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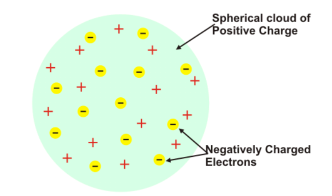
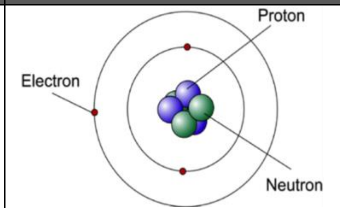
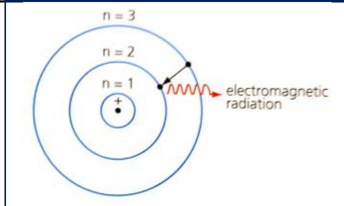
Section 1: Key Terms and Definitions

1	Atom	The smallest part of an element that can exist. All substances are made of atoms. Atoms have no overall electrical charge. They are very small with a radius of 0.1nm.
2	Element	An element contains only one type of atom. Found on the periodic table. There are over 100 elements.
3	Isotope	An atom of the same element with a different number of neutrons. All isotopes of a particular element have the same atomic number
4	Radioactive Decay	When an unstable nucleus changes to become more stable and emits radiation. Happens randomly
5	Radiation Dose	Measure of the exposure to radiation, measured in sieverts (Sv).
6	Activity	The rate at which decay occurs. Measured in Becquerel (Bq). 1 Becquerel is 1 decay per second.
7	Count Rate	Number of decays recorded each second by a Geiger-Muller Tube
8	Half Life	The time it takes for the number of nuclei of the isotope in a sample to halve. **Or,** The time it takes for the count rate (or activity) from a sample containing the isotope to fall to half its initial level.
9	Ionisation	Radiation can ionize by removing the electrons from atoms to form ions. If this happens in DNA it could lead to a mutation that causes cancer
10	Proton	Positively charged particle found in the nucleus
11	Neutron	Neutral (not charged) particle found in the nucleus
12	Electron	Negatively charged particle found orbiting the nucleus at different distances depending which shell it is in.
13	Nucleus	Centre of the atom 1/10,000 of the size of the atom but contains most of the mass of the atom.
14	Ion	An atom with either more or less electrons than the protons, giving it an overall positive or negative charge.
15	Background Radiation	Radiation present in the environment around us, comes from: • Natural sources such as rocks, soil and cosmic rays. • Man-made sources such as fallout from nuclear weapons exploding, radiation leaks from accidents at nuclear power stations.

Section 2: Development of the Atomic Model

Thomson's Plum Pudding Model	Rutherford's Nuclear Model	Bohr's Model
		
Thomson's Plum Pudding model of the atom showed that the atom was a **sphere of positive charge with negatively charged electrons** spread through it. **This model was** proven to be **incorrect** by Rutherford.	Rutherford's model suggested that **most of** the **atom** must be **empty space**. A **very small positively charged nucleus** surrounded by **electrons orbiting** it. Over time, this model was **refined by** the **discovery of** the **neutron**.	Bohr suggested a model of the atom where **electrons move round the nucleus in circular orbits**. In this model electrons can change their orbits. This further refined the work of Rutherford.

Energy Levels: Absorption of radiation may lead to electrons moving further from the nucleus (higher energy level)

Emission of radiation may lead to electrons moving closer to the nucleus (lower energy level)

Section 3: Atomic Number and Mass Number

Mass Number:
The total number of **protons and neutrons** → 132.91

Atomic Number: The number of protons within an atom.
(In an atom, the number of electrons would be the same) → 55

132.91
Cs
55

Section 4: Properties of Sub Atomic Particles

Sub-atomic Particle	Mass	Charge	Location in Atom
Proton	1	+1 (Positive)	In Nucleus
Neutron	1	0 (Neutral)	In Nucleus
Electron	$\frac{1}{2000}$	-1 (Negative)	Orbiting Nucleus

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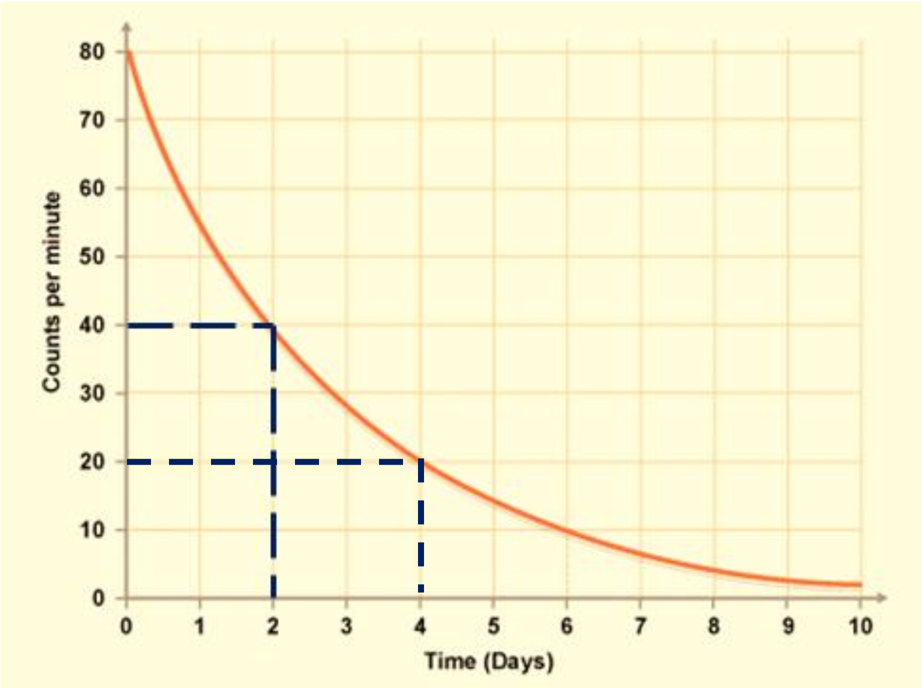
Section 5: Nuclear Radiation

Radiation	Range in Air	Absorbed by	Ionising Power	Consists of
Alpha, α	Short – up to 5cm	Paper and skin	Very High	2 protons and 2 neutrons (Helium nucleus)
Beta, β	Medium – about 1m	About 5mm of Aluminium	Medium	Electron
Gamma, γ	Unlimited	Several Centimetres of lead	Low	Electromagnetic Wave

Section 6: Decay Equations

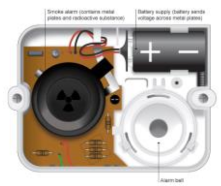
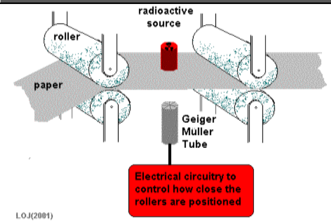
Alpha Decay	$^{219}_{86}Rd \rightarrow {}^{215}_{84}Po + {}^{4}_{2}He$ In alpha decay a helium nucleus (**2 protons and 2 neutrons**) is emitted. The new element formed has a **mass number** that has **decreased by 4** (219 – 215 = 4) and **atomic number** that has **decreased by 2** (86 – 84 = 2).
Beta Decay	$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$ In beta decay a neutron turns into a proton. An electron is emitted. The new element formed has a **mass number** that **stays the same** and an **atomic number** which **increased by 1**(6 + 1 = 7).
Gamma Ray Emission	Decay by Gamma emission causes no change in the mass or structure of the nucleus.

Section 7: Half-Life and Activity Counts



Halve the initial activity (80 ÷ 2 = 40)
Draw a line across on the graph until you reach the curve
Draw a line down (half-life = 2 days)
However, the activity **never** reaches zero.

Section 8: Uses of Radioactivity

Smoke Detectors	Thickness Control	Carbon Dating
		
Smoke detectors contain a small amount of Americium-241, an alpha emitter. Smoke in the detector blocks alpha particles, triggering the alarm.	A beta emitter with very long half-life is used. Radiation from the source is continually monitored. If the count rate drops, the thickness is too great and the rollers separate.	Used to find the age of ancient materials. Living wood has a tiny proportion of radioactive carbon C-14. The lower the proportion of C-14, the older the object being tested.

Section 9: Irradiation vs Contamination

Irradiation	Contamination
Objects that are near a radioactive source are irradiated by it. The object is exposed to the radiation, but irradiating it does not make the object radioactive.	If unwanted radioactive atoms get onto or into a material, then it is said to be contaminated. The radioactive atoms will then decay, releasing radiation which could cause harm.

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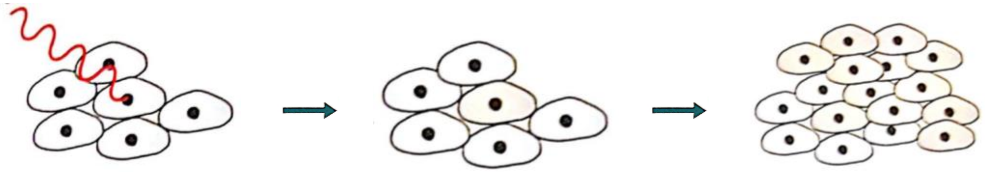
Section 10: Dangers of Radiation

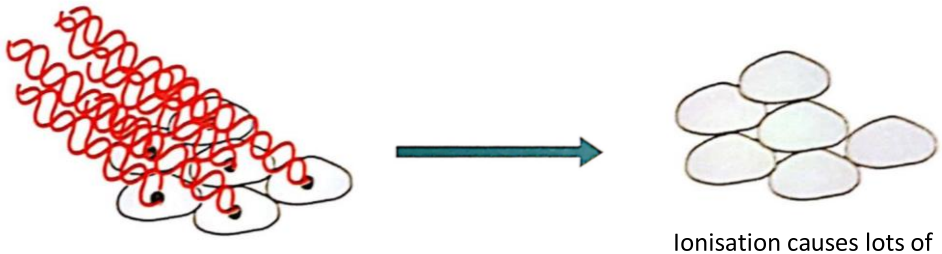


Normal cells exposed to a low dose of radiation.

Ionisation inside the cell leads to cell damage.

Damaged (mutant) cell divides uncontrollably forming cancer.

- Radiation can enter living cells and ionise atoms and molecules within them. This can lead to tissue damage.
- Lower dose tend to cause damage without killing the cells. This can lead to mutant cells which divide uncontrollably. (Cancer)



Normal cells exposed to a high dose of radiation.

Ionisation causes lots of damage to the cells, causing them to die.

- Higher doses kill cells completely, causing radiation sickness if a lot of cells get the dose at once.

Section 11: Uses of Radiation in Medicine

Radioactive Tracers

Image of a bone scan using radioactive technetium as a tracer.

Patients are injected with a radioactive isotope. The isotope should:

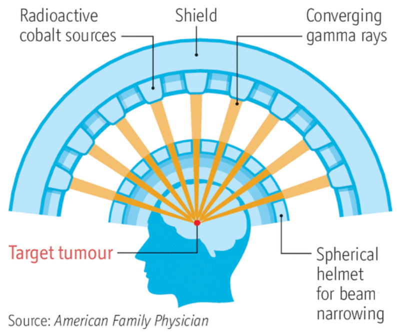
- Decay by gamma emission (to be detectable outside the body and reduce ionisation)
- Have a short half-life (long enough to complete the test, not long enough to leave patient irradiated for days)
- Decay into a stable isotope (so that there a no further dangers from alpha or beta decay within the body)

Common tracers include Iodine-123 and Technetium-99m.

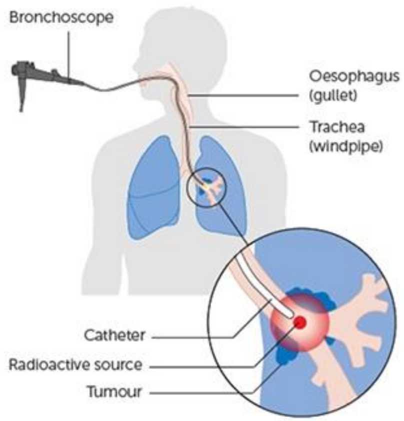
Radiotherapy – Cancer Treatment

High doses of radiation will kill cells. Cancers can be treated by bombarding tumours with high doses of radiation.

- Gamma rays can be used to target the tumour from different angles to minimise the damage to healthy cells.



- Radioactive compounds (usually beta emitters) can be injected into tumours.



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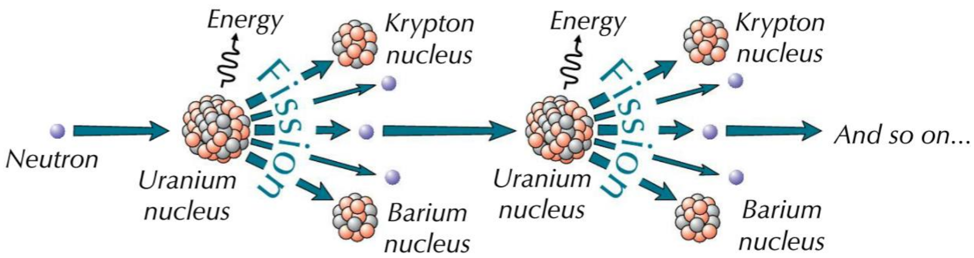
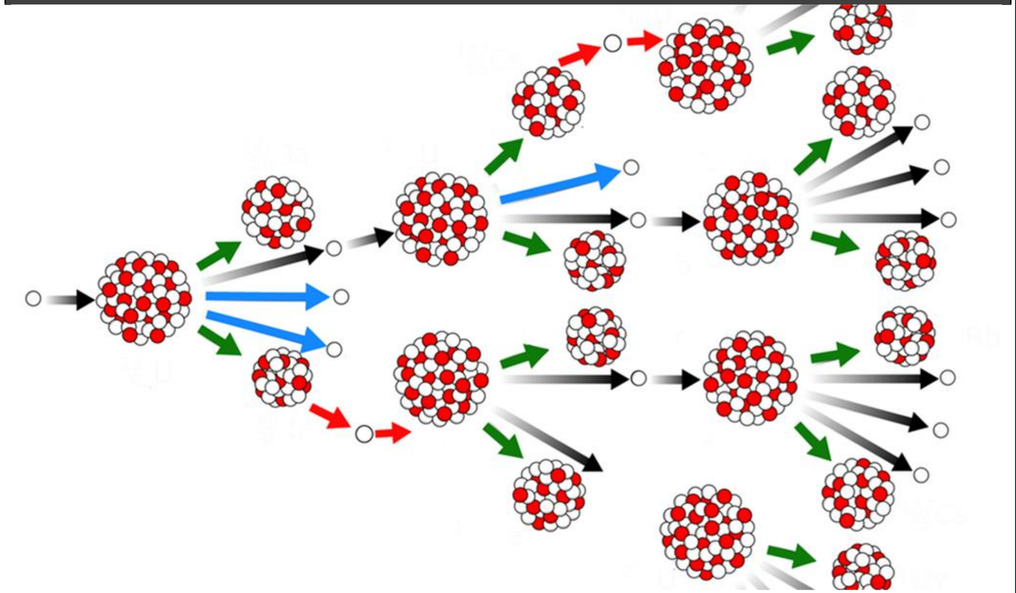
Section 12: Nuclear Fission

Heavy atomic nuclei such as Uranium-235 and Plutonium-239 can be split when struck by a fast moving neutron. These isotopes are said to be "fissionable materials".



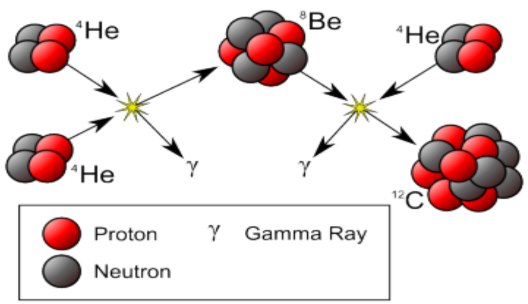
- Unstable nuclei are bombarded with neutrons.
- The nuclei undergo fission and split.
- Two smaller nuclei are formed plus neutrons.
- Energy is released.
- Released neutrons cause more nuclei to split which produces a chain reaction.
- The reaction is controlled using control rods which absorb the neutrons (slowing down the chain reaction).
- A water coolant removes the heat energy.

Section 13: Chain Reactions



When fissionable material is split, it produces 2 smaller atomic nuclei plus 2 or 3 extra neutrons.
These extra neutrons can collide with other fissionable nuclei to cause further fission reactions.
This is known as a chain reaction. In a nuclear reactor the chain is controlled so that each nuclei split only releases neutrons to split one further nuclei.

Section 14: Nuclear Fusion



- Two light nuclei join (fuse) to form a single heavier nucleus.
- For example, two Helium nuclei fuse to form a Beryllium nucleus.
- Energy is released when the nuclei fuse – more energy than when heavy nuclei split due to fission.

The sun releases energy due to the nuclear fusion reaction of fusing hydrogen into helium.

Section 15: Comparing Nuclear Fission and Nuclear Fusion

Nuclear Fission	Nuclear Fusion
Been used for over 50 years	A developing technology. Needs to be at a high temperature and pressure for reaction take place and generate electricity
Uses uranium (only found in some parts of the world)	Hydrogen fuel easily available as present in sea water.
Produces radioactive nuclear waste which has to be stored safely and securely	Produces no harmful waste.