= Tungsten =

Tungsten , also known as wolfram , is a chemical element with symbol W and atomic number 74 . The word tungsten comes from the Swedish language tung sten , which directly translates to heavy stone . Its name in Swedish is volfram , however , in order to distinguish it from scheelite , which in Swedish is alternatively named tungsten .

A hard , rare metal under standard conditions when uncombined , tungsten is found naturally on Earth almost exclusively in chemical compounds . It was identified as a new element in 1781 , and first isolated as a metal in 1783 . Its important ores include wolframite and scheelite . The free element is remarkable for its robustness , especially the fact that it has the highest melting point of all the elements . Its high density is 19 @.@ 3 times that of water , comparable to that of uranium and gold , and much higher (about 1 @.@ 7 times) than that of lead . Polycrystalline tungsten is an intrinsically brittle and hard material , making it difficult to work . However , pure single @-@ crystalline tungsten is more ductile , and can be cut with a hard @-@ steel hacksaw .

Tungsten 's many alloys have numerous applications , including incandescent light bulb filaments , X @-@ ray tubes (as both the filament and target) , electrodes in TIG welding , superalloys , and radiation shielding . Tungsten 's hardness and high density give it military applications in penetrating projectiles . Tungsten compounds are also often used as industrial catalysts .

Tungsten is the only metal from the third transition series that is known to occur in biomolecules , where it is used in a few species of bacteria and archaea . It is the heaviest element known to be essential to any living organism . Tungsten interferes with molybdenum and copper metabolism and is somewhat toxic to animal life .

= = Characteristics = =

= = = Physical properties = = =

In its raw form , tungsten is a hard steel @-@ grey metal that is often brittle and hard to work . If made very pure , tungsten retains its hardness (which exceeds that of many steels) , and becomes malleable enough that it can be worked easily . It is worked by forging , drawing , or extruding . Tungsten objects are also commonly formed by sintering .

Of all metals in pure form , tungsten has the highest melting point (3422 ° C , 6192 ° F) , lowest vapor pressure (at temperatures above 1650 ° C , 3000 ° F) and the highest tensile strength . Although carbon remains solid at higher temperatures than tungsten , carbon sublimes , rather than melts , so tungsten is considered to have a higher melting point . Tungsten has the lowest coefficient of thermal expansion of any pure metal . The low thermal expansion and high melting point and tensile strength of tungsten originate from strong covalent bonds formed between tungsten atoms by the 5d electrons . Alloying small quantities of tungsten with steel greatly increases its toughness .

Tungsten exists in two major crystalline forms : ? and ? . The former has a body @-@ centered cubic structure and is the more stable form . The structure of the ? phase is called A15 cubic ; it is metastable , but can coexist with the ? phase at ambient conditions owing to non @-@ equilibrium synthesis or stabilization by impurities . Contrary to the ? phase which crystallizes in isometric grains , the ? form exhibits a columnar habit . The ? phase has one third of the electrical resistivity and a much lower superconducting transition temperature TC relative to the ? phase : ca . 0 @.@ 015 K vs. 1 ? 4 K ; mixing the two phases allows obtaining intermediate TC values . The TC value can also be raised by alloying tungsten with another metal (e.g. 7 @.@ 9 K for W @-@ Tc) . Such tungsten alloys are sometimes used in low @-@ temperature superconducting circuits .

= = = Isotopes = = =

Naturally occurring tungsten consists of five isotopes whose half @-@ lives are so long that they

can be considered stable . Theoretically , all five can decay into isotopes of element 72 (hafnium) by alpha emission , but only 180W has been observed to do so with a half @-@ life of (1 @.@ 8 ± 0 @.@ 2) × 1018 years ; on average , this yields about two alpha decays of 180W in one gram of natural tungsten per year . The other naturally occurring isotopes have not been observed to decay , constraining their half @-@ lives to be :

182W , t1 / 2 > 7 @.@ 7 × 1021 years
183W , t1 / 2 > 4 @.@ 1 × 1021 years
184W , t1 / 2 > 8 @.@ 9 × 1021 years
186W , t1 / 2 > 8 @.@ 2 × 1021 years

Another 30 artificial radioisotopes of tungsten have been characterized , the most stable of which are 181W with a half @-@ life of 121 @.@ 2 days , 185W with a half @-@ life of 75 @.@ 1 days , 188W with a half @-@ life of 69 @.@ 4 days , 178W with a half @-@ life of 21 @.@ 6 days , and 187W with a half @-@ life of 23 @.@ 72 h . All of the remaining radioactive isotopes have half @-@ lives of less than 3 hours , and most of these have half @-@ lives below 8 minutes . Tungsten also has 4 meta states , the most stable being 179mW (t1 / 2 6 @.@ 4 minutes) .

= = = Chemical properties = = =

Elemental tungsten resists attack by oxygen , acids , and alkalis .

The most common formal oxidation state of tungsten is + 6 , but it exhibits all oxidation states from ? 2 to + 6 . Tungsten typically combines with oxygen to form the yellow tungstic oxide , WO3 , which dissolves in aqueous alkaline solutions to form tungstate ions , WO2 ?
4 .

Tungsten carbides (W2C and WC) are produced by heating powdered tungsten with carbon . W2C is resistant to chemical attack , although it reacts strongly with chlorine to form tungsten hexachloride (WCl6) .

In aqueous solution , tungstate gives the heteropoly acids and polyoxometalate anions under neutral and acidic conditions . As tungstate is progressively treated with acid , it first yields the soluble , metastable " paratungstate A " anion , W
7O6 ?
24 , which over time converts to the less soluble " paratungstate B " anion , H
2W
12O10 ?
42 . Further acidification produces the very soluble metatungstate anion , H
2W
12O6 ?
40 , after which equilibrium is reached . The metatungstate ion exists as a symmetric cluster of twelve tungsten @-@ oxygen octahedra known as the Keggin anion . Many other polyoxometalate anions exist as metastable species . The inclusion of a different atom such as phosphorus in place of the two central hydrogens in metatungstate produces a wide variety of heteropoly acids , such as phosphotungstic acid H3PW12O40 .

Tungsten trioxide can form intercalation compounds with alkali metals . These are known as bronzes ; an example is sodium tungsten bronze .

= = History = =

In 1781 , Carl Wilhelm Scheele discovered that a new acid , tungstic acid , could be made from scheelite (at the time named tungsten) . Scheele and Torbern Bergman suggested that it might be possible to obtain a new metal by reducing this acid . In 1783 , José and Fausto Elhuyar found an acid made from wolframite that was identical to tungstic acid . Later that year , at the Royal Basque Society in the town of Bergara , Spain , the brothers succeeded in isolating tungsten by reduction of this acid with charcoal , and they are credited with the discovery of the element .

In World War II , tungsten played a significant role in background political dealings . Portugal , as

the main European source of the element , was put under pressure from both sides , because of its deposits of wolframite ore at Panasqueira . Tungsten 's desirable properties such as resistance to high temperatures , its hardness and density , and its strengthening of alloys made it an important raw material for the arms industry , both as a constituent of weapons and equipment and employed in production itself , e.g. , in tungsten carbide cutting tools for machining steel .

= = = Etymology = = =

The name " tungsten " (from the Swedish tung sten , " heavy stone ") is used in English , French , and many other languages as the name of the element , but not in the Nordic countries . Tungsten was the old Swedish name for the mineral scheelite . The other name " wolfram " (or " volfram ") is used in most European (especially Germanic and Slavic) languages , and is derived from the mineral wolframite , which is the origin of its chemical symbol , W. The name " wolframite " is derived from German " wolf rahm " (" wolf soot " or " wolf cream ") , the name given to tungsten by Johan Gottschalk Wallerius in 1747 . This , in turn , derives from " lupi spuma " , the name Georg Agricola used for the element in 1546 , which translates into English as " wolf 's froth " , and is a reference to the large amounts of tin consumed by the mineral during its extraction .

= = Occurrence = =

Tungsten is found in wolframite (iron ? manganese tungstate (Fe , Mn) WO4 being a solid solution of the minerals ferberite FeWO4 and hübnerite MnWO4) and scheelite (calcium tungstate (CaWO4) . Other tungsten minerals are moderately to very rare and have no economical value . They include the recently approved native tungsten .

= = Production = =

About 61 @,@ 300 tonnes of tungsten concentrates were produced in the year 2009 , and in 2010 , world production of tungsten was about 68 @,@ 000 tonnes . The main producers were as follows (data in tonnes) :

There is additional production in the U.S. , but the amount is proprietary company information . U.S. reserves are 140 @,@ 000 tonnes .

Tungsten is considered to be a conflict mineral due to the unethical mining practices observed in the Democratic Republic of the Congo .

There is a large deposit of tungsten ore on the edge of Dartmoor in the United Kingdom , which was exploited during World War I and World War II as the Hemerdon Mine . With recent increases in tungsten prices , as of 2014 this mine has been reactivated .

Tungsten is extracted from its ores in several stages . The ore is eventually converted to tungsten (VI) oxide (WO3) , which is heated with hydrogen or carbon to produce powdered tungsten . Because of tungsten 's high melting point , it is not commercially feasible to cast tungsten ingots . Instead , powdered tungsten is mixed with small amounts of powdered nickel or other metals , and sintered . During the sintering process , the nickel diffuses into the tungsten , producing an alloy .

Tungsten can also be extracted by hydrogen reduction of WF6 :

WF6 + 3 H2 ? W + 6 HF

or pyrolytic decomposition :

WF6 ? W + 3 F2 (?Hr = +)

Tungsten is not traded as a futures contract and cannot be tracked on exchanges like the London Metal Exchange . The prices are usually quoted for tungsten concentrate or WO3 . If converted to the metal equivalent , they were about US $ 19 per kilogram in 2009 .

= = Applications = =

Approximately half of the tungsten is consumed for the production of hard materials ? namely

tungsten carbide ? with the remaining major use being in alloys and steels . Less than 10 % is used in other chemical compounds .

= = = Hard materials = = =

Tungsten is mainly used in the production of hard materials based on tungsten carbide , one of the hardest carbides , with a melting point of 2770 ° C. WC is an efficient electrical conductor , but W2C is less so . WC is used to make wear @-@ resistant abrasives , and " carbide " cutting tools such as knives , drills , circular saws , milling and turning tools used by the metalworking , woodworking , mining , petroleum and construction industries . Carbide tooling is actually a ceramic / metal composite , where metallic cobalt acts as a binding (matrix) material to hold the WC particles in place . This type of industrial use accounts for about 60 % of current tungsten consumption .

The jewelry industry makes rings of sintered tungsten carbide , tungsten carbide / metal composites , and also metallic tungsten . WC / metal composite rings use nickel as the metal matrix in place of cobalt because it takes a higher luster when polished . Sometimes manufacturers or retailers refer to tungsten carbide as a metal , but it is a ceramic . Because of tungsten carbide 's hardness , rings made of this material are extremely abrasion resistant , and will hold a burnished finish longer than rings made of metallic tungsten . Tungsten carbide rings are brittle , however , and may crack under a sharp blow .

= = = Alloys = = =

The hardness and density of tungsten are applied in obtaining heavy metal alloys . A good example is high speed steel , which can contain as much as 18 % tungsten . Tungsten 's high melting point makes tungsten a good material for applications like rocket nozzles , for example in the UGM @-@ 27 Polaris submarine @-@ launched ballistic missile . Tungsten alloys are used in a wide range of different applications , including the aerospace and automotive industries and radiation shielding . Superalloys containing tungsten , such as Hastelloy and Stellite , are used in turbine blades and wear @-@ resistant parts and coatings .

= = = Armaments = = =

Tungsten , usually alloyed with nickel and iron or cobalt to form heavy alloys , is used in kinetic energy penetrators as an alternative to depleted uranium , in applications where uranium 's radioactivity is problematic even in depleted form , or where uranium 's additional pyrophoric properties are not required (for example , in ordinary small arms bullets designed to penetrate body armor) . Similarly , tungsten alloys have also been used in cannon shells , grenades and missiles , to create supersonic shrapnel . Tungsten has also been used in Dense Inert Metal Explosives , which use it as dense powder to reduce collateral damage while increasing the lethality of explosives within a small radius .

= = = Chemical applications = = =

Tungsten (IV) sulfide is a high temperature lubricant and is a component of catalysts for hydrodesulfurization . MoS_2 is more commonly used for such applications .

Tungsten oxides are used in ceramic glazes and calcium / magnesium tungstates are used widely in fluorescent lighting . Crystal tungstates are used as scintillation detectors in nuclear physics and nuclear medicine . Other salts that contain tungsten are used in the chemical and tanning industries .

Tungsten oxide (WO_3) is incorporated into selective catalytic reduction (SCR) catalysts found in coal @-@ fired power plants . These catalysts convert nitrogen oxides (NO_x) to nitrogen (N_2) and water (H_2O) using ammonia (NH_3) . The tungsten oxide helps with the physical strength of the catalyst and extends catalyst life .

= = = Niche uses = = =

Applications requiring its high density include weights , counterweights , ballast keels for yachts , tail ballast for commercial aircraft , and as ballast in race cars for NASCAR and Formula One ; depleted uranium is also used for these purposes , due to similarly high density . 75 @-@ kg blocks of tungsten were used as " cruise balance mass devices " on the entry vehicle portion of the 2012 Mars Science Laboratory spacecraft . It is an ideal material to use as a dolly for riveting , where the mass necessary for good results can be achieved in a compact bar . High @-@ density alloys of tungsten with nickel , copper or iron are used in high @-@ quality darts (to allow for a smaller diameter and thus tighter groupings) or for fishing lures (tungsten beads allow the fly to sink rapidly) . Some cello C strings are wound with tungsten . The extra density gives this sting more projection and often cellists will buy just this string and use it with 3 strings from a different set .

Sodium tungstate is used in Folin @-@ Ciocalteu 's reagent , a mixture of different chemicals used in the " Lowry Assay " for protein content analysis .

= = = Gold substitution = = =

Its density , similar to that of gold , allows tungsten to be used in jewelry as an alternative to gold or platinum . Metallic tungsten is hypoallergenic , and is harder than gold alloys (though not as hard as tungsten carbide) , making it useful for rings that will resist scratching , especially in designs with a brushed finish .

Because the density is so similar to that of gold (tungsten is only 0 @.@ 36 % less dense) , tungsten can also be used in counterfeiting of gold bars , such as by plating a tungsten bar with gold , which has been observed since the 1980s , or taking an existing gold bar , drilling holes , and replacing the removed gold with tungsten rods . The densities are not exactly the same , and other properties of gold and tungsten differ , but gold @-@ plated tungsten will pass superficial tests .

Gold @-@ plated tungsten is available commercially from China (the main source of tungsten) , both in jewelry and as bars .

= = = Electronics = = =

Because it retains its strength at high temperatures and has a high melting point , elemental tungsten is used in many high @-@ temperature applications , such as light bulb , cathode @-@ ray tube , and vacuum tube filaments , heating elements , and rocket engine nozzles . Its high melting point also makes tungsten suitable for aerospace and high @-@ temperature uses such as electrical , heating , and welding applications , notably in the gas tungsten arc welding process (also called tungsten inert gas (TIG) welding) .

Because of its conductive properties and relative chemical inertness , tungsten is also used in electrodes , and in the emitter tips in electron @-@ beam instruments that use field emission guns , such as electron microscopes . In electronics , tungsten is used as an interconnect material in integrated circuits , between the silicon dioxide dielectric material and the transistors . It is used in metallic films , which replace the wiring used in conventional electronics with a coat of tungsten (or molybdenum) on silicon .

The electronic structure of tungsten makes it one of the main sources for X @-@ ray targets , and also for shielding from high @-@ energy radiations (such as in the radiopharmaceutical industry for shielding radioactive samples of FDG) . It is also used in gamma imaging as a material from which coded apertures are made , due to its excellent shielding properties . Tungsten powder is used as a filler material in plastic composites , which are used as a nontoxic substitute for lead in bullets , shot , and radiation shields . Since this element 's thermal expansion is similar to borosilicate glass , it is used for making glass @-@ to @-@ metal seals .

= = Biological role = =

Tungsten , at atomic number 74 , is the heaviest element known to be biologically functional , with the next heaviest being iodine (Z = 53) . It is used by some bacteria , but not in eukaryotes . For example , enzymes called oxidoreductases use tungsten similarly to molybdenum by using it in a tungsten @-@ pterin complex with molybdopterin (molybdopterin , despite its name , does not contain molybdenum , but may complex with either molybdenum or tungsten in use by living organisms) . Tungsten @-@ using enzymes typically reduce carboxylic acids to aldehydes . The tungsten oxidoreductases may also catalyse oxidations . The first tungsten @-@ requiring enzyme to be discovered also requires selenium , and in this case the tungsten @-@ selenium pair may function analogously to the molybdenum @-@ sulfur pairing of some molybdenum cofactor @-@ requiring enzymes . One of the enzymes in the oxidoreductase family which sometimes employ tungsten (bacterial formate dehydrogenase H) is known to use a selenium @-@ molybdenum version of molybdopterin . Acetylene hydratase is an unusual metalloenzyme in that it catalyzes a hydration reaction . Two reaction mechanisms have been proposed , in one of which there is a direct interaction between the tungsten atom and the C ? C triple bond . Although a tungsten @-@ containing xanthine dehydrogenase from bacteria has been found to contain tungsten @-@ molydopterin and also non @-@ protein bound selenium , a tungsten @-@ selenium molybdopterin complex has not been definitively described .

In soil , tungsten metal oxidizes to the tungstate anion . It can be selectively or non @-@ selectively imported by some prokaryotic organisms and may substitute for molybdate in certain enzymes . Its effect on the action of these enzymes is in some cases inhibitory and in others positive . The soil 's chemistry determines how the tungsten polymerizes ; alkaline soils cause monomeric tungstates ; acidic soils cause polymeric tungstates .

Sodium tungstate and lead have been studied for their effect on earthworms . Lead was found to be lethal at low levels and sodium tungstate was much less toxic , but the tungstate completely inhibited their reproductive ability .

Tungsten has been studied as a biological copper metabolic antagonist , in a role similar to the action of molybdenum . It has been found that tetrathiotungstates may be used as biological copper chelation chemicals , similar to the tetrathiomolybdates .

= = Precautions = =

Because tungsten is rare and its compounds are generally inert , the effects of tungsten on the environment are limited . The median lethal dose LD50 depends strongly on the animal and the method of administration and varies between 59 mg / kg (intravenous , rabbits) and 5000 mg / kg (tungsten metal powder , intraperitoneal , rats) .

People can be exposed to tungsten in the workplace by breathing it in , swallowing it , skin contact , and eye contact . The National Institute for Occupational Safety and Health (NIOSH) has set a recommended exposure limit (REL) of 5 mg / m3 over an 8 @-@ hour workday and a short term limit of 10 mg / m3 .

= = Patent claim = =

Tungsten is unique amongst the elements in that it has been the subject of patent proceedings . In 1928 , a US court rejected General Electric 's attempt to patent it , overturning U.S. Patent 1 @,@ 082 @,@ 933 granted in 1913 to William D. Coolidge .