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:
1. All 40 questions are compulsory and curated strictly as per the **New CBSE Class 11 Chemistry Syllabus (2026)** (NCERT, MTG, Xam Idea).
2. 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: $h = 6.626 \times 10^{-34}$ J s • $c = 3.0 \times 10^{8}$ m s^{-1} • $N_A = 6.022 \times 10^{23}$ mol^{-1} • $m_e = 9.109 \times 10^{-31}$ kg • $e = 1.602 \times 10^{-19}$ C • $R_H = 1.09677 \times 10^{7}$ 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 g mol^{-1}]
(b) 1.0 g of Na(s) [M = 23 g mol^{-1}]
(c) 1.0 g of Li(s) [M = 6.94 g mol^{-1}]
(d) 1.0 g of Cl_2(g) [M = 71 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) $n = 3, l = 2, m_l = -2, m_s = +½$
(b) $n = 4, l = 0, m_l = 0, m_s = -½$
(c) $n = 2, l = 2, m_l = +1, m_s = +½$
(d) $n = 5, l = 3, m_l = 0, m_s = -½$

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 H_2(g) reacts with 20.0 mL of O_2(g) to form water vapor at constant T and P, the volume of unreacted gas is:
(a) 10.0 mL of H_2(g)
(b) 5.0 mL of O_2(g)
(c) 15.0 mL of O_2(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 ($v > v_0$) 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 ≤ 1.0 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 [Ar] $3d^5\ 4s^1$ rather than [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 (NO_2).

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 (^{12}C) isotope.

Q16. Write the complete ground-state electronic configuration of the Fe^{3+} 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 (v_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)

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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:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

(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 7.0×10^{14} s^{-1}. When ultraviolet light of frequency $\nu = 1.2 \times 10^{15}$ 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 1.0×10^{-6} 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.

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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:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

A high-pressure industrial reactor is loaded with 50.00 kg of $N_2(g)$ and 10.00 kg of $H_2(g)$.

(a) Identify the limiting reagent by calculating the theoretical mole ratio.
(b) Calculate the theoretical yield of ammonia (NH_3) produced in kilograms.
(c) Calculate the mass of the excess reactant remaining unreacted at the completion of the process.
(d) 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 $Al_2(SO_4)_3$ solution in a reaction vessel. A dense white precipitate of barium sulfate ($BaSO_4$) forms immediately:

$$3BaCl_2(aq) + Al_2(SO_4)_3(aq) \rightarrow 3BaSO_4(s)\downarrow + 2AlCl_3(aq)$$

(a) Determine the limiting reagent in this precipitation reaction.
(b) Calculate the dry mass of $BaSO_4$ precipitate formed. [Molar mass of $BaSO_4$ = 233.33 g mol^{-1}]
(c) Assuming the solution volumes are additive ($V_{total} = 400.0\ mL$), 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.

(a) Calculate the percentage composition of Carbon, Hydrogen, and Nitrogen in the compound.
(b) Determine the empirical formula of the compound.
(c) 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 $\lambda = 253.7\ nm$. The lamp converts electrical energy into radiant energy with an efficiency of 85.0%.

(a) Calculate the radiant power output (in Joules per second) emitted by the lamp.
(b) Calculate the energy of a single emitted photon in Joules and in electron-volts (eV).
(c) Calculate the total number of photons emitted by the lamp during a 10.0-minute continuous exposure.
(d) If this radiant beam is completely absorbed by a sample of gaseous bromine molecules (Br_2) whose bond dissociation energy is 193.0 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 2.18×10^{-18} J $atom^{-1}$.

(a) Calculate the exact energy (in Joules and eV) required to excite the electron from the ground state ($n = 1$) to the second excited state ($n = 3$).
(b) 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.
(c) 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 $\lambda_1 = 450.0\ nm$. The emitted photoelectrons are brought to rest by an applied retarding potential (stopping potential) of $V_{0,1} = 0.60\ V$.

(a) Calculate the work function (Φ) of Cesium metal in electron-volts (eV) and in Joules (J).

(b) Calculate the threshold frequency (ν_0) and the maximum threshold wavelength (λ_0) for the Cesium cathode.

(c) If the incident light is replaced with ultraviolet radiation of wavelength $\lambda_2 = 300.0\ nm$, calculate:

- (i) The maximum kinetic energy (K_{max}) of the ejected photoelectrons in eV and Joules.
- (ii) The new stopping potential ($V_{0,2}$) required to extinguish the photocurrent.
- (iii) The maximum velocity (v_{max}) of the emitted photoelectrons.

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

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

(a) Calculate the de Broglie wavelength (λ) associated with each particle.

(b) Calculate the minimum uncertainty in the position coordinate (Δx) for both the electron and the helium atom.

(c) Compare the calculated position uncertainty (Δx) of the electron with the physical diameter of an atom ($\approx 10^{-10}$ 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 ($Na_2CO_3 \cdot xH_2O$) 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:

$$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

(a) Calculate the molarity (M) of the prepared sodium carbonate solution.

(b) Calculate the mass of anhydrous Na_2CO_3 present in the 250.0 mL stock solution.

(c) Calculate the mass and percentage of water of crystallization present in the 2.860 g crystal sample.

(d) Determine the exact integer value of x in the formula $Na_2CO_3 \cdot xH_2O$.

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.

(a) Calculate the number of moles and the mole fraction of each individual gas in the mixture.

(b) Calculate the total mass of oxygen gas (O_2) required for the complete stoichiometric combustion of the entire mixture to $CO_2(g)$ and $H_2O(l)$.

(c) Calculate the total volume of CO_2 gas produced at STP.

(d) 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 $\lambda = 97.25\ nm$, causing the absorption of photons and electronic transitions to an excited quantum level n_x.

(a) Using Rydberg's formula ($R_H = 1.09677 \times 10^7\ m^{-1}$), calculate the principal quantum number n_x to which the electrons are excited.

(b) Calculate the total number of possible spectral emission lines that can appear as these excited atoms cascade back down to the ground state.

(c) Identify the electronic transitions responsible for:

- (i) The emission line with the highest frequency (maximum energy / shortest wavelength).
- (ii) The emission line with the longest wavelength (lowest frequency / minimum energy).

(d) Calculate the exact wavelength (λ) of both transitions identified in part (c) and assign each to its respective spectroscopic series (Lyman, Balmer, or Paschen).