Preface

The attainment of extreme conditions and the examination and understanding of how matter behaves under previously unattainable conditions is a constant stimulus to scientists. The concept of an absolute zero of temperature has been with us for many years and the challenge of reaching as close as possible to that limit is nothing new. However, dramatic advances have been made in recent years and this book provides articles describing some of these advances, written by leading experts in these fields. The title of the volume also stresses '*molecule*s'; that is, here we are concerned with the production and behaviour of molecules — as distinct from atoms — under cold and ultra-cold conditions. In particular, emphasis is placed on the chemical reactions of species at low temperatures — and on how the study of chemical reactions can be pushed to ever lower temperatures.

It should be appreciated that the lowest temperatures known to science have been generated in earthly laboratories. The distribution of the cosmic background radiation with frequency corresponds to a temperature of 2.728 K. Although there are colder places in the universe, as far as we know at this time, temperatures below 1 K have only been achieved in laboratories. Molecules are observed in regions of space warmer than the cosmic background, but still extremely cold by most standards: the cold cores of dense interstellar clouds have temperatures of *ca.* 10 K. The first chapter in this book summarises our present state of knowledge regarding these huge interstellar regions, where most of the observed interstellar molecules are found. The next three chapters summarise experimental and theoretical efforts to explore chemical reactivity at these *low* temperatures and to provide the necessary information to incorporate into astrochemical models, which are constructed in order to see how well we understand the chemistry that leads to the observed interstellar molecules — and to the abundances of these species relative to that of molecular hydrogen, which is much the most abundant interstellar molecule.

Most of the known interstellar molecules have been identified from their spectra, either rotational spectra observed in emission using ground-based telescopes sensitive in the mmwave region of the electromagnetic spectrum, or *via* infrared spectroscopy conducted from satellites and using stars in the line-of-sight as background sources. In addition, in the laboratory — at least, the laboratories of chemical physicists — spectroscopic observations led the way in the use of gaseous expansions to generate very low temperatures. Chapter 5 describes some of the latest progress in this field, concentrating on the spectra of inherently unstable species, such as radicals and molecular ions and, in some senses, it acts as a bridge to the second half of the book, where the emphasis is on *ultra-low* temperatures and *ultra-cold* molecules.

A common theme in the second half of the book, Chapters 6 to 10, is the attainment of temperatures below, indeed well below, that of the cosmic background, 2.728 K. The holy grail in these experiments — or perhaps one of the holy grails — is to explore molecular collisions under conditions where the wavelength associated with the relative velocity of two species approaches or exceeds the size of the colliding species so that treatments of the collisions based on a classical approach to the dynamics of the relative motion are no longer appropriate.

Chapter 8 describes the examination of molecules in liquid helium droplets at 0.37 K (^{4}He) and 0.15 K (^{3}He). Initially, such experiments were spectroscopically led. They demonstrated the remarkable properties of helium as a 'soft' matrix that, in some cases, scarcely interacts with the molecules embedded in the droplets. Now this medium is being employed to study the dynamics of reactions.

The other chapters in this second half of the book explore approaches to producing ultra-cold charged or neutral molecules, with the ultimate objective of studying collisions at ultra-low relative velocities. The techniques vary from multi-pole traps in the case of molecular ions (Chapter 6), to kinematic methods of bringing molecules to rest (Chapter 8), to the use of rapidly switched electric fields to remove kinetic energy from neutral species (Chapter 9), and finally to methods more akin to those employed to generate atomic Bose-Einstein condensates (Chapter 10). All of these chapters describe work at the cutting-edge of research in molecular physics.

In all cases, the editor has encouraged the contributors both to give a critical survey of their field and to look forward to further developments in it. He believes that they have reacted splendidly to his exhortation. He further believes that this book should be of value to those already immersed in one or other of these areas of research, to newcomers to this field, and to more general readers who wish to know the present state-of-art in this very exciting area of chemical physics.

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