Resonance fluorescence of giant magnetic dipole states in $^{24}Mg^{\dagger}$

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γ-ray resonance fluorescence of three magnetic dipole states in ^{24}Mg at 9827 ± 3, 9967 ± 3, and 10711 ± 3 keV was observed using bremsstrahlung and a 100 cm^3 Ge(Li) detector. The measured intensity ratios to the first excited state and the ground state were found to be $0.28^{+0.26}_{-0.18}$, $0.45^{+0.16}_{-0.13}$, and $0.23^{+0.07}_{-0.06}$, respectively. Integrated scattering cross sections and decay widths of these levels were determined relative to the known $^{16}O(\gamma, x\gamma')$ cross section.

[NUCLEAR REACTIONS $^{24}Mg(\gamma,\gamma)$, $E_\gamma < 23.5$ MeV, bremsstrahlung; measured E_γ, I_γ; ^{24}Mg deduced levels, Γ^0, Γ^1, γ branching.]

Three giant magnetic dipole states in ^{24}Mg at 9827, 9967, and 10711 keV were observed in γ-resonance fluorescence experiments using a 100 cm^3 Ge(Li) detector mounted at 125° to the incident beam and bremsstrahlung from the University of Giessen 65 MeV electron linear accelerator. A portion of a γ-ray spectrum is shown in Fig. 1. These states had been only partially resolved in previous (γ,γ)-resonance fluorescence experiments with NaI detectors[1] and in inelastic electron scattering.[2,3]

The transition with the largest $M1$ strength was previously assigned to a state at 10731 keV[4,5] found in $^{23}Na(p,\gamma)$ work, but this state was not ob-

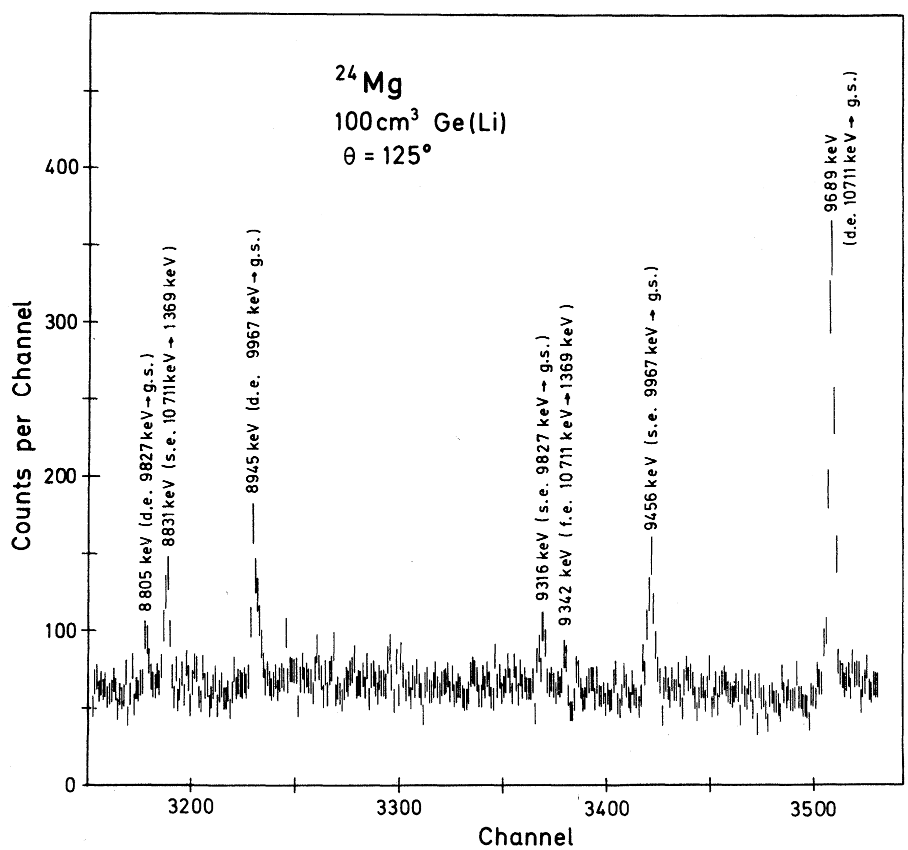

FIG. 1. Part of a spectrum of elastically and inelastically scattered photons from a 800 mg ^{24}Mg target. The tip energy of the bremsstrahlung was 23.5 MeV. The energy resolution is 2.7 keV per channel. Full energy, single-, and double-escape peaks are labeled with f.e., s.e., and d.e., respectively.

TABLE I. Comparison of the observed levels.

Endt, van der Leun [a]			Meyer *et al.* [b]		This work	
E_γ (keV)	J^π; T	Branching ratio	E_γ (keV)	Branching ratio	E_γ (keV)	Branching ratio
9827 ± 2	1^+	→ g.s. (85 ± 10)%	9827.3 ± 2.5	→ g.s. (85 ± 10)% → 4.12 (<15)% → 4.24 (<20)% 15% unknown	9827 ± 3	→ g.s. (78 ± 13)% → 1.37 (22 ± 13)% → 4.12, → 4.24 Not observed <10%
9965 ± 3	1^+; $T=1$	→ g.s. (90 ± 10)% → g.s. (70 ± 20)% [c] → 1.37 (30 ± 20)% [c]	9967 ± 3	→ g.s. (90 ± 20)% → 4.12 (<20)% 10% unknown	9967 ± 3	→ g.s. (69 ± 7)% → 1.37 (31 ± 7)%
					10711 ± 3	→ g.s. (81 ± 4)% → 1.37 (19 ± 4)% → 4.24 <4%
10731.4 ± 1.5	1^+; $T=1$	→ g.s. (40 ± 8)% [c] → 1.37 (48 ± 8)% [c] → 4.24 (12 ± 2)% [c]	10731.4 ± 1.5	→ g.s. (<40)% → 1.37 (75 ± 15)% → 4.12 (<30)% → 4.24 (25 ± 15)%	Not observed	

[a] Reference 5.
[b] Reference 4.
[c] Reference 7.

served in our fluorescence experiment, perhaps due to an insignificant decay width to the ground state. Our measurements, however, indicate that the largest $M1$ transition strength is associated with a state at 10711 ± 3 keV. This level could be identical with a 10703 keV state observed recently by Kuhlmann, Mamis, and Riess in a ^{23}Na$(d, n\gamma)$ experiment,[6] because a strong transition of this level to the ground state was found. Furthermore, we observed a transition to a state at 9827 ± 3 keV that presumably is identical with a $M1$ state at 9846 ± 20 keV observed in inelastic electron scattering by the Darmstadt group.[2] Intensity ratios for the decay of these states to the first excited state and the ground state have been obtained from the measured γ-ray spectra. The intensity ratios are $0.28^{+0.26}_{-0.18}$, $0.45^{+0.16}_{-0.13}$, and $0.23^{+0.07}_{-0.06}$ for the 9827, 9967, and the 10711 keV level, respectively.

The reduced branching ratio of the strongest transition at 10.711 keV ($0.35^{+0.11}_{-0.09}$) is smaller than 0.5, a value obtained from the collective model by the Alaga rule for interband $\Delta K = 1$, $\Delta J = 1$ transitions. The reduced branching ratios for the two lower transitions are in agreement with this intensity rule within the errors.

A comparison of the states and of the γ-ray branching from our measurement with data from

TABLE II. Integrated scattering cross sections I_s and derived γ-decay widths.

Transition (Energy in MeV)	Titze [a] Γ_γ^0 (eV)	Fagg [b] Γ_γ^0 (eV)	This work Γ_γ^0 (eV)	This work Γ_γ^1 (eV)	This work I_s (MeV mb)
10.71 → g.s.	15.9 ± 2.4	$17.6^{+3.5}_{-3.0}$	$17.8^{+8.9}_{-5.6}$		$1.45^{+0.64}_{-0.44}$
10.71 → 1.38				$4.2^{+1.9}_{-1.6}$	$0.33^{+0.17}_{-0.12}$
9.97 → g.s.	4.50 ± 0.73		$6.2^{+2.7}_{-2.2}$		$0.48^{+0.23}_{-0.16}$
9.97 → 1.38		$\Sigma = 7.6^{+1.5}_{-1.4}$		$2.8^{+1.2}_{-1.0}$	$0.22^{+0.11}_{-0.08}$
9.83 → g.s.	1.05 ± 0.26		$1.7^{+1.0}_{-0.7}$		$0.16^{+0.08}_{-0.06}$
9.83 → 1.38				$0.5^{+0.5}_{-0.4}$	$0.045^{+0.043}_{-0.036}$

[a] Reference 2.
[b] Reference 3.

(p, γ) and $(d, n\gamma)$ experiments is given in Table I. A $\Delta K = 2$ mixing between the first and second excited states in ^{24}Mg, which was extracted from the γ-ray branching observed in a ^{23}Na$(d, n\gamma)$ measurement,[7] could not be confirmed.

A second experiment was performed on MgO with a bremsstrahlung end point energy of 28.7 MeV in order to obtain absolute γ-ray decay widths Γ_γ^i for the three $J^\pi = 1^+$ levels. Absolute cross section data for the decay of the giant electric dipole resonance of ^{16}O to excited states of ^{15}N and ^{15}O are known from the work of Caldwell, Fultz, and Bramblett.[8] The subsequent deexcitation γ rays of these states were observed and a comparison of the ^{24}Mg(γ, γ) and ^{16}O$(\gamma, x\gamma')$ peak areas yielded absolute integrated cross sections for the $M1$ transitions. The shape of the bremsstrahlung spectrum was taken into account[10] and the data of Ref. 8 were corrected for the different angle of observation taking into consideration the results of Horowitz *et al.*[9] The errors quoted in Table II contain the statistical errors of the peak areas and the background as well as the reported errors from Caldwell *et al.* (±10%) and Horowitz *et al.* $(^{+21}_{-15})$% for the 6.323 MeV state in ^{15}N. The results are given in Table II and are compared with the data from Titze[2] and Fagg.[3]

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