Uranium

From Wikipedia, the free encyclopedia

Uranium is a chemical element with symbol **U** and atomic number 92. It is a silvery-white metal in the actinide series of the periodic table. A uranium atom has 92 protons and 92 electrons, of which 6 are valence electrons. Uranium is weakly radioactive because all its isotopes are unstable (with half-lives of the six naturally known isotopes, uranium-233 to uranium-238, varying between 69 years and 4.5 billion years). The most common isotopes in natural uranium are uranium-238 (which has 146 neutrons and accounts for over 99%) and uranium-235 (which has 143 neutrons). Uranium has the highest atomic weight of the primordially occurring elements. Its density is about 70% higher than that of lead, and slightly lower than that of gold or tungsten. It occurs naturally in low concentrations of a few parts per million in soil, rock and water, and is commercially extracted from uranium-bearing minerals such as uraninite.

In nature, uranium is found as uranium-238 (99.2739–99.2752%), uranium-235 (0.7198–0.7202%), and a very small amount of uranium-234 (0.0050–0.0059%).[4] Uranium decays slowly by emitting an alpha particle. The half-life of uranium-238 is about 4.47 billion years and that of uranium-235 is 704 million years,[5] making them useful in dating the age of the Earth.

Many contemporary uses of uranium exploit its unique nuclear properties. Uranium-235 has the distinction of being the only naturally occurring fissile isotope. Uranium-238 is fissionable by fast neutrons, and is *fertile*, meaning it can be transmuted to fissile plutonium-239 in a nuclear reactor. Another fissile isotope, uranium-233, can be produced from natural thorium and is also important in nuclear technology. Uranium-238 has a small probability for spontaneous fission or even induced fission with fast neutrons; uranium-235 and to a lesser degree uranium-233 have a much higher fission cross-section for slow neutrons. In sufficient concentration, these isotopes maintain a sustained nuclear chain reaction. This generates the heat in nuclear power reactors, and produces the fissile material for nuclear weapons. Depleted uranium (^{238}U) is used in kinetic energy penetrators and armor plating.[6] Uranium is used as a

Uranium, $_{92}U$

General properties	
Name, symbol	uranium, U
Appearance	silvery gray metallic; corrodes to a spalling black oxide coat in air
Uranium in the periodic table	
Atomic number (*Z*)	92
Group, block	group n/a, f-block
Period	period 7
Element category	□ actinide
Standard atomic weight (±) (A_r)	238.02891(3)[1]
Electron configuration	[Rn] $5f^3\ 6d^1\ 7s^2$
per shell	2, 8, 18, 32, 21, 9, 2
Physical properties	
Phase	solid
Melting point	1405.3 K (1132.2 °C,

colorant in uranium glass, producing lemon yellow to green colors. Uranium glass fluoresces green in ultraviolet light. It was also used for tinting and shading in early photography.

The 1789 discovery of uranium in the mineral pitchblende is credited to Martin Heinrich Klaproth, who named the new element after the planet Uranus. Eugène-Melchior Péligot was the first person to isolate the metal and its radioactive properties were discovered in 1896 by Henri Becquerel. Research by Otto Hahn, Lise Meitner, Enrico Fermi and others, such as J. Robert Oppenheimer starting in 1934 led to its use as a fuel in the nuclear power industry and in *Little Boy*, the first nuclear weapon used in war. An ensuing arms race during the Cold War between the United States and the Soviet Union produced tens of thousands of nuclear weapons that used uranium metal and uranium-derived plutonium-239. The security of those weapons and their fissile material following the breakup of the Soviet Union in 1991 is an ongoing concern for public health and safety.[7] See Nuclear proliferation.

Characteristics

When refined, uranium is a silvery white, weakly radioactive metal. It has a Mohs hardness of 6, sufficient to scratch glass and approximately equal to that of titanium, rhodium, manganese and niobium. It is malleable, ductile, slightly paramagnetic, strongly electropositive and a poor electrical conductor.[8][9] Uranium metal has a very high density of 19.1 g/cm^3,[10] denser than lead (11.3 g/cm^3),[11] but slightly less dense than tungsten and gold (19.3 g/cm^3).[12][13]

Uranium metal reacts with almost all non-metal elements (with an exception of the noble gases) and their compounds, with reactivity increasing with temperature.[14] Hydrochloric and nitric acids dissolve uranium, but non-oxidizing acids other than hydrochloric acid attack the element very slowly.[8] When finely divided, it can react with cold water; in air, uranium metal becomes coated with a dark layer of uranium oxide.[9] Uranium in ores is extracted chemically and converted into uranium dioxide or other chemical forms usable in industry.

	2070 °F)
Boiling point	4404 K (4131 °C, 7468 °F)
Density near r.t.	19.1 g/cm^3
when liquid, at m.p.	17.3 g/cm^3
Heat of fusion	9.14 kJ/mol
Heat of vaporization	417.1 kJ/mol
Molar heat capacity	27.665 J/(mol·K)

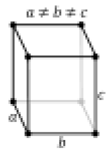
Vapor pressure

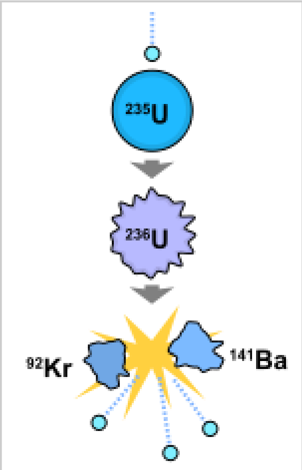
P (Pa)	**1**	**10**	**100**	**1 k**	**10 k**	**100 k**
at T (K)	2325	2564	2859	3234	3727	4402

Atomic properties

Oxidation states	**6**, 5, 4, 3,[2] 2, 1 (a weakly basic oxide)
Electronegativity	Pauling scale: 1.38
Ionization energies	1st: 597.6 kJ/mol 2nd: 1420 kJ/mol
Atomic radius	empirical: 156 pm
Covalent radius	196±7 pm
Van der Waals radius	186 pm

Miscellanea

Crystal structure	orthorhombic 
Speed of sound thin rod	3155 m/s (at 20 °C)
Thermal expansion	13.9 µm/(m·K) (at 25 °C)
Thermal	27.5 W/(m·K)



A neutron-induced nuclear fission event involving uranium-235

Uranium-235 was the first isotope that was found to be fissile. Other naturally occurring isotopes are fissionable, but not fissile. On bombardment with slow neutrons, its uranium-235 isotope will most of the time divide into two smaller nuclei, releasing nuclear binding energy and more neutrons. If too many of these neutrons are absorbed by other uranium-235 nuclei, a nuclear chain reaction occurs that results in a burst of heat or (in special circumstances) an explosion. In a nuclear reactor, such a chain reaction is slowed and controlled by a neutron poison, absorbing some of the free neutrons. Such neutron absorbent materials are often part of reactor control rods (see nuclear reactor physics for a description of this process of reactor control).

As little as 15 lb (7 kg) of uranium-235 can be used to make an atomic bomb.[15] The first nuclear bomb used in war, *Little Boy*, relied on uranium fission, but the very first nuclear explosive (the *Gadget* used at Trinity) and the bomb that destroyed Nagasaki (*Fat Man*) were both plutonium bombs.

Uranium metal has three allotropic forms:[16]

- α (orthorhombic) stable up to 668 °C. Orthorhombic, space group No. 63, *Cmcm*, lattice parameters a = 285.4 pm, b = 587 pm, c = 495.5 pm.[17]
- β (tetragonal) stable from 668 °C to 775 °C. Tetragonal, space group $P4_2/mnm$, $P4_2nm$, or $P4n2$, lattice parameters a = 565.6 pm, b = c = 1075.9 pm.[17]
- γ (body-centered cubic) from 775 °C to melting point—this is the most malleable and ductile state. Body-centered cubic, lattice parameter a = 352.4 pm.[17]

Isotopes

Natural concentrations

conductivity	
Electrical resistivity	0.280 µΩ·m (at 0 °C)
Magnetic ordering	paramagnetic
Young's modulus	208 GPa
Shear modulus	111 GPa
Bulk modulus	100 GPa
Poisson ratio	0.23
Vickers hardness	1960–2500 MPa
Brinell hardness	2350–3850 MPa
CAS Number	7440-61-1
History	
Naming	after planet Uranus, itself named after Greek god of the sky Uranus
Discovery	Martin Heinrich Klaproth (1789)
First isolation	Eugène-Melchior Péligot (1841)
Most stable isotopes of uranium	

iso	NA	half-life	DM	DE (MeV)	DP
^{232}U	syn	68.9 y	SF	–	–
			α	5.414	^{228}Th
^{233}U	trace	1.592×10^5 y	SF	197.93[3]	–
			α	4.909	^{229}Th
^{234}U	0.005%	2.455×10^5 y	SF	197.78	–
			α	4.859	^{230}Th
^{235}U	0.720%	7.04×10^8 y	SF	202.48	–
			α	4.679	^{231}Th
^{236}U	trace	2.342×10^7 y	SF	201.82	–
			α	4.572	^{232}Th
^{238}U	99.274%	4.468×10^9 y	α	4.270	^{234}Th
			SF	205.87	–
			$\beta^-\beta^-$	–	^{238}Pu

Natural uranium consists of three major isotopes: uranium-238 (99.28% natural abundance), uranium-235 (0.71%), and uranium-234 (0.0054%). All three are radioactive, emitting alpha particles, with the exception that all three of these isotopes have small probabilities of undergoing spontaneous fission, rather than alpha emission. There are also five other trace isotopes: uranium-239, which is formed when ^{238}U undergoes spontaneous fission, releasing neutrons that are captured by another ^{238}U atom; uranium-237, which is formed when ^{238}U captures a neutron but emits two more, which then decays to neptunium-237; and finally, uranium-233, which is formed in the decay chain of that neptunium-237. It is also expected that thorium-232 should be able to undergo double beta decay, which would produce uranium-232, but this has not yet been observed experimentally.[89]

Uranium-238 is the most stable isotope of uranium, with a half-life of about 4.468×10^9 years, roughly the age of the Earth. Uranium-235 has a half-life of about 7.13×10^8 years, and uranium-234 has a half-life of about 2.48×10^5 years.[90] For natural uranium, about 49% of its alpha rays are emitted by each of ^{238}U atom, and also 49% by ^{234}U (since the latter is formed from the former) and about 2.0% of them by the ^{235}U. When the Earth was young, probably about one-fifth of its uranium was uranium-235, but the percentage of ^{234}U was probably much lower than this.

Uranium-238 is usually an α emitter (occasionally, it undergoes spontaneous fission), decaying through the "Uranium Series" of nuclear decay, which has 18 members, into lead-206, by a variety of different decay paths.[14]

The decay series of ^{235}U, which is called the actinium series, has 15 members and eventually decays into lead-207.[14] The constant rates of decay in these decay series makes the comparison of the ratios of parent to daughter elements useful in radiometric dating.

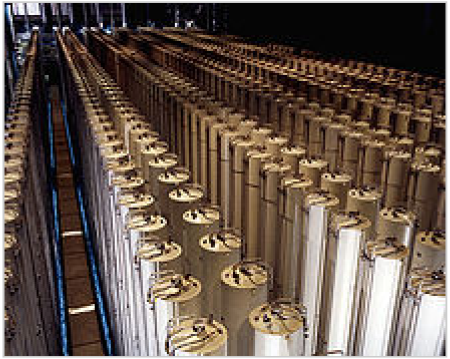
Uranium-234, which is a member of the "Uranium Series", decays to lead-206 through a series of relatively short-lived isotopes.

Uranium-233 is made from thorium-232 by neutron bombardment, usually in a nuclear reactor, and ^{233}U is also fissile.[9] Its decay series ends at bismuth-209 and thallium-205.

Uranium-235 is important for both nuclear reactors and nuclear weapons, because it is the only uranium isotope existing in nature on Earth in any significant amount that is fissile. This means that it can be split into two or three fragments (fission products) by thermal neutrons.[14]

Uranium-238 is not fissile, but is a fertile isotope, because after neutron activation it can produce plutonium-239, another fissile isotope. Indeed, the ^{238}U nucleus can absorb one neutron to produce the radioactive isotope uranium-239. ^{239}U decays by beta emission to neptunium-239, also a beta-emitter, that decays in its turn, within a few days into plutonium-239. ^{239}Pu was used as fissile material in the first atomic bomb detonated in the "Trinity test" on 15 July 1945 in New Mexico.[31]

Enrichment


Cascades of gas centrifuges are used to enrich uranium ore to concentrate its fissionable isotopes

In nature, uranium is found as uranium-238 (99.2742%) and uranium-235 (0.7204%). Isotope separation concentrates (enriches) the fissionable uranium-235 for nuclear weapons and most nuclear power plants, except for gas cooled reactors and pressurised heavy water reactors. Most neutrons released by a fissioning atom of uranium-235 must impact other uranium-235 atoms to sustain the nuclear chain reaction. The concentration and amount of uranium-235 needed to achieve this is called a 'critical mass'.

To be considered 'enriched', the uranium-235 fraction should be between 3% and 5%.[91] This process produces huge quantities of uranium that is depleted of uranium-235 and with a correspondingly increased fraction of uranium-238, called depleted uranium or 'DU'. To be considered 'depleted', the uranium-235 isotope concentration should be no more than 0.3%.[92] The price of uranium has risen since 2001, so enrichment tailings containing more than 0.35% uranium-235 are being considered for re-enrichment, driving the price of depleted uranium hexafluoride above $130 per kilogram in July 2007 from $5 in 2001.[92]

The gas centrifuge process, where gaseous uranium hexafluoride (UF_6) is separated by the difference in molecular weight between $^{235}UF_6$ and $^{238}UF_6$ using high-speed centrifuges, is the cheapest and leading enrichment process.[30] The gaseous diffusion process had been the leading method for enrichment and was used in the Manhattan Project. In this process, uranium hexafluoride is repeatedly diffused through a silver-zinc membrane, and the different isotopes of uranium are separated by diffusion rate (since uranium 238 is heavier it diffuses slightly slower than uranium-235).[30] The molecular laser isotope separation method employs a laser beam of precise energy to sever the bond between uranium-235 and fluorine. This leaves uranium-238 bonded to fluorine and allows uranium-235 metal to precipitate from the solution.[6] An alternative laser method of enrichment is known as atomic vapor laser isotope separation (AVLIS) and employs visible tunable lasers such as dye lasers.[93] Another method used is liquid thermal diffusion.[8]

External links

- Wikipedia: Uranium (https://en.wikipedia.org/wiki/Uranium)