NMR Characterization of Tetra-*meso*-substituted Porphyrins Synthesized by Mechanochemistry

Tamara. D. Hamilton, Paula Mackin, Hannah Shy (Barry University, Physical Sciences);
James R. Rocca (AMRIS)

Introduction

Solvent-free carbon-carbon bond forming reactions are becoming more sought-after, due to lower waste generation and potential access to products unattainable through solution synthesis. Porphyrins are usually synthesized under high dilution conditions in order to avoid linear byproducts, necessitating the use of large volumes of propionic acid or chlorinated organic solvent.[1] Yields from these reactions are low, ranging from 20-30% or even lower, depending on the substituents present on the aldehyde starting material. The reaction mechanism is a four-fold acid-catalyzed condensation between pyrrole and an aldehyde, followed by oxidation to produce the porphyrin. We are investigating a solvent-free approach involving automated grinding of reactants with an acid catalyst using a Retsch MM200 ball-mill grinder to produce significant amounts of porphyrin after oxidization. The method has proven effective using benzaldehyde as a reactant to produce tetraphenyl porphyrin (TPP) in significant yields. TPP has been characterized using UV-Vis spectroscopy, ^{1}H Nuclear Magnetic Resonance, and Mass Spectrometry. To investigate the general applicability of the approach, a series of substituted benzaldehydes were ground in the presence of pyrrole and toluene sulfonic acid as a catalyst. The product mixture was then oxidized and analyzed by UV-VIS to confirm the presence of porphyrin.

Experimental

Equimolar amounts of pyrrole and substituted benzaldehyde, and a catalytic amount (10%) of toluenesulfonic acid were added to a steel reaction capsule along with two stainless steel grinding balls. The capsule was placed in a Retsch MM200 ball-mill grinder and the mixture was shaken for 30 minutes at 30 Hz to yield a powder. The powder was oxidized immediately after grinding by adding 3 eq. 2,3-dichloro-5,6-dicyanobenzoquinone (DDQ) in 30 mL chloroform, and stirring for 30 minutes. The mixture was then passed through a one-centimeter plug of alumina to remove DDQ, and was analyzed by UV-Vis Spectroscopy to confirm the presence of a porphyrin in the mixture.

Results and Discussion

Various halogen and alkyl-substituted benzaldehydes as well as polycyclic aromatic aldehydes were used as starting material to produce the corresponding tetra-*meso*-substuted porphyrins, as evidenced by the presence of Soret Bands (around 420 nm) in their UV-Vis spectra (**Figure 1**). Further characterization (*i.e.* ^{1}H and ^{13}C NMR) of the purified components of the mixture is needed to confirm this result.

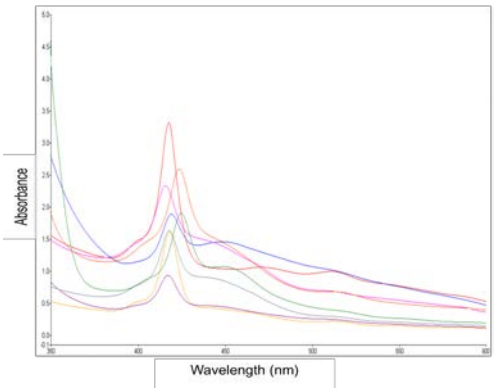

Figure 1: UV-Vis spectra of reaction mixtures.

Conclusions/Future Work

Solvent-free grinding holds promise for the synthesis of porphyrins and substituted porphyrins without the need for large amounts of chlorinated or caustic solvents. UV-Vis spectra confirm the presence of reaction porphyrins in the reaction mixture, but clearly, products need to be purified and confirmed with NMR spectroscopy. Once so confirmed, this study will help to establish solvent-free grinding as a viable synthetic method for porphyrins and related compounds.

Acknowledgements

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References

[1] Lindsey, J. S. *et al.,* J. Org. Chem., **52**, 827-836 (1987).