about 1, 2, and 5 micrograms/cm² in addition to the backing film.

These are considerably thinner than the sources previously reported. It is important to note that a source as thin as that used for Fig. 1C gives such large deviations from the straight-line Fermi plot, and these results emphasize the importance of using extremely thin sources for low energy measurements. Rough data also indicate that additional source backing (a collodion film of ~10 micrograms/cm²) noticeably distorts the low energy portion of the spectrum. This effect is being investigated further.

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* This letter is based on work performed under Contract AT-30-1-Gen-72, and the information covered therein will appear in the Manhattan Project Technical Series, as part of the contribution of Columbia University.

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Secondary Electron Emission by Fast Neutral Molecules and Neutralization of Positive Ions*

H. W. BERRY
Syracuse University, Syracuse, New York
August 4, 1948

WHEN a beam of positive ions passes through a gas at rest there occurs a weakening of the beam by a charge exchange with the gas atoms.[1] For most of these charge collisions the now fast atom undergoes little deviation. As a result there is little transfer of kinetic energy and we have, on removing any unneutralized ions, a beam of fast atoms with an energy equivalent to that of the original ion beam. One method of detection of such a neutral beam is to allow the atoms to strike a metal surface and measure the secondary electrons emitted under this bombardment.[2] The investigation here reported concerns the measurement of the number of these secondary

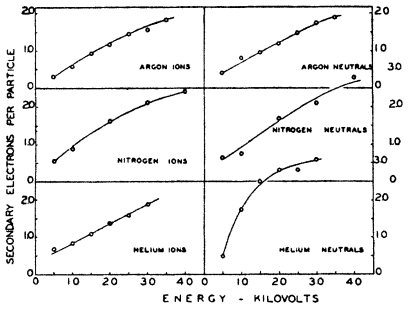

FIG. 1. Number of secondary electrons emitted from a tantalum surface per particle as a function of the energy of the particle in electron volts.

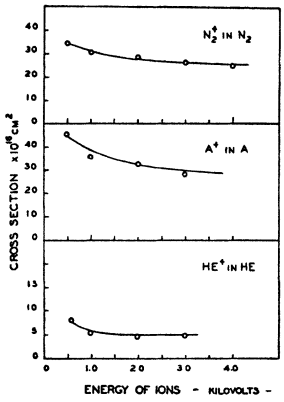

FIG. 2. Cross section for neutralization of ions in their own gas as a function of the ion energy in electron volts.

electrons removed from a tantalum surface by argon, helium, and nitrogen ions and molecules with energies ranging from 500 to 4000 electron volts.

A beam of positive ions of the desired energy is directed into a region where the same gas as that from which the positive ions are formed is present at a pressure of 10^{-4} to 10^{-3} mm of Hg. If in this neutralizing chamber a charge exchange collision should occur, the fast ion now becomes a neutral atom and a gas atom an ion. Most of these charge exchange collisions will be glancing, as is indicated by the much larger cross section for collisions obtained from various kinetic theory measurements. Hence most of the ions resulting from this charge exchange will be slow. These slow ions can be collected on an electrode by a small potential difference between the ends of the neutralizing chamber. In confirmation of this, it is found that as the potential difference between the electrodes at the ends of the neutralizing chamber is increased, the slow positive ion current collected by the electrodes increases rapidly with the voltage up to 40 or 50 volts. From 50 to 80 volts the current remains practically constant but beyond 80 volts rises again. The now neutralized fast atom may continue through a hole in the end of the neutralizing chamber and strike the tantalum surface from which the secondary electron emission occurs.

If E_+ = the ion current to the tantalum surface when it is positive, thus holding secondary electrons, E_- = the current to the tantalum surface (positives arriving, electrons leaving) when the surface is negative, and A = the slow positive ion current collected in the neutralizing chamber; then $E_- - E_+$ = the number of secondary electrons removed from the tantalum surface.

$$E_- - E_+ = k_+ E_+ + k_0 A,$$

where k_+ = number of electrons removed per positive ion striking the surface and k_0 = number of electrons removed per neutral atom striking the surface; so

$$(E_- - E_+)/E_+ = k_+ + k_0(A/E_+).$$

Now if the pressure in the neutralizing chamber is increased the slow positive ion current A will increase; since more ions are neutralized and since there are now,

proportionately, more atoms than ions in the beam, $(E_- - E_+)/E_+$ will also increase. When $(E_- - E_+)/E_+$ is plotted against A/E_+ (as abscissa) straight lines are obtained. The intercept of the line with the ordinate is the value of k_+, and the slope is k_0. Argon, nitrogen, and helium were investigated, and the values of k_+ and k_0 are shown in Fig. 1.

Since the current A is a measure of the number of neutralizing collisions occurring, it is possible with the same arrangement to measure the cross section for neutralization of each ion in its own gas for various ion energies. The cross section as a function of the ion energy is shown in Fig. 2.

* This work was supported in part by the Office of Naval Research under Contract N6Onr-248 T.O.I.

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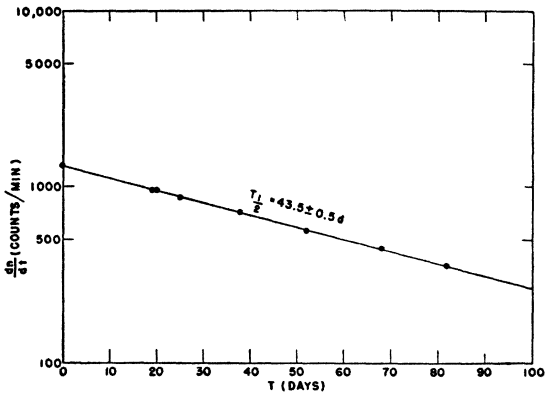

FIG. 1.

The Beta-Spectrum of $Hg^{(203)}_{(205)}$

D. SAXON
Argonne National Laboratory, Chicago 80, Illinois
August 19, 1948

THE 180° β-spectrometer has been used to measure the long-lived $Hg^{(203)}_{(205)}$ activity. In their final work, G. Friedlander and C. S. Wu[1] found 51.5±1.5 days for the half-file, 460 kev for the β-end point by absorption in Al, and a γ-ray of 300 kev by absorption in Pb. L. C. Miller and L. F. Curtiss,[2] using a thin lens spectrometer, obtained the β-end point as <0.3 Mev and the γ-energy as 0.28 Mev.

The sample, in the form of the oxide, was irradiated in the Argonne heavy-water pile. After allowing a month for the shorter activities to decay, the half-life measurements were started; at present they indicate a single activity of 43.5±0.5 days (see Fig. 1). The sample is still being followed to see if a longer-lived tail exists, possibly explaining the large difference between the present value and that of Friedlander and Wu.

The source for the spectrometer was of thickness ~2.4 mg/cm², mounted on Nylon backing of 0.54 mg/cm². The resolution $\Delta H\rho/H\rho$ finally used was 2 percent; a previous source used at 1 percent proved to be too weak.

In Fig. 2 the spectrum shape is shown for two values of window thickness—the first 0.05 mg/cm², the second ~0.2 mg/cm², both of Nylon. It is clear that the true β-end point is hidden in the K and L conversion lines of the γ-ray. The previous β-end-point measurements included these lines and are, accordingly, much too high. In that of Miller and Curtiss, the source was quite thick, 20 mg/cm² mounted on 3-mg/cm² backing, with the counter window 2.36 mg/cm². This means that, essentially, the continuous β-spectrum was not counted in their measurement.

To get the true end point, and a comparison for spectrum shape, the Kurie plot of the Fermi theory is shown in Fig. 3. Below the K line the plot is linear back to 40 kev, then falls rapidly as a result of window absorption. Extrapolating the linear portion through the base of the K line, the end point is obtained as 205±10 kev. Using this end point, with the half-life of 43.5 days, the ft value was computed at 2.6×10^6. This places the activity in the first forbidden empirical classification. However, from the linearity of the Kurie plot, the spectrum shape, where visible, is allowed. Thus the total forbidden correction factor is constant with energy, the theory giving this for $\Delta J=0, \pm1$, with any of the interactions for heavy elements.[3]

From the K and L conversion lines, the energy of the γ-ray is 286±5 kev, correction for the resolution having been made. This agrees well with the value of Miller and Curtiss.

The present result assumes the γ-ray after the simple β-transition to $Tl^{(203)}_{(205)}$, checked by the decay of the conversion lines with the Hg period.

The conversion coefficients are as follows:

$E(\gamma)$	K	L	M	K/L	L/M
286	18%	6%	≤0.5%	3	≥12

Assuming the radiation to be electric multipole, and extrapolating the theoretical ratio[4] for K/L to high Z, it is found that the γ-ray has $\Delta l=2$.

Friedlander and Wu produced the Hg activity with both fast and slow neutrons, and thus suggested the mass assignment of 203. No check on this was made with the

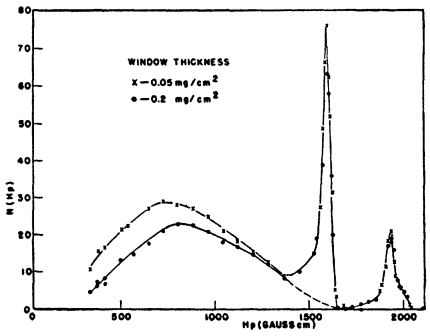

FIG. 2.