Nuclear Levels in Cs^{131}†

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Using enriched barium 130, activated in the pile, a spectrometric study has been made of the radiation from the resultant barium 131. Decaying by K capture with a half-life of 11.8 days, thirteen gamma-rays are found to be associated with the disintegration, eight of which have not been previously reported. From the relative intensities of the electron lines and the photoelectron peaks, the multipolarities of six of the transitions are given. A consistent nuclear level scheme of seven terms accounts completely for the observed gamma-transitions.

IN an early report on the radioactivity in barium it was concluded[1] that the isotope of mass 130 whose normal abundance is only 0.10 percent could by neutron capture produce a radioactive isotope of mass 131. This emitter, whose half-life is about 12 days, was believed to decay by K capture and gamma-radiation to a radioactive daughter product, Cs^{131}. This isotope in turn decays by K capture with a half-life of about 9.7 days, to stable xenon. Many subsequent investigations have been made, particularly to evaluate the energies of the associated gamma-rays. These energies as reported by various observers[1–7] are shown collected in Table I. Seven gamma-rays are listed in Table I. It now appears quite certain that the transition at 0.196 Mev does not exist, and it is quite unlikely that there is any radiation with energy above 1 Mev.

TABLE I. Previously reported gamma-energies.

Item	YGK^a	K^b	K^c	Z^d	C^e	CM^f	E^g
	Gamma-energies in Mev as reported by						
γ_1			0.122		0.16	0.122	0.122
γ_2						0.196	
γ_3	0.22		0.206			0.213	0.214
γ_4		0.26				0.241	0.241
γ_5			0.372		0.42	0.371	0.370
γ_6	0.50	0.50	0.494	0.496		0.497	0.494
γ_7	1.7	1.2			1.2		

a See reference 1.
b See reference 2.
c See reference 3.
d See reference 4.
e See reference 5.
f See reference 6.
g See reference 7.

In the present investigation it is shown that there are thirteen gamma-rays in addition to Auger radiation present in the disintegration. A sample of barium was kindly provided by the Oak Ridge National Laboratory in which the mass 130 was enriched from its normal abundance of 0.10 percent up to 27.5 percent. On irradiation in the Argonne heavy-water pile, sources of high specific activity were obtained for studies in photographic magnetic spectrometers. In addition to the electron lines resulting from internal conversion, the photoelectrons ejected from a lead radiator have been observed. A careful survey has been made in the double focusing spectrometer to detect the presence of any positrons in the decay, with negative results. Similarly, by the use of a scintillation spectrometer no evidence could be found to indicate the existence of the 0.82- or the 1.2-Mev gamma-rays as previously reported.[5]

In Table II the energies of the observed electron lines are presented in column 1. All but four lines decay with the same half-life, namely 11.8±0.2 days, and fit best the work functions for cesium. The other four lines have shorter half-lives and are K and L lines from isomeric transitions in Ba^{133} and Ba^{135}. Their K and L lines fit the work functions of barium. The interpretation of the lines and the resultant energy sums are shown in succeeding columns. The low energy Auger lines are broad as might be expected since x-rays of both cesium and xenon are present. The energies of the thirteen gamma-rays, eight of which have not been previously observed, are summarized in Table III. Arbitrary numbers are assigned in column 1, increasing in the order of increasing energy.

Traces were made of the photographic plates with a Leeds and Northrup recording microphotometer. When corrected for solid angle and the variation in emulsion sensitivity with energy, it becomes possible to express the K/L ratios for six of the gamma-rays, as shown in column 3. For three of the remaining gammas a visual estimate of the ratio is recorded. From these observed intensity ratios and a consideration of the results of other investigators, it becomes possible to make reasonably unique conclusions regarding the multipolarities of certain of the transitions. For example, the ratio of the photoelectric intensities of the 373-kev to the 497-kev gammas has been variously reported[3,6,7] as 0.07, 0.12, and 0.25. While these numbers differ widely and are uncertain as a result of the poor resolution of the

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TABLE II. Energy of electrons from Ba^{131} in kev.

Electron energy	Interpretation	Energy sum	Electron energy	Interpretation	Energy sum
24.8	Auger KL_1L_1		180.0	K	216.0
25.6	Auger KL_2L_2		203.5	K	239.5
30.1	Auger KLM		210.0	L_1	215.7
33.9	Auger KMM		213.0	K	249.0
42.7	K	78.7	230.7	K(Ba)	268.1
49.8	L_2	55.2	233.8	L	239.5
53.9	M	55.1	238.5	K(Ba)	275.9
56.3	K	92.3	243.0	L	248.7
73.1	L_2	78.5	262.1	L(Ba)	267.6
77.5	M	78.7	270.0	L(Ba)	275.6
88.1	K	124.1	337.5	K	373.5
97.5	K	133.5	368.5	L	374.0
118.4	L_2	123.8	461.5	K	497.5
122.4	M	123.6	492.0	L	497.5
123.4	N	123.6	549	K	585
127.6	L_1	133.3	584	K	620
132.1	M	133.3			

spectrometers employed, they probably give the correct order of magnitude. The corresponding ratio for the K-conversion peaks of the same gamma-rays in the present investigation is found to be 1:2.1. It should then follow that the inverse ratio of the K-conversion coefficients must lie somewhere between 0.14 and 0.53. By reference to the calculated K coefficients of Rose[8] at these energies it can be seen that of all the possible multipolarities consistent with K/L ratio measurement, as numerator or as denominator, only three combinations fall within the observed limits, namely, M_2/M_3 (0.13), M_3/M_3 (0.37), and E_2/E_2 (0.45). The K/L ratios of 6 ± 0.5 and 7.7 ± 0.5 would indicate that the 373-kev radiation could be $E2$ or $M3$ in character, and the 497-kev radiation could be $E2$, $M3$, $M2$ or $M1$. The lifetime of $M3$ radiation would probably be too long for the 373-kev transition, since coincidences have been observed.[3] It seems reasonable then to express a preference for the $E2$ assignments to both. In a similar way, each of the other designations shown in column 4 has

TABLE III. Energies and nature of the observed gamma-rays.

Arbitrary number	Energy, kev	K/L ratio	Type
1	55.2	$\lesssim 1$	$E2$
2	78.7	10 ± 2	$M1$
3	92.3		
4	123.8	3.6 ± 0.3	$(M1+E2)$
5	133.4	5.8 ± 0.5	$(M1+E2)$
6	215.8	9 ± 2	$M1$
7	239.3	$\gtrsim 6$	
8	248.8	$\gtrsim 6$	
9	373.5	6 ± 0.5	$E2$
10	488.5		
11	497.5	7.7 ± 0.5	$E2$
12	585		
13	620		
Ba^{133}	275.7		
Ba^{135}	267.9		

[8] Rose, Goertzel, and Perry, Oak Ridge National Laboratory Report No. 1023 (1951) (unpublished).

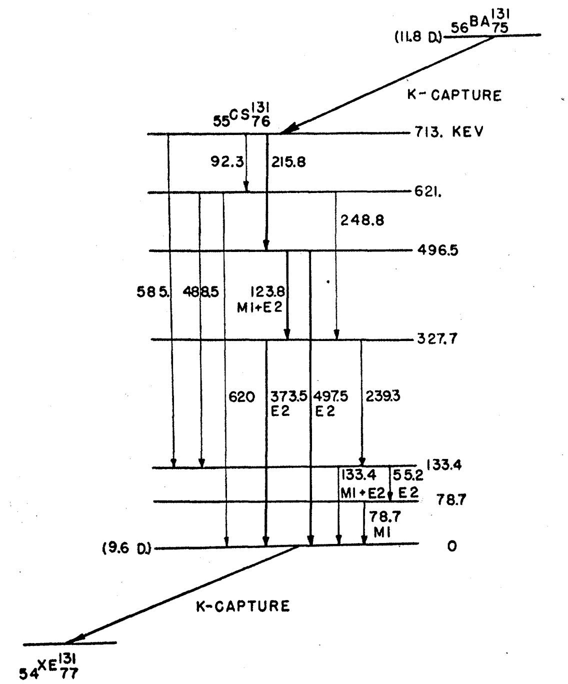

FIG. 1. Nuclear levels in Cs^{131} following K capture in Ba^{131}. (Note: the value 327.7 in the figure should read 372.7.)

been determined. For the low energy gamma-rays the assignment is aided by the relative intensities of the three L conversion lines.

The numerical values of the energies of the observed gamma-rays exhibit significant equivalent combinations, thereby suggesting a nuclear level scheme as shown in Fig. 1. All of the thirteen gamma-rays are satisfactorily accommodated as transitions between the seven nuclear levels.