Valorizing Carbon Dioxide into Commodity Chemicals (& Energy Carriers) using Catalysis

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Department of Chemistry

Mizzou CEI: Oct 3, 2024

What are Catalysts?

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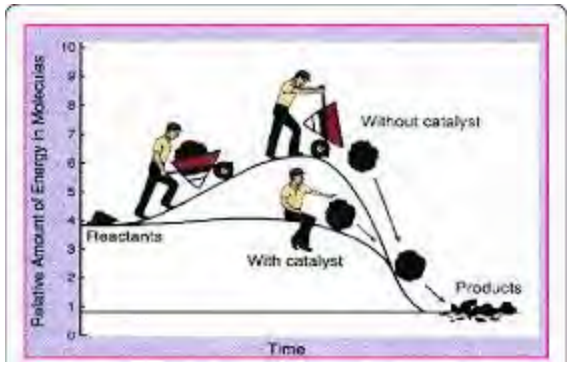

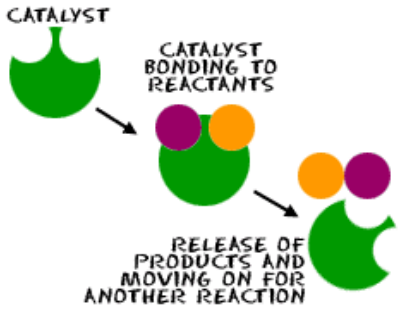

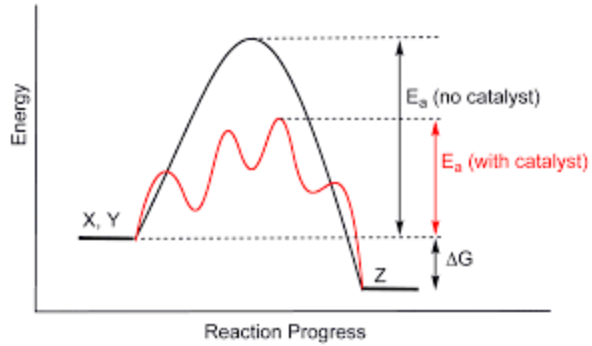

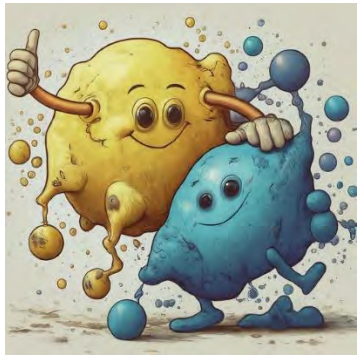

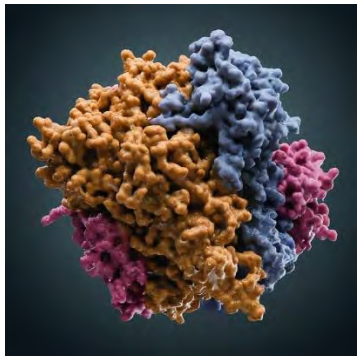

From web image search

From AI (Imagen 2)

What are Catalysts?

An alternate analogy

Catalysts are molecular machines…

…they assemble feedstock parts

After constructing product, they start the same process again

Motivations and Inspirations

CO_2-A Renewable C_1 Feedstock

- Highly abundant (10^{14} tons in atmosphere and oceans)
- Cheap availability
- Essentially non-toxic (compared to $Cl_2C{=}O$ & CO)
- It sticks to metals (the active part of most catalysts) reasonably well

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Commodity Chemicals

Molecular Energy Sources

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Commodity Chemicals

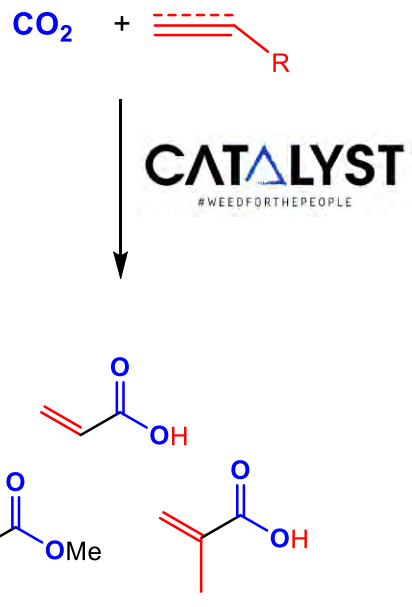
chemicals we use to make other stuff

Molecular Energy Sources

chemicals we use as fuels or to store fuels

Current & Recent CO_2 Catalysis Projects and $

Sustainable Polymer Building Blocks



Acrylic polymers:

Diapers, Plexiglass

NSF

Alfred P. Sloan Foundation 1934

Chevron Phillips Chemical Company LP

SEKISUI

Current & Recent CO_2 Catalysis Projects and $

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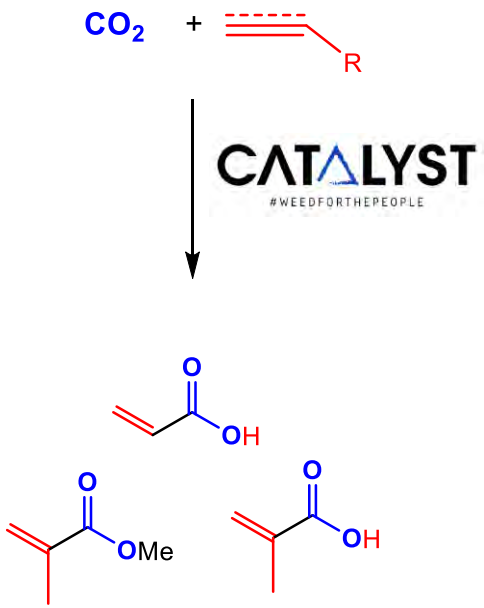

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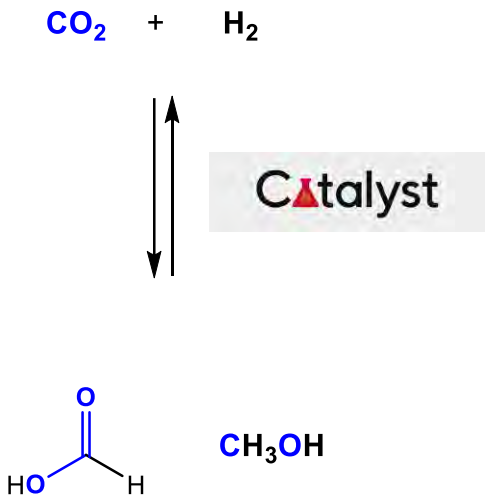
Methanol & Energy Storage



Input for Fuel Cells or Storage for Hydrogen

NSF

Alfred P. Sloan Foundation 1934

Chevron Phillips Chemical Company LP

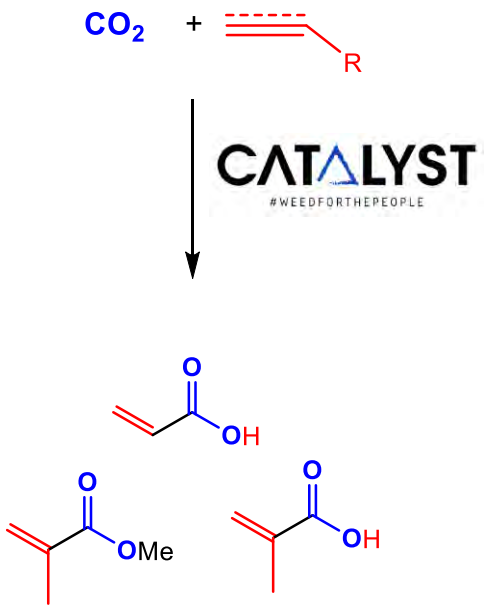
SEKISUI

Department of Energy United States of America

Yale

Current & Recent CO_2 Catalysis Projects and $

Sustainable Polymer Building Blocks



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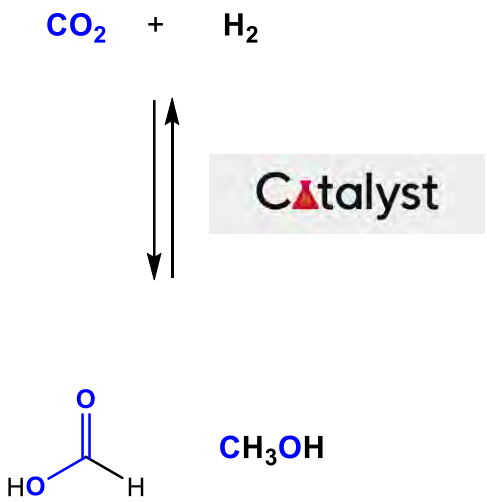
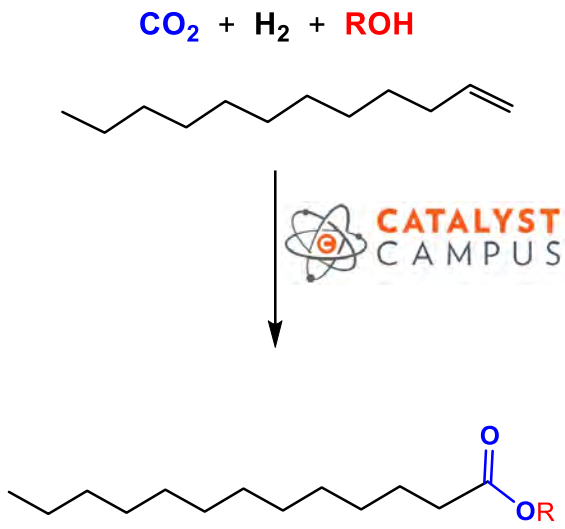


Input for Fuel Cells or Storage for Hydrogen

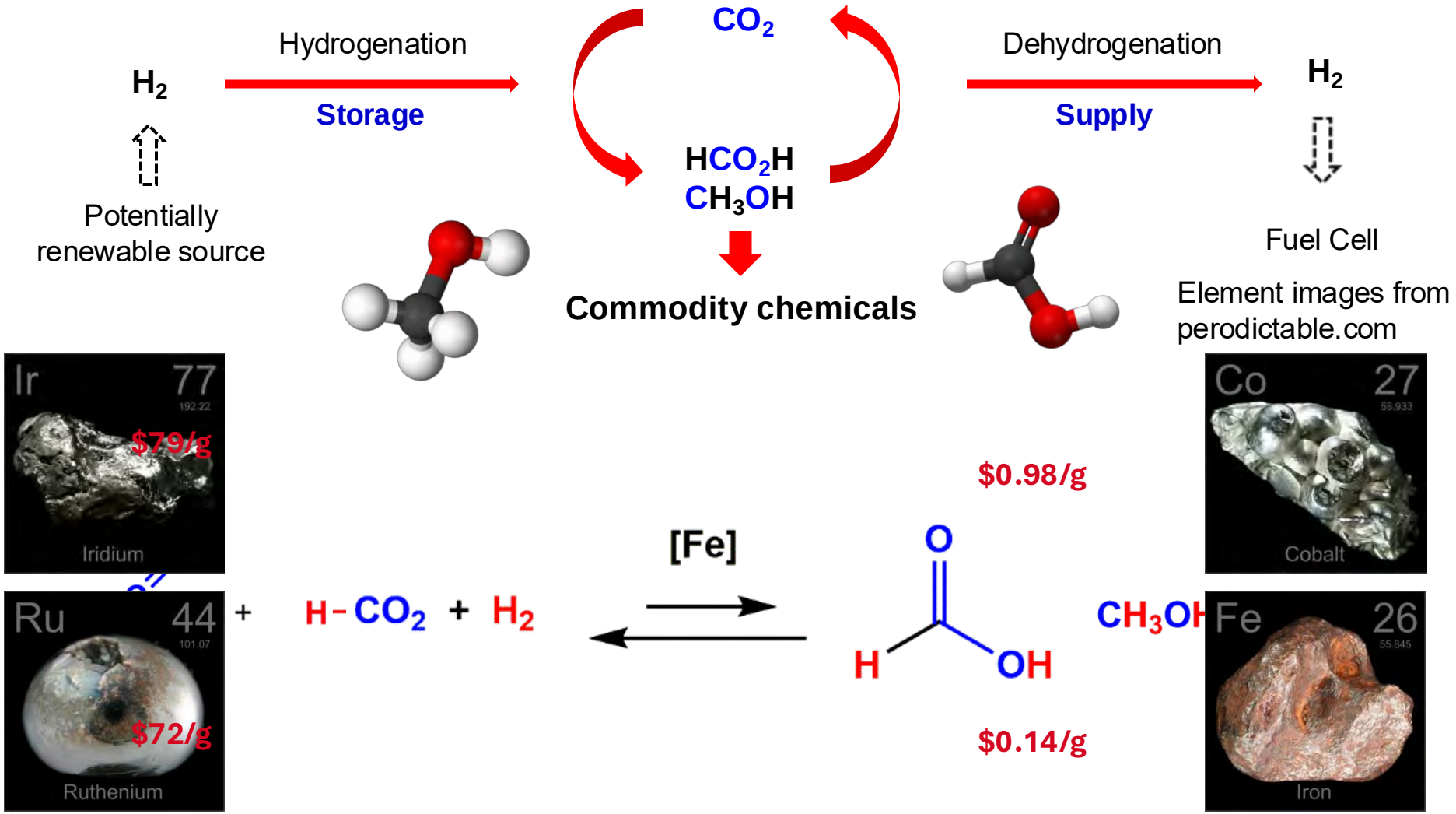
Lower Carbon Intensity Diesel



Diesel Fuel with Partial Renewable Carbon Input

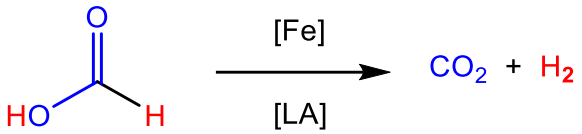
Reversible CO_2 Hydrogenation

For Chemicals & Energy



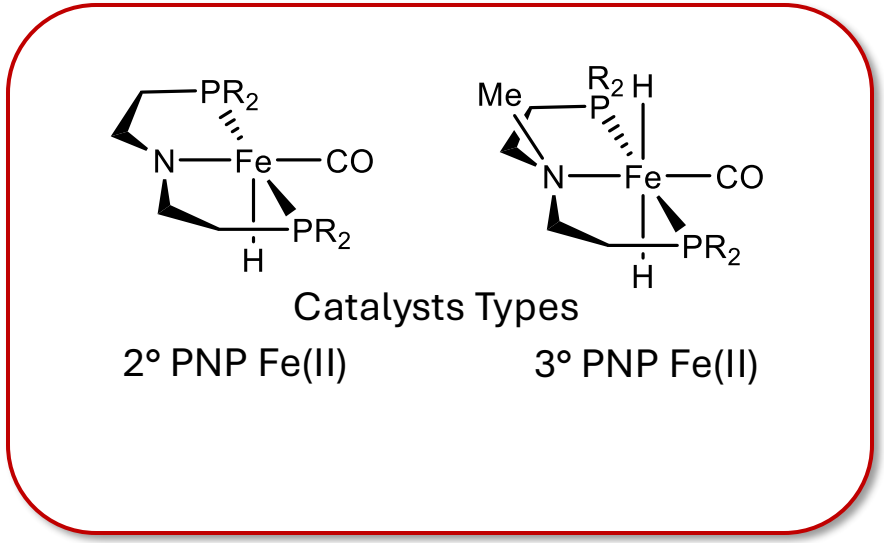
If At First You Fail...

Formic acid dehydrogenation

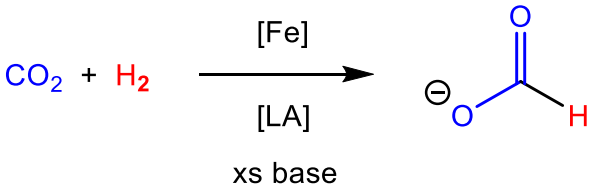


2° PNP Fe(II) w/o LA: 200 TON

J. Am. Chem. Soc. **2014**, *136*, 10234.



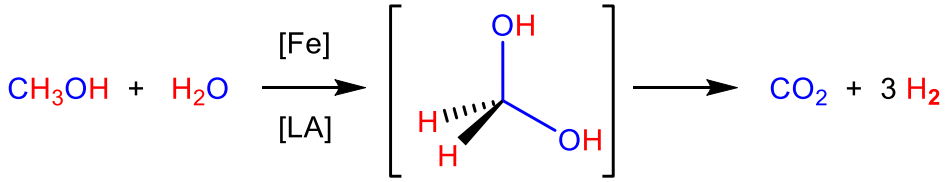
CO_2 hydrogenation to formate



2° PNP Fe(II) w/o LA: 900 TON
3° PNP Fe(II) w/o LA: 1100 TON

Chem. Sci. **2015**, *6*, 4291.

Methanol dehydrogenation

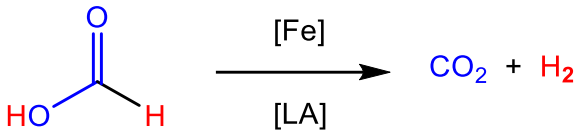


2° PNP Fe(II) w/o LA: 350 TON

ACS Catal. **2015**, *5*, 2404.

...Add Lewis Acid

Formic acid dehydrogenation



2° PNP Fe(II) w/o LA: 200 TON

2° PNP Fe(II) w/ LA: ~1 x 10^6 TON

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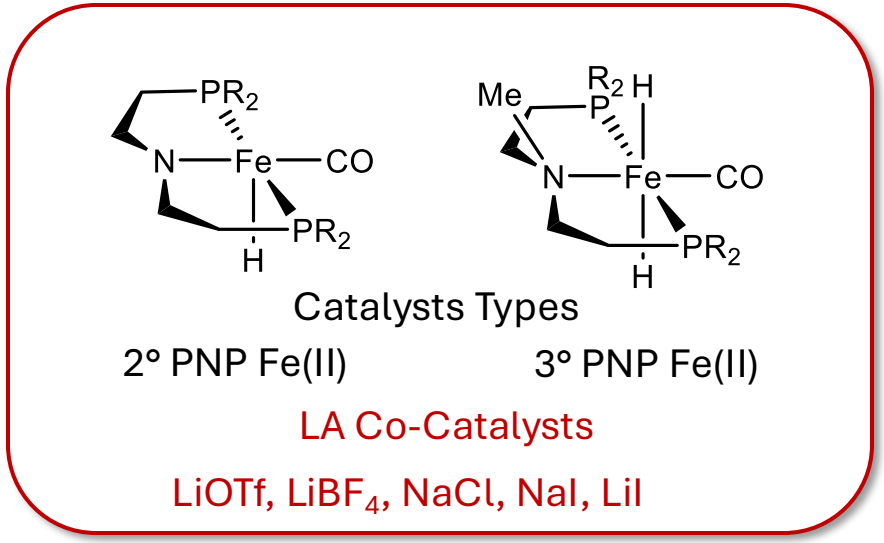

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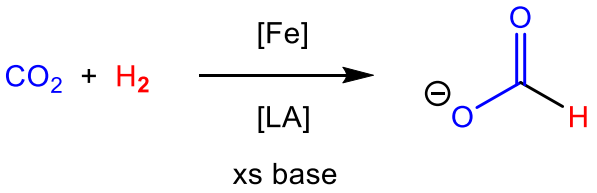

2° PNP Fe(II) w/o LA: 900 TON
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3° PNP Fe(II) w/ LA: 46,000TON

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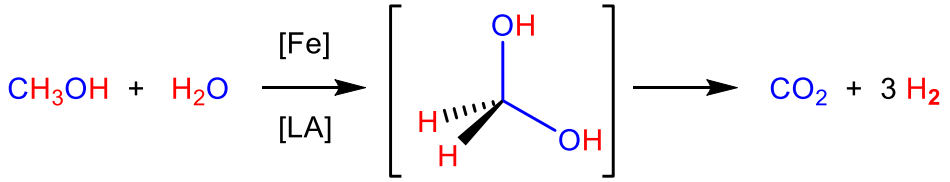

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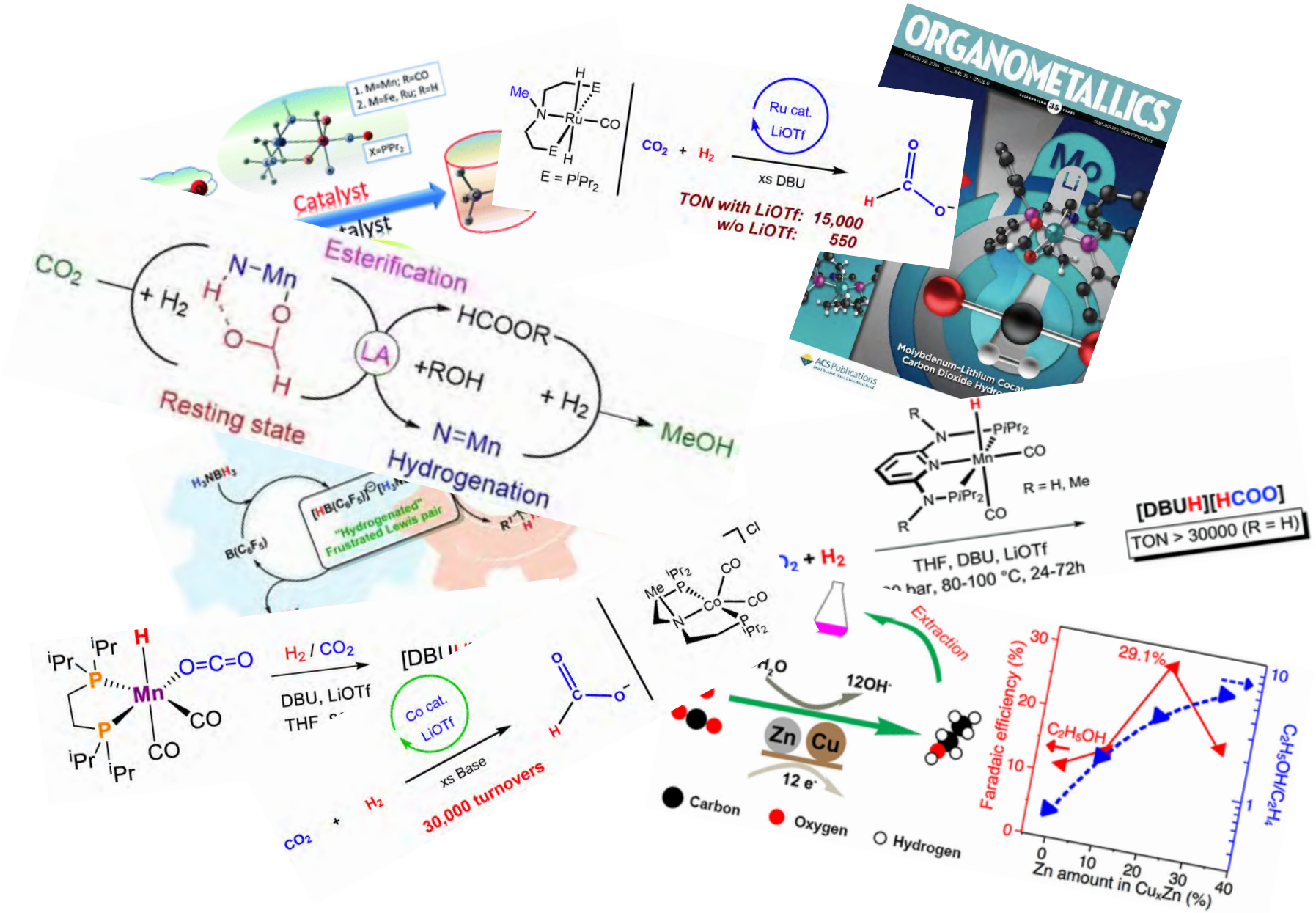
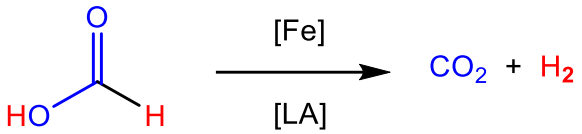
Lewis Acid Influence Is Widespread



So What is the Lewis Acid Doing?

Formic acid dehydrogenation



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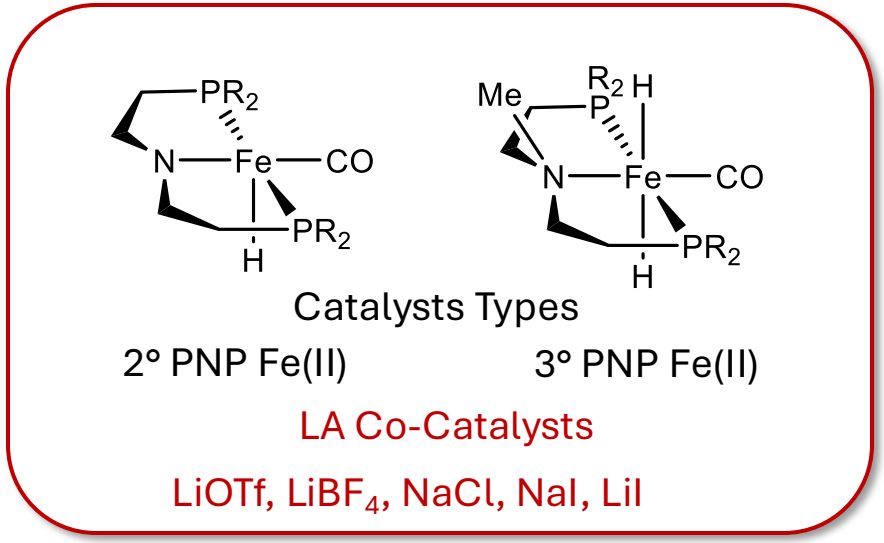

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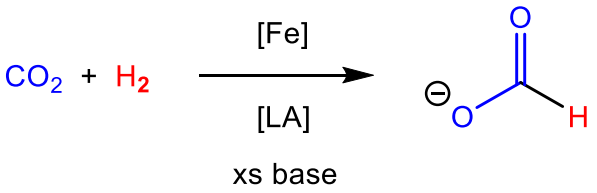

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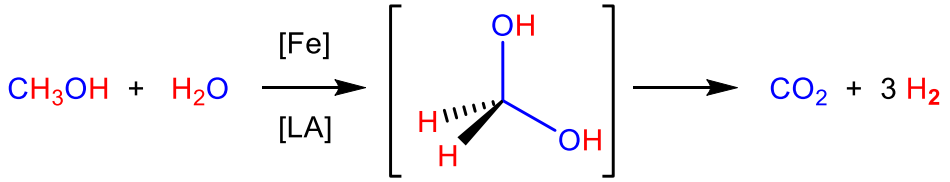

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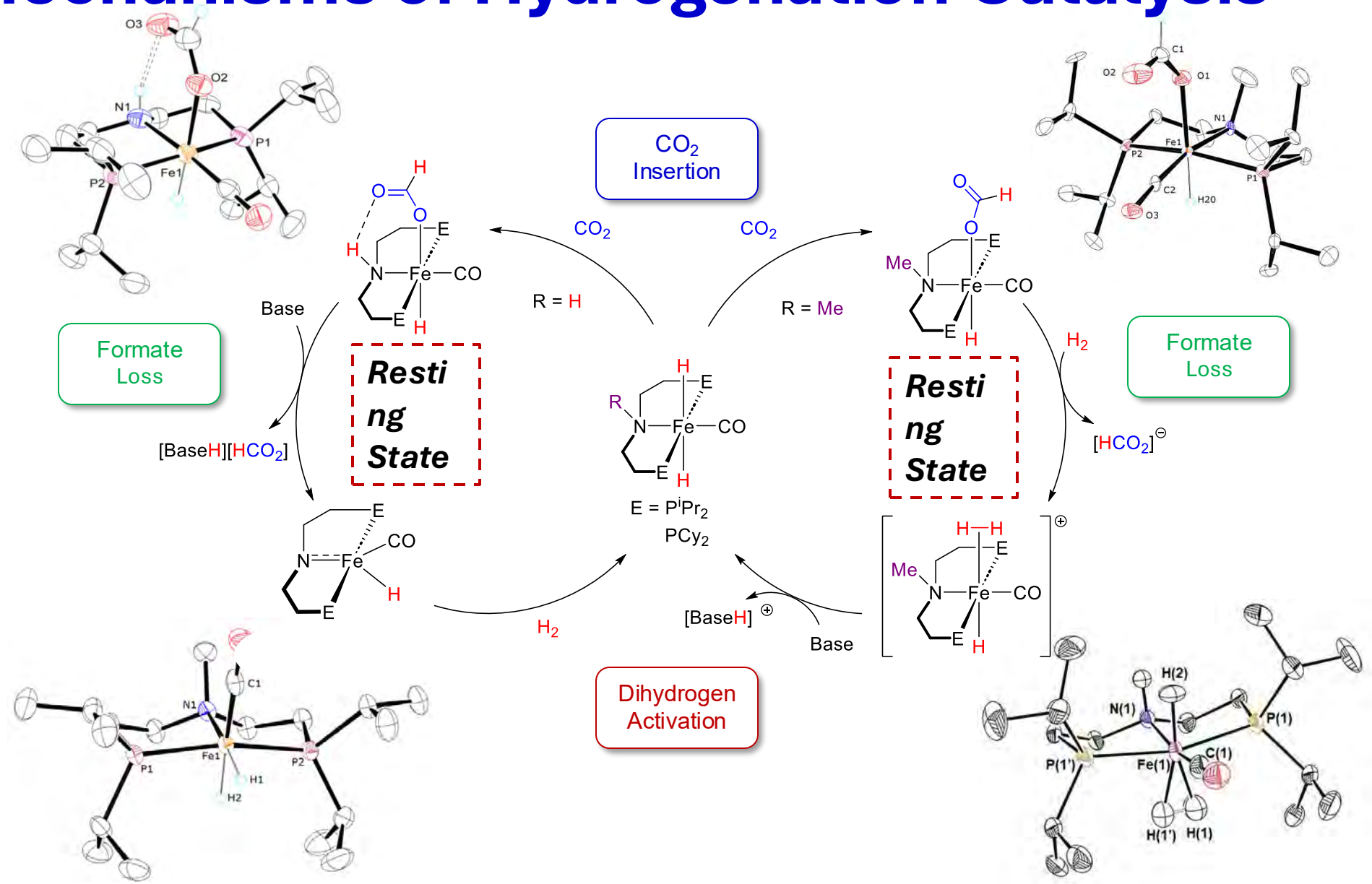
Mechanisms of Hydrogenation Catalysis



Chem. Commun. **2015**, *51*, 16201.

Am. Chem. Soc. **2021**, *143*, 10631.

Chem. Sci. **2015**, *6*, 4291.