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BOOK REVIEW

Heterogeneous Reaction Dynamics. Steven L. Bernasek. VCH, Weinheim, 1995.

This book is a quick read that serves as an introduction to the field of heterogeneous reaction dynamics—probing and understanding surface reaction mechanisms and dynamics on a molecular level. This field is an active one in the chemical physics community, as researchers aim to extend the elegant manipulations, spectroscopic probes, and close interactions with theory that characterizes gas phase reaction dynamics to the much more challenging arena of chemical reactions at surfaces. The promise is that the exquisite details that have been and are now being revealed concerning how reactions occur in the gas phase, in particular how energy is disposed within the reactant and product molecules, and even how to control these reactions will also be elucidated someday for surface reactions.

The author aims this book to be a primer to this field for students and researchers new to the subject matter. It contains only a handful of equations and one brief derivation. In addition, it is sort of a "progress report" for the field as of about 1990. The book is organized around case studies from the literature, all of which report on dynamics studies utilizing well-characterized surfaces (single-crystal substrates under ultrahigh vacuum conditions) and molecular-level characterization of the gas phase species. The scope of the book is not comprehensive, but rather is illustrative of the sorts of studies that can be done for several important aspects of heterogeneous reaction dynamics. Also, the coverage is limited to gas/solid interfaces and all of the examples considered in detail concern gas/metal interactions.

The sequence of the book is as follows: 1, Introduction; 2, Surface Characterization Methods; 3, Inelastic Scattering and Energy Transfer; 4, Adsorption, Epitaxial Growth, and Adsorbate Interactions; 5, Surface Diffusion; 6, Dynamics of Dissociative Adsorption; 7, Atom Recombination Dynamics; 8, Catalytic Oxidation; and 9, Small Molecule Decomposition Processes. Each of the seven chapters on dynamics has subsections on the experimental methods used in the case studies, illustrative examples and case studies, and summary comments by the author, including his opinions about future research directions.

The first two chapters are brief. In the Introduction, the author explains how heterogeneous reaction dynamics uses the same tools and approaches and stands on the foundation of gas phase molecular reaction dynamics exemplified by Levine and Bernstein. Chapter 2 provides a very brief introduction to some techniques used for surface analysis in the kinds of studies that will be discussed later in the book. Given the many excellent references that already exist on surface analysis, this very brief introduction is probably sufficient for the author's purposes, although vibrational spectroscopies as probes of molecules on surfaces are undersold and others are oversold. Chapter 3 starts the discussion of heterogeneous dynamics, with consideration of interactions causing translational to rotational ($T \rightarrow R$) energy transfer. This chapter is a nice introduction to internal quantum state information on scattered molecules obtained by using laser-induced fluorescence (LIF), resonantly enhanced multiphoton ionization (REMPI), and molecular beams and is very readable even without a knowledge of the corresponding gas phase dynamics (although that would be useful). Later chapters build on results from these methods as well. Chapter 4 discusses trapping at surfaces as probed primarily by thermal energy atom scattering (TEAS) with a number of applications. The comparison of results on Fe and Pt is interesting, although the stark differences in chemical reactivity of these two metals is minimized. Chapter 5 concerns diffusion of surface species and contains two case studies, one illustrating laser-induced desorption measurements and the other showing results from pulsed molecular beam studies.

In the next four chapters, the author discusses subjects at the heart of the title of the book—surface reactions—starting with the simplest cases of diatomics and dissociative adsorption and adatom recombination. The case studies in Chapter 6 show ways that molecular beam approaches can yield insight into how the initial state of the molecule controls the dissociative adsorption of N_2 on Fe(111), CH_4 on Ni(111), and H_2 on Pt(111). Chapter 7 discusses the dynamics of recombination desorption, with case studies detailing what can be learned from measurements of the angular distribution, velocity, and internal energy of desorbing N_2 and H_2 molecules. Chapter 8 focuses on catalytic oxidation of CO over Pt and Rh metals, providing "some of the most detailed dynamic information about a heterogeneous reaction presently available." Nonetheless, there is much we do not understand about energy disposal and dynamics even for such a simple reactive system as CO oxidation. The author turns to larger molecules (CH_3OH and CH_3SH) in the last chapter, where mechanistic questions about surface intermediates in decomposition reactions are still being answered primarily by typical surface spectroscopies (e.g., HREELS) and these reactions challenge the state-of-the-art in investigations of surface dynamics.

Especially in the last two chapters and throughout the book, the author presents an optimistic view for the usefulness of information derived from dynamics studies. Ultimately this is a correct view, but it is obvious that we are still on the ground floor of the endeavor to understand heterogeneous reaction dynamics. This is a readable and informative book and a useful first introduction to the study of gas/surface dynamics.

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