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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On the Viscosity of Gaseous He^3

OTTO HALPERN
University of Southern California, Los Angeles, California
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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 He^3 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 He^3, 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 He^3 raises the viscosity of He^3 with respect to He^4 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*

LUDWIG GRABNER AND VERNON HUGHES
Columbia University, New York, New York
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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 $Rb^{85}F$. This extra line group occurred exactly at one-half the frequency of the normal transition $(J=1,\ F_1=\frac{3}{2})\rightarrow(J=1,\ F_1=7/2)$, in which $\mathbf{J}$ is the molecular rotational angular momentum and $\mathbf{F}_1=\mathbf{I}_1+\mathbf{J}$, $\mathbf{I}_1$ being the spin of the Rb^{85} 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 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.

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

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 $Rb^{85}F$, $Rb^{87}F$, and $K^{39}F$, but with negative results.

* This research has been supported in part by the ONR.
[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 U^{238}

J. R. HUIZENGA, L. B. MAGNUSSON, P. R. FIELDS, AND M. H. STUDIER
Argonne National Laboratory, Chicago, Illinois
AND
R. B. DUFFIELD
Physics Research Laboratory, University of Illinois, Champaign, Illinois*
(Received April 5, 1951)

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 U^{238} 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 $U^{238}(\gamma, n)U^{237}$. The energy scale is determined relative to the threshold for the 10-minute activity from the $Cu^{63}(\gamma, n)Cu^{62}$ 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 U^{234} and U^{235} 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 U_3O_8 were prepared for counting by repeatedly painting and igniting many small portions of an organic uranium solution. The U^{237} activity was measured with a thin-window helium-filled Geiger tube with

sufficient aluminum absorber to cut out the uranium alpha-particles. The U^{237} counting rate was determined by using the least squares method to extrapolate the linear growth curve of the uranium daughters to an accurately controlled zero time (time of chemical purification). Such extrapolations with similar unirradiated uranium gave a background of 2 c/min (above counter background). The counting rate of U^{237} for each sample varied from 6 to 100 c/min. This activity decayed with a 6.6-day half-life.

The excitation function could be approximated by a parabola; hence it was possible to estimate the threshold from a linear extrapolation of the square root of the U^{237} yield plotted as a function of x-ray energy. The results are shown in Fig. 1, where

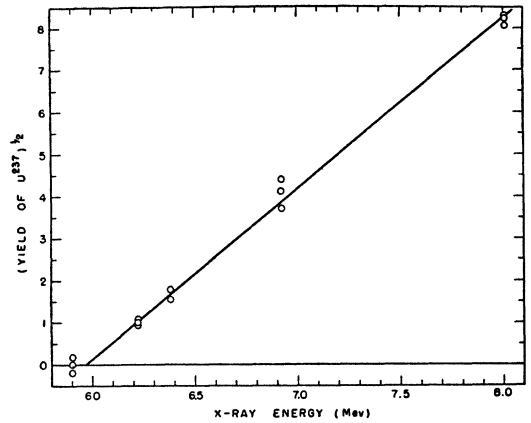

FIG. 1. Square root of the U^{237} yield plotted as a function of x-ray energy.

the yield is expressed in c/min of U^{237} for 50 mg of U_3O_8 given constant bombardment. Analysis of the data gives a threshold of 5.97 ± 0.10 Mev for the $U^{238}(\gamma, n)U^{237}$ reaction.

British workers[4] obtained a neutron emission threshold of 5.85 ± 0.15 Mev for natural uranium by an indirect measurement of the neutrons produced in photodisintegration. As Parsons and Collie[4] point out, their method of measurement does not yield a clearly defined threshold since the end product is not identified, and the source of the neutrons is uncertain. However, the close agreement between the two values leads one to believe that they were measuring the neutrons from the $U^{238}(\gamma, n)U^{237}$ reaction.

* This work was supported in part by the joint program of the AEC and ONR.

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Lithium Ammonium Tartrate Monohydrate, A New Ferroelectric Crystal*

WALTER J. MERZ
Department of Physics, Pennsylvania State College, State College, Pennsylvania
(Received March 26, 1951)

IN an investigation of the electrical properties of a series of tartrates we have found that $LiNH_4C_4H_4O_6\cdot H_2O$ is ferroelectric. (In a private communication to the author, Matthias has reported his parallel discovery of the ferroelectric behavior of this crystal.[1]) It appears that isomorphous salts such as LiRb- and LiTl-tartrate$\cdot H_2O$ are also ferroelectric. The electrical behavior of the $LiNH_4$ salt is reported in the present letter.

The crystals are orthorhombic, and the dielectric constants in all three axial directions are small (between 8 and 10) at room temperature. Upon lowering the temperature, ϵ_a and ϵ_c remain essentially constant, whereas ϵ_b shows a sudden and sharp peak at about 106°K (Fig. 1). Below this temperature we find a spontaneous electric polarization which establishes this transition as a Curie point (Θ).

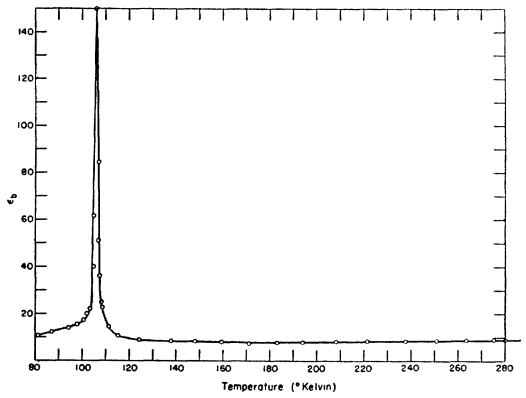

FIG. 1. Dielectric constant ϵ_b *versus* temperature.

The hysteresis loops (Fig. 2) show the onset of a spontaneous polarization P_s at the Curie point and its increase when the temperature is lowered. The saturated value at low temperatures is about $P_s=0.21\times10^{-6}$ coulomb/cm^2.

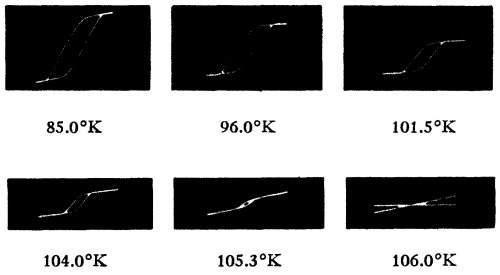

FIG. 2. Hysteresis loops *versus* temperature.

The crystal is strongly piezoelectric, with a modulus d_{25} of about 20×10^{-8} cgs at room temperature. The piezoelectric resonance frequencies show the usual sharp minimum at the Curie point (Fig. 3). Using these measurements of the dielectric constant

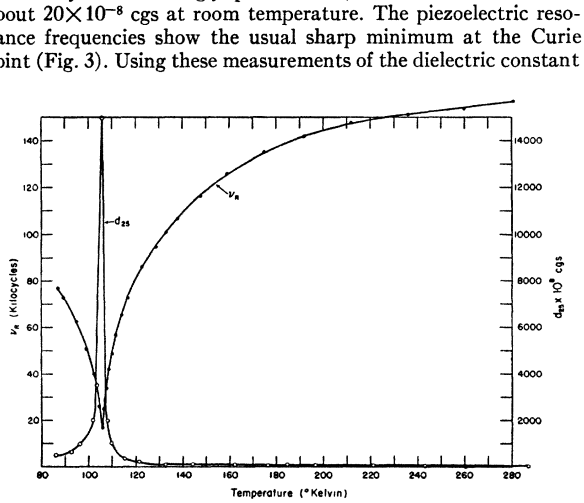

FIG. 3. Resonance frequency and piezo constant d_{25} *versus* temperature.