Chem 988
Spring 2009

Problem Set 1
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1) (a) ^{137}Cs

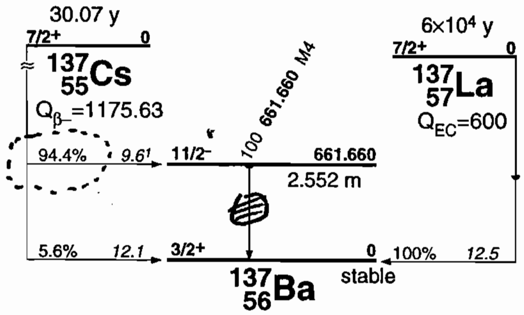


Table of Isotopes
8th Ed

$T_{1/2} = 30.07$ years

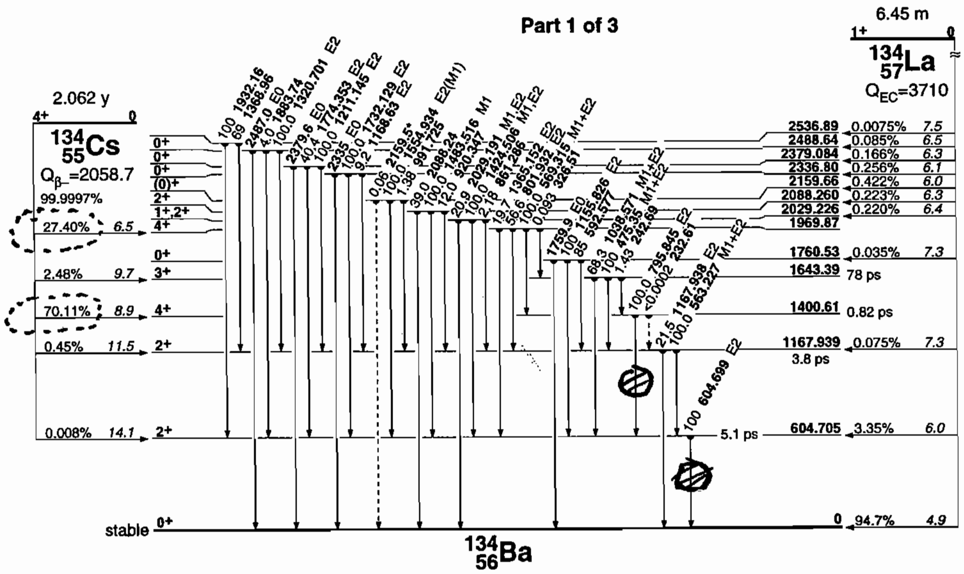
β^- $Q_\beta = 1175.$ keV
$- 661.$ keV

net = 514 keV

94.4% 514 β & 661 keV γ

5.6% 1175 keV β [only one ~~γ~~ most of time]

(b) ^{134}Cs



$T_{1/2} = 2.062$ yr

70.1% β^- Q_β = 2059 keV − 1401 keV = 658 keV plus 2 γ's $\left\{ \begin{array}{l} 795.8 \text{ keV} \\ 604.7 \text{ keV} \end{array} \right.$

27.4% β^- Q_β = 2059 keV − 1970 keV = 89 keV plus 3 γ's $\left\{ \begin{array}{l} 569.3 \text{ keV} \\ 795.8 \text{ keV} \\ 604.7 \text{ keV} \end{array} \right.$

Other branches weak β + 475, 795.8, 604.7 keV γ's

1) (c) ^{137}Cs one and only one γ ray per decay

^{134}Cs predominantly two γ rays per decay in coincidence

(d) pure Cs is ^{133}Cs (100%) $\rightarrow$ $^{133}Cs(n,\gamma)^{134}Cs$

$$A = \lambda N = (N_0 \sigma \phi)(1 - e^{\lambda t_1}) \qquad t_1 = 1.00\,\text{min} \quad \lambda = \frac{\ln 2}{2.062\,\text{yr}} \Rightarrow 6.39\times10^{-7}\,\text{min}^{-1}$$

$$A = \left[\left(\frac{50\times10^{-3}\,\text{g}\times6.022\times10^{23}/\text{mol}}{132.91\,\text{g/mol}}\right) 29\,\text{b}\times\frac{10^{2}\,\text{fm}^2}{\text{b}}\times10^{-30}\frac{\text{m}^2}{\text{fm}^2}\left(10^{13}/\text{s cm}^2\times\frac{10^{4}\,\text{cm}^2}{\text{m}^2}\right)\right](1-e^{-\lambda t_1})$$

$$A = 6.57\times10^{10}/\text{s}\,(1-e^{-\lambda t_1})$$

after 1 min in reactor

$$A = 6.57\times10^{10}/\text{s}\left(1 - e^{-\frac{\ln 2 \times 1\,\text{min}}{2.062\times365.25\times24\times60}}\right)$$
$$\qquad\qquad \text{yr} \quad \text{d/yr} \quad \text{h/d} \quad \text{m/h}$$

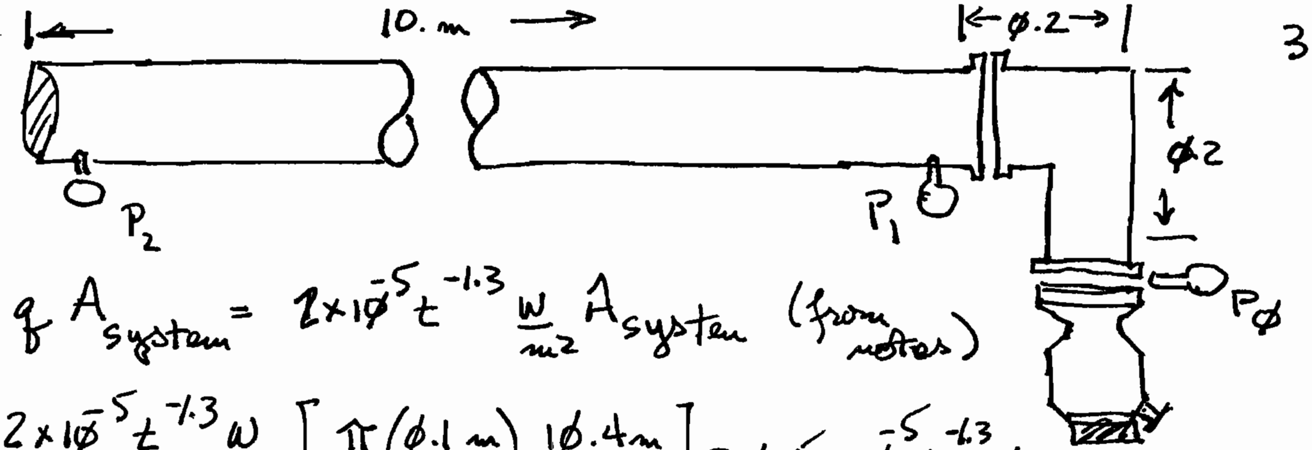
$$A = 6.57\times10^{10}/\text{s}\,(6.391\times10^{-7}) = 4.2\times10^{4}/\text{s}$$

N.B. in this case the growth is in the linear region of the curve and approx $= \lambda t_1$

(e) $$A = 4.2\times10^{4}/\text{s}\; e^{-\lambda t_2} = 4.2\times10^{4}/\text{s}\; e^{-\frac{\ln 2 \times 23\,\text{y}}{2.062\,\text{yr}}}$$

$$= 4.2\times10^{4}/\text{s}\; e^{-7.732} = 18./\text{s}$$

2)



$$Q = q\,A_{system} = 2\times10^{-5}\,t^{-1.3}\,\frac{W}{m^2}\,A_{system} \quad \text{(from notes)}$$

$$Q = 2\times10^{-5}\,t^{-1.3}\,\frac{W}{m^2}\left[\underbrace{\pi(0.1\,m)\,10.4\,m}_{3.27\,m^2}\right] = 6.5\times10^{-5}\,t^{-1.3}\,W$$

$3.27\ m^2 \leftarrow$ (plus end cap!)

① $$P_0 = Q/S_{TMP} = 6.5\times10^{-5}\,t^{-1.3} \Big/ 100\,\frac{l}{s}\times10^{-3}\,\frac{m^3}{l} = 6.5\times10^{-4}\,t^{-1.3}\ Pa$$

(5×10^{-6} torr)

② $$Q = C_{ELBOW}(P_1 - P_0) \rightarrow P_1 = P_0 + Q/C_{ELBOW}$$

$$C_{ELBOW} = a\,C_{APERTURE} = a\ 0.911\ \frac{m^3}{s}, \quad a = 0.35 \text{ from notes on figure}$$

$$P_1 = P_0 + \frac{6.5\times10^{-5}\,t^{-1.3}\,W}{0.319\ m^3/s} = 8.5\times10^{-4}\,t^{-1.3}\ Pa$$

(6×10^{-6} torr)

Note $\frac{1}{S_{eff}} = \frac{1}{C} + \frac{1}{S} \rightarrow S_{eff} = 76\ l/s$ at P_1

③ getting P_2 is a little more tricky because $Q \rightarrow 0$ as we move away from pump and the effective speed also drops.

→ Estimate Q' at P_2 is due to (only) end cap of pipe

$$Q' = 2.5\times10^{-5}\,t^{-1.3}\left[\pi(0.05)^2\right] = 2\times10^{-7}\,t^{-1.3}\,W$$

Estimate effective speed of pump at P_2, $(L/R)_{PIPE} = \frac{10}{0.05} = 200$

$a \rightarrow \frac{4d}{3l} = 1.3\times10^{-2}$

$$\frac{1}{S_{eff}} = \frac{1}{0.1} + \frac{1}{\underbrace{\frac{4}{3}\left(\frac{0.1}{10}\right)}_{1.2\times10^{-2}}\ 0.911} \rightarrow S_{eff} = 1.1\times10^{-2}\ \frac{m^3}{s}$$

$$P_2 \approx 2\times10^{-7}\,t^{-1.3} \Big/ 1.1\times10^{-2} = 1.8\times10^{-5}\,t^{-1.3}\ Pa$$

WRONG, (lower than P_1 !!)

Better estimate

$Q = \pi d L q \rightsquigarrow \frac{dQ}{dx} = \pi d q$ where x runs from ϕ to L

long pipe $C = \frac{4}{3}\frac{d}{L} C_{AP} \rightarrow \frac{dC}{dx} = \frac{4d}{3} C_{AP} \frac{-1}{x^2}$

$Q = C(P_2 - P_1) \rightsquigarrow \frac{dQ}{dx} = \frac{dC}{dx} P + C \frac{dP}{dx}$ where $P(x=\phi) = P_1$

substitute $\pi d q = \frac{4d}{3} C_{AP} \frac{-P}{x^2} + \frac{4d}{3x} C_{AP} \frac{dP}{dx}$

$$\frac{3\pi \cancel{d} q x}{4 \cancel{d} C_{AP}} = \frac{-P}{x} + \frac{dP}{dx}$$

this form $ax + \frac{y}{x} = dy/dx$ has the solution $y = ax^2$

$$P(x) = \frac{3\pi q}{4 C_{AP}} x^2 + P(x=0)$$

$$P(1\phi\,m) = \frac{3\pi \; 2\times 10^{-5} t^{-1.3} \, w/m^2}{4 \; \phi.911 \, m^3/s} (1\phi^2 m^2) + 8.5\times 1\phi^{-4} t^{-1.3} \, Pa$$

$$P_2 = 5.2\times 1\phi^{-3} t^{-1.3} \, Pa + 8.5\times 1\phi^{-4} t^{-1.3} \, Pa$$

$$= 6.\phi \times 1\phi^{-3} t^{-1.3} \, Pa$$

$\rightarrow (4.5\times 10^{-5}$ torr$)$