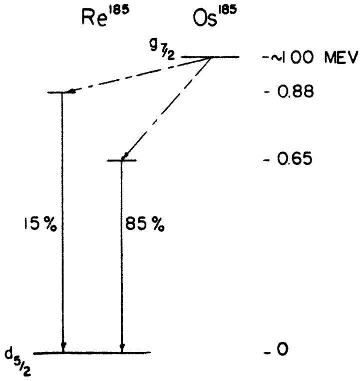

FIG. 2. Disintegration scheme of Os^{185}.

and the disintegration scheme are correct, the atomic mass difference between Os^{185} and Re^{185} may be estimated. This turns out to be about 1.0 Mev if the transition to the 0.88-Mev level is assumed to be first-forbidden, and slightly lower for an allowed transition.

The fraction of the total K capture to the ground state has been reported[8] to be no greater than 0.10. The amount of L capture feeding the excited states could not be estimated at that time and hence was not considered. The presence of L capture changes this value to 0.20, but does not essentially alter the interpretation of this transition as first-forbidden, in agreement with the shell model.

* This work was assisted by the joint program of the ONR and AEC.
1 West, Meyerhof, and Hofstadter, Phys. Rev. **81**, 141 (1951).
2 Bunker, Canada, and Mitchell, Phys. Rev. **79**, 610 (1950).
3 B. B. Kinsey, Can. J. Research **26**, Sec. A (1948).
4 W. Duane and W. Stenström, Proc. Natl. Acad. Sci. U. S. **6**, 477 (1920).
5 Lawrence S. Germaine, Phys. Rev. **80**, 937 (1950).
6 H. S. W. Massey and E. H. S. Burhop, Proc. Roy. Soc. (London) **A153**, 661 (1936).
7 M. E. Rose and J. L. Jackson, Phys. Rev. **76**, 1540 (1949).
8 M. Miller and R. Wilkinson, Phys. Rev. **82**, 981 (1951).

The Radiations of Tl^{199} and Tl^{200}

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THE internal conversion electron spectrum of $Hg^{199,200}$ resulting from the orbital electron decay of $Tl^{199,200}$ has been studied with a small 180° shaped field spectrometer. The thallium isotopes were produced by alpha-particle bombardment of gold in the Indiana University cyclotron, and were separated from the target material by standard chemical procedure. Carrier-free sources were obtained by electrodeposition of the thallium from a solution containing no gold or mercury. With a plating current of 150 ma, the major part of the activity was deposited on the platinum electrode within one to two hours. The deposit was removed from the electrode with nitric acid and laid down by evaporation on a thin zapon film.

A survey of the negatron spectrum showed the presence of twenty-five internal conversion lines, all of which decayed in intensity with either the 7-hour half-life of Tl^{199} or the 27-hour half-life of Tl^{200}. An analysis of the conversion lines of Tl^{199} shows that they arise from nine gamma-rays of energies 49, 78, 103, 157, 206, 245, 332, 454, and 490 kev. For Tl^{200} the observed conversion lines correspond to six gamma-rays of energies 365, 577, 622, 829, 1210, and 1360 kev. The figures quoted are accurate to within one percent.

In the case of Tl^{199} the results are in agreement with those of Hole,[1] who has found gamma-rays at 155 and 360 kev associated

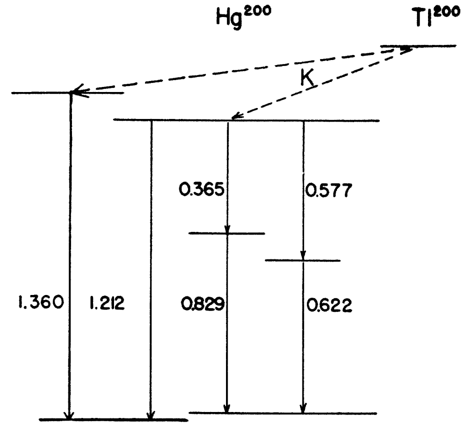

FIG. 1. A possible disintegration scheme for Tl^{200}. It is to be noted that the 1.212-Mev gamma-ray is not the cross-over for the cascade gamma-rays. The assignment of the 15-kev discrepancy as shown is arbitrary.

with an isomeric 43-minute activity in Hg, which has been assigned[2] to Hg^{199}. Scintillation spectrometer studies offer further evidence that these gamma-rays are coupled. It is found that the 157- and 332-kev gamma-rays are of about the same intensity and are probably in cascade. The 490-kev gamma-ray may be interpreted as the cross-over for these transitions. Similarly, the 245- and 206-kev gamma-rays are about equal in intensity and may be regarded as a cascade pair, with the 454-kev gamma-ray resulting from the alternative cross-over transition.

The first five gamma-rays of Tl^{199} listed above have essentially the same energies as those reported in a study[3] of the beta-decay of Au^{199} to Hg^{199}. It therefore appears that the decay scheme proposed by Beach *et al.* should be altered to take into account the higher levels which are evident in the K-capture process. Further work on this matter is in progress.

The energies of the gamma-rays of Tl^{200} are consistent with the tentative decay scheme shown in Fig. 1. While the absorption work of Cuffey[4] in this laboratory supports this picture, further study of the conversion electron spectrum in the low energy region and a complete study of the photoelectron spectrum are necessary before this scheme can be considered as certain.

No positrons were found in the case of either Tl^{199} or Tl^{200}.

* This work was assisted by the joint program of the ONR and AEC.
1 N. Hole, Arkiv. Mat. Astron. Fys. **36A**, No. 9 (1948).
2 "Nuclear data," Natl. Bur. Standards (U. S.) Circ. 499 (1950).
3 Beach, Peacock, and Wilkinson, Phys. Rev. **76**, 1585 (1949).
4 William Cuffey (to be published).

Electron Mobilities in Liquid Argon*

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THE work of Gerritsen,[1] of Davidson and Larsh,[2] and of Hutchinson[3] has shown that conductivity pulses due to ionizing radiation may be observed in liquid argon. Using a parallel plate chamber immersed in liquid argon, we have measured the mobility of electrons resulting from the ionization of liquid argon by the alpha-particles of ThC and ThC′.

The chamber was similar to that described by Davidson and Larsh,[2] with the plates $\frac{5}{8}$ inch in diameter and separated by various sizes of spacers made of Teflon. The source ThB was collected on the bottom plate by recoil. Commercial tank argon, supplied by Linde, and stated to be 99.91 percent pure, was liquefied by means of a small heat exchanger immersed in liquid air. Further purification was not undertaken.

Pulses resulting from electron collection were amplified and used to trigger the sweep of a fast synchroscope. They were also applied to the vertical deflection plates through a length of coaxial cable serving as a 0.2-microsecond delay line. The combined rise time of the preamplifier, amplifier, and vertical amplifier of the synchroscope is 0.02 microsecond. This is short compared with the pulse rise times observed, which were between 0.2 and 0.4 microsecond. Using a Kodak Retina camera (1 sec at f:3.5), photographs of the resulting traces at different counter voltages were taken. A straight line parallel to the average slope of the trace was drawn on the print. This line was extended from zero to maximum amplitude, and the projection of this line onto the time base line corresponded to the rise time. The sweep speed was approximately 6 inches per microsecond. In determining the rise time, corrections were made for the slight nonlinearity of the sweep.

To correct for the penetration of the alpha-particles into the chamber, the center of gravity of the resulting electron cloud was calculated. The center of gravity of the electrons produced by the 8.78-Mev alpha-particle of ThC′ is 0.038 mm from the source plane. The drift space is the distance from the center of gravity to the collecting electrode. From these data the drift velocity and the mobility were computed.

In Fig. 1, the mobility U *versus* the field is plotted for two plate separations (0.185 and 0.107 cm). The dotted curve is

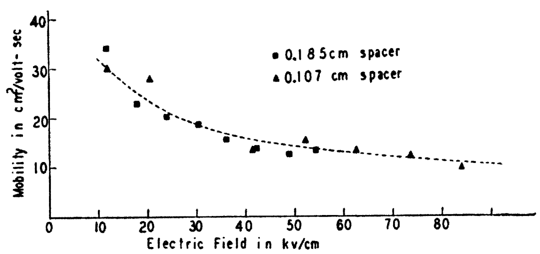

FIG. 1. Electron mobility U *vs* electric field E in liquid argon. The dashed curve is calculated for U proportional to $E^{-\frac{1}{2}}$ and fitted at one point.

calculated, assuming the mobility to be proportional to $E^{-1/2}$, where E is the field strength. The agreement here is well within the experimental accuracy, estimated to be about 15 percent.

Based on kinetic theory considerations, the formula for the mobility is

$$U = c^{3/4}(mM)^{-1/4}(e\lambda)^{1/2}E^{-1/2},$$

where m is the electron mass, M the mass of the argon atom, e the electronic charge, λ the mean free path. The constant c, which various corrections make uncertain, lies between $\frac{1}{2}$ and $\frac{2}{3}$. The value of λ may be calculated from this formula. The collision cross section q may be calculated from the general relation:

$$Nq\lambda = 1,$$

where N is the number of argon atoms per cc. According to the reasoning which leads to the mobility formula above, the mean energy of the electrons is about 10 ev. The collision cross section obtained in this manner for electrons of 10 volts mean energy is about 100 times smaller than the published values[4] for the gas.

Preliminary results in solid argon indicate an electron multiplication by a factor greater than 10, in agreement with Hutchinson's work. The mobility in the solid is much greater than that in the liquid. Conductivity pulses have also been observed in liquid helium, and measurements are being continued in solid argon and liquid and solid helium.

We wish to thank Professor H. Margenau for numerous discussions concerning the theoretical aspects of the problem.

* Assisted by the joint program of the ONR and AEC.

[1] A. N. Gerritsen, Physica 14, 381 (1948).
[2] N. Davidson and A. E. Larsh, Jr., Phys. Rev. 77, 706 (1950).
[3] G. W. Hutchinson, Nature 162, 610 (1948).
[4] R. S. Brode, Revs. Modern Phys. 5, 263 (1933).

The Angular Distribution in the Photodisintegration of the Deuteron at Low Energies

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THE angular distribution of the protons and neutrons produced in the photodisintegration of the deuteron has been determined by a number of authors[1–3] and for several γ-ray energies. So far the precisions of these measurements do not permit the establishment of agreement or disagreement between theory and experiment. The main difficulty arises from the low intensity obtained in experiments where sufficient angular definition of the photonucleons was provided.

We have made measurements with a new method, giving higher intensities. In this method one makes use of the fact that the energy of the photonucleons depends on the angle relative to the disintegrating γ-ray at which they are ejected (conservation of the linear momentum of the γ-ray). The energy of a photoproton in laboratory coordinates is:

$$E_p = \tfrac{1}{2}(E_\gamma - E_T) + \frac{E_\gamma^2}{8Mc^2} + \frac{E_\gamma}{2}\left(\frac{E_\gamma - E_T}{Mc^2}\right)^{\frac{1}{2}} \cos\theta.$$

The number of photoprotons ejected into unit solid angle at angle θ is:

$$I_\theta = (a + b\sin^2\theta),$$
$$a = \sigma_m, \quad b = \tfrac{3}{2}\sigma_e,$$

where θ is the angle between the photoproton and the incident quantum in center-of-mass coordinates. Combining these two equations we obtain the relation for Y_x, the number of protons per unit energy interval at energy x,

$$Y_x = A\{a + b - (b/\alpha^2)(x-d)^2\},$$

where $\alpha = \frac{1}{2}E_\gamma[(E_\gamma - E_T)/Mc^2]^{\frac{1}{2}}$, $d = \frac{1}{2}(E_\gamma - E_T)$, and A is a factor depending on the γ-ray flux, the number of deuterium nuclei per unit volume, and the wall effect. Table I shows the expected energy spread for the three γ-ray sources used in our measurements.

Originally this effect was established qualitatively with a deuterium-filled ionization chamber.[4] For the present measurement we used a proportional counter, to eliminate the positive ion effects, and to reduce the amplifier noise to negligible proportions.

The counters consisted of a long cylinder of copper or aluminium closed at each end by caps carrying Kovar-glass seals. The center wire was passed through these seals and connected to the first valve of an amplifier. Great care was taken to insure that the wires were central. X-ray radiographs showed that the wires were axial to within 1/10 mm. The sensitive volume of the counter was defined by thickening the center wire in the usual way. The end effects were reduced to 1 percent by using a long counter 30 cm in length, of diameter 2.54 cm, and placing the source at the middle.

The pressure of deuterium in the counter had to be adjusted for each γ-ray energy so as to avoid too high a γ-ray background on the one hand and too large a wall effect on the other.

The output pulses were examined with a kicksorter of the Wilkinson type. Distributions from each counter under various conditions of pressure and relative γ-background were in excellent agreement. Pulse heights were expressed relative to a standard pulse; the energy calibration in kev was established using the fact that the peak of the distribution occurs at the average photoproton energy [Eq. (1)]. Agreement to 0.5 percent was obtained

TABLE I. Expected energy spread for the gamma-ray sources used.

Source	Energy of protons	Spread of energy
Na^{24}	$E_p = (265.5 \pm 32.9 \cos\theta)$ kev	±12.4%
ThC″	$E_p = (194 \pm 26.6 \cos\theta)$ kev	±13.7%
Ga^{72}	$E_p = (138.5 \pm 21.6 \cos\theta)$ kev	±15.6%