Two-Phase Catalytic Cyanation Reaction In An Ionic Liquid

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***Abstract* — This discovery of a faster variation of the Rosenmund Von Braun reaction is a form of green chemistry due to the fact that it decreases reaction time down from 6 hours to about 1 hour. Consequently, the temperature of the reaction can be decreased.**

I. Introduction

The Rosenmund-von Braun reaction is a chemical process in which a cyanide anion replaces the halogen in an aryl halide, thereby producing a benzene ring with a nitrile group. Since the initial discovery in 1914, much research has been done on this reaction, for example, using different catalysts, cyanide salts, and solvents, all with the purpose of producing higher yields, conversion rates, and in general, faster reactions. Recently, according to Ren et al., an ethylene diamine (EDA)/ hydrated copper acetate ($Cu(OAc)_2$-H_2O)/ potassium iodide (KI) system, with the use of potassium ferrocyanide ($K_4[Fe(CN)_6]$) as the source of cyanide, can be a very effective catalyst system, especially since, copper is more abundant compared to the commonly used catalyst, palladium, (Y. Ren et al. 2008). However; reactions that use palladium have been effective.

Ionic liquids, or salts that are poorly coordinated, are liquid below 100 °C. Deep eutectic solvents are a type of ionic liquid that falls into the category, hydrogen bond donors. Almost all deep eutectic solvents contain a quaternary ammonium salt and also dissolve many salts making then a desirable substitute for polar solvents. Choline chloride-urea is a type of deep eutectic solvent, (A. Abbott et al. 2004).

Aromatic nitriles are crucial in pharmaceuticals, agrochemicals, dyes, herbicides, and insecticides, (S. Weissman et al., 2004). Many substituent benzonitriles have been developed as inhibitors of the aromatase enzyme for the treatment of estrogen dependent diseases. Benzonitrile is also used to make vildagliptin, an anti-diabetic drug.

Hypothesis: Due to the extreme conditions originally proposed by Ren et al., it was hypothesized that if the ionic liquid, choline chloride-urea and a solvent (toluene), were to be used for $K_4[Fe(CN)_6]$ in a dehydrated EDA/$Cu(OA_c)_2$/KI system, the rate of the reaction would increase, and the reaction would form a two layer system facilitating the extraction of product.

II. Results/Conclusion

The use of an ionic liquid (choline chloride-urea) aided the replacement of the cyanide ion from the $Fe(CN)_6^{4-}$ ion to coordinate with the copper catalyst which then replaced the halide to form benzonitrile. This procedure led to an overall faster reaction. Fourier Transform Infrared Spectroscopy (FTIR) results showed that the bromobenzene was consumed within 1 hour as opposed to Ren et al.'s reaction that took 6 hours. Additionally, toluene was added to the reaction in order to create a two-layer system, with choline chloride-urea, EDA, and N-methyl-2-pyrrolidone (NMP) in the bottom layer, and the toluene and bromobenzene in the top layer. The product, benzonitrile was found in the top layer within 2 hours, confirmed at 2227.5 cm^{-1}.

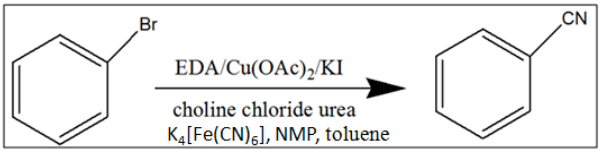

Figure 1: Variation of the Rosenmund-von Braun reaction which involves the use of the ionic liquid, choline chloride-urea.

For the reaction, shown in Figure 1 above, either a more active catalyst was created or conditions that activate the catalyst were provided. The proposed mechanism of this reaction involves the transferring of the cyanide ion from the potassium ferrocyanide to the copper acetate, which then gets transferred to the bromobenzene.

This discovery facilitates the process of extraction. The goal of this research is to make copper a more effective catalyst, which was achieved. After observing the performance of the reaction, alternative nonpolar solvents with higher boiling points could be used and different ionic liquids although can be costly can be tested. For further research, the oxidation state on the copper in the catalyst and the iron can be studied, and the mechanisms of this reaction can be studied to provide a better understanding.

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