High-Spin States in $^{68}$Ga

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The $^{68}$Ga nucleus has been studied via the reactions $^{65}$Cu($\alpha$, $n\gamma$)$^{68}$Ga at $E_\alpha = 12-21$ MeV and $^{66}$Zn($\alpha$, $pn\gamma$)$^{68}$Ga at $E_\alpha = 25-40$ MeV. The level scheme has been established by means of relative yield functions, electronic timing measurements, prompt and delayed $\gamma$-$\gamma$ coincidences, angular distributions and directional orientation coincidences. Spins up to $11^+$ were assigned to levels up to 4 MeV excitation and the higher ones were interpreted by coupling a $^{67}$Ga core with a ($v_1g_{9/2}$) neutron.

1. Introduction

First tentative to establish the level scheme of the $^{68}$Ga nucleus was performed by Rester et al. [1] by means of the study of the conversion electrons and $\gamma$-rays following the $^{68}$Zn($p, n$) reaction with $E_p = 1.5-5$ MeV. Then Birstein et al. [2] used the reactions $^{68}$Zn($p, n\gamma$) with $E_p = 3.1-5.2$ MeV and $^{65}$Cu($\alpha, n\gamma$) with $E_\alpha = 6.5-9.3$ MeV to assign the $1^+$ characteristics to the ground state, $2^{(+)}$ to the first excited state at 175 keV and $3^{(+)}$ to the state at 375 keV. But, the 375 keV level was suspected to be a doublet to explain the difficulty in assigning the spin and a discrepancy between the branching ratios deduced from both reactions. By means of the $^{68}$Zn($p, n$) reaction interpreted with the Hauser-Feshbach statistical formalism, Egan et al. [3] confirmed the $2^+$ characteristics of the first excited state. Bass et al. [4] used the same reaction and formalism to confirm the precedent hypothesis and found levels up to 1.6 MeV. Harms-Ringdahl et al. [5] have investigated the $^{68}$Ga nucleus by means of the $^{65}$Cu($\alpha, n\gamma$) reaction at $E_\alpha = 14$ MeV, but the likely isotropic $\gamma$-rays angular distributions they obtained, did not enable them to give a complete analysis. They attributed the angular distribution smearing to the existence of an isomeric state decaying by a 126 keV transition and to the non zero spin of the target. They did not indicate a doublet at 375 keV. All this data has been compiled by Lewis [6].

In order to study high spin levels of $^{68}$Ga nucleus, the reactions $^{65}$Cu($\alpha, n\gamma$) at $E_\alpha \approx 18$ MeV and $^{66}$Zn($\alpha, p\gamma$) at $E_\alpha \approx 30$ MeV were used, these energies being expected to give the maximum cross-section. Such reactions have already been used to reach spins up to $10^h$ in neighbouring nuclei [7, 8]. The $^{66}$Zn($\alpha, p\gamma$) reaction inconveniently takes place into an hexagonal crystal lattice target, of which the non-zero electric field gradient (EFG) may greatly perturb [9] the angular distribution of the delayed $\gamma$-rays following the 126 keV $E2$ transition above mentioned. High spin levels are expected in $^{68}$Ga because of the proximity of the ($v_1g_{9/2}$) shell at 607 keV above ($v_{2p_{3/2}}$) in $^{67}$Zn [10] and of the ($\pi_1g_{9/2}$) shell at 2,074 keV above ($\pi_2p_{3/2}$) in $^{67}$Ga [11]. As a proof it is very interesting to note the work of Lu et al. [12] who used ($\alpha, d$) reactions at $E_\alpha = 50$ MeV to strongly populate states with a $(j_{2j'+\alpha})$ configuration, to suggest a ($\pi_1g_{9/2}, v_1g_{9/2}$) state at 2.88 MeV in $^{68}$Ga.

2. Experimental Procedure

The following measurements using the $^{65}$Cu($\alpha, n\gamma$)$^{68}$Ga and the $^{66}$Zn($\alpha, p\gamma$)$^{68}$Ga reactions have been performed:
1) Yield functions of $\gamma$-rays: $E_\alpha = 12-21$ MeV for the $^{65}$Cu target and $E_\alpha = 25-40$ MeV for the $^{66}$Zn target.
2) Electronic timing measurement at $E_\alpha = 18$ MeV for $^{65}$Cu($\alpha, n\gamma$).
3) $\gamma$-$\gamma$ coincidences at $E_\alpha = 18$ MeV for the previous reaction ($\theta_1 = 90^\circ$, $\theta_2 = 55^\circ$).

* This work forms a part of a thesis.