RECENT ADVANCES IN NUCLEAR PHYSICS

A NEW series of meetings has been inaugurated at the Royal Society at which normally three Fellows will be invited to present statements on topics of current interest. Unlike the usual meetings for the reading of papers and the discussion meetings which are held periodically, the proceedings at these new meetings will not be published and the speakers will be free to treat the subject in a broader and perhaps more speculative manner than would be the case if their words were to be printed in the Society's *Proceedings* and *Transactions*.

The subject of the first meeting, held on February 20, was "Recent Advances in Nuclear Physics". Each of the three speakers, Profs. D. H. Wilkinson, W. E. Burcham and R. E. Peierls, spoke for half an hour. They chose to discuss aspects of what is probably the most significant advance made in the past twelve years, namely, the discovery that the motions of nucleons inside a nucleus are not strongly correlated but are largely independent of each other. In nuclear structure studies discussed by Prof. Wilkinson, this phenomenon has led to the establishment of the 'nuclear shell-model', in which, as a first approximation, nucleons in a nucleus move in an overall common potential V. The counterpart of the shell-model in nuclear reaction studies is the 'optical model' described by Prof. Burcham.

Prof. Wilkinson spoke specifically on "The Structure of Light Nuclei", using the shell-model to interpret the considerable body of data that has accumulated on nuclear-level schemes, transition probabilities, and magnetic moments. In applying the model, one introduces two types of forces acting on the nucleons over and above the common potential V. The first type of force is that acting between pairs of nucleons. By direct analogy with Coulomb forces acting between pairs of electrons in an atom, these forces tend to couple the orbits of the nucleons together to produce L–S coupling. The second type is that which couples the spin of each nucleon to its orbit (like the Thomas force in the atom) and tends to produce j–j coupling. In the presence of both types of forces, the coupling situation in a nucleus is described as intermediate and is characterized by the ratio of the effective strength of the inter-nucleon forces to the spin-orbit forces. This ratio is the most significant parameter available when attempting to fit observations.

Prof. Wilkinson showed an extensive series of slides representing the work of many people and containing comparisons of experimental data on various light nuclei with the predictions of the shell-model. The agreement is impressive, especially in such cases as carbon-13 and nitrogen-13, where the observed values of five different kinds of data are fitted with the same value of the parameter. A satisfactory feature of the fits is that the 'best values' of the effective strengths of the two types of forces vary smoothly with mass numbers and are in reasonable agreement with theoretical predictions.

Prof. Burcham discussed "The Optical Model and Nuclear Reactions". The optical model attempts to incorporate features of both the 'compound nucleus' model of nuclear reactions, and the shell-model of nuclear structure. Corresponding to the latter model, the effects of a nucleus on the motion of a bombarding nucleon can be represented by a real potential V, which merely deflects it. Compound nucleus formation, which occurs as a result of a collision in which the incident nucleon loses energy to a target nucleon, may be included by adding to V an imaginary iW. In the manner well known in optics, such a term represents absorption. Small values of W correspond to small absorption, that is, there is little probability of formation of compound nuclei; large values correspond to large absorption and large probability of formation of compound nuclei; moderate values correspond to intermediate situations in which the number of nucleons passing through the nucleus compares with the number that are absorbed into the compound nucleus. For any given values of V and W, one may calculate the absorption, shape-elastic and total cross-sections, and if a spin-orbit potential is included, the polarization of elastically scattered nucleons. Comparison with observation then enables the potentials to be determined.

At low energies (less than 5 MeV.) total cross-sections for neutrons exhibit variations with energy. Peaks occur at energies corresponding to single-particle resonances in the real potential V, and the fact that such peaks are observed at all means that W must be rather small (about 2 MeV., which is much less than the value of V, ~ 40 MeV.).

Observations at higher energies up to 1,000 MeV. suggest that W increases with energy up to 100 MeV., then flattens off and increases again at energies greater than 400 MeV., where absorption due to meson production is important. In contrast, V appears to decrease steadily until it becomes zero near 350 MeV. (This may be shown directly by use of the optical theorem stating that the total cross-section is equal, apart from known constant factors, to the imaginary part of the forward-scattering amplitude. The observed values of the total and forward scattering cross-sections at 350 MeV. show that the real part, which is proportional to V, must be very small.)

The optical model has proved to be very useful for the analysis of nuclear cross-sections, just as the shell-model is useful for interpreting data on nuclear structure. For many years, it was argued that the type of nucleon motion envisaged by the shell-model is in such contrast to the strong short-range nuclear forces that the model could not possibly be valid. Acceptance of the model has come only with its convincing success in applications. Now that the applicability of the shell and optical models in practice is so well confirmed, much attention has been given to the theoretical problem of understanding why the models work. Prof. Peierls devoted his talk, "The Theoretical Basis of the Shell-Model and Optical Model", to this matter.

It appears that the basic reason why nuclear forces are not nearly as effective in nuclear matter as one might guess is the action of the Pauli Principle. A system of Fermi particles with no interactions in its lowest state has one particle in each of the single-particle momentum states up to the Fermi level. When interactions are introduced, even though they may be strong and of short range, they will not seriously modify the state, since all collisions with small momentum transfers are forbidden. Unfortunately, such an approach, using interactions containing sufficient exchange forces to produce saturation, gives too little binding-energy. The source of this discrepancy appears to be the fact that nuclear saturation arises only partly from exchange forces, another cause being the infinitely repulsive core in the nuclear interaction. The presence of this core means that shell-model wave-functions cannot possibly be correct when any two nucleons are separated by just the range of the core. Nevertheless, since the range of the core is considerably smaller than the mean inter-nucleon spacing, they are expected to be correct otherwise. Mathematical techniques have been developed for taking account of the effects of the cores in the wave-functions, and it is believed that one has, in principle, a reliable scheme for computing nuclear properties, especially binding-energies, using realistic nuclear forces. The main trouble, in practice, is the great labour involved in calculation. This reduces to reasonable magnitude only when considering large hypothetical systems in which surface effects are negligible. An important by-product of such calculations is the estimation of the nuclear potential, V, as a function of the momentum of a nucleon. This emerges in an iteration procedure in which one assumes values for V, then calculates new values and continues until convergence is obtained. It can be identified with the real part of the potential of the optical model, and so the calculations predict this quantity as well as the nuclear binding energies.

The meeting ended after the speakers answered a few questions from the audience. A. M. LANE

BIOCHEMISTRY OF GLUTATHIONE

THE Biochemical Society arranged a symposium on glutathione, organized by Dr. E. M. Crook and held on February 15 at the Senate House, University of London. As indicated by Prof. R. H. S. Thompson's opening remarks, the subject is attractive in bringing together a wide range of disciplines: purely chemical and analytical studies, plant and animal biochemistry, and pharmacology, toxicology and general biology.

The metabolism of glutathione in plants is notable, as described by Dr. L. W. Mapson (Low Temperature Research Station, Cambridge), for the well-defined systems which catalyse both oxidation and reduction at its sulphide group. Glutathione reductase has been found in most organisms in which it has been sought. More characteristic of plants than animals is dehydroascorbic acid reductase, which catalyses the interaction of reduced glutathione with the oxidized form of ascorbic acid. The reduced ascorbic acid formed can be oxidized by established routes, and about a quarter or a half the oxygen uptake of preparations of germinating pea cotyledons may proceed by this route, providing an example of the respiratory function envisaged for glutathione by Hopkins and others. However, attempts to demonstrate the generation of high-energy bonds during these changes have so far been unsuccessful.

Glutathione in Animal Tissues

In animal tissues there appears relatively little scope for this route of oxidation; but oxidation by purely chemical routes, for example, by exchange with other disulphides, can readily occur. This and other aspects of the chemistry of glutathione were surveyed by Dr. F. A. Isherwood (Low Temperature Research Station, Cambridge); thus transacylation also occurs spontaneously between the thiol group of glutathione and S-acyl compounds. Oxidation and mercaptide formation at the glutathione thiol group form the basis of two analytical methods for glutathione described in detail by Dr. C. G. Thomson (Institute of Psychiatry, London), who compared results with these methods with those obtained using glyoxalase. A considerable measure of agreement was found when these techniques were applied to blood and to cerebral tissues. Each tissue, however, presents its own problems in fixation, extraction, and the presence of substances likely to interfere in assay, as was evident also from discussion.

Reviewing glutathione in animal tissues generally, Dr. P. C. Jocelyn (University of Edinburgh) described recent studies of its synthesis. Synthesis proceeds through γ-glutamylcysteine and is catalysed by two distinct synthetases in tissues including erythrocytes and liver. In the liver, the synthesis appears to be affected by growth hormone and adrenaline; the extent to which vitamin B_{12} is involved in the maintenance was also appraised. Although glutathione has been suggested as a substrate in the further synthesis of proteins, experiments on incorporation of amino-acids into ovalbumin, and other lines of evidence, have failed to support the idea.

In neural tissues, Prof. H. McIlwain (Institute of Psychiatry, University of London) described the determination of glutathione in the brain fixed rapidly *in situ*, and its maintenance during *in vitro* experiments. Assimilation, synthesis, and breakdown of glutathione in cerebral tissues proceed at relatively slow rates, as also does its acylation. Deacylation is more rapid, especially of an acetylglycyl glutathione. Enzyme catalysis of the oxidation of glutathione has not been found, but the tissue possesses a very active glutathione reductase which forms the main route of oxidation of reduced triphosphopyridine nucleotide. This system operates at nearly maximal rate at the low concentrations of oxidized glutathione and of reduced triphosphopyridine nucleotide which are native to the tissue. Indeed, its operation would appear to be the main factor in securing the great preponderance of the reduced form of glutathione normally found *in vivo*, and to be necessary if glutathione is to perform the role so often ascribed to it, of maintaining thiol enzymes and coenzymes in their active, reduced, forms. Participation of glutathione in cerebral carbohydrate metabolism is well established, and change in level of blood glutathione has been reported to be associated with mental disease. Administration of large quantities of glutathione to