



Attempt all questions before checking the answer key.
Use $E_n = -13.6/n^2$ eV and $r_n = 0.053n^2$ nm for hydrogen; $hc = 1240$ eV nm.

A. Very short answers - 1 mark each

1. What observation in alpha scattering suggests that an atom is mostly empty space?
2. Why did Rutherford's classical atomic model fail to explain stability?
3. State Bohr's angular-momentum quantisation condition.
4. What is the ionisation energy of ground-state hydrogen?
5. What is meant by a stationary orbit in Bohr's model?

B. Short answers / practice - 2 marks each

6. Find the radius and energy of the $n = 3$ orbit of hydrogen.
7. Calculate the excitation energy from $n = 1$ to $n = 2$ in hydrogen.
8. Compare speeds of the electron in the first and third Bohr orbits.
9. Explain why atomic emission spectra contain separate lines rather than all wavelengths.
10. Why are only a few alpha particles scattered through very large angles by a thin gold foil?
11. Can a ground-state hydrogen atom emit light without first gaining energy?
12. Find energy of hydrogen in $n = 4$.
13. Find ratio r_4/r_2 for hydrogen.
14. Find energy emitted in the hydrogen transition $2 \rightarrow 1$.
15. Why was a thin gold foil used in Rutherford's experiment?
16. Find angular momentum in the second Bohr orbit.
17. Does electron speed increase as the Bohr orbit number increases?
18. Find ionisation energy from $n = 4$.
19. Explain why large-angle scattering provides evidence of a compact nucleus.
20. Find the maximum number of emission lines in transitions among the first four levels.

C. Short answers - 3 marks each

21. An electron falls from $n = 3$ to $n = 2$ in hydrogen. Find the photon energy and wavelength and identify the spectral region.
22. Find the energy needed to ionise hydrogen from its $n = 2$ state. Compare with ionisation from the ground state.
23. A hydrogen atom absorbs a photon of 12.09 eV from its ground state. Identify the excited level approximately and list the possible downward transitions afterwards.
24. Use conservation of energy to obtain the distance of closest approach of an alpha particle of kinetic energy K to a heavy nucleus of charge Ze , neglecting recoil.
25. Explain the physical significance of negative total energy of an electron in a hydrogen atom and how energy varies with orbit number.

D. Long answers - 5 marks each

26. Describe Rutherford's alpha-scattering experiment, main observations and conclusions. State two limitations of the resulting atomic model.
27. Using Bohr's postulates and Coulomb attraction, derive the radius and electron speed in the n th orbit of hydrogen.
28. Derive the total energy of the electron in the n th hydrogen orbit. Discuss kinetic energy, potential energy and the meaning of ionisation.
29. Draw hydrogen energy levels $n = 1$ to 4 and mark an absorption transition, a visible emission transition and an ionisation process. Calculate the energy for each chosen transition.
30. Explain how Bohr's model accounts for hydrogen line spectra and atomic stability. Discuss its limitations and why the classical accelerating-charge argument does not apply to its postulated stationary states.

ANSWER KEY - Numerical / short answers

- 4) 13.6 eV. 6) 0.477 nm; -1.511 eV. 7) 10.2 eV. 8) $v_1/v_3 = 3$. 11) No. 12) -0.85 eV. 13) 4. 14) 10.2 eV. 16) $2\hbar = h/\pi$. 17) No; v is proportional to $1/n$. 18) 0.85 eV. 20) 6. 21) 1.889 eV; about 656.5 nm; visible. 22) 3.4 eV, one-quarter of ground-state value. 23) $n = 3$; $3 \rightarrow 2$, $3 \rightarrow 1$ and $2 \rightarrow 1$. 24) $r_{\min} = 2kZe^2/K$. 29) Example: $1 \rightarrow 2$ absorbs 10.2 eV; $3 \rightarrow 2$ emits 1.889 eV; $1 \rightarrow \infty$ needs 13.6 eV.