tistical probable errors the curve of Fig. 3 was obtained. The broken line of Fig. 3 represents the distribution in energy of fast neutrons inelastically scattered in wolfram, corrected for variation with energy of the n-p scattering cross section and acceptance probability. The distribution appears to be for the most part constant with energy, rising somewhat in the region of lower energies. Using Fig. 1(B) and a method of analysis previously described,[3] it is estimated that at 4.3 Mev the inelastic scattering cross section is less than three-fourths as large as the elastic one for W.

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Internal Conversion in I^{131}†

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The β-radiations from the decay of I^{131} to Xe^{131} have been investigated in a large ($\rho=50$ cm) double-focusing β-ray spectrometer to determine the internal conversion coefficients for the 284-, 364-, 638-, and 724-kev γ-rays. The continuous β-spectrum is resolved into 3 components with end points of 338, 606, and 807 kev. Conclusions about the multipole character of the γ-ray transitions are made.

The β-radiations from the decay of I^{131} to Xe^{131} have been investigated in a large ($\rho=50$ cm) double-focusing β-ray spectrometer[1] to determine the internal conversion coefficients for the 284-, 364-, 638-, and 724-kev γ-rays. Earlier work, prior to the time this investigation was started, on internal conversion coefficients in I^{131} due to Metzger and Deutsch,[2] Kern *et al.*,[3] and Feister,[4] is summarized in *Nuclear Data.*[5] For the 284- and 364-kev γ-rays, the results of references 2 and 4 are in agreement while both disagree with those of reference 3. The conversion coefficients for the 638- and 724-kev γ-rays had not been measured previously and the present investigation was undertaken to determine them. Conversion coefficients for the 284- and 364-kev γ-rays were also determined in an attempt to resolve the disagreement mentioned above, where possible, and as a check on our experimental method.

Three essentially weightless sources of I^{131} were prepared from solutions of "carrier-free" NaI (obtained from the Oak Ridge National Laboratory over a period of several months) by depositing the solution on 0.1 mg/cm² Ag foil on which a narrow line of Insulin solution had previously been deposited, and drying under a heat lamp. The Ag foil was backed with a zapon film of approximately 0.03 mg/cm² and covered over with another zapon film of about the same thickness. The strengths of the three sources were about 4 mc, 6 mc, and 10 mc, respectively; the second source was used in two runs.

Analysis of the Kurie plots resulted in the resolution of three β-components with endpoints of 338.6±9.7, 605.9±1.2, and 806.7±10.0 kev, and relative intensities of (13.3±0.3) percent, (84.7±0.3) percent, and 1.4 percent, respectively. These results are the weighted means of three runs for the softest component and four runs for the other two components. The errors listed are probable errors. Until recently only two components of the β-spectra had been resolved[2,3,6,7] with the end-point of the softer component varying from about 250 to 315 kev. While the present work was being carried out Verster *et al.*[8] reported the results of their investigation of I^{131}, in which they also resolved three β-components. Our results above generally agree with theirs, except for the intensity of the hard component, for which they report (0.56±0.10) percent. The results of others, for example, Emery,[9] who gives the value (0.8±0.1) percent as determined by means of a cavity

Table I. Results of internal conversion measurements in I^{131}. α_K is the K-shell internal conversion coefficient, N_K/N_L the ratio of K-shell to L-shell conversion electrons, and $N_K/(N_L+N_M)$ the ratio of K-shell to L- plus M-shell conversion electrons.

γ-ray energy (kev)	α_K	N_K/N_L	$\frac{N_K}{(N_L+N_M)}$
284	0.036 ±0.002	5.4±1.2	5.2±2.1
364	0.0174±0.0001	6.6±0.2	4.7±0.3
638	0.0021±0.0001		5.2±0.9
724	0.0037±0.0005		

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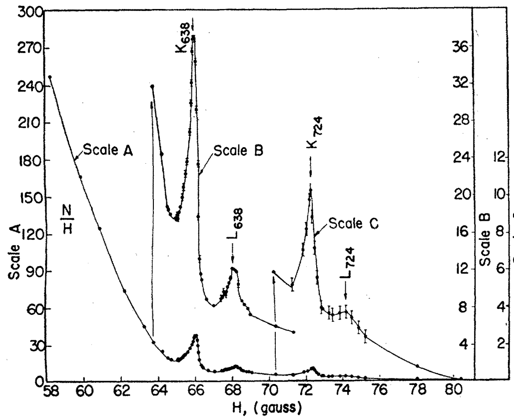

FIG. 1. Upper end of the momentum distribution of the negatrons from I^{131}. N is the intensity in counts per min, H the field strength in gauss. Scales for the ordinates of the magnified conversion peaks are shown at the right of the figure as scales B and C.

ionization chamber, substantiate their value for this component. We attribute the discrepancy to the effect of the background subtracted, which is larger than this weak β-component in the region beyond the 606 β-component. Inasmuch as the error in this hard component resulting from the background is larger than the errors computed on the basis of counting statistics, no error has been shown for the percentage of this component above. In any case, the effect of this component on the remainder of the spectrum is small and does not affect the values of the internal conversion coefficients. More recently Ketelle *et al.*,[10] by means of beta-gamma-coincidences, succeeded in resolving four components in the β-spectrum. We were unable to resolve this low intensity fourth component because of the large uncertainties in the least energetic component arising from successive subtraction of the β-components in the Kurie plot analysis.

For the calculation of the internal conversion coefficients, the number of conversion electrons arising from each γ-ray was determined from the area under the conversion peak after subtraction of the underlying continuous spectrum. The number of unconverted γ-rays was not measured directly. The total number of γ-rays, converted and unconverted, arising from each excited level was determined from the intensity of the β-decay branch leading to that level in those cases where the excited level was known to decay by emission of a single γ-ray, and, in addition, by the known branching ratio for the 364-kev level which is known to decay through two γ-rays in parallel. The ratio of the number, for example, of K-shell conversion electrons to the total number of γ-rays gives the quantity C_K related to the K-shell conversion coefficient, α_K, by the simple relation $C_K/(1-C_K)=N_e/N_\gamma$, where N_e= number of K-shell conversion electrons, and N_γ= number of unconverted γ-rays. These calculations of conversion coefficients are seen to be dependent on the decay scheme.

Two different decay schemes for I^{131} have been proposed recently which are modifications of the earlier decay schemes of references 2 and 3 to include the additional β-branches. The difference lies in considering the 638-kev γ-ray as a cross-over transition from a level at about 720 kev to the 80-kev level, or as a transition directly to the ground state of Xe^{131} with the higher energy γ-ray arising from a separate excited level. The work of Thulin,[11] in which he determined an energy difference of 85.7±0.4 kev for these two γ-rays from the photoelectric doublet of the K_{724} and L_{638} lines from a uranium converter, instead of an energy difference of 80.1 kev (which would give twice the measured doublet separation), excludes the possibility of a cross-over transition. Further convincing evidence excluding the cross-over transition is presented by Ketelle *et al.*[10] by their resolution of the two softer components leading to separate excited energy levels for the 724- and 638-kev γ-rays. Thulin also estimated the relative intensities of the 638- and 724-kev γ-rays to be 7.8:1 as determined from the heights of the K photoelectric lines from a uranium radiator, with the energies 638.0±0.6 kev and 723.9±0.7 kev. Our result of 13.3 percent for the two unresolved soft components, using this ratio of 7.8:1 yields 11.8 percent and 1.5 percent for these two γ-rays, respectively. These percentages and the branching ratio of 8:100 of Metzger and Deutsch[2] for the 284- and 364-kev γ-rays were used in determining the values of the K-shell internal conversion coefficients listed in Table I.

Figure 1, the upper end of the momentum distribution of the negatrons from I^{131}, shows the conversion peaks of the 638- and 724-kev γ-rays. Calibration of the spectrometer with the well-known values 284.1±0.1; 364.2±0.1 of Lind *et al.*[12] for these two γ-rays gives the following energies: for the 638-kev γ-ray, 638.8, 637.8 from the K- and L-peaks, respectively; for the 724-kev γ-ray, 723.7-kev from the K-peak. The L_{724} peak is shown resolved in Fig. 1, but the uncertainties in the points resulting from subtraction of the underlying continuous spectrum are too large for the measurement to be meaningful.

Table II shows a comparison of the interpolated values for the K-shell internal conversion coefficients

TABLE II. Comparison of calculated and experimental values of α_K. The last column lists the possible types of transitions.

γ-ray energy (kev)	Calculated values *E*1	*E*2	*M*1	*E*3	Experimental values	Transition type
284.1	0.0107	0.0423	0.0446	0.147	0.036 ±0.002	*E*2, *M*1
364.2	0.00578	0.0201	0.0239	0.0625	0.0174±0.0001	*E*2
638	0.00152	0.00417	0.00588	0.0102	0.0021±0.0001	*E*1
724	0.00116	0.00305	0.00436	0.00713	0.0037±0.0005	*E*2, *M*1

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taken from the calculations of M. E. Rose *et al.*,[13] from which conclusions may be drawn concerning the types of transitions involved. The probable types of transitions are listed in the last column. The N_K/N_L ratios in Table I give some additional information with regard to transition types on comparison with the empirical curves of Goldhaber and Sunyar.[14] From the K/L ratios for $E2$ transitions (Fig. 11 of reference 13) we have the following: for the 284-kev transition, the empirical value $K/L \simeq 5$, which is in agreement with the experimental value of 5.4 ± 1.2; for the 364-kev transition, the empirical value $K/L \simeq 6.5$ (on extrapolation of their empirical curve), which is in agreement with the experimental value of 6.6 ± 0.2. These do not definitely exclude admixtures of $M1$ for both these transitions. However, a self-consistent assignment of spin and parity for the 364-kev level and the level for the 80-kev γ-ray[15] (which is in cascade with the 284-kev γ-ray forming the parallel branch with the 364-kev γ-ray) appears to require that the 284 transition be pure $E2$ while permitting the 364 transition to be a mixture of $E2$ and $M1$.

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A Comparison of Penetrating Showers in Light and Heavy Elements. I*

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A comparison of the multiplicity of penetrating, particles has been made for penetrating showers originating in C and Pb, and for showers starting in Fe and paraffin. The comparison is made by observing the rates of different sized showers per mean free path of the generating material. Large differences are found in the comparison of Pb and C. The comparison of Fe and paraffin essentially gives a comparison of Fe and C as the showers originating in hydrogen were not recorded efficiently. The difference between showers starting in Fe and C is smaller than in the comparison of Pb and C. The ratio of neutral to charged primaries is determined to be 0.5 ± 0.15. The collision mean free path of charged primaries in paraffin is measured to be 56^{+12}_{-7} g/cm^2, and the mean free path of charged primaries in carbon is measured to be 76 ± 8 g/cm^2. A search was made for elastic scatterings of penetrating shower primary particles in which only a small amount of energy is transferred to a target nucleon. Only one example of such scattering was observed in the traversal of 11,960 g/cm^2 of carbon.

I. INTRODUCTION

IN the past few years much effort has been directed toward gaining a qualitative understanding of the processes involved in high energy π-meson production. Two of the extreme models which have been used to describe the process are the plural model and the multiple model. The plural model proposed by Heitler and Janossy[1] supposes that the primary particle loses its energy by making several collisions in one nucleus with only one meson produced in each collision. The multiple model originally proposed by Heisenberg[2] is based on the assumption that several π-mesons are produced in a single nucleon-nucleon encounter. This model has been used by Fermi in his statistical theory.[3]

The problem has been attacked by experimenters by comparing the multiplicities of the lightly ionizing or penetrating particles generated in penetrating showers in light and heavy elements. Investigators using photographic plates have found a strong correlation for primary energies of greater than 5 Bev between the number of heavy prongs and the number of shower particles.[4,5] Cloud-chamber investigations have given conflicting results.[6–9]

Gregory and Tinlot[8] found that for the production of

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