Chem 998
Winter/2006

Exam 1
2 Mar 2006

1 a) $1.0\,\mu Ci \times 10^{-6} \frac{Ci}{\mu Ci} \times 3.7\times10^{10} \frac{Bq}{Ci}\, e^{-\lambda t}$ $\quad t = 50\,yr$

$3.7\times10^{4}\,Bq\, e^{-\frac{\ln 2 \times 50}{351}}$ $\quad T_{1/2} = 351\,yr$

$3.7\times10^{4}\,Bq\,(0.9059) = 3.35\times10^{4}\,Bq$

b) ① alpha decay to 0.388 keV state (84%)
② gamma decay to groundstate 0.388 keV (81% of α)

c) $E_\alpha = \frac{245}{249}(Q_\alpha - E_\gamma^*) = \frac{245}{249}(6.295 - 0.388)\ MeV$

$E_\alpha = 5.812\ keV$

from figure 2.7 in text $\quad R \sim 28\,\mu m$

d) 388 keV γ is relatively penetrating radiation with ~~xxxx~~ high intensity → use a portable inorganic scintillation detector → eg NaI (Tl)

2 a) $RC = 50\,\Omega\,(300.\times10^{-12}F) = 1.5\times10^{-8}\,s \rightarrow 15\,ns$

$t_{collection} \simeq \frac{300\,\mu m}{\text{drift velocity}} = \frac{300.\times10^{-6}\,m}{10^{7}\,cm/s \times 10^{-2}\,\frac{m}{cm}} = 3\times10^{-9}\,s \rightarrow 3\,ns$

→ electronics are "slow" relative to signal time so the pulse will be integrated and the __max__ voltage will be produced

2 b) Eq 4.24

$$r_{TRUE} = \frac{r_{OBS}}{1 - r_{OBS}\tau} \quad , \quad r_{OBS} = \frac{123456 \text{ cts}}{60.\ s} = 2057.6 \text{ cps}$$

$$r_{TRUE} = \frac{2057.6 /s}{1 - (2057.6 \times 5\times10^{-6})}$$

$$= 2079 /s$$

3) $Q = P S_{eff}$

$$Q = q \times (\text{Area}) = 10^{-5} t^{-1.3} \frac{W}{m^2} \left[2\pi R^2 + 2\pi r h\right]$$

$$Q = 10^{-5} t^{-1.3} \left[2\pi\left(\tfrac{1}{2}\right)^2 + 2\pi\left(\tfrac{1}{2}\right)0.5 \ m^2\right]$$

$$Q = \frac{4\pi}{4} \times 10^{-5} t^{-1.3} \ W \quad , \quad t = 1 \text{ hr}$$

$$\frac{1}{S_{eff}} = \frac{1}{S} + \frac{1}{C} = \frac{1}{250 \frac{l}{s}} + \frac{1}{300 \ l/s}$$

$$\hookrightarrow S_{eff} = \frac{1}{\left[\frac{1}{250} + \frac{1}{300}\right]} = 136.4 \frac{l}{s}$$

$$P = \frac{Q}{S_{eff}} = \frac{\pi \times 10^{-5} \ W}{136.4 \frac{l}{s} \times 10^{-3} \frac{m^3}{l}} = 2.30 \times 10^{-4} \ Pa$$

$$\left[= 2.30 \times 10^{-4} \ Pa \times \frac{1 \text{ mbar}}{10^2 \ Pa}\right] = 2\times10^{-6} \text{ mbar}$$

$$\left[= 2.30 \times 10^{-4} \ Pa \times \frac{1 \text{ torr}}{133.3 \ Pa}\right] = 1.7\times10^{-6} \text{ torr}$$

4a) $p = \frac{3 \text{ events}}{1000 \text{ hrs}} = 3 \times 10^{-3} \frac{\text{evt}}{\text{hr}}$ $n = 48 \text{ hr}$

$\bar{x} = pn = 3 \times 10^{-3} / \text{hr} \times 48 \text{ hr} = 0.144$

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

$P(1) = (0.144)\, e^{-0.144} / 1 = 0.125$

which is 7 to 1 against seeing an event

4 b) $r_{OBS} = \frac{1990 \text{ evts}}{1000 \text{ hr} \times 60 \frac{m}{\text{hr}}} = 0.0332 \text{ evts}/\text{min}$

from Eq 3.70 $P(0) = e^{-rt} = e^{-0.0332/m \times 1 m}$

Prob of no events during interval $P(0) = 0.967$

[same result obtains from integration of interval distribution]

5 a) $\Delta E = 0.1$ MeV in BC-400   65% of antracene Table 8.1

NaI(Tl) is 230.%

Table 8.2 NaI(Tl) gives 38000 $\frac{\text{photons}}{\text{MeV}}$

$\# \text{photons} = 0.1 \text{ MeV} \times \frac{65}{230} \times 38000 \frac{\text{photons}}{\text{MeV}} = 1074 \text{ photons}$

b) $\lambda_{peak} = 423$ nm Table 8.1 , radiant sensitivity 95 mA/W from Table 9.1

→ use dimensional analysis to convert current/power into electrons/energy , use energy of photon

$$\text{Radiant Sensitivity} = 95\ \frac{mA}{W} \times 10^{-3}\ \frac{A}{mA} \times 1\ \frac{Coul/s}{A} \times \frac{1\ W}{J/s}$$

$$= 9.5 \times 10^{-2}\ \frac{Coul}{J} \times \frac{1\ \text{electron}}{1.602 \times 10^{-19}\ Coul}$$

$$= 5.93 \times 10^{17}\ \frac{\text{electrons}}{\text{Joule}}$$

$$E_{photon} = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34}\ J\text{-}s\ \ 3 \times 10^{8}\ m/s}{423 \times 10^{-9}\ m} = 4.699 \times 10^{-19}\ J$$

$$\#\ \text{electrons/photon} = 5.93 \times 10^{17}\ \frac{e^-}{J} \times 4.699 \times 10^{-19}\ J = 0.279$$

5c) $$\#\ \text{photoelectrons needed} = 10 = \#\ \text{photons created} * \epsilon_{collection} * \epsilon_{QUANTUM}$$

$$\epsilon_{collection} = 10 / 1074 * 0.279 = 0.033$$

need to collect only 3.3% of photons ...