WJEC Chemistry A-level

1.2: Basic Ideas about Atoms

Detailed Notes

Welsh Specification

Atomic Structure

The model for atomic structure has **evolved over time** as knowledge and scientific understanding have changed.

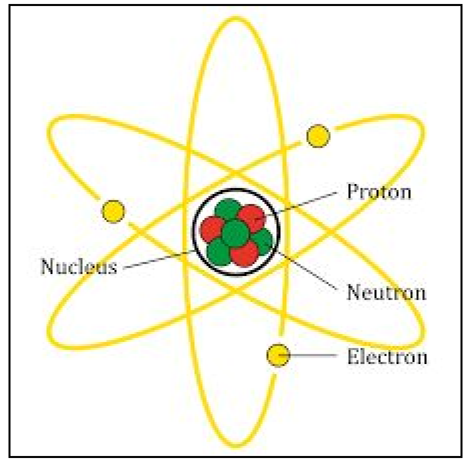
Plum Pudding Model

It was initially thought that atoms consisted of a **sphere of positive charge**, with **small negative charges distributed** evenly within it.

Electron Shell Model

It is now known that the atom consists of a **small, dense central nucleus** surrounded by **orbiting electrons** in electron **shells**. This was discovered in the Rutherford scattering experiment in 1911, when alpha particles were deflected by a central, positively charged body.

The nucleus consists of **protons and neutrons** giving it an overall **positive charge**. It contains almost the entire mass of the atom. In a neutral atom, the number of electrons is **equal to** the number of protons due to the relative charges.



(https://commons.wikimedia.org/wiki/File:Atom_Diagram.svg)
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Radioactivity

Not all nuclei of elements are **stable**. This means the **ratio** of protons and neutrons are **imbalanced**. In order to try and regain this balance, **radiation is emitted**, releasing excess protons, neutrons or both. Throughout these particle interactions, **neutrinos and antineutrinos** can be released in order to **conserve energy** and other **quantum values**.

Alpha Decay

Alpha decay is a type of radioactive decay, during which an atomic nucleus **loses two protons** and **two neutrons**. An alpha particle is equivalent to a helium nucleus with two protons and two neutrons. It reduces the atomic number by two and the mass number by four, making the element **more stable**.

Example:

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

Beta Decay

A beta particle, equivalent to an **electron**, is released, **reducing the proton number** by one. It is considered to have **zero mass**, so the mass number is not affected.

Example:

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

Beta$^+$ Decay

A beta plus particle is the **antiparticle to an electron**, meaning it has the **same mass** but **opposite charge**. Therefore, when released, it increases a nucleus' proton number by one and has no effect on mass number.

Example:

$$ p \longrightarrow {}^{0}_{+1}\beta + n + \nu_e $$

Electron Capture

This particle interaction occurs specifically **within the nucleus**. A proton interacts with an electron, producing a **neutron**. Therefore mass number remains the same and proton number is reduced by one.

Example:

$$ p + e \longrightarrow n + \nu_e $$

Gamma Radiation

Gamma radiation is a type of **electromagnetic radiation** rather than a particle. It has a very **short wavelength** and **high frequency**. Its wave nature means it is able to travel long distances.

Radiation Properties

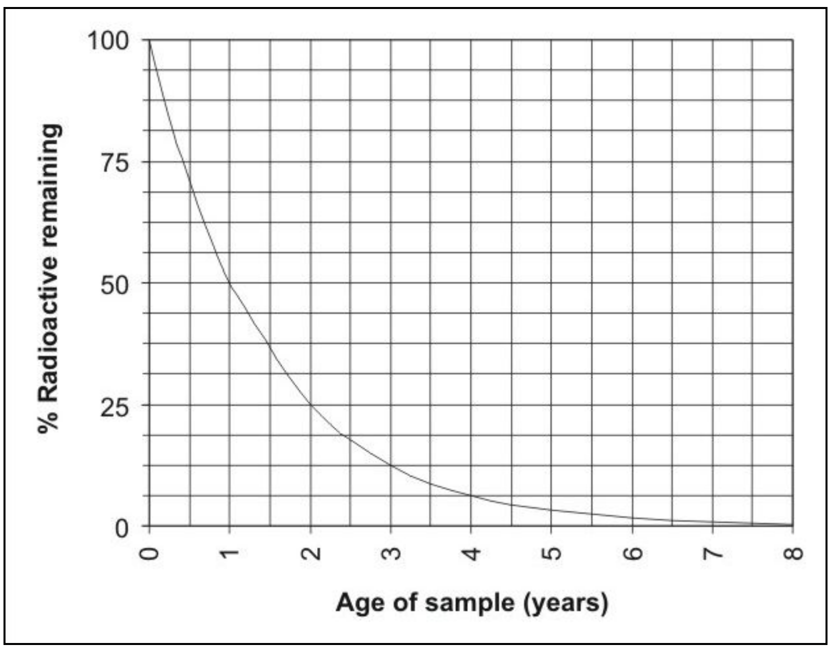
Alpha, Beta and Gamma radiations **vary in penetrating power** and can be affected by **electric and magnetic fields**.

	Range in Air	Ionising Power	Penetrating Strength
Alpha	< 5 cm	very strong	stopped by thin paper
Beta	< 1 metre	medium	stopped by thin metal
Gamma	infinite	weak	stopped by thick lead

Half Life

Radioactivity of a substance **decreases over time** as it gains a **more stable** composition. Half life is the time it takes for the radioactivity or the number of nuclei present to **halve**. This time period **remains the same** throughout the decay of the substance meaning radiation levels in the future can be **easily predicted**.

Example:



(https://commons.wikimedia.org/wiki/File:Radioactive_decay.png)
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Ionisation Energies

Standard Molar Ionisation Energies

Ionisation energy is defined as:

The minimum energy required to remove one mole of electrons from one mole of atoms in a gaseous state. It is measured in kJmol^{-1}.

$$Na_{(g)} \longrightarrow Na^{+}_{(g)} + e^{-}$$

Successive Ionisation Energies

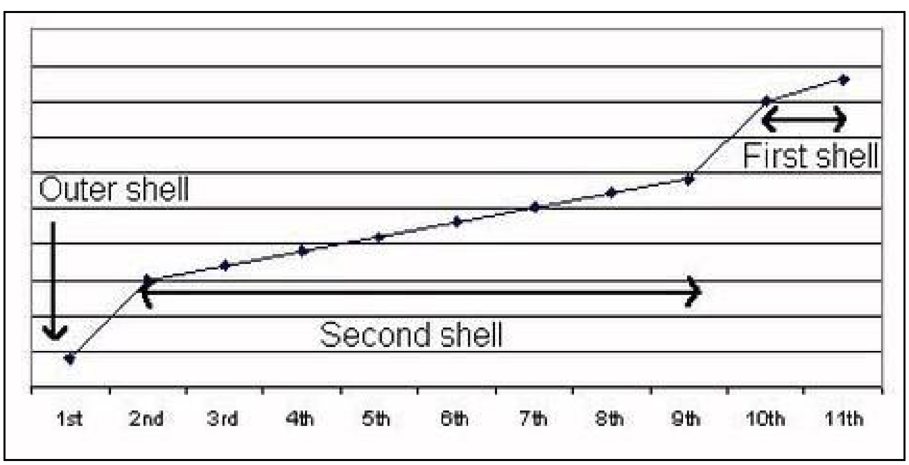
Successive ionisation energies occur when **further electrons are removed**. This usually requires **more energy** because, as electrons are removed, the **electrostatic force of attraction** between the positive nucleus and the negative outer electron **increases**. More energy is therefore needed to overcome this attraction so **ionisation energy increases**.

First ionisation energy follows trends within the Periodic Table:

Along a Period - first ionisation energy **increases** due to a decreasing atomic radius and greater electrostatic forces of attraction (due to the increasing number of protons).

Down a Group - first ionisation energy **decreases** due to an increasing atomic radius and increasing shielding which reduces the effect of the electrostatic forces of attraction.

When successive ionisation energies are plotted on a graph, a **sudden large increase** indicates a **change in energy level**. This is because the electron is being removed from an orbital closer to the nucleus so more energy is required to do so.



(https://ibchemninja.weebly.com/121-electron-configuration-hl.html)
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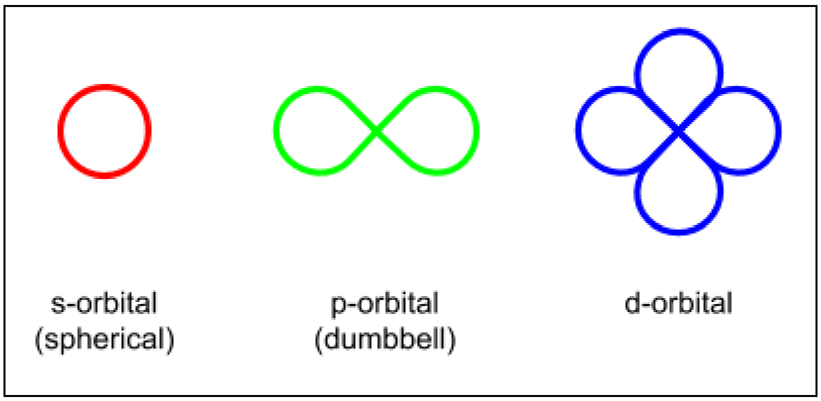
This large energy increase provides supporting evidence for the **atomic orbital theory**.

The first ionisation energy of aluminium is **lower than expected** due to **the outer electron in the 3p orbital being at a higher energy than the 3s electrons**. Therefore, it takes less energy than expected to remove the outer electron as we move from s block to p block.

Shapes of Electron Orbitals

Electrons are held in **clouds of negative charge** called **orbitals**. There are different types of orbital: *s*, *p*, *d* and *f.* Each one has a different shape.

Example:



Electron Transition Spectra

When an electron moves from a higher energy level to a lower energy level, a **photon is released** to help **conserve energy** and other quantum values. Likewise, when it gains energy to move up an energy level, **photons are absorbed** to provide the energy for this.

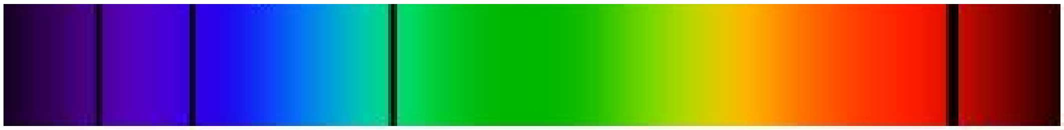
The specific **wavelengths and energies of photons** that are involved in the interactions can be seen using emission and absorption spectra.

Emission Spectra - This displays lines at the specific frequencies of **emitted** photons from when an electron moves **down an energy level**.

Example:

Absorption Spectra - This displays an entire spectrum with **black lines** for the 'missing' frequencies of photons that have been **absorbed** when an electron moves **up** an energy level.

Example:



(Modified from https://commons.wikimedia.org/wiki/File:Spectral_lines_en.PNG) User:Jhausauer / CC BY-SA 3.0

Energy, Wavelength & Frequency

These three quantities are linked in a series of relationships. Energy is **proportional** to frequency with **Planck's constant** (6.63×10^{-34} m^2kgs^{-1}).

Example:

$$E = hf$$

where E = energy (J), h = Planck's constant (J s), f = frequency of light absorbed (Hz)

Frequency, and therefore energy, is **inversely proportional** to wavelength, with the **speed of light in a vacuum** as the constant (3×10^8 ms^{-1}).

Example:

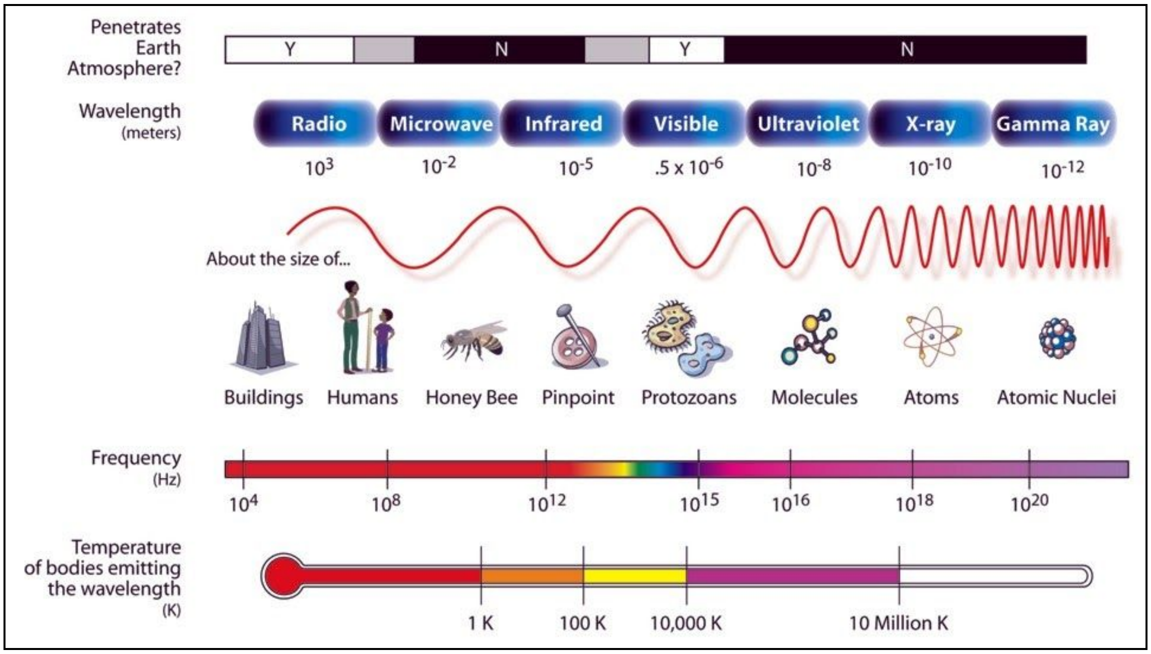
$$\lambda = \frac{c}{f} \qquad E = \frac{hc}{\lambda}$$

where λ=wavelength of light absorbed (m), c=speed of light, h=Planck's constant (J s), E=energy (J)

These relationships show that the **higher the frequency** of radiation, the **higher its energy.** Likewise, the **higher its wavelength** the **lower its energy**.

Applying this to the EM spectrum, **gamma** radiation has a high frequency and short wavelength and therefore has the **highest energy**. In comparison, **radio waves** have the longest wavelength and lowest frequency and therefore have the **lowest energy**.

Example:



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