“Green” Catalytic Systems for Solvent-Free Alcohol Oxidations

WiSys: T150040US03

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WiSys Technology Foundation is currently seeking a strategic partner interested in providing a route to market for the commercialization and wide dissemination of its novel catalyst systems. Lead catalysts have been shown to possess strong performance and versatility under environmentally benign ‘solvent-free’ reaction conditions.

Overview

Catalysts for organic chemical transformations, in particular those used for alcohol oxidations, are considered to be valuable commodities for the bulk, fine chemical as well as pharmaceutical industries as they are utilized in some of the most vital reactions that yield aldehydes and ketones. These products in turn are often useful as intermediates for other synthetic targets of economic significance. The majority of oxidation methodologies currently in use rely on catalysts containing expensive precious metals, require harmful and toxic oxidants, and involve the use of organic solvents. As such there is a growing demand for the development of ‘green’ catalytic methods that function in conjunction with environmentally benign oxidants and cost effective, easy to use catalysts that function either under solvent free conditions or in aqueous solution. In addition, the ability to produce desired products from a wide variety of substrates with good catalytic performance is also highly desired.

The Invention

Research from the University of Wisconsin-La Crosse has led to the discovery and development of a novel suite of catalytic systems for industrially-relevant green oxidations including the oxidative conversion of primary and secondary alcohols to value-added aldehydes and ketones. Similar systems have been developed for the oxidation of olefins to produce important epoxides, and for the oxidation of alkanes to produce alcohols. Specifically the team has developed a series of iron-based catalysts known as ‘helmet’ phthalocyaninaoto complexes of iron(III). Preliminary studies have focused on the use of what is commonly referred to as the ‘diiPc’ iron(III) system. Notably, the team has shown that this system is capable of catalytically oxidizing a diverse array of substrates including five non-benzylic alcohols (1-pentanol, 2-pentanol and cyclohexanol as well as 2,4-dimethyl-3-pentanol and 5-hydroxymethylfurfural) in the absence of added organic solvent. The presence of water as the monodentate axial ligand in the diiPc complex allows for markedly increased solubility in non-aromatic alcohols, making it an ideal catalyst for use with a much wider and more diverse range of substrates under solvent free conditions. It is envisaged that modification of the diiPc and related ligands will be undertaken to impart further enhancements to catalyst solubility in substrates or water, and/or superior stability in substrate alcohols. In addition to the diiPc system, the team have also developed a means of forming derivatized catalysts utilizing what is commonly referred to as a “helmet naphthalocyaninato” iron(III) complex. Specifically, a sulfonated version has been produced that possesses excellent solubility in water due to the added hydrophilic groups. To date, the sulfonated helmet naphthalocyaninato complex has been shown to provide for efficient formation of acetone from isopropanol as well as conversion of 2-pentanol to 2-pentanone using hydrogen peroxide as the primary oxidant. As such we anticipate that the same system would also be effective in the oxidation of 2-butanol to produce methyl ethyl ketone (MEK), an important commodity scale industrial chemical, and in many other commercially important transformations. Furthermore, preliminary studies have shown this molecule can be immobilized on various solid supports including anion-exchange resins, thereby resulting in a heterogeneous catalyst that can be utilized in the development of catalytic transformations that occur under flow conditions. Additionally, we now know that the sulfonated catalyst efficiently catalyzes the oxidation of phenol with hydrogen peroxide to produce para-benzoquinone. This transformation, along with other related reactions, is very important in the treatment of wastewater.

Applications

Alcohol oxidations

Key Benefits

- Iron based catalyst, hence cost competitive to those containing precious metals;
- Catalyst systems exhibit strong performance and versatility under environmentally benign 'solvent free' reaction conditions, further reducing costs and environmental impact;
- Select derivatives are soluble in water thereby providing for an aqueous phase catalytic system;
- Catalysts are capable of promoting a diverse array of alcohol oxidations producing ketones and aldehydes that can be used to produce pharmaceuticals, fine chemicals, pigments, disinfectants and more;
- Primary catalyst shows high selectivity and efficiency, and reactions proceed with high turnover numbers (TON) and turnover frequency (TOF) relative to related catalytic systems;
- Selectivity for the expected aldehyde and ketone products is excellent with no observable over-oxidation to carboxylic acids, thereby demonstrating excellent chemoselectivity.

Stage of Development

A suite of novel catalysts and associated techniques have been developed and characterized with reactions validated for a diverse array of substrates using batch methodology. Further work is currently being undertaken to develop a flow reactor system that could be scaled up for industrial/commercial applications. In addition, it is anticipated that further derivatization can be undertaken to yield more efficient catalysts.

Tech Fields

- Clean Technology : Biobased & renewable chemicals & fuels
- Materials & Chemicals : Biochemicals & biomaterials
- Materials & Chemicals : Synthesis

For current licensing status, please contact Jennifer Souter at jennifer@wisys.org or (608) 316-4131