# RADIATION SAFETY COURSE
## STUDY GUIDE

**Calculations and Conversions:** Each student should be able to perform the following calculations and/or conversions by using methods described in the class:

1. Calculate the radioactive decay of different isotopes,
2. Using detection efficiencies convert cpm to dpm,
3. Convert µCi to dpm and to dps (Bq),
4. Convert roentgens to rads, rads to rems, rads to grays and rems to sieverts,
5. Inverse square law (for determining exposure rates),
6. Calculate exposure rates using the specific gamma ray constant,
7. Calculate shielding requirements for gamma emitters, and
8. Determine beta shielding requirements using a graph.

### Numbers to memorize:

<p>| | | | |</p>
<table>
<thead>
<tr>
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</thead>
</table>
| 1. | 5 rem | 2. | $1/3 E_{\text{MAX}}$
| 4. | 5 mrem/h | 5. | 300 - 400 rads |
| 7. | $2.22 \times 10^6$ dpm | 8. | $3.7 \times 10^4$ dps |
| 9. | 37 MBq |

### Number prefixes:

- micro (µ) = $10^{-6}$
- milli (m) = $10^{-3}$
- centi (c) = $10^{-2}$
- kilo (k) = $10^3$
- mega (M) = $10^6$
- giga (G) = $10^9$
- tera (T) = $10^{12}$

### Units to memorize

<table>
<thead>
<tr>
<th></th>
<th>Conventional Units</th>
<th>SI Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity (quantity):</td>
<td>curie (Ci)</td>
<td>bequerel (Bq)</td>
</tr>
<tr>
<td>Exposure:</td>
<td>roentgen (R)</td>
<td>no unit</td>
</tr>
<tr>
<td>Absorbed dose:</td>
<td>rad</td>
<td>gray (Gy)</td>
</tr>
<tr>
<td>Dose equivalent:</td>
<td>rem</td>
<td>sievert (Sv)</td>
</tr>
</tbody>
</table>
Shielding and Inverse square problem

For the isotope $^{59}\text{Fe}$ with an activity of 5 mCi, what is the exposure rate at 10cm?

From the Table of Radioisotopes

Specific Gamma Ray Constant = $\Gamma = 6 \text{ R} / \text{hr} @ 1 \text{ cm per mCi}$

So for 5 mCi, $I_\circ = 6 \text{ R} / \text{(hr mCi)} \times 5 \text{ mCi} = 30 \text{ R} / \text{hr} = 30,000 \text{ mR} / \text{hr} @ 1 \text{ cm}$

At 10 cm the rate will be $(10 \text{ cm} / 1 \text{ cm})^2 = 100$ times less

$I = (30,000 \text{ mR} / \text{hr}) / 100 = 300 \text{ mR} / \text{hr}$

What will the exposure rate become if 1 cm of lead is used as a shield?

From the Table of Radioisotopes

Tenth Value Layer = TVL = 33.6 mm Pb = 3.36 cm Pb

Method 1:

$I = I_\circ (1 / 10)^n$, where $I_\circ = 300 \text{ mR} / \text{hr}$ \quad n = \#TVL's = 1 cm / 3.36 cm = 0.30

$I = 300 \text{ mR} / \text{hr} (1 / 10)^{0.3} = 300 \times 0.50 = 150 \text{ mR} / \text{hr}$

Method 2:

$I = I_\circ e^{-2.3 \times X / \text{TVL}}$, where $X$ = thickness of shield = 1 cm

$I = 300 \text{ mR} / \text{hr} \times e^{-(2.3 \times 1 / 3.36)} = 300 \times 0.50 = 150 \text{ mR} / \text{hr}$

Method 3:

Use of nomogram on page A10 of the manual

Number of TVL's = 1 cm / 3.36 cm = 0.30

The nomogram indicates that 50% of the exposure remains after passage of radiation through 0.30 TVL's

$I = 0.50 \times 300 \text{ mR} / \text{hr} = 150 \text{ mR} / \text{hr}$
RADIATION SAFETY COURSE
UNITS AND DOSES

1. PREFIXES: Complete the following conversions:

(a) \(6 \times 10^4 = \quad \text{mS} = \quad \text{mS}\)
(b) \(100 \mu\text{Ci} = \quad \text{Ci}\)
(c) \(3.3 \text{ Ci} = \quad \text{mCi}\)
(d) \(2 \times 10^6 \mu\text{Ci} = \quad \text{Ci}\)
(e) \(50 \text{ mrem} = \quad \text{rem}\)
(f) \(42 \text{ R/h} = \quad \text{mR/h}\)
(g) \(10^6 \text{ dpm} = \quad \mu\text{Ci}\)
(h) \(4 \mu\text{Ci} = \quad \text{dis/sec}\)

2. UNITS: Indicate the correct units:

(a) MPD for eyes of the radiation worker is 15 \(\quad \text{mrem/yr}\)
(b) Effective whole body dose equivalent from naturally occurring radiation sources is 300 \(\quad \mu\text{Ci/yr}\)
(c) The absorbed dose rate from an activity of 1 \(\mu\text{ci}\) per square centimeter of \(^{32}\text{P}\) deposited on the skin is 9 \(\quad \text{rads/cm}^2\)

3. RADIATION EXPOSURES: Absorbed Doses and Dose Equivalents

Select answers from:

- 0 mR, 20 mR, 5 R
- 0 mrem, 100 mrem, 340 rads
- 0 mrem, 5 mrem, 1250 mrem, 1 rem, 1.25 rem, 20 rem, 50 rem

(a) Max. permissible dose equivalent (gonads), radiation worker: \(\quad \text{mrem/yr}\)
(b) "Radiation Area" = whole body dose equivalent \(\geq \quad \text{mrem/yr}\)
(c) Whole body dose equivalents which gives cancer mortality risk of 4 in 10,000: \(\quad \text{mrem/yr}\)
(d) \(LD_{50}\) absorbed dose (with minimal treatment): \(\quad \text{mrem/yr}\)
(e) Exposure rate at 1 cm from 10 mCi of \(^{86}\text{Rb}\): \(\quad \text{mrem/yr}\)
(f) Dose equivalent from 1 rad of alpha radiation: \(\quad \text{mrem/yr}\)
(g) Absorbed dose threshold for induction of genetic effects: \(\quad \text{mrem/yr}\)
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.)

5. SI Unit Conversions
   a. 1 mGy to rads
   b. 4 µCi to Bq
   c. 74 kBq to µCi
   d. 5 mrads/h to mGy/h
   e. 1.25 rem to mrem, mSv, and Sv
   f. 4 mCi to Mbq
   g. 10 rads to 10 cGy
1. How much $^{125}$I activity remains 200 days after calibration if the initial activity is 10 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 40mR. 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:

8. The TIME were reduced to 2 hours? ________ mR

9. The DISTANCE were increased to 60 cm? ________ mR

10. If 1 cm of lead SHIELDING were used, what would the exposure be?
   (TVL=10 mm Pb) ________ mR

11. If all three of the above were done? ________ mR

3. What is the dose rate through the protective layer of skin from a 2 μCi / cm$^2$ deposition of $^{32}$P? (See Rules of Thumb for beta particles.)

4. What is the (gamma) exposure rate at 20 cm from a 3 mCi vial of $^{131}$I?
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 Pb is used for shielding?

6. What is the meaning of the following terms?

1. LD$_{50}$

2. Genetic effects of radiation

7. A person who has an annual intake of 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</th>
<th>Fraction or multiple of MPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^3$H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{125}$I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{45}$Ca</td>
<td>800 µCi</td>
<td>1.25</td>
</tr>
<tr>
<td>$^{14}$C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{99m}$Tc</td>
<td>80,000 µCi</td>
<td>0.01</td>
</tr>
</tbody>
</table>

On the basis of the above numbers, which isotope is most toxic: __________________; least toxic: ____________

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
- Cataracts
- Erythema
- Epilation
- Genetic effects
- Acute radiation syndrome

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?
10. Cancer induction by ionizing radiation:

What is the threshold for cancer induction?

Answer: ___________ rads

What is the latent period (for solid cancers)?

Answer: ___________ years

What is the risk factor?

Answer: ___________ fatal cancers / rem whole body dose

What is the risk of having a fetal cancer induced by a whole body radiation dose of 5 rads?

Answer: 1 chance in ___________