Discovery of Photo electricity

Hertz observed that the minimum voltage required to draw sparks from a pair of metallic electrodes **was reduced when they were bathed in ultraviolet (UV) light**, such as from a mercury vapour lamp. The more intense the UV light, the lower the required voltage became.

This was later named the "Photoelectric effect".

EM Radiation

EM Radiation travels at the speed of light in a vacuum or $3.00 \times 10^{8} ms^{-1}$. EM radiation has many forms and there is a "spectrum" of radiation which under the wave model propagates (moves) through space with both frequency and wavelength. **$c = f\lambda$**

We find that the spectrum has various interactions with matter and can be quite dangerous when λ is short i.e. gamma rays.

Visible Light

The energy *E*, frequency *f*, and wavelength λ of a photon are related by the formula;

$E = hf = hc/\lambda$

where *h* is Planck's constant and *c* is the speed of light. For example, the spectrum of visible light consists of wavelengths ranging from 400 nm to 700 nm. ($1nm = 1 \times 10^{-9}m$)

Photoelectricity

The idea of this is simple, when we shine a UV light source on a gold leaf electroscope which is charged negative (i.e. has lots of electrons) we find that the leaf falls. The conclusion is that electrons escape from the surface. This happens differently for different metals and different light sources.

PE - Frequency

When you change the frequency of light incident on the surface the energy radiant on the surface per photon or E = hf increases or decreases. This means that the energy of the electron emitted changes (increase or decrease). If you fall below a threshold frequency you don't have enough energy to emit a photon and it does not happen.

PE - Intensity

A Kaon also called K-meson is any one of a group of four mesons distinguished by the fact that they carry a quantum number called strangeness.
In the quark model they are understood to contain a single strange quark (or anti strange quark) and either an up or down or anti up or anti down.

PE- Formula

So if we consider we input some light energy to the surface (hf), then take away the work done to get the electron to the surface (ϕ), then the electron leaves with the leftovers (E_{Kmax})..

$\mathbf{E_{Kmax} = hf - \phi}$

Plotting a graph of this as $\mathbf{E_{Kmax} - Y}$ & f – X leaves "**h**" as the gradient which is always a constant no matter which surface and ϕ - the "work function" or energy to get to the surface!

PE - Threshold

If you consider the situation where the line graph…

$\mathbf{E_{Kmax} = hf - \phi}$ crosses the X axis this is when $\mathbf{E_{Kmax} = 0}$,

Hence we can say that $\mathbf{0 = hf_0 - \phi}$ or that $\mathbf{f_0 = \phi/h}$.

This is called the "threshold frequency.

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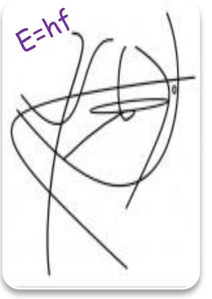

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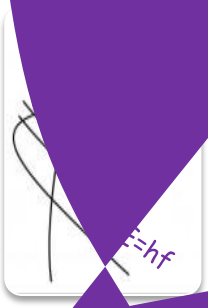

Plank's Model

Plank suggested that energy could be thought of a discrete values instead of a continuous scale. Where things only happened when the correct energy value was added.

He thought of atoms as having energy shells where electrons could be moved up a level by absorbing energy **E = hf**.

Conduction Electrons

Electrons in a metal move about as a disassociated sea. They can be given energy to form an electrical current but they have to have a large amount of energy per electron to be removed from the surface.

This can happen provided the light has enough energy **E = hf**.

Vacuum Photocell

Experiment for photoelectricity can be more accurately completed with a cell which has a cathode, anode and microammeter in a vacuum tube. $\mathbf{E_{Kmax} = hf - \phi}$

This shows $\mathbf{E_{Kmax} - Y}$ & f – X leaves "**h**" as the gradient which is always a constant no matter which surface and ϕ - the "work function" or energy to get to the surface!

Photon Models

We can use the idea of light as a coconut shy. Red light is a ping pong ball and UV is a brick.

No matter how many ping pong balls hit the coconut it will never fall off the shy.

Just like red on the surface of the metal

Orbital Electrons

These are electrons which obit the atom in fixed energy shells. They can be in what is called the ground state – the lowest energy level.

But if atoms absorb energy i.e. **E = hf** from photon or electron collision then they can move to what is called an excited state.

Ground State & Ionisation

Lowest energy state for an orbital electron. For hydrogen it is $\mathbf{-13.6eV/n^2}$. What this means is I have put in **13.6eV** or $\mathbf{8.16 \times 10^{-19}Jof}$ energy to remove that electron from the atom.

This is also called "ionization" and would make the hydrogen atom a lone proton.

Excitation/ De-excitation

This is when a photon **E = hf** of exactly the right energy is absorbed into an atom making an electron move 1 or more shells further out.

The reverse process is de-excitation.

Fluorescence & Tubes

The atoms of a fluorescent substance may get excited by incident uv light. We can coat a glass evacuated tube with this substance so then these atoms then de-excite emitting visible light.

This is a method of converting UV light to visible which we can use.

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Low Energy Bulbs

Most light bulbs waste most energy as heat. However, a high efficiency fluorescent tube is much more efficient and can also be run at a lower input power as well. This is better for the environment.

Efficiency = (useful energy out / total energy) x 100%

Geissler Tubes

The tube was invented in 1857 by Heinrich Geissler. It consists of a sealed, partially evacuated glass cylinder of various shapes with a metal electrode at each end which contains rarefied gasses. The light emitted is characteristic of the material within the tube, and is composed of one or more narrow spectral lines.

Excitation by Collision

When a high energy electron collides with an orbital electron if it has more energy than a shell jump it can excite the electron leaving any spare energy with the incoming electron to leave with that as its kinetic energy.

Energy Levels Formula

We find that we can work out the energy difference simply by the formula..

$$E = hf = E2 - E1 = hc/\lambda$$
$$= (-13.6eV/n_2^2 - 13.6eV/n_1^2)$$

We use the ground state of hydrogen as -13.6eV but for other atoms it would change. The n = 1,2,3,…. is the shell number. $-13.6eV/n^2$

De-Broglie Hypothesis

This was an idea that all matter in fact has a wavelength just like light…

$\lambda = h/mv = h/p$

(p is momentum, v = velocity, m = mass)

Wavelengths are very small for larger objects!

Dual Nature of Light

- The photo electric effect provides evidence of light being particle-like in nature
- The diffraction of light provides evidence of light being wavelike in nature

Dual Nature of Matter

- **Evidence** of matter being wavelike in nature (also electron deflection in electric and magnetic fields)
- **The** diffraction of an electron beam directed at a thin metal film provides
- **The** rows of atoms in the metal crystals behave like light passing through slits for it to happen should be λ similar to size of atoms.

Electron waves & Ring size

Speed of electrons effects the size of rings…

- Higher Anode Voltage = Faster Electrons
- Diffraction Rings are smaller
- The wavelength is smaller

$\lambda = h/mv = h/p$

(p is momentum, v = velocity, m = mass)

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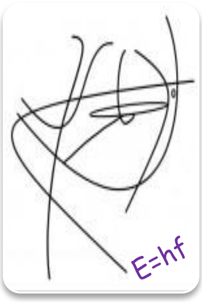

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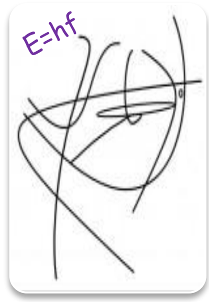

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TEM

Is a transmission electron microscope where electrons are accelerated to a high speed to produce a very short de Broglie wavelength.

Very detailed images can then be resolved.

MRI

Magnetic resonance imaging is when radio waves are emitted when hydrogen nuclei (eg in water molecules) change energy states in a strong magnetic field.

STM

A scanning tunnelling microscope can map surfaces using a quantum tunnelling effect where the a small tip is very close to surface.

SQUIDS

Superconducting quantum interference device - magnetic field detector.

Used to detect very weak magnetic fields from tiny electrical currents inside the brain and for feotal examinations.

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