Aqueous micellary systems formed by surfactant ionic liquids. Application in Diels-Alder reactions.

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Abstract. In the present work, our objective is to take advantage of the property presented by Ionic Liquids (ILs) based on 1-alkyl-3-methylimidazolium cations by having amphiphilic character when the alkyl group is a long hydrocarbon chain. These ILs can act as surfactants forming micelles in aqueous solution. In this sense, the micellar effect on a Diels-Alder reaction (DA) was analyzed taken as a reference. The reactive system studied consists of maleic anhydride and isoprene, variables such as diene:dienophile ratio and reaction temperatura among the most important were optimized. *N*, *N*-dodecylmethylimidazolium bromide was used at the critical micellar concentration (CMC) of 1 x 10^{-2} M.

These "new systems" microheterogeneous would allow, in addition to better solubilization of non-polar substrates, to adopt milder reaction conditions.

Keywords. Ionic Liquids, surfactants, micelles, Diels-Alder

Introduction

The Diels-Alder reaction represents, from a methodological point of view, one of the most significant and versatile tools currently used in the construction of six-member cyclic adducts, carbocyclic or heterocyclic. Due to the potential given by the possibility of forming carbon-carbon, carbon-heteroatom and heteroatom-heteroatom bonds, it is a versatile synthetic tool in the construction of both simple and complex molecules.[1,2]

In particular, for the polar Diels-Alder (DA) reaction one of the most relevant aspect is its dependence on the solvent. Generally, in this type of reactions, little polar organic

compounds are involved,. This is an inconvenience because molecular solvents are required as a reaction médium, which are highly polluting and toxical. In this direction and as an alternative to traditional solvents, ionic liquids (ILs) arise.

These compounds are organic salts that are being studied for their broad spectrum of applications. One of the greatest advantages of these compounds is that from the combination of the different anions and cations that compose them, it is posible to obtain a large number of new ILs with different properties.[3] Additionally, the substitution in the nitrogen of the cationic base by alkyl groups composed of linear chains with more than 8 carbon atoms, gives them amphiphilic characteristic. These characteristics cause the organization of this type of ILs in micelles in aqueous solution. In this way, new surfactants to the traditional ones are presented expanding the spectrum of applications such as micellar catalysis, solubilization, protein folding and drug transport, etc. In addition, the reactions developed in these micellar systems are framed within the green chemistry.

An example of these ILs are those based on 1-alkyl-3-methylimidazolium $[Cnmim]^+$ cations when the alkyl group has a hydrocarbon chain containing several carbon atoms. In this sense, our objective is to analyze the effect of the micellar médium on a DA cycloaddition reaction taken as a reference.

Results and Discussion

We worked with a reactant systems which produces cycloalkenes of industrial interest. Its behavior was analyzed in aqueous micellar systems formed by new surfactants whose structural basis is an imidazole ionic liquid. This reaction medium is extremely interesting to be explored as an alternative to optimize temperatures, reaction times and yields which will constitute a new contribution to chemical synthesis in water.

The reactive system tested consists of maleic anhydride and 2-methyl-1,3-butadiene (isoprene). This cycloaddition reaction generates a dicarboxylic adduct that is used as a monomer in obtaining aliphatic polyesters that have applications in the field of biology and medicine.

In order to optimize an aqueous reaction medium by implementing micellar systems, *N*,*N*-dodecylmethylimidazolium bromide ([DoMIm][Br]) was used. Its synthesis was carried out in our work group following the methodology reported. [4]

Cycloaddition reactions were carried out in a glass reactor equiped with magnetic stirring. 1.4 mmol of maleic anhydride, 4 mmol of isoprene and [DoMIm][Br] were used at a critical micellar concentration (CMC) of $1x10^{-2}$ M. The reactions developed at room temperatura for 24 and 48 hours (Fig. **1**).

After the reaction time was over, the products were extracted with ethyl acetate and purified using classical column chromatography using silica gel as stationary phase and hexane-athyl acetate mixtures as eluent. The reaction products were analyzed by sprectroscopic methods.

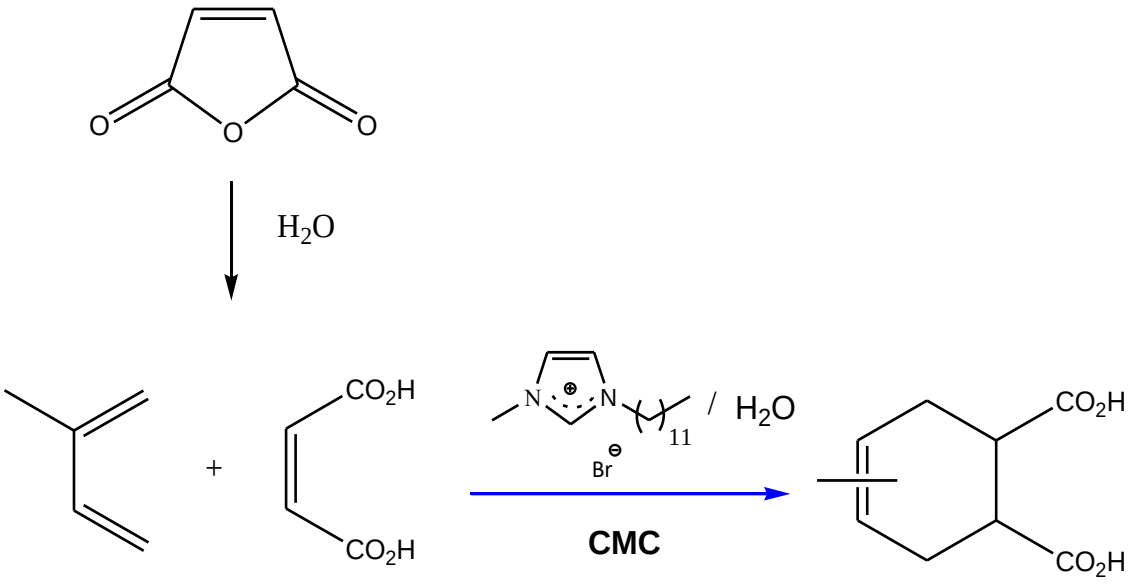

Fig. 1. Diels-Alder reaction in a micellar solution of [DoMIm][Br].

Conclusions

The micellar system selected as a reaction medium for the development of the cycloaddition between the mentioned diene and dienophile was found to be effective for the generation of cycloalkenes that present industrial interest. This statement is evidenced by the acceptable yield of the obtained cycloadducts: 24 hours, 60 %; 48 hours, 70% using more benign conditions than those reported.[5,6] The use of adequate reaction media in these "economic in atoms" processes provides an approach aimed at improving both the chemical

and environmental efficiency of these cycloaddition reactions. In this sense, it is intended to work with imidazole-based ILs with different length of carbon chain – 4, 8, 10 and 16 carbons in the imidazole ring-.

It is of interest to develop new microheterogeneous media with different microenvironments that allow the solubilisation of non-polar reactants and consequently access to more bening reaction conditions and with higher yields than those reported using molecular solvents, inorganic catalysts, higher temperatures and reaction times.

In addition, the results obtained will contribute to a better understanding of the effects of the environment in these reactions of utmost synthetic importance.

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References

1- Corey E. J., *Angew*. *Chem. Int. Ed*. **2002**, 41, 1650- 1667.

2- Friguelli, F., Taticchi, A. In *The Diels-Alder reaction: Selected Practical Methods*. Ed. Wiley **2002**. Cap. 6, pp 251-297.

3- Adam, C., Fortunato G., *J Surfact Deterg* (**2019**) 22: 501–513. DOI 10.1002/jsde.12260

4- Suarez, P., Einloft, S., Dullius, J., De Souza. R., Dupont, J. *J. Chem. Phys*. **1998**, 95, 1626-1639.

5- Walborsky, H. M., Barash, L., Davis, T. C. *Tetrahedron* **1963**, Vol. 19, pp 2333-2351.

6- Brown A. H., Sheares V. V., *Macromolecules* **2007**, 40, 4848-4853.