Chapter 7: Radioactivity

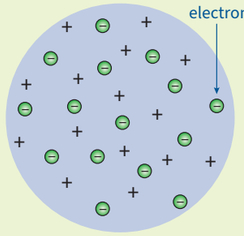
Knowledge organiser

Dalton's model

John Dalton thought the atom was a neutral solid sphere you cannot divide into smaller parts.

Plum pudding model

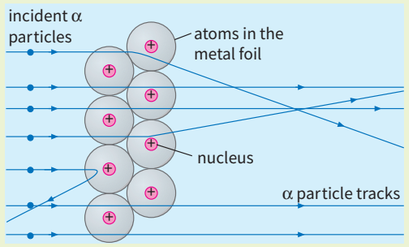
The discovery of negatively charged electrons led to the plum pudding model – a cloud of positive charge with electrons embedded in it.



Alpha scattering experiment

Positively charged alpha particles were fired at a thin sheet of gold foil.

- Most went straight through
- Some were deflected by small amounts
- 1 in 10 0000 deflected through large angles



Nuclear model

To explain the results, scientists deduced that there is a small positively charged nucleus at the centre of the atom where most of the mass is concentrated. The negative electrons orbit the nucleus.

Bohr's model

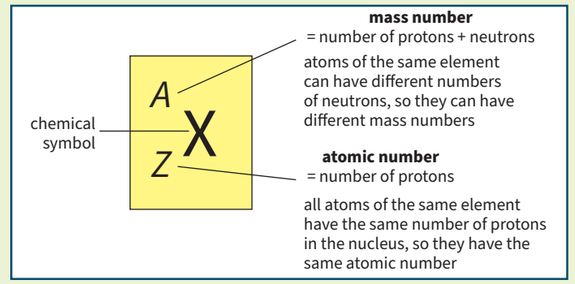
Bohr suggested the electrons orbit at specific distances called energy levels.

Basic structure of an atom

The nucleus, which is 10 000 times smaller than the radius of the atom, consists of two particles:

- positively charged protons
- neutrons which are neutral

An atom is uncharged overall and has equal numbers of protons and electrons.



Isotopes are atoms of the same element, with the same number of protons but a different numbers of neutrons.

Radioactive decay

Radioactive decay is when nuclear radiation is emitted by unstable atomic nuclei so that they become more stable. It is a *random* process. This radiation can knock electrons out of atoms in a process called **ionisation**.

Type of radiation	Change in the nucleus	Ionising power	Range in air	Stopped by	Decay equation
α alpha particle (two protons and two neutrons)	nucleus loses two protons and two neutrons	highest ionising power	travels a few centimetres in air	stopped by a sheet of paper	${}^{A}_{Z}\mathrm{X} \rightarrow {}^{(A-4)}_{(Z-2)}\mathrm{Y} + {}^{4}_{2}\alpha$
β beta particle (fast-moving electron)	a neutron changes into a proton and an electron	high ionising power	travels ≈ 1 m in air	stopped by a few millimeters of aluminium	${}^{A}_{Z}\mathrm{X} \rightarrow {}^{A}_{(Z+1)}\mathrm{Y} + {}^{0}_{-1}\beta$
γ gamma radiation (short-wavelength, high-frequency EM radiation)	some energy is transferred away from the nucleus	low ionising power	virtually unlimited range in air	stopped by several centimetres of thick lead or metres of concrete	${}^{A}_{Z}\mathrm{X} \rightarrow {}^{A}_{Z}\mathrm{X} + {}^{0}_{0}\gamma$

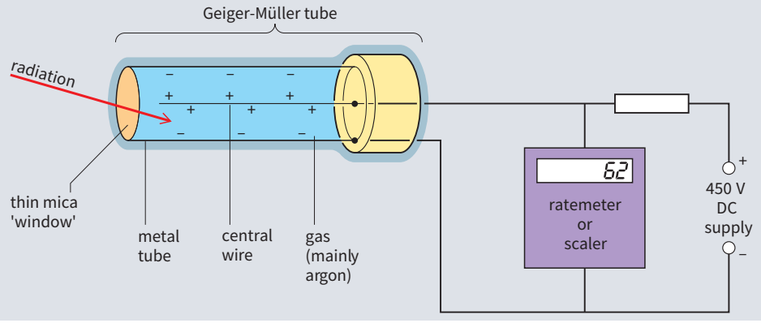
Activity and count rate

The **activity** of a radioactive source is the rate of decay of an unstable nucleus, measured in becquerel (Bq).

1 Bq = 1 decay per second

Detectors (e.g., **Geiger-Müller tubes**) record a **count rate** (number of decays detected per second).

$$\text{count rate after } n \text{ half-lives} = \frac{\text{initial count rate}}{2^n}$$



Half-life

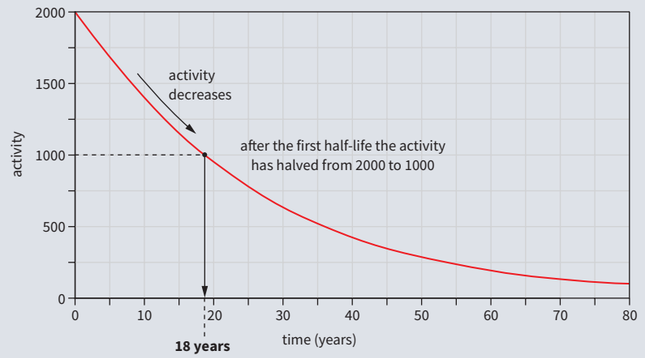
The **half-life** of a radioactive source is the time

- for half the number of unstable nuclei in a sample to decay
- for the count rate or activity of a source to halve.

The half-life of a source can be found from a graph of its count rate or activity against time.

To find the reduction in activity after a given number of half-lives:

1. calculate the activity after each half-life
2. subtract the final activity from the original activity.



The time taken for the activity to halve is 18 years. This is the half-life of this substance.

(HT only) Net decline can be given as a ratio: $\text{net decline} = \frac{\text{reduction in activity}}{\text{original activity}}$

Key terms

Make sure you can write a definition for these key terms.

atom alpha activity atomic number beta count rate electron gamma Geiger-Müller tube half-life ionisation irradiation isotope mass number net decline neutron plum pudding model proton radiation dose radioactive decay

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Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

	P7 questions	Answers
1	Describe the basic structure of an atom.	nucleus containing protons and neutrons, around which electrons orbit in fixed energy levels/shells
2	Describe the plum pudding model of the atom.	sphere of positive charge with negative electrons embedded in it
3	What charges do protons, neutrons, and electrons carry?	protons = positive, neutrons = no charge, electrons = negative
4	Why do atoms have no overall charge?	equal numbers of positive protons and negative electrons
5	What is the radius of an atom?	around 1×10^{-10} m
6	What is ionisation?	process which adds or removes electrons from an atom
7	What is the mass number of an element?	number of protons + number of neutrons
8	Which particle do atoms of the same element always have the same number of?	protons
9	What are isotopes?	atoms of the same element (same number of protons) with different numbers of neutrons
10	What were the two main conclusions from the alpha particle scattering experiment?	• most of the mass of an atom is concentrated in the nucleus • nucleus is positively charged
11	What are the three types of nuclear radiation?	alpha, beta, and gamma
12	Which type of nuclear radiation is the most ionising?	alpha
13	What is the range in air of alpha, beta, and gamma radiation?	a few cm, 1 m, and unlimited, respectively
14	What are the equation symbols for alpha and beta particles?	$^{4}_{2}\alpha$ and $^{0}_{-1}\beta$
15	What is meant by the half-life of a radioactive source?	time taken for half the unstable nuclei to decay or the time taken for the count rate to halve

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