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Letters to the Editor

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Energy Levels in Liquid He^3†

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RECENTLY, Price[1] and the author[2] have considered the interpretation of the nuclear magnetic susceptibility[3] of He^3 in terms of an approximation in which it is assumed that N atoms of He^3 can be divided into $N/2$ pairs which rotate. The lowest rotational state of a pair has no magnetic moment, since the spins are paired, but the next rotational level does have a moment (triplet state in the spins), and the susceptibility appears in terms of the probability of excitation of the second rotational state.

If the pair-rotator is conceived of as freely rotating in space, the space degeneracy of the first excited rotational state is three; also the spin degeneracy is three, so the total degeneracy is nine. If the rotator is thought of as a plane rotator, however, the degeneracy of this state is lowered to six, arising from the two possible directions of rotation and the triple spin degeneracy. If the idea of a plane rotator has any semblance of reality for He^3, it is because of the confining action of neighboring atoms on the pair-rotator. As a matter of fact, it is difficult to conceive of a hole in the liquid sufficiently large and symmetrical to allow the setting-up of the wave functions for a spatially symmetric rotator. The author expects the plane of rotation to be randomly determined by the neighbors, but, if the degeneracy is really reduced, it must be "zero-point randomness," not contributing to the entropy. In a private communication, Price has suggested a somewhat different picture in which the axes of rotation of neighboring pairs are correlated.

In reference 2, one step further was taken and it was assumed that the rotation was hindered. If we have a plane rotator with potential-energy barriers at angles of 0° and 180°, the rotational degeneracy in the first excited state is completely removed, since the rotation becomes a torsional oscillation, and the two directions of rotation no longer correspond to distinct quantum states. The total degeneracy is thus reduced to three.

An analysis by Temperley[4] shows that a pair-rotator model can account for the observed magnetic susceptibility, entropy, and specific heat of liquid He^3 only if it is assumed that the degeneracy of the first excited state is not more than three. It is seen that this is in accord with the idea of hindered rotation of the $N/2$ rotators. A hindered rotator is undoubtedly closer to the true physical situation than a free rotator, and there are reasons (see reference 2, including the note added in proof) for believing that it may give a better representation of the experimental results. The model is certainly a highly idealized one, but the coincidence of the observed degeneracy with the theoretical degeneracy for hindered rotation of a particular type is quite striking.

I wish to thank Dr. H. N. V. Temperley for allowing me to see his results before publication, and, without necessarily committing them to my view, to express my appreciation to him and Dr. P. J. Price for correspondence on this subject.

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[1] P. J. Price, Phys. Rev. **97**, 259 (1955).

[2] O. K. Rice, Phys. Rev. **97**, 263 (1955).

[3] Fairbank, Ard, and Walters, Phys. Rev. **95**, 566 (1954).

[4] H. N. V. Temperley, Phys. Rev. **97**, 835 (1955).

Bulk Formation of Helium-II in Capillaries

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AS observed by Dyba, Lane, and Blakewood,[1] liquid helium-II is formed in a capillary, up to the equilibrium capillary rise, h_m, if there is film flow contact between the helium bath and the inner wall of the capillary even when the lower end of the capillary is above the liquid helium-II bath level.

It seems to us that a simple reasoning gives an explanation for a kind of critical radius, r, for the capillary as a function of the height h_1 of the capillary above the liquid bath. Because of the curvature of the tube the film will have a tendency to increase its thickness, since the surface area per cm capillary length and thus also the surface energy is decreased in this way. By a decrease, Δr, of the radius of the liquid surface, the surface energy per cm height will change by $2\pi\Delta rH$, where H is the surface tension. However, this surface decrease will take place only when the potential energy required to effectuate the thicker helium layer (which means that a certain quantity of helium has to be lifted from the bath to the height, h) is smaller than the mentioned decrease in the surface energy. The mass of liquid required per cm capillary length in $2\pi r\Delta r\rho$; the potential energy $2\pi r\Delta r\rho gh$, where ρ is the liquid density and g the acceleration due to gravity. The