TABLE I. Transition probabilities in long-lived tellurium isomers.

Isomer	2^4m (kev)	2^5el (kev)	$\lambda 2^5/\lambda 2^4$ (old)	$\lambda 2^5/\lambda 2^4$ (new)	$t_{\frac{1}{2}}$ (sec) (new)	$t_{\frac{1}{2}}$ (sec) (exp)
Te^{121}	82	295	3.5×10^3	0.4	3.7×10^7	$1.33\times10^7(154d)$
Te^{123}	88.5	247.5	7.0×10^2	7.0×10^{-2}	2.7×10^7	$9.0\times10^6(104d)$
Te^{125}	109.7	145.1	1.0	2.0×10^{-4}	1.2×10^7	$5.0\times10^6(58d)$

2^4 transitions and of the expected cross-over electric 2^5 transitions. Column 4 gives the ratios of the total transition probabilities based on older formulas, as, for example, that used by Axel and Dancoff[3] in their classification of nuclear isomers. The same ratios, based on the new formula of Weisskopf, are given in column 5. Total transition probabilities include corrections required to take into account internal conversions, the coefficients of which were obtained from Rose's accurate tables,[4] either directly or by extrapolation. Values of K to L ratios were also required, and these were taken from the graphs of Lowen and Tralli.[5] Uncertainties involved in the knowledge of theoretical K to L ratios at this stage will not significantly change the transition probabilities of Table I.

Experimentally, all electric 2^5 transitions can be excluded at present to within approximately 5 percent of the magnetic 2^4 transitions. From Table I it is clear that although the older estimates would indicate the cross-over 2^5 transitions to be more probable than the 2^4, the new estimates of transition probabilities are essentially in agreement with experiment.

Theoretical lifetimes for the converted magnetic 2^4 transitions are listed in column 5. The new values are again in significantly better agreement with experimental lifetimes than are the older values.

It is interesting also to compare estimated lifetimes of the intermediate tellurium states with the upper limits established experimentally for these lifetimes. Theoretical estimates based on old and new formulas are shown in columns 3 and 4, respectively, of Table II. In one case, the 35.4-kev excited state of Te^{125}, the

TABLE II. Lifetimes of intermediate states of tellurium isomers.

Isomer	2^4m (kev)	$t_{\frac{1}{2}}$ (sec) (old)	$t_{\frac{1}{2}}$ (sec) (new)	$t_{\frac{1}{2}}$ (sec) (exp)
Te^{121}	213	7.65×10^{-10}	1.3×10^{-11}	$<3\times10^{-9}$ [a]
Te^{123}	159	3.05×10^{-9}	2.55×10^{-11}	$<2\times10^{-8}$ [b]
Te^{125}	35.4	4.6×10^{-7}	1.85×10^{-10}	$<5\times10^{-9}$ [c]

[a] M. Deutsch and W. E. Wright, Phys. Rev. **77**, 139 (1950).
[b] S. Frankel (thesis, University of Illinois, 1949).
[c] K. McGowan, Phys. Rev. **77**, 138 (1950).

present experimental evidence decides strongly in favor of the new estimates as opposed to the old.

Valuable criticism of this investigation by John M. Blatt is gratefully acknowledged.

[1] Privately circulated notes, to appear as part of a book on nuclear physics.
[2] R. D. Hill, Phys. Rev. **76**, 333 (1949); J. C. Bowe and G. Scharff-Goldhaber, Phys. Rev. **76**, 438 (1949); Katz, Hill, and Goldhaber, Phys. Rev. **78**, 9 (1950).
[3] P. Axel and S. M. Dancoff, Phys. Rev. **76**, 892 (1949).
[4] Rose *et al.*, *Tables of K-Shell Conversion Coefficients*.
[5] N. Tralli and I. S. Lowen, Phys. Rev. **76**, 1541 (1949).

Multiple Scattering of Electron Pairs from (Li, *p*) Gamma-Rays in Photographic Emulsions

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IN order to check multiple Coulomb scattering results obtained for high energy cosmic-ray particles with photographic emulsions,[1] we have made scattering measurements on electron pairs observed in emulsions exposed to Be^8 γ-rays from the bombardment of an evaporated lithium target with a 450-kev resolved proton beam. Ilford G5 emulsions 400μ thick were irradiated with about 10 milliroentgens of γ-radiation.

The scattering method follows that developed by Fowler,[2] in which the perpendicular coordinates of a track are recorded at equal intervals along the axis of motion of the microscope stage to which the track is made approximately parallel. The arithmetic mean $\langle|D|\rangle_{Av}$ of the second differences of the perpendicular coordinates is related to the projected mean angle between successive chords at intervals q by the expression $\langle\alpha(q)\rangle_{Av}=\langle|D|\rangle_{Av}/q$. From the multiple scattering theory of Williams,[3] as formulated by Rossi and Greisen,[4] $\langle\alpha(q)\rangle_{Av}=(K/p\beta)(q/100)^{\frac{1}{2}}$ degrees[5] where $K=32.7$, p is the particle momentum in units Mev/c, β is the velocity in units of c, and q is in microns of emulsion.

Observations have been made on a total of 100 electron pairs at intervals of 20 divisions (1 div$=0.88\mu$) for about 700μ along each track. Figure 1 shows the scattering distribution for one of

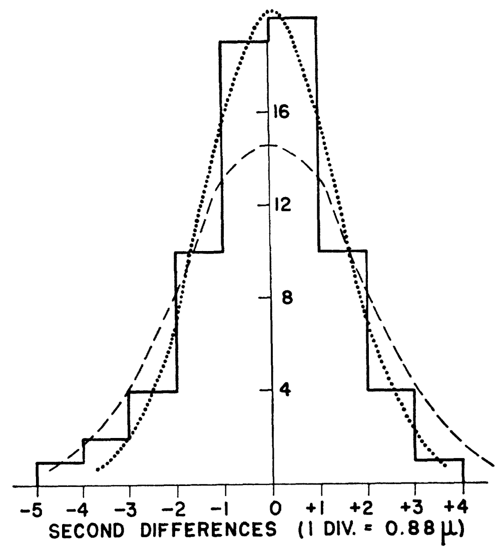

FIG. 1. Distribution of second differences for the tracks of an electron pair with equal energy division. The histogram represents 71 combined values for overlapping intervals of 40 div, and the dotted curve is a Gaussian with the same arithmetic mean ($\langle|D|\rangle_{Av}=1.09\pm0.09$ div).

the pairs which represents a case of almost equal energy division from the incident γ-ray. Using the observed value for $\langle|D|\rangle_{Av}$ the calculated total energy of each electron is 12.7 Mev, which corresponds to a γ-ray energy of 25.4 ± 2 Mev. This is to be compared with the maximum Be^8 γ-ray energy[6] (17.6 Mev). It would appear from this example that the experimental scattering distribution is approximately Gaussian, but K is too big.

The γ-ray energies deduced from the experimental values of $\langle|D|\rangle_{Av}$ for 100 electron pairs are shown in Fig. 2. Curve A is the Be^8 γ-ray spectrum as given by Walker and McDaniel[6] for a thin lithium target at 460-kev proton energy with a magnetic pair spectrometer. This shows the pronounced 17.6-Mev line and a very broad lower energy line. Curve B shows our results for 70 pairs observed in a plate exposed to γ-rays in the forward proton direction. Besides a shift of the spectrum to higher energies, this curve shows some evidence for two peaks, whose relative intensities differ considerably from those shown by Walker and McDaniel. It is difficult to attribute the shape of curve B as being a distortion of curve A due to some feature of the scattering method. We have therefore exposed plates at 90° to the proton beam direction to test for any noticeable angular asymmetry in the relative intensities of the two γ-ray lines.[7,8] Curve C shows preliminary results for 30 electron pairs from this irradiation, in which there is an indication of two γ-ray groupings which more nearly resemble the spectral distribution shown in curve *A*. It may be noted that the relative positions of the two groups in curves *B* and *C* are about the same as that given by the results of Walker and McDaniel.

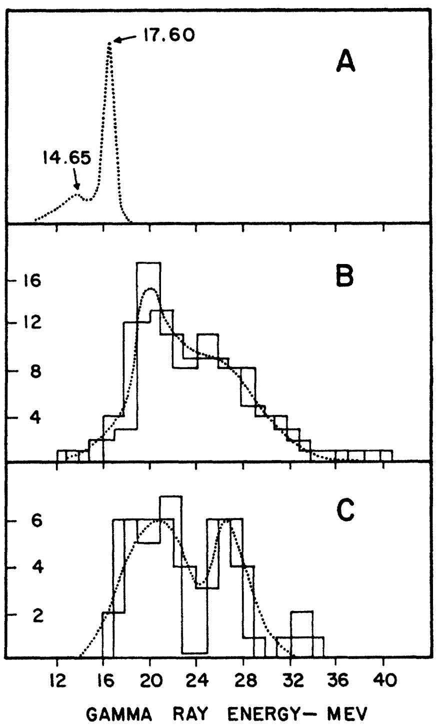

FIG. 2. Be^8 γ-rays. *A*—Results of Walker and McDaniel. *B*—Energy distribution of 70 electron pairs from γ-rays in forward proton direction. *C*—Energy distribution of 30 electron pairs from γ-rays at 90° to proton direction. In curves *B* and *C* the overlapping histograms show number of electron pairs per 2-Mev interval, dotted curves represent approximate smoothed results.

If we assume that the apparent groupings at energies 21 ± 1 and 26 ± 1 Mev in curves *B* and *C* are due to the 14.65- and 17.60-Mev γ-rays, and if we correct for energy losses by the electrons ($\sim$0.4 Mev) and spurious experimental scattering ($\sim$3 percent), then the constant K is reduced from 32.7 to a value 21.3, with an estimated probable error of 5 percent. This result is in agreement with recent measurements by Corson[9] on 115-Mev electrons.[10] Thus it would appear that energy values obtained by this scattering method using $K=32.7$ may be too high by about 35 percent.

It will be of interest to test the scattering of particles other than electrons. Further work will be done on the Be^8 electron pairs to investigate the apparent asymmetry of the spectrum and to establish the resolution of the multiple scattering method.

We are indebted to Mr. E. H. McLaren for the H.T. set irradiations and to Miss S. W. Young for searching the emulsions for electron pairs.

[1] Camerini, Fowler, Lock, and Muirhead, Phil. Mag. 41, 413 (1950); E. Pickup and L. Voyvodic, Phys. Rev. 80, 89 (1950). Camerini, *et al.* used $K=32.7$ determined from a proton calibration and we used their value.
[2] P. H. Fowler, Phil. Mag. 41, 169 (1950).
[3] E. J. Williams, Proc. Roy. Soc. 169, 531 (1939).
[4] B. Rossi and K. Greisen, Revs. Modern Phys. 13, 240 (1941).
[5] This was calculated using a radiation length of 2.86 cm of emulsion.
[6] R. L. Walker and B. D. McDaniel, Phys. Rev. 74, 315 (1948).
[7] The γ-ray orientation in reference 6 was not specified.
[8] S. Devons and M. G. N. Hine, Phys. Rev. 74, 976 (1948) observe a small asymmetry (near resonance) in the Be^8 γ-radiation and mention that observations on this asymmetry, as a function of γ-energy, indicate that the 17-Mev component is mainly responsible.
[9] D. R. Corson, Phys. Rev. 80, 303 (1950).
[10] It is also in fair agreement with the detailed statistical theory of Williams (reference 3) as will be discussed in a subsequent note.

Electron Bombardment Induced Conductivity in Germanium Point Contact Rectifiers

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ELECTRON bombardment experiments on insulators and semiconductors using electrons in the kev range have been reported. Some of this work dealt with the currents induced in the solid by the electron beam.[1-4] This is called electron bombardment induced conductivity (EBIC). Some workers have employed α-particles of several Mev energies, and were principally interested in the corresponding current pulses in insulators or semiconductor rectifiers as crystal counters.[5,6] This is a report of preliminary experiments on the bombardment of germanium rectifiers with electrons of several kev energy.

The technique employed here involves scanning the surface of the germanium crystal with an electron beam magnetically deflected in a standard 525 line television raster. The ac component of the current flowing in the probe circuit is used as a video signal which either modulates the grid of a kinescope which is being synchronously deflected, or modulates the vertical deflection of an ordinary oscilloscope. In the first case a two dimensional plot of the EBIC is obtained which shows immediately the effects of nonhomogeneity on the surface; in the second case a quantitative measure of the diode current is obtained.

The diodes studied consisted of $2.5\times2.5\times0.5$ mm pieces of Ge, large area heavily gold-plated base electrodes, and phosphor bronze probes inclined 45° to the Ge surface and to the beam, which strikes normally.

Figures 1a and b show the result on the kinescope of bombarding an *N*-type crystal biased in the back and forward direction respectively. The black level signal corresponds to an electron current from the probe into the Ge in the diode circuit; the white signal is the reverse. Thus the effect of the electron beam is always to increase the conductivity for both directions of bias. The sensitive region in the neighborhood of the point can be measured with accuracy by the scanning method, and a suitable scale is shown. The diameter of this sensitive region increases with increasing positive or negative bias. The size shown on the figure agrees with the rough estimate made by McKay[6] using α-particles and negative bias.

The magnitude of the EBIC effect can be seen from Fig. 2. Here δ is the ratio of the change of crystal probe current to beam current, given as a function of bias for three different beam voltages. The values plotted are maximum currents, obtained when the beam sweeps within 0.001″ of the point contact. Note that δ reaches saturation in the forward and reverse directions, but the values of δ_{sat} are not the same. Table I gives the ratio of δ_{-sat} (back direction) to δ_{+sat} (forward direction) for the beam voltages of Fig. 2. The ratio $\delta_{-sat}/\delta_{+sat}$ is constant within experimental error. Since the barrier at the contact is present in the back but not in the forward direction, $\delta_{-sat}/\delta_{+sat}$ has been tentatively interpreted as the current multiplication at the barrier, analogous to the "excess" values of α obtained in transistor experiments.[7] However, it is not yet certain whether some of this factor of 10 must be assigned to the normal current gain accompanying hole injection.

TABLE I. Saturation values of δ.

Beam voltage	δ_{+sat}	δ_{-sat}	$\delta_{-sat}/\delta_{+sat}$
5 kv	0.54×10^3	0.55×10^4	10.2
7.5	1.5	1.5	10.0
10	1.9	1.8	9.5

The advantage of the scanning technique in uncovering surface or subsurface effects as well as evidence for the motion of holes can be seen in Fig. 1c. The *N*-type crystal under bombardment