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_α = 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 over the energy range of interest and subtracted from all ground state neutron measurements. The energy-dependent neutron detection efficiencies of the scintillators were determined by means of the $^3H(p, n)^3He$ reaction, normalized to an absolute flux by a proton recoil telescope counter whose absolute efficiency is known. The target chamber [8]) and three detector systems [1]) are discussed elsewhere.

3. Target thickness and absolute cross-section determination

Targets of ^{29}Si were prepared by evaporating 2–5 mg of enriched silicon dioxide onto tantalum backings by electron bombardment. To determine the thickness of the targets used in this experiment, the 0° and 160° excitation functions for the $^{29}Si\ (\alpha, n)^{32}S$ reaction were measured over a nearly isolated resonance at $E_\alpha = 4.020$ MeV with two targets, one of which was thicker than the other. Consider the experimental width at half maximum for a sharp resonance as expressed by Richards [9])

$$W^2 = \Gamma^2 + d^2 + \Delta T^2 + t^2, \tag{3}$$

where Γ is the natural width of the resonance; d is the Doppler broadening due to thermal motion of target nuclei; ΔT is the energy spread of the incident beam, and t is the average energy loss in the target. Since accelerator settings were identical for the "thin" and the "thick" target measurement it can be assumed that Γ, d and ΔT remain constant. Therefore, the difference between the experimental widths of the resonances determined by the thick target (W_1) and those determined by the thin target (W_2) is given by

$$W_1^2 - W_2^2 = t_1^2 - t_2^2. \tag{4}$$

The thin target measurements also displayed a resonance at 3.865 MeV that had the smallest width at half maximum of any resonance and which was assumed to be approximately equal to t_2. From the 160° data the following values were obtained: $W_1 = 25$ keV, $W_2 = 18$ keV, $t_2 = 10$ keV, giving $t_1 = 20$ keV. This result means that the energy loss in the thick target can be as much as 20 keV (if $t_2 = 10$ keV) and not less than 17.5 keV (if $t_2 = 0$). Comparison of integrated thin and thick target yields for the 4.020 MeV resonance gives a calculated value of t_2 within 11 % of the 10 keV estimate. This target thickness was converted to the number N of ^{29}Si nuclei/cm^2 establishing the on-resonance laboratory differential cross section at $E_\alpha = 4.020$ MeV,

$$\left.\frac{d\sigma}{d\Omega}\right|_{lab} = \frac{Y}{\Delta\Omega \varepsilon I N},$$

where Y is the experimental yield previously corrected for background, ε the neutron detection efficiency, I the total number of impinging particles and $\Delta\Omega$ the solid angle subtended by the effective center of the scintillator detector. The 0° and 160° excitation functions were thus normalized to an absolute cross-section scale from an averaged value of t_2 incorporating both 0° and 160° data.