The Disintegration of I^{131}

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(Received May 28, 1952)

The results of the authors for internal conversion coefficients, K to L ratios and multipole assignments for the 284-, 364-, 638-, and 723-kev gamma-rays are reported. A review of recent decay schemes and a tabulation of internal conversion coefficients, K to L ratios, and relative intensities obtained by previous investigators are included. A level scheme is proposed which involves the forbiddenness of certain magnetic dipole transitions.

I. INTRODUCTION

THE disintegration of I^{131} has been of considerable interest in the field of nuclear spectroscopy. Emery[1] has postulated the most recent decay scheme which is an extension of the one proposed by Metzger and Deutsch.[2] It has been largely substantiated by the measurements of Ketelle *et al.*,[3] who used a thin lens spectrometer and a scintillation spectrometer to determine which beta-rays are in coincidence with the particular gamma-rays. Verster *et al.*,[4] as a result of their measurements, were able to apply shell model concepts to make a level assignment. The schemes proposed by the preceding authors are shown in Fig. 1.

The empirical curves of Goldhaber and Sunyar[5] for the K to L ratio, and the theoretical K conversion coefficients determined by Rose *et al.*,[6] give two approaches to the multipole assignment of gamma-rays. The purpose of this investigation is to check and extend the information on the K conversion coefficients and K to L ratios of the gamma-rays of Xe^{131}. Since the theoretical K conversion coefficients for $M1$ and $E2$ transitions of a 284-kev gamma ray are nearly the same, it is of interest to obtain a measurement of the K to L ratio. Also it is of interest to make a special effort to determine the internal conversion coefficient for the 723-kev gamma ray.

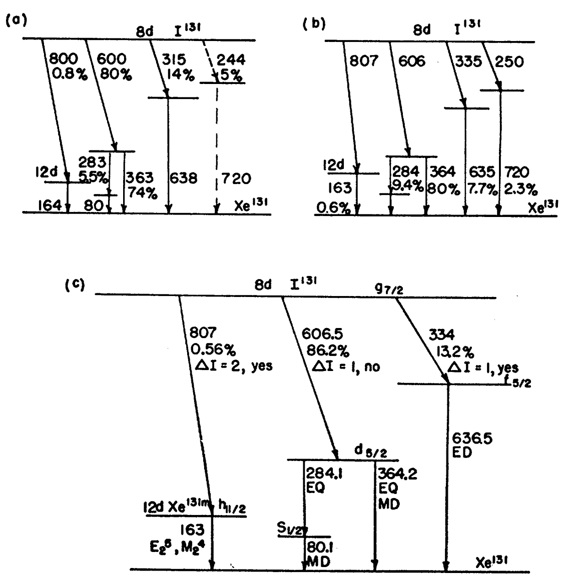

FIG. 1. Decay schemes for I^{131}. (a) Emery; Metzger and Deutsch. (b) Ketelle, Zeldes, Brosi, and Dandl. (c) Verster, Nijgh, Van Lieshaut, and Bakker.

[1] E. W. Emery, Phys. Rev. **83**, 679 (1951).
[2] F. Metzger and M. Deutsch, Phys. Rev. **74**, 1640 (1948).
[3] Ketelle, Zeldes, Brosi, and Dandl, Phys. Rev. **84**, 585 (1951).
[4] Verster, Nijgh, Van Lieshout, and Bakker, Physica Deil **17**, No. 7, 637 (1951).
[5] M. Goldhaber and A. W. Sunyar, Phys. Rev. **83**, 906 (1951).
[6] Rose, Goertzel, and Perry, Oak Ridge National Laboratory Report ORNL 1023 (1951).

II. EXPERIMENTAL PROCEDURES AND RESULTS

A magnetic thin lens spectrometer was used to obtain the negatron and photoelectron spectra.

To obtain relative intensities of the gamma-rays of Xe^{131}, the photoelectron spectrum was measured using tin, lead, and uranium as convertors. The spectrum using a tin convertor is shown in Fig. 2. Intensities were determined by finding areas under peaks in a plot of N/I *vs* I, after subtracting Compton background, and then correcting for photoelectric absorbtion coefficient. Photoelectric absorption coefficients were obtained with the aid of Gray's formula[7] and the theoretical calculations of Hulme *et al.*[8] The relative intensities are listed in Table I, where the 364-kev gamma-intensity is taken as 100.

The negatron spectrum was examined to obtain the relative intensities of the various groups of internal conversion electrons. Figure 3 shows this spectrum.

TABLE I. Experimental results.

Energy of gamma kev	Rel. int. of gamma	Rel. int. of conv. el. and 606-kev cont. beta		K/L ratio	K conv. coeff.
284	6	K	14.6	3.3	0.052
		L	4.7		
364	100	K	100	5.6	0.021
		L	16.7		
638	10	K+L	1.8		0.0040
723	3	K+L	0.5		0.0034
		606 beta	5400		

[7] L. H. Gray, Proc. Cambridge Phil. Soc. **27**, 103 (1931).
[8] Hulme, McDougall, Buckingham, and Fowler, Proc. Roy. Soc. (London) **149**, 131 (1935).

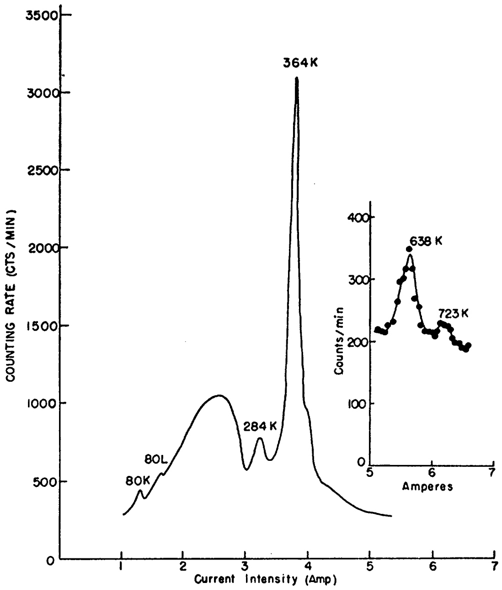

FIG. 2. I^{131} photoelectron spectrum using a 12-mg/cm² tin convertor at 2.3 percent resolution setting. Inset: High energy photopeaks using a 30-mg/cm² tin convertor at 3.6 percent resolution setting.

The dashed lines are calculated from the Fermi plot with correction being made, at the end points of the 334-kev and the 606-kev continuous spectra, for resolution of the spectrometer. The relative intensities of the internal conversion groups and the 606-kev continuous spectrum are found in Table I, where the intensity of the 364-kev internal group is taken as 100.

In neither the photoelectric nor the internal conversion spectrum is an intensity estimate made for the 80-kev gamma-ray, since the Geiger tube window and scattering in the convertors distort results too much at this low energy.

The K-shell internal conversion coefficients were determined using as a standard the value 0.097 for the K shell conversion coefficient of the 663-kev gamma-ray of Cs^{137}.[9] Sources of Cs^{137} and I^{131} were made, so that, in each case, the same sample could be used to measure both internal conversion and photoelectrons. The same sample holder, convertor, and geometry were used in the two cases.

The K shell internal conversion coefficients and the K to L ratios which we obtained are listed in Table I. Some values of K shell internal conversion coefficients obtained from Rose's tables[6] and K to L ratios taken from the curves of Goldhaber and Sunyar[5] are given in Table II. A comparison of our results with the values listed in this table, leads us to assign the 284-kev, 364-kev, and 638-kev, and 723-kev gamma-rays to electric quadrupole transitions.

TABLE II. Theoretical conversion coefficients (see reference 6) and empirical K/L ratios (see reference 5).

Energy of gamma, kev	Multipole	K/L ratio	K conv. coeff.
284	$E2$	4.6	0.042
	$M1$	7.9	0.045
364	$E2$	5.6	0.020
	$M1$	8	0.024
638	$E1$		0.0015
	$E2$		0.0042
	$M1$		0.0060
723	$E1$		0.0011
	$E2$		0.0031
	$M1$		0.0044

III. DISCUSSION

In Table III is given a tabulation of the results obtained by previous investigators for relative intensities, K conversion coefficients and K to L ratios of the gamma-rays of Xe^{131}. Our results are included in this table.

The 80-kev gamma-ray has been assigned as $M1$ by Verster *et al.*[4] The half-life measurements of Graham and Bell[10] support this assignment. On the basis of the results of Bergström,[11] Goldhaber and Sunyar[5] list the 163-kev gamma-ray as an $M4$ transition. This agrees with the scheme of Verster *et al.*,[4] where the transition goes from $h11/2$ to $d3/2$.

We find no alternative to Verster *et al.*'s assignment of $d5/2$ to the 364-kev level, even though we believe

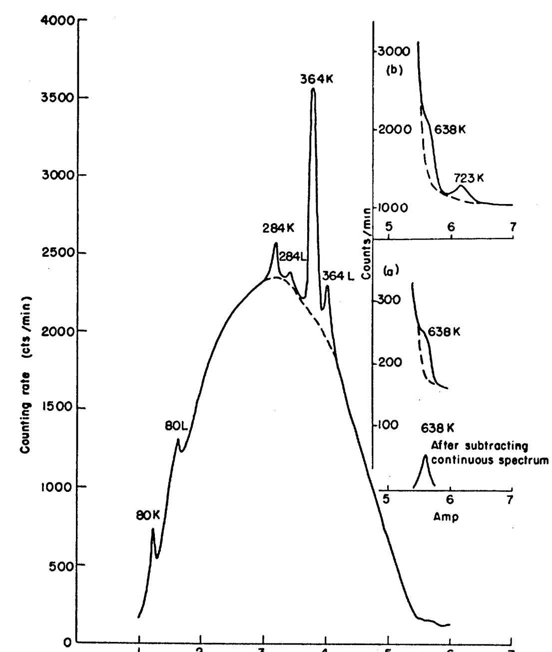

FIG. 3. I^{131} negatron spectrum. Inset (a): Expanded scale to show conversion electrons of 638-kev gamma-ray. Inset (b): Conversion electrons of 638-kev and 723-kev gamma-rays using high activity source.

[9] M. A. Waggoner, Phys. Rev. **82**, 906 (1951).

[10] R. L. Graham and R. E. Bell, Phys. Rev. **84**, 380 (1951).

[11] Ingmar Bergström, Phys. Rev. **80**, 114 (1951).

TABLE III. Gamma-rays of Xe^{131}.

Energy (kev)	Author	Rel. int.	K/L ratio	K conv. coeff.	Other related measurements
80	Metzger[a]	7.6	5.5	0.8	
	Kern[b]	21.8	8.4	0.17	
	Verster[c]	7.6	7.0	0.7	
163	Verster	0.56			$N_K/(N_L+N_M)=1.67$
	Bergström[d]		2.34		$N_L/N_M=3.4$
	Brosi[e]			~20	
284	Metzger	7.6	>2	0.05	
	Kern	17.2		0.079	
	Verster	7.6		0.039	
	Ketelle[f]	11.8			
	Lind[g]	8.7			
	Authors	6	3.3	0.052	
364	Metzger	100	5.2	0.019	
	Kern	100	4.0	0.018	
	Verster	100	4.2	0.0185	
	Ketelle	100			
	Lind	100			
	Authors	100	5.6	0.021	
638	Metzger	19		<0.005	
	Kern	6.9			
	Verster	14.2		0.0019	
	Ketelle	9.6			
	Zeldes[h]				4×10^{-4} conv. per $606\beta^-$
	Authors	10		0.0040	
723	Verster				5×10^{-5} conv. per disint.
	Ketelle	2.9			
	Thulin[i]				638γ int./723γ int. $=7.8$
	Zeldes				723 conv./638 conv. $=\frac{1}{8}$
	Authors	3		0.0034	

[a] See reference 2.
[b] Kern, Mitchell, and Zaffarano, Phys. Rev. **76**, 94 (1949).
[c] See reference 4.
[d] See reference 11.
[e] Brosi, DeWitt, and Zeldes, Phys. Rev. **75**, 1615 (1949).
[f] See reference 3.
[g] Lind, Brown, Klein, Miller, and Dumond, Phys. Rev. **75**, 1544 (1949).
[h] Zeldes, Brosi, and Ketelle, Phys. Rev. **83**, 642 (1951).
[i] Sigvard Thulin, Phys. Rev. **83**, 860 (1951).

that the 364-kev gamma-ray is an $E2$ transition and Weisskopf's[12] theory would predict an $M1$ transition to be many times more probable. This may be explained if it is postulated that $M1$ transitions are forbidden with respect to $E2$ transitions between levels with the same L and with I differing by 1 (between a $d5/2$ level and a $d3/2$ level). However, where two levels have L differing by two and I differing by one, $M1$ is the more probable transition (between an $s1/2$ level and a $d3/2$ level).

[12] V. F. Weisskopf, Phys. Rev. **83**, 1073 (1951).

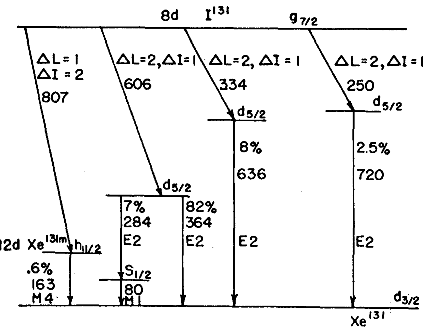

FIG. 4. Proposed level scheme for I^{131}.

The $\log(ft)$ values for the three beta-ray transitions with energies of 606 kev, 334 kev, and 250 kev, and having 89 percent, 8 percent, and 2.5 percent for their respective relative abundances, are 6.7, 6.8, and 6.9, respectively. Nordheim's[13] classification allows these transitions to have selection rules of either $\Delta L=1$ and $\Delta I=0, 1$ or $\Delta L=2$ and $\Delta I=1$. Using $g7/2$ for the ground state of I^{131} and $d3/2$ for the ground state of Xe^{131}, the selection rules $\Delta L=1$ and $\Delta I=1$ for a beta-transition would give an excited level $f5/2$ and an $E1$ transition to the ground state of Xe^{131}. The selection rules $\Delta L=2$ and $\Delta I=1$ would give an excited level $d5/2$ with an $M1$ or $E2$ transition to the ground state.

Since our measurements indicate that the 638-kev and the 723-kev transitions are both $E2$, we propose the level scheme in Fig. 4 with the 364-kev, 638-kev, and 723-kev levels all $d5/2$ and with the requirement that $M1$ transitions with selection rules $\Delta L=0$ and $\Delta I=0, 1$ are forbidden.

These results were obtained before the appearance of a recent publication on I^{131} by Bell and Graham and support[14] their multipole assignments.

The authors wish to express their gratitude to the Ohio State University Development Fund for grants to carry on this research.

[13] L. W. Nordheim, Phys. Rev. **78**, 294 (1950).
[14] R. E. Bell and R. L. Graham, Phys. Rev. **86**, 212 (1952).