$\Delta v = \Delta E/P_m \sim kT/(2ME_m)^{\frac{1}{2}}$. The mean free path Λ is given by

$$\Lambda \approx \frac{M}{\rho S(\Delta v/v_m)^2} \approx \frac{M}{\rho}\frac{1}{S}\left(\frac{E_m}{kT}\right)^2, \tag{2}$$

where S is the collision cross section.

In a degenerate Fermi-Dirac gas, the coefficients of viscosity η and heat conductivity χ may be written in the familiar form

$$\eta = \alpha_\eta \tfrac{1}{3}\rho\bar{v}\Lambda_\eta, \tag{3a}$$

$$\chi = \alpha_\chi \tfrac{1}{3}\rho\bar{v}C_v\Lambda_\chi. \tag{3b}$$

where α's are the numerical factors and $\bar{v}$ is the mean velocity of the particles. The specific heat C_v per unit mass is given by

$$C_v = \pi^2/2(k^2T/ME_m). \tag{4}$$

Using (2) and (4) in (3) we have

$$\eta_3 = \alpha_{\eta}\frac{1}{3}\frac{h^5}{2^{5/2}M_3{}^2}\left(\frac{3\rho_4}{8\pi M_4}\right)^{5/3}\frac{1}{S}\frac{1}{(kT)^2}, \tag{5a}$$

$$\chi_3 = \alpha_\chi \frac{\pi^2}{12}\frac{h^3}{M_3{}^2}\left(\frac{3\rho_4}{8\pi M_4}\right)\frac{1}{ST}, \tag{5b}$$

where we have taken $\rho_3/M_3 = \rho_4/M_4$.[1]

In the following rough calculation we have assumed $S = \pi d^2$, where $d = 2.9\times 10^{-8}$ cm, and have taken α to be equal to unity.* We shall also assume $\rho_4 = 0.145$ g/cc, since the density of He^4 does not change appreciably over the whole range of temperatures for which He^3 constitutes a degenerate gas (the degeneracy parameter $A = 10T^{-\frac{3}{2}}$). In Table I we have given (1) the changes in viscosity for $x = 0.01$ and (2) $x\chi_3$.

TABLE I. Calculated values for the change in viscosity for $x=0.01$ and for the product $x\chi$

T in °K	1.6	1.8	2.0	2.1	2.2	2.4	3	4
η_4 in μp^2	0.18	0.35	0.80	1.5	15	22	25	28
Ter Haar $\Delta\eta/\eta_4$	0.35	0.18	0.079	0.042	0.0042	0.0029	0.0025	0.0022
Our value $\Delta\eta/\eta_4$	6.4	2.6	0.92	0.44	0.040	0.023	0.013	0.0065
$x\chi_3$ in c.g.s.	58.8	52.3	47.1	44.8	42.8	39.2	31.4	23.5

The values as computed by us are higher than those given by Ter Haar and Wergeland, as is expected. The values are, however, uncertain on account of our lack of exact knowledge of α and S.

It may be noted that the maximum value of heat conductivity of He^4, as determined experimentally, is nearly 300 cal. cm^{-1} deg.$^{-1}$ sec.$^{-1}$ at 2°K; whereas this value for pure He^3, at the same temperature, as computed by us is 4710 c.g.s. units.

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[1] D. Ter Haar and H. Wergeland, Phys. Rev. 75, 886 (1949).
[2] W. H. Keesom, *Helium*, p. 271.
* In an exact calculation the numerical coefficients α and the collision cross section S will have to be evaluated rigorously. We shall do so in a future paper.

Polarization of Mesons Produced at Threshold in Gamma-Nucleon Collisions

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WENTZEL[1] has proposed using the anisotropy in the angular distribution of μ-mesons resulting from the decay of a polarized beam of integral spin mesons to determine the spin of the π-meson. Such a beam can be produced near threshold in nucleon-nucleon collisions; however, as pointed out by Wentzel, precession in strong magnetic fields, which will occur during the π-meson lifetime, which varies by about 10^{-8} sec. will blur the polarization effect, and hence the experiment cannot be performed directly inside a cyclotron tank.

The polarization of mesons produced in gamma-nucleon collisions, as from the gamma-ray beam from a synchrotron, has accordingly been examined. The ratio of the cross sections for production of longitudinal and transverse mesons has been calculated at exact threshold, taken to be mc^2 ($m = \pi$-meson mass) since terms of order m^2/M^2 (M = nucleon mass) are neglected. This quantity has the values shown in Table I. 0 denotes complete transverse polarization, ∞ complete longitudinal polarization.

TABLE I.

Field	Coupling	Cross section ratio
Vector	Vector	0
Vector	Tensor	0.4
Pseudovector	Pseudovector	∞
Pseudovector	Dual-tensor	0

The complete polarization will be reduced by terms of order m^2/M^2, which will be a small effect.

These results, and, in particular, the difference between vector and pseudovector fields, can be simply understood as follows. There are four processes which can produce this effect: a direct interaction coupling the four particles involved, and three others involving the creation of virtual mesons or nucleons and the absorption of the photon. For example, for vector-type coupling, the direct interaction term is of the form,

$$u_n{}^* o u_p \mathbf{A}\cdot\mathbf{V}, \tag{1}$$

the u's being the nucleon wave function, $\mathbf{A}$ the transverse vector potential, and $\mathbf{V}$ the meson wave function. For a vector field o is the unit operator, and for a pseudoscalar field it is γ_5. Since near threshold, $\gamma_5 = v/c = m/M$, the contribution of the term (1) to the cross section is smaller by m^2/M^2 for pseudovector fields than for vector fields. Thus, while this term will produce transversely polarized mesons of both types, it will not be appreciable for the pseudovector field. A similar investigation of other terms shows that they give mainly longitudinal polarization, which dominates for the pseudovector field.

The corresponding analysis for the vector field with tensor coupling, together with the fact that one must average over the unknown polarization of the incident gamma-rays, verifies the result that only this case does not give complete polarization.

The anomalous magnetic moment of the nucleon will enter only in the one process which involves the photon-nucleon interaction. This term is of the form

$$\lambda(m/M)(e\hbar/mc)u_n{}^*\beta\boldsymbol{\sigma}\cdot\mathbf{H}u_p;$$

since the photon's momentum is mc, the factor m/M means that this contribution will never be a dominant one.

In an actual experimental situation, one must consider both the internal motion of the bombarded nuclei and the fact that a continuous gamma-ray beam producing mesons with a wide range of kinetic energies is actually used. For mesons with a kinetic energy up to about 20 Mev, the values of v/c involved are of the order m/M; new terms introduced into the matrix elements will be of this order and lead to terms in the cross section of order m^2/M^2, which have been consistently neglected.

It is thus possible to produce near threshold a beam of polarized integral-spin mesons by the synchrotron gamma-ray beam. Since there appear to arise no new depolarizing effects other than those discussed by Wentzel, and since the experiment can be performed outside the tank, thereby eliminating the effect of magnetic fields on Wentzel's experiment, it seems that such an experiment might give useful information on the π-meson spin.

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[1] G. Wentzel, Phys. Rev. 75, 1810 (1949).