Chapter 30: Questions

(1) 12 points  **What do different isotopes of a given element have in common? How are they different?**

Different isotopes of a given element have the same number of protons and electrons. Because they have the same number of electrons, they have almost identical chemical properties. Each isotope has a different number of neutrons from other isotopes of the same element. Accordingly, they have different atomic masses.

(5) 10 points  **Why are the atomic masses of many elements (see the periodic table) not close to whole numbers?**

The atomic mass of an element as shown in the periodic table is the average atomic mass of all naturally-occurring isotopes. Other smaller effects include the fact that the masses of the nucleons are not exactly 1 atomic mass unit, and that some small fraction of the mass energy of the total set of nucleons is in the form of binding energy.

(11) 12 points  **Describe, in as many ways as you can, the difference between α, β, and γ rays.**

Alpha rays are made up of helium nuclei, are the most massive of the three particles, and have a charge of +2e. Beta rays are made up of electrons or positrons, are either positively or negatively charged, and are accompanied by either a neutrino or an anti-neutrino upon decay. Gamma rays are neutrally charged, are made up of high energy photons, and have no mass.

(17) 12 points  **The alpha particles from a given alpha-emitting nuclide are generally monoenergetic; that is, they all have the same kinetic energy. But the beta particles from a beta-emitting nuclide have a spectrum of energies. Explain the difference between these two cases.**

In alpha decay, assuming the energy of the parent nucleus is known, then the unknowns after the decay are the energies of the daughter nucleus and the alpha particle. These two values can be uniquely determined by energy and momentum conservation (two equations; two unknowns). In beta decay, however, there are three unknown post-decay energies since there are three particles present after the decay. The conditions of energy and momentum conservation are not sufficient to uniquely determine the energy of each particle, and so a range of values is possible.

Chapter 30: Problems

(10) 12 points  **(I) Use Fig. 30-1 to estimate the total binding energy of (a) \( ^{238}_{92} \text{U} \), and (b) \( ^{84}_{36} \text{Kr} \).**

(a) From Figure 30-1, we see that the average binding energy per nucleon at \( A = 238 \) is 7.5 MeV. Thus, the total binding energy for \( ^{238}_{92} \text{U} \) is

\[
(238)(7.5 \text{ MeV}) = 1.8 \times 10^3 \text{ MeV}.
\]

(b) From Figure 30-1, we see that the average binding energy per nucleon at \( A = 84 \) is 8.7 MeV. Thus, the total binding energy for \( ^{84}_{36} \text{Kr} \) is

\[
(84)(8.7 \text{ MeV}) = 730 \times 10^3 \text{ MeV}.
\]
(16) 20 points (III) How much energy is required to remove (a) a proton, (b) a neutron, from $^{16}\text{O}$? Explain the difference in your answers.

We find the required energy for separation from the masses.

(a) Removal of a proton creates an isotope of nitrogen:

$$E = (m^{(15}\text{N}) + m^{(1}\text{H}) - m^{(16}\text{O})]c^2$$

$$= [(15.000108u) + (1.007825u) - (15.994915u)]c^2(931.5 \text{ MeV}/uc^2) = 12.1 \text{ MeV}.$$  

(b) Removal of a neutron creates another isotope of oxygen:

$$E = (m^{(15}\text{O}) + m^{(1}\text{n}) - m^{(16}\text{O})]c^2$$

$$= [(15.003065u) + (1.008665u) - (15.994915u)]c^2(931.5 \text{ MeV}/uc^2) = 15.7 \text{ MeV}.$$  

The nucleons are held by the attractive nuclear force. It takes less energy to remove the proton because there is also the repulsive electric force from the other protons.

(26) 12 points (II) What is the maximum KE of the emitted $\beta$ particle during the decay of $^{60}\text{Co}$?

The reaction is $^{60}\text{Co} \rightarrow ^{60}\text{Ni} + \beta^- + \nu$. Ignoring the mass of the $\beta$ particle and the neutrino, the maximum kinetic energy of the $\beta$ particle is

$$K_{\text{max}} = (m^{(60}\text{Co}) - m^{(60}\text{Ni})]c^2 = [(59.933822u) - (59.930791u)]c^2(931.5 \text{ MeV}/uc^2) = 2.82 \text{ MeV}.$$  

(40) 10 points (I) What fraction of a sample is left after exactly 6 half-lives?

The fraction left is

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^6 = 0.015625.$$