CATALYSIS FOR CLEAN ENERGY

PURDUE ENERGY CAMP
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WHAT IS A CATALYST AND HOW DOES IT WORK?
CATALYSTS ACCELERATE REACTION RATES

PROVIDES ENERGY FAVORABLE PATHWAY FOR REACTION BY SPEEDING UP THE SLOWEST STEP

Reaction coordinate

Energy

without catalyst

with catalyst

$E_a$

$\Delta E_{rxn}$
HOW DOES THE REACTION HAPPEN?

CATALYTIC REACTIONS OCCUR IN A SEQUENCE OF STEPS

**Adsorption**
- Reactants adsorb on surface
- Bonds weaken or break

**Reaction**
- Adsorbed species react on surface

**Desorption**
- Products desorb from surface
- Regenerate active site
WHAT DO CATALYSTS LOOK LIKE?

EXAMPLES OF CATALYTIC MATERIALS

Automotive catalytic converter¹

Co-Mo/γ-Al₂O₃ Distillate hydro-treating catalyst²

Transmission electron micrograph of Pt/Al₂O₃

¹chtruckparts.com ²criterioncatalysts.com
CATALYSIS FOR CLEAN FUELS
PRODUCTION OF HIGH OCTANE GASOLINE

CATALYTIC CRACKING: BREAKING LARGE MOLECULES INTO SMALLER ONES

Crude oil → Refinery → Gasoline

Catalytic Cracking

large hydrocarbon molecules → smaller hydrocarbons

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SHAPE-SELECTIVE CRACKING CATALYST

MOLECULES ENTER CATALYST PORES TO REACT ON ACTIVE SITE

Cracking catalyst\(^1\) (zeolite)

\[^1\text{http://en.wikipedia.org/wiki/Faujasite}\]

\[^2\text{http://www.univie.ac.at/en/}\]
HYDRO-TREATING CATALYSTS

+ H₂

Mo-S-Mo-S-Mo

- H₂S

Mo-S-Mo-S-Mo

+ 3 H₂

Mo-S-Mo-S-Mo

- C₄H₁₀

S

("ring-opened" thiophene
bound to Mo)

hydrodesulfurization of thiophene

Co-Mo-S nanocluster

CATALYSIS FOR CLEAN RENEWABLES
BIOMASS CONVERSION TO LIQUID FUELS

**BIO-OIL HYDRODEOXYGENATION**

**Petroleum**

\[
CH_2 \quad \text{\textit{n}}
\]

- Low moisture content
- Good viscosity
- High energy density

**Bio-oil**

\[
CH_2O \quad \text{\textit{n}}
\]

- High moisture content
- Low pH
- Low energy density

\[H_2, \text{cat., } \Delta, H_2O \rightarrow \text{bio-oil} \rightarrow \text{liquid fuels}\]
H₂+O₂: THE POWER OF CATALYSIS
How can we use this energy?

\[ 2H_2(g) + O_2(g) \rightarrow 2H_2O(g) + \text{heat} \quad \Delta H_{Rx} = -286 \text{ kJ mol}^{-1} \]

Proton-Exchange Membrane (PEM) Fuel Cell

- Covert chemical energy directly into electrical energy
- Pt catalyst breaks down H\(_2\) into protons and electrons

Anode: \[ 2H_2(g) \rightarrow 4H^+ + 4e^- \]

Cathode: \[ 4H^+ + 4e^- + O_2(g) \rightarrow 2H_2O(g) \]

Overall: \[ 2H_2(g) + O_2(g) \rightarrow 2H_2O(g) \]

THANK YOU

“Unless someone like you cares a whole awful lot,
Nothing is going to get better. It's not.”
— Dr. Seuss, The Lorax

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