CHEM1612 Worksheet 13 – 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: The Atomic Symbol

1.

	number of electrons	number of protons	number of neutrons
(a)	12	12	12
(b)	12	12	14
(c)	35	35	44

2.

	charge	mass
(a)	+2	4
(b)	-1	0*
(c)	+1	0*
(d)	0	0†

3.

	charge	mass
(a)	-1	0*
(b)	+1	1
(c)	0	1

Model 2: Radioactive Decay

1.

	change in number of neutrons (*N*)	change in number of protons (*Z*)
(a)	*reduced by 2*	*reduced by 2*
(b)	*reduced by 1*	*increased by 1*
(c)	*increased by 1*	*reduced by 1*
(d)	*increased by 1*	*reduced by 1*
(e)	*reduced by 1*	*unchanged*
(f)	*unchanged*	*unchanged*

2.
(a) $^{234}_{90}Th$
(b) $^{14}_{7}N$
(c) $^{11}_{5}B$
(d) $^{55}_{25}Mn$
(e) $^{12}_{4}Be$
(f) ^{99}Tc

3.

	type of decay	change in mass number	change in *N* / *Z*
(a)	α decay	reduced by 4	(small) increase
(b)	β^- decay	no change	reduced
(c)	β^+ decay	no change	increased
(d)	electron capture	no change	increased
(e)	Neutron emission	reduced by 1	reduced
(f)	γ decay	no change	no change

* The masses of an electron and a positron are ≈ 1/1800 that of a proton or neutron.
† The rest mass of a photon is zero

Model 3: Predicting the Mode of Decay

1. $^{75}_{33}$As has N = (75 – 33) = 42 and Z = 33. For this nuclide, N / Z = 1.3.
   $^{66}_{33}$As has N = (66 – 33) = 33 and Z = 33. For this nuclide, N / Z = 1.0.
   After Z = 20, the N / Z ratio needs to exceed 1. The extra neutrons are needed to stabilize the large repulsion between the positively charged protons in the nucleus.

2. β^- decay.

3. β^+ decay or electron capture.

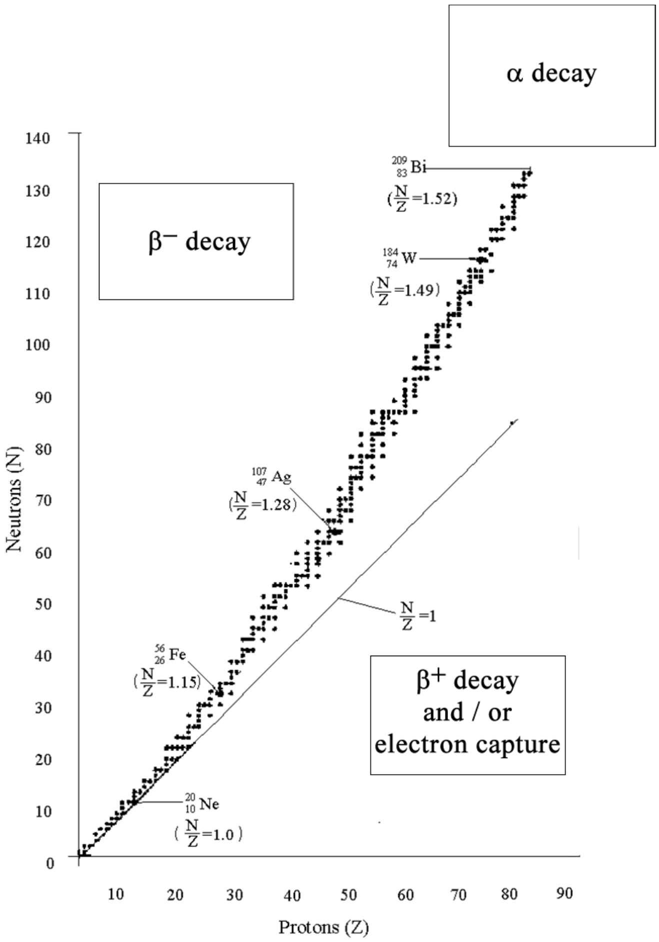
4. α decay.

5. For each of the following radioactive nuclides, calculate their N / Z ratios and hence predict the mode(s) of nuclear decay they are likely to undergo.

   (a) $^{12}_{5}$B has N / Z = 7 / 5 = 1.4. As this ratio is too high for this region, it will probably undergo β^- decay.

   (b) $^{234}_{92}$U has N / Z = 142 / 92 = 1.5. As Z > 83, it is too heavy to lie within the band and will probably undergo α decay to decrease its total mass.

   (c) $^{127}_{57}$La has N / Z = 70 / 57 = 1.2. As this ratio is too low for this region, it will probably undergo either β^+ emission or electron capture (or both).



Model 4: The Rate of Radioactive Decay

The number of radioactive nuclei decaying per unit time is proportional to the number present. If the initial number present is N_0 and the the number remaining at time t is N_t then:

$$\ln\frac{N_t}{N_o} = -\lambda t$$ where λ is the decay constant (units s^{-1}).

Critical thinking questions

1. If $N_t = N_0 / 2$,

$$\ln\frac{N_t}{N_o} = \ln\frac{1}{2} = -\lambda t_{1/2}$$

$t_{1/2} = \ln(2) / \lambda$ or $\lambda = \ln(2) / t_{1/2}$

2. Lucas Heights in Sydney makes many radioactive isotopes for medical applications in Australia and overseas. ^{131}I is used in treating thyroid cancers and in imaging. It has a half life of 8.02 days.

(a) $\lambda = \ln(2) / t_{1/2} = \ln(2) / (8.02 \text{ days}) = 0.0864 \text{ days}^{-1}$

(b) As N_t = 2.0 mg when t = 2.000 days, the amount initially required, N_0, is given by

$$\ln\frac{(2.0 \text{ mg})}{N_o} = -(0.0864 \text{ days}^{-1}) \times (2.000 \text{ days})$$

so

$N_0 = 2.4$ mg

3. If $N_0 = 2.5 \times 10^6$ times the legal limit and N_t = the legal limit:

$$\frac{N_t}{N_o} = \frac{\text{the legal limt}}{2.5 \times 10^6 \times \text{the legal limit}} = \frac{1}{2.5 \times 10^6}$$

$$\ln \frac{1}{2.5 \times 10^6} = -(0.0864 \text{ days}^{-1}) \times t$$

$t = 170$ days