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.

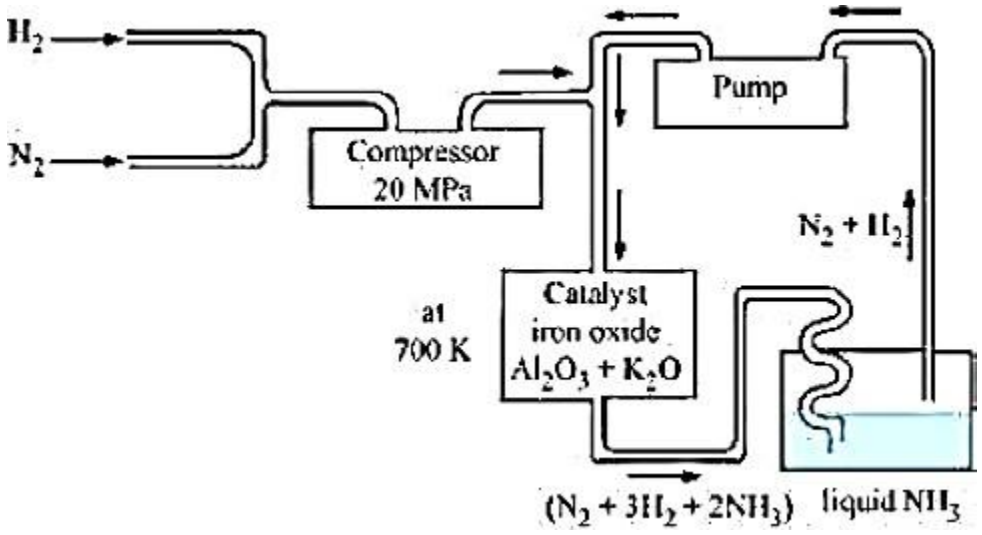
$$N_2(g) + H_2(g) \xrightarrow{f} 2NH_3(g) + 46.1kJmol^{-1}$$

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.

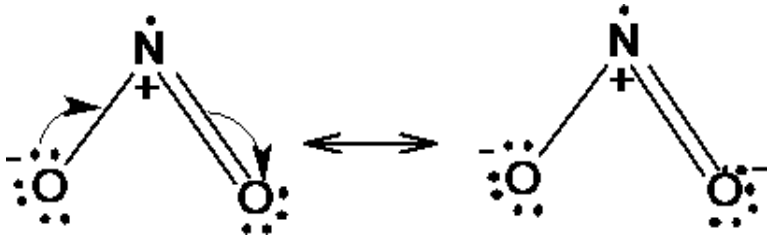
Solution 7: Concentrated nitric acid is a strong oxidizing agent It is used for oxidizing most metals. The products of oxidation depend on the concentration of the acid, temperature, and also on the material undergoing oxidation.

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

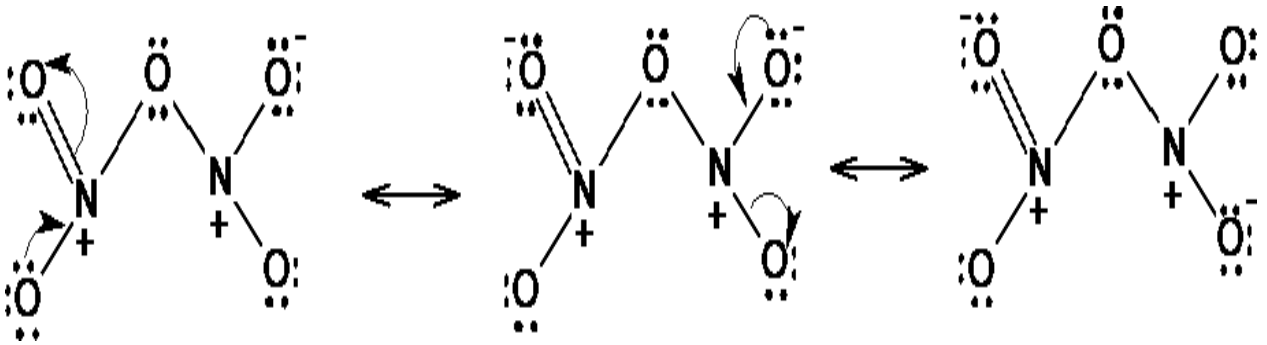
$$Cu + 4HNO3(conc) \longrightarrow Cu(NO3)2 + 2NO2 + 2H2O$$

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.

Question 12: Nitrogen exists as diatomic molecule and phosphorus as P4. Why?

Solution 12: Nitrogen owing to its small size has a tendency to form $p\pi - p\pi$ multiple bonds with it. Nitrogen thus forms a very stable diatomic molecule, N2. 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 P4 state**.**

Question 13: Write main differences between the properties of white phosphorus and red phosphorus.

Solution 13:

White phosphorus	**Red phosphorus**
It is a soft and waxy solid. It possesses a garlic small	It is hard and crystalline solid, without any small.
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
It is both solid and vapour states, it exists as a p_4 molecule	.It exists as a chain of tetrahedral p_4 units

Question 14: Why does nitrogen show catenation properties less than phosphorus?

Solution 14: 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.

Question 15: Give the Disproportionation reaction of H_3PO_3 .

Solution 15: On heating, orthophosphorus acid disproportionates to give orthophosphoric acid (H_3PO_3), (H_3PO_4) and phosphine (PH_3)

The oxidation states of P in the various species involved in reaction are mentioned below. +3, +5 and +3

$$4H_3PO_3 \longrightarrow 3H_3PO_4 + PH_3$$

Question 16: Can PCl_5 act as an oxidizing as well as a reducing agent? Justify.

Solution 16: PCl_5 can only act as an oxidizing agent. The highest oxidation state that P can show is+5. In PCl_5, phosphorus is in its highest oxidation state (+5). However, it can decrease its oxidation state and act as an oxidizing agent.

Question 17: 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.

Solution 17: 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: As these elements have six valence electrons ($ns^2\ np^4$), 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 (H_2O_2) , zero (O_2), 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.

(iii) The heavier elements of the group show an oxidation state of +2, +4, and +6 due to the availability of d-orbitals.

Question 18: Why is dioxygen a gas but sulphur a solid?

Solution 18: 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 O2 (O==O) molecule. Also, the intermolecular forces in oxygen are weak Vander Wall's, which cause it to exist as gas. On the other forces in oxygen are weak Vander Wall's, which cause it to exist as gas. On the other hand, sulphur does not form $p\pi - p\pi$ bonds but exists as a puckered structure held together by strong covalent bonds. Hence, it is a solid.

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