

Chemical Applications of Molybdenum

Understanding
molybdenum chemistry
and applications

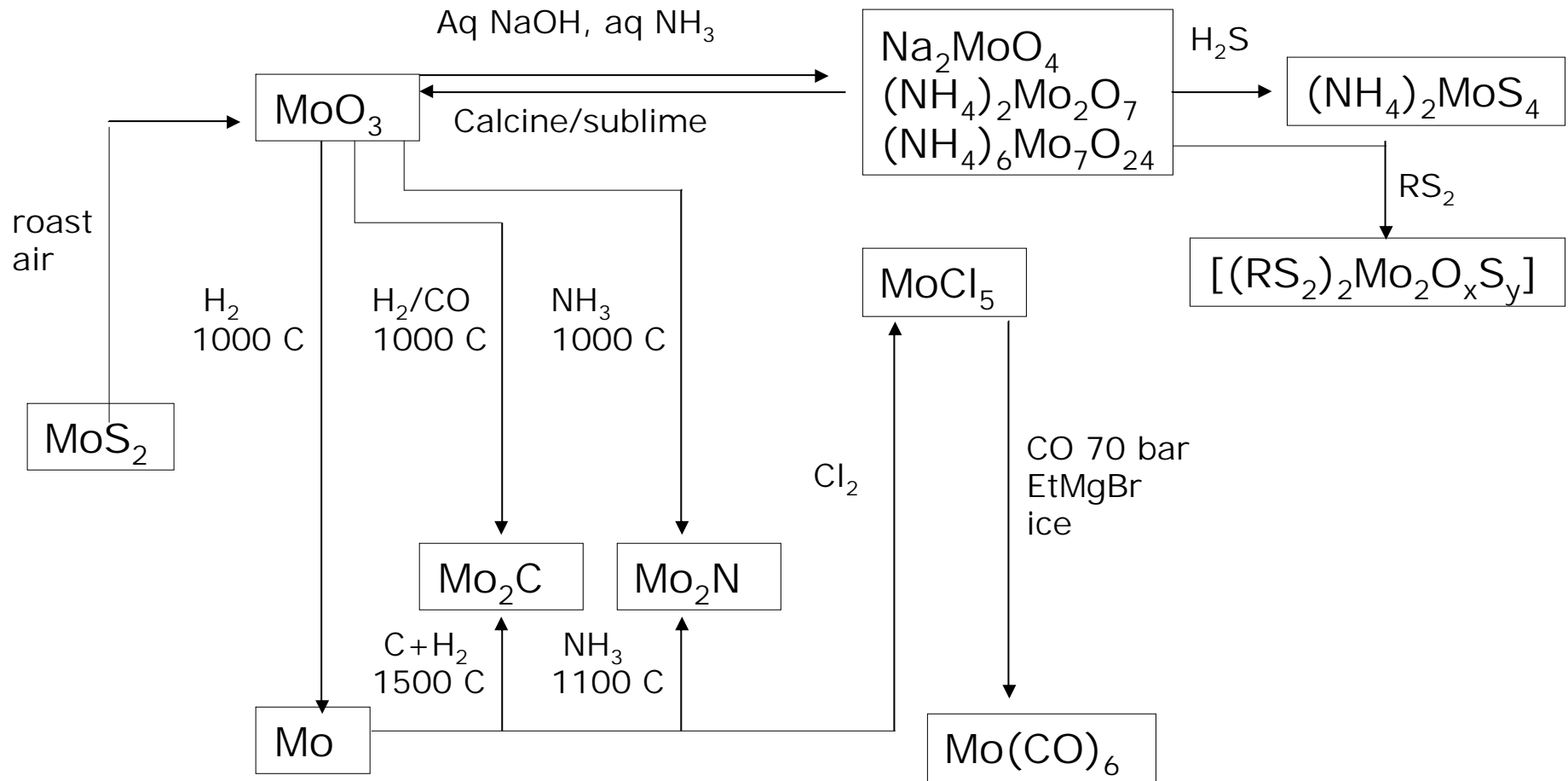
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The purpose of the presentation is to show how technical applications of molybdenum compounds exploit fundamental molybdenum chemistry.

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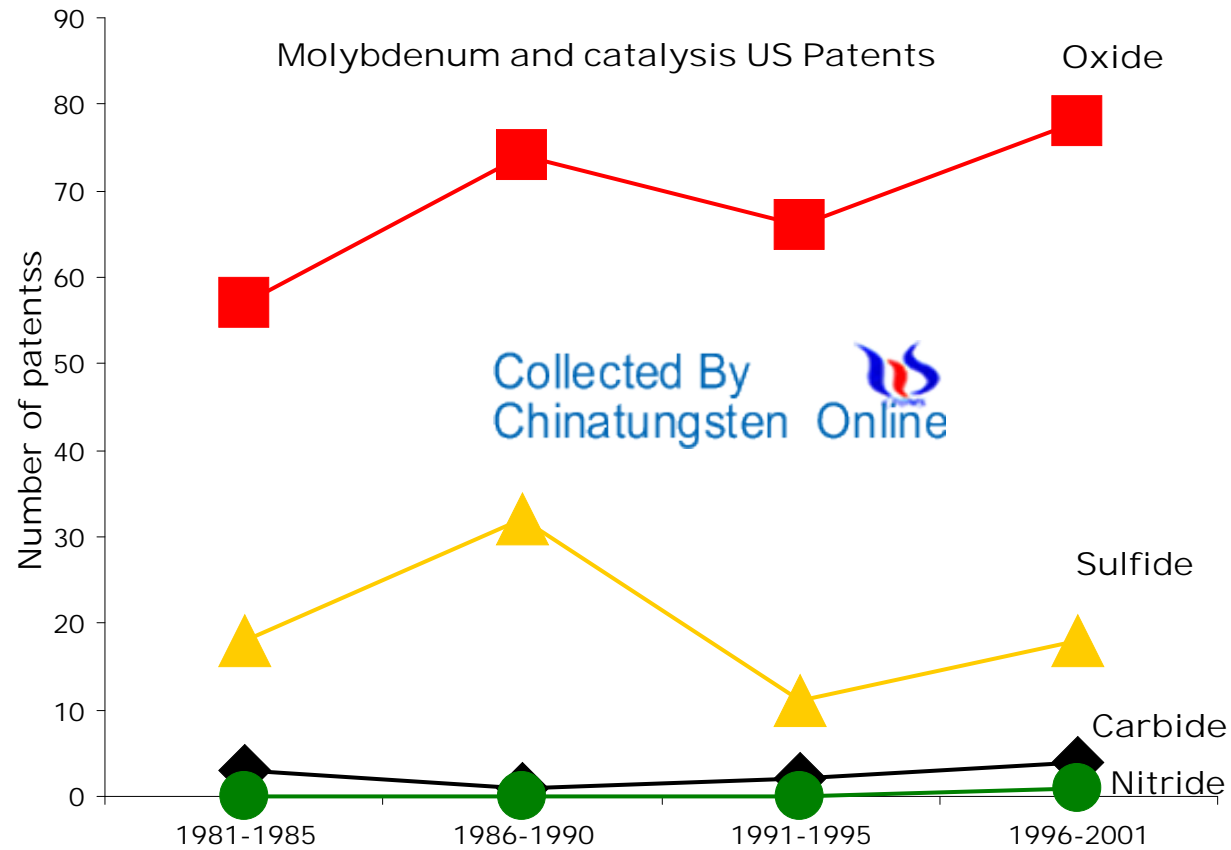
Molybdenum Chemistry



Molybdenum Compounds Applications

Application	Partner					
	C	N	O	Si	P	S
	Mo ₂ C	Mo ₂ N	MoO ₃ molybdate	MoSi ₂	MoP	MoS ₂
Catalysis	☆	☆	★		☆	★
Lubrication						★
Corrosion inhibition			★			
Pigments			★			
Smoke suppression			★			
Ceramics				★		
Nanomaterials	☆					

Molybdenum Catalysts US Patents



Molybdenum Catalysts

Hydrotreatment of petroleum

Remove S = hydrodesulfurisation = HDS

Remove N, O compounds

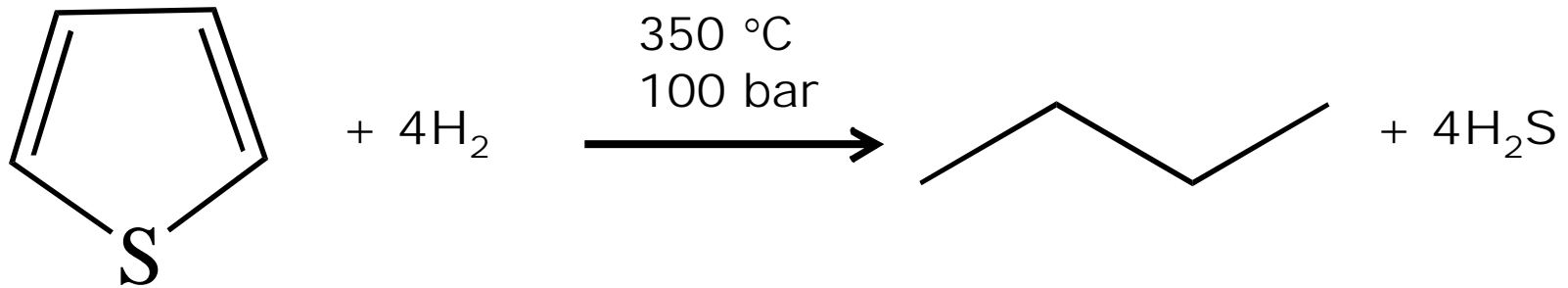
Selective oxidation

Methanol to formaldehyde

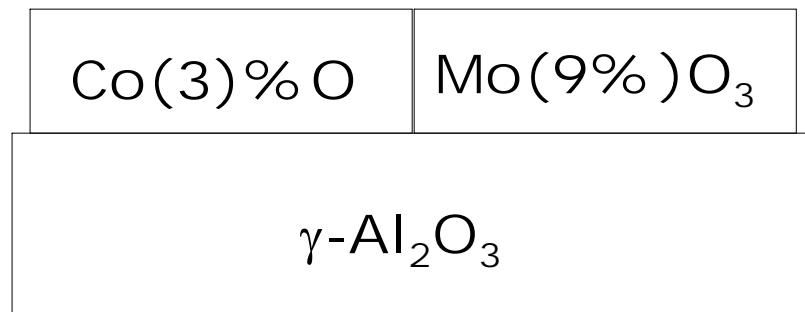
Propene to acrolein and acrylonitrile

For polymers and plastics

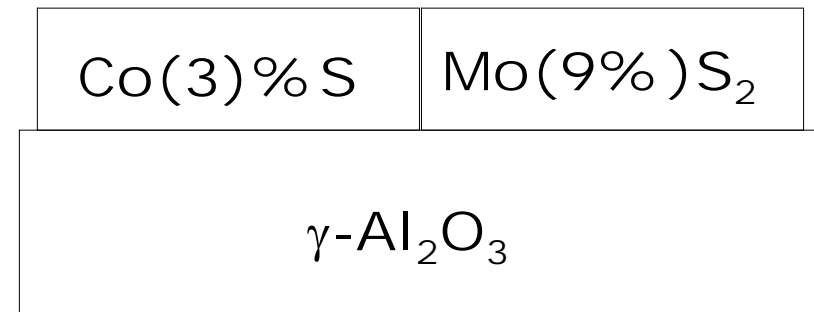
Thiophene Desulfurisation



Molybdenum Hydrodesulfurisation Catalyst



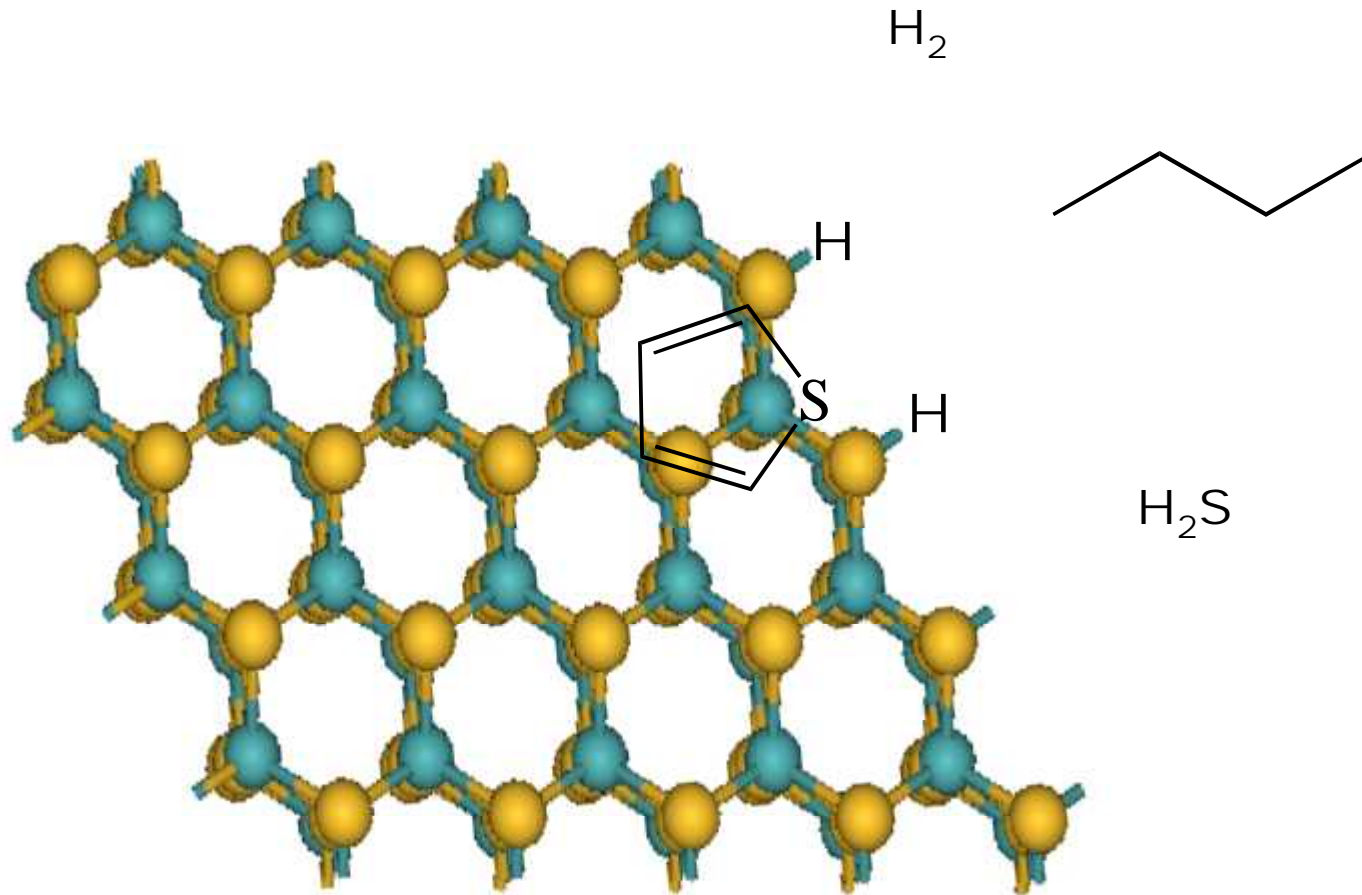
Pre-cursor
Oxide form



Active catalyst
Sulfide

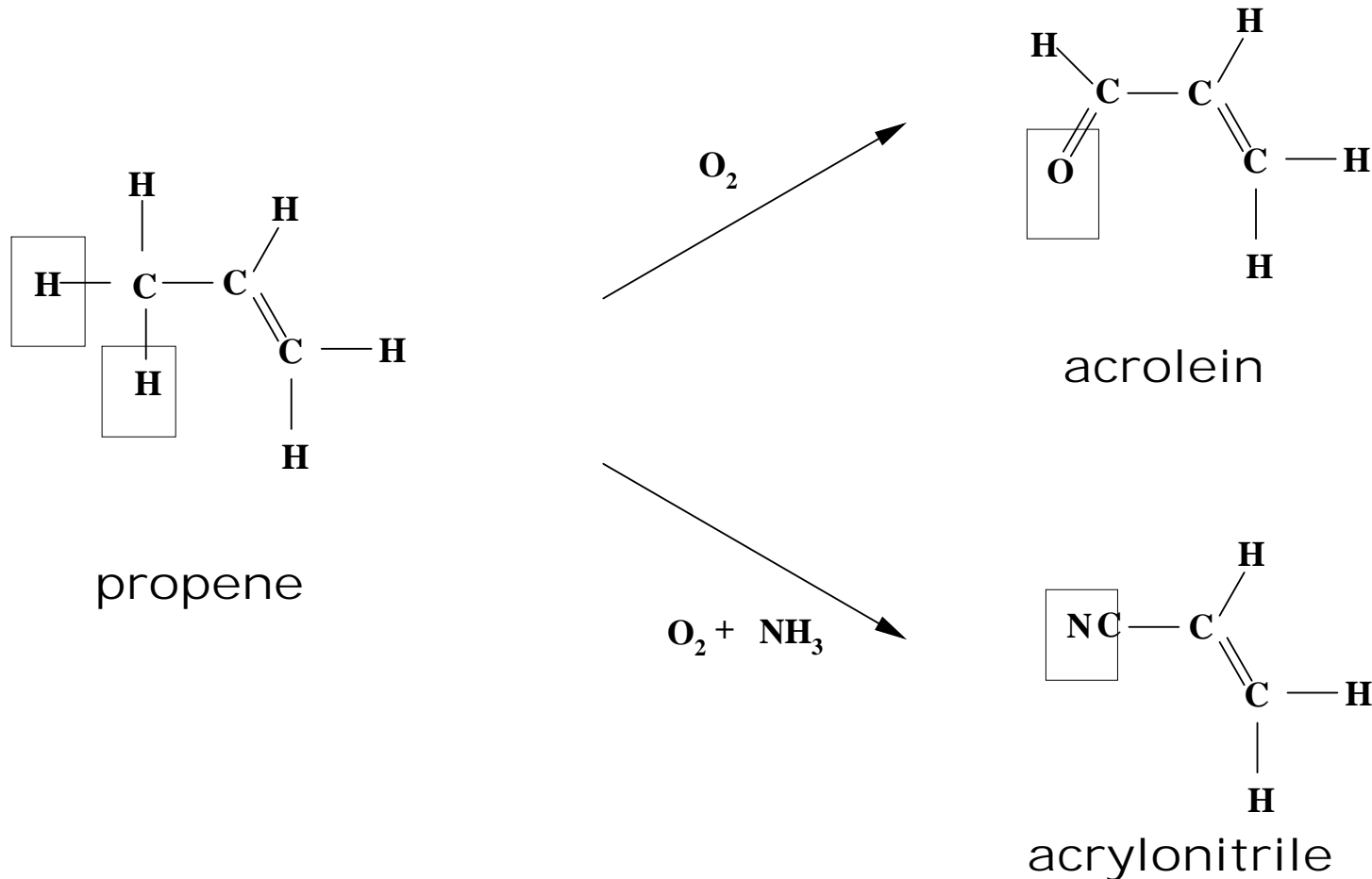
MoS₂ Catalyst

Thiophene Hydrodesulfurisation

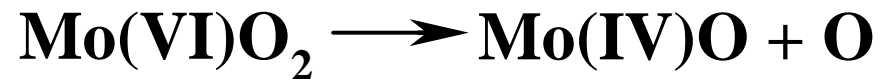
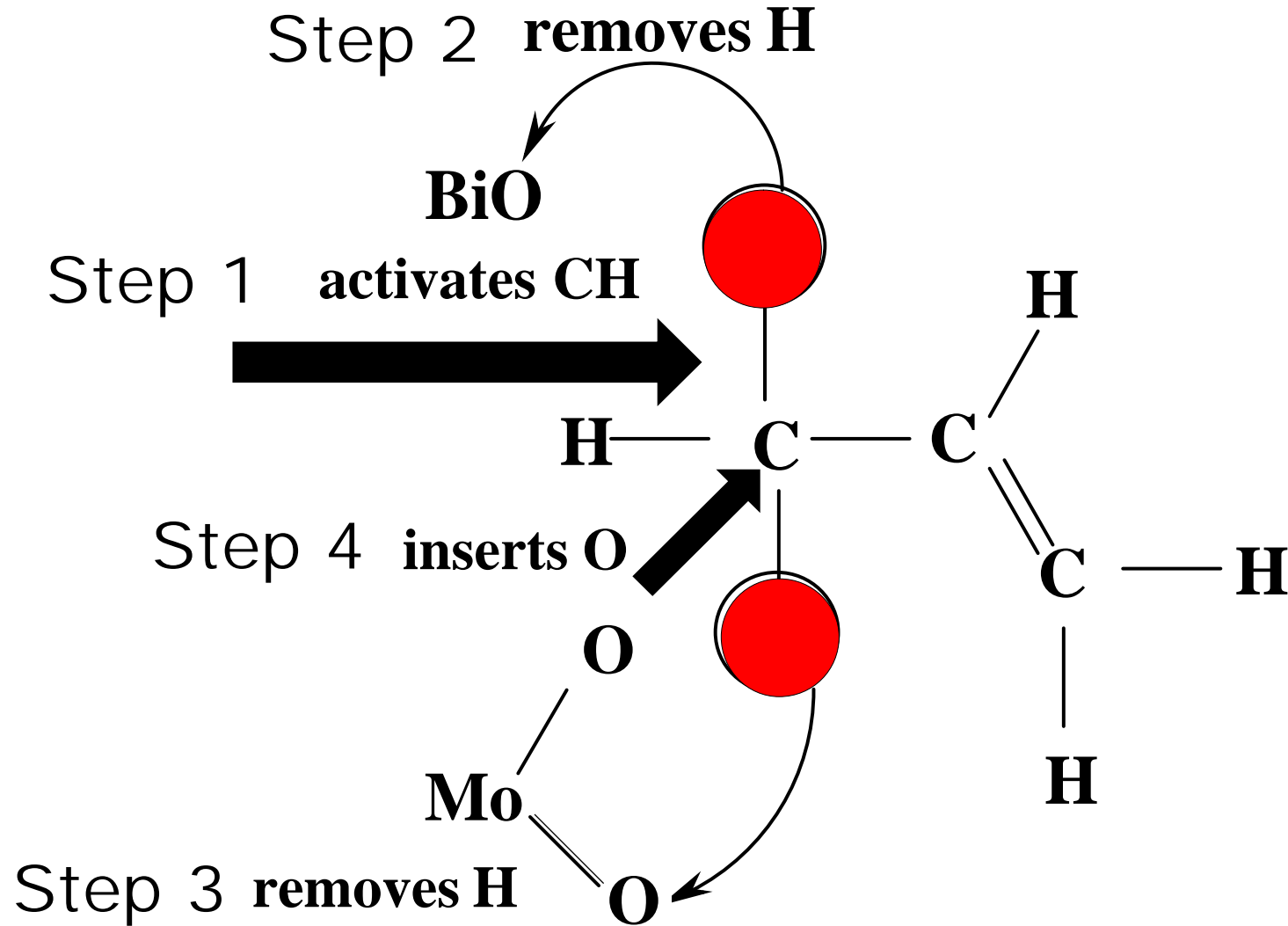


Selective Oxidation of Propene

Bismuth molybdate $\text{Bi}_2(\text{MoO}_4)_3$



How Selective Oxidation Works



Molybdenum sulfur Compounds in Lubrication

13

Molybdenum disulfide

Dry lubricant

Used in e.g.
greases,
dispersions,
friction materials and
bonded coatings.

Molybdenum complexes

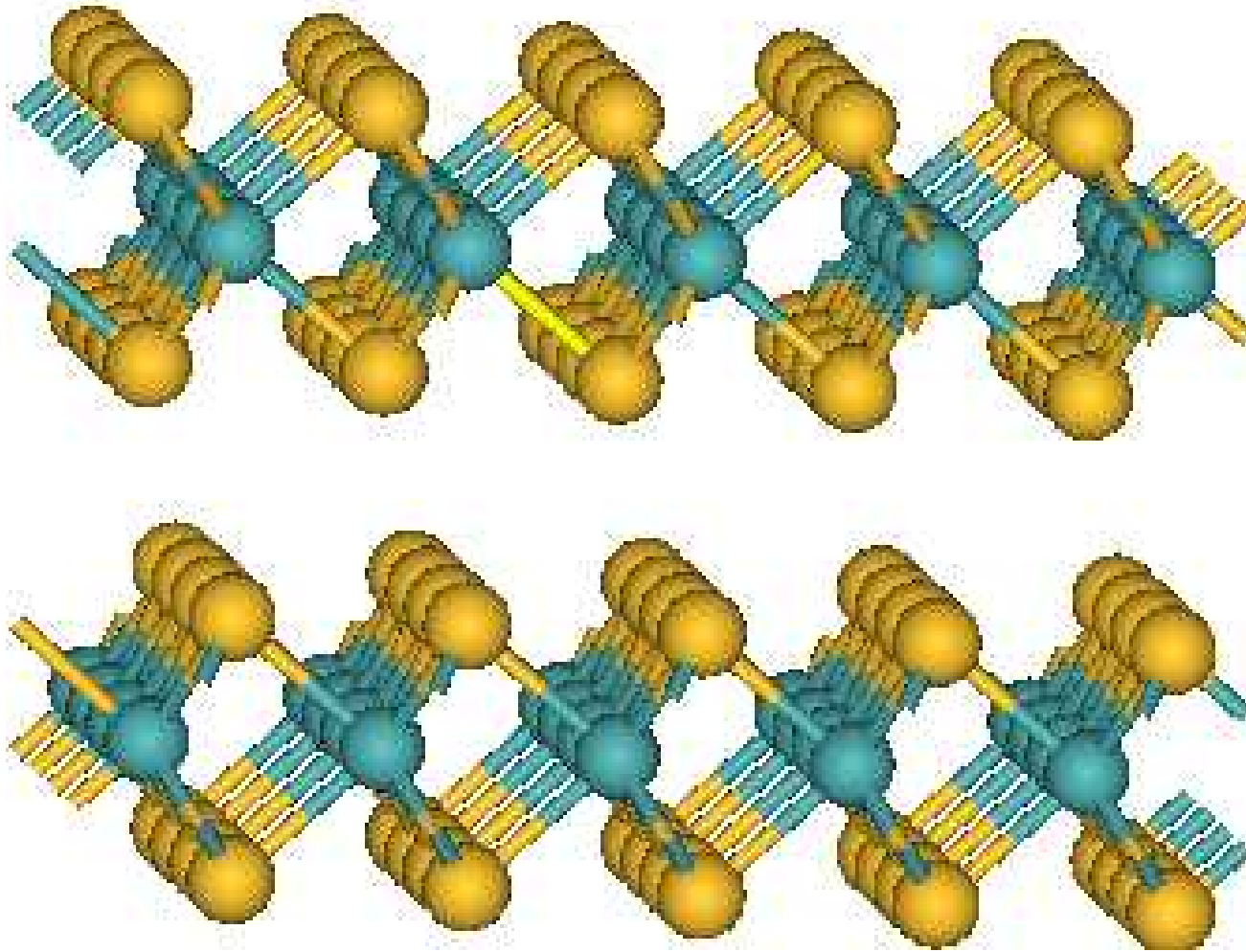
soluble in petroleum oils
and other organic solvents

antiwear and
extreme pressure additives

Decompose at
hot metal surface
Protective film
MoS₂ layer

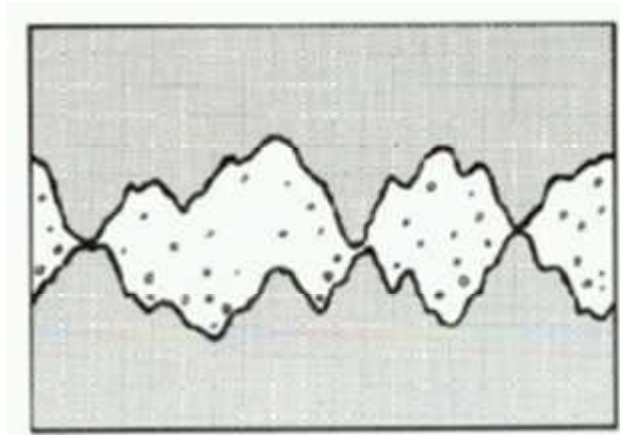
friction modifiers
in lubricating oils and
greases.

MoS₂ Structure



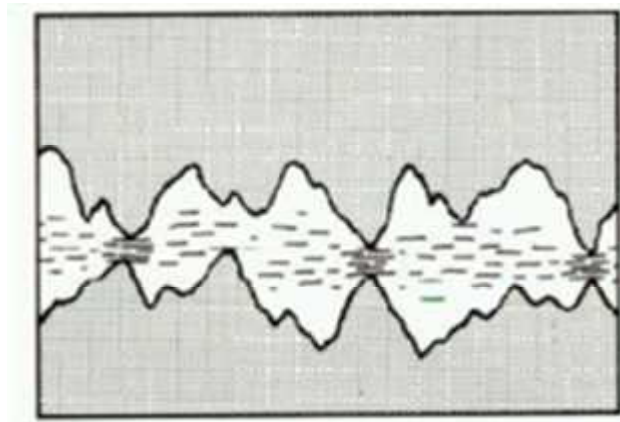
MoS₂ Lubricating Action

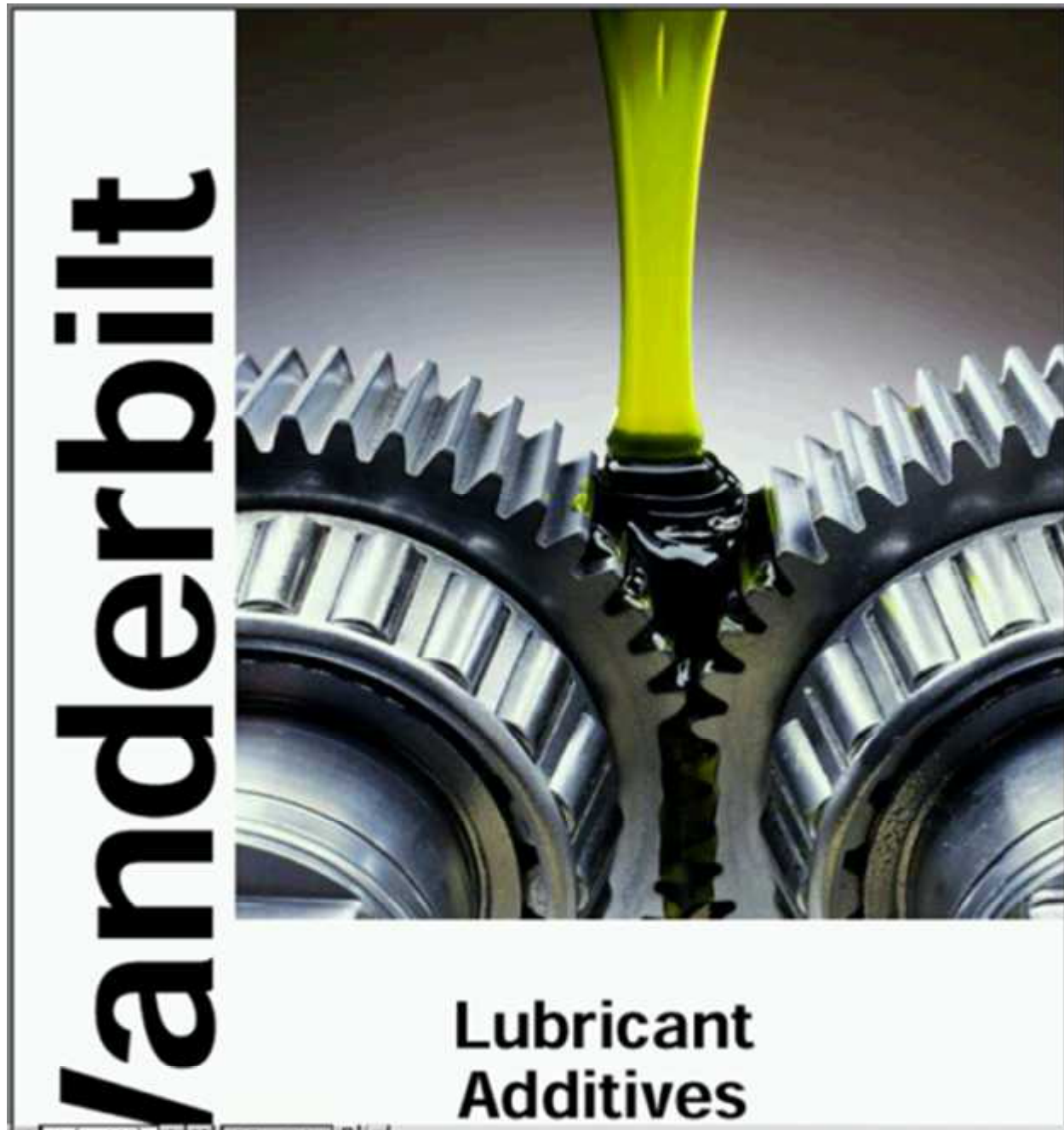
No MoS₂



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With MoS₂



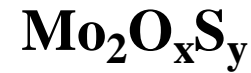
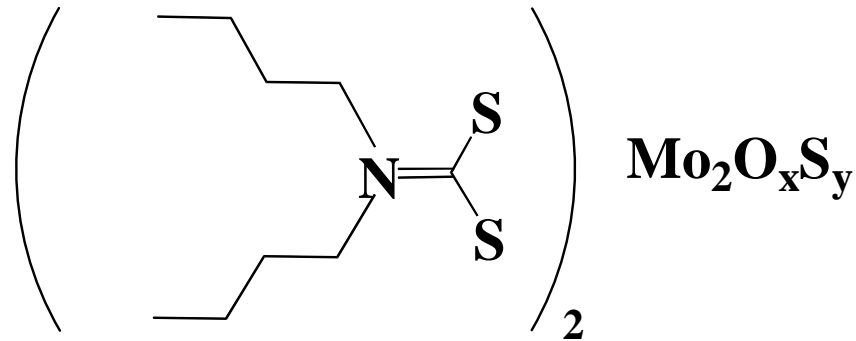


From R.T. Vanderbilt Company, Inc. Lubricants Information Brochure
<http://www.rtvanderbilt.com/petro/p981.pdf>

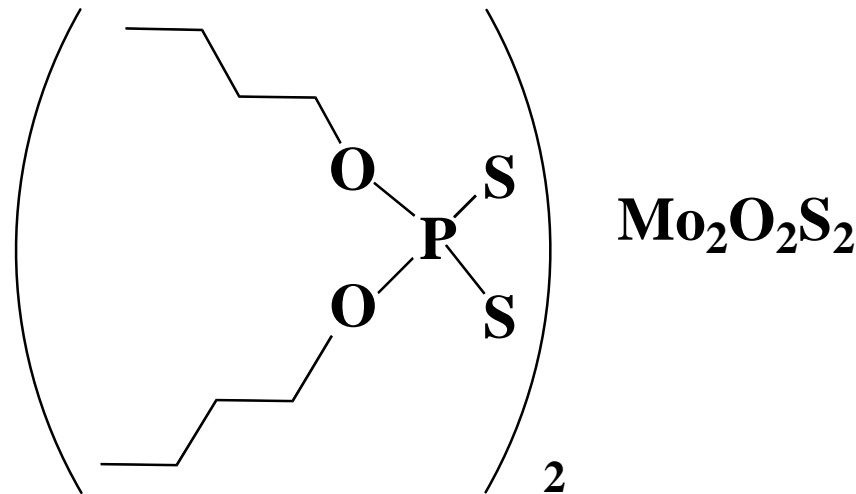
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Molybdenum Complexes

Anti-friction, Anti-wear, Anti-oxidant



dithiocarbamate



dithiophosphate

Corrosion Inhibitors and Pigments

18

Replace toxic chromate by molybdate

Application	
Steel, Al, Cu	Sodium molybdate
Central heating systems	
Automobile engine coolant	
Paints plastics rubber ceramics	Zinc, calcium, strontium molybdate Molybdenum orange: lead molybdate + lead chromate Phosphomolybdates

Calcium Zinc Phosphomolybdate¹⁹ Corrosion Test



Reproduced with permission from *Paint and Coatings Industry* magazine 2001

Industry Update: Molybdate Corrosion Inhibitors

By Charles Simpson Moly-White Pigments Group, Cleveland, OH

<http://www.pcimag.com>.

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Mechanism of Protective Action of Molybdate

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Interacts with the metallic substrate adsorption.

Fills gaps and promotes the formation of an adherent oxide layer.

Prevents corrosion of the underlying substrate passivation.

Molybdates as Smoke Suppressants

Non-volatile Mo oxide remains in char.

Application	Compound
PVC cable carpet backing building materials	Ammonium octamolybdate MoO_3

Mechanism of Smoke Suppression by Molybdate

Plasticizers greatly enhance the polymer combustibility.

Molybdate reduces smoke from burning PVC.

The char produced from the AOM containing compound was MoO_2 .

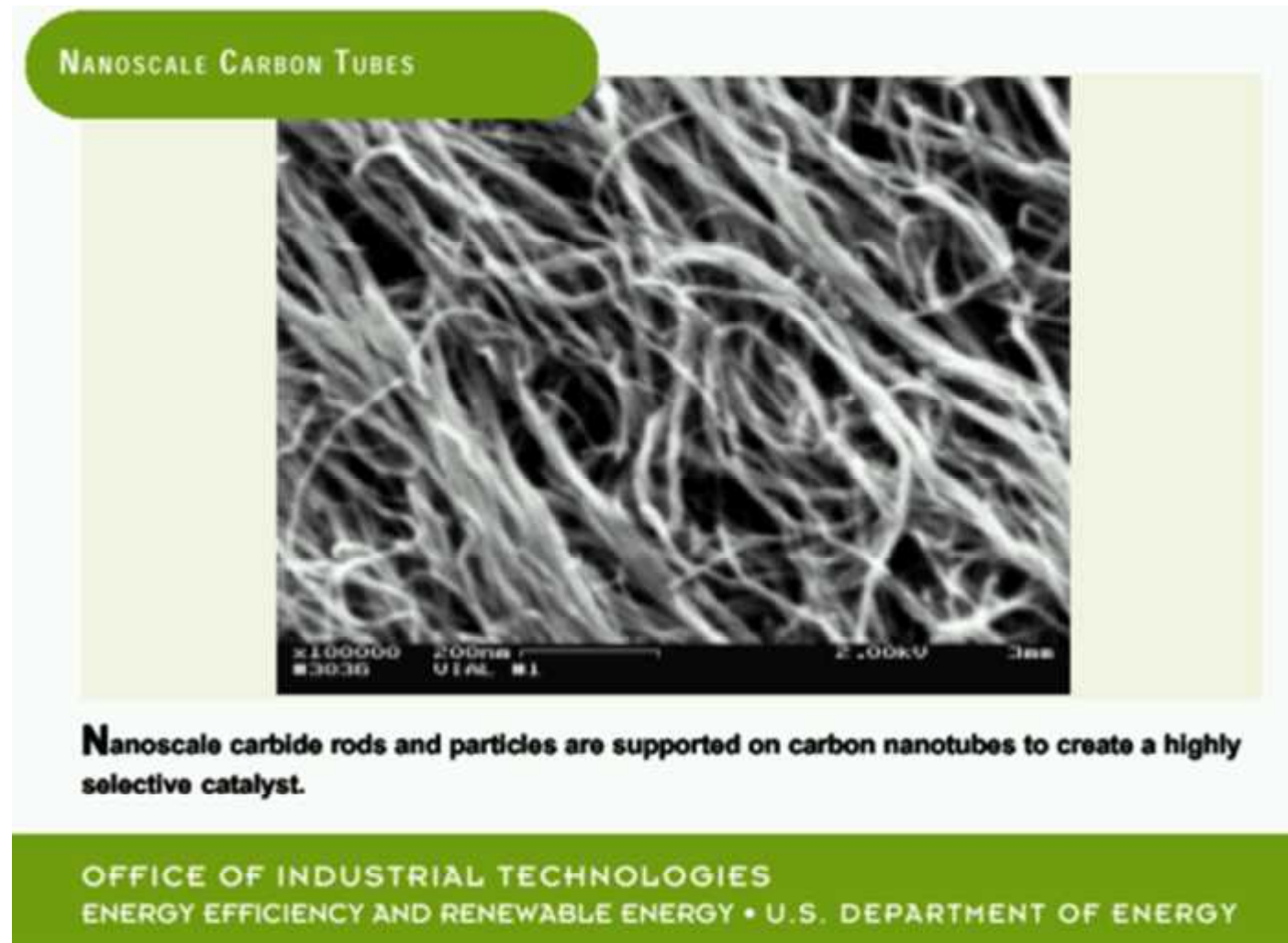
Cross-links the plastic to form a surface char..

Molybdenum Disilicides

Ceramics, advanced materials, composites

Application	Properties
Heating elements air furnaces	<ul style="list-style-type: none"> • High melting point 2030 C • Moderate density 6.24 g cm⁻³ • Excellent oxidation resistance
Gas burner	
Diesel engine glow plugs	
Molten metal lances	
Aerospace gas turbine engines blade outer seal	

Molybdenum Carbide Catalyst Nanotubes

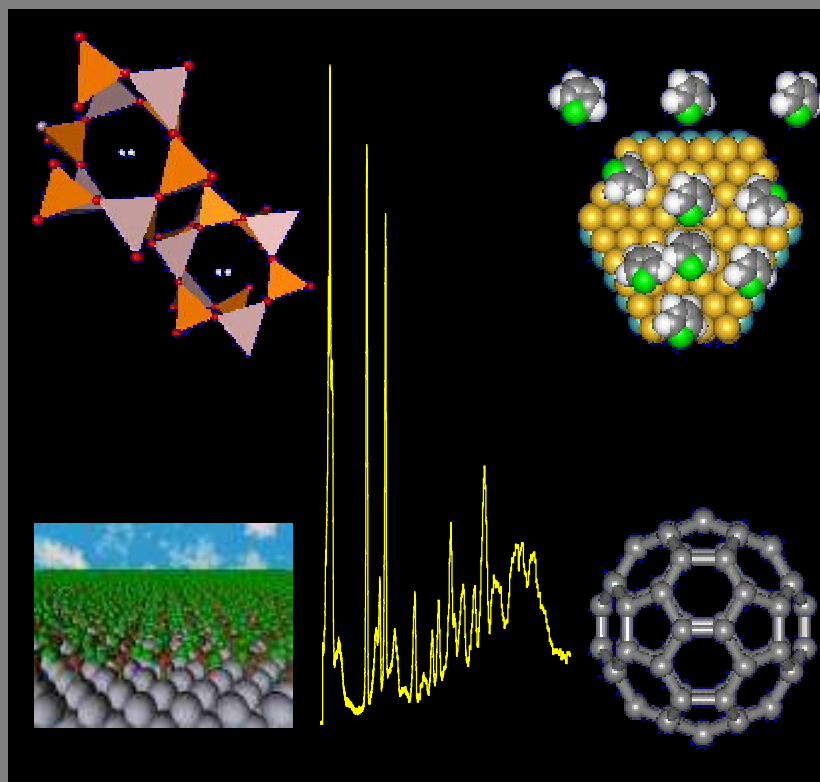


From U.S. Department of Energy 2002
<http://www.oit.doe.gov/chemicals/factsheets/nanoscale.pdf>

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Vibrational Spectroscopy with Neutrons

With Applications in Chemistry, Biology, Materials Science and Catalysis

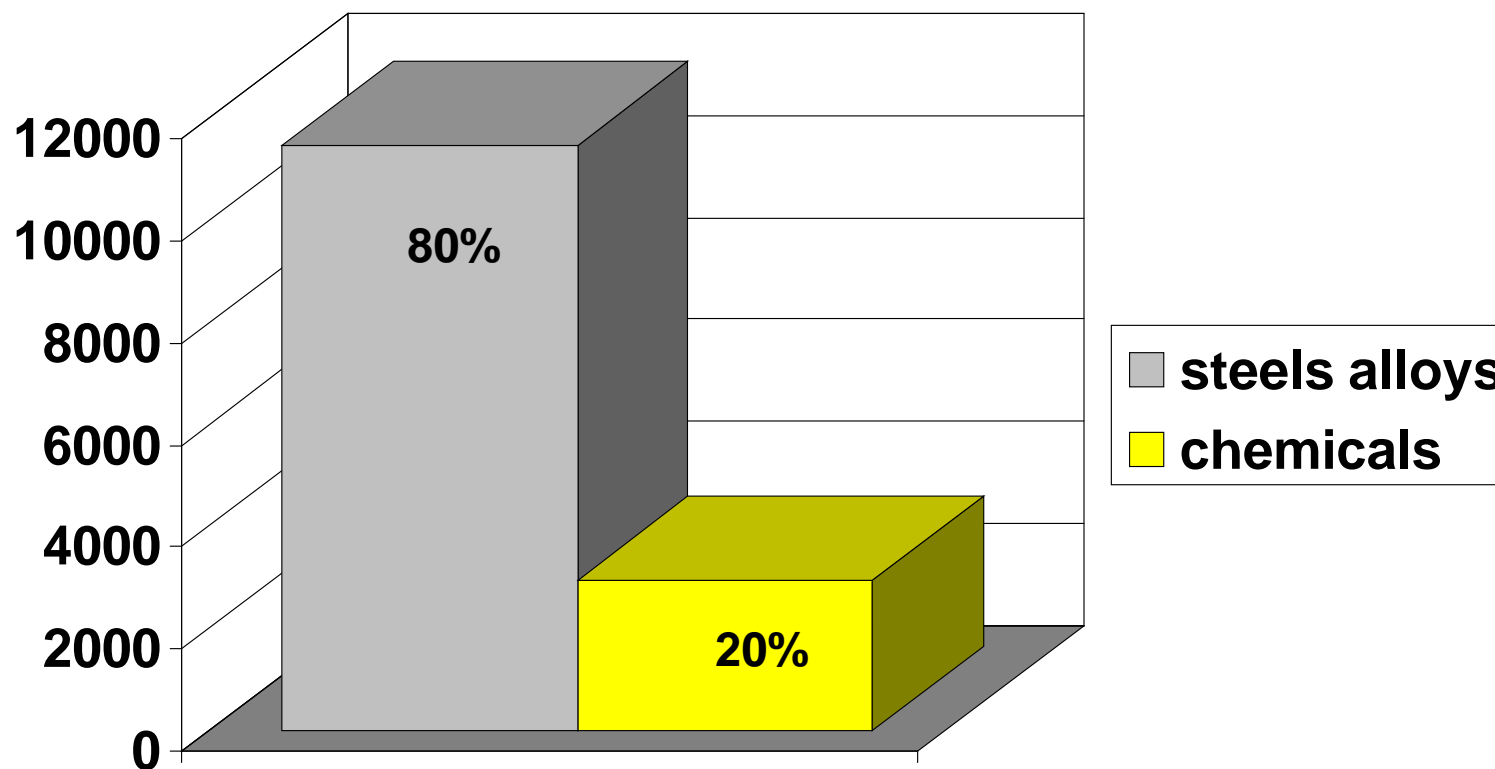


PCH Mitchell, SF Parker,
AJ Ramirez-Cuesta and J Tomkinson

World Scientific

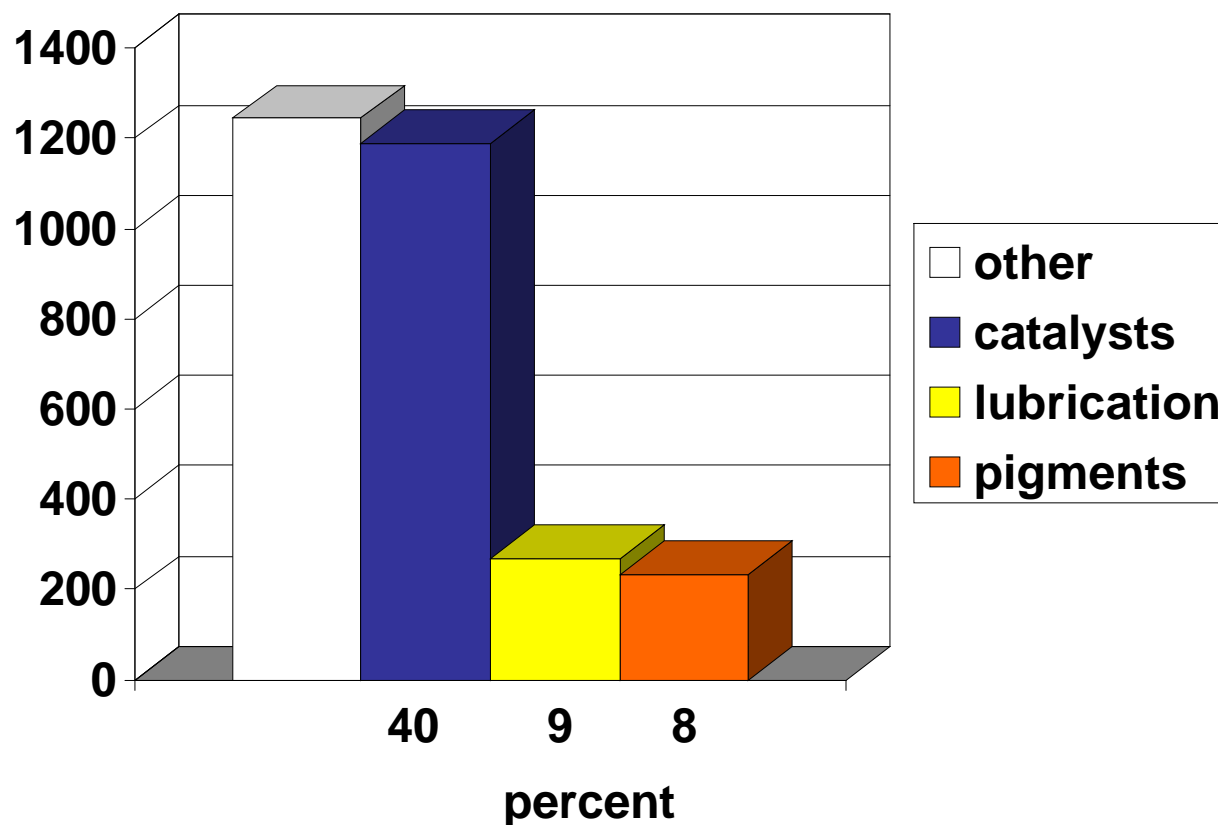
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Molybdenum Usage United States 2002 metric tonnes



Molybdenum Chemicals Usage United States 2002 metric tonnes

27




US Geological Survey Minerals Division

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Challenges 1

Discovery

Applications	Mo compounds	
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old		
new	The hydrogen economy	

Challenges 2

Substitution

Catalysts	Vanadium? Iron?
Lubrication	Ashless additives to eliminate sulfur, phosphorus and ash
Pigments and coatings	Organics?

Optimism

U.S. Geological Survey Mineral Commodity Summaries

January 2004

The variety of uses for molybdenum materials, few of which afford acceptable substitution, has resulted in a doubling of demand in the Western World to about 136,000 metric tons per year (t/yr) (300 million pounds per year) in 2000 from about 68,000 t/yr (150 million pounds per year) in 1983.

WHY USE MOLYBDENUM?

Chemical versatility

Low toxicity

ALWAYS WORTH THINKING
MOLYBDENUM

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