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HELIUM II IN ROTATION*

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In a recent experiment,[1] Pellam has reported some measurements concerned with the velocity field of He II when contained in a simply connected vessel subject to steady rotation about its vertical axis of symmetry. These results are interesting, and unexpected, since they are contrary to the predictions of any current theory of liquid helium. We felt it important, therefore, to examine the problem using a different approach.

In our experiment the helium is contained in a light cylindrical glass vessel (bucket) which can be given an angular velocity about the vertical axis. The volume occupied by the helium was approximately 2.5 cm in diameter by 11 cm in depth. The bucket and its contents are suspended from a Beams type magnetic bearing, the whole system being enclosed in a high vacuum. Under these circumstances the parasitic rotational drag on the system was less than 5×10^{-6} dyne cm which, for our purposes, was negligible.

The procedure consists in giving the system, initially at rest, a sudden (~1/2 sec) rotational impulse and thence allowing it to coast freely. Observations are then made of the angular velocity of the system as a function of time and Fig. 1 shows two typical results, one above and the other below the λ point. As seen, the velocity of the system decreases with time and eventually reaches a steady value. Since angular momentum is conserved, the slow-down of the system must mean that the liquid, initially at rest, is slowly accelerated into rotation by the walls of the bucket. The "reaction time" is sharply temperature dependent, being the faster the higher the temperature, and this indicates that the mechanism of interaction between bucket and liquid is different for the normal and superfluid components of the helium.

Control experiments show that no appreciable angular momentum is transmitted to the liquid in the very short initial period during which the system is being brought into rotation. Hence a simple calculation, making use of readily measured constants, permits us to find the angular momentum acquired by the helium in reaching its equilibrium state.

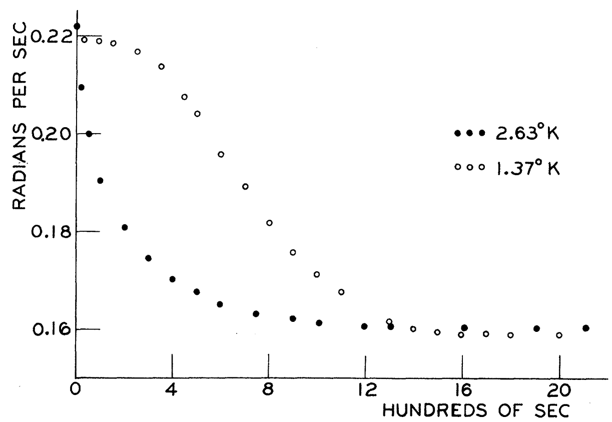

FIG. 1. The angular velocity of the system, subject to no external torques, as a function of time. Two runs are shown, for He I and He II, respectively, illustrating the very different types of interaction in the two fluids.

The result, in all cases, shows that this angular momentum is always classical to within an average experimental error of about five percent. By classical is meant that, at equilibrium, the helium is rotating in solid body type motion with the same angular velocity which the bucket then possesses—a situation which would also occur in the case of an ordinary viscous fluid. This behavior, of course, is precisely that predicted for a pure superfluid by the Onsager-Feynman[2] vortex line theory and this theory has met with some success in accounting for a variety of other superfluid experiments.

Figure 2 is a plot of the ratio of the angular momentum so measured (L) to the classical value (L_c) as a function of temperature. The above ratio is identical to Pellam's ρ_{eff}/ρ and his results are therefore included on the same graph for comparison.

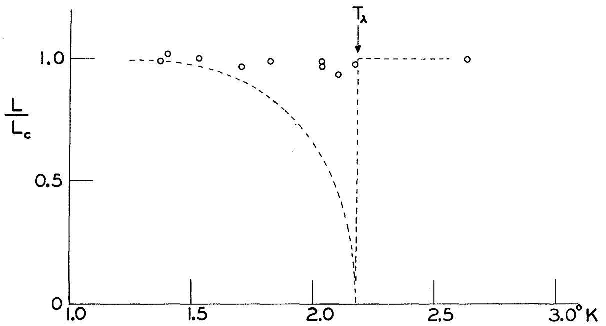

FIG. 2. The angular momentum of the helium (L) compared to the classical value (L_c) as a function of temperature. Circles are the present experiment and the dashed curve is Pellam's result (reference 1). The rotational velocity in all runs was near 2 rpm.

The most obvious difference between our technique and that of Pellam lies in the fact that his Rayleigh disk provides a semimicroscopic measure of the velocity field whereas ours provides an average over such a field. But this fact alone can hardly explain the vast difference in results which the two experiments show. It must be pointed out that earlier experiments on angular momentum by Hall[3] and Walmsley and Lane[4] are at variance with both of the above experiments and, of course, with the theory. Plausible, though not entirely certain, reasons can be advanced to explain this discrepancy with our present result but not, at all obviously, with Pellam's.

The present experiment is the only one of those cited which is in concordance with current theories of He II. Further, our method appears to subject the helium to much less extraneous disturbance, such as induced turbulence in the liquid, than do any of the others. We suggest, in consequence, that Pellam's result is possibly connected with some such extraneous effect.

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MAGNETIC MOMENT OF TRANSITION METAL ATOMS IN DILUTE SOLUTION AND THEIR EFFECT ON SUPERCONDUCTING TRANSITION TEMPERATURE

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We have found a decisive experiment which shows the conditions under which the magnetic moment of a transition metal atom remains localized when in dilute solution in another transition metal. We have correlated this effect with a drastic lowering of the superconducting transition temperature in a particular superconductor.

Some time ago a series of observations was reported which showed that the superconducting transition temperature of various metals and alloys could be greatly decreased by the presence of small amounts of rare earth metals.[1] This effect has been identified as due to an exchange interaction between the conduction electrons and the localized f-shell electrons.[2] In contrast to this behavior, it has been reported that the addition of transition metal impurities raises the superconducting temperature of titanium by an order of magnitude[3] and that of zirconium somewhat less.[4] In the case of the fifth column elements vanadium and niobium, dilute transition-metal impurities lower the transition temperature in a way strictly in accord with the electron concentration.[5] This behavior is consistent with the fact that even large concentrations of iron dissolved in Ti, V, or Nb do not show any magnetic interaction or temperature-dependent susceptibility. As far as we are aware no localized moment has been observed for a transition-metal impurity in dilute solution in another transition metal of the fourth or fifth column.

In this paper we now report a strong lowering of the transition temperature of the superconducting alloy $Mo_{0.8}Re_{0.2}$ by the solution of small amounts of metals belonging to the first-row transition series. These experiments are re-