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LETTER TO THE EDITOR

Spin and parity assignments to the $E_p = 504$ keV and $E_p = 506$ keV resonance levels in $^{27}Al(p,\gamma)^{28}Si$

The resonance level at $E_p = 504$ keV in the $^{27}Al(p, \gamma)^{28}Si$ reaction has been known [1]) for some time to be, in fact, a doublet. Since an earlier study of this reaction had led to a spin and parity assignment [2]) of 2^+ when it was still thought to be single, it was decided to re-investigate the components separately under the conditions of improved resolution recently attained [3]) with the Utrecht 850 keV cascade generator. The instrumental separation of the components of the doublet (hereafter referred to as the 504 keV and the 506 keV resonance levels) was satisfactory [4]), although the build-up of target contamination with time imposed an upper limit on the statistical accuracy achievable in one run.

The assignments of spin and parity to the two resonance levels have been made on the basis of the following measurements:

1) The angular distribution of the ground-state transition of the 504 keV level. The measurement led to an angular distribution of $W(\theta) \sim 1 + (0.01 \pm 0.02) \cos^2 \theta$;
2) The angular distribution of the first excited state transition of the 506 keV level. The measurement yielded in this case $W(\theta) \sim 1 - (0.08 \pm 0.02) \cos^2 \theta$;
3) Both levels decay to both the ground state (0^+) and the first excited state (2^+) of ^{28}Si. The 504 keV level also decays to the second excited state of ^{28}Si, whereas the 506 keV level does not [5]). This state has recently been conclusively proved to be a 4^+ level [6])[5]);
4) The 504 keV resonance level emits alpha particles to the ground state of $^{24}Mg(0^+)$, the strength $\omega(\Gamma_\alpha \Gamma_p / \Gamma_t)$ having been determined to be 0.76 ± 0.08 eV [7]). The 506 keV resonance level, on the other hand, does not; $\omega(\Gamma_\alpha \Gamma_p/\Gamma_t) < 0.14$ eV [7]).

As a result of these measurements the spins and partities of the 504 keV and the 506 keV resonance levels are determined to be 2^+ and 1^+ if orbital angular momentum mixing of the captured protons is left out of consideration.

The reasoning leading to these assignments is as follows.

The 504 keV resonance level. From the isotropy of the angular distribution the possible assignments are 2^+ and 3^+ (s-capture) or 1^+ (d-capture) if a suitable channel spin mixing ratio is assumed. An assignment of 1^- (p-capture with channel spin 2^+) leads to the uniquely determined angular distribution $W(\theta) \sim 1 - 0.27 \cos^2\theta$, which is completely ruled out by the measured isotropy. Spin 0 is impossible because of the existence of a ground-state transition. In addition the alpha particle emission rules out 1^+, 2^- and 3^+. The first of these is in any case highly improbable because of the existence of a decay mode to the 4^+ second excited state, and the other two (as well as higher spins) are likewise improbable because of the ground state transition.

Thus the assignment of 2^+ is considered to be very safely established [8]).

The 506 keV resonance level. As above, spin 0 is ruled out uniquely by the existence of a ground-state transition. A 1^- assignment would lead to an angular distribution of the transition to the first excited state of $W(\theta) = 1 - 0.015 \cos^2\theta$

for unmixed $E1$ radiation. An admixture of $M2$ radiation with a mixing parameter of 0.33 would be required to explain the observed anisotropy. This is highly improbable, and the failure of the state to emit alpha particles strengthens this argument. A 2^+ assignment would lead to isotropy as well as to emission of alpha particles, and thus is rejected. In view, however, of the fact that a small mixture of d-capture could produce the observed anisotropy, and also that the failure to emit alpha particles could be a consequence of the isotopic spin selection rule, it is worth noting that two states of the same spin and parity would not be expected to lie only two kilovolts apart. Even if the isotopic spins of the states were different, the coloumb interaction would probably separate two levels of the same spin and parity by several tens of kilovolts. Since the assignment of the 504 keV level is absolutely certain, this same assignment can be rejected immediately for the 506 keV level. A 2^- assignment could lead to the observed anisotropy for suitably chosen channel spin mixing, but is rendered most unlikely by the transition to the ground state which would have to be $M2$. Higher spins are also rejected on the basis of the existence of a ground-state transition.

An assignment of 1^+ to the resonance level could lead to the observed anisotropy for a wide range of values of the $E2/M1$ mixing parameter, and the channel spin mixing ratio. It is thus concluded that this assignment is by far the most likely. The non-emission of alpha particles merely reinforces the argument, but is not taken to be of paramount importance.

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8) Recent measurements in this laboratory by P. J. M. Smulders and of one of the authors (P.B.S.) on the angular distribution of the gamma radiation from this same level reached by means of the $^{24}Mg(\alpha, \gamma)^{28}Si$ reaction confirm the 2^+ assignment unequivocally.