

Chemical Bonding and Molecular Structure — Assignment 2

Class 11 Chemistry · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
(2) Give all answers with correct SI units. $g = 10 \text{ m/s}^2$ unless stated.
(3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Octet Rule and Lewis Structures

1. State the octet rule and its two main limitations.
2. Draw the Lewis structure of the water molecule showing lone pairs.
3. Name one molecule that does not obey the octet rule.

Ionic (Electrovalent) Bond

1. Explain the formation of an ionic bond between sodium and chlorine giving the Lewis structures.
2. Explain why ionic compounds conduct electricity in the molten state but not in the solid state.
3. Define lattice enthalpy and state the factors on which it depends.

Covalent Bond and Polarity

1. Explain the formation of a covalent bond in the Cl_2 molecule.
2. Distinguish between a polar and a non-polar covalent bond with examples.
3. Explain the formation of a coordinate bond in the ammonium ion.

VSEPR Theory — Molecular Shapes

1. State VSEPR theory and explain the shapes of CH_4 and NH_3 .
2. Predict and explain the shape of the H_2O molecule using VSEPR theory.
3. Predict the shape of the BF_3 molecule and justify it.

Hybridisation of Atomic Orbitals

1. Define hybridisation and explain sp^3 hybridisation with the methane molecule.
2. Explain sp^2 hybridisation using the BF_3 molecule.
3. State the hybridisation of carbon in ethyne and explain its shape.

Bond Parameters, Resonance and Bond Order

1. Define bond order and explain how it is related to bond length and bond enthalpy.
2. Explain resonance with the example of the carbonate ion.
3. Calculate the bond order of the oxygen molecule.

Part B — Integrated problems (multi-topic)

1. Draw the Lewis structures of CO_2 , NH_3 and H_2O and state the number of lone pairs on the central atom in each.
2. Predict the shapes of CH_4 , NH_3 and H_2O using VSEPR theory and explain the trend in bond angles.
3. Determine the hybridisation and shape of the central atom in BF_3 , CH_4 and PCl_5 .
4. Calculate the bond order of O_2 , O_2^- and O_2^{2-} and arrange them in order of increasing bond length.
5. Explain why, although both ammonia and water have lone pairs, their shapes differ.

Answer Key

Octet Rule and Lewis Structures

Atoms tend to attain eight electrons in the valence shell. Limitations: molecules with incomplete octets (BF_3 , BeCl_2) or expanded octets (PCl_5 , SF_6). In water, oxygen has two bond pairs and two lone pairs.

Ionic (Electrovalent) Bond

Formed by the transfer of electrons from a metal to a non-metal. $\text{Na} \rightarrow \text{Na}^+ + \text{e}^-$; $\text{Cl} + \text{e}^- \rightarrow \text{Cl}^-$. Lattice enthalpy depends on ionic charge and the distance between ions (q_1q_2/r). Ionic compounds conduct only when molten/in solution because the ions are free to move.

Covalent Bond and Polarity

Formed by sharing a pair of electrons. Polar bonds arise from an electronegativity difference; identical atoms give non-polar bonds. In NH_4^+ , the lone pair of nitrogen is donated to the proton (coordinate bond).

VSEPR Theory — Molecular Shapes

Electron pairs around the central atom repel and take positions of maximum separation. CH_4 : tetrahedral (109.5°); NH_3 : trigonal pyramidal (107°); H_2O : bent (104.5°). Repulsion order: $\text{lp-lp} > \text{lp-bp} > \text{bp-bp}$.

Hybridisation of Atomic Orbitals

Mixing of atomic orbitals of similar energy to give equivalent orbitals. sp^3 : CH_4 (tetrahedral); sp^2 : BF_3 (trigonal planar); sp : C_2H_2 (linear, 180°).

Bond Parameters, Resonance and Bond Order

Bond order = $\frac{1}{2}(\text{bonding} - \text{antibonding electrons})$. Higher bond order $\rightarrow$ shorter, stronger bond. Resonance: delocalisation described when a single Lewis structure is inadequate (CO_3^{2-}). O_2 bond order = 2.

Integrated problems

1: CO_2 (0 lone pairs on C), NH_3 (1 on N), H_2O (2 on O). 2: Shapes tetrahedral $\rightarrow$ trigonal pyramidal $\rightarrow$ bent; angles $109.5^\circ > 107^\circ > 104.5^\circ$. 3: BF_3 sp^2 , trigonal planar; CH_4 sp^3 , tetrahedral; PCl_5 sp^3d , trigonal bipyramidal. 4: $\text{O}_2 = 2$, $\text{O}_2^- = 1.5$, $\text{O}_2^{2-} = 1$; bond length $\text{O}_2^{2-} > \text{O}_2^- > \text{O}_2$. 5: NH_3 has one lone pair (trigonal pyramidal), H_2O has two (bent).