11.1: Radioactivity

The actual discovery of radioactivity is generally attributed to the French scientist, Henri Becquerel in 1896. As with most discoveries, he was working on something else. In this case it was the nature of phosphorescence; the property of some substances to "glow in the dark" after being exposed to light. In the course of his work, he allowed photographic plates to come in contact with uranium salts, only to find out that the uranium had "fogged" the unexposed plates. Further work by Becquerel and others (including Marie Curie) led to the realization that certain elements spontaneously produced a variety of particles, some of which were charged (both positive and negative) and one class that was of higher energy, but appeared to be neutral. The three basic classes of particles were characterized and identified as "alpha", "beta", and "gamma" particles. Alpha particles were positive, relatively massive and, subsequent work showed that they were identical to the nucleus of the helium atom, containing two protons and two neutrons. Beta particles had a very small mass. They were of higher energy and they carried a negative charge; equivalent in mass and charge to an electron. Gamma particles (actually referred to as gamma rays) were much more energetic, appeared to be neutral and were comparable to a high-energy photon of light. Although it was not apparent immediately, one of the most surprising observations regarding radioactive elements was that as they emitted particles, the identity of the element slowly changed; uranium, for example, slowly became enriched with lead.

When alpha, beta or gamma particles collides with a target, some of the energy in the particle is transferred to the target, typically resulting in the promotion of an electron to an "excited state". In many "targets", especially gasses, this results in *ionization*, and alpha, beta and gamma radiation is broadly referred to as **ionizing radiation**. A **Geiger counter** (or Geiger-Müller counter) takes advantage of this in order to detect these particles. In a Geiger tube, the electron produced by ionization of a captive gas travels to the anode and the change in voltage is detected by the attached circuitry. Most counters of this type are designed to emit an audible "click" in response to the change in voltage, and to also show it on a digital or analog meter.

Today, we recognize that radioactive decay is actually quite complex, but the basic principles and patterns that were established over 100 years ago still stand. The three basic subatomic particles that occur in radioactive decay are the alpha particle, the beta particle and the gamma ray. The gamma ray is of highest energy (and perhaps the greatest ultimate danger), but from a chemistry standpoint, the alpha and beta particles are of the greatest interest. An alpha particle consists of two protons and two neutrons. It has a mass of four amu and a charge of +2. It is identical with the helium nucleus, and when a radioactive element emits an alpha particle, it loses four amu from its nucleus, including two protons. Because the number of protons in a nucleus define the identity of the element, the atomic number of the element decreases by two when it loses an alpha particle; thus uranium ($^{238}_{92}\mathrm{U}$) loses an alpha particle and becomes an atom of thorium ($^{234}_{90}\mathrm{Th}$); we will discuss this process further in the following section. In order for a beta particle (an electron) to emerge from the nucleus, it must be formed by the decomposition of a neutron (on a very simple scale, think of a neutron as being composed of a positive proton bound to a negative electron). When a neutron decays and emits a beta particle, it leaves behind the newly formed proton. Again, this changes the identity of the element in question.