and by applying metabolic inhibitors, it was shown that movement of phosphate through the fungal layer into the host plant was probably through the living cells of the fungus, when the material was suspended in dilute solutions.

It was concluded that physiological studies on salt uptake have a contribution to make to ecology, provided that due allowance is made for the differing conditions in the laboratory and in Nature.

J. F. SUTCLIFFE

STATISTICAL MECHANICS OF TRANSPORT PROCESSES

INTERNATIONAL COLLOQUIUM

THE International Union of Pure and Applied Physics arranged a five-day conference at Brussels during August 27–31, which was attended by approximately a hundred scientists who are interested in the statistical theories of irreversible processes. Twenty years earlier, this subject would neither have been worth a conference on its own nor would it have been accredited the title of 'statistical mechanics', which was reserved for the theory of equilibrium. The new name and the attendance of the conference are indications of the progress made within two decades.

The foremost subject of the conference was the problem of reconciling macroscopic irreversibility with the reversible character of molecular mechanics, Newtonian or quantal. The problem is old and its discussion earlier than 1910 is summarized in the famous article by P. and T. Ehrenfest which is even now not out of date. The discussion has only recently gained in importance after the theory of transport processes had increased its scope of validity. In technical terms, the problem put before the conference has the form of deducing the collision equation of Maxwell and Boltzmann or its quantum-mechanical analogue from the Liouville equation or the principles of quantum mechanics, respectively. In considering this subject it was assumed that both, premises and conclusion, are well established, but that the intermediate steps of the deduction are in need of clarification.

It was generally agreed that the validity of the Boltzmann equation depends upon some kind of coarse graining of the distribution in full-phase space. There was, however, no agreement with respect to the method of coarse graining. It was argued that irreversibility is the result of time-smoothing of phase-space distributions and that this process of time-smoothing can and should also be applied in the quantum mechanical theory. An alternative (not necessarily contradictory) view was put forward, according to which irreversibility arises asymptotically in the limit of 'large' time-intervals after motion started from well-defined initial conditions. These are by no means the only current views on the nature of irreversibility; but they can claim the best foundation in molecular dynamics.

It would appear that the main progress in this old discussion consists in replacing guesswork by hard-and-fast mathematical results. It was emphasized in the discussion—very much to the surprise of part of the assembly—that irreversibility is, by necessity, limited to the time interval between two characteristic times, that is, the molecular relaxation or correlation time and the period of a Poincaré cycle.

In the quantum mechanical theory, interest was primarily concentrated on the assumption of 'randomness' which has to be made in the course of the deduction. Whereas previously this assumption was, without questioning, interpreted as the necessity of taking an average with respect to the phases of the wave functions at all times, a somewhat more critical attitude emerged in recent years. In the conference it was shown that the phase-averaging can be avoided and that there are various different ways of deducing irreversibility in statistical quantum mechanics.

Another subject on the agenda concerned the fundamental theory of those transport processes—in particular processes in liquids and solids—to which the Boltzmann equation cannot be applied. Contributions to this subject were—by its nature—less systematic and of greater originality and perhaps of greater importance for future research. To mention an example, the use in this field of electronic computation was shown; it is employed for solving a cumbersome problem in the dynamics of molecules but assumes peculiar significance as standing halfway between theory and experiment. Whereas measurements of transport coefficients reveal only an average over a large number of samples, the electronic computer produces the samples themselves and shows how their fluctuating properties are smoothed out with increasing numbers.

As another example, the use of elastic rigid spheres as models for molecules should be mentioned. This is apparently a somewhat trivial matter. It was, however, shown that the mathematics of this model have some entirely unexpected features and are likely to be of importance in handling more realistic models of molecules.

Apart from the basis of the theories, the conference had obviously to deal with their application to specific phenomena. So far as transport processes in gases are concerned, this requires appropriate solutions of the Boltzmann equation. A number of papers were read showing that these solutions are not obtained by routine procedures but by careful mathematics and plenty of physical intuition. A wide variety of systems other than gases were considered; contributions included thermal conduction in solids and liquids, relaxation of molecular oscillations, transport of charge and energy by electrons in metals, transport processes in liquid helium, viscosity of electrolytes, fission of uranium and, in some detail, the statistical hydrodynamics of turbulent flow. In these talks and discussions the progress in the theory of irreversibility was demonstrated beyond doubt.

Apart from transport processes, the modern theory of irreversibility is concerned with the extension of thermodynamics to non-equilibrium conditions. During the conference plenty of time and attention were given to the principle of minimum entropy production, which has been widely discussed and would, if fully established, have a wide range of applicability. So far, the significance of this principle has not yet been clarified. Some of the speakers presented deductions of the principle depending upon clear-cut premises; on the other hand, instances were produced in which the principle is not strictly valid. Various alternative aspects of off-equilibrium thermodynamics were presented. Conclusive new results were not offered; but there is increasing

interest in the subject. Finally, a fair number of experimental papers were read, largely concerning measurements of the diffusion coefficient or thermal diffusion ratio of mixtures.

This colloquium differed in various respects from meetings of a similar kind. One of its characteristics was the interest shown in the consistency rather than in the result of deductions, an attitude frequently dismissed as 'academic'. Speakers were unanimous in their attempts at clarifying the assumptions underlying their own and other speakers' arguments, concentrating on the physical aspects of the problem and avoiding any form of mathematical pedantry. This again is an exceptional attitude, since there is a widespread habit of adorning dubious physical assumptions with a wealth of good mathematics.

Time provided for discussions was ample ; speakers could state their case without any fear of being cut short by a harassed chairman. Discussions were conducted as a free exchange of views, not necessarily perfect views, and without the purpose of scoring debating points. As a consequence, subjects of interest were talked over in their widest aspects and by a large number of speakers, conveying thorough clarification and stimulating ideas to the listeners.

The theory of transport processes emerges from this colloquium as a new branch of statistical mechanics which should have a status comparable with equilibrium theory.

This new branch has to a considerable extent been initiated by the work of H. Falkenhagen, J. G. Kirkwood, L. Onsager, G. Uhlenbeck and J. Yvon, who were among the distinguished visitors attending the colloquium. Its success was largely due to Prof. I. Prigogine, partly in his capacity as organizer and even more by the contributions made by him and his school. Thanks are due to the Université Libre de Bruxelles for hospitality and to the American Air Force for generous help. R. Eisenschitz

CHEMICAL ENGINEERING IN THE COAL INDUSTRY

CONFERENCE AT THE COAL RESEARCH ESTABLISHMENT, NATIONAL COAL BOARD

THROUGHOUT the world there has been a renaissance in the application of scientific methods to coal and its treatment. This is not the result of a desire for science for its own sake; but is directly connected with the world-wide problems of energy supply and resources.

A notable feature of this new research work is the increasing application to the coal industry of new chemical engineering techniques developed by other progressive industries. The time seemed ripe, therefore, to bring together the research workers in different countries, from industrial and university laboratories, interested in this new outlook on coal.

An international conference on "Chemical Engineering in the Coal Industry" was therefore organized by the Coal Research Establishment at Stoke Orchard of the National Coal Board. It was held during June 26–29, and was attended by a hundred representatives from Britain and overseas.

Mr. A. H. A. Wynn (scientific member, National Coal Board) in his address of welcome to the delegates, pointed to the fact that all estimates of energy requirements, including those of the U.S.S.R., indicate that the economy of almost every country over at least the next twenty or thirty years will depend fundamentally on the prosperity and technical progress of the coal industry. Mr. Wynn underlined the great variety of coals produced in Britain and the different end-uses to which they are put. It is in the subject of efficient use, particularly of those coals not of the highest quality, that the chemical engineer can play an important part. Some of the economic problems of Western Europe, in his opinion, arise from the insufficient application of modern science to the basic industries.

Three chief problems were considered at the conference : the modification of coal to render it suitable for subsequent processing ; the briquetting of coal ; and the treatment of by-products resulting from new processes. A remarkable feature of the conference was that, although all the countries represented are interested in these three subjects, their interests are to a large extent directed towards different objectives. Whereas the aim in Great Britain is the production of efficient, solid smokeless fuels, in France the aim is the improvement of metallurgical coke. For both purposes, however, the carbonization of high-volatile coals in fluidized beds shows much promise. Again, there is a parallel of interests in Great Britain and Germany in the production of carbonized briquettes from those coals which are not normally considered suitable for carbonization by traditional methods. In Britain the objective is again the production of smokeless fuels ; but Germany considers the process to be promising as a method of producing regular-sized hard coke for metallurgical purposes.

The conference was organized into four technical sessions, which reviewed the following topics : (*a*) the modification of coal properties by oxidation ; (*b*) the briquetting of small coal ; (*c*) the carbonization of powdered coal in fluid beds ; and (*d*) the utilization of the by-products from new carbonizing processes. Papers were presented on both fundamental and technical aspects of these subjects.

Modification of Coal Properties by Oxidation

A paper entitled "The Controlled Oxidation of Coal", which was presented by M. A. F. Boyer (Centre d'Études et Recherches des Charbonnages de France), described some recent work on the rates of oxidation, the activation energies involved, and the depth of penetration of the oxidation reaction into coal particles.

In the production of carbonized briquettes, marked fusion and swelling of the coal is disadvantageous ; but these characteristics may be modified or destroyed by a number of methods, principal among which is oxidation. The addition of as little as 1 per cent of oxygen, for example, to the coal can eliminate these adverse effects. However, the fundamental changes which occur on oxidation, particularly the mechanisms of the chemical changes, are as yet not understood. Dr. D. W. Gillings (formerly of the Coal Research Establishment, National Coal Board) pointed out that one effect of oxidation is to decrease the plasticity of the coal. M. Boyer believes this to be an unimportant effect, and considers that the important effect of oxidation is to change the shrinkage characteristics of the coal on carbonization. Dr. J. Bronowski (Coal Research Establishment)