

11.1 Atoms, nuclei and radiation

Name: _____ Class: _____ Date: _____ **Total: 18 marks**

KEY WORDS nucleus 原子核 • proton 质子 • isotope 同位素 • nuclide 核素 • neutron 中子

Objective

Build the skills to answer exam questions on **atoms, nuclei and radiation** — the nuclear model, nuclide notation, decay equations, and conservation.

You must be able to:

- describe the **nuclear atom** and the α -scattering evidence
- use ${}_Z^AX$ notation; find protons, neutrons and electrons
- complete α and β **decay equations** (including the (anti)neutrino)
- apply **conservation** (charge, nucleon number, momentum) to a decay

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ The nuclear atom

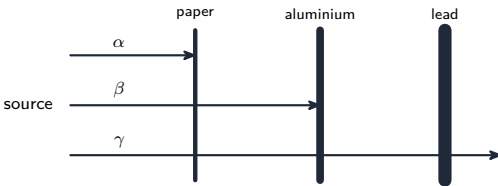
α -scattering showed the atom is **mostly empty space** (most pass straight through) with a **tiny, dense, positive nucleus** (rare large deflections). The atom has **protons** (+ e) and **neutrons** (0) in the nucleus, with **electrons** ($-e$) around it.

■ Notation and counting

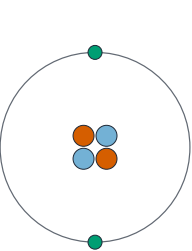
${}_Z^AX$: Z = **proton number** (fixes the element), A = **nucleon number** (protons + neutrons). For a nuclide: **protons** = Z , **neutrons** = $A - Z$, and a **neutral atom** has **electrons** = Z . **Isotopes** are the same element (Z) with different neutron numbers.

Worked example. Tritium ${}_1^3\text{H}$: protons = 1, neutrons = $3 - 1 = 2$, electrons (neutral) = 1.

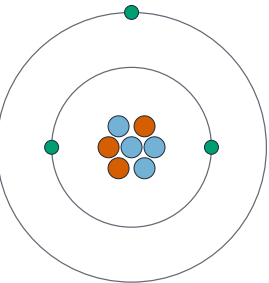
■ Radiation



a) helium



b) lithium



- proton (charge $+e$) ● neutron (no charge)
● electron (charge $-e$)

The nuclear model of the atom

	composition	charge	mass (u)
α	2 protons + 2 neutrons	$+2e$	4
β^-	an electron	$-e$	≈ 0
γ	EM photon	0	0

α has **discrete** energies; β has a **continuous** range (an (anti)neutrino shares the energy).

■ Decay equations

Balance the top numbers (A) and the bottom numbers (Z) on each side.

- α decay: ${}_{92}^{238}\text{U} \rightarrow {}_{90}^{234}\text{Th} + {}_2^4\alpha$.
- β^- decay (a neutron $\rightarrow$ proton): ${}_1^3\text{H} \rightarrow {}_2^3\text{He} + {}_{-1}^0\beta + {}_0^0\bar{\nu}$. The **antineutrino** $\bar{\nu}$ carries away 0 charge and 0 nucleon number, so it does not change the balance.

■ Conservation and recoil

In any decay, **charge** (proton number), **nucleon number**, **(linear) momentum** and **mass-energy** are all conserved. If a **stationary** nucleus decays, the two products fly apart with **equal and opposite momentum**:

Worked example. A stationary nucleus emits an α -particle (mass 4 u) at $1.5 \times 10^7 \text{ m s}^{-1}$; the daughter nucleus has mass 234 u. Momentum: $m_\alpha v_\alpha = m_R v_R$, so
$$v_R = \frac{4 \times 1.5 \times 10^7}{234} = 2.6 \times 10^5 \text{ m s}^{-1}.$$

2 Practice

Now apply the methods above.

2.1 State **two** conclusions Rutherford drew from the α -scattering experiment. [2]

2.2 For ${}^{14}_6\text{C}$, state the number of **protons**, **neutrons** and **electrons** (neutral atom). [2]

2.3 Define **isotopes**. [1]

2.4 Complete the β^- decay: ${}^{14}_6\text{C} \rightarrow \text{N} + {}^0_{-1}\beta + ?$ — give the missing nuclide numbers and name the last particle. [2]

3 Exam-style questions

3.1 Which radiation is stopped by a sheet of **paper**? [1]

- | | |
|---|---|
| A | B |
| C | D |
- A α
B β
C γ
D X-rays

3.2 A stationary nucleus decays into a nucleus R and an α -particle.

(a) State **three** quantities that are conserved during the decay. [2]

(b) The α -particle (mass 4 u) leaves at $1.6 \times 10^7 \text{ m s}^{-1}$; nucleus R has mass 222 u. Calculate the **speed** of R. [3]

3.3 Explain why β -particles are emitted with a **continuous range** of energies. [2]

3.4 State the **charge** and the **mass** (in u) of α , β^- and γ radiation. [3]