β and β''-aluminas, with their potentially large scale use in the Na/S battery (Ch. 27), deserve the special attention given to their structure and defects (Ch. 16.).

Anionic conductivity (F^-, O^{2-}) in the CaF_2 (ZrO_2) or LaF_3 (Ch. 19, 19) related structures and its enhancement by cation polarizability (PbF_2, Bi_2O_3) is described. ZrO_2-based electrolytes now cover a variety of applications — for thermodynamic measurements (Ch. 28, 29), fuel cells (Ch. 25) or high temperature resistors (Ch. 30).

Beyond the scope of electrolytes alone, the study of mixed conductors (Ch. 21) opens the field of high-energy electrode materials, or electrochromic displays.

This book covers relatively completely, with well documented papers, the field of solid electrolytes. However, in this fast moving field, the delay between the call for papers and publication of the book makes a satisfactory updating difficult. This is especially noticeable for solid electrolytes as dispersed phases and for ill-condensed materials (glasses, Ch. 17) with potential applications almost equal to that of β-alumina (Na/S battery).

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Lead–Acid Batteries
by H. Bode, John Wiley, New York, 1977, 387 pp.

The lead–acid battery is the faithful old retainer of electricity — it has seen honourable service for over one hundred years and has demonstrated its reliability, versatility, and cheapness in a wide variety of automotive, stationary and traction applications. Why then has there been a renaissance in lead–acid battery research during the past decade?

Initially, the renewed interest lay in the application of modern analytical techniques developed in other disciplines to examine further the chemical and physical processes taking place in battery plates. Investigations using techniques such as scanning electron microscopy and electron probe microscopy became commonplace and the scientific press was bombarded with a kaleidoscope of electron micrographs that revealed both positive and negative active materials in a variety of crystal habits during preparation, formation, and utilization of battery plates. Such studies, in turn, gave rise to an avalanche of theories on the mechanism, limitations, and failure modes of the system.

More recently, research on lead–acid batteries has been stimulated through recognition that world energy supplies are very much dependent on petroleum fuels. The situation is becoming particularly serious in the transportation sector, and difficulties in guaranteeing continuous oil supplies,

understanding that reserves are indeed finite, and problems in meeting exhaust emission controls, have led to renewed interest in vehicles powered by electrochemical systems. Of the two types of electrochemical power source available — the secondary storage battery and the fuel cell — batteries appear to be more suitable for traction applications, and of the many electrochemical couples proposed, the lead–acid battery remains the only technology commercially available in the near-term for electric vehicles. However, this battery is only marginally capable of meeting the needs of on-the-road vehicle propulsion, and current research and development is therefore directed towards improving the system to give greater energy and power density, increased service life, more rapid rechargeability, and reduced size and cost. Other work is aimed at developing stationary lead–acid batteries to meet energy storage requirements of electric utilities (*e.g.*, load-levelling), and to provide storage facilities for discontinuous, 'alternative' energy sources such as tides, winds, and the sun.

Despite this latter-day activity and the use of sophisticated investigative techniques, the nature of the electrochemical and physico-chemical processes occurring in lead–acid battery plates during charge/discharge cycling still remains something of a mystery. It is to be expected, therefore, that a new treatise on this complicated system will be welcomed enthusiastically by both battery technologist and research worker. For too long, expert and novice alike have had to rely on Vinal's *Storage Batteries* — classic volume though it is.

Dr. Hans Bode's book, *Lead–Acid Batteries*, excellently translated by R. J. Brodd and Karl V. Kordesch, presents a new and refreshing approach to the subject, particularly from the research point of view. The practical battery man, muttering spells over his simmering Barton pot, may find the sections dealing with complex crystal structures and morphologies, and the accounts of the detailed thermodynamical and electrochemical properties of the active materials somewhat daunting, but to the fundamentalist this is bread-and-butter stuff.

An obvious failing of this publication is the haphazard fashion in which the information has been assembled within only four chapters. Take, for instance, the chapter discussing the 'Fundamentals of the Preparation of Active Materials'. In the first and third sections, the author deals with the physical and chemical properties of these materials, devotes the second and fourth sections to electrochemical characteristics, in the fifth section regurgitates (with obvious hindsight) the theoretical basis of concepts used in the first four sections, returns again to physical properties in the sixth section and finally throws in an account of X-ray studies for good measure. After this, the bemused reader may justifiably be left with the frustrating feeling that the information he seeks is probably tucked away somewhere in the text, but where? As a reference source, therefore, this volume does not appeal.

The chapter dealing with the 'Manufacture of Active Materials' brings up to date much of the information contained in the earlier, more pragmatic,

approach of Vinal. In particular, much discussion is given to modern investigations of crystallographic, morphological, and rheological processes that occur during plate preparation and formation. The influence on battery life and capacity of additives to the positive and negative pastes, electrolyte, and grids is reported, but the use of lead–calcium, lead–calcium–tin and lead–strontium grid alloys is ignored. This is a glaring omission in view of the importance of such materials in the development of maintenance-free systems. These batteries are rapidly securing the automotive battery market and hopefully will move on to replace conventional traction systems.

In the final chapter, Dr. Bode evaluates the performance of lead–acid cells in terms of capacity, voltage characteristics, charge acceptance and retention, and life expectancy. The section on capacity is particularly well handled with the author distinguishing between the effects of both discharge conditions (current density, temperature, acid concentration, etc.) and design features (chemical composition and crystal morphology of active materials, pore structure, etc.). On the other hand, the review of charging procedures is disappointing and newcomers to the field are left unaware that a reliable charger, with a charging regime conducive to maximum battery life, is still eagerly awaited for traction systems.

A further disappointment awaits the reader in the final section which discusses the subject of cell life. Unfortunately, whereas traction systems are now attracting the greatest attention, and offer the greatest commercial rewards, most of the discussion centres around automotive (SLI) batteries. Among the factors which determine the cycle life of lead–acid cells, the influence of temperature, acid concentration, degree of overcharge, and depth of discharge are briefly discussed. Comments on the influence of temperature are scattered throughout the text without reference in the index and again leave the reader confused. For example, a warning to keep cell temperatures below 55 °C is given on page 307, further information on pages 331 and 337 states that failure sets in above 45 °C and finally, on page 336, data show that a 4:1 improvement in battery life can be obtained on increasing the temperature to 48 °C. In the light of these findings, a co-ordinated review of the effect of elevated temperatures on battery life is desirable and, in particular, some indication of current opinion on optimum operational temperatures for different applications would have been welcome.

The book ends with a brief account of failure modes such as active material 'sludging', grid corrosion and growth of positive plates, sulfatation (or is it sulfation?) and leading of negative plates, and deterioration of separators.

Dr. Bode's book has been published at a time when the lead–acid battery is on the crest of a new wave of interest, especially in its application to electric vehicle propulsion. There is, surprisingly, very little published information on the behaviour of lead–acid traction cells operating under duty cycles normal to electric vehicle service, and it would therefore be harsh to overly criticize the author for omitting detailed discussion on the characteristics of the system when operating under such motive power

conditions as intermittent discharge, high-speed pulse discharge, and regenerative charging. Nevertheless, a state-of-the-art review of traction battery performance and some indication of areas in which further research and development is needed would have provided a fitting finale to Bode's modern account of the characteristics of this historic and intriguing application of electrochemistry in our everyday lives.

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Principles and Applications of Solar Energy,
by P. N. Cheremisinoff and T. C. Regino, published by Ann Arbor Science Publishers Inc. and distributed by John Wiley and Sons Ltd. Published 1978, price £ 9.45.

Sometimes, during the past years, I have been invited to give a talk on solar energy to audiences consisting of college students and their professors. Often, not only technical persons were present, but also teachers of human and social sciences who appeared able to resist incipient sleep only when I succeeded in avoiding technicalities, without on the other hand being imprecise or incorrect.

This is just the aim of this book which, starting from B.C. with the Egyptians and Archimedes and their burning mirrors, journeys through the Middle Ages to our time before starting a detailed description of modern solar energy opportunities.

Typical of this book is to give preference to active systems, leaving to other books the discussion of passive systems and energy conservation, although a little space is given to the consideration that for millenia man has used the sun in a very rational way, accumulating knowledge that has been forgotten with the advent of cheap energy from fossil fuels.

Thermal collector devices are discussed as a means of obtaining hot water for residential use or for power generation; non-concentrating and concentrating collectors are fully covered but described in a very qualitative way which, however, fulfills the scope of simply informing the reader more on the concept than on performances. Also, excellent information is given on realisations and applications.

Less space and emphasis is given to photovoltaic devices, and this is presumably due to unfamiliarity of the authors with this field. For this reason one tends to pass over such naiveties as "the (silicon) purification process entails high temperature melting of the sand and simultaneous reduction in the presence of hydrogen", concentrating, if you please, into