

1a) ² $E_{\text{ray}} \approx \text{BE of electron} + \text{KE of electron}$, $\text{BE} \approx \% \text{ ray Energy}$

thus: $E_{\text{xray}}^{(1)} = 662 - 656 \text{ keV} \quad \text{or} \quad E_{\text{ray}}^{(2)} = 662 - 624 \text{ keV}$
 $= 6 \text{ keV} \quad \quad \quad = 38 \text{ keV}$

1b) ⁵ attenuate 38 keV photon by 1ϕ

$I/I_0 = e^{-\mu x}$, μ_0 from figure in cm^2/g $\mu_0 \approx 0.5 \text{ cm}^2/\text{g}$ Al

$\ln(1/10) = -\mu_0 x = -0.5 x \rightarrow x = 4.61 \text{ g/cm}^2$ (areal density)

convert to distance $\frac{x}{\rho} = \frac{4.61 \text{ g/cm}^2}{2.70 \text{ g/cm}^3} = 1.71 \text{ cm}$

1c) ⁴ $E_\gamma = 662 \text{ keV}$ $\mu_0 \approx 0.074$ from figure

$I/I_0 = e^{-0.074 \times 4.61} = e^{-0.341} = 0.71$

1d) ⁵ from fig 2.14 Range * Density $\approx 0.4 \text{ g/cm}^2$ @ $\sim 660 \text{ keV}$

thus Range $\sim \frac{0.4 \text{ g/cm}^2}{2.70 \text{ g/cm}^3} = 0.15 \text{ cm}$

1e) ⁴ $Q_\beta = 1176 \text{ keV}$ but β^- goes to excited state so maximum beta energy is $\sim Q_\beta - 662 \text{ keV} = 514 \text{ keV}$

this is less than conversion electron, so range is

shorter than that of conversion electron

\rightarrow fully absorbed

2a) observed rate vs. real rate is double-valued
thus \rightarrow paralyzable

2 of 4

2b) for a paralyzable system $rate_{obs} = rate_{true} e^{-rate_{true} \tau}$
 $r_{obs} = r e^{-r \tau}$

take a data point from the graph supplied with exam

e.g. $r = 2 \times 10^5$, $r_{obs} = 3 \times 10^4$ (line crosses at convenient place)

$$3 \times 10^4 = 2 \times 10^5 e^{-2 \times 10^5 \tau}$$

$$\ln\left(\frac{3 \times 10^4}{2 \times 10^5}\right) = -2 \times 10^5 \tau \quad \Rightarrow \quad \tau = 9.5 \times 10^{-6}$$

3a) Pirani gauge measures the ability of the residual gas inside the tube to conduct the heat away from a heated wire. In a certain pressure regime the more gas the more cooling. Note this will also depend on the type of gas, particularly near atm pressure.

3b) The filament in a hot-cathode vacuum gauge emits the electrons that are accelerated by the grid to ionize the residual gas ~~to~~ to be measured.

3c) water, desorbed from the chamber walls

3d) laminar flow: $C \propto r^4$
(molecular flow r^3 give 2 pts)

$$3e) \quad \frac{1}{R_{\text{eff}}} = \frac{1}{R} + \frac{1}{C} \rightarrow \frac{1}{25\phi} + \frac{1}{15\phi}$$

$$\frac{1}{R_{\text{eff}}} = 4 \times 10^{-3} + 6.67 \times 10^{-3} = 1.067 \times 10^{-2}$$

$$R_{\text{eff}} = \frac{1}{1.067 \times 10^{-2}} = 94. \Omega$$

$$4) \quad Q = \frac{\Delta E}{\omega} \times M \times q_e, \quad V_{\text{max}} \sim \frac{Q}{C}, \quad \omega = 29.1 \text{ eV} \quad \text{Table 5.1 in text}$$

$$\ln M = \frac{V}{\ln(b/a)} \frac{\ln 2}{\Delta V} \left(\frac{\ln V}{p a \ln(b/a) K} \right) \quad \text{Eq 6.10 in text}$$

$$\text{methane} \quad \Delta V = 36.5 \text{ V}, \quad K = 6.9 \times 10^4 \text{ V/cm-atm} \quad \text{Table 6.1 in text}$$

$$\ln M = \left[\frac{850 \text{ V} \ln 2}{\underbrace{\ln\left(\frac{4.3 \times 10^2}{12.5 \times 10^6}\right)}_{8.143} 36.5 \text{ V}} \right] \ln \left(\frac{850 \text{ V}}{\underbrace{0.2 \text{ atm} \times 12.5 \times 10^{-4} \text{ cm} \ln\left(\frac{b}{a}\right)}_{8.143} 6.9 \times 10^4 \text{ V/cm-atm}} \right)$$

$$\ln M = 1.982 \ln(6.051) = 3.569$$

$$M = 35.5$$

thus

$$V_{\text{max}} \sim \frac{1 \text{ MeV} \times 10^6 \text{ eV/MeV} \times 35.5 \times 9}{29.1 \text{ eV} \times 10^2 \times 10^{-12} \text{ F}}$$

$$\sim 1.95 \times 10^{-3} \text{ V}$$

4a) ¹⁰ 13% Ge detector means 13% of a NaI(Tl) ^{4 of 4} at 25 cm
(p. 459 in the text) $3'' \times 3''$

$$\epsilon_{\text{NaI}}^{\text{TOTAL}} = \epsilon^{\text{Geometry}} * \epsilon^{\text{INTRINSIC}} = 1.2 \times 10^{-3} \quad \text{for NaI(Tl)} \quad \textcircled{5}$$

$$\text{thus } \epsilon_{\text{Ge}}^{\text{TOTAL}} = 1.3 * 1.2 \times 10^{-3} = 1.56 \times 10^{-3}$$

$$\epsilon_{\text{NaI}}^{\text{Geo}} \sim \frac{\pi R^2}{4\pi (25 \text{ cm})^2} \quad \text{where } R = \frac{3''}{2} * 2.54 \frac{\text{cm}}{''} = 3.81 \text{ cm}$$

$$\epsilon_{\text{NaI}}^{\text{Geo}} \sim 5.806 \times 10^{-3}$$

$$\epsilon_{\text{Ge}}^{\text{INTRINSIC}} = \frac{\epsilon_{\text{Ge}}^{\text{TOTAL}}}{\epsilon_{\text{NaI}}^{\text{Geo}}} = \frac{1.56 \times 10^{-3}}{5.806 \times 10^{-3}} = 0.269 \quad \textcircled{5}$$

4b) ² see fig 12.4, negative bias on outside, electrons move to the center and are collected on central contact

4c) ⁴ most likely multiple Compton scatterings and then finally a photoelectric collision to deposit all energy
- note $E_\gamma = 1.0 \text{ MeV} < \text{threshold for pair production}$
- also $E_\gamma = 1.0 \text{ MeV}$ - one photoelectron is unlikely

4d) ⁴ true coincidence summing occurs when two photons from the same decay (or nuclear) reactions strike a gamma-ray detector within the resolving time.

random summing occurs when two photons from two different nuclei (or nuclear reactions) strike a gamma-ray ~~det~~ detector within the resolving time of that detector / electronics system.