19.6: Neutron Bombardment

Since a neutron has no charge, it is not electrostatically repelled by the nucleus it is bombarding. Because of this, neutrons do not need to be accelerated to high energies before they can undergo a nuclear reaction. Nuclear reactions involving neutrons are thus easier and cheaper to perform than those requiring positively charged particles.

Though neutron-bombardment reactions are often carried out in a nuclear reactor (which will be described later), they can also be very conveniently performed in a small laboratory using a *neutron source*. Usually a neutron source consists of an α emitter such as $^{222}_{86}\mathrm{Rn}$ mixed with Be, an element whose nuclei produce neutrons when bombarded by α particles:

$$^{9}_{4}\mathrm{Be} + ^{4}_{2}\mathrm{He} \rightarrow ^{12}_{6}\mathrm{C} + ^{1}_{0}\mathrm{n} \tag{19.6.1}$$

This reaction was originally used in 1932 by Sir James Chadwick (1891 to 1974) to demonstrate the existence of the neutron. (Previous to this it was believed that electrons were present in the nucleus together with protons.) The neutrons produced by Equation 19.6.1 have a very high energy and are called **fast neutrons**. For many purposes the neutrons are more useful if they are first slowed down or **moderated** by passing them through paraffin wax or some other substance containing light nuclei in which they can dissipate most of their energy by collision. The **slow neutrons** produced by a moderator are then able to participate in a larger number of **neutron-capture reactions** of which the following two are typical:

$$^{34}_{16}\mathrm{S} + ^{1}_{0}n \rightarrow ^{35}_{16}\mathrm{S} + \gamma \tag{19.6.2}$$

$$^{200}_{80}\mathrm{Hg} + ^{1}_{0}n \rightarrow ^{201}_{80}\mathrm{Hg} + \gamma \tag{19.6.3}$$

In such a reaction a different isotope (often an unstable isotope) of the element being bombarded is produced, with the emission of a γ ray. Radioactive isotopes of virtually all the elements can be produced in this way.

An important neutron-capture reaction is that undergone by the most common isotope of uranium, namely, $^{238}\mathrm{U}$:

$$^{238}_{92}\mathrm{U} + ^{1}_{0}n \rightarrow ^{239}_{92}\mathrm{U} + \gamma \tag{19.6.4}$$

The uranium-239 produced in this way decays by β emission to produce the first and most important of the transuranium elements, namely, neptunium:

$$^{239}_{92}\mathrm{U} \rightarrow ^{239}_{93}\mathrm{N} + ^{0}_{-1}e \tag{19.6.5}$$

When nuclei are bombarded by fast neutrons, a secondary particle is emitted—usually a proton or an α particle:

$$^{11}_{5}\mathrm{B} + ^{1}_{0}n \rightarrow ^{11}_{4}\mathrm{Be} + ^{1}_{1}\mathrm{H} \tag{19.6.6}$$

$$^{27}_{13}\mathrm{Al} + ^{1}_{0}n \rightarrow ^{24}_{11}\mathrm{Na} + ^{4}_{2}\mathrm{He} \tag{19.6.7}$$

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