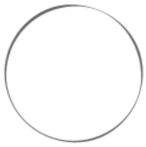
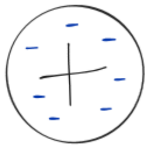
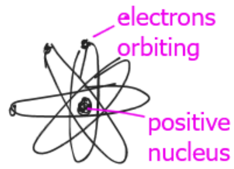
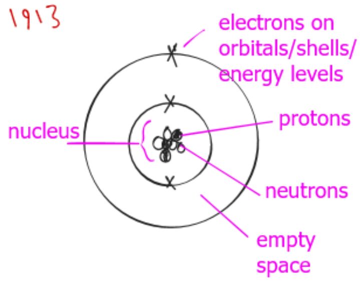
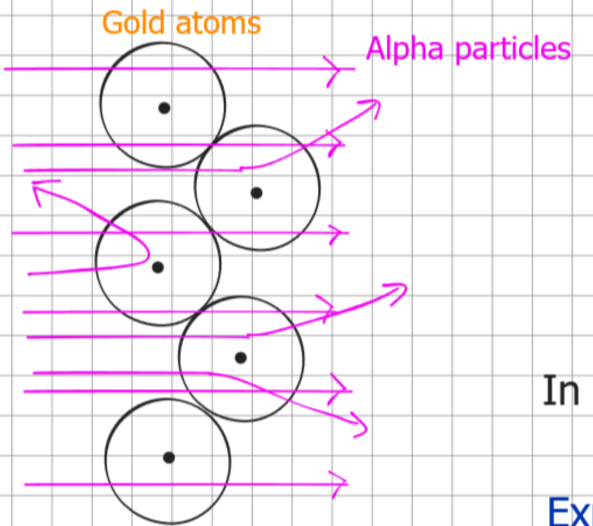
| | | Dalton model | Plum Pudding model | Nuclear model | Bohr model (current) |
|---|---|---|---|---|---|
| | Description & diagrams | 1803  Small spheres that are INDIVISIBLE. ~10nm diameter They have no overall charge. | 1904  A solid region of positive charge with negative electrons scattered throughout it. No empty space. Same amount of positive charge and negative charge. (JJ Thomson) | 1911   99.9% empty space Mass and positive charge concentrated in the nucleus. (as protons) Negative electrons orbit at some distance from the nucleus. | 1913   Atoms are neutral, so they must contain the same number of protons as electrons |
| Properties the model explains: | Small & indivisible | ✓ | ✓ | ✓ | ✓ |
| | Neutral | ✓ | ✓ | ✓ | ✓ |
| | Has electrons | | ✓ | ✓ | ✓ |
| | Is mostly empty space | | | ✓ | ✓ |
| | Has a nucleus | | | ✓ | ✓ |
| | Has electrons orbiting nucleus | | | ✓ | ✓ |
| | Has electron shells (energy levels) | | | | ✓ |
| | Contains neutrons | | | | ✓ James Chadwick 1932 |

## Rutherford Alpha Scattering

9th Oct




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

The plum pudding model showed that most alpha particles should pass straight through undeflected.

In reality: MOST alpha particles pass straight through.

Explanation: Atoms are 99.9% empty space

SOME alpha particles were DEFLECTED by SMALL ANGLES

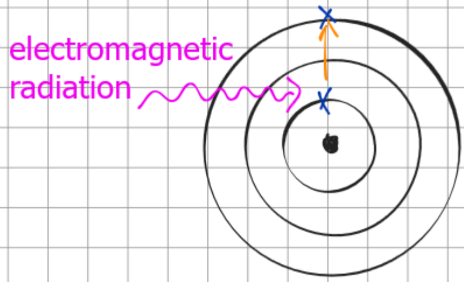
Explanation: There is a small, positively charged NUCLEUS.

FEW particles were DEFLECTED by LARGE ANGLES

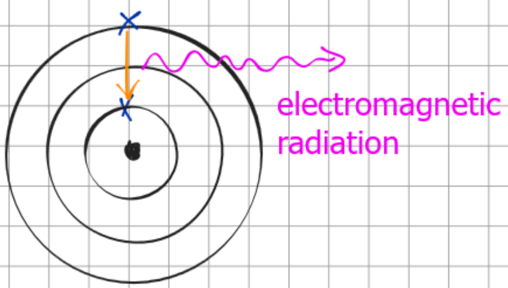
Explanation: Most of the MASS is concentrated in the positive nucleus.

## Atoms and Light

15th Oct



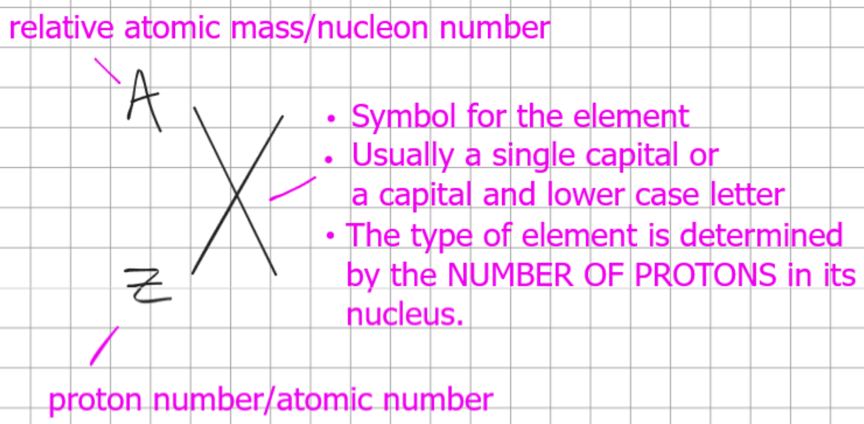

When an electron ABSORBS electromagnetic radiation it becomes EXCITED and moves to a higher energy level, and FURTHER AWAY FROM THE NUCLEUS.




Eventually the electron will move a lower energy level and EMIT energy in the form of electromagnetic radiation, and move CLOSER TO THE NUCLEUS.

## Nuclear Notation and Isotopes

22nd Oct

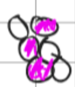



$$A = Z + N$$

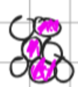
number of neutrons in the nucleus

 $^{5}_{3}Li$

Lithium - 5

 $^{6}_{3}Li$

Lithium - 6

 $^{7}_{3}Li$

Lithium - 7

These are all ISOTOPES of lithium. They all have the SAME NUMBER OF PROTONS in the nucleus. They have different relative mass numbers as they have DIFFERENT NUMBERS OF NEUTRONS.

Some atomic nuclei are UNSTABLE.

This means, at some stage in their lifetime, they will DECAY. When they do they emit energy in the form of NUCLEAR RADIATION.

The nucleus will become MORE STABLE after decay.

We cannot predict exactly when an unstable nucleus will decay. This means radioactive decay is a RANDOM process.

## Nuclear Radiation

23rd Oct

All nuclear radiation is IONISING.

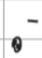
This can cause MUTATIONS (a change in the structure of your DNA).

MUTATIONS can increase the risk of developing CANCERS.

Larger (acute) doses of radiation can KILL CELLS.

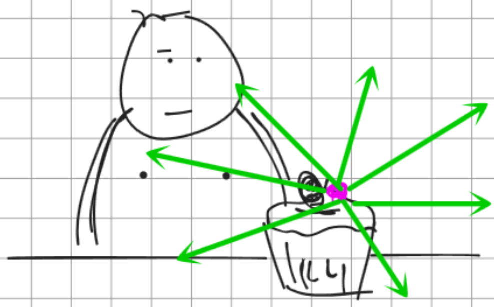
The level of risk is linked to the DOSAGE of radiation (your level of exposure). Radiation dose is measured in millisieverts (mSv).

When we undergo any medical treatment that involves ionising radiation we will weigh up the risks of any dose with the benefits of the treatment.

| Type of radiation | Symbol, charge and composition | Range | Penetrative Power | Deflected by Electric or Magnetic Field? |
|---|---|---|---|---|
| Alpha |  Two protons and two neutrons<br>$^4_2\alpha$ $^4_2He$ Helium nucleus | Few cm in air | Low; can be stopped by paper.<br>Most ionising. | Yes, as it has a charge of 2+. |
| Beta |  High speed electron, emitted from the nucleus when a neutron decays into a proton<br>$^0_{-1}\beta$ $^0_{-1}e$ | Up to a metre in air | Moderate; can be stopped by a few mm of aluminium<br>Moderately ionising | Yes, as it has a charge of -1. |
| Gamma | A high frequency electromagnetic wave | No limit in air | High; can be stopped by a few cm of lead.<br>Least ionising | No, as waves have no charge. |

# Irradiation and Contamination

24th Oct

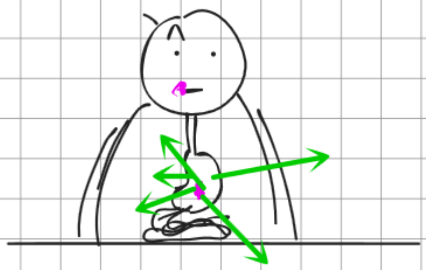


This person is at risk due to IRRADIATION.

They are being exposed to nuclear radiation.
They do not become radioactive.

They can reduce the risk of harm by:

- Minimising exposure time
- Keeping their distance from the source
- Wearing lead shield



The person is now at risk due to CONTAMINATION.

Contamination is the unwanted presence of radioactive materials ON or INSIDE an object.

The person can now irradiate others, they do become radioactive.

To minimise the risk of harm we can:

- Handle sources with tongs
- Wear airtight protective clothing

Alpha sources are the MOST IONISING so pose a large risk due to contamination, but they are the LEAST PENETRATIVE so pose little risk due to irradiation.

Gamma sources are the LEAST IONISING so pose a smaller risk due to contamination, but they are the MOST PENETRATIVE so pose a larger risk from irradiation.

# Nuclear Decay Equations

24th Oct

We need to know that during nuclear decay:

- Mass number before and after the decay must not change
- Charge before and after the decay must not change

Example:

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

Mass: 234 + 4 = 238
Charge: 90 + 2 = 92

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$$

Mass: 14 + 0 = 14
Charge = 7 + (-1) = 6

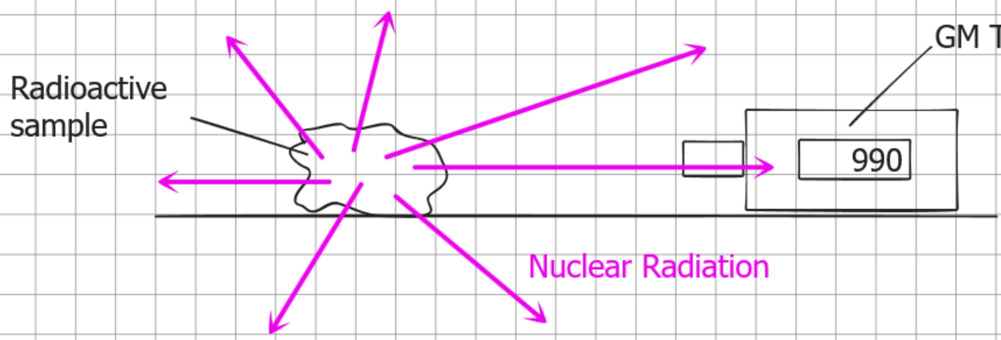
## Count Rate and Activity

5th Nov

The COUNT RATE tells us the number of radioactive decays we DETECT in a certain time i.e. counts per second, counts per minute etc.

A CORRECTED COUNT RATE is one where the level of BACKGROUND RADIATION has been measured and SUBTRACTED from the COUNT RATE detected from a source.

For example: If I detect 1000 cps from a source, but I know the mean background count is 10 cps then the corrected count rate would be 990 cps.




The ACTIVITY of a sample tells us the NUMBER OF DECAYS PER SECOND.

It has the unit of the BECQUEREL (Bq). 1 Bq = 1 decay per second.

The count rate from a sample is often LOWER than the activity; not every decay that happens is detected. Some radiation may miss the detector, or some may be absorbed by the air before it reaches the detector.

## Half Life

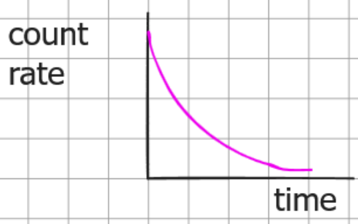
12th Nov

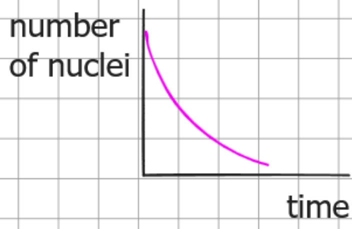
The HALF-LIFE of a particular isotope tells us how long it takes for the activity of a sample to halve.

Note: you may see 'count rate' in this definition in place of activity, or you may see the alternative definition 'the time taken for the number/mass of the unstable nuclei to halve'.

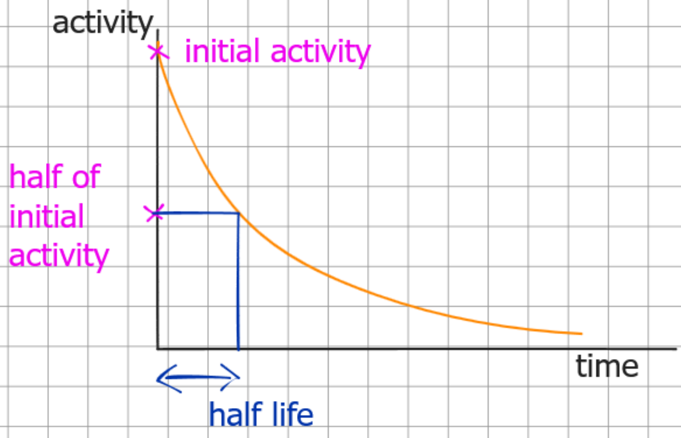
Example: If an isotope has an initial activity of 1000 Bq and a half-life of 2 hours, then 2 hours after our initial measurement the activity would have dropped to 500 Bq. It would be down to 250 Bq after 4 hours, and 125 Bq after 6 hours.

We can find the half life of a substance from any of the following graphs:


We use the following technique:



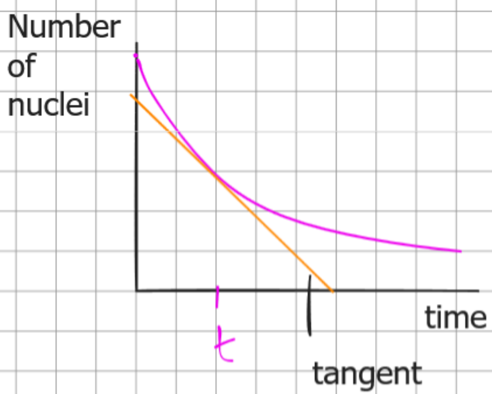

Calculate half of the initial activty/count rate/number of nuclei.

Draw a ruled horizontal line across from this value to the line of best fit

Draw a vertical line down to the time axis to find the half life.

## Activity from a Graph

14th Nov




If we are shown a graph of the number nuclei changing over time then the ACTIVITY can be found from the GRADIENT of the graph.

As the graph is curved, the gradient is CHANGING. So we have to draw a TANGENT to the curve and the gradient of this.

## Uses of Radiation

27th Nov

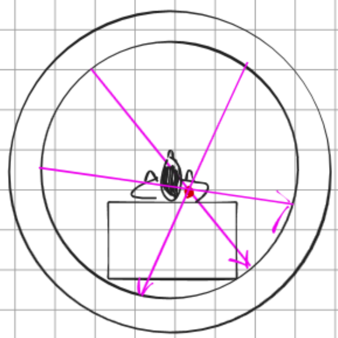
The properties of radiation dictate the uses it may have.

Nuclear radiation is IONISING, which means it can damage DNA and even kill cells.

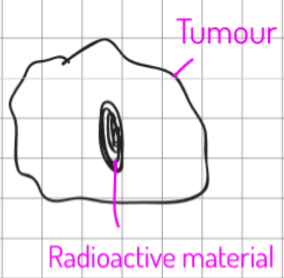
This means we can use radiation to treat cancer; we use the ionising radiation to kill the cancer cells.

### Uses of Radiation

**Radiotherapy** – Where we use ionising radiation to kill cancerous cells by damaging their DNA.



- Gamma rays are emitted through the cancerous cells.
- Multiple low intensity rays are aimed so that they overlap at the tumour site.

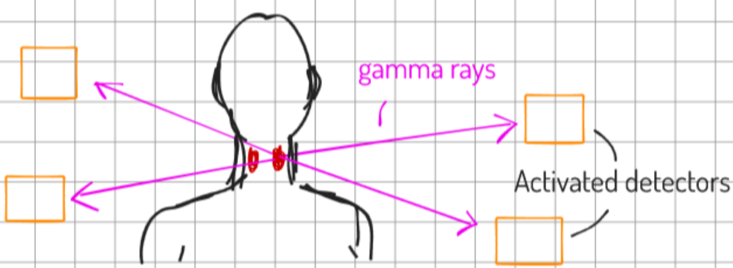



- An alpha emitter is placed inside a tumour
- It is very ionising so cannot travel far, and kills the cells closest by.
- We would like a half life of a few days; the activity of the source would eventually drop to a low level and minimise long term harm.

## More Uses of Radiation

22nd Nov

**Tracer**



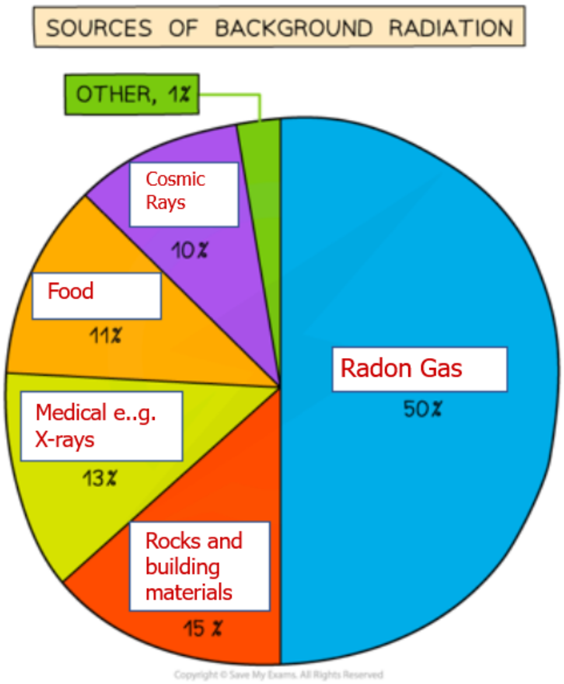

A radioactive isotope is injected into a person, which is usually a gamma emitter.

Gamma radiation can be detected outside of the body.

It is also not very ionising, so is less likely to damage body tissues.

We would normally use an isotope with a half of a few hours. This allows time to scan the patient, but does not expose the patient to harmful radiation ong.

# Background Radiation




The level of background radiation is random, but we must correct for it when measuring the count rate from a radioactive source.

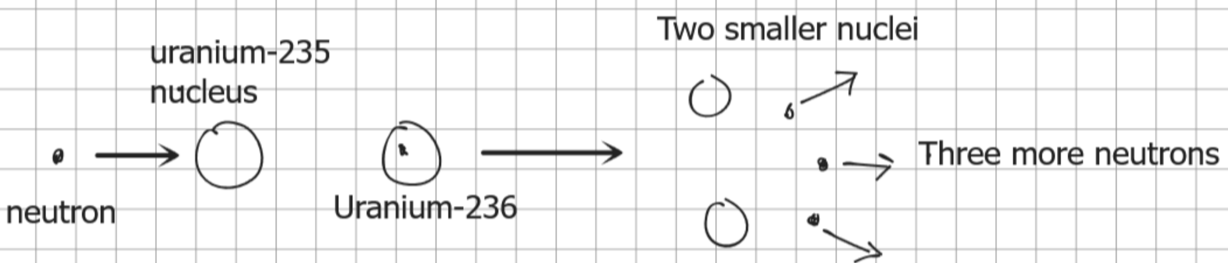
So we can measure the background count a few times and take a mean.

We can then subtract this mean from any future measurements to get a CORRECTED COUNT RATE.

## Fission and Fusion

3rd Dec

Nuclear FISSION is the splitting of a LARGE NUCLEUS into several SMALLER NUCLEI, some NEUTRONS and ENERGY.




- A neutron is fired at a nucleus of U-235
- The neutron is absorbed to create U-236
- The U-236 is very unstable and splits into; 2 daughter nuclei and 3 neutrons
- Each of these neutrons may cause further fission reactions; this is a CHAIN REACTION.
- In this process gamma radiation can be released, and all of the products have kinetic energy.

$$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{236}_{92}U \rightarrow ^{92}_{36}Kr + ^{141}_{56}Ba + 3\,^{1}_{0}n$$

In a nuclear power station, this reaction is controlled. We block some of the neutrons that are released. Nuclear fission does not happen naturally.

Nuclear FUSION is when two SMALL/LIGHT NUCLEI join together to form a LARGER/HEAVIER NUCLEUS - some of the MASS is converted directly into ENERGY.

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$$

Nuclear fusion happens naturally in STARS.

For nuclear fusion to work on Earth we would need to heat the hydrogen up to VERY HIGH TEMPERATURES (around 150,000,000 K).

At higher temperatures the nuclei have HIGHER KINETIC ENERGY, so they can overcome the force of REPULSION between the POSITIVE protons they contain.