Molybdenum

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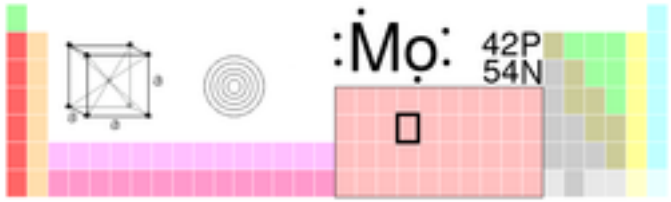
Molybdenum [mah-LIB-den-um] is a chemical element in the periodic table. Its symbol is **Mo** and its atomic number 42.

Contents

42	niobium ← molybdenum → technetium
Cr ↑ **Mo** ↓ W	 periodic table

General	
Name, Symbol, Number	molybdenum, Mo, 42
Chemical series	transition metals
Group, Period, Block	6, 5, d
Appearance	gray metallic 
Atomic mass	95.94(2) g/mol
Electron configuration	[Kr] $4d^5\ 5s^1$
Electrons per shell	2, 8, 18, 13, 1
Physical properties	
Phase	solid
Density (near r.t.)	10.28 $g \cdot cm^{-3}$
Liquid density at m.p.	9.33 $g \cdot cm^{-3}$
Melting point	2896 K (2623 °C, 4753 °F)
Boiling point	4912 K (4639 °C, 8382 °F)
Heat of fusion	37.48 $kJ \cdot mol^{-1}$

Notable characteristics

Molybdenum is a transition metal. The pure metal is silvery white in color, fairly

soft, and has one of the highest melting points of all pure elements. In small quantities, molybdenum is effective at hardening steel. Molybdenum is important in plant nutrition, and is found in certain enzymes, including xanthine oxidase.

The pure metal has a tendency to flake apart during machining.

Molybdenum prices have increased from a low of about $2/pound in 2000, to about $25/pound as of June 2006, down from a high of $40/pound in May of 2005[1].

Applications

Over 2/3 of all molybdenum is used in alloys. Molybdenum use soared during World War I, when demand for tungsten (Wolfram) made tungsten scarce and high-strength steels were at a premium. Molybdenum is used to this day in high-strength alloys and in high-temperature steels. Special molybdenum-containing alloys, such as the Hastelloys, are notably heat-resistant and corrosion-resistant. Molybdenum is used in oil pipelines, aircraft and missile parts, and in filaments. Molybdenum finds use as a

Heat of vaporization	617 kJ·mol^{-1}
Heat capacity	(25 °C) 24.06 J·mol^{-1}·K^{-1}

Vapor pressure

P/Pa	1	10	100	1 k	10 k	100 k
at *T*/K	2742	2994	3312	3707	4212	4879

Atomic properties	
Crystal structure	cubic body centered
Oxidation states	2, 3, 4, 5, **6** (strongly acidic oxide)
Electronegativity	2.16 (Pauling scale)
Ionization energies (more)	1st: 684.3 kJ·mol^{-1}
	2nd: 1560 kJ·mol^{-1}
	3rd: 2618 kJ·mol^{-1}
Atomic radius	145 pm
Atomic radius (calc.)	190 pm
Covalent radius	145 pm
Miscellaneous	
Magnetic ordering	no data
Electrical resistivity	(20 °C) 53.4 nΩ·m
Thermal conductivity	(300 K) 138 W·m^{-1}·K^{-1}
Thermal expansion	(25 °C) 4.8 µm·m^{-1}·K^{-1}
Speed of sound (thin rod)	(r.t.) 5400 m·s^{-1}
Young's modulus	329 GPa
Shear modulus	20 GPa
Bulk modulus	230 GPa
Poisson ratio	0.31
Mohs hardness	5.5
Vickers hardness	1530 MPa
Brinell hardness	1500 MPa

catalyst in the petroleum industry, especially in catalysts for removing organic sulfurs from petroleum products. Mo-99 is used in the nuclear isotope industry. Molybdenum ranges are pigments ranging from red-yellow to a bright red orange and used in paints, inks, plastics, and rubber compounds. Molybdenum disulfide is a good lubricant, especially at high temperatures. Molybdenum is also used in some electronic applications, as the conductive metal layers in thin-film transistors (TFTs).

CAS registry number	7439-98-7				
Notable isotopes					
Main article: Isotopes of molybdenum					
iso	**NA**	**half-life**	**DM**	**DE (MeV)**	**DP**
^{92}Mo	14.84%	Mo is stable with 50 neutrons			
^{93}Mo	syn	4×10^{3} y	ε	-	^{93}Nb
^{94}Mo	9.25%	Mo is stable with 52 neutrons			
^{95}Mo	15.92%	Mo is stable with 53 neutrons			
^{96}Mo	16.68%	Mo is stable with 54 neutrons			
^{97}Mo	9.55%	Mo is stable with 55 neutrons			
^{98}Mo	24.13%	Mo is stable with 56 neutrons			
^{99}Mo	syn	65.94 h	β-	0.436, 1.214	^{99}Tc
			γ	0.74, 0.36, 0.14	-
^{100}Mo	9.63%	7.8×10^{18} y	β-β-	?	^{100}Ru
References					

History

Molybdenum (from the Greek *molybdos* meaning "lead-like") is not found free in nature, and the compounds that can be found were, until the late 18th century, confused with compounds of other elements, such as carbon or lead. In 1778 Carl Wilhelm Scheele was able to determine that molybdenum was separate from graphite and lead, and isolated the oxide of the metal from molybdenite. In 1782 Hjelm isolated an impure extract of the metal by reducing the oxide with carbon. Molybdenum was little used and remained in the laboratory until the late 19th century. Subsequently, a French company, Schneider and Co, tried molybdenum as an alloying agent in steel armor plate and noted its useful properties.

Occurrence

Though molybdenum is found in such minerals as wulfenite ($PbMoO_4$) or powellite ($CaMoO_4$), the main commercial source of molybdenum is molybdenite (MoS_2). Molybdenum is mined directly, and is also recovered as a byproduct of copper mining. Molybdenum is present in ores

from 0.01% to about 0.5%. About half of the world's molybdenum is mined in the United States, with Phelps Dodge Corporation being a primary provider.

The Russian Luna 24 mission discovered a single grain (1 × 0.6 µm) of pure molybdenum in a pyroxene fragment taken from Mare Crisium on the Moon.

See also molybdenum minerals.

Biological role

Molybdenum has been found to have a role in the biology of all classes of organisms. It is found in two groups of enzymes, the nitrogenases and the molybdopterins.

The nitrogenases are found in bacteria, and are involved in the pathways of nitrogen fixation. The bacteria may be found inside plants. The molybdenum atom is present in a cluster(see cluster chemistry), which includes iron and sulfur atoms. The name molybdopterin is misleading as the group of enzymes includes tungsten-containing enzymes, and the word "molybdopterin" does not actually refer to the metal atom. The group may also be referred to as the "mononuclear molybdenum enzymes" as the metal atom is not present in a cluster. This group of enzymes is involved in a variety of processes, as part of the global sulfur, nitrogen and carbon cycles, and generally involve an oxygen atom transfer as part of the process.

There is a trace requirement for molybdenum in plants, and soils can be barren due to molybdenum deficiencies. Plants and animals generally have molybdenum present in amounts of a few parts per million. In animals molybdenum is a cofactor of the enzyme xanthine oxidase which is involved in the pathways of purine degradation and formation of uric acid. In some animals, adding a small amount of dietary molybdenum enhances growth.

Francis Crick suggested that since molybdenum is an essential trace element that plays an important role in many enzymatic reactions, despite being less abundant than the more common elements, such as chromium and nickel, that perhaps this fact is indictative of "Panspermia." Crick

theorized that if it could be shown that the elements represented in terrestrial living organisms corelate closely with those that are abundant in some class of star - molybdenum stars, for example, that this would provide evidence of such Directed Panspermia.

Isotopes

Molybdenum has six stable isotopes and almost two dozen radioisotopes, the vast majority of which have half-lives measured in seconds. Mo-99 is used in sorpation generators to create Tc-99 for the nuclear isotope industry. The market for Mo-99 products is estimated to be on the order of US$100 million per year.

Precautions

Molybdenum dusts and molybdenum compounds, such as molybdenum trioxide and water-soluble molybdates, may have slight toxicities if inhaled or ingested orally. Laboratory tests suggest, compared to many heavy metals, that molybdenum is of relatively low toxicity. Acute toxicity in humans is unlikely because the dose required would be exceptionally large. There is the potential for molybdenum exposure in mining and refining operations, as well as the chemical industry, but to date, no instance of harm from this exposure has been reported. Though water-soluble molybdenum compounds can have a slight toxicity, those that are insoluble, such as the lubricant molybdenum disulfide, are considered to be non-toxic.

However, environmental chains of events can end in serious molybdenum-related health consequences. In 1996, an increase in acid rain near Uppsala, Sweden caused a depletion in the natural foods of moose in nearby rural areas. This caused the moose to venture into the fields of oat farmers who had been heavily liming their soil to compensate for the effect of the acid. The lime caused changes to the levels of cadmium and other trace metals in the soil, causing the oat crops to uptake trace molybdenum in large quantities. Ingestion of the oats by hundreds of moose brought on a severe disturbance in the ratio of molybdenum to copper in their livers, which caused emaciation, hair discoloration, ulcers, diarrhea, convulsions, blindness, osteoporosis and finally heart failure.

OSHA regulations specify maximum molybdenum exposure in an 8-hour day (40-hour week) to be 15 milligrams per cubic meter. NIOSH recommends exposure limit of 5000 mg per cubic meter.

Toxicity in animals

In ruminants, the molybdenum toxicity occurs if the animals are let to graze on soil rich in molybdenum, but deficient in copper. The molybdenum causes excretion of copper reserves from the animal and cause copper deficiency. In young calves, the molybdenum toxicity is manifested as "teart" or shooting diarrhoea, where the dung is watery, full of air bubbles and with a fetid odor. In pigs and sheep, molybdenum toxicity combined with copper deficiency can lead to a condition called sway back or paralysis of hind quarters. In black coated animals, the toxicity of this metal is characterized by depigmentation of the skin surrounding the eyes, which is often referred to as "spectacled eyes"

See also

- Molybdenum compounds.

References

- Los Alamos National Laboratory – Molybdenum

External links

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- WebElements.com — Molybdenum
- International Molybdenum Association — environmental data

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