# Nuclear Technology

## Radioactivity Calculations

# Example 1

- α – particles ionise 95 000 atoms per cm of air.
- α – particles lose 42 eV per ionised atom
- Q1.How much energy (Joules) will α – particles lose per cm of air ?
- Q2.How far does α – particles travel before it loses 4.8 MeV of energy ?

# Answer 1

- Q1. 95 000 atoms per cm.42 eV per atom.
- 95 000 x 42 = 3.99 MeV per cm of air
- 1 eV = 1.6 x $10^{-19}$ Joules (J)
- (3.99 x $10^{6}$) x (1.6 x $10^{-19}$) = 6.384 x $10^{-13}$ J
- Q2.4.8 MeV = 4.8 x $10^{6}$ eV
- (4.8 x $10^{6}$)/42 = 114 285 atoms
- 114 285/95 000 = 1.20 cm of air

# Example 2

- Bi-214 has $T_{1/2}$ = 19.7 min. Bi-214 is an active component in a new medical technique for treating lung cancer.
- The patient requires 22 mg of Bi-214 and the delivery time is 5 hours from the Lucas Height Nuclear Reactor to Royal Perth Hospital.
- How much Bi-214 is in the original sample produced at Nuclear Reactor ?

# Answer 2

- Use $N_t = N_o(1/2)^{t/T_{1/2}}$

- $22 \times 10^{-3} = N_o(1/2)^{300/19.7}$
- $22 \times 10^{-3} = N_o(2.61 \times 10^{-5})$

- $N_o = (22 \times 10^{-3})/(2.61 \times 10^{-5})$

- $N_o = 844.57$ g

# Example 3

- An isotope decays over an unknown time with an initial mass of 1.23 g and final mass of 0.087 g. The isotope has a half-life of 9.8 years.
- What was the length of decay for isotope ?

# Answer 3

- $N = N_o(1/2)^{t/T1/2}$ Let $X = t/(T1/2)$
- $0.087 = 1.23 \times (1/2)^X$
- $\text{Log}(0.087/1.23) = X\log(1/2)$
- $-1.1504 = X(-0.3010)$
- $X = 1.1504/0.3010$
- $X = 3.822$ half lives or $X = t/(T1/2) = t/9.8$
- $t = 3.822 \times 9.8 = 37.5$ years

# Example 4

- A woman receives 300μSv for a pelvic X-ray. The woman weighs 76 kg and undergoes medical treatment using a radioactive isotope that emits α-particles.
- The α-decay exposes 300μSv of radiation to patient.
- Compare the energy difference between the pelvic X-ray and the radioactive isotope ?

# Answer 4

- Dose equivalent (DE) = Absorbed dose (AD) x Quality factor (QF)
- X-ray: $300 \times 10^{-6}$ Sv= AD x 1
- AD = Energy/Mass
- Energy = $(300 \times 10^{-6}) \times (76)$
- Energy = 0.0228 or $2.28 \times 10^{-2}$ J
- α-decay = $300 \times 10^{-6}$ = AD x 20
- AD = $(300 \times 10^{-6})/20 = 1.5 \times 10^{-5}$
- Energy = $(1.5 \times 10^{-5}) \times (76) = 1.14 \times 10^{-3}$ J
- Thus energy of X-ray > α-decay

# Example 5

A Lethal Dose that kills X% of exposed people in a specific time period can be summarised by this example LD50/20= 3Sv. This indicates that 3Sv of a specific radiation is a lethal dose that kills 50% of exposed people in 20 days.

# Question

- An X-ray technician receives a dangerous dose of radiation of 100 mSv. A warning label on the X-ray equipment states LD80/15 = 2.5 Sv.
- How many similar doses of radiation can the technician absorb before it reaches the limit ?
- How many days of exposure to radiation before a lethal dose ?
- What is the chance that technician will not die from lethal dose ?

# Answer 5

- 2.5 Sv/100 mSv = 2.5/(100 x $10^{-3}$)
- = 25 doses
- 15 days for exposure to radiation
- Lethal dose at 2.5 Sv over 15 days at 80% chance
- 20% chance that technician will not die