radicals are not too dissimilar from those in non-aqueous media and are quite independent of those of any longer-lived radicals in suspended polymer particles.

Full characterization of a solution of a polymer requires a knowledge of the structure, sizes and shapes of all the polymer molecules present and of its equilibrium properties as manifested in partial molal values of thermodynamic functions of solvent and solute. Many of the papers were concerned with this topic in one or other form. One, by Drs. W. H. Beattie and J. T. Bailey, was a timely cautionary reminder, generally acknowledged, of the need for a sharpening of our perception of the significance of the number, weight, Z and $Z + 1$ averages obtained from light scattering. Another, by Dr. W. Cooper and his associates of the Dunlop Rubber Co., Ltd., showed that second-order virial coefficients obtained from light scattering measurements on polybutadiene are strongly dependent on chain branching and revealed that the branch points are preferentially susceptible to mechanical breakdown. One of the most exciting contributions was that in which Prof. W. Heller of Wayne State University described his attempts to "walk around" macromolecular particles oriented in a streaming solution by observing the light which they scatter when illuminated from chosen directions. Already this fascinating but technically very difficult approach has not only indicated the shape of rigid particles but has also given insight into molecular elasticity by providing indications of the change of shape of flexible coiled macromolecules under the influence of shearing forces. If this method could possibly be extended to the use of polarized light an immensely powerful tool would become available. A further paper on polymer solutions by Dr. B. E. Conway dealt with the thermodynamics of the polar system polyoxypropylene glycol in methanol. The decrease in hydroxyl content with increase in molecular weight of the polyoxypropylene glycol leads to a change of sign in the heat of mixing; the experimental entropies and free energies of mixing can be accounted for by the Münster theory, which takes into account specific solvent orientation effects.

A number of the authors described the application of new experimental techniques to the solution of polymer problems. Dr. L. A. McLeod has fractionated elastomers such as *cis*-1,4-polybutadiene using elution chromatography, and Dr. Bacon Ke showed that differential thermal analysis is not only useful in determining transition temperatures and heats of fusion of simple polyamides but may also give information concerning the structures of copolymers. Dr. W. Prins described a versatile osmometer which is capable, among other things, of measuring the de-swelling of polyelectrolyte gels. In this application the gel and solvent are separated by a porous stainless steel disk of porosity 5–65μ, and the change in gel volume is measured when pressures of up to 200 atmospheres are applied to the gel phase.

Some interesting developments in the field of new polymers and copolymers were described. The strong and highly extensible elastomers produced by the incorporation of 2,4-toluene diamine in copolymers of polyoxypropylene glycol and 2,4-toluene di*iso*cyanate were discussed by A. J. Havlik of the California Institute of Technology. Poly (5-methyl, 3-vinyl, oxazolidine-2-one), of which the surprising properties in water were reported by W. E. Walles at the ninth Forum, forms strong complexes with a wide variety of organic compounds. The complex with phenol in which one phenol molecule may be bound per monomer unit in the polymer owes its strength to hydrogen bonding, but more unusual are the fairly strong complexes of the polyoxazolidinone with methyl bromide and bromine.

It is a tradition of these meetings to have a guest speaker who delivers the Conference lecture. This year the speaker was Prof. F. S. Dainton and his topic was "Why Polymerization Occurs". The central theme was that addition polymerization, which is usually regarded only from the point of view of the kineticist, is merely the aggregation of freely translating monomer molecules into larger molecules in which the basic units are joined by primary chemical valencies. Except in the nature and strength of the inter-unit linkage it is thus entirely analogous to physical aggregation processes such as condensation and crystallization and like these can be examined thermodynamically. The now familiar[2] notions of 'ceiling' and 'floor' temperatures, monomer–polymer equilibria and metastability phenomena were treated by the lecturer in relation to a wide range of systems. Recent calorimetric values of heats of polymerization and the entropies of polymers were used to illustrate the large effects on the heats and the minor effects on the entropies of polymerization of certain structural groupings in the monomer.

F. S. DAINTON
K. E. RUSSELL

[1] *Nature*, **184**, 835 (1959); **186**, 283 (1960).
[2] See Dainton, F. S., and Ivin, K. J., *Quart. Rev.*, **12**, 61 (1958).

PHILOSOPHY OF SCIENCE

THE British Society for the Philosophy of Science held its fifth annual conference at Wills Hall, University of Bristol, during September 23–25. The four formal meetings and discussions, organized by Dr. Mary Hesse (Cambridge), were attended by fifty members and guests.

At the first meeting, with Prof. H. Heilbronn (Bristol) in the chair, two papers on the relation between pure and applied mathematics were read. Accepting the views of Frege, Cantor and others that the concepts of pure mathematics are exact, and of Waismann and others that empirical concepts are inexact, Prof. S. Körner (Bristol) introduced a new generalized logic which embraced relations not only between exact concepts but also between inexact concepts and between exact and inexact concepts. He showed that 'purely exact' and 'internally inexact' concepts, as he defined them, could be identified with pure mathematical and empirical concepts respectively, and that they were logically unconnected. He thus described the application of mathematics as a threefold process: inexact empirical concepts are

replaced by exact concepts, exact conclusions are then deduced and, finally, the exact mathematical concepts are replaced by empirical concepts.

Prof. R. L. Goodstein (Leicester) traced the evolution of formal systems, using the development of geometry, mechanics and arithmetic to exemplify his thesis. The stages of evolution were successively the formulation and application of rules, the discovery of relations between rules and development of the concept of proof, the analysis of the rules of proof (metamathematics) and, finally, formal codification of metamathematics. He concluded that in applying mathematics we retrace its evolutionary development, replacing theorems by statements of observation. A mathematical proposition thus has a dual role. The ensuing lively discussion centred on the part to be taken by Körner's generalized logic in clarifying the problem, and on the strangeness of the fact that the exact concepts of pure mathematics could sometimes be successfully applied to the 'open-textured' concepts of empirical science.

Echoes of this first discussion were heard next morning when the theme was the relation between universality and necessity. Mr. W. C. Kneale (Exeter College, Oxford) gave a critical historical review of the question whether necessity can be defined by reference to universality. He traced three attempts at such definition: that, derived from Hume, in which necessity appears as a by-product of arguments the major premises of which are universal statements about Nature; that, derived from Bolzano and recently revived by Tarski, in which necessity is based on the universal validity of patterns of argument in which the only essential words are logical; and that, propounded by Popper in an appendix to "The Logic of Scientific Discovery", in which a Leibnizian reference to possible worlds seems to be related to a modified Bolzano–Tarski theory. Having explained the difficulties he found in all these reductionist programmes, Kneale advanced his own views that formal logic is pure theory of necessitation, that necessity is a fundamental notion, and that (with Wittgenstein) "all necessity is logical".

The second paper was given by Dr. I. Lakatos (London School of Economics), who first analysed the differences between the arguments of Popper and Kneale on both the ontological and epistemological planes. His witty theological formulation of the controversy, in which he sided more with Popper than with Kneale, included the startling credo that "the natural laws uttered by God were of infinite length" (and that therefore all universal statements, whether contingent or necessary, are false) and then he summarily dismissed the controversy as metaphysical and therefore meaningless. As a fallibilist, not only in science but also in logic and mathematics also, he could only regard both Popper and Kneale as mistaken in their "epistemological optimism", different though the forms of their optimism might be.

The chairman, Mr. J. W. N. Watkins (London School of Economics), then offered for discussion a model neatly designed to emphasize the conflicting views that had been propounded. In discussion, attempts were made to clarify the relation between logical and physical necessity. Do they form a linear continuum? Or are they homogeneous? But before complete clarification had been achieved, Dr. Lakatos silenced all further discussion by proving that any proof refutes the proposition it proves!

After strenuous discussion of closely knit philosophical arguments, the members turned with relief and pleasure to view the intriguing optical devices used by Mrs. M. L. J. Abercrombie (Guy's Hospital) to illustrate her paper on learning to perceive. The chairman was Prof. J. E. Harris (Bristol). Mrs. Abercrombie explained that perception is a process of interaction between the observer's sensory input and his store of previously acquired information. In this interaction only parts of the total information available are used by the observer, selection being made both from the field observed (clues) and from the store (schemata). The observer makes a guess about what he perceives, acts on his guess and modifies it as other clues and other relevant schemata interact. She described how training to improve perception is possible by reference to her recent experiments in training medical students to improve their skill in diagnosis.

The second paper was given by Dr. M. H. Pirenne (Oxford), who described his experiments to determine the threshold intensity of light visible to the human eye. The physical and psychological factors impeding exact measurements were explained. The subject's eye had to be fixed and adapted to darkness; the subject had to be willing to co-operate and to be trained and tested for reliability. Difficulties were caused by day-to-day variation of response and by the phenomenon of 'subjective light'. There was not a sharp transition from visibility to invisibility as the energy of a light-flash was decreased, and the threshold was defined by an arbitrary statistical measure in the range of critical intensities. His results showed that the human eye could detect flashes of about 100 quanta in the narrow band of blue-green wave-lengths to which the periphery of the retina was most sensitive. Of these 100 quanta in the light-flash, only about 10 reached the retina and were there distributed among about 500 rods.

Discussion of these two papers was divided between questions of methodology and the implications of the empirical observations reported on current theories of perception. There seemed to be little evidence of, or need for, the pure sense-datum required in some theories.

At the final meeting, with Prof. M. H. L. Pryce in the chair, two theoretical physicists discussed the relation between methods of investigation and the characteristics of physical laws. In the first paper, Dr. D. Bohm (Bristol) criticized current views of the role of hypotheses in science. Implicit in Popper's view that scientific hypotheses could only be falsified was the assumption that questions giving answers in the form 'yes' or 'no' could always be put to Nature. But at the boundary of new scientific domains we knew the relevant questions only when the answers were already known. He also criticized the emphasis given to prediction and retrodiction in accounts of scientific method and expressed dismay at the degree of specialization enforced on scientists by the overwhelming mass of data which confronts them. It was important to establish a sound natural philosophy if the full potential of scientific method was to be realized.

The second paper, by Dr. P. W. Higgs (University College, London), reviewed the present untidy field of particle physics and discussed some of the implicit assumptions in this field that theoretical physicists were beginning to question. In particular, the effect of the gravitational field, hitherto regarded as negligible in strength compared with the other fields of particle interaction, seemed to deserve more careful exploration. In the discussion the main points were about the nature of the possible alterna-

tives to prediction and retrodiction as tests of the 'fitness' of hypotheses. What forms could 'diction' take? In what sense were the micro-particles of physics to be regarded as 'ultimate' or 'fundamental'? What exactly was meant by saying that one science or one branch of a science was 'reducible' to another? These were some of the many questions raised and left not wholly answered.

The Vice-Chancellor of the University of Bristol kindly invited the members to a sherry party at Wills Hall on the Saturday evening. Thereafter, small informal groups, oblivious to everything except their own intense discussion, seemed to be generated spontaneously in all the many pleasant corners of Wills Hall and its gardens. At the conclusion of a stimulating week-end, expressions of thanks to the hosts at the University of Bristol, to the staff of Wills Hall and to the organizing secretary were more than mere formalities.

B. C. Brookes

THE NATIONAL RESEARCH COUNCIL OF CANADA

THE forty-third annual report of the National Research Council of Canada, covering the year 1959–60, includes besides the report of the president, Dr. E. W. R. Steacie, of the nine divisions, two regional laboratories and the National Aeronautical Establishment and the financial statement, the annual report of Canadian Patents and Development, Ltd.*.

During the year the Council provided 8·7 million dollars in support of pure research in the universities, compared with 6·3 million dollars in 1958–59, of which 84 per cent was for 875 research grants and the remainder for 425 postgraduate scholarships, fellowships and associateships. The Council's scientific research staff of 658 included 137 postdoctorate Fellows, and in addition 916 technical personnel and 866 general service and administrative staff were employed. Claiming that neither the United States nor the United Kingdom possesses the clear but flexible delineation of administrative authority for science that exists in Canada, Dr. Steacie suggests that in Canada the responsibilities of the Minister for Science are constitutionally exercised by the chairman of the Privy Council Committee on Scientific and Industrial Research, and that in this respect Canada is forty years ahead of the United Kingdom. The problem in Canada is to ensure that scientific activities are so organized as to encourage the full development of the scientific and technical resources of the country. The first responsibility of a national science policy must be support of research in the universities, and the problem is how to maintain the strength and depth of the university science departments and, at the same time, satisfy the requirements of defence, industry and development of national resources with the vigour and competence demanded by international competition, without over-emphasizing technology at the expense of other activities. Dr. Steacie, noting that the Research Council has proved in the past to be an effective channel for supporting science in the universities, urges the need for a continual review of the support of science in the universities to ensure that procedures continue to evolve with the growth of science and changes in administrative practice. Further, while in Canada those departments of Government with administrative responsibilities for natural resources are responsible for the basic research to support their programmes, the Research Council has the function of ensuring the general adequacy of all remaining basic research, but Dr. Steacie stresses the importance of backing Canadian industry by an industrial research effort as great as the scientific resources of the country can support.

Of the work of the Division of Applied Biology, the report notes a co-operative project with the Department of Agriculture on the design and performance of jacketed cold-storage rooms requiring fundamental knowledge of the factors determining low-velocity airflow through shallow ducts, and a study by the Biometrics Section of agricultural meteorology as an extension of the statistical study of protein variability in wheat and wheat exports. Preparations were begun, including design of equipment, for an international expedition to study adaptation to cold by Eskimos. The work of the Division of Applied Chemistry on metals has gradually expanded during recent years, and now includes investigations of the effect of composition and structure on the optical and magnetic properties of a wide variety of alloys. A new technique, developed by the Division about eight years ago for the contacting of fluids and solids, has now been put into commercial operation in grain drying. The Division of Pure Chemistry has shown that ionization potentials of radicals prepared by pyrolytic reactions can be measured by electron impact in the mass spectrometer, and a study of the diffusion of chloride ions in single crystals of sodium chloride and of potassium chloride has shown that the diffusion is very sensitive to the presence of gross imperfections such as dislocations and grain boundaries in the crystals, while attempts to correlate the accumulated observations in the photo-oxidation of ketones have led to the conclusion that not only the rate but also the nature of the products of the reactions of methyl radicals with oxygen depend on the total pressure in the system as well as the presence of molecules containing easily abstractable hydrogen.

In the Division of Applied Physics a new group has been established for plasma research, work was completed in the interferometry laboratory which contributed to an international agreement to base the unit of length, the international metre, on a particular wave-length of the spectrum of an isotope of krypton, and the experiment to determine g, the acceleration due to gravity, by direct observations on a falling body was completed. The group in the Division of Pure Physics concerned with cosmic ray work is still devoting much of its efforts to international co-operation of the type started during the International Geophysical Year, and the development of a space research programme in Canada has permitted cosmic ray measurements with rockets flown to high altitudes. In the X-ray diffraction laboratory

* Forty-third Annual Report of the National Research Council of Canada, 1959–60, including the Annual Report of Canadian Patents and Development, Limited. (N.R.C. No. 5665.) Pp. 40. (Ottawa: Queen's Printer, 1960.)