# Physics 56400 Assignment # 1.

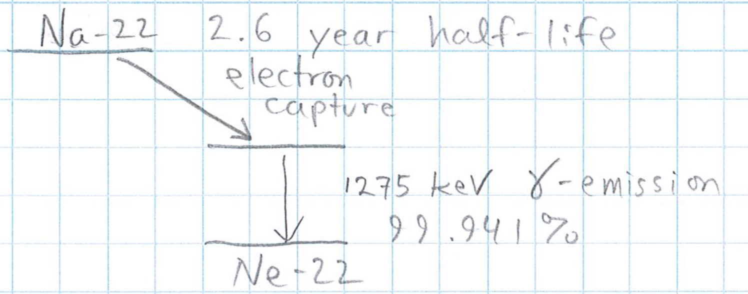


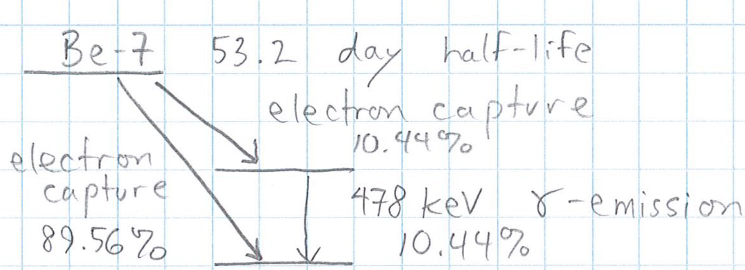
1 (a) The surface area of the gamma ray detector is $a = \pi r^2$ where $r = 3$ cm. The surface area of a sphere of radius $R = 23$ cm is $A = 4\pi R^2$.

The acceptance of the detector is then

$$\varepsilon = a/A = \tfrac{1}{4} r^2/R^2 = \frac{(3\,\text{cm})^2}{4(23\,\text{cm})^2} = 0.0043$$

(b)




(c) The total decay rate is the measured rate divided by the acceptance,

$$R = \frac{1.79\ s^{-1}}{0.0043} = 416.3\ s^{-1}$$

If the sample was irradiated 266 days before it was analyzed then the original activity was

$$R_0 = R \cdot 2^{t/t_{1/2}}$$

where $t_{1/2} = (2.6 \text{ years})(365.25 \text{ days/year}) = 949.7$ days.

Hence, $t/t_{1/2} = 0.28$ and

$$R_0 = (416.3\ s^{-1}) \cdot 2^{0.28}$$

$$= 505.5\ s^{-1}.$$

(d) Just after the irradiation was complete, the activity was $505.5\ s^{-1}$. This is related to the number of Na-22 atoms present by

$$R_0 = -\frac{dN}{dt} = \frac{N_0}{\tau}$$

where $\tau = \dfrac{t_{1/2}}{\log 2}$.

Hence, $N_0 = R_0 \tau$

$$= \frac{(505.5\ s^{-1})(949.7\ \text{days})(86400\ \text{sec/day})}{\log 2}$$

$$= 59.8 \times 10^9.$$

The probability that one proton makes an Na-22 atom is

$P = \dfrac{N\sigma}{A}$ where $N$ is the number of target nuclei in a sample with area $A$.

But $N = \dfrac{t \cdot A \cdot \rho}{m} \cdot N_A$

where $\rho$ is the density of aluminum, $t$ is the thickness of the sample and $m$ is the molecular mass.

Hence, $P = \frac{t \cdot \rho}{m} \cdot \sigma N_A$

Given that
$\sigma = 15 \times 10^{-3}$ barn
$t = 0.025$ mm
$\rho = 2.7 \ g \cdot cm^{-3}$
$m = 26.98 \ g \cdot mol^{-1}$
$N_A = 6.02 \times 10^{23} \ mol^{-1}$

$$P = \frac{(2.5 \times 10^{-3} cm)(2.7 g \cdot cm^{-3})(15 \times 10^{-27} cm^2)(6.02 \times 10^{23} mol^{-1})}{26.98 \ g / mol}$$

$$= 2.26 \times 10^{-6}$$

Therefore, if there were $59.8 \times 10^9$ Na-22 atoms produced, then the number of protons on target was

$$N_{POT} = \frac{59.8 \times 10^9}{2.26 \times 10^{-6}} = 26.5 \times 10^{15}$$

(e) The number of Be-7 atoms produced by the proton beam can be calculated by scaling the number of Na-22 atoms by the ratio of the cross sections:

$$N_{Be7} = N_{Na\text{-}22} \cdot \frac{\sigma_{Be7}}{\sigma_{Na22}} = \frac{(59.8 \times 10^9)(6.4 \ mb)}{(15 \ mb)}$$

$$= 25.5 \times 10^9$$

The Be-7 decay rate is

$$1/\tau_{Be7} = \frac{\log 2}{(53.2 \ days)(86400 \ s/day)}$$

$$= 0.151 \times 10^{-6} \ s^{-1}$$

Hence, the Be-7 activity just after irradiation was

$$R_{Be7} = \frac{N_{Be7}}{\tau_{Be7}} = (25.5 \times 10^{9})(0.151 \times 10^{-6}\, s^{-1})$$
$$= 3.85 \times 10^{3}\ s^{-1}$$

After 266 days the activity will be

$$R'_{Be7} = R_{Be7} \cdot \left(\frac{1}{2}\right)^{t/t_{1/2}}$$
$$= (3.85 \times 10^{3}\ s^{-1})\left(\frac{1}{2}\right)^{266/53.2}$$
$$= 120\ s^{-1}.$$

However, the branching fraction for Be-7 to produce a $\gamma$ is only 10.44% and the detector acceptance is only 0.0043. Therefore the observed Be-7 counting rate is only

$$R = (120\ s^{-1})(0.1044)(0.0043)$$
$$= 0.054\ s^{-1}.$$