and inorganic precipitation and dissolution of calcium carbonate; one must ask why different organisms prefer to use different types of carbonate, and what the equilibria of calcium-magnesium carbonates with sea water are really like.

H. Borchert deals with the formation of marine sedimentary iron ores (chap. 18) and of oceanic salt deposits (chap. 19) and gives the inorganic chemist food for thought. Borchert treats very competently the salt deposits in Germany and various theories on their origin. One might, perhaps, have liked to see a comparison with present-day salt deposits in the Dead Sea, in Kara-Bogaz, and perhaps in some other salt lakes. Even if they are not "oceanic," they may be similar enough to be interesting.

G. D. Nicholls' chapter on the geochemical history of the ocean may need more revision than any other as our understanding of the past develops.

J. P. Riley (chap. 21) discusses the analytical chemistry of sea water. Every chemist and geochemist must be kept aware of the importance of good analytical work. Many difficulties are inherent in the analysis of sea water: marine life changes its composition even after sampling, trace elements are precipitated or adsorbed in the vessels, carbon dioxide and other gases may be lost. Determinations of minor elements are really difficult, and even a seemingly standardized procedure like the Winkler titration for oxygen may get out of control. (A Scandinavian chemist, looking at page 310, may ask why analytical chemists in other countries cling to use of the $\Delta E/\Delta V$ method for finding equivalence points rather than the much more accurate linear Gran functions.)

J. D. Burton (chap. 22) discusses the use of radioactive nuclides: long-lived nuclides, cosmic-radiation produced nuclides, and "artificially produced" (that is, bomb-produced) nuclides. Among other things one learns that the hydrogen bombs, in addition to making a muddle of future radiocarbon datings, may have left some useful tracers for the study of water movement in the ocean.

This treatise is perhaps not one that every reader should read from the first page to the last. However, each chapter is inspiring reading in its own way, because each points to many unsolved problems in oceanic chemistry. One must hope that *Chemical Oceanography* will be read, not only by those who are already devoted to various branches of ocean chemistry, but also by a fair number of other chemists, that it will interest them in some chemical problems of the ocean. The number of independent research workers in ocean chemistry is still so small that a fresh impulse from other branches of chemistry would be most welcome.

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Titanium Metallurgy in the U.S.S.R.

Hydrogen is a ubiquitous impurity that plagues metals and metallurgists with impartiality, whether they be Americans or Russians. The now flourishing titanium industry in the United States was almost sunk before it was well afloat by a rash of hydrogen-induced titanium failures during the years 1954 to 1956. From 1955 to 1960 a tremendous effort was made in the United States to learn how to measure, control, and remove hydrogen in commercial titanium alloys. At the same time, a considerable scientific effort was made to understand the mechanism whereby hydrogen did its dirty work of embrittling otherwise perfectly useful titanium products.

It is of considerable interest to review the paralleled Russian effort in the same field in this recently published book, **Hydrogen in Titanium** (Israel Program for Scientific Translations, Jerusalem; Davey, New York, 1965. 208 pp., $10.25), by V. A. Livanov, A. A. Bukhanova, and B. A. Kolachev. The book was translated from the Russian edition (Moscow, 1962) by A. Aladjem. It is apparent that the Russians have followed very closely our considerable research and development effort in the field, for that effort is reported faithfully and accurately in the book. It is also apparent that the Russian effort was phased sufficiently far behind the American effort for them to avoid some of our painful experiences.

Hydrogen in Titanium begins with an interesting review of titanium metallurgy and the status of titanium alloys in America and Russia. This section is independent of the hydrogen embrittlement problem. In general, the Russian titanium alloys follow the American and English alloy types, in some cases covering identical compositions. Presumably, an advantage of this procedure would be that it allowed them to take better advantage of the voluminous Western information on these alloys. An interesting exception is greater Soviet emphasis on chromium as an alloying element. The thermal instability associated with precipitation of titanium dichromide during elevated temperature exposure under stress has pretty well limited American use of chromium to beta-type alloys, and even here the use of chromium is decreasing. The Soviet VT3 alloy is an alpha-beta Titanium-Aluminum-Chromium alloy containing about 3 percent chromium. Thermal instability is aggravated by the presence of hydrogen, as has also been noted by the Russians, and their use of this alloy is being de-emphasized in favor of more thermally stable alloys containing molybdenum.

The book, which covers both scientific and technological information on absorption, diffusion, measurement, and contamination of titanium with hydrogen, appears to include all known information from Western and Soviet sources up to 1962. The Russian appraisal of the effects of hydrogen closely follows American thinking and evaluation to the extent that the authors seem to favor an American-supported view when there is a conflicting Russian viewpoint. There is remarkably good agreement between the American and Russian investigations on the effects of hydrogen and the mechanical properties of titanium. The hydrogen tolerances, that is, the maximum permissible hydrogen contents in various alloys, agree remarkably well.

Interesting and speculative comments are made on the nature of the interstitial solution of hydrogen in exothermic solvents like titanium (solvents in which hydrogen solubility increases with decreasing temperature). The authors state, without providing references to supporting data, that hydrogen is not completely ionized to a proton when it enters a solid solution in titanium, but exists as an excited and partially ionized atom, which is much larger than a proton, and occupies an interstitial site in the lattice. These hydrogen atoms are said to be bound to the metal atoms by certain chemical forces, the nature of which is not disclosed. As far as I know, this is a new concept, but its validity cannot be evaluated because no supporting data or references are given.

A major surprise is the report that vacuum annealing of commercially pure and alpha titanium alloys renders them subject to notch-impact embrittlement over a period of years, presumably as a result of absorption of hydrogen from water vapor at room temperature on the active titanium surface resulting from vacuum annealing. This implies that a clean titanium surface can reduce water vapor at room temperature. No Western information supports this startling report. A great deal of vacuum-annealed commercial titanium is being produced in the United States for use in chemical equipment. One may be sure that there will be some scurrying around our titanium plants to find some well-aged material on which to check the Russian report. I am inclined to discount the validity of the report because a titanium dioxide film forms rapidly on titanium surfaces, and after a short time there should be little difference between a vacuum-annealed or non vacuum-annealed surface. The book does not cover the more recently discovered effect that cooling alpha titanium through the hydride precipitation field under stress results in hydride platelets precipitating normal to the applied tensile stresses. Hydride precipitated in such a way is more embrittling than the normal random precipitation.

There are few comments that one can make about a book like **Phase Diagrams of Titanium Alloys** (Israel Program for Scientific Translations, Jerusalem; Davey, New York, 1965. 318 pp., $15.25), by E. K. Molchanova, except to say whether or not it provides a complete and accurate summary of the available literature in a readily accessible form. Molchanova's book, which was translated from the second Russian edition by A. Halbreich, N. Kaner, and M. Statter and which is an updating of the book by Molchanova and Glazunov (1954), does not appear to do this very well, although the information on constitution is supplemented by data on metastable phases formed in heat treatment, and includes ternary alloy systems as well as binary. The data on the constitution of alloys is brought up to 1962, the same period covered by R. P. Elliott's recent supplement to the classic *Constitution of Binary Alloys* by Hansen and Anderko, which brought the binary phase diagram literature up to 1956 and 1957. The Defense Metals Information Center at Battelle Institute's Columbus laboratories brought the literature on binary and ternary titanium phase diagrams up to September 1960.

The situation on titanium phase diagrams is in a muddle as a result of controversy over the constitution of the titanium-aluminum (Ti-Al) system, where a sluggish ordered phase forms in the terminal hcp alpha-phase field. Aluminum is the most important alloying element in titanium alloys, and is a constituent in most commercial alloys. Thus, information about the existence of the ordered phase in alpha titanium is crucial to a good understanding of the metallurgy of titanium alloys. It was disappointing, therefore, to find inadequate and superficial coverage of the controversial Ti-Al system in Molchanova's book where only passing reference is made to the subject. The 1956 diagram of Sagel, Schulz, and Zwicker is presented, with only citations to the more recent work.

In addition to information on constitution, the book gives data on the mechanical properties, some physical properties (resistivity), and chemical properties (oxidation). This is certainly desirable. I checked a number of well-known cases, and it appears that important American references on mechanical properties have been overlooked or disregarded. The phase diagrams are grouped according to type of diagram rather than in a useful alphabetical arrangement. This may be appealing scientifically, but it makes the book much more difficult to use as a reference source.

Despite its limitations, the phase diagram book contains very useful information and, along with *Hydrogen in Titanium*, deserves a place in the library of engineers and scientists who are concerned with titanium metallurgy.

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Ichthyology

The first four parts of this monumental work, *Fishes of the Western North Atlantic*, were reviewed in *Science* on 7 May 1965 (*Science* **148**, p. 834). This fifth part, **Order Iniomi, Order Lyomeri** (Sears Foundation for Marine Research, Yale University, New Haven, Conn., 1966. 662 pp., $27.50), contains accounts of two major groups of soft-rayed fishes of the area extending from Hudson Bay to the Amazon and from the mid-Atlantic east of Bermuda to the estuaries of the coastal plain.

Most of the volume is devoted to the order Iniomi, a group of offshore species known mainly by ichthyologists, except for the lizard fish and allied species found along the tropic and temperate coasts.

The order Lyomeri, which is discussed in the final portion of the book, is a small group of bizarre deep-sea creatures of extraordinary form. The major part of the volume is the work of the editor-in chief, Giles W. Mead; the other portions were prepared by nine collaborating ichthyologists: William W. Anderson, Frederick H. Berry, James E. Bohlke, Rolf L. Bolin, Jack W. Gehringer, Robert H. Gibbs, Jr., William A. Gosline, N. B. Marshall, Robert Rofen, and Norman J. Wilimovsky. Parts 6, 7, and 8 will be published in future years to complete the work.

HILARY DEASON

AAAS

New Books

Mathematics, Physical Sciences, and Engineering

Accélérateurs Circulaires de Particules: Introduction à la Théorie. Henri Bruck. Institut Natl. des Sciences et Techniques Nucléaires, Saclay; Presses Universitaires de France, Paris, 1966. 370 pp. Illus.

Advances in Programming and Non-Numerical Computation. L. Fox, Ed. Pergamon, New York, 1966. 226 pp. Illus. $10. Nine papers given at the 1963 Summer School, Oxford University: "Introduction to automatic computing" by S. Gill; "List programming" by P. M. Woodward; "Programming" by D. W. Barron and C. Strachey; "Artificial languages" by J. M. Foster; "Aλ-calculus approach" by P. J. Landin; "A survey of non-numerical applications" by S. Gill; "Theorem-proving in computers" by D. C. Cooper; "Game-playing and game-learning automata" by D. Michie; and "Information retrieval and some cognate computing problems" by R. M. Needham.

The Analytical Chemistry of the Noble Metals. F. E. Beamish. Pergamon, New York, 1966. 623 pp. Illus. $18.50. International Series of Monographs in Analytical Chemistry, vol. 24.

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