

= Molybdenum =

Molybdenum is a chemical element with symbol Mo and atomic number 42 . The name is from Neo Latin molybdaenum , from Ancient Greek ???????? molybdos , meaning lead , since its ores were confused with lead ores . Molybdenum minerals have been known throughout history , but the element was discovered ( in the sense of differentiating it as a new entity from the mineral salts of other metals ) in 1778 by Carl Wilhelm Scheele . The metal was first isolated in 1781 by Peter Jacob Hjelm .

Molybdenum does not occur naturally as a free metal on Earth ; it is found only in various oxidation states in minerals . The free element , a silvery metal with a gray cast , has the sixth highest melting point of any element . It readily forms hard , stable carbides in alloys , and for this reason most of world production of the element ( about 80 % ) is used in steel alloys , including high strength alloys and superalloys .

Most molybdenum compounds have low solubility in water , but when molybdenum bearing minerals contact oxygen and water , the resulting molybdate ion  $\text{MoO}_4^{2-}$  ?

4 is quite soluble . Industrially , molybdenum compounds ( about 14 % of world production of the element ) are used in high pressure and high temperature applications as pigments and catalysts .

Molybdenum bearing enzymes are by far the most common bacterial catalysts for breaking the chemical bond in atmospheric molecular nitrogen in the process of biological nitrogen fixation . At least 50 molybdenum enzymes are now known in bacteria and animals , although only bacterial and cyanobacterial enzymes are involved in nitrogen fixation . These nitrogenases contain molybdenum in a form different from other molybdenum enzymes , which all contain fully oxidized molybdenum in a molybdenum cofactor . These various molybdenum cofactor enzymes are vital to the organisms , and molybdenum is a essential element for life in all higher eukaryote organisms , though not in all bacteria .

= = Characteristics = =

= = = Physical properties = = =

In its pure form , molybdenum is a silvery grey metal with a Mohs hardness of 5 . It has a melting point of 2 623 ° C ( 4 753 ° F ) ; of the naturally occurring elements , only tantalum , osmium , rhenium , tungsten , and carbon have higher melting points . Weak oxidation of molybdenum starts at 300 ° C ( 572 ° F ) . It has one of the lowest coefficients of thermal expansion among commercially used metals . The tensile strength of molybdenum wires increases about 3 times , from about 10 to 30 GPa , when their diameter decreases from ~ 50 ? 100 nm to 10 nm .

= = = Isotopes = = =

There are 35 known isotopes of molybdenum , ranging in atomic mass from 83 to 117 , as well as four metastable nuclear isomers . Seven isotopes occur naturally , with atomic masses of 92 , 94 , 95 , 96 , 97 , 98 , and 100 . Of these naturally occurring isotopes , only molybdenum 100 is unstable .

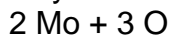
Molybdenum 98 is the most abundant isotope , comprising 24 . 14 % of all molybdenum . Molybdenum 100 has a half life of about 1019 y and undergoes double beta decay into ruthenium 100 . Molybdenum isotopes with mass numbers from 111 to 117 all have half lives of approximately 150 ns . All unstable isotopes of molybdenum decay into isotopes of niobium , technetium , and ruthenium .

As also noted below , the most common isotopic molybdenum application involves molybdenum 99 , which is a fission product . It is a parent radioisotope to the short lived gamma emitting daughter radioisotope technetium 99m , a nuclear isomer used in various imaging

applications in medicine . In 2008 , the Delft University of Technology applied for a patent on the molybdenum @-@ 98 @-@ based production of molybdenum @-@ 99 .

= = = Compounds and chemistry = = =

Molybdenum is a transition metal with an electronegativity of 2 @.@ 16 on the Pauling scale and a standard atomic weight of 95 @.@ 95 g / mol . It does not visibly react with oxygen or water at room temperature , and the bulk oxidation occurs at temperatures above 600 ° C , resulting in molybdenum trioxide :



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The trioxide is volatile and sublimes at high temperatures . This prevents formation of a continuous protective ( passivating ) oxide layer , which would stop the bulk oxidation of metal . Molybdenum has several oxidation states , the most stable being + 4 and + 6 ( bolded in the table at left ) . The chemistry and the compounds show more similarity to tungsten than to chromium ; the instability of molybdenum ( III ) and tungsten ( III ) compounds , for example , contrasts with the stability of the chromium ( III ) compounds . The highest oxidation state is seen in molybdenum ( VI ) oxide ( MoO<sub>3</sub> ) , while the normal sulfur compound is molybdenum disulfide MoS<sub>2</sub> .

Molybdenum ( VI ) oxide is soluble in strong alkaline water , forming molybdates ( MoO<sub>4</sub><sup>2-</sup> ) . Molybdates are weaker oxidants than chromates , but they show a similar tendency to form complex oxanions by condensation at lower pH values , such as [ Mo<sub>7</sub>O<sub>24</sub> ]<sup>6-</sup> and [ Mo<sub>8</sub>O<sub>26</sub> ]<sup>4-</sup> . Polymolybdates can incorporate other ions , forming polyoxometalates . The dark @-@ blue phosphorus @-@ containing heteropolymolybdate P [ Mo<sub>12</sub>O<sub>40</sub> ]<sup>3-</sup> is used for the spectroscopic detection of phosphorus . The broad range of oxidation states of molybdenum is reflected in various molybdenum chlorides :

Molybdenum ( II ) chloride MoCl<sub>2</sub> ( yellow solid )

Molybdenum ( III ) chloride MoCl<sub>3</sub> ( dark red solid )

Molybdenum ( IV ) chloride MoCl<sub>4</sub> ( black solid )

Molybdenum ( V ) chloride MoCl<sub>5</sub> ( dark green solid )

Molybdenum ( VI ) chloride MoCl<sub>6</sub> ( brown solid )

The structure of the MoCl<sub>2</sub> is clusters of Mo<sub>6</sub>Cl<sub>8</sub><sup>4+</sup> and four chloride ions compensating the charge .

Like chromium and some other transition metals , molybdenum forms quadruple bonds , such as in Mo<sub>2</sub> ( CH<sub>3</sub>COO )<sub>4</sub> . This compound can be transformed into Mo<sub>2</sub>Cl<sub>8</sub><sup>2-</sup> , which also has a quadruple bond .

The oxidation state 0 is possible with carbon monoxide as ligand , such as in molybdenum hexacarbonyl , Mo ( CO )<sub>6</sub> .

= = History = =

Molybdenite ? the principal ore from which molybdenum is now extracted ? was previously known as molybdena . Molybdena was confused with and often utilized as though it were graphite . Like graphite , molybdenite can be used to blacken a surface or as a solid lubricant . Even when molybdena was distinguishable from graphite , it was still confused with the common lead ore PbS ( now called galena ) ; the name comes from Ancient Greek ????????? molybdos , meaning lead . ( The Greek word itself has been proposed as a loanword from Anatolian Luvian and Lydian languages ) .

Although ( reportedly ) molybdenum was deliberately alloyed with steel in one 14th @-@ century Japanese sword ( mfd. ca . 1330 ) , that art was never employed widely and was later lost . In the West in 1754 , Bengt Andersson Qvist examined a sample of molybdenite and determined that it did not contain lead and thus was not galena .

By 1778 Swedish chemist Carl Wilhelm Scheele stated firmly that molybdena was ( indeed ) neither

galena nor graphite . Instead , Scheele correctly proposed that molybdena was an ore of a distinct new element , named molybdenum for the mineral in which it resided , and from which it might be isolated . Peter Jacob Hjelm successfully isolated molybdenum using carbon and linseed oil in 1781 .

For the next century , molybdenum had no industrial use . It was relatively scarce , the pure metal was difficult to extract , and the necessary techniques of metallurgy were immature . Early molybdenum steel alloys showed great promise of increased hardness , but efforts to manufacture the alloys on a large scale were hampered with inconsistent results , a tendency toward brittleness , and recrystallization . In 1906 , William D. Coolidge filed a patent for rendering molybdenum ductile , leading to applications as a heating element for high @-@ temperature furnaces and as a support for tungsten @-@ filament light bulbs ; oxide formation and degradation require that molybdenum be physically sealed or held in an inert gas . In 1913 , Frank E. Elmore developed a froth flotation process to recover molybdenite from ores ; flotation remains the primary isolation process .

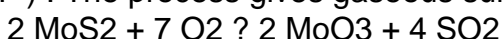
During the World War I , demand for molybdenum spiked ; it was used both in armor plating and as a substitute for tungsten in high speed steels . Some British tanks were protected by 75 mm ( 3 in ) manganese steel plating , but this proved to be ineffective . The manganese steel plates were replaced with much lighter 25 mm ( 1 @. @ 0 in ) molybdenum steel plates allowing for higher speed , greater maneuverability , and better protection . The Germans also used molybdenum @-@ doped steel for heavy artillery , like in the super @-@ heavy howitzer Big Bertha , because traditional steel melts at the temperatures produced by the propellant of the one ton shell . After the war , demand plummeted until metallurgical advances allowed extensive development of peacetime applications . In World War II , molybdenum again saw strategic importance as a substitute for tungsten in steel alloys .

= = Occurrence and production = =

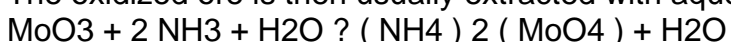
Molybdenum is the 54th most abundant element in the Earth 's crust and the 25th most abundant element in its oceans , with an average of 10 parts per billion ; it is the 42nd most abundant element in the Universe . The Russian Luna 24 mission discovered a molybdenum @-@ bearing grain (  $1 \times 10^{-6} \mu\text{m}$  ) in a pyroxene fragment taken from Mare Crisium on the Moon . The comparative rarity of molybdenum in the Earth 's crust is offset by its concentration in a number of water @-@ insoluble ores , often combined with sulfur in the same way as copper , with which it is often found . Though molybdenum is found in such minerals as wulfenite (  $\text{PbMoO}_4$  ) and powellite (  $\text{CaMoO}_4$  ) , the main commercial source is molybdenite (  $\text{MoS}_2$  ) . Molybdenum is mined as a principal ore and is also recovered as a byproduct of copper and tungsten mining .

The world 's production of molybdenum was 250 @, @ 000 tonnes in 2011 , the largest producers being China ( 94 @, @ 000 t ) , United States ( 64 @, @ 000 t ) , Chile ( 38 @, @ 000 t ) , Peru ( 18 @, @ 000 t ) and Mexico ( 12 @, @ 000 t ) . The total reserves are estimated at 10 million tonnes , and are mostly concentrated in China ( 4 @. @ 3 Mt ) , US ( 2 @. @ 7 Mt ) and Chile ( 1 @. @ 2 Mt ) . By continent , 93 % of world molybdenum production is about evenly shared between North America , South America ( mainly in Chile ) , and China . Europe and the rest of Asia ( mostly Armenia , Russia , Iran and Mongolia ) produce the remainder .

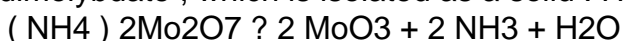
In molybdenite processing , the ore is first roasted in air at a temperature of  $700^\circ\text{C}$  (  $1 @, @ 292^\circ\text{F}$  ) . The process gives gaseous sulfur dioxide and the molybdenum ( VI ) oxide :



The oxidized ore is then usually extracted with aqueous ammonia to give ammonium molybdate :

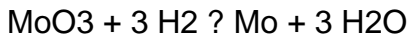


Copper , an impurity in molybdenite , is less soluble in ammonia . To completely remove it from the solution , it is precipitated with hydrogen sulfide . Ammonium molybdate converts to ammonium dimolybdate , which is isolated as a solid . Heating this solid gives molybdenum trioxide :



The crude trioxide can be further purified by sublimation at  $1 @, @ 100^\circ\text{C}$  (  $2 @, @ 210^\circ\text{F}$  ) .

Metallic molybdenum is produced by reduction of the oxide with hydrogen :



The molybdenum for steel production is reduced by the aluminothermic reaction with addition of iron to produce ferromolybdenum . A common form of ferromolybdenum contains 60 % molybdenum .

Molybdenum has a value of approximately \$ 30 @, @ 000 per tonne as of August 2009 . It maintained a price at or near \$ 10 @, @ 000 per tonne from 1997 through 2003 , and reached a peak of \$ 103 @, @ 000 per tonne in June 2005 . In 2008 the London Metal Exchange announced that molybdenum would be traded as a commodity on the exchange .

== History of molybdenum mining ==

Historically , the Knaben mine in southern Norway , opened in 1885 , was the first dedicated molybdenum mine . It was closed from 1973 to 2007 , but was reopened that year. and now produces 100 @, @ 000 kilograms ( 98 long tons ; 110 short tons ) of molybdenum disulfide per year . Large mines in Colorado ( such as the Henderson mine and the Climax mine ) and in British Columbia yield molybdenite as their primary product , while many porphyry copper deposits such as the Bingham Canyon Mine in Utah and the Chuquibambilla mine in northern Chile produce molybdenum as a byproduct of copper mining .

== Applications ==

== Alloys ==

About 86 % of molybdenum produced is used in metallurgy , with the rest used in chemical applications . The estimated global use is structural steel 35 % , stainless steel 25 % , chemicals 14 % , tool & high @-@ speed steels 9 % , cast iron 6 % , molybdenum elemental metal 6 % , and superalloys 5 % .

Molybdenum can withstand extreme temperatures without significantly expanding or softening , making it useful in environments of intense heat , including military armor , aircraft parts , electrical contacts , industrial motors , and filaments .

Most high @-@ strength steel alloys ( for example , 41xx steels ) contain 0 @. @ 25 % to 8 % molybdenum . Even in these small portions , more than 43 @, @ 000 tonnes of molybdenum are used each year in stainless steels , tool steels , cast irons , and high @-@ temperature superalloys .

Molybdenum is also valued in steel alloys for its high corrosion resistance and weldability . Molybdenum contributes corrosion resistance to type @-@ 300 stainless steels ( specifically type @-@ 316 ) and especially so in the so @-@ called superaustenitic stainless steels ( such as alloy AL @-@ 6XN , 254SMO or 1925hMo ) . Molybdenum increases lattice strain , thus increasing the energy required to dissolve iron atoms from the surface . Molybdenum is also used to enhance the corrosion resistance of ferritic ( for example grade 444 ) and martensitic ( for example 1 @. @ 4122 and 1 @. @ 4418 ) stainless steels .

Because of its lower density and more stable price , molybdenum is sometimes used in place of tungsten . An example is the ' M ' series of high @-@ speed steels such as M2 , M4 and M42 as substitution for the ' T ' steel series , which contain tungsten . Molybdenum can also be used as a flame @-@ resistant coating for other metals . Although its melting point is 2 @, @ 623 ° C ( 4 @, @ 753 ° F ) , molybdenum rapidly oxidizes at temperatures above 760 ° C ( 1 @, @ 400 ° F ) making it better @-@ suited for use in vacuum environments .

TZM ( Mo ( ~ 99 % ) , Ti ( ~ 0 @. @ 5 % ) , Zr ( ~ 0 @. @ 08 % ) and some C ) is a corrosion @-@ resisting molybdenum superalloy that resists molten fluoride salts at temperatures above 1 @, @ 300 ° C ( 2 @, @ 370 ° F ) . It has about twice the strength of pure Mo , and is more ductile and more weldable , yet in tests it resisted corrosion of a standard eutectic salt ( FLiBe ) and salt vapors used in molten salt reactors for 1100 hours with so little corrosion that it was difficult to measure .

Other molybdenum @-@ based alloys that do not contain iron have only limited applications . For example , because of its resistance to molten zinc , both pure molybdenum and molybdenum / tungsten alloy ( 70 % / 30 % ) are used for piping , stirrers and pump impellers that come into contact with molten zinc .

= = = Other applications as the pure element = = =

Molybdenum powder is used as a fertilizer for some plants , such as cauliflower .

Elemental molybdenum is used in NO , NO<sub>2</sub> , NO<sub>x</sub> analyzers in power plants for pollution controls . At 350 ° C ( 662 ° F ) , the element acts as a catalyst for NO<sub>2</sub> / NO<sub>x</sub> to form NO molecules for detection by infrared light .

Molybdenum anodes replace tungsten in certain low voltage X @-@ ray sources for specialized uses such as mammography .

The radioactive isotope molybdenum @-@ 99 is used to generate technetium @-@ 99m , used for medical imaging .

= = = Compounds ( 14 % of global use ) = = =

Molybdenum disulfide ( MoS<sub>2</sub> ) is used as a solid lubricant and a high @-@ pressure high @-@ temperature ( HPHT ) antiwear agent . It forms strong films on metallic surfaces and is a common additive to HPHT greases ? in the event of a catastrophic grease failure , a thin layer of molybdenum prevents contact of the lubricated parts . It also has semiconducting properties with distinct advantages over traditional silicon or graphene in electronics applications . MoS<sub>2</sub> is also used as a catalyst in hydrocracking of petroleum fractions containing nitrogen , sulfur and oxygen .

Molybdenum disilicide ( MoSi<sub>2</sub> ) is an electrically conducting ceramic with primary use in heating elements operating at temperatures above 1500 ° C in air .

Molybdenum trioxide ( MoO<sub>3</sub> ) is used as an adhesive between enamels and metals . Lead molybdate ( wulfenite ) co @-@ precipitated with lead chromate and lead sulfate is a bright @-@ orange pigment used with ceramics and plastics .

The molybdenum @-@ based mixed oxides are versatile catalysts in the chemical industry . Some examples are the catalysts for the selective oxidation of propylene to acrolein and acrylic acid , the ammoxidation of propylene to acrylonitrile . Suitable catalysts and process for the direct selective oxidation of propane to acrylic acid are being researched .

Ammonium heptamolybdate is used in biological staining .

Molybdenum coated soda lime glass is used in CIGS solar cells .

Phosphomolybdic acid is a stain used in thin layer chromatography .

Molybdenum @-@ 99 is a parent radioisotope of the daughter radioisotope technetium @-@ 99m , used in many medical procedures . The isotope is handled and stored as the molybdate .

= = Biological role = =

= = = Nitrogenases = = =

The most important role of the molybdenum in living organisms is as a metal heteroatom at the active site in certain enzymes . In bacterial nitrogen fixation , the nitrogenase enzyme involved in the terminal step of reducing molecular nitrogen usually contains molybdenum in the active site ( though replacement of Mo with iron or vanadium is also known ) . The structure of the catalytic center of the enzyme is similar to that in iron @-@ sulfur proteins : it incorporates a Fe<sub>4</sub>S<sub>3</sub> and multiple MoFe<sub>3</sub>S<sub>3</sub> clusters .

The reaction that nitrogenase enzymes perform is :

<formula>

With protons and electrons from the electron transport chain , nitrogen is reduced to ammonia and

free hydrogen gas . This is an energy @-@ using process , requiring the splitting ( hydrolysis ) of ATP into ADP plus free phosphate ( Pi ) .

In 2008 , evidence was reported that a scarcity of molybdenum in the Earth 's early oceans was a limiting factor for nearly two billion years in the further evolution of eukaryotic life ( which includes all plants and animals ) . The chain of causation is as follows :

The relative lack of oxygen in the early ocean resulted in a scarcity in dissolved molybdenum . Most molybdenum compounds have low solubility in water , but the molybdate ion  $\text{MoO}_4^{2-}$  is soluble and forms when molybdenum @-@ containing minerals are in contact with oxygen and water .

The lack of dissolved molybdenum limited the growth of prokaryotic nitrogen @-@ fixing bacteria , which require molybdenum @-@ bearing enzymes for the process

The lack of prokaryotic nitrogen @-@ fixing bacteria limited the growth of ocean eukaryotes , which require oxidized nitrogen suitable for the production of organic nitrogen compounds or the organics themselves ( like proteins ) from prokaryotic bacteria .

However , once oxygen had been created in seawater by the limited eukaryotes , it reacted with water and the molybdenum in minerals on the sea bottom to produce soluble molybdate , making it available to nitrogen @-@ fixing bacteria . Those bacteria provided fixed usable nitrogen compounds for higher forms of life . In 2013 , it was suggested that boron and molybdenum catalyzed the production of RNA on Mars , and that life was transported to Earth by a meteorite around 3 billion years ago .

Although oxygen once promoted nitrogen fixation by making molybdenum available in water , it also directly poisons nitrogenase enzymes . Thus , in Earth 's ancient history , after oxygen arrived in large quantities in Earth 's air and water , organisms that continued to fix nitrogen in aerobic conditions isolated and protected their nitrogen @-@ fixing enzymes from too much oxygen in heterocysts or equivalent structures . This structural isolation of nitrogen fixation reactions in aerobic organisms continues to the present .

== Molybdenum cofactor enzymes ==

Though molybdenum forms compounds with various organic molecules , including carbohydrates and amino acids , it is transported throughout the human body as  $\text{MoO}_4^{2-}$  . At least 50 molybdenum @-@ containing enzymes were known by 2002 , mostly in bacteria , and the number is increasing with every year ; those enzymes include aldehyde oxidase , sulfite oxidase and xanthine oxidase . In some animals , and in humans , the oxidation of xanthine to uric acid , a process of purine catabolism , is catalyzed by xanthine oxidase , a molybdenum @-@ containing enzyme . The activity of xanthine oxidase is directly proportional to the amount of molybdenum in the body . However , an extremely high concentration of molybdenum reverses the trend and can act as an inhibitor in both purine catabolism and other processes . Molybdenum concentration also affects protein synthesis , metabolism , and growth .

In animals and plants , a tricyclic compound called molybdopterin ( which , despite the name , contains no molybdenum ) is reacted with molybdate to form a complete molybdenum @-@ containing cofactor called molybdenum cofactor . Other than the phylogenetically @-@ ancient nitrogenases ( discussed above ) that fix nitrogen in some bacteria and cyanobacteria , all molybdenum @-@ using enzymes ( so far identified ) use the molybdenum cofactor , where molybdenum is in the oxidation state of VI , similar to molybdate . Molybdenum enzymes in plants and animals catalyze the oxidation and sometimes reduction of certain small molecules in the process of regulating nitrogen , sulfur , and carbon .

== Human dietary intake and deficiency ==

Molybdenum is a trace dietary element necessary for the survival of humans and the few mammals that have been studied . Four mammalian Mo @-@ dependent enzymes are known , all of them harboring a pterin @-@ based molybdenum cofactor ( Moco ) in their active site : sulfite oxidase , xanthine oxidoreductase , aldehyde oxidase , and mitochondrial amidoxime reductase . People

severely deficient in molybdenum have poorly functioning sulfite oxidase and are prone to toxic reactions to sulfites in foods . The human body contains about 0 .07 mg of molybdenum per kilogram of body weight , with higher concentrations in the liver and kidneys and in lower in the vertebrae . Molybdenum is also present within human tooth enamel and may help prevent its decay .

The average daily intake of molybdenum varies between 0 .12 and 0 .24 mg , depending on the molybdenum content of the food . Pork , lamb , and beef liver each have approximately 1 .5 parts per million of molybdenum . Other significant dietary sources include green beans , eggs , sunflower seeds , wheat flour , lentils , cucumbers and cereal grain . Acute toxicity has not been seen in humans , and the toxicity depends strongly on the chemical state . Studies on rats show a median lethal dose ( LD50 ) as low as 180 mg / kg for some Mo compounds . Although human toxicity data is unavailable , animal studies have shown that chronic ingestion of more than 10 mg / day of molybdenum can cause diarrhea , growth retardation , infertility , low birth weight , and gout ; it can also affect the lungs , kidneys , and liver . Sodium tungstate is a competitive inhibitor of molybdenum . Dietary tungsten reduces the concentration of molybdenum in tissues .

Low soil concentration of molybdenum in a geographical band from northern China to Iran results in a general dietary molybdenum deficiency , and is associated with increased rates of esophageal cancer . Compared to the United States , which has a greater supply of molybdenum in the soil , people living in those areas have about 16 times greater risk for esophageal squamous cell carcinoma .

Molybdenum deficiency has also been reported as a consequence of non -molybdenum supplemented total parenteral nutrition ( complete intravenous feeding ) for long periods of time . It results in high blood levels of sulfite and urate , in much the same way as molybdenum cofactor deficiency . However ( presumably since pure molybdenum deficiency from this cause occurs primarily in adults ) , the neurological consequences are not as marked as in cases of congenital cofactor deficiency .

== Related diseases ==

A congenital molybdenum cofactor deficiency disease , seen in infants , is an inability to synthesize molybdenum cofactor , a heterocyclic molecule that binds molybdenum at the active site in all known human enzymes that use molybdenum . The resulting deficiency results in high levels of sulfite and urate , and neurological damage .

== Copper -molybdenum antagonism ==

High levels of molybdenum can interfere with the body 's uptake of copper , producing copper deficiency . Molybdenum prevents plasma proteins from binding to copper , and it also increases the amount of copper that is excreted in urine . Ruminants that consume high levels of molybdenum suffer from diarrhea , stunted growth , anemia , and achromotrichia ( loss of fur pigment ) . These symptoms can be alleviated by copper supplements , either dietary and injection . The effective copper deficiency , can be aggravated by excess sulfur .

Copper reduction or deficiency can also be deliberately induced for therapeutic purposes by the compound ammonium tetrathiomolybdate , in which the bright red anion tetrathiomolybdate is the copper -chelating agent . Tetrathiomolybdate was first used therapeutically in the treatment of copper toxicosis in animals . It was then introduced as a treatment in Wilson 's disease , a hereditary copper metabolism disorder in humans ; it acts both by competing with copper absorption in the bowel and by increasing excretion . It has also been found to have an inhibitory effect on angiogenesis , potentially by inhibiting the membrane translocation process that is dependent on copper ions . This is a promising avenue for investigation of treatments for cancer , age -related macular degeneration , and other diseases that involve a pathologic proliferation of blood vessels .

## = = Precautions = =

Molybdenum dusts and fumes , generated by mining or metalworking , can be toxic , especially if ingested ( including dust trapped in the sinuses and later swallowed ) . Low levels of prolonged exposure can cause irritation to the eyes and skin . Direct inhalation or ingestion of molybdenum and its oxides should be avoided . OSHA regulations specify the maximum permissible molybdenum exposure in an 8 @-@ hour day as 5 mg / m<sup>3</sup> . Chronic exposure to 60 to 600 mg / m<sup>3</sup> can cause symptoms including fatigue , headaches and joint pains . At levels of 5000 mg / m<sup>3</sup> , molybdenum is immediately dangerous to life and health .