Solutions

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

2.1

- **spontaneous**: the decay is not affected by anything outside the nucleus, so changing the temperature, pressure or chemical state does not change the rate
- **random**: it is impossible to predict which nucleus will decay next or when, and every undecayed nucleus has the same probability of decaying in the next interval

2.2

- the source's activity is effectively constant, so any difference between readings cannot be a change in the source
- the readings **fluctuate about a mean**, which is what a random process produces; a predictable process would give the same count every time

2.3

- convert the half-life to seconds first

$$t_{1/2} = 4.5 \text{ hours} \times 3600 \text{ s hour}^{-1} = 1.62 \times 10^4 \text{ s}$$

- then

$$\lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{1.62 \times 10^4 \text{ s}} = \mathbf{4.3 \times 10^{-5}} \text{ s}^{-1}$$

2.4

- use $A = \lambda N$

$$A = 2.2 \times 10^{-8} \text{ s}^{-1} \times 6.0 \times 10^{20} = \mathbf{1.3 \times 10^{13}} \text{ Bq}$$

2.5

- a **straight line** with a **negative** gradient, starting at $\ln A_0$ on the vertical axis
- the gradient is $-\lambda$, so the decay constant is minus the gradient

2.6

- $\frac{1}{8} = \left(\frac{1}{2}\right)^3$, so **3 half-lives**

3.1 B

- $800 \to 400 \to 200 \to 100$ is **three** halvings
- 27 min $\div$ 3 = 9.0 min. **A** divides by the wrong number of halvings; **C** assumes two; **D** assumes one

3.2

(a)

- decay is a **random** process, so the number of nuclei decaying in any 10 s interval is not fixed

- the counts therefore **fluctuate about a mean** value; the variation is in the counting, not in the source

(b)

- add the five readings and divide by five, then by the interval

$$\bar{C} = \frac{412 + 389 + 405 + 421 + 398}{5} = 405 \text{ counts per } 10 \text{ s} = \mathbf{40.5} \text{ s}^{\mathbf{-1}}$$

(c)

- the detector records a fixed fraction of the emitted radiation

$$A = \frac{40.5 \text{ s}^{-1}}{0.012} = \mathbf{3.4 \times 10^3} \text{ Bq}$$

3.3

(a)

- taking logs of $C = C_0 e^{-\lambda t}$ gives $\ln C = \ln C_0 - \lambda t$
- this has the form $y = c + mx$, so $\ln C$ against t is a straight line **only if** the decay is exponential; the points lying on a line is therefore the evidence

(b)

- the gradient of the line is $-\lambda$

$$\text{gradient} = \frac{3.44 - 5.60}{900 \text{ s} - 0} = -2.4 \times 10^{-3} \text{ s}^{-1}$$

$$\lambda = \mathbf{2.4 \times 10^{-3}} \text{ s}^{\mathbf{-1}}$$

(c)

- use $\lambda = \dfrac{0.693}{t_{1/2}}$

$$t_{1/2} = \frac{0.693}{2.4 \times 10^{-3} \text{ s}^{-1}} = \mathbf{290} \text{ s}$$

(d)

- the intercept is $\ln C_0$, so take the exponential of it

$$C_0 = e^{5.60} = \mathbf{270} \text{ s}^{\mathbf{-1}}$$

(e)

- the background count is a **constant** added to every reading, and it does **not** decay
- so at long times the measured count rate tends towards the background instead of towards zero, $\ln C$ levels off, and the graph **curves away** from the straight line rather than continuing down