cussion be identified with the transition ${}^1B_1 \rightarrow {}^1A_1$ and should consist of perpendicular-type bands.

The preceding probable identification of the CF_2 bands lends support to the obtuse-angled model with ${}^1A_1$ ground state for CH_2. The presence of partial double-bond formation in CF_2 does not alter this conclusion, since the strength of π (i.e., $2p_x$) bonding in an AB_2 molecule is readily seen to be insensitive to the apex angle.]

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Internal Conversion in Ni^{60}

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The coefficients of internal conversion for the two gamma-rays accompanying the decay of Co^{60} have been measured. For the 1.17-Mev gamma-ray we find $\alpha = 2.3 \times 10^{-4}$, for the 1.33-Mev ray $\alpha = 1.8 \times 10^{-4}$. Comparison with theoretical values indicates that the parity change must be the same in both transitions and that the two gamma-rays are probably electric quadrupoles.

ALTHOUGH the decay of Co^{60} has been studied in considerable detail, no measurement of the coefficients of internal conversion of the two well-known gamma-rays has been published. We have used a large, double-focusing spectrometer of 50-cm radius of curvature to measure these coefficients. This instrument admits a solid angle of about 0.12 steradian and, with the extended sources used in these experiments, permits a resolution of about one percent. The magnetic field is measured by balancing the induced e.m.f. of a rotating coil against that of another coil rotating on the same shaft in the field of a set of Helmholz coils. The current through the latter is measured with a precision ammeter. The precision of the field measurements is estimated to be about ± 0.1 percent. An absolute momentum calibration was obtained by the measurement of several well-known electron lines from ThB and of secondary electrons produced by annihilation radiation.

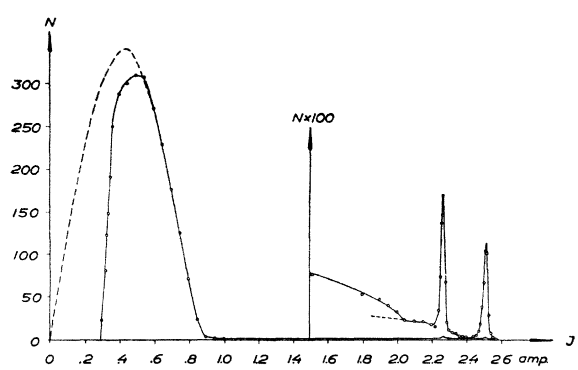

Fig. 1. The electron spectrum of Co^{60}.

Figure 1 shows a momentum spectrum of the electrons from Co^{60}. A counter window of about 3 mg/cm² thickness was used. The two internal conversion lines are shown again in the insert, with the ordinate multiplied by 100. Although the number of conversion electrons is only of the order of 10^{-4} of the number in the primary spectrum, the peaks are well resolved since they appear beyond the end point of the continuum. The low intensity continuous high energy "tail" on the distribution is due to Compton electrons ejected from the source and parts of the spectrometer. The conversion coefficients were determined by comparing the area under each of the peaks with that under the continuous spectrum. The integration of the latter is made difficult by the effect of the counter window, which seriously distorts the spectrum below about 0.15 Mev. Above this energy the observed spectrum is well represented by an allowed Fermi plot and we assumed that the low energy part also follows the allowed shape. The effect of source thickness is probably to cause us to underestimate the number of beta-rays since retardation in the source will reduce the relative number of high energy particles on which our extrapolation is based. The two sources used in our experiments were 8 mg/cm² and 2 mg/cm² thick, respectively, which may cause some error in this direction. Another factor which may cause us to overestimate the conversion coefficients is the production of photo-electrons in the cobalt of the source material. These could not be resolved from the conversion electrons from the nickel product nucleus. From the known source thickness we estimate that this error should be only a few percent. This was confirmed by the fact that the area under the two peaks remained practically unchanged when the source was covered with 18 mg/cm² of copper. If the peaks were largely due

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TABLE I. Experimental and theoretical values of internal conversion in the K shell, $\alpha K \times 10^4$.

Gamma-energy Mev	Experiment	Electric 2^l-pole $l=1$	$l=2$	$l=3$	Magnetic 2^l-pole $l=1$	$l=2$
1.17	2.12	0.74	1.58	3.17	1.24	2.93
1.33	1.68	0.60	1.17	2.11	0.97	2.13
Ratio	1.26	1.23	1.35	1.50	1.28	1.37

to external photo-electrons, the additional conversion in the copper would have increased their intensity. Instead, their height was decreased and their width increased as one would expect from straggling of electrons traversing the copper. At the same time the peaks were shifted to lower energies by 16 kev as shown in Fig. 2. The magnitude of this shift is in good agreement with theoretical expectation[1] and agrees within about ten percent with a value for the stopping power of copper obtained by interpolation between the experimental values for other elements.[2]

Using the areas under the distribution as described above, we find for the internal conversion coefficients of the two gamma-rays the values $\alpha_{1.17}=2.32\times10^{-4}$ and $\alpha_{1.33}=1.83\times10^{-4}$. If we subtract from these values eight percent for the unresolved L conversion electrons, as indicated by the calculations of Hebb and Nelson,[3] we obtain the values for the K conversion coefficients shown in Table I. This table also gives the theoretical coefficients according to recent calculations of M. E. Rose and co-workers.† Three significant figures are given for the experimental values because their *ratio*, also indicated in Table I, is known with much greater accuracy than the absolute values. The latter seem to be in error by about 30 percent, the discrepancy from the nearest theoretical values which are believed to be quite accurate. From our discussion of experimental errors it seems more probable that we overestimated the coefficients so that it is likely that the two gamma-rays are both electric quadrupole transitions. This would be in good agreement with their angular correlation.[4] If one prefers to be more conservative in evaluating the experimental uncertainties, it can still be stated that both radiations are either quadrupole or possibly electric octupole. Thus the first excited state in Ni^{60} has probably spin 2 or possibly 3. From the ratio of the two conversion coefficients it is also quite certain that the two gamma-rays have the same parity. For example, if one of them is a magnetic quadrupole having odd parity, the other cannot be an electric quadrupole (even parity) but could be either magnetic quadrupole or electric octupole. Thus the total change in parity for the cascade must be even and the 2.50-Mev state in Ni^{60} has the same parity as the ground state.

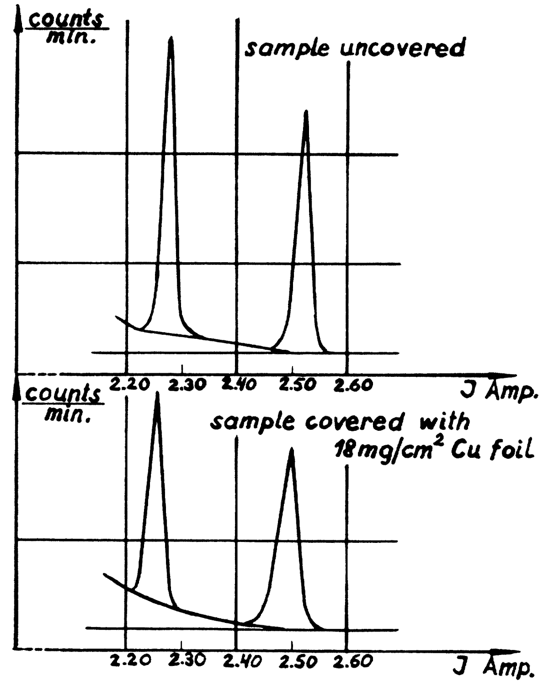

FIG. 2. Photo-electron lines of Co^{60}.

In the course of these experiments we also measured the energies of the two gamma-rays both by the energies of the conversion lines and by those of photo-electrons ejected from a 4-mg/cm² lead converter. Internal conversion electrons from the thinner sample gave the energies 1.177 Mev and 1.342 Mev, those from the thicker sample 1.171 Mev and 1.332 Mev, respectively. A weighted mean of the K and L photo-electrons from the lead converter yielded the values 1.172 Mev and 1.335 Mev. We adopted the values $E_1=1.174\pm0.005$ Mev and $E_2=1.338\pm0.005$ Mev until we became aware of the results of Lind, Brown, and DuMond.[5] The excellent agreement of these two very different determinations is gratifying.

It is a pleasure to express our gratitude for the cooperation of our colleagues at the Nobel Institute and for the hospitality extended by the Institute to one of us (M.D.) during his stay in Sweden.

[1] See W. Heitler, *Quantum Theory of Radiation* (Oxford University Press, London, 1944), p. 219, Eq. (5) and p. 221, Eq. (9).
[2] Rutherford, Chadwick, and Ellis, *Radiations from Radioactive Substances* (Cambridge University Press, London, 1930), pp. 98–100.
[3] M. H. Hebb and E. Nelson, Phys. Rev. **58**, 486 (1940).
† Private communication.
[4] E. L. Brady and M. Deutsch, Phys. Rev. **74**, 1541 (1948).
[5] Lind, Brown, and DuMond, Phys. Rev. **76**, 591 (1949).