CHEMISTRY 163
NUCLEAR CHEMISTRY WORKSHEET
SUMMER 2014

1. Supply the missing information in each of the following nuclear equations representing a radioactive decay process.
   a. $^{160}_{74}$W $\rightarrow ^{72}_{?}$Hf + $^{4}_{2}$He
   b. $^{38}_{17}$Cl $\rightarrow ^{38}_{?}$Ar + $^{0}_{-1}$e
   c. $^{214}_{83}$Bi $\rightarrow ^{214}_{84}$Po + $^{0}_{-1}$e
   d. $^{32}_{17}$Cl $\rightarrow ^{32}_{16}$S + $^{0}_{-1}$e

2. Iodine-129 is a product of nuclear fission, whether from an atomic bomb or a nuclear power plant. It is a beta emitter with a half-life of 1.7x10^7 years. How many disintegrations per second would occur in a sample containing 1.00 mg of $^{129}$I?

\[
R = \frac{\text{6.67 x 10}^{-8} \times 1.3 \times 10^{-15}}{6.1 \times 10^3 \text{ d/p}} = \text{6.1 x 10}^{-15} \text{ s}^{-1}
\]

3. What should be the mass ratio $^{208}$Pb/$^{232}$Th in a meteorite that is approximately 2.7x10^9 years old? The half-life of $^{232}$Th is 1.3x10^10 years. $^{232}$Th $\rightarrow ^{208}$Pb + ? Fission reaction

\[
K = \frac{0.693}{1.39 \times 10^{10}} = 4.99 \times 10^{-11} \text{ d/p}
\]

\[
\ln \frac{N_f}{N_0} = -kt = -(4.99 \times 10^{-11} \text{ d/p})(2.7 \times 10^{10})
\]

\[
\frac{N_f}{N_0} = e^{-0.13} = 0.88
\]

4. Calculate the number of neutrons that could be created with 6.75x10^6 MeV of energy.

\[
E = mc^2 = 1.66 \times 10^{-27} \text{Kg}^2
\]

\[
E = 1.66 \times 10^{-27} \text{Kg}^2 \left(2.998 \times 10^8 \text{ m/s} \right)^2 = 1.49 \times 10^{-18} \text{ J}
\]

\[
\frac{1.49 \times 10^{-18}}{1.602 \times 10^{-19}} = 9.30 \times 10^2 \text{ eV}
\]

\[
\text{6.75x10}^6 \text{ MeV} = \frac{2.76 \times 10^5 \text{ neutrons}}{9.30 \times 10^2 \text{ MeV}}
\]
5. Circle the member of the following pairs of nuclides would you expect to be most abundant in natural sources: Explain!
   a. $^{40}_{20}\text{Ca}$ or $^{42}_{20}\text{Ca}$
   b. $^{31}_{15}\text{P}$ or $^{32}_{15}\text{P}$
   c. $^{65}_{30}\text{Zn}$ or $^{64}_{30}\text{Zn}$

6. The measured mass of the nucleus of an atom of silver-107 is 106.879289 amu. For this atom, determine the binding energy per nucleon in megaelectronvolts.

$$
\Delta m = \frac{11.1}{24 \times 12 \times 20 \times 3600} = 6.27 \times 10^{-7} \text{ s}
$$

7. Radioactive copper-64 decays with a half-life of 12.8 days.
   a. What is the value of $k$ in s$^{-1}$?

$$
\frac{\text{BE}}{\text{nucleon}} = \frac{107.8651 - 106.879289}{167 \text{ nucleons}} = 8.58 \text{ MeV amu}^{-1}
$$

b. A sample contains 28.0 mg of $^{64}\text{Cu}$. How many decay events will be produced in the first second? Assume the atomic mass of $^{64}\text{Cu}$ is 64.0 amu.

$$
R = \frac{8.58 \times 10^3 \text{ MeV amu}^{-1}}{1.37 \times 10^{-3}} = 6.27 \times 10^{-12} \text{ decays/s}
$$

c. A chemist obtains a fresh sample of $^{64}\text{Cu}$ and measures its radioactivity. She then determines that to do an experiment, the radioactivity cannot fall below 25% of the initial measured value. How long does she have to do the experiment?

25% $^{64}\text{Cu}$ remains after 2 half-lives

8. The binding energy per nucleon for Mg-27 is $1.326 \times 10^{-12}$ j/nucleon. Calculate the atomic mass of Mg-27.

$$
1.326 \times 10^{-12} \text{ j/nucleon} = -3.580 \times 10^{-11} \text{ j/nucleon}
$$

$$
\Delta m = \frac{-3.580 \times 10^{-11} \text{ j/nucleon}}{1.6605 \times 10^{-27} \text{ kg/nucleon}} = -0.2399 \text{ amu}
$$

$$
x = \text{ mass Mg-27 nucleus (12 P + 15 N)} = x - \left[ 2 \left( 1.0078 \text{ amu} + 15 \left( 1.0086 \text{ amu} \right) \right) \right]
$$

$$
\text{at mass } = \frac{x}{(12 \text{ mg} + 15 \text{ Mn})} = x - \left[ 2 \left( 1.0078 \text{ amu} + 15 \left( 1.0086 \text{ amu} \right) \right) \right]
$$

$$
\text{x = mass Mg-27 nucleus at mass } = \frac{26.9764 + 12(5.9949)}{17.0033}
$$