SPIN AND PARITY ASSIGNMENTS FOR ^{33}S LEVELS FROM THE ^{29}Si(α, n)^{32}S REACTION

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Abstract: In ^{29}Si(α, n$_0$)^{32}S excitation functions measured at 0° and 160° between E_α = 3.5–5.5 MeV, sharp resonances have been located corresponding to ^{33}S levels at excitation energies between 10.19 and 11.98 MeV. Forty-two on-resonance angular distributions were measured and normalized to an absolute cross-section scale. Spin $\frac{1}{2}$, $\frac{3}{2}$, $\frac{5}{2}$ and $\frac{7}{2}$ states in ^{33}S have been identified via the characteristic shape of the single-level angular distributions. An analysis employing both single-level and coherently admixed two-level theory which is sensitive to both shape and magnitude of the on-resonance distributions has furnished spin and parity assignments to single- and twin-level resonances. An optical potential of the Woods-Saxon volume-absorption type has been deduced for α-particles providing agreement with the ^{13}C, ^{19}F, ^{29}Si and ^{31}P α-particle scattering and alpha-nucleon data.

E | NUCLEAR REACTION ^{29}Si(α, n), (α, α), E = 3.5–5.5 MeV; measured absolute $\sigma(E, E_n, \theta)$; deduced optical potential. ^{33}S deduced levels, J, π, l. Enriched target.

1. Introduction

In our continuing involvement with entrance and exit channel spin $\frac{1}{2}$ reactions [1,2]) to extract spin-parity assignments for levels in the compound nucleus, a study of the ^{29}Si(α, n$_0$)^{32}S reaction over an energy range E_α = 3.5–5.5 MeV is now presented. It will be demonstrated that these measurements are well represented by a single-level or coherent two-level analysis which relies on both the shape and magnitude of the on-resonance angular distributions to arrive at spin-parity assignments.

This analysis procedure was first introduced in the ^{13}C(α, n$_0$)^{16}O reaction [1]) although severely overlapping ^{17}O levels caused the two-level analysis to be of limited applicability for several of the resonances. The reaction cross section also exhibited only a weak sensitivity to parity for $J \leqq \frac{5}{2}$.

By contrast the ^{35}Cl resonances excited in the ^{31}P(α, p$_0$)^{34}S reaction [2]) were in good agreement with a single-level and two-level analysis. An almost equal number of resonances fell into the pure and the two-level categories; there was no need to

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invoke three-level or multiple-level involvement. The $^{31}P(\alpha, p_0)^{34}S$ reaction also demonstrated a strong parity selectivity exhibited by an order-of-magnitude cross-section difference for $J \geqq \frac{5}{2}$. This reaction proved therefore to be a far better testing ground for the analysis procedure and established empirically that only a single normalization factor independent of energy, spin and parity was required to bring the theoretical cross sections into agreement with the experimental data.

Within our energy resolution ($\approx$ 10 keV), the single-level and two-level approach is supported by a recent high-resolution 4π detector experiment of Balakrishnan *et al.* [3]) which established that $\langle \Gamma \rangle = 5.2 \pm 1$ keV and $\langle \Gamma \rangle / \langle D \rangle \approx 0.25$ at these excitation energies. The Gilbert-Cameron high-energy level-density formula [4]) estimates level densities as 91.6, 152.2 and 247.0 MeV^{-1} for $E^* = 10$, 11 and 12 MeV, respectively, in complete accord with our analysis.

Since little is known of the optical potential of the α-particle at these low energies, a considerable effort was made to find a set of potential parameters which would apply in a consistent manner to all reactions under study, i.e., the three aforementioned reactions and $^{19}F(\alpha, p_0)^{22}Ne$. To that end elastic scattering from ^{19}F, ^{29}Si and ^{31}P was measured and the $^{13}C(\alpha, \alpha)^{13}C$ data of Kerr, Morris and Risser [5]) were included to establish such an optical potential. The resulting consistent set of potential parameters for the α-particle are incorporated in the present analysis.

As the single- or two-level theory incorporated in code MIA has been thoroughly expounded elsewhere [1,2,6]), we refer the reader to these publications.

2. Experimental details

Thin ($\approx$ 10 keV) silicon dioxide targets enriched to 92.0 % in ^{29}Si were bombarded by the α-beam of the Lowell Technological Institute 5.5 MeV Van de Graaff accelerator to measure excitation functions for the $^{29}Si(\alpha, n_0)^{32}S$ reaction at 0° and 160° in the incident energy range between 3.5 and 5.5 MeV. These excitation functions measured in steps of 5 keV exhibited 45 well-defined resonances. An on-resonance angular distribution for the outgoing neutrons was measured for 42 of the above mentioned resonances using NE-213 liquid scintillators to detect the neutrons and γ-rays produced in the reaction. An n-γ pulse shape discriminator circuit of the Goulding-Ortec type [7]) was employed to eliminate counts due to the γ-ray background.

To discriminate against neutrons leaving the residual nucleus in an excited state, three discrimination levels were used during these measurements as follows: from $E_\alpha = 3.50$–4.45 MeV the discrimination level was set at the ^{57}Co 0.122 MeV γ-ray Compton edge ($E_n \approx 0.3$ MeV); from 4.40–5.00 MeV the discrimination level was set at $\frac{1}{3}$ of the ^{137}Cs 0.662 MeV γ-ray Compton edge ($E_n \approx 0.8$ MeV), and from 4.96–5.50 MeV the discrimination level was changed to the ^{22}Na 0.511 MeV γ-ray Compton edge ($E_n \approx 1.5$ MeV). The neutron background which typically was less than 20 % of the on-resonance value of a moderately strong peak was also measured