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LETTER TO THE EDITOR

The $^{43}Ca(^{3}He, d)$ reaction and the parity of the 425 keV state of ^{44}Sc

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Abstract. The Harwell multi-angle magnetic spectrograph and tandem accelerator have been used to study the 425 keV state of ^{44}Sc populated in the $^{43}Ca(^{3}He, d)^{44}Sc$ reaction. Comparison of the measured angular distribution of the deuteron group populating the 425 keV state with predictions based on the distorted wave Born approximation suggests that population of the state proceeds by $l = 2$ proton transfer. The consequent assignment of negative parity to the 425 keV state removes an inconsistency which has existed within earlier particle transfer reaction studies of this state.

The low-lying states of ^{44}Sc have been the subject of recent γ ray studies in which spin assignments were made (Dracoulis *et al* 1973a, b). In those works, the parities of several of the excited states were taken from the l values assigned in particle reaction studies leading to ^{44}Sc. However, an inconsistency was noted between the results of the $^{43}Ca(^{3}He, d)^{44}Sc$ reaction (Schwartz 1968) which assigned positive parity to the 425 keV state and the results of the later (d, t), (^{3}He, t) and (d, α) studies of Ohnuma and Sourkes (1971), Manthuruthil and Prosser (1972) and Wallen and Hintz (1972) which assigned negative parity to this state.

Negative parity was assumed in the γ ray work and subsequently the parities of the 68 and 146 keV states were shown to be the same as that of the 425 keV state. The importance of the parity assignment is evident since the characteristic γ decays of these states were explained on the basis of their identification as members of a $K^{\pi} = 0^{-}$ rotational band (Dracoulis *et al* 1973a, b).

In an attempt to resolve the discrepancy, the $^{43}Ca(^{3}He, d)^{44}Sc$ reaction ($Q = 1{\cdot}213$ MeV) has been re-examined. The transfer reaction was carried out with a 13·5 MeV ^{3}He beam from the AERE, Harwell, tandem accelerator and the reaction deuterons were analysed in the multi-angle magnetic spectrograph and detected in Ilford K2 emulsions. The integrated $^{3}He^{++}$ beam current was 23, 195 μC. The target (of approximate thickness 30 μg cm^{-2}) was made by vacuum evaporation of the enriched carbonate (composition by atomic per cent ^{40}Ca: 12·78, ^{42}Ca: 0·65, ^{43}Ca: 81·2, ^{44}Ca: 5·4, ^{46}Ca: <0·05, ^{48}Ca: 0·05).

A deuteron spectrum measured at a laboratory angle of 20·0° is shown in figure 1. The measured angular distributions of the deuteron groups populating the ground state, the 271 keV state (1), the 350 keV state (2), and the 425 keV state (3) are shown in figure 2. The curves presented are the results of calculations based on the DWBA

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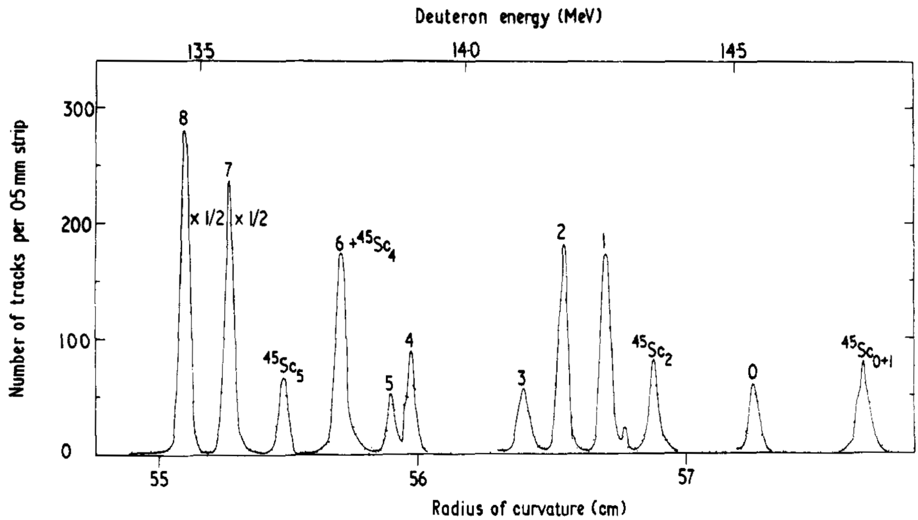

Figure 1. A deuteron spectrum from the bombardment of ^{43}Ca with 13·5 MeV ^{3}He ions at a laboratory angle of 20·0° (B = 13·623 kG). The number of deuterons scanned within a 9 mm wide zone on the photographic emulsion is plotted against the distance along the plate. The calibration of the spectrograph provides the energy scale indicated. Deuteron groups corresponding to levels in the final nucleus ^{44}Sc are numbered according to table 1. Target impurity groups are labelled by the chemical symbol of the final nucleus, with a subscript indicating the order of the excited state.

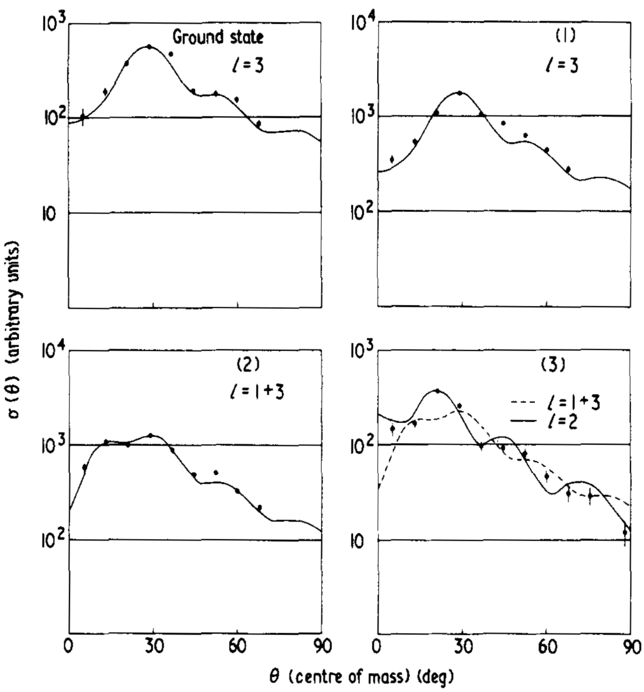

Figure 2. Angular distributions of the deuteron groups from the ^{43}Ca (^{3}He, d)^{44}Sc reaction measured at an incident ^{3}He energy of 13·5 MeV. The numbers in parentheses are the group numbers of figure 1 and table 1. The curves shown with the distributions are DWBA predictions.

and using the optical model parameters of Schwartz (1968). The present work is in agreement with the l value assignments of Schwartz (1968) for the transitions to the ground state ($l = 3$), 271 keV state ($l = 3$), and 350 keV state ($l = 1+3$). Further, for these states, the relative spectroscopic factors of the present work agree well with those of Schwartz (1968) (see table 1). For the 425 keV state, figure 2 shows both an $l = 2$ DWBA prediction and a least-squares fit of $l = 1+3$ to the data. The $l = 1+3$ fit (the assignment proposed by Schwartz 1968) completely fails to reproduce the principal maximum of the measured angular distribution whereas the $l = 2$ prediction, while not in detailed agreement with the experimental data, does reproduce the general shape at forward angles. The spectroscopic strength for the 425 keV level, assuming that population of the state in (^{3}He, d) proceeds by $l = 2$ transfer, is small (0·11), as is expected for the suggested configuration of a deformed state built on a $d_{3/2}$ proton hole (Dracoulis *et al* 1973a, b).

Table 1. A comparison of the (^{3}He, d) work of Schwartz (1968) with the present work for the low-lying states of ^{44}Sc.

Group number	E_x (MeV)	Schwartz (1968) l_p	Schwartz (1968) $\frac{2J_f+1}{2J_i+1}C^2S(l)$	Present experiment l_p	Present experiment $\frac{2J_f+1}{2J_i+1}C^2S(l)$†
0	0	3	0·28	3	0·28
1	0·271	3	0·73	3	0·81
2	0·350	1, 3	0·023(1), 0·450(3)	1, 3	0·026(1), 0·53(3)
3	0·425	1, 3	0·004(1), 0·084(3)	2	0·11

† Spectroscopic strengths normalized to 0·28 for the $l = 3$ ground state transition.

These results suggest that the 425 keV state of ^{44}Sc is populated by an $l = 2$ proton transfer in the (^{3}He, d) reaction and hence that the parity of the state is negative, in disagreement with the earlier work of Schwartz (1968). The inconsistency within the particle transfer reaction studies is thus removed.

It is worthwhile noting that an independent negative-parity assignment for the 68 keV state has been suggested by Morinaga *et al* (1973) from the results of a counter ratio technique and the (p, n) reaction. As pointed out earlier, the 425 keV state has the same parity as the 68 keV state (because they are connected by an E2 transition) and therefore negative parity can be assigned to the 425 keV state.

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