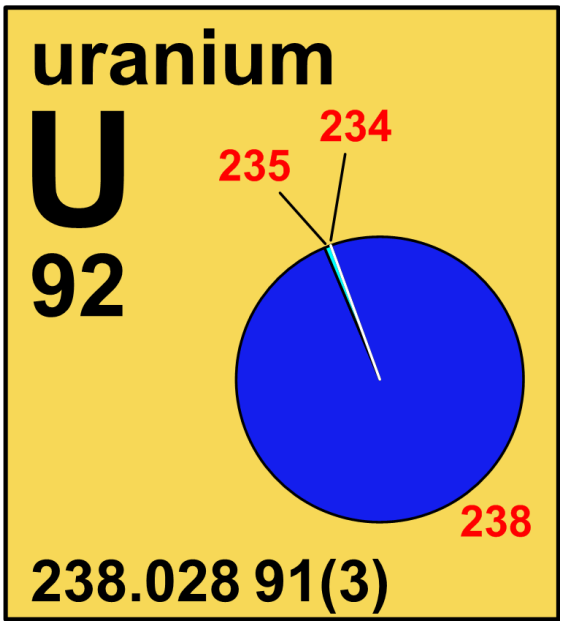
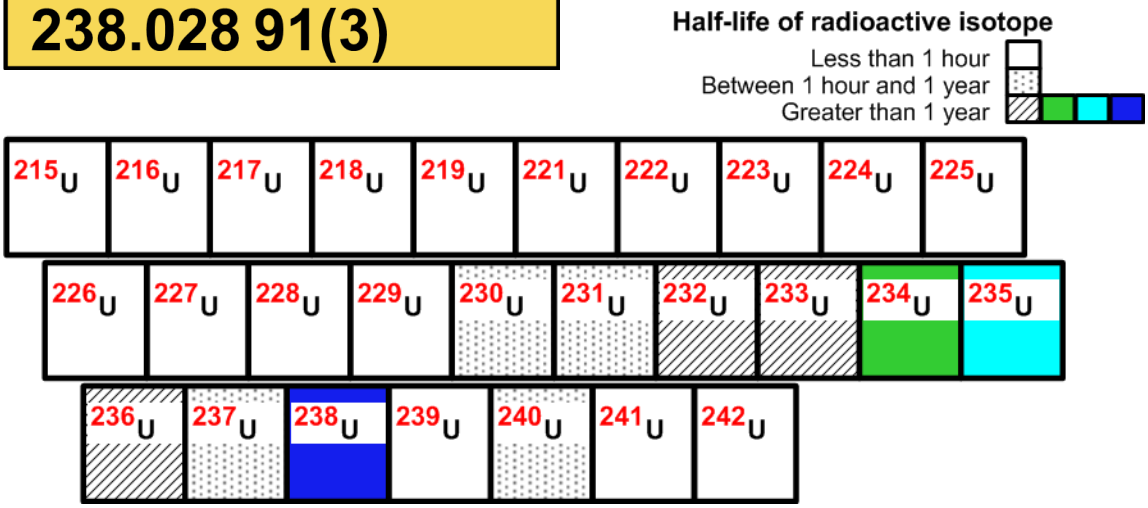
4.92 uranium



Stable isotope	Relative atomic mass	Mole fraction
$^{234}U^{\dagger}$	234.040 95	0.000 054
$^{235}U^{\dagger}$	235.043 93	0.007 204
$^{238}U^{\dagger}$	238.050 79	0.992 742

† **Radioactive isotope** having a relatively long **half-life** and a characteristic terrestrial **isotopic composition** that contributes significantly and reproducibly to the determination of the **standard atomic weight** of the **element** in **normal materials**. The half-lives of ^{234}U, ^{235}U, and ^{238}U are 2.453×10^5 years, 7.03×10^8 years, and 4.47×10^9 years, respectively.



4.92.1 Uranium isotopes in Earth/planetary science

^{234}U is a **daughter product** of ^{238}U and makes up only 0.0054 percent of the total uranium today. During the decay of the **parent radionuclide** ^{238}U nucleus (first to ^{234}Th by **alpha decay**, then to ^{234}Pa by beta-minus, and finally to ^{234}U by beta-minus), the energy released will damage the chemical and physical bonds holding the ^{234}U product nuclei in a mineral. As a result, ^{234}U may be leached more easily from water or rock samples than ^{238}U, and the **isotope-amount ratio** $n(^{234}U)/n(^{238}U)$ will vary depending on the extent of water-rock interaction [595].

4.92.2 Uranium isotopes in geochronology

The three natural **radioactive decay** chains beginning with ^{238}U, ^{235}U, and ^{232}Th each have comparable **half-lives** that are much longer than the **radioactive isotopes** that follow until the production of **stable isotopes** of ^{206}Pb, ^{207}Pb, and ^{208}Pb, respectively. When undisturbed, the activities of daughter **isotopes** in each decay chain are equal to their parents and one can measure the accumulation of the stable isotopes of lead to date the time that has elapsed since a mineral became a closed system (a system that does not exchange matter with its surroundings). The half-life of ^{238}U is 4.47×10^6 years, and the half-life of ^{234}U is 2.453×10^5 years. Rocks formed hundreds of millions to billions of years ago can be dated using this technique [588]. If a mineral is disturbed at some point during the decay and isotopes in the decay chain are preferentially removed from the system, the equilibria in a decay sequence will be disturbed. For example, one can measure the excess of ^{230}Th relative to the ^{234}U parent radionuclide to date carbonates (speleothems or corals) that are less than 5×10^5 years old [588].

4.92.3 Uranium isotopes in industry

Nuclei of ^{235}U are split when bombarded by **thermal neutrons**. The process is known as nuclear **fission** and can release tremendous amounts of energy per uranium nucleus. The nucleus that splits will release additional **neutrons** that, if slowed down sufficiently, can cause subsequent fission events. When properly controlled, ^{235}U fission can be used to generate heat to drive steam turbines, which in turn produces electricity (Figure 4.92.1). If the fission process is not controlled, then a rapid and explosive release of energy will occur similar to that of nuclear weapons [596]. Uranium depleted in ^{235}U by fission in nuclear reactors (and hence greatly enriched in ^{238}U compared to “natural” uranium) is used in the manufacture of DUCRETE concrete (Figure 4.92.2). The incorporation of the large ^{238}U nuclei makes this material an effective absorber of neutrons and **gamma rays**, and DUCRETE concrete is used to reduce fluxes of neutrons and high-energy **photons**. The **alpha particles** produced by the decay of ^{238}U are effectively absorbed by the concrete and do not pose a health risk. DUCRETE is being proposed as a suitable material for the storage of radioactive waste [597, 598].

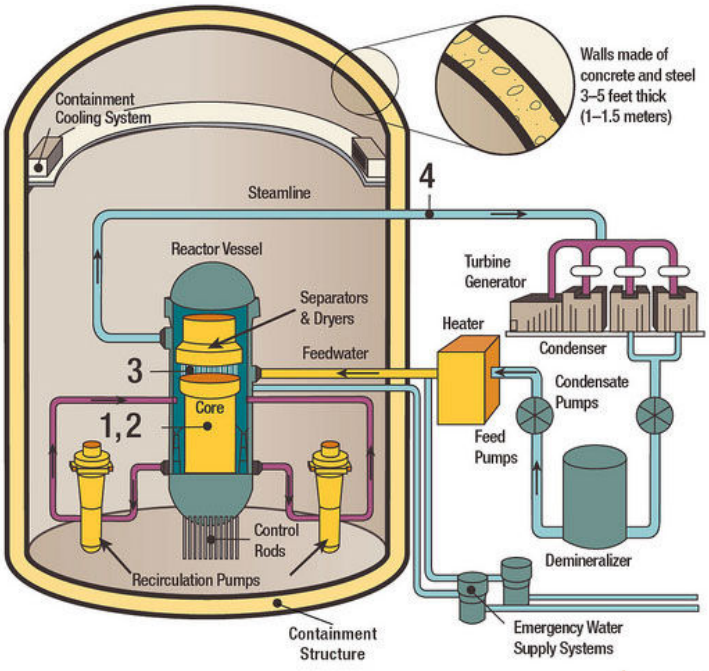


Fig. 4.92.1: Boiling water reactor fuel can be ^{235}U enriched as uranium dioxide, which would be located in the core and is identified as "Core". (Diagram Source: U.S. Nuclear Regulatory Commission) [599].

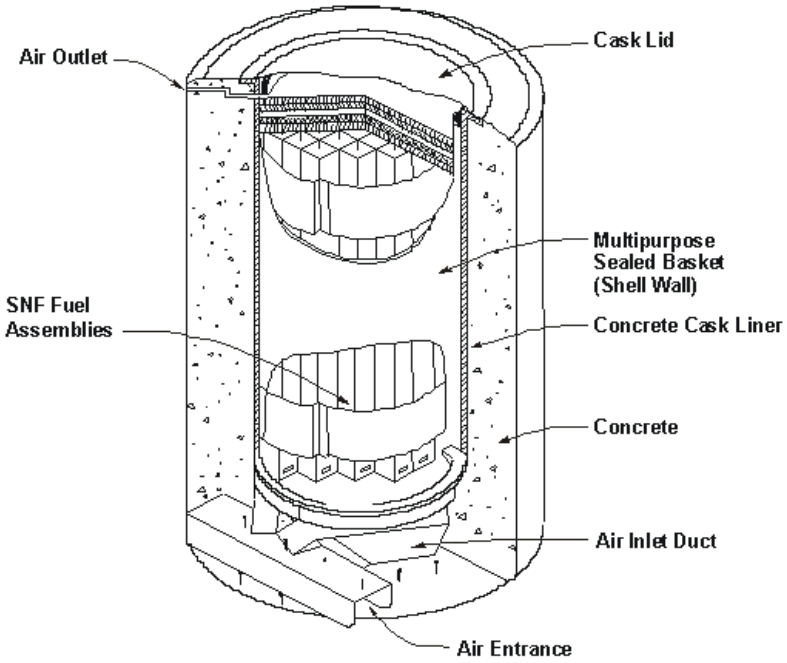


Fig. 4.92.2: DUCRETE cask diagram. DUCRETE is being proposed as a suitable material for the storage of radioactive waste. (Diagram Source: Argonne National Laboratory) [598].