Quantum Physics

Photoelectric effect is the ejection of an electron from a metal surface when the surface is irradiated with electromagnetic radiation of a high enough frequency.

Work function energy is the *minimum* energy required to eject an electron from a metal surface in the photoelectric effect.

Stopping potential is the minimum value of the retarding potential difference required to prevent any photoelectron (not even those with maximum kinetic energy) from reaching the collector.

$$\boxed{KE_{max} = eV_s}$$

$$\frac{1}{2} m_e v_{max}^{2} = eV_s$$

A **photon** is a quantum of electromagnetic energy.

$$\boxed{E = hf}$$

$$\boxed{E = \frac{hc}{\lambda}}$$

Intensity of electromagnetic radiation

$$\text{Intensity} = \frac{\text{Power of the incident electromagnetic beam}}{\text{Area of surface exposed to radiation}}$$

$$= \frac{\text{Total energy incident}}{\text{Area of surface exposed to radiation x time}}$$

$$= \frac{NE}{At} = \frac{Nhf}{At} \Rightarrow \text{Intensity} \propto \frac{\text{N}}{\text{t}}\left(\frac{\text{f}}{\text{A}}\right)$$

Einstein's Photoelectric Equation

$$\boxed{hf = \phi + \text{KE}_{\text{max}}}$$

Threshold frequency *f_o* is the minimum frequency of electromagnetic radiation incident on a metal surface required for photoelectric effect to take place, that is, to eject electrons from that surface.

$$\boxed{\phi = hf_0}$$

$$\boxed{hf = hf_0 + KE_{max}}$$

Wave-Particle Duality

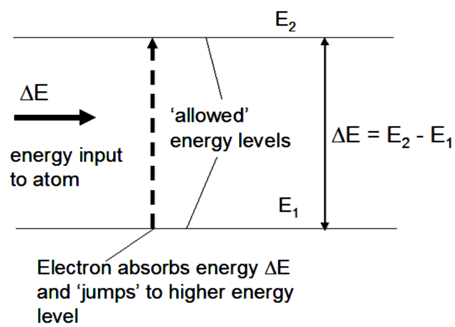
While the interference and diffraction phenomena of electromagnetic radiation prove the wave nature of electromagnetic radiation, the photoelectric effect provides evidence for the particulate nature of electromagnetic radiation. This shows the wave-particle duality of electromagnetic radiation. This led de Broglie to suggest that matter might also exhibit this duality and have wave properties.

de Broglie Wavelength

$$\boxed{\lambda = \frac{h}{p}}$$

Energy levels

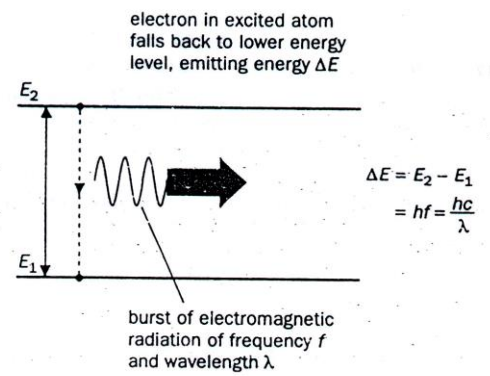
As shown below is an example of an energy level diagram showing 2 electron energy levels.



As a result of absorbing the **exact amount** of energy (ΔE), an electron can transit from a lower energy level (E_1) to a higher energy level (E_2).

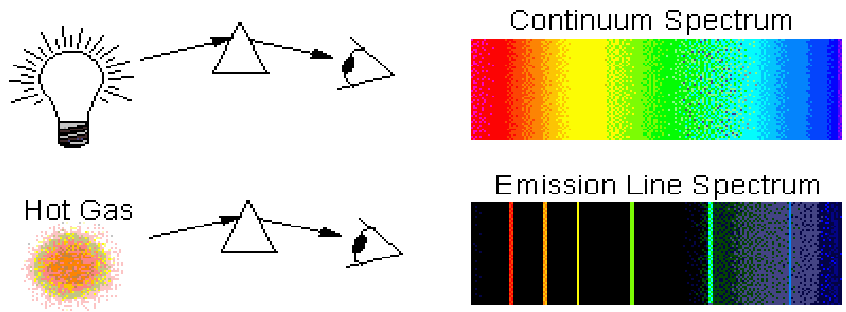
At E_2, the electron is said to be in an *excited state*. The electron is in an unstable state, and it will return rapidly and spontaneously to a lower energy level.

As shown below is the de-excitation of the atom in which the electron falls back from E_2 to E_1, and **the energy difference ΔE is emitted as a photon (a burst of electromagnetic radiation) of a particular frequency *f***.



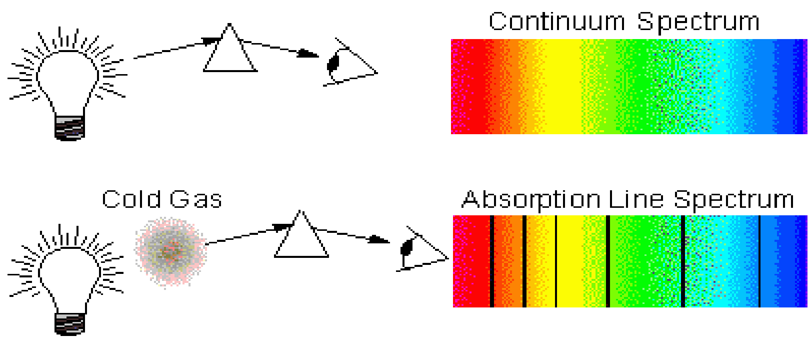
Line Spectra

Emission Line Spectrum



In an emission line spectrum, **bright coloured lines** are seen against a **dark background**.

Absorption Line Spectrum



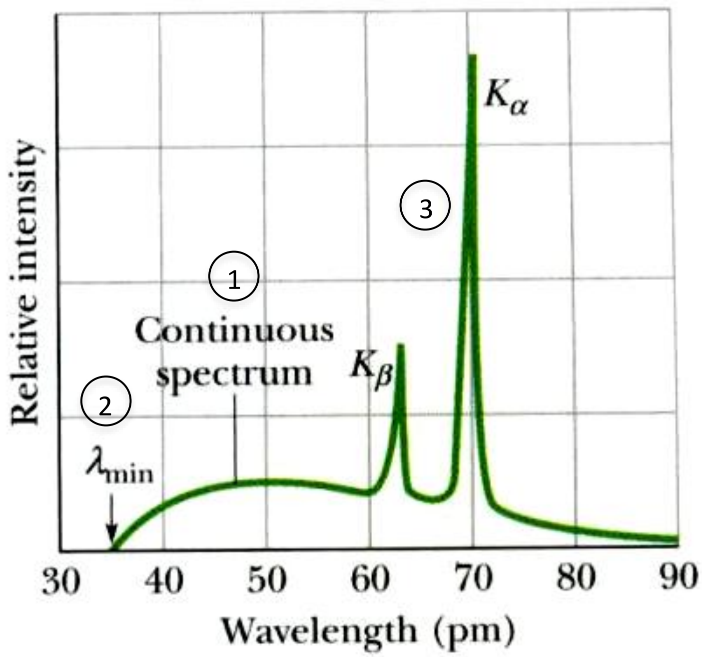
In an absorption line spectrum, **dark lines** are seen against a **continuous coloured background**.

X-rays

A common way for producing X-rays is by firing a beam of high-speed electrons at a metal target.

The processes involved in X-ray emission includes Bremsstrahlung and transitions of target atom's electrons.

An X-ray spectrum is observed from the experiment and is represented as a graph of **relative intensity of X-rays** against **X-ray wavelength.**



$$\text{Energy of photon} = \text{Total loss of KE of incident electron}$$

$$hf_{max} = eV$$

$$\frac{hc}{\lambda_{min}} = eV$$

$$\lambda_{min} = \frac{hc}{eV} \quad \text{(Bremsstrahlung limits)}$$

Position-Momentum Uncertainty Principle

$$\boxed{\Delta p \Delta x \gtrsim h}$$

The position and momentum of a particle cannot be *simultaneously* measured with arbitrarily high precision. If a measurement of position is made with uncertainty Δx and a simultaneous measurement of linear momentum is made with uncertainty Δp, then the product of the two uncertainties can never be smaller than h.