

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

Ans. 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*3bonding 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^+

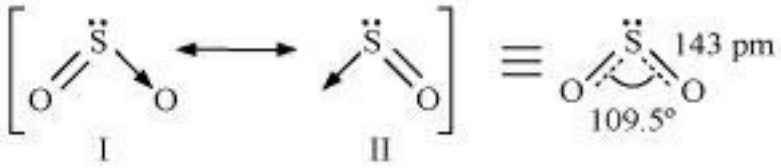
PH_3

Concept insite: the long pair-bond pair repulsion is more than bond pair-bond pair repulsion.

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

Ans. 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 $p\pi - p\pi$ bond with one oxygen atom and the other forms $p\pi : p\pi$ bond with the other oxygen. 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.

5. Discuss the general characteristics of Group 15 elements with reference to their electronic configuration, oxidation state, atomic size, ionisation enthalpy and electronegativity.

Ans. General trends in group15 elements

(i) Electronic configuration: All the elements in group 15 have 5 valence electrons. Their general electronic configuration is $ns^2\ np^3$.

(ii) Oxidation states: All these elements have 5 valence electrons and require three more electrons to complete their octets. However, gaining electrons is very difficult as the nucleus will have to attract three more electrons. This can take place only with nitrogen as it is the smallest in size and the distance between the nucleus and the valence shell is relatively small. The remaining elements of this group show a formal oxidation state of -3 in their covalent compounds. In addition to the -3 state, N and P also show -1 and -2 oxidation states.

All the elements present in this group show +3 and +5 oxidation states. However, the stability of +5 oxidation state decreases down a group, whereas the stability of +3 oxidation state increases. This happens because of the inert pair effect.

(iii) Ionization energy and electronegativity

First ionization decreases on moving down a group. This is because of increasing atomic sizes. As we move down a group, electronegativity decreases, owing to an increase in size.

(iv) Atomic size: On moving down a group, the atomic size increases. This increase in the atomic size is attributed to an increase in the number of shells.

6. Discuss the trends in chemical reactivity of group 15 elements.

Ans. General trends in chemical properties of group - 15

(i) Reactivity towards hydrogen:

The elements of group 15 react with hydrogen to form hydrides of type EH_3, where E = N, P, As, Sb, or Bi. The stability of hydrides decreases on moving down from NH_3 to BiH_3.

(ii) Reactivity towards oxygen:

The elements of group 15 form two types of oxides: E_2O_3 and E_2O_5, where E = N, P, As, Sb, or Bi. The oxide with the element in the higher oxidation state is more acidic than the other. However, the acidic character decreases on moving down a group.

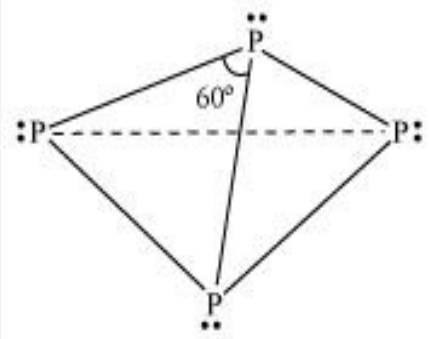
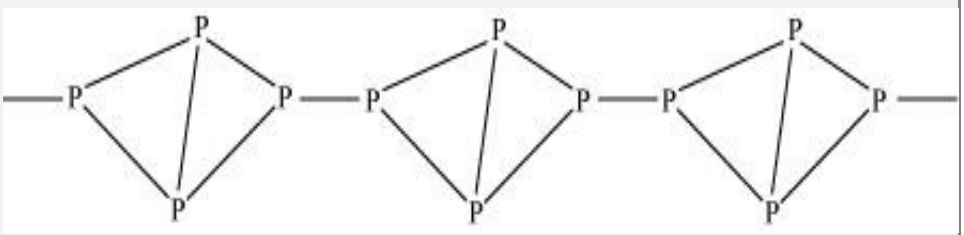
(iii) Reactivity towards halogens: The group 15 elements react with halogens to form two series of salts: EX_3 and EX_5. However, nitrogen does not form NX_5 as it lacks the *d*-

orbital. All trihalides (except NX_3) are stable.

(iv) Reactivity towards metals: The group 15 elements react with metals to form binary compounds in which metals exhibit -3 oxidation states.

7. Write main differences between the properties of white phosphorus and red phosphorus.

Ans.

White phosphorus	Red Phosphorus
It is a soft and waxy solid. It possesses a garlic smell.	It is a hard and crystalline solid, without any smell.
It is poisonous.	It is non-poisonous.
It is insoluble in water but soluble in carbon disulphide.	It is insoluble in both water and carbon disulphide.
It undergoes spontaneous combustion in air.	It is relatively less reactive.
In both solid and vapour states, it exists as a P4 molecule. 	It exists as a chain of tetrahedral P4 units. 

8. Justify the placement of O, S, Se, Te and Po in the same group of the periodic table in terms of electronic configuration, oxidation state and hydride formation.

Ans. The elements of group 16 are collectively called chalcogens.

(i) Elements of group 16 have six valence electrons each. The general electronic configuration of these elements is $ns^2\,np^4$, where n varies from 2 to 6.

(ii) Oxidation state:

Asthese elements have six valence electrons $\left(ns^2\,np^4\right)$, they should display an oxidation state of -2. However, only oxygen predominantly shows the oxidation state of -2 owing to its high electronegativity. It also exhibits the oxidation state of -1 $\left(H_2O_2\right)$, zero $\left(O_2\right)$, and +2

(OF_2). However, the stability of the -2 oxidation state decreases on moving down a group due to a decrease in the electronegativity of the elements. The heavier elements of the group show an oxidation state of +2, +4, and +6 due to the availability of *d*-orbitals.

(iii) Formation of hydrides:

These elements form hydrides of formula H_2E, where E = O, S, Se, Te, PO. Oxygen and sulphur also form hydrides of type H_2E_2. These hydrides are quite volatile in nature.

9. Describe the manufacture of H_2SO_4 by contact process?

Ans. Sulphuric acid is manufactured by the contact process. It involves the following steps:

Step (i): Sulphur or sulphide ores are burnt in air to form SO_2.

Step (ii): By a reaction with oxygen, SO_2 is converted into SO_3 in the presence of V_2O_5 as a catalyst.

$$2SO_{2(g)} + O_2 \xrightarrow{V_2O_5} 2SO_{3(g)}$$

Step (iii): SO_3 produced is absorbed on H_2SO_4 to give $H_2S_2O_7$ (oleum).

$$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$$

This oleum is then diluted to obtain H_2SO_4 of the desired concentration.

In practice, the plant is operated at 2 bar (pressure) and 720 K (temperature). The sulphuric acid thus obtained is 96-98% pure.

10. How is SO_2 an air pollutant?

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

1. It combines with water vapour present in the atmosphere to form sulphuric acid. This causes acid rain. Acid rain damages soil, plants, and buildings, especially those made of marble.

2. 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.

3. 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.

11. What are the oxidation states of phosphorus in the following:

(i) H_3PO_3 **(ii)** PCl_3 **(iii)** $Ca3P_2$

(iv) Na_3PO_4 **(v)** POF_3 **?**

Ans. Let the oxidation state of p be x.

(i) H_3PO_3

3+x+3(–2) = 0

3 + x – 6 = 0

x – 3 = 0

x = +3

(ii) PCl_3

x + 3(–1) =

x – 3 = 0

x = +3

(iii) Ca_3P_2

3(+2) + 2(x) = 0

6 + 2x = 0

2x = –6

x = –3

(iv) Na_3PO_4

3(+1) + x + 4(–2) = 0

3+x–8=0

x –5 = 0

x = +5

(v) POF_3

x + (–2) + 3(–1) = 0

x – 5 = 0

x = +5

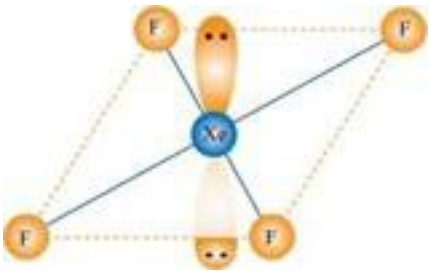
12. Give the formula and describe the structure of a noble gas species which is isostructural with:

(i) ICl_4^-

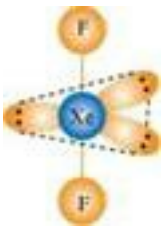
(ii) IBr_2^-

(iii) BrO_3^-

Ans. (i) XeF_4 is isoelectronic with ICl_4^- and has square planar geometry.



(ii) XeF_2 is isoelectronic to IBr_2^- and has a linear structure.



(iii) XeO_3 is isostructural to BrO_3^- and has a pyramidal molecular structure.