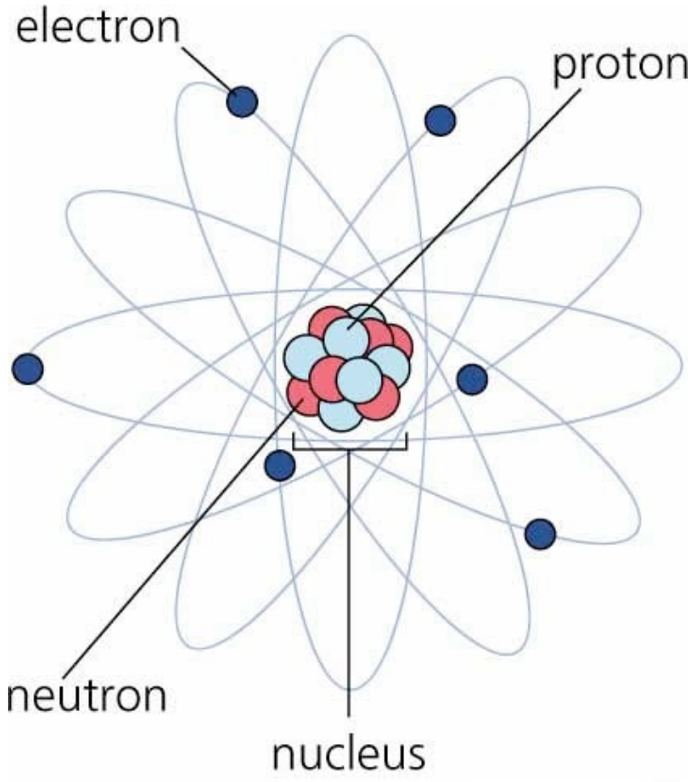
Radioactivity

- The structure of atoms
- Isotopes
- Stable & unstable isotopes
- Alpha decay
- Beta decay
- Gamma radiation
- Neutron capture
- Properties of α , β & γ radiation

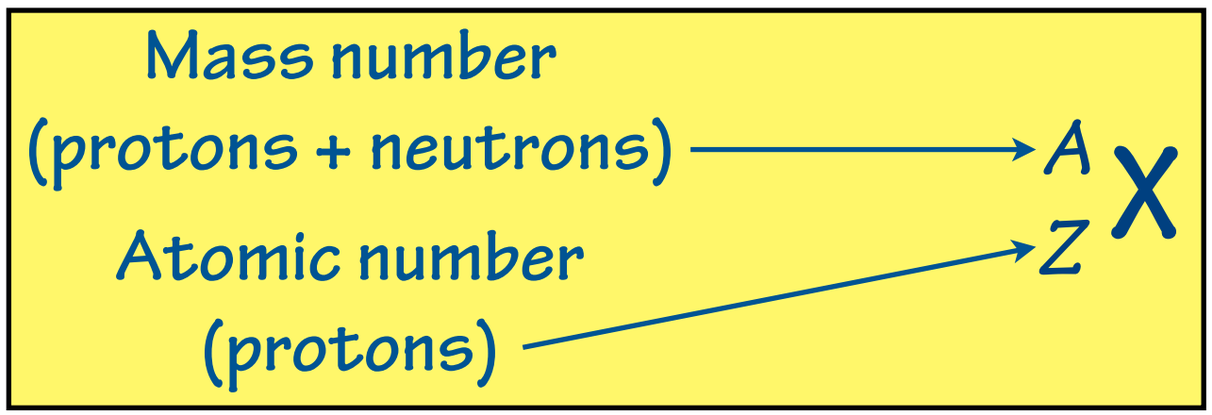
The structure of atoms

- Rutherford's model of the atom at the start of the 20th century gave a good model of the arrangement of particles in the atom.
- The nucleus of the atom is made up of positively charged **protons** & uncharged **neutrons**. **Electrons** orbit around the nucleus.
- This nucleus makes up 99.99% of them mass of the atom, but only takes up .01% of the space. (Most is empty.)
- Chemical reactions take place when the electrons of one atom form bonds to those in another atom.



Isotopes

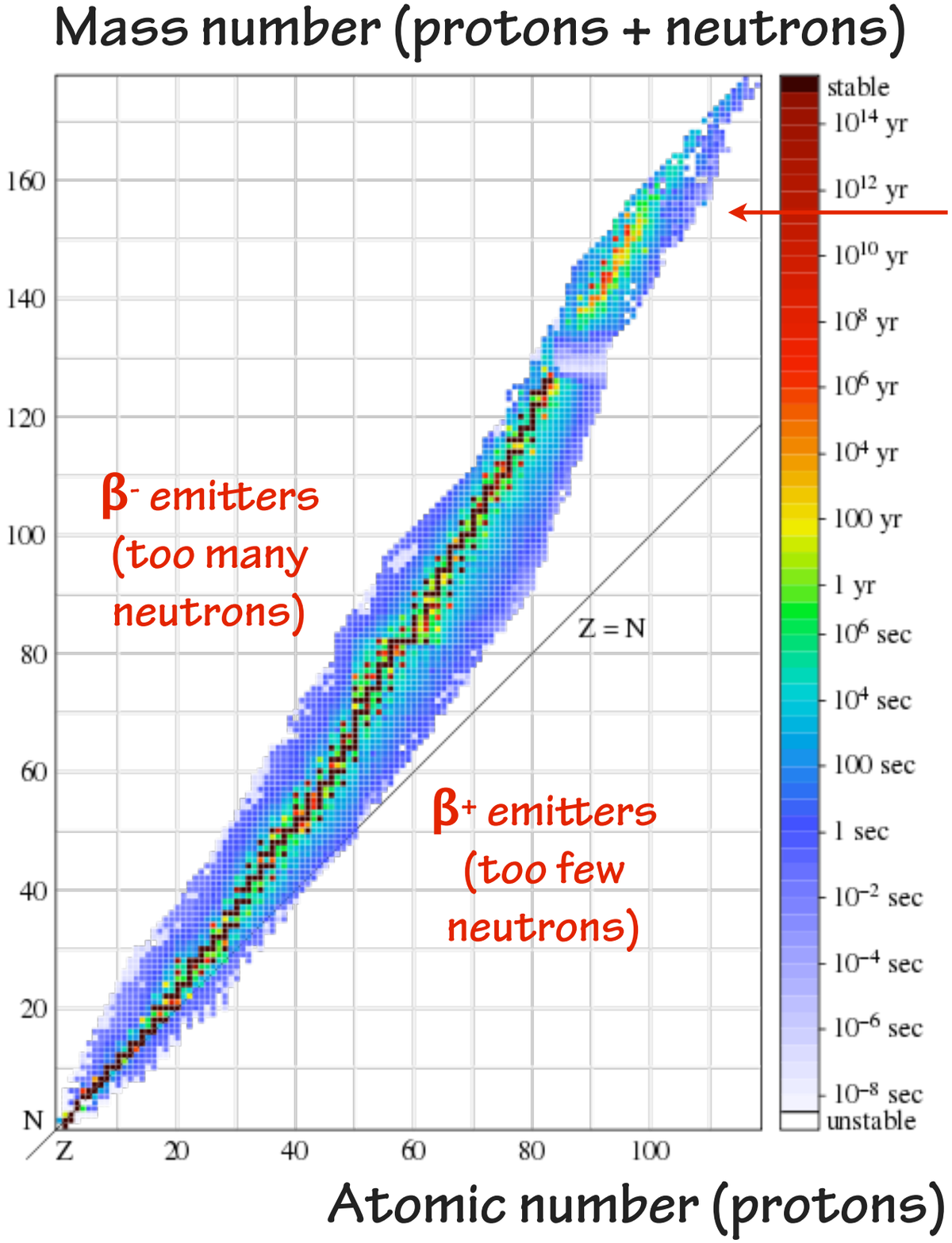
- All chemical elements exist as a number of different **isotopes**.
- Isotopes are forms of the same element, but with different numbers of neutrons.
- Isotopes of the same element have the same chemical properties, but differ slightly in their physical properties (boiling, melting....).
- For example, oxygen is commonly found as oxygen-16 (99.75%) & oxygen-18.
- Some isotopes are stable - others may have too few or too many neutrons & be **radioactive**.
- At some time, they will decay into another isotope or element.
- Not all isotopes are found in nature - some are produced artificially in nuclear reactors.



$^{18}_{8}O$

Oxygen-18 has 8 protons + 10 neutrons

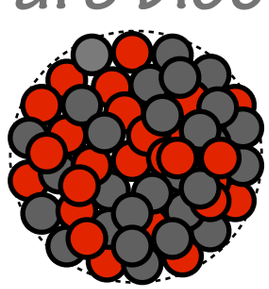
Stable & unstable isotopes



- This chart shows the relationship between the mass & atomic numbers for different isotopes.
- The black dots represent stable isotopes.
- With too many or few neutrons, isotopes are unstable & will decay over a period of time.
- The length of the half life is a measure of stability.

Alpha decay (α)

- An alpha particle contains two protons & two neutrons.
- It is the same as the nucleus of a helium atom - a He^{2+} ion.
- Alpha particles are the most dangerous of the nuclear particles due to their strong **ionising** charge & high energy (~5MeV).
- The size and mass of α particles means that they penetrate only a few mm through air are blocked by virtually any solid matter (such as skin).



Transmutation of U 238 into Th 234

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

Mass numbers:
238 nucleons

Atomic numbers:
92 protons

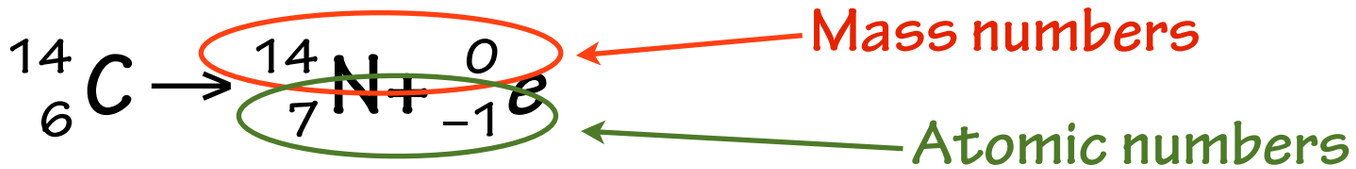
Thorium-234 is the daughter isotope

Nuclear energy is usually measured in small units called electron volts.

$1eV = 1.6 \times 10^{-19}\ J$

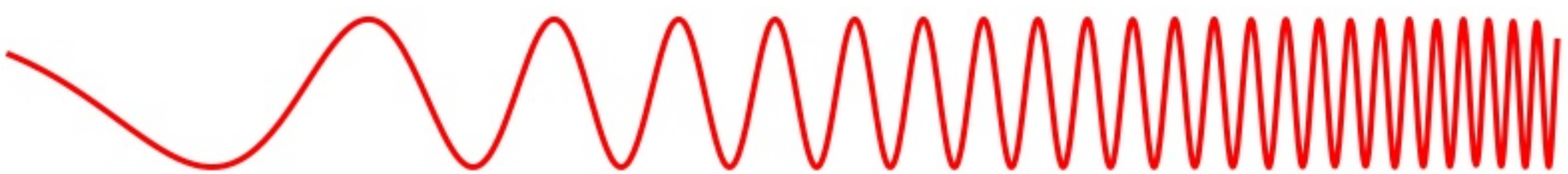
Beta decay (β)

- Beta decay involves the changes of neutrons ↔ protons;
- β^- decay occurs when a neutron decays into a proton by emitting an electron. (This electron is produced in the nucleus, not from the shells).
- There is no change to the mass number of the daughter isotope. (The total number of protons & neutrons is the same.)
- β^+ decay occurs when a proton decays into a neutron by emitting a positron. (Positively charged electron)
- β particles can penetrate a few metres of air, or a few mm in solid matter. The typical energy is ~ 1 MeV.



Gamma radiation (γ)

- Gamma radiation is a form of **electromagnetic radiation**.
- Gamma radiation is very high energy, short wavelength radiation.
- There is no change to the isotope as the energy is released.
- Gamma radiation has less ionising effect than α or β. But it is not blocked much by air & can penetrate through several cm of lead.



Radiation Type	**Radio**	**Microwave**	**Infrared**	**Visible**	**Ultraviolet**	**X-ray**	**Gamma ray**
Wavelength (m)	10^{3}	10^{-2}	10^{-5}	0.5×10^{-6}	10^{-8}	10^{-10}	10^{-12}

Neutron capture

- Another form of transmutation occurs when the nucleus of an atom captures a neutron.
- This is responsible for the chain reaction used in nuclear power generation and weapons.

$$^{27}_{13}Al + ^{1}_{0}n \rightarrow ^{27}_{12}Mg + ^{1}_{1}p$$

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{148}_{57}La + ^{85}_{35}Br + 3\,^{1}_{0}n$$

Properties of α , β & γ radiation

	α	β	γ
Mass	~ 4 atomic units	~ 1/2000 of an atomic unit	0
Charge	+2	-1	0
Energy	~ 5 MeV	~ 1 MeV	~ 0.1 MeV
Ionisation	High	Low	Very low
Range in air	~ 1 cm	~ 1 m	~ 100 m
Penetration through most matter	~0.01 mm	~ 1 mm	~ 1m

- Alpha radiation is the most dangerous form of radiation if inside the body.
- Gamma radiation has the most penetration - very hard to shield.