chapter 3

Effects of Radiation on Humans

Prior Knowledge: Pre-calculus Mathematics or Applied Mathematics students will have seen exponential functions. Students will need to review the concept of "e" (2.71828183…) as well as scientific notation to complete calculations in this chapter.

Terms You Should Know: The list below highlights important terms beyond what is listed at the end of the chapter in the Student Resource. Teachers could use either list as a knowledge activation activity—have students create a concept map or definitions frame—or as a review of concepts.

Note that this list of terms is not intended to be a list for memorization or to provide lists of definitions. It is here to assist the teacher in the incorporation of new concepts and terminologies into the learning activities.

- absorbed dose
- absorption coefficient (μ)
- alpha decay
- alpha particle
- anaemia
- beta particle
- biologically equivalent dose
- DNA
- dose rate
- electron
- gamma radiation
- genetic damage
- gray (Gy)
- incident intensity (I0)
- infrared light
- ionize
- malignant tumour
- metastasis
- microcephaly
- microwaves
- neutrino
- non-ionizing radiation
- positron
- quality factor (QF)
- radiation absorbed dose (rad)
- relative biological effectiveness (RBE)
- roentgen (R)
- roentgen equivalent, man (rem)
- sievert (Sv)
- somatic damage
- Systeme Internationale (SI)
- ultraviolet A, B, or C (UVA, UVB, UVC)

Chapter Summary: This chapter includes an analysis of the four types of ionizing radiation: alpha, beta, gamma, and X. It also includes an analysis of non-ionizing radiation, getting into the somatic and genetic effects as well as measurement units for radiation. The relationship between types of radiation and the electromagnetic spectrum is highlighted in Figure 3-4.

Page 32 | "Activity: SunSense"

Check out the package of information and activities you can get called SunSense from the Canadian Cancer Society. It even includes some experiments that show how different sunblock lotions work! To obtain a free package for yourself (or for your whole class), go to http://www.cancer.ca Locate the regional office nearest you!

Page 34 | “Practice Questions”

1. Compare the number of non-absorbed gamma rays for a substance with a thickness of 30 cm and absorption coefficients of 0.000025 for an energy level of 1000 keV and 0.00027 for an energy level of 120 keV.

   First scenario: $I(d) = I_0 e^{-\mu d}$

   $I(d) = I_0 e^{-(0.000025x30)} = I_0 (0.99925)$

   Second scenario: $I(d) = I_0 e^{-\mu d}$

   $I(d) = I_0 e^{-(0.00027x30)} = I_0 (0.99193)$

   The second scenario has almost as many gamma rays absorbed as the first scenario.

2. If a substance that is 10 cm thick has 35 times as much gamma radiation passing through it when the rays carry 90 keV compared to 30 keV, determine the absorption coefficient for the higher energy gamma ray scenario. Assume $\mu = 0.018$ for 30 keV.

   We can use our knowledge of exponent rules to help us solve for μ.

   $35 = I_0 e^{-(10\mu)} / I_0 e^{-(0.018x10)}$

   or… $35 = e^{-(10\mu)} / e^{-(0.18)}$

   therefore… $35 = e^{-10}e^{\mu}/0.83527$

   so… $29.2345 = e^{-10} e^{\mu}$

   or… $29.2345/e^{-10} = e^{\mu}$

   $e^{\mu} = 643931.78$ *therefore* $\mu = \ln(643931.78) = 13.375$

Page 36 | “Cancer Warrior”

NOVA has provided this documentary online as well as activities and questions available for free use. Check out http://www.pbs.org/wgbh/nova/cancer/program.html for more details.

Page 36 | “In the Media: Questions”

How accurately does the movie portray the criticality incident? How accurately does the movie portray Louis Slotin?

The movie portrays the criticality incident with reasonable accuracy, with the exception of the blue “flash” (which, if researched, is still a phenomenon that is debated). Louis Slotin is portrayed as an individual from Chicago (with a different name), and his character is mostly fictitious in comparison to the real-life Winnipegger of that name. Teachers may want to read the biography of Louis Slotin found in the Winnipeg Free Press publication Greatest Manitobans.

Page 37 | “Questions”

1. What is standard temperature and pressure? How might the amount of ionization in air due to radiation change as temperature increases? How might the amount of ionization in air due to radiation change as pressure increases?

   Standard temperature and pressure is defined by IUPAC (International Union of Pure and Applied Chemists) as air at zero degrees Celsius and one atmosphere of pressure (101.325 kPa).

2. In human tissue, one Roentgen of gamma radiation exposure results in about one rad of absorbed dose. Why is this number (1 rad) an approximation?

   One Roentgen is approximately equal to one rad of absorbed dose because absorbed dosage depends on the type of tissue that is absorbing the radiation. Therefore this number is an average or an approximation.

Page 38 | "Research Questions"

1. Fiestaware was a popular style of dishes in the 1960s. However, we now know that Fiestaware releases low levels of radiation. Research why, and how much radiation (in rems) is released.

   Fiestaware contains Uranium-235, a radioactive isotope in a form of mineral pigment known as uraninite (uranium oxide, U3O8). The dye used in the glaze for these products contains the uranium isotope, chosen to be part of the glaze because it made the orange and red colours brighter and more vivid. Red Fiestaware, in particular, had higher amounts of uranium added to make the pottery a brighter red. Depending on the colour of the Fiestaware, pottery items can release anywhere from 50 to 5000 rems of radiation. Compare this to typical naturally occurring background radiation amounts which tend to be less than 2500 rems.

2. How many rems of radiation was Switzerland exposed to when the toxic cloud of radiation blew over their country from the Chernobyl disaster?

   Researchers have determined that the average individual effective dose Switzerland was exposed to ranged anywhere from 1 to 10 milliSieverts (or up to 1 rem) of radiation from 1986 onward.

Page 39 | "Calculation Questions"

1. An individual is exposed to the following forms of radiation: 20 mrad of gamma rays, 35 mrad of electrons, 10 mrad of protons, and 5 mrad of slow neutrons (RBE=2). Rank the types of radiation from highest to lowest, according to their biologically equivalent dose.
2. *Biologically equivalent dose=absorbed dose (in rads) x RBE*
   RBEs for gamma rays, electrons and protons are given in chapter 3 on page 9.

   Protons: Biologically equivalent dose = (0.005) x (10) = 0.05 rem
   Slow neutrons: Biologically equivalent dose = (0.005) x (2) = 0.01 rem
   Gamma Rays: Biologically equivalent dose = (0.005) x (1) = 0.005 rem
   Electrons: Biologically equivalent dose = (0.005) x (1) = 0.005 rem

3. If an individual is exposed to two different types of radiation where the absorbed doses are the same but RBEs are different, which type of radiation—the one with the larger RBE or the smaller RBE—will cause the greater damage?

   The one with the larger RBE will cause the greater damage.

4. The typical biologically equivalent dose for a chest x-ray is 2.5x10-2 rem. If the mass of exposed tissue is 19 kg and the energy absorbed is 5.9x10-3 J, what is the RBE for this type of radiation on chest tissue? How does this compare to the RBE for gamma rays?

   absorbed dose = energy absorbed/mass of absorbing material
   Biologically equivalent dose = absorbed dose x RBE
   therefore…   RBE = (biologically equivalent dose) / absorbed dose
   $RBE = (2.5x10^{-2})/[(5.9x10^{-3})/(19)] = 80.5$

   This is eighty times larger than the RBE for gamma rays.

5. If you stand in an area where the dose rate for an unknown source of radiation is 40 mrem/hr for half an hour, what would your total dose of radiation be? If this radiation was aimed at your chest (as in question #3), with the same mass of exposed tissue and the same amount of energy absorbed, what is the RBE for this unknown source of radiation?

   total radiation dose = 0.040 x 0.5 = 0.020 or 20 mrem
   RBE = biologically equivalent dose/absorbed dose
   $RBE = (0.020)/[5.9x10^{-3})/(19)] = 64.4$