

know a good deal more about the spectroscopy of this comparatively unknown group of substances. Fortunately most of the basic theory was already available, in Condon and Shortley's classic book, *The Theory of Atomic Spectra*, and with an extension to take account of crystal field effects, the stage was set for rapid developments in the whole field of the spectroscopy of rare earth ions in solids. In fact, the development did not occur at all rapidly and even excursions into the actinide series did not attract a great deal of attention. Nevertheless a solid core of good work was done, which has served as the foundation for the recent very exciting developments with rare earth solid-state lasers. Much remains to be done, of course, but with many more physicists now engaged in understanding rare earth spectra there is a need to be sure that the theoretical techniques which are used are as powerful as possible.

Now the methods given in Condon and Shortley, and their crystal field extension, have served us well, but there is no doubt that they can be extremely tedious to use. Further, it commonly happens that the end result of a lengthy calculation is quite simple, and one is left wondering whether or not there was a 'better way' of doing it. Well in many cases there was, and it is the purpose of this book to explain what we should have done.

The new method is based on the work of Prof. Racah, who examined in considerable depth the structure of many-electron wave-functions and their associated operators, using, particularly, group theoretical ideas. The result was a very elegant and instructive new way of dealing with problems in atomic spectroscopy, particularly those concerned with unfilled shells of electrons of high orbital angular momenta. Unfortunately the mathematical background is outside the range of knowledge of most spectroscopists, so that having coped with Condon and Shortley they are now faced with an even less familiar field.

Prof. Judd writes extremely clearly and gives his reader every help, with lots of examples and illuminating comments. Even so there is little doubt that a typical response will be to ask whether it is really necessary. The answer will of course depend a great deal on the reader, and the time which he is prepared to devote to what is really a large subject. The average experimental spectroscopist is probably best advised to leave this topic alone, unless he is a particularly good mathematician, though he should certainly look through the book and try to obtain some feeling for the mathematical techniques which his theoretical colleagues are using. The theoretical spectroscopists, on the other hand, should delve much more deeply, for this is the modern way of dealing with many-electron atoms, and here is one of the principal exponents explaining it to them. They should, indeed, read carefully and thank Prof. Judd for leading them so smoothly into this comparatively difficult and unfamiliar branch of theoretical physics.

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## METALLURGY, ARCHÆOLOGY AND THE BRITISH ISLES

### Metallurgy in Archaeology

A Prehistory of Metallurgy in the British Isles. By Dr. R. F. Tylecote. Pp. xvi+368+28 plates. (London: Edward Arnold (Publishers) Ltd., 1962.) 84s.

THE original object of this book was to gather together the wealth of information on metallurgical aspects of archaeology contained mainly in the appendices to excavation reports. . . . It was not long before it became clear that the information available amounted to a prehistory of metallurgy in the British Isles," and it is to those Islands that the author's attention is mainly, though by no means exclusively, directed. It will come as somewhat of a surprise to many readers to discover how great this wealth, in fact, is. In garnering

in his harvest, Dr. Tylecote has performed a most valuable service: between seven and eight hundred references to pertinent journals, many quite obscure, are provided and the mere physical labour of making this collection and visiting the museums and other sources of his material is beyond praise. In this work he pays generous tribute to the help accorded by his wife. It must not, however, be assumed that this is a mere catalogue; the information brought together has then been sifted and welded into coherence, a task for which the author, both a trained engineer and metallurgist, is unusually well qualified to perform.

Starting with the native metals, and such gold as has been recorded in England, Scotland, Wales and Ireland—a nugget weighing 21.5 oz. was found in Ireland in the eighteenth century—the story is carried on to the final development of the blast furnace and the production of molten iron around 1500 A.D. The earlier chapters, necessarily devoted to the non-ferrous metals, are concerned with copper and its alloys, the production of tin and tin alloys, lead and silver. How much work has in fact been done is demonstrated by the 22 pages of analyses of copper and bronze samples alone.

Meteoric iron of indigenous origin is practically unknown in Great Britain, the Iron Age being introduced by Hallstatt people from the Continent probably between 500 and 400 B.C. It is reasonable to assume, therefore, that these immigrants were already familiar with bellows-driven bowl furnaces, knew something of the strengthening effect of carbon on iron, but were more or less ignorant of the technique of hardening carburized iron by water-quenching. After discussing the iron industry during the Roman occupation the author has a relatively short, but very important, chapter on iron during the 'Dark Ages' and the early medieval period. His conclusion is interesting. "In conclusion, we can say that there has been no advance on the pre-Roman techniques themselves, but that the knowledge of the processes of carburizing and heat-treatment is now more widespread" and "in certain cases brought together with great effect". In the Anglo-Saxon-Viking period "it would appear that smelting and smithing techniques carried on where the pre-Roman technique left off".

In the course of his discussion of pre-Roman iron, the author has collected the available data relating to no less than 71 of the curious 'currency bars'. This information is subjected to a rough statistical analysis, the whole representing perhaps the most detailed discussion of these pieces yet available and amounting to a real and intensely interesting piece of research.

Sandwiched in between the accounts of the non-ferrous materials and iron is the longest chapter in the book on methods of fabrication. This is a section of great value and is outstandingly well done. Those whose curiosity is still unsatisfied will find, in the 151 references, food for still more intensive study. Here, as indeed throughout the book, the sketches add immensely to the descriptions. Details of more than a hundred crucibles found in the Islands, their provenance, date, shape and capacity, are given; analyses of typical slags, and descriptions of methods of manufacture of vessels are but part of the ground covered. Methods used in the manufacture of gold torcs, how the late Bronze Age sword was repaired, the way the Irish trumpet was constructed or the reasons why certain castings of a similar date had had to be scrapped are examples of the range of problem discussed.

It would be too much to expect that at all points Dr. Tylecote's views coincide completely with those of any reviewer, but that this is a thoroughly reliable account of a subject which bristles with difficulties there can be no doubt: the illustrations are excellently reproduced and the index all that the most exacting reader could need. The labour which has gone into its preparation is immense and the result a work of outstanding value and interest.

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