

Book Review

Catalysis by Metals. By G. C. BOND. Academic Press, London and New York, 1962, $x + 519$ pp. Price \$15.50, 100 s.

We cannot, as yet, refer to a book on catalysis for answers to the questions we must frequently ask; questions relating to the mechanisms of reactions, to methods of improving activity and yield characteristics, how to select catalysts and operating conditions to achieve a desired result, etc. These answers are not available. What we can expect from a book on catalysis is a presentation of the available information on the subject of interest, a description of how this information was obtained, and a discussion of what it means in terms of the latest theories and hypotheses. If we are fortunate, the author may present suggestions as to what further information would be useful and how it might be obtained. It is in this light that a book on catalysis must be judged, swallowing our disappointment that it cannot, at least for now, have a "happy ending."

The book under review can logically be divided into three sections:

I. Chapters 1-6, pp. 1-122. This section is a description of the physics and chemistry of metals and of the adsorption-desorption process.

II. Chapters 7-14, pp. 123-352. This is a study of exchange and hydrogenation over metal films with hydrogen-deuterium exchange and ortho-para hydrogen conversion as the most important tools.

III. Chapters 15-21, pp. 353-490. This section is a description of other catalytic processes, e.g., Fischer-Tropsch synthesis, ammonia synthesis, oxidation, hydrogenolysis, reforming, etc.

By far the largest section of the book is devoted to the quite academic subject of reactions of hydrogen and hydrocarbons over metal films. The large amount of data available on this subject offers a formidable task for any author desiring to present it in a systematic manner. Workers in this field will be grateful that Dr. Bond has applied himself to this task for these chapters are virtually an encyclopedia on the subject. Most of the data available from metal film work consist (aside from adsorption measurements) of determinations of deuterium exchange with hydrogen from hydrogen molecules or from various hydrocarbons. The hydrogen-deuterium exchange data are supplemented by a large body of data on ortho-para hydrogen conversion. The

author has presented many of the theories and arguments advanced in the literature to explain the varied phenomena observed. He has called attention to the evidence upon which these arguments are based, as well as citing the objections to them. He has also, of course, presented his own discussion of many of these measurements. Every worker in the field of catalysis and adsorption on metal films will want to have a copy of this book available.

The reviewer would like to interpose a few comments at this time. It is interesting to note that even here, where every effort has been devoted to obtain an understanding of the causes and effects basic to these catalyzed reactions, a clear and consistent picture cannot be drawn. The various theories of the adsorption processes, the exchange and hydrogenation reactions, etc., are almost always based on models. Agreement between model and experiment does not prove the validity of the model, it only indicates its usefulness for further interpretations. These models are quite empirical and the reader should remember that their relation to reality may be very slight.

Part of the difficulty in the way of understanding these processes lies in the fact that while there seems to be a vast amount of data available a large part of it is of little use in such an endeavor. For example, considerable work has been reported based on film weight rather than on surface area. In such cases the extent of surface coverage, the activation energy, and the frequency factor are unknown. Other problems of inadequate data presentation arise and Dr. Bond refers to many of them in this book. It seems to this reviewer that the present worker in this field should exercise great care to ensure that he obtains all the information necessary to interpret his data and that he report thoroughly enough to enable future use to be made of his work.

The last section in this arbitrary division of the book will probably be of interest to a greater number of people than the chapters on metal films just discussed. In the last seven chapters the author describes rather briefly the salient features of many different catalytic reactions. These chapters should be useful as a general survey to both the student and the worker in the field of catalysis.

Fischer-Tropsch synthesis and ammonia synthesis are treated in some detail while twenty pages are devoted to the decomposition of formic

acid. The importance of understanding the mechanism of this decomposition lies not in the importance of the reaction itself but rather in that it is frequently used as a test reaction to study the properties of various catalysts.

The final chapter in the book discusses the theoretical bases for chemisorption and catalysis with emphasis on electronic effects. It outlines some of the interrelations between the catalytic, adsorptive, and physical properties of the various metals. It also presents several correlations from the literature, correlations between catalytic properties and such parameters as the latent heat of sublimation of the metal, the initial heat of adsorption of hydrogen on the metal, the heat of formation of closely corresponding bulk compounds, etc.

The reviewer feels that the answers to the fundamental questions in catalysis, questions concerning the basic mechanisms, questions concerning which of the properties of the metals influence the catalyzed reaction, and in what way, are to be sought in the field described in the first section of the book. I feel that if any inadequacies exist in this book they lie in the treatment of the theory of metals and the adsorption-desorption processes. A worker interested in catalysis over metals will certainly need to extend his understanding of the theories of metals far beyond the brief discussion given here. While on exhaustive treatment of the theory of metals is of course beyond the scope of this book I would have wished for a considerably more extended treatment than that given.

The reviewer would like to again interpose a few comments. They concern the use of correlations in attempts to understand catalysis. This is overdone. Many correlations in this field are made between two *effects* with no knowledge or understanding of the underlying *cause*. Correlations can also be made between functions having no relation to each other. If two functions vary monotonically with a third it is frequently possible to discover "correlations" between the former pair. Another correlation that can be meaningless occurs when one function varies marginally while the other changes much more markedly. An example is Fig. 5 of Chap. 21 of this book. In this figure the relative efficiency in H atom recombination is plotted against the latent heat of sublimation for several metals. All such a plot shows is that the former property varies only between 60 and 80, in a rather hit

or miss manner, for almost all of the metals tested while the latter property varies from 50 to 200 kcal/g atom. It does not demonstrate, or even imply, any real correlation between these two properties. A fourth type of correlation even less convincing is demonstrated by Fig. 8 of Chap. 21 where the mean deuterium count of exchanged ethanes is plotted as a function of the latent heat of sublimation for several metals. The data points look as though they may have been impressed upon the plot with a shot-gun. They can be just about as well fitted by a solid circle as by the line shown.

Correlations can provide poor foundations for theories and they should be used very carefully.

A few words are in order regarding the "mechanical" side of the book. Typographical errors are few and most of them are not bothersome. I recall only two that caused a moment's consternation. The reference on p. 76 to Table IV should be to Table III and the reference on p. 473 to Table XII of Chap. 4 should read Table XII of Chap. 5.

A reader can always find areas of disagreement with the phraseology of an author. Most of these must be attributed to differences in writing techniques, however differences in terminology also occur and these can occasionally be somewhat confusing. On p. 14 the author defines the magnetic susceptibility κ of a solid without referring it to unit volume. On p. 141 the author refers to a negative temperature as imaginary, a term I would reserve for the nonreal part of a complex number. On p. 150 he describes the paramagnetic mechanism for the conversion of ortho to para hydrogen and uses charcoal as a prime example. Charcoal is a poor example to demonstrate this point since it is diamagnetic and various surface paramagnetic states have been postulated to explain its activity for this reaction.

Putting aside these minor differences, I would like to iterate two points made above, every worker in the field of catalysis and adsorption on metal films will want to have a copy of this book available. In addition, the first and last sections of this book, about one-half the book, should serve as a useful general survey to both students and to workers in any phase of heterogeneous catalysis.

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