USGS
science for a changing world

41 Nb [Kr]5s[1]4d[4] 92.91

73 Ta [Xe]6s[2]4f[14]5d[3] 180.9

USGS Mineral Resources Program

Niobium and Tantalum—Indispensable Twins

As part of a broad mission to conduct research and provide information on nonfuel mineral resources, the U.S. Geological Survey (USGS) supports science to understand

- *How and where niobium and tantalum resources form and concentrate in the Earth's crust*
- *How niobium and tantalum resources interact with the environment to affect human and ecosystem health*
- *Trends in the supply of and demand for niobium and tantalum in the domestic and international markets*
- *Where undiscovered sources of niobium and tantalum might be found*

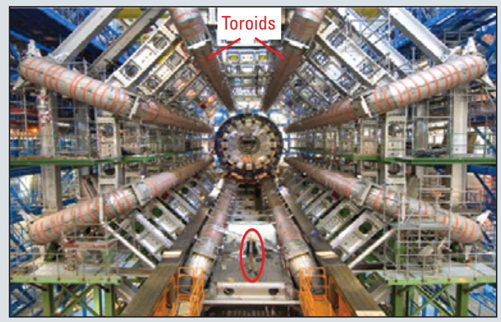
Why is this information important? Read on to learn about niobium and tantalum and the important role they play in the national economy, in national security, and in the lives of Americans every day.

Launch of the Gemini 12 space mission (image courtesy of NASA). Thousands of pounds of niobium have been used in advanced air frame systems such as were used in the Gemini space program.

Niobium and tantalum are transition metals almost always paired together in nature. These "twins" are difficult to separate because of their shared physical and chemical properties. In 1801, English chemist Charles Hatchett uncovered an unknown element in a mineral sample of columbite; John Winthrop found the sample in a Massachusetts mine and sent it to the British Museum in London in 1734. The name columbium, which Hatchett named the new element, came from the poetic name for North America—Columbia—and was used interchangeably for niobium until 1949, when the name niobium became official. Swedish scientist Anders Ekberg discovered tantalum in 1802, but it was confused with niobium, because of their twinned properties, until 1864, when it was recognized as a separate element. Niobium is a lustrous, gray, ductile metal with a high melting point, relatively low density, and superconductor properties. Tantalum is a dark blue-gray, dense, ductile, very hard, and easily fabricated metal. It is highly conductive to heat and electricity and renowned for its resistance to acidic corrosion. These special properties determine their primary uses and make niobium and tantalum indispensable.

How Do We Use Niobium and Tantalum?

The steel industry uses nearly 80 percent of the world's produced niobium to manufacture high-strength low-alloy steels. Niobium, a grain refiner and precipitation hardener, enhances the steels' mechanical strength, toughness, high-temperature strength, and corrosion resistance for use in pipelines, transportation, and structural applications. Appreciable amounts (>20 percent) of niobium are used in nickel-, cobalt-, and iron-based superalloys for high-temperature applications in jet engines, gas turbines, rocket subassemblies, turbocharger systems, and combustion equipment. Niobium alloys are used to manufacture superconducting magnets for medical hardware such as magnetic resonance imaging (MRI) and nuclear magnetic resonance (NMR) instruments. A new use of niobium is in a solid niobic acid that catalyzes the conversion of palm oil to bio-diesel fuel. Niobium's uses are specialized; substituting an alternative can lead to reduced performance and increased cost.

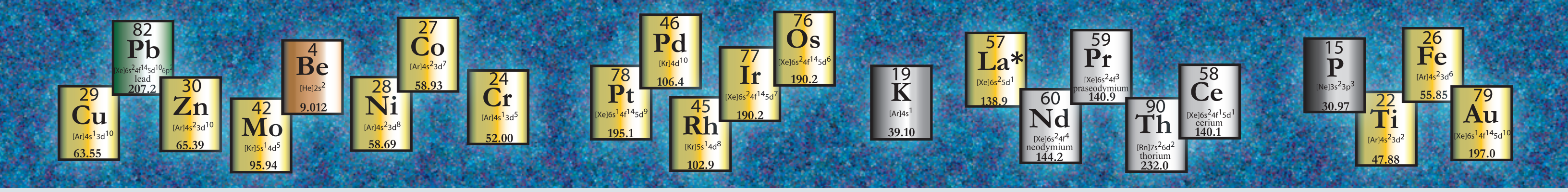


Central view of the ATLAS detector in the Large Hadron Collider with its eight superconducting magnets (toroids) around the calorimeter (note person standing in lower center of photograph for scale). This is the world's largest superconducting magnet. (Image from European Council for Nuclear Research [CERN]).

Tantalum has a unique ability to store and release energy, which is why the electronics industry consumes more than one-half of tantalum production. Tantalum-based components can be exceptionally small, and other elements cannot serve as substitutes without degrading the performance of electronic devices. As a result, tantalum is used in components for items as ubiquitous as cell phones, hearing aids, and hard drives. Tantalum's low mechanical strength and high biocompatibility allow it to coat stronger substrates, like stainless steel, for medical applications. It is used for blood vessel support stents, plates, bone replacements, and suture clips and wire. In the chemical industry, tantalum's corrosion resistance makes it useful as a lining for pipes, tanks, and vessels. Tantalum oxide can increase the refractive index of lens glass, while the hardness of tantalum carbide makes it an ideal component in the manufacture of cutting tools.

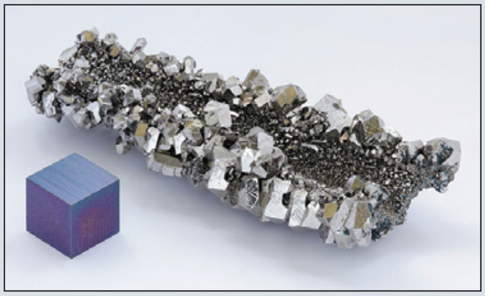
Where Do Niobium and Tantalum Come From?

The average abundance of niobium and tantalum in bulk continental crust is low, with 8.0 parts per million (ppm) niobium and 0.7 ppm tantalum. Their chemical characteristics reduce their potential to substitute for more common elements in rock-forming minerals and make them practically immobile in many aqueous solutions. Niobium and tantalum do not occur naturally as pure metals, but are concentrated in rare oxide and hydroxide minerals and in a few rare silicate minerals. The economically important ore minerals for niobium and tantalum production are all oxides. Niobium is primarily derived from the complex oxide minerals of the pyrochlore group ($(Na,Ca,Ce)_2(Nb,Ti,Ta)_2(O,OH,F)_7$), which are found in some alkaline (igneous rocks containing certain sodium- or potassium-rich minerals) granite-syenite and carbonatite complexes (igneous rocks composed more than 50 percent by volume of primary carbonate minerals). Tantalum is derived mainly from the mineral tantalite ($(Fe,Mn)(Ta,Nb)_2O_6$), which is found as an accessory mineral in rare-metal granites and pegmatites enriched in lithium and cesium (termed the LCT family).

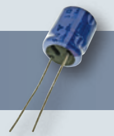


The Future of Niobium and Tantalum: Worldwide Supply and Demand

Estimated global reserves and resources of niobium and tantalum are large and more than sufficient to meet global demand for the foreseeable future, possibly the next 500 years. Therefore, geologic availability does not appear to be a major concern for the supply of niobium or tantalum. Brazil, Canada, and Australia are the leading global producers of niobium and tantalum mineral concentrates. Brazil produces the greatest amount of niobium mineral concentrates (~90 percent), while Australia and Brazil together lead in the production of tantalum mineral concentrates. A number of African countries—Burundi, Democratic Republic of Congo, Ethiopia, Mozambique, Nigeria, Rwanda, Uganda—mine for tantalum minerals (such as columbite-tantalite, also called coltan) through artisanal mining or are establishing mining operations. Primary production of niobium or tantalum in the United States has not been reported since the late 1950's; therefore, the United States has to meet its current and expected future needs by importing primary mineral concentrates and alloys, and by recovering them from foreign and domestic alloy scrap.



High-purity niobium crystals, electrolytic made, as well as a high-purity 1 cubic centimeter anodized niobium cube for comparison (photograph from Wikipedia).

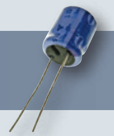


Did you know... ***Niobium alloys are contained in the superconducting magnets used in particle accelerators like the Large Hadron Collider in Europe.***

Fluctuating market conditions, as with the recent worldwide economic crises, interrupted operations at a number of production sites, and future economic instability has the potential to generate supply problems. Other possible disruptions include war, civil unrest, political changes, natural disasters, environmental issues and market manipulation. For example, rebel sales of "conflict coltan" in the Democratic Republic of Congo, amidst a civil war, have led to discussions about supply-line transparency and traceability as tools for excluding illegal columbite-tantalite while keeping the market open for legitimate, small-scale artisanal mining in central Africa.

To help predict where future niobium and tantalum supplies might be found, USGS scientists study how and where these resources are concentrated in the Earth's crust and then assess the likelihood that undiscovered resources may exist. Techniques to assess mineral resource potential have been developed by the USGS to support the stewardship of Federal lands and better evaluate mineral resource availability in a global context. The USGS also compiles statistics and information on the worldwide supply, demand, and flow of niobium and tantalum. These data help support the U.S. economy and national security.

The large Mibra (Volta Grande) open-pit pegmatite mine operated by Companhia Industrial Fluminense's in Brazil (Itamar Resende). (Image from Tantalum-Niobium International Study Center).



Did you know... ***Niobium is widely used for body piercing, and when put through an anodizing process results in varying colors of jewelry without the use of toxic inks or dyes.***

For More Information

- On production and consumption of niobium and tantalum: http://minerals.usgs.gov/minerals/pubs/commodity/niobium/
- On historical statistics on niobium and tantalum: http://minerals.usgs.gov/ds/2005/140/
- On recycling of niobium and tantalum in the United States: http://pubs.usgs.gov/circ/2004/1196am/

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The USGS Mineral Resources Program is the principal Federal provider of research and information on niobium, tantalum, and other nonfuel mineral resources.

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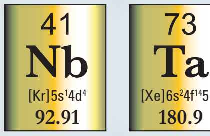

ISSN 2327–6932 (online)
http://dx.doi.org/10.3133/fs20143054