romagnetic lattice. Thus the present model favors ferromagnetism when the density of Zener electrons is low. If the density of Zener electrons increases and both the lower and upper subbands are filled, that is, the case of one electron per atom, the energy difference between the ferromagnetic and nonmagnetic lattices disappears. Then a simple extension of our previous calculation[2] will lead to the conclusion that an antiferromagnetic sublattice structure yields a lower energy, illustrating the intricate dependence of magnetic ordering in the present model on the density of electrons.

The present model suggests that Hund's-rule coupling, rather than the Hartree-Fock field, is the key mechanism for the spin-polarized splitting of bands responsible for ferromagnetism in transition metals. The Hartree-Fock splitting assumed in the band theory of ferromagnetism is believed to be suppressed when the Wigner-type correlations are included, while the present mechanism is exact in the atomic limit.

Ferromagnetic materials such as Fe and Co have more than one $3d$ hole per atom and the Hund's-rule coupling must play an important role in the magnetic properties as discussed here. It is widely speculated[4] that $3d^8$ configurations in Ni are of crucial importance for its stability, suggesting that the present theory is also applicable to the ferromagnetism of Ni.

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Prominent Two-Body Effects in the Processes $p(^3\mathrm{He}, pd)p$ and $d(d, pd)n$

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A coincidence study of three-body breakup of the $^3\mathrm{He}+p$ and the $d+d$ system has been made with the multidetector system BOL at 69-MeV $^3\mathrm{He}$ energy and 26-MeV deuteron energy. Strong contributions from quasi two-body reactions (final-state interaction and quasifree scattering) are found. The Watson-Migdal theory and the plane-wave impulse approximation model do not consistently explain the data. The discrepancies are particularly striking where different two-body mechanisms overlap.

The crucial feature of multiparticle nuclear reactions is the complicated dependence of the differential cross section on several kinematic variables, a major challenge to contemporary experimental techniques. In single-counter experiments, the cross section is implicitly integrated over a large part of the available phase space. Often this integration masks even prominent characteristics of the contributing reaction mechanisms. In more time-consuming, kinematically complete coincidence measurements, different processes can be optimally identified though they usually cover only a small region of the total phase space. The multidetector system BOL[1] allows one to investigate a large part of phase space, yet in a kinematically complete way. Thus an overall view of the reaction is obtained and, in addition, any desired detail can be investigated. Normal and deuterated polyethylene targets ($\simeq 2$ mg/cm^2) were bombarded by 69-MeV ^{3}He particles and 26-

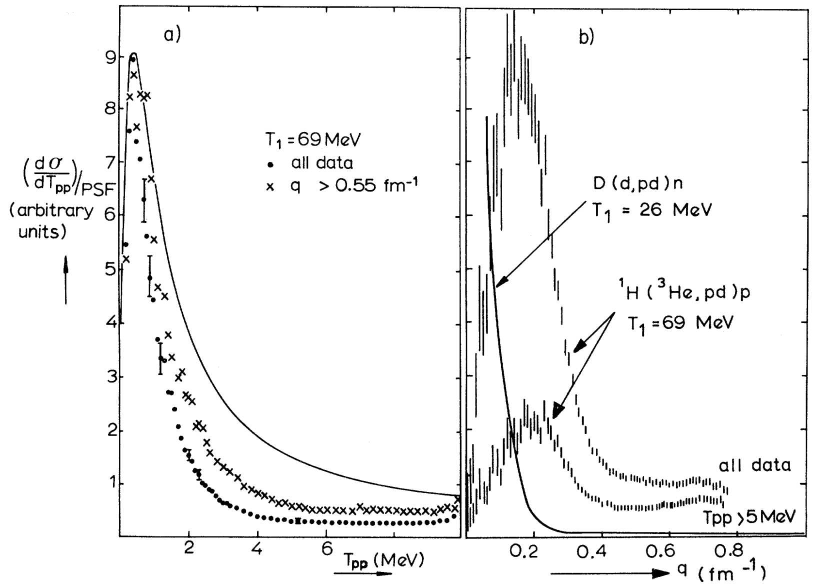

FIG. 1. Differential cross sections relative to phase-space predictions for (a) $p(^3\text{He}, pd)p$ as a function of the relative proton-proton energy T_{pp} and for (b) $d(d,pd)n$ and $p(^3\text{He},pd)p$ as a function of the momentum transfer q. Combined errors due to statistics in experiment and in the Monte Carlo simulation method are shown. The solid line in (a) represents a fit according to the Watson-Migdal theory with parameters according to free p-p scattering.

MeV deuterons, accelerated in the IKO synchrocyclotron. For each experiment a total number of 10^7 coincident events was recorded on magnetic tape. The detection-sensitive surface around the target covered $\simeq 10\%$ of 4π, while the angular resolution was $1°$ in polar angle and $1°-3°$ in azimuthal angle. Events from the reactions $^3\text{He}+p \rightarrow p+p+d$ and $d+d \rightarrow p+d+n$ were selected using particle-identification methods and kinematic criteria.[2] The overall characteristics of the reaction processes were investigated in terms of kinematic invariants (generalized Dalitz plots[3]). Furthermore, at specific angles, the energy correlation spectra were studied. The data were corrected for detection efficiency and divided by the phase-space distribution using a Monte Carlo simulation method.[2]

Both processes, $d(d,pd)n$ and $p(^3\text{He},pd)p$, are predominantly coplanar, indicating that the reactions proceed preferentially as quasi two-body reactions. Quantitatively, within $\pm 5°$ from the reaction plane, $d(d,pd)n$ events are enhanced 3.3 times with respect to the phase-space prediction, and $p(^3\text{He},pd)p$ events 2.5 times.

The $p(^3\text{He},pd)p$ process is dominated by the p-p final-state interaction (FSI).[4] Figure 1(a) shows integrated data as a function of the p-p relative energy T_{pp}. The sharp enhancement at $T_{pp} = 0.4$ MeV is due to the singlet p-p FSI. The Watson-Migdal (WM) theory[5] only fits the experimental data for relative energies below 1 MeV, but predicts an appreciably broader peak. Removing the events near the p-d quasifree scattering (QFS) condition leaves a smaller though still significant discrepancy. In our data on the same reaction but with two protons detected, both p-p and p-d QFS are relatively far removed from the kinematic region satisfying the p-p FSI condition. Although the WM model gives a better fit for these data than for those with a proton and a deuteron detected, still no satisfactory agreement is obtained. Strong contributions from the p-p FSI are also observed in the $p(^3\text{He},pd)p$ energy correlation spectra at various angles. For some spectra where both the momentum transfer q between the two protons is quite large and T_{pp} is small, the WM model gives a reasonable fit.[4] The p-p FSI enhancement, however, becomes quite narrow when kinematic conditions for FSI and QFS come close [Fig. 2(a)]. Neither the WM model nor the plane-wave impulse approximation (PWIA) model, modified by a multiplicative FSI enhancement factor, explains these data for any reasonable ^{3}He wave function.

Figure 1(b) shows integrated data as a function of q for both $d(d,pd)n$ and $p(^3\text{He},pd)p$. The enhancement near $q=0$ for the $d(d,pd)n$ data is due to p-d QFS leaving the target neutron as a spectator. A similar result is obtained for momentum transfer to the projectile neutron. The $p(^3\text{He},pd)p$

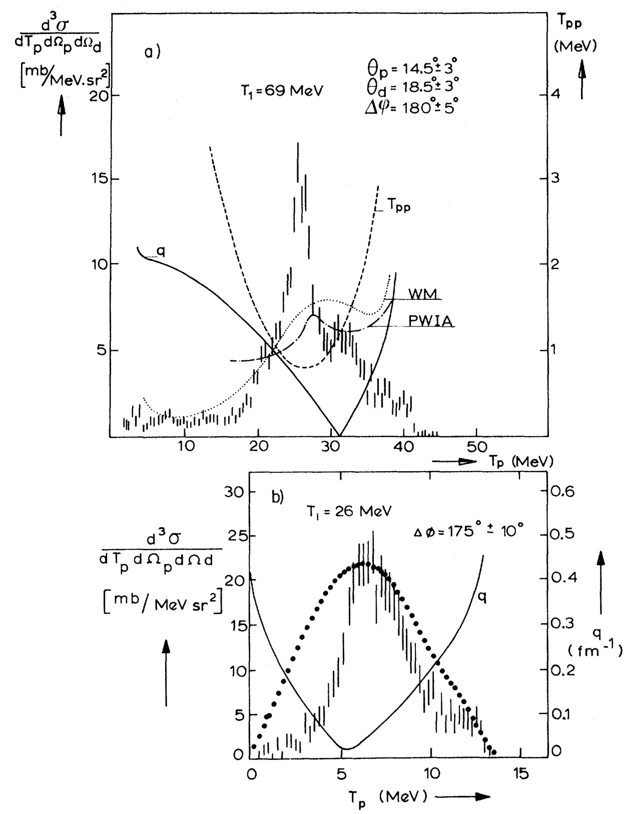

FIG. 2. (a) Proton-energy spectrum for $p(^3\mathrm{He},pd)p$ displaying both p-p FSI and p-d QFS. (b) Proton-energy spectrum for $d(d,pd)n$ at $\theta_p = 47.4°$ and $\theta_d = 16.5°$, showing QFS. Dots represent the PWIA prediction normalized to the data using a factor 0.57.

data, on the contrary, do not show an enhancement at $q = 0$ but at $q \simeq 0.15$ fm^{-1}. This indicates that in this reaction the primary mechanism is not simply p-d QFS.[6] If one selects data with T_{pp} larger than 5 MeV, still no clear contribution of p-d QFS at $q = 0$ is observed [Fig. 1(b)].

For the reaction $d(d,pd)n$, the Dalitz plots demonstrate that here nucleon-deuteron QFS[7] is the predominant process. The same trend is seen in the energy correlation spectra at specific angles. Figure 2(b) represents a typical kinematically complete proton energy spectrum. The PWIA predicts too broad a peak, and the calculated absolute magnitude of the cross section is about a factor 2 too high. These discrepancies are well-known deficiencies of the PWIA model.[8] For other pairs of angles near quasifree conditions the ratio $\sigma_{\mathrm{expt}}/\sigma_{\mathrm{PWIA}}$ varies from 0.1 to 0.6. Nucleon-nucleon QFS in the $p+d$ system has been explained rather successfully by introduction of a cutoff radius R_0 in the wave function.[9] For the $d(d,pd)n$ data we could not find a consistent value of R_0 for which both the absolute magnitude and the shape of the peak are explained by this model. In order to find agreement between the calculated- and measured-peak cross section, R_0 had to be varied from 4.5 to 11 fm depending on the angles chosen. Contrary to the University of California at Los Angeles–University of Southern California results on p-d QFS in $^3\mathrm{He}(p,pd)p$, the QFS peak position in our $d(d,pd)n$ data is predicted correctly by the PWIA model. Small enhancements are observed in regions of low p-n energy, with peak shapes that cannot be reconciled with an isospin-allowed p-n triplet FSI only.[2] This result is in agreement with measurements from Rice.[10] We are inclined to believe that the enhancement is mainly due to the primary reaction mechanism rather than to singlet n-p FSI.

The comparison between $d(d,pd)n$ and $p(^3\mathrm{He},pd)p$ data points to important coherent effects in the region where QFS and FSI might compete. The nucleon-nucleon FSI is very important in the reaction $p(^3\mathrm{He},pd)p$. It is not in the reaction $d(d,pd)n$ because of isospin conservation. No effects could be attributed to the nucleon-deuteron FSI.

A successful model of the $^3\mathrm{He}+p$ three-body breakup reaction should consistently explain single-counter deuteron spectra (PWBA with and without cutoff predicts too broad spectra) and coincidence spectra, also in the regions where $T_{pp} > 6$ MeV and q is low (QFS enhancements shifted[6]), and where $T_{pp} \simeq 0.5$ MeV and $Q \simeq 0.1$ fm^{-1} bands cross each other (very narrow enhancements).

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Precise Coulomb Excitation $B(E2)$ Values for First 2^+ States of the Actinide Nuclei*

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Precise transition probabilities have been measured for the first 2^+ states of ^{230,232}Th, ^{234,236,238}U, ^{238,240,242,244}Pu, ^{244,246,248}Cm, and ^{252}Cf by Coulomb excitation with 17- and 18-MeV α particles. Comparison is made with theoretical values. An excitation energy of 44.0 ± 0.5 keV was measured for the first excited level of ^{252}Cf.

Theoretical predictions of the existence of superheavy nuclei are based on the calculated properties of heavy nuclei, as functions of the deformation, and the location of single-particle orbitals within deformed potentials.[1-4] The transuranic nuclei furnish a testing ground for these theories where calculated transition rates and moments may be compared with experiment. Precise measurements of the $E2$ transition probabilities for the first 2^+ states in actinide nuclei are presented here for comparison with theoretical values.

Measurement of $B(E2)$ values in this mass region is difficult because of the large internal conversion coefficients and the hazardous nature of the target material. However, extremely accurate measurements are made possible by observation of the inelastically scattered particles, which requires only a small amount of material and no knowledge of the conversion coefficients. Many of the present $B(E2)$ values had not been previously determined or were known only indirectly from lifetime measurements.

α particles were accelerated to 17 and 18 MeV in the Oak Ridge National Laboratory tandem Van de Graaff. The inelastically scattered α particles were detected at the focal plane of an Enge split-pole spectrograph[5] by a 20-cm-long position-sensitive proportional counter. This is a single-wire detector,[6,7] of the type designed by Borkowski and Kopp, in which the central anode is an 8000-Ω/mm quartz fiber with pyrolytic carbon coating. Details of the construction of the present detector and its application with this spectrograph have been presented.[8]

Isotopically pure targets were prepared using a 150-cm-radius isotope separator.[9] The material was implanted into thin Ni backings at an incident ion energy of 4 keV to yield a target spot 0.06 cm wide and 1 cm high. Such targets were typically 20 μg/cm^2 thick containing a total of about 1 μg of material, and had a width ideally suited to optimize the resolution of the spectrograph.

Figure 1 shows the spectra for 17-MeV α particles scattered from ^{246}Cm at a laboratory angle of 150°. The ground state and excited 2^+ and 4^+ states at 43 and 142 keV, respectively, are seen. The energy resolution is about 14 keV. Determining the total number of counts in each peak yields the 0^+ to 2^+ transition probability as $B(E2) = (15.03 \pm 0.45)e^2$ b^2. The major sources of error are the estimation of the elastic tail under the peak for the 2^+ state, despite the good peak-to-valley ratio, and the uncertainty in the incident beam energy which is estimated to be 50 keV.