

“The Pigments of Life”

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I. INTRODUCTION:

Porphyrins and their derivatives are a class of naturally occurring macrocyclic compounds with intense colour, that have been extensively studied due to the key role played in some life processes and involving their special aromatic structure (18π -electrons). Suitable examples that can be given as for oxygen transport (haem), electron transport

(cytochrome c) and, most fundamentally, photosynthesis (chlorophyll a). Indeed, without the chlorophylls and bilins (e.g. phycocyanin which acts as a light harvester in algae) life as we know it would not exist on this planet. These are the reasons why porphyrin-derived pigments are called “the Pigments of Life”.

e.g.



(A) Chlorophyll a



(B) Heme



(C) Cyanocobalamin(Vitamin B12)

❖ A Brif History:

The history of the study of metalloporphyrins' activities began in 1747 when Menghini demonstrated for the first time the presence of iron in blood. Hoppe and Seyler in 1871 isolated porphyrins from blood, describing these compounds as pyrrole derivatives, and in 1940 the structure and biological functions of iron porphyrin complexes were well established .

Nowadays, this kind of metalloporphyrins is well known since they are prosthetic group of an important class of proteins and enzymes called hemoproteins.

Chlorophyll was first isolated and named by Joseph Bienaimé Caventou and Pierre Joseph Pelletier in 1817. The presence of magnesium in chlorophyll

was discovered in 1906, and was that element's first detection in living tissue.

Vitamin B12 (Cobalamin) has been a challenging problem in biochemistry and medicine since the discovery by George Minot and William Murphy in 1926 that pernicious anemia can be treated by feeding the patient large amounts of liver. Metalloporphyrins have also been widely studied as bioinspired models of cytochrome P-450 (hemoproteins), and have exhibited catalytic activity for highly selective monooxygenation reactions, which proceed via formation of a high valence metal oxygen complex intermediate. In 1979, Groves and co-workers developed the first oxidation system using a synthetic metalloporphyrin as a bioinspired catalyst.

❖ Catalytic Effects of the Porphyrins:

It is important to highlight that porphyrin derivatives are special molecular scaffolds, which present relevant and cost-competitive transform in this fields, thus it deserves attention. In this

review, the intention is to cover the most relevant scalable porphyrin-catalysed procedures, showing how these compounds represent broad applications in chemistry.

1. Oxidation Reactions with Porphyrin and Metalloporphyrin-Based Catalysts:

Oxidation reactions are important synthetic tools, and a number of applications can be found in the chemical industry. The manufacture of products obtained from oxidation of organic substrates and the production of pharmaceutical ingredients (APIs) are of major importance. This cytochrome family of enzymes play a key role in aerobic oxidation reactions in biological systems under mild conditions, such as highly selective hydroxylation of alkanes (C–O bond formation via saturated C–H bond functionalization) (Scheme 1). Metalloporphyrins with ruthenium, iron, manganese, among other metals, constitute the family of catalysts which are efficient to mediate C–H oxidations with high selectivity and good yields.

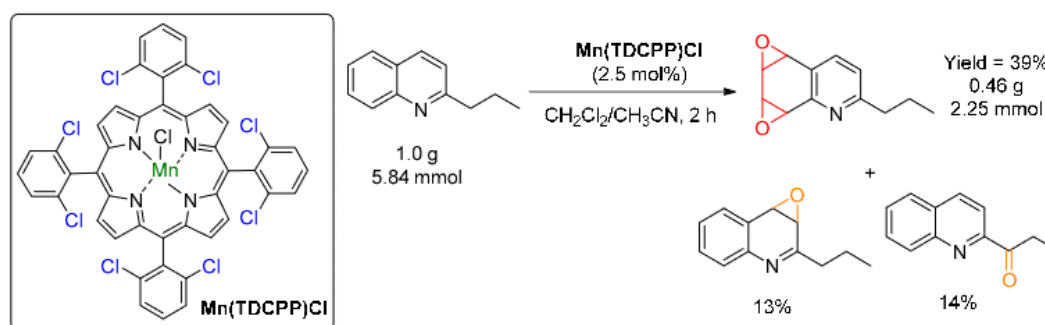


Scheme 1: First industrial-scale bioinspired oxidation of cyclohexane with CoTPP.

2. Epoxidation:

The epoxidation of alkenes is one of the processes of great importance in the fine chemical industry from an economic point of view, because epoxides are useful intermediates in the production

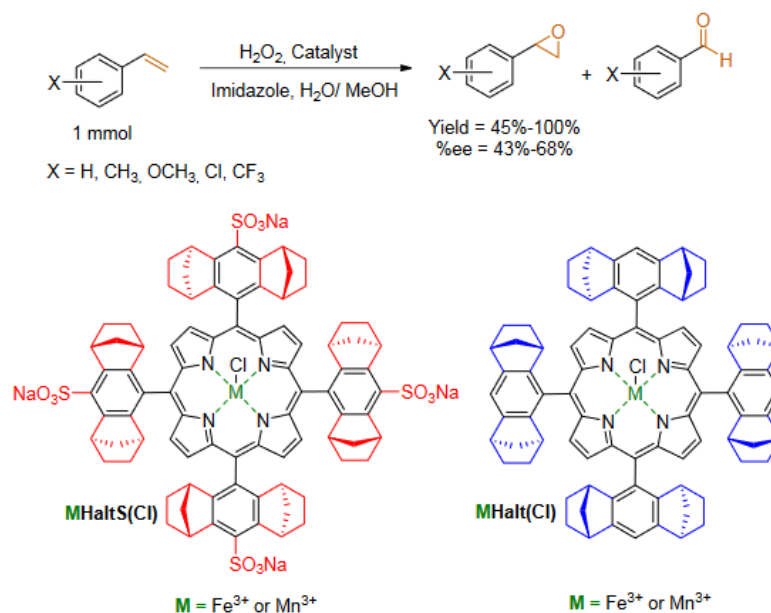
and manufacture of high-value commercial polymers like polyurethane, polyamides, resins, and polyesters. In addition, this transformation is used to carry out bioinspired oxidations to produce drug candidates or metabolites (Scheme 2).



Scheme 2: Metalloporphyrin catalysed bioinspired oxidation of 2-propylquinolin.

However, Simonneaux and co-workers reported in 2012 the enantioselective epoxidation of styrene derivatives using H₂O₂ (ee up to 68%), in water-methanol solutions using chiral water-soluble manganese and iron porphyrins as catalysts

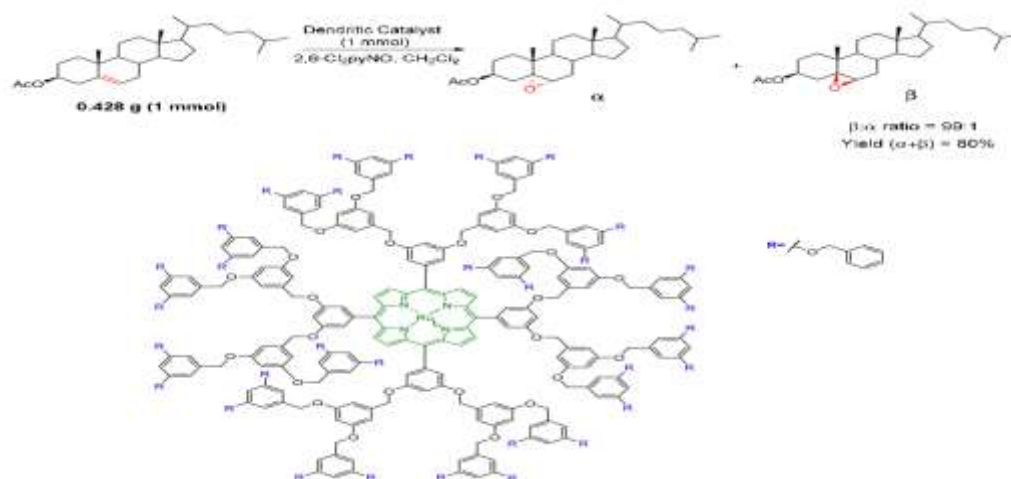
(Scheme 3). They also studied various factors which affect the catalytic epoxidation of olefins and found that the water present in the methanol is quite useful.



Scheme 3: Epoxidation of styrenes using manganese porphyrins as catalyst and H₂O₂.

Employing dendritic ruthenium porphyrins as catalysts, and 2,6-Cl₂pyNO, t-BuOOH or O₂, some authors have described efficient epoxidations of different alkenes in high yields and turnover numbers (>700).

Che and co-workers investigated the catalytic properties of the catalyst for the epoxidation of unsaturated cholesteryl esters with 2,6-Cl₂pyNO in dichloromethane using just 0.1 mol % of the dendritic ruthenium porphyrin catalyst (Scheme 4).

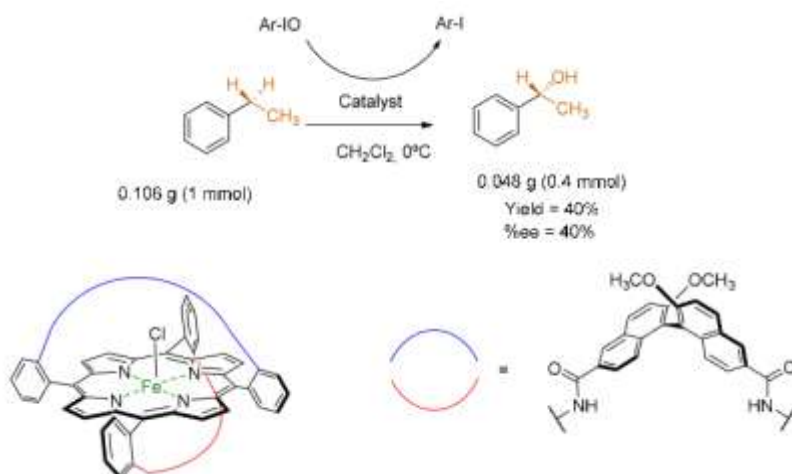


Scheme 4: Dendritic Ru-porphyrin catalysed epoxidation of cholesteryl ester.

3. Hydroxylation:

The first report of metalloporphyrin-catalysed hydroxylation of saturated C–H bonds was published by Groves and co-workers in 1979, where they showed the catalytic activity of [Fe(TPP)Cl] towards oxidation of cyclohexane and adamantane with iodosylbenzene to give the corresponding alcohols. Approximately 10 years

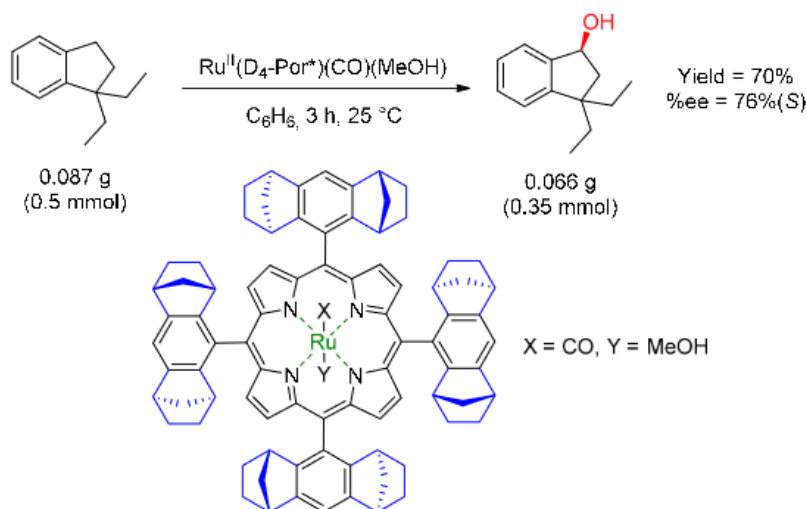
later, Groves and Viski reported for the first time, the enantioselective hydroxylation of ethylbenzenes catalysed by a chiral iron porphyrin with up to 77% ee using PhIO as oxidant (Scheme 5). When manganese was used, higher yields were obtained, but the enantioselectivity decreased and ketones were also observed as by-products in the catalytic reactions.



Scheme 5: Enantioselective hydroxylation of ethylbenzene by a chiral iron-porphyrin.

Che and co-workers reported the Ru-catalysed enantioselective hydroxylation of aromatic hydrocarbons with benzylic C–H bonds. Using 2,6-Cl₂pyNO as oxidant, the chiral ruthenium porphyrin was shown to be an effective

catalyst for hydroxylating a series of aromatic hydrocarbons to form the corresponding secondary alcohols. Although the conversion of the substrates was incomplete, the Ru-based hydroxylation gave yields up to 76% ee (Scheme 6).



Scheme 6: Ruthenium catalysed asymmetric alkane hydroxylation.

4. Oxidation of Alcohols to Carbonyl Compounds:

The transformation of primary alcohols to the corresponding aldehydes or carboxylic acids is

important for organic synthesis, since these are versatile functional groups which are present in many building blocks (Scheme 7).



Scheme 7: Oxidation of benzylic alcohols to carbonyl compounds with a Mn-porphyrin.

Other important reactions where the Porphyrins acts as catalyst are:

5. Sulfides to Sulfoxides

6. Photochemical Reactions

II. CONCLUSION:

Over the last few decades, synthetic organic chemists have taken advantage of the catalytic activity of porphyrin derivatives to develop novel laboratory procedures and to enhance existing protocols, but normally on a small scale. Recently some scaled-up reactions have been described showing that these macrocycles are very useful for increasing the scope of available multiple catalysts. The challenge now is to explore the broad potential and applications of these catalysts for the synthesis of important products from an economic point of view, for the industrial and pharmaceutical industries.

In addition, another challenge is to introduce simple and cost-competitive synthetic routes to access porphyrinods, since historically these compounds are considered rare due to low synthetic yields and tedious purification protocols. Therefore, it is necessary to incorporate enabling techniques for the optimisation of the production and utilization of these fascinating naturally inspired catalysts, and chemists must now consider these robust compounds for many new purposes.

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