8.7: Making radioisotopes for medical uses

Natural radioisotopes usually have a long half-life and are not best suited for medical applications. The medical application usually requires short-lived radioisotopes. The radioisotopes are usually produced in nuclear reactors where particles, like α-particles, β-particles, and neutrons, are abundant. Particle accelerators, such as the one shown in Fig. 8.7.1 also accelerate and direct the nuclear particles at the targets. The high-energy nuclear particles may be absorbed by and transmute the target nuclei to radioisotopes in a nuclear reaction.

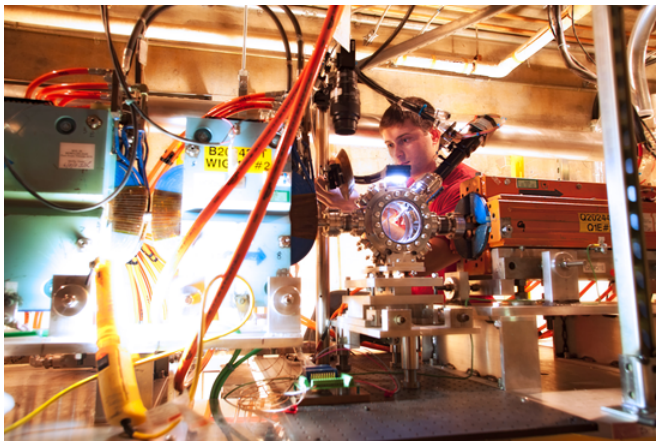

Figure 8.7.1: SLAC's particle accelerator may be two miles long, but researchers at FACET are working to develop more compact versions that could be widely used in medicine and industry -- particle accelerators are used for cancer research, processing computer chips, and even producing the shrink wrap used to keep your Thanksgiving turkey fresh. Source: ENERGY.GOV / Public domain

Radioisotopes in medical applications are usually produced by the particle bombardment method. One reaction that happens naturally by neutron bombardment from cosmic rays on nitrogen-14 is the following.

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

An example of an artificial nuclear reaction initiated by α-particle bombardment on nitrogen, observed by Rutherford that lead to the discovery of proton, is illustrated in Fig. 8.7.2.

$$^{4}_{2}\mathrm{He} + ^{14}_{7}\mathrm{N} \longrightarrow ^{17}_{8}\mathrm{O} + ^{1}_{1}\mathrm{p}$$

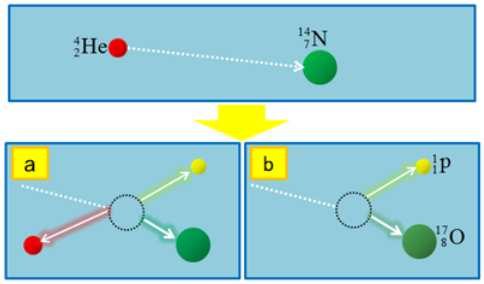

Figure 8.7.2: A nuclear reaction observed by Rutherford using a cloud chamber. When an alpha ray strikes nitrogen, reaction "a" (proton knock-off) does not occur; reaction "b" (α-p) occurs.). Source: アリオト / Public domain

Another example is the nuclear reaction initiated by α-particles on beryllium, observed by James Chadwick, which lead to the discovery of the neutron.

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

An example of radioisotope production for medical uses is the following. Gold-198, used as a tracer in the liver, is produced by neutron bombardment on gold-197.

$$^{197}_{79}\mathrm{Au} + ^{1}_{0}\mathrm{n} \longrightarrow ^{198}_{79}\mathrm{Au}$$

Similarly, gallium-67 used in medical diagnostics is produced by proton bombardment on zinc-66.

$$^{66}_{30}\mathrm{Zn} + ^{1}_{1}\mathrm{p} \longrightarrow ^{67}_{31}\mathrm{Ga}$$

Molybdenum-99 is a radioactive isotope produced in a nuclear reactor by neutron bombardment of molybdenum-98.

$$^{98}_{42}\mathrm{Mo} + ^{1}_{0}\mathrm{n} \longrightarrow ^{99}_{42}\mathrm{Mo} + \gamma$$

Molybdenum-99 is also produced as a fission product of uranium-235. Molybdenum-99 decays to technetium-99m that has several uses in nuclear medical imaging and treatment.

$$^{99}_{42}\mathrm{Mo} \longrightarrow ^{99\,\mathrm{m}}_{43}\mathrm{Tc} + ^{0}_{-1}\mathrm{e}$$

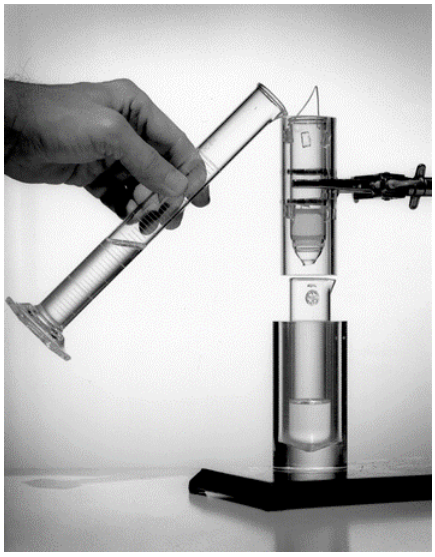

Figure 8.7.1: The first technetium-99m generator developed at Brookhaven National Laboratory, circa 1958, shown without shielding. A Tc-99m pertechnetate solution is being eluted from Mo-99 molybdate bound to a chromatographic substrate. Source: Brookhaven National Laboratory. / Public domain

Technetium-99m is short-lived (half-life 6 h), and needs to be produced in the hospital to minimize its decay during the transport. Its parent molybdenum-99 has a half-life of 66h and can be transported without significant decay during the transport. Molybdenum-99/technetium-99m generators are supplied to the hospitals in a shielded container. Fig. 8.7.3 illustrates the first Molybdenum-99/technetium-99m generator developed at Brookhaven National Laboratory. Molybdate (MoO_4^{2}) ion is adsorbed onto alumina adsorbent in a column. When molybdenum-99 decays to technetium-99m, the ion change to pertechnetate (TcO_4^{-}), which is less tightly bound to the alumina. Pouring a saline solution through the column elutes the technetium-99m as TcO_4^{-} ion, which is then used for medical purposes in the hospitals.

Destruction of an inoperable tumor has also been tested by α-emission from boron-10 upon neutron bombardment.

$$^{1}_{0}\mathrm{n} + ^{10}_{5}\mathrm{B} \longrightarrow ^{7}_{4}\mathrm{Li} + ^{4}_{2}\mathrm{He}$$
