pendicular orientation have been made on both Nd^{145} and Nd^{143} and will be discussed in a complete paper on this subject. The main difficulty in the analysis of the data for the perpendicular orientation is in the fitting of the results to the spin-Hamiltonian (2). Formulas of fourth or higher order perturbation theory must be used to obtain sufficiently accurate values of the parameters inasmuch as, particularly in the case of Nd^{143}, the normal second- and third-order contributions to the hyperfine effects are very much larger than that coming from $g_{N_I}'\beta_N \mathbf{H}\cdot\mathbf{I}$.

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Anomalous Behavior of $Al^{27}(p,\alpha)Mg^{24}$ Differential Cross Sections*

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THE partial success of Butler's direct interaction theory[1] in fitting the experimental $C^{12}(\alpha,p)N^{15}$ angular distributions suggested an investigation of (p,α) reactions. The differential cross sections of $Al^{27}(p,\alpha_0)Mg^{24}$ ($Q=1.60$ Mev) and $Al^{27}(p,\alpha_1)Mg^{24*}$ ($Q=-0.23$ Mev) have been measured for protons of approximately 11 Mev from the Brookhaven National Laboratory 60-inch cyclotron. Alpha-particle groups are separated from proton and deuteron groups by a (dE/dx) *vs* E proportional counter scintillation counter telescope. This counter, the scattering chamber, and associated equipment have been described elsewhere.[2] Beam energy and energy spread are determined by range measurements using the range curves of Aron, Hoffman, and Williams. The initial proton energy varies between 10.3 Mev and 11.0 Mev depending on cyclotron operation conditions, and the energy spread is approximately 200 kev. Lower proton energies are obtained by degrading the beam with aluminum absorbers.

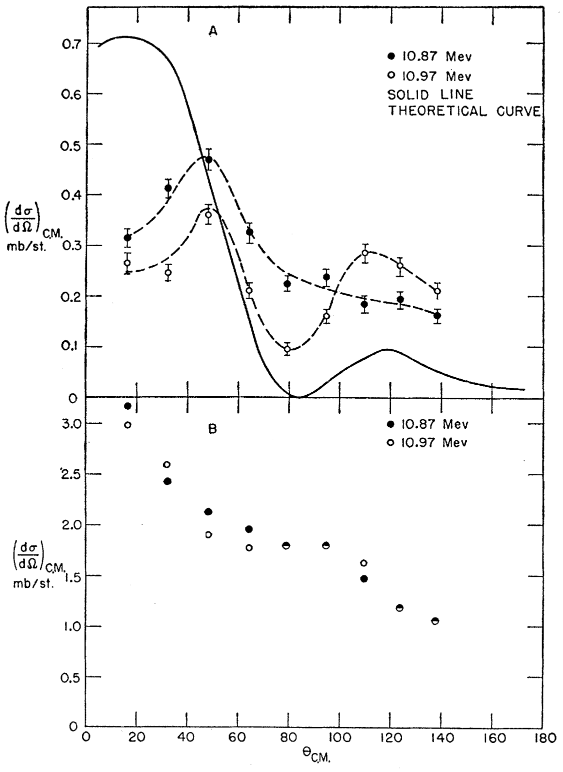

FIG. 1. (A) Angular distributions of alpha particles from $Al^{27}(p,\alpha_0)Mg^{24}$ ($Q=+1.60$ Mev) for 10.97-Mev and 10.87-Mev protons. Theoretical curve calculated from Butler's[1] Eq. (58) for $r=4.50\times10^{-13}$ cm and for 10.9-Mev protons. $\mathbf{Q}=(23/27)\mathbf{k}_p-(23/24)\mathbf{k}_\alpha$. (B) Angular distributions of alpha particles from $Al^{27}(p,\alpha_1)Mg^{24*}$ ($Q=+0.23$ Mev) for 10.97-Mev and 10.87-Mev protons.

Figure 1 shows the angular distributions measured for the $Al(p,\alpha)$ reactions leading to the ground and first excited states of Mg^{24} respectively, both at 10.97 and 10.87 Mev incident proton energy. Figure 2 shows the differential cross sections at laboratory angle 45° for these reactions as well as for protons scattered elastically from aluminum, as a function of proton energy. The curves in Fig. 2 were obtained after a major cyclotron shutdown and it was not possible to bring the beam energy up to its previous value of 10.97 Mev. The estimated maximum experimental error is 15% for the differential cross sections. The absolute bombarding energy is believed to be known to 100 kev. Energy changes are known to 2%.

The theoretical curve in Fig. 1 was calculated from Eq. (58) of Butler's paper[1] for 10.9-Mev protons. The nuclear radius used, $r=4.50\times10^{-13}$ cm, was that which gave the best fit to the minimum and second maximum. It was not possible to reproduce the first maximum with a reasonable value for the radius. Butler's theoretical expression predicts less forward peaking than is observed for (α,p) reactions.[1,3] Hunting and Wall[3] obtain a much improved fit to their (α,p) data with the expression $\exp(-Q^2/Q_0^2)|j_l(Qr)|^2$ for the differential cross section, taking the Fermi momentum into account. For $Al^{27}(\alpha,p)Si^{30}$ they required a radius of 4.98×10^{-13} cm for a fit to their data. However, for $Al^{27}(p,\alpha_0)Mg^{24}$ The Butler theory predicts more forward peaking than

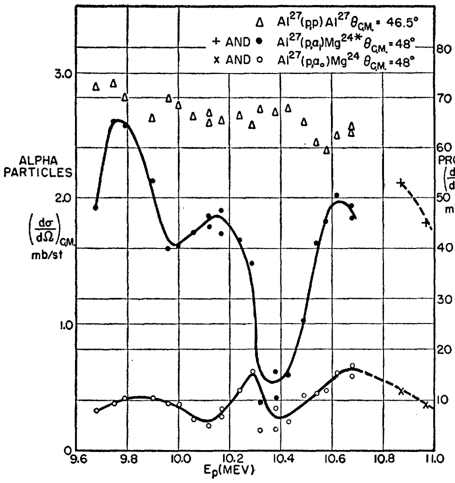

FIG. 2. Differential cross sections for $Al^{27}(p,p)Al^{27}$, $Al^{27}(p,\alpha_0)$ Mg^{24}, and $Al^{27}(p,\alpha_1)Mg^{24*}$ at $\theta_{lab}=45°$ as a function of proton energy.

is observed (Fig. 1) and the expression used by Hunting and Wall makes this disagreement worse. That a smaller radius is required to fit $Al(p,\alpha)$ data than $Al(\alpha,p)$ data probably reflects the extent of the incoming particle.

The sharp energy dependence observed for these $Al(p,\alpha)$ differential cross sections was not expected. Two lines of discussion, however, may be advanced to account for these observations:

(1) Direct-interaction theories,[4] calculated by using plane waves, predict a very slow variation with energy. Cross-section expressions derived for (p,p') reactions by Levinson and Banerjee[5] using distorted wave functions are too complex to permit an easy calculation, but single-particle resonances would probably have widths of the order of 1 Mev.[6] Thus, a distorted-wave calculation for $Al(p,\alpha)$ reactions would probably also not yield as sharp an energy dependence as was observed. However, Owen and Madansky[7] obtained a good theoretical fit to their $B^{11}(d,n)C^{12}$ angular distributions, which display a large energy dependence, by including heavy-particle or exchange stripping in a Born approximation calculation. An analogous approach may yield agreement with these $Al(p,\alpha)$ data.

(2) Compound-nucleus processes might be expected to yield a sharp energy dependence if either the continuum or statistical assumptions about the compound nucleus were violated. However, in this case, the continuum assumption is probably valid, since the compound nucleus, Si^{28}, would have up to 22.7 Mev of excitation. Certainly, the mean level spacing[8] is much less than the beam energy spread. If the statistical assumption is not satisfied (e.g., the decay-channel reduced-width amplitudes are correlated), then an energy dependence might be expected from either purely compound-nucleus processes or interference between compound-nucleus and direct-interaction processes.[9] The failure of the statistical assumption has also been suggested by Eisberg and Hintz[10] as a possible explanation of their $A^{40}(p,p')A^{40*}$ angular distributions.

To summarize: the partial fit of the $Al^{27}(p,\alpha_0)Mg^{24}$ data by a curve of the general form $|j_2(Qr)|^2$ suggests that direct-interaction processes play a substantial role in determining the differential cross section. Thus, either interference between various direct-interaction processes or between direct-interaction and compound-nucleus processes, implying a failure of the statistical assumption, or both, are responsible for the sharp energy dependence. Experiments of high resolution are in progress.

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Hyperfine Structure Measurements on Neptunium-239†

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THE atomic-beam magnetic-resonance method has been used to investigate 2.36-day Np^{239} in the low-field or Zeeman region of hyperfine structure. The spin of this nuclide is found to be 5/2 in agreement with the conclusions of Hollander, Smith, and Mihelich from beta- and gamma-spectroscopy[1] and with the predictions of the Bohr-Mottelson model, but apparently in conflict with measurements by the methods of optical[2] and paramagnetic-resonance[3] spectroscopy. The principal observations have been made in a low-lying electronic state with measured $J=11/2$, $g_J=0.6551 \pm 0.0006$, which is probably the ground state of the electronic configuration $(5f)^4(6d)^1(7s)^2$.