

BOOK REVIEWS

Dioxygen Activation and Homogeneous Catalytic  
Oxidation

(Studies in Surface Science and Catalysis, Vol. 66) ed. L.I. Simándi. Elsevier Science Publishers, Amsterdam and New York\* 1991 xiv + 700 pages. Price; US \$ 225.50/Dfl. 395.00

This volume of the series contains the proceedings of the Fourth International Symposium on Dioxygen Activation and Homogeneous Catalytic Oxidation held in Balatonfüred, Hungary, September 10-14, 1990.

Dioxygen activation and homogeneous catalytic oxidation attract great interest in academic and industrial domains. Beside the classical oxidation processes involving radical chain reactions new areas of the field developed rapidly such as biometric oxygenations, chemo-, regio- and enantioselective oxidations for diverse organic substrates, the utilization of new primary oxidants or modified application of old ones, and new small and large scale processes with more safety and friendlier environmental effects. Much effort is being made for the elucidation of the mechanistic aspects of both oxygenation and oxidation reactions in order to have access to better control of the reactions and to the design of new catalyst systems.

The main aim of the symposium was to gather all scientists from all over the world to present their most recent results in the field of oxidation and dioxygen activation from academic and industrial spheres. Even a minisymposium on industrial application of oxidation reactions has been organized as a part of the conference.

The material of the book, following a brief introduction by the editor, is organized in the following sections: (i) Oxidation of Saturated Hydrocarbons; (ii) Oxidation of Unsaturated Hydrocarbons; (iii) Oxidation of Aromatic Hydrocarbon Derivatives; (iv)

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Oxidation of Hydroxy Compounds; (v) Biomimetic Oxidations; (vi) Copper Complexes as Catalysts; (vii) Iron Complexes as Catalysts; (viii) Cobalt Complexes as Catalysts; (ix) Oxidation with Oxo and Peroxo Complexes and  $H_2O_2$ ; (x) Singlet Oxygen Reactions; (xi) Industrial Applications and (xii) Miscellaneous Systems.

In chapter (i) papers by Barton, Schuchardt and Lee are concerned with Gif type systems. There is a comparison in the mechanism of the various modifications and reasonings for selectivity. Species with  $\mu$ -oxo and hydroxo ligands are believed to be possible intermediates in these very complex systems. Further papers argue on the importance of higher valent  $M=O$  functionalities of Ru, Fe (Taqi Khan, Lee, Shilov) in these effective oxygenation systems, even by isopolytungstates (Hill), while methyl group oxygenation proceeds by a radical chain reaction (Simándi).

Chapter (ii) concerns minor aspects of alkene and alkyne oxidations. Mechanistic classifications and philosophies of studies (Read, Drago) for the oxygenations are given. Special cases of oxidants such as nitrate and nitrite (Likholobov), cobalt Schiff base catalysts (Nishinaga), metalloporphyrins (Iwanejko) and heteropolyanions (Neuman) are applied as catalysts for these conversions.

Aromatics such as fused heterocyclic compounds (Hara) and naphthalene (Sasaki) oxygenated with the  $RuCl_3 + NaOCl$  system and on supported Pd pretreated with Cu(II) give aromatic *o*-dicarboxylic acids, naphthols and 1,4-quinones, respectively. The next topic is the oxidation of hydroxy compounds. Selective oxidation of secondary alcohols to ketones by dioxiranes (Curci) and by  $OCl^-$  with Ru(III) as catalyst in biphasic system are said to be of good preparative value. Autoxidation of aminophenol to heterocyclic compounds on cobalt phthalocyanine (Simándi), *p*-hydroquinone autoxidation to *p*-quinone on supported cobalt bpy complex (Yakunovich) and a kinetic work on catechol autoxidation (Kiss) along with C-C bond splitting in *vic*-diols (Sasaki) shows the steady interest in this field.

A large part of the book is devoted to biomimetic oxidations. Systems with the most important metal ions such as copper, iron and cobalt are organized in separate chapters. A good summary of Ru and Rh catalyzed nonradical oxidations of a broad panel of substrates are treated by James involving metaloxo and metal peroxo species based on intermediates detected and kinetic data. Metalloporphyrins were also used as catalysts. Further papers in this section by Watanabe, Bedioui and Le Mest disclosed O-transfer reactions of iron porphyrins, electroassisted oxidation of olefins and adamantane by  $O_2$  on manganese porphyrin films and cobalt face-to-face diporphyrins for four electron reduction of  $O_2$ .

In the field of copper catalysts in biomimetic oxygenation, papers by Karlin and Moro-oka presented structural data on  $2Cu:O_2$  chemistry. Dicopper-peroxo compounds with tripodal ligands have been isolated and characterized. Structure - reactivity relationship shows usefulness for the understanding the mechanism of some of the copper-containing enzyme reactions such as tyrosinase and catecholase. Skilled kinetic studies of copper dioxygen interactions unveiled that kinetic reasons are responsible for the instability of most of the copper dioxygen complexes (Zuberbühler). The isolation and oxygenation of flavonolato copper compounds provided insight into the coordination mode and the possible ring-splitting step in quercetinase (Speier). Papers by Sawyer, Davies, Tajima and Shimada deal with the mode of O-O bond scission by the reaction of iron porphyrins in the reaction with  $O_2$  or  $H_2O_2$ . In the various cases of organic substrates the intermediacy of M=O bonds of the metalloporphyrins play a crucial role in O-transfer reactions. For non-heme iron enzyme models with salen and nitriloacetato ligands the ferric centers are not reduced in catecholase-like reactions. Ligand to metal electron transfer is a prerequisite for the reaction with  $O_2$  (Fujii).

The activation of dioxygen by dicobalt(II) macrocyclic compounds with ligands such as BISDIEN leads to a peroxidic

dinuclear Co(III) complex which is able to oxidize oxalate and catechol (Martell). A theoretical treatment on bimetallic peroxide compounds confirms the possibility of this type of compounds with copper and cobalt ions (Solomon). In the catecholase activity of cobalt(III)-tetraammine complexes, semiquinone complexes are detectable intermediates during the oxidative ring cleavage reaction (Nishinaga).

The largest section of the book deals with oxidations with oxo and peroxy complexes and with  $H_2O_2$ . Of course other primary oxidants leading to this type of compounds are also included. Epoxidation of olefins by  $H_2O_2$  using polyoxometallates and molybdates or tungstates under phase transfer conditions with mechanistic details are established (Csányi, Brégeault). Peroxotungstophosphates catalyze the  $H_2O_2$  oxidation of internal alkenes under two-phase conditions to  $\alpha,\beta$ -epoxy ketones and  $\alpha,\beta$ -unsaturated ketones as principal products (Ishii). The olefin epoxidation using air on organoplatinum compounds shows the formation of organoplatinum hydroperoxide and  $H_2O_2$  responsible for the epoxidation step (Wenzel). Benzene can successfully be hydroxylated to phenol by V(V) peroxocomplexes. Influences of conditions of the reaction make an attack of radical M-O species on the aromatic ring plausible (Bronchio). Phenols can be hydroxylated to catechols or hydroquinone by  $H_2O_2$  using metallophthalocyanines (Masri). An electrophilic substitution for the reaction is assumed. Intramolecular oxo transfer in benzyl oxo molybdenum compounds leads to oxygenated products via the formation of carbene complexes (Arzoumanian). The formation of OH functionality on aromatics can be effected by Pd insertion into the C-H bond and subsequent oxygenation gives C-OPd (Alsters). Oxidative ring cleavage on the indole ring can be achieved by Fe(III) porphyrin catalyzed oxygenation (Tajina). Baeyer-Villiger oxidation of ketones with  $H_2O_2$  using Pt phosphine complexes can be substantiated. PtOOH species play probably a crucial role in these reactions (Del Todesco Frisone). A number of papers are devoted to the oxidation of alcohols to

aldehydes and ketones. Dioxo ruthenium and osmium carboxylato complexes catalyze the oxidation of alcohols to ketones by amine oxides (Griffith). Good selectivity is observed by the use of oxo-diperoxo-molybdenum compounds (Camprestini), while polyoxo-metallates with  $O_2$  or  $H_2O_2$  - irradiation - are of good value (Hiskia). The  $Cu(II)-H_2O_2$  system involving ill-defined peroxy and superoxy species gives rise to alcohol oxidation but also amines are oxidatively deaminated, and side chains in aromatics and phosphorus(III) oxygenated (Capdevielle). A modified Sharpless system (metal:ligand=1:4) shows better properties in the enantioselective oxygenation of sulfides to sulfoxides (Conte).  $Co(salen)$  compounds with alkyl hydroperoxides are useful for the dehydrogenation of amines to imines (Maruyama). The usefulness of these systems for very versatile oxidations of organic substrates still generates much activities in this area.

On singlet oxygen chemistry Jefford gives an excellent account for the preparation of 1,2,4-trioxanes by capture of zwitterionic peroxides by ketones, followed by a study on the regioselectivity of singlet oxygen ene reactions (Orfanopoulos).

In the industrial section Sheldon gives an excellent overview of main types of oxidation reactions based on mechanistic considerations. Alternative oxidation processes are compared and evaluated due to the most recent requirements for industrial processes such as cheap feedstocks, simple routes, zero emission plants, high selectivities and fine chemicals. The industrially important  $Cu$  catalyzed oxidative polymerization of phenols involves at least three  $Cu$  complexes operating. The process seems to be electrophilic and the rate is diffusion controlled (Buijs). The use of ozone for large scale applications in organic synthesis is outlined by Ledon initiated by the cheaper availability of the oxidant. The deactivation in liquid phase oxidation using  $Co/Mn/Br$  catalyst due to the catalyst metal precipitation in side chain oxidation of aromatics is discussed by Partenheimer. The possibility of increasing the yields of alcohols and ketones in liquid phase oxidation is outlined by

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Ciborowski. Under miscellaneous systems there are contributions on alkyl carbonate synthesis from alcohols, CO and O<sub>2</sub> catalyzed by Cu-zeolites (Lee), oxidation of ethylbenzene by electrogenerated phenazine-di-N-oxide radical cation (Koldasheva), phosphine oxygenation catalyzed by iron triphenylphosphine oxide complexes (Ondrejovicová), a mechanistic study of the formation of maleic anhydride on vanadyl phosphate (Schiott), oxidations by oxocopper(III) compounds (Maumy) and cobalt Schiff-base catalyzed epoxidations of olefins by NaOCl (Nishinaga).

The book contains an author index, subject index and a list of previous volumes of the series "Studies on Surface Science and Catalysis".

The book is well organized in chapters showing the main recent interests in the field. The large number of contributions demonstrates still growing activities in catalytic oxidation chemistry and dioxygen activation. The book represents also the state of art in this area of research. It is an excellently printed, hard cover book which has to be available in all libraries of academic and industrial institutions. It is indispensable for researchers and students who are engaged in this area of research.

G. Speier

University of Veszprém  
Department of Organic Chemistry

## Mechanisms of Inorganic and Organometallic Reactions. Vol. 7

Edited by M.V. Twigg. Plenum Press, New York and London. 1991  
xvi + 463 pages.

The objective of the series "Mechanisms of Inorganic and Organometallic Reactions" is to cover periodically the literature on the subject matter in a way that helps the reader to get rapidly oriented among the various reaction types. With only slight changes in the chapter titles relative to previous volumes, Volume 7 treats the papers published in the period from July 1988 through December 1989. In Critical reviews are provided of the literature concerned with the study of reaction mechanisms. Although it is impossible to be absolutely complete, a total of 2149 references has been cited, which suggests a very thorough evaluation of published work on reaction mechanisms.

The volume is divided into four Parts, viz. (I) Electron Transfer Reactions, (II) Substitution and Related Reactions, (III) Reactions of Organometallic Compounds, and (IV) Compilations of Numerical Data. Each part is subdivided into chapters on separate subjects, of which there is a total of 15.

Chapters 1-3 (73 pages) are concerned with redox reactions. Chapter 1 (J.F. Endicott) carries the title "Electron Transfer: General and Theoretical", and discusses electronic coupling, free-energy dependences and the effects of solvent dynamics. In the chapter "Redox Reactions between Two Metal Complexes", D.H. Macartney is concerned with electron transfer between metal aqua ions, complexes, and reactions involving metalloproteins,

providing a large number of tabulated rate constants and activation parameters. Metal-ligand redox reactions (Chapter 3. A. McAuley and T.W. Whitcombe) are organized according to the non-metallic component (ligand).

Chapters 4 through 9 (141 pages) are concerned with substitution reactions. Separate chapters are devoted to nonmetallic elements (G. Steadman), inert-metal complexes with coordination numbers of 4 and 5 (R.J. Cross), complexes of chromium (D.A. House), cobalt (R.W. Hay), and other inert metals (J. Burgess), as well as to labile metal complexes (S.F. Lincoln).

In chapters 10 to 14 the reactions of organometallic compounds are treated (147 pages). Here one encounters a chapter on substitution and insertion (A.J. Poë). Discussion of metal-alkyl and -hydride bond formation and fission, and oxidative addition and reductive elimination (R.D. Pike) is followed by a chapter on the reactivity of coordinated ligands (R.W. Hay, E.C. Constable, and L.A.P. Kane-Maguire) in cobalt (III) and other metal complexes and organometallics with reference to stoichiometric reactions. Rearrangement, exchange and isomerization of organometallic compounds are the subjects of a chapter by K.G. Orell. Homogeneous catalysis of organic reactions by transition metal complexes is reviewed by M. Bochmann. For some reason, catalytic oxidations are not included in this chapter. A compilation of volumes of activation (in tabulated form) for the reaction types surveyed is provided by R. van Eldik and K. Schneider. The volume is complete with a subject index.

This book is an excellent source of condensed information for scientists engaged in the study of inorganic and organometallic reaction mechanisms in solution. The stated objective of covering papers published within a certain period of time has been realized with success. The subject matter is well organized: the reader can easily locate what he or she is interested in. Perhaps a greater emphasis on homogeneous catalytic reactions would attract an even wider audience. This series



can be recommended to advanced students and research scientists wishing to be well informed about the progress achieved in understanding reaction mechanisms.

László I. Simándi  
Central Research Institute for  
Chemistry  
Hungarian Academy of Sciences,  
Budapest

Zeolite Microporous Solids: Synthesis, Structure and  
Reactivity

Proc. NATO Advanced Study Institute, Sintra-Estoril, Portugal,  
May 13-25, 1991. Nato Advanced Science Institutes Series C:  
Mathematical and Physical Sciences 352. Eds. E.G. Derouane,  
F. Lamos, C. Naccache, F.R. Ribeiro. Kluwer Academic Publisher,  
Dordrecht, The Netherlands 1992, pp. 656. Price: Dfl. 320;  
US\$ 183.0; UK£ 108.0

The volume is a comprehensive, critical and unified survey of the current state-of-the art knowledge of zeolite science. Outstanding scientists contributed to the success of the NATO ASI meeting, the lectures covered the whole, broad field of this modern branch of chemistry and physics.

The ever increasing number of syntheses and applications of novel zeolite types mean a real challenge for chemists, whereas the sophisticated methods for characterizing the products thus obtained include almost all fields of physics.

The book is divided into four large parts: Synthesis; Characterization; Modification, reactivity and catalytic activity; Novel developments and vistas.

In the first part both fields, theoretical basis of zeolite crystallization (P.A. Jacobs), and practice, e.g. the use of templates (J.P. Gilson) are discussed. A new trend is the synthesis of lamellar solids, which usually do not belong to zeolites: they are mainly clay minerals. However, similarity between the properties and applications of these two classes of crystalline aluminium silicates brings them together in this volume. T.J. Pinnavia et al. describe the molecular engineering of these layered structures and the possibilities for preparing so-called pillared clays. A separate chapter (by J.L. Guth) is devoted to nonconventional microporous solids; methods and theoretical basis are described for developing structures not known till now, e.g. a hexagonal polytype of faujasite. The directive role of templates is also outlined.

Part II deals with the characterization of zeolites. A number of modern methods is utilized, such as sorption experiments (L.V.C. Rees, et al.) for calculating isotherms, thermodynamic data and separation factors, diffusion measurements by the frequency response method to determine diffusivity of hydrocarbons (L.V.C. Rees and D. Shen), diffraction studies on zeolites (J.M. Newsam) by different radiations (X-ray, electron neutron, synchrotron X-ray). Perhaps the most important tools for studying zeolites are the different kinds of spectroscopic studies, IR, NMR, ESR, XPS, Raman, etc.). D. Barthomeuf points out the possibilities of mainly IR spectroscopy for determining zeolite structures, surface sites or species (OH-groups, cations, acid or basic sites), extraframework phases (oxides, hydroxides, supported metals) and adsorbed phases.

Nowadays, in addition to traditional spectroscopic methods, the highest impact on zeolite science is made by solid state NMR, the so-called "magic angle spinning" or MAS-NMR. This method can provide information e.g. on the number and occupancies of T-sites, the distribution of Si and Al atoms between T-sites, nature and mobility of guest molecules (mainly water), and it can follow "in situ" the progress of catalytic reactions. This and the next chapter are written by C.A. Fyfe et al.

Experiments with highly siliceous zeolites are performed by using  $^{29}\text{Si}$  NMR.

Part III is more heterogeneous due to its broad scope. Modification of zeolites is represented by the paper of H.G. Karge, on ion exchange with a particular emphasis on solid-state ion exchange. The whole spectrum of important zeolites and of exchangeable cations is dealt with. A very significant fact is that by this technique, ion-exchanged forms of zeolites can be prepared which cannot be produced by exchange in liquid phase, i.e. in aqueous solutions.

As acid-base catalysis is one of the most wide-spread fields of zeolite application, the formation and analysis of acid and basic sites on zeolite surfaces deserve 2 chapters in the volume, both written by J. Dwyer. Procedures are described for modifying these properties as well as for the quantitative determination of the acidic and basic sites formed.

Ben Taarit discusses catalytic properties of zeolites with respect to the catalytic sites, which may be cations (e.g. for addition, elimination or substitution reactions), oxides (e.g. for side chain alkylation), or framework elements (e.g. hydroxylation). Zeolites find most frequent application in hydrocarbon reactions. A. Corma describes their role in oil reforming and petrochemistry. Due to the many-sided possibilities of reactions catalyzed by zeolites, a number of industrially important tasks can be performed by them. These include cracking, isomerization, aromatization, etc.

Zeolite deactivation by coking is a serious problem in catalytic reactions. Reasons for this phenomenon and possibilities to eliminate or at least to reduce them are dealt with by M. Guisnet and P. Magnoux. Regeneration procedures are also provided.

In the fourth part, nonconventional methods, applications and properties are discussed, such as: "Molecular sieves with pore openings consisting of more than 12 T-atoms" (J.A. Martens et al.), "Chemical bonding in zeolites" (R.A. Van Santen et al.), "Some aspects of molecular shape-selective catalysis with hy-

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drocarbons in zeolites" (J.A. Martens, P.A. Jacobs), "New applications of nonclassical molecular sieve catalysts" (J.A. Rabo), "Enzyme mimicking with zeolites" (R. Parton et al.) and "Microporous materials in organic synthesis" (W.F. Hölderich).

In concluding remarks S.M. Csicsery aptly mentioned that the meeting followed the "life span" of zeolites from birth (synthesis) to death (deactivation), and provided even hope for resurrection (regeneration).

This volume is the most up-to-date collection of knowledge in zeolite science, and can be recommended not only for those who are already engaged in zeolite research, but also for scientists intending to do that in the future.

E. Czárán  
Central Research Institute for  
Chemistry  
Hungarian Academy of Sciences,  
Budapest

### Olefin Metathesis and Polymerization Catalysts

Synthesis Mechanism and Utilization. Proc. NATO Advanced Study Institute, Akcay, Turkey, September 10-22, 1989. Nato Advanced Science Institutes Series C: Mathematical and Physical Sciences 326. Eds. Y. Imamoğlu, B. Zümreoglu-Karan, A.J. Amass. Kluwer Academic Publisher, Dordrecht, The Netherlands 1991, pp. 592.

Price: Dfl. 285; US\$ 176.00; UK£ 76.00

This volume of the series is the proceedings of the NATO Advanced Study Institute, held in Akcay, Turkey, September 10-22, 1989.

Olefin metathesis can be considered as one of the most successful organic reactions with many applications in the low molecular weight range and also in the polymer field. These reactions do not occur spontaneously. They all require the media-

tion of a catalyst system containing a transition metal compound, frequently in conjunction with a second compound (cocatalyst) and sometimes a third (promoter). These reactions fall into three groups, such as (1) disproportionation of linear chain olefins (OM), (2) ring opening polymerization of cycloolefins (ROMP), and (3) degradative metathesis of polymers (DM). The carbene mechanism is now well documented and accepted: the olefin coordination leads to a metallocyclobutane which rearranges to a new olefin and a new metallocarbene. The use of catalysts with their selective and effective transformation properties is of growing interest.

The main aim of this ASI was to gather several research groups and also people from industry to present existing knowledge and the latest results in the field. The list of contributors contains the names of excellent scientists from the USA, Japan and the European countries. The volume, as well as the lectures are addressed to the research workers of the area of metathesis/polymerization systems as well as to those who are using them.

The text, following a brief introduction by the editors consists of six sections; A Historical Perspective, I. Homogeneous Systems, II. Heterogeneous Systems, III. Industrial Aspects, IV. Short Contributions, and V. Research Prospects.

The first paper is much more than a historical view. The early observations, rationalizations and the special terminology is followed by a well balanced review on the latest results of the mechanistic studies including the formation of the carbenes the application of the well defined carbene complex catalysts, spectroscopic indications of the transient catalytic species as well as the thermodynamic and stereochemical aspects of the metathesis (Ivin).

The most substantial part (202 pages) on homogeneous systems contains recent accounts of the stereochemistry of ROMP and OM (Basset), electrochemical generation of carbenes (Petit), metathesis of functionalized olefins (Mol), and various aspects of ring opening homo and co-polymerizations of cycloolefins

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(Amass, Bencze, Hummel and Ivin).

As expected from the authors who are main contributors to their respective fields, the topics covered in the heterogeneous catalytic part include: surface studies of chromium and molybdenum containing supported catalysts (Ellison, Krauss, Garone) and generation of transition metal carbene surface compounds by organometallic cocatalysts (Mol, Tanaka). Reading this part, little doubt remains that metathesis reactions and Phillips polymerizations are mechanistically very closely related.

It is, in general, characteristic for the above two parts, that the newest results included corresponding to the recent activities of the authors.

Industrial aspects of olefin metathesis/polymerization catalysts are discussed in three subsequent papers by R. Streck. The main topics covered are: (i) historical developments, (ii) present industrial status and outlook, and (iii) technological properties and applications of metathesis polymers. The author is not hopelessly trying to convince the reader "that not only the mechanism of the olefin metathesis is fascinating, but also its products".

Short contributions and poster abstracts are collected in the last two parts of the volume. The standards of the papers are high, their contents are informative.

The quality of the book is good, and the well chosen chapters present a timely account of exciting and unexpected aspect of olefin metathesis, while offering tempting glimpses of possible future developments. The timing of the volume is also good: no books have been published for the last 7-8 years covering these subjects adequately. It is a highly recommended reading for experts as well as newcomers in olefin methatesis science.

L. Bencze

University of Veszprém  
Department of Organic Chemistry

Carbonylation.  
Direct Synthesis of Carbonyl Compounds

by H.M. Colquhoun, D.J. Thompson and M.V. Twigg.  
Plenum Press, New York and London, 1991, 296 pp.

Carbonylation is our old-new acquaintance. It is old, because it has been providing essential products for many years. It is new as well, because it does not seem to stop presenting unexpected and surprising new features. The book of H.M. Colquhoun, D.J. Thompson and M.V. Twigg is devoted to make us familiar with this promising field of chemistry.

The monograph describes the preparation of organic substances by using carbon monoxide as the source of the carbonyl group. As a consequence, other reactions of carbon monoxide like the synthesis of hydrocarbons (Fischer-Tropsch synthesis) or manufacturing of methanol from CO and H<sub>2</sub> are beyond the scope of this book.

The backbone of the monograph consists of the chapters dealing with the synthesis of different carbonyl compounds. Not surprisingly, the emphasis is on processes requiring catalytic amounts of transition metals but the possibility of using stoichiometric quantities of a metal carbonyl reactant is not neglected either.

After a historical overview in the Introduction, the authors summarize the basic knowledge about the physical and chemical properties of free and coordinated carbon monoxide in Chapter 1. Sections introducing the elementary reactions in organo-transition metal chemistry and presenting examples for the mechanistic patterns in carbonylation catalysis are also worth reading in order to get acquainted with the terminology used all along this book.

The theoretical considerations are followed by rather practical ones. Data about the solubility of CO in commonly used solvents, a detailed list of the physical properties of metal

carbonyls or a short characterisation of other carbonylation catalysts can all come in handy any day in a laboratory. Chapter 3 also helps to construct a "home-made" glass apparatus or choose the most suitable commercially available high-pressure reactor.

Chapter 4 about the preparation of aldehydes opens the row of synthetic procedures. In contrast to the early redox-based procedures, the carbonylation chemistry offers a limited number, but both selective and high-yield synthetic routes to aldehydes. Halocarbons and alkenes are the most easily accessible starting materials. The conversion of the latter is known as hydroformylation, which is discussed in detail, not omitting the latest results reported on asymmetric hydroformylation and silylformylation.

The next chapter is a rich reservoir of reactions leading to the formation of symmetrical and asymmetrical ketones. Organometallic compounds play an important role in this section.

Chapter 6 makes unquestionable that the chemistry of the synthesis of carboxylic acids by using carbon monoxide is at least as extensive as that of the oxo compounds. Co, Pd and Rh are involved in the catalytic cycles in most of the cases. Mechanistic aspects of the famous Monsanto-process, one of the commercialized carbonylation technology is briefly discussed as well.

The syntheses of esters have attracted much attention because of their direct applicability and the ease with which they can be converted into other derivatives. One by one, Chapter 7 takes the substrates that can be catalytically transformed to esters. Halocarbons, alkenes, alkynes together with main-group organometallic compounds can serve as starting materials. The chapter discusses some newly established reactions as well, e.g. carbonylation of allyl or propargyl carbamates to esters.

Chapter 8 summarizes the synthetic possibilities of amides, anhydrides and acyl halides. The section also deals with the relatively young, commercially not yet important N-carbonylation reactions leading to the formation of carbamic acid deri-



vatives and aromatic isocyanates.

The synthesis of five-membered ( $\gamma$ ) lactones is the main topic of Chapter 9. Four-membered cyclic ethers, ethynyl alcohols, halogenated homoallylic alcohols, etc., can be carbonylated to the target molecules. Pd-based complexes provide some extremely clean and facile syntheses, including routes to  $\alpha$ -methylene- $\gamma$ -lactones.

The search for routes to lactames (Chapter 10) has led to the synthesis of products that have application in pharmaceutical industry. Because of their practical importance, there is no doubt that this area will attract growing interest of researchers in the future.

Catalytic decarbonylation of aldehydes and acyl halides may have both theoretical and practical importance. The authors draw attention to cases where the decarbonylation proceeds with the retention of stereochemistry.

Chapter 12 contains plenty of useful information on the preparation and physical properties of metal complexes that have been mentioned in the book as catalyst precursors. This section can save time and money especially for those who apply derivatives of precious metals in their study. Beside some executable procedures for the recovery of palladium and platinum, the reader can find a list of suppliers where wastes with significant amount of platinum group metals can be sent for recycling.

The book is nicely printed, the illustrations are clear. The text is frequently interrupted by short recipes which shed light on the experimental details of the reaction type being discussed - the best guide for a laboratory chemist.

The number of references exceeds 600 and cover the literature of this area till 1989.

This book can be recommended not only for newcomers to the field of carbonylation but may also be a handy source of tremendous information for those who have specialized in this area.

G. Besenyei  
Central Research Institute  
for Chemistry, Budapest, Hungary