actions that need answering, and which appear to be answerable with the machine as it is today, but are beyond the range of lower energy machines. Second, improvements to the machine and the detectors will widen the scope of these investigations, and it is not unreasonable to suppose that new surprising discoveries will be made. Finally the investment made in the ISR has given Europe a unique facility which could be made a stepping-stone into a completely new energy region. ☐

Pair-breaking in superfluid ³He

from P. V. E. McClintock

STUDIES of the way in which negative ions move through liquid ³He have resulted in a particularly revealing demonstration of the superfluid properties which it exhibits in the temperature range around 1 mK. The experiments, carried out at Helsinki Technical University by A. I. Ahonen, J. Kokko, O. V. Lounasmaa, M. A. Paalanen, R. C. Richardson, W. Schoepe and Y. Takano, and reported in *Physical Review Letters* (**37**, 511; 1976), represent the first successful investigation of ion motion in the recently discovered superfluid phases of the liquid.

The so-called ion formed when an excess electron is injected into liquid helium is actually a semi-macroscopic spherical structure with a diameter of around 3 nm and an effective mass about a hundred times greater than that of a helium atom. Being negatively charged, ions may be directed by means of externally applied electric fields and their arrival at a collecting electrode may be detected as a current. They therefore constitute particularly convenient probes for elucidating the behaviour of the liquid, and they have already been employed to excellent effect in gaining insights into the nature and fundamental properties of superfluid ⁴He. Comparable investigations of superfluid ³He are, of course, considerably more difficult because of the exceedingly low temperatures which must be achieved and maintained: the superfluid transition temperature of ³He is near 2 mK, or about a thousand times colder than that of ⁴He.

The ³He in the Helsinki experiment was refrigerated, using a nuclear demagnetisation cryostat, to temperatures less than half that of the superfluid transition. The measurements themselves, based on a technique recently developed at Lancaster University, were in essence exceedingly simple. Bunches of ions, injected into the liquid from a field emission tip,

were gated into a drift space of known length which they traversed under the influence of a fairly uniform electric field, finally arriving at a collecting electrode where they were detected as pulses of current. By measuring the time taken to cross the drift space, the characteristic velocity of the ions could thus be determined for a number of different temperatures and electric fields.

Some typical experimental results for the B phase (the form of superfluid ³He which is stable at low pressure) are shown in Fig. 1. It is strikingly evident that, for any given electric field, the ions travel much faster as the liquid is cooled below the temperature T_c of the superfluid transition. By analogy with the behaviour of ions in liquid ⁴He, it is natural to try and account for the general shape of these curves on the assumption that there are two separate types of mechanism by which the kinetic energy of a moving ion may be dissipated: (1) at all finite temperatures the ion travels through the residual gas of normal, that is, unpaired, ³He atoms which tend to impede its progress; (2) if the velocity of the ion is high enough, additional dissipative mechanisms can come into play whereby the ion creates excitations in the liquid. On this model, the ionic drift velocity which is measured in practice represents an average over the numerous individual scattering and possible excitation creation events which occur during the transit.

For sufficiently small ionic drift velocities, where only (1) need be considered, the velocity-field characteristic is expected to be linear with its gradient defining the ionic mobility. It may be noted from the figure that this is indeed the case and that, as the temperature is reduced, the mobility increases rapidly, consistent with the expected decrease in scattering as more and more of the ³He atoms fall into the paired states that comprise the superfluid. Indeed, at the lowest temperatures, the mobility apparently became so large that it was impossible to observe the linear region at all. Comparing these results quantitatively with theoretical predictions by T. Soda (in *Proc. 14th Int. Conf. on Low Temp. Phys.*, edit by Krusius, M. and Vuorio, M., **1**, 13, North-Holland, Amsterdam, 1975) and R. M. Bowley (*J. Phys.*, **C9**, L151; 1976), Ahonen *et al.* point out that both of these calculations substantially underestimate the magnitude of the superfluid mobilities. Probably, however, we will not have to wait very long for the theorists to improve their calculations, now that they have the stimulus of some real experimental data.
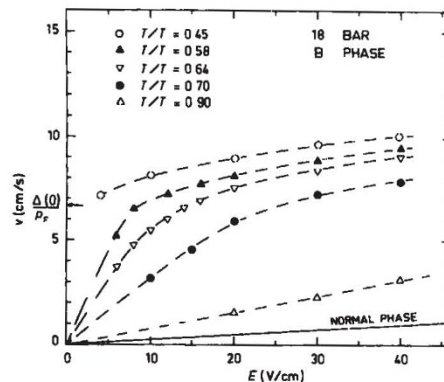

Fig. 1 The drift velocity *v* of negative ions moving through superfluid ³He under the influence of an electric field *E*, for various temperatures. The behaviour in normal (non-superfluid) ³He is shown by the full line, and the predicted value of Landau critical velocity for pair-breaking is indicated by an arrow.

Assuming that the observed bending over of the characteristics for velocities above a few cm s⁻¹ is the result of mechanisms of type (2), it is natural to enquire into the nature of the excitations which are being created, and there are several possible candidates. For each of these there will be a so-called Landau critical velocity v_L which the ion must exceed if the general requirement for simultaneous conservation of energy and momentum is to be satisfied during the creation process. At very low temperatures, where dissipation through (1) may be ignored, one would expect that an ion moving under the influence of a small electric field will accelerate without hindrance until it reaches v_L, and that it will then continue moving at a constant drift velocity equal to v_L while dissipating, in the form of excitations, the energy gained from the electric field. Thus, the position where the lowest temperature curve in the figure, that for $T = 0.45 T_c$, cuts the velocity axis gives a value of v_L which can be used to try and deduce the nature of the excitations. The simplest assumption, by analogy with the superfluid electron gas in a superconductor which in many respects is a similar system, is that the excitations emitted by the ion are just unpaired ³He atoms. The Landau critical velocity for breaking apart the pairs of ³He atoms forming the superfluid may be estimated as about $v_L = 6.7$ cm s⁻¹, and is indicated by an arrow in the figure. The fact that the curve looks as though it would extrapolate back to cut the velocity axis very close to this point is thus of considerable interest and significance, implying that energy dissipation under these conditions is indeed through the anticipated pair-breaking mechanism, rather than through crea-

tion of the (vortex-like?) excitations which may have given rise to the much lower critical velocities observed in the flow experiment recently performed by R. M. Mueller, E. B. Flint and E. D. Adams (*Phys. Rev. Lett.*, **36**, 1460; 1976) at the University of Florida.

Although a number of important conclusions may be drawn from the present data, the Helsinki experiment —as the authors themselves point out— is really only a beginning. Their principal achievement is to have demonstrated the technical feasibility of using ions to probe the superfluid phases of ^{3}He. It is to be hoped that future experiments of this type, taken in conjunction with improvements in the theoretical situation, will enable the temperature dependence of the energy gap separating the paired atoms of the superfluid from the (unpaired) excited states of the liquid to be mapped out in detail; it should be possible, using a more carefully designed geometry, to explore the anisotropy of the A phase; and the use of positive ions, to judge from earlier experience in superfluid ^{4}He, may perhaps enable completely new types of excitation to be created and identified. □

Nitrogen aggregates in diamond

from John Walker

As regular readers of News and Views may remember, nitrogen is a common impurity in diamond, though how exactly it got there and the precise forms it adopts within the crystal are only poorly understood. But a recent paper by G. Davies (*J. Phys. C : Solid St. Phys.*, **9**, L537–L542; 1976) partly resolves the latter question. The question is important, and not only for scientific reasons since it bears on the synthesis of diamond.

Synthetic diamonds are usually yellow, because they contain a small amount (perhaps one part per million) of dispersed nitrogen. That is, each nitrogen atom is isolated from the other nitrogen atoms, and replaces one carbon atom in the diamond lattice. In the current classification these are type Ib diamonds. Natural diamonds of this type are rare—one in a thousand.

The majority of natural diamonds, and all the large, well-formed ones suitable for adorning sceptres and film stars' fingers, are what we call type Ia stones. They also contain nitrogen impurity, in quite large proportions (up to almost one per cent); but in contrast to type Ib the nitrogen is aggregated. It appears that in growing her diamonds

Nature did not use the same process as General Electric and De Beers (fortunately for the gem industry, since yellow diamonds, though quite pretty, lack the sparkle and fire of water-white stones).

So what is the form of these aggregates? Until a couple of years ago we thought we knew the answer. The nitrogen gathered in large clusters, many thousands of angstroms in diameter, along {100} planes—the "platelets" that Evans and Phaal (*Proc. R. Soc. Lond.*, **270**, 538–552; 1962) had discovered by electron microscopy. Unfortunately we were wrong. We do not know what the platelets are, but thanks to earlier work by Davies (*Nature*, **228**, 758; 1970) and by E. V. Sobolev *et al.* (*Sov. Phys. Dokl.*, **12**, 665–668; 1967) we know that they contain little if any nitrogen.

We do know that there are at least two different types of aggregate, the so-called A and B forms, which give rise to characteristic infrared and ultraviolet absorption. What Davies has done in his most recent paper is to study one of the A bands, in fact a sharp line, under uniaxial stress. That is, he has squeezed a rectangular diamond block between two anvils, at stresses of the order of 20,000 atmospheres. As Wedlake has remarked, for diamond this is only a romantic squeeze; but it can nonetheless produce interesting results. Although the diamond lattice is cubic, under stress its symmetry is reduced (to tetragonal, trigonal or rhombic depending on the direction of stress), causing absorption bands to split into two or more components (just like the Zeeman effect in atomic spectroscopy—the splitting of spectral lines by a magnetic field).

Davies has deduced from the splitting pattern that the defect responsible for the A form of nitrogen has trigonal symmetry. The simplest atomic arrangement consistent with this is a pair of nitrogen atoms next to each other ("nearest neighbours"), replacing a pair of carbon atoms in the diamond lattice. Such a model fits in with the other constraints placed by current experimental knowledge: it is not paramagnetic, it is too small to be detected by electron microscopy, and it accounts for the slight increase in lattice parameter observed in nitrogen-bearing diamonds compared with pure specimens.

In a further paper (*Proc. R. Soc. Lond.*, **A351**, 245–265; 1976) Davies and his colleagues, again using uniaxial stress, demonstrate that the well-known H3 absorption and luminescence system in irradiated and annealed diamond has rhombic I symmetry. Davies (*J. Phys. C : Solid St. Phys.*, **5**, 2534–2542; 1972) has already shown that the H3 defect is produced when the A form of nitrogen traps a vacancy or interstitial

carbon atom produced during irradiation. Rhombic symmetry follows neatly from the trigonal symmetry of the A aggregate.

What we do not yet know is did the nitrogen aggregate into pairs by diffusion, or was it created like that during synthesis? What is the atomic arrangement of the B aggregate, and is nitrogen involved in the formation of the platelets? We still have many questions left to answer. □

Electron transfer systems in microorganisms

from D. O. Hall

An International Symposium on Electron Transfer Systems in Microorganisms was held at the CNRS Laboratory of Chemical Bacteriology, Marseilles on November 2–5, 1976.

THE Marseilles laboratory has been active in the biochemistry of electron transfer in anaerobic bacteria for many years and the meeting was held to discuss the requirements of electron transfer at both the cellular and the molecular level.

The genetics of yeast metabolism has been a fruitful subject for research for some time. P. Slonimski (Laboratory of Molecular Genetics, Paris) discussed some of the recently discovered mitochondrial mutants (MIT$^-$) which result in deficiencies in various aspects of mitochondrial metabolism. More than a thousand mutants are now available, opening up the possibility that mitochondrial functions for many different electron transfer reagents and enzymes will be available to biochemists to study the details of electron transport and ATP formation.

B. Haddock (University of Dundee) described his work on electron transfer systems in *E. coli* and *Paracoccus denitrificans*. It is becoming clear that

Correction

In the article "Eukaryotic mRNA: trouble at the 5′-end" (*Nature*, **263**, 188; 1976) the formula on page 190 was printed incorrectly. The correct formula is given below.

(and its tautomer)