Organometallics & Materials Chemistry Lab, Chemistry

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Besides, we have developed a straightforward yet scalable approach to isolate another pharmaceutical ingredient, such as ferrocene coumarin. This was achieved through the highly efficient yet sustainable multi-component Knoevenagel condensation approach to isolate the ferrocene coumarin using well-defined, air- and moisture-stable diimine Zn(II) catalysts.

Thioethers are a significant pharma component and one of the challenging molecules to isolate through mild reaction conditions. We have demonstrated the first discrete zinc(II) catalyst-mediated C-S cross-coupling reactions between aryl halides and thiophenols without scrubbing the oxygen and moisture. This methodology is a cheap yet effective alternative for expensive metal catalysts along with a broad substrate scope.

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Role of catalysts for sustainable future for food, fuels, and commodity products

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The global population is anticipated to double by 2050, with cascading effects on the shrinkage of cultivation land, food and energy resources crisis, and damage increasing environmental pollution. India is already facing a petroleum crisis and relies on ~84% of imports to meet the fuel/chemical demands. Technological innovation must be directed at addressing these futuristic sustainability challenges. The catalysts (bio-, chemo-, and electro-catalysis) will continue to play a pivotal role in the sustainable sourcing of fuels, chemicals, and food/feed products from renewable resources and by valorising/utilizing waste streams and maintaining environment cleanliness. Technological innovations are also progressing radically to produce fuels/chemicals from renewable biomass and organic carbon-rich waste streams in an integrated biorefinery approach. Our current research is directed at producing gasoline, aviation, and diesel range hydrocarbons from renewables or waste carbon sources using chemo-catalysis, thermo-catalytic, or integrated fermentative and chemo-catalytic approaches. Unlike traditional biofuels, these green biofuels are compatible with current infrastructure, have the same fuel mileage, are readily acceptable to customers, and can easily penetrate the market. The aviation sector is expected to grow drastically in the coming years. So, market-ready technology for sustainable aviation fuel (SAF) is thus the need of the hour, as this sector has no alternative energy-sourcing options.

Our recent work demonstrated the proof-of-concept for SAF production from the furanic precursor. The process involves the bioproduction of furanic molecules, followed by its catalytic upgrading into high molecular weight fuel precursors and catalytic deoxygenation to SAF, centred around C14 branched alkanes with better combustion and cold flow properties than n-paraffin and aromatics (Figure-1).

Petroleum and natural gas are the primary raw materials for petrochemicals and fertilizers. Our work is also directed to produce drop-in/platform chemicals/hydrogen from renewable organic resources. Butanediols (BDO) are exemplary platform molecules with tremendous derivative chemistry. The integrated biochemical and chemo-catalytic approach could diversify product opportunities via butanediol, including 1,3-butadiene, methyl ethyl ketone, aromatics, olefins, etc. (Figure-2). Organic carbon wastes and residues from crops, food, industry, and municipality are posing significant environmental problems. Channelling these carbohydrate-rich organic waste carbon streams into value addition products like BDO and its derivatives is a more profitable approach than traditional anaerobic digestion, burning, disposal, or treatment, reducing the effort for waste management and disposal issues.

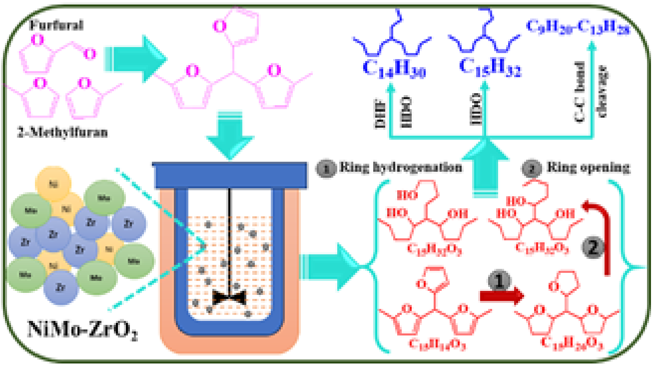

Figure-1: Sustainable aviation fuel from furanics

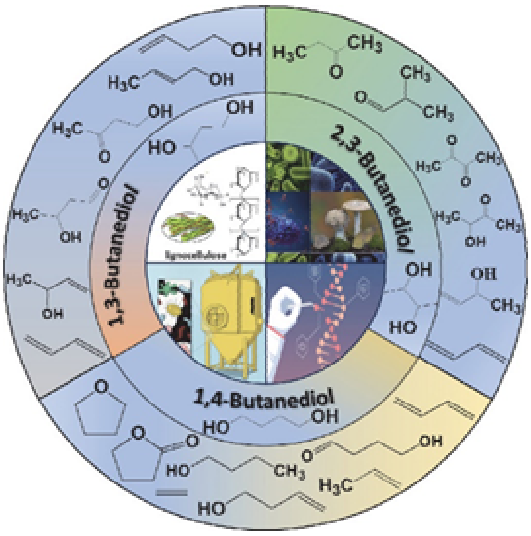

Figure-2: Biorefinery via butanediols platform

These kinds of breakthroughs will eventually mitigate dependence on fossil reservoirs for fuels/chemicals and carbon emission/waste management challenges. Expanding food production by around 70% from alternative sources is another need to overcome the futuristic challenge of feeding the massive global population. Microalgae could be a promising alternative to plant and animal-based food/feed sources, such as protein. However, the success of biorefining technologies depends mainly on techno-economic viability and environmental sustainability concerning existing petroleum technologies. Our work also encompasses techno-economic and life cycle analysis of the biorefining processes. Though environmental benefits are evident, economics are currently not favourable for all biorefining processes but will be eventually viable when petroleum scarcity reaches its peak. The policy should be framed to deploy successful biorefining processes systematically to meet long-term sustainability goals for fuels, commodity products, and food.

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Use of Earth-abundant Metal Catalysts for sustainable and atom-efficient Reactions Synthetic Organometallic Chemistry and Catalysis Lab (SOMCC Lab)

KID: 20230415

Motivation:

Our research group is working on innovative projects in organic and organometallic chemistry. We believe that great efficiency in all organic reactions is necessary to prevent the creation of hazardous contaminations, minimize waste and byproducts, and ensure the sustainability of chemical production in contemporary industrial processes. To accomplish this, well-defined organometallic complexes must be integral to homogeneous catalysis in methods that are safe for the environment. Catalysis plays a pivotal role in many areas of chemistry and has resulted in the creation of several sustainable and atom-efficient methodologies. Therefore, chemists play a specific role in this research area to find suitable alternatives to these non-renewable plastics and value-added products from renewable sources.

Problem Statement & Solution:

Transition metals, lanthanides, have received more extensive research which are relatively expensive, low abundance, toxic, and disposal of these metals can have negative impacts on ecosystems and humans. On the other hand, earth-abundant metal complexes based on alkali metals, alkaline earth metals, aluminium, and zinc shine as sustainable and affordable alternatives to precious metal catalysts, offering a crucial solution to our environment and resources, particularly in large-scale organic transformations and ring-opening polymerization reactions. The substitution of less expensive, safer, and ecologically friendly main-group metals for transition metals is widely desired due to the inherent disadvantages of transition metals. After considering all these drawbacks and issues, our group has been interested in exploring these earth-abundant metal complexes in the field of catalysis.