water-solvent-green-chemistry

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Cruising Review

Using Water as a Solvent for Green Chemistry

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This article seeks to describe the benefits of using water as the primary solvent in chemical processes due to its environmentally benign impact and its many unique properties.

PDF Version of the webpage (first pages)

The Principles of and Reasons for Using Water as a Solvent for Green Chemistry

1. This article seeks to describe the benefits of using water as the primary solvent in chemical processes due to its environmentally benign impact and its many unique properties.
2. Water is the primary solvent found in nature, but under normal conditions, water is only able to dissolve polar compounds. Historically, this has lead to the use of volatile organic compounds (VOCs) as solvents in chemical processes involving non-polar solutes. These VOCs tend to have much more significant environmental and health impacts than water and incur a greater cost.
3. Previous works have shown that it is possible to utilize both the hydrophilic and hydrophobic properties of water in the same well-designed process. Compound that are attracted to water are said to be hydrophilic, while the opposite is true for hydrophobic compounds.
4. The authors investigated different glucose chain structures which created molecule with polar areas around the periphery and internal areas that were non-polar. When mixed into water with other solutes, the polar structures attached to the water molecules while non-polar compounds were attracted to the internal structure, allowing the water to act as a solvent for the previously insoluble non-polar compounds.
5. Experiments using specifically designed cyclodextrin molecules, quote – indicated the enormous rate accelerations that can be achieved using the hydrophobic effect to promote catalyst-substrate binding – unquote.
6. By using water as the solvent for a non-polar solute along with a well-designed third compound, the hydrophobic effect can be used to force interactions between solutes vastly improving reaction times.
7. Another test involved creating a mimic of ribonuclease, the enzyme responsible for cleaving ribonucleic acid (RNA). A similar approach was used with water as the process solvent and an engineered catalyst that utilized the hydrophobic nature of the other solutes to improve reaction times.
8. The most important result of the testing involving RNA was that the hydrophobic cavity of the engineered catalyst must be very precise to offer significant reaction benefit.
9. In another investigation, the authors, quote – synthesized artificial enzymes linking thazolium ions to cyclodexrins, to use again the hydrophobic binding of substrates in water – unquote, and in doing so were able to offer a replacement catalyst for the cyanide ion previously used. Cyanide, being highly toxic is not ideal for biologic systems.
10. It was observed in multiple trails that design of the hydrophobic cavity could be defined in such a way as to selectively control the product compounds isomeric structure. In some instances, a well- designed cavity could be used in conjunction with system pH to select the product isomer.
11. When working with Diels-Alder reactions, the authors came to realize that some reactions proceeded significantly more quickly in water than in other solvents, even without the introduction of an engineered catalyst.
12. Some of the Diels-Alder reactions were not even truly solutions but rather suspensions of insoluble reactants in water. The hydrophobic nature of the reactants in these suspensions was found to be beneficial to the rate of reaction. This indicates that suspensions of non-polar / insoluble compounds may also benefit from water-based processes.
13. The hydrophobic effect in water can be increased through the addition of, quote – simple salts such as lithium chloride ... by contracting the water volume – unquote.
14. The addition of, quote – antihydrophobic salts such as guanidinium chloride decrease the hydrophobic effect in water – unquote.
15. This paper concludes that water offers a valuable solvent option even in instances where a true solution cannot be formed. Even in the creation of suspensions, it is possible to utilize the hydrophobic effect to drive reactions that would otherwise be prohibitively slow. The authors mention other beneficial factors regarding the selection of water as a solvent, but little discussion is dedicated to the other reasons. Overall, this is a highly technical piece describing multiple investigations of the hydrophobic effect of water and how it can be harnessed to influence reactions.

Source: Breslow R. The Principles of and Reasons for Using Water as a Solvent for Green Chemistry. *Handbook of Green Chemistry.* 2010. doi:10.1002/9783527628698.hgc047

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