MEDSTERN CANADA LLP

RELIABLE. AUTHENTIC.

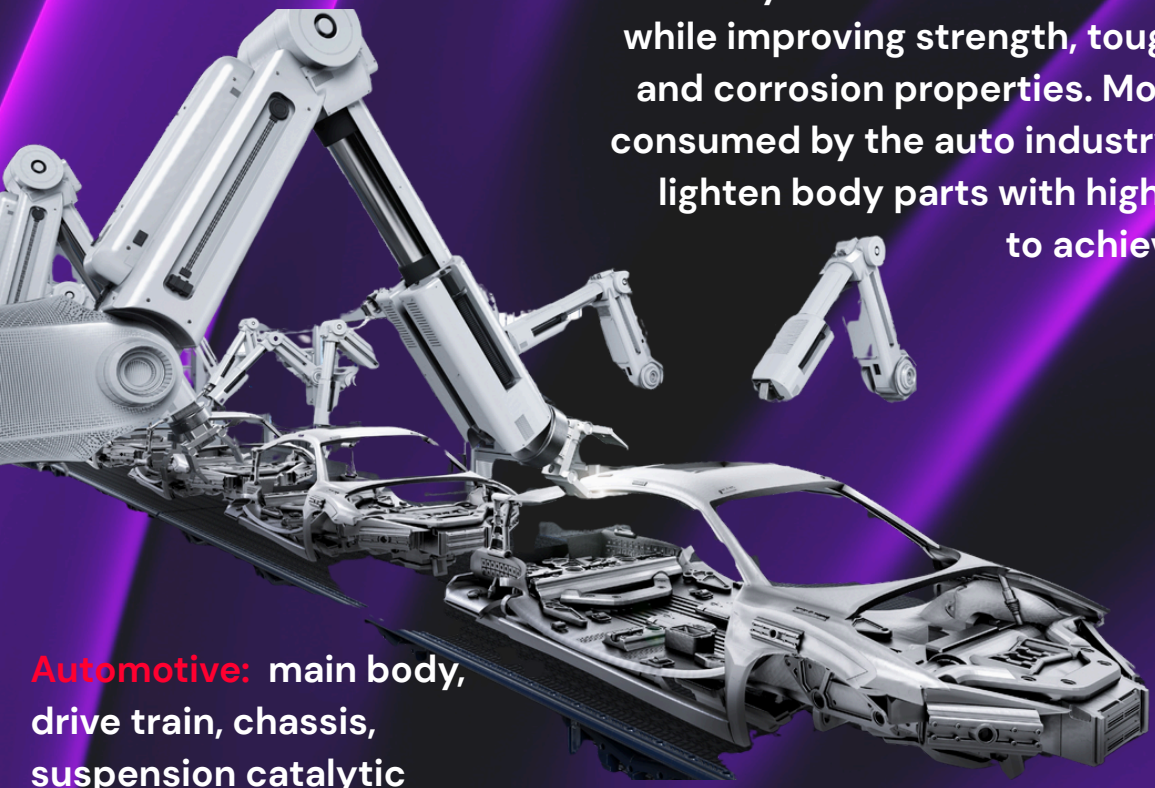
EDITION

SUMMER 2025

RELIABLE MOLYBDENUM

For Modern Industries

Molybdenum (Mo) is a valuable material, primarily used as an alloy in steels. Mo makes steel easier to work with while improving strength, toughness, wear resistance, and corrosion properties. More than 40,000 tons are consumed by the auto industry each year. Mo helps to lighten body parts with high strength requirements to achieve higher fuel efficiency.



Automotive: main body, drive train, chassis, suspension catalytic converters, exhaust system, etc.

CLEAN ENERGY

Wind and Hydro Power, Hydrogen

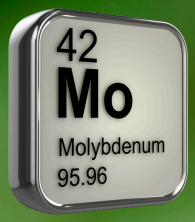
Key component for renewable energy generation, e.g., shafts, bearings, converters of large windmills with geared turbines (about 100kg Mo per MW power capacity installed), hydropower turbines, generators, catalysts for hydrogen electrolysis using (MoS_2), high-temperature fuel cell parts.

ELECTRONICS

Components, Parts

Molybdenum is used in various electronic components, including heating elements, electrodes, filaments, power electronics, and heat sinks, due to its high melting point and electrical conductivity. Mo is also important for advanced microelectronics, including LED devices, thin film transistors TFTs, etc.

INVESTMENT OPPORTUNITIES



Sustainable Mining, Metals, and Galvanic Industries

Canada boasts a diverse range of minerals, including traditional commodities like base metals, as well as critical minerals. The country is home to a large number of mining companies and is a leading destination for international mining finance. Foreign direct investment (FDI) in the Canadian mining sector was $65.1 billion in 2022.

Status 2024/2025

ACCESS RESOURCES, GROW SUPPLY BASE

MINES, MINERAL DEPOSITS | **METAL, GALVANIC INDUSTRIES** | **LOGISTIC INFRASTRUCTURE**

Including extraction, services, primary and downstream manufacturing, the Canadian Mining and Metals Sector contributed a total of $108.5 billion to GDP in 2022. Canada has a well-established mining sector with a supportive regulatory framework, including established stock exchanges. Investors who can guarantee offtake agreements contribute significantly to the economy. Reliable and robust technologies are the key to leaving behind only clean water, healthy landscapes, and achieving greater competitive strength through value-added mining and metal commodities.

AUTHENTIC MOLYBDENUM

Physical and Chemical Properties

95.96 42
[Kr]4d⁵5s¹
Mo
Transition Metal
MOLYBDENUM

Atomic Structure, Molybdenum, Mo

Electron Affinity	-71.90 kJ/mol	Electronegativity (Pauling)	2.16

Periodic Table of the Elements

Molybdenum, Mo
Period 6
Group 5

Physical Properties, Molybdenum, Mo

Density at 20 °C	10280 kg/ m^3
Spec. Heat Capacity	251 J/ (kg * K)
Melting point	2896 K, 2623 °C
Boiling point	4912 K, 4639 °C

Isotopes, Molybdenum, Mo

^{92}Mo	^{95}Mo	^{96}Mo	^{98}Mo	^{100}Mo
91.9068 u	94.9058 u	95.9046 u	97.9054 u	99.9074 u

PHYSICAL

Appearance: Silvery-white metal, grey powder
Crystal Structure: Body-centered cubic
Hardness: 5.5 Mohs Scale, depending on purity
Malleability: Can be shaped into various forms
Conductivity: Conductor of heat, electricity
Young's Modulus: 329 GPa

CHEMICAL

Corrosion Resistance: resistant to corrosion in chloride-rich environments, e.g., seawater
Thermal Expansion (25°C): 4.8 µm ($m^{-1} \cdot K^{-1}$)
Common Oxidation States: from −2 to +6
Molybdenum Compounds: e.g., Molybdenum trioxide (MoO_3), Molybdenum dioxide (MoO_2)

MOLYBDENUM MINERALS

Mining Industry, Raw Materials

Powellite
($CaMoO_4$)

Calcium Molybdate
Strunz:
7.GA.05

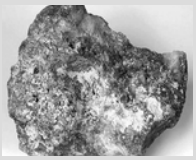
Wulfenite
($PbMoO_4$)

Lead Molybdate
Strunz:
7.GA.05

Molybdenite
(MoS_2)

Molybdenum disulfide
Strunz:
2.EA.30

Molybdite
(MoO_3)



Molybdenum trioxide
Strunz:
4.EA.10

FROTH FLOTATION

Ore Preparation Phase: From Gangue Material to Molybdenum Disulfide Ore Concentrate

Crushing → Grinding → Classification → **Beneficiation**

- Jaw-, Cone-, Impact Crushers, Ball Mills
- Smaller sized rocks, finer fragments
- Hydrocyclones, screens
- Molybdenum content in mined ore, 0.01 - 0.25% Mo
- Froth flotation, gravity spirals

Froth Flotation Process

- Slurry Preparation
- Addition of water, collectors, e.g., kerosene, diesel oil, xanthates, frothers, e.g., methyl isobutyl carbinol
- Aeration, foam layer skimming, dewatering
- Making MoS_2-containing particles hydrophobic
- MoS_2 concentrate often > 57 % Mo

MOLYBDENUM PROCESSING

The Metal and Galvanic Industries

From Molybdenum Disulfide MoS_2 to Ammonium Orthomolybdate $(NH_4)_2MoO_4$

Roasting

- Molybdenite (MoS_2): $2MoS_2 + 7O_2 \rightarrow \mathbf{2MoO_3} + 4SO_2$
- Hearth Furnace, 500 °C to 750 °C, Molybdenum Trioxide: MoO_3

Dissolution

- Dissolution in Ammonia, NH_3 at 80°C, alkaline conditions
- Soluble ammonium molybdate species: $(NH_4)_2MoO_4$

Purification

- e.g., via crystallization, desiccator
- e.g., ion exchange, resin column, etc.

From Ammonium orthomolybdate $(NH_4)_2MoO_4$ to Molybdenum Powder Mo

Heating

- Heating $(NH_4)_2MoO_4$ at 350 °C to 450 °C
- Pure Molybdenum Trioxide: MoO_3

1st Stage

- $MoO_3 + H_2 \rightarrow \mathbf{MoO_2} + H_2O$, at 650 °C
- Molybdenum dioxide, $\mathbf{MoO_2}$

2nd Stage

- $MoO_2 + H_2 \rightarrow \mathbf{Mo} + H_2O$, at 1150 °C
- Molybdenum powder, **Mo**

ELECTRIC ARC FURNACE

Sintering

- e.g. Vacuum Arc Melting Furnace, clean, high-purity melts, alloying
- Molybdenum Mo powder at >1800 °C

Melting

- Compact metal: > 99.97% Mo
- EAF, Argon inert gas: at >2700 °C
- Cooling to ingots

TRANSPORTATION SUPPORT SERVICES

Supply Chain Integration

Tailored logistics support services are available to B2B Partners, outsourcing their supply chain needs, including secure storage in warehouses, freight rail transportation, and specialized service providers for cargo handling and management, to ensure products get to market on time and within budget.

MODES OF TRANSPORTATION

- Trucks: for short distance hauls and last-mile delivery
- Trains: for long-distance transport of products, goods
- Ships: for large volumes of commodities via ocean freight

TRANSLOADING FACILITIES

- Access to distribution centers, warehouses, and storage space
- Secure transfer of commodities between modes of transportation, e.g., rail-to-ship

LOGISTICS SUPPORT SERVICES

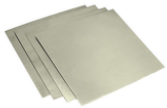
- Optimized shipping processes, analysis, including route planning, cost calculation, carrier identification, shipment tracking. and tracing for precision, real-time product movement
- Automated reporting

MOLYBDENUM PRODUCT FORMATS

Industrial Formats for Molybdenum, Mo

Tailored product formats can be made accessible to B2B Partners, based on achieved off-take agreements. The highlighted products on this page are a selection of possible product alternatives available for trade.

Molybdenum Disulfide, MoS_2 Concentrate	Molybdenum Trioxide, MoO_3 Concentrate	Molybdenum Dioxide, MoO_2 Concentrate	Ammonium orthomolybdate
			

Ingots	Briquettes	Plates	Sheets, Flats
			

Molybdenum-Nickel, Rods, Mo-Ni	Molybdenum-Copper, Wires, Mo-Cu	Molybdenum-Titanium, Tubes, Mo-Ti-Zr-C	Molybdenum-Rhenium, Cups, Mo-Re
			

PRIMARY MOLYBDENUM COMMODITIES

Classes and Standards

Refined Molybdenum, Mo

- ❑ **High-Purity Molybdenum, unalloyed**
  - ❑ ASTM B386/387
  - ❑ Ingots, Sticks, Plates, Rods, Wires, Sheets, Strips, Foils
    - ❑ Purity ≥ 99.95%
- ❑ **High-Purity Molybdenum, unalloyed**
  - ❑ ASTM B386-361, produced via powder
  - ❑ Purity ≥ 99.9%, 3N High Purity
- ❑ **High-Purity Molybdenum, unalloyed**
  - ❑ Purity ≥ 99.999%, 5N Very High Purity
  - ❑ Purity ≥ 99.99%, 4N High Purity

Molybdenum-based Alloys

- ❑ **Molybdenum-Titanium Alloys, Mo-Ti-Zr-C**
  - ❑ TZM Prime, Discs, Ingots, Tubes, Rods
- ❑ **Molybdenum-Nickel Alloys, Mo-Ni**
  - ❑ ASTM B333-03, Plates, Sheets, Stripes
- ❑ **Molybdenum-Copper Alloys, Mo-Cu**
  - ❑ DIN 17660, Bars, Rods, Wires
- ❑ **Molybdenum-Nickel-Chromium Alloys, Mo-Ni-Cr**
  - ❑ DIN 17744:2020, Sheets, Rods, Sticks, Wires
- ❑ **Molybdenum-Rhenium Alloys, Mo-Re**
  - ❑ ASTM F3273-17, Bars, Flats, Sheets
- ❑ **Molybdenum-Iron Alloys, Mo-Ni-Cr-Fe**
  - ❑ AISI 316, CF8M, corrosion/chloride-resistant

Measurement Standards

- ❑ ISO 4289, Surface Quality
- ❑ EN 10273, Weldability Bars
- ❑ DIN EN ISO 3183, Steel Pipes
- ❑ DIN 17034, ISO 17025, Laboratories
- ❑ ASTM-B329, Metal Powders Density
  - ❑ Molybdenum Disulfide, MoS_2
  - ❑ Molybdenum Trioxide, MoO_3
  - ❑ Molybdenum Dioxide, MoO_2

GLOSSARY

Abbreviations, Definitions

Froth Flotation	a mineral processing technique that separates valuable materials from tails based on differences in their surface properties, specifically their hydrophobicity (water-repelling) or hydrophilicity (water-attracting).
Electric Arc Furnace	a furnace that uses an electric arc to heat and melt metals, by passing an electric current through them. Key components are a furnace chamber, electrodes (e.g. graphite), a power source, and a system for charging and discharging the furnace.
Electrowinning	an electrolytic process used to recover metals from a solution by depositing them onto a cathode using an electric current. Base metals like zinc, nickel, copper, and cobalt can be recovered through electrowinning.
Standardization Institutes	ISO: International Organization for Standardization EN: European Norm/ Standard ASTA: American Society for Testing Materials DIN: Deutsches Institut für Normung

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- Business Consulting
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