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Decay of ^{125}Cs, ^{127}Cs, and ^{129}Cs

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Neutron-deficient isotopes of cesium (^{129}Cs, ^{127}Cs, and ^{125}Cs) were produced by the α-particle bombardment of natural iodine. γ-ray energies and intensities were measured with Ge(Li) detectors. In the decay of 32-h ^{129}Cs, among others, 372- and 582-keV γ rays were detected. In the decay of 6.2-h ^{127}Cs, new γ rays have been detected, and new levels at 1430, 1805, and 1829 keV have been proposed. In the decay of 45-min ^{125}Cs, the following levels in ^{125}Xe (percentage feeding in parentheses) have been proposed: ground state (54%), 112 keV (2%), 526 keV (30%), 540 keV (4%), 712 keV (6%), 1311 keV (0.33%), 1326 keV (0.43%), 1579 keV (0.5%), 1698 keV (0.7%), 2154 keV (0.2%), 2523 keV (0.2%), and 2545 keV (0.1%). These decay schemes show that the β decay of these cesium isotopes takes place preferentially to the excited states in the daughter xenon isotopes.

INTRODUCTION

Although one expects 32-h ^{129}Cs ($\frac{1}{2}^+$) to decay, on the basis of normal β-decay selection rules, predominantly to the ground state ($\frac{1}{2}^+$) and 39.6 keV ($\frac{3}{2}^+$) of ^{129}Xe, some 60% of the decay takes place to the states at 411.3 keV and 588.8 keV.[1-4] The recent study of the decay of ^{127}Cs[5] shows that the transitions to the ground state ($\frac{1}{2}^+$) and first excited state (124.7 keV $\frac{3}{2}^+$) of ^{127}Xe have large log*ft* values, as in the decay of ^{129}Cs, and that 80% of the decay of ^{127}Cs lands on levels in ^{127}Xe at 410.7 and 587.7 keV.

In this paper, we report on our studies of the decay of ^{129}Cs, ^{127}Cs, and ^{125}Cs. In the decay of ^{129}Cs, we report the observation of some low-intensity transitions. We have observed some new γ rays and measured the γ-ray energies in the decay of ^{127}Cs more accurately than reported by Spalek *et al.*[5] We have measured the energies and intensities of the γ rays emitted in the decay of ^{125}Cs and drawn up a partial decay scheme.

The decay of ^{125}Cs ($\frac{1}{2}^+$) to the ground state ($\frac{1}{2}^+$ of ^{125}Xe) is about 10 times slower than expected and the decay to the 526-keV level is about normal.

SOURCE PREPARATION AND γ-RAY STUDIES

The sources of ^{129}Cs, ^{127}Cs, and ^{125}Cs were prepared by the bombardment, in the variable-energy cyclotron of the Crocker Laboratory, of a calcium iodide target by α particles of about 30, 55, and 80 MeV, respectively. The reactions utilized were (α, 2n), (α, 4n), and (α, 6n), respectively. The target was dissolved in nitric acid, and all iodine was driven off by heating, and all calcium was removed in the form of carbonate. From this solution, the cesium activity was precipitated with the help of silicotungstic acid.

The radiations were studied with two 35-cm^3 Ge(Li) detectors in coincidence with the resolving time of 100 μsec. The data were collected in 1024-channel groups in a nuclear data analyzer. Low-energy γ rays were studied with a Ge(Li) detector having a resolution of 250 eV at 50 keV.

^{129}Cs

The early studies of the decay of ^{129}Cs have been adequately complemented by the work of Graeffe and Walters.[3] For completeness, we studied the γ rays from ^{129}Cs with a good Ge(Li) detector. In the spectrum of the γ rays, given in Fig. 1, the existence of the γ rays, reported by Graeffe and Walters, are all confirmed. Some new γ rays, shown in the figure and in Table I, lend further support to the levels in ^{129}Xe, proposed by Graeffe and Walters, given in Fig. 2. The level at 411 keV does not decay to the 322-keV state (which probably is $\frac{5}{2}^+$ state). Langhoff[4] prefers $\frac{3}{2}^+$ assignment for the 411-keV state. The 589-keV state decays to the ground state ($\frac{1}{2}^+$), 39.4-keV state ($\frac{3}{2}^+$), and the 322-keV state ($\frac{5}{2}^+$), which indicates that probably this state has a spin and parity $\frac{3}{2}^+$.

^{127}Cs

The radiations from 6.2-h ^{127}Cs have been studied by Spalek *et al.*[5] They made measurements on the γ rays with a 6.5-cm^3 Ge(Li) detector, having a resolution of 5 to 6 keV. The positron spectrum and internal-conversion electrons were measured with a β-ray spectrometer. Based on these measurements, they made up a decay scheme of ^{127}Cs with levels in ^{127}Xe at the following energies (in keV): 124.7, 300, 321.2, 411.2, 586.5, 929,

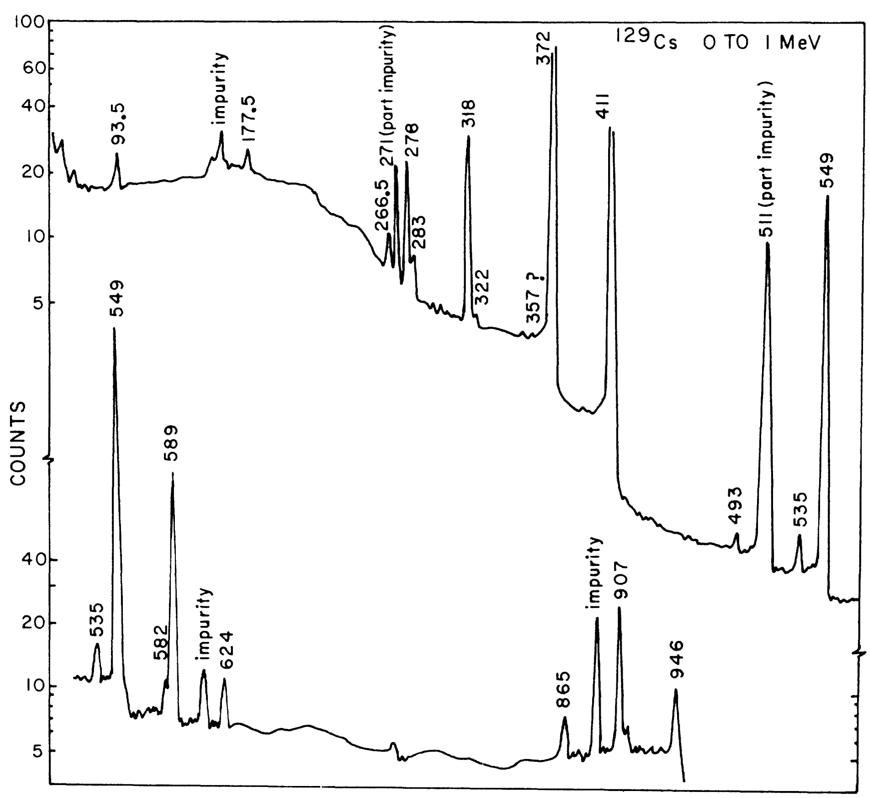

FIG. 1. γ-ray spectrum of ^{129}Cs.

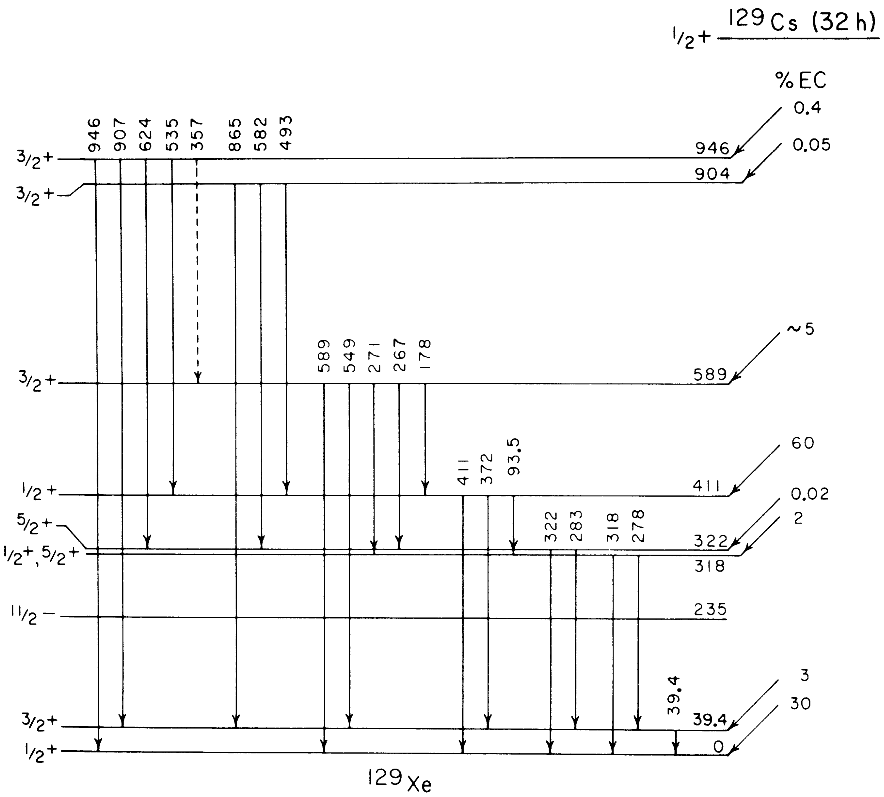

FIG. 2. Decay scheme of ^{129}Cs.

1195±, 1305, 1582, 1775, and 1975. They estimated that the log*ft* for the transition to the ground state and the 124.7-keV states are 6.5 and 6.6, respectively, the feeding being about 12% and 7%. This indicated that, contrary to the speculation of Geiger, Graham, and Gelletly,[6] the spin and the parity of the ground state and the first excited state (124.7 keV) in ^{127}Xe are $\frac{1}{2}^+$ and $\frac{3}{2}^+$, respectively. They found that the feeding of the 411.2- and 586.5-keV states are 68% and 10%, respectively.

The spectrum of γ rays emitted in the decay of ^{127}Cs, taken with a Ge(Li) detector having an energy resolution of 3 keV at 1.3 MeV, is given in Figs. 3 and 4. The energies and the intensities of the γ rays are given in Table II. Almost all the γ rays reported by Spalek *et al.*[5] are confirmed and some new ones have been detected. γ rays in coincidence with the 124.7-keV γ ray were measured. The decay scheme given by Spalek *et al.*[5] was found to be very satisfactory. Three new levels at 1430, 1805, and 1829 keV were introduced. Many more γ rays could be accomodated by these levels, as shown in the revised level scheme of Fig. 5. 12 γ rays in Table II could not be fitted into the new decay scheme. From

TABLE I. γ rays observed in the decay of ^{129}Cs.

E_γ (keV) This work	Intensity	E_γ (keV) (Ref. 3)
	9.2	39.4
93.5	2.4	93.5
177.5	0.94	177.2
266.5	0.90	266.6
271	0.56	270.5
278	4.4	278
283	0.81	282.6
318	7.8	317.9
322	0.15	322
357		
372	100	371.9
411	69	411.3
493	0.04	492.8
511		
535	0.1	534.8
549	10.3	549.3
582	Weak	
589	1.75	588.8
624	0.09	624.5
865	0.10	866.5
907	0.72	907
946	0.21	946.3

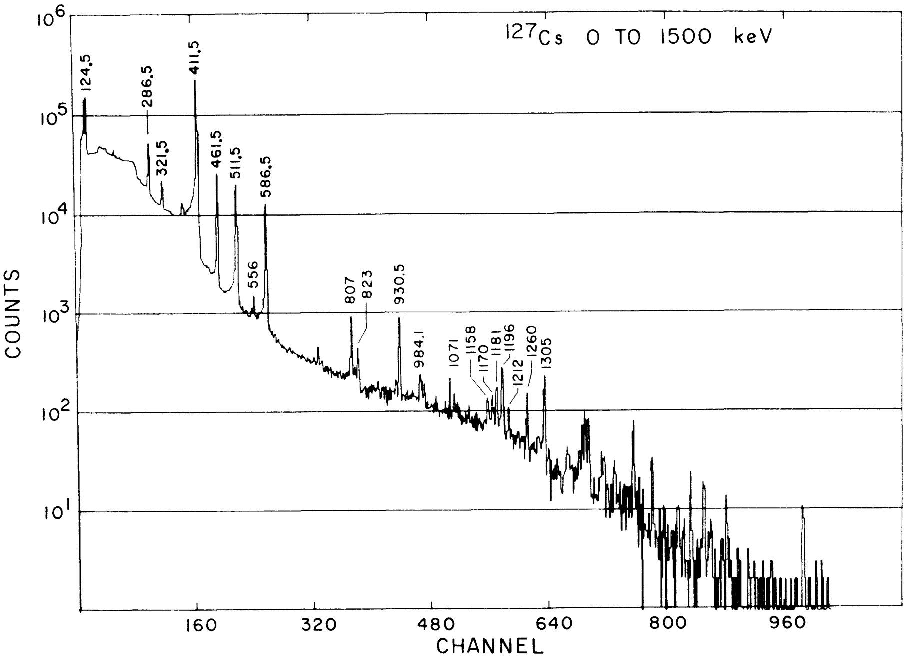

FIG. 3. γ-ray spectrum of ^{127}Cs up to 2200 keV.

detailed studies of the positron spectrum and internal-conversion-coefficient measurements, Spalek *et al.*[5] showed that the logft values for β decay to the ground state, 124.5-keV state, and 321.5-keV states are 6.5, 6.6, and 7.5, respectively, while the logft for the decay to 411.5- and 586.5-keV levels are 5.5 and 6.2, respectively.

^{125}Cs

The only information one has about the decay of ^{125}Cs is that it decays by positron emission with a decay energy of 3 MeV and a half-life of 45 min. From the study of ^{125m}Xe,[7] the first excited state ($\frac{3}{2}^+$) has been established at 112 keV.

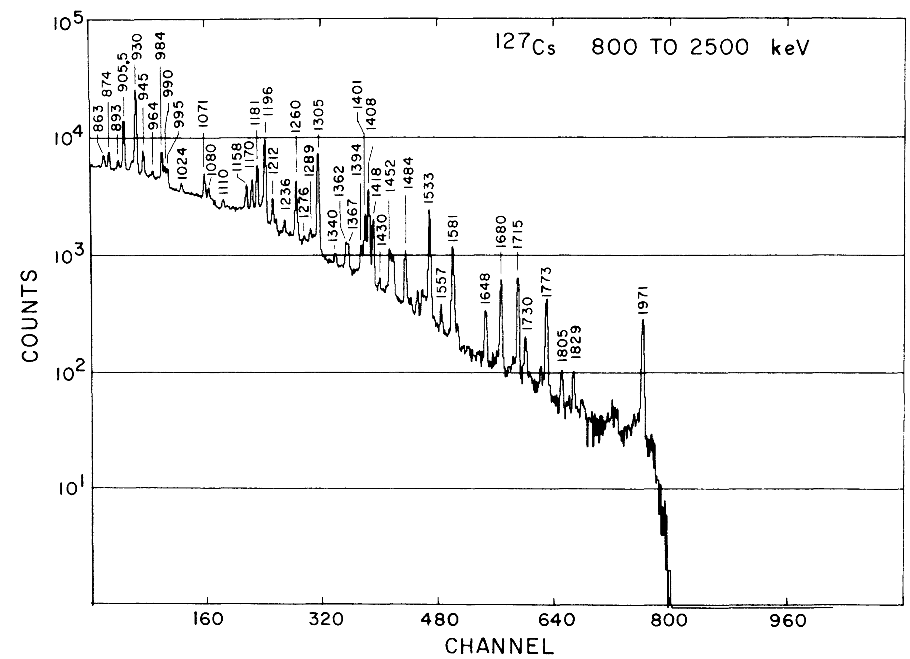

FIG. 4. γ-ray spectrum of ^{127}Cs up to 2800 keV.

TABLE II. γ rays observed in the decay of ^{127}Cs.

E_γ (keV) This work	Intensity	E_γ (keV) (Ref. 5)	E_γ (keV) This work	Intensity	E_γ (keV) (Ref. 5)
	235		1212	0.95	1213
124.5	255	125	1236	0.4	1232
196	7		1260	2.5	1260
286.5	73	287	1276	0.1	
321.5	16	321	1289	0.4	1290
411.5	1200	411	1305	5.5	1305
461.5	100	462	1340	0.2	1240
511.5	123	511	1362	0.5	1364
556	3.1		1367	0.5	
586.5	90	587	1394	0.4	1392
807	8.3	804	1401	1.3	1402
823	2.8	823	1408	3.0	1409
874	0.9	874	1418	1.4	1418
893	0.35	892	1430	0.1	
930.5	10.2	929	1452	0.8	1453
945	1.5		1484	0.8	1484
964	0.25		1533	2.4	1535
984	1.8	984	1557	0.2	1554, 1561
990	0.8	991	1582	1.3	1583
995	0.8		1648	0.4	1649
1024	0.4		1680	0.7	1681
1071	1.1	1070	1715	0.8	1702, 1718
1080	0.5		1730	0.2	
1110	0.3		1773	0.6	1776
1158	1.0	1158	1805	0.1	
1170	1.3	1169, 1181	1829	0.1	
1196	5.5	1196	1971	0.5	1975

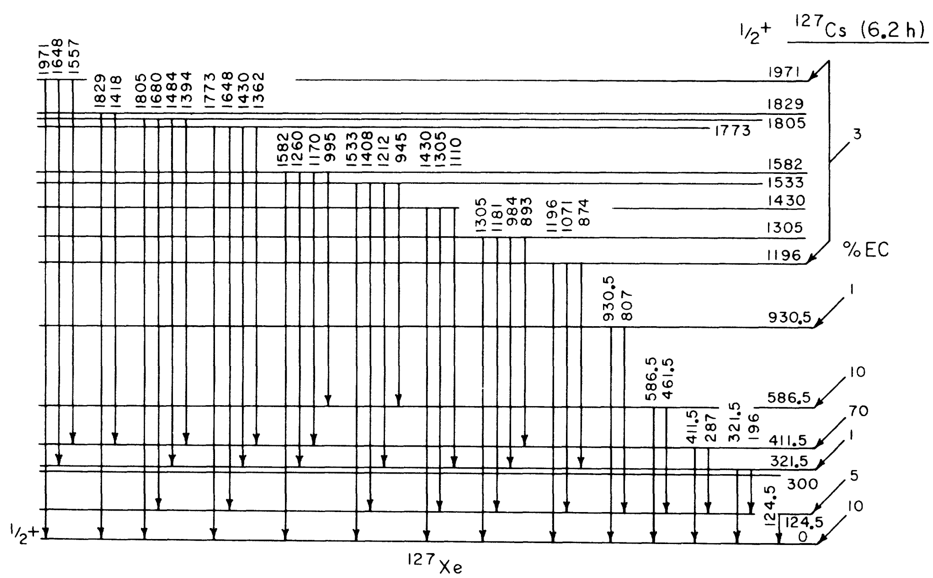

FIG. 5. Decay scheme of ^{127}Cs.

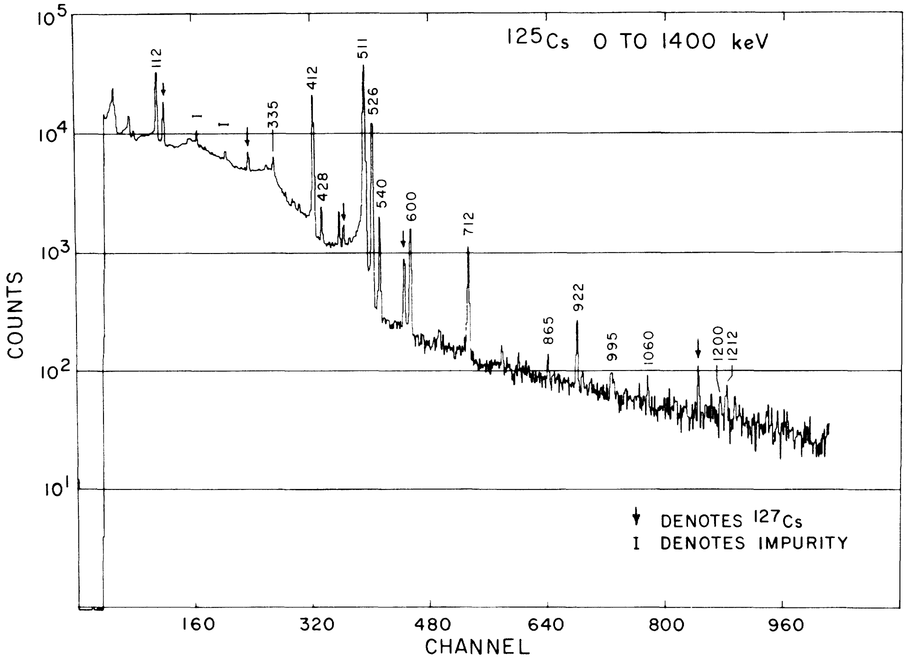

FIG. 6. γ-ray spectrum of ^{125}Cs (low-energy portion). Some of these γ rays have been observed by W. R. Kane, Bull. Am. Phys. Soc. 16, 551 (1971).

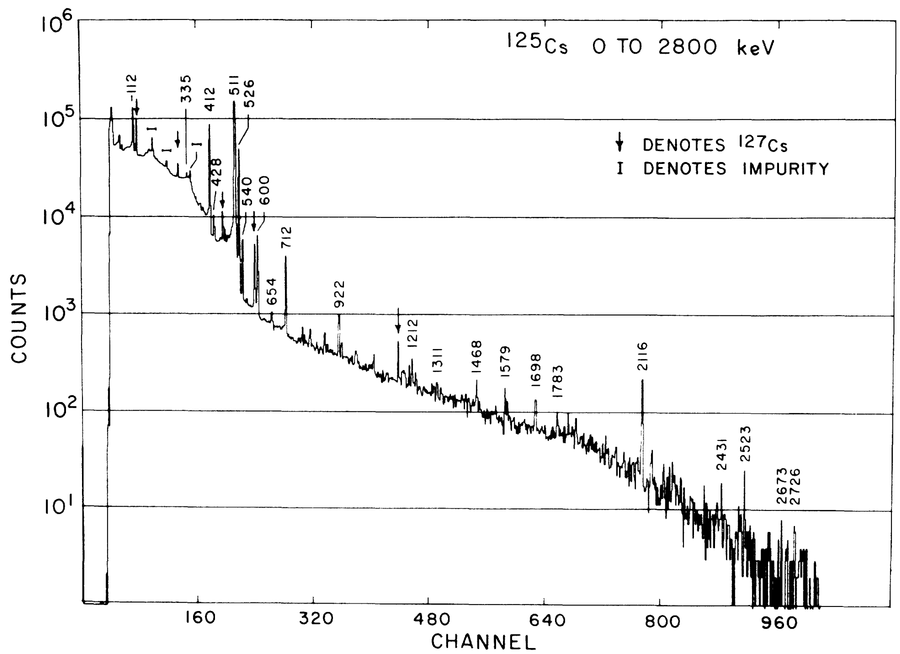

FIG. 7. γ-ray spectrum of ^{125}Cs (from 100 to 3000 keV).

TABLE III. γ rays observed in the decay of ^{125}Cs.

E_γ (keV)	I_γ	E_γ (keV)	I_γ
112	278	1311	7
335	66	1326	3
412	170	1468	8.5
428	51	1579	9
511	2550	1698	9
526	792	1783	7
540	100	1825	4
600	100	1855	6
654	14	2044	2
712	114	2116	26
780	7	2154	6
808	2.5	2201	4
865	9.8	2269	4
922	27	2371	Weak
995	17	2414	1.5
1060	5.9	2431	2
1158	14	2523	4
1200	6	2545	0.8
1212	11	2623	1.5
1228	5	2726	1.5

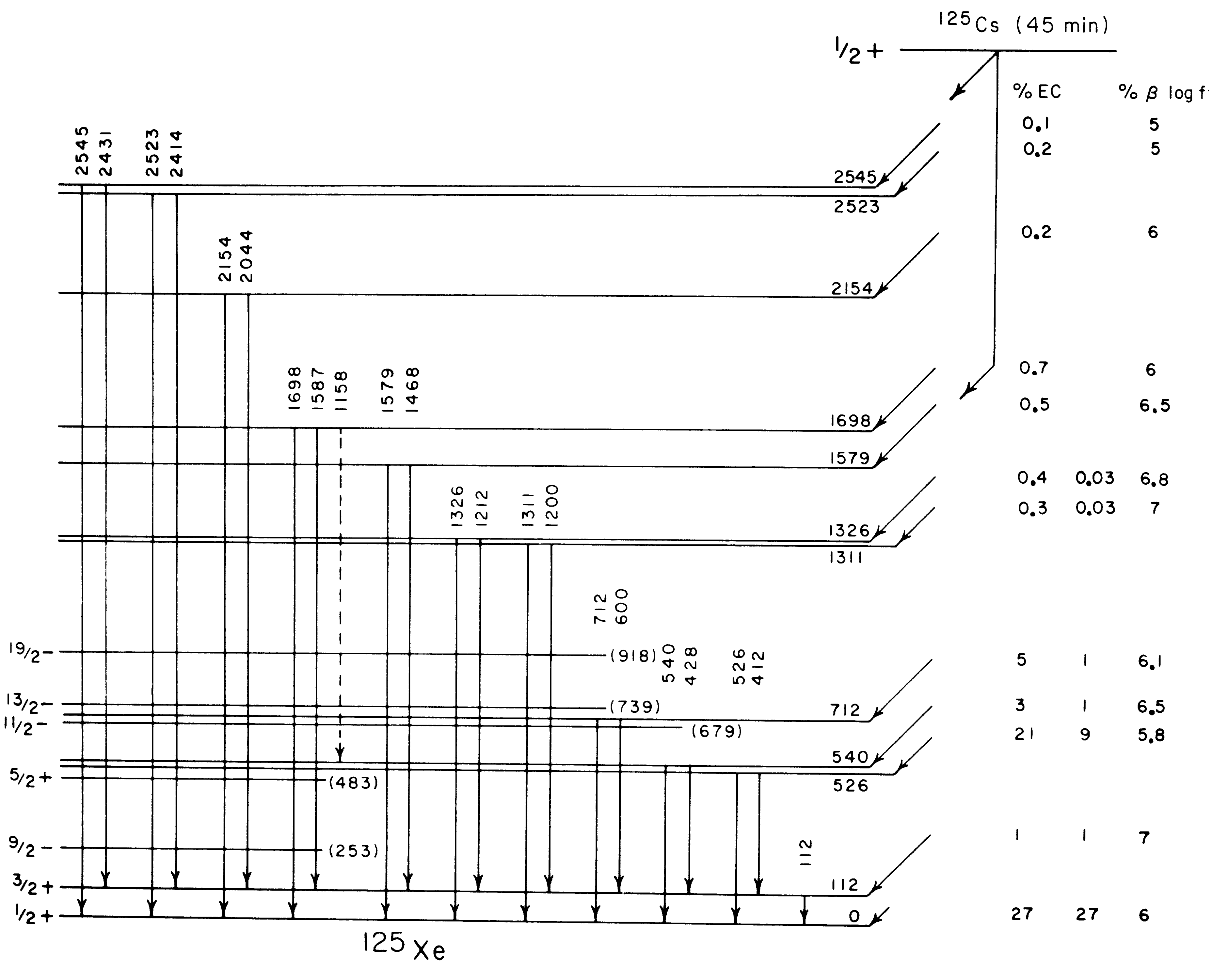

FIG. 8. Decay scheme of ^{125}Cs.

The source of ^{125}Cs, prepared by us, had some ^{127}Cs as an impurity and ^{125}Xe (19 h) as the decay product. We followed the decay of the intensity of the γ-ray peaks (Fig. 6 and Fig. 7). The energies and the intensities of the γ rays decaying with a half-life of 45 min are given in Table III. The intensity of the 125-keV γ rays was used to estimate the contribution of ^{127}Cs to the intensity of the 412-keV γ ray and the annihilation radiation (the intensities given in Table III are the corrected intensities).

Some of these γ rays could be fitted into a decay scheme (Fig. 8) from the consideration that the difference of the energy of the two γ rays was equal to 112 keV, which is the energy of the first excited state of ^{125}Xe. These γ-ray transitions include about 90% of the decay. From the intensity of the γ rays emanating from a level, the β-decay feeding of this level has been calculated. The electron-capture decay energy available for the feeding of a level has been used to calculate the ratio of the electron capture and positron emission. In this way, all but 27% of the positrons could be accounted for. This 27% of the total number of positrons was attributed to the ground-to-ground transition.

Thus it has been inferred that the following levels (with the intensity of feeding and $\log ft$ in the parentheses) are excited in the decay of ^{125}Cs: ground state (54%, 6), 112 keV (2%, 7), 526 keV (30%, 5.8), 540 keV (4%, 6.5), 712 keV (6%, 6.1), 1311 keV (0.33%, 7), 1326 keV (0.43%, 6.8), 1579 keV (0.5%, 6.5), 1698 keV (0.7%, 6), 2154 keV (0.2%, 6), 2523 keV (0.2%, 5), and 2545 keV (0.1%, 5). From this, it can be seen that in the decay of ^{125}Cs also, as in the decay of ^{129}Cs and ^{127}Cs, the decay to an excited state is favored over the ground-to-ground transition. The anomaly in the intensity of decays in ^{125}Cs is not as large as in the case of ^{127}Cs and ^{129}Cs.

DISCUSSION

In support of the supposition that the ground state of ^{129}Cs, ^{127}Cs, and ^{125}Cs is deformed, the following comments should be made. The even-even nuclei $^{124,126,128}Ba$ and $^{124,126,128,130}Xe$ have low-lying levels which are characteristic[8] of deformed nuclei. One could then infer that the odd-A nuclei in the same region would be deformed, also. Kisslinger and Sorensen[9] attributed spin $\frac{1}{2}^+$ of $^{125,127,129}Cs$ to the coupling of a phonon (2^+) to the ($\frac{5}{2}^+$) quasiparticle and they estimated the ground-state magnetic moment to be $0.45\mu_N$. This may be compared with the measured value of the spin and the magnetic moment of ^{125}Cs, $\frac{1}{2}$, and $(+1.40\pm0.02)\mu_N$, respectively.[10] The magnetic moments of ^{127}Cs and ^{129}Cs are known to be $(1.46\pm0.02)\mu_N$ and $1.479\mu_N$, respectively.[11] These values of magnetic moment can be shown to be in accord with the deformed nature of these ground states.[10] Conlon[12] has studied the excited state of ^{127}Cs associated with the 55-μsec 451.3-keV isomeric state. He attributes an oblate deformation to these excited states and a prolate deformation to the ground state of ^{127}Cs. A similar evidence for ^{125}Cs and ^{129}Cs does not exist. The levels of ^{129}Cs in the decay of ^{129}Ba have been studied by Ishii, Nageyama, and Aoke[13] but the nature of these levels is not known.

It may be pointed out that the order of the low-lying levels in ^{129}Xe is $\frac{1}{2}$, $\frac{3}{2}$, and $\frac{11}{2}^-$ as one would expect from the predictions of the spherical shell model. The order of the low-lying levels in $^{125,127}Xe$[5,6] is $\frac{1}{2}$, $\frac{3}{2}$, $\frac{9}{2}^-$. As Rezanka *et al.*[14] have pointed out, the deformation and heavily perturbed rotational pattern of the excited states can describe the nuclei $^{125,127}Xe$. Qualitatively speaking, our results on the β-decay transition probabilities are consistent with this picture.

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