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P8 ATOMIC PHYSICS

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P8.1 The nuclear atom

The nucleus is made of

- protons
- neutrons

- Proton number = Z
- Nucleon number = A = (protons + neutrons)

- An isotope ~~are~~ is atoms of the same element that have the same number of protons and different number of neutrons in the nucleus.

- Nuclide is the name for different types of nuclei, each with a certain number of protons and neutrons in its nucleus.

- $^{A}_{Z}X$

where X is the element symbol

for example:

$^{4}_{2}He$

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P8.2 Radioactivity

P8.2.1 Characteristics of three kinds of emission

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- Radioactive emission occurs randomly. It is not influenced by anything.
- Unstable nuclei decay and emit radiation.
- A Geiger counter measures radiation.

Identification of type of emission

Identification	Alpha (α)	Beta (β)	Gamma (γ)
Nature	+	−	no charge
Relative ionising effect	very strong	weak	very weak
Relative penetrating abilities	not very penetrating stopped by paper	penetrating stopped by thin aluminium	highly penetrating stopped by thick lead

When in a magnetic or electric field:

1. β-radiation is easily deflected as it consists of electrons.
2. α-radiation is deflected in the direction opposite to β-radiation because an α-radiation particle has a positive charge. It is harder to deflect as it has much more mass than a β-particle.
3. γ-radiation is not deflected.

Alpha radiation has very strong ionising effect as it has much more mass than beta particles. It moves slower, having much more effect with the atoms it encounters.

- Ionising radiation is the process of creating charged atoms (ions) when radiation from a radioactive source passes through a substance.

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Uses of radioactive isotopes depend on their half-life and the type of radiation it emits (for how penetrating it is).

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1. Automatic thickness monitoring
- used in the production of metal foil

A source that emits β-radiation is used.
- needs to have a long activity so activity hardly changes. This ensures variations in count rates are only because of the variation in the thickness of the foil.

• if the thickness is too much, the detector reading drops. The detector sends a signal to rollers to increase the pressure on the metal sheet. This makes the foil thinner.

2. Radioactive tracers
- used to trace the flow of a substance through a system.

The radioactive isotope of iodine, $^{131}_{53}I$, is used for finding out if a person's kidney is blocked.
- The patient drinks water with a tiny amount of the radioactive substance.

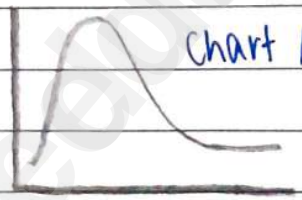

Chart A
- not blocked as radioactive iodine isotope enters and exits.

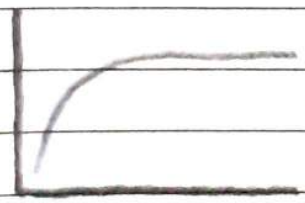

Chart B
- blocked as radioactive iodine isotope does not exit.

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$^{131}_{53}I$ is used as:

- its half-life is 8 days
- emits gamma radiation so it can penetrate out of the body. (detect outside)
- decays into a safe and stable product.

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3. Radioactive dating

- used to find how old an ancient material is.

carbon dating - used to find age of ancient wood

- for finding the age:

measure count rate of dead wood and compare with count rate of same mass of living wood.

cannot be used for living wood as there is nothing to compare the half-life.

uranium dating - used to find age of ingenous rocks

- for finding the age:

measure number of atoms of uranium and lead (lead formed due to the decay of $^{238}_{92}U$).

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P8.2.2 Detection of radioactivity

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Background radiation

alpha, beta or gamma radiation emitted by radioactive substances that occur natuarally all around us.

A Geiger counter is used to detect radioactivity.
The counter clicks each time a particle of radiation enters it.

- Alpha-particles can be stopped by some mm of paper.
- Beta-particles can be stopped by some thickness of aluminium.
- Gamma rays penetrate everything; it spreads without getting absorbed but it gets weaker.

P8.2.3 Radioactive decay

Radioactive decay is the change that happens to an unstable nucleus when it emits alpha, beta or gamma radiation.

- When a nucleus emits an α- or β-particle, the nucleus changes into a different element.

potassium ⟶ calcium + (beta-particle)

$^{40}_{19}K \longrightarrow ^{40}_{20}Ca + ^{0}_{-1}\beta$

nucleon no. stays the same
proton no. increases by 1.

uranium ⟶ thorium + (alpha-particle)

$^{238}_{92}U \longrightarrow ^{234}_{90}Th + ^{4}_{2}\alpha$

P8.2.4 Half-life

The half-life of a radioactive isotope is the time taken for the number of nuclei of an isotope in a sample to decay by half.

Count rate is the number of counts per second.

Count rate = background count rate + count rate by sample
(due to background radiation)

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count rate by sample = total count rate - background count rate

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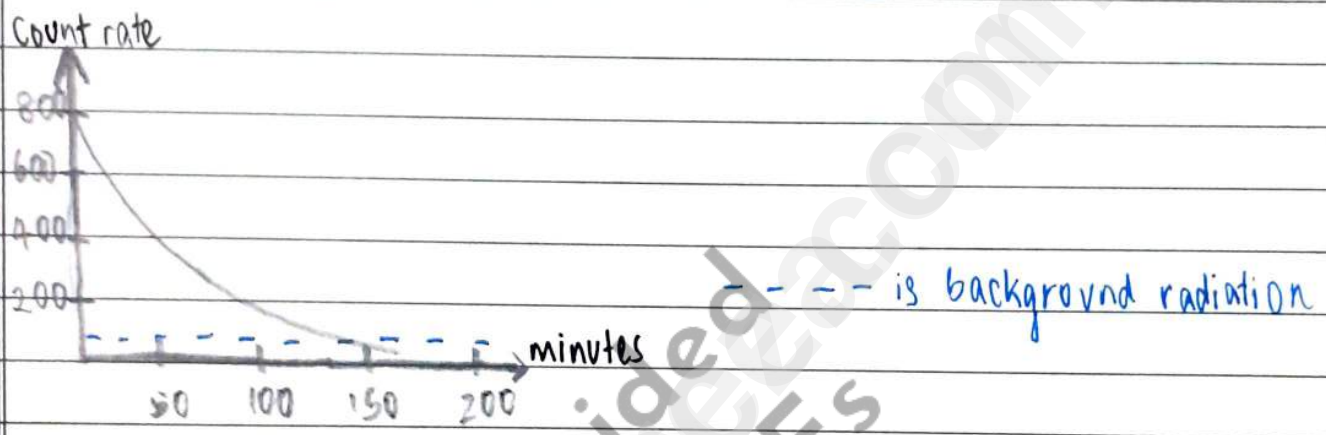
The half-life of a radioactive substance is the time it takes to:
- the number and mass of parent nuclei in a sample to halve
- the count rate from the original substance to fall to half its initial level.



P8.2.5 safety precautions

Ionisation in a living cell can dumage or kill the cell. Damage to genes can be passed on if the cell generates more cells.
- mutations, cancer, kill a cell

Radioactive materials are:
- stored in a thick lead container in a secure location.
- • kept at a safe distance when being used
  • seperated by thick lead screens when being used
  • used for a short period of time
  • moved using long-handled tools

Radiation workers carry a radiation monitoring device and are supposed to wear HAZMAT (hazardous material) suits.

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