which for large magnetic fields is

$$F_c = -\tfrac{4}{3}\left(\frac{2\pi mc^2}{kT}\right)^{1/2}\frac{e^2 c}{B^2}\frac{\partial}{\partial x}[n^2(x)]. \qquad (5)$$

However, the interesting feature of (4) is that, while β will depend on the electron distribution, no matter what value β may in fact take, $\langle \Delta x^2 \rangle$ cannot exceed

$$\langle \Delta x^2 \rangle_m = \langle u_0^2 \rangle / \omega = \tfrac{2}{3}\, cW/eB, \qquad (6)$$

where W is the mean ion energy.

It will be recognized that, apart from a numerical factor, (6) leads to the value of diffusion suggested by Bohm, the value given by (6) being

$$F = -\tfrac{1}{4}(c/eB)(\partial p/\partial x),$$

where we have taken p, the total pressure, to be twice the ion pressure. One concludes, therefore, that this diffusion is the maximum that can be attained with ions of a specified mean energy in a magnetic field of value B.

It will be noted that we have not considered the effect of the first-order moment $\langle \Delta x \rangle$, which cannot easily be obtained from (1) since it depends on variations in β. However, it can be demonstrated that, provided the mean ion and electron energies are equal, the first-order contribution vanishes for ions of $Z = 1$.

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CRYSTAL STRUCTURE OF THE β FORM OF He⁴[†]

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(Received February 13, 1961)

In 1953 Dugdale and Simon[1] reported that upon investigating the thermal properties of solid He⁴ they observed a first order transition whose equilibrium line cuts the melting curve at 14.9°K. The nature of the transition indicated a change in crystal structure. Since the calculated entropy and volume change associated with the transition were very small, they assumed that on crossing the equilibrium line from the low-temperature side the structure changed from the already known hexagonal closest packing, α-phase, to cubic closest packing, β-phase. Whether helium solidifies in the cubic closest packed structure as the other inert gases do has been of theoretical interest. Barron and Domb[2] from theoretical considerations have shown that one might expect a transition to the cubic form to occur in solid He⁴ at an elevated temperature. We have therefore investigated by x-ray diffraction the structure of the new phase discovered by Dugdale and Simon.

The cryostat and camera arrangement previously used[3,4] for crystal structure studies at low temperatures was modified to permit oscilla-tion photographs to be taken. This was done by replacing the cylindrical Dewar by another which had the cross section of an annulus, thus permitting a shaft to be inserted down the geometric center of the Dewar. The upper end of the shaft projected through the top of the cryostat case where it connected to a cam and follower arrangement for oscillating it. As shown in Fig. 1, at the bottom of the shaft a beryllium cell was attached into which the helium was solidified. The cell had a 0.8-mm bore and a 0.4-mm wall. The open end of the cell was connected to the filling tube by a compression closure which consisted of a 59-degree cone tightened into a 60-degree seat with a brass gland nut. The differential in thermal contraction between brass and beryllium is such as to cause the joint to become tighter with lower temperature. The cell was cooled by the bath of liquid hydrogen through three braided copper straps. These and the filling and thermometer capillaries were attached with sufficient flexibility to allow the shaft to oscillate through an angle of 30 degrees. Not shown in Fig. 1 is the liquid-nitrogen-cooled copper radiation shield
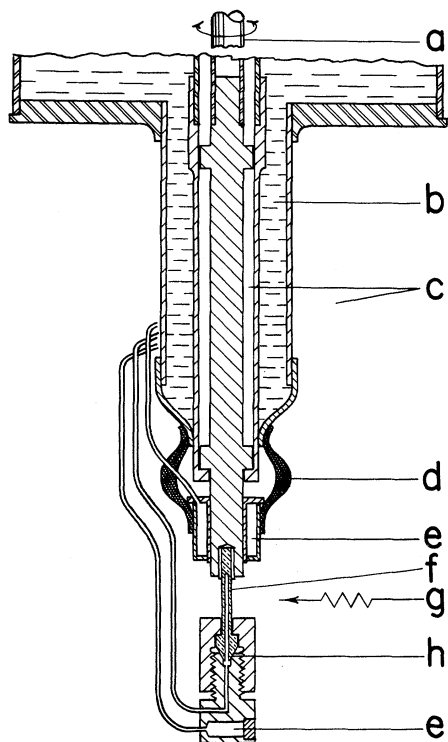
FIG. 1. Arrangement of the x-ray diffraction cell. (a) Cam-oscillated shaft; (b) liquid H_2 bath; (c) vacuum space; (d) flexible copper braid; (e) H_2 vapor pressure bulb; (f) Be cell; (g) x-ray beam; (h) high-pressure conical seal.

which surrounded the cell. The shield had windows for the entrance and exit of the x rays. The temperature at each end of the cell was measured with a hydrogen vapor-pressure thermometer. The two temperatures were averaged to give the temperature at the center of the cell. The pressure in the cell inlet capillary was measured to ±10 psi with a 0-20000 psi Heise gauge previously calibrated with a free-piston gauge. The photographs were taken with a 4×5 inch flat plate camera placed 5 cm from the sample. The radiation used at different times was filtered K_α from an iron, copper, or molybdenum target.

The usual procedure was to put helium at 1000 psi into the cell and then to cool it to the neighborhood of 20°K by adding liquid hydrogen to the refrigerant pot. The helium pressure was then raised to the amount desired for the experiment, 18440 psi, and the helium was next solidified by cooling the cell to 16°K. This latter cool-down required around $2\frac{1}{2}$ hours. It was hoped that the slow cooling would promote the growth of strain-free crystals. In a single attempt to produce a

powder, the cell temperature was first lowered to 16°K, and then the helium pressure was suddenly increased from just below the freezing pressure, 14000 psi, to 18440 psi. This proved to be unsuccessful because no more than a few large crystals were produced. During the x-ray exposures of from $2\frac{1}{2}$ to 7 hours, the pressure on the helium varied no more than ±20 psi and the cell temperature remained between 16.15 and 15.45°K.

In every exposure more than one crystal appeared in the beam. This had the advantage of giving a greater number of reflections in each photograph from which to derive the average value of the interplanar spacing, d_{hkl}, of each type of reflecting plane.

All of the reflections obtained could be indexed on the basis of a cubic lattice. The indices were always all even or all odd, indicating the face-centered cubic structure.

The indices of the types of reflections obtained from one photograph, the interplanar spacings, and the corresponding length of the unit cell edge, A, are as follows:

hkl	d_{hkl} (A)	A (A)
111	2.447	4.288
200	2.128	4.256
220	1.487	4.205
131	1.273	4.221
222	1.230	4.251
		Average 4.232

The average value of A from 7 photographs, weighted as to the number of types of reflections, is 4.240±0.016 A. The cell edge of 4.240 A corresponds to a molar volume of solid helium of 11.48 cc. This is 2.7% smaller than the value of 11.80 cc which can be computed from the data of Grilly and Mills[5] at a corresponding temperature and pressure.

†Work performed under the auspices of the U. S. Atomic Energy Commission.

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