Applications. This last chapter, on Applications, is a very long one—351 pages, or more than half of the book.

In general, the authors have done a good job of bringing together in one volume all of the factors that are relevant to the subject of NAA utilizing small accelerators as neutron sources. In fact, this is the only book on this specific subject, so far as this reviewer is aware. It is not designed as a textbook, but rather as a reference book—useful both to newcomers to the field and to persons already quite experienced in this field. In this reviewer's opinion, the book is unnecessarily long, adding to the cost of the book without a proportional addition to its useful content. The treatment of health physics is unnecessarily detailed, and the element activation and decay curves (234 curves) in the chapter on Applications add a great deal to the length of the book without adding much information of real value, inasmuch as all of the resulting information can readily be obtained from a single activation straight-line plot of log (1-S) versus $t_i/t_{0.5}$ and a single decay straight-line plot of log A/A_0 versus $t_d/t_{0.5}$, plus the 78 element activation/counting tables included in the chapter. Many of the 48 graphs in Chap. 2 are of little use, and could well have been eliminated. Three other criticisms of the book are (a) the undue attention devoted to NAA with 3-MeV (d,d) neutrons, (b) the inadequate attention devoted to thermal-neutron activation analysis, using a moderator to thermalize the 14-MeV neutrons, and (c) the inadequate discussion of the great advantage of modern sealed-tube 14-MeV neutron generators, compared with the far more troublesome drift-tube generators.

In general, the book appears to be unusually free of typographical errors [one exception being Eq. (2.12), in which the product should be ^{3}He, not ^{3}H]. In Table 2.6, the half life of ^{197m}Au should be shown as 7.2 sec (the units were omitted). On p. 52 it is stated that $(n,2n)$ reactions are predominantly endoergic, whereas all $(n,2n)$ reactions are endoergic. On p. 57, reference is made to the analysis of nitrogen in hydrocarbons, whereas it should be referred to as the determination of nitrogen in impure hydrocarbons (or as the analysis of impure hydrocarbons for nitrogen). Especially in Chap. 3, the authors use many English units, rather than using metric units or giving both. In Chap. 4, the authors refer to buildup of T_2O in the body, whereas any tritium present in the body as water is entirely in the form of HTO. The authors still use the old terminology of "beta rays," rather than "beta particles." In Chap. 6, on Sources and Reduction of Systematic Error, no mention is made of the most precise and most accurate oxygen determinations yet made by anyone, using 14-MeV neutrons—namely, the fine work done and published by Alexis Volborth. In Chap. 7, the NAA method is compared with the atomic absorption method, but only the flame method is cited. The better sensitivities attainable for many elements by the flameless atomic absorption method (using a graphite furance or a tantalum ribbon) are not mentioned. In Appendix II, specific activities of various reaction products are tabulated for an irradiation time of 10 h, which is extremely unrealistic. Nowhere in the book is the Activation Analysis Service of General Atomic mentioned, although this commercial service (started in 1961) included 14-MeV NAA measurements as well as reactor NAA measurements, and the 14-MeV neutron service for oxygen determinations still operates through Intelcom. During its 14 yr of operation, this service has performed more than 100 000 oxygen determinations for a large number of clients.

Coverage of the literature in the book is extensive. A total of 471 references are cited (including a number of repeats). However, although the manuscript was completed in early 1973, the literature coverage essentially stops with 1970, with only two 1971 references and only two 1972 references. One particular omission from the references—noted with chagrin by this reviewer (!)—is the extensive (29 pp.) review article on "Neutron Activation Analysis with Small Accelerators," presented by this reviewer at the First Oak Ridge Conference on Small Accelerators, and published in the *Proceedings*. Failure to cite this fairly extensive reference is even more strange when it is noted that Eq. (2.26) in the book, and all of the discussion pertaining to this equation, is taken from this review article, and the equation was derived by this reviewer. Whereas Appendix III in the book tabulates experimentally determined 10^9 flux 14-MeV-neutron [and 10^7 n/(cm^2 sec) thermal-neutron] sensitivities for various elements, no mention is made of similar experimental sensitivity tables obtained in this reviewer's former laboratory (General Atomic) and published in two extensive NAA chapters in widely used books: the *Treatise on Analytical Chemistry*, and *Physical Methods of Chemistry*. The authors list one reference as a private communication from this reviewer, and that one is given completely wrong!

To repeat the comment made at the outset of this review, however—despite some shortcomings, a number of which have been cited above—this is a good book on the subject, and a useful addition to the literature.

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About the Reviewer: Again we welcome Vincent Guinn, professor of chemistry on the Irvine campus of the University of California, to these columns as a reviewer of books on radioisotopes and their uses. Prof. Guinn earned his PhD in physical chemistry at Harvard in 1949 and, before returning to the academic world, had wide experience in industry, most recently with Gulf General Atomic. His principal interests are in radiochemistry, radioactive tracers, and activation analysis.

Functional-Analytic Concepts and Structures of Neutron Transport Theory. Vols. 1 and 2. By Marjan Ribarič. Slovene Academy of Sciences and Arts, Ljubljana, Yugoslavia (1973). 1104 pp.

These volumes represent the organization of a large number of physical assumptions about the transport of neutrons into a large mathematical framework. The work is very ambitious, containing over 1100 pages and representing 11 years of labor. It is very theoretical and should have appeal to readers with strong interests in applied functional analysis and transport theory. However, it may not be of much interest to readers who are concerned mostly with practical applications.

The author's main effort is to develop a mathematical theory based on a large number of physical assumptions about the behavior of neutron "traffics" on the surface of a material body, D. In particular, the author is concerned about the mathematical relationship between the neutron traffic i_+ that leaves D and the entering neutron traffic i_-.

The author formulates a connection between these quantities of the form $i_+ = Ai_- + q$, where A is the "albedo" operator for D, and q represents neutrons exiting from D that arise from independent interior sources. Using a lengthy list of physical assumptions, the author derives a lengthy list of mathematical properties of the operator A, without ever arriving at a closed-form, analytic expression for A. These mathematical properties of A and their physical implications are the author's main results.

The approach is thus to treat the physical body D as a black box that transforms an input, i_-, into an output, i_+. The author is unconcerned about the description of neutron densities in the interior of D and about the methods that have been developed to describe such densities. However, as the author himself points out, the black-box approach is a generalization of the invariant embedding approach to transport theory; thus his aims are not without precedent.

Volume 1 consists of 5 parts. In Part 1, the albedo operator, A, for a single body is defined and many of its properties are deduced. For example, A is (supposedly) proved to be compact, and certain time-averaged properties of A for an infinite time interval are derived. Among the various physical assumptions used to develop the theory is the assumption that the growth and decay of solutions for supercritical and subcritical domains is exponential.

In Part 2, certain properties of an albedo operator for a compound body are determined in terms of the properties of the albedo operators of its constituent parts. (A compound body consists of two or more bodies of the type considered in Part 1. Thus the neutron traffic emerging from the compound body can be discussed in certain ways in terms of the traffics across the interior boundaries of its parts.)

In Part 3, the problem of measuring and experimentally determining neutron densities is considered. Part 4 deals with determining the properties of a body from knowledge of the properties of its parts. Part 5 deals with special topics. Among these is a brief discussion about the connection between the black-box approach to transport theory and the "field theory," which is based on the Boltzmann equation.

Volume 2 consists of two long appendices and a very complete list of references. These appendices contain most of the actual mathematical derivations, the results of which are used in Volume 1.

The two volumes are organized very carefully, and the literary style is exceptionally clear. However, the volumes are not bound in a very durable way and so they must be handled carefully.

Although the work seems very complete, I feel that there are certain topics that could have been elaborated on more completely and others that could have been handled much more carefully.

First, much has been made of the fact that, for a small subcritical body, the time decay of neutron densities following an initial burst is not exponential; this is not considered here. In fact, the author explicitly assumes that the time decays *are* exponential. Therefore, there is a discrepancy between experiment and the author's assumptions for small subcritical bodies.

Second, a detailed connection (if possible) between the author's black-box approach and that using the linear Boltzmann equation would seem worthwhile. In other words, the brief discussion about this in Part 5 seems inadequate.

One would expect that the Boltzmann equation, which is derived using a minimum number of physical assumptions, does not lead to different theoretical results than the black-box approach, which is derived using a large number of assumptions. Yet this is not the case; an analysis of the Boltzmann equation shows that the albedo operator, A, for a finite body is not compact.[1] (However, if one writes $A = B + C$, where B describes uncollided and once-collided neutrons, then C is compact, whereas B is not. Thus, the author's results agree with the linear Boltzmann analysis only if one separates off the uncollided and the once-collided neutrons.)

Actually, in Part 5, the author does consider the possibility that A is not compact by writing $A = D + E$, where D describes uncollided neutrons and (presumably) E is compact. However, E contains the once-collided neutrons and so, from the point of view of the Boltzmann equation, even E is not compact.

I hope not to have belabored the issue of the noncompactness of A, but rather to have emphasized the following point. Obtaining useful information directly from the linear Boltzmann equation is not easy, and this has, in part, dictated the author's method of attack: to replace the Boltzmann equation with a list of physical assumptions. However, the technical difficulty of the Boltzmann equation is itself an indication that the Boltzmann equation describes very subtle processes, some of which are not yet completely understood. Therefore, very great physical and mathematical insight must be used if one wishes to bypass this equation, as the author has attempted to do. It is not clear that he has always done so correctly.

Overall, I regard this very theoretical work with interest, but also with caution. To a mathematician, there are many challenging questions that the author has raised, which I might perhaps summarize as follows: Which of the properties of A can be proved from a rigorous analysis of the Boltzmann equation, and which cannot?

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April 21, 1975

About the Reviewer: Professor Edward Larsen has been an assistant professor of mathematics at New York University since 1971. During that time he has worked at the Courant Institute on applied mathematical methods in transport theory. Dr. Larsen did his undergraduate and graduate work at Rensselaer Polytechnic Institute. Aside from transport theory, his other main interests lie in asymptotic methods and applied functional analysis.

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[1] Edward W. Larsen, "Solution of Neutron Transport Problems in L_1," to be published in *Comm. Pure Appl. Math.*