Light and Matter

Planck's equation

$$f = \frac{c}{\lambda}$$

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

$$h = 6.63 \times 10^{-34}\,\text{Js} = 4.12 \times 10^{-15}\,\text{eVs}$$

Force of electrons

$$F = evB$$

Photoelectric effect

- V_{supply} does not affect photocurrent
- if $V_{\text{supply}} > 0$, e- are attracted to collector anode
- if $V_{\text{supply}} < 0$, e- are attracted to illuminated cathode, and $I \to 0$
- v of e- depends on ionisation energy (shell)

Threshold frequency

- *threshold frequency* f_0 - minimum frequency for photoelectrons to be ejected
- x-intercept of frequency vs E_K graph
- if $f < f_0$, no photoelectrons are detected

Work function

- *work function* ϕ - minimum energy required to release photoelectrons
- magnitude of y-intercept of frequency vs E_K graph
- ϕ is determined by strength of bonding

$$\phi = hf_0$$

Kinetic energy

$$E_{\text{k-max}} = hf - \phi$$

voltage in circuit = max E_K in eV

Stopping potential

Smallest voltage to achieve minimum current

$$V_0 = \frac{E_{K\,\text{max}}}{q_e} = \frac{hf - \phi}{q_e}$$

De Broglie's theory

$$\lambda = \frac{h}{\rho} = \frac{h}{mv}$$

$$\rho = \frac{hf}{c} = \frac{h}{\lambda}$$

$$E = \rho c$$

- impossible to confirm de Broglie's theory of matter with double-slit experiment, since wavelengths are much smaller than for light, requiring an equally small slit ($< r_{\text{proton}}$)
- confirmed by Davisson and Germer's apparatus (diffraction pattern like double-slit)
- also confirmed by Thomson - e- diffraction pattern resembles x-ray (wave) pattern

X-ray and electron interaction

- electron is only stable in orbit if $mvr = n\frac{h}{2\pi}$ where $n \in \mathbb{Z}$
- rearranging this, $2\pi r = n\frac{h}{mv}$ (circumference)
- if $2\pi r \neq n\frac{h}{mv}$, interference occurs, standing wave cannot be established

Spectral analysis

- $\Delta E = hf = \frac{hc}{\lambda}$ between ground / excited state
- f of a photon emitted or absorbed can be calculated from energy difference: $E_2\check{}E_1 = hf$ or $= hc$
- Ionisation energy - min E required to remove e-
- EMR is absorbed/emitted when $E_{\text{K-in}} = \Delta E_{\text{shells}}$ (i.e. $\lambda = \frac{hc}{\Delta E_{\text{shells}}}$)

Indeterminancy principle

measuring location of an e- requires hitting it with a photon, but this causes ρ to be transferred to electron, moving it. $\therefore, \sigma E \propto \frac{1}{\sigma t}$

$$\sigma E \sigma t \geq \frac{h}{4\pi}$$

Wave-particle duality

wave model:

- cannot explain photoelectric effect
- f is irrelevant to photocurrent
- predicts delay between incidence and ejection

particle model:

- explains photoelectric effect
- rate of photoelectron release $\propto$ intensity
- no time delay - one photon releases one electron
- double slit: photons interact as they pass through slits
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    - interference pattern still appears when a dim light source is used so that only one photon can pass at a time