CHEMICAL BONDING - IV

Exercise # 1

PART - I : SUBJECTIVE QUESTIONS

Section (A) : Dipole moment

A-1. Inorganic benzene is more reactive than organic benzene. Why?

A-2. trans–1, 2 dichloro ethene have zero dipole moment while its cis- form has some dipole moment. Explain.

A-3. Why CCl_4 have zero dipole moment but $CHCl_3$ have some dipole moment ?

A-4. Arrange in increasing order of dipole moment ; H_2O, H_2S, BF_3.

A-5. Dipole moment of LiF was experimentally determined and was found to be 6.32 D. Calculate percentage ionic character in LiF molecule Li—F bond length is 156 pm.

Section (B) : Intermolecular forces of attraction and H-bonding

B-1. In which of the following the hydrogen bonding is strongest. Explain briefly ?
(A) O – H – – – S (ℓ) (B) S – H – – – O (ℓ) (C) F – H – – – F^- (s) (D) F – H – – – O (ℓ)

B-2. Why D_2O has higher viscosity than H_2O ?

Section (C) : Applications of H-bond

C-1. Why glucose, fructose, sucrose etc. are soluble in water though they are covalent compounds ?

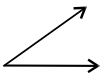
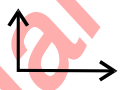
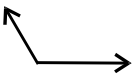
C-2. Ethanol has higher boiling point than diethyl ether. Why ?

PART - II : OBJECTIVE QUESTIONS

*** Marked Questions may have more than one correct options.**

Section (A) : Dipole moment

A-1. Which has maximum dipole moment ?

(A)  (B)  (C)  (D) 

A-2. Of the following molecules, the one, which has permanent dipole moment, is :
(A) SiF_4 (B) BF_3 (C) PF_3 (D) PF_5

A-3. Which of the following has the least dipole moment ?
(A) NF_3 (B) CO_2 (C) SO_2 (D) NH_3

A-4. Which of the following compounds possesses zero dipole moment?
(A) Benzene (C_6H_6) (B) Carbon tetrachloride
(C) Boron trifluoride (D) All of these

A-5. Which of the following statements is false for XeO_3F_2 ?
(A) Hybridisation of central atom xenon is sp^3d. (B) The compound is non-polar.
(C) The compound has $p\pi$-$d\pi$ bonding. (D) None.

A-6. The geometry of H_2S and its dipole moment are : **[JEE–1999, 2/80]**
(A) angular and non zero (B) angular and zero
(C) linear and non zero (D) linear and zero

A-7. Which of the following has been arranged in order of decreasing dipole moment ?

(A) $CH_3Cl > CH_3F > CH_3Br > CH_3I$ (B) $CH_3F > CH_3Cl > CH_3Br > CH_3I$

(C) $CH_3Cl > CH_3Br > CH_3I > CH_3F$ (D) $CH_3F > CH_3Cl > CH_3I > CH_3Br$

A-8. The gaseous HX molecule has a measured dipole moment of 4.0 D, which indicates that it is a very polar molecule. The separation between the nuclei in this molecule is 2.67×10^{-8} cm then the percentage ionic character in HX molecule is :

(A) 78% (B) 31.25% (C) 50.25% (D) None of these

A-9. The dipole moment of chlorobenzene is 1.73 D. The dipole moment of p-dichlorobenzene is expected to be :

(A) 3.46 D (B) 0.00D (C) 1.73 D (D) 1.00 D

Section (B) : Intermolecular forces of attraction and H-bonding

B-1. Which of the following is not correctly matched with respect to the intermolecular forces existing amongst the molecules (Hydrogen bonding is not taken as dipole-dipole attraction) ?

(A) Benzene – London dispresion forces

(B) Orthophosphoric acid – London dispresion force, hydrogen bonding.

(C) Hydrochloric acid – London dispresion force, dipole-dipole attraction

(D) Iodine monochloride – London dispersion force

B-2. Which of the following models best describes the bonding within a layer of the graphite structure ?

(A) metallic bonding (B) ionic bonding

(C) non-metallic covalent bonding (D) van der Waals forces

B-3. Which of the following factor is responsible for van der Waals forces ?

(A) Instantaneous dipole-induced dipole interaction.

(B) Dipole-induced dipole interaction and ion-induced dipole interaction.

(C) Dipole-dipole interaction and ion-induced dipole interaction.

(D) All of these.

B-4. Which of the following bonds/forces is weakest ?

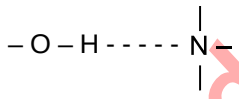
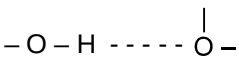
(A) Covalent bond (B) Ionic bond (C) Hydrogen bond (D) London force

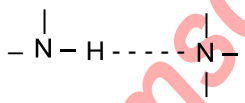
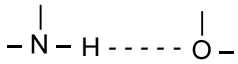
B-5. In which of the following compound, intra–molecular H–bonding is not observed :

(A) O–hydroxy benzyaldehyde (B) O–nitrophenol

(C) Chloral hydrate (D) Boric acid

B-6. Consider the following sets of H-bonds

P :  Q : 

R :  S : 

The correct order of H-bond strengths is :

(A) Q > P > S > R (B) R > Q > S > P

(C) R > S > P > Q (D) P > Q > R > S

B-7. Which of the following compounds would have significant intermolecular hydrogen bonding ?

HF, CH_3OH, N_2O_4, CH_4

(A) HF, N_2O_4 (B) HF, CH_4, CH_3OH

(C) HF, CH_3OH (D) CH_3OH, CH_4

Section (C) : Applications of H-bond

C-1. Amongst NH_3, PH_3, AsH_3 and SbH_3 the one with highest boiling point is :
(A) NH_3 because of lower molecular weight
(B) SbH_3 because of higher molecular weight
(C) PH_3 because of H-bonding
(D) AsH_3 because of lower molecular weight

C-2. Which of the following statement is not true ?
(A) CCl_4 has higher boling point that $CHCl_3$.
(B) The HF_2^- ion exists in the solid state and in liquid HF solution , but not in dilute aqueous solutions.
(C) Hydrogen bonding maintains the planar H_3BO_3 units in layers in solid state.
(D) None of these.

C-3. **S_1 :** In the solid $B(OH)_3$ units are hydrogen bonded together into two-dimensional sheets with almost hexagonal symmetry.
S_2 : Na_2CO_3 can be isomorphous with Na_2SO_3 as both have similar formula type.
S_3 : XeO_3F_2 has one lone pair of electron on central xenon atom.
S_4 : D_2O has higher boiling point than H_2O

(A) T F T F (B) T F F T (C) T T F F (D) T T T T

C-4. The correct order of boiling point is :
(A) $H_2O < H_2S < H_2Se < H_2Te$
(B) $H_2O > H_2Se > H_2Te > H_2S$
(C) $H_2O > H_2S > H_2Se > H_2Te$
(D) $H_2O > H_2Te > H_2Se > H_2S$

C-5. Which of the following compounds has the highest boiling point
(A) HCl (B) HBr (C) H_2SO_4 (D) HNO_3

C-6. Which is correct about D_2O
(A) Its boiling point is higher than that of H_2O (ℓ)
(B) O – D - - - - O bond is stronger than O – H - - - - O bond.
(C) D_2O(s) sinks in H_2O (ℓ).
(D) all the above are correct.

PART - III : ASSERTION / REASONING

Each question has 5 choices (A), (B), (C), (D) and (E) out of which ONLY ONE is correct.
(A) STATEMENT-1 is true, STATEMENT-2 is true and STATEMENT-2 is correct explanation for STATEMENT-1
(B) STATEMENT-1 is true, STATEMENT-2 is true and STATEMENT-2 is not correct explanation for STATEMENT-1
(C) STATEMENT-1 is true, STATEMENT-2 is false
(D) STATEMENT-1 is false, STATEMENT-2 is true
(E) Both STATEMENTS are false

1. **Statement-1 :** NF_3 has little tendency to act as a donor molecule.
Statement-2 : The highly electronegative F atoms attract electrons and these moments partly cancel the moment from the lone pair.

2. **Statement-1 :** Fluoromethane (CH_3F ; μ = 1.85 D) has a smaller dipole moment than chloromethane (CH_3Cl ; μ = 1.87 D)
Statement-2 : Fluorine has less electron affinity than that of chlorine.

3. **Statement-1 :** Acetylene is not soluble in H_2O but is highly soluble in acetone.
Statement-2 : Acetylene forms inter molecular H–bond with acetone easily but not with H_2O as water molecular themselves are highly associated through inter molecular H–bonds.

4. **Statement-1 :** Crystals of hydrated calcium sulphate (gypsum : ($CaSO_4 . 2H_2O$)) are soft and easily cleaved.
Statement-2 : Crystals of anhydrous calcium sulphate (anhydride : $CaSO_4$) are very hard and very difficult to cleave.

5. **Statement-1 :** In case of persulphuric acid, the $K_1 >> K_2$.
Statement-2 : The anion of persulphuric acid is intermolecular hydrogen bonded.

6. **Statement-1 :** Ortho boric acid crystal are hard and cannot be broken easily into the powder form.
Statement-2 : In the solid state $B(OH)_3$ units are hydrogen bonded together into two dimensional sheets.

7. **Statement-1 :** The crystal structures of $NaHCO_3$ and $KHCO_3$, both show intermolecular hydrogen bonding but are different.
Statement-2 : In $NaHCO_3$ the HCO_3^- ions are linked together through intermolecular hydrogen bonds into an infinite chain , while in $KHCO_3$, HCO_3^- ions form dimeric anions through intermolecular hydrogen bonds.

8. **Statement-1 :** Fluorine (F_2) is gas while iodine (I_2) is solid at room temperature.
Statement-2 : A larger molecule or heavy atom is more polarizable and has larger dispersion forces because it has many electrons some of which are less tightly held and are farther from the nucleus.

9. **Statement-1 :** Noble gases are liquefied at very low temperature. Hence they have low boiling points.
Statement-2 : Noble gases being monoatomic have no other interatomic forces except weak dispersion forces.

Exercise # 2

PART - I : SUBJECTIVE QUESTIONS

1. Why $CH_3 - O - H$ is having more dipole moment than $CH_3 - S - H$?

2. Out of trimethylamine and trimethyphosphine, which one has higher dipole moment ?

3. Benzene has zero dipole moment and therefore, experiences no dipole-dipole forces but it is a liquid rather than a gas at room temperature. Explain.

4. Br_2 and ICl have the same number of electrons but ICl has higher boiling point than Br_2. Why, explain ?

5. Explain why o-hydroxybenzaldehyde is a liquid at room temperature while p-hydroxybenzaldehyde is a high melting solid.

6. If bond length of HCl is 1.2 Å and dipole moment is (μ) = 1.44 D, then find the % covalent character in HCl ($q_e = 4.8 \times 10^{-10}$ esu)

7. Why CH_3Cl is having higher dipole moment than CH_3F ?

PART - II : OBJECTIVE QUESTIONS

Single choice type

1. **S_1 :** In CrO_5 , the oxidation number of Cr is +6.
S_2 : Out of CH_3Cl and $CHCl_3$, CH_3Cl has higher dipole moment
S_3 : Hybridisation of sulphur in SO_3 and in its trimer is the same, sp^2 .
(A) T F T (B) T T F (C) T F F (D) T T T

2. Among the XeF_2, SF_2Cl_2, $XeOF_2$, ICl_2^- , $IOCl_4^-$ and F_2ClO^{+1}
S_1 : XeF_2, ICl_2^- , $XeOF_2$ have zero dipole moment
S_2 : $IOCl_4^-$ and F_2ClO^{+1} have different electronic arrangement (geometry) at central atom
S_3 : SF_2Cl_2 , $IOCl_4^-$ and F_2ClO^+ have equal number of lone pairs of electrons at the central atom.
S_4 : All bond angle in each of species , $XeOF_4$, $IOCl_4^-$, SF_2Cl_2 and F_2ClO^+ are identical
The correct order for the above statements is :
(A) F T T F (B) F F F F (C) T T F F (D) T F T F

3. Which of the following would be expected to have a dipole moment of zero on the basis of symmetry?
(A) $SOCl_2$ (B) OF_2 (C) SeF_6 (D) ClF_5

4. If molecule MX_3 has Zero dipole moment, the hybrid orbitals used by M (Atomic No. < 21) are
(A) Pure p (B) sp hybrid (C) sp^2 hybrid (D) sp^3 hybrid

5. Given the species N_2, CO, CN^- and NO^+ . Which of the following statement is incorrect .
(A) All the species are diamagnetic (B) All the species are isoelectronic
(C) All the species have dipole moment (D) All the species are linear

6. Which of the following are incorrect for dipole moment ?
(A) Lone pair of elements present on central atom can give rise to dipole moment
(B) Dipole moment is vector quantity
(C) PF_5 (g) molecule has non zero dipole moment
(D) Difference in electronegativities of combining atom can lead to dipole moment

7. Which of the following orders are correct regarding mentioned properties
(A) $SO_3 < CCl_4 < XeF_2$ (Bond angle).
(B) $SOF_2 > SOCl_2 > SOBr_2$ (Bond angle)
(C) $CH_3COO^- > CO_3^{2-} > CH_3COCH_3$ (C — O bond length)
(D) $CH_3Cl > CH_3F < CD_3F$ (dipole moment).

8. CH_3Cl has more dipole moment than CH_3F because :
(A) electron affinity of chlorine is greater than that of fluorine.
(B) the charge separation is larger in CH_3Cl compared to CH_3F.
(C) the repulsion between the bond pairs and non-bonded pairs of electrons is greater in CH_3Cl than CH_3F.
(D) chlorine has higher electronegativity than fluorine.

9. **S_1 :** In ozone molecule, O – O bond lengths are equal, this can be explained on the basis of resonance.
S_2 : Ion-dipole attraction is responsible for hydration of ions.
S_3 : Intermolecular H-bonding decreases the boiling point.
S_4 : A symmetrical molecule with identical bonds have non zero dipole moment.
(A) T F T F (B) T T F T (C) T T F F (D) T T T F

10. H - bonding is maximum in
(A) C_6H_5OH (B) C_6H_5COOH (C) CH_3CH_2OH (D) CH_3COCH_3

11. Select the correct statement.
(A) The order of Xe–F bond length in various fluorides of Xenon is $XeF_2 < XeF_4 < XeF_6$
(B) PH_5 can undergo sp^3d hybridisation to have octahedral geometry.
(C) Dipole moment of CH_3F is greater than that of CH_3Cl
(D) Increasing strength of hydrogen bonding is Cl–H----Cl < N–H----N < O–H----O < F–H----F

12. Which of the following compounds would have significant intermolecular hydrogen bonding ?
HF, CH_3OH, N_2O_4, CH_4, $NH_3(\ell)$
(A) HF, N_2O_4, $NH_3(\ell)$ (B) HF, CH_4, CH_3OH (C) HF, CH_3OH, $NH_3(\ell)$ (D) CH_3OH, CH_4, $NH_3(\ell)$

13. Which one of the following does not have intermolecular H-bonding ?
(A) H_2O (B) o-nitro phenol (C) HF (D) CH_3COOH

14. The increasing order of the strength of hydrogen bond in the following mentioned linkages is :
(i) O—H---S (ii) S—H---O (iii) F—H---F (iv) F—H---O
(A) (i) < (ii) < (iv) < (iii) (B) (ii) < (i) < (iv) < (iii) (C) (i) < (ii) < (iii) < (iv) (D) (ii) < (i) < (iii) < (iv)

15. Give the correct order of initials T or F for following statements. Use T if statement is true and F if it is false.
S_1 : HF boils at a higher temperature than HCl
S_2 : HBr boils at lower temperature than HI
S_3 : Bond length of N_2 is less than N_2^+
S_4 : F_2 has higher boiling point than Cl_2
(A) T F T T (B) T T F F (C) T T T F (D) T T T T

16. **S_1 :** The polarising power of a cation and polarisability of an anion, both are directly proportional to their sizes.
S_2 : H_2^+ and He_2^+ have same bond order but H_2^+ is more stable than He_2^+ .
S_3 : The strength of hydrogen bond does not depend at all on the availability of the lone pair of electrons on the atom forming H-bond.
S_4 : OF_2 and Cl_2O both are sp^3 hybridised and bond angle in $C\ell_2O$ is greater than 109º28'.
(A) T F F T (B) F F F T (B) F T F T (D) T T T T

17. Which of the following has minimum melting point
(A) CsF (B) HCl (C) HF (D) LiF

18. **Consider the following statements.**
S_1 : The percentage of s-character in the orbital forming S – S bonds and P – P bonds in S_8 and P_4 molecules respectively are same.
S_2 : In SF_4 the bond angles, instead of being 90º and 180º are 89º and 177º respectively due to the repulsions between lone pair and bond pairs of electrons.
S_3 : Aqueous H_3PO_4 is syrupy (i.e more viscous than water)
S_4 : SiO_2 crystal may be considered as giant molecule in which eight-membered rings are formed with alternate silicon and oxygen atoms.
Of these :
(A) S_1 & S_4 are correct only. (B) S_2, S_3 & S_4 are correct only.
(C) S_1, S_2, S_3 & S_4 are correct. (D) S_1,S_2 & S_3 are correct only.

19. Select the correct statement for the sulphuric acid.
(I) It has high boiling point and viscosity.
(II) There are two types of bond lengths in its bivalent anion.
(III) $p\pi$-$d\pi$ bonding between sulphur and oxygen is observed.
(IV) Sulphur has the same hybridisation that is of boron in diborane.
(A) II and III only (B) II, III and IV only
(C) I, III and IV only (D) III and IV only

20. Intermolecular hydrogen bonding increases the enthalpy of vaporization of a liquid due to the :
(A) decrease in the attraction between molecules.
(B) increase in the attraction between molecules.
(C) decrease in the molar mass of unassociated liquid molecules.
(D) increase in the effective molar mass of hydrogen - bonded molecules.

More than one choice type

21. The halogen form compounds among themselves with formula XX′, XX'_3, XX'_5 and XX'_7 where X is the heavier halogen. Which of the following pairs representing their structures and being polar and non-polar are correct?
(A) XX′ – Linear – polar (B) XX'_3 – T-shaped – polar
(C) XX'_5 – square pyramidal – polar (D) XX'_7 – Pentagonal bipyramidal – non-polar

22. Which of the following is/are correct statement(s) for dipole moment ?
(A) Lone pair of electrons present on central atom can give rise to dipole moment.
(B) Dipole moment is vector quantity.
(C) CO_2 molecule has dipole moment.
(D) Difference in electronegativities of combining atoms can lead to dipole moment.

23. Which of the following molecules have intermolecular hydrogen bonds ?
(A) KH_2PO_4 (B) H_3BO_3
(C) $C_6H_2CO_2H$ (D) CH_3OH

24. Which is **correct** statement :
(A) Borazine has higher intermolecular force of attraction as compared to benzene.
(B) Ka_2 fumaric acid is more than Ka_2 of maleic acid due to intra molecular hydrogen bonding in maleic acid.
(C) The O – O bond length in $O_2[AsF_4]$ is shorter then KO_2.
(D) The bond angle order in halogen – S – halogen is $OSF_2 < OSCl_2 < OSBr_2$

25. Select the correct statement(s).
(A) Br_2 and ICl have the same number of electrons and thus both have nearly the same boiling points.
(B) N_2H_4 is pyramidal about each N-atom.
(C) In P_4S_3 molecule, there are six P-S bonds, three P-P bonds and ten lone pairs of electrons (on all atoms).
(D) In ClO_4^-, all Cl – O bonds are identical and there is strong $p\pi - d\pi$ bonding between chlorine and oxygen atoms.

26. Which of following is correct

(A) $PH_3 < AsH_3 < SbH_3 < NH_3$	order of boiling point
(B) $D_2O(s) > H_2O(\ell)$	order of density
(C) Mn > Ca > Sr > Rb	order of metallic bond strength
(D) $H_2 < CO_2 < H_2O$	increasing order of intermolecular forces of attraction

PART - III : MATCH THE COLUMN

1.

Column – I	**Column – II**
(A) SO_3 (gas)	(p) Polar with $p\pi$–$d\pi$ bonds and identical S–O bond, lengths.
(B) OSF_4	(q) One lone pair and $p\pi - d\pi$ bond.
(C) SO_3F^-	(r) Non–polar with $p\pi - p\pi$ and $p\pi - d\pi$ bonds. Identical S–O bond lengths.
(D) $ClOF_3$	(s) Polar with $p\pi - d\pi$ bond.

2.

Column – I	**Column – II**
(A) IF_2^-	(p) sp^3d
(B) ClF_3	(q) polar
(C) XeO_3F_2	(r) one of the bond angles is 180^0 .
(D) SF_4	(s) one lone pair

3.

Column-I	**Column-II**
(A) HCl < HF	(p) Strength of hydrogen bonding
(B) $PH_3 < NH_3$	(q) Dipole moment
(C) $H_2O < D_2O$	(r) Boiling point
(D) $F_2 < Cl_2$	(s) Bond energy

4.

Column-I	**Column-II**
(A) Blue vitriol	(p) Ionic bond
(B) Gypsum	(q) Covalent bond
(C) Pure orthophosphoric acid	(r) Hydrogen bond
(D) Chloral hydrate	(s) Resonance stabilisation

5.

Column-I	**Column-II**
(A) Liquid bromine	(p) Hydrogen bond
(B) Solid hydrogen fluoride	(q) Ion-dipole force
(C) Solution of sodium fluoride in water	(r) Dispersion force.
(D) Liquid methylamine	(s) Dipole induced dipole interaction.
(E) Noble gas clathrate.	

PART - IV : COMPREHENSION

COMPREHENSIONS :

Read the following passage carefully and answer the questions.

Comprehension : 1

The degree of polarity of a covalent compound is measured by the dipole moment (μ_{bond}) of the bond defined as:

μ_{bond} = Charge on one of the poles $\times$ bond length

μ_{bond} is a vector quantity. The dipole moment of a molecule is the vector addition of all the bond dipole moments present in it. For a triatomic molecule, containing two bond's like H_2O, $\mu_{molecule}$ is given by

$$\mu^2_{molecule} = \mu^2_{bond} + \mu^2_{bond} + 2\mu_{bond} \cdot \mu_{bond} \cos\theta$$

θ = bond angle

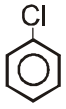
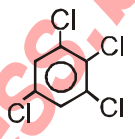
The % ionic character of a bond is calculated using the equations

$$\% \text{ ionic character} = \frac{\mu_{obs}}{\mu_{ionic}} \times 100$$

μ_{ionic} = dipole moment when the molecule is assumed to be completely ionic.

1. Which of the follwing molecule has non-zero dipole moment :

(A) XeF_2 (B) ClF_3 (C) XeO_2F_4 (D) XeF_4

2. The dipole moment of  is 1.5 D. The dipole moment of  will be -

(A) 0 D (B) 1.5 D (C) 2.86 D (D) 2.25 D

3. Which of the following compound has Zero dipole moment -

(A) PCl_3 (B) PCl_2F_3 (C) PCl_3F_2 (D) $PClF_4$

Comprehension : 2

Molecular geometry is the general shape of a molecule as determined by the relative positions of the atomic nuclei. VSEPR model predicts the shape of the molecules & ions in which valence shell electron pairs are arranged about the atom as far away from one another as possible, thus minimizing pair repulsion information about the geometry of a molecule can sometimes be obtained from an experimental quantity called dipole moment.

4. The dipole moment of a triatomic molecule AX_2 was found to be equal to the bond moment of A – X bond. Which of the following information regarding geometry of the molecule can be drawn from the above observation.

(A) Molecule is linear

(B) Molecule is V shaped with $\angle$ X – A – X = 90°

(C) Molecule is V shaped with $\angle$ X–A–X = 120°

(D) Molecular geometry can not be predicted with the given information

5. Which of the following inter-halogen compounds is non-polar in nature:

(A) ClF_3 (B) BrF_5 (C) IF_7 (D) BrCl

Comprehension : 3

Nitrogen, oxygen and fluorine are the higly electronegative elements. When they are tied to a hydrogen atom to form covalent bond , the electrons of the covalent bond are shifted towards the more electronegative atom. This partially positively charged hydrogen atom forms a bond with the other electronegative atom. This bond is called as hydrogen bond and is weaker than covalent bond. For example, in HF molcule, the hydrogen bond exists between hydrogen atom of one molecule and fluorine atom of another molecule as depicted :

$– – – H^{\delta+} – F^{\delta-}$ $– – – H^{\delta+} – F^{\delta-}$ $– – – H^{\delta+} – F^{\delta-}$

Here, hydrogen bond acts as a bridge between atoms which holds one atom by covalent bond and the other by hydrogen bond. Hydrogen bond is represented by a dotted line (– – –) while a solid line represents the covalent bond. Thus, hydrogen bond can be defined as the attractive force which binds hydrogen atom of one molecule with the electronegative atom (F, O or N) of another molecule.

6. What would be correct about bonding in chloral hydrate $CCl_3CH(OH)_2$?
(A) Only intra molecular H-bonding (B) Only inter molecular H-bonding
(C) Both inter and intra molecular H-bonding (D) No hydrogen bonding

7. If boiling point of ortho–nitro phenol and para nitro phenol are t_1 and t_2 respectively and mixture of these two are heated at temperature 't' where 't' is between these two temperature. Vapours will contains
(A) Only ortho nitro phenol (B) Only para nitro phenol
(C) Both ortho and para nitro phenol (D) None of these

8. What statement is **incorrect** about D_2O (solid)
(A) It will float in D_2O liquid
(B) It will sink in H_2O liquid
(C) It has maximum density at 4°C
(D) It has less volume than H_2O solid for same mass of both compound.

Exercise # 3

PART - I : IIT-JEE PROBLEMS (LAST 10 YEARS)

*** Marked Questions may have more than one correct option.**

1. Amongst H_2O, H_2S, H_2Se and H_2Te the one with highest boiling point is : **[JEE–2000, 1/35]**
(A) H_2O because of H-bonding. (B) H_2Te because of higher molecular weight.
(C) H_2S because of H-bonding. (D) H_2Se because of lower molecular weight.

2. Identify the correct order of boiling points of the following compounds : **[JEE–2002, 3/90]**

$CH_3CH_2CH_2CH_2OH$ (1) $CH_3CH_2CH_2CHO$ (2) $CH_3CH_2CH_2COOH$ (3)

(A) 1 > 2 > 3 (B) 3 > 1 > 2 (C) 1 > 3 > 2 (D) 3 > 2 > 1

3. The number of water molecule (s) directly bonded to the metal centre in $CuSO_4.5H_2O$ is : **[JEE–2009, 4/160]**

PART - II : AIEEE PROBLEMS (LAST 10 YEARS)

1. An ether is more volatile than an alcohol having the same molecular formula. This is due to: **[AIEEE-2003]**
(A) dipolar character of ethers. (B) alcohols having resonance structures.
(C) inter-molecular hydrogen bonding in ethers. (D) inter-molecular hydrogen bonding in alcohols.

2. Which of the following pair of molecules will have permanent dipole moments for both members? **[AIEEE-2003]**
(A) SiF_4 and NO_2 (B) NO_2 and CO_2 (C) NO_2 and O_3 (D) SiF_4 and CO_2

3. The states of hybridization of boron and oxygen atoms in boric acid (H_3BO_3) are respectively : **[AIEEE-2004]**
(A) sp^2 and sp^2 (B) sp^2 and sp^3 (C) sp^3 and sp^2 (D) sp^3 and sp^3

4. Which of the following hydrogen bonds is the strongest ? **[AIEEE-2007, 3/120]**
(A) O – H ... O (B) O – H ... F (C) F – H ... H (D) F – H ... F

5. What is the best description of the change that occurs when $Na_2O(s)$ is dissolved in water ? **[AIEEE-2011, 4/120]**
(A) Oxide ion accepts sharing in a pair of electrons
(B) Oxide ion donates a pair of electrons
(C) Oxidation number of oxygen increases
(D) Oxidation number of sodium decreases

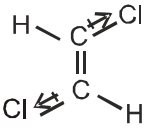
Answers

EXERCISE - 1

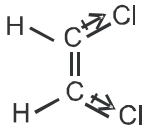
PART-I

A-1. Inorganic benzene ($N_3B_3H_6$) contains polar covalent B – N bonds while benzene (C_6H_6) contains non-polar covalent C–C bonds.

A-2.



trans-form
Two chlorine atom lie opposite direction, so net dipole moment will be zero



cis-form
Two chlorine atom lie on the same side of C = C. So there will be some net dipole moment

A-3. CCl_4 is a symmetrical and non polar molecule while $CHCl_3$ is an unsymmetrical and polar molecule.

A-4. $BF_3 < H_2S < H_2O$.

A-5. 84.5%

B-1. Very strong hydrogen bonding occurs in the alkali metal hydrogen fluorides of formula $M[HF_2]$; there is a liner symmetrical anion having an over all, F–H–F distance of 2.26 Å.

$[F - H - - - F]^- \longleftrightarrow [F - - - H - F]^-$

$F^- + HF \longrightarrow [FHF]^-$; $\Delta H = -161 \pm 8$ kJ mol^{-1}

B-2. Deuterium is more electropositive than hydrogen. Therefore, stronger H-bonding is found in D_2O than in H_2O. D_2O is also denser than H_2O.

C-1. These compounds contain polar–OH groups which can form H-bonds with water.

C-2. In ethanol, there is H-bonding but in diethyl ether, there is no H-bonding (because O-atom is attached to C-atom) but there exists weak dipole-dipole attraction in diethyl ether.

PART-II

A-1.	(A)	**A-2.**	(C)	**A-3.**	(B)	**A-4.**	(D)	**A-5.**	(D)
A-6.	(A)	**A-7.**	(A)	**A-8.**	(B)	**A-9.**	(B)	**B-1.**	(D)
B-2.	(C)	**B-3.**	(D)	**B-4.**	(D)	**B-5.**	(D)	**B-6.**	(D)
B-7.	(C)	**C-1.**	(B)	**C-2.**	(D)	**C-3.**	(B)	**C-4.**	(D)
C-5.	(C)	**C-6.**	(D)						

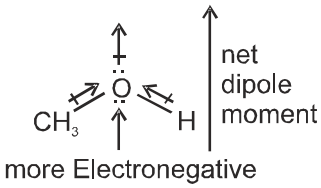
PART-III

1.	(A)	**2.**	(B)	**3.**	(A)	**4.**	(B)	**5.**	(C)
6.	(D)	**7.**	(A)	**8.**	(A)	**9.**	(A)		

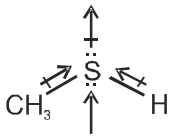
EXERCISE - 2

PART-I

1. $CH_3 - O - H$ is having more dipole moment than $CH_3\ddot{S}H$ because in $CH_3\ddot{O}H$ the central oxygen atom is more electronegative then sulphur atom. So net dipole moment is more in $CH_3\ddot{O}H$.

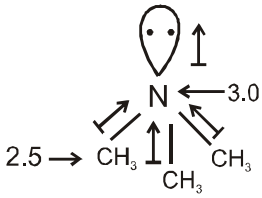


more Electronegative

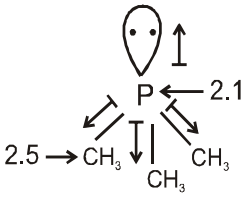


Less. Electronegative
then Oxygen

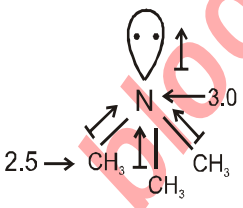
2. Nitrogen is more electronegative than phosphorus.



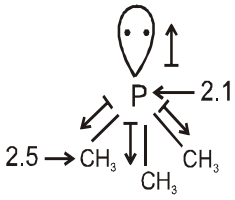
μ = 5.02 D



μ = 1.19 D



μ = 5.02 D

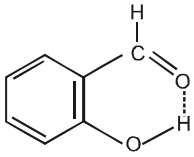


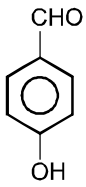
μ = 1.19 D

So, dipole moment of trimethylamine is greater than trimethy phosphine.

3. Benzene molecules are held together by dispersion London forces (a type of van der Waal's forces)

4. ICl has dipole - dipole attraction due to polar nature but Br_2 being non-polar experiences very weak dispersion London forces.

5. 

o-hydroxy benzaldehyde has intramolecular H-bonding, hence, it does not associate with other molecules to significant extent. Therefore, it exists in liquid state. However, in 

, due to intermolecular H-bonding, there is association of molecules leading to solid state.

6. 80% covalent

7. Dipole moment is product of charge and the bond length. In CH_3F the charge is higher but due to greater bond length in CH_3Cl the dipole moment comes out to be higher (remember as a fact)

PART-II

1.	(B)	**2.**	(A)	**3.**	(C)	**4.**	(C)	**5.**	(C)
6.	(C)	**7.**	(D)	**8.**	(B)	**9.**	(C)	**10.**	(B)
11.	(D)	**12.**	(C)	**13.**	(B)	**14.**	(A)	**15.**	(B)
16.	(B)	**17.**	(B)	**18.**	(C)	**19.**	(C)	**20.**	(B)
21.	(A,B,C,D)	**22.**	(A,B,D)	**23.**	(A,B,C,D)	**24.**	(A,B,C,D)	**25.**	(B,C,D)
26.	(B,C,D)								

PART-III

1. (A – r) ; (B – s) ; (C – p) ; (D – q)

2. (A – p , r) ; (B – p , q) ; (C – p , r) ; (D – p , q , s)

3. (A – p, q, r, s) ; (B – p, q, r, s) ; (C – p, q, r, s) ; (D – r, s)

4. (A – p, q, r, s); (B – p, q, r, s); (C – q, r); (D – q, r)

5. (A – r) ; (B – p, q, r) ; (C – p, q, r) ; (D – p, r) ; (E – p, r, s).

PART-IV

1.	(B)	**2.**	(B)	**3.**	(C)	**4.**	(C)	**5.**	(C)
6.	(A)	**7.**	(A)	**8.**	(C)				

EXERCISE - 3

PART-I

1.	(A)	**2.**	(B)	**3.**	4

PART-II

1.	(D)	**2.**	(C)	**3.**	(A)	**4.**	(D)	**5.**	(B)

Advanced Level Problems

PART - I : OBJECTIVE QUESTIONS

Single choice type

1. Among the following compounds the one that is polar and has central atom with sp^3 hybridisation is :
(A) H_2CO_3 (B) SiF_4 (C) BF_3 (D) $HClO_2$

2. Which of the following are polar
(A) XeF_4 (B) SO_3 (C) $XeOF_4$ (D) ICl_4^-

3. Which of the following statemets is true?
(A) The dipole moment of NF_3 is zero
(B) The dipole moment of NF_3 is less than NH_3
(C) The dipole moment of NF_3 is more than NH_3
(D) The dipole moment of NH_3 is zero

4. Among the following compounds, the correct order of the polarity of the bonds is :
SbH_3 , AsH_3 , PH_3 , NH_3 .
(A) $SbH_3 < AsH_3 < PH_3 < NH_3$
(B) $AsH_3 < SbH_3 = PH_3 < NH_3$
(C) $PH_3 < AsH_3 < SbH_3 < NH_3$
(D) $AsH_3 < PH_3 < SbH_3 < NH_3$

5. Among the following, van der Waals forces are maximum in :
(A) HBr (B) LiBr (C) LiCl (D) AgBr

6. Intermolecular hydrogen bond is present in which of the following pair of molecules ?
(A) SiH_4 and SiF_4
(B) $CH_3-\overset{\overset{O}{\|}}{C}-CH_3$ and $CHCl_3$
(C) $H-\overset{\overset{O}{\|}}{C}-OH$ and $CH_3-\overset{\overset{O}{\|}}{C}-OH$
(D) CH_3OCH_3 and H_2O_2

7. Which of the following exhibits H-bonding ?
(A) CH_4 (B) H_2Se (C) N_2H_4 (D) H_2S

8. Bicarbonate (HCO_3^-) exists in $KHCO_3$ and $NaHCO_3$ respectively as :
(A) Dimeric and polymeric chain like structure.
(B) Polymeric chain and dimeric structure.
(C) Dimeric and trimeric structure.
(D) Trimeric and dimeric structure.

9. Covalent compounds have low melting point because
(A) Covalent bond is less exothermic
(B) Covalent molecules have definite shape
(C) Covalent bond is weaker than ionic bond
(D) Covalent molecules are held by weak Vander Waal's force of attraction

10. $SnCl_2.2H_2O$ readily loses one molecule of water at 80^0 C because :
(A) One water molecule is coordinated to lone pair of electrons on $SnCl_2$ and the other is hydrogen bonded to coordinated water molecule.
(B) One water molecule is bonded to $SnCl_2$ by coordinate covalent bond and the other is held by ion-dipole attractive forces to central metal ion.
(C) Both the water molecules are coordinated to lone pairs of electrons on pyramidal $SnCl_2$.
(D) Both the water molecules are bonded to pyramidal $SnCl_2$ by hydrogen bonds.

11. The pairs of bases in DNA are held together by
(A) Hydrogen bonds (B) Ionic bonds (C) Phosphate groups (D) Deoxyribose groups

12. The bond that determines the secondary structure of a protein is
(A) Coordinate bond (B) Covalent bond (C) Hydrogen bond (D) Ionic bond

13. Pure phosphoric acid is very viscous, because :
(A) It is a strong acid (B) It is tribasic acid (C) It is hygroscopic
(D) It has PO_4^{3-} groups which are bonded by many hydrogen bonds

14. Which of the following is least volatile ?
(A) HF (B) HCl (C) HBr (D) HI

15. Which of the following is false ?
(A) Van der Waals forces are responsible for the formation of molecular crystals.
(B) Branching lowers the boiling points of isomeric organic compounds due to reduction in the van der Waals force of attraction.
(C) In graphite, van der Waals forces act between the carbon layers.
(D) Boiling point of NH_3 is greater than SbH_3.

More than one choice type

16. Which of the following statements is/are correct :
(A) Individual oxidation number of two sulphur atoms in thiosulphate ($S_2O_3^{2-}$) ion are +4 and 0, however the average oxidation number of sulphur is +2.
(B) The reason for $Ka_2 <<< Ka_1$ for peroxymonosulphuric acid is, intramolecular H–bonding in the anion of acid after first ionisation.
(C) NH_3 has a higher boiling point than SbH_3, because of H–bonding between NH_3 molecules.
(D) Among HCl, HBr and HI, HI is the strongest acid while HCl is the weakest acid while among HOCl, HOBr and HOI, HOCl is the strongest acid while HOI is the weakest acid.

17. Which of the following are polar ?
(A) XeF_4 (B) XeF_6 (C) $XeOF_4$ (D) XeF_5^-

18. Which of the following statement(s) is/are correct?
(A) Ethyne gas is more soluble in acetone than in water.
(B) CH_3F is more polar than CD_3F due to deuterium (D) being less electronegative than hydrogen (H).
(C) Silyl isocyanate (SiH_3NCO) is linear in shape while methyl isocyanate (CH_3NCO) is bent in shape.
(D) All of these

19. Which of the following statements is **correct** regarding phosphoric acid ?
(A) $p\pi$–$d\pi$ back bonding exist between O and P
(B) The anion is resonance stablized
(C) It is a dibasic acid
(D) Inter molecular H bonding between molecules make it a syrupy (viscous) liquid.

20. The critical temperature of water is higher than that of O_2 because the H_2O molecule has :
(A) fewer electrons than O_2 (B) two covalent bonds
(C) V - shape (D) dipole moment

PART - II : SUBJECTIVE QUESTIONS

1. Which among the following will have zero dipole moment.

H_2O, CO_2, BF_3, NH_3

2. Out of the given bonds, which one is most polar?

(a) C–O (b) C–F (c) O–F (d) N–F

3. HF forms H-bonding with acetylene while it is a non polar molecule. Explain.

4. It is said that two –OH groups present on a carbon are unstable. But choral hydrate $CCl_3CH(OH)_2$ is fairly stable. Explain.

5. Thio - ethers have higher boiling point than ethers. Explain.

6. Two atoms A and B have electronegativities as 2.1 and 3.5. These two atoms are covalently single bonded and compound AB has experimental dipole moment equal to 1.4 D. Calculate AB bond length in Å(Use Hanny smith formula for calculation of percentage ionic character).

7. Dipole moment of LiF was experimentally determined and was found to be 6.0 D. Calculate percentage of ionic character in LiF molecule. LiF bond length is 2.5 Å.

8. The gaseous mettalic chloride (MCℓ type) molecule has a measured dipole moment of 9.0 D, which indicates that it is a very polar molecule. The separation between the nuclei in this molecule is 2.25×10^{-8} cm. Calculate the percentage ionic character in KCl molecule. [1.6×10^{-19}, C = 4.8×10^{-10} esu]

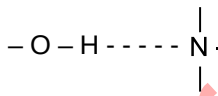
9. The bond angle in H_2S is 97º and its dipole moment is 1.5 D. The S – H bond distance is 0.15 nm. Therefore, approximate percentage ionic character of S – H bond is (neglect the effect of dipole moment of lone pair on sulphur atom in H_2S). (Given [cos 97º = – 0.12] and $\sqrt{0.88}$ = 0.94)

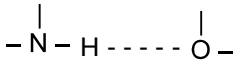
10. Arrange the following in the increasing order as stated below :

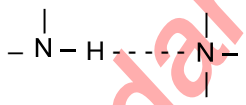
(i) Polarisibility (for the same cation) : O^{2-}, F^-, N^{3-}

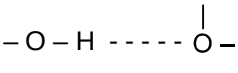
(ii) Covalent character : LiI, LiBr, LiF

(iii) H-bond strength :

P : 

Q : 

R : 

S : 

(iv) Boiling point : NH_3, AsH_3, PH_3

11. Answer the following questions :

(P) The number of $p\pi$-$d\pi$ bonds in S_3O_9.

(Q) The bond order of the underlined species ; $\underline{NO}HSO_4$.

(R) The number of vacant hybrid orbitals which participate in the formation of 3-centre 2 electron bonds i.e., banana bonds in diborane structure.

(S) The number of intramolecular H-bonds formed in a molecule of chloral hydrate.

(P)	(Q)	(R)	(S)

12. The dipole moment of HBr is 2.60×10^{-30} Cm and the inter-atomic distance is 1.41 Å. What is the per cent ionic character of HBr ?

13. A diatomic molecule has a dipole moment of 1.2 D. If bond length is 1.0 Å, what percentage of an electronic charge exists on each atom.

14. Arrange the following

(i) N_2, O_2, F_2, O^+_2; in increasing order of bond dissociation energy.

(ii) O, S, F, Cl, N; in increasing strength of hydrogen bonding (X – H – – – X).

(iii) N_3^-, BF_3, NH_3, XeF_4. in increasing bond angle.

15. Explain the H-bonding in crystalline $NaHCO_3$ and $KHCO_3$?

16. The dipole moment of a molecule is really the vectorial sum of the individual bond moment present in it. To compute the dipole moment it is necessary to find out the values of various bond moment. in the following table dipole moment of different bonds are as given.

Bond	$\overrightarrow{H—C}$	$\overrightarrow{C—Cl}$	$\overrightarrow{C=O}$
Bond moments	0.4 D	1.5 D	2.5 D

The group moments of few group as given

Group	NO_2	OH	CN	CH_3
direction of dipole	toward N	towards O	toward N	away from CH_3
Dipole moment	4D	1.6 D	3.8 D	0.4 D

(i) In CH_3CCl_3 (I), $CHCl_3$ (II) and CH_3Cl (III) the normal tetrahedral bond angle is maintained. Also given $\cos 70.5^\circ = \frac{1}{3}$. Find dipole moments of the given compounds. (given due to – I effect of Cl, the Bond moment of H—C bond directed toward the H in $CHCl_3$)

(ii) In the acetone molecule considering the normal planer structure, find the observed dipole moment of acetone molecule.

Answers

PART-I

1.	(D)	**2.**	(C)	**3.**	(B)	**4.**	(C)	**5.**	(D)
6.	(C)	**7.**	(C)	**8.**	(A)	**9.**	(D)	**10.**	(A)
11.	(A)	**12.**	(C)	**13.**	(D)	**14.**	(A)	**15.**	(D)
16.	(B, D)	**17.**	(B, C)	**18.**	(A, C)	**19.**	(A,B,D)	**20.**	(D)

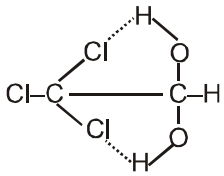
PART-II

1. CO_2 $:\overset{\leftarrow}{O}=C=\vec{O}:$ and BF_3

2. C–F bond is most polar due to maximum difference in electronegativity.

3. H–C≡ C– H sp Hybridisation.
Due to sp hybridisation of C atom, the electronegativity of C is more and hence can form H-bond with HF.

4. The structure of chloral hydrate is a follows



Its stability is due to intermolecular H-bonding.

5. Thio-ethers have higher boiling points due to their higher molecular weights than that of ethers.

6. 1 Å **7.** 50%. **8.** 83.33% **9.** 16 %

10. (i) $N^{3-} > O^{2-} > F^-$ (ii) LiI > LiBr > LiI (iii) P > S > R > Q (iv) $NH_3 > AsH_3 > PH_3$

11.

6	3	2	2
(P)	(Q)	(R)	(S)

12. 11.5% **13.** 25%

14. (i) $F_2 < O_2 < O_2^+ < N_2$ (ii) S < Cl < N < O < F (iii) $XeF_4 < NH_3 < BF_3 > N_3^-$

15. Inter molecular H–bonding in both but $KHCO_3$ forms dimers through H–bonding and $NaHCO_3$ form infinite long chains through H–bonding.

16. (i) I = 1.9 D , II = 1.1 D , III = 1.9 D (ii) 2.9 D