SPECTROSCOPIC STRENGTHS FOR 6Li-INDUCED ALPHA-PARTICLE TRANSFERS ON 24Mg²⁺.

J. P. DRAAYER*, H. E. GOVL, J. P. TRENTELMAN,
N. ANANTARAMAN and R. M. DAVIES
Niels Bohr Institute, University of Rochester, Rochester, New York 14627, USA

Received 7 November 1974

This letter deals with a study of the low-lying states of 24Mg by the 24Mg(6Li, d) reaction and its purpose is two-fold: (1) to report relative α-particle spectroscopic strengths extracted from exact finite-range (EFR) DWBA fits to the experimental α-particle distributions and (2) to compare the results, where possible, with (α, α') angular distributions from other α-particle transfer reactions on 24Mg, such as (16O, 12C) [1, 2] and (17O, 12C) [3], and (b) theoretical predictions [4] from a calculation using shell-model results for the eigenstates of 24Mg and 23Si. A preliminary version of this work has already been presented [5].

Structure calculations using realistic effective two-body interactions have been carried out for both 24Mg [6, 7] and 23Si [7, 8]. Using the interaction of Rho [9], the ground state of 24Mg was determined in the full sd-shell model space to have 73% pure SU3 symmetry [13], with spurious symmetry admixtures accounting for 27% of the remaining strength [443] (023) = 9% [443] (133) = 7%, etc.

With the same interaction and taking into account the dominant (α, α') in the six leading spatial symmetry classes, the theoretical group at Darmstadt [7] determined the ground state of 24Mg to have 67% pure [444] (0,13) symmetry and the first excited state, which energetically corresponded to the state at 6.96 MeV excitation, to be 79% pure [444] (12, 0).

The ground state was shown to contain a 228

* Work supported by a grant from the Nuclear Science Foundation.

**Supported by the US Atomic Energy Commission.

[443] (1, 10) admixture while the [443] (10, 1) admixture in the excited 0+ state was only 5%. The absence in the theoretical calculation of a state which could be clearly identified with the 0+ state at 4.98 MeV is consistent with inelastic electron scattering data [10], which show this state to be more strongly populated by a factor of eight than the 6.69 MeV state. Since 0+ → 1+ transitions within a single oscillator shell are forbidden, the electron scattering data suggest that the 4.98 MeV state contains large particle-hole admixtures.

A self-supporting target of 24Mg, isotopically pure to better than 99%, was bombarded with a 36 MeV 11Li beam of about 300 nA from the University of Rochester tandem accelerator. Deuteron spectra were recorded with an overall energy resolution of about 70 keV on photographic plates placed in the focal plane of an Engel split-pole spectrometer.

Fig. 1 shows the experimental angular distributions for transitions to the first three 1+ states of 24Mg fitted by EFR DWBA calculations using the code LIO1A [11]. Fig. 2 shows the angular distributions and fit for the 2" and 4" members of the ground-state rotational band. The calculations were made assuming a cluster transfer mechanism with optical model parameters that were obtained from fits to the elastic scattering of 11Li on 40Ca [12] (Y = 72.6 MeV, r1 = 1.6 fm, a = 0.97 fm, W = 8.0 fm, r2 = 2.3 fm, n = 0.8 fm), and average deuteron parameters [13]. A bound-state well of radius 1.3 A and diffuseness 0.55 fm was employed for all but the L = 4 transition, for which a well of radius 1.0 A gave a better fit to the data. The spectroscopic strengths
given in Table 1 are, however, those determined with a constant bound-state radius of 1.3 A. For all including the L = 4 transfer.

Several other optical potentials and -particle bound-state parameters that gave reasonable fits to the L = 0 and L = 2 angular distributions with comparable relative spectroscopic strengths did not give a good fit to the L = 4 distribution. The calculated curves all tended to peak several degrees forward of the experimental peak. What seems to be special about the 4Li optical potential of ref. [15] is the very large radius for the imaginary part. Calculations using this potential, and this potential only, give good fits to the L = 4 (111, d) angular distributions for other -shell nuclei as well.

Table 1 compares the relative -particle spectroscopic strengths extracted from this experiment using the code LOLA with those extracted from 54Mg[16O, 12C] and 54Mg[16O, 9Be] data as well as with theoretical predictions for a 0 (8) -particle transfer from the ground state of 54Mg, assumed to have pure (44) (84) symmetry, to members of the (0, 12) oblate ground-state band of 54Si and to the (12, 0) prolate band head at 6.69 MeV. A theoretical prediction is not given for the 4.98 MeV state as a single dominant (90) assignment is apparently inappropriate for it. As shown, agreement between theory and experiment is satisfactory.

<table>
<thead>
<tr>
<th>E(4Li, d) (MeV)</th>
<th>J^π</th>
<th>S(4Li, d)</th>
<th>S(90, 12C)</th>
<th>S(90, 16O, 12C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0^+</td>
<td>0.10</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>1.78</td>
<td>0^+</td>
<td>0.10</td>
<td>0.23</td>
<td>0.21</td>
</tr>
<tr>
<td>4.62</td>
<td>0^+</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>4.98</td>
<td>0^+</td>
<td></td>
<td>0.22</td>
<td>0.22</td>
</tr>
<tr>
<td>6.69</td>
<td>0^+</td>
<td>0.28</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table 1 Relative spectroscopic strengths measured in 54Mg[4Li, d] compared with those measured in 54Mg[16O, 12C] [2] and in 54Mg[16O, 9Be] [3] reactions and with theoretical predictions calculated assuming the states populated in 54Si to have the (90)^+ shown.
and the (6L, d) results for transitions to members of the ground-state band is very good. The agreement is in fact much better than that obtained for 16.19 GeV/c(6L, d) transitions to members of the ground-state band in 208Pb [14]. It may well be that particle-hole effects, known to be strong in the oxygen isotopes, account for the difference. It can also be seen that there is good agreement among the (16O, 11C, 12C, 13B) and (6L, d) results as regards the ratio of the spectroscopic strengths for the ground state and the 2+ excited state in 208Pb. The results from a study of the 24Mg(6L, t) reaction have been published [15], but without quoting spectroscopic strengths.

Theoretically, an s-particle transfer to the 0° member of the (0, 12) doublet ground-state band is expected to be about three times stronger than that to the 0° member of the (11, 0) proton band. The speculation [15] that a p-particle transfer from one proton state to another should be favored over that from a proton to an oblate state is therefore incorrect. Since the spatial symmetry of the prolate and the oblate shapes in 208Pb is identical, a simple explanation of the effect based on nucleonic deformation symmetry alone is impossible. It is simply a turning of the (04A)(60) + (0, 12) over the (4A)(60) + (12, 0) coupling.

Experimentally, the two band heads are observed to be populated with approximately equal strengths. Symmetry admixtures in the target and final nuclear states can, of course, affect the theoretical results. For example, assuming destructive interference between the (6A)(60) + (0, 12) and (04A)(60) + (1, 10) ground-state band admixtures increases the predicted relative strength of the 6.69 MeV state from 0.28 to 0.41, in closer agreement with experiment. A detailed calculation taking into account all admixture admixtures in both 24Mg and 208Pb is currently under study.

It is important to note, however, that the (92)X(280) + (1, 10) and (73)X(480) + (1, 10) amplitudes agree in magnitude (and phase) to within 10% for each t-transfer with the corresponding (84)X(280) + (0, 12) member. This is a special feature of the couplings, quite unexplained and not to be construed as a general feature of the model. It implies that (92) and (73) admixing in the ground state of 24Mg and/or (1, 10) admixing in 208Pb will not alter the theoretical predictions for relative spectroscopic strengths of members of the ground-state band. The agreement between theory and experiment within the ground-state band cannot therefore be taken as proof of the SU3 purity of the states. However, and perhaps most importantly, it does justify a high level of confidence in the theoretical numbers, free from first-class uncertainties related to O(100) admixtures.

In conclusion, one can say that the 24Mg(6L, d) angular distributions for transitions to low-lying states in 208Pb are well reproduced with EFR-DWBA curves using the 91 optical parameters of ref. [1]. The spectroscopic strengths of the members of the oblate band, extracted from the analysis in agreement with theoretical predictions and with corresponding members, are observable, obtained from analyses of 140Ce and 12C, 16O reactions. Our results differ both qualitatively and quantitatively from those reported for the 24Mg(t) reaction.

It is a pleasure to thank P. Marukes, H. Feldmeier, and M. Course for permission to quote numbers from their unpublished 24Mg calculation and to thank P. Marukes for pointing out the significance of the (e, e') data in regard to the structure of the 4.98 MeV state in 208Pb. Thanks are due to K.T. Ford for providing us, prior to publication, results for SU3 coefficients of fractional parentage.

Reference:
[2] J.B. Hicks et al., to be submitted for publication.