Constituents of an Atom

An atom is formed from 3 constituents: protons, neutrons and electrons.

Protons and neutrons (called neutrons) are found in the nucleus at the centre

Electrons orbit around the nucleus in shells/energy levels.

The diameter of the nucleus is about 1 femtometre (10^{-15} m)

The diamerer of an atom is roughly 100,000 times larger, or 10^{-10} m

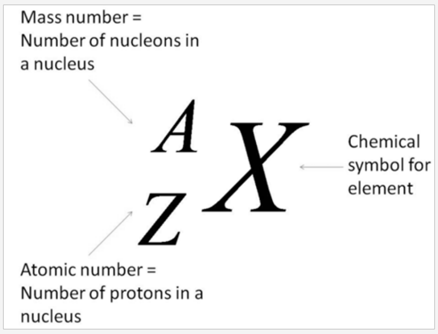
Specific charge is the charge-mass ratio, calculated by dividing a particle's charge by its mass

Specific charge (C kg^{-1}) = charge of particle/mass of particle

Particle Properties

Particle	Proton	Neutron	Electron
Charge (C)	$+1.6\times10^{-19}$	0	-1.6×10^{-19}
Relative Charge	+1	0	-1
Mass (kg)	1.67×10^{-27}	1.67×10^{-27}	9.11×10^{-31}
Relative Mass	1	1	0.0005
Specific Charge	9.58×10^{7}	0	1.76×10^{11}

Atom Notation



Isotopes

Atoms of the same element always have the same number of protons, and therefore the same atomic number

However, they can have different amounts of neutrons, which are called isotopes

We can use isotopes for carbon-dating, a method of estimating the age of living organisms like fossils

Organisms are made of carbon, which has a radioactive isotope (carbon-14) and decays at a known half-life once the organism is dead

Therefore we can use the amount of carbon-14 left to determine how old it is by how much carbon remains

Stable and unstable nuclei

The nucleus is held together by the strong nuclear force (one of 4 fundamental forces)

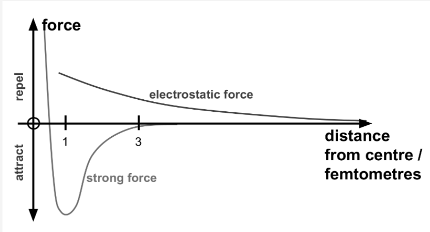
It provides an attractive force between nucleons with a range of about 3 femtometres (3×10^{-15} m)

This overcomes the repulsive electrostatic force exerted by positively charged protons on each other

Stable and unstable nuclei (cont)

At distances less than about 0.5 fm the strong nuclear force is repulsive and prevents the nucleus collapsing into a point

Variation of strong nuclear force with distance



Alpha and beta decay

Unstable nuclei have too many protons/neutrons/both, where the SNF is not enough to keep them stable

They will often decay via α (alpha) or β- (beta minus) emission in order to become stable, where the type of decay is dependent on the number of each nucleon

Alpha decay occurs in large nuclei with too many of both nucleons.
Beta-minus decay occurs in neutron-rich nuclei.
Beta-plus decay occurs in neutron-deficient nuclei.

The existence of the neutron was hypothesised in the conversation of energy law in the beta decay equation

Alpha decay equation

$${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$$

Beta- decay equation

$$^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\nu}_e$$

Beta+ decay equaion

$$^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}\beta + {}^{0}_{0}\nu_e$$

Particles and antiparticles

For every type of particle, there is a corresponding antiparticle

Examples of these include:
electron and positron
proton and anitproton
neutron and antineutron
neutrino and antineutrino

Comparison of particles/antiparticles

Electron (e^-) mass=9.11×10^{-31} kg rest energy=0.51MeV relative charge=-1	Positron (e^+) mass=9.11×10^{-31} kg rest energy=0.51MeV relative charge=+1
Neutron mass=$1.67\text{x}10^{-27}$ rest energy=940MeV relative charge=0	Antineutron mass=$1.67\text{x}10^{-27}$ rest energy=940MeV relative charge=0
Neutrino mass=0 relative charge=0	Antineutrino mass=0 relative charge=0

In short, particles and their corresponding antiparticles will have the same mass and rest energy, but different relative charges

The antineutron and antineutrino symbols are the same as the particle ones but with a line above them

Photon model of Electromagnetic (EM) Radiation

EM Radiation, or light, travels as small packets of energy known as photons

Photons transfer energy but have no mass themselves

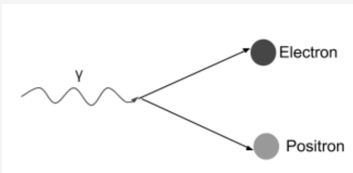
Since EM waves travel at the speed of light and follow Planck's constant, we can use the following equation:
Energy of a photon = (Planck's Constant x Speed)/Wavelength

Particle/Antiparticle interactions

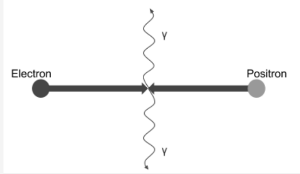
Pair production is where a photon is converted into an equal amount of matter and antimatter
This only happens when the photon has a energy greater than the total rest energy of both particles, and any excess energy is converted into kinetic energy of the particles.

Annihilation is where a particle and its corresponding antiparticle collide, resulting in both of their masses being converted into energy (in the form of 2 photons moving in opposite directions as to conserve momentum).

Pair Production diagram



Annihilation diagram



Fundamental Interactions

There are 4 main fundamental forces: strong nuclear, weak nuclear, electromagnetic and gravity.

Forces between particles are caused by exchange particles, which carry energy and momentum between the particles experiencing the force.
Each fundamental force has its own exchange particles.

Particle Interactions

Interaction	Exchange Particle	Range (m)	Acts on
Strong	Gluon/-Pions	$3\text{x}10^{-15}$	Hadrons
Weak	W boson (both +/-)	10^{-18}	All particles
Electromagnetic	Virtual photon (λ)	Infinite	Charged particles
Gravity	Graviton (not on spec)	Infinite	Particles with mass

Feynman Diagrams