Towards Semisynthetic Bioorganometallic Protein Catalysts: Cyclopropanation of Styrene with Ruthenium(II)-Modified Porphyrin Cofactors in Aqueous Solution

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Presumably because of their low bioavailability, platinum metals are not found in metalloproteins; however, they are powerful catalysts for many organic transformations and thus hold great promise as synthetic cofactors in modified enzymes. In a number of hemoproteins, including myoglobin and horseradish peroxidase, the iron-porphyrin cofactor can be readily exchanged with a modified synthetic porphyrin-cofactor. In this study we have investigated the properties of various ruthenium(II)-porphyrin derivatives as potential cofactors for the design of semisynthetic organometallic biocatalysts. The water-soluble Ru(II)-porphyrin complexes proved to be effective catalysts for the cyclopropanation of styrene in neat aqueous solution over an extended pH range between 6.0 to 8.0. The reactions provided the corresponding cyclopropanation products with good yields and excellent cis/trans selectivities around 1:90, which is significantly higher than previously observed for the same reaction in organic solvents. The formation of small amounts of diethylmaleate was also observed, but no diethylfumarate could be detected in the reaction mixture. The second order rate constant for the formation of the carbene intermediate was determined to be k_{obs} = 5.2 +/- 0.1 M^{-1} s^{-1}. Furthermore, we have investigated the influence of axial ligand coordination on the reactivity of the catalyst and overall product distribution. Initial experiments showed that apo-horse heart myoglobin can be readily reconstituted with the synthetic ruthenium(II)-cofactor.