be likely to be confused with the total transition. B. Hamermesh reports no structure in the high energy end of the capture γ-ray spectrum of mercury.[9] This would indicate $J=0$ for the capture state, since in cases where the total transition is allowed, it is observed to be 10 to 20 percent of the total intensity. The present work, however, favors $J=1$.

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[2] T. Brill and H. V. Lichtenberger, Phys. Rev. **72**, 585 (1947).
[3] E. Fermi and L. Marshall, Phys. Rev. **71**, 666 (1947).
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On the Viscosity of Gaseous He³

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THE effect of the similarity of particles on their gas-kinetic properties was studied[1] some time ago and in particular, attention was drawn to the influence exerted by the presence of nuclear spins. Since then, the discovery of He³ has offered an opportunity to apply these theoretical concepts (with proper modifications) to a case in which sizable effects may well be observed rather conveniently.

If we denote collision cross sections for particles with symmetric or antisymmetric wave functions of their relative motion by σ_S and σ_A, respectively, and the corresponding cross section for the collision of two otherwise equivalent but *dissimilar* particles by σ_D, then one can easily show that $\sigma_S + \sigma_A = 2\sigma_D$. In the case of He³, the cross section for the collision of two atoms is, obviously,

$$\tfrac{1}{4}\sigma_S + \tfrac{3}{4}\sigma_A = \sigma_D - \tfrac{1}{2}(\sigma_S - \sigma_D).$$

Since[2] $\sigma_S > \sigma_D$ we find that the nuclear spin of He³ raises the viscosity of He³ with respect to He⁴ very appreciably (quite apart from the influence of the masses).

We shall present the quantitative details of this effect and some related phenomena in a following paper.[3]

[1] O. Halpern and E. Gwathmey, Phys. Rev. **52**, 944 (1937).
[2] Mott and Massey, Theory of Atomic Collisions (Oxford University Press, London, 1933), p. 231.
[3] Figure 1 on p. 951 of reference 1 was based on the assumption, since discarded, that a nucleus of even (odd) Z follows Bose (Fermi) statistics, and has therefore to be replaced by a different diagram.

Further Evidence for a Two Quantum Transition in Molecular Spectroscopy*

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IT has been pointed out[1] that an extra line group was observed in a study by the molecular beam electric resonance method of transitions between the electrical quadrupole hyperfine structure levels of Rb⁸⁵F. This extra line group occurred exactly at one-half the frequency of the normal transition ($J=1$, $F_1=\tfrac{3}{2}$)→($J=1$, $F_1=7/2$), in which J is the molecular rotational angular momentum and $F_1 = I_1 + J$, I_1 being the spin of the Rb⁸⁵ nucleus. It was suggested that this line group might arise as a two quantum transition in which two half-frequency quanta supply the energy for the transition. The theory of this two quantum transition was presented as a second-order time-dependent perturbation.

A simple extension of this theory indicates that the two quantum transition should be observed if two separate frequencies (f_1 and f_2) are applied, provided $f_1 + f_2 = \Delta E/h$, in which ΔE is the energy difference associated with the normal transition. We arranged experimentally to apply two frequencies in the C-field region and did indeed observe the·peak of the zeroth vibrational line to occur

TABLE I.

f_1 Mc/sec	f_2 Mc/sec	f_1+f_2 Mc/sec
3.928	2.400	6.328
3.828	2.500	6.328
3.628	2.700	6.328
3.528	2.800	6.328

as predicted. The pairs of frequencies at which this transition occurred are indicated in Table I. The rf field intensity associated both with f_1 and f_2 was ~4 volts/cm. A weak static C-field of ~14.2 volts/cm was applied. The frequency for the normal transition is 6.328 Mc/sec and for the extra·line 3.160 Mc/sec.

It was observed further that, with $f_1 = 3.528$ Mc/sec and $f_2 = 2.800$ Mc/sec and the rf field intensities as above, the line intensity increased by a factor of two when the static field was reduced from 14.2 volts/cm to 2.0 volts/cm, and the line was present at the higher intensity when no static field was applied. This increase in line intensity is in qualitative agreement with the theory; no adequate quantitative theory of line intensities has been worked out. Also, the presence of the line at zero applied static field, which we were not able to observe previously, is strong evidence in support of the two quantum theory. No known change was made in the apparatus which would account for our present success in observing the line at zero static field; it is likely that whether or not the line is present at zero static field depends critically upon interfield conditions because of nonadiabatic transitions, and these conditions are not easily controllable.

It is still not understood why other half-frequency lines are not observed. Further search was made with higher rf field intensities (from 5 to 15 volts/cm) at static fields from 0 to 8 volts/cm for half-frequency lines in the spectrum of Rb⁸⁵F, Rb⁸⁷F, and K³⁹F, but with negative results.

[1] V. Hughes and L. Grabner, Phys. Rev. **79**, 314 (1950); V. Hughes and L. Grabner, Phys. Rev. **79**, 829 (1950).

Threshold for Photoneutron Reaction in U²³⁸

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RECENT experimental neutron binding energy measurements[1] in the region of lead give energy differences between the radioactive series. Additional binding energy measurements to bridge the radioactive series in the region of uranium would serve as valuable checks in closing energy cycles. The binding energy of a neutron in U²³⁸ is of particular interest, since some uncertainty exists in the energy difference between the $4n+1$ and $4n+2$ radioactive series.[2]

X-rays produced by the 22-Mev betatron at the University of Illinois were used to measure the threshold for the photoneutron reaction U²³⁸(γ, n)U²³⁷. The energy scale is determined relative to the threshold for the 10-minute activity from the Cu⁶³(γ, n)Cu⁶² reaction which is taken as 10.9 Mev. The experimental arrangements are similar to those described elsewhere.[3]

Five 150-mg samples of uranium oxide were bombarded at different energies in a probe inside the x-ray donut for periods of time ranging from four to thirty-four hours. The uranium was depleted in U²³⁴ and U²³⁵ to decrease neutron fission activity and to reduce the growth of the 25-hour UY activity after chemical purification. The bombarded uranium was chemically purified to constant specific activity. Fifty-mg samples of U₃O₈ were prepared for counting by repeatedly painting and igniting many small portions of an organic uranium solution. The U²³⁷ activity was measured with a thin-window helium-filled Geiger tube with