CHEMISTRY (CODE - 043)

CHAPTER TEST - STEP-BY-STEP SOLUTIONS AND MARKING SCHEME

Class XI (2026-27) | Chapter 2: Structure of Atom

Max. Marks: 35

SECTION A (12 × 1 = 12 marks)

Each correct answer carries 1 mark.

Q1. Ans: B. 30 [1]

Mass number A = 56, atomic number Z = 26. Neutrons = A − Z = 56 − 26 = **30**. (The charge changes only the number of electrons: 26 − 3 = 23.)

Q2. Ans: A. (first option) [1]

Path 1: most α-particles pass straight through because most of the atom is empty space.

Path 2: a few are deflected by small angles — repelled by the small, dense, positively charged nucleus.

Path 3: very few (about 1 in 20 000) rebound — they hit the nucleus head-on.

Q3. Ans: A. 5×10^{14} Hz [1]

$\nu = c/\lambda = (3 \times 10^{8}\ \text{m s}^{-1}) \div (600 \times 10^{-9}\ \text{m}) = \mathbf{5 \times 10^{14}\ Hz}$

Q4. Ans: C. 16 [1]

Number of orbitals in a shell = $n^2 = 4^2 = \mathbf{16}$ (1 + 3 + 5 + 7 for s, p, d, f).

Q5. Ans: B. 2d [1]

For n = 2, l can be 0 and 1 only (l = 0 to n − 1), so there is no d subshell (l = 2). **2d** is not possible.

Q6. Ans: A. P and S are isotopes; P, Q and R are isobars [1]

Mass numbers: P = 18 + 22 = 40; Q = 19 + 21 = 40; R = 20 + 20 = 40; S = 18 + 20 = 38.

P and S have the same atomic number (18) but different mass numbers → isotopes.

P, Q and R have the same mass number (40) but different atomic numbers → isobars.

Q7. Ans: C. Hund's rule of maximum multiplicity [1]

Nitrogen has 7 electrons: $1s^2 2s^2 2p^3$.

In the diagram, two electrons are paired in one 2p orbital while another 2p orbital is empty. By Hund's rule, each of the three 2p orbitals must get one electron (parallel spins) before pairing starts.

Q8. Ans: B. 1 [1]

Radial nodes = n − l − 1 = 3 − 1 − 1 = **1**.

Q9. Ans: A. -2.18×10^{-18} J [1]

$E_n = -2.18 \times 10^{-18} \times Z^2/n^2$ J

For He^+ (Z = 2), n = 2: $E = -2.18 \times 10^{-18} \times 4/4 = \mathbf{-2.18 \times 10^{-18}\ J}$

Q10. Ans: A. Both A and R are true, and R is the correct explanation of A. [1]

A shifts one electron from 4s to 3d to get the half-filled $3d^5$ arrangement, which has extra stability (symmetry and exchange energy). R correctly explains A.

Q11. Ans: C. A is true but R is false. [1]

Bohr's model explains the hydrogen spectrum (and H-like species such as He^+), so A is true. It fails for multi-electron atoms, so R is false.

Q12. Ans: D. A is false but R is true. [1]

The (n + l) values are 3d = 5 and 4s = 4, so 4s is filled first. In potassium the last electron goes into 4s ($4s^1$), so A is false. R is the correct (n + l) rule.

SECTION B (4 × 2 = 8 marks)

Q13. [2]

(i) The slope of the KE versus ν line is **Planck's constant, h** (6.626×10^{-34} J s), from KE = h(ν − ν_0). Both metals have the same slope because h is a universal constant. [1]

(ii) Metal Y has the higher work function. $W_0 = h\nu_0$, and Y has the larger threshold frequency ($\nu_{02} > \nu_{01}$). [1]

Q14. [2]

(i) $E = hc/\lambda = (6.626 \times 10^{-34} \times 3 \times 10^{8}) \div (500 \times 10^{-9}) =$ **3.98×10^{-19} J** [1]

(ii) Number of photons = 1 J ÷ 3.976×10^{-19} J = **2.5×10^{18}** photons [1]

Q15. [2]

Rules: l = 0 to (n − 1); m_l = −l to +l; m_s = +½ or −½.

(a) Not possible – for l = 2, m_l can only be −2 to +2, so −3 is not allowed. [½]

(b) Not possible – for n = 2, l can be only 0 or 1; l = 2 is not allowed. [½]

(c) Possible – 4p orbital (n = 4, l = 1, m_l = 0, m_s = +½). [½]

(d) Not possible – m_s can be only +½ or −½, not +1. [½]

Q16. [2]

(i) P: spherical → **2s**; Q: two lobes along the z-axis → **$2p_z$**; R: two lobes along the x-axis → **$2p_x$**. [1]

(ii) Q and R ($2p_z$ and $2p_x$) are degenerate: same n and l, so same energy. 2s has a different energy from 2p in a multi-electron atom. [½]

A p orbital (l = 1) has **1 angular node** (the plane perpendicular to the lobes). [½]

OR

(n + l): 3p = 3 + 1 = **4**; 4s = 4 + 0 = **4**; 3d = 3 + 2 = **5**; 4p = 4 + 1 = **5**. [1]

For equal (n + l), the orbital with lower n has lower energy: 3p < 4s and 3d < 4p.

Order: 3p < 4s < 3d < 4p [1]

SECTION C (2 × 3 = 6 marks)

Q17. [3]

(i) $E = hc/\lambda = 3.976 \times 10^{-19}$ J. In eV: $3.976 \times 10^{-19} \div 1.602 \times 10^{-19} =$ **2.48 eV**. [½]

Emission occurs only if E ≥ work function: Cs (1.9 eV) ✓, K (2.3 eV) ✓, Na (2.75 eV) ✗. **Cs and K show photoelectric emission; Na does not.** [½]

(ii) KE = E − W_0 = 2.48 − 1.9 = 0.58 eV [½]

= $0.58 \times 1.602 \times 10^{-19} =$ **9.3×10^{-20} J** [½]

(iii) KE = ½ $m_e v^2$ → $v = \sqrt{(2 \times 9.3 \times 10^{-20} \div 9.11 \times 10^{-31})}$ [½]

= $\sqrt{(2.04 \times 10^{11})} =$ **4.5×10^{5} m s^{-1}** [½]

Q18. [3]

de Broglie relation: λ = h/(mv)

(i) $\lambda = 6.626 \times 10^{-34} \div (9.11 \times 10^{-31} \times 1.0 \times 10^{6})$ [1]

= 7.27×10^{-10} m = **727 pm (7.3 Å)** [½]

(ii) $\lambda = 6.626 \times 10^{-34} \div (0.15 \times 40) = 6.626 \times 10^{-34} \div 6$ [½]

= **1.1×10^{-34} m** [½]

(iii) The wavelength (10^{-34} m) is far too small to be detected or to show any wave effect, because of the large mass of the ball. [½]

SECTION D (1 × 4 = 4 marks)

Q19. [4]

(i) A (n = 3 → 2) – **Balmer series**; C (n = 2 → 1) – **Lyman series**; D (n = 5 → 3) – **Paschen series**. [1]

(ii) B is the transition n = 4 → n = 2. $1/\lambda = R_H(1/2^2 - 1/4^2) = 1.097 \times 10^7 \times (1/4 - 1/16) = 1.097 \times 10^7 \times 0.1875 = 2.057 \times 10^6\ m^{-1}$

$\lambda = 4.86 \times 10^{-7}$ m = **486 nm** (visible, blue-green) [1]

(iii) $\Delta E = 2.18 \times 10^{-18}\ (1/1^2 - 1/2^2) = 2.18 \times 10^{-18} \times 0.75 =$ **1.64×10^{-18} J** ($\approx 1.635 \times 10^{-18}$ J) [1]

(iv) Number of lines = $n(n-1)/2 = 5 \times 4/2 =$ **10 lines** [1]

SECTION E (1 × 5 = 5 marks)

Q20. [5]

(i) Pauli's exclusion principle: no two electrons in an atom can have the same set of four quantum numbers (an orbital holds at most two electrons, and they must have opposite spins). [1]

Hund's rule: pairing of electrons in the orbitals of the same subshell does not take place until each orbital has one electron (singly occupied, parallel spins). [1]

(ii) Cr (Z = 24): **$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$** (expected $3d^4 4s^2$). [½]

Cu (Z = 29): **$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$** (expected $3d^9 4s^2$). [½]

Reason: one electron shifts from 4s to 3d because half-filled (d^5) and completely filled (d^{10}) subshells are extra stable, due to symmetrical distribution and larger exchange energy. [1]

(iii) Fe: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$. Of the six 3d electrons, one orbital is paired (↑↓) and four orbitals have one electron each → **4 unpaired electrons**. [1]

OR

(i) (any two) (a) The electron moves in certain fixed circular orbits (stationary states) around the nucleus, without radiating energy. (b) Each orbit has a fixed energy; the energies are quantised. (c) Energy is absorbed or emitted only when the electron jumps between orbits: $\Delta E = h\nu$. (d) The angular momentum of the electron in an orbit is an integral multiple of $h/2\pi$. [1 + 1]

(ii) $r_n = 52.9 \times n^2/Z$ pm $= 52.9 \times 9/3 =$ **158.7 pm** [1]

(iii) $E_2 = -2.18 \times 10^{-18} \times Z^2/n^2 = -2.18 \times 10^{-18} \times 9/4 =$ **-4.9×10^{-18} J** [1]

(iv) Bohr's model treats the electron as a particle in a definite orbit, ignoring its wave nature and violating the Heisenberg uncertainty principle; it also ignores electron–electron repulsions. (any one) [1]

***** END OF SOLUTIONS *****