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Article

Solvent Regeneration Methods for Combined Dearomatization, Desulfurization, and Denitrogenation of Fuels Using Deep Eutectic Solvents

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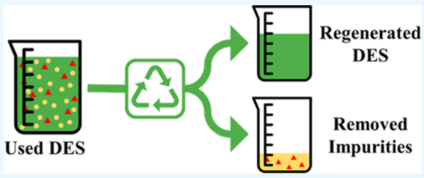
ABSTRACT: Deep eutectic solvents (DESs) can be used as potential solvents for various applications. However, their recovery depends on both economic and environmental considerations. In this study, the possibilities for the recovery of methyl triphenyl phosphonium bromide/triethylene glycol (MTPPB/TEG 1:4) after the application of combined dearomatization, desulfurization, and denitrogenation of fuels are investigated. The DES was first prepared and characterized for its density, viscosity, and water content. Then, the single-stage liquid−liquid extraction was conducted in addition to testing the repetitive use of the DES. After that, two regeneration methods were studied: the stripping method (with *n*-heptane) and the washing method (with distilled water or diethyl ether). In addition, a parametric study was conducted to optimize the regeneration methods. The results showed that washing the used DES with distilled water was significantly more effective than stripping the DES with *n*-heptane. In terms of quinoline reduction, distilled water reduced the quinoline content in the DES from 3.2 to 2.1 wt %, while *n*-heptane showed a minor reduction in the quinoline content (3.2 to 3 wt %). It was also found that a much more effective recovery could be achieved by (i) increasing the DES-to-regeneration solvent mass ratio and (ii) increasing the number of wash cycles. Furthermore, the regeneration temperature did not have a significant effect on the recyclability of the DES. The results demonstrated that the regenerated DES was as effective in extraction as a fresh batch of DES.



1. INTRODUCTION

Deep eutectic solvents (DESs) have attracted attention as promising, effective, and eco-friendly solvents in various processes.[1−3] They were first coined by Abbott *et al.*,[4] where a DES composed of choline chloride and urea in a molar ratio of 1:2 was reported. According to Abbott *et al.*,[4] this designer solvent could form a eutectic mixture by mixing one or more hydrogen bond acceptors (HBAs) and one or more hydrogen bond donors (HBDs), which can include hydrogen bonding between its constituents. Nevertheless, the definition of the solvent remains a point of contention. More recently, Martins *et al.*[5] claimed that a DES could be defined as "*a mixture of two or more pure compounds for which the eutectic point temperature is below that of an ideal liquid mixture presenting significant negative deviations from ideality. Additionally, the temperature depression should be such that the mixture is liquid at operating temperature for a specific composition range. Otherwise, a more specific term 'eutectic solvent' could describe mixtures that do not fulfill these criteria*". Nevertheless, there is still room for improvement in the definition.[6−8]

DESs have been actively applied as a promising alternative to volatile organic compounds and ionic liquids.[9−12] DESs are attractive for several reasons, including their inexpsensive to moderate cost of synthesis, the absence of purifying steps required before use, their low flammability, and their biodegradability.[1,13−15] Since their discovery, the application of DESs in various fields has shown the bright future of DESs as a promising solvent.[16−19] Such an example could be found in fuel purification processes, where DESs led their effectiveness in improving the quality of fuels.[20−23] One of the most advanced applications of DESs in fuel purification is the simultaneous removal of different aromatics. Choline chloride was used as an HBA in the DESs developed by Larriba *et al.*[24] to eliminate BTEX (*i.e.*, benzene, toluene, ethylbenzene, and xylene), along with some HBDs (including ethylene glycol, glycerol, levulinic acid, phenylacetic acid, malonic acid, and urea). The results confirmed that DESs are a potential candidate to replace the extraction solvents for the removal of aromatics. Other studies have also investigated the

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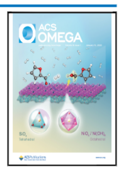

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