

# PARITY DETERMINATION OF TWO RESONANCES IN $^{23}\text{Na}(p, \alpha\gamma)^{20}\text{Ne}$

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Even parity has been determined for the 308 and 738 keV resonances in the  $^{23}\text{Na}(p, \alpha\gamma)^{20}\text{Ne}$  reaction from measurements of  $\gamma$ -ray angular distributions. Significant orbital-momentum mixture occurs in the formation of the 308 keV resonance. The alpha particles are emitted with the lowest possible angular momentum at both resonances.

The measurement and analysis of  $(p, \gamma)$  angular correlations often yield the spins of resonances and the occupation probabilities of their magnetic substates. However, a unique determination of the resonance parity from the latter quantities remains an exception, due to the possibility of orbital-momentum and channel-spin mixtures. For resonances decaying via emission of alpha particles, the parity determination from the angular distributions of these particles has a larger probability of succeeding, as only orbital-momentum mixtures can occur. It is the purpose of this letter to show that also the angular distributions of  $\gamma$  rays following alpha-particle decay may be sensitive indicators of the resonance parity.

As an example, we have measured such angular distributions at the 308 and 738 keV resonances in the  $^{23}\text{Na}(p, \alpha\gamma)^{20}\text{Ne}$  reaction. Levels at 11.98 and 12.39 MeV of the compound nucleus  $^{24}\text{Mg}$  are excited at these energies (see fig. 1). The spins,  $J = 2$  and  $3$ , respectively, and the occupation probabilities of the magnetic substates have been determined by Glaudemans and Endt [1] from  $(p, \gamma\gamma)$  triple correlations. They also suggest even parity for both resonances on the basis of radiation strengths. On the other hand, Grant et al. [2] suggest odd parity for the 308 keV resonance from consideration of the formation parameters. The decay of the resonances proceeds for 11 and 44%, respectively, via alpha-particle emission to the first excited ( $2^+$ ) state in  $^{20}\text{Ne}$ , which decays via emission of a 1.63 MeV  $\gamma$  ray to the ( $0^+$ ) ground state, see ref. 3. No alpha-particle emission has been observed to the  $^{20}\text{Ne}$  ground state, see ref. 4.

The angular distribution measurements were performed with the Utrecht cascade generator, with the experimental set-up described in ref. 1. The intensities of the 1.63 MeV line in  $^{20}\text{Ne}$  at

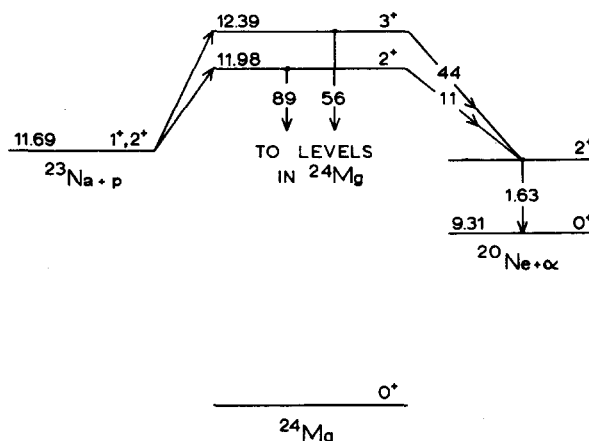


Fig. 1. Formation and decay of 308 and 738 keV resonances in  $^{24}\text{Mg}$ .

the angles  $\theta = 0, 35, 55$  and  $90^\circ$  with respect to the proton beam were analysed from  $\gamma$ -ray spectra. In these spectra the 1.63 MeV line was easily distinguishable from the strong 1.37 MeV line from the  $\gamma$  decay of the resonances. The angular distributions were analysed in terms of a series of Legendre polynomials  $W(\theta) \propto 1 + A_2 P_2(\cos \theta) + A_4 P_4(\cos \theta)$ . The results are

$$A_2 = -0.260 \pm 0.026;$$

$$A_4 = +0.075 \pm 0.028 \text{ at the 308 keV resonance,}$$

$$A_4 = +0.053 \pm 0.018;$$

$$A_4 = -0.079 \pm 0.019 \text{ at the 738 keV resonance.}$$

These results are not yet corrected for solid-angle attenuation.

The parity of a resonance is determined by comparison of the measured value of the  $A_k$  co-

efficients with the theoretical values. The last ones depend on the orbital-momentum mixing of the emitted alpha particles in the following way:  $A_k = (1 - \epsilon^2)A_k(l_{\min}) + \epsilon^2 A_k(l_{\min} + 2)$ . Here the coefficients  $A_k(l_{\alpha})$  can be calculated using the occupation probabilities of the magnetic substates, which are given in ref. 1. They contain uncertainties stemming from the errors in the occupation probabilities. The parameter  $\epsilon^2$  is varied in the analysis until the best fit is obtained. No interference term occurs, as the alpha particles are not observed experimentally.

Good fits are obtained for even parity at both resonances, yielding  $J^{\pi} = 2^{+}$  and  $3^{+}$ , respectively. These assignments are unique because the odd parity possibilities yield a value of  $\chi^2$  exceeding the 0.1% probability limit. The best fits for the parameters  $\epsilon^2$  are

$$\epsilon^2 = 0.00 \begin{matrix} +0.14 \\ -0.00 \end{matrix} \text{ (with } l_{\alpha} = 0.2)$$

for the 308 keV resonance,

$$\epsilon^2 = 0.06 \begin{matrix} +0.14 \\ -0.06 \end{matrix} \text{ (with } l_{\alpha} = 2.4)$$

for the 738 keV resonance.

Evidently, in both cases the alpha particles are emitted with the lowest possible angular momentum.

For the 308 keV resonance the even parity assignment implies that the proton capture pro-

ceeds not only via  $l_p = 0$ , but also at least 10% (and most probably 50%) via  $l_p = 2$ , see ref. 1. This proves that orbital-momentum mixtures may be important even at very low energies. If the resonance strength given in ref. 1 is corrected according to the accurate yield measurements, recently performed by Engelbertink and Endt [5], the reduced proton width appears to be at least  $\theta_p^2 = 0.08$  for d capture. The reduced widths for s waves at the 308 keV resonance and for d waves at the 738 keV resonance are small.

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#### References

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2. P.J. Grant et al., Proc. Phys. Soc. A68 (1955) 369.
3. P.W.M. Glaudemans and P.M. Endt, Nuclear Phys. 30 (1962) 30.
4. J. Kuperus, P.W.M. Glaudemans and P.M. Endt, Physica 29 (1963) 1281.
5. G.A.P. Engelbertink and P.M. Endt, Nuclear Phys. to be published.

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#### ERRATUM

N. Mangelson, M. Reed, C.C. Lu and F. Ajzenberg-Selove, The masses and excited states of  $^{24}\text{Al}$  and  $^{28}\text{P}$ , Physics Letters 21 (1966) p. 661.

Table 1, page 663, levels of  $^{24}\text{Al}$  reads:  
 $E_X = 4.48 \text{ MeV} \pm 60 \text{ keV}$  should be:

$$E_X = 5.48 \text{ MeV} \pm 60 \text{ keV}.$$