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Satoshi Yamamoto

Introduction to Astrochemistry

Chemical Evolution from Interstellar Clouds to Star and Planet Formation

Springer

Satoshi Yamamoto
Department of Physics
The University of Tokyo
Tokyo, Japan

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Preface

In modern astronomy and astrophysics, chemistry is becoming increasingly important. Molecules are found everywhere in the universe owing to rapid progress of spectroscopic observations particularly in the radio, infrared, and optical regimes. Exploring chemical compositions of astronomical sources itself is of fundamental importance in understanding evolution of matter in the history of the universe. Moreover, chemical compositions are widely used as a powerful tool for investigating physical conditions and formation processes of astronomical sources. Such a chemical approach will rapidly be expanded to various areas of astronomical and astrophysical studies in the near future. Astrochemistry is now one of the fundamental subfields of astronomy and astrophysics.

Astrochemistry is becoming more and more complicated as it progresses rapidly. Hence, it is not easy even for experts to understand its whole scope in detail. When researchers working in astronomy and astrophysics employ astrochemistry to cope with actual problems, they may sometimes utilize a small, particular part of astrochemistry for their studies without careful consideration of assumptions and limitations hidden in the background. In order to make full use of the power of astrochemistry, a deep understanding of its fundamental astrochemical concepts based on physics and chemistry is essential.

On the other hand, astrochemistry is deeply related to molecular science, which includes molecular physics, molecular spectroscopy, chemical dynamics, and theoretical chemistry. Because chemical processes in the universe are generally ongoing under extreme physical conditions of low density and low temperature in comparison with terrestrial conditions, astrochemistry has been posing new and interesting research subjects in molecular science. In order for researchers in molecular science to discover new chemical and physical phenomena in astronomical studies, a deep understanding of the fundamental concepts of astrochemistry will be very useful.

This book is organized to describe those fundamental concepts for researchers and students in the broad fields of astronomy, astrophysics, and molecular science. For this reason, recent topics are not always included, although some of them are

introduced as examples. Furthermore, this book does not cover the entire field of astrochemistry but puts a particular emphasis on outlining chemical evolution from molecular clouds to star and planet formation. For other subfields of astrochemistry (e.g., external galaxies and late-type stars), readers should refer to available review articles, although the basic part of the astrochemical concept in this book will still be useful for understanding their contents.

Twenty-five years ago, I moved from the spectroscopic field to the astrochemistry field, triggered by fortuitous discoveries of some new interstellar molecules. Since then, I have been studying the chemical evolution of molecular clouds toward star and planet formation with my colleagues and graduate students. Because of my limited experience and knowledge of this field, I am afraid that some important issues might be missing or poorly presented. However, I was encouraged by the younger generation desiring an introductory book on astrochemistry, and I have made up my mind to publish this work. I welcome any suggestions and criticisms from readers.

Finally, I express my sincere gratitude to all my colleagues and collaborators, particularly to Nami Sakai, Tomoya Hirota, Takeshi Sakai, Yoshimasa Watanabe, Shuji Saito, Masatoshi Ohishi, Norio Kaifu, and the late Hiroko Suzuki. I also thank the members of my group for their valuable comments.

I dedicate this book to my wife, Keiko.

Tokyo, Japan Satoshi Yamamoto
November 17, 2014

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