interest in teaching in modern departments of chemistry.

The proposal to have a final 'applied' year for an honours degree was rejected by the university representatives. They pointed out that students should study a full applied or a full academic course. Doubt was expressed about the intellectual content of the proposed applied year. A man taking it would be committed to applied chemistry as a career and would lose the freedom of choice that an honours graduate now received from his all-round basic training in chemistry. Further, the normal final year is essential to round off the work of the previous years. The present course is not too long by comparison with continental practice or with that of twenty years ago when there was so much less ground to be covered.

For the rest, the conference discussed with rather less tension a number of topics of interest, among them the teaching of science in schools. The point was made that so far as possible modern knowledge should be fed back to school classes and an effort made to introduce electronic theory at an early stage. Generally the lack of trained laboratory technicians was a stumbling block alike to the efficient presentation of chemistry and to the recruitment of teachers. Otherwise there was an optimistic note about science teaching in boys' schools. The position in girls' schools left more to be desired. Stress was laid on the possibility of increasing the supply of chemists by a wider recruitment of women. However, it was mentioned that their susceptibility to matrimony involves their frequent untimely removal from the profession.

Mathematics and physics were regarded as first-choice ancillary subjects for the chemistry degree. But most of all the necessity for a thorough grounding in the English language was stressed. Precision and clarity so essential in discussing science depend on skill in manipulating language. The ability to think is largely dependent on the ability to use language. It was not thought that with the present overloading of the courses in chemistry the student could find much time for the study of cultural subjects. These must be left to his home and school environment.

The importance of technical colleges in training a large number of students who otherwise would have no opportunity of receiving professional qualifications in chemistry was recognized. There was support for the view that it is wasteful for a young student of ability to have to undertake a chemical education solely through evening classes. Transfer to full-time or sandwich courses was recommended. It appeared, however, that it is often more awkward for chemical than for engineering firms to fit in with sandwich courses. The difficulties of students from technical colleges who frequently have to sit externally assessed examinations, such as those of the Royal Institute of Chemistry, with no published syllabus was mentioned. Both teachers and students should have a reasonably precise statement of the course to be covered and should not have to depend on previous papers.

To return to the main issue, the impression gained was that some industrialists resemble patients, who could not care less whether their doctor has studied the premedical and preclinical sciences, if he can treat the common diseases and recognize an acute state needing hospitalization. Similarly, the employers require their chemists to have merely the theoretical knowledge and practical skill adequate to the duties assigned. It matters little if a professional chemical employee cannot recognize a lone pair of electrons if he sees one, or thinks an axial bond relates to pre-war diplomacy—provided his duties do not require a knowledge of these concepts. In this respect the industrialists follow the great Locke, who wrote in 1693: "Could it be believed . . . that a child should be forced to learn the rudiments of a language, which he is never to use in the course of life that he is designed to, and neglect all the while the writing of a good hand, and casting of accounts". The universities, of course, hold with Newman that science should be studied as a discipline and that general culture of the mind is the best aid to professional and scientific study. They reject the criterion that utility should be the basis of what is taught. They do not seek to train students to be professional practitioners, but rather to educate them so that eventually they become professional men of full stature. How to continue to accomplish these aims and also to modify the courses to satisfy the employers, if indeed this is desirable, remains for the future to solve.

T. S. WHEELER

PHYSICS OF LIQUID HELIUM

ORAL discussion between scientists who are unable to visit each other easily is commonly brought about by means of large-scale conferences. In the case of low-temperature physics, for example, international conferences are held at two-yearly intervals. They are attended by perhaps two hundred and fifty people and usually cover about eight more or less separate subjects. The high cost of travel to foreign countries, and the limited size of the conferences compared with the number of people actually engaged in the work, make it difficult or impossible for a young research worker to attend these meetings except when they take place in his own country. Moreover, when he is able to attend, he finds the atmosphere generally formal and indeed on occasion somewhat competitive, and the amount of time available for discussion is in any event strictly limited.

The Low Temperature Committee of the Physical Society, under the chairmanship of Dr. K. Mendelssohn, therefore considered that there is a place for occasional smaller meetings, in which it would be possible for young research workers as well as others directly interested to discuss informally the subject of their research. In order to provide for this, a series of one-day discussion meetings has been initiated, the first of which, on the subject of liquid helium, was held on November 2 at the Institute of Physics, and attended by about forty people. While it was not intended that the meeting should be an international one, it was thought that the discussion would benefit from a report on recent work in Leyden, and an invitation was sent to one research worker from the Kamerlingh Onnes Laboratory. The principal aim of the meeting was to allow adequate time for discussion of the work: the contributors were therefore asked to restrict the length of their papers to about ten minutes, and a rather longer time than this was allowed for discussion of each paper.

With a meeting of this kind, which is intended to be informal, it is neither possible nor desirable to make a full record of the individual contributions to the discussion. In the following report I have therefore summarized as completely as space allows the main points brought out in papers and discussions together, without attempting to separate the two. I have been greatly assisted in writing this by Dr. E. Mendoza and Messrs. L. J. Challis, L. Grimes, M. J. White and R. W. Whitworth, who made notes of the proceedings.

The opening of the meeting was overshadowed by the very recent death of Sir Francis Simon. A tribute was paid to him by Dr. K. Mendelssohn, who has been associated with him for thirty years, and the meeting stood for a few moments in silence in his memory.

In the first paper, Mr. O. V. Lounasmaa (Oxford, on leave from Turku University, Finland) described recent measurements of the specific heat of liquid helium, carried out at Oxford in collaboration with Dr. R. W. Hill. These experiments, which cover the range from 1·8° K. to the critical point under the saturation vapour pressure, are particularly interesting for two reasons. In the first place, the measurements below the lambda-point finally resolve the discrepancy which has existed for some time between earlier results obtained in Oxford and in Leyden, since they agree closely with the Leyden results. It is unfortunate that the reason for the error in the earlier Oxford results is unknown, since it is still impossible to assess with certainty any error which may be present in the results at higher densities which were obtained at the same time. In the second place, the specific heat above the lambda-point is now known with much more accuracy than hitherto. This is especially important in view of the present discussions on the helium temperature scales, since the scale of van Dijk and Durieux makes use of these data. The new results agree fairly well with the previously available data of Keesom and Clusius, and so it is not to be expected that any great change will ensue in this scale; but the considerably increased accuracy and number of the measurements will give more certainty than it possessed before, and make possible a more realistic comparison with the American experimental scale.

Observations on the osmotic pressure of helium-3/helium-4 mixtures were discussed in contributions from Dr. H. London (Atomic Energy Research Establishment, Harwell) and Mr. Wansink (Kamerlingh Onnes Laboratory, Leyden). In Dr. London's experiments, which were performed with Dr. E. Mendoza (H. H. Wills Physical Laboratory, Bristol), a helium-3/helium-4 solution is made to communicate with pure liquid helium-4 through a superleak, and the temperatures of the two liquids adjusted until their fountain pressures balance, with no net flow of liquid through the superleak. The difference between the measured fountain pressure and the fountain pressure of pure helium-4 (calculated from the temperature difference across the superleak) gives the osmotic pressure of helium-3. At helium-3 concentrations X from 0·019 to 0·023, and for temperatures between 1·0° K. and 1·7° K., the osmotic pressure is found to have approximately the value one would expect for helium-3 in perfect solution, namely, $\pi = -\frac{RT}{V_{\text{mol.}}}\ln[(1-X)f_4]$ with the activity coefficient f_4, which indicates departure from ideality, equal to unity. At higher concentrations of 0·14–0·16, the osmotic pressure is less than this, so that $f_4 > 1$; but the results are not yet accurate enough to give more detail. These experiments extend the temperature range of some measurements already made in Leyden, using a similar technique, and Mr. Wansink described further results which again follow the same equation with $f_4 > 1$. Values of f_4 can also be calculated from the vapour pressure, and in this way a corrected vapour pressure versus concentration relation has been constructed at 1·2° K., replacing previous unreliable results. Some discussion took place concerning the possibility of cavitation in the slit due to complete sucking out of the liquid to the warmer side, which was encountered in London's experiments, but apparently not in Leyden. It was suggested that this might be due to a slightly different experimental arrangement, but no satisfactory reason emerged.

Theoretical contributions to the meeting were made by Mr. H. N. V. Temperley (Atomic Weapons Research Establishment, Aldermaston), Dr. R. K. Eisenschitz (Queen Mary College, London) and Dr. C. G. Kuper (St. Andrews). Mr. Temperley discussed recent treatments of liquid helium based directly on the many-atom Hamiltonian. He began by reviewing the considerable achievements of the two-fluid picture which, although in the first place a purely phenomenological model, was later shown to follow from an energy spectrum involving two kinds of excitations. Landau was led to such an energy spectrum, which could also correlate certain other phenomena in helium-3 and helium-4, through the quantization of the equations of hydrodynamics, but it is uncertain whether this is consistent with the Hamiltonian. More recently, attempts have been made to derive the two-fold spectrum directly from the Hamiltonian, either by means of a transformation of wave-functions (Bijl, Feynman) or of co-ordinates; in the latter case one can use either a solid-like approach (Debye–Peierls) or a plasma-like approach (Bohm–Pines, Tomonaga, Zubarev, Brenig, Bogolyubov and others). In all cases the difficulty is to ensure that the correct boundary conditions are obeyed. Dr. R. Eisenschitz dealt with various aspects of the phonon representation as put forward by Zubarev and Bogolyubov, and having applied this representation to the flow of momentum and energy as derived from the principles of quantum mechanics, concluded that the naïve picture of phonons carrying momentum and energy is of limited validity. A more stringent test of the theory could be made by evaluating the Russian authors' expression for the velocity of sound; so far, only an elementary estimate of its upper limit has been made, but more accurate calculations are in progress.

The possible importance of surface excitations in determining the behaviour of helium II was pointed out by Dr. Kuper. Landau showed that a massive body moving in liquid helium II at less than a certain velocity could not create excitations and so would suffer no retardation. Considering only volume excitations (phonons and rotons), these critical velocities were estimated to be of the order of 10^4 cm./sec., whereas experimentally they are found to be only a few centimetres per second. For a surface wave on a deep liquid, on the other hand, the critical velocity for the creation of 'ripplons' turns out to be about 10 cm./sec., and although in the bulk liquid the small values of critical velocity are probably due to the effect suggested by Feynman —the creation of vortex lines—these surface excitations might be the determining factor in the case of the film. One might also expect them to form an appreciable part of the normal fluid in the unsaturated film, thus lowering its temperature of onset of superfluidity, as observed. However, this lowering of the onset of superfluidity is also found in the flow of 'bulk' liquid helium through channels narrower than the film thickness, and it is not clear how the theory would apply in this case where there is no free surface. Experiments on the flow of helium through such narrow channels were actually described later in the day by Mr. D. C. Champeney (Clarendon Laboratory, Oxford). The average width of the channels was about 50 A. (that is, approximately half the saturated film thickness), and the onset temperature agreed with the value for an unsaturated film of this thickness. An appreciable flow of liquid was found even above the depressed onset temperature, with no significant change at the normal lambda-point, the flow being proportional to the square root of the pressure head, that is, corresponding to turbulent flow in a classical liquid. In passing through the onset temperature, the flow-rate increased by a factor of more than 20,000 within 0·2 deg. K., and was still strongly dependent on pressure. With experiments such as these, the possibility occurs of dependence upon pressure in superflow due to the heat developed in the reservoir by the mechano-caloric effect. It seems that this possibility has been eliminated, since the deliberate introduction of additional heating makes no significant difference to the dependence on pressure.

During the past few years, much research has been done in Bristol on the formation and properties of the helium film, using the now well-known optical technique. The investigations there, as in other laboratories, have been mainly directed to deciding whether the film is formed by purely van der Waals adsorption or is due to some quantum mechanism. The purpose of the latest work, described by Dr. L. C. Jackson, is to see if the film formed from the saturated vapour has the same thickness and profile as when it is in contact with the liquid. The main problem in this experiment is to mount the mirror on which the film is formed in such a way that it receives no extraneous heat input which might evaporate the film, without contact with the liquid. This is solved in an ingenious way, by floating a magnet above a superconducting lead cup in the manner first described by Arkadiev, and suspending the mirror from the magnet by a fine thread. The method works surprisingly well, and there is a quite sufficient degree of stability. The results are so far only preliminary, but the thickness and profile of the film seem to be very similar to those when it is in contact with liquid.

Considerable progress towards the understanding of liquid helium has lately been made through Landau's theory of excitations and the Onsager–Feynman theory of quantized vortex lines, and the remaining papers presented to the meeting dealt with further experiments which could be described in terms of these theories. By consideration of the relaxation processes occurring in a phonon–roton gas, Landau and Khalatnikov have worked out theories of the absorption of sound, and of the normal fluid viscosity of liquid helium. Additional evidence of the essential correctness of these theories was presented by Dr. K. Dransfeld and Mr. D. O. Edwards (both of the Clarendon Laboratory, Oxford). The absorption of sound has been measured by Dransfeld, Newell and Wilks as a function of temperature, pressure and frequency. As the temperature is reduced from 2° K., the absorption rises to a maximum at about 0·9° K. and then falls off quite quickly. Above the maximum, the absorption is mainly due to Khalatnikov's process of second viscosity, whereas below the maximum this effect is negligible, the absorption being determined principally by heat conduction, which is dominant at the lower temperatures because of the long phonon mean free path. At the maximum itself both processes contribute in a complex manner, and it is difficult to decide the magnitude of each; but the variation of the height and position of the maximum with pressure and frequency agree qualitatively with Khalatnikov's theory. Extremely good agreement between experiment and the theory of Landau and Khalatnikov is also found in the viscosity experiments described by Edwards. These measurements are made not by the rotating cylinder method, but by measuring the sub-critical heat conduction in capillary tubes, which also yields the normal component viscosity. Values of the viscosity for tubes of diameter 0·05 mm. and 0·1 mm. suggest that it is necessary to make corrections for a phonon mean free path effect, and when this is done the results for both tubes fall on one curve, giving to within a few per cent the dependence on temperature predicted by theory between 1·15° K. and 1·7° K. The measurements agree very well in magnitude with rotating-cylinder viscometer values and it now seems safe to conclude that the divergence between these and the oscillating disk results is due to some defect in the latter measurements, probably the presence of unwanted heat flows. Experiments were also made at pressures up to about 30 atm., where the main effects are large positive dependence on pressure at temperatures above about 1·8° K., and small dependence on pressure at lower temperatures.

For the purpose of the viscosity measurements, the heat flow in these experiments is kept to such a low value that the superfluid experiences no frictional forces and the heat resistance is constant to a first approximation. Dr. D. F. Brewer (Clarendon Laboratory, Oxford) described the effects occurring when, using the same capillary tubes, the heat flow is increased. Above a certain critical velocity there is first a well-defined transition region where the resistance rises sharply, and then a region where the resistance increases more slowly. Over a restricted range of temperature and mutual velocity, the resistance increases with the fourth power of the mutual velocity for the narrowest tube, changing to an approximately third-power law for the widest tube (0·36 mm. diameter); many of the results cannot be described by a power law at all. Other curious effects are observed, such as extreme sensitivity to vibration, and pronounced hysteresis and time effects. These can be given a plausible explanation along the lines of the Onsager–Feynman theory, but it is unlikely that a quantitative explanation can be given owing to the small number of vortex lines involved, and the possible influence of the surface condition of the capillary tubes.

On the other hand, a quantitative theory can be given when there is a large number of vortex lines and the influence of the neighbouring surfaces is negligible. Dr. W. F. Vinen (Royal Society Mond Laboratory, Cambridge) has performed experiments on the propagation of second sound in uniformly rotating helium II, which gave a marked excess attenuation dependent on the direction of propagation and the axis of rotation. Detailed interpretation in terms of the two-fluid model indicate a mutual friction proportional to the product of the angular velocity of rotation and the mutual velocity, and dependent on the angle between them. Previous heat-conduction measurements in wide tubes had given a third-power mutual friction of the Gorter–Mellink type associated with turbulence in the superfluid, and it was suggested that this turbulence took the form of a confused tangle of vortex lines, mutual friction being due to collisions between normal fluid excitations and the vortex lines. A calculation based on this mechanism leads to a cubic mutual friction of the right order of magnitude with a collision diameter for roton–vortex line collisions of about 10 A., but a number of difficulties arise in attempting to derive a complete theory. It now appears that different results obtained at Yale with a similar experiment can be reconciled with the present observations.

The theory of vortex lines is again used in explaining the results of experiments by Dr. H. E. Hall (Cambridge), in which measurements are made of the forces producing angular acceleration and retardation of helium II contained between closely spaced disks. For an angular velocity of 1 rad./sec. the amount of angular momentum collected on stopping the rotation has the full classical value, but for smaller angular velocities it falls progressively below this, the missing angular momentum corresponding to a persistent current which is probably irrotational and has a lifetime of more than 0·25 hr. The simplest mechanism for the generation of such persistent currents is the removal of vortex lines by the Magnus effect, but the actual mechanism is probably more complicated. Comparison of the frictional forces observed using spacers of different diameters between the disks suggests that at an early stage in the retardation process the superfluid becomes turbulent with an irrotational mean flow. At superfluid velocities less than a critical value turbulence decays on the disk surfaces and retardation stops.

Following the success of this first discussion day, plans are going forward for a second meeting, which will be concerned with low-temperature distillation, and will take place early in the present year.

D. F. BREWER

THE TEACHING OF METEOROLOGY IN SCHOOLS

IN the past, the teaching of meteorology in British schools was largely a matter of climates and trade winds, with but little study of the actual weather outside the windows or much relevance to the future lives of most of the pupils. The October 1956 number of the Royal Meteorological Society's magazine *Weather*, which has the teaching of meteorology as its main theme, gives evidence of the coming of a more vivid, physical and realistic approach.

A group of H.M. Inspectors of Schools contribute the main article, "Meteorology in Secondary Schools", which deals with the reasons for studying physical meteorology as well as geographical climatology in schools and provides an outline course of study. The group points out that the weather may be of vital importance to some pupils after they have left school and will at least be of interest to all. Apart from future use of knowledge of the processes of weather, study of them provides illustrations of important physical principles and, in simple observing work, an introduction to scientific accuracy and method. The outline course opens with the basic physics of radiation, condensation, relation of wind to pressure, etc., and goes on to properties of air masses and fronts and methods of observation. It is stressed that the teacher should correlate his lesson on air-masses by reference to the weather of the day but does not mention the interpretation of the broadcast forecasts. The latter is the most obvious omission in the course and is regrettable because weather forecasts will be used to greater or lesser degree by all the pupils in adult life. An amusing note is provided by the examples of awkward questions which pupils might ask on matters not understandable without more advanced physics or mathematics.

Mr. J. B. Rigg describes the meteorological studies at Watford Grammar School. These begin at the age of 11 years with the making of simple rain-gauges. In the sixth form the geography students, who include many also taking physics and mathematics, carry out much practical work with the comprehensive collection of instruments.

A number of publications, such as the "Observer's Handbook", are mentioned in the articles. Reference might also have been made to the Ministry of Agriculture pamphlet, "Weather and the Land", written by the Agriculture Branch of the Meteorological Office, which gives admirable guidance in the interpretation of the broadcast weather forecasts to meet local conditions.

An editorial discusses whether it is likely to be possible to teach any of the more recently gained knowledge in meteorology in sixth forms. It considers that there is a great opportunity for physics teachers to show the operation of basic physics in the weather, but little possibility of modern dynamical meteorology being taught because in their honours courses most mathematics teachers have not learnt real hydrodynamics with vorticity and viscosity.

UNUSUAL UPPER-AIR REFRACTION PHENOMENON

THE optical phenomenon of 'looming' which occurs when the air temperature increases very markedly with height is well known at low altitudes, especially in the polar regions. The rays of light from distant objects are then much more strongly curved in an arc convex upwards than usual, so that distant objects are apparently raised and multiple images successively upright and inverted are seen. This is the effect opposite to the mirage associated with a very steep fall of temperature with height, in which the rays become convex downwards and the sky is seen on looking along the ground.

The August number of the *Meteorological Magazine* contains an account by C. S. Durst, G. A. Bull and E. J. Sumner of 'looming' of distant clouds seen from a Canberra aircraft of the Royal Air Force flying north-east at 45,000 ft. some 200 miles off the west coast of Norway at lat. 66° 20′ N., long. 2° 30′ E., at midday on November 29, 1955. The crew, Flying Officers E. E. Kortens and F. P. Fraser, saw a cloud like a bowler hat protrude upwards above the cirrus cloud before and ahead of them. It expanded vertically and sideways. Then another cloud lump appeared at the top of the first one and also spread sideways and vertically. Next a mushroom-like top appeared and finally another lump on top of the