

gas SO_x reduction, including SO_x chemistry, and preparation, characterization, and mechanism of action of SO_x reduction catalysts, e.g., CeO_2 -Mg aluminite spinel. Brief discussions on catalytic NO_x reduction and refinery CO control via combustion additives are also included. The final chapter on environmental considerations in FCC by R. E. Evans and G. P. Quinn begins with a brief history of FCCU design. Historical perspectives on FCC regenerator stack emissions (e.g., particulates, CO, SO_x , NO_x) and environmental impact of FCC products (e.g., fuel gas, HFO, LCO, naphtha), as well as disposal of waste FCC catalyst, are provided. The chapter concludes with predictions on what process and catalyst changes will be required to respond to environmental regulations in the late 1990s.

Perhaps a chapter focusing exclusively on mechanistic aspects might also have been helpful, but both the breadth and depth of this volume are outstanding. For anyone working in or planning to enter the FCC field, this book is highly recommended.

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Spectroscopy in Catalysis. By J. W. Niemantsverdriet.
VCH, Weinheim, 1993.

This is a truly valuable book that could be used as an introductory text for a graduate course on catalyst characterization. Although the subject has already been addressed in a number of previous books, most of them were meant for more or less experienced researchers. As a consequence, they were not easily adapted as textbooks for introductory courses. By contrast, the style and organization of the book written by Professor Niemantsverdriet make it particularly attractive for students starting their research in catalysis. For the same reason, it will also be very useful for industrial practitioners who need to be aware of the type of information that can be obtained from modern surface spectroscopies. The book covers most of the characterization techniques relevant to catalysis, with the two important exceptions of EPR and NMR.

It starts with a brief introduction in which the author emphasizes the importance of materials characterization in modern catalysis research and the need to identify fundamental relationships between the state of a catalyst and its catalytic properties. At the same time, the reader is warned that spectroscopy is not a simple discipline and that the best way to obtain meaningful and correctly interpreted results is by collaborating with an expert spectroscopist.

In the following chapter, the author describes the temperature-programmed techniques (TPR, TPO, TPD, etc.), giving a brief theoretical background and pointing out the type of information that can be obtained from these techniques. Unfortunately, transport limitations, particularly important in the case of TPD, have not been discussed here, because the section on thermal desorption is restricted to surface science systems

rather than to supported catalysts. However, in most of the other chapters, a good balance is maintained between surface science studies performed on single crystals and those performed on real catalysts.

In the chapter dedicated to photoelectron spectroscopies (XPS, UPS, and Auger), the author explains very well the physics behind these techniques and analyzes important applications, such as the use of XPS to estimate the dispersion of supported particles. Among the different applications of UPS, he presents an interesting description of the principles and uses of PAX (photoemission of adsorbed xenon). This site-selective titration technique is highly surface sensitive and allows titration of heterogeneous surfaces. Other highly surface sensitive techniques are described in a separate section that covers all the ion spectroscopies (SIMS, SNMS, RBS, and LEIS).

In another section of the book, the author clearly explains the fundamental principles of Mössbauer spectroscopy and includes some examples of its application to Fe, Ir, and Pt catalysts. He notes that one of the main advantages of this technique is the possibility of conducting *in situ* studies. A separate chapter deals with techniques that use the scattering of radiation to obtain structural information. XRD and LEED are discussed as examples of techniques that require relatively long-range order and, as a consequence, provide information on relatively large parts of the sample. By contrast, EXAFS is presented as a technique that provides information about the local structure. In a separate chapter, the author briefly describes the principles of electron microscopy, as well as the recently developed scanning probe microscopy. He gives a clear picture of the potential uses and limitations of the two new techniques, STM and AFM. The last type of techniques reviewed is the vibrational spectroscopies: infrared, electron energy loss spectroscopy, and Raman spectroscopy. In this chapter, the author offers a very pictorial and easily understandable description of the fundamental principles involved in these techniques and gives interesting examples of applications.

To demonstrate that the best results are obtained when a combination of techniques are employed to study one particular catalytic system, the author has dedicated a chapter to describing three typical case studies. The selected cases are metal-support interactions occurring in supported Rh catalysts, the nature of the active phase in Co-Mo sulfide HDS catalysts, and the effect of alkali promoters on noble metals. Each case demonstrates how different techniques can provide complementary information which, when combined with catalytic activity measurements, may result in a clear representation of the system under reaction conditions.

The book ends with a list of ingredients for a successful research program in catalysis, which has a superb pedagogic value. In those brief remarks, the author emphasizes the need for *in situ* characterization, the combination of several techniques, and the use of realistic model catalysts and suitable references.

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