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γ-γ Sum-Coincidence Effects on Relative γ-Ray Intensities in the Decay of ^{147}Nd-^{147}Pm

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The decay scheme of ^{147}Pm has been studied precisely to provide more detailed and accurate experimental information of level structure and linking em-transitions in the decay. The γ-γ sum-coincidences are found significant in most of the transitions as intensities of 410, 594, 680 and 685 keV transitions are largely affected. The intensity of 594 keV transition has gained 23 % summing contributions from (196 + 398) keV and (275 + 319) keV transitions. The levels at 91, 410, 489, 531, 680 and 686 keV are established whereas none of the transitions linking the levels at 182, 228, 276, 319, 408 and 725 keV are observed.

Key Words: Coincidence-sum corrections, Chance coincidences, Crossover transitions, Cascading γ transitions, Relative γ-ray intensities.

INTRODUCTION

The decay of ^{147}Nd has been of interest for many workers in the past. The nucleus ^{147}Pm (N = 86) lies just before the onset of stable nuclear deformation at N > 90. For this reason it has attracted some interest in the past[1-5]. Attempts have been made by Jacobs *et al.*[1] and Choudhury and O'Dwyer[2] to describe the level structure of odd-mass promethium nucleus by considering the doubly even neodymium nucleus and coupling an odd proton to this core. The strength of this coupling was such that the nuclear shape did not change and the possible single particle states were superimposed on its quasi-vibrational structure. This treatment has had some limited success in providing a description of the data that have been available to date. Despite the extensive efforts that have been made over the past many years, there are still many conflicts in the published work. The precise values of relative intensities and also of intensities per decay for multi-γ-ray sources are valuable not only for the investigation of nuclear fuel but also for many other fields of study. The main cause of the controversies over intensities by various authors could be seen from the decay scheme of ^{147}Nd-^{147}Pm in Fig. 1. The various cross-over γ-rays in the decay are also having their corresponding cascading γ-transitions due to which the coincidence summing will be considerable even though the sources were placed

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at larger distances from the face of the detector. It puts an essential need to apply sum-coincidence corrections in order to evaluate true γ-ray intensities. Semkow *et al.*[3] developed a new technique to calculate coincidence summing corrections in γ-ray spectroscopy. This technique was extended to incorporate coincidence summing effects due to X-rays by Korun and Martincic[4]. Dirk Arnold and Octavian Sima[5,6] have made extensive calculations on coincidence summing effects in special cases and even for sum peaks with X-ray contributions. In one of the recent studies, DeFelice *et al.*[7] developed new means to avoid close geometry detector calibrations finding thereby an alternative route to coincidence summing corrections. However the phenomenon of chance or random summing, which is also equally important when the distance between the source and detector is small, has not been probed thoroughly. The aim of the present investigations is to obtain as precise as possible the intensities of controversial γ lines in the decay of ^{147}Nd decay by carrying out singles measurements.

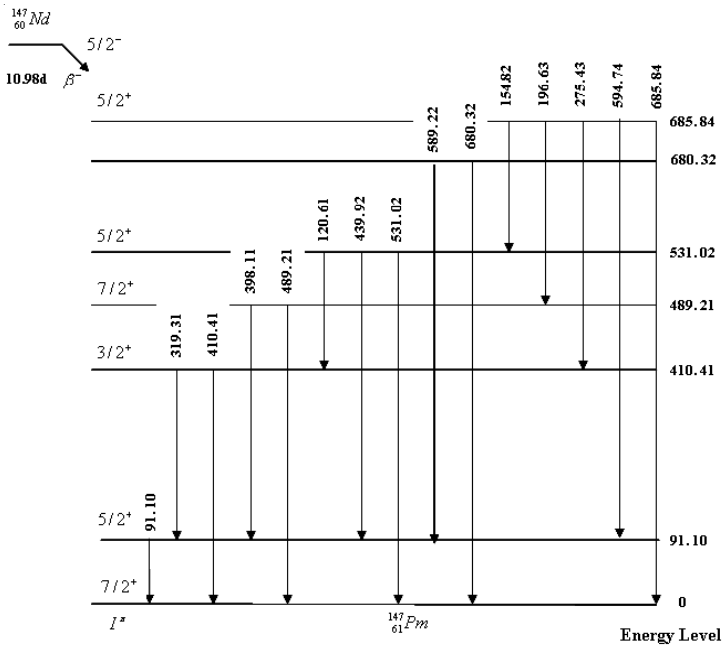

Fig. 1. Decay scheme of ^{147}Nd with present energies and intensities

EXPERIMENTAL

The nuclear reactor produced radioactive source of ^{147}Nd (10.8y) in HCl and in the chemical form of $NdCl_3$ was procured from Bhaba Atomic Research Centre, Trombay, Mumbai, India. For energy and relative intensity measurements, the source was placed on the axial line of the detector at a distance of 25 cm. Energy calibration of the 120 cc HPGe detector was done only externally using the strong and well known γ lines from ^{57}Co, ^{60}Co, ^{133}Ba, ^{137}Cs, ^{152,154}Eu, ^{182}Ta and ^{203}Hg. The γ-intensities

with least uncertainties were used as relative γ-intensity standards to obtain the detection efficiency curve. For γ-ray energies and relative intensity measurements, singles spectra were recorded using 120 cc HPGe, a high resolution coaxial and high purity germanium detector coupled to Nd-62 4K channel analyzer. Seven runs of singles spectra were recorded for different durations so as to follow the decay in order to ensure that the spectra were associated with ^{147}Nd decay.

Chance and sum coincidence corrections: The sum coincidence corrections are applied to various γ-ray transitions recorded in large sized 120 cc HPGe detector. As the life times of the nuclear levels for γ decay are usually much shorter than the charge collection time in a semiconductor detector, the two γ-rays emitted in cascade may happen to deposit energy in the detector to form a composite pulse indistinguishable from that due to the single event. The areas of peaks corresponding to these γ-rays will therefore get affected. Thus the intensity measurements will be affected by two kinds of summing effects: (a) sum peak due to accidental coincidence counts and (b) the sum coincidence peak produced due to the cascading events detected in the detector. The accidental coincidences depend on the charge collection time and the count rate of the events being detected.

RESULTS AND DISCUSSION

The coincidence sum peak areas estimated from single peak areas are given in Table-1. The sum-coincidence corrections (%) applied to the areas of various γ-ray transitions are presented in the last column. The energies and relative intensities of the γ-rays from the decay of ^{147}Nd obtained in the present work are compared with other works (Table-2).

TABLE-1
ESTIMATED AREAS AND PER CENT SUMMING CORRECTIONS OBTAINED FROM SUM-COINCIDENCE CORRECTIONS FOR CROSS-OVER AND CASCADING TRANSITIONS IN THE DECAY OF ^{147}Nd

Crossover transitions (energies in keV)	Cascading transitions (energies in keV)	Estimated areas	Summing correction (%)
		Sum-coincidences (random + true)	
410.41	319 + 91	0.01780(3)	-6.000
489.21	398 + 91	0.00650(5)	-2.400
531.02	439 + 91, 120 + 410	0.02100(2)	-0.086
594.74	196 + 398, 275 + 319	0.02500(2)	-23.00
680.32	589 + 91	0.00015(11)	-2.630
685.84	196 + 489, 275 + 410, 594 + 91	0.02500(2)	-2.200

The levels only at 91, 410, 489, 531, 680 and 686 keV energies are established by singles measurements in the present work. As none of the transitions linking the levels at 182, 228, 276, 319 and 725 keV is observed, the existence of these levels could not be supported. As evident from Table-1, the γ-γ summing is found to be significant and the applied sum coincidence corrections have severely affected the

intensities of most of the transitions. The intensities of the 410, 594, 680 and 685 keV transitions are largely affected from summing events, as the 594 keV transition intensity gaining 23 % summing contribution from (196 + 398) keV and (275 + 319) keV cascading transitions. An upper limit is placed on the intensity of 154 keV transition.

TABLE-2
PRESENT ENERGIES AND RELATIVE γ-RAY INTENSITIES IN THE DECAY OF ^{147}Nd TO ^{147}Pm

Energy (keV)	Relative intensities I (91) = 100			Summing correction (%)
	Present work	Singh *et al.*[8]	Nuclear data sheets[9]	
91.10	100.000	100.00	100.00	0.05
120.51	1.540(3)	1.24(18)	1.42(15)	0.07
154.82	< 0.034	–	< 0.20	–
196.63	1.012(27)	0.73(12)	0.73(6)	1.50
275.43	3.320(5)	3.05(20)	2.87(18)	1.50
319.31	8.010(12)	7.60(70)	7.00(4)	0.70
398.11	3.680(7)	3.35(25)	3.12(20)	0.60
410.41	0.790(2)	0.55(15)	0.50(3)	4.80
439.92	5.200(7)	5.10(3)	4.30(3)	0.30
489.21	0.530(7)	0.60(1)	0.55(3)	-0.30
531.02	47.20(24)	53.5(15)	46.90(26)	-0.09
589.22	0.224(6)	0.20(2)	0.164(16)	0.30
594.74	0.586(14)	1.10(1)	0.95(6)	-23.0
680.32	0.072(5)	0.17(8)	0.070(15)	-2.60
685.84	2.430(5)	3.50(2)	2.91(18)	-2.20

Conclusion

Though present results are more reliable and better determined because of better statistics collected under the γ-ray peaks and better efficiency determination of HPGe (120 cc) detector in the energy region 80-2000 keV. In addition to other factors considered for accuracy, there is still need of continued efforts leading to precise investigations on decay parameters in the decay of ^{147}Pm as this nucleus is gaining importance for studies on hyperfine interactions in complex molecular structures using ^{147}Nd as a nuclear probe.

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