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Multipole mixing ratio of γ-transitions in ^{72}Ge

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Nuclei in the region of Ge (Z=32–36, N=34–38) are situated rather away from both, the proton and neutron shell closures at particle numbers 28 and 50 respectively, and their structure may be described as resulting, in part, from surface vibrations. In particular for ^{72}Ge, some of the low-lying states agree with the vibrational model. The 2^+ state at 834 keV could be identified as the one quadrupole phonon state, the levels at 1464 keV (2^+) and 1728 keV (4^+) are consistent with the expected pattern of a two-phonon triplet and also the 2025 keV (3^+) and 2464 keV (4^+) states may be members of three quadrupole phonon group. However, several experiments, including nuclear reactions, $\gamma\gamma$ and $\beta\gamma$ angular correlations[1, 2] have been performed to explore the nuclear structure of the ^{72}Ge and they have shown that its structure is rather complex and cannot be explained in the framework of the vibrational model. Besides, the knowledge of the multipole character of the γ-rays was far from complete. In view of this, the present study was undertaken to measure the angular correlation of a large number of additional gamma cascades in ^{72}Ge, including transitions of intermediate intensities using two Ge detectors in order to determine the multipole mixing ratios for as many gamma transitions as possible and to better define the spins of some levels. The multipole mixing ratios are important parameters which serve to determine the relative importance of the collective and single-particle effects in any attempt to describe the level structure of the nucleus.

The samples of ^{72}Ga were obtained by neutron activation of natural Ge in the reactor at IPEN/SP. Approximately 10mg of Ga_2O_3 were irradiated in a flux of 10^{13} n/cm^{2}s for a period of 5 minutes. The samples were stored for 3 hours to allow for the decay of ^{70}Ga ($T\frac{1}{2}$ = 21min), formed during the irradiation. A total of 40 sources were used for the entire experiment. The $\gamma\gamma$ spectrometer consisted of two HPGe detectors. The fixed and the movable detectors had volumes of 89 and 50cm^3, respectively. The measurements were carried out at angles of 90°, 120°, 150° and 180° and were analyzed using a computer code[3].

The results of the directional correlation coefficients A_{kk}, corrected for the finite solid-angle effects[4], and the multipole mixing ratios for the γ transitions in ^{72}Ge are presented in Table 1. The results of others studies are included in this table for comparison.

Table 1. Results of directional correlation coefficients and multipole mixing ratios of γ transitions in ^{72}Ge

Transition Energy (keV)	Spin Sequence $I_1 \rightarrow I_2$	γ Cascade (keV-keV)	A_{22}	A_{44}	Multipole Mixing Ratio(δ)
289	$3^- \rightarrow 2^-$	289-2201	−0.148±0.051	0.088±0.074	−0.21±0.06
336	$3^+ \rightarrow 4^+$	336-894	−0.011±0.038	−0.273±0.058	21^{+29}_{-8}
381	$3^- \rightarrow 3^-$	381-2109-834	0.200±0.025	0.021±0.038	−1.41±0.15
		381-2109	−0.229±0.051	−0.002±0.071	−1.237±0.030
428	$3^- \rightarrow 3^-$	428-786-894	−0.126±0.038	−0.001±0.056	0.97±0.07
449	$3^- \rightarrow 3^+$	449-600	0.364±0.055	−0.005±0.085	−0.47±0.12
479	$3^- \rightarrow 4^+$	479-1000	−0.108±0.056	−0.158±0.084	−0.04±0.06
600	$3^+ \rightarrow 2^+$	600-1464	−0.345±0.021	−0.070±0.031	4.57±0.06
		600-630-834	0.004±0.022	−0.007±0.036	4.0±0.6[a]
630	$2^+ \rightarrow 2^+$	630-834	−0.113±0.004	0.304±0.006	22^{+10}_{-5}
		630-834	−0.095±0.010	0.308±0.016	32.6±5.7[a]
		630-834	−0.002±0.009	0.311±0.012	−10.3±1.3[b]
633	$2^- \rightarrow 2^+$	633-1710	0.424±0.104	0.015±0.159	−0.269±0.029
735	$4^+ \rightarrow 4^+$	735-894	0.011±0.026	−0.535±0.039	0.49±0.06
		735-894-834	0.117±0.070	−0.005±0.110	−1.6±0.2[a]
786	$3^- \rightarrow 4^+$	786-894-834	−0.123±0.008	−0.011±0.012	−0.021±0.005
		786-894-834	−0.090±0.025	−0.035±0.030	0.05±0.01[a]
810	$3^- \rightarrow 3^-$	810-1050	−0.198±0.022	−0.004±0.032	−0.208±0.011
827	$2^- \rightarrow 3^-$	827-1050	−0.017±0.071	0.046±0.109	−0.146±0.054
878	$3^- \rightarrow 3^+$	878-600	0.117±0.062	0.050±0.095	0.187±0.025
894	$4^+ \rightarrow 2^+$	894-834	0.115±0.007	0.019±0.011	0.028±0.008
		894-834	0.116±0.015	0.023±0.023	E2[a]
		894-834	0.125±0.005	−0.005±0.007	−0.039±0.009[b]
970	$2^- \rightarrow 3^+$	970-600	−0.102±0.016	−0.025±0.024	−0.066±0.008
975	$3 \rightarrow 4^+$	975-1000	−0.223±0.103	−0.079±0.150	$3.98^{+0.83}_{-0.63}$
1000	$4^+ \rightarrow 2^+$	1000-630	0.001±0.019	−0.012±0.029	$-0.04^{+0.13}_{-0.15}$
		1000-630-834	−0.022±0.059	0.012±0.091	0.05±0.09[a]
1032	$2 \rightarrow 3^+$	1032-600	0.357±0.063	−0.010±0.098	$-0.74^{+0.09}_{-0.12}$
1050	$3^- \rightarrow 2^+$	1050-630	0.013±0.006	0.015±0.010	−0.08±0.04
		1050-1464	−0.071±0.032	−0.008± 0.049	−0.024±0.020
		1050-630-834	0.062±0.020	0.005±0.031	−0.29±0.02[a]
1215	$3^- \rightarrow 4^+$	1215-894	−0.075±0.021	−0.064±0.031	−0.078± 0.022
		1215-894-834	−0.913±0.020	−0.005± 0.031	−0.09±0.04
		1215-894-834	−0.051±0.066	0.016± 0.100	−0.10±0.01[a]
1230	$3^+ \rightarrow 2^+$	1230-834	−0.430±0.015	−0.140±0.021	−2.83± 0.33
		1230-834	−0.418±0.050	0.002± 0.090	−0.53±0.07[a]

[a] Value from ref.[1]
[b] Value from ref.[5]

Table 1. Continued.

Transition Energy (keV)	Spin Sequence $I_1 \rightarrow I_2$	γ Cascade (keV-keV)	A_{22}	A_{44}	Multipole Mixing Ratio(δ)
1260	$3^- \rightarrow 3^+$	1260-600	0.178±0.018	0.025±0.027	0.085±0.012
1276	$2^- \rightarrow 3^+$	1276-600	−0.113±0.015	−0.026±0.022	−0.057± 0.007
1568	$2^+ \rightarrow 2^+$	1568-834	0.163±0.046	−0.217±0.069	0.15±0.10
1571	$2^- \rightarrow 2^+$	1571-630	0.008±0.021	−0.003±0.032	0.40±0.04
1596	$3^- \rightarrow 4^+$	1596-894	−0.110±0.014	−0.039±0.021	−0.023± 0.014
		1596-894-834	−0.114±0.010	−0.020± 0.015	−0.033±0.010
		1597-894-834	−0.121±0.033	0.035±0.050	−0.01±0.03[a]
1680	$3^- \rightarrow 2^+$	1680-834	−0.152±0.021	0.077±0.032	−0.075± 0.025
		1680-834	0.123±0.065	−0.113± 0100	0.29±0.05[a]
1711	$3^- \rightarrow 4^+$	1711-894	−0.183±0.067	0.110±0.098	0.18±0.03
1837	$3^- \rightarrow 4^+$	1837-894	0.150±0.051	0.061±0.077	−0.365± 0.026
		1837-894-834	0.059±0.053	−0.046± 0.109	−0.26±0.19
1860	$3^- \rightarrow 2^+$	1860-1464	−0.036±0.034	0.051±0.052	0.058±0.016
		1860-630-834	−0.017±0.026	0.005± 0.039	0.21±0.01[a]
1877	$2^- \rightarrow 2^+$	1877-630	0.027±0.046	−0.040±0.069	$0.48^{+0.19}_{-0.16}$
2109	$3^- \rightarrow 2^+$	2109-834	−0.035±0.032	0.050±0.048	0.084±0.033
		2109-834	0.057±0.064	−0.068± 0.092	0.17±0.02[a]
2201	$2^- \rightarrow 2^+$	2201-834	0.268±0.005	0.001±0.007	−0.025± 0.001
		2201-834	0.269±0.016	−0.022± 0.024	−0.03±0.01[a]
2214	$2^+ \rightarrow 2^+$	2214-630	0.019±0.049	0.027±0.073	$0.45^{+0.024}_{-0.19}$
2491	$3^- \rightarrow 2^+$	2491-834	−0.057±0.009	−0.010±0.014	0.017± 0.003
		2491-834	−0.074±0.034	−0.004± 0.052	0.00±0.02[a]
2508	$2^- \rightarrow 2^+$	2508-834	0.239±0.007	0.013±0.011	0.014±0.003
		2508-834	0.209±0.025	−0.001± 0.040	0.09±0.05[a]
2621	$2^- \rightarrow 2^+$	2621-834	0.178±0.067	−0.283±0.104	0.09±0.08
2844	$2^+ \rightarrow 2^+$	2844-834	0.292±0.059	0.081±0.091	−0.057± 0.021

[a] Value from ref.[1]
[b] Value from ref.[5]

The directional angular $\gamma\gamma$ correlations in ^{72}Ge have been measured following the β^- decay of ^{72}Ga. Measurements have been carried out for 44 γ-cascades, 32 of them for the first time, resulting in the determination of multipode mixing ratios for 40 γ-transitions. The results show that a large number of γ-transitions are predominantly of electric dipole character, which is difficult to explain in terms of a simple vibrational model. The present results permitted assignments of spins to some of the levels involved.

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