Tantalum

From Wikipedia, the free encyclopedia

Tantalum is a chemical element with symbol **Ta** and atomic number 73. Previously known as *tantalium*, its name comes from *Tantalus*, a villain from Greek mythology.[4] Tantalum is a rare, hard, blue-gray, lustrous transition metal that is highly corrosion-resistant. It is part of the refractory metals group, which are widely used as minor components in alloys. The chemical inertness of tantalum makes it a valuable substance for laboratory equipment and a substitute for platinum. Its main use today is in tantalum capacitors in electronic equipment such as mobile phones, DVD players, video game systems and computers. Tantalum, always together with the chemically similar niobium, occurs in the minerals tantalite, columbite and coltan (a mix of columbite and tantalite).

Tantalum, $_{73}$Ta

Spectral lines of tantalum

General properties	
Name, symbol	tantalum, Ta
Appearance	gray blue
Tantalum in the periodic table	
Atomic number (*Z*)	73
Group, block	group 5, d-block
Period	period 6
Element category	transition metal
Standard atomic weight (±) (A_r)	180.94788(2)[1]
Electron configuration	[Xe] $4f^{14}$ $5d^3$ $6s^2$
per shell	2, 8, 18, 32, 11, 2
Physical properties	
Phase	solid
Melting point	3290 K (3017 °C, 5463 °F)

Characteristics

Physical properties

Tantalum is dark (blue-gray),[19] dense, ductile, very hard, easily fabricated, and highly conductive of heat and electricity. The metal is renowned for its resistance to corrosion by acids; in fact, at temperatures below 150 °C tantalum is almost completely immune to attack by the normally aggressive aqua regia. It can be dissolved with hydrofluoric acid or acidic solutions containing the fluoride ion and sulfur trioxide, as well as with a solution of potassium hydroxide. Tantalum's high melting point of 3017 °C (boiling point 5458 °C) is exceeded among the elements only by tungsten, rhenium and osmium for metals, and carbon.

Tantalum exists in two crystalline phases, alpha and beta. The alpha phase is relatively ductile and soft; it has body-centered cubic structure (space group *Im3m*, lattice constant *a* = 0.33058 nm), Knoop hardness 200–400 HN and electrical resistivity 15–60 µΩcm. The beta phase is hard and brittle; its crystal symmetry is tetragonal (space group *P42/mnm*, *a* = 1.0194 nm, *c* = 0.5313 nm), Knoop hardness is 1000–1300 HN and electrical resistivity is relatively high at 170–210 µΩcm. The beta phase is metastable and converts to the alpha phase upon heating to 750–

775 °C. Bulk tantalum is almost entirely alpha phase, and the beta phase usually exists as thin films obtained by magnetron sputtering, chemical vapor deposition or electrochemical deposition from an eutectic molten salt solution.[20]

Chemical properties

Tantalum forms oxides with the oxidation states +5 (Ta_2O_5) and +4 (TaO_2).[21] The most stable oxidation state is +5, as seen in tantalum pentoxide.[21] Tantalum pentoxide is the starting material for several tantalum compounds. The compounds are created by dissolving the pentoxide in basic hydroxide solutions or by melting it in another metal oxide. Such examples are lithium tantalate ($LiTaO_3$) and lanthanum tantalate ($LaTaO_4$). In the lithium tantalate, the tantalate ion TaO_3^- does not occur; instead, this part of the formula represents linkage of TaO_6^{7-} octahedra to form a three-dimensional perovskite framework; while the lanthanum tantalate contains lone TaO_4^{3-} tetrahedral groups.[21]

The fluorides of tantalum can be used for its separation from niobium.[22] Tantalum forms halogen compounds in the oxidation states of +5, +4, and +3 of the type TaX_5, TaX_4, and TaX_3, although multi-core complexes and substoichiometric compounds are also known.[21][23] Tantalum pentafluoride (TaF_5) is a white solid with a melting point of 97.0 °C and tantalum pentachloride ($TaCl_5$) is a white solid with a melting point of 247.4 °C. Tantalum pentachloride is hydrolyzed by water and reacts with additional tantalum at elevated temperatures by forming the black and highly hygroscopic tantalum tetrachloride ($TaCl_4$). While the trihalides can be obtained by reduction of the pentahalides with hydrogen, the dihalides do not exist.[21] A tantalum-tellurium alloy forms quasicrystals.[21] Tantalum compounds with oxidation states as low as −1 have been reported in 2008.[24] As in the cases of most other refractory metals, the hardest known compounds of tantalum are its stable nitrides and carbides. Tantalum carbide, TaC, like the more commonly used tungsten carbide, is a very hard ceramic that is used in cutting tools. Tantalum(III) nitride is used as a thin film insulator in some microelectronic fabrication processes.[25] Chemists at the Los Alamos National Laboratory in the United States have developed a tantalum carbide-graphite composite material that is one of the hardest materials ever synthesized. Korean

Boiling point	5731 K (5458 °C, 9856 °F)
Density near r.t.	16.69 g/cm^3
when liquid, at m.p.	15 g/cm^3
Heat of fusion	36.57 kJ/mol
Heat of vaporization	753 kJ/mol
Molar heat capacity	25.36 J/(mol·K)

Vapor pressure

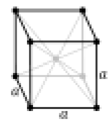
P (Pa)	**1**	**10**	**100**	**1 k**	**10 k**	**100 k**
at T (K)	3297	3597	3957	4395	4939	5634

Atomic properties

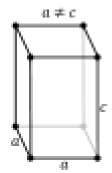
Oxidation states	**5**, 4, 3, 2, 1, −1, −3 (a mildly acidic oxide)
Electronegativity	Pauling scale: 1.5
Ionization energies	1st: 761 kJ/mol 2nd: 1500 kJ/mol
Atomic radius	empirical: 146 pm
Covalent radius	170±8 pm

Miscellanea

Crystal structure body-centered cubic (bcc)[2] α-Ta



Crystal structure tetragonal[2] β-Ta



Speed of sound thin rod	3400 m/s (at 20 °C)
Thermal	6.3 µm/(m·K)

researchers have developed an amorphous tantalum-tungsten-copper alloy that is more flexible and two to three times stronger than commonly used steel alloys.[26] There are two tantalum aluminides, $TaAl_3$ and Ta_3Al. These are stable, refractory, and reflective, and they have been proposed[27] as coatings for use in infrared wave mirrors.

Isotopes

Natural tantalum consists of two isotopes: ^{180m}Ta (0.012%) and ^{181}Ta (99.988%). ^{181}Ta is a stable isotope. ^{180m}Ta (*m* denotes a metastable state) is predicted to decay in three ways: isomeric transition to the ground state of ^{180}Ta, beta decay to ^{180}W, or electron capture to ^{180}Hf. However, radioactivity of this nuclear isomer has never been observed, and only a lower limit on its half life of 2.0×10^{16} years has been set.[28] The ground state of ^{180}Ta has a half life of only 8 hours. ^{180m}Ta is the only naturally occurring nuclear isomer (excluding radiogenic and cosmogenic short-living nuclides). It is also the rarest isotope in the Universe, taking into account the elemental abundance of tantalum and isotopic abundance of ^{180m}Ta in the natural mixture of isotopes (and again excluding radiogenic and cosmogenic short-living nuclides).[29]

Tantalum has been examined theoretically as a "salting" material for nuclear weapons (cobalt is the better-known hypothetical salting material). An external shell of ^{181}Ta would be irradiated by the intensive high-energy neutron flux from a hypothetical exploding nuclear weapon. This would transmute the tantalum into the radioactive isotope ^{182}Ta, which has a half-life of 114.4 days and produces gamma rays with approximately 1.12 million electron-volts (MeV) of energy apiece, which would significantly increase the radioactivity of the nuclear fallout from the explosion for several months. Such "salted" weapons have never been built or tested, as far as is publicly known, and certainly never used as weapons.[30]

Tantalum can be used as a target material for accelerated proton beams for the production of various short-lived isotopes including ^{8}Li, ^{80}Rb, and ^{160}Yb.[31]

expansion	(at 25 °C)
Thermal conductivity	57.5 W/(m·K)
Electrical resistivity	131 nΩ·m (at 20 °C)
Magnetic ordering	paramagnetic[3]
Young's modulus	186 GPa
Shear modulus	69 GPa
Bulk modulus	200 GPa
Poisson ratio	0.34
Mohs hardness	6.5
Vickers hardness	870–1200 MPa
Brinell hardness	440–3430 MPa
CAS Number	7440-25-7
History	
Discovery	Anders Gustaf Ekeberg (1802)
Recognized as a distinct element by	Heinrich Rose (1844)

Most stable isotopes of tantalum

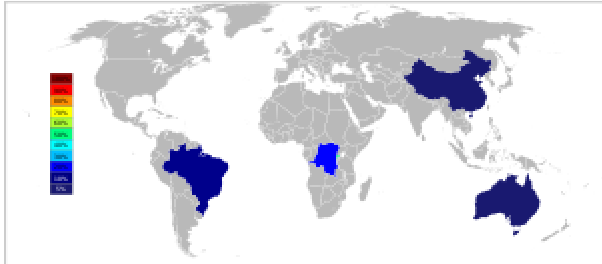
Occurrence

Tantalite, Pilbara district, Australia

Tantalum is estimated to make up about 1 ppm[32] or 2 ppm[23] of the Earth's crust by weight. There are many species of tantalum minerals, only some of which are so far being used by industry as raw materials: tantalite, microlite, wodginite, euxenite, polycrase. Tantalite (Fe, Mn)Ta_2O_6 is the most important mineral for tantalum extraction. Tantalite has the same mineral structure as columbite (Fe, Mn)(Ta, Nb)$_2O_6$; when there is more tantalum than niobium it is called tantalite and when there is more niobium than tantalum is it called columbite (or niobite). The high density of tantalite and other tantalum containing minerals makes the use of gravitational separation the best method. Other minerals include samarskite and fergusonite.

iso	NA	half-life	DM	DE (MeV)	DP
^{177}Ta	syn	56.56 h	ε	1.166	^{177}Hf
^{178}Ta	syn	2.36 h	ε	1.910	^{178}Hf
^{179}Ta	syn	1.82 y	ε	0.110	^{179}Hf
^{180}Ta	syn	8.125 h	ε	0.854	^{180}Hf
			$β^−$	0.708	^{180}W
^{180m}Ta	0.012%	is stable with 107 neutrons			
^{181}Ta	99.988%	is stable with 108 neutrons			
^{182}Ta	syn	114.43 d	$β^−$	1.814	^{182}W
^{183}Ta	syn	5.1 d	$β^−$	1.070	^{183}W

The primary mining of tantalum is in Australia, where the largest producer, Global Advanced Metals, formerly known as Talison Minerals, operates two mines in Western Australia, Greenbushes in the Southwest and Wodgina in the Pilbara region. The Wodgina mine was reopened in January 2011 after mining at the site was suspended in late-2008 due to the global financial crisis.[33] Less than a year after it reopened, Global Advanced Metals announced that due to again "... softening tantalum demand ...", and other factors, tantalum mining operations were to cease at the end of February 2012.[34] Wodgina produces a primary tantalum concentrate which is further upgraded at the Greenbushes operation before being sold to customers.[35] Whereas the large-scale producers of niobium are in Brazil and Canada, the ore there also yields a small percentage of tantalum. Some other countries such as China, Ethiopia, and Mozambique mine ores with a higher percentage of tantalum, and they produce a significant percentage of the world's output of it. Tantalum is also produced in Thailand and Malaysia as a by-product of the tin mining there. During gravitational separation of the ores from placer deposits, not only is cassiterite (SnO_2) found, but a small percentage of tantalite also included. The slag from the tin smelters then contains economically useful amounts of tantalum, which is leached from the slag.[12][36]



Tantalum producers in 2015 with Rwanda being the main producer

World tantalum mine production has undergone an important geographic shift since the start of the 21st century when production was predominantly from Australia and Brazil. Beginning in 2007 and through 2014, the major sources of tantalum production from mines dramatically shifted to the DRC, Rwanda, and some other African countries.[37] Future sources of supply of tantalum, in order of estimated size, are being explored in Saudi Arabia, Egypt, Greenland, China, Mozambique, Canada, Australia, the United States, Finland, and Brazil.[38][39]

It is estimated that there are less than 50 years left of tantalum resources, based on extraction at current rates, demonstrating the need for increased recycling.[40]

Source

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