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# Low Temperature Physics

Low temperature physics has become a field of great activity, much of which is now in the United States. Prior to the war there existed in this country about half a dozen laboratories in which experiments could be carried out at temperatures within a few degrees of absolute zero; now the number is approximately five times as great and is still increasing. Much of this rapid growth must be attributed to the commercial development by Arthur D. Little, Inc., of a compact helium liquefaction plant based on Collins' helium expansion engine.

Current research is predominantly concerned with various phases of superconductivity, the properties of liquid helium, and the magnetic properties of matter—the latter both for fundamental knowledge and for information useful in reaching still lower temperatures by means of nuclear demagnetization. Temperatures ranging in the ten-thousandths to hundred-thousandths of a degree above absolute zero have been predicted by this method and may be realized in the not-too-distant future. At present .0014° K appears to be the lowest yet reached by the now well-known method of adiabatic demagnetization of paramagnetic salts. This process, formerly practiced only in the great centers of cryogenic research, is now finding widespread use.

The search for new superconductors at temperatures below 1° K has recently added uranium, osmium, and ruthenium to the known list of elements, bringing the total to twenty-one. The addition of new elements always renews speculation regarding the superconductivity of all the metals at the lowest temperatures. There is experimental evidence against this conclusion, and the recent theories of superconductivity postulated by Bardeen and Fröhlich agree with a negative answer. These theories also contain a relation governing the "isotope effect" (discovered in 1950), which asserts that the transition temperature of a metal varies with its isotopic constitution. The predicted relation is $M^{\frac{1}{2}}T =$ constitution, where M is the mean atomic weight and $T$ the transition temperature of the metal. Experimental results with mercury and tin fully support this theoretical equation; but serious objections to the derivation have appeared, and it can only be hoped that the difficulties will be overcome.

In the last few years sufficient $He^3$ has been available to determine its low temperature properties and to compare them with those of $He^4$. The researches in this field have been followed with unusual interest since, theoretically, very different behavior could be expected. Applying Einstein-Bose statistics to $He^4$, London and Tisza developed a two-fluid model for the liquid below 2.19° K (the λ point). Thus, below 2.19° K, the liquid (He II) is presumed to be a mixture of atoms having normal thermal motions (normal fluid) and those having only zero point motion (superfluid). With the aid of quantum arguments, plausible models follow for "second sound" (the propagation of temperature waves through the liquid), the thermomechanical, or "fountain," effect, and the creeping film. Pellam's experiments with second sound using a Rayleigh disk appear to confirm the two-fluid hypothesis, but measurements of the velocity of second sound at about 0.1° K support Landau's theory based on quantum hydrodynamics, rather than Tisza's, based on the two-fluid model.

Fermi-Dirac statistics applied to $He^3$ do not lead to a λ point for this liquid, nor to any of the above phenomena, and experimentally none have been found. The normal boiling point (3.19° K) of $He^3$ is lower than $He^4$, and present evidence points strongly to the liquidity of both down to absolute zero. Solid $He^3$ is obtained by the increase of pressure, as in the case of $He^4$.

It is apparent that low temperature physics will probably remain a fertile field for research for some time to come.

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