Uranium

Symbol:	**U**
Atomic Number: *(protons in nucleus)*	**92**
Atomic Weight: *(naturally occurring)*	**238**

What Is It? Uranium is a radioactive element that occurs naturally in low concentrations (a few parts per million, ppm) in soil, rock, surface water, and groundwater. It is the heaviest naturally occurring element, with an atomic number of 92. Uranium in its pure form is a silver-colored heavy metal that is nearly twice as dense as lead. In nature, uranium exists as several isotopes: primarily uranium-238, uranium-235, and a very small amount of uranium-234. (Isotopes are different forms of an element that have the same number of protons in the nucleus but a different number of neutrons.) In a typical sample of natural uranium, almost all the mass (99.27%) consists of atoms of uranium-238. Less than 1% (about 0.72%) of the mass consists of atoms of uranium-235, and a very small amount (0.0055% by mass) is uranium-234.

Uranium decays very slowly by emitting an alpha particle. The half-life of uranium-238 is 4.5 billion years, which means it is not very radioactive as indicated by its low specific activity. The very long half-lives of these isotopes are the reason why uranium still exists on earth. Three additional isotopes (uranium-232, uranium-233, and uranium-236) are not naturally present but can be produced by nuclear transformations. These three isotopes also decay by emitting an alpha particle.

Radioactive Properties of Key Uranium Isotopes and Associated Radionuclides

Isotope	Half-Life	Natural Abundance (%)	Specific Activity (Ci/g)	Decay Mode	Radiation Energy (MeV)		
					Alpha (α)	Beta (β)	Gamma (γ)
U-232	72 yr	0	22	α	5.3	0.017	0.0022
U-233	160,000 yr	0	0.0098	α	4.8	0.0061	0.0013
U-234	240,000 yr	0.0055	0.0063	α	4.8	0.013	0.0017
U-235	700 million yr	0.72	0.0000022	α	4.4	0.049	0.16
Th-231	*26 hr*		*540,000*	β	-	*0.17*	*0.026*
U-236	23 million yr	0	0.000065	α	4.5	0.011	0.0016
U-238	4.5 billion yr	>99	0.00000034	α	4.2	0.010	0.0014
Th-234	*24 days*		*23,000*	β	-	*0.060*	*0.0093*
Pa-234m	*1.2 min*		*690 million*	β	-	*0.82*	*0.012*

Ci = curie, g = gram, and MeV = million electron volts; a dash means the entry is not applicable. (See the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients for an explanation of terms and interpretation of radiation energies.) Properties of thorium-231, thorium-234, and protactinium-234m are included here because these radionuclides accompany the uranium decays. Values are given to two significant figures.

Where Does It Come From? While small amounts of natural uranium are found almost everywhere in soil, rock, and water, uranium ores are found in just a few places – usually in hard rock or sandstone, in deposits normally covered with earth and vegetation. Uranium has been mined in the southwest United States, Canada, Australia, parts of Europe, the former Soviet Union, Namibia, South Africa, Niger, and elsewhere. It is a contaminant at many U.S. Department of Energy sites (including Hanford) and other facilities that used natural uranium, including mining, milling, and production facilities.

How Is It Used? For many years, uranium was used to color ceramic glazes, producing colors that ranged from orange-red to lemon yellow. It was also used for tinting in early photography. The radioactive properties of uranium were not recognized until 1896, and its potential for use as an energy source was not realized until the middle of the 20th century. In nuclear reactors, uranium serves as both a source of neutrons (via the fission process) and a target material for producing plutonium. (Plutonium-239 is produced when uranium-238 absorbs a neutron.) Today, its primary use is as fuel in nuclear power reactors to generate electricity. Uranium is also used in small nuclear reactors to produce isotopes for medical and industrial purposes around the world. Natural uranium must be enriched in the isotope uranium-235 for use as a nuclear fuel in light-water reactors, and this enrichment has generally been achieved by gaseous diffusion techniques. Highly enriched uranium is a primary component of certain nuclear weapons. A byproduct of the enrichment process is depleted uranium, i.e., uranium depleted in the isotope 235. *(See the companion fact sheet for Depleted Uranium.)*

What's in the Environment? Uranium is naturally present in all environmental media at very low concentrations (a few parts per million). Higher levels are present in certain areas, including those with natural uranium ores such as in the southwestern United States. In its natural state, uranium occurs as an oxide ore, U_3O_8. Additional compounds that may be present include other oxides (UO_2, UO_3) as well as fluorides, carbides or carbonates, silicates, vanadates, and phosphates. In addition to the three naturally occurring isotopes, uranium-232, uranium-233, and uranium-236 are present at Hanford. At that site, uranium-233 was produced in targets and disposed of in the 300 Area; uranium-236 measurements in groundwater there have been used to distinguish the presence of natural uranium from uranium associated with reprocessed nuclear fuel. The environmental transport of uranium is strongly influenced by its chemical form. It is generally one of the more mobile radioactive metals and can move down through soil with percolating water to underlying groundwater. Uranium preferentially adheres to soil particles, with a soil concentration typically about 35 times higher than that in the interstitial water (the water between the soil particles); concentration ratios are usually much higher for clay soils (e.g., 1,600). Uranium can bioconcentrate in certain food crops and in terrestrial and aquatic organisms. However, data do not indicate that it biomagnifies in terrestrial or aquatic food chains. The U.S. Environmental Protection Agency (EPA) established a maximum contaminant level (MCL) for uranium in drinking water of 0.030 milligram per liter (mg/L). This equates to about 27 picocuries (pCi) per liter considering the ratio of isotopes typically present in drinking water sources.

What Happens to It in the Body? Uranium can be taken into the body by eating food, drinking water, or breathing air. Gastrointestinal absorption from food or water is the main source of internally deposited uranium in the general population. After ingestion, most uranium is excreted within a few days and never enters the bloodstream. The small fraction (0.2 to 5%) that is absorbed into the bloodstream is deposited preferentially in bone (about 22%) and kidneys (about 12%), with the rest being distributed throughout the body (12%) and excreted. Most of what goes to the kidneys leaves within a few days (in urine), while that deposited in bone can remain for many years. After inhalation, generally only a small fraction penetrates to the lung's alveolar region, where it can remain for years and from which it can also enter the bloodstream.

What Are the Primary Health Effects? Uranium is a health hazard only if it is taken into the body. External exposure is generally not a major concern because uranium emits only a small amount of low-energy gamma radiation. While uranium-235 has a much higher gamma component than either uranium-234 or uranium-238, uranium-235 only comprises about 2% of the total activity of natural uranium. The primary means of exposure are ingestion of food and water containing uranium isotopes and inhalation of uranium-contaminated dust. Ingestion is usually the exposure of concern unless there is a nearby source of airborne dust, such as a uranium mine or mill. Because uranium is absorbed much more readily if inhaled rather than ingested, both exposure routes can be important. The major health concern is kidney damage caused by the chemical toxicity of soluble uranium compounds. That effect can be reversible depending on the level of exposure. (Uranium has also been implicated in reproductive effects in laboratory animals and developmental effects in young animals, but it is not known if these problems exist for humans.) A second concern is for uranium deposited in bone, which can lead to bone cancer as a result of the ionizing radiation associated with its radioactive decay products.

What Is the Risk? Lifetime cancer mortality risk coefficients have been calculated for nearly all radionuclides, including uranium *(see box at right).* Although ingestion is generally the common means of entry, these risk coefficients are much lower than those for inhalation so both exposure routes need to be considered. Similar to other radionuclides, the risk coefficients for tap water are about 75% of those for dietary ingestion. On an activity (curie) basis, the risk coefficients are essentially the same for all uranium isotopes (although the factor for ingesting uranium-232 is somewhat higher), so the risk is essentially independent of the ratio of various isotopes in a compound. For this reason, the risk from exposure to depleted uranium is essentially the same as for enriched uranium on an activity basis. Uranium-235 also poses an external gamma exposure risk. To estimate a lifetime cancer mortality risk, if it is assumed that 100,000 people were continuously exposed to a thick layer of soil with an initial concentration of 1 pCi/g uranium-235, then 3 of those 100,000 people would be predicted to incur a fatal cancer. (This is in comparison to about 20,000 people from the group predicted to die of cancer from all other causes per the U.S. average.) Uranium can also kidney damage due to its chemical toxicity. The toxicity value used to estimate the potential for non-cancer effects following ingestion is a reference dose (RfD), which is an estimate of the highest dose that can be taken in every day over a lifetime without causing an adverse health effect. In addition to the on-line RfD shown above, EPA more recently derived a value of 0.0006 mg/kg-day to support the drinking water MCL. These values were developed by analyzing the biological effects of test animals given relatively large amounts of uranium, then adjusting and normalizing the results to a mg/kg-day basis for humans.

Radiological Risk Coefficients

This table provides selected risk coefficients for inhalation and ingestion. Recommended default absorption types were used for inhalation, and dietary values were used for ingestion. These values include contributions from short-lived uranium decay products. Risks are for lifetime cancer mortality per unit intake (pCi), averaged over all ages and both genders (10^{-9} is a billionth, and 10^{-12} is a trillionth). Other values, including for morbidity, are also available.

Isotope	Lifetime Cancer Mortality Risk	
	Inhalation (pCi^{-1})	Ingestion (pCi^{-1})
Uranium-232	1.8×10^{-8}	2.7×10^{-10}
Uranium-233	1.1×10^{-8}	6.3×10^{-11}
Uranium-234	1.1×10^{-8}	6.1×10^{-11}
Uranium-235	9.5×10^{-9}	6.2×10^{-11}
Uranium-236	9.9×10^{-9}	5.8×10^{-11}
Uranium-238	8.8×10^{-9}	7.5×10^{-11}

For more information, see the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients and the accompanying Table 1.

Chemical Toxicity Value
Non-Cancer Effect: *Oral RfD* *(soluble salts)*
0.003 mg/kg-day