The Approach to the Absolute Zero *

THERE is no upper limit to the temperatures which could conceivably be reached; in marked contrast to this, there is on the low temperature side a sharp boundary at − 273·1° C. —the absolute zero of temperature. The boiling point of the most volatile gas, helium, lies about 4° C. above this limit; by reducing the pressure over liquid helium, it is easy to reach a temperature of 1° K., whilst 0·7° K. has been attained by the use of extremely powerful pumps. The contrast between the ease with which a high temperature can be generated—an electric torch is an example—and the complicated apparatus necessary to obtain a low one, is striking. It is due essentially to the fact that when a substance is heated there is not only an increase in its energy, but also in the internal disorder among its particles. In illustration, there is complete disorder in a gas, whereas a substance cooled sufficiently to cause it to crystallise has its constituents arranged with a high degree of order. In all affairs, it is easier to decrease order than to increase it; it is highly improbable that shaking a tray containing a number of black and white balls would increase the regularity of their arrangement.

In the last example, the orderliness depends on one variable only; the possibility of attaining low temperatures depends on the fact that the orderliness among the molecules of real substances is governed by more than one variable. Consequently, orderliness introduced by the agency of a change in one variable, say, the volume, has its effect on the other variables, such as the temperature. From this point of view, a method commonly used for liquefying helium operates as follows: as the gas is compressed, the decrease in volume tends to increase the order, so that the disorder due to the heat motion has to increase; in other words, the temperature rises. The compressed gas is now cooled, which increases the total order again, and when it expands again, the resulting decrease in order due to volume must be compensated by an increase in the thermal orderliness, that is, by a fall in temperature.

In the practical application of this method, starting at moderate temperatures, the cooling effects obtained are quite small, owing largely to the overwhelming heat capacity of the container. At low temperatures this difficulty disappears, since, for example, at 12° K., 1 c.c. of helium gas at 100 atmospheres has the same heat capacity as 1 kgm. of copper.

Fig. 1 is a diagrammatic sketch of the actual apparatus used for liquefying helium and for reducing its temperature after liquefaction. The helium is contained in *C*, *D* being the liquid hydrogen bath, and the space *S* being evacuated. The vessel *E* can be filled with liquid helium through the tube *T*, and is of a shape suitable for applying a magnetic field to its contents. By lowering the pressure in *E*, the temperature can be brought down to about 2° K. The gas thermometer is represented by *G*.

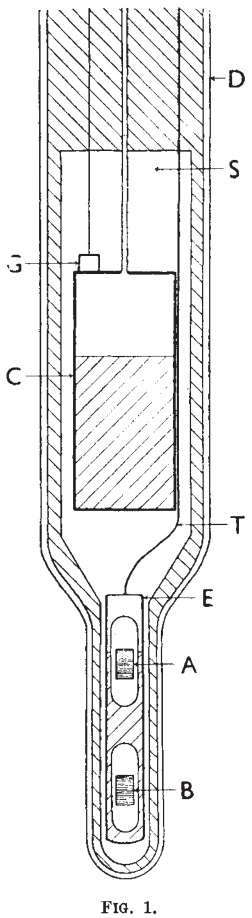

FIG. 1.

At very low temperatures, the gas thermometer is impracticable and one other means of measuring temperatures is to utilise Curie's law, according to which the susceptibility of a paramagnetic substance is inversely proportional to its absolute temperature. This method has the great advantage that it increases in sensitivity as the temperature is lowered.

It has already been remarked that the lowest temperature reached by decreasing the temperature over liquid helium was about 0·7° K. No substantial progress is to be anticipated by this method, and we have to seek some other disordered systems than gases on which to operate. Such systems are to hand in the paramagnetic salts mentioned above. In them, there are elementary magnets which, owing to the thermal agitation, are directed at random. When a magnetic field is applied, the magnetic orderliness is increased, so that the thermal order decreases, that is, the temperature rises. If the substance is now cooled by contact with its surroundings, so as to increase the total order, and the field afterwards removed, order is transferred from the magnetic to the thermal mode, and the temperature falls again. This method was proposed by Debye and Giauque about ten years ago, and has been successfully used in recent years by Giauque, de Haas, and Kürti and Simon.

Iron ammonium alum, with a field of 14,000 gauss, gives by this method temperatures down

* Substance of a discourse delivered at the Royal Institution by Dr. F. Simon on Friday, February 1.

to 0·04° K., whilst with potassium chromium alum, and the large magnet of the Leyden laboratory, de Haas has reached 0·015° K.

Insulation at these temperatures is an easy matter, since radiation becomes negligible, whilst the vacuum round the substance is very high on account of the low temperature itself. This is illustrated forcibly in the accompanying table, which shows the vapour pressures of helium (the gas with the highest vapour pressure) at various temperatures.

Vapour Pressures of Helium

T (°K)	p (mm.)
1·0	$1·5 \times 10^{-1}$
0·7	$3·2 \times 10^{-3}$
0·5	$2·5 \times 10^{-5}$
0·3	7×10^{-10}
0·2	3×10^{-15}
0·1	3×10^{-31}
0·05	4×10^{-62}
0·03	6×10^{-103}

It is interesting to note that the temperatures obtained by the demagnetisation technique are below any found in Nature. Even in inter-stellar space, radiation maintains a body at least 2° K. above absolute zero.

To examine the properties of other substances at these very low temperatures, a small pellet is made by mixing the substance to be examined with the paramagnetic salt. By this means, several new supra-conductors have been discovered, though even at 0·05° K. there are metals which do not show supra-conductivity. Again, it immediately becomes evident if the specific heat of the admixed body is abnormal, and consequently gives an indication of any phenomena involving energy changes in this region.

Finally, it must be emphasised that research in this low temperature region will be productive of fresh results; the effort to progress towards the absolute zero is not merely directed to the creation of fresh 'records' but to actual study of changes associated with energy increments of such magnitude that only in this region can they be observed.

During the course of the lecture, the liquefaction of helium by the method explained above, of compressing the gas to 100 atmospheres, cooling it to 12° K. with solid hydrogen and then allowing it to expand, was demonstrated. The phenomenon of supra-conductivity in lead was shown at the temperature of the liquid helium, the current being produced and its existence shown by magnetic means.

Norwich Meeting of the British Association

THE preliminary programme of the British Association meeting in Norwich on September 4–11 has now been issued. The president, Prof. W. W. Watts, announces the subject of his address as "Form, Drift, and Rhythm of the Continents". It would be difficult to conceive a title better capable of intriguing thoughtful laymen. That continents possess form they will no doubt appreciate, but the ideas that continents should drift, and possess rhythm, ought to make them eager to learn. It is to be hoped that it may be made easy for them to do so, for, to say truth, the Association in its endeavours in recent years to apply the advancement of science to the needs of its members, by reinforcing the voices of presidents through amplification, has been singularly ill-served as a rule.

The building in which the address will be given is not yet settled, but the other rooms which will be in use by the Association are very conveniently placed. In St. Andrew's Hall, formerly the fifteenth century church of a Dominican foundation, the business of the Reception Room will have a most imposing setting. None of the section rooms is so much as half a mile from it; seven of them are immediately adjacent to it. Norwich, once the visitor has learned the intricacies of its medieval streets, is unusually well provided with the type of accommodation demanded by the Association. As for the lodging of visiting members, the local committee, foreseeing some possibility of difficulty if members were left to make their own arrangements, offer to procure hotel or other accommodation for them, and indeed advise them not to communicate with hotels direct. In this connexion it should be remembered that those who wish to combine a holiday with the meeting, and are not too closely tied by the business of the Association, have unusual opportunity to obtain pleasurable accommodation elsewhere than in the city. The preliminary programme includes a long list of hotels (with prices) at Bacton, Caister, Cromer, Gorleston, Yarmouth, Holt, Lowestoft, Mundesley, Overstrand, Scole, Sheringham, West Runton and Wroxham, as well as in Norwich itself.

The two customary evening discourses are announced. That by Dr. S. J. Davies will deal with Diesel engines in relation to coastwise shipping—a subject of topical interest (as it may be surprising to some to know), for the number of coastwise trading vessels which make their way up-river to Norwich has increased of late years. The other discourse will enter a field of still wider public interest: Dr. C. S. Myers will speak on the help of psychology in the choice of a career.