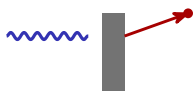
Photons

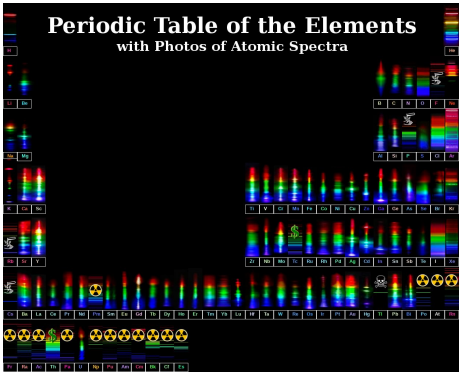
A2 Physics ▪ Topic 22

A-Level Physics



What we will cover

1. The photon $E = hf$
2. The photoelectric effect
3. Wave–particle duality
4. Energy levels in atoms
5. Recap



Light comes in packets

A **photon** 光子 is a quantum of light with energy

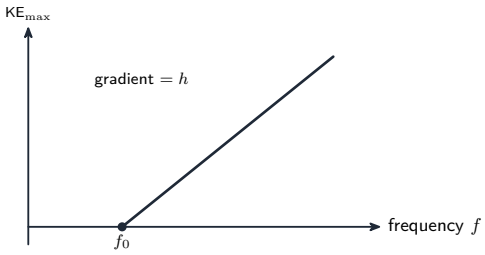
$$E = hf = \frac{hc}{\lambda}, \qquad h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$$

- energy $\propto$ frequency, not brightness
- the **electronvolt** 电子伏特: $1\,\mathrm{eV} = 1.6 \times 10^{-19}\,\mathrm{J}$

$$E = hf = \frac{hc}{\lambda}, \qquad p = \frac{E}{c}$$

> Brightness is the number of photons per second; colour is the energy of each one.

The photoelectric effect



solar panels

Worked example – maximum kinetic energy

Light of $5.0 \times 10^{14}\,\mathrm{Hz}$ falls on a metal of work function $1.4\,\mathrm{eV}$. Find the maximum KE of the electrons.

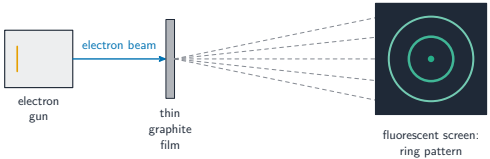
$hf = (6.63 \times 10^{-34})(5.0 \times 10^{14}) = 3.3 \times 10^{-19}\,\mathrm{J}$

$\phi = 1.4 \times 1.6 \times 10^{-19} = 2.2 \times 10^{-19}\,\mathrm{J}$

$E_{k,\max} = hf - \phi = 1.1 \times 10^{-19}\,\mathrm{J}$

Convert the work function from eV to joules before subtracting. A negative answer means you are below threshold – no emission.

Wave–particle duality



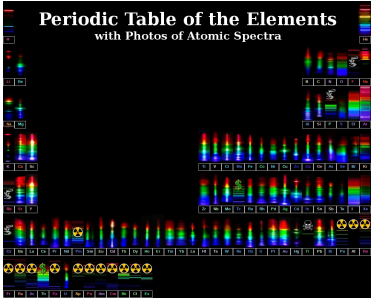
Light is a wave (diffraction) and a particle (photoelectric). Matter is the same:

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

- electrons diffract through a crystal
- the faster they go, the shorter the wavelength

de Broglie 德布罗意: everything has a wavelength – but for anything bigger than an atom it is far too small to notice.

Energy levels in atoms



Electrons occupy discrete energy levels. A jump between them emits or absorbs one photon:

$$hf = E_2 - E_1$$

- down a level: emits (bright line)
- up a level: absorbs (dark line)

> Because the levels are fixed, only certain photon energies appear – a **line spectrum** 线状光谱 is an atom's fingerprint.

Topic 22 – key takeaways

1 Photon

$E = hf = hc/\lambda$ – energy in packets

2 Photoelectric

$hf = \phi + E_{k,\max}$ – threshold frequency

3 Duality

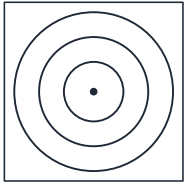
$\lambda = h/p$ – electrons diffract too

4 Levels

$hf = E_2 - E_1$ – line spectra

Check yourself

1. Double the frequency – what happens to E?
2. Below threshold, does brighter light help?
3. What has the shorter λ: slow or fast electron?
4. Why is a line spectrum discrete?



diffraction rings

Answers **1.** it doubles **2.** no **3.** the fast one **4.** energy levels are fixed