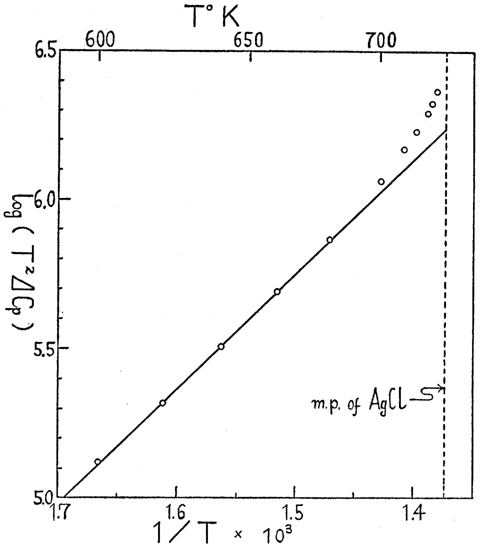

FIG. 1. Plots of $\log(T^2\Delta C_p)$ vs $1/T$.

centration of Schottky defects. If the curve is resolved into two lines, the upper component may be used to estimate the concentration of the pairs of vacant sites associated with the Schottky defect. If we assume that the concentration of Frenkel defects in AgCl obeys the relation (1) with $\Delta H = 35{,}200$ cal/mole and that the mutual interaction between the defects of both types is very small, we obtain 36 cal/mole as the excess enthalpy associated with Schottky defects. This appears to suggest that the magnitudes of ΔH for both types of defect are nearly equal and that Schottky defects are present to an extent of 20 percent of the total at 724°K.

I wish to express my sincere thanks to Professor F. Ishikawa and Assistant Professor I. Higuchi for their guidance and to Professor F. Seitz for his encouragement.

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Measurements of Some *K*-Shell Internal Conversion Coefficients

F. K. McGowan
Oak Ridge National Laboratory, Oak Ridge, Tennessee
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K-SHELL internal conversion coefficients of four γ-rays in neighboring nuclei have been measured with a NaI scintillation spectrometer. In three cases it is possible to classify the transitions and assign angular momenta to the nuclear states.

A NaI scintillation detector 1.5 inches in diameter and 1 inch long has an intrinsic efficiency of unity for γ-radiation less than 100 kev. Thus, it is possible under favorable circumstances to obtain *K*-shell internal conversion coefficients of γ-rays by measuring the intensity ratio of the *K* x-ray to γ-ray provided the appropriate corrections are made for fluorescent yield, effective detection efficiency, and escape peak intensity.

A typical spectrum of the *K* x-ray and the 85-kev γ-ray following the β^--decay of Tm^{170} is shown in Fig. 1. The solid curves represent the line shapes (Gaussian) into which the pulse-height distribution has been resolved. The peak at 23.9 kev is the escape peak whose energy is the difference between the energy of the *K* x-ray from the source and the *K* x-ray of iodine. The peaks at 52.5 and 85 kev correspond to the full energy of the *K* x-ray and the γ-ray from the source being dissipated in the detector. The corresponding escape peak of the 85-kev γ-radiation is in the high energy edge of the 52.5-kev line; the escape peak intensity for 85-kev γ-radiation is only about 6.5 percent.

The escape peak intensity relative to the total intensity of γ-radiation incident on the detector has been measured experimentally for γ-radiation at 8 different energies distributed between 41.6 and 73 kev. The measured escape intensities agree reasonably well with computed escape intensities for a collimated beam of γ-radiation entering a semi-infinite crystal of NaI normal to its plane surface. The ratio of the *K* x-ray to γ-ray intensity is obtained from the areas of the Gaussian components. Results for the experimental *K*-shell internal conversion coefficients are tabulated in Table I.

Only an upper limit is indicated for $\alpha_{\mathrm{exp}}{}^K$ in the case of Ho^{165} because there are several other γ-rays at higher energies which, if there is any internal conversion of these in the *K*-shell, will contribute to the observed *K* x-ray intensity. In the case of Dy^{160} the ratio of the *K* x-ray to γ-ray intensity was measured in coincidence with a 200-kev γ-ray preceding the 85-kev transition.

Although relativistic *K*-shell internal conversion coefficients for $E_\gamma < 150$ kev are not yet available, there is a method for obtaining extrapolated values of the coefficients at low energies. The ratio of the relativistic coefficients[1] to the nonrelativistic coefficients[2] is plotted for $E_\gamma \geqslant 150$ kev, and the ratio is extrapolated to one at zero electron energy.[3] Low energy *K*-shell conversion coefficients for electric radiation are obtained by multiplying the nonrelativistic values by a correction factor from the ratio plot. Similarly, for magnetic radiation, extrapolated coefficients are obtained by multiplying the extrapolated coefficient for electric radiation by a correction factor from a plot of β_{l-1}/α_l extrapolated to zero electron energy. To check this extrapolation procedure there are some low energy relativistic conversion coefficients for electric dipole, quadrupole, and magnetic dipole for $Z = 29$, 49, 84, and 92 obtained by Reitz.[4] A comparison shows that the extrapolated values agree with Reitz's results for $E_\gamma = 70$ kev to within 15

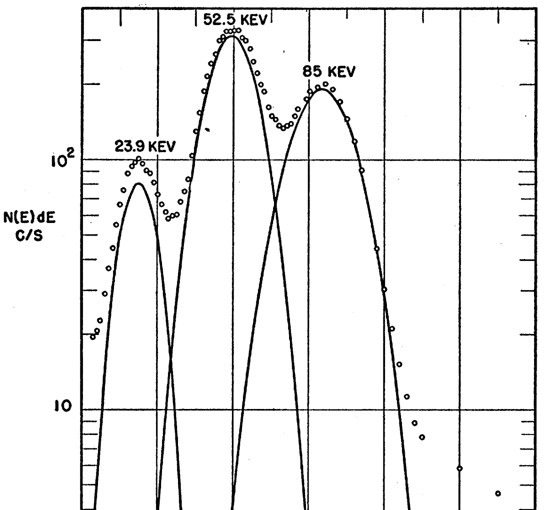

FIG. 1. Spectrum of the γ-radiation from $\mathrm{Tm}^{170} \xrightarrow{\beta^-} \mathrm{Yb}^{170}$.

TABLE I. Experimental and theoretical K-shell conversion coefficients.

Nucleus	E_γ, kev	$T_{1/2}$, sec	$\alpha_{\mathrm{exp}}{}^K$	$(\alpha_2{}^K)_{\mathrm{extrap}}$
$_{66}\mathrm{Dy}^{160}$	85	1.8×10^{-9}	1.65 ± 0.2	1.75
$_{67}\mathrm{Ho}^{165}$	95	$<.8\times10^{-9}$	≤ 2.9	1.40
$_{68}\mathrm{Er}^{166}$	81	1.7×10^{-9}	$1.9\ \pm0.3$	1.94
$_{70}\mathrm{Yb}^{170}$	85	1.6×10^{-9}	$1.5\ \pm0.2$	1.65

percent which justifies the foregoing procedure at least for electric dipole, quadrupole, and magnetic dipole.

The extrapolated K-shell conversion coefficients for electric quadrupole radiation are listed in Table I. Corresponding values for electric dipole and magnetic dipole radiation are about 4 times smaller and 3.5 to 7 times larger than $\alpha_2{}^K$, respectively.

In the case of Dy^{160}, Er^{166}, and Yb^{170}, the isomeric transitions are to the ground state in even-even nuclei which presumably have spin zero and therefore only pure multipole radiation is possible. Thus, these transitions are of the $E2$ type and the spin of the excited state is two.

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Classification of the γ-Radiation of Hf^{177}

F. K. McGowan, E. D. Klema, and P. R. Bell
Oak Ridge National Laboratory, Oak Ridge, Tennessee
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THREE γ-rays of Hf^{177} following the β^--decay of Lu^{177} are classified, and the angular momentum and relative parity of the nuclear states are assigned by measurements of the directional angular correlation of successive gamma-quanta and the K-shell internal conversion coefficients.

The 6.7 day Lu^{177} β^--activity is known to decay by three beta-groups to Hf^{177}.[1] The lowest energy beta-group leads to an excited state in Hf^{177} followed by two γ-rays in cascade with energies 206 and 112 kev.

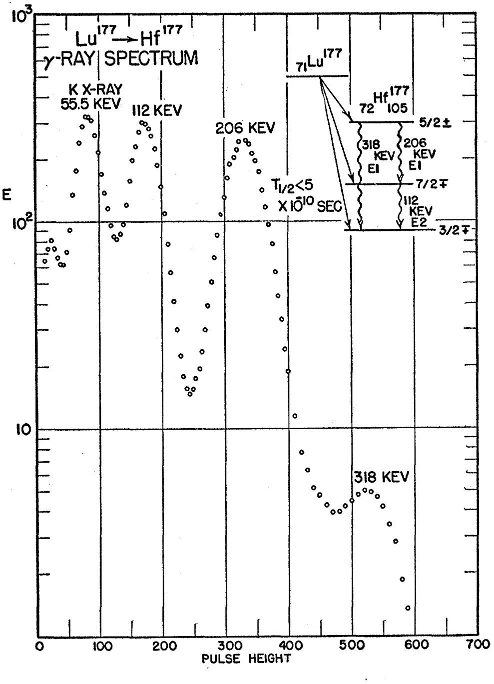

FIG. 1. Spectrum of the γ-radiation following the β^--decay of Lu^{177}.

The half-life of the excited state at 112 kev above the ground state is $T_{\frac{1}{2}}<5\times10^{-10}$ sec as measured with a delayed coincidence scintillation spectrometer using anthracene detectors. The γ-ray spectrum has been examined with a NaI scintillation spectrometer and is shown in Fig. 1. The spectrum was taken at such a geometry that the 318-kev peak is due to the 318-kev crossover transition alone. The peaks have been resolved into Gaussian components and the intensity of the crossover transition from the 318-kev excited state is (4.5 ± 0.5) percent.

Since the lifetime of the intermediate state at 112 kev is sufficiently small, the 206- and 112-kev γ-ray cascade appeared to be an ideal case in which to investigate the directional angular correlation of successive gamma-quanta. The angular correlation, measured with a coincidence scintillation spectrometer using NaI detectors, is found to be anisotropic. The γ-rays entering in the angular correlation measurement are selected according to their energy. One detector selects the 206-kev γ-radiation and the other detector the 112-kev γ-radiation. The coincidence resolving time is 10^{-7} sec and the angular resolution is ±12.7°. Under these conditions the true coincidence rate is of the order of 2.5 counts/sec while the random rate is 8 percent of this. Figure 2 shows the observed angular distribution. The ordinate represents

$$\epsilon(\theta)=[n(\theta)-n(\tfrac{1}{2}\pi)]/n(\tfrac{1}{2}\pi)=W(\theta)-1, \tag{1}$$

where

$$W(\theta)=1+\sum_{i=1}^{n} a_{2i}\cos^{2i}\theta.$$

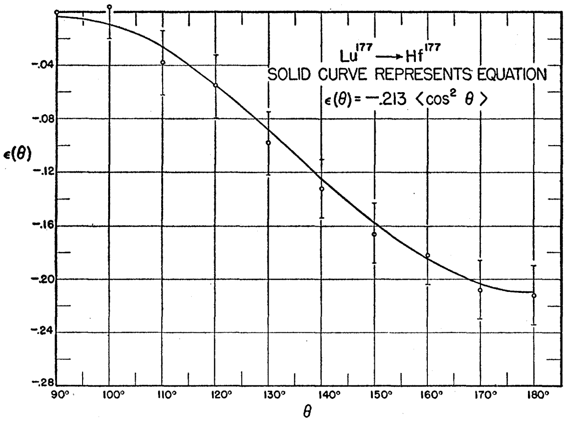

FIG. 2. Directional angular correlation of the 206- and 112-kev γ-ray cascade from Hf^{177}.

The solid curve represents $\epsilon(\theta)=-0.213\cos^2\theta$, where $\cos^2\theta$ has been averaged over the finite angular resolution of the apparatus. $W(\theta)=1-0.213\cos^2\theta$ is characteristic of a dipole-quadrupole cascade with angular momenta $5/2\rightarrow7/2\rightarrow3/2$ for the three states in order of decreasing excitation energy. Other dipole→quadrupole combinations with the correct magnitude ($a_2=-0.21\pm0.02$) of the anisotropy may be excluded either on the basis of the observed shape of the angular correlation distribution or from the requirement that the ground state be restricted to $J\leq3/2$.[2] The measured contribution of the 318-kev transition by a Compton scattering between the two detectors is 0.01 percent of the true coincidence rate.

By measuring the intensity ratio of the K x-ray to the γ-ray in coincidence with the other γ-ray of the cascade, one obtains the K-shell internal conversion coefficient of each γ-ray in the cascade. The observed intensity ratio must be corrected for fluorescent yield,[3] escape peak intensity, fraction of the detected γ-rays appearing in the full energy peak, and effective detection efficiency. These are tabulated in Table I. The experimental error for $\alpha^K(206)$ is rather large because there is the additional interference from back-scattered photons by the Compton process from one detector