Nuclear Chemistry

- Think of the forces that you know about already in chemistry …
- We all know about gravity and of course electrical forces can hold one atom to another
- Think about the nucleus of an atom. What is it made of? Protons and neutrons.
- How can the protons stay clumped together if they all have a + charge?
- The answer lies in the strong nuclear force. It is stronger than gravity or electrical force.
- When you split apart the nucleus you release this powerful force
- The energy required to separate nucleons (protons and neutrons) is called the binding energy

Nuclear Chemistry

- Some atoms are not stable, that is, they can spontaneously decay. We call these atoms radioactive.
- Most elements in their common form are not radioactive, however many isotopes exist of common elements that are radioactive. Even common elements like potassium and iron have radioactive isotopes. There are about 1500 different isotopes of all elements, of which only 250 are NOT radioactive.
- Polonium and higher are all radioactive
- A Geiger counter detects alpha, beta, gamma, and x-rays

Half Life

- Radioactive decay rates are constant.
- The way we look at the decay rates is in terms of half life -- the time it takes for half of a sample to decay
- See your textbook for some half-lives
- We'll talk more about radiocarbon dating later and do a lab on half lives

Atomic Structure Review

- Atomic number is the lower left-hand number
- Mass number is the upper left-hand number
- Example: Carbon-14 has 6 protons and 8 neutrons: $^{14}_{6}\mathrm{C}$
- Electron Proton Neutron

$^{0}_{-1}\mathrm{e}$ $^{1}_{1}\mathrm{p}$ $^{1}_{0}\mathrm{n}$

Nuclear Particles and Reactions

Alpha particle (α) emission: an alpha particle is really a helium nucleus. Because of its size it does not travel fast or far.

$$^{241}_{95}\mathrm{Am} \rightarrow ^{237}_{93}\mathrm{Np} + ^{4}_{2}\mathrm{He}^{+2}$$

^{241}Am is used in smoke detectors -- it ionizes the air and a sensor can tell when smoke interrupts the flow. The alpha particles can't get out of the plastic smoke detector case.

Nuclear Particles and Reactions

Beta (β) particle emission: a beta particle is a high energy electron. 100 times more penetrating ability than alpha particles. Can be stopped by several layers of aluminum foil. (You can also use the β symbol instead of the electron)

$$^{131}_{53}\mathrm{I} \rightarrow ^{131}_{54}\mathrm{Xe} + ^{0}_{-1}\mathrm{e}^{-}$$

(note that a neutron becomes a proton in the process)

Nuclear Particles and Reactions

Gamma (γ) rays: high energy electromagnetic radiation (higher than X rays!). Most dangerous type of radioactive emission. Look at how gamma (γ) rays are produced for the following decay of cobalt-60 which is used in cancer treatment.

$$^{60}_{27}\mathrm{Co} \rightarrow ^{60}_{28}\mathrm{Ni} + ^{0}_{-1}\mathrm{e}^{-} + \gamma$$

(note that gamma rays are accompanied by beta emission)

Nuclear Particles and Reactions

Positron emission: A positron is a particle with the same size and mass as an electron, but with a positive charge.

$$^{207}_{84}\mathrm{Po} \rightarrow ^{0}_{+1}\mathrm{e} + ^{207}_{83}\mathrm{Bi}$$

Nuclear Particles and Reactions

Electron capture: An electron is captured to turn a proton into a neutron

$$^{7}_{4}\mathrm{Be} + {}^{0}_{-1}\mathrm{e} \rightarrow {}^{7}_{3}\mathrm{Li}$$

Animation at http://www2.wwnorton.com/college/chemistry/gilbert/tutorials/ch2.htm

Radioactive Dating

- Radiocarbon dating is useful only for dating formerly living things
- While an organism is alive it takes in carbon -- most of it as carbon-12 but a small % is carbon-14 (a radioactive form of carbon).
- Carbon-14 is formed in the atmosphere by the following process (helped along by cosmic rays)

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

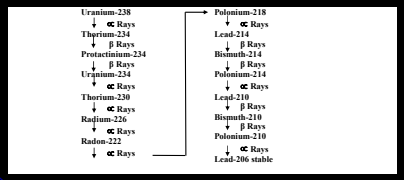
Radioactive Dating

- As soon as the organism dies, it stops taking in carbon. The amount of carbon 12 stays the same over time, but the amount of carbon 14 decreases as it decays.
- Carbon-14 has a half life of 5715 years. It decays by the following process:

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

- Geologists and archeologists can use the ratio of carbon-12 to carbon-14 to determine how old an object is

As atoms decay, they give up radiation and produce various unstable elements on their way to producing a stable element. Uranium-238 goes through 14 transformations on its way to becoming Lead-206.



The uranium decay chain