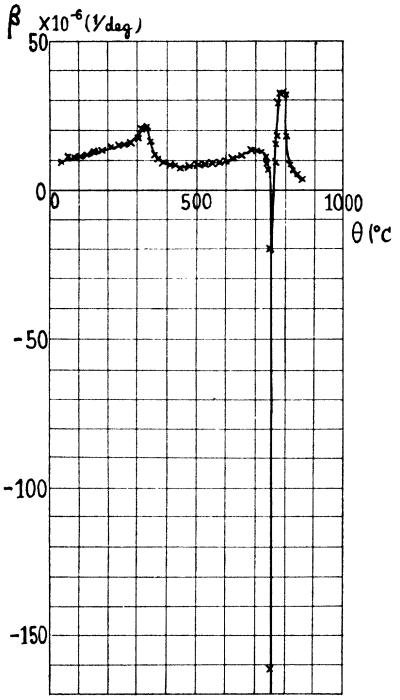

FIG. 1. Linear thermal expansion coefficient *vs* temperature.

and by Blattner *et al.*[4] for $BaTiO_3$. The specific heat was found to be normal near 330°C, and its behavior near 740°C, measured by heating at a rate of about 1°C/min, is shown in Fig. 2. The amount of anomalous heat capacity near 740°C is about 450 cal/mol, the corresponding entropy change being about 0.2 R, and the peak value is observed at 728°C. This temperature is lower than the one at which the thermal expansion coefficient shows a negative peak. Although a part of this discrepancy will be eliminated by the c_p-c_v correction, the residual part may be caused by defects of our apparatus. Previously the anomalies were observed at a lower temperature, i.e., at 710°C, probably owing to the impurity of our previous sample.

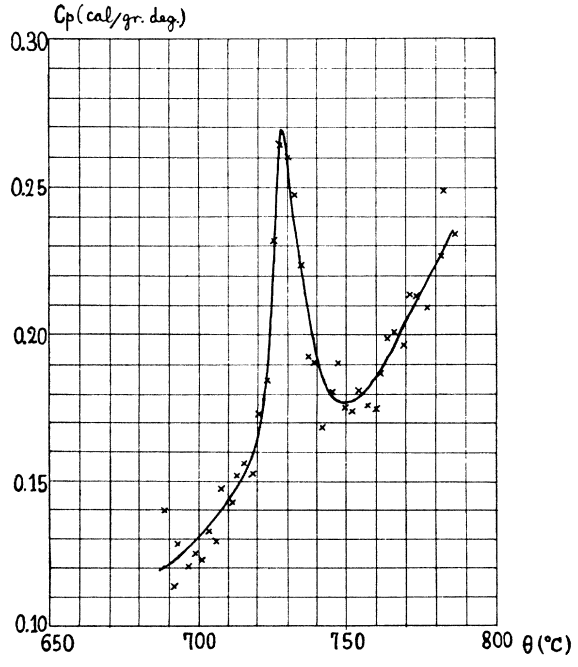

FIG. 2. Isobaric specific heat *vs* temperature.

Although the apparent behavior of the 740°C transition of tungsten oxide thus resembles closely that of the 120°C transition of barium titanate, its essential nature will be revealed only by further thorough investigations. Our observation of an anomaly in the thermal expansion near 330°C, on the other hand, agrees with an anomaly in the dc resistance observed by Nagasawa and Fukui,[5] but it seems yet to be doubtful whether this temperature is a transition point which is closely related to the ferroelectricity of the substance.

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Isotope Shifts in Erbium

L. WILETS* AND L. C. BRADLEY, III
Palmer Physical Laboratory, Princeton University, Princeton, New Jersey
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AN investigation of the isotope shifts in erbium ($Z=68$) is being conducted in this laboratory using a Fabry-Perot interferometer for the necessary resolving power. The oxide is excited in a hollow cathode discharge cooled with liquid nitrogen, similar to the type described by Arroe and Mack.[1]

Three components of the isotope shift are clearly resolved in more than fifty lines in the region between 4250A and 6000A. The three components can be unambiguously attributed to the isotopes Er^{166}, Er^{168}, and Er^{170} on the basis of the intensity of the components compared with the relative abundances of the isotopes. Natural erbium contains six isotopes: Er^{162} (0.136 percent), Er^{164} (1.56 percent), Er^{166} (33.4 percent), Er^{167} (22.9 percent), Er^{168} (27.1 percent), and Er^{170} (14.9 percent). The odd isotope, Er^{167}, is reported[2] to have a nuclear spin of 7/2. Despite its relatively large abundance, the components caused by the odd isotope are not resolved, and this may be attributed to the large number of components into which the 167 component is split as a result of its magnetic hyperfine structure. In only a few lines do the intensities deviate from the expected values sufficiently to be attributed to the presence of the odd isotope.

In a few overexposed lines a fourth component has been detected; on the basis of intensity and position it could be attributed to Er^{164}, although it is also possible that it is the result of Er^{167}. Measurements have not yet been completed on this component. Table I shows the results of measurements on 11 lines using four different spacer sizes. The individual measurements are probably accurate to within ± 0.0015 cm^{-1}, and the mean is accurate to within ± 0.0010 cm^{-1}. These limits do not include the possibility of disturbing effects as a result of the odd isotope. The ratio $(\nu_{168}-\nu_{170})/(\nu_{166}-\nu_{168})$ is in most cases quite close to unity, and as far as the measurements have proceeded, there is no evidence that the ratio is other than unity.

The shifts have been taken as positive where the heaviest isotope has the smallest wave number, and negative where the converse is true. To the best of our knowledge, the occurrence of both positive and negative shifts in rare earth spectra has not been reported before. According to the nuclear volume picture of isotope shifts,[3] s-electrons are more tightly bound in light isotopes than in heavy isotopes. Since electrons with greater orbital angular momentum (except $p_{\frac{1}{2}}$) are not affected appreciably by the nuclear charge distribution, observable isotope shifts appear only in transitions between levels which have different numbers of

TABLE I. Isotope splittings in erbium, in wave-number units. $\Delta\nu_{mean}$ are the mean values of measurements using four different spacer sizes. The upper numbers are $\nu_{168}-\nu_{170}$ and the lower numbers are $\nu_{166}-\nu_{168}$. R gives the ratio of the splittings.

λ, A	$\Delta\nu_{mean}$	R	λ, A	$\Delta\nu_{mean}$	R
4729	0.046$_6$	1.00	4496	0.044$_2$	0.96
	0.046$_6$			0.046$_8$	
4722	−0.050$_6$	0.99	4426	−0.047$_2$	0.94
	−0.051$_2$			−0.050$_6$	
4673	−0.049$_5$	1.06	4424	−0.043$_8$	1.08
	−0.046$_9$			−0.040$_4$	
4606	−0.045$_6$	1.00	4409	−0.045$_1$	0.98
	−0.045$_6$			−0.046$_2$	
4552	0.045$_8$	0.96	4331	−0.053$_0$	1.02
	0.047$_6$			−0.052$_0$	
4531	0.047$_5$	1.07			
	0.044$_6$				

s-electrons. For instance, the usual change of a p-electron to an s-electron would give a positive shift. No analysis is available for erbium, but the isotope structure may give useful clues. The hollow cathode source usually enhances the ionized spectra, and since the shifts are of the magnitude to be expected from the second spectrum, it is presumed that the lines showing the shifts are caused by Er II. The positive isotope shifts probably arise from the electronic transitions $4f^{12}6p$ to $4f^{12}6s$ and $4f^{11}6s6p$ to $4f^{11}6s^2$, and the negative shifts probably arise from the two-electron transition $4f^{11}6s6p$ to $4f^{11}5d^2$. The configurations $4f^{12}6s$ and $4f^{11}6s6p$ should give similar splittings; the configuration $4f^{11}6s^2$ would give splittings twice as great if it were not that the mutual screening of the $6s$-electrons tends to reduce the effect.

The work is being continued, lines are being measured in other regions of the spectrum, and the complete results will be reported later.

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* AEC Predoctoral Fellow.

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Threshold Values of Internal Conversion Coefficients for the K-Shell

B. I. SPINRAD AND L. B. KELLER
Argonne National Laboratory, Chicago, Illinois
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RECENT computations of the internal conversion coefficients for the K-shell have been reported for various Z and for k (γ-ray energy) greater than 0.3–0.5 electron masses.[1] The extrapolation of these results to lower energies is uncertain for two reasons: first, the mathematical formulation of the problem is of such complexity that no simple extrapolation rule can be used; second, the numbers are computed for unscreened wave functions.

In an attempt to resolve the mathematical difficulties, computations have been made on the threshold values of the conversion coefficients. These computations were performed by taking the limiting values of the formulas of reference 1, as p, the electron momentum, approaches zero positively. Under these conditions many simplifications arise, and it is possible to compute the results on a desk machine.

TABLE I. Threshold values of internal conversion coefficients for the K-shell.

Z	α_1	α_2	α_3	α_4	α_5
10	7.329(3)	8.184(5)	4.281(7)	1.340(9)	2.867(10)
20	4.510(2)	1.251(4)	1.596(5)	1.232(6)	6.459(6)
30	8.720(1)	1.030(3)	6.060(3)	1.922(4)	4.338(4)
40	2.403(1)	1.606(2)	5.600(2)	9.300(2)	1.123(3)
50	1.085(1)	3.741(1)	8.317(1)	8.112(1)	5.926(1)
60	5.190(0)	1.081(1)	1.623(1)	1.035(1)	4.834(0)
70	2.713(0)	3.604(0)	3.721(0)	1.598(0)	5.479(−1)
80	1.636(0)	1.334(0)	9.516(−1)	3.152(−1)	8.995(−2)
88	9.989(−1)	6.622(−1)	3.551(−1)	1.094(−1)	2.977(−2)
96	6.691(−1)	3.661(−1)	1.848(−1)	4.991(−2)	8.452(−3)

Z	β_1	β_2	β_3	β_4	β_5
10	4.222(2)	2.219(5)	3.472(7)	2.587(9)	1.124(11)
20	1.087(2)	1.415(4)	5.471(5)	9.874(6)	1.084(8)
30	5.075(1)	2.893(3)	4.867(4)	3.919(5)	1.841(6)
40	3.072(1)	8.942(2)	8.830(3)	3.892(4)	1.003(5)
50	2.123(1)	3.881(2)	2.374(3)	6.466(3)	1.032(4)
60	1.737(1)	2.033(2)	8.215(2)	1.484(3)	1.626(3)
70	1.548(1)	1.225(2)	3.393(2)	4.257(2)	3.158(2)
80	1.528(1)	8.304(1)	1.605(2)	1.436(2)	7.637(1)
88	1.764(1)	6.582(1)	9.549(1)	6.576(1)	2.714(1)
96	2.313(1)	5.608(1)	6.060(1)	3.394(1)	1.034(1)

The results are given in Table I. The notation is that of reference 1. Since screening has been ignored, the threshold energies for which these results were computed were those obtained from the relativistic single-electron model, given by $k=1-(1-[\alpha Z]^2)^{\frac{1}{2}}$. Figures in parentheses indicate the power of 10 by which the number must be multiplied.

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Primary Specific Ionization of Cosmic Rays in Hydrogen*

M. H. SHAMOS, *Washington Square College, New York University, New York, New York*
AND
I. HUDES, *Brooklyn College, Brooklyn, New York*
(Received October 17, 1951)

MANY attempts have been made to test the dependence of primary specific ionization upon momentum for high energy particles. Such measurements have been made by Kunze,[1] Corson and Brode,[2] J. G. Wilson,[3] Sen Gupta,[4] and Hazen[5,6] by the use of cloud chamber techniques. Except for Sen Gupta, who reported an increase for electrons but not for mesons, the other observers were unable to support the relativistic increase in ionization beyond the minimum as predicted in the theory of collision loss given by Bethe.[7]

Low efficiency counters have been employed by Danforth and Ramsey,[8] Cosyns,[9] and most recently by Hereford.[10] Of these, Hereford obtained results in substantial agreement with theory upon comparing the primary specific ionization of 1-Mev electrons with that of the sea-level cosmic radiation. This technique makes use of the unique dependence of the efficiency of a counter, operating in the Geiger region, upon the primary specific ionization,

$$\text{efficiency}=1-\epsilon^{-JLP/76}.$$

The present experiment makes use of this technique to compare the primary specific ionization in hydrogen of two groups of cosmic-ray particles of different average momenta. The efficiency of a low pressure (2.0 cm Hg) hydrogen-filled counter was measured at sea level and under ~140 feet of rock. These measurements were made with a fourfold coincidence telescope which included the hydrogen counter and 20 cm of lead. The average momentum of the sea-level cosmic radiation (presumed to be principally μ-mesons because of the Pb filter), computed on the basis of the