Exercise walk-through

Properties of Photons ▪ 3.12

eXercise

You must be able to

- use $E = h\nu$ and $c = \lambda\nu$
- convert between energy, frequency, and wavelength
- find the energy of a photon or a mole of photons

Method — The photon equations

$$E = h\nu, \qquad c = \lambda\nu, \qquad E = \frac{hc}{\lambda},$$

with $h = 6.63 \times 10^{-34}$ J s and $c = 3.00 \times 10^{8}$ m s^{-1}.

Method — Frequency from wavelength

For $\lambda = 500$ nm $= 5.00 \times 10^{-7}$ m:

$$\nu = \frac{c}{\lambda} = \frac{3.00 \times 10^{8}}{5.00 \times 10^{-7}} = 6.00 \times 10^{14} \text{ Hz}.$$

Method — Energy of one photon

$$E = h\nu = (6.63 \times 10^{-34})(6.00 \times 10^{14}) = 3.98 \times 10^{-19}\ \text{J}.$$

Method — Energy per mole

Multiply by Avogadro's number: $E_{\text{mol}} = E \times 6.022 \times 10^{23}$. Here $\approx 2.4 \times 10^{5}$ J/mol $= 240$ kJ/mol.

Practice 2.1 ▪ 1 mark

Write the equation linking a photon's energy and frequency.

Solution 2.1

Method: Energy of one photon

Worked steps

$E = h\nu$ (B1).

Practice 2.2 ▪ 2 marks

Find the frequency of light with $\lambda = 6.00 \times 10^{-7}$ m.

Solution 2.2

Method: Frequency from wavelength

Worked steps

$$\nu = \frac{3.00 \times 10^{8}}{6.00 \times 10^{-7}} = 5.00 \times 10^{14}\ \text{Hz}$$ M1 A1.

Practice 2.3 ▪ 2 marks

Find the energy of a photon of frequency 5.0×10^{14} Hz.

Solution 2.3

Method: Energy of one photon

Worked steps

$E = (6.63 \times 10^{-34})(5.0 \times 10^{14}) = 3.3 \times 10^{-19}$ J **M1** **A1**.

Exam-style 3.1 ▪ 1 mark

The energy of a photon is

A inversely proportional to frequency

B proportional to frequency

C independent of frequency

D proportional to wavelength

Solution 3.1

Method: Energy of one photon

A inversely proportional to frequency

B proportional to frequency ✓

C independent of frequency

D proportional to wavelength

Worked steps

B — $E = h\nu$, proportional to frequency.

Exam-style 3.2 ▪ 3 marks

A laser emits light of wavelength 650 nm.
(a) Convert to metres and find the frequency.
(b) Find the energy of one photon.

Solution 3.2

Worked steps

(a) $650\ \text{nm} = 6.50 \times 10^{-7}\ \text{m};\ \nu = \dfrac{3.00 \times 10^{8}}{6.50 \times 10^{-7}} = 4.62 \times 10^{14}\ \text{Hz}$ M1 M1 A1.

(b) $E = h\nu = (6.63 \times 10^{-34})(4.62 \times 10^{14}) = 3.06 \times 10^{-19}\ \text{J}$ M1 A1.

Exam-style 3.3 ▪ 2 marks

Explain why UV photons are more damaging to skin than visible photons, in terms of photon energy.

Solution 3.3

Method: Energy of one photon

Worked steps

UV light has a shorter wavelength and higher frequency, so by $E = h\nu$ each UV photon carries more energy — enough to break bonds/damage molecules that visible photons cannot **M1** **A1**.