Radiation Safety Course

Review Session

1. Prefixes, continued

   e. 50 mrem x \( \frac{1 \text{ rem}}{1,000 \text{ mrem}} \) = 0.05 rem

   f. 42 R/h x \( \frac{1,000 \text{ mR/h}}{1 \text{ R/h}} \) = 42,000 mR/h

   g. \( 10^6 \text{ dpm} \times \frac{1 \muCi}{2.22 \times 10^6 \text{ dpm}} \) = 0.45 µCi

   h. 4 µCi x \( \frac{3.7 \times 10^4 \text{ dps}}{1 \muCi} \) = 1.48 \times 10^5 \text{ dps}

2. Units: Indicate the correct units:

   a. MPD for eyes of a radiation worker is 15

      ___ mrem/y ___ rem/y ___ R/y

   b. Effective whole body dose equivalent from naturally occurring radiation sources is 300

      ___ µCi/y ___ rem/y ___ mrem/y

   c. The absorbed dose rate from an activity of 1 µCi per cm² of \(^{32}\text{P}\) deposited on the skin is 9

      ___ rads/h ___ rads/cm² ___ µCi/cm²

3. Radiation Exposures: Absorbed Doses & Dose Equivalents

   Select answers from: 0 mR, 20 mR, 5R/h, 0 mrad, 100 mrad, 340 rads, 0 mrem, 5 mrem, 1250 mrem, 1 rem, 1.25 rem, 20 rem, 50 rem

   a. Maximum permissible dose equivalent (gonads) radiation worker: 50 rem/y, 20 rem/year - implied

   b. “Radiation Area” = whole body dose equivalent ≥ 5 mrem/hour.

   c. Whole body dose equivalents which gives cancer mortality risk of 4 in 10,000: 1 rem

   d. LD₅₀ absorbed dose (with minimal treatment): 340 rads

   e. Exposure rate at 1 cm from 10 mCi of \(^{86}\text{Rb}\): 5 R/hour.

   f. Dose equivalent from 1 rad of alpha radiation: 20 rem.

   g. Absorbed dose threshold for induction of genetic effects: 0 mrads.
4. What is the total dose equivalent which should be recorded in a person’s dosimetry records if he/she has received the following individual doses? (Give answer in conventional and SI units.)

- **x-rays:** 210 mrad x 1 = 210 mrem
- **alpha rays:** 60 mrad x 20 = 1200 mrem
- **beta rays:** 150 mrad x 1 = 150 mrem
- **gamma rays:** 30 mrad x 1 = 30 mrem
- **thermal neutrons:** 10 mrad x 2.3 = 23 mrem

**TOTAL:** 1613 mrem

1613 mrem x 1 rem/1000 mrem = 1613 rem

1613 rem x 10 mSv/1 rem = 16.13 mSv

5. SI Units:

- **a.** 1 mGy x 100 mrad = 100 mrad
- **b.** 4 µCi x 3.7 x 10⁶ Bq = 1.48 x 10⁵ Bq
- **c.** 74 kBq x 1,000 Bq x 1 µCi = 2 µCi
- **d.** 5 mrad/h x 0.01 mGy/h = 0.05 mGy/h

5. SI Units, cont.

- **e.** 1.25 rem x 1,000 mrem = 1250 mrem

1.25 rem x 10 mSv/1 rem = 12.5 mSv

1.25 rem x 0.01 Sv/1 rem = 0.0125 Sv

- **f.** 5 mCi x 37 MBq/1 mCi = 185 MBq

- **g.** 10 rads x 1 cGy/1 rad = 10 cGy

### Problem Set: Basics of Radiation Safety

1. How much ¹²⁵I activity remains 200 days after the calibration date if the initial activity is 10 mCi?

**A. Nomogram method**

Half-life of ¹²⁵I = 60 days

# of half-lives = 200 days/60 days = 3.33

From nomogram (p. A11), 10% of the initial activity remains, so:

A = 0.1 x 10 mCi = 1 mCi

**B. Formula method**

Half-life of ¹²⁵I = 60 days

A = A₀e^{(0.693)(t/T)} = 10e^{(0.693)(200/60)}

= 10 x 2.31 = 23.1

= 10 x 0.099 = 0.99 mCi

(or)

A = A₀(1/2)^N = 10(1/2)^{(200/60)}

= 10 x 0.099 = 0.99 mCi
2. A certain procedure which involves the use of $^{198}$Au is performed over a 4 hour period at a working distance of 20 cm. If the exposure rate from the $^{198}$Au is 10 mR/hr, the total integrated exposure to the radiation worker would be 40 mR. Assume that it is possible to change the working parameters of the procedure in order to reduce the exposure. What would the exposure be if

a. The **time** were reduced to 2 hours? 20 mR
   (Time and therefore dose are cut in half.)

b. The **distance** were increased to 60 cm?
   \[ I_2 = I_1 \left(\frac{d_1}{d_2}\right)^2 \quad I_2 = 40 \text{ mR}(20/60)^2 = 4.4 \text{ mR} \]

c. If 1 cm of lead **shielding** were used? (TVL = 10 mm Pb)
   \[ I = I_0 e^{-2.3\times(TVL)} = 40 \text{ mR}e^{-2.3(10\text{mm}/10\text{mm})} = 4 \text{ mR} \]

d. If all three of the above were done?
   \[ 40 \text{ mR} \times \frac{20}{40} \times 4.4/40 \times 4/40 = 0.22 \text{ mR} \]

3. What is the dose rate through the protective layer of skin from a 2 µCi deposition of $^{32}$P? (See ‘Rules of Thumb for Beta Particles’ on page A10.)
   \[ D(\text{rad/h}) = 9 \text{ B} = 9 \times 2 \text{ µCi} = 18 \text{ rads/h/cm}^2 \]

4. What is the exposure rate (gamma) at 20 cm from a 3 mCi vial of $^{131}$I?
   \[ \Gamma = 2.1 \text{ R/h @ 1 cm per mCi (From Table)} \]

   The dose rate for 3 mCi:
   \[ 3 \times 2.1 = 6.3 \text{ R/h @ 1 cm} \]

   Using the inverse square law (page A11):
   \[ I_2 = I_1 \left(\frac{d_1}{d_2}\right)^2 = 6.3(1/20)^2 \]
   \[ = 6.3(1/400) = 0.0158 \text{ R/h} = 15.8 \text{ mR/h} \]

5. If the exposure rate from some $^{51}$Cr with no shielding is 20 mR/hr, what is the exposure rate reduced to if 2 mm of Pb is used for shielding? (The TVL is 6.3 mm of Pb.)
   \[ A. \text{ Nomogram Method} \]
   \[ \# \text{ of TVL’s} = 2/6.3 = 0.32 \]
   \[ \text{From the nomogram on p. A10, 48% is remaining.} \]
   \[ I = 20 \text{ R/h} \times 0.48 = 9.6 \text{ mR/h} \]

   \[ B. \text{ Formula Method} \]
   \[ I = I_0 e^{2.3\times(TVL)} \]
   \[ = (20 \text{ mR/h})e^{2.3(2)} = 20(0.482) = 9.6 \text{ mR/h} \]
   \[ \text{(or)} \]
   \[ I = I_0(1/10)^n, \text{ where } n = \# \text{ of TVL’s} \]
   \[ = (20 \text{ mR/h})(1/10)^{0.32} = (20 \text{ mR/h})(0.48) = 9.6 \text{ mR/h} \]

6. What is the meaning of the following terms?

   a. LD$_{50}$
      50% of the exposed population is expected to die within 60 days.

   b. Genetic effects of radiation
      Effects passed on to offspring.
7. A person who has an annual intake of a radioisotope equal to the
ALI (Annual Limit on Intake) will receive an absorbed dose
equal to the MPD (maximum permissible dose). What fraction
of the MPD is received if a person has an intake of 1 mCi for the
following isotopes?

<table>
<thead>
<tr>
<th>Isotope</th>
<th>ALI (µCi)</th>
<th>Fraction or multiple of MPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^3$H</td>
<td>80,000</td>
<td>0.013</td>
</tr>
<tr>
<td>$^{125}$I</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>$^{45}$Ca</td>
<td>800</td>
<td>1.25</td>
</tr>
<tr>
<td>$^{14}$C</td>
<td>2,000</td>
<td>0.5</td>
</tr>
<tr>
<td>$^{99m}$Tc</td>
<td>80,000</td>
<td>0.013</td>
</tr>
</tbody>
</table>

On the basis of the above numbers, which isotopes
most toxic? $^{125}$I , which is least toxic? $^3$H, $^{99m}$Tc

8. All of the following biological effects may result
from exposure to radiation. Most, however, require
large doses of radiation (there is a threshold below
which the effect does not occur). Indicate those for
which there is no known threshold, i.e., may have a
possibility of occurring even with low doses.

- mutations  _ nausea  _ leukemia
- sterility  _ dermal necrosis  _ cancer
- erythema  _ acute radiation syndrome
- genetic effects  _ epilation

9. The radiological half-life of $^{125}$I is 60 days.
The biological half-life is 138 days (for
soluble forms). What is the effective half-
life?

$$ T_{\text{eff}} = \frac{T_{1/2}\cdot T_b}{T_{1/2} + T_b} $$

$$ = \frac{(60)(138)}{(60 + 138)} = 41.8 \text{ days} $$


- What is the threshold for cancer induction? 0 rads
- What is the latent period for solid cancers? 10 to 35 years
- What is the risk factor? 4/10,000 fatal
cancers/rem of whole body dose (0.0004)
- What is the risk of having a fatal cancer induced
by a whole body radiation dose of 5 rem?

$$ \frac{5 \text{ rem} \times \frac{4}{10,000}}{10,000} = \frac{20}{500} = \frac{1}{25} $$

11. What is the major risk to the embryo or
fetus during the:

- first 8 days of pregnancy  C
- remainder of the first trimester  A
- last 6 or 7 months of pregnancy  D

(a) birth defects
(b) fetal death
(c) death of embryo
(d) increased risk of childhood cancer