Chemistry Study Materials for Class 12

(NCERT Intext and Exercise Questions –Answers)

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The p-Block Elements

Question 1: Discuss the general characteristics of Group 15 elements with reference to their electronic configuration, oxidation state, atomic size, ionization and electronegativity.

Solution 1: General trends in group 15 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.

Question 2: Why does the reactivity of nitrogen differ from phosphorus?

Solution 2: Nitrogen is chemically less reactive. This is because of the high stability of its molecule, N2. In N2, 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.

Question 3: Discuss the trends in chemical reactivity of group 15 elements.

Solution 3: 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 EH3, 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: E203 and E205, 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: EX3 and EX5. However, nitrogen does not form NX5 as it lacks the d-orbital. All trihalides (except NX3) are stable,

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

Question 4: Why does NH3 form hydrogen bond but PH3 does not?

Solution 4: Hydrogen bond is always formed between highly electronegative atom and H atom. Nitrogen is highly electronegative compared to phosphorus as electronegativity decreases down the group. Hence, the extent of hydrogen bonding in PH3 is very less as compared to NH3.

Question 5: How is nitrogen prepared in the laboratory? Write the chemical equations of the reactions involved.

Solution 5: An aqueous solution of ammonium chloride is treated with sodium nitrite.

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

NO and HNO3 are produced in small amounts. These are impurities that can be removed on passing nitrogen gas through aqueous sulphuric acid, containing potassium dichromate.

Question 6: How is ammonia manufactured industrially?

Solution 6: Ammonia is prepared on a large-scale by the Haber's process.

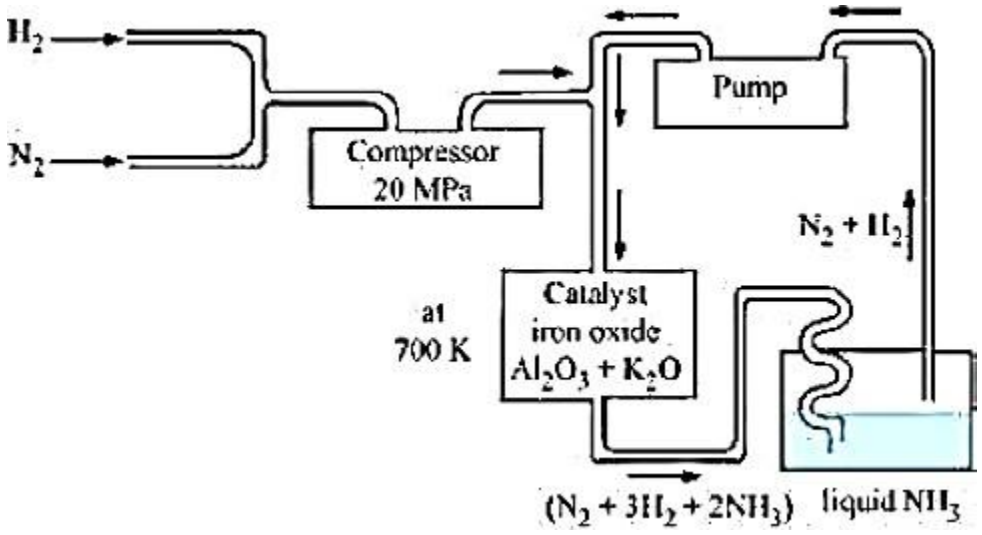
$$N_2(g) + H_2(g) \xrightarrow{f} 2NH_3(g) + 46.1kJmol^{-1}$$

The optimum conditions for manufacturing ammonia are:

(i) Pressure (around 200 ×105 Pa)

(ii) Temperature (4700 K)

(iii) Catalyst such as iron oxide with small amounts of $A1_2O_3$ and K_2O



Question 7: Illustrate how copper metal can give different products on reaction with HNO_3.

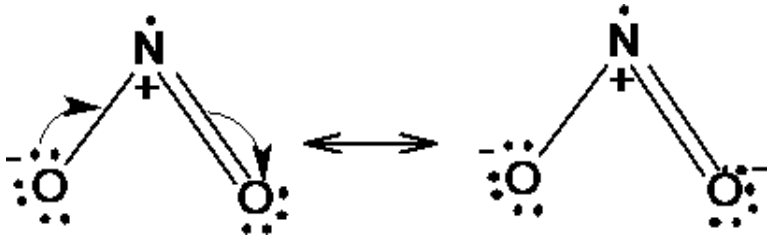
Solution 7: Concentrated nitric acid is a strong oxidizing agent It is used for oxidizing most metals. The products of oxidation depend on the concentration of the acid, temperature, and also on the material undergoing oxidation.

$$3Cu + 8HNO3(dilute) \longrightarrow 3Cu(NO3)2 + 2NO + 4H2O$$

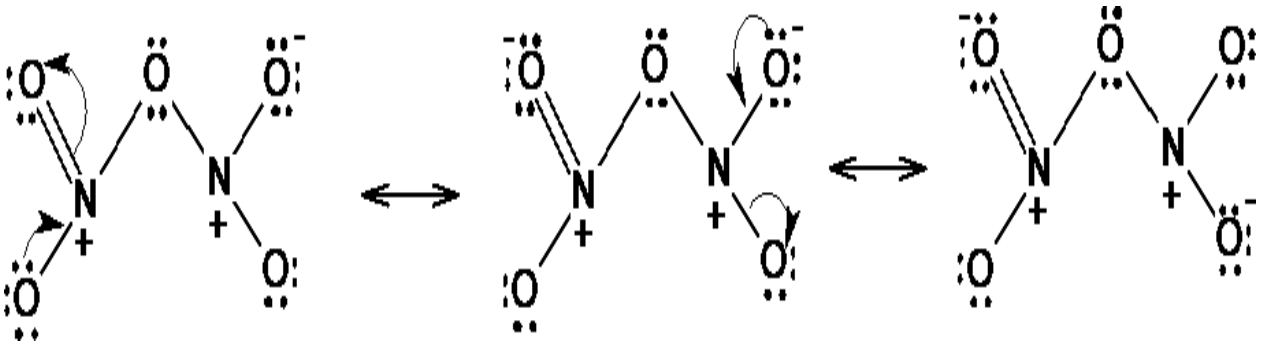
$$Cu + 4HNO3(conc) \longrightarrow Cu(NO3)2 + 2NO2 + 2H2O$$

Question 8: Give the resonating structures of NO_2 and N_2O_5

Solution 8: Resonating structures of **NO_2**



Resonating structures of N_2O_5



Question 9: 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 NH3 and only s-p bonding between hydrogen and other elements of the group].

Solution 9: Hydride NH3 PH3 AsH3 SbH3 H-M-H angle 107^0, 92^0, 91^0, 90^0

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.

Question 10: Why does R3P = 0 exist but R3N = 0 does not (R = alkyl group)?

Solution 10: N (unlike P) lacks the d-orbital. This restricts nitrogen to expand its coordination number beyond four. Hence, R3N = 0 does not exist.

Question 11: Explain why NH3 is basic while BiH3 is only feebly basic.

Solution 11: 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.

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