St Andrew's Scot Sr Sec School

CH-3, Ch-4

ASSIGNMENT QUESTION.

Class: XI (Science)	Subject: Chemistry (Code: 043)	Standard: CBSE Board & Competition (JEE / NEET)	Ref: 11th New NCERT & MTG

SECTION A: Multiple Choice Questions (Level 1 & 2 — Competition & Board Focus)

Each question has four options, out of which only one is correct. Choose the most appropriate option.

Q1. **According to the IUPAC systematic nomenclature for superheavy elements, the official symbol and temporary name for the element with atomic number $Z = 120$ are:**

(a) Ubn, Unbinilium
(b) Ube, Unbiennium
(c) Utn, Untrinilium
(d) Uun, Ununnilium

Q2. **Which of the following represents the correct increasing order of ionic radii for the given isoelectronic species?**

(a) $Al^{3+} < Mg^{2+} < Na^{+} < F^{-} < O^{2-} < N^{3-}$
(b) $N^{3-} < O^{2-} < F^{-} < Na^{+} < Mg^{2+} < Al^{3+}$
(c) $Na^{+} < Mg^{2+} < Al^{3+} < F^{-} < O^{2-} < N^{3-}$
(d) $Al^{3+} < Na^{+} < Mg^{2+} < O^{2-} < F^{-} < N^{3-}$

Q3. **The correct order of first ionization enthalpy ($\Delta_i H_1$) for the second-period elements Li, Be, B, C, N, O, F, Ne is:**

(a) Li < B < Be < C < O < N < F < Ne
(b) Li < Be < B < C < N < O < F < Ne
(c) Li < B < Be < C < N < O < F < Ne
(d) Li < Be < B < C < O < N < F < Ne

Q4. **Which of the following Group 16 elements possesses the least negative electron gain enthalpy ($\Delta_{eg}H$)?**

(a) Sulfur (S)
(b) Selenium (Se)
(c) Tellurium (Te)
(d) Oxygen (O)

Q5. **Among the following pairs of elements, a prominent diagonal relationship is observed between:**

(a) Li and Na
(b) Be and Al
(c) B and P
(d) C and N

Q6. **In the Lewis resonance structure of the ozone molecule (O_3), the formal charges on the central, single-bonded, and double-bonded oxygen atoms are respectively:**

(a) 0, +1, −1
(b) +1, −1, 0
(c) +1, 0, −1
(d) −1, +1, 0

Q7. **Although fluorine is more electronegative than nitrogen, the net dipole moment of NH_3 (1.47 D) is significantly greater than that of NF_3 (0.24 D). This occurs because:**

(a) In NF_3, the orbital dipole of the lone pair and the resultant bond dipoles act in opposite directions.
(b) NF_3 possesses a strictly planar triangular geometry.
(c) The N−F bond length is significantly smaller than the N−H bond length.
(d) Nitrogen undergoes sp^2 hybridization in NF_3 and sp^3 in NH_3.

Q8. **According to Fajan's rules, which of the following compounds exhibits the highest degree of covalent character?**

(a) NaCl
(b) $MgCl_2$
(c) $AlCl_3$
(d) LiCl

Q9. **According to VSEPR theory, the molecular geometries of SF_4, ClF_3, and XeF_4 are respectively:**

(a) Tetrahedral, Trigonal planar, Square planar
(b) See-saw, T-shaped, Square planar
(c) Square planar, See-saw, T-shaped
(d) See-saw, Trigonal pyramidal, Tetrahedral

Q10. **The state of hybridization of the central atom in PCl_5, SF_6, and $[I_3]^-$ are respectively:**

(a) sp^3d, sp^3d^2, sp^3d
(b) sp^3d^2, sp^3d, sp^3
(c) sp^3, sp^3d^2, sp^3d
(d) sp^3d, sp^3d^2, sp^3

Q11. According to Molecular Orbital Theory (MOT), the correct order of bond orders for the species O_2, O_2^+, O_2^-, and O_2^{2-} is:

(a) $O_2^{2-} < O_2^- < O_2 < O_2^+$
(b) $O_2^+ < O_2 < O_2^- < O_2^{2-}$
(c) $O_2^{2-} < O_2 < O_2^- < O_2^+$
(d) $O_2^- < O_2^{2-} < O_2 < O_2^+$

Q12. Which homonuclear diatomic molecule contains only π (pi) bonds according to Molecular Orbital Theory?

(a) Be_2
(b) B_2
(c) C_2
(d) N_2

Q13. An element E exhibits successive ionization enthalpies: $IE_1 = 800$, $IE_2 = 2427$, $IE_3 = 3658$, and $IE_4 = 25024$ kJ/mol. Element E belongs to:

(a) Group 1
(b) Group 2
(c) Group 13
(d) Group 14

Q14. The abnormally high boiling point of water (H_2O) compared to hydrogen fluoride (HF) is primarily due to:

(a) Higher electronegativity of oxygen relative to fluorine.
(b) Formation of an average of 4 hydrogen bonds per H_2O molecule compared to 2 in HF.
(c) Stronger individual O−H···O hydrogen bond strength than F−H···F.
(d) Greater molecular mass of water.

Q15. The total number of σ (sigma) and π (pi) bonds present in a molecule of Tetracyanoethylene [$C_2(CN)_4$] are respectively:

(a) 9σ, 9π
(b) 5σ, 9π
(c) 9σ, 7π
(d) 8σ, 8π

Q16. The correct sequence of penetrating power of different subshells towards the nucleus in a multielectron atom is:

(a) s > p > d > f
(b) f > d > p > s
(c) s > d > p > f
(d) p > s > d > f

Q17. Which of the following pairs of chemical species is both isoelectronic and isostructural?

(a) CO_3^{2-} and NO_3^-
(b) SO_3 and SO_3^{2-}
(c) NH_3 and BF_3
(d) ClO_3^- and CO_3^{2-}

Q18. In gaseous PCl_5, the axial P−Cl bonds are longer and weaker than equatorial P−Cl bonds because:

(a) Axial bond pairs experience greater repulsion from 3 equatorial bond pairs at 90°.
(b) Axial orbitals involve pure d_{z^2} character without s-orbital hybridization.
(c) Equatorial bonds have a bond angle of 180°.
(d) Phosphorus has an incomplete octet.

Q19. The second electron gain enthalpy of oxygen ($O^-(g) + e^- \rightarrow O^{2-}(g)$) is positive (endothermic) because:

(a) O^{2-} ion has an inherently unstable electronic shell configuration.
(b) Strong electrostatic repulsion between incoming electron and negatively charged O^- ion exceeds nuclear pull.
(c) Oxygen has high electronegativity.
(d) The 2p subshell of O^- is completely filled.

Q20. Which set of thermodynamic conditions strongly favors the formation of a highly stable ionic solid?

(a) Low ionization enthalpy of metal, high negative electron gain enthalpy of non-metal, and high lattice enthalpy.
(b) High ionization enthalpy of metal and low electron gain enthalpy of non-metal.
(c) Large ionic size of both cation and anion with low ionic charges.
(d) High sublimation enthalpy of metal and low lattice energy.

SECTION B: Assertion - Reason Questions (Level 2 & 3 — Conceptual Rigor)

Directions (Q21 – Q28): In each of the following questions, a statement of **Assertion (A)** is followed by a statement of **Reason (R)**. Choose the correct option from the choices given below:
(A) Both (A) and (R) are true, and (R) is the correct explanation of (A).
(B) Both (A) and (R) are true, but (R) is NOT the correct explanation of (A).
(C) (A) is true, but (R) is false.
(D) (A) is false, but (R) is true.

Q21. Assertion (A): The electron gain enthalpy ($\Delta_{eg}H$) of Chlorine is more negative than that of Fluorine.
Reason (R): Due to the compact 2p-subshell in Fluorine, strong interelectronic repulsions resist the addition of an incoming electron.

Q22. Assertion (A): The first ionization enthalpy of Nitrogen is higher than that of Oxygen.
Reason (R): Nitrogen possesses an exactly half-filled 2p subshell ($2s^2\ 2p_x^1\ 2p_y^1\ 2p_z^1$), which confers extra exchange stability.

Q23. Assertion (A): Ortho-nitrophenol has a lower boiling point and is more steam-volatile than para-nitrophenol.
Reason (R): Ortho-nitrophenol exhibits intramolecular hydrogen bonding (chelation), whereas para-nitrophenol exhibits intermolecular hydrogen bonding leading to molecular association.

Q24. Assertion (A): Liquid oxygen (O_2) is attracted towards the poles of a strong magnetic field (paramagnetic).
Reason (R): According to MOT, the molecular orbital configuration of O_2 contains two unpaired electrons in degenerate antibonding π^*2p_x and π^*2p_y orbitals.

Q25. Assertion (A): The H−O−H bond angle in water (H_2O) is 104.5°, which is smaller than the standard tetrahedral angle of 109.5°.
Reason (R): According to VSEPR theory, lone pair − lone pair repulsion is greater than lone pair − bond pair repulsion, which in turn exceeds bond pair − bond pair repulsion.

Q26. Assertion (A): The He_2 molecule does not exist under ordinary conditions.
Reason (R): The number of bonding electrons in He_2 equals the number of antibonding electrons, yielding a bond order of zero.

Q27. Assertion (A): Anhydrous $AlCl_3$ is covalent, but when dissolved in water, it acts as an ionic electrolyte.
Reason (R): The exceptionally high hydration enthalpy of the Al^{3+} ion overcomes the high sum of the first three ionization enthalpies of Aluminium.

Q28. Assertion (A): The BF_3 molecule has a planar triangular geometry with a net dipole moment (μ) equal to zero.
Reason (R): The three polar B–F bond dipoles cancel each other vectorially due to the symmetrical 120° trigonal planar arrangement.

SECTION C: Conceptual, Analytical & Descriptive Questions (Level 2 & 3)

Answer the following questions systematically with appropriate chemical principles, orbital diagrams, and reasoning.

Q29. Periodic Radius Anomalies:

(a) Explain why the atomic radius of a noble gas (e.g., Argon) is reported to be significantly larger than that of the preceding halogen (e.g., Chlorine) in the same period.

(b) The atomic radius of Gallium (135 pm) is slightly smaller than that of Aluminium (143 pm), despite Gallium being positioned below Aluminium in Group 13. Justify this anomaly on the basis of screening effect of 3d electrons.

Q30. Periodic Trends in Oxide Chemistry:

Account for the sequential transition in chemical nature of the oxides of third-period elements across the series:

$$Na_2O \rightarrow MgO \rightarrow Al_2O_3 \rightarrow SiO_2 \rightarrow P_4O_{10} \rightarrow SO_3 \rightarrow Cl_2O_7$$

Classify each oxide as basic, amphoteric, or acidic, and correlate this behavior with electronegativity difference and ionic vs covalent character.

Q31. Ionic vs Atomic Radii and Nuclear Charge Dynamics:

(a) Prove why a cation is always smaller than its parent neutral atom, whereas an anion is always larger than its parent atom.

(b) For the isoelectronic series Mg^{2+}, Na^{+}, and F^{-}, compare their effective nuclear charge (Z_{eff}) and arrange them in order of strictly increasing ionic radius.

Q32. Formal Charge & Lewis Formulations:

(a) Draw all contributing Lewis resonance structures for the Nitrite ion (NO_2^{-}).

(b) Calculate the formal charge on each individual atom (Nitrogen, single-bonded Oxygen, double-bonded Oxygen) using the relation:

$$\text{Formal Charge} = V - L - \tfrac{1}{2} S$$

Q33. VSEPR Geometry and Molecular Shape Predictions:

Using VSEPR theory, determine the number of bond pairs, lone pairs, electron-domain geometry, and actual molecular shape for each of the following species:

(a) BrF_5 | **(b)** XeF_2 | **(c)** $[ICl_4]^{-}$

Q34. Valence Bond Overlap Fundamentals:

(a) Distinguish clearly between a σ (sigma) bond and a π (pi) bond on the basis of: (i) mode of orbital overlap, (ii) free rotation about the internuclear axis, and (iii) relative bond strength.

(b) Explain why a π bond cannot form independently in a stable molecule without the prior formation of a σ bond.

Q35. Orbital Mixing in Homonuclear Diatomic Molecules:

(a) Explain why the energy sequence of molecular orbitals exhibits an inversion for light diatomic species ($Z \leq 7$: B_2, C_2, N_2) where the $\pi 2p_x = \pi 2p_y$ orbitals lie lower in energy than $\sigma 2p_z$.

(b) Write the complete molecular orbital configuration of the C_2 molecule and demonstrate why its double bond consists purely of two π bonds.

Q36. Bond Parameters & Structural Comparisons:

(a) Correlate the bond order, bond length, and bond dissociation enthalpy for the homonuclear series: N_2, O_2, and F_2.

(b) Arrange the following hydrides in decreasing order of bond angle and justify the trend using VSEPR / hybridization concepts: CH_4, NH_3, H_2O, H_2S.

Q37. Hydrogen Bonding Typology & Physical Manifestations:

(a) Define intermolecular and intramolecular hydrogen bonding with one clear structural example of each.

(b) Explain why glycerol [$CH_2OH{-}CHOH{-}CH_2OH$] has an unusually high viscosity and boiling point compared to propanol [C_3H_7OH].

Q38. Fajan's Polarization Analysis:

Applying Fajan's rules, arrange the following sets of compounds in increasing order of covalent character, stating the underlying principle:

(a) LiCl, NaCl, KCl, RbCl

(b) $FeCl_2$ vs $FeCl_3$

(c) AgCl vs NaCl (Hint: compare pseudo-noble gas vs noble gas cation configurations).

Q39. Covalency Limits and Valence Shell Expansion:

Nitrogen forms only NCl_3 and cannot form NCl_5, whereas Phosphorus forms both PCl_3 and PCl_5. Explain this fundamental difference based on:

(a) Valence shell orbital availability (d-orbital participation).

(b) Atomic size and steric crowding around the central atom.

Q40. Resonance Hybridization and Bond Equivalence:

In the Carbonate ion (CO_3^{2-}), all three carbon-oxygen bond lengths are experimentally identical (128 pm), which lies intermediate between a standard C−O single bond (143 pm) and C=O double bond (120 pm).

(a) Draw all canonical resonance structures of CO_3^{2-}.

(b) Calculate the fractional average C−O bond order in the resonance hybrid.

SECTION D: Word Problems, Case-Based & Deductive Application Problems (Level 3 & 4)

Strictly integrated word problems, deductive multi-concept puzzles, and Born-Haber thermochemical cycles.

Q41. Deductive Element Identification via Successive Ionization Enthalpies:

An unknown representative element X belonging to the 3rd period of the periodic table exhibits the following successive ionization enthalpies:

$$IE_1 = 578 \text{ kJ/mol}, \quad IE_2 = 1817 \text{ kJ/mol}, \quad IE_3 = 2745 \text{ kJ/mol}, \quad IE_4 = 11578 \text{ kJ/mol}, \quad IE_5 = 14842 \text{ kJ/mol}$$

(a) Deduce the number of valence electrons in element X and pinpoint its exact Group number in the modern periodic table.

(b) Identify element X by name and write the chemical formulas of its stable oxide and anhydrous chloride.

(c) State the acid-base nature of its oxide and deduce the hybridization and geometry of element X in its dimeric vapor phase (X_2Cl_6).

Q42. Deductive Structural Problem on Interhalogen Chemistry:

A neutral interhalogen gas A is composed entirely of Chlorine and Fluorine. Chemical analysis reveals that the central chlorine atom exists in a +3 oxidation state and is bonded covalently to fluorine atoms.

(a) Determine the molecular formula of interhalogen gas A.

(b) Using VSEPR theory, determine the number of bond pairs and lone pairs on the central chlorine atom.

(c) State the electron-domain geometry and the actual observed molecular shape of gas A.

(d) Explain why the molecule adopts a bent T-shape rather than a trigonal planar geometry, specifying which sites (equatorial vs axial) the lone pairs occupy and why.

Q43. Case-Based Problem on Isoelectronic Series and Periodic Energies:

Three consecutive elements P, Q, and R have atomic numbers $Z - 1$, Z, and $Z + 1$ respectively, where $Z = 10$ represents the noble gas Neon (Ne).

(a) Write the ground-state electronic configurations and the formulas of the most stable monoatomic ions formed by P and R.

(b) Arrange the ions of P and R, along with the neutral atom Q, in strictly increasing order of their radii, providing a physical justification based on effective nuclear charge.

(c) Compare the first ionization enthalpies ($\Delta_i H_1$) of P, Q, and R. Explain why element R exhibits a dramatically lower first ionization enthalpy than both P and Q.

Q44. Thermochemical Word Problem on Lattice Enthalpy & Born-Haber Cycle:

The synthesis of crystalline magnesium fluoride [$MgF_2(s)$] from its constituent elements in their standard states is represented by:

$$Mg(s) + F_2(g) \rightarrow MgF_2(s) \quad [\Delta_f H^\circ = -1124 \text{ kJ/mol}]$$

You are provided with the following experimental thermodynamic data:

- Enthalpy of sublimation of Mg(s): $\Delta_{sub}H = +147 \text{ kJ/mol}$
- 1st Ionization Enthalpy of Mg(g): $IE_1 = +738 \text{ kJ/mol}$
- 2nd Ionization Enthalpy of Mg(g): $IE_2 = +1451 \text{ kJ/mol}$
- Bond dissociation enthalpy of $F_2(g)$: $\Delta_{diss}H = +158 \text{ kJ/mol}$
- Electron gain enthalpy of F(g): $\Delta_{eg}H = -328 \text{ kJ/mol}$

(a) Construct and sketch a fully labeled Born-Haber thermodynamic cycle for solid MgF_2.

(b) Calculate the lattice enthalpy ($\Delta_{lattice}H^\circ$) of crystalline $MgF_2(s)$ in kJ/mol.

Q45. Deductive Identification of Oxides & Molecular Orbital Analysis:

A Period 2 non-metallic element A reacts with element B (atomic number 8) to form two distinct binary gaseous oxides, X and Y. In oxide X, the mass ratio of $A : B$ is $3 : 4$, whereas in oxide Y, the mass ratio of $A : B$ is $3 : 8$.

(a) Identify elements A and B, and determine the molecular formulas of oxides X and Y.

(b) Using Molecular Orbital Theory, construct the complete MO configuration for the 14-electron diatomic oxide X. Determine its bond order and magnetic character (paramagnetic or diamagnetic).

(c) State the hybridization of element A in oxide Y. Determine its bond angle and justify whether oxide Y possesses a permanent dipole moment.

Q46. Multi-Concept Word Problem on Geometry, Polarity, and Lewis Acid-Base Adducts:

Two volatile covalent hydrides, MH_3 and NH_3, are formed by second-period elements M (Group 13) and N (Group 15) respectively.

(a) Identify MH_3 and NH_3 by writing their specific molecular formulas.

(b) State the hybridization of the central atom in each hydride and explain why MH_3 is non-polar (μ = 0 D) while NH_3 possesses a permanent dipole moment (μ = 1.47 D).

(c) When gaseous MH_3 reacts with NH_3, a coordinate covalent adduct [$MH_3 \leftarrow NH_3$] is formed readily. Explain the driving force of this reaction and describe the change in hybridization and geometry around atom M before and after adduct formation.

Q47. Comparative Physical Chemistry Word Problem on Fajan's Rules:

Two solid monovalent chlorides, Salt 1 (NaCl) and Salt 2 (CuCl), contain cations of nearly identical ionic radii (Na^+ = 102 pm, Cu^+ = 96 pm). However, laboratory measurements reveal:

• NaCl has a high melting point (801°C) and dissolves completely in water to form a conducting solution.
• CuCl has a much lower melting point (430°C) and is virtually insoluble in water.

(a) Explain this disparity on the basis of cation electronic configurations and polarizing power.

(b) State the governing rule and contrast the polarizing power of an 18-electron pseudo-noble gas shell ($s^2p^6d^{10}$) against an 8-electron noble gas octet (s^2p^6).

Q48. Deductive Problem on Tetrafluoride Geometries and Polarity:

Two tetrafluorides, ZF_4 and WF_4, are synthesized in a laboratory. Element Z belongs to Group 16 (Period 4), while element W belongs to Group 14 (Period 2). Spectroscopic data reveals that ZF_4 is polar (μ ≠ 0), whereas WF_4 is non-polar (μ = 0).

(a) Identify central elements Z and W.

(b) Deduce the steric number, hybridization, and actual shape of both ZF_4 and WF_4.

(c) For molecule ZF_4, explain why the axial $Z-F$ bonds are longer than equatorial $Z-F$ bonds.

(d) Predict the geometry and hybridization of the anion formed when ZF_4 reacts with a fluoride ion (F^-) to form $[ZF_5]^-$.

Q49. Periodic Electronic Configuration & Chemical Reactivity Profile:

Four elements A, B, C, and D have the following ground-state valence electron configurations:

Element A: [Ne] $3s^1$ | Element B: [Ne] $3s^2\ 3p^5$ | Element C: [Ar] $3d^{10}\ 4s^1$ | Element D: [He] $2s^2\ 2p^5$

(a) Which element possesses the most negative electron gain enthalpy? Explain why its value is more negative than that of element D.

(b) Identify the element having the lowest first ionization enthalpy.

(c) Compare the lattice energies of the ionic compounds formed between (A + D) and (A + B). Which ionic compound possesses the higher melting point?

(d) Explain why the homonuclear diatomic molecule of element D (D_2) has an unexpectedly lower bond dissociation energy than that of element B (B_2).

Q50. Comprehensive Molecular Orbital Case Investigation:

During a spectrochemical analysis of homonuclear diatomic species derived from Nitrogen (Z = 7), three species were evaluated: neutral dinitrogen (N_2), its univalent cation (N_2^+), and its univalent anion (N_2^-).

(a) Write the complete Molecular Orbital electronic configurations for all three species (N_2, N_2^+, N_2^-), using the appropriate energy order for $Z \leq 7$.

(b) Calculate the bond order for each species using:

$$\text{Bond Order} = \tfrac{1}{2}(N_b - N_a)$$

(c) Arrange the three species in strictly increasing order of: (i) bond length, (ii) bond dissociation energy.

(d) State the magnetic character of each species. Since both N_2^+ and N_2^- have the same bond order (2.5), explain on the basis of antibonding electron occupancy which species is thermodynamically more stable.