ANSWER KEY & MARKING SCHEME · CBSE CLASS 11

Structure of Atom

Chemistry · Chapter 2 · Use this with the Board Paper · Companion to Quick Drill

HOW TO USE

Attempt the Board Paper first (closed-book, full time). Then come here. For 2-mark+ questions, compare your answer to the model. For 3-4 mark questions, also consult the **Topper Templates** below — these show the exact step-by-step structure that scores full marks per CBSE marking-scheme conventions.

MODEL ANSWERS · BOARD PAPER

Section A — MCQ / Very Short (1 mark each)

Q1. Who discovered the neutron? **[1 mark]**

Ans: James Chadwick (1932).

Q2. Write the value of the Bohr radius for the first orbit of H atom. **[1 mark]**

Ans: 0.529 Å (or 5.29 x 10^-11 m).

Q3. State the value of the principal quantum number for the M shell. **[1 mark]**

Ans: n = 3.

Q4. Define the term 'isotones' with one example. **[1 mark]**

Ans: Atoms with the same number of neutrons but different Z. Example: 14-C (N=8) and 16-O (N=8).

Q5. Write the maximum number of electrons that can be accommodated in the L shell. **[1 mark]**

Ans: Max in n=2 shell = 2n^2 = 8 electrons.

Section B — Short Answer (2 marks each)

Q6. Write the four quantum numbers for the LAST electron in the ground-state configuration of chlorine (Z=17). **[2 marks]**

Ans: Cl: 1s^2 2s^2 2p^6 3s^2 3p^5. Last electron in 3p subshell: n=3, l=1, m_l = +1 (or -1 or 0), m_s = -1/2 (since one orbital is already paired). Acceptable: n=3, l=1, m_l=-1/0/+1, m_s=±1/2.

Q7. Calculate the de Broglie wavelength of an electron moving with velocity 1.0 x 10^6 m/s. **[2 marks]**

Ans: lambda = h/(m*v) = 6.626e-34 / (9.11e-31 × 1.0e6) = 6.626e-34 / 9.11e-25 = 7.27 x 10^-10 m = 0.727 nm.

Q8. Differentiate between an ORBIT and an ORBITAL (any 4 differences). **[2 marks]**

Ans: (1) Orbit is a 2D circular path (Bohr); orbital is a 3D probability region (QM). (2) Orbit has fixed radius; orbital has fuzzy boundary. (3) Orbit violates Heisenberg; orbital is consistent with it. (4) Orbit holds 2n^2 electrons total; orbital holds max 2 electrons.

Section C — Long Answer (3 marks each)

Q9. State the three postulates of Bohr's model of the hydrogen atom. **[3 marks]**

Ans: (1) Electrons revolve in fixed circular stationary orbits without radiating energy. (2) Angular momentum is quantised: mvr = nh/(2π), n = 1, 2, 3, ... (3) Energy is emitted/absorbed only on transition between orbits: dE = E_high - E_low = h*nu (Planck's relation).

Q10. Calculate the wavelength of the first line of the Balmer series in the hydrogen spectrum. (R_H = 1.097 x 10^7 m^-1). **[3 marks]**

Ans: First Balmer line: n1=2, n2=3. 1/lambda = R_H × (1/n1^2 - 1/n2^2) = 1.097e7 × (1/4 - 1/9) = 1.097e7 × (5/36) = 1.524 x 10^6 m^-1. lambda = 6.563 x 10^-7 m = 656.3 nm. Visible (red) region — H-alpha line.

Q11. State Heisenberg's uncertainty principle. Explain why it is not significant for macroscopic objects. **[3 marks]**

> **Ans:** Statement: It is impossible to determine simultaneously the exact position AND exact momentum of a microscopic particle; Dx × Dp >= h/(4π). For macroscopic objects (e.g., cricket ball, m=0.15 kg), h/(4π*m) is ~10^-34/(1.88 × 0.15) ≈ 4 × 10^-34 m·m/s — completely undetectable. So we can simultaneously know position and velocity of large objects to any practical precision. The principle is fundamental to nature, not a measurement limitation.

Section D — Case-based / Long Answer (5 marks each)

Q12. (a) Write the electronic configurations of Cr (Z=24) and Cu (Z=29). (b) Justify why these configurations differ from the naive Aufbau prediction. (c) State Hund's rule of maximum multiplicity. **[5 marks]**

> **Ans:** (a) Cr = [Ar] 3d^5 4s^1; Cu = [Ar] 3d^10 4s^1 (2 marks for both configs). (b) Half-filled (d^5) and fully-filled (d^10) subshells have extra stability due to: (i) maximum exchange energy from parallel spins, (ii) symmetric distribution of electron density around the nucleus. So one 4s electron 'promotes' to 3d in Cr and Cu (2 marks). (c) Hund's rule: in a set of degenerate (same-energy) orbitals, electrons singly occupy each orbital with parallel spins before any pairing occurs — minimises electron-electron repulsion (1 mark).

Q13. (a) State the photoelectric effect. (b) Write Einstein's photoelectric equation. (c) The work function of a metal is 3.2 x 10^-19 J. Calculate (i) the threshold frequency, (ii) the maximum KE of the ejected electron if light of frequency 8 x 10^14 Hz is incident on the metal. **[5 marks]**

> **Ans:** (a) When light of suitable frequency falls on a metal surface, electrons are ejected. This is the photoelectric effect (1 mark). (b) h*nu = W0 + KE_max, where W0 = work function, KE_max = max KE of ejected electron (1 mark). (c)(i) nu0 = W0/h = 3.2e-19 / 6.626e-34 = 4.83 x 10^14 Hz (1.5 marks). (ii) E_incident = h*nu = 6.626e-34 × 8e14 = 5.30 x 10^-19 J. KE_max = E_incident - W0 = 5.30e-19 - 3.2e-19 = 2.10 x 10^-19 J = 1.31 eV (1.5 marks).

★ TOPPER ANSWER TEMPLATES

5 TEMPLATES · MEMORISE THE FORMAT

★ TOPPER TEMPLATE — Calculate wavelength/energy/frequency of a spectral line in H-atom

90% of papers (3-marker)

Step 1 [1 mark]	**Identify series + transition**	First Balmer line: transition from n=3 to n=2. Series ends at n=2 (visible region).
Step 2 [1 mark]	**Apply Rydberg / Bohr formula**	1/lambda = R_H * (1/n1^2 - 1/n2^2) = 1.097e7 * (1/4 - 1/9) = 1.097e7 * (5/36) m^-1 = 1.524e6 m^-1.
Step 3 [1 mark]	**Compute lambda + verify region**	lambda = 1/1.524e6 = 6.563e-7 m = 656.3 nm. Lies in visible (red) region — H-alpha line. ✓

COMMON LOSS OF MARKS:

- Using n1=2,n2=3 in (1/n2^2 - 1/n1^2) order — gives negative answer; always larger n is n2
- Forgetting to convert m to nm or A in the final line — examiners want SI + practical unit
- Not stating the spectral region (visible / UV / IR)

★ TOPPER TEMPLATE — State Bohr's postulates (3 marks)

75% of papers

Step 1 [1 mark]	**Postulate 1: Stationary orbits**	Electrons revolve around the nucleus in certain fixed circular paths called stationary states or orbits. In these orbits, electrons do NOT radiate energy.
Step 2 [1 mark]	**Postulate 2: Quantisation of angular momentum**	Angular momentum of an electron in an allowed orbit is an integral multiple of h/(2*pi), i.e., mvr = n*h/(2*pi), where n = 1, 2, 3, ... is the principal quantum number.
Step 3 [1 mark]	**Postulate 3: Quantised emission/ absorption**	Energy is emitted or absorbed ONLY when an electron jumps between orbits. dE = E_high - E_low = h*nu (Planck's relation).

COMMON LOSS OF MARKS:

- Writing only 2 postulates instead of 3 — full 3 marks needs all three
- Saying 'electron jumps' without explicitly writing dE = h*nu
- Forgetting 'n is integer' / 'integral multiple of h/2pi'

★ TOPPER TEMPLATE — Define / give four quantum numbers (2-3 marks)

70% of papers

Step 1 [1 mark]	**Principal (n) and Azimuthal (l)**	n = 1,2,3...: gives shell, size and energy. l = 0,1,...(n-1): gives subshell shape — s (l=0), p (l=1), d (l=2), f (l=3).
Step 2 [1 mark]	**Magnetic (m_l) and Spin (m_s)**	m_l = -l, ...0,..., +l: gives orientation of orbital in space, (2l+1) values. m_s = +1/2 or -1/2: gives spin direction of electron.
Step 3 [1 mark]	**Apply to specific electron (e.g., last e- of Cl)**	Cl (Z=17): 1s^2 2s^2 2p^6 3s^2 3p^5. Last e- in 3p: n=3, l=1, m_l = -1 or 0 or +1, m_s = +1/2 or -1/2 (any consistent set acceptable).

COMMON LOSS OF MARKS:

- Giving m_l range as 0 to +l (missed negatives)
- Writing m_s = 1/2 only (must be ±1/2)
- Confusing 'shape' (l) with 'orientation' (m_l)

★ TOPPER TEMPLATE — Calculate KE / threshold / W0 in photoelectric effect (3 marks)

50% of papers

Step 1 [1 mark]	**Write Einstein equation + compute h*nu of incident light**	h*nu = W0 + KE_max. h*nu_incident = 6.626e-34 * (incident frequency).
Step 2 [1 mark]	**Substitute W0 + solve for KE_max**	KE_max = h*nu - W0. (Both in Joules.)
Step 3 [1 mark]	**Convert to eV + comment**	KE_max in eV = (J value) / 1.6e-19. If KE_max comes out negative, NO emission occurs (nu < nu0). Threshold nu0 = W0/h.

COMMON LOSS OF MARKS:

- Mixing eV and J in same equation
- Forgetting to take nu_threshold = W0/h
- Saying 'high intensity will eject more energetic electrons' — wrong; intensity only changes NUMBER

★ TOPPER TEMPLATE — Limitations of Bohr's atomic model (3 marks)

60% of papers

Step 1 [1 mark]	**Multi-electron failure**	Bohr's model successfully explains H-atom spectrum but FAILS for atoms with more than one electron (He, Li, Be, ...) because it ignores electron-electron repulsion.
Step 2 [1 mark]	**Wave nature + uncertainty violations**	It assumes a definite circular orbit (definite position AND momentum simultaneously), which violates Heisenberg's uncertainty principle. It also ignores wave-particle duality of electrons (de Broglie).
Step 3 [1 mark]	**Cannot explain fine structure / splitting**	It cannot explain (i) fine structure of H-spectrum, (ii) Zeeman effect (splitting in magnetic field), (iii) Stark effect (splitting in electric field), (iv) chemical bonding or 3D shape of molecules.

COMMON LOSS OF MARKS:

- Writing only 'it fails for He' — examiner wants 3 distinct points
- Forgetting to mention Heisenberg / de Broglie
- Confusing limitations with postulates

MARKING SCHEME — GENERAL NOTES

- Section A: 1 mark for fully correct answer. No partial credit.
- Section B: 1 mark for correct formula/identification, 1 mark for correct numerical answer with units. Half marks for working without final units.
- Section C: marks split as indicated in answer; deduct 0.5 mark per missing point in postulate/list questions.
- Section D Q1: configurations 2 marks (1 each for Cr and Cu), justification 2 marks (1 each for half-filled and full-filled stability), Hund's rule 1 mark.
- Section D Q2: definition 1, equation 1, threshold calc 1.5, KE calc 1.5. Deduct 0.5 for unit errors. Accept eV or J for KE.
- Cross-check: total = 5 + 6 + 9 + 10 = 30 marks. Time = 8 + 15 + 22 + 30 = 75 minutes.