Nuclear Physics

IGCSE Physics ▪ Topic 5

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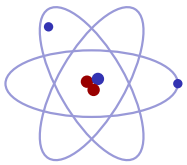


What we will cover

1 The atom

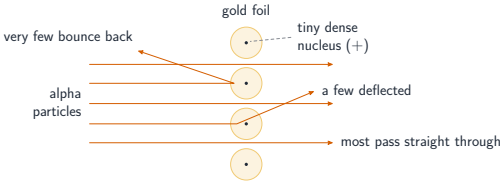
The nuclear atom

A tiny positive **nucleus** 原子核 (protons and neutrons) holds nearly all the mass. Electrons orbit in shells.

- proton number Z – the element
- nucleon number A – protons + neutrons

> **Isotopes** 同位素 have the same Z, different A – same chemistry, different nuclear behaviour.

Alpha-scattering evidence



Alpha particles α 粒子 on gold foil:

- most pass straight → mostly empty
- a few deflect → positive nucleus
- a very few bounce back → tiny, heavy nucleus

Inside the nucleus

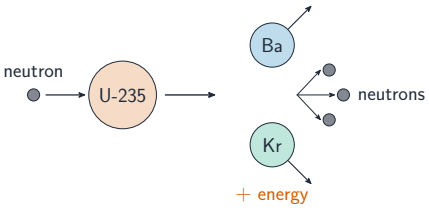
Nucleons 核子: **protons** 质子 $(+1)$ and **neutrons** 中子 (0). Notation ${}^{A}_{Z}\mathrm{X}$.

- Z = proton number; A = nucleon number; neutrons = $A - Z$
- **isotopes** 同位素: same Z, different A

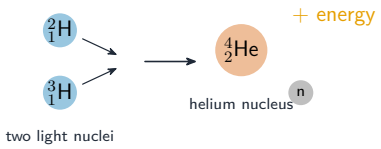
carbon-12
6 protons, 6 neutrons

carbon-14
6 protons, 8 neutrons

Fission and fusion



fission 核裂变*: a heavy nucleus splits*



fusion 核聚变*: light nuclei join (the Sun)*

Both lose a little mass, turned into energy; the A and Z numbers balance on each side.

2 Radioactivity

Radioactivity

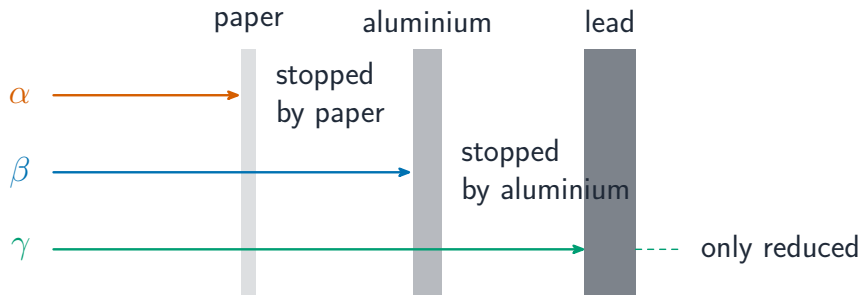
An **unstable** 不稳定 nucleus **decays** 衰变, giving out radiation. Decay is spontaneous and random. **Background radiation** 背景辐射 (radon, rocks, cosmic rays) is always present – subtract it:

250 next to source, 30 background

corrected = 220 counts/min

Three types of radiation

- α – He nucleus $(+2)$: most **ionising** 电离, stopped by paper
- β – fast electron (-1): aluminium
- γ – EM wave (0): least ionising, only reduced by lead



Deflection in fields

Charged α and β bend opposite ways; the lighter β bends more. Uncharged γ is not deflected.

> α is ${}^{4}_{2}\mathrm{He}^{2+}$; β is an electron (or positron); γ is a photon. Charge and mass decide the bend.

3 Decay and half-life

Decay equations

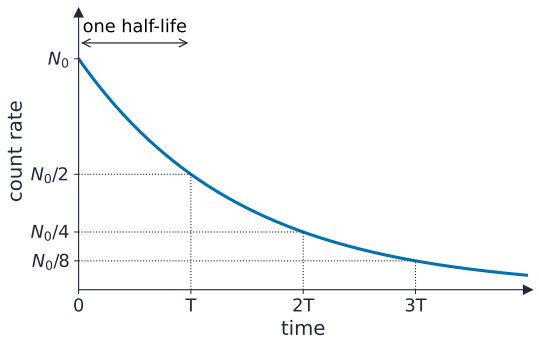
$$\alpha : {}^{A}_{Z}\mathrm{X} \rightarrow {}^{A-4}_{Z-2}\mathrm{Y} + {}^{4}_{2}\alpha$$
$$\beta : {}^{A}_{Z}\mathrm{X} \rightarrow {}^{A}_{Z+1}\mathrm{Y} + {}^{0}_{-1}\beta$$

γ emission: only energy leaves, A and Z unchanged.

${}^{226}_{88}\mathrm{Ra}$ emits α

${}^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\alpha$

Half-life



Half-life 半衰期: the time for half the unstable nuclei (or the count rate) to halve.

800 → 100 counts/min, $T = 5$ days

three halvings ⇒ 15 days

Uses and safety

Match the source to the job:

- smoke alarms – α
- **sterilising** 消毒 – penetrating γ
- thickness gauge – β

Lower the **dose** 剂量: less time, more distance, **shielding** 屏蔽 (lead).

Handle with tongs; store in a lead box.

4 Recap

Topic 5 – key takeaways

1 Nucleus

${}^{A}_{Z}\mathrm{X}$; isotopes share Z

2 Radiation

α (paper), β (Al), γ (lead)

3 Decay

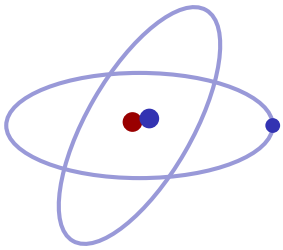
A & Z balance; α, β, γ

4 Half-life

count rate halves each half-life

Check yourself

1. How many neutrons in ${}^{197}_{79}\mathrm{Au}$?
2. Which radiation is stopped by paper?
3. ${}^{24}_{11}\mathrm{Na}$ emits β – the new proton number?
4. After 2 half-lives, what fraction is left?



Answers **1.** $197 - 79 = 118$ **2.** alpha **3.** 12 **4.** one quarter