

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 Most alpha particles passed straight through: the atom is mostly empty space; a few deflected through large angles or bounced back: almost all positive charge and mass concentrate in a tiny dense nucleus.

2.2 A = nucleon number (protons + neutrons); Z = proton number, and X the chemical symbol of the element.

2.3 Electrons occupy discrete energy levels, so only specific energy gaps exist; each line is a photon of one exact frequency, $f = \Delta E/h$ – a continuum would need a continuous range of allowed energies.

2.4 Starlight passed through a spectrometer shows absorption lines that match an element's known pattern – the element's presence in the star's atmosphere.

3.1 $\Delta E = 1.9 \text{ eV} = 3.0 \times 10^{-19} \text{ J}$; $f = E/h = (3.0 \times 10^{-19})/(6.6 \times 10^{-34}) = 4.6 \times 10^{14} \text{ Hz}$; ionization from -1.5 eV needs the electron lifted to zero: 1.5 eV .

3.2 Straight through: the atom's mass and positive charge are not spread out – the space between nuclei is empty; bounce back: a head-on encounter with a concentrated positive charge whose electrostatic repulsion reverses the alpha – so nearly all the mass sits in that tiny nucleus.

3.3 Absorption lines arise when atoms absorb exactly the photon energies of their upward transitions – the same gaps that produce emission lines; matching the star's dark-line pattern against element X's laboratory fingerprint identifies X's presence, because no other element shares the same set of level spacings.

3.4 Proton number $Z = 92$; nucleon number $A = 235$; neutrons $= A - Z = 143$.