Solutions

Each answer shows the steps, then the **result**.

2.1

- $E = hf$ (or $E = hc/\lambda$)

2.2

- $h = 6.63 \times 10^{-34}$ J s

2.3

- $E = hf$

$$E = (6.63 \times 10^{-34}\ \text{J s})(5.0 \times 10^{14}\ \text{Hz}) = \mathbf{3.3 \times 10^{-19}}\ \text{J}$$

2.4

$$E = \frac{3.3 \times 10^{-19}\ \text{J}}{1.6 \times 10^{-19}\ \text{J eV}^{-1}} = \mathbf{2.1}\ \text{eV}$$

3.1 B

- photon momentum $p = E/c$

3.2

- $E = hc/\lambda$

$$E = \frac{(6.63 \times 10^{-34}\ \text{J s})(3.0 \times 10^{8}\ \text{m s}^{-1})}{500 \times 10^{-9}\ \text{m}} = \mathbf{4.0 \times 10^{-19}}\ \text{J}$$

3.3

- $p = E/c$

$$p = \frac{4.0 \times 10^{-19}\ \text{J}}{3.0 \times 10^{8}\ \text{m s}^{-1}} = \mathbf{1.3 \times 10^{-27}}\ \text{kg m s}^{\mathbf{-1}}$$

3.4

- a **quantum (packet) of electromagnetic energy**

3.5

(a) a photon is a **quantum (discrete packet) of electromagnetic radiation**

- carrying energy $E = hf$

(b) $E = 0.050 \times 1.60 \times 10^{-13}\ \text{J} = 8.0 \times 10^{-15}\ \text{J}$

$$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34}\ \text{J s})(3.00 \times 10^{8}\ \text{m s}^{-1})}{8.0 \times 10^{-15}\ \text{J}} = \mathbf{2.5 \times 10^{-11}}\ \text{m}$$

(c) $p = E/c$

$$p = \frac{8.0 \times 10^{-15}\ \text{J}}{3.00 \times 10^{8}\ \text{m s}^{-1}} = \mathbf{2.7 \times 10^{-23}}\ \text{N s}$$

(d) momentum is conserved and the nucleus started at rest, so it must recoil with momentum **equal and opposite** to the photon's

$$v = \frac{p}{m} = \frac{2.67 \times 10^{-23}\ \text{kg m s}^{-1}}{(234)(1.66 \times 10^{-27}\ \text{kg})} = \mathbf{6.9 \times 10^{-2}}\ \text{m s}^{\mathbf{-1}}$$

(e) the nucleus has **discrete energy levels**

- the photon energy is the difference between two definite levels, and a single wavelength means every nucleus in the sample makes the **same** transition