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*"Gh. Asachi" Technical University of Iasi, Romania*

## *Book Review*

# HANDBOOK OF HETEROGENEOUS CATALYSIS

Second, Completely Revised and Enlarged Edition
Volume 1

Gerhard Ertl, Helmuth Knözinger, Ferdi Schüth, Jens Weitkamp (Editors)

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The first edition of the *Handbook of Heterogeneous catalysis*, published in 1997 by Wiley-VCH, has already became a "classical" in the field, that succeeded to describe and order all important aspect of catalysis, from the scientific fundamentals to the chemical engineering of catalytic processes. This is the totally revised and considerably enlarged 2nd edition of the Handbook.

The contributions from the first edition were updated to cover the recent literature up to 2005 and 2006. Several chapters were deeply revised or entirely re-written, while a large number of topics that were not addressed in the first edition have been added. Therefore, in this 2nd edition, some of the most important and rapidly growing fields of heterogeneous catalysis are discussed from an up to date point of view.

The Handbook is divided in eight volumes, containing nearly 200 chapters, authored by ca. 330 experts. To ensure a rapid access to the wealth of information included in the new Handbook, a detailed subject index was added, with up to three hierarchical levels.

The first volume is organized in two parts: *Introduction* and *Preparation of solid catalysts*.

The *Introduction* starts with a general (or philosophical) approach of the most important principles of heterogeneous catalysis, including some definitions, main steps in a heterogeneous catalytic process and some considerations on catalyst design and development.

The development of the science of catalysis from an historical point of view, the origins and the evolution of the main concepts, illustrated by several selected examples (from ammonia synthesis and acid catalysis on zeolites to hydrogenation and oxidation processes) are presented in the following section.

In the final chapter of the first part, the authors give a general view of the main industrial applications of heterogeneous catalysts, which will be discussed in detail in the last 4 volumes of this Handbook. Thus, the main areas covered here are: the catalytic processes for the conversion of raw materials, the synthesis of bulk and fine chemicals, and environmental catalysis.

The second and the most extended part of the first volume, is devoted to the ***synthesis of heterogeneous catalysts*** and is divided in six chapters.

This part starts with the *introduction* of some central aspects of the development of industrial catalysts. The following chapter deals with the *computer-aided design* of solid catalysts. The main emphasis of this chapter is placed on the combination of fundamental and empirical knowledge in preparing new catalysts, as well as on the design of catalytic experiments and the assessment of experimental data. Combinatorial methodologies, with their ability to cover a wide range of variables during the development process, are also presented here.

In the following fifteen chapters of the first volume the preparation methods of ***bulk catalysts and supports are described***. Although a small number of heterogeneous catalysts are prepared by the *fusion* of mixtures of oxidic or metallic precursors, they are of great importance for the industry. The sulfuric acid catalyst is the classical example discussed here, followed by some considerations on the synthesis of amorphous metals (metallic glasses).

The tribochemical synthesis of catalysts by high-energy ball milling and the mesostructure of fused catalyst materials are also quickly reviewed.

The next chapter is mainly concerned with the preparation, properties and applications of promoted and unpromoted skeletal nickel and *skeletal* copper catalysts which are produced by the selective leaching of aluminium from binary or ternary alloys.

*Precipitation and co-precipitation* are among the most important methods in catalyst preparation. The general principles and the physical, chemical and process consideration are clearly presented by the authors. The final part is devoted to the preparation of aluminas and silicas, together with other industrially important catalysts.

In the next chapter, the physico-chemical basis of *sol-gel* processing will be discussed, as well as details of the synthesis parameters that control the properties of the obtained material, namely structure/texture and catalytic performance. Attention is focused on the three types of sol-gelderived catalysts: bulk inorganic mono- and multimetallic pahses, bulk multiphasic materials and uniphasic and multiphasic coatings, films and membranes.

In the following chapter, the hydrothermal synthesis of zeolites is rationalized in a broad chemical sense, and illustrated with industrial zeolite crystallisation processes. Aluminosilicate zeolites and hydrothermal synthesis form the central topic of this chapter, as these materials and their condition of synthesis cover the majority of industrial zeolite products. After discussing the key parameters governing zeolites synthesis, two zeolite growth models are presented: the nucleation and grow process and the aggregation model. Some basic information concerning the preparation of several industrial zeolites, synthesized in the absence or in the presence of organic compounds (templeates) are included at the end of the chapter.

Today, ordered *mesoporous* solids clearly form their own specific class of molecular sieves. These periodic materials consist of extended inorganic or inorganic-organic hybrid arrays with long-range ordering, tunable textural and surface properties, and controlled pore size and geometry. After an introductory part on the ordered mesoporous molecular sives (MCM-41) attention was paid to their synthesis, by inorganic polymerization and self-assembly with surfactants and by liquid crystal templating. Then, the evolution of the research on the structure and synthesis of mesoporous silica was presented.

The methods which allow the control of the pore size in mesoporous materials are discussed in the next part, which is followed by the main synthesis strategies used nowadays to produce such solids.

The new compositions of mesoporous materials others than silica are also reviewed, including nonsilica materials, metal-doped mesoporous silicas, hybrid organic-inorganic mesostructure as well as metal oxides, phosphates, semiconductors, carbons and metallic mesoporous materials. Other interesting topics, such as template removal, functionalization, hard templating, morphology control are also reviewed here.

The following three chapters review the synthesis, properties and applications of three categories of catalysts: pillared clays, porous metal-organic frameworks and oxo-anion modified oxides.

Then, the broad class of acidic resin catalysts and the innovations to produce more stable and more acidic catalysts with enhanced accessibility to the acidic groups are summarized in a new chapter.

The next chapter deals with pyrogenic oxides prepared by flame hydrolysis methods. Pyrogenic silica, alumina and the classical photocatalyst Degussa P 25 are illustrative examples of catalysts or supports prepared by this method.

In the flowing chapter, the main topic is the use of solid-state transformations of a certain precursors to a homogeneous oxide or a finely interdispersed mixture of oxides, with the preparation of hydrotalcite-like catalysts as specific example.

The structure and catalytic properties of various polyoxometalates are describes in the thirteenth chapter of this part. Different types of heteropoly compounds, including free heteropolyacids, their soluble and insoluble salts and the supported/encapsulated forms, possessing acid, redox or bifunctional catalytic functionalities are briefly described. The structure and properties of transition metal carbides, nitrides and phosphides are presented in the introductory part of the next chapter. Then, the preparation methods and the main reactions catalyzed by these compounds are reviewed.

The next chapter is devoted to the presentation of the intensive and diversified research into *carbon* materials with respect to catalysis and surface chemistry.

The next part of this work, consisting in twelve chapters, covers the preparation of ***supported catalysts***. The methods presented in separate chapters are: deposition-precipitation, ion-exchange and impregnation, solid-state ion exchange and metal clusters in zeolites, grafting and anchoring of transition metal complexes to inorganic, chemical vapour deposition and related techniques to obtain thin layers, spreading and wetting, mechano-chemical methods, immobilization of molecular catalysts, zeolite-entrapped metal complexes, supported liquid catalysts and immobilization of biological catalysts.

The fifth chapter of the second part deals with the ***formation of the final catalyst***, with a focus on the catalyst activation. The role of precursor, the nature of the catalytic support and their interactions and the effect of promoters are also discussed.

The second part of this chapter deals with the forming of the industrial catalysts and the equipment used in these processes.

Finally, the sixth and the last chapter include the classification and the description of some ***standard catalysts***, divided in two categories: non-zeolitic and zeolite-standard catalysts. The first class

contain then so-called EUROCAT catalysts, proposed by the European Association of Catalysis: metal catalysts (Pt and Ni on various supports), vanadia-titania oxides, TS-1 and gold reference catalysts.

The verified synthesis methods of standard zeolites and the catalytic testing in disproportionation of ethylbenzene are considered in the last part of this final chapter.

***Cezar Catrinescu***
*Department of Environmental Engineering*
*and Management*
*Technical University of Iasi*