MASS SPECTROMETRY

Applications in Science and Engineering

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PREFACE

Analytical instrumentation is more than an ancillary tool of science and engineering; it is an integral part of science itself. Visible portions of the electromagnetic spectrum are captured by the telescope and the microscope, and the infrared spectrometer permits the determination of energy levels in molecules and semiconductors. The x-ray spectrometer reveals the internal symmetry of crystals, and the radiofrequency portion of the spectrum can probe both outer space and the inner structure of the atomic nucleus. The laser is also of great analytical significance, as it makes possible the generation of coherent radiation of high intensity and narrow bandwidth.

However, few analytical instruments have a broader range of application than mass spectrometers that can identify all the atoms and molecules that comprise gases, liquids, and solids. Even the so-called fourth and fifth states of matter, plasmas and clusters, can be characterized by mass spectral techniques. In university laboratories throughout the world, mass spectrometers are being applied to studies in chemistry, physics, biology, pharmacology, agriculture, geology, metallurgy, environmental science, and to many advanced engineering investigations. The technological impact of mass spectrometry in industrial research and development is equally profound. The prediction made over a century ago by the eminent philosopher, Auguste Comte, has even been refuted—"there are some things of which the human race must remain forever in ignorance, for example, the chemical constitution of the heavenly bodies"—because mass spectrometers have revealed the composition of the lunar surface and the planetary atmospheres. Thus, mass spectrometry now stands at the crossroads of virtually every scientific discipline.

This book has two principal objectives. The first is to provide an interdisciplinary overview of modern mass spectrometry in its many and diverse forms. The second is to have it serve as a catalyst for generating additional and innovative mass spectrometric measurements. It is further hoped that this monograph will complement the many excellent publications that focus on organic chemistry.

A majority of applications and examples cited in this work refer to the recent international literature, but a limited amount of material has been

borrowed from a former book (F. A. White, *Mass Spectrometry in Science and Technology*, Wiley, New York, 1968). Furthermore, in order to provide a broader perspective of the role of mass spectrometry in science and engineering, some material has been included that is not circumscribed by mass spectrometry, per se.

The organization of the book affords options for its use in seminars, formal courses, or independent study. The discussion of any single topic is brief, but the references at the end of each chapter should be useful. Part 1 begins with an introduction that points out the relevance of mass spectrometry in industrial research and development, traces its historical evolution, and reviews some early salient measurements. Six chapters follow relating to instrumentation: the production, analysis, and detection of ions, data processing, and chromatograph-spectrometer systems. Part 2 focuses on applications in engineering and the physical sciences: geochemistry, atmospheric and space science, structural and electronic materials, electrophysics, and the utilization of mass spectrometry as a diagnostic tool for energy-generating and conversion systems. A chapter on "on-line" applications is also included, because mass spectrometric instrumentation is becoming increasingly important in high technology manufacturing and process control.

Part 3 presents mass spectrometry as the common denominator for selected topics in the life sciences. Areas in which it is an analytical imperative include environmental monitoring, agriculture and food science, clinical medicine, pharmacology, toxicology, and forensic investigations. A final chapter envisions some new challenges for both mass spectrometry and ion beam technology. This new frontier includes the characterization of very large molecules and of charged particles in the MeV range. Energetic and highly focused ion beams also offer the potential for synthesizing materials and for producing a new generation of large-scale integrated circuits by means of ion beam lithography.

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