Week 6 Discussion Answers.

1) U-238 is an unstable nuclide that undergoes the following series of decays to become more stable: α, β, β, α, α. Fill in the daughter isotope for each step along the sequence:

Main Decay Sequence: $^{238}_{92}U \rightarrow {}^{234}_{90}Th \rightarrow {}^{234}_{91}Pa \rightarrow {}^{234}_{92}U \rightarrow {}^{230}_{90}Th \rightarrow {}^{226}_{88}Ra$

Other Decay sequence: $+^{4}_{2}\alpha \quad +^{0}_{-1}\beta \quad +^{0}_{-1}\beta \quad +^{4}_{2}\alpha \quad +^{4}_{2}\alpha$

2) Write a nuclear equation for the indicated decay of each nuclide:

a) Alpha decay of Ac-227

$$^{227}_{89}Ac \rightarrow {}^{223}_{87}Fr + {}^{4}_{2}\alpha$$

b) Beta decay of Pb-214

$$^{214}_{82}Pb \rightarrow {}^{214}_{83}Bi + {}^{0}_{-1}\beta$$

c) Gamma decay of Co-51

$$^{51}_{27}Co \rightarrow {}^{51}_{27}Co + \gamma$$

d) Positron emission by F-19

$$^{19}_{9}F \rightarrow {}^{19}_{8}O + {}^{0}_{+1}\beta$$

e) Electron Capture by Cr-63

$$^{63}_{24}Cr + {}^{0}_{-1}e \rightarrow {}^{63}_{23}V$$

3) Imagine that a stable atom of $^{296}_{117}Q$ were discovered. Write a balanced nuclear chemical reaction for one reasonable way that this nuclide of Q could be formed from an element that already exists on the periodic table.

This question was written in 2015, so there might be a lot of answers. The following is reasonable:

$$^{296}_{116}Uuh \rightarrow {}^{0}_{-1}\beta + {}^{296}_{117}Q$$

4) Write a balanced nuclear reaction that represents the most likely first natural decay pathway for each of the following nuclides:

a) The A=22 isotope of the element in period 2 that requires the highest ionization energy.

Ne-22 is neutron rich. So β-decay:

$$^{22}_{10}Ne \rightarrow {}^{0}_{-1}\beta + {}^{22}_{11}Na$$

b) Radon-222

Rn-222 is heavy ⇒ α-decay

$$^{222}_{86}Rn \rightarrow {}^{4}_{2}\alpha + {}^{218}_{84}Po$$

c) A nuclide of the 2nd largest alkaline earth metal that contains 76 neutrons.

Ba-132 is neutron poor. So e^- capture.

$$^{132}_{56}Ba + {}^{0}_{-1}e \rightarrow {}^{132}_{55}Cs.$$

Note: positron emission is NOT a natural form of decay.

5) Radon-222 is unstable, decaying by the following sequence of emissions: α, α, β, β, α, β, β, α. Write the sequence of nuclear reactions leading to the final product nucleus, which is stable.

α: $^{222}_{86}Rn \rightarrow {}^{218}_{84}Po + {}^{4}_{2}He$

α: $^{218}_{84}Po \rightarrow {}^{214}_{82}Pb + {}^{4}_{2}He$

β: $^{214}_{82}Pb \rightarrow {}^{214}_{83}Bi + {}^{0}_{-1}e^- + \bar{\nu}$

β: $^{214}_{83}Bi \rightarrow {}^{214}_{84}Po + {}^{0}_{-1}e^- + \bar{\nu}$

α: $^{214}_{84}Po \rightarrow {}^{210}_{82}Pb + {}^{4}_{2}He$

β: $^{210}_{82}Pb \rightarrow {}^{210}_{83}Bi + {}^{0}_{-1}e^{-} + \bar{\nu}$

β: $^{210}_{83}Bi \rightarrow {}^{210}_{84}Po + {}^{0}_{-1}e^{-} + \bar{\nu}$

α: $^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}He$

(6) Uranium-231 undergoes positron emission.

a) Write the balanced nuclear reaction.

$^{231}_{92}U \rightarrow {}^{231}_{91}Pa + {}^{0}_{1}e^{+} + \nu$

Charged Conserved: $^{231}_{92}U \rightarrow {}^{231}_{91}Pa^{-} + {}^{0}_{1}e^{-} + \nu$

b) Is this process spontaneous? How do you know.

$\Delta m = \left(m\,{}^{231}_{91}Pa + 2m\left({}^{0}_{1}e^{+}\right)\right) - m\left({}^{231}_{92}U\right)$

$= 231.035879\,u + 2(0.0005485799\,u) - 231.036294\,u$

$\Delta m = 0.0006872\,u > 0$

So NOT spontaneous since $\Delta m > 0$.

c) How much energy in MeV does this process either release or require?

$\Delta E = c^2 \Delta m$

$= (6.872 \times 10^{-4}\,u)\left(931.494\,\frac{MeV}{u}\right)$

$= 0.6401\,MeV$

Requires 0.6401 MeV

7) A sample of wood from a Thracian chariot was found in an excavation in Bulgaria. It has a carbon 14 activity of 11.2 disintegrations per minute per gram.

a) Carbon-14 is produced continuously in the atmosphere when cosmic rays of very high energy cause nuclear reactions to produce neutrons. These neutrons can collide with nitrogen-14 to yield carbon-14 + hydrogen. Write the balanced nuclear reaction for this process:

$^{14}_{7}N + {}^{1}_{0}n \rightarrow {}^{14}_{6}C + {}^{1}_{1}H$

b) Organisms get carbon-14 from the atmosphere while simultaneously losing it through β-decay. This equilibrium leads to a fairly constant amount of C-14 in living organisms, and hence a fairly constant C-14 activity. When the organism died, the exchange of carbon with the atmosphere stops, and the activity of carbon-14 decreases as β-decay of C-14 continues. Write the balanced nuclear reaction for the β-decay of C-14.

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e^{-} + \bar{\nu}$$

c) If the activity of C-14 in living materials is 15.3 disintegrations per minute per gram and the half-life of C-14 is 5.73×10^3 years, estimate the age of the Chemist.

$$A = A_i e^{-kt} \qquad \frac{A}{A_i} = e^{-kt} \Rightarrow t = -\frac{1}{k}\ln\left(\frac{A}{A_i}\right)$$

$$k = \frac{\ln 2}{t_{1/2}} \Rightarrow k = \frac{\ln 2}{5.73 \times 10^3 y} = 1.21 \times 10^{-4}\ year^{-1}$$

$$t = -\frac{1}{1.21 \times 10^{-4}\ year^{-1}} \ln\left(\frac{11.2}{15.3}\right) = 2.579 \times 10^3\ years$$

$$= \boxed{2579\ years}$$

d) What year was the Chemist made?

$2022 - 2579 = -557$

year 0 didn't happen

$-557 - 1 = -558$

$\Rightarrow$ $\boxed{558\ BC \text{ or } BCE}$