Marks

- Explain why a sustained fission chain reaction can only occur when a critical mass is prepared. **2**

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

- The half life of ^{3}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. **2**

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

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

Answer: **1.2×10^2 years**

- Consider the following list of unstable isotopes and their decay mechanisms. **3**

$^{33}_{17}Cl \rightarrow {}^{0}_{+1}e + {}^{33}_{16}S$ half-life = 2.5 s

$^{32}_{15}P \rightarrow {}^{0}_{-1}e + {}^{32}_{16}S$ half-life = 14.3 days

$^{199}_{82}Pb \rightarrow {}^{0}_{+1}e + {}^{199}_{81}Tl$ half-life = 90 minutes

$^{13}_{7}N \rightarrow {}^{0}_{+1}e + {}^{13}_{6}C$ half-life = 10 minutes

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	**$^{13}_{7}N$**	**Positron emitter, non-toxic and has sufficiently long half life to be chemically incorporated.**
Decay represents the transformation of a neutron into a proton	**$^{32}_{15}P$**	**This nuclide is a β-emitter. The nuclear charge increases from 15 to 16 and the mass is unaffected. The charge is conserved by the emission of an electron.**
The isotope with the highest molar activity	**$^{35}_{17}Cl$**	**It has the shortest half-life and, as $\lambda = \frac{\ln 2}{t_{1/2}}$. it therefore has the highest activity.**