A MEASUREMENT OF THE BRANCHING RATIO FOR THE GAMMA TRANSITIONS FROM THE 4·235 MeV LEVEL OF ^{24}Mg

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Abstract

The branching ratio for the γ-transitions from the 4·235 MeV level of ^{24}Mg has been measured following a study of the ^{23}Na(p, γ) resonances at 1021 and 1416 keV bombarding energy. The result, which is considerably more accurate than those reported previously, is compared with the predictions of the rotational model and shell model calculations.

The 4·235 MeV level of ^{24}Mg is the band head of a $K^{\pi} = 2^{+}$ rotational band and decays by γ-ray emission as indicated in Figure 1. It is important to have accurate measurements of the branching ratio R for decay by the 2·866 and 4·235 MeV transitions as they can provide an extremely sensitive test of theoretical models of ^{24}Mg (see Cohen and Cookson 1962). Previous measurements of R have been 34 ± 6 % (Batchelor *et al.* 1960), 29 ± 4 % (Cohen and Cookson 1962), 29 ± 4 % (Glaudemans and Endt 1962), and 30 ± 3% (Meyer *et al.* 1972). A more accurate measurement is described here in which a 35 cm^3 Ge(Li) detector was used to observe γ-rays from the ^{23}Na(p, γ)^{24}Mg reaction. The experimental method was designed to minimize the error due to uncertainties in the detector efficiency versus γ-energy curve which is usually the largest error associated with a measurement of this type.

A 100 μg cm^{-2} NaCl target on a water-cooled 25 μm thick tantalum backing was bombarded with a 30 μA beam of H$^+$ ions from the Australian National University 2 MeV Van de Graaff accelerator. The γ-rays emitted following excitation of the 1021 and 1416 keV resonances were detected using the Ge(Li) detector at 55° to the beam direction with its front face 4 cm from the target. Spectra were recorded using a 4096-channel pulse height analyser for 6 hr in both cases. Based on the results shown in Figure 1, it was deduced that R could be obtained using the formula

$$R = R_1 R_2 E_1 E_2 D_1 D_2 C, \tag{1}$$

where R_1 is the ratio of the number of counts in the 2·866 MeV peak to the number in the 8·434 MeV γ-ray second escape peak which were observed in the 1021 keV resonance spectrum, R_2 is the ratio of the number in the 8·829 MeV γ-ray second escape peak to the number in the 2·752 MeV peak which were observed in the 1416 keV resonance spectrum, E_1 and E_2 are ratios of peak efficiencies for detecting 2·752 to 2·866 MeV and 8·434 to 8·829 MeV γ-rays respectively, C is a factor used to account for the fact that the 4·235 MeV level is weakly populated by a cascade of

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γ-rays through the $8 \cdot 860$ MeV level, and D_1 and D_2 are angular distribution factors described below.

The γ-ray angular distributions with respect to the beam direction have the form

$$W(\theta) = I\{1 + a_2 P_2(\cos\theta) + a_4 P_4(\cos\theta)\}. \qquad (2)$$

As $P_2(\cos\theta) = 0$ at 55°, the peak intensities observed here differ from the spatially averaged values by $a_4 P_4(\cos 55°)$ and this is taken into account by D_1 and D_2. From angular distribution measurements for the 1416 keV resonance it was found that $a_4 = -0 \cdot 026$ and $-0 \cdot 056$ for the $8 \cdot 829$ and $2 \cdot 752$ MeV transitions respectively, which gave $D_1 = 1 \cdot 01$. The data of Baxter *et al.* (1969) were used for the 1021 keV resonance and gave $a_4 = 0$ for both the $8 \cdot 434$ and $2 \cdot 866$ MeV transitions, and thus $D_2 = 1 \cdot 00$.

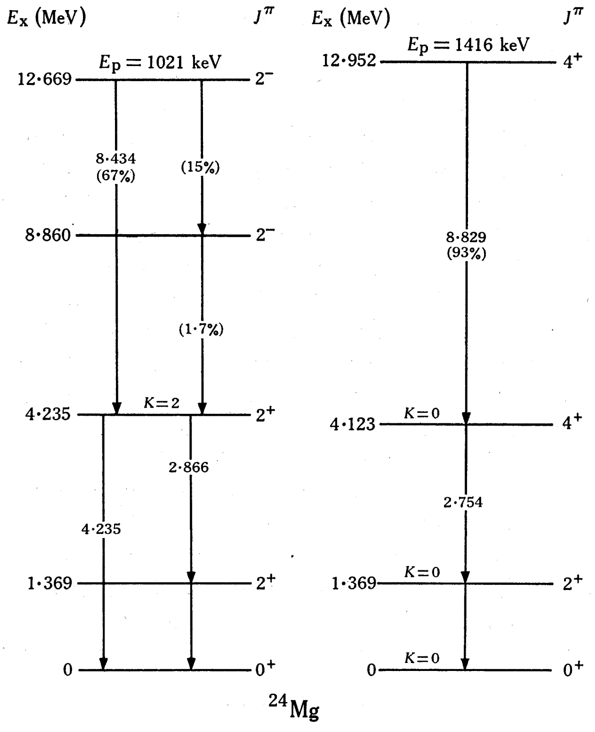

Fig. 1.—Partial decay schemes of ^{24}Mg for the 1021 and 1416 keV ^{23}Na(p, γ) resonance levels. The branching ratios shown are from Meyer *et al.* (1972).

From equation (1) the present measurements gave $R = 26 \cdot 02 \pm 0 \cdot 96$ %, and when this was combined with the previous results it yielded the final value $R = 26 \cdot 79 \pm 0 \cdot 86$ %. The multipole mixing parameter δ(E2/M1) for the $2 \cdot 866$ MeV transition has been measured by Batchelor *et al.* (1960), who obtained $\delta = 23 \pm 9$ which implies that it is an almost pure E2 transition. The ratio of the reduced E2 transition strengths $B(\mathrm{E2}, 2 \cdot 866)/B(\mathrm{E2}, 4 \cdot 235)$ was therefore obtained by multiplying this result by $(4\cdot235/2\cdot866)^5$. The derived value is shown below, together with the predictions of the rotational model, SU_3 calculations (by (3) Harvey 1968 and (4) Strottman 1972), Hartree–Fock (H.F.) calculations (by (5) Y. Abgrall, personal communication and (6) A. Watt, personal communication), a calculation using the *j–j* coupling scheme (McGory and Wildental 1971), and a calculation using a Kuo–Brown (K.B.) interaction modified by a noncentral interaction (H. Feldmeier, personal communication).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exp. ratio	Rot. model	SU_3	SU_3	H.F.	H.F.	*j–j*	K.B.
$1\cdot89\pm0\cdot06$	$1\cdot43$	$1\cdot32$	$8\cdot2$	$6\cdot2$	$4\cdot2$	$0\cdot85$	$1\cdot1$

Only those calculations which give the absolute strengths of the $1\cdot369$ MeV transition and most of the transitions between the higher rotational levels in reasonable agreement with experiment have been considered here. The fact that the rotational model prediction does not agree exactly with the experimental result may be due to a small degree of mixing between the $K = 0$ and 2 rotational bands. Proceeding in the same manner as Cohen and Cookson (1962) and using the ratio of intrinsic quadrupole moments $Q_{00}/Q_{20} = 3\cdot82\pm0\cdot38$ found by Branford *et al.* (1973), a value of $\alpha_2 = 0\cdot013\pm0\cdot003$ was obtained for the amplitude of the mixing between the 2^+ levels. Of the shell model calculations considered, the result (3) of Harvey (1968) is in closest agreement with the value reported here. However, this is probably fortuitous since only the leading (8, 4) SU_3 representation was considered in this calculation and the predicted absolute strengths for the $2_2^+ \rightarrow 0_1^+$ and $2_2^+ \rightarrow 2_1^+$ transitions are two–three times stronger than those observed. Of the other models, only the K.B. calculation gives a result that is close to the experimental one. It is interesting to note that this calculation is also the only one to give the correct energy spacing between the $K = 0$ and 2 levels. It predicts absolute values of $2\cdot87$ and $3\cdot16$ W.u. respectively for the $4\cdot235$ and $2\cdot866$ MeV transitions, which agree reasonably well with the respective absolute values of $1\cdot4\pm0\cdot3$ and $2\cdot7\pm0\cdot4$ W.u. obtained from lifetime measurements by Branford *et al.* (1973).

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