

6 Summary

The aim of this thesis was the investigation and development of new synthetic methods for functionalized asymmetric porphyrins with organolithium reagents. Specifically, the following results were obtained :

First, an experimental verification of the reaction mechanism of the S_NAr reaction of porphyrins with LiR was performed. For this the free bases of 5,15-diphenyl- and 5,15-dibutylporphyrin and the corresponding Ni^{II}-complexes were used as test cases. The intermediates in each step of the reaction with LiBu were systematically investigated using UV/vis spectroscopy, deuterium labeling, trapping of the intermediates with electrophiles, and variation of the pH of the reaction mixture. It was found, that the nucleophilic reaction of free bases and Ni^{II}-complexes proceeds through different intermediates which after the addition of LiBu showed similar UV/vis spectra typical for a phlorin but exhibited different chemical reactivity in the reaction with electrophiles. Here, only Ni^{II}-complexes reacted at the *meso*-position opposite to that of the LiR attack with alkyl iodides. Furthermore, a direct oxidation (with DDQ under nonaqueous conditions) of the anionic intermediates of free bases allowed a dimerization giving directly *meso-meso* linked bisporphyrins. Upon lowering the pH-value of the reaction mixture, different UV/vis spectra were obtained for the intermediates resulting from free bases (phlorin) and Ni^{II}-complexes (porphodimethene). Additionally the investigation showed, that the intermediate resulting from Ni^{II}-complexes is stable under the reaction conditions in the presence of water and no protonation was observed. According to the results from the investigation of deuterium labeling experiments, the negative charge in the Ni^{II}-complexes is preferentially localized at the *meso*-position opposite to the LiR attack, whereas in the free base the negative charge should be more localized at the nitrogen atoms. A model using a conformational analysis of the intermediates was introduced to explain the different chemical reactivities of free bases and metal complexes.

The regioselectivity for *meso* and β positions is important for potential applications of the reaction. For a detailed study, 5,15-disubstituted and 5,10,15-trisubstituted aryl- and alkylporphyrins were treated with phenyl- and alkyl lithium reagents (alkyl- = Bu, Prⁱ, Bu^s and Bu^t). Complete regioselectivity and excellent yields for the substitution of the *meso* positions was found with sterically undemanding organolithium reagents (LiBu, LiPh) whereas more byproducts were observed in the reactions with sterically hindered LiR (R = Prⁱ, Bu^s and Bu^t) and the corresponding target compounds were obtained only in low yields. In addition, simple

variation of the reaction conditions provided a route to directly *meso-meso* linked bisporphyrins in high yields.

The influence of the porphyrin central ion on the reactivity of the intermediates was investigated by using Li^I-, Zn^{II}-, Ni^{II}- and Pd^{II}-complexes. Only the intermediates derived from Ni^{II}-complexes reacted with alkyl iodides indicating that the postulation that conformational effects govern the chemical reactivity of the intermediates was correct again. In the course of further studies on the reactivity various organolithium reagents with different reactivities such as alkyl-, alkenyl-, alkynyl-, phenyl-, benzyl- and heteroaryllithium were used for reaction with 5,15-diphenylporphyrin. Aryl- and *n*-alkyllithium reagents generally gave the best yields.

On the basis of the results discussed above, a general synthetic method for functionalized A₂B- and A₂BC-porphyrins was developed. Especially noteworthy is the reaction of the monoanionic Ni^{II}-intermediates, prepared *in situ* by reaction with LiR, with alkyl iodides. This constitutes a one-flask synthesis that allows the regioselective introduction of two different substituents in the porphyrin system. Using the reaction discussed above, many novel porphyrins with functional groups like -OH, -CHO, -C≡CH, -COOH, -COOEt, -CN, -I and -NH₂ were prepared in good yields.

In order to test the chemical reactivity of the functional groups introduced, the synthesized porphyrins were employed as reaction precursors for further connections with target molecules. All introduced functional groups showed a satisfactory chemical reactivity and can be used as reaction centers for the synthesis of complex tetrapyrrole systems with special chemical and physical properties.

In addition, a new synthesis way leading to 5,5',15,15'-tetrasubstituted functionalized asymmetric porphodimethenes was found. This reaction involved trapping of monoanionic Ni^{II}-intermediates with alkyl iodides with small substituents such as (ICH₂)₄CN, MeI, and NCCH₂I. The structure and conformation of the novel porphodimethenes was investigated via NOE and ¹H-¹³C-NMR experiments.

The present work has resulted in the development of several facile and efficient synthetic strategies for a regioselective introduction of almost any functional group into the porphyrin system allowing the synthesis of asymmetrically substituted porphyrins for further synthetic studies on tetrapyrroles.