interval. The statistical uncertainty is about 15 percent. A background plate, obtained under identical conditions by accelerating tritons into the same target filled with He^4, indicated that the number of background neutrons over the complete spectrum was less than 1 percent.

One notices in Fig. 1 that two broad peaks appear at 10.4 and 8.1 Mev. We attribute these peaks to reactions (a) and (b), respectively. The corresponding ground state peak (a) has also been observed in the neutron spectrum obtained by Sanders, *et al.*[1] Although the variation of the incident triton energy was large, the high Q of the reaction greatly reduces the effect of the energy variation on the peak widths. The lines bracketing the peaks in Fig. 1 indicate the extent of peak broadening to be expected from the spread of incident triton energy. The remainder of the peak width is readily attributed to the finite resolution of the neutron detection system. The remainder of the neutrons are presumed to arise from various other possible reactions such as:

(c) $T+T \rightarrow He^4+n+n+11.4$ Mev;
(d) $T+T \rightarrow He^4+n^2+Q$;
(e) $He^5 \rightarrow He^4+n+0.87$ Mev;
(f) $He^{5*} \rightarrow He^4+n+3.5$ Mev.

Reactions (e) and (f) represent the disintegration of the unstable He^5 formed in reactions (a) and (b). The occurrence of special interactions in the three particle disintegration could conceivably produce energy groups in the neutron spectrum. However, we feel that this possibility is a considerably less likely source of groups than the reactions (a) and (b). The greatest neutron energy expected from reactions (d), (e), and (f) occurs in reaction (f) and is less than 6.2 Mev. Consequently, these reactions would not contribute to the observed neutron energy groups at 10.4 Mev and 8.4 Mev.

The idea of He^5 having an excited state in the vicinity of 2.6 Mev above its ground state is not new nor inconsistent with previous results. As suggested by Goldstein,[2] a $P_{1/2}$ level above a $P_{3/2}$ ground state could provide satisfactory agreement between theory and the existing data on the low lying levels of He^5 as obtained from n-He^4 scattering.[3-6] Adair[7] reports that his analysis of the n-He^4 total cross-section measurements of Bashkin *et al.*[8] indicates the existence of a widely spaced inverted doublet in He^5.

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Scattering of Thermal Neutrons by Mercury

C. T. HIBDON, C. O. MUEHLHAUSE, G. R. RINGO, AND T. R. ROBILLARD
Argonne National Laboratory, Chicago, Illinois
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THERMAL neutron scattering by mercury should be strongly affected by the resonance[1] at -2.0 ev. In particular, one would expect a large positive coherent scattering length. We have recently measured three thermal cross sections of mercury: σ_{coh} (coherent scattering), $\sigma_{th\text{-}s}$ (total scattering), and $\sigma_{th\text{-}a}$ (absorption). In addition, we have measured the potential scattering cross section, σ_p, near thermal (19.5 ev). These data have been used to calculate the -2.0 ev resonance parameters in Hg^{199} in an attempt to assign a compound angular momentum value (J) to the capturing level.

The coherent scattering cross section is not easily measured by crystal diffraction schemes because of the high thermal absorption cross section (370*b*). Instead, it was measured by finding the critical wavelength for reflection of a beam of thermal neutrons incident on a surface of liquid mercury at a given angle. Observations were made at two angles, using a time-of-flight velocity selector.[2] An additional observation was made at a third, larger angle by comparison of intensities with the first two angles. The critical wavelength and the angle determine the index of refraction, which in turn determines the coherent scattering amplitude.[3] Results are given in Table I. From this it can be seen that mercury

TABLE I. Observed coherent scattering cross section of Hg for thermal neutrons.

Angle (min)	Wavelength (angstroms)	σ_{coh} (barns)
8.29	1.84	22.1
12.25	2.63	24.8
20.22	4.70	18.4
		av 21.5 ± 2

makes a particularly good neutron mirror. The surface is easy to prepare and is stable for at least several days with only ordinary care.

It is appropriate to take an average value of σ_{coh} since no energy dependence is to be expected, and none is observed.

Measurement of $\sigma_{th\text{-}s}$ was done with the use of a 4π-annular neutron scattering counter.[4] The counter is provided with an axial hole through which a neutron beam from the pile may pass. A scattering material is placed transverse to the beam on the axial center of the counter. Known thicknesses of gold-mercury amalgam and vanadium metal foil were placed separately in the counter, and their counting rates compared. The effect of gold scattering was subtracted after observing the counting rate from a gold foil of the same thickness as that used in the Au-Hg amalgam. Vanadium was chosen as a standard ($\sigma_{th\text{-}s}=\sigma_{inc}=5.00$ barns) since thermal neutron scattering from vanadium is almost entirely incoherent.[5] This and the mercury amalgam minimize diffraction effects. $\sigma_{th\text{-}s}$ (Hg) so obtained was 26.5 ± 0.1 barns.

By using a resonance beam, placing a resonance neutron scattering detector[6] of W^{186} in the annular counter, and observing the transmission of Hg, σ_p was measured at 19.5 ev. The value obtained was 13.3 barns. This is in good agreement with σ_p measurements at 120 ev and 350 ev.[7] The thermal absorption cross section, $\sigma_{th\text{-}a}=370$ barns, was taken from recent pile-oscillator measurements.[8]

If one assumes $4\pi R^2=13.3$ barns where R is the nuclear radius (spin independent and identical for all isotopes), one can calculate the resonance parameters for the -2.0-ev level as well as σ_{coh}. A one-level Breit-Wigner set of formulas is assumed. The results of this calculation are given in Table II.

TABLE II. Resonance parameters for the -2.0-ev level of Hg, and calculated coherent scattering cross section, for $J=0$ and $J=1$.

	$J=0$	$J=1$
Γ_n	0.053 ev	0.027
Γ_γ	0.225 ev	0.149
Γ	0.278 ev	0.176
σ_{coh}	17.1	20.0

One sees here a definite preference for the case $J=1$, though the case $J=0$ cannot be ruled out with certainty.

Hg^{199} has spin $\frac{1}{2}$ and on neutron capture goes to Hg^{200}, an even-even nucleus with ground-state angular momentum equal to zero. An interesting consequence of the value of J for the compound capture state had to do with the resulting cascade γ-ray spectrum. A γ-ray transition of energy equal to binding in Hg^{200} is forbidden for $J=0$ and allowed for $J=1$. Furthermore, the first transition in the cascade is usually of sufficient energy that no other γ-ray will

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]

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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.

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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