
Preface

Soluble organometallic catalysts are an inevitable tool in contemporary organic synthesis. Two Nobel Prizes in the first decade of the 21st century emphasise the continuing scientific progress and technical relevance of this principle. In fact, homogenous catalysts have long made their way into an increasing number of industrial applications on all scales, ranging from bulk chemicals to complex multi-step processes. Among the most prominent examples are the Monsanto and Cativa processes for the production of acetic acid, various processes for the hydroformylation of olefins to yield aldehydes and other oxo-products, the production of (-)-menthol at Takasago, and the synthesis of the blockbuster herbicide Metolachlor at Syngenta. These successful technical processes are, however, only the tip of an iceberg of potential applications involving the general strategy of homogeneous transition-metal catalysis. One of the major obstacles to an even broader use of homogeneous catalysts is the inherent difficulty to isolate the products from the reaction mixture containing the dissolved catalyst and to recycle the metal-containing component in active and selective form. The development of innovative and generic methodologies for catalyst immobilisation is therefore key to the future development of this important field of chemical science and technology.

The soluble nature of the active species is the basis for this success story as it allows modification and optimization of the catalytic performance on a molecular level. At the same time, it is also the main drawback of the approach, as products and catalysts are contained in the same phase at the end of the reaction. Efficient separation is often crucial, however, because the costly and highly specialized catalysts should be recovered and recycled for economic and environmental reasons. Furthermore, the specifications and applications do not allow even trace amounts of metals or other catalyst components in many products.

A very elegant solution to solve this problem is the introduction of either a permanent or a temporary phase boundary between the molecular catalyst and the product phase. The basic principle of multiphase catalysis has already found implementation on an industrial scale in the Shell higher olefin process (SHOP) and the Ruhrchemie/Rhône-Poulenc propene hydroformylation process. Over the years, the idea of phase-separable catalysis has inspired many chemists to design new families of ligands and to develop new separation

and recycling strategies. The fundamental challenge in this field is to meet the right balance between sufficient contact of the substrates with the active species during the reaction step and distinct partitioning of catalyst components and products in the separation step. This can be influenced across all scales, by the molecular design of the catalyst, the choice of the reaction medium and solvent, and finally the reaction engineering implementation.

In 2002, the German network of competence for catalysis *ConNeCat* initiated a program through the Federal Ministry for Science and Education to establish selected Lighthouse Projects for emerging trends in catalysis research. One of these projects was devoted to tuneable systems for organometallic multiphase catalysis, aiming to develop innovative technologies for the immobilization of organometallic catalysts in solution. In particular, the project was dedicated to novel approaches using specially designed reaction media (smart solvents) and catalysts (smart ligands). The common key feature of the systems under investigation was the possibility to minimise mass transfer limitations during reaction and to optimise phase separation during work-up by control of process parameters, such as temperature, pressure, or composition. Seven academic groups formed the scientific consortium and four industrial partners covering the supply chain from bulk chemicals to specialized products supported and accompanied the research activities.

The present volume provides an overview of the different strategies followed within this network. The individual approaches are put into the context of the general development in the field and at the same time provide detailed information and hands-on experience with practical aspects of multiphase catalysis. The individual chapters address different and in many ways complementary approaches. The results and discussion emphasise that no single solution can give a universal answer to the problem of catalyst immobilization, but different strategies need to be developed for reaction types comprising substrates and products of various polarities and solubility properties. At the same time, general patterns emerge to provide guidelines of how to control the solubility and partitioning properties of catalytic systems for a given reaction/separation sequence.

The scientific adventure of this unique project was an exciting experience for us and we are most grateful to all fellow scientists and their motivated and enthusiastic group members that were part of the team. Their hard work and their achievements are cited and featured in this volume. In addition, we would like to thank Dr. Katja Stephan from Projekträger Jülich for accompanying the cluster throughout the program with a perfect balance between scientific freedom and administrative clarity. We also gratefully acknowledge the continuous support of Dr. Kurt Wagemann and Dr. Dana Demtröder at DECHEMA, which was vital for the formation, dissemination, and structural impact of the Lighthouse Project. In particular, the initiation of the biannual conference series on “Green Solvents” was an important stepping stone in this process. Finally, thanks are due to the Springer team for their help throughout

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