Class: 12th

Subject: Chemistry

Chapter 4: GROUP VA AND GROUP VIA ELEMENTS

Q3: Multiple choice question

1. Out of all the elements of Group VA, the highest ionization energy is possessed by:

(a) P

(b) Sb

(c) Bi

(d) N ✅

2. Among Group VA elements, the most electronegative element is:

(a) Sb

(b) N ✅

(c) P

(d) As

3. Oxidation of NO in air produces:

(a) N_2O

(b) N_2O_3

(c) N_2O_4

(d) N_2O_5 ✅

4. The brown gas formed when metal reduces HNO_3 is:

(a) N_2O_5

(b) N_2O_3

(c) NO_2 ✅

(d) NO

5. Laughing gas is chemically:

(a) NO

(b) N_2O ✅

(c) NO_2

(d) N_2O_4

6. Out of all the elements of Group VIA, the highest melting and boiling points are shown by:

(a) Te ✅

(b) Se

(c) S

(d) Pb

7. SO_3 is not absorbed in water directly to form H_2SO_4 because:

(a) The reaction does not go to completion

(b) The reaction is quite slow

(c) The reaction is highly exothermic ✅

(d) SO_3 is insoluble in water

8. Which catalyst is used in the Contact Process?

(a) Fe_2O_3

(b) V_2O_5 ✅

(c) SO_3

(d) Ag_2O

9. Which of the following species has the maximum number of unpaired electrons?

(a) O_2 ✅

(b) O_2^+

(c) O_2^-

(d) O_2^{2-}

🩸 Important MCQs:

1. When N_2O is passed over red-hot copper, it gives:

(a) $Cu(NO_3)_2$

(b) CuO and N_2 ✅

(c) $CuSO_4$

(d) $CuCl_2$

2. In Group VA, nitrogen and phosphorus are:

(a) Metals

(b) Non-metals ✅

(c) Metalloids

(d) Alloys

3. Arsenic and antimony are classified as:

(a) Metals

(b) Non-metals

(c) Metalloids ✅

(d) Noble gases

4. Phosphorus and other Group VA elements can use which orbitals in bonding?

(a) f-orbitals

(b) s-orbitals

(c) d-orbitals ✅

(d) g-orbitals

5. Common oxides of nitrogen include:

(a) N_2O, NO, NO_2, N_2O_3, N_2O_5 ✅

(b) NO_2, N_2O_6, N_2O_8

(c) N_2O_4 only

(d) None of these

6. The unstable oxyacid of nitrogen which exists only in solution is:

(a) HNO_2

(b) HNO_3

(c) HNO ✅

(d) H_2NO_3

7. Which acid acts as a strong acid as well as a strong oxidizing agent?

(a) HNO_3 ✅

(b) H_2SO_4

(c) H_3PO_4

(d) H_3PO_3

8. Aqua regia is a mixture of:

(a) HCl and H_2SO_4

(b) HNO_3 and H_2SO_4

(c) HNO_3 and HCl ✅

(d) H_2SO_4 and H_3PO_4

9. The correct ratio of acids in aqua regia is:

(a) 1 part HNO_3 and 2 parts HCl

(b) 1 part HNO_3 and 3 parts HCl ✅

(c) 3 parts HNO_3 and 1 part HCl

(d) Equal parts of both acids

10. White phosphorus compared to red phosphorus is:

(a) Less reactive

(b) More reactive ✅

(c) Equally reactive

(d) Non-reactive

11. Phosphorus forms two types of chlorides:

(a) PCl_2 and PCl_5

(b) PCl_3 and PCl_5 ✅

(c) PCl and PCl_2

(d) PCl_4 and PCl_6

12. Phosphorus forms two types of oxides:

(a) P_2O_2 and P_2O_4

(b) P_2O_3 and P_2O_5 ✅

(c) P_2O_6 and P_2O_7

(d) None of these

13. Phosphoric acid (H_3PO_4) is a:

(a) Strong monobasic acid

(b) Weak tribasic acid ✅

(c) Strong dibasic acid

(d) Neutral compound

14. Group VIA contains only one metal, which is:

(a) Sulphur

(b) Selenium

(c) Tellurium

(d) Polonium ✅

15. Sulphuric acid is prepared by the oxidation of SO_2 in the presence of a catalyst (V_2O_5) in the:

(a) Haber process

(b) Contact process ✅

(c) Ostwald process

(d) Solvay process

16. The elements of Group VA include:

(a) C, Si, Ge, Sn, Pb

(b) N, P, As, Sb, Bi ✅

(c) O, S, Se, Te, Po

(d) F, Cl, Br, I, At

17. Nitrogen and phosphorus show typical properties of:

(a) Metals

(b) Non-metals ✅

(c) Metalloids

(d) Transition elements

18. Which element of Group VA shows definite metallic properties?

(a) Phosphorus

(b) Arsenic

(c) Bismuth ✅

(d) Antimony

19. The metallic character in Group VA elements:

(a) Decreases down the group

(b) Remains constant

(c) Increases down the group ✅

(d) First increases then decreases

20. Phosphorus can form three or five covalent bonds because it can use:

(a) 3s and 3p orbitals only

(b) 3s, 3p, and empty 3d orbitals ✅

(c) 3d orbitals only

(d) 4p orbitals only

21. The major constituent of air by volume is:

(a) Oxygen

(b) Nitrogen ✅

(c) Carbon dioxide

(d) Argon

22. Percentage of nitrogen in air by volume is about:

(a) 21%

(b) 50%

(c) 78% ✅

(d) 90%

23. Nitrogen is comparatively inactive because:

(a) It is a metal

(b) It has a triple bond between N atoms ✅

(c) It is a light gas

(d) It reacts readily with oxygen

24. In combined state, nitrogen is found in living matter as:

(a) Fats

(b) Proteins, urea, and amino acids ✅

(c) Starch

(d) Cellulose

25. Common oxides of nitrogen are:

(a) N_2O, NO, NO_2, N_2O_3, N_2O_5 ✅

(b) N_2O, N_2O_6, NO_4, NO_6

(c) NO, NO_3, NO_5

(d) N_2O, N_3O, NO_2, N_4O

26. Dinitrogen oxide (N_2O) is commonly known as:

(a) Nitric oxide

(b) Laughing gas ✅

(c) Nitrous oxide

(d) Nitrogen dioxide

27. Dinitrogen oxide is prepared by heating:

(a) Ammonium nitrate ✅

(b) Ammonium chloride

(c) Sodium nitrite

(d) Sodium nitrate

28. Dinitrogen oxide is:

(a) Colourless gas with pleasant smell ✅

(b) Yellow gas with pungent smell

(c) Colourless liquid

(d) Brown gas with choking smell

29. PCl_3 reacts with chlorine to form:

(a) $POCl_3$

(b) PCl_5 ✅

(c) PH_3

(d) H_3PO_4

30. When N_2O is passed over red-hot copper, it gives:

(a) $Cu(NO_3)_2$

(b) CuO and N_2 ✅

(c) $CuSO_4$

(d) $CuCl_2$

31. Nitric oxide (NO) is prepared by the action of dilute nitric acid on:

(a) Silver

(b) Iron

(c) Copper ✅

(d) Lead

32. Nitric oxide is:

(a) Brown gas

(b) Colourless gas ✅

(c) Blue gas

(d) Green gas

33. Oxidation of NO in air produces:

(a) N_2O

(b) N_2O_3

(c) NO_2 ✅

(d) N_2O_5

34. The brown ring test for nitrates depends on the formation of:

(a) NO_2

(b) $FeSO_4.NO$ complex ✅

(c) NOCl

(d) NOBr

35. Nitrogen dioxide (NO_2) is obtained by heating:

(a) Lead nitrate ✅

(b) Sodium nitrate

(c) Ammonium chloride

(d) Ammonium nitrate

36. NO_2 is a:

(a) Colourless gas

(b) Reddish brown gas with pungent smell ✅

(c) Blue gas

(d) Yellowish gas

37. On cooling, NO_2 converts into:

(a) Nitric oxide

(b) Nitrogen

(c) Dinitrogen tetroxide (N_2O_4) ✅

(d) Nitrogen monoxide

38. When NO_2 dissolves in water in the absence of air, it forms:

(a) HNO_3 only

(b) HNO_2 and HNO_3 ✅

(c) HNO_2 only

(d) NH_4NO_3

39. Nitrous acid (HNO_2) can be prepared by dissolving:

(a) N_2O_3 in water ✅

(b) NO_2 in water

(c) N_2O_5 in water

(d) NH_4NO_3 in water

40. Nitric acid (HNO_3) in the laboratory is prepared by heating:

(a) $NaNO_3$ and H_2SO_4

(b) KNO_3 and H_2SO_4 ✅

(c) NaCl and H_2SO_4

(d) NH_4Cl and H_2SO_4

41. The name phosphorus comes from a Greek word meaning:

(a) Heat bearing

(b) Light bearing ✅

(c) Rock forming

(d) Fire stone

42. Phosphorus does not occur in free state in nature because:

(a) It is very inert

(b) It is highly reactive ✅

(c) It is a noble gas

(d) It is insoluble in water

43. The most important mineral source of phosphorus is:

(a) Rock salt

(b) Gypsum

(c) Phosphate rock ($Ca_3(PO_4)_2$) ✅

(d) Quartz

44. Bone ash contains about:

(a) 50% calcium phosphate

(b) 60% calcium phosphate

(c) 80% calcium phosphate ✅

(d) 90% calcium phosphate

45. White phosphorus exists as:

(a) P_2 molecules

(b) P_4 molecules ✅

(c) P_3 molecules

(d) P_5 molecules

46. White phosphorus is:

(a) Stable and non-poisonous

(b) Very reactive and poisonous ✅

(c) Black in colour

(d) Insoluble in benzene

47. Red phosphorus is prepared by heating white phosphorus:

(a) In presence of air

(b) In presence of iodine or sulphur at 250°C ✅

(c) In sunlight

(d) With steam

48. Black phosphorus is obtained by heating red phosphorus at:

(a) Low temperature and pressure

(b) High temperature and pressure ✅

(c) Room temperature

(d) In absence of air

49. Phosphorus trichloride (PCl_3) is prepared by:

(a) Reaction of phosphorus with chlorine ✅

(b) Reaction of P_2O_5 with water

(c) Heating PCl_5

(d) Mixing HCl and $POCl_3$

50. PCl_3 reacts with chlorine to form:

(a) $POCl_3$

(b) PCl_5 ✅

(c) PH_3

(d) H_3PO_4

51. PCl_3 reacts with water to form:

(a) Phosphorus acid (H_3PO_3) and HCl ✅

(b) Phosphoric acid (H_3PO_4) only

(c) $POCl_3$

(d) Phosphine

52. Phosphorus pentachloride (PCl_5) decomposes on heating to give:

(a) PCl_3 and Cl_2 ✅

(b) $POCl_3$

(c) HCl and H_3PO_4

(d) P_2O_3

53. PCl_5 reacts with water to finally produce:

(a) H_3PO_4 and HCl ✅

(b) PCl_3 and Cl_2

(c) $POCl_3$ only

(d) PH_3

54. Phosphorus trioxide (P_2O_3) reacts with cold water to form:

(a) H_3PO_4

(b) H_3PO_3 ✅

(c) $H_4P_2O_7$

(d) PH_3

55. Phosphorus pentoxide (P_2O_5) with hot water gives:

(a) Metaphosphoric acid

(b) Orthophosphoric acid (H_3PO_4) ✅

(c) Pyrophosphoric acid

(d) Phosphorus acid

56. The elements of Group VIA are also called:

(a) Halogens

(b) Noble gases

(c) Chalcogens ✅

(d) Transition elements

57. The term chalcogen is derived from Greek meaning:

(a) Ore giver ✅

(b) Light bearer

(c) Salt former

(d) Air former

58. Which of the following elements of Group VIA is a radioactive metal?

(a) Sulphur

(b) Selenium

(c) Tellurium

(d) Polonium ✅

59. The metallic character in Group VIA elements:

(a) Decreases down the group

(b) Increases down the group ✅

(c) Remains constant

(d) First increases then decreases

60. Oxygen is the most electronegative element after:

(a) Nitrogen

(b) Fluorine ✅

(c) Carbon

(d) Sulphur

61. Which of the following elements shows allotropic forms α, β, and γ?

(a) Oxygen

(b) Sulphur ✅

(c) Selenium

(d) Tellurium

62. The property of forming long chains of the same atoms is called:

(a) Polymerization

(b) Catenation ✅

(c) Oxidation

(d) Ionization

63. The property of catenation among Group VIA elements:

(a) Increases down the group

(b) Decreases down the group ✅

(c) Remains constant

(d) First increases then decreases

64. Oxygen attains noble gas configuration by:

(a) Losing 2 electrons

(b) Gaining 2 electrons ✅

(c) Sharing 4 electrons

(d) Gaining 1 electron

65. The +6 oxidation state in sulphur compounds arises when:

(a) One electron from s-orbital is promoted to a vacant d-orbital ✅

(b) Both s and p orbitals are completely filled

(c) Two electrons are lost from the nucleus

(d) One electron is gained from oxygen

66. Sulphuric acid was first prepared by:

(a) Ibn Sina

(b) Jabir bin Hayyan ✅

(c) Al-Razi

(d) Knietsch

67. Sulphuric acid was called in early Europe as:

(a) Spirit of salt

(b) Aqua regia

(c) Oil of vitriol ✅

(d) Spirit of sulphur

68. The commercial process for the manufacture of sulphuric acid is:

(a) Haber process

(b) Contact process ✅

(c) Ostwald process

(d) Lead chamber process

69. The contact process was developed by:

(a) Haber

(b) Knietsch ✅

(c) Faraday

(d) Lavoisier

70. In the contact process, the catalyst used is:

(a) Fe_2O_3

(b) V_2O_5 ✅

(c) MnO_2

(d) Ni

71. The best yield of SO_3 in the contact process is obtained at:

(a) 200–300°C

(b) 400–500°C ✅

(c) 600–700°C

(d) Room temperature

72. In the purifying unit, arsenic oxide is removed by:

(a) Water washing

(b) Steam treatment

(c) Ferric hydroxide ✅

(d) Lime solution

73. The beam of light in the testing box is used to:

(a) Check temperature

(b) Detect solid particles ✅

(c) Measure acidity

(d) Detect gases

74. The reaction in the contact tower is:

(a) $SO_3 + H_2O \longrightarrow H_2SO_4$

(b) $2SO_2 + O_2 \longrightarrow 2SO_3$ ✅

(c) $SO_2 \longrightarrow S + O_2$

(d) $SO_3 \longrightarrow SO_2 + \frac{1}{2}O_2$

75. The oxidation of SO_2 to SO_3 is:

(a) Endothermic

(b) Exothermic ✅

(c) Reversible and endothermic

(d) Neither endothermic nor exothermic

76. SO_3 is absorbed in 98% H_2SO_4 to form:

(a) Pyrosulphuric acid (Oleum) ✅

(b) Sulphurous acid

(c) Phosphoric acid

(d) Sulphur dioxide

77. The specific gravity of pure H_2SO_4 at 18°C is:

(a) 1.234

(b) 1.834 ✅

(c) 1.500

(d) 1.900

78. The boiling point of pure sulphuric acid is:

(a) 100°C

(b) 238°C

(c) 338°C ✅

(d) 400°C

79. Sulphuric acid should always be:

(a) Poured into water ✅

(b) Mixed with alcohol first

(c) Added to alkali first

(d) Heated before mixing

80. Pure H_2SO_4 is a non-conductor of electricity because:

(a) It is covalent ✅

(b) It contains ions

(c) It is highly volatile

(d) It reacts with metals

81. Cold dilute H_2SO_4 reacts with metals to produce:

(a) Hydrogen gas ✅

(b) Oxygen gas

(c) Sulphur dioxide

(d) Hydrochloric acid

82. Hot concentrated H_2SO_4 acts as:

(a) Reducing agent

(b) Oxidizing agent ✅

(c) Neutral salt

(d) Weak base

83. When H_2SO_4 acts as a dehydrating agent with sugar, it forms:

(a) Carbon and water ✅

(b) CO_2 and CO

(c) SO_2 and H_2O

(d) H_2 and carbon

84. The reaction of H_2SO_4 with benzene produces:

(a) Benzoic acid

(b) Benzene sulphonic acid ✅

(c) Nitrobenzene

(d) Phenol

85. Sulphuric acid is used in the manufacture of:

(a) Fertilizers

(b) Dyes and drugs

(c) Explosives and batteries

(d) All of these ✅

🩸 Important Short Questions:

(i) How does the metallic character change down the Group VA elements?

Answer:

The metallic character increases down the group. Nitrogen and phosphorus are non-metals, arsenic and antimony are metalloids, while bismuth is a metal.

(ii) Which elements of Group VA can use d-orbitals in bonding and why?

Answer:

Phosphorus, arsenic, and antimony can use d-orbitals in bonding because their d-orbitals have suitable energy to participate in bond formation.

(iii) Name common oxides of nitrogen.

Answer:

Common oxides of nitrogen are N_2O, NO, NO_2, N_2O_3, and N_2O_5.

(iv) Write the names of two oxyacids of nitrogen.

Answer:

The two oxyacids of nitrogen are nitrous acid (HNO_2) and nitric acid (HNO_3).

(v) Why is nitric acid (HNO_3) called a strong oxidizing agent?

Answer:

Nitric acid is called a strong oxidizing agent because it readily releases oxygen and oxidizes metals and non-metals.

(vi) What is aqua regia?

Answer:

Aqua regia is a mixture of one part concentrated nitric acid (HNO_3) and three parts concentrated hydrochloric acid (HCl).

(vii) Why is aqua regia used to dissolve gold and platinum?

Answer:

Aqua regia produces nascent chlorine which reacts with gold and platinum to form soluble chlorides, thus dissolving them.

(viii) How many allotropic forms of phosphorus exist?

Answer:

Phosphorus exists in six allotropic forms, among which white and red phosphorus are the most common.

(ix) Which form of phosphorus is more reactive?

Answer:

White phosphorus is more reactive than red phosphorus because its molecules have more strain and are less stable.

(x) Name two oxides of phosphorus.

Answer:

The two oxides of phosphorus are phosphorus trioxide (P_2O_3) and phosphorus pentoxide (P_2O_5).

(xi) Write the names of two oxyacids of phosphorus.

Answer:

The two oxyacids of phosphorus are phosphorous acid (H_3PO_3) and phosphoric acid (H_3PO_4).

(xii) What is the basicity of phosphoric acid (H_3PO_4)?

Answer:

Phosphoric acid is a weak tribasic acid; it can give three hydrogen ions in aqueous solution.

(xiii) Which is the only metallic element in Group VIA?

Answer:

Polonium is the only metallic element in Group VIA.

(xiv) Name two most abundant elements of Group VIA.

Answer:

Oxygen and sulphur are the most abundant elements of Group VIA.

(xv) What is the Contact Process?

Answer:

The Contact Process is the industrial method for manufacturing sulphuric acid by oxidation of SO_2 to SO_3 in the presence of a catalyst (V_2O_5).

EXERCISE

Q1. Fill in the blanks:

(i) The elements _____ of group VA are called metalloids.

Answer: arsenic and antimony ✅

(ii) In Birkeland and Eyde's process _____ is prepared from atmospheric oxygen and nitrogen.

Answer: nitric oxide (NO) ✅

(iii) The tendency to form long chain of atoms is called _____.

Answer: catenation ✅

(iv) All the elements of group VIA show the property of _____.

Answer: allotropy ✅

(v) Selenium shows two allotropic forms which are called _____ forms.

Answer: red and grey ✅

(vi) Specific gravity of H_2SO_4 at 18°C is _____.

Answer: 1.834 ✅

(vii) H_2 is produced by reacting H_2SO_4 with metals, like _____.

Answer: zinc, iron or magnesium ✅

(viii) The elements of group VIA exhibit maximum oxidation state of _____.

Answer: +6 ✅

(ix) The outermost shell of group _____ elements contain six electrons.

Answer: VIA ✅

(x) Oxygen shows _____ behaviour due to the presence of unpaired electrons.

Answer: paramagnetic ✅

(xi) Conc. phosphoric acid acts as a _____.

Answer: weak tribasic acid ✅

(xii) Nitrogen is a gas while other elements of the same group are _____.

Answer: solids ✅

(xiii) Noble metals like gold and platinum are dissolved in _____.

Answer: aqua regia ✅

(xiv) Sulphur is different from oxygen because it shows _____ oxidation states.

Answer: multiple ✅

(xv) HNO_3 is used in the manufacture of _____ fertilizers.

Answer: nitrogenous ✅

Q.2 Indicate True or False:

(i) True ✅ – The metallic character of Group VA and VIA elements increases down the group.

(ii) True ✅ – The elements of Group VA show a maximum oxidation state of +5.

(iii) False ❌ – The ionization energy of nitrogen is higher than that of phosphorus.

(iv) True ✅ – The electronegativity of oxygen is greater than all other elements of Groups VA and VIA.

(v) True ✅ – V_2O_5 acts as a catalyst for the oxidation of SO_2 to SO_3 in the contact process.

(vi) False ❌ – The oxides of nitrogen are generally acidic or neutral, not basic in nature.

(vii) False ❌ – Aqua regia is prepared by mixing 1 part conc. HNO_3 with 3 parts conc. HCl, not the other way around.

(viii) True ✅ – TNT (Trinitrotoluene) is prepared by the nitration of toluene using nitric acid.

(ix) True ✅ – P_2O_3 reacts with cold water to form phosphorous acid (H_3PO_3) and with hot water to form phosphoric acid (H_3PO_4).

(x) True ✅ – Sulphur occurs in many organic compounds of animal and plant origin.

Q.4 Short Questions

(i) How does nitrogen differ from other elements of its group?

Answer:

Nitrogen differs from other elements of its group due to its small atomic size, high electronegativity, and absence of d-orbitals.

It can form multiple bonds (like N≡N), while other elements cannot.

(ii) Why does aqua regia dissolve gold and platinum?

Answer:

Aqua regia (a mixture of conc. HCl and conc. HNO_3) dissolves gold and platinum because:

HNO_3 oxidizes gold/platinum to their ions.

HCl provides chloride ions to form soluble chloro-complexes such as $[AuCl_4]^-$ and $[PtCl_6]^{2-}$.

🧪 **Equation:**

$Au + HNO_3 + 4HCl \longrightarrow H[AuCl_4] + NO + 2H_2O$

(iii) Why do the elements of group VIA other than oxygen show more than two oxidation states?

Answer:

The elements of group VIA other than oxygen (like S, Se, Te) possess vacant d-orbitals, which allow the promotion of electrons and formation of oxidation states +2, +4, and +6 in addition to −2.

Oxygen lacks d-orbitals; hence it usually shows only −2 oxidation state.

(iv) Write down a comparison of the properties of oxygen and sulphur.

Answer:

Property	**Oxygen**	**Sulphur**
Physical state	Gas	Solid
Allotropy	O_2, O_3	Rhombic, Monoclinic, Plastic
Oxidation state	Mostly −2	−2, +2, +4, +6
Catenation	Weak	Strong
Electronegativity	Higher	Lower

Both are non-metals, divalent, and form oxides and sulphides with metals.

(v) Write down the equation for the reaction between conc. H_2SO_4 and copper and explain what type of reaction it is.

Answer:

🧪 **Equation:**

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

This is an oxidation-reduction (redox) reaction, where:

- Copper (Cu) is oxidized to Cu^{2+}
- Sulphur in H_2SO_4 is reduced from +6 to +4 (in SO_2 gas).

🌟 **Q.5 (a) Explain the Birkeland and Eyde's Process for the Manufacture of Nitric Acid.**

❖ **Introduction:**

Nitric acid (HNO3) is an important industrial chemical used for making fertilizers, explosives, and dyes. In Birkeland and Eyde's process, nitrogen and oxygen from air are combined using an electric arc at very high temperature to form nitric oxide which is then converted into nitric acid.

Step 1: Formation of Nitric Oxide (NO)

- Air (a mixture of nitrogen and oxygen) is passed through an electric arc at about 3000°C.
- Nitrogen reacts with oxygen to form nitric oxide.

Reaction: $N_2 + O_2 \longrightarrow 2NO$

Step 2: Formation of Nitrogen Dioxide (NO_2)

- The nitric oxide gas is cooled rapidly and then mixed with more oxygen.

Reaction: $2NO + O_2 \longrightarrow 2NO_2$

Step 3: Formation of Nitric Acid (HNO_3)

- The nitrogen dioxide gas is absorbed in water in an absorption tower where nitric acid is formed.

Reaction: $4NO_2 + 2H_2O + O_2 \longrightarrow 4HNO_3$

The nitric oxide produced in this step is again sent back to the oxidation chamber for reuse.

✦ **Summary of the Process:**

Air ⟶ Electric Arc ⟶ Nitric Oxide ⟶ Nitrogen Dioxide ⟶ Absorption in Water ⟶ Nitric Acid

(b) Metals that Evolve Hydrogen with Nitric Acid

- Generally, nitric acid does not evolve hydrogen gas because it is a strong oxidizing agent.

However, when very dilute nitric acid is used, some metals like magnesium, manganese, and zinc produce hydrogen gas.

Examples:

1. Magnesium + dilute nitric acid ⟶ Magnesium nitrate + Hydrogen gas

2. Manganese + dilute nitric acid ⟶ Manganese nitrate + Hydrogen gas

3. Zinc + dilute nitric acid ⟶ Zinc nitrate + Hydrogen gas

Note: Concentrated nitric acid does not give hydrogen gas because it oxidizes hydrogen into water.

(c) What is Meant by Fuming Nitric Acid?

Definition:

- Fuming nitric acid is a highly concentrated form of nitric acid that contains dissolved nitrogen dioxide gas (NO_2).
- Because of this, it appears reddish-brown and gives off dense fumes in moist air.

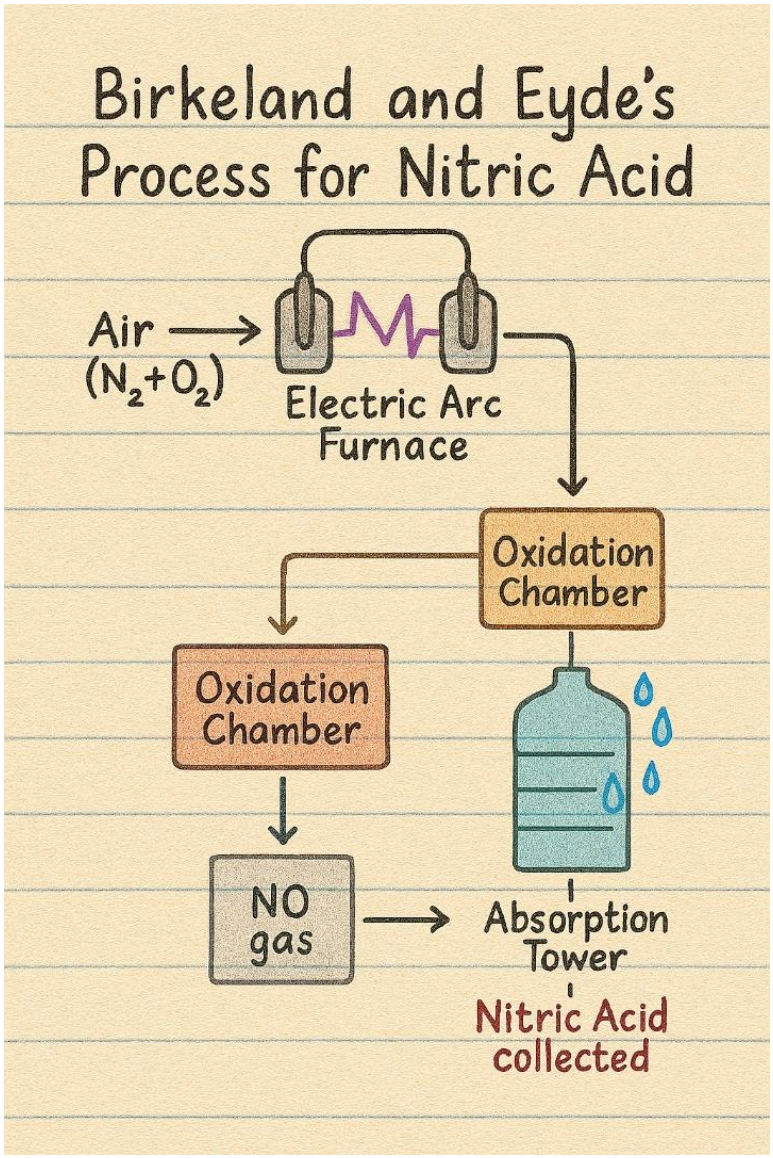
Characteristics:

- It gives reddish fumes.
- It is highly corrosive and volatile.
- It acts as a very strong oxidizing agent.
- It is used in making explosives, nitration reactions, and rocket fuels.

Chemical Explanation:

- When concentrated nitric acid partially decomposes, it releases nitrogen dioxide gas which remains dissolved in it.
- This gives the acid a fuming appearance and a strong smell.

✦ **Digram:**



✦ **Summary:**

- In Birkeland and Eyde's process, air is passed through an electric arc at 3000°C to form nitric oxide, which is converted into nitric acid by oxidation and absorption.
- Metals like magnesium, zinc, and manganese evolve hydrogen gas with very dilute nitric acid.

- Fuming nitric acid is concentrated nitric acid containing dissolved nitrogen dioxide gas.

🌟 Q.6

(a) Sulphuric acid is said to act as an acid, an oxidizing agent, and a dehydrating agent. Describe two reactions in each case to illustrate the truth of this statement.

(b) Give the advantages of the contact process for the manufacture of sulphuric acid.

❖ Answer:

(a) Action of Sulphuric Acid

- Sulphuric acid (H_2SO_4) is a very important chemical in industry and laboratory.

It shows three main types of chemical behavior:

1. As an acid

2. As an oxidizing agent

3. As a dehydrating agent

🧪 1. Sulphuric Acid as an Acid

- Sulphuric acid behaves as a strong acid because it ionizes completely in aqueous solution to give hydrogen ions (H^+).
- It reacts with metals and bases forming salts and water.

Examples:

(i) With Sodium Hydroxide (Base):

$H_2SO_4(aq) + 2NaOH(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$

➡️ This reaction forms sodium sulphate and water — showing the acidic nature of H_2SO_4.

(ii) With Zinc (Metal):

$Zn(s) + H_2SO_4(dil.) \longrightarrow ZnSO_4(aq) + H_2(g)$

➡️ Dilute sulphuric acid reacts with active metals to liberate hydrogen gas.

⚡ 2. Sulphuric Acid as an Oxidizing Agent

- Concentrated sulphuric acid acts as a strong oxidizing agent because it contains oxygen which can oxidize other substances, while itself getting reduced to sulphur dioxide (SO_2).

Examples:

(i) With Copper:

$Cu(s) + 2H_2SO_4(conc.) \longrightarrow CuSO_4(aq) + 2H_2O(l) + SO_2(g)$

➡️ Sulphuric acid oxidizes copper to copper sulphate and releases sulphur dioxide gas.

(ii) With Carbon:

$C(s) + 2H_2SO_4(conc.) \longrightarrow CO_2(g) + 2SO_2(g) + 2H_2O(l)$

➡️ Carbon is oxidized to carbon dioxide while sulphuric acid is reduced to sulphur dioxide.

💧 3. Sulphuric Acid as a Dehydrating Agent

- Concentrated sulphuric acid has a strong attraction for water.
- It removes hydrogen and oxygen atoms (as H_2O) from many organic compounds.

- Therefore, it acts as a powerful dehydrating agent.

Examples:

(i) With Sugar ($C_{12}H_{22}O_{11}$):

$C_{12}H_{22}O_{11}(s) \longrightarrow 12C(s) + 11H_2O(l)$

➡️ Sulphuric acid removes water from sugar and black carbon is left behind.

(ii) With Ethanol (C_2H_5OH):

$C_2H_5OH(l) \longrightarrow C_2H_4(g) + H_2O(l)$

➡️ When ethanol is heated with concentrated H_2SO_4, water is removed and ethene gas is formed.

(b) Advantages of the Contact Process

- The Contact Process is the modern industrial method for manufacturing sulphuric acid.
- It has replaced the older Lead Chamber Process due to its efficiency and purity.

✅ Main Advantages:

1. High Yield:

- Almost complete conversion of SO_2 into SO_3 gives a high yield of H_2SO_4.

2. High Purity:

- The sulphuric acid obtained is extremely pure and suitable for industrial as well as laboratory use.

3. Economical Process:

- The process is efficient and less expensive due to the use of the V_2O_5 catalyst working at moderate temperature (about 450°C).

4. Continuous Process:

- The process can be operated continuously with easy control of temperature and pressure.

5. Less Pollution:

- The gases are purified before oxidation, reducing environmental pollution.

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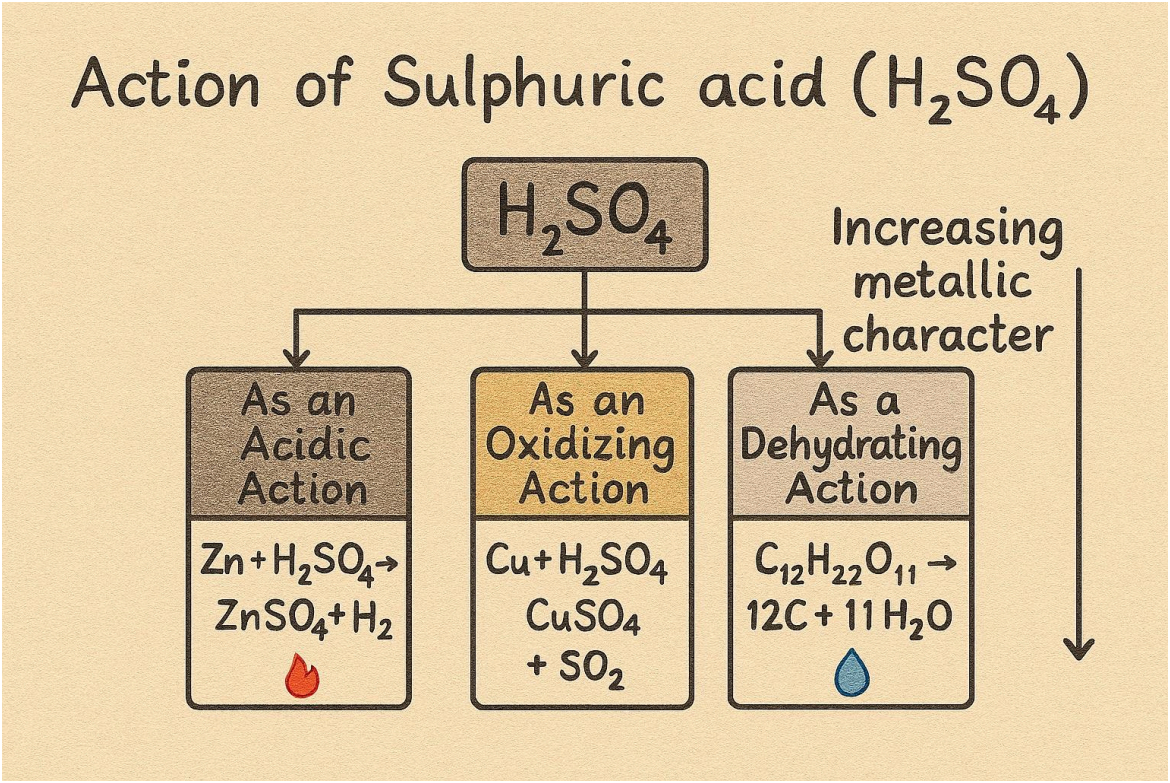


✦ **Summary:**

Sulphuric acid acts as an acid, oxidizing agent, and dehydrating agent through different reactions. It shows strong reactivity with metals, removes water from compounds, and oxidizes substances like copper. The Contact Process provides an efficient and economical method for its large-scale and pure production.

🌟 **Q.7 (a) Describe the chemistry of the industrial preparation of sulphuric acid from sulphur by the Contact Process.**

👉 **Answer:**

The Contact Process is the most widely used industrial method for manufacturing sulphuric acid (H_2SO_4). It involves three main steps:

Step 1: Production of Sulphur Dioxide (SO_2)

- Sulphur or sulphide ores are burned in excess air to produce sulphur dioxide.

Equation:

$S + O_2 \longrightarrow SO_2$

Step 2: Conversion of SO_2 to Sulphur Trioxide (SO_3)

- Sulphur dioxide is oxidized to sulphur trioxide in the presence of a V_2O_5 (vanadium pentoxide) catalyst at 450°C and 1–2 atm pressure.

Equation:

$2SO_2 + O_2 \rightleftharpoons 2SO_3 \quad (\Delta H = -196\ kJ/mol)$

Step 3: Formation of Sulphuric Acid

- Sulphur trioxide is absorbed in concentrated sulphuric acid to form oleum ($H_2S_2O_7$), which is then diluted with water to produce sulphuric acid.

Equations:

$SO_3 + H_2SO_4 \longrightarrow H_2S_2O_7$

$H_2S_2O_7 + H_2O \longrightarrow 2H_2SO_4$

🌟 Q.7 (b) Why is SO_3 dissolved in H_2SO_4 and not in water?

👉 Answer:

- Sulphur trioxide (SO_3) is not dissolved directly in water because it reacts very violently with water, producing a dense white mist of sulphuric acid that is difficult to condense.
- To avoid this explosive reaction, SO_3 is dissolved in concentrated H_2SO_4 to form oleum ($H_2S_2O_7$), which can then be safely diluted with water.

🌟 Q.7 (c) Explain the action of sulphuric acid on metals along with chemical equations.

👉 Answer:

Sulphuric acid acts both as an acid and as an oxidizing agent depending on its concentration and temperature.

(i) Action of Dilute Sulphuric Acid:

- It reacts with active metals to form metal sulphates and hydrogen gas.

Example:

$Zn + H_2SO_4$ (dilute) $\longrightarrow ZnSO_4 + H_2$ ⬆️

(ii) Action of Concentrated Sulphuric Acid:

- Concentrated acid acts as an oxidizing agent, producing sulphur dioxide (SO_2) instead of hydrogen.

Example:

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

✦ **Summary:**

The Contact Process produces sulphuric acid efficiently from sulphur through oxidation and absorption steps using V_2O_5 as a catalyst. SO_3 is dissolved in H_2SO_4 (not water) to prevent

violent reactions, forming oleum. Sulphuric acid reacts with metals — dilute acid gives hydrogen gas, while concentrated acid gives sulphur dioxide due to its oxidizing power.

🌟 Q.8 Describe the preparation of NO_2 gas. Also give its reactions.

🔹 Preparation of nitrogen dioxide (NO_2)

1. By thermal decomposition of lead(II) nitrate (laboratory method)

- When lead nitrate is strongly heated it decomposes to give lead(II) oxide, nitrogen dioxide and oxygen:

$$2\ Pb(NO3)2\ (s) \longrightarrow 2\ PbO\ (s) + 4\ NO2\ (g) + O2\ (g)$$

Explanation: nitrates of heavy metals decompose on heating to oxides, NO_2 and O_2.

2. By action of concentrated nitric acid on copper (laboratory method)

Concentrated nitric acid oxidizes copper to copper(II) nitrate while producing nitrogen dioxide and water:

$$Cu\ (s) + 4\ HNO3\ (conc.) \longrightarrow Cu(NO3)2\ (aq) + 2\ NO2\ (g) + 2\ H2O\ (l)$$

Explanation: with concentrated HNO_3 the oxidizing power of the acid produces NO_2 (brown fumes).

3. By oxidation of nitric oxide (NO) (preparative/industrial route)

Nitric oxide formed elsewhere (for example from an arc or other source) is oxidized by oxygen to NO_2:

$$2\ NO\ (g) + O2\ (g) \longrightarrow 2\ NO2\ (g)$$

Explanation: NO readily oxidizes in air to the brown NO_2 gas.

4. From dissociation of dinitrogen tetroxide (N_2O_4)

Dinitrogen tetroxide and nitrogen dioxide are in equilibrium. On warming N_2O_4 dissociates to NO_2:

$$N2O4\ (g) \rightleftharpoons 2\ NO2\ (g)$$

Note: at low temperature the colourless N_2O_4 predominates; at higher temperature the brown NO_2 predominates.

Physical properties (brief)

- **Colour:** reddish-brown gas (characteristic brown fumes)

- **Odour**: sharp, choking, pungent
- **Magnetism**: paramagnetic (has an unpaired electron)
- **Solubility:** reacts with water (see hydrolysis); dissolves forming acidic solutions
- **Toxicity:** very toxic and irritating — causes severe respiratory damage

Important reactions of NO_2 (with equations and brief explanation)

1. Dimerisation (temperature dependent equilibrium)

$2\ NO2\ (g) \rightleftharpoons N2O4\ (g)$

Explanation: at low temperature colourless N_2O_4 is favoured; at higher temperature the equilibrium shifts to brown NO_2.

2. Hydrolysis (in absence of excess oxygen) — gives nitric and nitrous acids

$2\ NO2\ (g) + H2O\ (l) \longrightarrow HNO3\ (aq) + HNO2\ (aq)$

Explanation: NO_2 reacts with water to give a mixture of nitric acid and nitrous acid.

3. Hydrolysis with excess oxygen — gives nitric acid

$4\ NO2\ (g) + 2\ H2O\ (l) + O2\ (g) \longrightarrow 4\ HNO3\ (aq)$

Explanation: in presence of O_2 the nitrous acid is oxidized to nitric acid so the net product is HNO_3.

4. Reaction with alkalis — formation of nitrate and nitrite salts

2 NO2 (g) + 2 NaOH (aq) ⟶ NaNO3 (aq) + NaNO2 (aq) + H2O (l)

Explanation: passage of NO_2 into a base produces a mixture of nitrate and nitrite.

5. Oxidation of hydrogen sulphide (example of redox)

H2S (g) + 2 NO2 (g) ⟶ H2O (l) + S (s) + 2 NO (g)

Explanation: NO_2 oxidizes H_2S to sulfur while being reduced to NO.

6. Oxidation of ferrous sulphate to ferric sulphate (example with iron)

2 FeSO4 (aq) + H2SO4 (aq) + 2 NO2 (g) ⟶ Fe2(SO4)3 (aq) + 2 NO (g) + H2O (l)

Explanation: Fe^{2+} is oxidized to Fe^{3+} and NO_2 is reduced to NO.

7. Oxidation of iodide to iodine

2 KI (aq) + 2 NO2 (g) ⟶ 2 KNO2 (aq) + I2 (s)

Explanation: NO_2 oxidizes I^- to I_2 and is itself reduced to nitrite.

8. Thermal decomposition to NO and O_2 at high temperature

2 NO2 (g) ⟶ 2 NO (g) + O2 (g)

Explanation: on strong heating NO_2 decomposes to nitric oxide and oxygen.

9. Reaction with phosphorus or sulfur (combustion in NO_2)

Example: 2 P (s) + 5 NO2 (g) ⟶ P2O5 (s) + 5 NO (g)

Explanation: elements that burn in oxygen can also combust in NO_2 because NO_2 supplies oxygen on decomposition.

Laboratory notes & safety

- NO_2 is toxic and corrosive; prepare and handle only in a fume hood with proper PPE (gloves, goggles, respirator if needed).

- The brown fumes strongly irritate eyes and lungs; avoid inhalation.
- Cold traps favor N_2O_4 formation; some procedures use low temperature to condense N_2O_4 and release NO_2 on warming.
- Do not bubble NO_2 into unprotected water sources — it forms acids and corrosive fumes.

✦ **Short summary:**

Nitrogen dioxide (NO_2) is a reddish-brown, paramagnetic, toxic gas prepared in the lab by heating lead(II) nitrate or by reacting copper with concentrated nitric acid, and preparatively by oxidation of NO or dissociation of N_2O_4. It dimerizes to N_2O_4 at low temperatures, hydrolyses to give nitric and nitrous acids (or nitric acid in presence of excess oxygen), reacts with alkalis to give nitrate and nitrite salts, and acts as an oxidizing agent in many redox reactions (for example oxidizing H_2S, I^- or Fe^{2+}). Handle with care in a fume hood.

🌟 **Q.9 How PCl_3 and PCl_5 can be used for the preparation of other chemical compounds.**

❖ **Answer:**

Phosphorus trichloride (PCl_3) and phosphorus pentachloride (PCl_5) are important chlorides of phosphorus used as reactive intermediates in the preparation of many other chemical compounds. Both compounds are highly reactive due to the presence of polar covalent P–Cl bonds. Their reactions

involve substitution or replacement of chlorine atoms with oxygen or organic groups.

(a) Preparation and Reactions of Phosphorus Trichloride (PCl_3):

Preparation:

Phosphorus trichloride is prepared by the direct chlorination of white phosphorus.

Equation:

$P_4 + 6Cl_2 \longrightarrow 4PCl_3$

It is a colorless, fuming liquid having a strong, pungent odor.

Reactions of PCl_3:

1. Reaction with Water:

PCl_3 reacts violently with water to form phosphorous acid (H_3PO_3) and hydrogen chloride (HCl) gas.

Equation:

$PCl_3 + 3H_2O \longrightarrow H_3PO_3 + 3HCl$

2. Reaction with Alcohols:

When PCl_3 reacts with alcohols, it forms alkyl chlorides and phosphorous acid.

Example:

$3C_2H_5OH + PCl_3 \longrightarrow 3C_2H_5Cl + H_3PO_3$

3. Reaction with Carboxylic Acids:

It reacts with carboxylic acids to form acid chlorides.

Example:

$3CH_3COOH + PCl_3 \longrightarrow 3CH_3COCl + H_3PO_3$

(b) Preparation and Reactions of Phosphorus Pentachloride (PCl_5):

Preparation:

Phosphorus pentachloride is obtained by the further chlorination of phosphorus trichloride.

Equation:

$PCl_3 + Cl_2 \longrightarrow PCl_5$

It is a yellowish-white crystalline solid that fumes in moist air.

Reactions of PCl_5:

1. Reaction with Water:

PCl_5 reacts with cold water to form phosphoryl chloride ($POCl_3$) and hydrogen chloride, and with excess hot water to produce phosphoric acid (H_3PO_4).

Equations:

$PCl_5 + H_2O \longrightarrow POCl_3 + 2HCl$

$POCl_3 + 3H_2O \longrightarrow H_3PO_4 + 3HCl$

2. Reaction with Alcohols:

It reacts with alcohols to give alkyl chlorides and phosphoric acid.

Example:

$C_2H_5OH + PCl_5 \longrightarrow C_2H_5Cl + POCl_3 + HCl$

3. Reaction with Carboxylic Acids:

PCl_5 converts carboxylic acids into acid chlorides.

Example:

$CH_3COOH + PCl_5 \longrightarrow CH_3COCl + POCl_3 + HCl$

✦ **Summary:**

- PCl_3 and PCl_5 are both important chlorinating agents.
- PCl_3 forms phosphorous acid and acid chlorides.
- PCl_5 forms phosphoric acid, phosphoryl chloride, and alkyl or acid chlorides.

Both compounds are widely used in organic synthesis and industrial chemical preparation because of their strong chlorinating ability.

🌟 Q.10 Answer the following questions:

(i) Describe "Ring test" for the confirmation of the presence of nitrate ions in solution.

❖ **Answer:**

This test is used to confirm the presence of nitrate ions (NO_3^-) in a solution.

Procedure:

1. Take the test solution in a clean test tube.

2. Add freshly prepared ferrous sulfate ($FeSO_4$) solution.

3. Carefully pour concentrated H_2SO_4 along the side of the test tube so that it forms a separate layer below the aqueous solution.

4. A brown ring appears at the junction of two layers — confirming the presence of nitrate ions.

Chemical reactions:

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

$Fe^{2+} + NO \longrightarrow [Fe(H_2O)_5NO]^{2+}$ (brown ring complex)

Result:

Formation of the brown ring confirms nitrate ions.

(ii) N_2O_4 / NO_2 is a strong oxidizing agent. Prove the truth of this statement giving examples.

❖ **Answer:**

Nitrogen dioxide (NO_2) is a strong oxidizing agent because it readily accepts electrons and oxidizes other substances while being reduced to nitric oxide (NO) or nitrite (NO_2^-).

Examples:

1. $H_2S + 2NO_2 \longrightarrow S + 2NO + H_2O$

(Hydrogen sulfide is oxidized to sulfur)

2. $2KI + 2NO_2 \longrightarrow 2KNO_2 + I_2$

(Iodide is oxidized to iodine)

3. $2FeSO_4 + H_2SO_4 + 2NO_2 \longrightarrow Fe_2(SO_4)_3 + 2NO + H_2O$

(Ferrous ions oxidized to ferric ions)

Conclusion:

In all these reactions, NO_2 acts as an oxidizing agent and is reduced to NO.

(iii) Write down the chemical equations and names of the products formed as a result of the reaction of HNO_3 with arsenic and antimony.

❖ **Answer:**

Concentrated nitric acid oxidizes arsenic and antimony to their corresponding oxyacids.

Equations:

For Arsenic:

$As + 5HNO_3 \longrightarrow H_3AsO_4 + 5NO_2 + H_2O$

(**Product:** Arsenic acid)

For Antimony:

$Sb + 5HNO_3 \longrightarrow H_3SbO_4 + 5NO_2 + H_2O$

(**Product:** Antimonic acid)

Result:

Both reactions produce nitrogen dioxide gas and oxyacids of arsenic and antimony.

(iv) Give the methods of preparation of PCl_3.

❖ **Answer:**

Phosphorus trichloride (PCl_3) can be prepared by the following methods:

1. By direct combination:

$P_4 + 6Cl_2 \longrightarrow 4PCl_3$

(White phosphorus reacts directly with chlorine)

2. By action of thionyl chloride ($SOCl_2$):

$2P + 4SOCl_2 \longrightarrow 2PCl_3 + 2SO_2 + S_2Cl_2$

Note: PCl_3 can also react with chlorine to form PCl_5.

$PCl_3 + Cl_2 \longrightarrow PCl_5$

(v) P_2O_5 is a powerful dehydrating agent. Prove giving examples.

❖ **Answer:**

Phosphorus pentoxide (P_2O_5) has a great tendency to absorb water and hence acts as a powerful dehydrating agent.

Examples:

1. $P_2O_5 + 3H_2O \longrightarrow 2H_3PO_4$

(Formation of phosphoric acid — shows high affinity for water)

2. $2CH_3COOH + P_2O_5 \longrightarrow (CH_3CO)_2O + 2HPO_3$

(Acetic acid converted to acetic anhydride)

3. $C_2H_5OH \longrightarrow C_2H_4 + H_2O$ (in presence of P_2O_5)

(Alcohol dehydrated to alkene)

Result:

These reactions show that P_2O_5 removes water from other substances, proving it is a strong dehydrating agent.

✦ **Summary:**

Ring Test: Detects nitrate ions by forming a brown ring complex.

NO_2: Acts as a strong oxidizer forming NO.

HNO_3 with As/Sb: Produces their oxyacids and NO_2 gas.

PCl_3: Prepared by reacting phosphorus with chlorine or $SOCl_2$.

P_2O_5: Removes water from compounds, showing its strong dehydrating power.

🌟 Q.11 Complete and Balance the Following Chemical Equations

(i) Phosphorus and Nitric Oxide

Equation:

P + NO ⟶ ?

Balanced Equation:

$2P + 5NO_2 \longrightarrow P_2O_5 + 5NO$

Explanation: Phosphorus reacts with nitrogen oxides to form phosphorus pentoxide and nitric oxide.

(ii) Nitric Oxide and Chlorine

Equation:

$NO + Cl_2 \longrightarrow ?$

Balanced Equation:

$2NO + Cl_2 \longrightarrow 2NOCl$

Explanation: Chlorine reacts with nitric oxide to form nitrosyl chloride, a reddish-yellow gas.

(iii) Hydrogen Sulphide and Nitrogen Dioxide

Equation:

$H_2S + NO \longrightarrow ?$

Balanced Equation:

$H_2S + 2NO_2 \longrightarrow S + 2NO + H_2O$

Explanation: Sulphur is precipitated and nitric oxide is regenerated.

(iv) Lead Nitrate on Heating

Equation:

$Pb(NO_3)_2 \longrightarrow ?$

Balanced Equation:

$2Pb(NO_3)_2 \longrightarrow 2PbO + 4NO_2 + O_2$

Explanation: Thermal decomposition of lead nitrate forms lead oxide, nitrogen dioxide, and oxygen.

(v) Nitrogen Dioxide and Water

Equation:

$NO_2 + H_2O \longrightarrow ?$

Balanced Equation:

$2NO_2 + H_2O \longrightarrow HNO_3 + HNO_2$

Explanation: Nitrogen dioxide reacts with water to form nitric acid and nitrous acid.

(vi) Nitrogen Dioxide and Sulphuric Acid

Equation:

$NO_2 + H_2SO_4 \longrightarrow ?$

Balanced Equation:

$4NO_2 + 2H_2O + O_2 \longrightarrow 4HNO_3$

Explanation: Used in the industrial preparation of nitric acid during the Ostwald process.

(vii) Nitrous Acid and Hydroiodic Acid

Equation:

$HNO_2 + HI \longrightarrow ?$

Balanced Equation:

$2HNO_2 + 2HI \longrightarrow 2H_2O + 2NO + I_2$

Explanation: Nitrous acid oxidizes hydroiodic acid, liberating iodine.

(viii) Nitrous Acid and Ammonia

Equation:

$HNO_2 + NH_3 \longrightarrow ?$

Balanced Equation:

$HNO_2 + NH_3 \longrightarrow NH_4NO_2$

Explanation: The product, ammonium nitrite, decomposes easily into nitrogen gas and water.

(ix) Nitrous Acid and Urea

Equation:

$HNO_2 + CO(NH_2)_2 \longrightarrow ?$

Balanced Equation:

$2HNO_2 + CO(NH_2)_2 \longrightarrow 2N_2 + CO_2 + 3H_2O$

Explanation: Urea reacts with nitrous acid to evolve nitrogen gas.

(x) Potassium Nitrate and Sulphuric Acid

Equation:

$KNO_3 + H_2SO_4 \longrightarrow ?$

Balanced Equation:

$KNO_3 + H_2SO_4 \longrightarrow KHSO_4 + HNO_3$

Explanation: This reaction is used for laboratory preparation of nitric acid.

✦ **Summary:**

These reactions illustrate important transformations of nitrogen and oxygen compounds — including oxidation, reduction, and acid-base reactions. Many of them play a vital

role in the industrial preparation of nitric acid and other nitrogen compounds.

🌟 Q.12 Describe the methods of preparation of Phosphorus Pentoxide (P_2O_5) and explain its reactions.

❖ Introduction:

- **Phosphorus pentoxide** (P_2O_5) is a white, crystalline, non-volatile solid compound formed by the combustion of elemental phosphorus in excess oxygen.
- It is one of the most important **oxides of phosphorus** and is highly hygroscopic (absorbs moisture readily).

🔹 Preparation of Phosphorus Pentoxide

Method:

- Phosphorus pentoxide is prepared by burning white phosphorus in a current of dry air or oxygen.

Chemical Equation:

$$4P + 5O_2 \longrightarrow 2P_2O_5$$

Explanation:

- When white phosphorus is heated in a sufficient supply of dry oxygen, it burns with a bright white flame producing dense white fumes of phosphorus pentoxide.
- These fumes are collected and condensed in a cool, dry vessel to obtain the solid product.

Physical Appearance:

- White powdery solid
- Sublimes on heating
- Has a strong affinity for water (very hygroscopic)

🌡️ Reactions of Phosphorus Pentoxide

- Phosphorus pentoxide is a powerful dehydrating agent and reacts with water and other compounds very vigorously.

(1) Reaction with Water

It reacts exothermically with water to form phosphoric acid (H_3PO_4) or phosphorous acid (H_3PO_3) depending on the quantity of water used.

Equations:

(a) With excess water:

$P_2O_5 + 3H_2O \longrightarrow 2H_3PO_4$

(b) With limited water:

$P_2O_5 + H_2O \longrightarrow 2HPO_3$

Explanation:

Thus, phosphorus pentoxide can form various oxyacids of phosphorus.

(2) Reaction with Organic Compounds (Dehydrating Action)

Phosphorus pentoxide removes water from organic compounds.

Examples:

Converts alcohols into alkenes

$C_2H_5OH \longrightarrow C_2H_4 + H_2O$

Converts amides into nitriles

$RCONH_2 \longrightarrow RCN + H_2O$

Explanation:

In these reactions, P_2O_5 acts as a strong dehydrating agent, removing water molecules.

(3) Reaction with Sulphuric Acid

P_2O_5 dehydrates sulphuric acid to form sulphur trioxide (SO_3):

Equation:

$$P_2O_5 + H_2SO_4 \longrightarrow SO_3 + HPO_3$$

(4) Reaction with Hydrochloric Acid

When treated with concentrated HCl, phosphorus pentoxide produces phosphoryl chloride ($POCl_3$):

Equation:

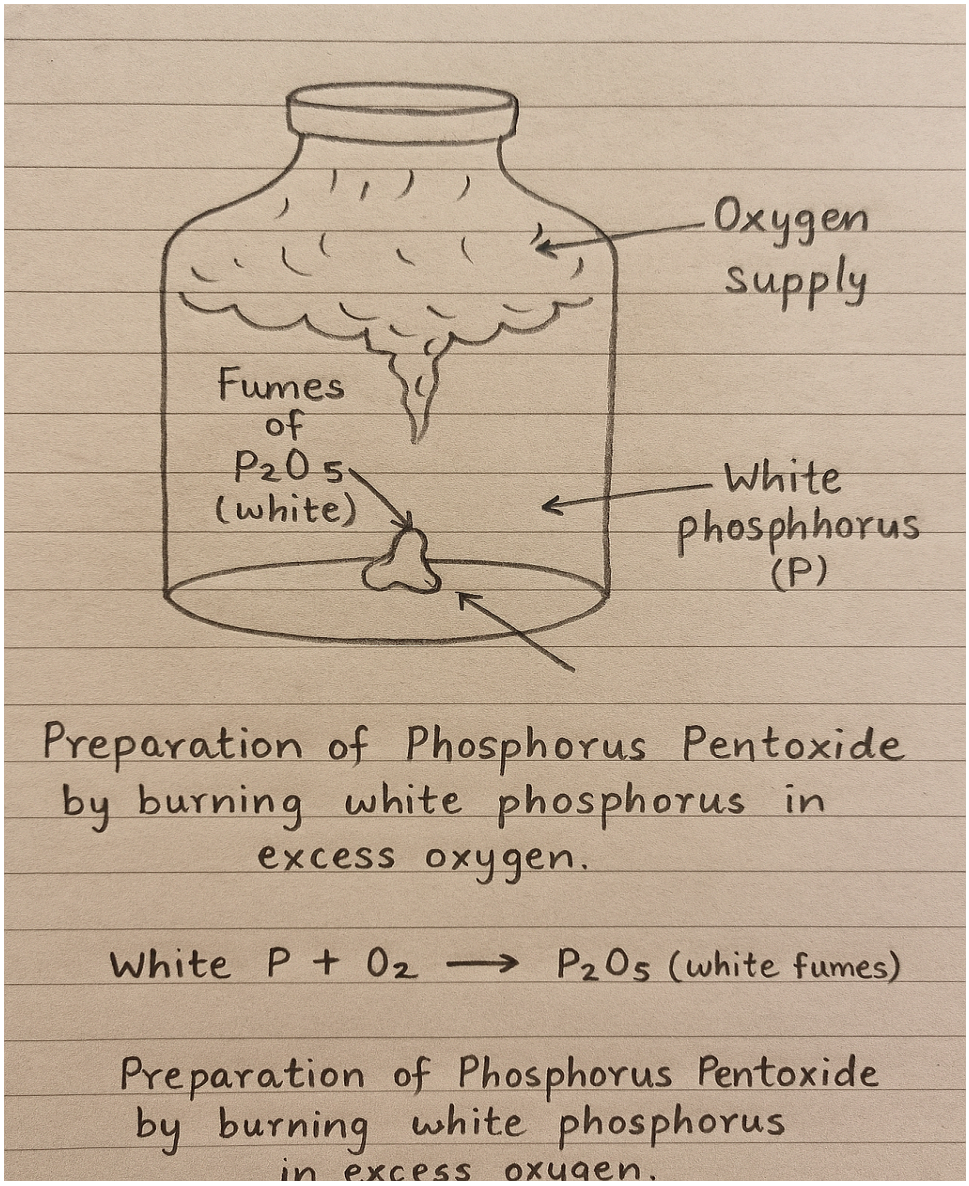
$$P_2O_5 + 6HCl \longrightarrow 2POCl_3 + 3H_2O$$

✦ **Properties Summary:**

- **Appearance:** White crystalline powder
- **Odour:** Odourless

- **Nature:** Acidic oxide
- **Solubility:** Reacts vigorously with water
- **Melting Point:** Sublimes without melting

✦ **Digram:**



Preparation of Phosphorus Pentoxide by burning white phosphorus in excess oxygen.

✦ **Summary:**

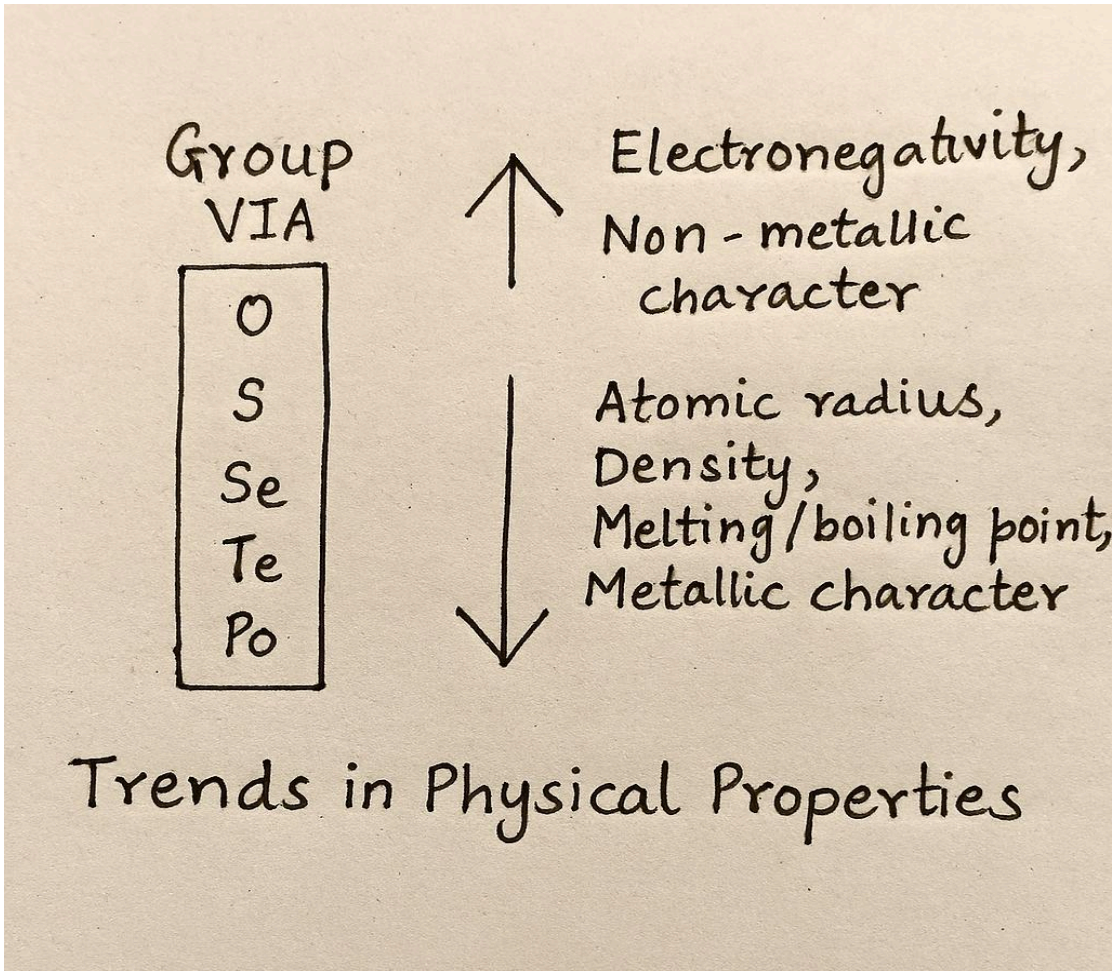
Phosphorus pentoxide (P_2O_5) is prepared by burning white phosphorus in dry oxygen. It is a powerful dehydrating agent, reacting violently with water to form phosphoric acid and removing water from organic and inorganic compounds. It also reacts with acids like H_2SO_4 and HCl forming SO_3 and $POCl_3$ respectively.

🌟 Q.13 Discuss the trends in physical properties of Group VIA elements.

❖ Introduction:

- Group VIA elements are oxygen family elements, also called chalcogens (from Greek “chalkos” meaning copper, because they occur in copper ores).
- This group includes Oxygen (O), Sulphur (S), Selenium (Se), Tellurium (Te), and Polonium (Po).
- These elements show a gradual change in their physical properties from top to bottom in the group due to increasing atomic number and metallic character.

✦ **Digram:**



1. Physical State

- Oxygen is a gas at room temperature.
- **Sulphur**, Selenium, and Tellurium are solids.
- Polonium is a radioactive metal.

👉 **Thus**, the physical state changes from gaseous (O) to metallic (Po) down the group.

2. Atomic and Ionic Radii

- The atomic and ionic radii increase from oxygen to polonium.
- This is due to the increase in the number of electron shells.

👉 **Trend**: O < S < Se < Te < Po

3. Melting and Boiling Points

- Both melting and boiling points increase down the group.
- This is because of increased atomic size and stronger intermolecular forces in heavier elements.

👉 **Example:**

O_2 (b.p. −183°C) < S_8 (b.p. 444°C) < Se < Te < Po

4. Density

- Density increases down the group.
- Heavier atoms are more tightly packed, so the elements become denser.

👉 **Trend**: O < S < Se < Te < Po

5. Electrical and Thermal Conductivity

- Oxygen and sulphur are non-conductors,
- Selenium and tellurium are semi-conductors,
- Polonium is a metallic conductor.

👉 The metallic character and conductivity increase down the group.

6. Colour and Appearance

Oxygen: Colourless gas

Sulphur: Yellow solid

Selenium: Red or grey solid

Tellurium: Silvery-grey solid

Polonium: Shiny metallic

👉 Colour becomes darker and metallic lustre increases down the group.

7. Allotropy

All members show allotropy (existence in different physical forms):

- Oxygen ⟶ O_2 and O_3 (ozone)
- Sulphur ⟶ Rhombic, monoclinic, and plastic
- Selenium ⟶ Red and grey forms
- Tellurium ⟶ Crystalline and amorphous
- Polonium ⟶ Two metallic allotropes

👉 The tendency for allotropy decreases down the group.

8. Solubility

- Oxygen is soluble in water to some extent.
- Solubility decreases from oxygen to polonium.

9. Electronegativity and Ionization Energy

- Both decrease down the group because atomic size increases and nuclear attraction decreases.
- Oxygen is the most electronegative element after fluorine.

👉 **Trend**: O > S > Se > Te > Po

✦ **Summary:**

In Group VIA elements:

- Atomic size, density, and metallic character increase down the group.
- Electronegativity, ionization energy, and solubility decrease.
- Physical state changes from non-metallic (O) to metallic (Po).
- Allotropy and covalent bonding are most prominent in lighter members.

Note:

This chapter is designed to provide a solid foundation of knowledge, with the goal of deepening understanding and encouraging further exploration of the subject. The content has been carefully selected to support effective learning and inspire students to engage with the topic more deeply.

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Purpose: To contribute to education by offering insightful, valuable content that enhances learning and understanding.