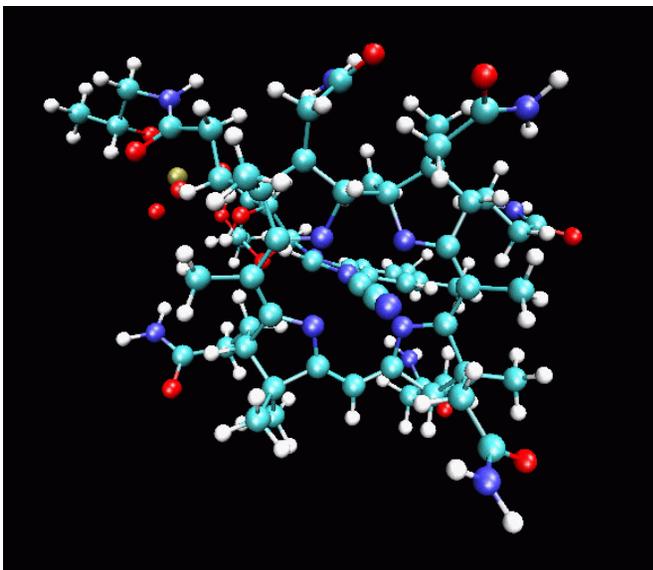


Heterogeneous Catalysis Research Laboratory



Heterogeneous catalysts prepared in our lab are often composed of small metal particles supported on a high surface area carrier. The particles have been shown to contribute to the overall rate and selectivity of a catalytic reaction. A wide variety of analytical techniques are used to examine the metal particles and metal-support interface. These include adsorption of simple gases, temperature programmed desorption, TEM, FT-IR, laser Raman, and UV-vis spectroscopy, as well as X-ray absorption spectroscopy using synchrotron radiation. Detailed kinetic studies of selected probe reactions are also carried out over catalysts in laboratory microreactors.

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“Developing new or improved catalytic materials by studying how the structure of a catalyst affects its performance in a chemical reaction allowing for new relationships between catalyst structures and chemical reactivity to be discovered.”



Base Catalysis

Solid bases are heterogeneous catalysts that have not been broadly exploited as solid acids. Our work with cesium compounds inside cages of zeolite supports and on surfaces of metal oxides has revealed surface properties and chemical reactivities for a variety of probe molecules and base-catalyzed transformations. Recently investigated materials are layered double hydroxides known as hydrotalcites and Mg-Al mixed oxides formed by decomposition of hydrotalcites. Thermal decomposition of hydrotalcites followed by controlled rehydration creates an active Brønsted base catalyst that can be used for transesterification. We have also studied the intercalation of ions into layered materials to improve or change their thermal and chemical stability.

Gold Catalysis

Our research focuses on understanding the factors responsible for high catalytic activity and stability of the gold nanoparticles supported on different supports (carbon, titania, alumina, etc.) for vapor phase and aqueous phase oxidation reactions. Previous work demonstrated the roles of metal particle size and the metal-support interface on the catalytic activity of Au nanoparticles. Additionally, in-situ X-ray absorption spectroscopy indicated that metallic gold is the active state of the element for our reactions of interest. Ongoing research emphasizes the importance of the metal-solvent interface during reaction mechanism studies over gold catalyzed oxidation reactions.

Conversion of Biorenewable Resources

Biorenewable resources such as carbohydrates are alternative feedstocks for the production of oxygenated chemicals. In some processing schemes, conversion of carbohydrates involves the hydrogenation of a simple sugar, such as glucose, to the sugar alcohol sorbitol. The subsequent hydrogenolysis of sorbitol yields lower molecular weight polyols like glycerol, propylene glycol and ethylene glycol, along with organic acids such as lactic acid. Glycerol, which is also a byproduct from biodiesel production, reacts further to glycols and lactic acid. We are investigating the oxidation of various renewable molecules such as glycerol, hydroxymethylfurfural, and short-chain diols as a promising route for creating specialty chemicals and pharmaceutical intermediates. In addition, we are exploring the deoxygenation of fatty acids to paraffins and olefins used for biorenewable fuels and chemicals.

Syngas to Alcohols

Ongoing work involves the exploration of alkali-promoted, supported molybdenum carbide nanoparticles as a potential catalyst for the synthesis of higher alcohols (for use as fuel additives or chemical precursors) from CO and H₂.

RECENT RESEARCH DEVELOPMENTS

- The mechanism of selective oxidation of aqueous glycerol, ethanol, and 5-hydroxymethylfurfural at high pH over Pt and Au catalysts requires molecular oxygen for the oxidation reaction to proceed, but the oxygen plays an indirect role by removing electrons deposited into the supported metal particles.
- A ReO_x-promoted Pt/C catalyst is shown to be selective in the aqueous phase hydrogenolysis of secondary C-O bonds by exposing bifunctional active sites composed of both metallic and acidic sites.

RECENT GRANTS

- Member of the Center for Biorenewable Chemicals (CBiRC), an NSF-sponsored Engineering Research Center (ERC)

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