

The University of Jordan / Physics Department  
 solutions for suggested problems

Giancoli / Seventh edition / chapter 31

Prof. Mahmoud Jaghoub

$$Q38] \quad ED_{\alpha} = ED_{x\text{-rays}}$$

$$AD_{\alpha} RBE_{\alpha} = AD_x RBE_x$$

$$350 \times 20 = AD_x \times 1$$

$$\Rightarrow AD_{x\text{-ray}} = 7000 \text{ rad.}$$

$$Q40] \quad AD = 2.5 \text{ Gy} = 2.5 \times \frac{1 \text{ J}}{\text{kg}} = 2.5 \text{ J/kg.}$$

$$m = 65 \text{ kg} \Rightarrow$$

$$\text{Absorbed energy} = 2.5 \frac{\text{J}}{\text{kg}} \times 6 \text{ kg} = 162.5 \text{ J.}$$

L2

Q4]  $E_p = 1.2 \text{ MeV} = 1.2 \times 10^6 \times 1.6 \times 10^{-19} \text{ J}$

tumor mass = 0.20 kg.

a)  $ED = AD \times RBE \Rightarrow 1.0 \text{ rem} = AD \times (1)$   
 $\Rightarrow AD = 1.0 \text{ Rad} (= 0.01 \text{ Gy})$ .

b) absorbed energy by tumor  $E_{\text{tumor}}$

$$\begin{aligned} E_{\text{tumor}} &= M_{\text{tumor}} \times AD \\ &= 0.2 \text{ kg} \times 0.01 \text{ J/kg} \\ &= 0.002 \text{ J}. \end{aligned}$$

$\Rightarrow$  number of absorbed protons is  $n$

$$n = \frac{E_{\text{tumor}}}{E_p} = \frac{0.002 \text{ J}}{1.2 \times 10^6 \times 1.6 \times 10^{-19} \text{ J/proton}}$$

$$\therefore n \approx 1.04 \times 10^{10} \text{ protons.}$$

$$\begin{aligned}
 Q44] \quad A &= 1.6 \text{ mCi} \\
 &= 1.6 \times 10^{-3} \times 3.7 \times 10^{10} \text{ Bq} \\
 &= 5.92 \times 10^7 \text{ Bq} \quad (1 \text{ Bq} = 1 \text{ decay/s})
 \end{aligned}$$

L3

Need to administer 32 Gy to a tumor.

$$1 \text{ mCi} \rightarrow 10 \text{ mGy/min}$$

$$1.6 \text{ mCi} \rightarrow X$$

$$\begin{aligned}
 \therefore X &= \frac{1.6 \text{ mCi}}{1 \text{ mCi}} \times 10 \text{ mGy/min} \\
 &= 16 \text{ mGy/min}
 \end{aligned}$$

$\Rightarrow$  a 1.6 mCi delivers 16 mGy/min

required time  $t$  is given by

$$t = \frac{32 \text{ Gy}}{16 \text{ mGy/min}} = \frac{32 \text{ Gy}}{16 \times 10^{-3} \text{ Gy/min}}$$

$$= 2000 \text{ min} \approx 33.3 \text{ hrs} \approx 1.4 \text{ days.}$$

Q46]  $^{57}_{27}\text{Co}$  emits 122 keV  $\gamma$ -rays. [4]

energy of each  $\gamma$  is  $E_\gamma = 122 \times 10^3 \times 1.6 \times 10^{-19} \text{ J}$

$$A = 1.55 \mu\text{Ci} = 1.55 \times 10^{-6} \times 3.7 \times 10^{10} \text{ Bq}$$

$$= 57350 \text{ decays/s (Bq)}$$

Radiated energy per second  $E$  is given by

$$E = A E_\gamma \quad (\text{in units of J/s})$$

Absorbed energy by person per second is

$$E_{\text{absorbed}} = 0.5 E \quad (\text{J/s})$$

↑ Since only 50% of  $\gamma$ -rays interact with the body.

$$\text{Absorbed energy } \underline{\text{per day}} \quad E_{\text{tot}} = E_{\text{absorbed}} \times 24 \times 60 \times 60$$

$$\therefore E_{\text{tot}} = 0.5 \left( A E_\gamma \frac{\text{J}}{\text{s}} \right) \left( 24 \times 60 \times 60 \frac{\text{s}}{\text{day}} \right)$$

$$= 0.5 A E_\gamma \times 24 \times 3600 \frac{\text{J}}{\text{day}} =$$

$$\Rightarrow AD = \frac{E_{\text{tot}}}{m} = \frac{E_{\text{tot}}}{65} \approx \frac{4.836 \times 10^{-5} \text{ J/day}}{65 \text{ kg}}$$

$$\approx \frac{7.44}{10^7} \cdot \frac{\text{J}}{\text{kg}} \times \frac{1}{\text{day}} = 7.44 \times 10^{-7} \frac{\text{Gy}}{\text{day}}$$

Solution to Example 31-12, chapter 31  
Giancoli / 7<sup>th</sup> edition.

L1

Note that the radiation that passes the body of the worker is only a fraction of the total radiation emitted by the source.

The fraction of the energy passing through her body call it  $E_{\text{worker}}$  is given by

$$\frac{E_{\text{worker}}}{E_{\text{total}}} = \frac{A_{\text{worker}}}{A_{\text{sphere}}}$$

$\rightarrow E_{\text{total}}$   
total radiated  
energy

$A_{\text{worker}}$ : area of the body of the worker

$A_{\text{sphere}}$ : area of sphere whose radius is the distance from the center of the sphere (where source is located) to the position of the worker.  
(see figure).

$$\Rightarrow E_{\text{worker}} = \frac{A_{\text{worker}}}{A_{\text{sphere}}} E_{\text{total}} = \frac{1.5 \text{ m}^2}{4\pi r^2} E_{\text{total}}$$

Note that  $E_{\text{worker}} \propto \frac{1}{r^2}$  i.e inversely proportional to the square of the distance from the source.

$$E_{\text{worker}} = \frac{1.5}{4\pi(4)^2} E_{\text{total}} = 7.5 \times 10^{-3} E_{\text{total}} \quad L2$$

Energy radiated per decay  $E_\gamma = (1.33 + 1.17) = 2.5 \text{ MeV}$ .

$$E_{\text{total}} = A \times E_\gamma = \underbrace{40 \times 10^{-3} \times 3.7 \times 10^{10}}_{\text{s}^{-1}} \times \underbrace{2.5 \times 10^6 \times 1.6 \times 10^{-19}}_{\text{J}}$$

$$\therefore E_{\text{total}} = 5.92 \times 10^{-4} \text{ J/s} \quad \begin{array}{l} \text{(total radiated energy by)} \\ \text{(the source each second)} \end{array}$$

Energy deposited in the worker's body per second is

$\downarrow$  only 50% of  $\gamma$ -rays interact with the worker's body

$$E = \left(\frac{1}{2}\right) E_{\text{worker}} = \left(\frac{1}{2}\right) (7.5 \times 10^{-3} E_{\text{total}})$$

$$= \left(\frac{1}{2}\right) (7.5 \times 10^{-3} \times 5.92 \times 10^{-4} \frac{\text{J}}{\text{s}}) = 2.22 \times 10^{-6} \text{ J/s}$$

$$\text{Absorbed dose } AD = \frac{E}{m} = 3.17 \times 10^{-8} \frac{\text{J}}{\text{kg}} \times \frac{1}{\text{s}} \\ = 3.17 \times 10^{-8} \text{ Gy/s}$$

$$\text{In four hours } AD_{\text{tot}} = 3.17 \times 10^{-8} \frac{\text{Gy}}{\text{s}} \times 4 \times 60 \times 60 \text{ s} \\ = 4.56 \times 10^{-4} \text{ Gy}$$

$$ED = AD_{\text{tot}} \times RBE = 4.56 \times 10^{-4} \text{ Gy} \times 1 = 4.56 \times 10^{-4} \text{ Sv}$$

$$ED = 456 \times 10^{-6} \text{ Sv} = 456 \mu\text{Sv} = 0.456 \text{ mSv} \\ = 45.6 \text{ mrem.}$$

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Solutions for Extra Suggested Problems

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Q47]  $AD = 4.5 \text{ kGy} = 4.5 \times 10^3 \frac{\text{J}}{\text{kg}}$  (allowed limit)

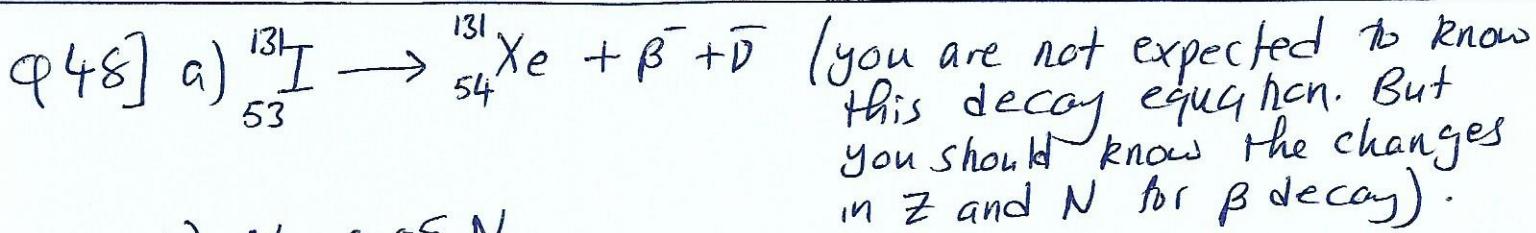
$$E_{e^-} = 1.6 \text{ MeV} = 1.6 \times 10^6 \times 1.6 \times 10^{-19} \text{ J}$$

$$E_{\text{total}} = 4.5 \times 10^3 \frac{\text{J}}{\text{kg}} \times 5 \text{ kg}$$

(allowed total energy)

$$= 22.5 \times 10^3 \text{ J}$$

$\therefore$  number of  $e^-$  (to reach allowable limit) =  $\frac{E_{\text{tot}}}{E_{e^-}} \approx 8.79 \times 10^{16}$



b)  $N = 0.05 N_0$

$$\frac{N}{N_0} = 0.05 = e^{-\lambda t}$$

$$0.05 = e^{-\frac{\ln 2}{t_{1/2}} t} \Rightarrow \ln(0.05) = -\frac{\ln 2}{t_{1/2}} t$$

$$t = -\frac{\ln(0.05)}{\ln 2} t_{1/2} = \frac{-\ln(0.05)}{\ln 2} (8) \approx 34.6 \text{ days.}$$

$$(c) A = \lambda N \Rightarrow N = \frac{A}{\lambda} = \frac{A}{\frac{\ln 2}{t_{1/2}}} = \frac{A t_{1/2}}{\ln 2} \quad L^2$$

$$\therefore N = \frac{(1 \times 10^{-3} \times 3.7 \times 10^{10} \text{ s}^{-1}) (8 \times 24 \times 60 \times 60 \text{ s})}{\ln 2}$$

$$N = 3.6896 \times 10^{13} \text{ nuclei}$$

$$\nearrow n = \frac{N}{N_A} = 6.129 \times 10^{-11} \text{ moles.}$$

number of  
moles

$$\text{mass} = n \times \text{molar mass}$$

$$= 6.129 \times 10^{-11} \text{ moles} \times 131 \frac{\text{grams}}{\text{mole}} = 8 \times 10^{-9} \text{ grams}$$

$$= 8 \frac{\text{grams}}{\text{nano}} = 10^{-9}$$

Q7] All three sources have the same activity

$$A = 35 \text{ mCi} = 35 \times 10^{-3} \times 3.7 \times 10^{10} \text{ s}^{-1}.$$

$$A = 1295 \times 10^6 \text{ s}^{-1} \text{ (or decays/s)}$$

To determine their relative danger of the three sources we should compare their relative effective doses.

$$\text{Remember } ED = AD \times RBE$$

for source A

$$ED_A = \underbrace{\left( \frac{A E_\gamma}{m} \right)}_{\text{AD per second}} \times RBE$$

L3

$$ED_A = \frac{A}{m} \times 1 \text{ MeV} \times 1 = \left( \frac{A}{m} \cdot \text{MeV} \right) \text{ (in units of Sv/s)}$$

$$ED_B = \frac{A}{m} \times 2 \text{ MeV} \times 1 = 2 \left( \frac{A}{m} \cdot \text{MeV} \right)$$

$$ED_C = \frac{A}{m} \times 2 \text{ MeV} \times 20 = 40 \left( \frac{A}{m} \cdot \text{MeV} \right)$$

$$\Rightarrow ED_C : ED_B : ED_A$$

$$40 : 2 : 1$$

$\Rightarrow$  In order of increasing danger we have

