There are a few minor inaccuracies such as the statement that 43-million-electron-volt $O^{16}$ ions can be obtained from a tandem with 6-million-volt terminal (the beam intensity would be miniscule) and the statement that alpha-particles are excluded from two- or three-stage (tandem) acceleration because helium cannot be produced as a negative ion. Because the design of accelerators has become a very specialized field and because it is relatively rare for those in this field also to be users of accelerators, many users, particularly biologists, chemists, solid state physicists, and physicians, should find this monograph useful. It would have been helpful if the bibliography had listed references according to the various types of accelerators described in the text for those who want more detailed information about a particular type.

H. E. Gove  
*Nuclear Structure Research Laboratory,*  
*University of Rochester,*  
*Rochester, New York*

## Three-Body Problem

**Three-Particle Scattering in Quantum Mechanics.** Proceedings of the Texas A & M Conference, College Station, 1968. J. Gillespie and J. Nuttall, Eds. Benjamin, New York, 1968. x + 462 pp., illus. $15.

This volume summarizes a conference held in April 1968. The speedy publication is commendable, but the volume has had to be printed directly from a typescript prepared by the editors. This of course means some sacrifice esthetically, but also rather few (less than 200) words to a page.

Abstracts of contributed papers occupy about 20 pages of the volume, and are useful in giving some flavor of the sort of problems which are being tackled in this area, though the abstracts are too brief to be of much more use than that. The main part of the book consists of eight invited papers plus a relatively short summary paper by R. Blankenbecler.

As was to be expected, the Faddeev formalism is the main theme running through the book, though the variational approach is also prominent. The papers by R. D. Amado on three-nucleon collisions and by D. Y. Wong on the ($3\alpha$) and the ($e$-$H$) systems fall into the first category, as does the longest paper in the book, by H. P. Noyes and H. Fiedeldey on the calculation of three-nucleon low-energy parameters. The bibliography of this article contains some 150 references, around 100 to work published after 1964, giving some indication of the interest and activity in a field that might look, at first sight, rather narrow and specialistic. About half of the references in the book as a whole are related to this article.

In the second category, there are articles by L. Spruch and by L. M. Delves on the variational approach. Although, as Spruch points out, variational principles can often provide compact unifying formulations of physical laws, both these articles are concerned with the variational approach as a computational tool. In his article, Delves makes a strong plea for more systematic use of the variational approach, both with linear and nonlinear parameters. His work is concerned with the use of realistic local potentials, and he pays considerable attention to the rate of convergence of the method, as well as presenting some numerical results for the three-body problem. A novel feature is his plot of the variational estimates of the triton binding energy against the year of Our Lord, an asymptote appearing at—6.5 Mev! Delves also points out that the variational approach may afford another valuable attack on the Faddeev equation with local potentials.

The remaining three papers are more formal, though no less interesting to the present reviewer. R. L. Omnès and J. L. Basdevant discuss the limitations of the relativistic versions of the Faddeev equation as well as the use of the separable approximation in this area. Analyticity properties of nonrelativistic three-particle scattering amplitudes are discussed by R. L. Sugar, who also points out that the question of the analytic structure of the three-particle amplitudes in the complex angular momentum plane remains unsolved. In the discussion, which is also summarized in the book, it emerges that knowledge of the analytic properties of the amplitude provides a general framework for discussing the threshold laws for cross-sections. The paper by C. Schwartz on generalized Bethe-Salpeter equations for coupled two- and three-body amplitudes makes interesting reading, though it is again somewhat formal. The volume as a whole has a good balance between formal theory and practical calculation and forms a useful progress report in this field.

N. H. March  
*Department of Physics, University of Sheffield, Sheffield, England*

## Measuring Trace Elements

**Atomic Absorption Spectroscopy.** Walter Slavin. Interscience (Wiley), New York, 1968. xviii + 310 pp., illus. $12.95. Chemical Analysis, vol. 25.

During the past ten years, simple combustion flames have become one of the most useful devices available for the quantitative determination of trace elements in solution. Their usefulness stems from the very simple way in which flames of various types can release free atoms of the metallic elements when they are found in solution. All that is necessary is to make an aerosol or spray of the solution and introduce it into the flame. A fraction of the dissolved metal atoms is eventually converted into free atoms, which the analyst can then detect at the trace level by three simple but different spectroscopic techniques, namely, atomic absorption, atomic emission, or atomic fluorescence. This book is concerned with the atomic absorption method.

The author has been deeply involved in the popularization of this analytical technique in the United States, and his many experiences are reflected in the valuable pragmatic approach he has employed.

In the preface, three main purposes of the book are identified. First, "the book is intended to supply the spectroscopist and the analytical chemist with an understanding of *why* atomic absorption spectroscopy works as it does, as well as information on *how* to apply the technique." The author has done this task well, although I believe that topics related to flame chemistry and structure, to the effect of flame stoichiometry on free-atom formation processes, and to spatial distribution of free atoms in flames deserved more discussion.

Another stated purpose of the book is to "guide the developer of new analytical methods, the chemist who is being introduced into the discipline, and the prospective purchaser of equipment." The author has done this well.

The author also expresses the hope that the book will serve as a "critical guide through the large literature that has developed." Here he is less successful. There is a tendency throughout the book to sidestep critical commentary. Let me cite some important examples. In the preface, the author notes that "the use of flame emission spectroscopy . . . applied to the determination of metals has waned considerably as a result of the upsurge in atomic absorption spectroscopy." That statement is, indeed, a fair assessment of the relative popularity of the two techniques. A number of factors have contributed to the phenomenal growth of atomic absorption spectroscopy. First, the instrument manufacturers early sensed that here was a technique that would appeal to the practicing analyst and, as a consequence, played a leading role in making atomic absorption spectroscopy fashionable. Second, exaggerated or fictitious claims regarding the superiority of the atomic absorption technique over the flame atomic emission method have repeatedly been published. The author of this book can be included among the many early proponents of this technique who tended to be overzealous. Since the book does not provide an ordered, critical examination of these claims, it seems appropriate to examine a few of them in this review.

One of the disputable claims whose validity the author does not examine has to do with powers of detection. The claim has been and still is being made that atomic absorption is obviously far more sensitive than the observation of emission spectra because the overwhelming majority of free atoms remain in the nonemitting ground state. That most of the atoms remain in the ground state is true [the ratio of $N$ (excited) to $N_0$ (ground) is rarely larger than $10^{-4}$], but there has been no experimental documentation that the powers of detection of the atomic absorption technique are superior. In fact, the latest scorecard of published detection limits reveals that emission shows superior powers of detection for 27 elements and essentially equivalent powers for 28 others; for only 15 does the absorption technique show superiority. C. Th. J. Alkemade has recently shown theoretically why the population-ratio concept cannot support the claims that the atomic absorption technique is superior. There is no discussion of this important point in the book, which is unfortunate because reiteration of these claims has led many analysts to accept them as fact.

Fictitious statements regarding "chemical" or "solute vaporization" interferences in flame atomic absorption or emission spectroscopy have also gained considerable standing, primarily because they, too, have been repeated often. Typically, these statements imply that there are few interelement effects in atomic absorption measurements, presumably in marked contrast to atomic emission observations. Again, these deductions have not been supported by either theoretical or experimental evidence. The most widely observed "chemical" interferences or "interelement effects" arise from the influence that other chemical constituents (concomitants) in the sample exert on the degree of conversion of aerosol droplets into free atoms of the element (analyte) to be determined. Since the free atoms released in the flame may be measured either in absorption or emission, the effect must be the same for both techniques, unless the excited-state population of the analyte is affected by the concomitants. Theoretical considerations indicate that such "excitation" or "quenching" interferences are not likely to occur, and experimental documentation of them is lacking. Thus it is entirely expected that the same degree of interference should be observed in absorption as in emission. Slavin sets the record straight when he writes, "This effect, called a chemical interference, is present to the same extent in emission flame photometry," but then he adds that "the specificity of atomic absorption usually makes the control of these chemical interferences easier" (p. 68). The reader logically inquires in what way control is easier. If he is perceptive, he will realize that there is no justification for the addendum.

A third misconception resulting from repeated publication of sweeping generalizations concerns the relative temperature effects in flame atomic absorption and emission spectroscopy. On page 3 Slavin provides an excellent summary of many similar deductions in the published literature: "Since changes in temperature produce an exponential growth in the number of atoms that can emit light, while having an *insignificant* [my italics] effect on the number of atoms that can absorb (that is, merely depleting their number by loss to an excited state), it follows that emission methods are very sensitive to changes in temperature, while absorption methods are relatively insensitive to such changes. This freedom from the effect of changes in the vapor producing environment is one of the most attractive features of atomic absorption." If such statements are examined critically, their credibility largely disappears. First, in a well-controlled flame of the type used in analysis, why should there be any significant temperature change? Several investigators have shown definitively that the addition of analyte to the flame does not cause a measurable temperature change. If through carelessness or other causes a different flame temperature prevails, is there any experimental evidence that flame emission observations are more affected than are absorption measurements? This reviewer is not aware of any. Moreover, from theoretical considerations De Galan and Wineforder concluded in 1966 that if atomization processes, and especially compound formation, are considered, the temperature dependences of the absorption and emission methods are found to be of the same order of magnitude.

The author has handled several bibliographic and historical aspects rather carelessly. The reviewer noticed several of these because they are concerned with his own work. Pages 38 to 49 summarize the historical development of fuel-rich flame environments for the release of free atoms of the "refractory" or monoxide-forming elements. Ten references are cited, but the first report by Fassel and Mossotti on the use of fuel-rich flames for the determination of refractory elements in fuel-rich acetylene flame is not. On page 8, the author refers to a paper by Mossotti and Fassel which is supposed to describe a scanning photoelectric technique for observing atomic absorption spectra when a primary continuum is employed. Actually, a photographic technique was employed. In the discussion of the determination of the lanthanide elements similar faults can be found.

The book contains a subject index, with this rather apologetic foreword: "This Subject Index is not complete. Certain topics are distributed so broadly throughout the book that they are not indicated below although, logically, they should be." In a reference book the index is of paramount importance, and it is unfortunate that there are no entries for such important topics as hollow cathode tubes, temperature (of flames), sensitivity, detection limits, ionization, plasma sources, and light scattering, all of which are discussed in the text. To counterbalance this deficiency, there are a fine bibliography of published papers and an author index that appears to be reasonably complete.

Up to now this review has been both complimentary and critical. Let me close by emphasizing that the book is timely and valuable and that it contains a vast amount of useful information.

VELMER A. FASSEL
*Department of Chemistry,*
*Iowa State University, Ames*