1 Matter and radiation

1.1 Inside the atom

Rutherford's alpha-scattering investigations shows every atom contains

- Positively charged **nucleus** composed of **nucleons**, and
- **Electrons** surrounding the nucleus.

where mass is concentrated in the nucleus, the electrostatic force of attraction between the electrons and the nucleus traps them in the atom.

The atom consists of mostly empty space. An uncharged atom as equal number of protons and electrons, it becomes an ion if it gains or loses electrons.

	Charge/C	Relative charge	Mass/kg	Relative mass
proton	$+1.6 \times 10^{-19}$	1	1.6×10^{-27}	1
neutron	0	1	1.6×10^{-27}	1
electron	-1.6×10^{-19}	1	9.1×10^{-31}	0.0005

- The **atomic number** Z is the proton number.
- The **mass number** A is the nucleon number.

Every atom of a given element has the same atom number. **Isotopes** are atoms with the same number of protons but different number of neutrons.

The **isotope notation** can be used to label isotopes.

$$^{A}_{Z}X$$

The **specific charge** of a charge particle is defined as $\frac{\text{charge}}{\text{mass}}$.

1.2 Stable and unstable nuclei

The **strong nuclei force** must exist to over come the electrostatic force of repulsion between protons. It has the same effect between any two nucleons.

- Attractive from 0.5fm to 3fm,
- Repulsive <0.5fm to prevent nucleons being pushed into each other.

Three types of decays

α. **Alpha radiation** emits alpha particles $^{4}_{2}\alpha$.

β. **Beta radiation** emits fast-moving electrons β^{-} and an antineutrino $\bar{\nu_e}$.

γ. **Gamma radiation** is emitted by a nucleus with too much energy, following an alpha or beta emission.

1.3 Photons

Light is a small part of the **electromagnetic spectrum**. **Electromagnetic waves** consists of an electric and magnetic wave vibrating in phase and right angle to each other.

Light travels at $c = 3.0 \times 10^8 \text{ms}^{-1}$ in vacuum. Its frequency and wavelength are related by

$$f\lambda = c$$

Electromagnetic waves are emitted when

- A charged particle is **accelerated**.
- An **atomic electron** moves to a different shell.

EM waves are emitted in wave packets known as **photons**. The photon theory is used to explain the **photoelectric effect**.

$$\text{photon energy } E = hf$$

where $h = 6.63 \times 10^{-34}\text{Js}$ is **Planck's constant**.

1.4 Particles and antiparticles

Dirac's theory of antiparticles predicted that every type of particle has a corresponding antiparticle that

- **Annihilates** if they meet, converting their total mass into photons.
- Has the **same mass** but **opposite charge** as the particle.

Annihilation occurs when a particle and antiparticle pair meets and their mass is converted into radiation energy **-** **two photons** are produced in the process.

$$\text{energy of each photon} = \text{rest mass energy of each particle}$$

A photon creates a particle and antiparticle pair in **pair production**. The minimum energy of the photon is $2E_0$ where E_0 is the rest mass energy of each particle.

Energy of particles are express in **MeV**, one electron volt (eV) is the energy transferred when an electron moves through a p.d. of 1 volt.

1.5 Particle interactions

Momentum is transferred between objects through equal and opposite forces when two objects interact.

Electromagnetic force

between charged objects is due to the exchange of **virtual photons**

- Cannot be detected directly.
- Stops the force acting if intercepted.

Weak nuclear force

causes the β^- and β^+ decay.

These interactions are due to the exchange of **W bosons**

- Have a non-zero rest mass.
- Very short range around 0.001fm.
- Can be charged W^+ and W^-.

The W boson meets a neutrino or antineutrino, changing them into a β^- or β^+ particle respectively.

A proton in a proton-rich nucleus turns into a neutrons through **electron capture**, it weakly interacts with an inner-shell electron outside the nucleus.

The photon and W boson are known as **force carriers** because they are exchanged when the electromagnetic or weak force act.