Chem 988
Winter/09

Final Exam
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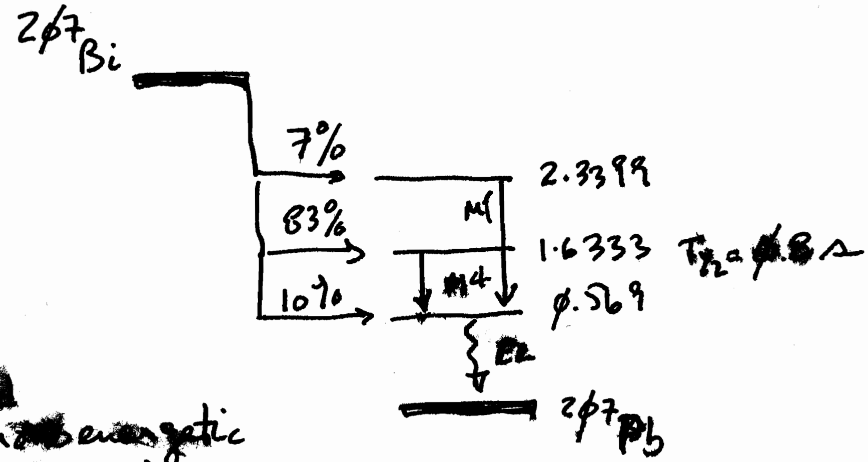
1) (a) $^{207}_{83}Bi \rightarrow$ ec/β^+ 100%

Lisott $T_{1/2} = 31.55$ yr

NuBase $T_{1/2} = 32.9$ yr

$E_\gamma = 569,\ 1064,\ 1770$ keV
(100%) (83%) (7%)



(b) The 1064 γ is M4, slow and highly converted into monoenergetic electrons. $E(e^-) = E_\gamma - BE(e^-)$

$E(e^-) = 1064 - 88$ keV for K electrons - most likely - (in Pb)

$E(e^-) = 976$ keV

2) $p = (\text{rate}) = \dfrac{3 \text{ events}}{11 \text{ day}}$, $\bar{x} = pn = \dfrac{3}{11 \text{ day}} \times \dfrac{1 \text{ hr}}{24 \text{ hr/d}} = 0.01136$

Prob that you get 1 event in this time period $= P(1) = (\bar{x})^1 e^{-\bar{x}} / 1!$

$$P(1) = \frac{0.01136\ e^{-0.01136}}{1} = 0.01123$$

or about 89/1 against

3) $Q = PS \rightarrow P = \dfrac{Q}{S}$, $Q = q * \text{Area}$, $\text{Area} = 2\pi r h + 2(\pi r^2)$

$= 2\pi\, 0.65\,(0.4 + 0.65)\ m^2$
$= 4.288\ m^2$

$$P = \frac{84 \times 10^{-7}\ \frac{Pa \cdot m}{s}\ t^{-1} \times 4.288\ m^2}{250\ l/s \times 10^{-3}\ m^3/l}$$

$P = 1.44 \times 10^{-4}\ t^{-1}\ Pa \rightarrow 1.08 \times 10^{-6}\ t^{-1}$ torr

4) (a) An active base for a PMT has transistors across the last few dynodes to maintain the voltage difference during high rate use. Passive bases only have capacitors to maintain the voltage and the voltage can sag giving a lower gain.

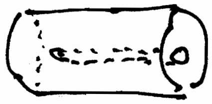
4)(b) Quantum efficiency is the ratio of photo-electrons to incident photons in a PMT. A typical value is 0.2 – 0.25 for visible photons. The number of photo electrons is the determining factor in the resolution of a scintillator.

(c) $$\text{Ratio} \frac{PMT_1}{PMT_2} = \frac{\delta_1^{N_1}}{\delta_2^{N_2}} = \frac{(5.1)^{10}}{(4.7)^{12}} = 0.1025$$

(d) A large amount of development has gone into photocathodes that are sensitive to visible light such as that emitted by NaI(Tl) crystals. IE more efficient photocathodes exist for visible light compared to uv light.

5)(a) End-cap

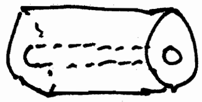
Ge "cap"



- plus is high effecency for low energy photons incident on end
- minus is slow and uneven signal rise time due to large range of electric field gradient in end-cap

true coax

through hole



- plus is uniform electric field throughout crystal creates uniform collection and rise-times
- minus is low efficiency in the center of detector due to hole in center that goes all the way through

5)(d) $^{137}Cs \xrightarrow{\beta^-}$ emits 662 keV γ <u>85%</u> of time

→ 75% efficiency means 75% of 3" x 3" NaI(Tl) <u>at</u> 25 cm

- need $\epsilon(NaI) = 1.2 \times 10^{-3}$ for 1332 keV on p. 450 in text
- need to correct for difference between energies $f(E)$
- need to correct for different distances. Ω_1/Ω_2

$$\text{Rate} = 10\,\mu Ci \times 10^{-6} \frac{Ci}{\mu Ci} \times 3.7\times10^{10} \frac{/s}{Ci} \times 0.85 \times 1.2\times10^{-3} \times f(E) \times \frac{\Omega_1}{\Omega_2}$$

$$= 377./s \times f(E) \times \frac{\Omega_1}{\Omega_2} \leftarrow \frac{25^2}{50^2} = \underline{\underline{153/s}}$$

$\uparrow \simeq \frac{26}{16}$ from fig 12.31

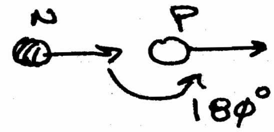
$$= 377. \times \frac{26}{16} \times \frac{25^2}{50^2} = 153./s$$

6) (a) most important reaction is $H(n,n')p$ scattering of neutrons on hydrogen in plastic material

energy transfer: billiard-ball scattering

$$E_{Recoil} = \frac{2A}{(1+A)^2}(1-\cos\theta_{CMS})E_n \qquad \text{eq } 15.1$$

$$E_R = 4A/(1+A)^2 \cos^2\theta_{LAB} E_N \qquad \text{eq } 15.3$$



$$E_R = \frac{4(1)}{(1+1)^2}(-1)^2\ 1.5\,\text{MeV} = 1.5\,\text{MeV}$$

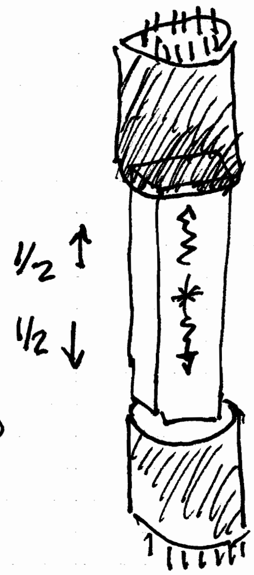
(b) $I = I_0 e^{-\mu x}$

$$\frac{I(x=29)}{I(x=1)} = \frac{I_0 e^{-\mu 29}}{I_0 e^{-\mu 1}} = \frac{1}{3}$$

$$e^{-\mu(29-1)} = \frac{1}{3}$$

$$\mu\, 28\text{cm} = \ln 3$$

$$\mu = \ln 3/28_{cm} = 3.92\times10^{-2}/\text{cm}$$



(c) need light output from BC-408 & Q Efficient of PMT

⇒ 64% of anthracene ⇒ 90 μA/lm @ 555 nm

Anthracene 20k photons/MeV

$$\text{fraction \# photons} = \frac{1}{2}e^{-\frac{\ln 3}{28}18.0} = 0.2776 \text{ to end}$$

$$\#\,\text{photoelect} = 1.00\,\text{MeV} * 0.64 * 20{,}000 * \eta * f$$
$$= (1.76\times10^3\ \text{photo } e^-)\,0.2776$$
$$= 488.$$

$$\eta = \frac{90\times10^{-6}\ \frac{\text{coul}}{s}}{1.602\times10^{-19}\ \frac{\text{coul}}{e^-}} \cdot \frac{\text{lm}}{} * 683\frac{\text{lm}}{W}\,\frac{hc}{\lambda}$$

$$\eta = 3.84\times10^{17}\ \frac{e^-}{J} \times 3.58\times10^{-19}\ \frac{J}{\text{photon}}$$

$$\eta = 0.137$$

(d) $Q = \#\,\text{photoelect} \times \text{Gain} \times q_e$

$$= 1760 \times 0.2776 \times 3\times10^6 \times 1.602\times10^{-19} = 2.35\times10^{-10}\ \text{coul}\ (235.\ \text{pC})$$