Modern Physics

AP Physics 2 ▪ Unit 15

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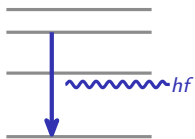
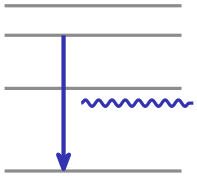


What we will cover

1. Photons and wave-particle duality
2. The Bohr model and energy levels
3. Spectra and blackbody radiation
4. The photoelectric effect
5. Compton scattering
6. Nuclear physics



Photons and wave-particle duality

Light comes in packets called **photons** 光子, each carrying:

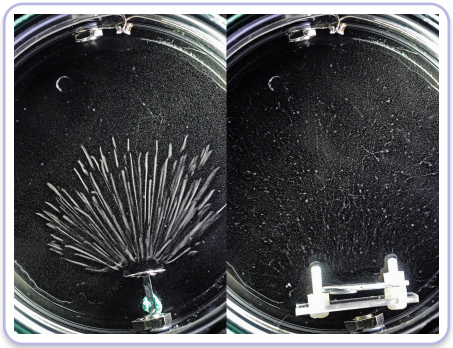
Photon energy

$$E = hf$$

Matter waves

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

the **de Broglie wavelength** 德布罗意波长.



Particles leave tracks of ionisation

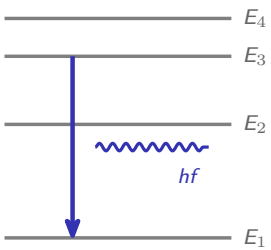
The Bohr model and energy levels

The **Bohr model** 玻尔模型: electrons occupy only certain **energy levels** 能级 – energy is quantized.

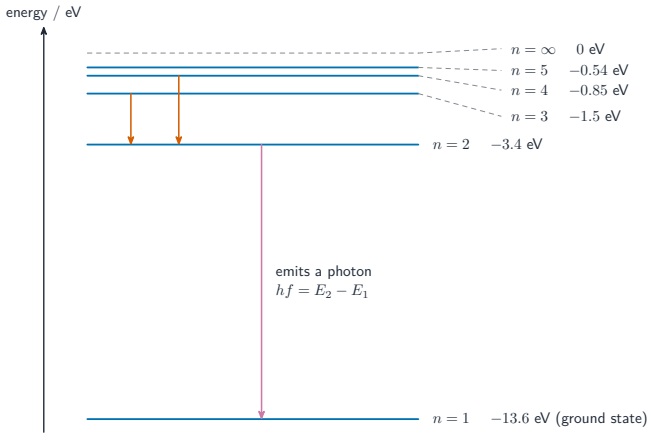
A jump emits or absorbs a photon

$$E = hf = E_i - E_f$$

Hydrogen $-3.4 \to -13.6\,\mathrm{eV}$: emits a $10.2\,\mathrm{eV}$ photon.



The Bohr model and energy levels



Spectra and blackbody radiation

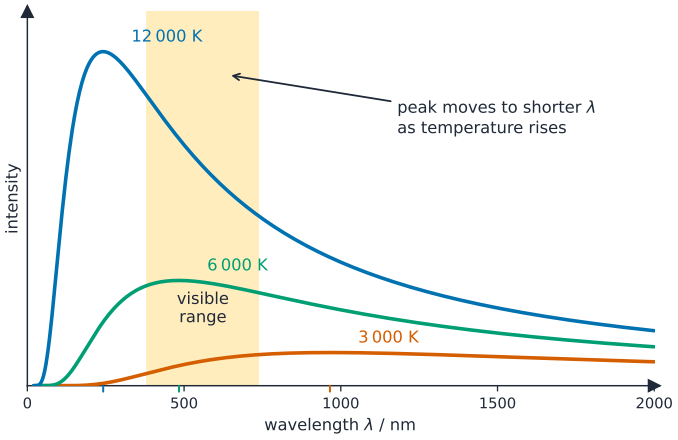
Discrete levels give sharp spectral lines – a fingerprint of each element:

- **emission** 发射光谱: bright lines (electrons drop)
- **absorption** 吸收光谱: dark lines in a rainbow (photons absorbed)

> A hot **blackbody** 黑体 glows across all wavelengths; hotter ⇒ peak shifts to shorter λ (**Wien's law** 维恩定律).

Nuclear energy is released from the nucleus

Spectra and blackbody radiation



The photoelectric effect

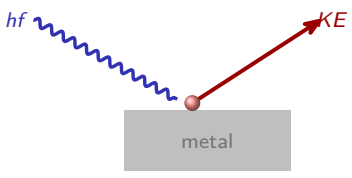
Light ejects electrons from a metal – only if each photon is energetic enough:

One photon, one electron

$$E = hf = \phi + KE_{max}$$

work function 逸出功 ϕ = energy to escape.

Below the **threshold frequency** 截止频率, no electrons come out – however bright the light.



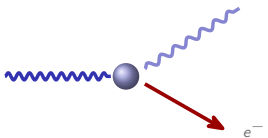
Compton scattering

A photon collides with an electron like two billiard balls – proof photons carry **momentum** 动量:

Photon momentum

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

The scattered photon loses energy, so it comes away with a longer wavelength. Both energy and momentum are conserved.



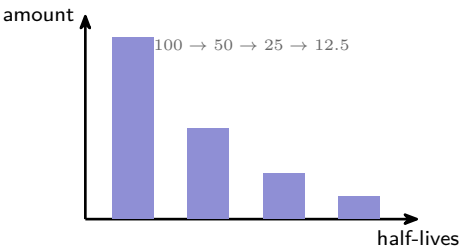
Nuclear physics

The nucleus releases huge energy when it changes – the lost mass becomes energy:

Mass-energy

$$E = mc^2$$

- **fission** 裂变: split a heavy nucleus
- **fusion** 聚变: join light nuclei (the Sun)
- **alpha** 阿尔法 / **beta** 贝塔 / **gamma** 伽马 decay – conserve nucleons & charge



Half-life 半衰期: time for half to decay.

Nuclear physics

Nuclear physics

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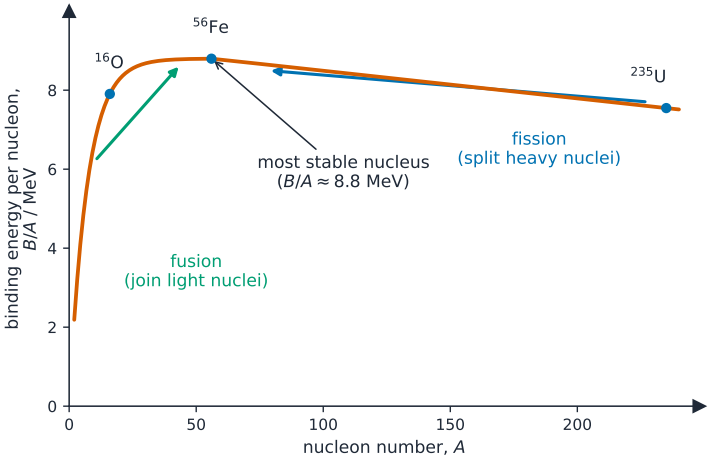


Unit 15 – key takeaways

1 Duality

$E = hf$; matter has $\lambda = h/p$; wave and particle both

2 Atoms

quantized levels; a jump gives $hf = E_i - E_f$ – sharp lines

3 Photoelectric

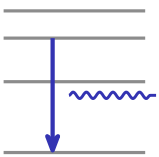
$hf = \phi + KE_{max}$; a threshold frequency, not brightness

4 Nuclear

fission, fusion, decay; $E = mc^2$; half-life

Check yourself

1. What sets a single photon's energy?
2. Why does an atom emit only certain colours?
3. Below the threshold frequency, does brighter light eject electrons?
4. After two half-lives, what fraction of a sample remains?



Answers **1.** its frequency ($E = hf$) **2.** quantized energy levels **3.** no **4.** one quarter