**Name(s)**

Jacob Leeman

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**Project Title**

# Trends in Catalytic Properties of Tetra-Ammonium-Based Post-Transitional Metal Chloride Deep Eutectic Solvents

## Abstract

**Objectives**

This research project aims to find trends, in reactivity and in chain length, among similar deep eutectic solvents (DES) in order to design more catalytically efficient DESs. Currently, though there have been many isolated studies on the qualities of individual DES catalysts, there have been no studies that show trends in catalytic activity. This research will attempt to elucidate the relationship between physical properties of DES and their catalytic performance in biodiesel transesterification.

**Methods**

Six transesterification reactions of soybean oil and methanol which produce biodiesel and glycerol were run in parallel along with positive (sulfuric acid) and negative (no catalyst) controls. Six catalysts were prepared by combining three ionic compounds of different carbon-chain length, tetraethylammonium chloride (TEA), tetrapropylammonium chloride (TPA), and tetrabutylammonium bromide (TBA), and two metal chloride ligands (AlCl3 and InCl3).

**Results**

This study demonstrates that there are significant trends.AlCl3 was overall more catalytically efficient than InCl3. AlCl3-TBA catalyzed 100%, AlCl3-TPA catalyzed 65%, and AlCl3-TEA catalyzed 95% of the oil to biodiesel reaction. InCl3 which was much less efficient at InCl3-TBA at 70 percent, InCl3-TPA at 65 percent, and InCl3-TEA at 49 percent efficiency. As a control, the sulfuric acid catalysed reaction, the industry standard, was 60% complete at two hours. In addition, longer carbon chain length was correlated with higher catalytic effect. The AlCl3-TBA was more effective than both the AlCl3-TPA and AlCl3-TEA (100 percent compared to 65 and 95 percent). InCl3-TBA was more efficient than both InCl3-TPA and InCl3-TEA (70 percent compared to 65 and 49 percent).

**Conclusions**

The trends among type I (quaternary ammonium salts with metal halides) DES that can be exploited to design DES with greater catalytic effect. Primarily, the effect of chain length on catalytic effect is not well explored, yet increasing chain length clearly increases efficiency. A second effect is the increased effect of more reactive metal halide species, namely Al vs In. Furthermore, in larger scale applications, DES are significantly easier to separate compared to H2SO4 and other commonly used homogeneous catalysts; this is due to the physical properties of DES. In conclusion, this study has demonstrated that type I DES have carbon chain length trends in activity which should be further explored. Further studies should include explorations of aromaticity, phosphonium-based quaternary ions, other metal halides, and other catalyzed

**Summary Statement**

I found trends in catalytic efficiency based on carbon chain length and metal ligand, among similar deep eutectic solvents (DES), which allows for improvement of DESs.

**Help Received**

Greg Murray of Schmahl Science Center helped scope out the project. Francine Farouz and Jeremy Jacquot, of the Nueva High School provided lab space, safety review, chemicals and support.