E.1 Structure of the atom

Practice Worksheet — name: ________________________ date: _____________

FORMULAS FOR THIS TOPIC

PHOTON ENERGY $E = hf = \frac{hc}{\lambda}$ HYDROGEN ENERGY LEVELS (HL) $E_n = -\frac{13.6}{n^2}$ eV

QUANTISED ANGULAR MOMENTUM (HL) $mvr = \frac{nh}{2\pi}$ NUCLEAR RADIUS (HL) $R = R_0 A^{\frac{1}{3}}$

SECTION A — MULTIPLE CHOICE

A1. In the Geiger–Marsden experiment, the observation that a small fraction of alpha particles deflected through more than 90° implies that:

- A Atoms are mostly empty space
- B Electrons orbit the nucleus
- C The positive charge is concentrated in a tiny, massive nucleus
- D Alpha particles are positively charged

A2. An electron in hydrogen falls from $n = 3$ (-1.51 eV) to $n = 2$ (-3.40 eV). The emitted photon has energy:

- A 1.89 eV
- B 4.91 eV
- C 3.40 eV
- D 1.51 eV

A3. Nucleus A has 8 times as many nucleons as nucleus B. The ratio of their radii R_A/R_B is:

- A 8
- B 4
- C 2
- D $\sqrt{8}$

SECTION B — SHORT ANSWER

B1. Explain how an absorption spectrum is formed and why its dark lines match the bright lines of the same element's emission spectrum. [3 marks]

B2. Show that the density of nuclear matter is approximately the same for all nuclei. [3 marks]

B3. An alpha particle (charge $2e$, energy 5.0 MeV) approaches a gold nucleus ($Z = 79$) head-on. Calculate the distance of closest approach. [4 marks]

ANSWER KEY

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Section A

A1: The positive charge is concentrated in a tiny, massive nucleus — Large-angle scattering needs a huge repulsive force from something more massive than the alpha particle — impossible if positive charge were spread thinly (as in the plum-pudding model). The RARITY of such events shows the nucleus is tiny; most alphas passing straight through shows the atom is mostly empty.

A2: 1.89 eV — Photon energy is the level difference: $-1.51 - (-3.40) = 1.89 \text{ eV}$ — the red Hα line of the Balmer series at 656 nm.

A3: 2 — $R = R_0 A^{1/3}$, so the ratio is $8^{1/3} = 2$. Volume scales with A — which is why nuclear density is the same for all nuclei.

Section B

B1: White light passing through a cool gas is absorbed at exactly the photon energies matching gaps between the gas's energy levels; the excited atoms re-emit in all directions, leaving dark lines in the forward beam. The same level differences set both absorption and emission energies, so the line positions coincide.

B2: Mass $\propto A$ (each nucleon contributes ~u). Volume $= \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A \propto A$. Density = mass/volume $\propto A/A$ — independent of A, about $2 \times 10^{17} \text{ kg m}^{-3}$ for every nucleus.

B3: At closest approach all kinetic energy is electric potential energy: $E_k = \frac{kq_1q_2}{d}$. So $d = \frac{(8.99\times10^9)(2)(79)(1.6\times10^{-19})^2}{5.0\times10^6\times1.6\times10^{-19}} \approx 4.5 \times 10^{-14} \text{ m}$ — an upper bound on the nuclear radius.