Problem 4-1 Explain the biological effects of radiation which are categorized as follows:

- somatic effects
- : the effects on somatic cells of exposed individual itself
- hereditary effects
- : the effects on germ cells and the effects appear on one's descendants
- in-utero effects
- : the effects on fetus/embryo cells and they are not hereditary effects even though the effects appear on one's descendant but rather a special case of the somatic effect
- acute effects
- : the fast responses due to mostly high radiation exposure
- delayed (or chronic) effects
- : latent effects.
- stochastic effects
- : probabilistic effects with no threshold and proportional to probability of occurrences
- deterministic effects

: non-stochastic effects and proportional to the severity of the effects with threshold.

- detrimental effects
- : harmful effects of radiation
- hormesis effects
- : beneficial effects of radiation, mostly from low level exposure

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Problem 4-2 Compute ALI and DAC of I-131 through inhalation

data: SEE(thyroid ← thyroid) = 10 MeV/kg/t (controlling)
f_{thy} = fractional uptake to the thyroid after inhalation (= 0.2)
radiological half-life of I-131 = 8.05 days
biological half-life of iodine in the thyroid = 138 days

solution:

T_R=8.05days T_B=138days

$$T_E = \frac{T_B \times T_R}{T_B + T_R} = \frac{8.05 \times 138}{8.05 + 138} = 7.6 days$$

$$\lambda_E = \frac{0.693}{T_E} = 9.11 \times 10^{-2} [d^{-1}]$$

여기서 1Bq에 해당하는 양을 흡입하였을 때, 일어나는 총 transformation 수를 구하며 다음과 같다.

$$U_{thy} = \frac{q_{thy}(0)}{\lambda_E} = \frac{1Bq}{9.11\times10^{-2}}(24\times3600) = 9.5\times10^5[transformation/Bq]$$

SEE=10Mev/kg/t

그러므로 단위 activity 흡입당 20%만이 흡수되므로, 받게 되는 dose는

$$H_{50} = 0.2\times1.6\times10^{-10}\times(9.5\times10^5)(10\times10^{-3}) = 3.0\times10^{-7}[Sv/Bq]$$

weighting을 고려하면

$$w_{thy}\cdot H_{50,thy} = 0.03\times3.0\times10^{-7} = 9.0\times10^{-9}[Sv/Bq]$$

1) limit on effective dose equivalent(5rem/year)

$$ALI(stochastic) = \frac{0.05Sv/yr}{9.0\times10^{-9}Sv/yr} = 5.6\times10^6[Bq/yr]$$

$$\therefore DAC = \frac{ALI}{2.4\times10^3} = 2333.3Bq/m^3$$

2) limit on organ dose(50rem/year)

$$ALI(non-stochastic) = \frac{0.5Sv/yr}{3.0\times10^{-7}Sv/Bq} = 1.7\times10^6 Bq/yr$$

$$\therefore DAC = \frac{ALI}{2.4\times10^3} = 694.4Bq/m^3$$

Problem 4-3 Explain the adaptive responses of low-level radiation on the activity of the **DNA damage control biosystem.**

Solution:

The activity of the **DNA damage control biosystem** is decreased by high-dose radiation (e.g., >30 cGy) radiation, but adaptively responds with increased activity to low-dose radiation (e.g., <30 cGy). The efficiency of this biosystem is increased by the adaptive responses to low-dose ionizing radiation.

The operative effect of reducing *metabolic* mutations by the adaptive response of the DNA damage-control biosystem to low-dose radiation is the critical factor, not reduction of the relatively negligible number of mutations produced by low-dose radiation. This critical factor must be considered in order, "to judge the balance between stimulated cellular repair and residual damage." Assuming a 20% increased efficiency of biosystem control in response to a tenfold increase of annual radiation from 0.1 cGy/y to 1 cGy/y, *radiation* mutations would indeed increase from 1x10^{-7} /cell/d to 8x10^{-7} /cell/d, but *metabolic* mutations would *decrease* from ~1/cell/d to ~0.8/cell/d. "The balance between stimulated cellular repair and residual damage" is a 20% *decrease* of mutations from an average of ~1 mutation/cell/d (Figure 1) to ~0.8 mutation/cell/d (Figure 3). ***The biologic effect of radiation is not determined by the number of DNA mutations it creates, but by its effect on the biosystem that controls the relentless enormous burden of oxidative DNA damage.*** High-dose radiation *impairs* this biosystem with consequent significant *increase* of *metabolic* mutations and corresponding *risk increments.* Low-dose radiation *stimulates* the DNA damage-control biosystem with consequent significant *decrease* of *metabolic* mutations and corresponding *risk decrements* .

Problem 4-4 BF$_3$ counter which is filled with 99% enriched B^{10}F$_3$ gas. The pressure is 20 mmHg at 20°C. When a thermal neutron counting is 500 counts per minute, what is the thermal neutron flux? The absorption X-section of B-10 for 0.0253 eV neutron is 4,010 barns.

Solution:
부피가 주어져 있지 않으므로, note 를 참고하여 부피를 가정함.

# of B-10 atoms in the counter

$$N = \frac{(\pi \times 1^2 \times 20)(10^{-3})l}{22.4l}\left(\frac{20}{760}\right)\left(\frac{273}{273+20}\right)(6.02 \times 10^{23})(0.99) = 4.99 \times 10^{19}\, atoms$$

The average absorption X-section of B-10 is,

$$\overline{\sigma_a} = (20°C) = \frac{\sqrt{\pi}}{2}\left(\frac{293}{293}\right)^{1/2}(4010b) = 3553b$$

The total reaction rate becomes,

$$N\sigma_a\phi = (4.99 \times 10^{19})(3553 \times 10^{-24})\phi = 8.33 counts / \sec$$

$$\therefore \phi = 46.98 neutrons / cm^2 \sec$$

Problem 4-5 5 measurements taken. Gross for 5-minute and background for 20 minutes for each measurement. Measurements are as follows:

Measurement	Gross counts	Background counts
1	230	220
2	229	210
3	228	200
4	227	190
5	234	230

Find the net count rate (cpm) with standard deviation.

Solution:

$$n_g = \frac{1}{5}(230 + 229 + 228 + 227 + 234) = 229.6$$

$$n_b = \frac{1}{5}(220 + 210 + 200 + 190 + 230) = 210$$

$$r_n = \frac{229.6}{5} - \frac{210}{20} = 45.92 - 10.5 = 35.42$$

$$\sigma_n = \sqrt{(\frac{45.92}{5} + \frac{10.5}{20})} = 3.12$$

$$\therefore r_n \pm \sigma_n = 35.42 \pm 3.12[cpm]$$