Marks 7

- A cyclotron facility can produce beams of neutrons or protons. Theoretically, $^{188}_{75}Re$ can be produced by irradiation of $^{186}_{74}W$ with either particle followed by radioactive decay of the intermediate nuclide. Give the relevant equations to describe both sequences of reactions.

neutron bombardment

$$^{186}_{74}W + ^{1}_{0}n \rightarrow ^{187}_{74}W$$

$$^{187}_{74}W + ^{1}_{0}n \rightarrow ^{188}_{74}W$$

$$^{188}_{74}W \rightarrow ^{188}_{75}Re + ^{0}_{-1}e \quad \textbf{(beta decay)}$$

proton bombardment

$$^{186}_{74}W + ^{1}_{1}p \rightarrow ^{187}_{75}Re$$

$$^{187}_{75}W + ^{1}_{1}p \rightarrow ^{188}_{76}Os$$

$$^{188}_{76}Os \rightarrow ^{188}_{75}Re + ^{0}_{1}p \quad \textbf{(positron emission)}$$

In practice, only the sequence using neutron bombardment is used. Give one possible reason why proton bombardment is not used.

Energy required to add positively charged protons to nucleus is large.

Intermediate in proton bombardment ($^{188}_{76}Os$) is stable.

THE ANSWER CONTINUES ON THE NEXT PAGE

Rhenium-188 is used for the relief of cancer-induced bone pain and has a half life of 16.7 hours. What mass of $^{188}_{75}Re$ needs to be produced to allow shipment 24 hours later of a solution with a specific activity of 500 mCi?

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

$$\lambda = \frac{\ln 2}{(16.7 \times 60 \times 60\,s)} = 1.15 \times 10^{-5}\ s^{-1}$$

As $A = \lambda N$, the activity of one mole is,

$$A_m = (1.15 \times 10^{-5}) \times (6.022 \times 10^{23})$$

$$= 6.94 \times 10^{18}\ Bq\ mol^{-1} = \frac{6.94 \times 10^{18}}{3.70 \times 10^{10}} = 1.88 \times 10^{8}\ Ci\ mol^{-1}$$

For ^{188}Re, the atomic mass = 188 and hence the activity per gram is,

$$A_g = \frac{1.88 \times 10^{8}}{188} = 1.00 \times 10^{6}\ Ci\ g^{-1}$$

As the number of nuclei is proportional to the activity, the activity decreases with time according to the equation,

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

Hence, if A = 500 mCi after 24 hours,

$$\ln\left(\frac{A_0}{500 \times 10^{-3}}\right) = (1.15 \times 10^{-5}) \times (24 \times 60 \times 60)$$

$$A_0 = 1.35\ Ci$$

Hence,

$$\text{mass required} = \frac{\text{activity required}}{\text{activity per gram}} = \frac{A_0}{A_g} = \frac{1.35}{1.00 \times 10^{6}}$$

$$= 1.35 \times 10^{-6}\ g = 1.35\ \mu g$$

Answer: **1.35 μg**