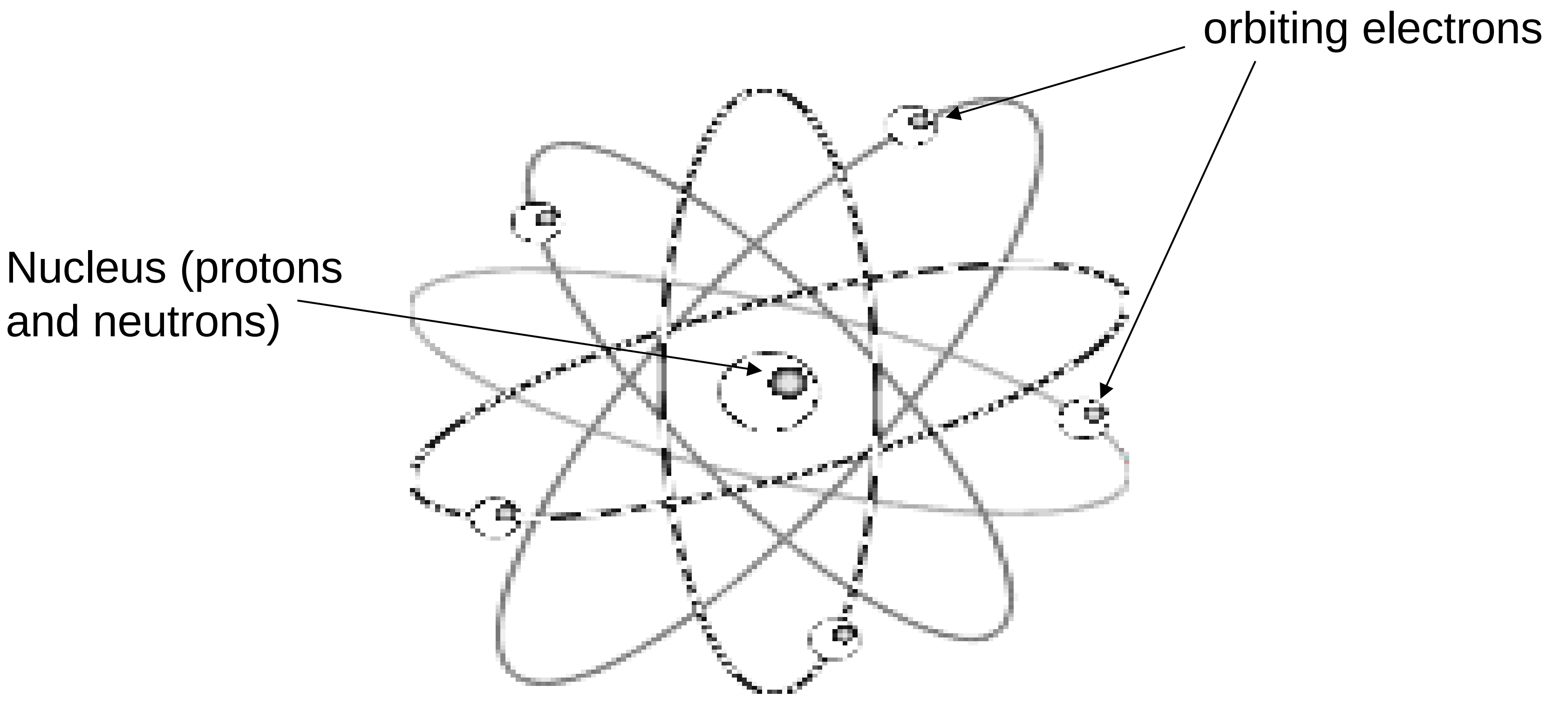
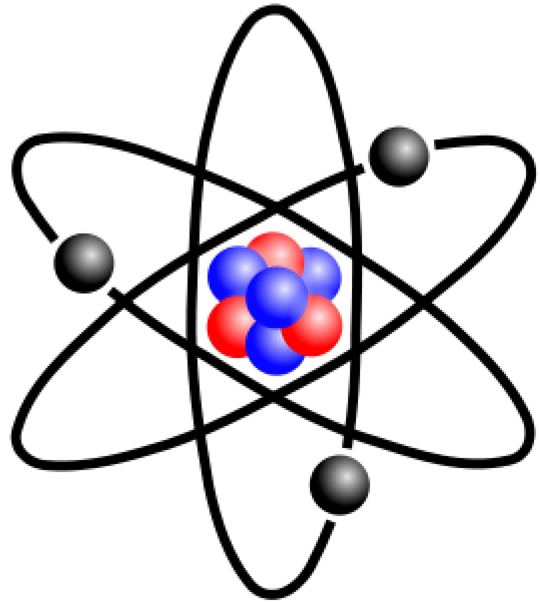
The atom



Atomic structure

An **atom** consists of a small central nucleus composed of **protons** and **neutrons** surrounded by **electrons**.

An atom will always have the same number of electrons as protons.



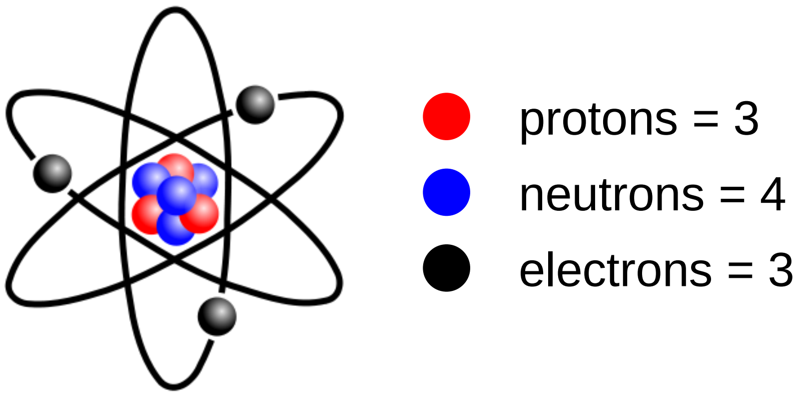
A Lithium atom

- **protons**
- **neutrons**
- **electrons**

Atomic and mass number

The **atomic number (Z)** of an atom is equal to the number of **protons** in its nucleus.

The **mass number (A)** of an atom is equal to the number of **protons plus neutrons** in its nucleus.



This Lithium atom has:

atomic number = 3

mass number = 7

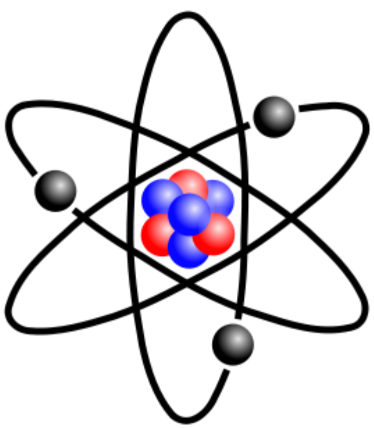
Properties of protons, neutrons and electrons

	Position in the atom	***Relative mass***	***Relative electric charge***
PROTON	**nucleus**	1	**+ 1**
NEUTRON	**nucleus**	1	**0**
ELECTRON	**outside nucleus**	0.005	**- 1**

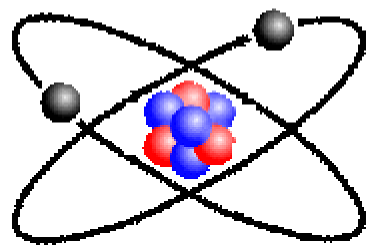
Ions

An atom becomes an ion when it loses or gains one or more electrons.

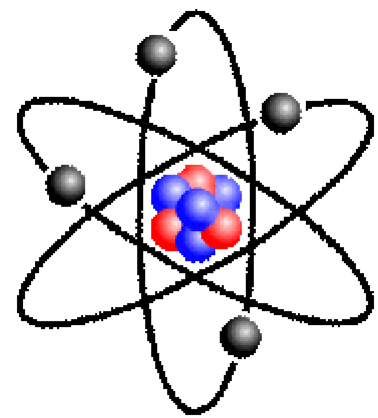
Lithium atom



Positive Lithium ion



Negative Lithium ion



electrons **protons** **neutrons**

Isotopes

The atoms of an element always have the same number of protons.

Isotopes are atoms of the same element with different numbers of neutrons.

The three isotopes of hydrogen ○ neutrons

hydrogen 1	hydrogen 2 (deuterium)	hydrogen 3 (tritium)

Note: The number after 'hydrogen' is the mass number of the isotope.

Isotopes

It is possible for the nuclei of the same element to have different numbers of neutrons in the nucleus (but it must have the same number of protons)

4 neutrons → $^{7}_{3}\mathrm{Li}$

3 neutrons → $^{6}_{3}\mathrm{Li}$

Nuclear notation

An isotope of carbon consists of 6 protons and 8 neutrons.
This can be written as:

carbon 14

Number of protons PLUS neutrons (Mass number)

OR:

$$^{14}_{6}\mathrm{C}$$

Number of protons (Atomic number)

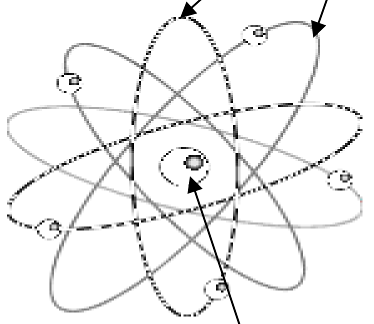
Chemical symbol

Nuclide notation

Atomic mass (mass number) = number of protons and neutrons

$$^{7}_{3}\mathrm{Li}$$

Atomic number (proton number) = number of protons



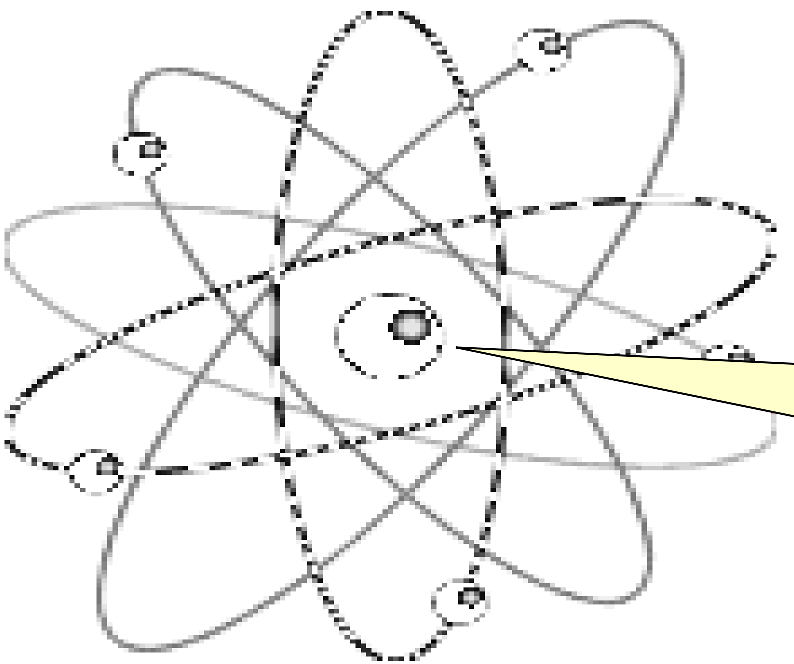
Relative atomic mass

On average, lithium atoms have a mass of 6.941 (relative to Carbon 12)

$$^{6.941}_{3}\mathrm{Li}$$

Unstable nuclei

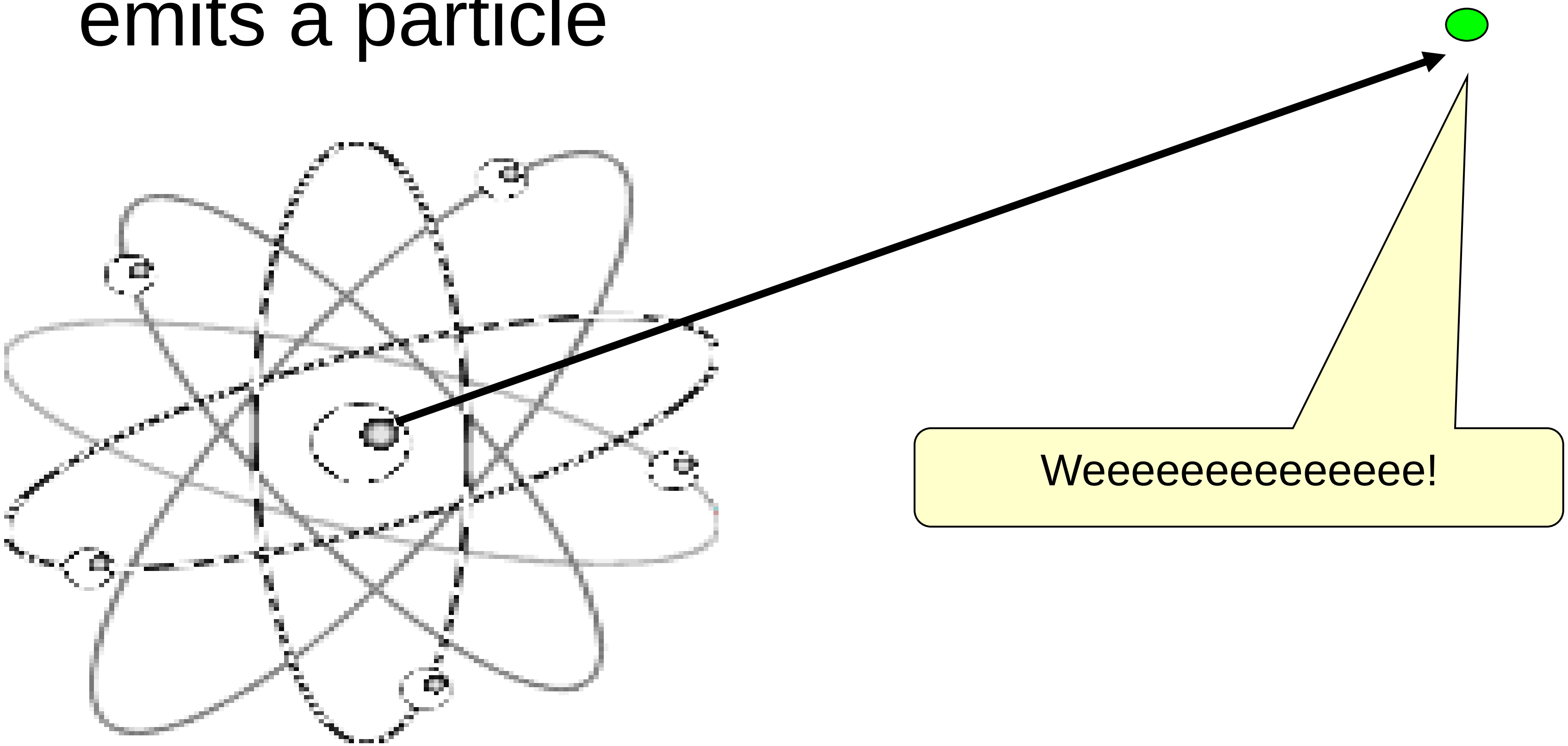
Some nuclei are unstable, for example Uranium 235



Hi! I’m uranium-235 and I’m unstable. I really need to lose some particles from my nucleus to become more stable.

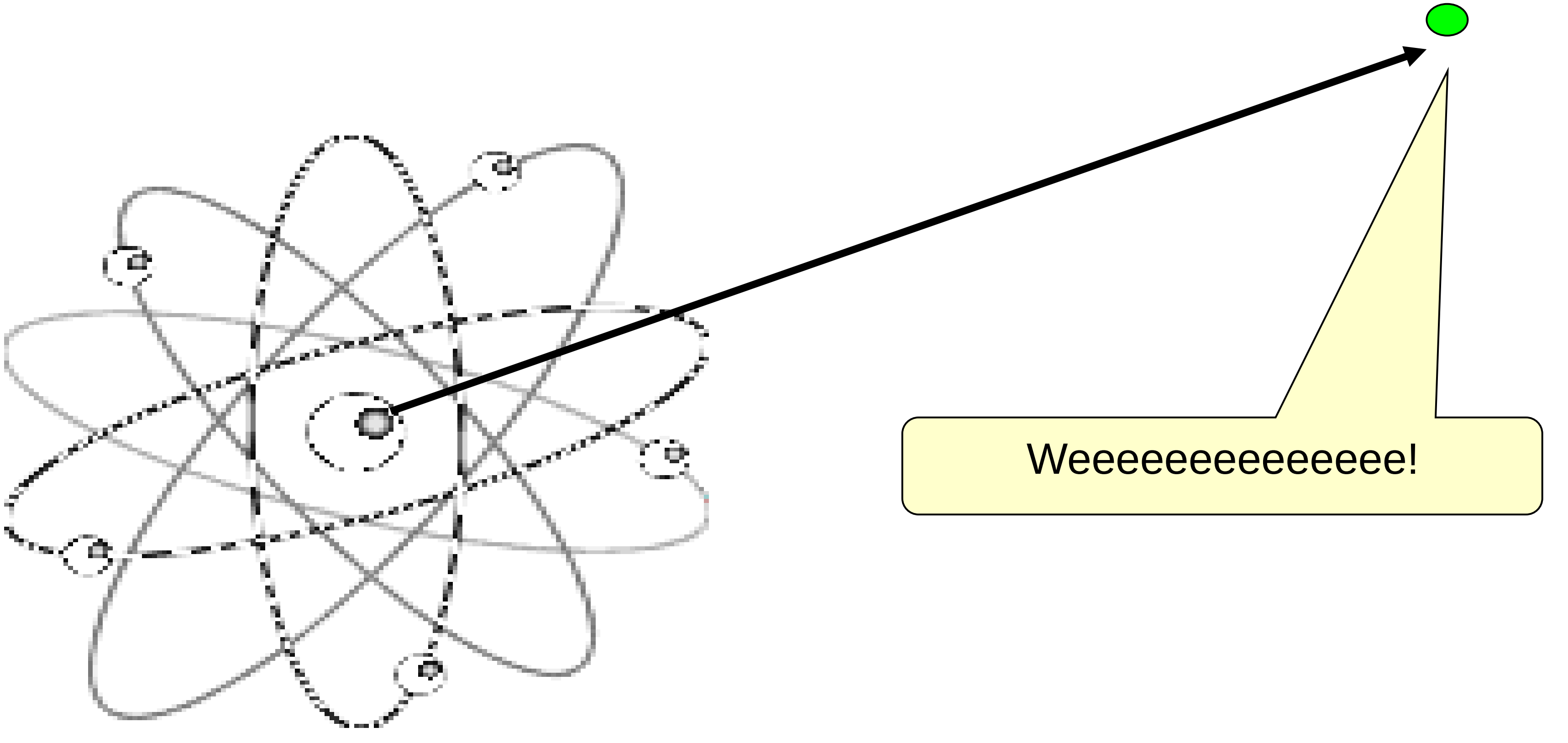
Unstable nuclei

To become stable, an unstable nuclei emits a particle



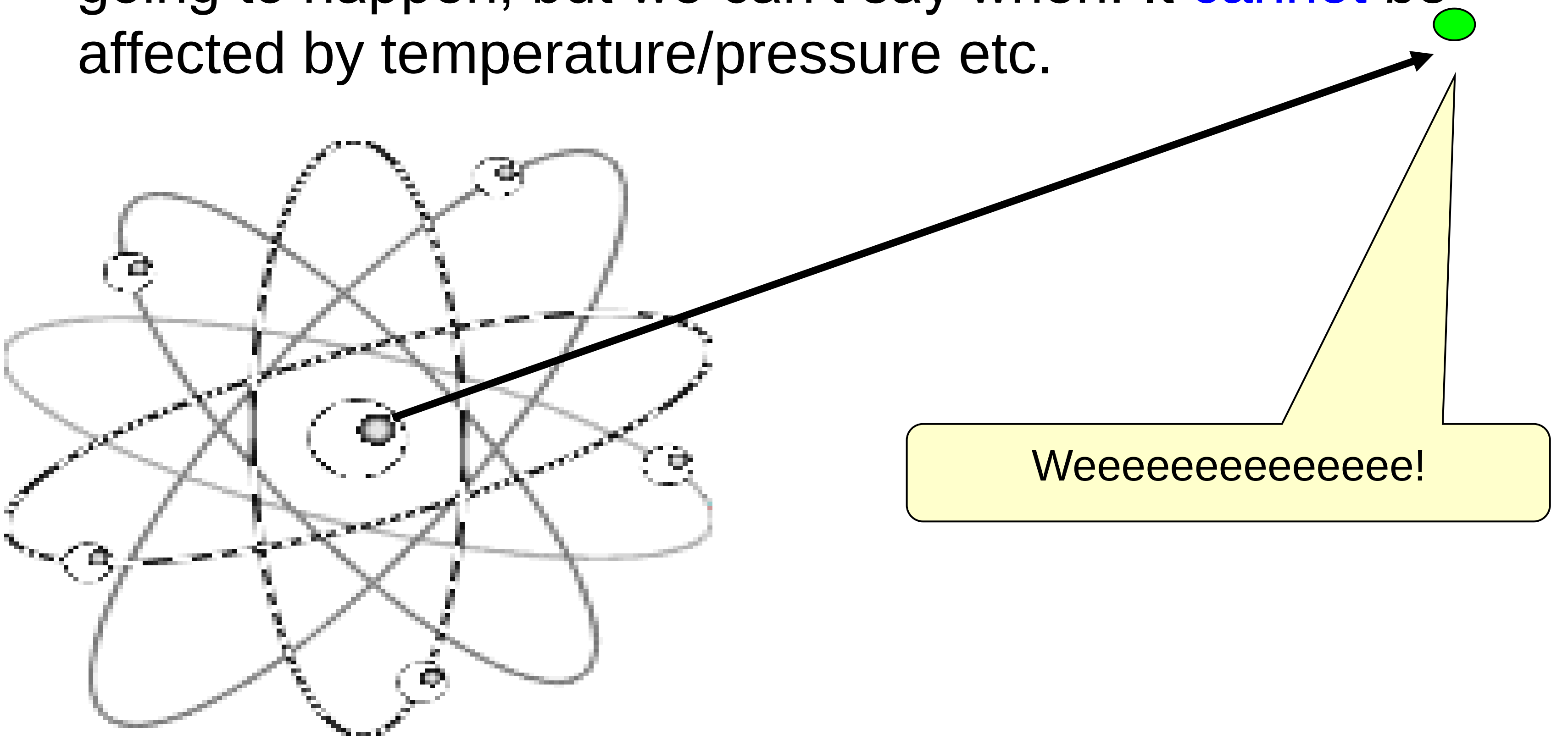
Unstable nuclei

We say the atom has decayed



Unstable nuclei

The decay of an unstable nucleus is random. We know it's going to happen, but we can't say when! It cannot be affected by temperature/pressure etc.



Becquerels (Bq)

- The amount of radioactivity given out by a substance is measured in Becquerels.
- One becquerel is one particle emitted per second.

Detection

- Particles can be detected by photographic film
- Particles can also be detected (and counted) by a Geiger-Müller tube (GM tube) connected to a counter

Background radiation

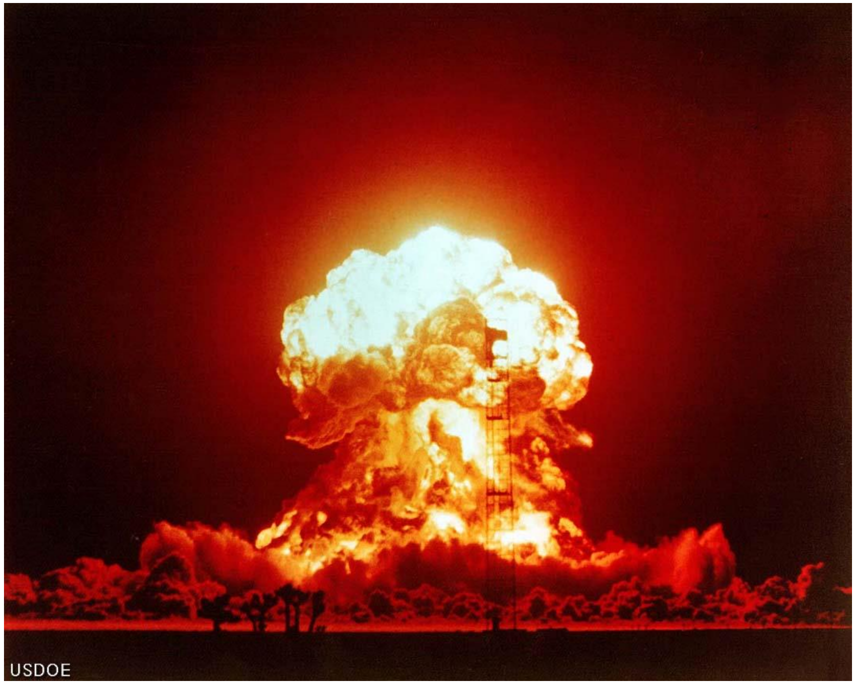
There are small amounts radioactive particles around us all the time.

This is called background radioactivity. The amount varies depending on location.

Background radiation

Background radiation comes from

- Cosmic rays from space
- Radioactive rocks in the ground
- Nuclear tests
- Nuclear bombs
- Nuclear accidents



Radiation safety

- Keep the distance between you and a radioactive source as big as possible (use tongs etc.)
- Limit the time you are exposed to radiation.
- Put a barrier between you and the radiation source that can absorb the radioactive particles (normally lead)

Alpha particles

- 2 protons and 2 neutrons joined together
- The same as the nucleus of a helium atom
- Stopped by paper or a few cm of air
- Highly ionising
- Deflected by electric and strong magnetic fields

$$^{4}_{2}\mathrm{He}^{2+}$$

Alpha Decay

Atomic mass goes down by 4

$$^{235}_{92}U \longrightarrow \, ^{231}_{90}Th + \alpha$$

Atomic number goes down by 2

Beta particles

- Fast moving electrons
- Stopped by about 3 mm of aluminium
- Weakly ionising
- Deflected by electric and magnetic fields

$$^{0}_{-1}e$$

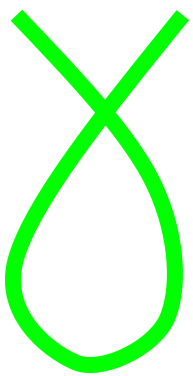
Beta decay

- In the nucleus a neutron changes into an electron (the beta particle which is ejected) and a proton (which stays in the nucleus)
- During beta decay the mass number stays the same but the proton number goes up by 1.

$$^{231}_{90}\mathrm{Th} \longrightarrow {}^{231}_{91}\mathrm{Pa} + {}^{0}_{-1}\mathrm{e}$$

Gamma rays

- High frequency electromagnetic radiation
- Stopped by several cm of lead
- Very weakly ionising
- NOT affected by electric or magnetic fields



Gamma rays

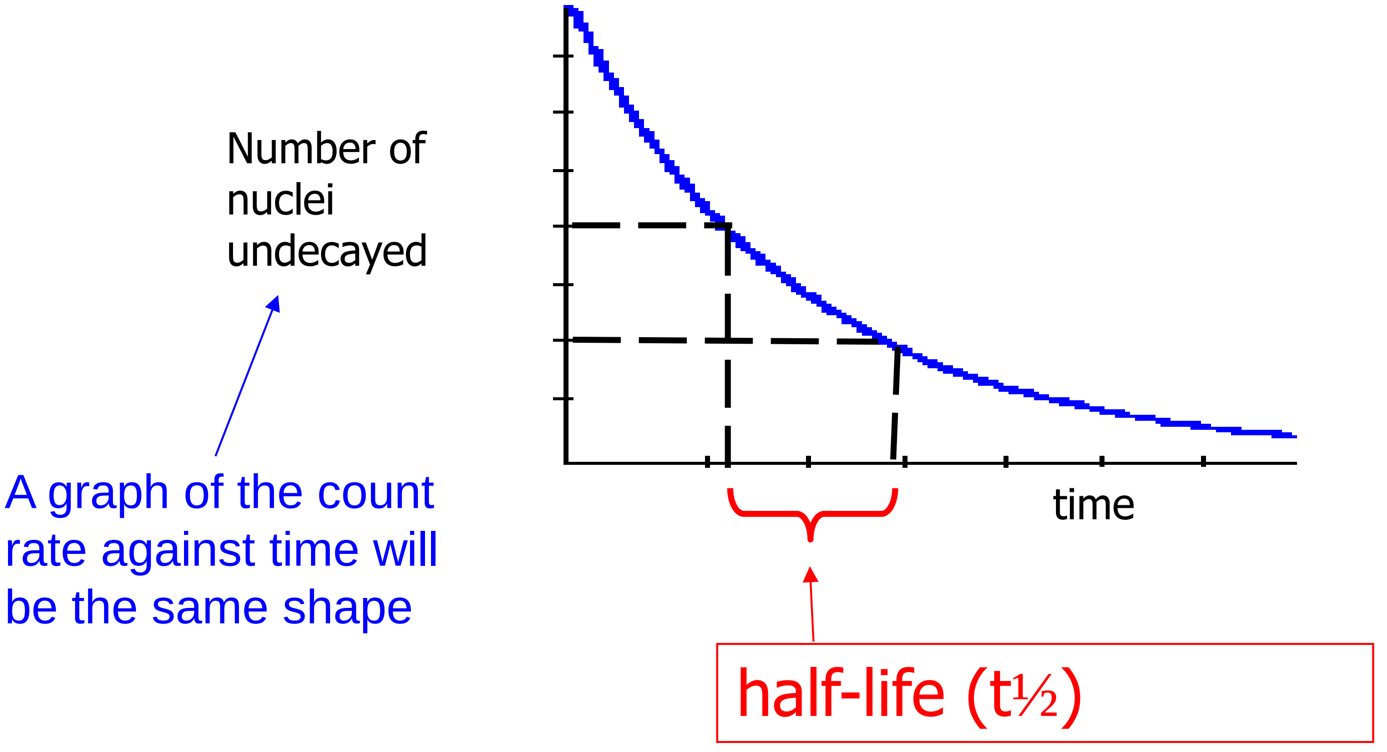
γ

Associated with alpha decay

$$^{235}_{92}U \rightarrow {}^{231}_{90}Th + \alpha$$

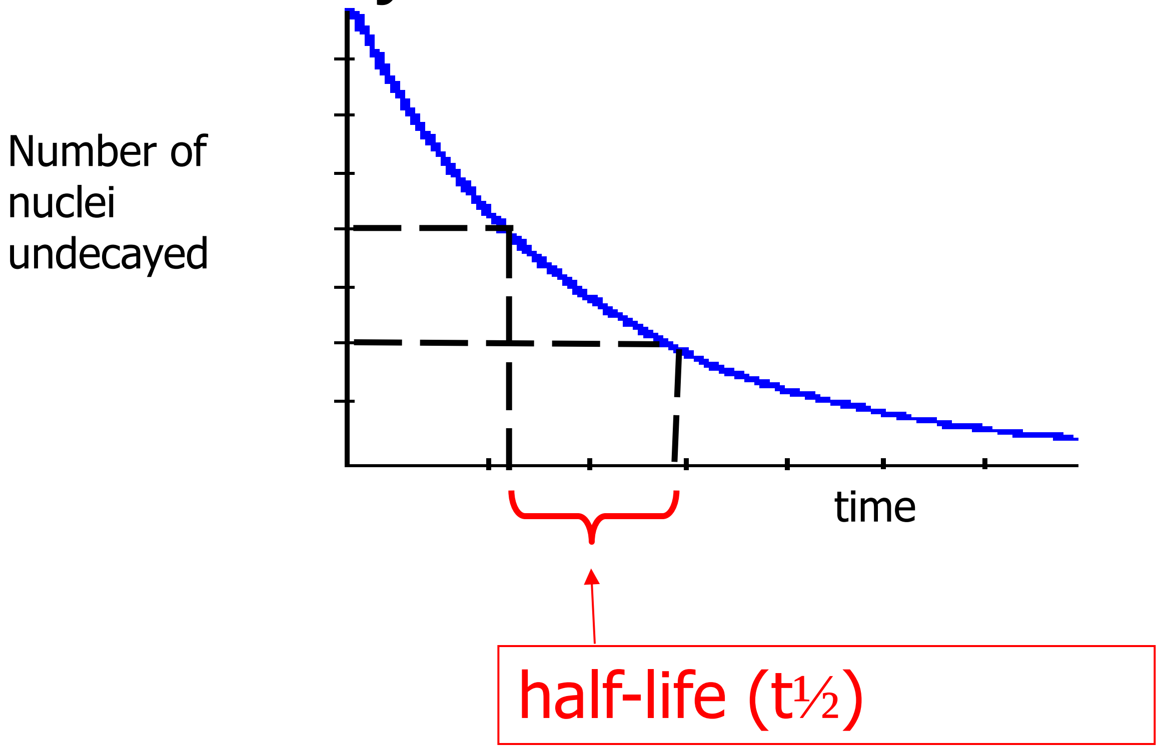
½ - life

- This is the time it takes half the nuclei to decay

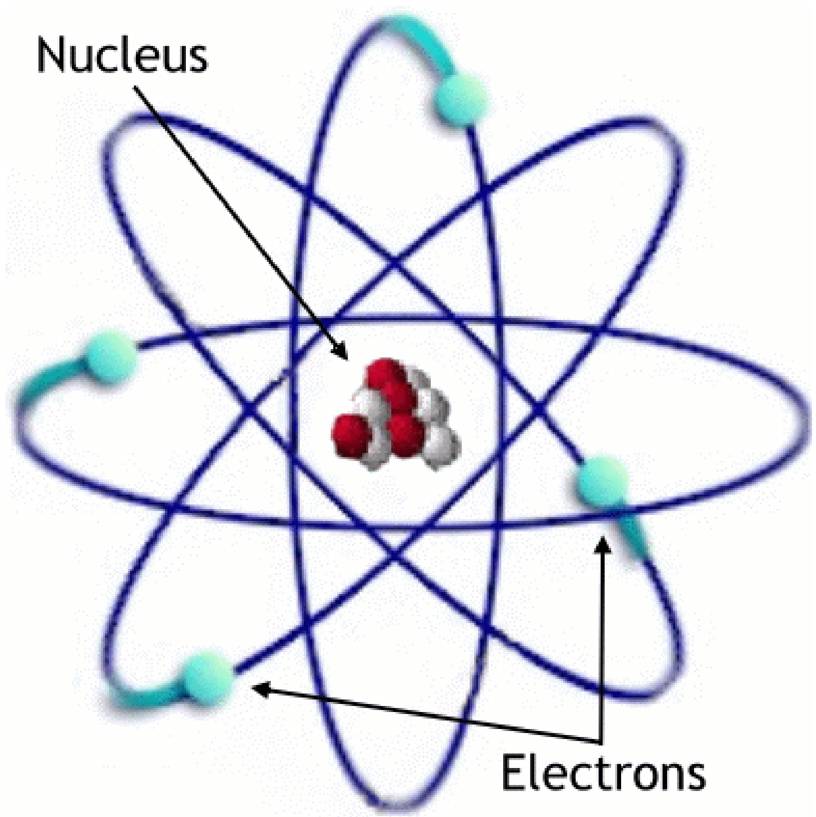


Different ½ - lives

- Different isotopes have different half-lives
- The ½-life could be a few milliseconds or 5000 million years!

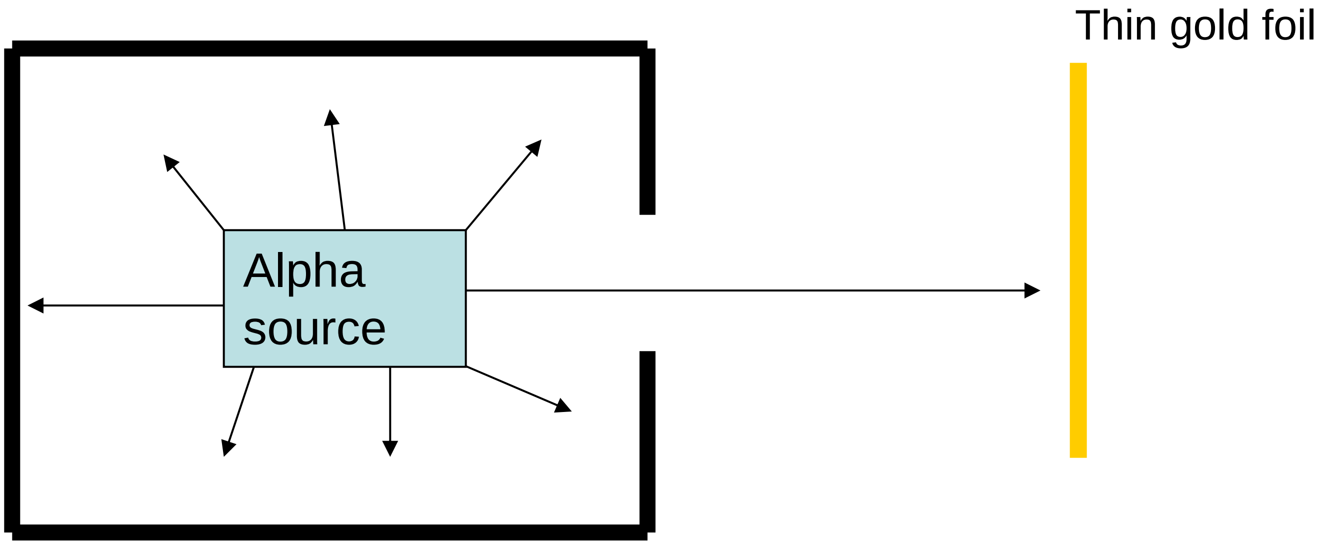


How do we know the structure of the atom?



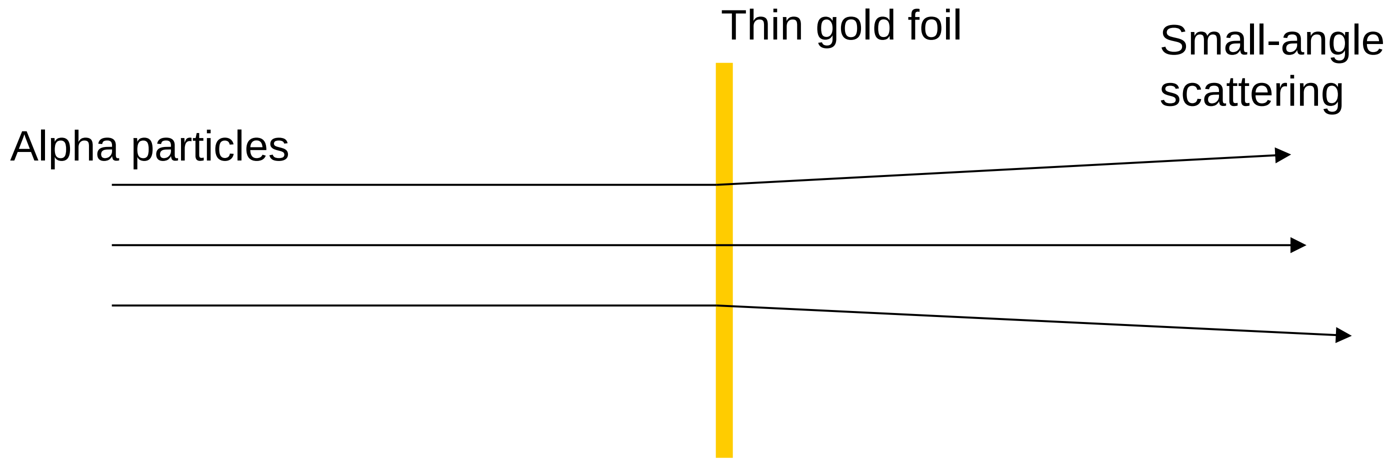
The famous Geiger-Marsden Alpha scattering experiment

In 1909, Geiger and Marsden were studying how alpha particles are scattered by a thin gold foil.



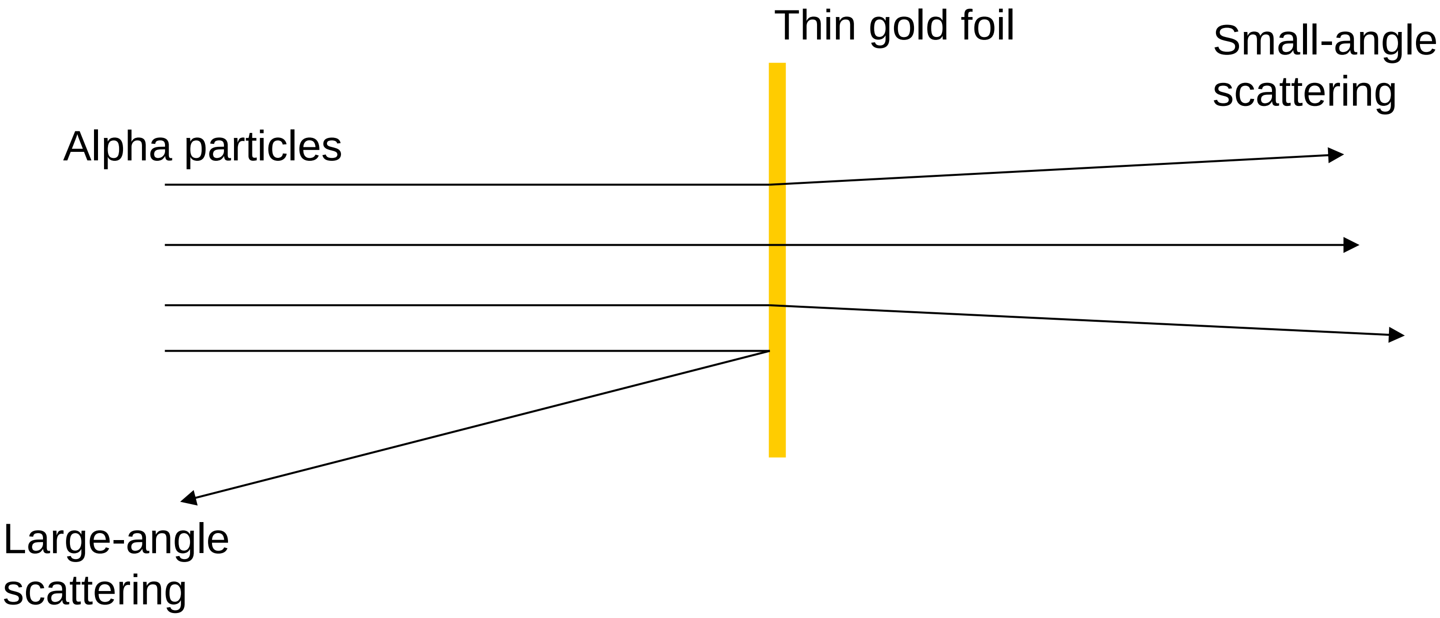
Geiger-Marsden

As expected, most alpha particles were detected at very small scattering angles



Geiger-Marsden

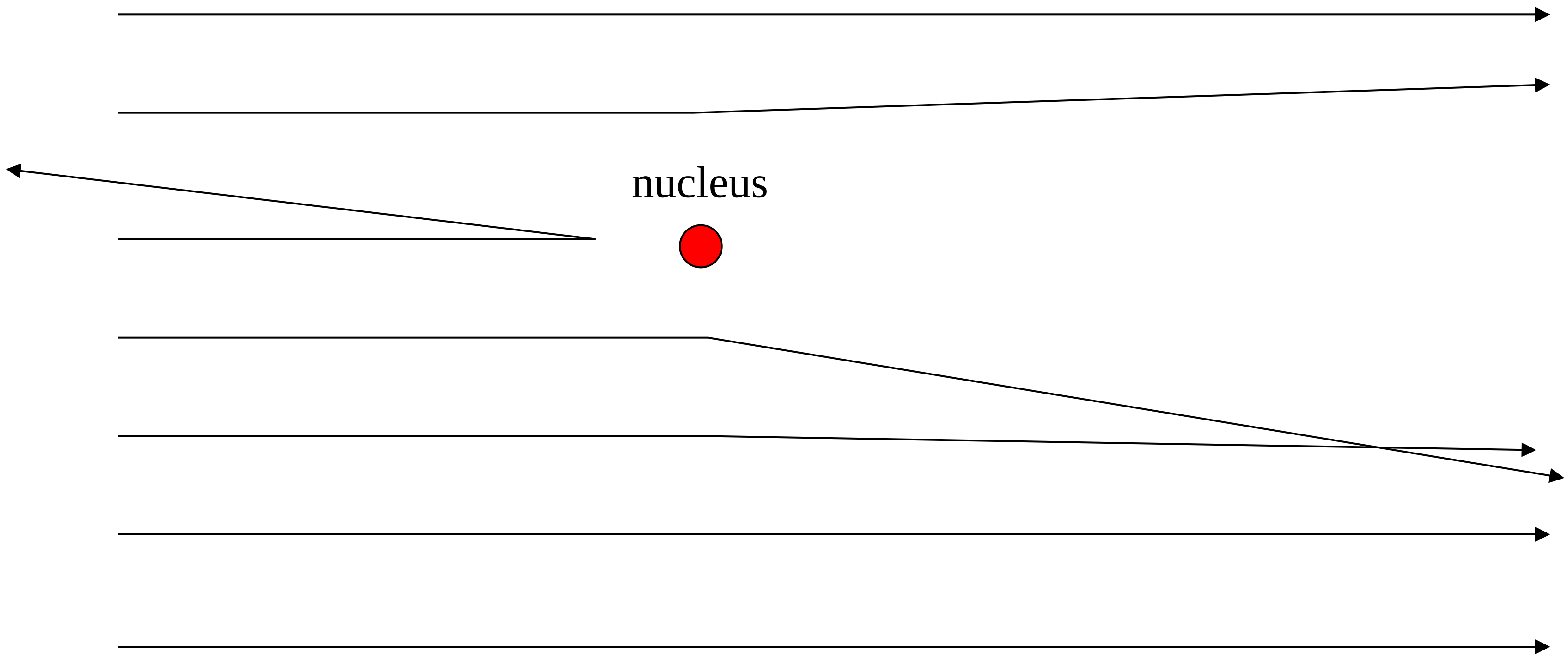
To their great surprise, they found that some alpha particles (1 in 20 000) had very large scattering angles



Explaining Geiger and Marsdens' results

The results suggested that the positive (repulsive) charge must be concentrated at the centre of the atom.

Most alpha particles do not pass close to this so pass undisturbed, only alpha particles passing very close to this small nucleus get repelled backwards (the nucleus must also be very massive for this to happen).



Rutherford did the calculations!

Rutherford (their supervisor) calculated theoretically that the atomic nucleus was confined to a diameter of about 10^{-15} metres.

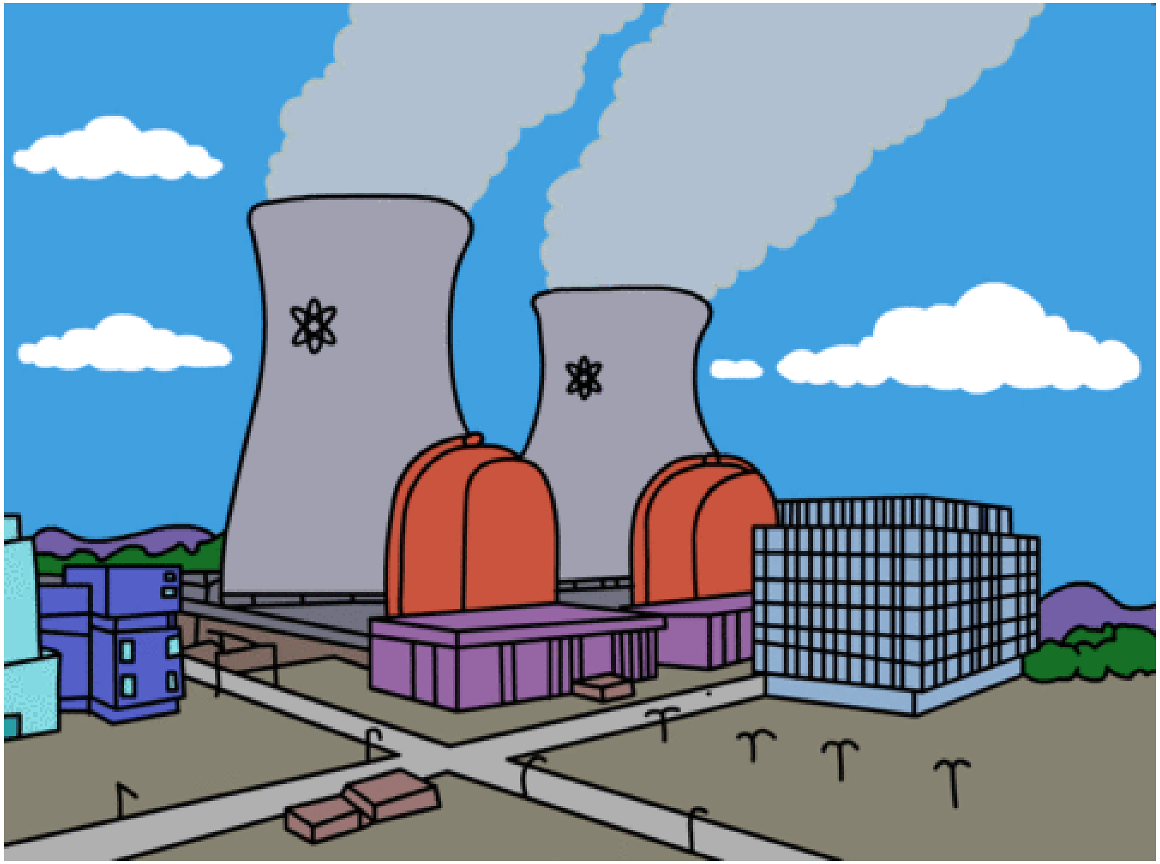
That’s 10 000 times smaller than the size of an atom (about 10^{-10} metres).

Rutherford did the calculations!

If the nucleus of an atom was a ping-pong ball, the atom would be the size of a football stadium (and mostly full of nothing)!

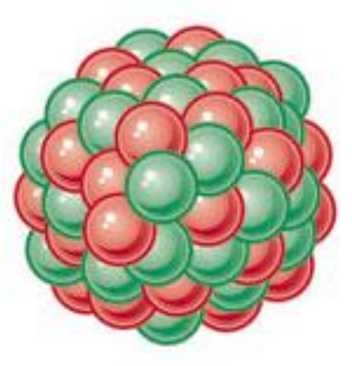
Nucleus (ping-pong ball

Nuclear Fission



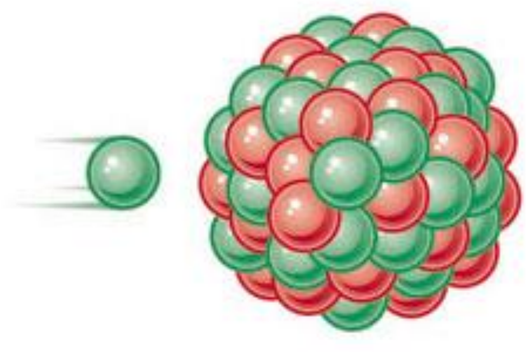
Uranium

Uranium 235 has a large unstable nucleus.



Capture

A lone neutron hitting the nucleus can be captured by the nucleus, forming Uranium 236.



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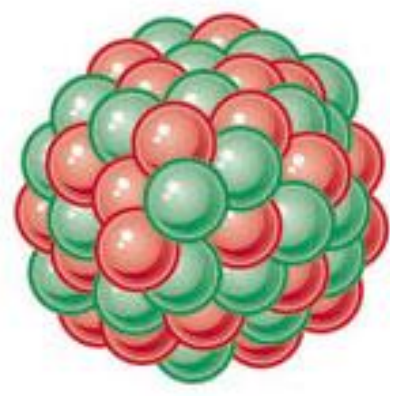
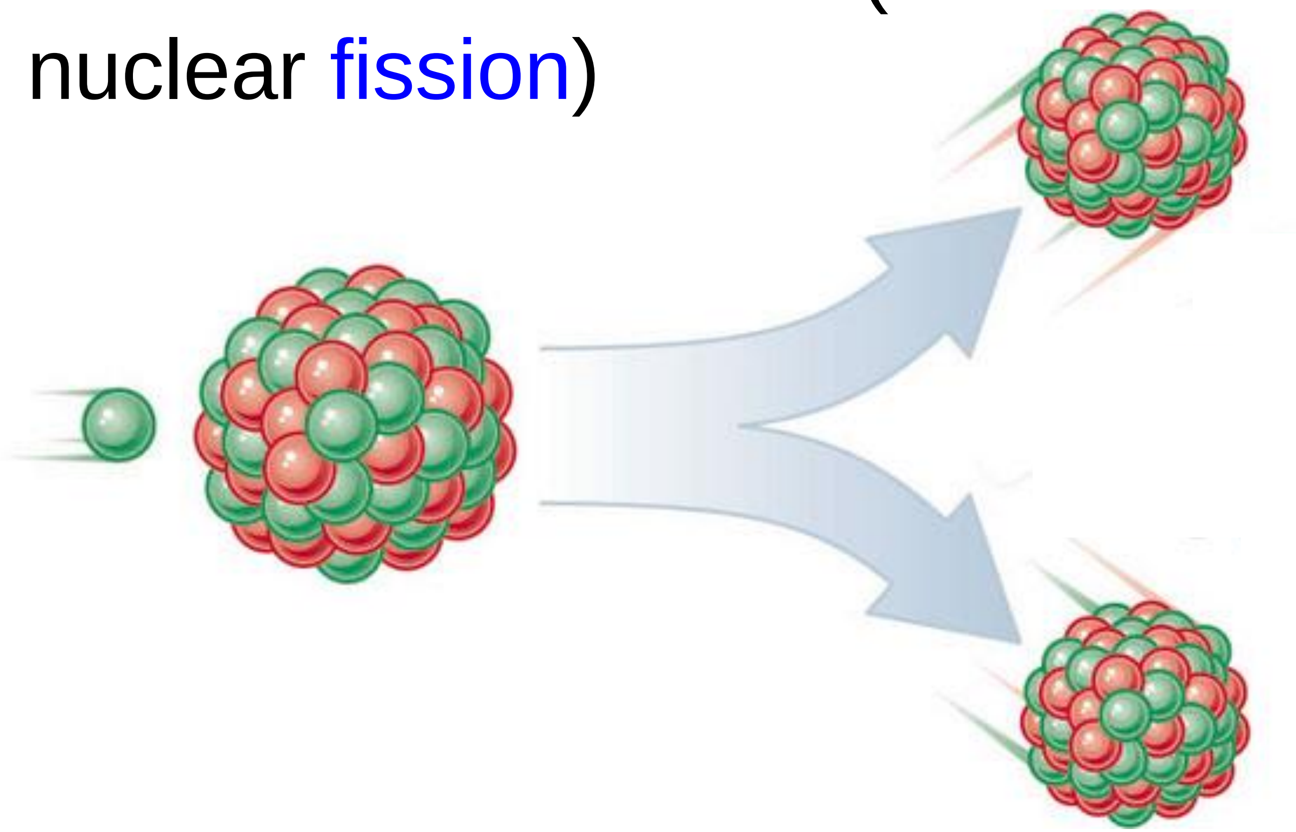


Fission

The Uranium 236 is very unstable and splits into two smaller nuclei (this is called nuclear fission)

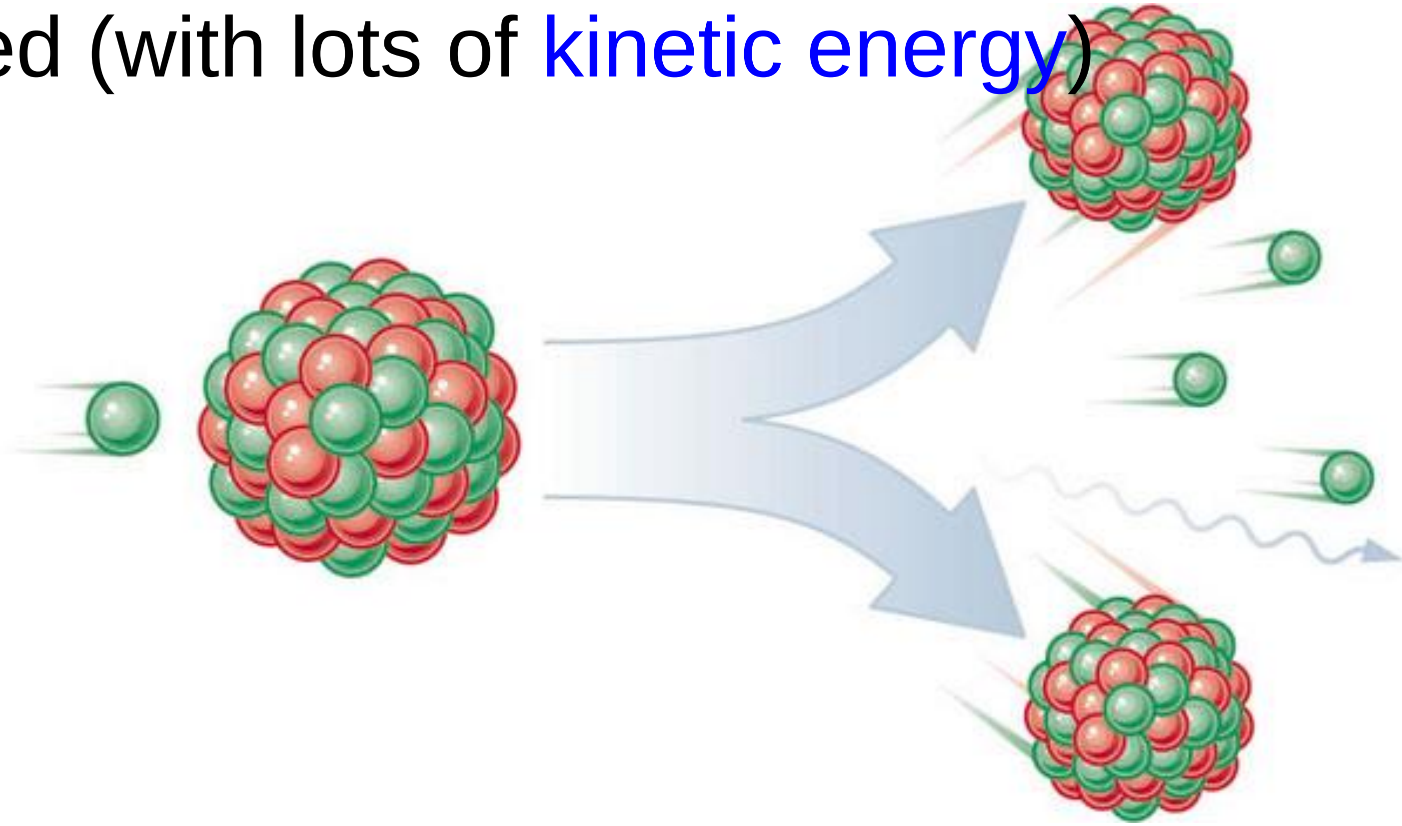


Fission

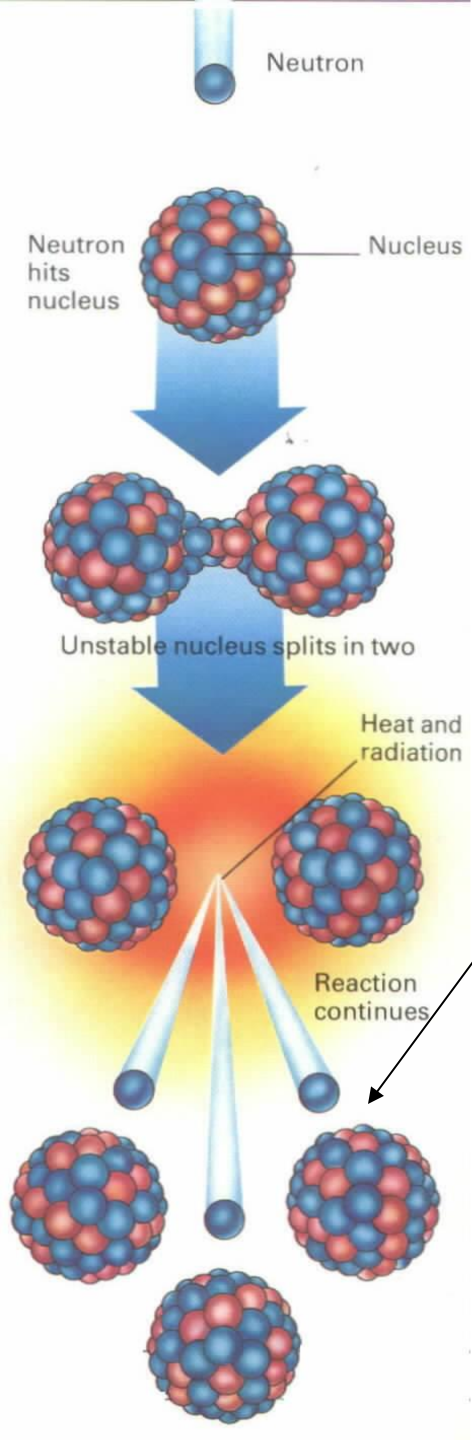
The Uranium 236 is very unstable and splits into two smaller nuclei (this is called nuclear fission)

Free neutrons

As well as the two smaller nuclei (called daughter nuclei), three neutrons are released (with lots of kinetic energy)



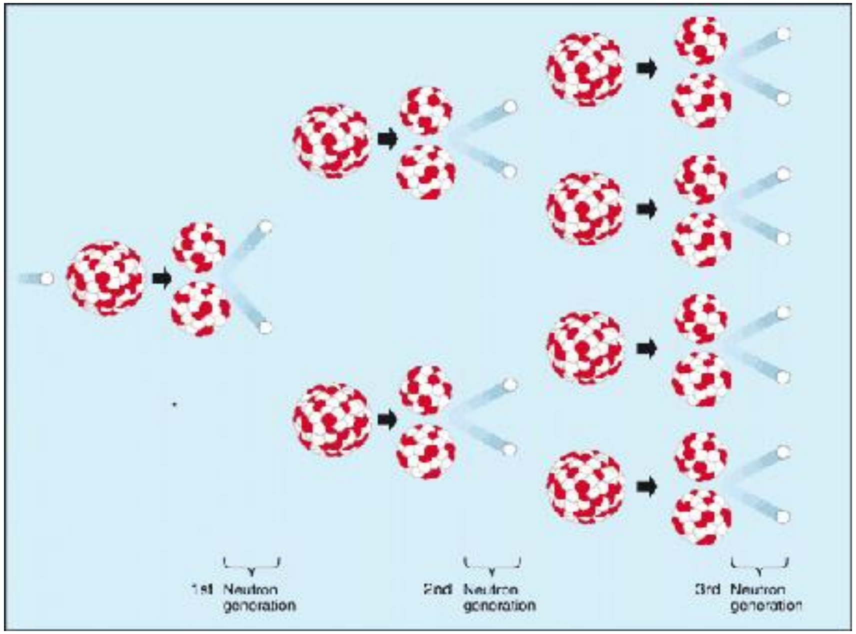
Fission



These free neutrons can strike more uranium nuclei, causing them to split.

Chain Reaction

If there is enough uranium (critical mass) a chain reaction occurs. Huge amounts of energy are released very quickly.



Chain Reaction

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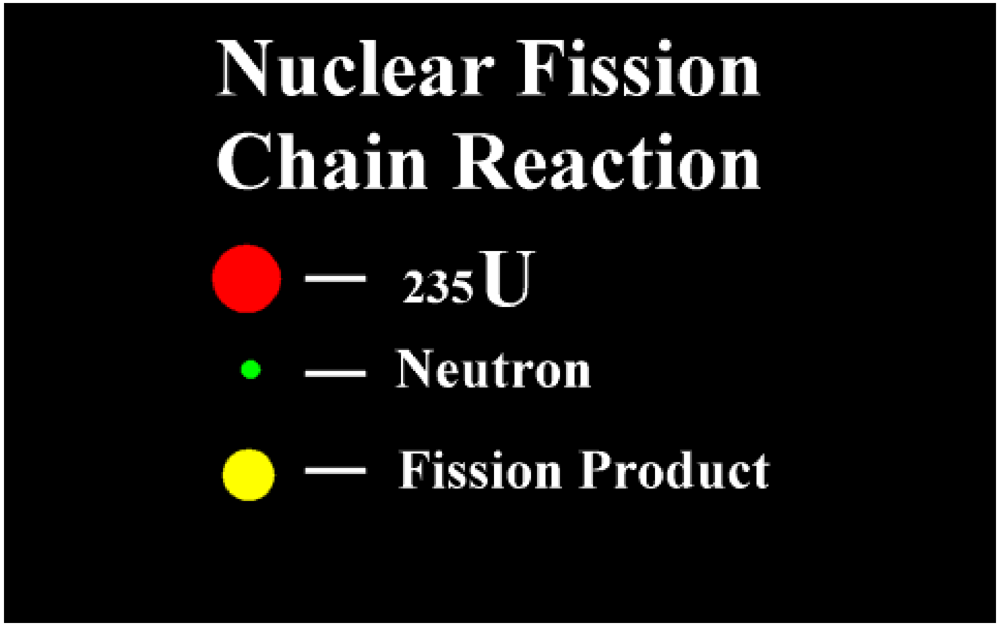
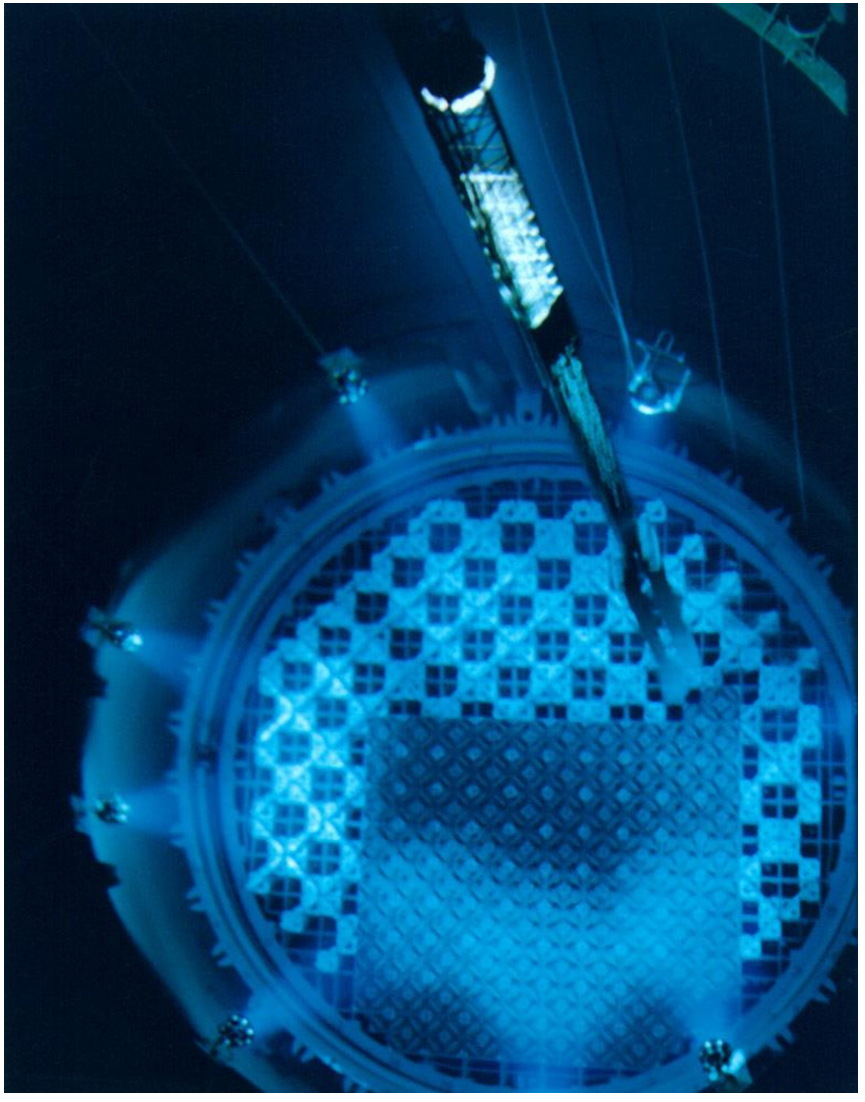
YouTube - Mousehunt Movie part 4 (English)Related Videos



Bang!

This can result in a nuclear explosion! YouTube - nuclear bomb 4

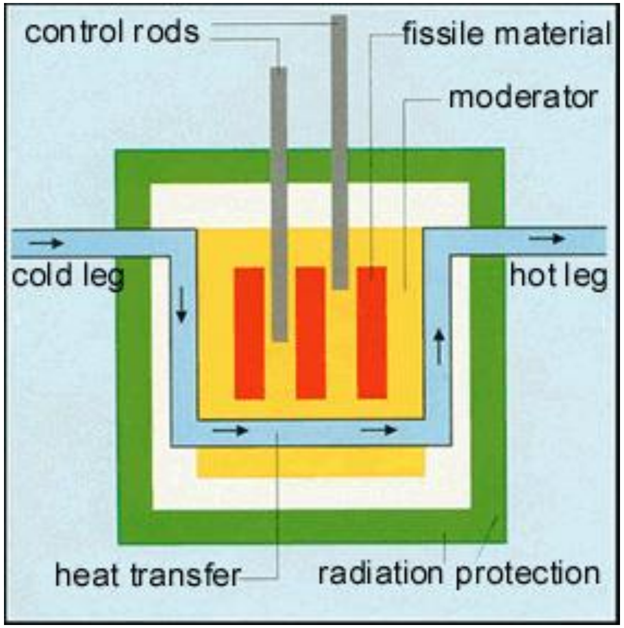
Controlled fission



The chain reaction can be controlled using control rods and a moderator. The energy can then be used (normally to generate electricity).

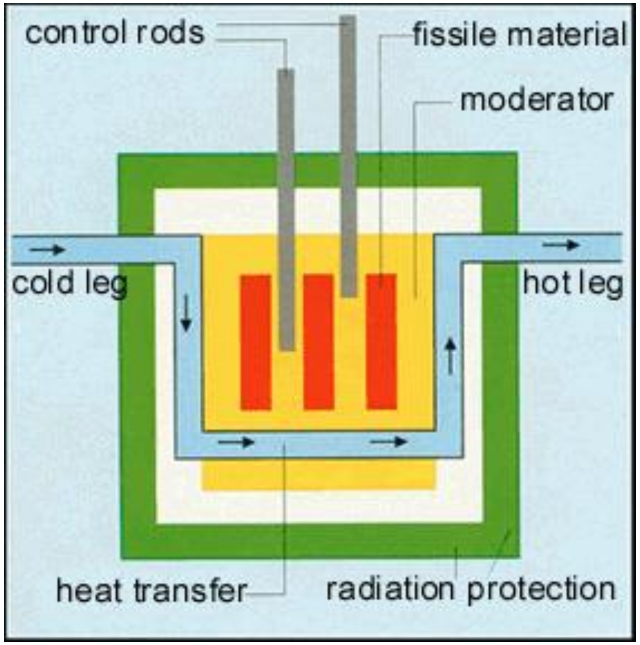
Moderator

This slows the free neutrons down, making them easier to absorb by the uranium 235 nuclei. Graphite or water is normally used.



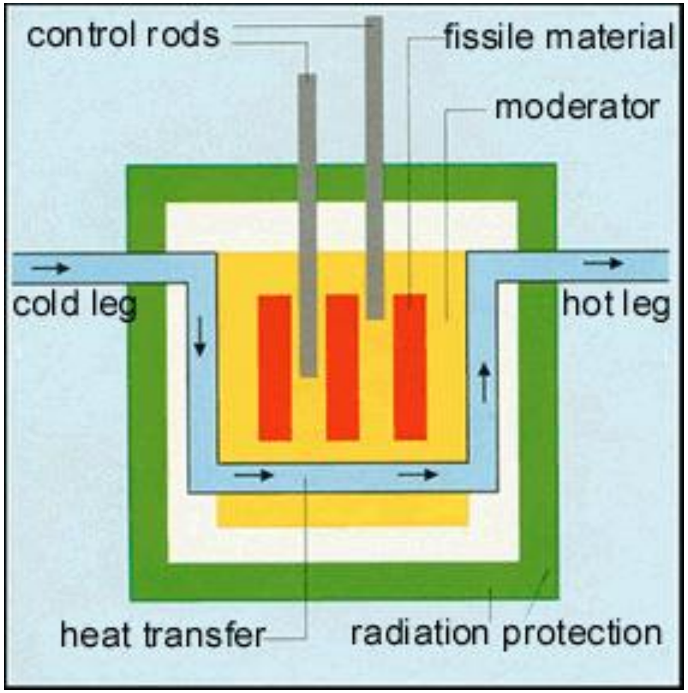
Control rods

These absorb excess neutrons,making sure that the reaction does not get out of control. Boron is normally used.



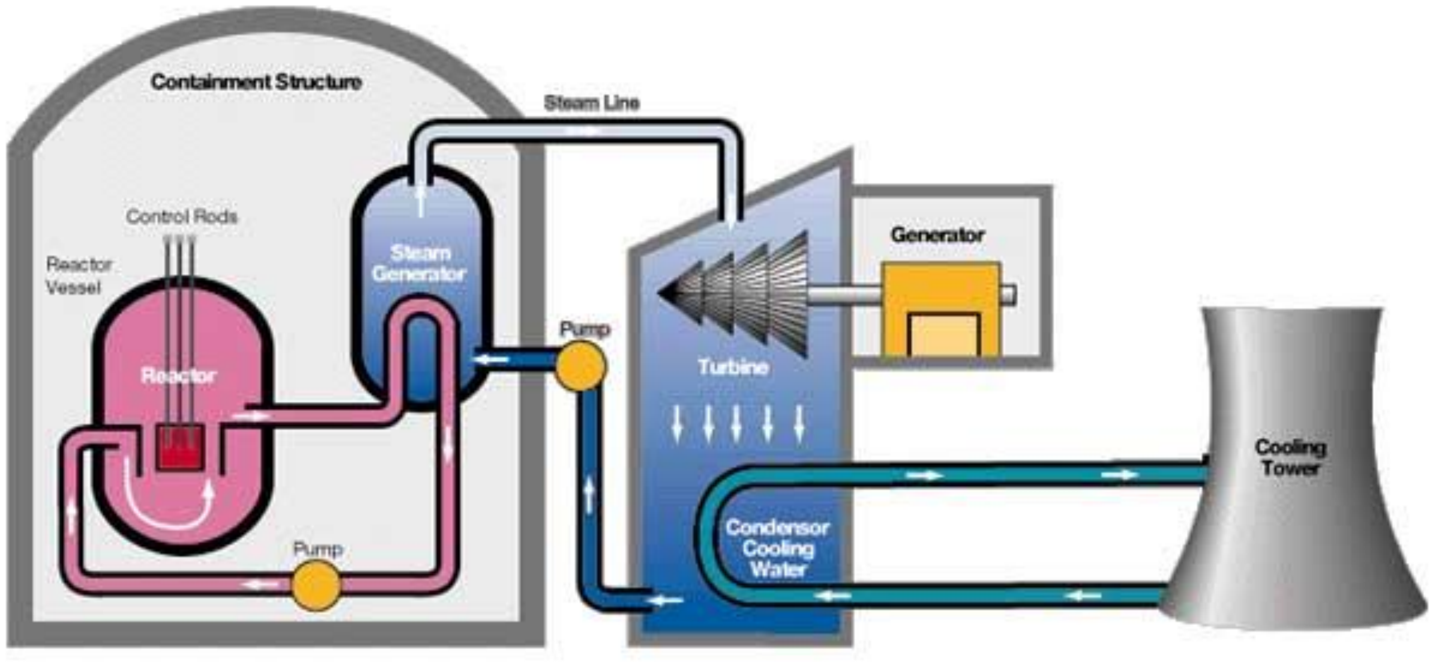
Heat

The moderator gets hot from the energy it absorbs from the neutrons.

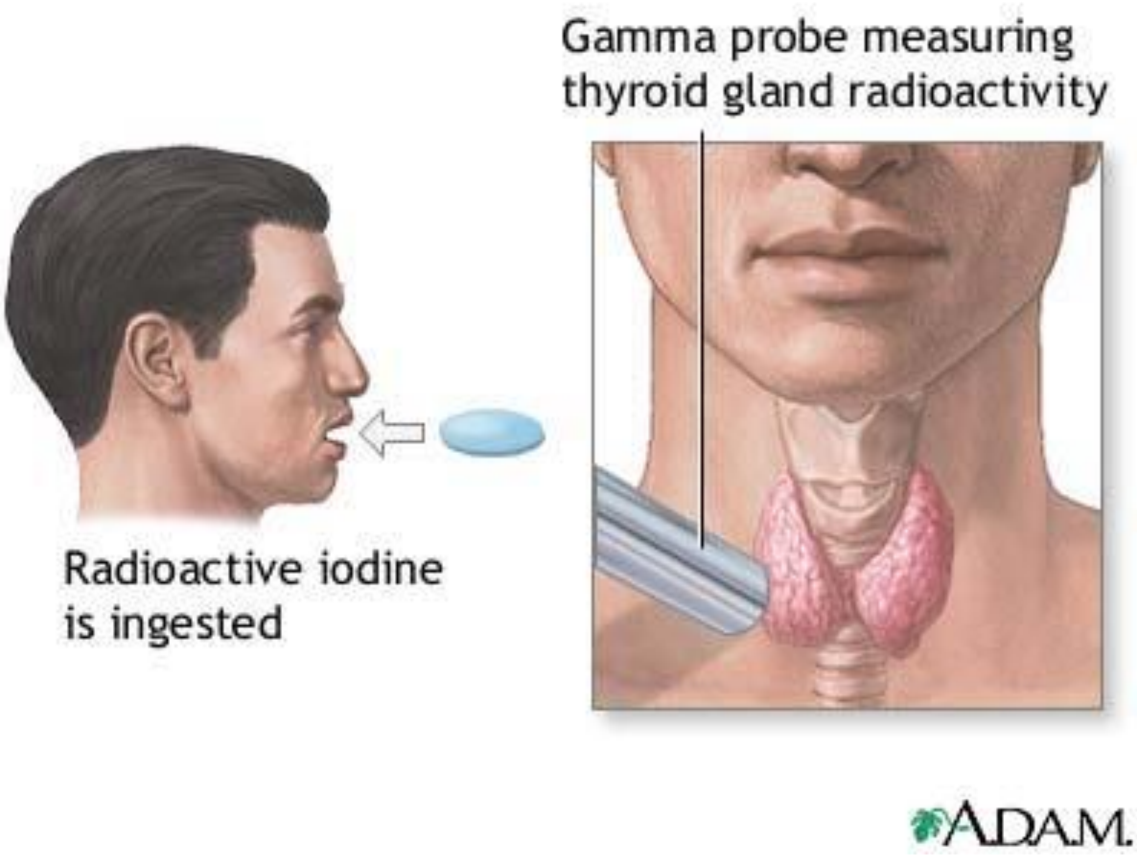


Heat

This heat is used to heat water, to make steam, which turns a turbine, which turns a generator, which makes



Used as Tracers



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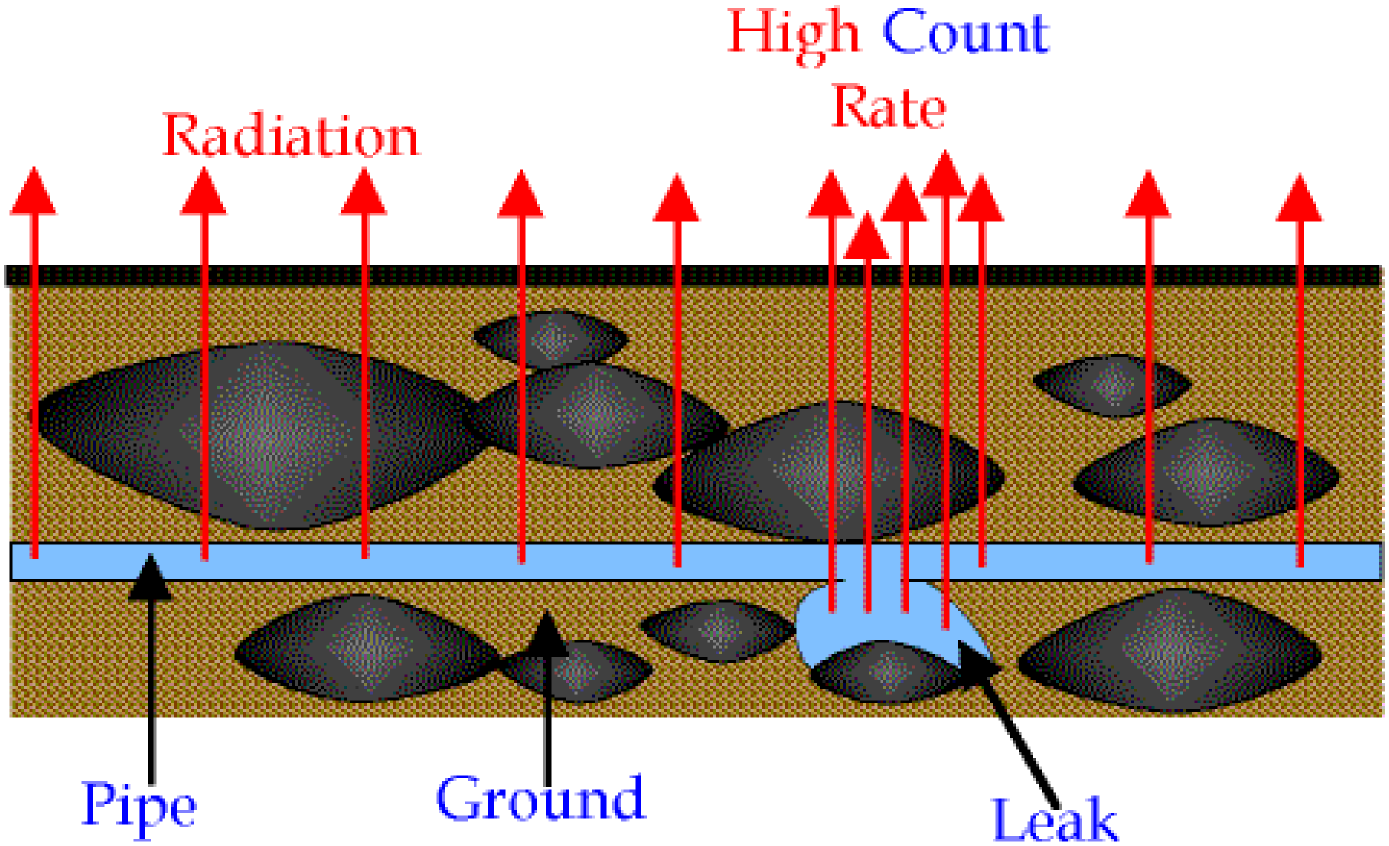
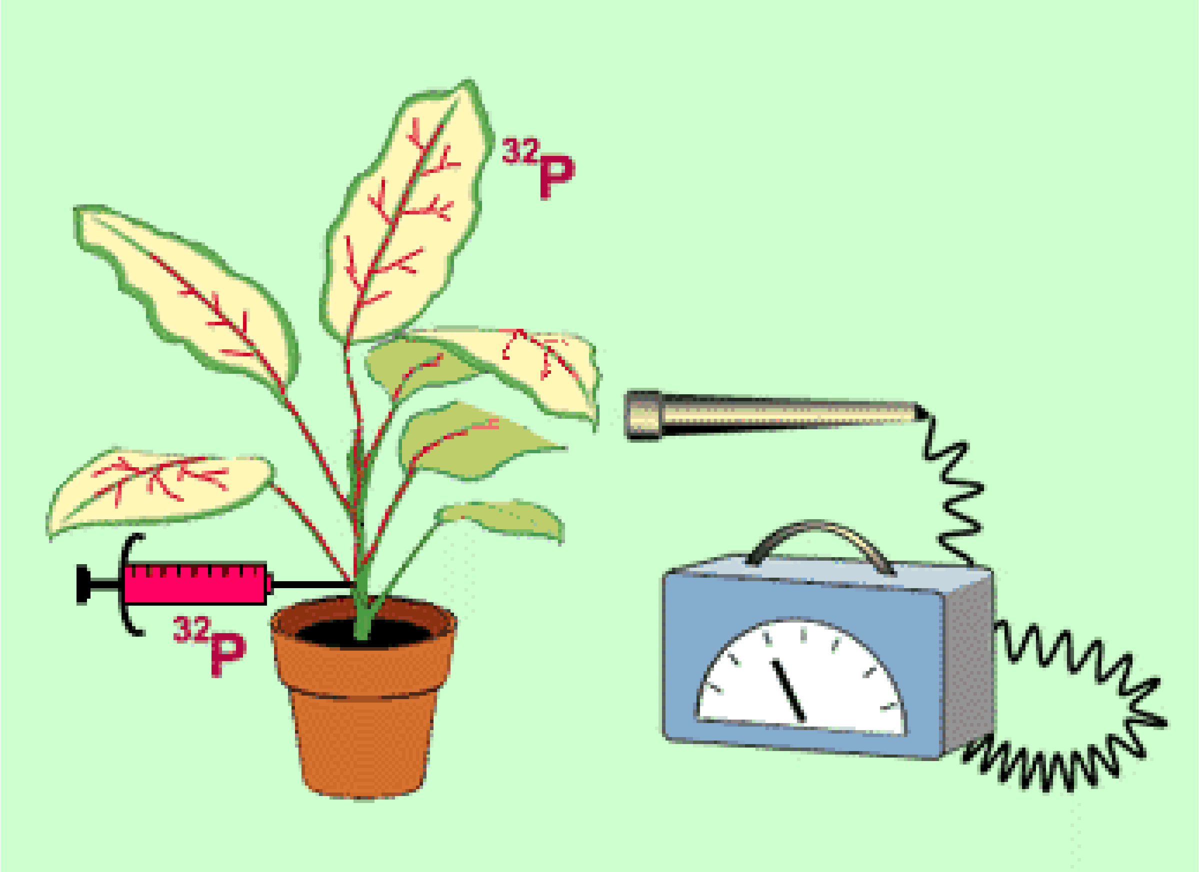
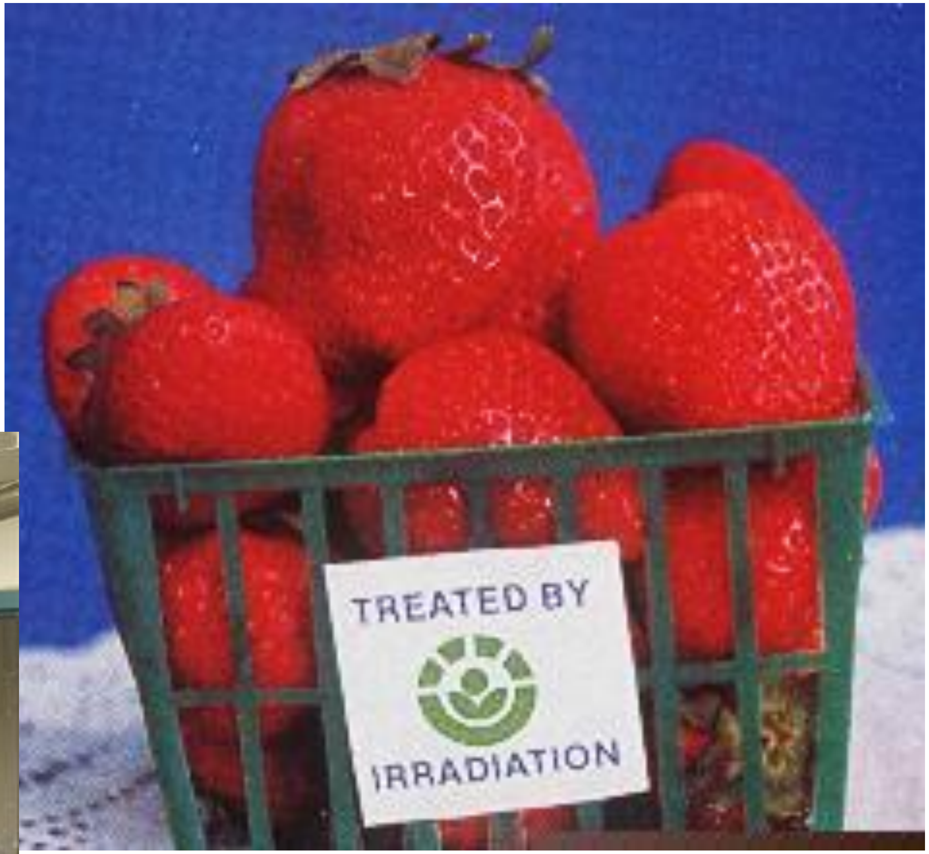


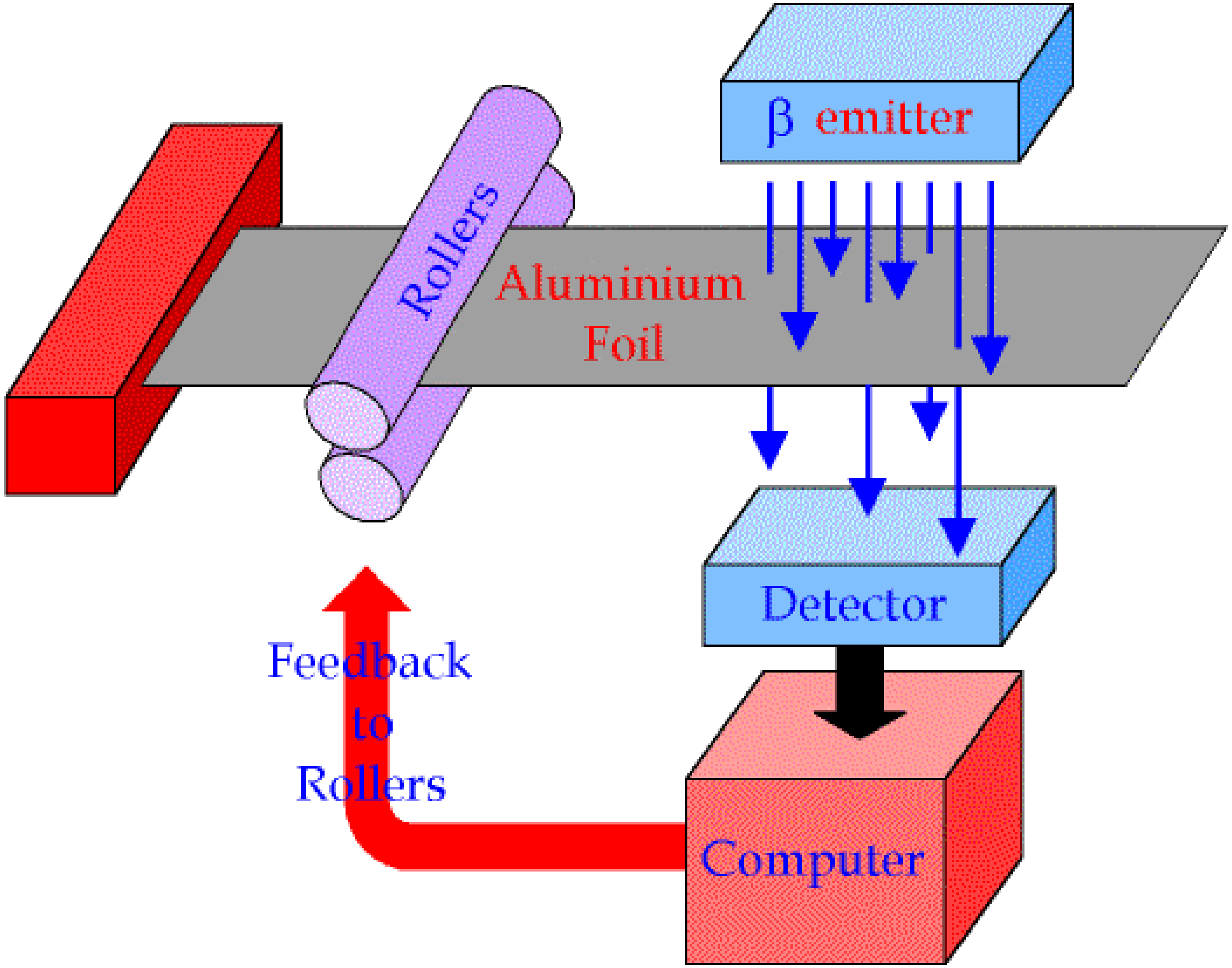
Used as Tracers



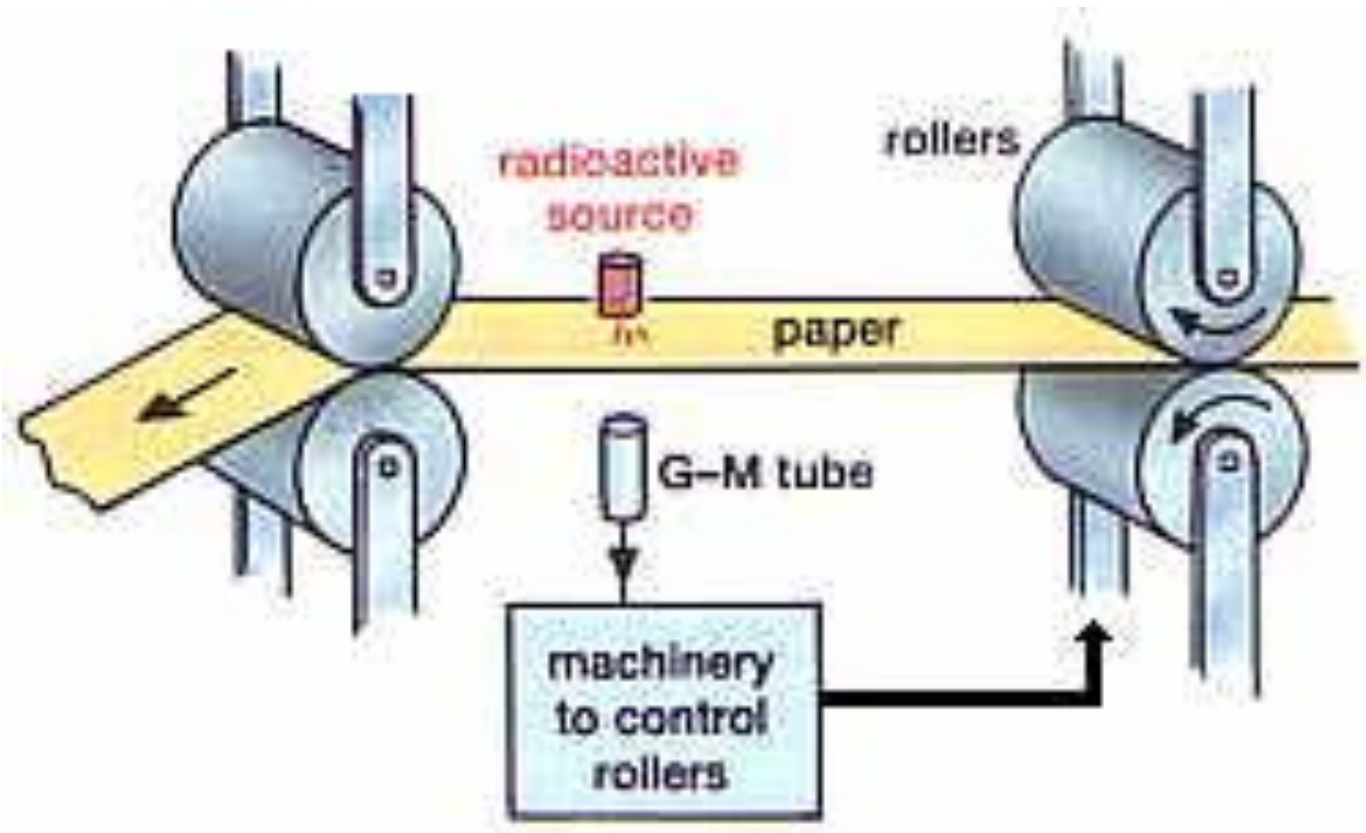
Killing microbes



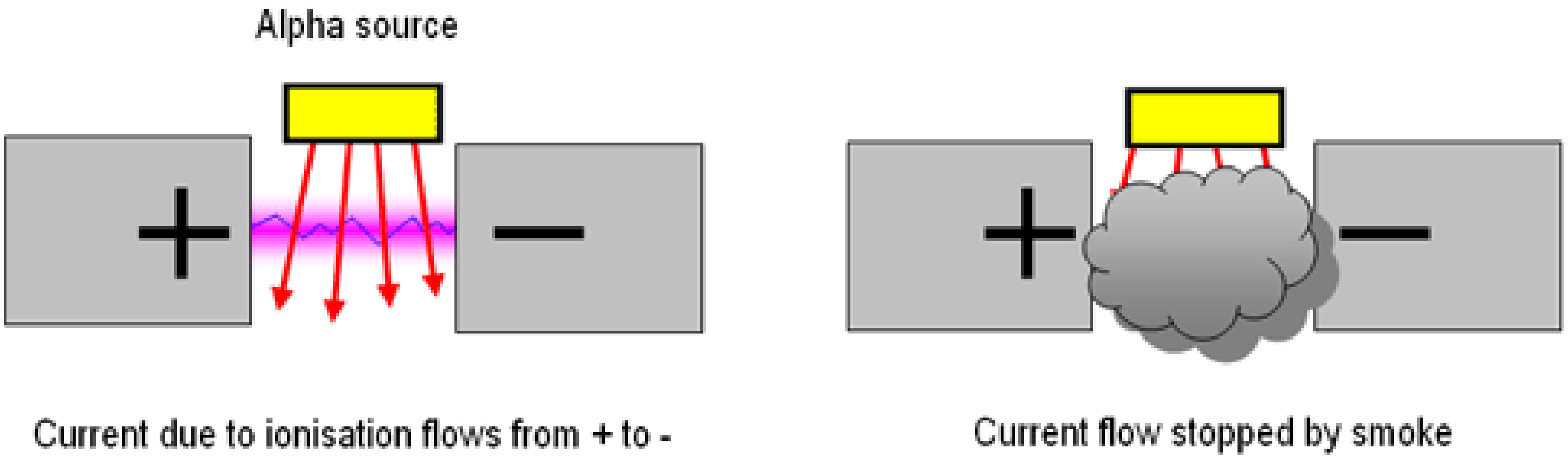
Thickness control



Thickness control



Smoke detection



(Diagram: resourcefulphysics.org)

Radioactive dating