



Attempt all questions before checking the answer key.
Use $h = 6.626 \times 10^{-34} \text{ J s}$, $c = 3.00 \times 10^8 \text{ m/s}$, $m_e = 9.11 \times 10^{-31} \text{ kg}$; $E_n = -2.18 \times 10^{-18} Z^2/n^2 \text{ J}$.

A. Very short answers - 1 mark each

1. Define isotopes and give an example.
2. Which quantum number determines the shape of an orbital?
3. How many orbitals occur in a p subshell?
4. State the maximum number of electrons in the $n = 3$ shell.
5. Which orbitals have spherical symmetry?
6. What is the physical significance of $|\psi|^2$?

B. Short answers / practice - 2 marks each

7. Find protons, neutrons and electrons in $^{23}_{11}\text{Na}^+$.
8. Explain why Rutherford's model could not explain atomic stability.
9. Calculate photon energy for wavelength 500 nm.
10. State Pauli's exclusion principle and Hund's rule.
11. Which quantum-number sets are impossible: $(n, l, m) = (2, 2, 0), (3, 1, -1), (1, 0, 0)$? Give reasons.
12. Write electronic configurations of Cr ($Z = 24$) and Cu ($Z = 29$) and explain the exceptions qualitatively.
13. Find total orbitals in the $n=4$ shell.
14. Can $n=2$ contain a d orbital?
15. Find maximum electrons in a d subshell.
16. Find frequency of radiation of wavelength 600 nm.
17. Find angular nodes of a 4f orbital.
18. Write allowed spin quantum numbers for an electron.

C. Short answers - 3 marks each

19. Calculate energy and radius of the first orbit of He^+ using $r_n = 0.0529n^2/Z \text{ nm}$.
20. Find the wavelength of an electron moving at $2.0 \times 10^6 \text{ m/s}$, assuming non-relativistic motion.
21. An electron's speed uncertainty is $1.0 \times 10^5 \text{ m/s}$. Find its minimum position uncertainty using $\Delta x \Delta p \geq h/(4\pi)$.
22. Write allowed quantum numbers for electrons in the 3d subshell and find its maximum electron capacity.

23. Compare 2s and 2p orbitals in shape, radial/angular nodes and energy in hydrogen versus a many-electron atom.

24. Arrange 3p, 4s, 3d and 4p in increasing Aufbau energy. Explain the $n + l$ rule and its tie-breaking rule.

D. Long answers - 5 marks each

25. State Bohr's postulates. Explain how quantised energy levels account for hydrogen absorption and emission spectra, and describe limitations of the model.
26. Using the given energy formula, find the energy needed to excite hydrogen from $n = 1$ to $n = 3$, photon wavelength for $n = 3$ to $n = 2$, and ionisation energy from $n = 3$.
27. Explain all four quantum numbers, their allowed values and significance. List the possible l and m values for $n = 3$ and account for its electron capacity.
28. Compare the classical orbit and quantum-mechanical orbital. Explain de Broglie's relation, Heisenberg's uncertainty principle and why a definite electron trajectory is not retained.
29. Write configurations of Fe ($Z = 26$), Fe^{2+} , Fe^{3+} , Cu ($Z = 29$) and Cu^{2+} . Count unpaired electrons and explain why 4s electrons are removed before 3d electrons in these ions.
30. Draw orbital-box diagrams for N, O and Ne ($Z = 7, 8, 10$). Apply Aufbau, Pauli and Hund rules; identify unpaired electrons and compare stability of half-filled and filled subshells qualitatively.

ANSWER KEY - Numerical / short answers

3) 3 orbitals. 4) 18. 7) 11 protons, 12 neutrons, 10 electrons. 9) $3.976 \times 10^{-19} \text{ J}$. 11) (2,2,0) is impossible because $l < n$. 13) 16. 14) No; l can only be 0 or 1. 15) 10. 16) $5.0 \times 10^{14} \text{ Hz}$. 17) 3. 18) $+1/2$ and $-1/2$. 19) $-8.72 \times 10^{-18} \text{ J}$; 0.02645 nm . 20) $3.637 \times 10^{-10} \text{ m}$. 21) $5.79 \times 10^{-10} \text{ m}$. 22) $n=3, l=2, m=-2, -1, 0, 1, 2$; $m_s = \pm 1/2$; capacity 10. 23) 2s: 1 radial, 0 angular node; 2p: 0 radial, 1 angular node. 26) Excitation $1.938 \times 10^{-18} \text{ J}$; $\lambda \approx 656.5 \text{ nm}$; ionisation $2.422 \times 10^{-19} \text{ J}$. 27) $l=0, 1, 2$; corresponding m sets $\{0\}, \{-1, 0, 1\}, \{-2, -1, 0, 1, 2\}$; 18 electrons. 29) Fe $[\text{Ar}]3d^6 4s^2$ (4 unpaired); Fe^{2+} $[\text{Ar}]3d^6$ (4); Fe^{3+} $[\text{Ar}]3d^5$ (5); Cu $[\text{Ar}]3d^{10} 4s^1$ (1); Cu^{2+} $[\text{Ar}]3d^9$ (1). 30) Unpaired electrons: N 3, O 2, Ne 0.