separating the collector region C, taken to be n-type from the base B. This base-collector structure resembles an n–p–n transistor, similar to a p–n–p transistor. Holes arriving at M will be held by a "hook" in the potential energy curve and will bias the p–n junction M–C forward and provoke an electron flow from C into M. If M is thin, the electrons will diffuse through it and fall through the potential drop across B–M; B–M is an n–p junction biased in reverse by the collector voltage. The theory of p–n–p transistors can be applied to this process and it can be seen that very high values of α can arise in this way.

I am indebted to many of my colleagues for discussions of theories and experiments related to high values of α.

[1] J. Bardeen and W. H. Brattain, Phys. Rev. **75**, 1208 (1949).
[2] This reasoning is very similar to that of L. P. Hunter, Phys. Rev. **77**, 558 (1950).
[3] W. G. Pfann, personal communication.
[4] W. Shockley, Bell Sys. Tech. J. **28**, 435 (1949).

Internal Conversion Coefficients for Co^{60}

M. A. Waggoner, M. L. Moon, and A. Roberts
Department of Physics, State University of Iowa, Iowa City, Iowa
March 9, 1950

Recently several papers[1,2] have appeared in which the results of elaborate calculations of internal conversion coefficients are given. These are believed to be accurate to a few percent. It was our purpose in undertaking this investigation to attain sufficient accuracy in the experimental determinations to provide a significant test of the theory. For this reason we selected for our first experiments Co^{60} for which the gamma-rays are known to be quadrupole from angular correlation experiments.[3]

The measurements were made by means of a double-coil, thin-lens spectrometer in which considerable care had been taken to reduce the background due to scattering. For the setting used in these experiments the transmission was 2.40 percent and the half-width about 3.0 percent. Since it was necessary for us to use sources of slightly different diameters (ranging from 4.45 to 5.50 mm) we calibrated half-width against source diameter and found a slight increase with source diameter. Accurate knowledge of the half-width is essential to the integration of the β-spectrum. In measuring the transmission of the spectrometer we used the β-spectrum of several Co^{60} sources which had been calibrated by coincidence measurements. Because of window effects our data were not good below about 120 kev and we reconstructed the momentum plot by extrapolating to zero the straight Fermi plot (allowed) observed at higher energies. The end point for the β-spectrum was found to be 318.7±4.0 kev. The Co^{60} used was high specific activity material obtained from the Oak Ridge National Laboratory and was mounted on a 3-ply laminated backing (zapon-Formvar-zapon) and then covered with a single zapon film. Each of these films was less than 30 $\mu g/cm^2$. The three strongest sources were less than 0.20 mg/cm^2; the other three used, less than 0.016 mg/cm^2. Effects due to source charging were eliminated. The spectrometer was calibrated against the crystal spectrograph values[4] for the Co^{60} gamma-ray lines.

The values we obtain for the coefficients of conversion in the K, L, M shells together (unresolved) for the two gamma-rays from Co^{60} and the theoretical values[1] of the conversion coefficients for electric quadrupole radiation in the K shell are shown in Table I.

For all other types of radiation the conversion coefficients differ from those for EQ by a factor of at least two. Supposing the $L+M$ conversion and screening effects to contribute about 10 percent, our results classify both gamma-rays as electric quadrupole. Comparison with angular correlation measurements[3] then fixes the spins and parities of the three nuclear levels involved as: 0, 2, 4; same (even).

TABLE I. Internal conversion in excited states of Ni^{60}.

E (Mev)	$\alpha_{exp}\times10^4$	Theoretical value: $\alpha_K^{(2)}\times10^4$
1.1715	1.733±0.061	1.545
1.3316	1.286±0.035	1.175

Although agreement between theory and experiment seems quite good, more exact comparison cannot be made until the theoretical values for the effects of $L+M$ conversion and screening have been calculated. The present results are in agreement with those published by Deutsch and Siegbahn[5] within the relatively large error of the latter; however, the classification of both gamma-rays now seems unambiguous.

[1] Rose, Goertzel, Spinrad, Harr, and Strong, Phys. Rev. **76**, 184 (1949).
[2] J. R. Reitz, Phys. Rev. **77**, 10 (1950).
[3] E. L. Brady and M. Deutsch, Phys. Rev. **74**, 1541 (1948).
[4] Lind, Brown, and Du Mond, Phys. Rev. **76**, 591 (1949).
[5] M. Deutsch and K. Siegbahn, Phys. Rev. **77**, 680 (1950).

Comment on Mobility Anomalies in Germanium

G. L. Pearson, J. R. Haynes, and W. Shockley
Bell Telephone Laboratories, Murray Hill, New Jersey
March 17, 1950

It appears probable that the simple theory of spherical energy surfaces in the Brillouin zone for both holes and electrons in germanium may have to be modified in view of experimental results on mobility and magneto-resistance.

In this letter we shall quote the results of three methods of determining mobility:

Drift mobility. The technique of obtaining the mobility of injected current carriers in germanium by the direct measurement of their transit times over known distances and under the influence of known electric fields has been improved so that measurements with an error of less than 5 percent are obtained. This improvement over earlier equipment[1,2] consists largely in the substitution of pulse techniques for d.c. measurements leading to an unambiguous determination of transit time. The measurements include data on samples of both n- and p-type single crystals as well as on crystals grown by different techniques.

Hall mobility. Only under certain simplifying assumptions is $(8/3\pi)R\sigma$ theoretically equal to the mobility. We shall refer to the experimentally determined value of $R\sigma$ as the *Hall mobility*. Hall mobilities were obtained using the identical samples described above, excepting that the electron mobility values were obtained on n-type material and hole mobility on p-type, the reverse of the drift experiment. The most probable values for $(8/3\pi)$ times the Hall mobility are 1700 cm^2/volt-sec. for holes and 2600 cm^2/volt-sec. for electrons[3] although the experimental accuracy of this method is equal to that of the drift method, the spread in mobility values from sample to sample is much larger, being 1600 to 2200 cm^2/volt-sec. for holes and 2400 to 2900 cm^2/volt-sec. for electrons. (We do not find the large spreads or very high values reported by Dunlap.[4])

Conductivity mobility. Samples of germanium with radioactively determined concentrations of added antimony were found to have a conductivity which was linear in the added antimony and corresponded[5] to the mobility given in Table I. The experimental uncertainty in this work was quite large, due in part to grain boundary effects for which corrections were attempted. Agreement between drift and conductivity mobility is to be expected unless electron-hole collisions are important or appreciable trapping is involved, neither of which is probable for germanium.

TABLE I. Mobilities in cm^2/volt-sec. in germanium.

	$(8/3\pi)\times$Hall mobility	Drift mobility	Conductivity mobility
Electrons	2600±300	3600±180	3350±400
Holes	1700+500−100	1700±90	——

An interpretation, planned for later publication, of the Hall coefficient formula[5a] shows that the Hall mobility may be much