Marks 3

- A solution of sodium iodide containing the radioisotope ^{131}I has an activity of 20 mCi L^{-1} when freshly prepared. Fifteen days later, a patient is given 0.50 mL of this solution. Calculate the dose of ^{131}I (in microcurie, μCi) received by the patient. The half-life of ^{131}I is 8.04 days.

The decay constant, λ, is related to the half life, $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{8.04 \text{ days}} = 0.0862$ days^{-1}

The activity is proportional to the number of radioactive nuclei, $A = \lambda N$, and the activity reduces with time according to:

$$\ln\left(\frac{A_0}{A_t}\right) = \lambda t$$

With an initial activity of 20 mCi L^{-1}, the activity after 15 days is given by,

$$\ln\left(\frac{20\times10^{-3}\ \text{mCi L}^{-1}}{A_t}\right) = (0.0862) \times 15$$

Hence A_t = 0.00549 Ci L^{-1} = 5.49 mCi L^{-1}

Hence, a solution of 0.50 mL will have a dosage of:

dosage = activity × volume

$$= (5.49 \times 10^{-3}\ \text{mCi L}^{-1}) \times (\frac{0.50}{1000}\ \text{L}) = 2.7 \times 10^{-6}\ \text{Ci} = 2.7\ \mu\text{Ci}$$

Answer: **2.7 μCi**

Marks

- Technetium-99 is used in imaging internal organs in the body, and is often used to assess heart damage. The rate constant for decay of ${}^{99m}_{43}Tc$ is 0.116 hour^{-1}. What is the half life of this nuclide? **2**

The half life is related to the decay constant, λ:

$$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{0.116\ \text{hours}^{-1}} = 5.98\ \text{hours}$$

Answer: **5.98 hours**

What fraction is left after 30 minutes?

The number of radioactive nuclei present reduces with time according to:

$$\ln\left(\frac{N_0}{N_t}\right) = \lambda t = 0.116 \times \frac{30}{60} \quad \text{so} \quad \frac{N_0}{N_t} = 1.06$$

Hence, 6% has decay and the fraction remaining is 94%

Answer: **94%**

- Boron-13 is a synthetic (not naturally occurring) isotope of boron. Using the *N*/*Z* ratio, predict a possible mode of decay for the isotope boron-13. Give a reason for your choice and write the nuclear equation for this decay. **2**

The most stable nuclei tend to have $N \sim Z$.

${}^{13}B$ has 8 neutrons and 5 protons. As $N > Z$, the nucleus has too many neutrons and will decay by beta decay: conversion of a neutron into a proton and an electron:

$$^{13}_{5}B \rightarrow {}^{13}_{6}C + {}^{0}_{-1}e$$

◦

Marks
2

- If a medical procedure calls for 2.0 mg of ^{48}V, what mass of isotope would be required to be able to use it exactly one week later? The half life of ^{48}V is 1.61 days.

The decay constant is related to the half life as $t_{1/2} = \frac{\ln 2}{\lambda}$**. Thus,**

$$\lambda = \frac{\ln 2}{1.61} = 0.431 \text{ days}^{-1}$$

The number of radioactive nuclei decreases with time according to the equation,

$$\ln\left(\frac{N_0}{N_t}\right) = \lambda t$$

If N_t **= 2.0 mg after t = 7 days,**

$$\ln\left(\frac{N_0}{2.0\times10^{-3}}\right) = (0.431) \times 7.00 \qquad \text{so } N_0 = 0.041 \text{ g} = 41 \text{ mg}$$

Answer: **4.1 mg**

- The half life of the radioactive isotope ^{16}N is 7.13 s. Calculate how long it takes to reduce the radioactivity of a given sample to 71.6% of the initial value. **2**

As the half life, $t_{1/2}$, is related to the decay constant, λ, by $t_{1/2} = \frac{\ln 2}{\lambda}$:

$$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{7.13} = 0.0972 \text{ s}^{-1}$$

The number of radioactive nuclei, N_t, at time t is related to the initial number N_0 by $\ln\frac{N_0}{N_t} = \lambda t$. As the activity is directly proportional to the number of radioactive nuclei, the radioactivity will be 71.6% of its initial value when $\frac{N_t}{N_0} = 0.716$ or $\frac{N_0}{N_t} = \frac{1}{0.716}$. Hence,

$$\ln\left(\frac{1}{0.716}\right) = (0.0972)t \quad \text{and so } t = 3.44 \text{ s}$$

Answer: **3.44 s**

- Outline the rules that determine nuclear stability.

Marks 3

The ratio of neutrons to protons (*N*/*Z*) is approximately 1 for low atomic numbers ($Z \leq 20$), but it slowly rises to about 1.5 as *Z* increases.

All elements with $Z > 83$ are unstable.

Atoms with even numbers of *N* and *Z* tend to be more stable than those with odd numbers. There are some particularly stable nuclei where the number of neutrons and or protons = 2, 8, 20, 28, 50, 82 and 126.

- Radioactive elements are used in medicine both as tracers and to treat diseases such as cancer. Describe what the ideal half-life of an element is for each application, and state the reasons for your choices. **3**

As a tracer, the element should ideally have a short half-life, of around a few hours, long enough for it to be produced, administered and imaged, but short enough for it to decay quickly so that it stops being radioactive in the body of the patient.

A longer half-life would be more suited for a topical treatment of cancer, to impose radiation to the affected area with a higher activity for a longer time.