cannot be presupposed in a philosophical argument.

Unfortunately the book does not treat Einstein's general relativity. In that theory, space–time has properties of its own (such as curvature), and it acts upon and is acted upon by matter. In spite of its name, general relativity poses a more serious challenge to the purely relational concept of space–time than did any earlier theory.

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Anomalous Scattering

S. Ramaseshan, S. C. Abrahams, eds.
539 pp. Munksgard, Copenhagen, 1975. 200 Danish Kroner

Anomalous Scattering constitutes the proceedings of an international conference with that title held in Madrid in April of 1974. The credentials of the publisher (International Union of Crystallography) and the editors (S. C. Abrahams, Bell Telephone Laboratories, Murray Hill, N. J., and S. Ramaseshan, National Aeronautical Lab., Bangalore, India) are first rate. As opposed to many other hard-cover conference proceedings, *Anomalous Scattering* does not smack of commercialism. The intent, both by the International Union and the editors, was to provide a collection of material useful to the crystallographer and the diffraction physicist.

Anomalous scattering in its simplest approximation is that contribution to an atom's scattering amplitude attributable to discrete energy states of that atom. For x rays this means that the atomic scattering factor has an additional term (in general, complex) that is absent when the incident-beam energy is very far from any absorption edges of the atom (for certain gamma rays this could include both electronic and nuclear levels). For neutron diffraction this would involve neutron resonances in the thermal range.

Why is anomalous scattering useful in the determination of crystal structures? Interestingly, and somewhat surprisingly, the diffraction pattern of a crystal of any symmetry is always centrosymmetric if we are not in the regime of anomalous scattering; this is a formal statement of Friedel's law. This remarkable result says that the diffraction pattern of a crystal with a double helix, such as DNA, as its basic structural unit will produce a pattern that shows complete centrosymmetry. When the energy of the incident radiation approaches a critical edge of one of the atoms of the structure, anomalous scattering can produce a pattern no longer centrosymmetric.

A simple application of this technique takes place in the determination of the polar axis in a semiconductor-device material such as gallium arsenide. Gallium arsenide can be derived from the diamond structure by replacing alternate body-diagonal planes with gallium and arsenic atoms. The gallium–arsenic spacing differs from that of arsenic–gallium as one proceeds into the crystal in the body-diagonal (111) direction. Proceeding along this direction from a given face of the crystal, one sees a sequence Ga–As (space) Ga–As. Entering the crystal from the opposite sense, the sequence appears as As–Ga (space) As–Ga. The crystal is thus unidirectional and possesses a polar axis.

Given a parallel slab of gallium arsenide bounded by body-diagonal planes, one can, through anomalous scattering, determine which end is up. That is, the "absolute configuration" of the atomic arrangement can be related through anomalous scattering with some physical property of the macroscopic crystal. The faces of the above crystal would in general show different behavior under chemical etching. One face, say the A face, would display a characteristic array of triangular pits. The B face would also have pits of three-fold symmetry, but these would have a different morphology from those in the A face. Thus, one could readily identify the A face by chemical etching, but it would only be through a technique such as anomalous scattering that one could establish in an absolute sense which of the two sequences of layering was actually associated with this face.

In its more esoteric form, anomalous scattering can give important information to aid in determining crystal structures. In x-ray crystallography one experimentally determines the intensities of many Bragg reflections. Each intensity is proportional to the square of the amplitude of a Fourier coefficient whose related Fourier series constitutes a spatial representation of scattering matter within the three-dimensional crystal. In order to reconstruct the crystal mathematically and hence "determine its structure," one needs to know not only the magnitude of the Fourier coefficients but also their relative phases. Anomalous scattering techniques provide additional information that helps the crystallographer to make intelligent guesses of these relative phases.

One technique used by crystallographers consists of isomorphous substitution. In this case the crystallographer tries to obtain a derivative compound of the structure he is after by substituting heavier atoms in known places in the crystal without appreciably altering the arrangement of the original atoms. The heavier atom represents a strong amplitude of scattering; when added to the scattering of the relatively light atoms, it produces intensity information related to the relative phases of the atoms in the

basic unit cell. There exists a close analogy between isomorphous substitution and optical holography. In holography a reference light wave strikes a recording film, which has a specific phase relationship with the scattering from the object in question. The superposition of the reference and scattered waves produces intensity modulations on the film that are related to the relative phases of the scatterers in the object. Thus one converts phase information to intensity information, which can be recorded on the film. In isomorphous substitution the heavy atom acts as the reference wave.

Anomalous scattering can be thought of as a form of isomorphous substitution. One first obtains x-ray scattering data from a crystal at a wavelength far from any characteristic frequencies of the atoms in the structure. The experiment repeats the task with a wavelength close to an absorption edge of a particular atom. Consider as an example the iron atom in a hemoglobin molecule: In the second diffraction pattern, one can think of the iron atom as an isomorphous substitution (since it now scatters differently than before) and hence as a source of a reference phase. Thus one gets phase information through anomalous scattering.

If one were to consider the individual papers in *Anomalous Scattering* as potential papers for one of the standard scientific journals, it is most probable that 90% of them would not be acceptable for publication. As free-standing papers many of them appear incomplete, and many discuss work already published. For the most part the reports do not present a sufficiently clear and detailed description of the work to be of direct use to the reader. Several do not really belong in a discussion of anomalous scattering. One, for instance, on electron diffraction states at the outset that anomalous scattering, although present in electron diffraction, is a small effect compared to other dynamical diffraction effects. With this preamble, the paper goes on to discuss structure determinations by electron diffraction and ignores for the most part the entire concept of anomalous scattering.

The introduction to *Anomalous Scattering* states the goal as "a book that would be of immediate and continued value to all who measure or make use of anomalous scattering, whether in structural investigations, in solid-state physics, or in x-ray diffraction physics." I do not believe that these proceedings have attained that goal. One finds a patchwork-quilt collection of chewed-over work interspersed with some reasonably good review papers on specific topics. The subject needs a carefully orchestrated series of chapters written specifically for the purpose of reviewing a current aspect of anomalous scattering. Several papers in the book approach this goal and are useful, particularly those by the editors themselves. The paper by G. Kartha on applications to protein structure analysis is written from this point of view. A few other papers could also be considered as reviews but their scope is not very large.

The editors further state in the introduction that it is a remarkable fact that in spite of the widespread use of anomalous scattering no book has previously been written on the subject; this remarkable situation, unfortunately, remains with us. The editors have done a much better than average job of putting together proceedings of a conference. But conference proceedings do not make a treatise on a subject as specialized as anomalous scattering, and they surely do not provide a document by which a specialist in diffraction and crystallography can learn of the current advances in an important technique in crystallography. This book serves rather as a reference guide to specific papers in the field. I for one would like to see the editors initiate a true treatise on the subject by commissioning half a dozen important contributors in the field to write a well coordinated series of chapters. When one writes not only about his own work, one tends to be a better promulgator of useful information.

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Electromagnetic Excitation: Theory of Coulomb Excitation with Heavy Ions

K. Alder, A. Winther
364 pp. North-Holland, Amsterdam, 1975. $45.95

This book constitutes a classic in its field by two of the leading participants in the work. Worldwide interest in the study of heavy-ion reactions has stimulated the authors to complete their writing task begun two years ago. When one takes this book together with Larry Biedenharn and Paul Brussard's *Coulomb Excitation* (Clarendon Press, Oxford, 1965) and Kurt Alder and Aage Winther's collection of reprints with the same title (Academic Press, New York, 1966), one has the work of the masters easily accessible; this is good, because a great deal of our knowledge about nuclei comes from processes involving Coulomb excitation.

The present book limits itself to processes in which the projectile energy is well below the Coulomb barrier. The semiclassical treatment of the motion of the projectile dominates. The authors deal with the quantum-mechanical treatment in Chapter 9. Hans Uberall's *Electron Scattering from Complex Nuclei* treats excitation by high-energy muons or electrons, which are highly relativistic and penetrate the nucleus.