Thermal Neutron Induced Charged Particle Reactions in Radioactive Targets of $^{37}$Ar, $^{109}$Cd, $^{125}$Xe, $^{127}$Xe, and $^{132}$Cs

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Thermal neutron induced charged particle reactions in a radioactive target of $^{37}$Ar have been studied. Upper limits of the cross-sections for the (n,p) reaction in radioactive targets of $^{109}$Cd, $^{125,127}$Xe, and $^{132}$Cs have been obtained. The isotopically pure targets were produced at the ISOLDE facility at CERN and irradiated with thermal neutrons at the high flux reactor of the Institute Laue-Langevin in Grenoble. Charged particles from (n,p) and (n,α) reactions in $^{37}$Ar were observed with cross-sections of $69\pm 14$ b and $1900\pm 330$ b, respectively. The Q-values for these reactions were determined to be $1600\pm 12$ keV and $4630\pm 7$ keV, in agreement with existing mass data. The branching ratio $I_\gamma/I_p$ of the $^{37}$Ar capturing state was found to be $28.5\pm 2.7$. An upper limit of the cross-section for the (n,γ) reaction in $^{37}$Ar was obtained.

1. Introduction

Irradiation with thermal neutrons is known to induce (n,p) and (n,α) reactions in a limited number of nuclides [1–4]. Investigations of the spectra of charged particles following such reactions results in information on some of the properties of highly excited compound nuclear states, such as spins, parities and relative widths for different reaction channels, as well as cross-sections and precision Q-values. Moreover from studies of the similar but very rare (n,γ) reaction [8–10] the spectral distribution of primary gamma rays from these states can be determined.

The number of stable nuclides for which these reactions are energetically favoured are quite small. However, the number of promising targets can be increased by using neutron-deficient radioactive nuclides [5–6], a concept that recently has become feasible due to the improved [7] production capacity of the ISOLDE facility at CERN.

In this paper we report the results obtained from neutron irradiations of radioactive targets of $^{37}$Ar, $^{109}$Cd, $^{125,127}$Xe, and $^{132}$Cs.

2. Experimental Techniques

Radioactive nuclides were produced in spallation reactions by bombarding a target with 600 MeV protons from the CERN Synchro-cyclotron. Details on the different target-ion source systems used can be found in the References [11–13].
Table 1

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Half-life</th>
<th>Irradiation time (h)</th>
<th>Amount of target material (atoms)</th>
<th>Reaction</th>
<th>Q-value (MeV)</th>
<th>Cross-section (b)</th>
<th>Refs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{37}$Ar</td>
<td>34.8 d</td>
<td>139</td>
<td>$1.98 \times 10^{13}$</td>
<td>$(n_{th}, p)$</td>
<td>1.60</td>
<td>$69 \pm 14$</td>
<td>This work</td>
</tr>
<tr>
<td>$^{109}$Cd</td>
<td>453 d</td>
<td>190</td>
<td>$1.54 \times 10^{14}$</td>
<td>$(n_{th}, x)$</td>
<td>7.02</td>
<td>$\leq 0.05$</td>
<td>This work</td>
</tr>
<tr>
<td>$^{125}$Xe</td>
<td>16.8 h</td>
<td>47</td>
<td>$1.4 \times 10^{15}$</td>
<td>$(n_{th}, x)$</td>
<td>8.85</td>
<td>$\leq 0.03$</td>
<td>This work</td>
</tr>
<tr>
<td>$^{132}$Cs</td>
<td>6.5 d</td>
<td>130</td>
<td>$4.0 \times 10^{14}$</td>
<td>$(n_{th}, x)$</td>
<td>6.98</td>
<td>$\leq 0.15$</td>
<td>6</td>
</tr>
</tbody>
</table>

The beam extracted from the ion source was separated into its constituent masses by the ISOLDE isotope separator [7]. The selected beam was intercepted by a 10µm thick foil of ultra-pure aluminium, and the 60 keV ions were implanted into a 0.2 cm² area of the foil. The neutron irradiations were performed at the end of a 87 m curved neutron guide ($10^9$ neutrons/cm²·s) at the ILL high-flux reactor. The target position was viewed by a 450 mm², 100 µm thick silicon surface-barrier detector with a resolution of 35 keV FWHM. The detector was placed 45 mm from the target, outside the neutron beam. The energy calibration was made with alpha particles from sources of $^{241}$Am (5.486 MeV) and $^{232}$Th (5.786 and 8.785 MeV). In addition to these standard sources the alpha peak from the $^6$Li$(n_{th}, x)^3$H reaction (2.056 MeV) was also used. The energies, found for the proton and alpha peaks present in the $^{37}$Ar...