Chem I

Notes: Radioactivity and the Atomic Nucleus

I. Radioactivity is the spontaneous decay of an atomic nucleus. The result is one or more smaller nuclei and one or more of the following radioactive rays:

1) Alpha particles (αparticles)
   - made of two protons and two neutrons
   - identical to the nucleus of a helium atom
   - each has a +2 charge
   - symbol is $^{4}_{2}\mathrm{He}$

2) Beta particles (β particles)
   - is just a fast moving electron
   - each has a -1 charge
   - they come from the nucleus!
     a. a neutron is actually a proton and an electron stuck together
     b. when a beta particle leaves a nucleus, a neutron turns into a proton
   - symbol is $^{-1}_{0}\mathrm{e}$

3) Gamma rays (γ rays)
   - high energy electromagnetic radiation (note: light rays and x-rays are slower forms of electromagnetic radiation)
   - each has a neutral charge
   - symbol is γ

II. Radiation Penetrating Power:

1) Alpha particles can be stopped by a few sheets of paper.

   i. Why? It's big, relatively slow, and its double positive charge interacts with the nuclei and electrons in its path. It leaves behind a lot of ions (positive or negatively charged ions) in its path. Even in air it stops after a couple of centimeters, grabbing a couple of electrons and turning into a harmless helium atom.

2) Beta particles can be stopped by a sheet of aluminum foil.

   i. Why? It's faster than an alpha particle, but loses its energy easily when it interacts with the electrons of the atoms in its path. When it slows down it just joins the atoms it is near.

3) Gamma rays can be stopped by a thick layer of lead.

   i. Why? It has no charge, so it's the most penetrating of the three. It takes a direct hit with a nucleus or an electron to stop it.

III. What keeps the nucleus together in the first place?

1. There are two main forces at work in the nucleus:
   a. the nuclear force (aka the strong force)
      - it's a strong force that attracts protons and neutrons to each other
      - it only works over very small distances (they have to be almost touching in order for it to work)

   b. the electrical force
      - it's a strong force that's due to the electrical repulsion of the positively charged protons in the nucleus
      - it's effective over much greater distances than the nuclear force.

   c. The result?
      - If you just have two protons, the nuclear force tries to keep them together but can't quite overcome the electrical force
      - Add in a couple of neutrons: the nuclear force is now strong enough to overcome the electrical force
      - Neutrons keep protons from flying apart!

   d. The more protons there are in a nucleus the more neutrons you need to hold them together. Why? Because the bigger the nucleus gets the farther apart the protons are. When they're far apart the electrical force is still doing its repulsion thing, but the nuclear force can't compete as well because of the increased distance. So the nucleus needs more neutrons to keep it all together.

IV. Examples of Radioactive Decay

1. Alpha decay:

$$^{226}_{88}\text{Ra} \text{ --> } ^{222}_{86}\text{Rn} + ^{4}_{2}\text{He}$$

Notice that the numbers on the top are equal on each side of the arrow and the numbers on the bottom are equal on each side of the arrow.

2. Beta Decay:

$$^{14}_{6}\text{C} \text{ --> } ^{14}_{7}\text{N} + ^{0}_{-1}\text{e} + \text{a neutrino}$$

A neutrino is a tiny neutral massless particle that's the subject of all kinds of physics research. We won't deal with it here, but I wanted to let you know they exist.

3. Gamma Decay: Since gamma rays are really just pure energy (not particles), there really aren't any equations that show what's happening. Gamma decay just happens when excited atoms readjust themselves down to a more relaxed energy level.