PRAMANA — journal of physics
© Indian Academy of Sciences
Vol. 57, No. 1
July 2001
pp. 175–179

High spin spectroscopy of ^{139}Pr

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Abstract. The high spin states in $N = 80$ ^{139}Pr have been investigated by in-beam γ-spectroscopic techniques following the reaction ^{130}Te (^{14}N, $5n$) reaction at $E = 75$ MeV, using a gamma detector array, consisting of seven 23% compton-suppressed high purity germanium detectors and a multiplicity ball of fourteen bismuth germanate elements. Based on γ–γ coincidence data, the level scheme of ^{139}Pr has been considerably extended up to 7.2 MeV excitation. Tentative spin-parity assignments are done for the newly proposed levels on the basis of the DCO ratios corresponding to strong gates and the available information from the earlier light ion experiments.

Keywords. High spin states; nuclear structure; gamma-ray spectroscopy; ^{139}Pr energy levels.

PACS Nos 21.10.-k; 23.20.-g; 27.60.+j; 29.30.Kv

1. Introduction

The transitional nuclei in the $A = 140$ region with N between 77 and 81 are interesting as it offer good scope to look for possible shape changes, similar to heavier transitional nuclei close to $Z = 82$ magic number. From the systematics of even-A, $N = 80$ isotones around $A = 140$, the presence of neutron hole states at moderate excitation energy and spin have been confirmed in which $1h_{11/2}$ and $2d_{5/2}$ orbits are involved. One does not see much of collective vibrational states, as expected, though the first excited 2^+ state in the said nuclei is collective in nature. This makes the level scheme of the neighbouring odd-A isotones quite complex. With the view of extending the high spin systematics of odd-A, $N = 80$ isotones, we have already investigated the γ-rays following the reaction ^{133}Cs(^{12}C, $4n\gamma$)^{141}Pm, using dc and pulsed beam [1]. In the present work, we report results on prompt spectroscopy of $N = 80$ ^{139}Pr using the reaction ^{130}Te(^{14}N, $5n$) reaction. Previous in-beam spectroscopic studies, done in 80's [2,3], used light ion beams and few Ge detectors, which restricted the population of states beyond 4.5 MeV and spin 25/2$\hbar$. One of these groups [2] suggested an oblate triaxial shape for the positive parity states of this nucleus, which does not reflect well for the higher lying negative parity states. Prior to our work, Barci *et al* [4] studied the high spin states in ^{139}Pr using ^{128}Te(^{14}N, $3n\gamma$) reaction at 60 MeV. Their work, however, suffers from few shortcomings. Firstly the projectile energy was not optimum as is evident from the relative excitation function data (cf. figure 1 of ref. [4]) which depicts higher relative yields for γ-rays belonging to $A = 138$ channels compared to ^{139}Pr. The relatively low fusion l-grazing ($\approx 22\hbar$) for the system: ^{128}Te $+$ 60 MeV ^{14}N, as predicted by PACE2 calculations [5], is responsible for the low yield of higher spin states in their reaction, resulting in poor statistics in coincidence spectra and making unambiguous spin-parity assignments of higher lying levels difficult. The level scheme, up to 2.9 MeV excitation, as suggested by these authors, is however, in good agreement with the light ion work [2,3]. With this background, we have studied the reaction ^{130}Te $+$ ^{14}N at 75 MeV, where according to PACE2 calculation [5], the cross-section for $5n$ channel producing ^{139}Pr residual nuclei peaks, with an angular momentum distribution extending up to $36\hbar$.

2. Experimental details and results

The present experiment was done using 75 MeV ^{14}N beam, obtained from the 15UD Pelletron accelerator of Nuclear Science Centre, New Delhi. The target used was prepared by vacuum evaporation of 1.1 mg/cm^2 enriched (99.9%) ^{130}Te metal on 480 μg/cm^2 Au backing. It was covered from the top by a 20 μg/cm^2 Au-foil. The residual ^{139}Pr nuclei were producd by ^{130}Te (^{14}N, $5n$) reaction. Typical beam currents of $\approx$ 2 pnA were put on target. The gamma detector array (GDA) with seven 23% Compton-suppressed n-type HPGe detectors, fixed on two horizontal rings at $\pm$ 25° and a multiplicity ball of fourteen hexagonal (38 mm $\times$ 75 mm) BGO detectors was used for high statistics γ–γ coincidence experiment. Out of the seven Ge detectors, four were so arranged around 90° hemisphere that those subtend 99° in the median plane with respect to the beam direction. The three detectors, placed in the backward hemisphere, similarly subtend 153° with respect to beam direction. The on-line CAMAC-based data acquisition system, ‘FREEDOM’ [6], was used which is configured under LINUX platform.

Around 90 $\times$ 10^6 two and higher fold events were recorded in list mode in which each coincidence event was tagged by the condition that at least one of the BGO detectors has fired. The list mode data were sorted into a 4096 $\times$ 4096 total $E_\gamma - E_\gamma$ matrix from which the coincidence spectra were generated using the program ‘NSCSORT’ [7]. The salient steps followed for the analysis of the list data have been briefly discussed in ref. [8]. The γ-rays belonging to various residual nuclei were identified by putting gates on known strong transitions, which are already assigned to respective nuclei by earlier workers. In figures 1a, b, coincidence spectra corresponding 900 and 1330 keV gates are shown which confirm the presence of additional γ rays from the de-excitation of the residual ^{139}Pr nucleus, presumably from levels at higher spin and excitation energy, favoured in our reaction. The relative intensity of some of the γ-rays, such as, 199 and 402 keV, has been appropriately corrected for their contribution from the neighbouring ^{138}Pr residual channel, by a proper subtraction of the total projection spectrum.

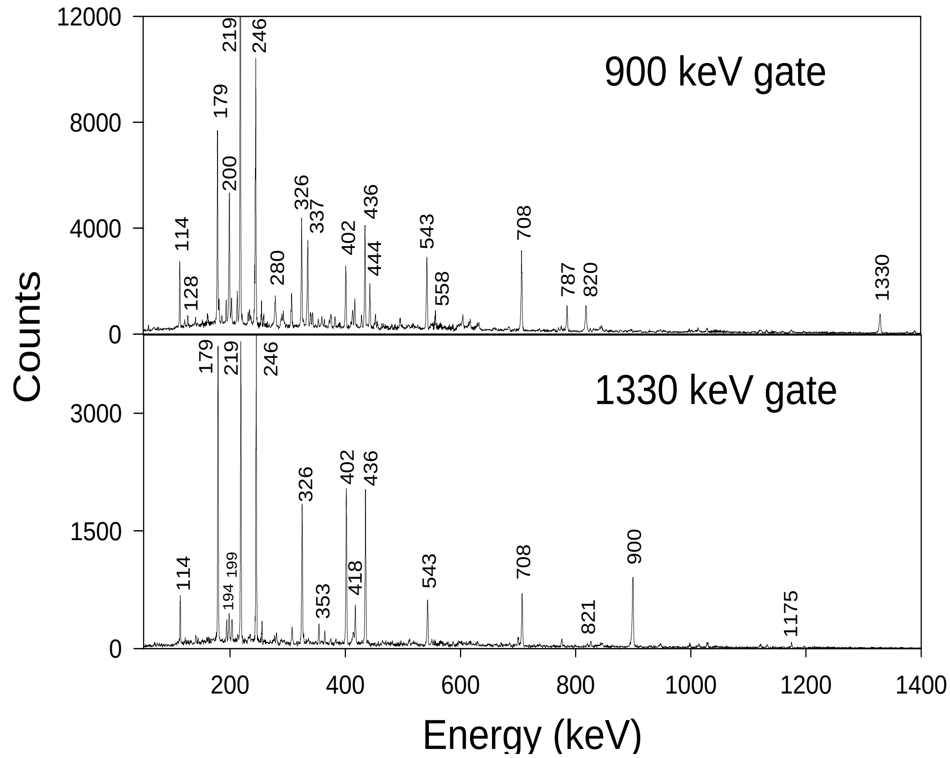

Figure 1. Representative γ–γ coincidence spectra in the reaction ^{130}Te(^{14}N, $5n$) at $E = 75$ MeV, corresponding to selected gates, as indicated.

3. Level scheme of ^{139}Pr and discussion

On the basis of prompt coincidence data, we have extended the level scheme of ^{139}Pr, shown in figure 2, which corroborates well with the schemes, suggested by the earlier workers [2,4,3]. The notable addition to the level scheme is the extension of the yrast sequence up to 7.2 MeV excitation, above the 1330.7–402.8–436.0–326.0 cascade, tentatively placed by Aryaeinejad and McHarris [3] in their level scheme. The discrepancy in respect of the placement of 336 and 543 keV cascade γ-rays, by the earlier workers [4,3], has been resolved in our work by a second placement of a 543.5 keV γ-ray above the 4862.8 keV level in the main yrast sequence on the basis of a careful analysis of pertinent coincidence spectra and intensity balance. The spin-parity assignments of the states, as indicated in figure 2, are tentative and based on the available information on conversion co-efficients and mutipolarities from the earlier in-beam work [2,3] and a preliminary analysis of the DCO ratios corresponding to strong gates from the present work. The said assignments for states up to 3.7 MeV were discussed at length by the previous workers [2–4]. The tentative assignments for the higher excited levels are done on the assumption of increasing angular momentum with increasing excitation energy and need to be con-

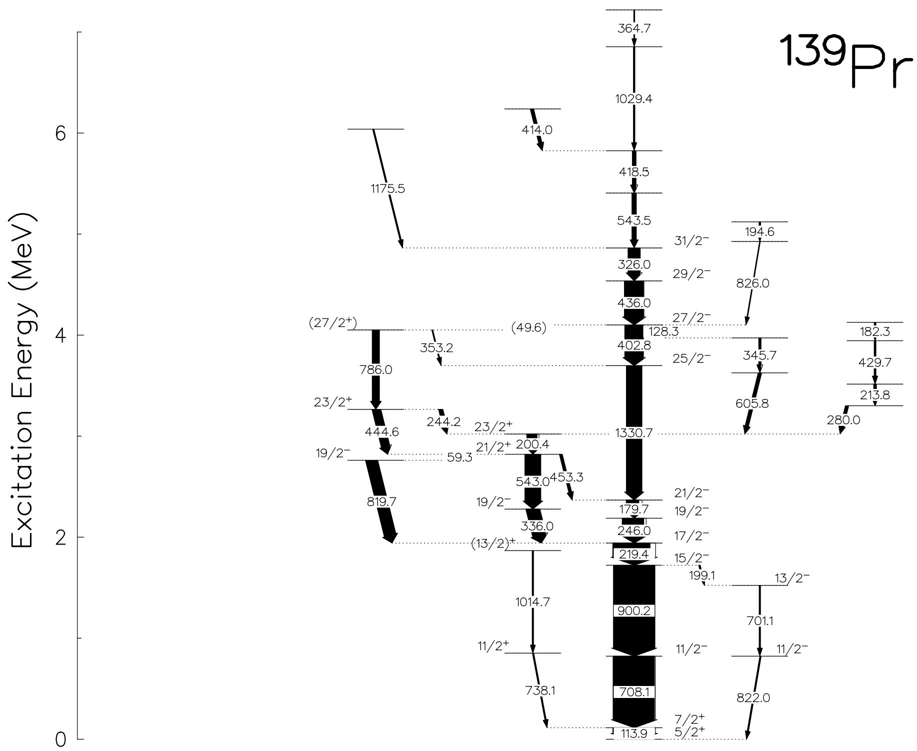

Figure 2. Level scheme of ^{139}Pr, as proposed in the present work.

firmed by complimentary measurements for the said states. Further experiments are being planned in that direction.

Acknowledgements

The authors are grateful to the staff of the NSC Pelletron laboratory for their helpful co-operation.

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