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LETTER TO THE EDITOR

Deformed states in ^{46}Sc

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Abstract. The lifetimes of the low-lying negative parity states in ^{46}Sc have been measured using the Doppler shift attenuation method. The E2 transition strengths determined from these lifetimes are enhanced and confirm a suggestion that the 142·5 (1^-), 289·5 (2^-), 584·8 (3^-) and 1124·4 (4^-) keV states of ^{46}Sc form a rotational band based upon the $(f_{7/2})^7\,(d_{3/2})^{-1}$ configuration.

A considerable amount of information (Maurenzig 1971) is now available concerning the positive partity hole states in odd mass Sc and Ti isotopes. These states arise from the promotion of an (s–d) shell proton to the $f_{7/2}$ shell. The resultant *n*p–1h (*n* even) structure is deformed and a $K^\pi = \frac{3}{2}^+$ rotational band appears, characterized by enhanced E2 transitions within the band and inhibited E1 decays to the normal parity $(f_{7/2})^{n-1}$ states. The *K* quantum number of these bands is indicative of a prolate shape.

In the case of odd–odd isotopes of Sc, deformed states of $(n+1)$p–1h structure may be expected. For the nucleus ^{46}Sc these prolate states lead to the odd neutron being in the $\Omega_n = \frac{5}{2}^-$ [312] Nilsson orbit, and the odd proton in the $\Omega_p = \frac{3}{2}^+$ [202] Nilsson orbit. The spins will couple to form rotational bands with $K^\pi = 1^-$ and 4^-. Evidence for states of similar structure has been found in the neighbouring odd–odd isotope ^{44}Sc (Dracoulis *et al* 1973).

The properties of the levels of ^{46}Sc have been extensively studied by means of direct reactions (Rapaport *et al* 1966, Lewis 1969, Lewis 1970, Yntema 1971) and the ^{45}Sc (n, γ) reaction (Raju and Spicer 1970, van Assche 1971). The study of ^{46}Sc by neutron capture led Raju and Spicer (1970) to propose a band of states based upon a 1^- level at 142·5 keV in excitation (figure 1). The particle–hole nature of the 142·5, 289·5 and 584·8 keV levels is confirmed by the population of these states in proton pick-up reactions (Lewis 1969, 1970) and their non-observation in the (d, p) reaction (Rapaport *et al* 1966). At that time the only information on decay rates of members of this proposed band was the lifetime upper limits of Fossan *et al* (1968), obtained by the delayed coincidence technique. The purpose of the present experiment has been to determine the lifetimes of the negative parity states of ^{46}Sc using the Doppler shift attenuation method. The levels of ^{46}Sc were populated by the ^{43}Ca (α, p) ^{46}Sc ($Q_0 = -1{\cdot}504$ MeV) reaction. The experiment was performed at the University of Liverpool EN tandem accelerator, using α particle beams of energy 6·5 and 7·5 MeV. The experimental and analysis techniques have been described elsewhere (Sharpey-Schafer *et al* 1971, Durell *et al* 1972).

The results of the present experiment are presented in table 1 together with the lifetime limits of Fossan *et al* and the recently measured (Delang *et al* 1972) mixing ratios for the $\Delta J = 1$ transitions. Also shown are the transition strengths deduced from the lifetimes and mixing ratios, and the branching ratios (shown in figure 1). The following

Table 1. Electromagnetic properties of the low-lying negative parity states of ^{46}Sc

Level	J^π	Lifetime (ps)		Transition	Mixing ratio	Transition Strengths (Wu)		
		This work	Fossan *et al*		Delang *et al*	M1	E1($\times 10^4$)	E2
289·5	2^-	>5	<380	$2^- \to 1^-$	$-0{\cdot}03^{+0{\cdot}03}_{-0{\cdot}06}$	>0·026 <2·0	—	—
584·8	3^-	6±3	<270	$3^- \to 1^-$	0	—	—	12^{+12}_{-4}
				$3^- \to 2^-$	$-0{\cdot}07^{+0{\cdot}03}_{-0{\cdot}02}$	$0{\cdot}13^{+0{\cdot}13}_{-0{\cdot}04}$	—	20^{+60}_{-7}
				$3^- \to 4^+$	†	—	$2{\cdot}1^{+2{\cdot}1}_{-1{\cdot}7}$	—
				$3^- \to 3^+$	†	—	$0{\cdot}14^{+0{\cdot}14}_{-0{\cdot}05}$	—
1124·4	4^-	1·6+0·2	—	$4^- \to 2^-$	0	—	—	18·1±2·3
				$4^- \to 3^-$	$-0{\cdot}08^{+0{\cdot}06}_{-0{\cdot}07}$	0·10±0·02	—	$5{\cdot}8^{+14{\cdot}5}_{-5{\cdot}7}$
				$4^- \to 4^-(3^-)$	†	0·0097±0·0012	—	—
627·5	$4^-(3^-)$	>5	<200	$4(3)^- \to 3^+$	†	—	>0·13 <5·1	—
				$4(3)^- \to 4^+$	†	—	>0·14 <5·6	—

† It is assumed that there is no M2 admixture in these transitions.

points from the table are to be noted. Firstly, the E1 decays from the negative parity states are inhibited by a factor of the order of 10^4, consistent with those observed in neighbouring odd mass nuclei for transitions between the p–h deformed band and the ground state configuration. Secondly, the E2 transitions between the negative parity

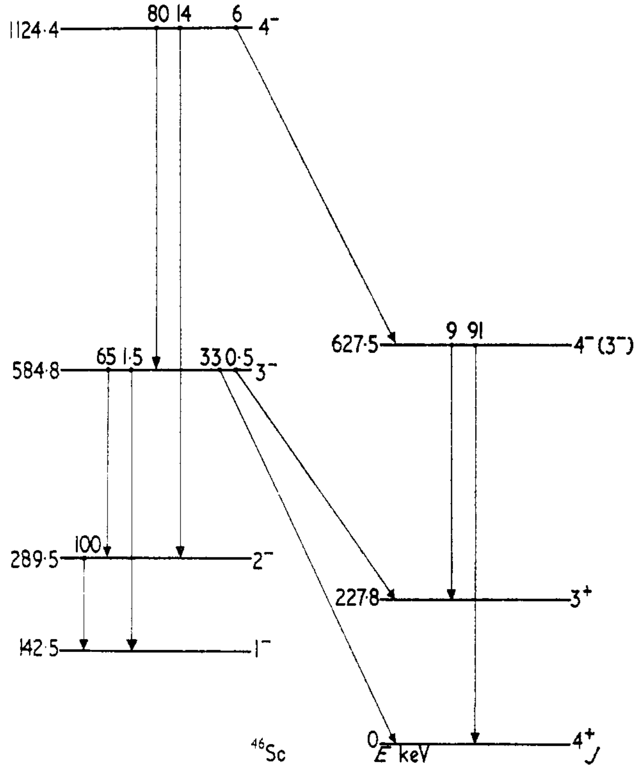

Figure 1. Decay scheme of the low-lying negative parity states of ^{46}Sc. The branching ratios are taken from van Assche (1971).

states are enhanced over the single particle value by a factor of 10–20. In fact, within the rather large errors on some of the transition strengths, the ratios of E2 strengths agree well with the simple predictions for a $K = 1$ rotational band.

The measurement of the lifetimes of the low-lying negative parity states of ^{46}Sc has confirmed the suggestion of Raju and Spicer that the levels at 142·5 (1^-), 289·5 (2^-), 584·8 (3^-) and 1124·4 (4^-) keV in excitation are members of a $K^\pi = 1^-$ band arising from the antiparallel coupling of a neutron and proton in Nilsson orbits $[312]_\nu$ and $[202]_\pi$. The inhibited E1 decays from the $4(3)^-$ level at 627·5 keV, suggest that this state may be the $J^\pi = K^\pi = 4^-$ intrinsic state arising from the parallel coupling of the odd neutron and proton.

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