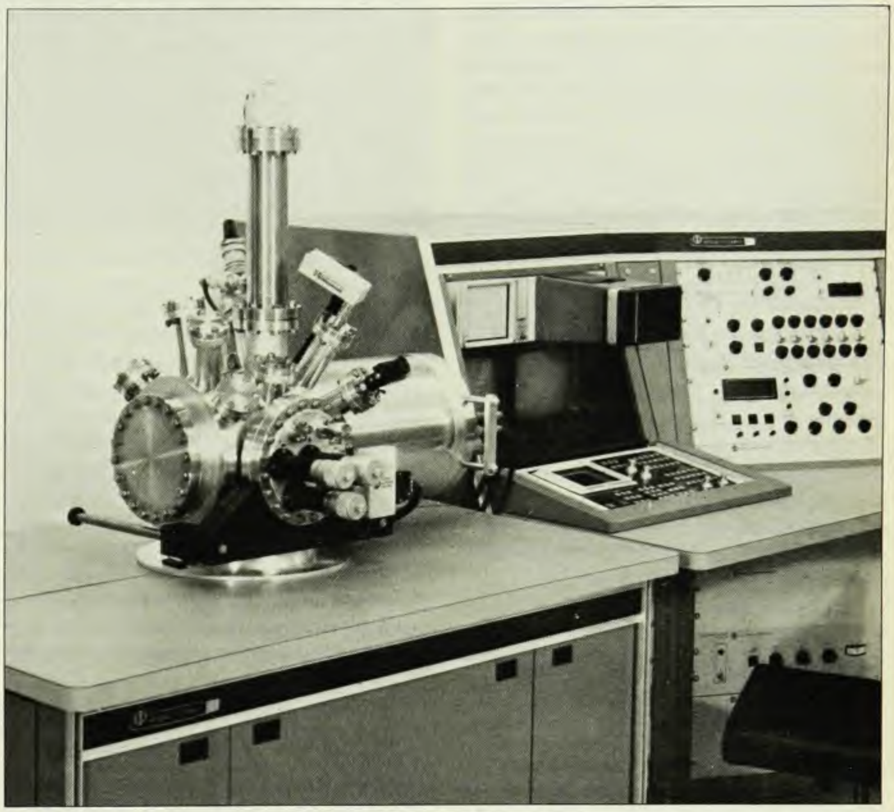
books

"How-to" guide for the experimenter

Photoelectron and Auger Spectroscopy

T. A. Carlson
417 pp. Plenum, New York, 1975. $32.50

Reviewed by Homer D. Hagstrum



Scanning Auger microprobe. Used in surface analysis, the apparatus provides electron-energy spectra for objects as small as 0.5 microns × 10 Å. (Physical Electronics Industries, Inc).

An electron spectroscopy constitutes a means of deriving "spectroscopic" information about matter from a measurement of the kinetic energy of electrons. These electrons may be those that are scattered by or ejected from an atom, a molecule or a solid, which suggests classification into scattering and emission spectroscopies. The electronic transition process induced in the atomic system being studied also characterizes an electron spectroscopy. The spectroscopic information obtained comprises the distributions in energy of the electronic states of the system studied and of electrons produced by auxiliary or secondary processes. The many and varied electron spectroscopies now in use constitute a major component of current investigations into the electronic structure of matter, which is of interest to an increasing number of workers in both science and technology. Electron spectroscopists' interests range from electronic transition processes and energy levels in atoms, molecules and solids, to chemical bonding effects and atomic identification.

Thomas Carlson has chosen as his principal topics the emission spectroscopies based on the photoelectric effect in atoms and molecules and the Auger electron emission from gases and solids. These represent, in fact, major segments of the total field, to which the author has himself made substantial contributions. If one wishes to treat the chosen subject matter in some depth, in a book of reasonable size, the author must limit his scope. This is essential because of the explosive increase in work in the field and the development of a sizable list of distinguishable spectroscopies, each possessed of its own peculiar set of characteristics and range of applicability. The book, however, gives the reader a broader perspective of the whole field of electron spectroscopy than these limitations might suggest, because it also presents shorter descriptions of other areas of the total field.

Carlson first discusses experimental methods and procedures with the avowed purpose of telling the reader how to "do" electron spectroscopy. Here he discusses the physical principles involved in the excitation of electron emission from the target sample, the handling of the sample itself (gas, solid or condensed vapor), the electron-energy analyzer, detection methods and data analysis. He writes at such a level that the reader will understand the design principles of the commercially available apparatus, also reviewed critically.

Under the heading "Fundamental Concepts" one finds a descriptive overview of the theory of atoms and molecules and of the relevant electronic transitions which can occur in them. Topics include electron binding energy, the nature of final states, primary photoprocesses and secondary mechanisms, as well as a "descriptive evaluation" of molecular-orbital theoretical models. Carlson also presents specific theoretical problems, discussed at a descriptive level, elsewhere in the book. Copious references point the reader to detailed original literature.

Carlson divides photoelectron spectroscopy into that of outer or valence electron shells (which he dubs PESOS) and of inner shells (PESIS). With respect to outer electron shells, the reader encounters quite detailed discussions of the energy-level scheme, means of orbital identification, and a survey of the literature for molecules of increasing complexity. The section on valence orbitals in solids or of molecules adsorbed at solid surfaces, however, is limited to three brief examples. The chapter on the spectroscopy of atomic inner shells in molecules and solids constitutes the longest and most detailed portion of the book; this chapter presents both the theory of and experimental data on chemical shifts of core electrons. Extensive tabular data on binding energies, subshell separations and core-level shifts are given in the text and in three appendices. One third of the 1002 literature references in the book refer to work on inner shells.

Auger electron spectroscopy, in which two electrons transit between energy levels in the atomic system studied, receives a more balanced treatment between its uses with solid surfaces and gases as the target samples. A discussion of the theory of Auger processes leads into a particularly good comparison of the Auger phenomenon with the photoelectric effect and x-ray emission. Presentation of representative work with Auger electron spectroscopy for atoms, molecules and solid surfaces follows.

Carlson's book contributes significantly to the literature of electron spectroscopy in spite of its limitations in scope. In a readable style, he successfully achieves a level of presentation suitable to the experimentalist interested in photo- and Auger processes in atoms and molecules. True, he does not maintain this level uniformly for the reader interested in solid surfaces, but at least for inner-shell and Auger phenomena at surfaces one finds a start into the relevant concepts and literature. I commend Carlson for the considerable and successful effort he has expended in producing this book.

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Measurements and Time Reversal in Objective Quantum Theory

F. J. Belinfante
142 pp. Pergamon, New York, 1975. $10.00

Students of the foundations of quantum mechanics will recognize Fredrick J. Belinfante as the author of the comprehensive 1973 treatise, *A Survey of Hidden-Variables Theories*. On seeing the title of his latest work, one might therefore anticipate a similar scholarly review of various formulations of the quantum theory of measurement, comparable perhaps to Max Jammer's recent excellent survey entitled *The Philosophy of Quantum Mechanics*. The new Belinfante volume, however, is nothing of this sort, nor was it intended to be. Instead one has a booklet that records its author's opinions concerning two broad issues in quantum-natural philosophy. Belinfante himself quite accurately describes the work as a "reply to scientific papers written ... about fundamental questions," but he does also suggest that the presentation could serve as an appropriate supplement to textbooks on quantum theory. As a teacher of quantum mechanics, I would reject that suggestion unless the supplementary readings included not only Belinfante's work but also equally detailed rebuttals composed by representatives of other schools of thought.

The term "objective quantum theory," which appears in the title, refers to the fact that the physical significance of quantum states lies in their association with statistical ensembles rather than individual systems. Thus Belinfante conscientiously describes all quantal problems in terms of ensembles and thereby avoids for the most part the philosophical entanglements which arise in subjectivistic treatments of well known correlated-state problems like Schrödinger's cat and Wigner's friend. However, it will seem strange to students of the history and philosophy of quantum physics that Belinfante regards this approach as being consonant with the Copenhagen interpretation, for if that were strictly true the celebrated Einstein–Bohr controversy would have been devoid of significant content.

One of the two controversial issues with which Belinfante deals is the well known so-called "problem of measurement"; the other constitutes the more esoteric question as to whether the quantum theory of measurement is symmetrical with respect to the reversal of time. Because the conclusions that can be drawn from any logical analysis obviously depend upon the presuppositions, it may prove helpful to the present task of summarizing Belinfante's complex arguments to quote several phrases from the booklet that clearly establish the direction of his considerations.

Let E_z denote an ensemble of quantum systems prepared in the nondegenerate eigenstate $|z\rangle$ of an observable Z, and suppose we are contemplating measurements of an observable A which has a nondegenerate eigenvalue a with corresponding eigenstate $|a\rangle$. Belinfante asserts that in this ensemble E_z, "there is a probability $|\langle a|z\rangle|^2$ for finding the result a for a *following* measurement of A." The italics are mine, inserted to emphasize a subtle claim with which many quantum theorists would disagree. To Belinfante, this familiar quantity $|\langle a|z\rangle|^2$ is inherently predictive as opposed to "postdictive," and he regards it as generally useful only for states $|z\rangle$ which are prepared as opposed to "postpared." Thus he argues that, apart from special circumstances, which are thoroughly discussed in the monograph, the formula lacks time-reversal symmetry because it is usually untrue that $|\langle a|z\rangle|^2$ is also the probability that an earlier measurement of Z yielded z given that the later measurement of A yielded a, or, to use Belinfante's jargon, given that there later occurred a "postparation" of the state $|z\rangle$.

In rejoinder, many quantum mechanicians would say that the word *following* in the foregoing quotation should be omitted and that no distinction should be made between preparation and "postparation," that $|\langle a|z\rangle|^2$ in fact represents just the probability for finding a at the (present) instant when the state is $|z\rangle$. Indeed, it seems to me that the verb *to prepare*, as it is actually employed in physics, really means only *to pare*, a now archaic English word derived from the Latin *parare* which means to make ready or to form, without essential reference to past or future.

At any rate, whether the reader finally interprets Belinfante's analysis as enlightened or bizarre, this material on time reversal makes fascinating reading. As important supplements to the main text, there are several appendices in which these dichotomous notions of prediction–postdiction and preparation–postparation are applied critically to discredit related work by Bernard d'Espagnat, Leslie E. Ballentine, Henry Margenau and myself. It is doubtful, however, that these physicists will accept such criticisms based on Belinfante's time-reversal theory, since the latter is itself based upon premises that none of them will likely ratify.

Following the quotation already given, Belinfante writes, "a fraction $|\langle a|z\rangle|^2$ of the members of E_z form the subensemble E_{za} of systems O on which the measurement of A yields a." Then to make quite clear the interpretation of $|\langle a|z\rangle|^2$ being espoused, he states, "This axiom or rule implies that the successful completion of the measurement of A must have changed the ensemble E_z of systems O into a mixed state." This clarification, which some physicists will accept and others will regard as a *non sequitur*, defines what for Belinfante is the problem of measurement. In the booklet, more attention is devoted to the rational justification of this interpretation of $|\langle a|z\rangle|^2$ than to any other topic. The treatment did not strike me as particularly unusual except for the careful interpretation of all quantal propositions in terms of ensembles. It is nevertheless a very well written presentation of that popular but questionable view of the measurement process in which the infamous projection postulate—here occurring as a license for subensemble selection following a "successful" measurement—plays a central role. This work is certainly worthy of scrutiny by anyone who is seriously interested in the foundations of quantum mechanics.

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Chemistry of the Atmosphere

M. J. McEwan, L. F. Phillips, eds.
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The authors, Murray J. McEwan and Leon F. Phillips, have been actively involved in laboratory studies related to