Letters to the Editor

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The 5-Ev Neutron Resonance in Ag

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UNTIL the past year or so, the resolution of slow-neutron spectrometers has been so low that it has not been possible to determine the exact shape and strength of resonances occurring much above 1 ev. Now, however, considerably higher resolution is available, and it is possible to determine resonance parameters for resonances up to 5 or 10 ev, if one assumes only that the one-level Breit-Wigner resonance formula gives the correct variation of cross section near an isolated resonance; this assumption is adequately supported by experimental data. The 5-ev resonance in Ag has been investigated, to give an example of the results possible, and the peak cross section σ_0 and natural width Γ have been determined to within about 10 percent.

The method used is basically independent of both the resolution and the Doppler effect. It consists of determining (1) $\sigma_0\Gamma$ from the "absorption integral" of a thin sample, and (2) $\sigma_0\Gamma^2$ from the cross section far from resonance. The "absorption integral," obtained by a transmission measurement, is defined as

$$A=\int(1-T)dE,$$

where T is the transmission of the sample, and E is energy. The integral, A, is simply related to the quantity $\sigma_0\Gamma$ and to the sample thickness, but only for very thin samples. For thicker samples, A no longer increases as fast as the sample thickness.

Unfortunately, for a very thin sample $(1-T)$ is small and the relative error in A is much greater than that in T. It would therefore be hard to determine A (and thus $\sigma_0\Gamma$) accurately from a measurement on a single very thin sample, because present spectrometers of the time-of-flight type have such low counting rates at high resolution that many hours are required to obtain a statistical accuracy of a few percent in T. Hence measurements were made with several sample thicknesses, A was plotted against the thickness, and $\sigma_0\Gamma$ determined from the slope of the curve at the origin. Figure 1 shows the results of the measurements on one of the four sample thicknesses used. These measurements were made with the new rotating-shutter time-of-flight spectrometer[1] at the Argonne Laboratory.

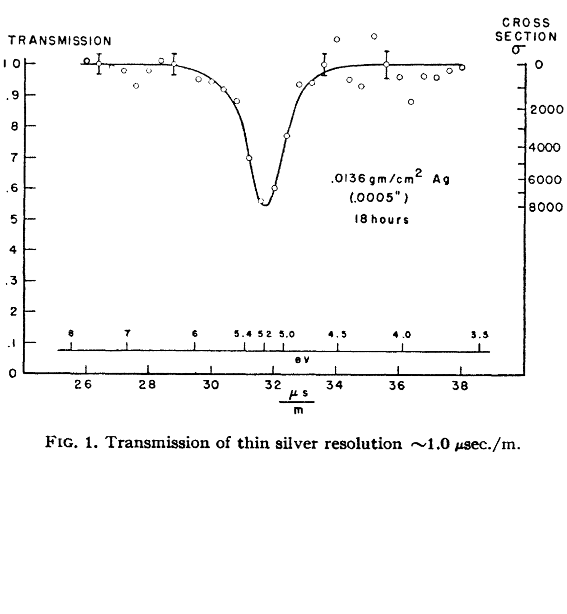

FIG. 1. Transmission of thin silver resolution ~1.0 μsec./m.

As mentioned, σ_0 and Γ, both uncorrected for Doppler effect, were determined without having to introduce the effect of the resolution, or even to assume its form. However, a simple rough calculation of the effect of resolution and Doppler broadening gave an excellent check with the experimental results, and permitted considerable reduction of the probable-error limits on σ_0. The resolution used was roughly triangular in shape, and of a base width about three times the separation between points in Fig. 1. The effect of the resolution, at the resonance peak, was to lower the apparent cross section to 8000 barns from a calculated true value of 10,000 (at room temperature).

The constants for this resonance, as measured in the normal element, are:

$E_r=(5.17\pm0.08)$ ev
$\Gamma=(0.17\pm0.02)$ ev } uncorrected for Doppler effect
$\sigma_0=(12{,}000\pm1500)$ barns }
$(10{,}000\pm1300)$ barns—corrected for Doppler effect.

With values of this accuracy, and with values of Γ_n/Γ which have been obtained by other workers, it is easily possible to determine the neutron width Γ_n, and the spin of the compound nucleus, J. For the isotope having the 5-ev resonance, Ag^{109}, the value of Γ_n/Γ averaged over the resonances in a $1/E$ flux has been found[2] to be ~0.04. From this it can be shown that, for the 5-ev resonance, $J=1$, and $\Gamma_n\approx0.011$ ev.

[1] W. Selove, Phys. Rev. 76, 187A (1949). A detailed description of this apparatus and a more detailed description of measurements made with it are in preparation.
[2] C. C. Muehlhause (unpublished).

Angular Correlation of Successive Internal Conversion Electrons

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AN effect similar to the now well-established angular correlation of successive gamma-rays is a correlation of the corresponding conversion electrons. Such measurements may be rather difficult due to unwanted beta-rays and to multiple scattering in the source and the air. Au^{197}, resulting from K-capture in $25h$ Hg^{197}, was selected for the experiment because it offers a cascade of two strong conversion lines without disturbance by a beta-spectrum (Fig. 1).

The source is prepared in the following way: A gold target is irradiated in the cyclotron with protons. The layer of gold containing the Hg^{197} is placed in a carbon crucible. By heating to ~900°C in a vacuum, the radioactive mercury atoms diffuse out of the gold, evaporate and are directed onto a thin aluminum film on a rocksalt backing. At the same time, a steady stream of inactive gold vapor from a second crucible falls on the aluminum, effectively fixing the mercury.

The aluminum film is then detached from the rocksalt by immersion in water and is transferred onto a collodion foil. The total thickness of source and backing was always less than 0.25 mg/cm².

Coincidences were measured in a vacuum vessel with two G-M counters at angular intervals of 45°. The window thickness of 6-mg/cm² mica cut off the beta-lines of $65h$ Hg^{197} and the K-electrons of $25h$ Hg^{197}, so that mostly coincidences between the

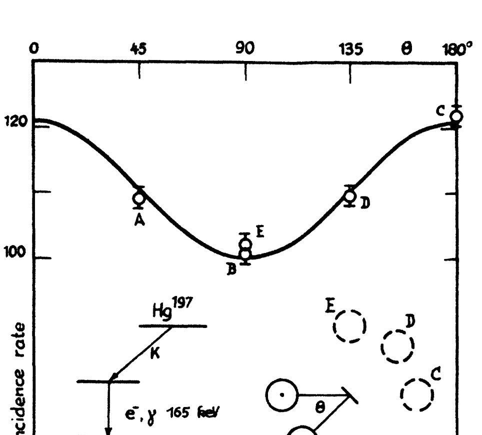

FIG. 1. Angular variation of coincidence rate of successive L-electrons from Au^{197}.

L-electrons were recorded. The contribution from M-electrons is relatively small. To diminish back-scattering the whole apparatus was lined with material of low Z. The points measured in three independent runs are shown in Fig. 1. Assuming a correlation function of the form $(1+A\cos^2\theta)$, with $A=0.24$, and taking into account multiple scattering and the finite solid angles of source and counters we find the solid curve of Fig. 1. The value of A mentioned above gives the best agreement with the measured points, the statistical accuracy being about 0.03.

A rather large contribution from a term of the form $\cos^4\theta$, with the same sign, cannot be excluded because the curve is very insensitive to such terms.

Detailed reports on the measurements and the preparation of the sources will appear in *Helvetica Physica Acta*.

We thank Professor P. Scherrer for his continuous interest and his valuable advice.

Physical Interpretation of Type A Transistor Characteristics

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A METHOD of analysis of a transistor characteristic is described which enables one to distinguish between the effects of the efficiency of current carrier injection by the emitter, the effects of the utilization of these carriers at the collector, and the effects of the current carrier mobility ratio. The fundamental assumption involved is that the back conductance of a crystal rectifying barrier is directly proportional to the number of current carriers in the neighborhood of the barrier which are of the type not impeded by the barrier in their passage from the semiconductor to the metal (holes in an N type crystal and electrons in a P type crystal).

The simple expression for hole injection efficiency, γ, in an N type semiconductor as given by Shockley[1] for a filamentary transistor is

$$\gamma=\frac{I_e+I_b}{I_e}\frac{1-G_0/G}{1+b}. \qquad (1)$$

For our case of a Type A transistor we will define: I_e+I_b is the collector current, I_c; I_e is the emitter current, I_e; G_0 is the d.c. conductance of the collector probe held at given negative voltage with no emitter current; G is the d.c. conductance of the collector probe at the same voltage but with emitter current flowing; b is the ratio of the electron mobility to the hole mobility; and γ is the fraction of the emitter current carried by holes.

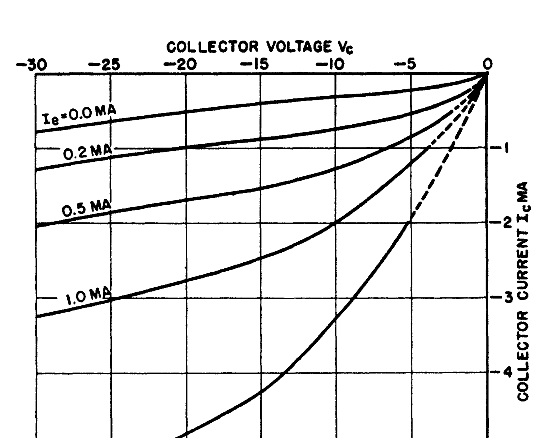

FIG. 1. Typical transistor output characteristics.

From the typical transistor output characteristics of Fig. 1 the above quantities may be obtained, and the value of $\gamma(1+b)$ calculated from (1). A plot of $\gamma(1+b)$ against collector voltage (Fig. 2) produces a set of performance characteristics from which several interesting properties of the transistor may be deduced.

From Fig. 2 it can be seen that none of the performance characteristics exceed the value 2.5 for $\gamma(1+b)$. From a study of a number of good transistors it was found that the saturation value of the performance characteristics never exceeded 2.5. It seems reasonable to assume that this value of $\gamma(1+b)$ then represents a hole injection efficiency of 100 percent, or a γ of 1.0. The mobility ratio, b, for these samples of germanium is then seen to be about 1.5. This value of b is in good agreement with other measurements.[2]

Many poor transistors show saturation values of performance characteristics much lower than 2.5. In these cases the mobility ratio is probably still about 1.5 but the hole injection efficiency of the emitter is low and may be computed from the saturation value of $\gamma(1+b)$ by dividing by 2.5. These considerations would

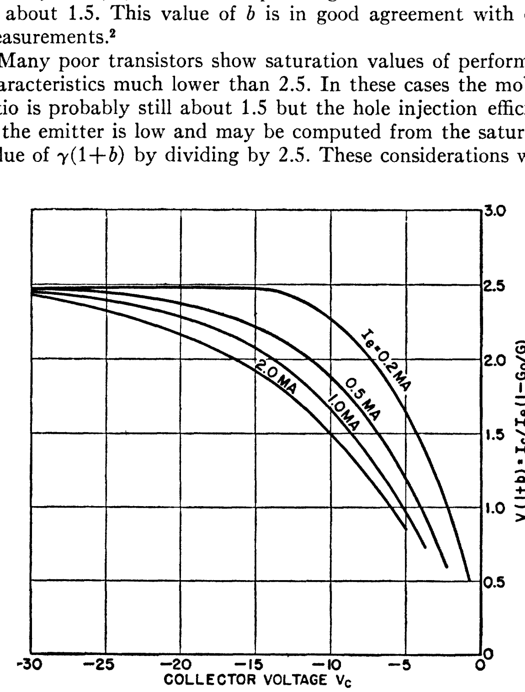

FIG. 2. Typical transistor performance characteristics.