Homework 8 Solutions

Nuclear Engineering 162

Due April 9 2008

VII.1 Turner 13.2 (Page 443)
What reactive species exist in pure water at times > 10^{-12}s after irradiation?
H_3O^+, OH, e^-_{aq} and H

VII.2 Turner 13.8 (Page 443)
How far would a water molecule with thermal energy (0.025 eV) travel in 10^{-12}s in a vacuum?

$$\frac{1}{2}mv^2 = 0.025\text{eV}$$

$$v = \sqrt{\frac{2 \cdot 0.025\text{eV}}{m}} = \sqrt{\frac{2 \cdot 0.025 \cdot 1.6022 \cdot 10^{-13}}{18 \cdot 1.6605 \cdot 10^{-27}\text{kg}}} = 520\text{m}/s$$

$$x = vt = 520\text{m}/s \cdot 10^{-12}\text{s} = 5.2 \cdot 10^{-10}\text{m}$$

VII.3 Turner 13.19 (Page 444)
Distinguish between the "direct" and "indirect" effects of radiation. Give a physical example of each.
Direct: Direct effects are produced by the initial action of the radiation itself.
Example: A strand break in DNA caused by an ionization in the DNA molecule itself.
Indirect: Indirect effects are caused by the chemical action of the free radicals and other radiation products.
Example: A DNA strand break that results from an OH radical attack on a base sugar at a time following the initial radiation interaction with free water (10^{-12} to 10^{-9}s later).

VII.4 Turner 13.20 (Page 444)
Give examples of two stochastic and two deterministic biological effect of radiation.
Deterministic: Erythema, cataract
Stochastic: Hereditary illnesses, cancer

VII.5 Turner 13.31 (Page 444)
For multitarget, single-hit survival with D_0 = 7.5 Gy and an extrapolation number n= 4, what fraction of cells survive a dose of 10 Gy?

$$\frac{S}{S_0} = 1 - \left(1 - e^{-D/D_0}\right)^n = 1 - \left(1 - e^{-10\text{Gy}/7.5\text{Gy}}\right)^4 = 70.6\%$$

VII.6 Turner 13.39 (Page 445)
The cell-survival data in Table 13.9 fit a multitarget, single-hit survival curve. Find the slope at high doses and the extrapolation number. Write the equation that describes the data.

TABLE 13.9. Data for Problem 39

Dose (GY)	Surviving Fraction
0.10	0.993
0.25	0.933

0.50	0.729
1.00	0.329
2.00	0.0458
3.00	0.00578
4.00	0.00072

Multi-target, single hit survival (MTSH) curve:

$$\frac{S}{S_0} = 1 - \left(1 - e^{-D/D_0}\right)^n \approx 1 - \left(1 - ne^{-D/D_0}\right) = De^{-D/D_0}$$

Where n is the extrapolation number, n=3

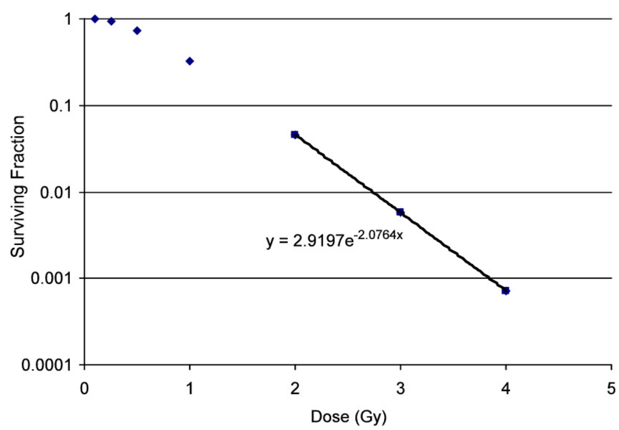

Figure 1: Semilogarithmic plot of surviving fraction S/S_0 as a fucntion of dose D

The slope of the equation is given by:

$$\frac{1}{D_0} = \frac{-1}{0.48} = -2.0764$$

$$\frac{S}{S_0} = 1 - \left(1 - e^{-D/0.48}\right)^3$$

VII.7 Turner 14.7 (Page 471)

Show that 50 mSv y^{-1} is equivalent to an average rate of 0.025 mSv h^{-1} for 40 h wk^{-1}, 50 wk y^{-1}.

$$\frac{0.025\text{mSv}}{\text{h}} \cdot \frac{40\text{h}}{\text{wk}} \cdot \frac{50\text{wk}}{\text{y}} = \frac{50\text{mSv}}{\text{y}}$$

VII.8 Turner 14.8 (Page 471)

A worker receives uniform, whole-body doses of 0.30 mGy from 100-keV neutrons, 0.19 mGy from 1.5-MeV neutrons, and 4.3 mGy from gamma rays. Calculate the effective dose.

$$E = \sum_T w_T H_T = \sum_T w_T \sum_R w_R D_{TR}$$

For the whole body dose, $\sum_T w_T = 1$

$$E = \sum_R w_R D_{TR} = 10 \cdot 0.3\text{mGy} + 20 \cdot 0.19\text{mGy} + 1 \cdot 4.3\text{mGy} = 11.1\text{mSv}$$

VII.9 Turner 14.16 (Page 472)
Calculate the effective dose for an individual who has received the following exposures:
1 mGy alpha to the lung
2 mGy thermal neutrons, whole body
5 mGy gamma, whole body
200 mGy beta to the thyroid.

1 mGy alpha to the lung:

$$w_T = 0.12$$
$$w_R = 20$$

2 mGy thermal neutrons, whole body:

$$w_T = 0.1$$
$$w_R = 5$$

5 mGy gamma, whole body:

$$w_T = 1$$
$$w_R = 1$$

200 mGy beta to the thyroid:

$$w_T = 0.05$$
$$w_R = 1$$

$$E = \sum_T w_T H_T = \sum_T w_T \sum_R w_R D_{TR}$$
$$E = 0.12 \cdot 20 \cdot 1\text{mGy} + 1 \cdot 5 \cdot 2\text{mGy} + 1 \cdot 1 \cdot 1\text{mGy} + 0.05 \cdot 1 \cdot 200\text{mGy}$$
$$E = 27.4\text{mSv}$$