A Summary of Atoms, Radioactive Decay, and Neutron Activation

The Atom: An atom has electrons, protons, and usually neutrons (the main exception is hydrogen). The nucleus of an atom contains the protons and neutrons. Electrons form a diffuse cloud surrounding the atom.

Stable and Unstable Atoms: In a stable atomic nucleus, the number of protons and neutrons remains constant. On the other hand, some nuclei spontaneously change their number of protons and/or neutrons. These nuclei are unstable, are radioactive* and decay.

* Some radioactive atoms change how much energy is contained in the nucleus. These atoms are also radioactive even though the number of protons and neutrons remains constant.

Radioactive Decay: There are three common types of radioactive decay. They are *alpha (α), beta (β)* and *gamma (γ)*. Alpha (α) decay is the ejection of an alpha particle (which is a nucleus of two protons and two neutrons). Beta (β) decay is the ejection of a beta particle (which is an electron). An electron is emitted when a neutron is decays into a proton (n $\Rightarrow$ p + e). Gamma (γ) radiation is the emission of a photon when an excited nuclei decays to its ground state.

Radioactive decay can be modeled by the following equation: $N = N_0 e^{-\lambda t}$, where N_0 is the initial number of radioactive atoms, N is the remaining number of radioactive atoms after a time t has elapsed, and λ is the decay constant. The decay constant, λ, is related to the half-life time, $t_{1/2}$, by $\lambda = \dfrac{0.693}{t_{1/2}}$.

Notation for an Atom: The complete description of all aspects of a given isotope is given by the symbols ${}^{A}_{Z}X$ where X stands for the chemical symbol of the element. Z is called the *atomic number* and is the number of protons. A is called the *atomic mass number* and it is equal to the sum of the number of protons plus the number of neutrons. As an example, the symbol ${}^{226}_{88}\mathrm{Ra}$ stands for the isotope of radium with 88 protons and 138 neutrons since 88 + 138 = 226. Other isotopes of radium must have 88 protons but can have different numbers of neutrons. This atomic isotope may also be typed as "radium-226" or "Ra-226".

Neutron Activation: In these experiments we use a neutron source to create radioactive isotopes of indium, silver, copper, and aluminum. The source contains highly radioactive plutonium-239 (^{239}Pu or Pu-239) covered with beryllium to produce neutrons. The sample elements are then placed next to the source and are bombarded with neutrons. The neutrons are produced through the following reactions:

$$ {}^{239}_{94}Pu \rightarrow {}^{235}_{92}U + {}^{4}_{2}He $$

$$ {}^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{1}_{0}n + {}^{12}_{6}C $$

Helium-4 (without the electrons) is an alpha particle. The alpha particles produced in the first reaction are used in the second reaction to produce the neutrons. These neutrons have very high initial energies, and may be absorbed by the sample atom's nucleus.