

**Marks**  
**2**

- Explain why a sustained fission chain reaction can only occur when a critical mass is prepared.

**Below the critical mass, so many neutrons are lost from the material that a chain reaction cannot be sustained.**

**2**

- The half life of  $^3\text{H}$  is 12 years. Calculate how long it takes (rounded to the nearest year) for the activity of a sample of tritium to have dropped to 0.1% of its original value.

From  $t_{1/2} = \frac{\ln 2}{\lambda}$ , the activity coefficient  $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{12 \text{ years}} = 0.058 \text{ years}^{-1}$

As the activity is directly proportional to the number of radioactive nuclei, the activity,  $A_t$ , at time  $t$  is related to the initial activity,  $A_0$ , by  $\ln\left(\frac{A_0}{A_t}\right) = \lambda t$

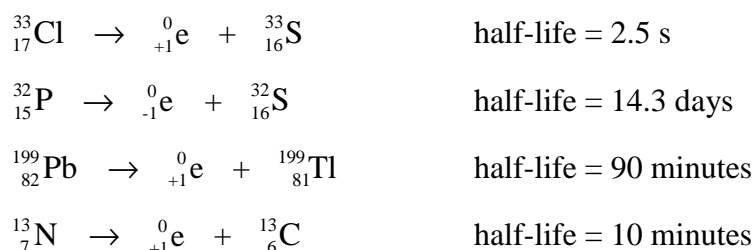
With  $A_t = 0.001 \times A_0$ , the ratio  $\frac{A_0}{A_t} = 1000$ . Hence,

$$\ln(1000) = (0.058)t \quad \text{or } t = 120 \text{ years} = 1.2 \times 10^2 \text{ years}$$

Answer:  $1.2 \times 10^2$  years

**3**

- Consider the following list of unstable isotopes and their decay mechanisms.



From this list, select the isotope that best satisfies the following requirements. Provide a reason for your choice in each case.

Requirement	Isotope	Reason for choice
Isotope used in medical imaging	$^{13}_7\text{N}$	<b>Positron emitter, non-toxic and has sufficiently long half life to be chemically incorporated.</b>
Decay represents the transformation of a neutron into a proton	$^{32}_{15}\text{P}$	<b>This nuclide is a <math>\beta</math>-emitter. The nuclear charge increases from 15 to 16 and the mass is unaffected. The charge is conserved by the emission of an electron.</b>
The isotope with the highest molar activity	$^{35}_{17}\text{Cl}$	<b>It has the shortest half-life and, as <math>\lambda = \frac{\ln 2}{t_{1/2}}</math>, it therefore has the highest activity.</b>