CHEM1901/3 Worksheet 2 – Answers to Critical Thinking Questions

The worksheets are available in the tutorials and form an integral part of the learning outcomes and experience for this unit.

Model 1: Calculating radioactive decay

1. $N$ is the number of nuclei, $t$ is the time and $\lambda$ is the decay constant. $N(t)$ is the number of nuclei at time $t$ and $N(0)$ is the number of nuclei at time $t = 0$.

   The SI unit for time is seconds (s) and the SI unit for the decay constant is inverse seconds (s$^{-1}$).

Model 2: Calculating half life, $t_{1/2}$

1. When $t = t_{1/2}$, $N(t_{1/2}) = 0.5 \times N(0)$:

   $0.5N(0) = N(0)e^{-\lambda t_{1/2}}$
   $0.5 = e^{-\lambda t_{1/2}}$
   $\ln(0.5) = -\lambda t_{1/2}$
   $\ln(2) = +\lambda t_{1/2}$
   $t_{1/2} = \ln(2) / \lambda$

2. $t_{1/2}$ is the half life. It is the time taken the number of nuclei to halve. The SI unit for time is seconds (s). $\lambda$ is the decay constant. The SI unit for the decay constant is inverse seconds (s$^{-1}$).

3. See below.

Model 3: Calculating activity

1. $\lambda$ is the decay constant and has SI units of inverse seconds (s$^{-1}$). $N$ is the number of nuclei. $A$ is the activity and is the number of disintegration per seconds. It has units of disintegration s$^{-1}$ or Bq.

2. Avogadro’s constant.

3. $5.37 \times 10^{12}$ Bq

4. $\lambda = 2.6 \times 10^{-6}$ s$^{-1}$ and $t_{1/2} = 2.6 \times 10^{5}$ s

Model 4: Carbon-14 Dating

1. 6330 years before 1950

2. 120 years

3. 99 Bq
Model 5: Working in SI units

1. 4.4 days (using the approximation that the amount of $^{37}$Ar does not change significantly).  
4.5 days (allowing for the small decrease in the amount of $^{37}$Ar over this period).

Challenge Question – Simultaneous decay

Equation:

$$\frac{dN_{Ar}}{dt} = +\lambda_K N_K - \lambda_{Ar} N_{Ar}$$

Explanation:

The first decay route leads to an increase in the amount of $^{37}$Ar and this is shown by the positive sign. The rate of this increase is equal to the decay constant for $^{37}$K multiplied by the amount of $^{37}$K left.

The second decay route to a decrease in the amount of $^{37}$Ar and this is shown by the negative sign. The rate of this decrease is equal to the decay constant for $^{37}$Ar multiplied by the amount of $^{37}$Ar present.

The decay constant for the second process is much slower than for the first process. The amount of $^{37}$Ar grows initially as it is made much faster than it decays. As the amount of $^{37}$K left decreases, the rate of formation of $^{37}$Ar slows until it is comparable to the slow rate of its decay. At this stage, there is little overall change and the graph is level. Once all of the $^{37}$K has gone, there is exponential loss of $^{37}$Ar.