Lett. 30A, 322 (1969); T. H. DiStefano, thesis, Stanford University, 1970 (unpublished)]. In all cases the width of the EDC's from the valence bands of these materials were much larger than the O^{--} widths found here for $L<10$ L, whereas, the widths for 20 and 40 L were consistent with the widths found in the alkali halides.

[9]An alternate model might involve the formation of islands of SrO on the Sr surface similar to the formation of AgS on Ag, described by H. E. Bennett, R. L. Peck, D. K. Burge, and J. M. Bennett, J. Appl. Phys. 40, 3351 (1969). Since in this case the islands are made up entirely of the compound, one would expect little dependence of the EDC width on concentration, in contradiction to experiment. It should also be noted that AgS is quite covalent and Bennett *et al.* attribute the formation of AgS islands to the small attractive forces between the AgS covalent molecule and free Ag. The situation will be very different for SrO because of the ionic nature of the molecule. Here the O^{--} ion will seek as many Sr neighbors as possible, since the Coulombic repulsive forces between two neighboring O^{--} ions would be quite large. Since a Sr film will oxidize quickly and to completion at room temperature, it is clear that diffusion of the oxide through the film takes place rapidly, which is not the case for AgS on Ag. Certainly the getter action of Sr argues strongly against an SrO island-formation model. Thus it appears that such a model can be rejected.

[10]Bennett, Peck, Burge, and Bennett, Ref. 9.

[11]If the oxidation rates are large enough and the diffusion coefficient into the bulk small enough, the surface can saturate with O^{--}. In the present experiments the maximum rates were approximately 10^{-2} monolayer per second and the exposure times relatively short, so that appreciable saturation would not occur. The concept of a metal-rich surface would therefore only strictly be correct when the oxygen pressure is zero at the metal vacuum interface.

Energy Dependence of Quasifree Scattering in Deuteron Breakup under α-Particle Bombardment from 30 to 80 MeV

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α-particle–induced quasifree scattering in deuteron breakup exhibits no difference between kinematically equivalent α-p and α-n channels, in contrast to previously measured proton-induced breakup. This supports the hypothesis that spin and statistics play a dominant role in deuteron breakup reactions and that previously postulated charge and final-state effects cannot explain the proton data.

Recently a large and as yet unexplained difference in the quasifree scattering (QFS) cross section for the two kinematically equivalent modes of deuteron breakup under proton bombardment has been observed.[1] The ratio of the two cross sections is strongly energy dependent, being as large as 5 around 20 MeV. In a simple impulse approximation (SIA) calculation the only difference between the $D(p,pp)n$ and $D(p,pn)p$ QFS is in the free (p,p) and (p,n) scattering cross section. This difference in free scattering cross sections is, however, much too small to explain the observed ratio. The measured peak cross sections can be explained by a modified impulse approximation with energy-dependent cutoff radii that are different for the two breakup channels.[2] However, even the introduction of cutoff radii will not explain the observed angular variation.[3] Final-state interaction (FSI) as well as Coulomb effects have been postulated as possible causes for the observed large difference in cross section for the two deuteron breakup channels. It has been shown[3] that FSI effects alone cannot, in any simple manner, explain the angular variation. Bassel and Langworthy[4] have developed a semiphenomenological theory, based on distorted wave methods, which treats the spin of the three-body system exactly. Since one of the QFS channels has two identical particles (protons) interacting, spin and statistics considerations break the SIA amplitude into several terms which are different for the (p,p) or (p,n) QFS, thus predicting a branching difference. A branching difference is predicted only for the case in which there are two identical particles in the exit channel. Similar conclusions regarding the importance of the Pauli exclusion principle in deuteron breakup have been reached by Cahill.[5] His approach is based on the Amado[6] model, ignoring Coulomb effects. No complete calculations of the Coulomb effects over the entire range of bombarding energies exist, even though some D(p, *pp*)*n* data at 38–50 MeV[7] has been fitted by Oryu[8] in the framework of the Amado model. If charge effects play an important role in the proton-induced QFS, they should be present in all charged-particle QFS reactions. By using the spinless α particle for the bombarding particle, we hope to isolate spin statistics from Coulomb effects.

In order to minimize effects of fluctuations of beam current and target deterioration, we measured the reactions D(α, αp)n and D(α, αn)p simultaneously over an incident α-particle energy of 30 to 80 MeV. The proton and neutron detectors were outside an ORTEC 30-in. scattering chamber at the 45° beam ports on opposite sides of the beam. The α-particle detectors were solid-state detectors mounted inside the chamber on two independently rotating tables and were positioned to give a minimum spectator energy for each bombarding energy. The target was a deuterated polyethylene foil. Neutron energy was measured by standard time-of-flight techniques; neutron efficiencies were calculated with the Kurz code.[9] Coincidences between the α-particle detector on one side of the beam and the corresponding proton (or neutron) detector on the opposite side of the beam were recorded and analyzed with an EMR 6050 on-line computer. The neutron cross section was corrected for in-scattering from the walls of the chamber.

The results are shown in Fig. 1. In Fig. 1(a) we show the measured cross sections for the two α-particle–induced breakup channels. For clarity of presentation some error bars have been omitted. All error bars represent statistical errors only. The absolute cross section is estimated to be accurate to ± 20%. Two separate runs were taken on the proton data and are shown as closed and open circles. The two proton runs are separately normalized and show the reproducibility of the data. Only the open circles have a corresponding neutron point.

The reaction D(α, αp)n has also been studied by Assimakopoulos[10] but his interest was only in FSI. Bonbright[11] has studied the QFS extensively at 78 MeV. His peak cross section agrees with ours taken at similar angles. Warner and Bercaw[12] have been investigating the reaction at 42 MeV. They are mostly interested in FSI, but their one measurement that comes closest to our data shows a peak cross section of the same magnitude as ours. However, Tanabe's[13] result at 29.2 MeV is twice as large as ours.

In Fig. 1(b) we plot the ratio of the two α-particle–induced cross sections as a function of incident α-particle energy. The center-of-mass energy (7–20 MeV) for the scattered nucleon covers a range of center-of-mass energies also studied in the proton-induced QFS. For the α-particle-induced QFS, the ratio of the two cross sections is close to 1, and within the errors of measurement does not change over the entire energy range. This is in marked contrast to the proton-induced reaction where deviations as large as a factor of 5 are seen after correcting for differences in the free (p,p) and (p,n) scattering cross sections. Since the free (α,p) and (α,n) cross sections are very similar over the energy range studied,[14] no correction has been applied in calculating the ratio. We see FSI peaks (e.g., ^{5}He and ^{5}Li) whose separation from the QFS peak is different for the two α-particle–induced cases. While the separation of QFS and FSI peaks changes with incident energy, they are well separated

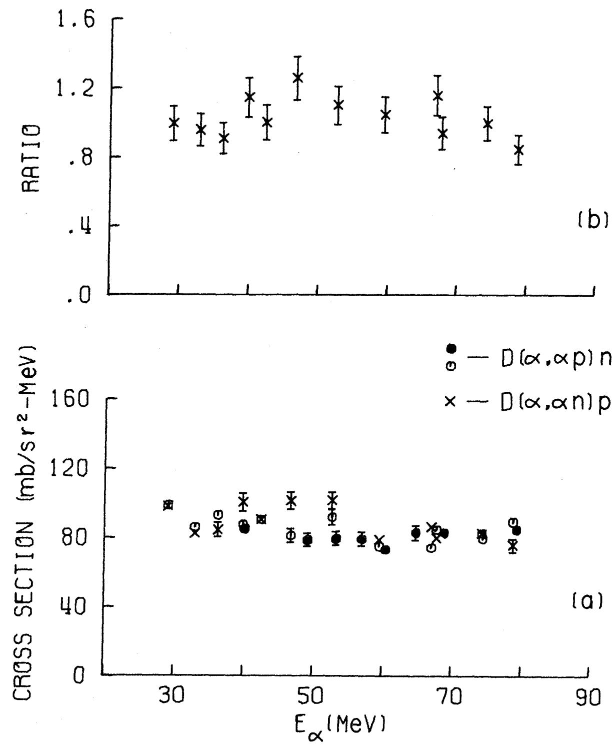

FIG. 1. (a) The peak cross section for the reactions D(α,αp)n and D(α,αn)p. Open and closed circles are for two independent runs for the reaction D(α,αp)n. The proton and neutron detectors were fixed at 45° on opposite sides of the beam; however, the α-particle detectors were rotated between 9.8° and 12.8° to give a minimum spectator energy at each bombarding energy. (b) The ratio of the peak cross sections for reactions D(α,αn)p and D(α,αp)n as a function of incident α-particle energy.

in all cases. As no branching difference is seen for the α-particle–induced QFS, it appears that the FSI does not substantially affect the well-separated QFS peaks. The size and separation of the FSI peaks seen in this experiment are similar to those in the proton-induced case. The absence of a branching difference in the α-particle–induced QFS makes less likely the postulate[15] that the tails of FSI peaks contribute markedly to the proton-induced branching difference.

The study of the QFS reactions $D(\alpha, \alpha n)p$ and $D(\alpha, \alpha p)n$ over an incident α-particle energy of 30–80 MeV shows no difference in cross section, thus indicating that spin statistics play a dominant role in the deuteron breakup reactions, and that charge and FSI effects are unimportant when the QFE conditions are satisfied.

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$E1$ Decay of Members of the Low-Lying $K^\pi = \frac{1}{2}^-$ Band in ^{23}Na†

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A state at $E_x = 6.350$ MeV in ^{23}Na is shown to have $J^\pi = \frac{9}{2}^-$ and is assigned to the rotational band based on the $\frac{1}{2}^-$ state at 2.640 MeV. Its γ-ray decay lifetime and branching ratios are determined and combined with known information about the proposed $J = \frac{1}{2}$ to $\frac{7}{2}$ members of this band to show that there is an anomalous $E1$ decay pattern between the members of this band and the members of the ground-state band. This anomalous pattern can be explained using the Nilsson model with band mixing.

It is well known that heavy-ion reactions are particularly favorable for the study of high-spin states.[1,2] Recent studies at McMaster using the reaction $^{12}C(^{12}C, p)^{23}Na$ ($Q = +2.24$ MeV) have shown that known high-spin states in ^{23}Na are preferentially populated. In particular, the $\frac{7}{2}^+$, $\frac{9}{2}^+$, $\frac{11}{2}^+$, and $\frac{13}{2}^+$ members of the ground-state rotational band are strongly excited. In addition, a number of other states, of unknown spin, are also strongly populated in this reaction. One such state is that at $E_x = 6.350$ MeV. This Letter reports angular correlation and lifetime measurements for this state which lead to a $J^\pi = \frac{9}{2}^-$ assignment and to the suggestion that this level is the fifth level belonging to a $K^\pi = \frac{1}{2}^-$ rotational band.

A target consisting of 80 $\mu g/cm^2$ of ^{12}C evaporated onto a thick gold backing was bombarded using a 28.2-MeV ^{12}C beam from the McMaster FN tandem accelerator. Protons were detected using an annular surface-barrier detector centered at 180° with respect to the beam direction and