

ST ANDREW'S SCOT SR SEC SCHOOL

CH- 1 MOLE CONCEPTS & CH-2 STRUCTURE OF ATOM

ASSIGNMENT QUESTION.

Class: XI (Science) • Subject: Chemistry (043)

Session: 2026–27 (CBSE Pattern)

Max. Marks: 100 • Time: 3 Hours

General Instructions & Syllabus Specifications:

- All 40 questions are compulsory and curated strictly as per the **New CBSE Class 11 Chemistry Syllabus (2026)** (NCERT, MTG, Xam Idea).
- Paper Structure: **Section A** (Q1–Q10: 1 Mark each), **Section B** (Q11–Q20: 2 Marks each), **Section C** (Q21–Q30: 3 Marks each), and **Section D** (Q31–Q40: 5 Marks each — *Comprehensive Word Problems*).

Useful Constants: $h = 6.626 \times 10^{-34} \text{ J s}$ • $c = 3.0 \times 10^8 \text{ m s}^{-1}$ • $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$ • $m_e = 9.109 \times 10^{-31} \text{ kg}$ • $e = 1.602 \times 10^{-19} \text{ C}$ • $R_H = 1.09677 \times 10^7 \text{ m}^{-1}$ • STP Molar Volume = 22.7 L mol^{-1} (22.4 L at 1 atm).

SECTION A — OBJECTIVE & ASSERTION-REASON QUESTIONS (1 Mark Each)

Difficulty Level: Basic Recall, Core Fundamentals & Direct Conceptual Logic

- Q1.** Which of the following samples contains the largest total number of atoms?
- (a) 1.0 g of Au(s) [$M = 197 \text{ g mol}^{-1}$] (b) 1.0 g of Na(s) [$M = 23 \text{ g mol}^{-1}$]
(c) 1.0 g of Li(s) [$M = 6.94 \text{ g mol}^{-1}$] (d) 1.0 g of $\text{Cl}_2(\text{g})$ [$M = 71 \text{ g mol}^{-1}$]
- Q2.** Which of the following sets of four quantum numbers (n, l, m_l, m_s) is **not permissible** for an electron in an atom?
- (a) $n = 3, l = 2, m_l = -2, m_s = +\frac{1}{2}$ (b) $n = 4, l = 0, m_l = 0, m_s = -\frac{1}{2}$
(c) $n = 2, l = 2, m_l = +1, m_s = +\frac{1}{2}$ (d) $n = 5, l = 3, m_l = 0, m_s = -\frac{1}{2}$
- Q3.** Which of the following concentration terms is strictly independent of temperature variations?
- (a) Molarity (M) (b) Molality (m)
(c) Mass by volume percentage (% w/V) (d) Normality (N)
- Q4.** The total number of radial nodes and angular nodes present in a $4d$ orbital are respectively:
- (a) 1 and 2 (b) 2 and 1
(c) 2 and 2 (d) 3 and 0
- Q5.** If 30.0 mL of $\text{H}_2(\text{g})$ reacts with 20.0 mL of $\text{O}_2(\text{g})$ to form water vapor at constant T and P , the volume of unreacted gas is:
- (a) 10.0 mL of $\text{H}_2(\text{g})$ (b) 5.0 mL of $\text{O}_2(\text{g})$
(c) 15.0 mL of $\text{O}_2(\text{g})$ (d) 0.0 mL (completely reacted)
- Q6.** The ratio of the de Broglie wavelength of an α -particle ($m = 4 u$) to that of a proton ($m = 1 u$) with identical kinetic energy is:
- (a) 1 : 1 (b) 1 : 2
(c) 2 : 1 (d) 1 : 4
- Q7.** In a photoelectric experiment, when incident frequency ($\nu > \nu_0$) is doubled at constant intensity, the kinetic energy of photoelectrons will:
- (a) Remain unchanged (b) Be doubled
(c) Become more than double (d) Become halved
- Q8.** Two oxides of a metal contain 50.0% and 40.0% of metal by mass respectively. These data illustrate the:
- (a) Law of Conservation of Mass (b) Law of Definite Proportions
(c) Law of Multiple Proportions (d) Law of Reciprocal Proportions
- Directions for Q9 & Q10:** Statement of **Assertion (A)** is followed by **Reason (R)**.
(a) Both A and R true, R correct explanation of A • (b) Both true, R not correct explanation • (c) A true, R false • (d) A false, R true
- Q9. Assertion (A):** The molality of an aqueous solution is always numerically greater than its molarity if density is $\leq 1.0 \text{ g mL}^{-1}$.
Reason (R): Molality is defined per kilogram of solvent, whereas molarity is defined per liter of total solution.
- Q10. Assertion (A):** The ground-state electronic configuration of Chromium ($Z = 24$) is $[\text{Ar}] 3d^5 4s^1$ rather than $[\text{Ar}] 3d^4 4s^2$.
Reason (R): Half-filled and fully-filled subshells possess extra stability due to greater exchange energy and symmetrical distribution.

SECTION B — CONCEPTUAL, REASONING & VSA QUESTIONS (2 Marks Each)

Difficulty Level: Conceptual Clarity, Precise Definitions & Theoretical Reasoning

Q11. State the **Law of Multiple Proportions**. Demonstrate this law quantitatively with binary oxides of nitrogen, specifically nitric oxide (NO) and nitrogen dioxide (NO₂).

Q12. Explain why the radius of the first Bohr orbit for a Hydrogen atom is 0.529 Å, whereas for a He⁺ ion it shrinks to 0.2645 Å. State the general mathematical formula relating the orbit radius (r_n) to the principal quantum number (n) and nuclear charge (Z).

Q13. Explain why molality (m) is preferred over molarity (M) in accurate thermodynamic experiments and temperature-dependent solution studies.

Q14. State **Heisenberg's Uncertainty Principle**. Show mathematically why this principle has significant physical consequence for micro-particles like electrons ($m \approx 9.1 \times 10^{-31}$ kg), but is practically negligible for macro-objects ($m \approx 0.1$ kg).

Q15. Define the unified atomic mass unit (u). Explain why the international standard for atomic mass was shifted from Oxygen-16 to the Carbon-12 (¹²C) isotope.

Q16. Write the complete ground-state electronic configuration of the Fe³⁺ ion ($Z = 26$). Determine the number of unpaired electrons and calculate its spin-only magnetic moment (μ_s) in Bohr Magnetons (BM).

Q17. Distinguish clearly between **precision** and **accuracy** in scientific measurements using an illustrative example of three students measuring the mass of a certified 2.000 g standard object.

Q18. State **Hund's Rule of Maximum Multiplicity** and **Pauli's Exclusion Principle**. Illustrate how these two principles dictate the degenerate orbital occupancy in a ground-state Nitrogen atom ($Z = 7$).

Q19. Why was classical wave theory unable to explain:

- (a) The existence of a characteristic threshold frequency (ν_0) in the photoelectric effect?
- (b) The instantaneous ejection of photoelectrons with no observable time lag?

Q20. Determine the number of significant figures in each of the following recorded quantities:

- (a) 0.004050 g
- (b) 2.008×10^3 s
- (c) 500.0 mL
- (d) 20 chairs (exact count)

SECTION C — SHORT ANSWER & ANALYTICAL APPLICATION QUESTIONS (3 Marks Each)

Difficulty Level: Analytical Thinking, Formula Application & Multi-Step Derivations

Q21. An electron is accelerated until its kinetic energy reaches 3.0×10^{-25} J. Calculate:

- (a) The velocity of the electron ($m_e = 9.109 \times 10^{-31}$ kg).
- (b) The de Broglie wavelength (λ) associated with this electron.

Q22. A gaseous fuel mixture contains 80.0% methane (CH_4) and 20.0% ethane (C_2H_6) by volume. Calculate the total volume of oxygen gas (O_2) required at standard temperature and pressure (STP) for the complete combustion of 10.0 L of this fuel mixture.

Q23. An electron in a hydrogen atom undergoes a de-excitation transition from the $n = 5$ level to the $n = 2$ level.

- (a) Calculate the wave number ($\bar{\nu}$), wavelength (λ), and frequency (ν) of the emitted photon.
- (b) Name the spectral series to which this line belongs and state the electromagnetic region in which it appears.

Q24. In an experiment, 20.0 g of pure calcium carbonate (CaCO_3) is treated with 20.0 g of hydrochloric acid (HCl) according to the balanced equation:



- (a) Identify the limiting reagent with proper calculations.
- (b) Calculate the maximum mass of CaCl_2 formed.
- (c) Determine the mass of the excess reactant remaining unreacted.

Q25. The threshold frequency (ν_0) for a clean potassium surface is $7.0 \times 10^{14} \text{ s}^{-1}$. When ultraviolet light of frequency $\nu = 1.2 \times 10^{15} \text{ s}^{-1}$ strikes the metal plate:

- (a) Calculate the work function (Φ) of potassium in Joules and in electron-volts (eV).
- (b) Calculate the maximum kinetic energy and maximum speed of the ejected photoelectrons.

Q26. An organic liquid on quantitative elemental analysis gave: Carbon = 54.55%, Hydrogen = 9.09%, and the balance is Oxygen. The vapor density of the compound is experimentally determined to be 44.0.

- (a) Determine the empirical formula of the compound.
- (b) Determine the molecular mass and the molecular formula of the compound.

Q27.

- (a) Write the complete set of four quantum numbers (n, l, m_l, m_s) for the outermost valence electron of a ground-state Potassium atom ($Z = 19$).
- (b) For the principal energy level $n = 3$, calculate the total number of subshells, the total number of individual orbitals, and the maximum number of electrons that can be accommodated.

Q28. A commercial bottle of concentrated sulfuric acid (H_2SO_4) is labeled as 98.0% by mass and has a measured density of 1.84 g mL^{-1} .

- (a) Calculate the molarity (M) and molality (m) of this concentrated solution.
- (b) What volume of this concentrated acid is required to prepare exactly 2.50 L of 0.20 M H_2SO_4 solution?

Q29. Applying Bohr's postulates for single-electron hydrogenic species:

- (a) Calculate the radius of the 3rd orbit of a Li^{2+} ion.
- (b) Calculate the ratio of the orbital frequency (revolutions per second) of an electron in the 1st orbit of H ($Z = 1, n = 1$) to that in the 2nd orbit of He^+ ($Z = 2, n = 2$).

Q30. A microscopic particle having a mass of $1.0 \times 10^{-6} \text{ kg}$ moves with an average speed of 10.0 m s^{-1} . If its speed is measured with an uncertainty of 0.005%:

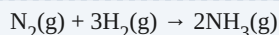
- (a) Calculate the minimum uncertainty in measuring its simultaneous position (Δx).
- (b) Comment on the practical significance and observability of Heisenberg's uncertainty principle for this macroscopic particle versus an electron.

SECTION D — COMPREHENSIVE WORD PROBLEMS & NUMERICAL EXERCISES (5 Marks Each)

Difficulty Level: Advanced Problem Solving, Multi-Concept Integration & Applied Stoichiometry (Strict Word Problems)

Q31. [Industrial Stoichiometry & Percentage Yield]

In the commercial synthesis of ammonia via the Haber-Bosch process, dinitrogen gas and dihydrogen gas are combined at high temperature and pressure in the presence of an iron catalyst:



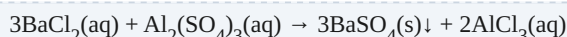
A high-pressure industrial reactor is loaded with 50.00 kg of $\text{N}_2(\text{g})$ and 10.00 kg of $\text{H}_2(\text{g})$.

- Identify the limiting reagent by calculating the theoretical mole ratio.
- Calculate the theoretical yield of ammonia (NH_3) produced in kilograms.
- Calculate the mass of the excess reactant remaining unreacted at the completion of the process.
- If the actual mass of pure ammonia isolated from the condenser is 42.50 kg, calculate the percentage yield of the Haber synthesis.

Q32. [Precipitation Reaction & Solution Speciation]

An analytical chemist mixes 150.0 mL of 0.50 M BaCl_2 solution with 250.0 mL of 0.20 M $\text{Al}_2(\text{SO}_4)_3$ solution in a reaction vessel.

A dense white precipitate of barium sulfate (BaSO_4) forms immediately:



- Determine the limiting reagent in this precipitation reaction.
- Calculate the dry mass of BaSO_4 precipitate formed. [Molar mass of $\text{BaSO}_4 = 233.33 \text{ g mol}^{-1}$]
- Assuming the solution volumes are additive ($V_{\text{total}} = 400.0 \text{ mL}$), calculate the final molar concentration of every individual ionic species present in the filtrate (Ba^{2+} , Al^{3+} , Cl^- , and SO_4^{2-}) after filtering out the precipitate.

Q33. [Elemental Quantitative Analysis & Structural Formula Determination]

A newly synthesized volatile liquid containing only Carbon, Hydrogen, and Nitrogen is analyzed by two independent quantitative methods:

- Complete combustion of 0.300 g of the pure compound yields 0.440 g of carbon dioxide (CO_2) and 0.360 g of water (H_2O).
 - In a separate Dumas nitrogen estimation, 0.150 g of the same substance produces 56.0 mL of dry N_2 gas collected at STP.
- Calculate the percentage composition of Carbon, Hydrogen, and Nitrogen in the compound.
 - Determine the empirical formula of the compound.
 - If 0.050 moles of this compound has an experimentally measured mass of 3.00 g, calculate its true molecular mass and deduce its molecular formula.

Q34. [Photochemistry, Quantum Yield & Photodissociation Dynamics]

A laboratory ultraviolet lamp operates with an electrical power input of 200 W and radiates monochromatic light at a wavelength of $\lambda = 253.7 \text{ nm}$. The lamp converts electrical energy into radiant energy with an efficiency of 85.0%.

- Calculate the radiant power output (in Joules per second) emitted by the lamp.
- Calculate the energy of a single emitted photon in Joules and in electron-volts (eV).
- Calculate the total number of photons emitted by the lamp during a 10.0-minute continuous exposure.
- If this radiant beam is completely absorbed by a sample of gaseous bromine molecules (Br_2) whose bond dissociation energy is $193.0 \text{ kJ mol}^{-1}$, calculate the maximum kinetic energy carried away by each photo-dissociated bromine atom.

Q35. [Atomic Orbit Transitions & Multi-Electron Ionization Energies]

The experimental ionization energy of a ground-state Hydrogen atom ($n = 1$) is $2.18 \times 10^{-18} \text{ J atom}^{-1}$.

- Calculate the exact energy (in Joules and eV) required to excite the electron from the ground state ($n = 1$) to the second excited state ($n = 3$).
- When the electron drops directly back from $n = 3$ to $n = 1$, calculate the wavelength (λ), frequency (ν), and wave number ($\bar{\nu}$) of the emitted photon.
- Calculate the ionization energy of a hydrogen-like Beryllium ion (Be^{3+} , $Z = 4$) in units of kJ mol^{-1} using the Bohr energy formula.

SECTION D (CONTINUED) — COMPREHENSIVE WORD PROBLEMS (5 Marks Each)

Difficulty Level: Advanced Problem Solving, Multi-Concept Integration & Applied Stoichiometry (Strict Word Problems)

Q36. [Photoelectric Effect & Stopping Potential Analysis]

A clean Cesium metal photocathode inside an evacuated cell is illuminated with monochromatic light of wavelength $\lambda_1 = 450.0 \text{ nm}$. The emitted photoelectrons are brought to rest by an applied retarding potential (stopping potential) of $V_{0,1} = 0.60 \text{ V}$.

- Calculate the work function (Φ) of Cesium metal in electron-volts (eV) and in Joules (J).
- Calculate the threshold frequency (ν_0) and the maximum threshold wavelength (λ_0) for the Cesium cathode.
- If the incident light is replaced with ultraviolet radiation of wavelength $\lambda_2 = 300.0 \text{ nm}$, calculate:
 - The maximum kinetic energy ($K_{\max}$) of the ejected photoelectrons in eV and Joules.
 - The new stopping potential ($V_{0,2}$) required to extinguish the photocurrent.
 - The maximum velocity ($v_{\max}$) of the emitted photoelectrons.

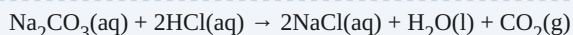
Q37. [Wave-Particle Duality & Failure of Deterministic Orbits]

An electron ($m_e = 9.11 \times 10^{-31} \text{ kg}$) and a neutral Helium atom ($m_{\text{He}} = 6.64 \times 10^{-27} \text{ kg}$) are each traveling with a velocity of $2.20 \times 10^6 \text{ m s}^{-1}$, measured with an experimental uncertainty of 0.10%.

- Calculate the de Broglie wavelength (λ) associated with each particle.
- Calculate the minimum uncertainty in the position coordinate (Δx) for both the electron and the helium atom.
- Compare the calculated position uncertainty (Δx) of the electron with the physical diameter of an atom ($\approx 10^{-10} \text{ m}$). Explain why this result proves that well-defined classical Bohr orbits are physically meaningless for electrons, justifying the wave-mechanical model.

Q38. [Volumetric Acid-Base Titration & Hydrate Stoichiometry]

A sample of commercial hydrated washing soda crystals ($\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$) weighing 2.860 g is dissolved in distilled water and diluted to make exactly 250.0 mL of solution in a volumetric flask. A 25.0 mL aliquot of this carbonate solution is pipetted into a conical flask and titrated against standard 0.100 M HCl solution using methyl orange indicator. Complete neutralization to the pink end-point requires 20.00 mL of the acid:



- Calculate the molarity (M) of the prepared sodium carbonate solution.
- Calculate the mass of anhydrous Na_2CO_3 present in the 250.0 mL stock solution.
- Calculate the mass and percentage of water of crystallization present in the 2.860 g crystal sample.
- Determine the exact integer value of x in the formula $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

Q39. [Gaseous Mixture Stoichiometry & Subatomic Valence Counting]

A rigid glass vessel having a fixed volume of 4.480 L at STP (0°C and 1.0 atm) contains a dry gaseous mixture of carbon monoxide (CO) and propane (C_3H_8). The total mass of the gas mixture inside the vessel is 7.600 g.

- Calculate the number of moles and the mole fraction of each individual gas in the mixture.
- Calculate the total mass of oxygen gas (O_2) required for the complete stoichiometric combustion of the entire mixture to $\text{CO}_2(\text{g})$ and $\text{H}_2\text{O}(\text{l})$.
- Calculate the total volume of CO_2 gas produced at STP.
- Calculate the total number of valence electrons present in the initial gaseous mixture within the vessel.

Q40. [UV Photon Excitation & Complete Spectral Cascade Dynamics]

A sample containing 1.008 g of atomic hydrogen gas (H) in its ground electronic state ($n = 1$) is enclosed in an absorption cell. The atoms are irradiated with a monochromatic ultraviolet beam of wavelength $\lambda = 97.25 \text{ nm}$, causing the absorption of photons and electronic transitions to an excited quantum level n_x .

- Using Rydberg's formula ($R_H = 1.09677 \times 10^7 \text{ m}^{-1}$), calculate the principal quantum number n_x to which the electrons are excited.
- Calculate the total number of possible spectral emission lines that can appear as these excited atoms cascade back down to the ground state.
- Identify the electronic transitions responsible for:
 - The emission line with the highest frequency (maximum energy / shortest wavelength).
 - The emission line with the longest wavelength (lowest frequency / minimum energy).
- Calculate the exact wavelength (λ) of both transitions identified in part (c) and assign each to its respective spectroscopic series (Lyman, Balmer, or Paschen).