CEM 987 / PHY 905   Exam - I

1(a) $\text{Rate}_{\text{Production}}(t) = N_0 \phi \sigma (1 - e^{-\lambda t})$

$$\lambda = \frac{\ln 2}{2.0\times10^{4}\,yr \times 365.25 \times 24}$$

$\lambda = 3.466\times10^{-5}/yr$

$\lambda = 1.098\times10^{-12}/sec$

$\lambda = 3.95\times10^{-9}/hr$

(5)

λ is so small that Rate is approximately constant during 6 hr bombardment

$N_0 = 6.473\times10^{22}$

$$R = N_0 \phi \sigma = \left(\frac{10g}{93\,g/mole} N_A\right)\left(10^{12}/sec\cdot cm^2\right)\left(20\,mb \times 10^{-27}\frac{cm^2}{mb}\right)$$

$$N = R\Delta t = \left(1.295\times10^{9}/sec\right)\left(6\,hr \times 3600\,\frac{sec}{hr}\right) = 2.80\times10^{13}$$

$$A = \lambda N = \lambda R \Delta t = \left(3.95\times10^{-9}/hr\right)\left(1.295\times10^{9}/sec\right)\left(6\times3600\,sec\right)$$

$= 1.10\times10^{5}/hr \rightarrow$ 30.6/sec or Bq

$\rightarrow$ 826. pCi

(b) Specific activity $\equiv$ activity/mass $\rightarrow \frac{30.6\,Bq}{10g} = 3.06\,Bq/g$

(5)

or $\frac{826\,pCi}{10g} = 82.6\,pCi/g$

(c) from decay figure $^{94}Nb \xrightarrow[\beta^-\ 100\%]{} {}^{94}Mo^{4+}$

$\hookrightarrow {}^{94}Mo^{2+} + \gamma$

$\hookrightarrow {}^{94}Mo(gs) + \gamma$

(5)

$\gamma_1 = 0.70263$ MeV

$\gamma_2 = 0.8711$ MeV

$\beta^-_{max} \sim 2.65\,MeV - 1.57\,MeV$

~ 1.08 MeV

(d) very long $T_{1/2}$ .. this source will be around long past the time of any utility in lab!

(5)

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LITHO IN U. S. A.

2(a) $\bar{x} = \dfrac{1968 \text{ events}}{306.4 \text{ days}} = 6.42/\text{day}$

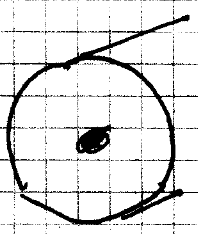
Poisson [eq. 3.24] $P(0) = (\bar{x})^0 e^{-\bar{x}} / 0! = e^{-6.42} = 1.62 \times 10^{-3}$

(b) for 5.3σ then prob that the truth lies outside the range is $1 - \int_{-5.3\sigma}^{+5.3\sigma}$ gaussian function

use graph/table .. area for 5.3σ is 0.999 999 884

$\text{Prob} = 1 - 0.999\,999\,884 = 1.16 \times 10^{-7}$ (not very likely)

3



$r_a = 10\,\mu m$ $V_0 = 1500\,V$ P-5 gas

$r_b = 2.54$ cm $K = 4.5 \times 10^4$ V/cm·atm, $\Delta V = 21.8$ V } table 6.1

$$\ln M = \frac{V_0}{\ln b/a} \frac{\ln 2}{\Delta V} \left(\ln \frac{V_0}{pa \ln b/a\, K} \right)$$

$$= \frac{1500 \ln 2}{\ln\left(\frac{2.54}{10 \times 10^{-4}}\right) 21.8} \left(\ln \left[\frac{1500}{1\,(10 \times 10^{-4}) \underbrace{\ln\left(\frac{2.54}{10 \times 10^{-4}}\right)}_{7.840} 4.5 \times 10^{4}} \right] \right)$$

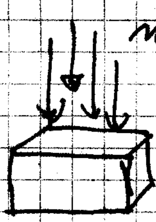
$\ln M = 6.083 \left(\ln (4.252) \right) = 8.805$

$M = 6665.$

$$V_R = \frac{Q}{C} = \frac{n_0 M q}{C} = \frac{(1)\, 6665 \times 1.602 \times 10^{-19} \text{ coul}}{10.0 \times 10^{-12} \text{ F}}$$

$= 1.07 \times 10^{-4}$ Volts

4



n , 1GeV ΔE each

$V = 1\,cm^2 \times 0.5\,cm = 0.5\,cm^3$, $\rho \sim 1\ g/cm^3$

mass $\sim 0.5\,cm^3 \times 1\ g/cm^3 = 0.5\,g$

Problem Dose $= 10^3\ Gy \times 10^2 \dfrac{Rad}{Gy} \times 2.58\times10^{-4} \dfrac{\text{Coul of Ion Pairs}}{kg\ Rad}$

Problem Dose $= 25.8$ coul/kg

Problem in detector $= 25.8 \dfrac{coul}{kg} \times 0.5\times10^{-3}\ kg = 1.29\times10^{-2}$ Coul of I.P.

$$\#\ \text{Particles} = \frac{1.29\times10^{-2}\ \text{Coul of IP} \ \big/\ 1.602\times10^{-19}\ \text{Coul/Ion Pair}}{\left[10^9 \frac{eV}{Part} \Big/ W\ eV/IP\right]}$$

← need a guess for W!

guess $W \sim 30$ eV/IP ... typical number we have used ...

Particles $\approx 2\times10^9$ → about 3 weeks @ 10^3/sec
→ about 5 hours @ 10^5/sec

5 a Y - comes from a measurement of the drift time of the electrons to the anode - must be measured against another detector

X - measurement of the distribution of signals induced on the stripes by the motion of the ⊕ charge in the avalanche around the anode wire

b $\mathcal{E}(r) = \dfrac{V_0}{r\ln(b/a)}$ $\qquad \mathcal{E}_{AVAL}(r) = 10^6 \dfrac{V}{m} = \dfrac{850}{r \ln\left(\frac{4.31}{6.25\times10^{-4}}\right)}$

$$r = \frac{850}{10^6 \underbrace{\ln\left(4.31/6.25\times10^{-4}\right)}_{8.839}}$$

$r_{AVAL} = 96\ \mu m$ $\qquad r = 9.62\times10^{-5}\ m$

5(c) $\mathcal{E}(y) \sim \dfrac{-2000+10\ V}{30\ cm}$ drift field, assume linear

$$\tau_{Drift} \sim \frac{\Delta y}{v_{electron}} = \frac{15\ cm}{v_{electron}}$$

$v = \dfrac{\mu}{p}\mathcal{E}$ (long way...)

$$\tau_D \sim \frac{15\ cm}{8\times10^{6}\ cm/sec} = 1.9\times10^{-6}\ sec$$

v_{elect} from fig 6.15

$$\mathcal{E}/p = \frac{66.33\ V/cm}{140.\ torr}$$

$$v_{el} \sim 8\times10^{6}\ \frac{cm}{sec} \longleftarrow \mathcal{E}/p = 0.474\ \frac{V}{cm\text{-}torr}$$

$$\frac{\sigma_y}{y} = \frac{100.\times10^{-6}}{15.\times10^{-2}} = \sigma_\tau/\tau \quad \text{because } y \propto ToF = \tau_{Drift}$$

$$6.66\times10^{-4}\ \tau = \sigma_\tau$$

$$1.2\times10^{-9}\ sec = \sigma_\tau$$

(1 ns seems reasonable)

6 (a) $\#photons = (\Delta E) * \text{light output}/keV$ [table 8.1] (rel. to NaI)

$$n = \left(2\ \frac{keV}{mg/cm^2} * 1.032\ g/cm^3 \times10^3\ \frac{mg}{g} \times 0.5\ cm\right) \times 0.65 \times \left(\frac{38000\ photons}{2.30\ keV}\right)$$

$$n = 1.11\times10^{4}\ photons$$

(b) assume only loss due to 80% transmission & attenuation in light guide

$$n_{TRANS} = (1.11\times10^{4}) * 0.80 * \underbrace{e^{-1.0\,m/2.50\,m}}_{0.67} \longleftarrow \text{from Table 8.1}$$

$$= 5943.\ photons$$

(c) "K" in Table 9.1 HAM 1306 $= 95.\ \dfrac{mA}{W}$ $\rightsquigarrow$ $Q.E. = \dfrac{\#e}{\#photons}$

$$QE = \left[\frac{95\times10^{-3}\ coul/sec}{(1.6\times10^{-19}\ coul/elec)(joule/sec)}\right] * \left(\frac{6.626\times10^{-34}\times3\times10^{8}}{400\times10^{-9}}\right)\frac{Joule}{photon} = 0.295$$

6 (d) $Q = \#\text{photons} * QE * M * 1.602\times10^{-19}$ Coul

$M \leftarrow$ Table 9.1 "I" 0.27×10^{6}

$Q = 5943 * 0.295 * 0.27\times10^{6} * 1.602\times10^{-19}$ Coul

$Q = 7.58\times10^{-11}$ Coul (4.73×10^{8} electrons)