Separation of Azeotropic Mixtures with Aprotic Solvents

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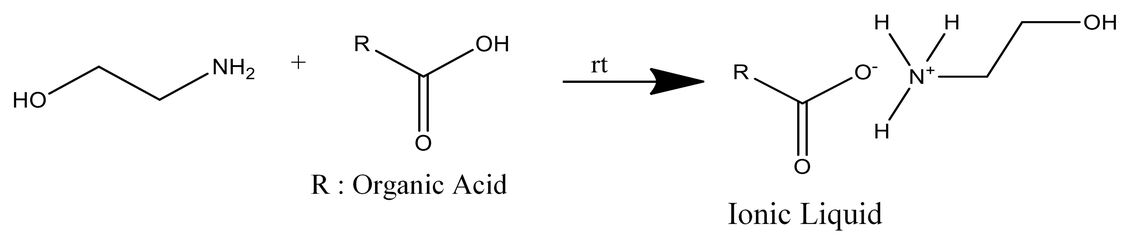
Introduction

Nowadays, the development of effective methodologies for the separation of alcohol and alkane mixtures is a challenge for chemical engineers. The main reason is due to the proximity of the boiling points of these azeotropic mixtures [1]. One of the most common separation techniques is the azeotropic or extractive distillation. However, extreme conditions (high temperatures and high pressures) are required to carry out this kind of processes. Therefore, a large amount of energy is necessary to successfully achieve the separation, which makes it economically unattractive due to the increased production costs. Liquid-liquid extraction is a technique based on the immiscibility of two liquid phases which can have different economically advantages when solvents that are not volatile are used. In this case, the solvents can be recovered and no special equipment is required. This process is a respectful alternative with the environment.

In recent years, the azeotropic separation of an alcohol and an aliphatic hydrocarbon (ethanol-hexane and ethanol-heptane) have been studied using ionic liquids (ILs) as extraction solvents. ILs have emerged as a more ecological alternative to replace the volatile organic solvents used in the chemical industry in this type of processes. However, one of the great disadvantages of using ionic liquids as extraction solvents on an industrial scale is the high cost, and complex synthesis [2], compared to those of traditional organic solvents. In this matter, the aprotic ionic liquids have attained a greater attention to be used in separation processes. These ionic liquids derive from the neutralization reaction between organic acids and ethanolamine, reducing the costs and complexity of the synthesis methodology [3].

The main goal of this work was to used three aprotic ionic liquids (2-hydroxyethylammonium formate, $[N_{0002(OH)}][HCO_2]$, 2-hydroxyethylammonium propanoate, $[N_{0002(OH)}][C_2H_5CO_2]$, and 2-hydroxyethylammonium butyrate, $[N_{0002(OH)}]$ $[C_3H_7CO_2]$) in the separation of azeotropic mixtures ethanol + hexane and ethanol + heptane. In this way, these ILs were synthesized and afterwards the liquid-liquid equilibria (LLE) of the aforementioned systems were determined at 101.2 kPa and 298.15 K.

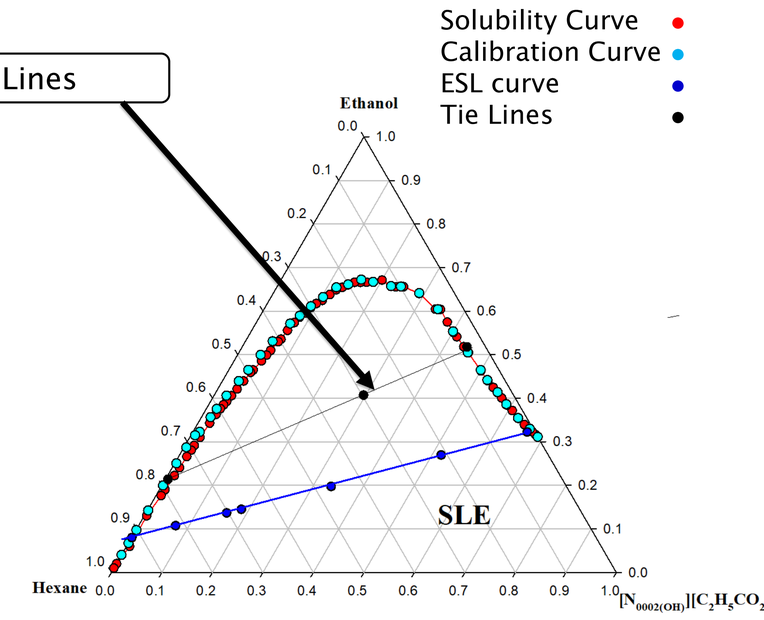
Experimental Procedure



Tie Lines

Phase rich in hydrocarbons

Phase rich in ionic liquid



Results and Discussion

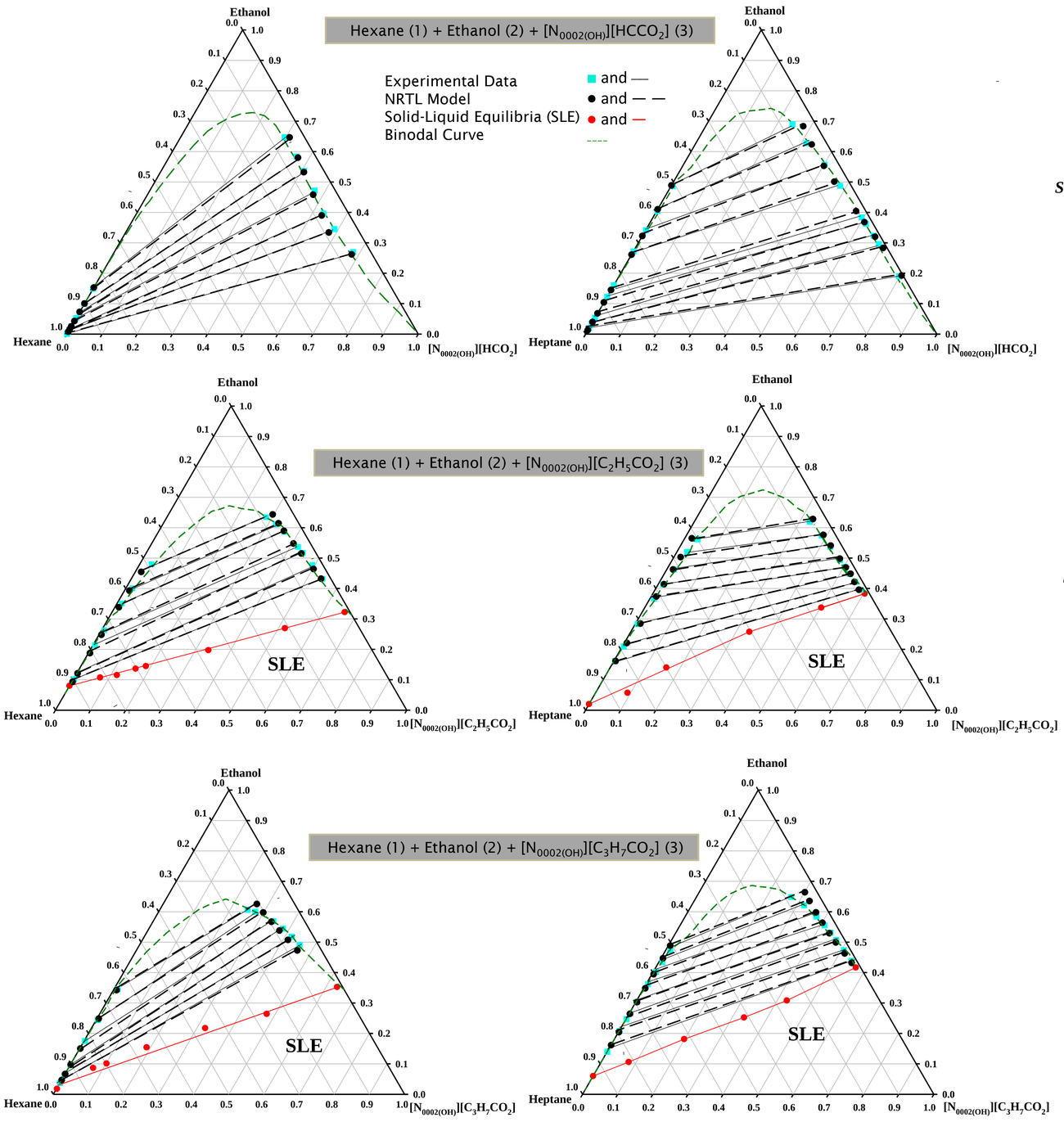


Figure 1. LLE diagrams for the ternary mixtures Hydrocarbon + Ethanol + Ionic Liquid at 298.15 K.

Selectivity (*S*)

Distribution Coefficients (β)

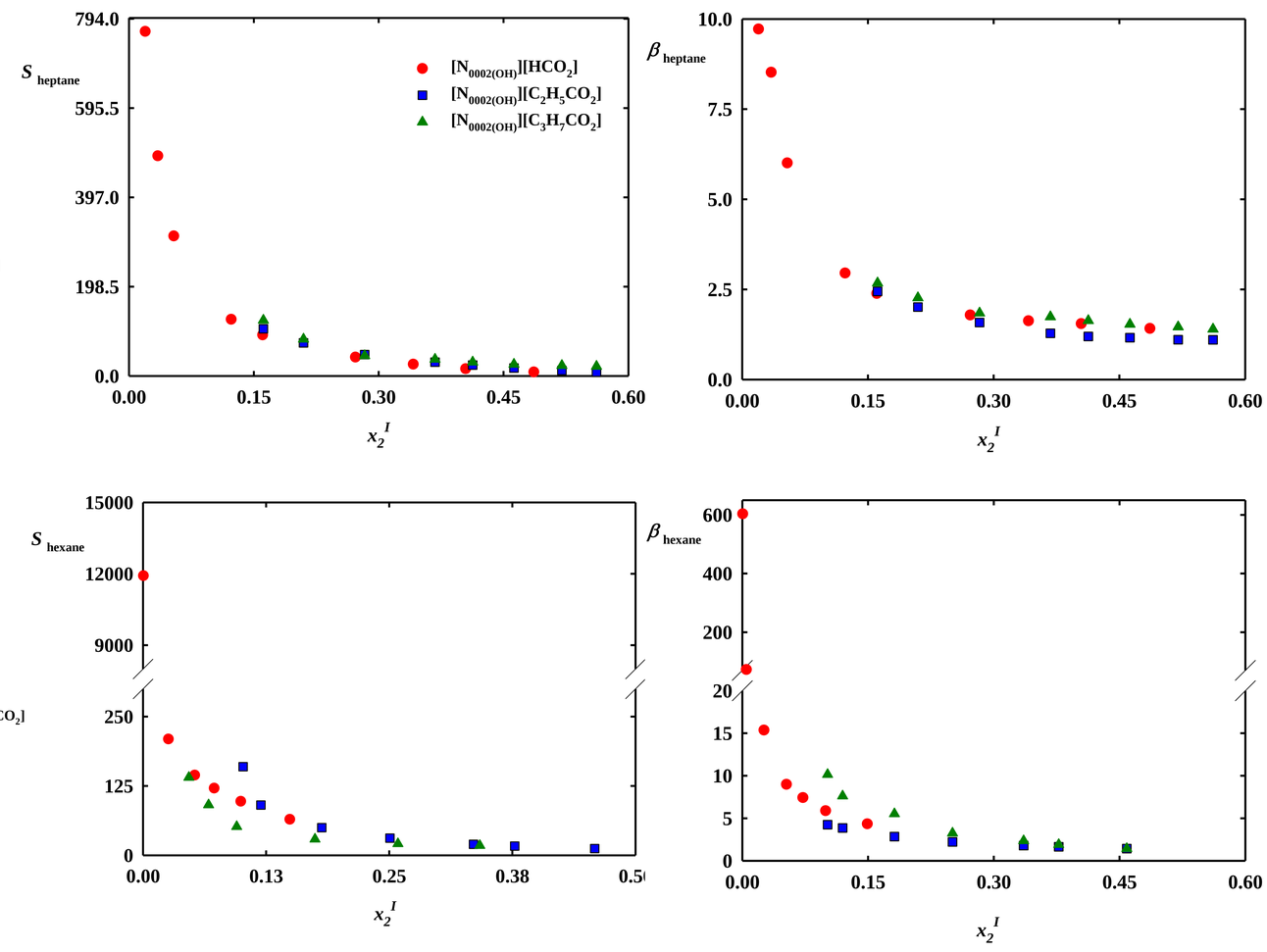


Figure 2. Selectivities and ethanol distribution coefficients for the ternary mixtures Hydrocarbon + Ethanol + Ionic Liquid at 298.15 K.

Conclusions

The effectiveness of extracting the ethanol from the azeotropic binary mixtures is given by the selectivity and coefficient distribution, which are the measure of the ability of the ionic liquid to separate the ethanol from the heptane or hexane mixtures. Taking into account these data, we can say that these protic ionic liquids are excellent extractive agents. This process leads to an environmentally friendly extraction process in the separation of azeotropic mixtures as alternative to the azeotropic distillation.

References: [1] A. Pucci, Pure and Applied Chemistry, 61 (1989) 1363-1372; [2] M. Francisco, A. van den Bruinhorst, M.C. Kroon, Angewandte Chemie International Edition, 52 (2013) 2–14; [3] N. J. Bicak, Journal of Molecular Liquids, 116 (2005) 15–18.

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