ratio τ prevents the formation of a nonequilibrium state.

This model is an inverse of the fission process. τ is the most critical parameter for reaching superheavy elements by an inverse fission process.

Obviously, for the O^{16}-O^{16} case our model is only a rough approximation. For heavier elements and higher bombarding energies the model should become better. The following general conclusions of this model hold for all heavy ion reactions: (i) The attractive part of the real potential is shallow. At higher bombarding energies its depth should increase somewhat because of larger penetration. (ii) The depth of the imaginary potential is also shallow, and (iii) the strength of the repulsive core is of the order of 100 MeV.

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*National Science Foundation trainee.

†Supported in part from private means.

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PROTON-POLARIZATION MEASUREMENTS AND DISTORTED-WAVE CALCULATIONS FOR $^{52}Cr(d,p)^{53}Cr$ AT 11 MeV

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(Received 1 April 1969)

The proton polarization and the vector analyzing power for the reaction $^{52}Cr(d,p)^{53}Cr$(g.s.) were measured. From an analysis of the $^{52}Cr(d,d)^{52}Cr$ and $^{53}Cr(p,p)^{53}Cr$ elastic scattering cross sections and polarizations, potentials were obtained which, when used in a distorted-wave Born-approximation calculation, provided a good fit to the proton polarization and the deuteron analyzing power.

Stripping and pickup reactions have for some time been important tools in nuclear spectroscopy. In deuteron stripping reactions, $A(d,p)B$, a neutron is transferred from the incoming deuteron to the target nucleus A to form the final nucleus B in the ground state or in one of its excited states. The angular distribution of the outgoing protons depends primarily upon the orbital angular momentum l of the captured neutron.[1] The value of l is generally determined by a comparison between the angular distribution of the outgoing protons and cross sections calculated from distorted-wave Born approximation (DWBA). The DWBA has been very successful in reproducing the cross-section angular distributions at forward angles.

Polarization measurements in stripping reactions have long been of interest, not only as a further test of the DWBA theory, but also because such measurements may allow one to determine the total angular momentum of the captured neutron, $j_n = l \pm \frac{1}{2}$. The polarization P_p^{γ} of the outgoing protons from stripping reactions has been measured in several cases.[2] A problem of long standing in stripping theory is that DWBA calculations have not been able to reproduce these measurements. Recently, measurements have also been made of the vector analyzing power[3] P_d^{γ} for stripping reactions, i.e., of the asymmetry of outgoing protons when the reaction $A(d,p)B$ is initiated with vector-polarized deuterons. Surprisingly, it was found that these measurements are well reproduced by DWBA calculations.[4]

There are several possible explanations for the failure of the proton polarization calculations. First, extensive measurements of the proton polarization in stripping reactions have been made primarily for light target nuclei so that the discrepancies might be caused by the presence of compound-nuclear resonances. Measurements for heavier elements are generally of much poorer accuracy and often observations extend only over a few forward angles[5] because double-scattering experiments are very difficult to perform. Second, the proton polarization may be particularly sensitive to the optical-model parameters used in the DWBA calculations and the parameters may not be well known enough to obtain correct predictions. Finally, it is possible that the distorted-wave method is intrinsically inadequate to describe the reaction mechanism[6,7] or that one or more of the approximations commonly made to facilitate calculations[8,9] (such as neglect of the deuteron D state, deuteron-tensor interaction, and coupling to other channels) is responsible for the disagreement.

The present experiment was undertaken to measure the proton polarization over a wide range of angles. A double-scattering experiment can be avoided by initiating the inverse reaction with polarized protons from an accelerator and by measuring the asymmetry of the outgoing deuterons. This asymmetry is equal to the proton polarization following the (d,p) reaction.[10] Also, the experiment was intended to obtain information on the optical-model parameters by measuring the elastic scattering cross section and polarization for the deuterons in the entrance channel and the protons in the exit channel. The reaction studied was ^{52}Cr$(d,p)^{53}$Cr ($l_n = 1$, $j_n = \frac{3}{2}$), leading to the ground state of ^{53}Cr.

The polarized deuteron beam from the Wisconsin tandem accelerator was used to measure the analyzing power P_d^S for 11-MeV deuteron elastic scattering from ^{52}Cr and to measure the analyzing power P_d^{γ} for the (d,p) reaction to the ground state of ^{53}Cr. These results and the elastic scattering cross section of Andrews et al.[11] are shown in panels (a), (c), and (e) of Fig. 1. The polarized proton beam from the Saclay variable-energy cyclotron was used to measure the cross section and analyzing power P_p^S for 16.6-MeV proton elastic scattering from ^{53}Cr and to measure the analyzing power P_p^{γ} for the (p,d) reaction to the ground state of ^{52}Cr. The proton energy was chosen so that the center-of-mass energy is the same for the (p,d) and (d,p) experiments. These results are shown in panels (b), (d), and (f) of Fig. 1. Panel (g) of Fig. 1 shows the cross section of Alty et al. for the reaction ^{52}Cr$(d,p)^{53}$Cr.[12]

Optical-model parameters for the DWBA calculations were obtained by analyzing the elastic scattering data.[13] As is well known, the optical-model parameters describing the elastic processes are not unique. For this reason several parameter sets for both the entrance and exit channels were tried in the DWBA calculations.[14]

One combination of parameters (see Table I) was found which gave a considerably better fit to

Table I. Optical-model parameters used in the calculations. (The notation is the same as in Ref. 4.)

Particle	V (MeV)	r_0 (fm)	a (fm)	W_s (MeV)	W_d (MeV)	r_0' (fm)	a' (fm)	V_s (MeV)	r_0'' (fm)	a'' (fm)	r_c (fm)
d	79.2	1.3	0.674	11.22		1.642	0.62	5.37	0.9	0.6	1.25
p	58.1	1.1	0.75		8.51	1.35	0.55	6.2	0.96	0.55	1.25
n	48.2[a]	1.3	0.7								

[a]Adjusted by program to give the correct neutron binding energy. The neutron potential contains a spin-orbit coupling $\lambda_{\mathrm{s.o.}} = 25$.

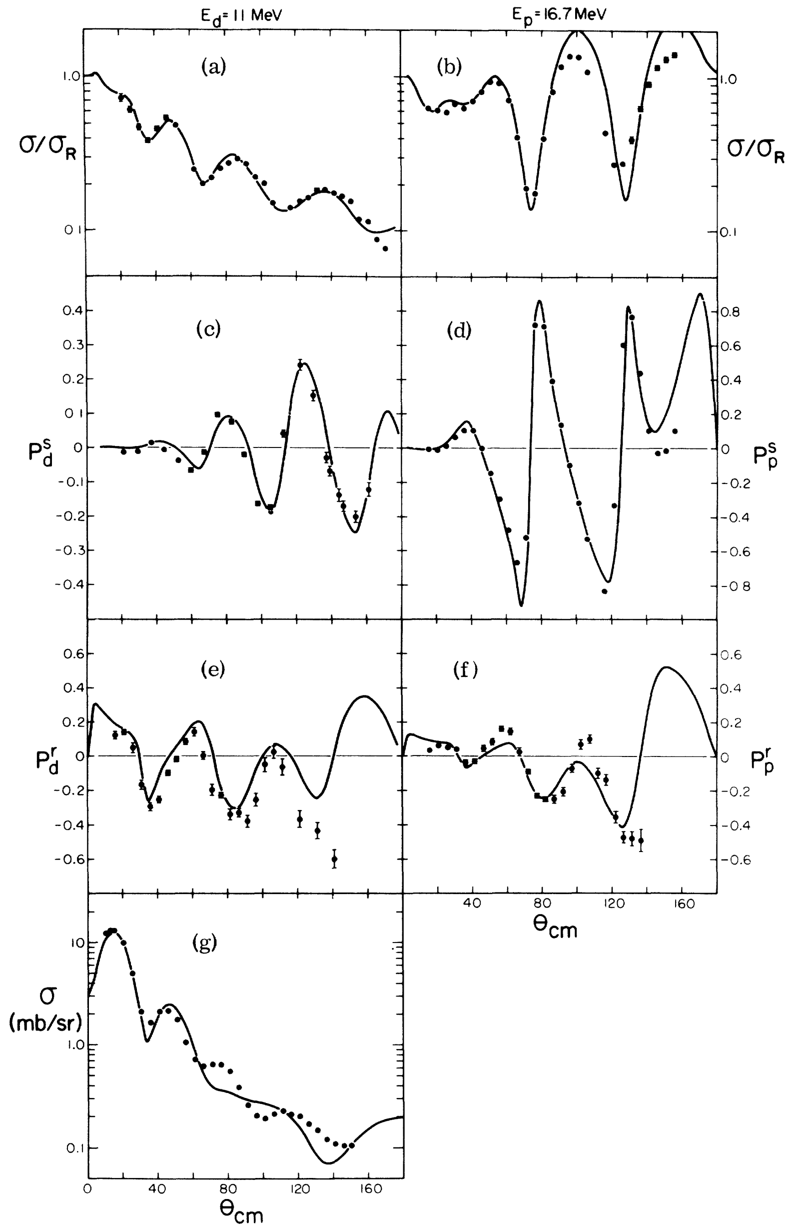

FIG. 1. Cross section and analyzing powers for $^{52}Cr(d,d)^{52}Cr$, $^{53}Cr(p,p)^{53}Cr$, $^{52}Cr(d,p)^{53}Cr_{g.s.}$, and $^{53}Cr(p,d)^{52}Cr$. On all panels of the figure, the solid lines are theoretical curves described in test. (a) Differential cross sections for $^{52}Cr(d,d)^{52}Cr$ at 11 MeV. The data are from Ref. 11. (b) Differential cross section for $^{53}Cr(p,p)^{53}Cr$ at 16.6 MeV. (c) Vector analyzing power for $^{52}Cr(d,d)^{52}Cr$ at 11 MeV. (d) Analyzing power for $^{53}Cr(p,p)^{53}Cr$ at 16.6 MeV. (e) Vector analyzing power of $^{52}Cr(d,p)^{53}Cr$ at 11 MeV. (f) Analyzing power of $^{53}Cr(p,d)^{52}Cr$ at 16.6 MeV. (g) Differential cross section of $^{52}Cr(d,p)^{53}Cr$. The data are from Ref. 12.

P_p^r than has been obtained in previous attempts to fit (d,p) polarization data. Curves calculated with these potentials are shown in Fig. 1. The most important feature of the potentials with respect to fitting P_p^r is the use of volume absorption in the deuteron channel. Calculations with surface absorption in the deuteron channel showed the correct number of oscillations for P_p^r but their magnitude was greatly reduced.

Although the present calculations give an acceptable fit to the $^{52}Cr(d,p)^{53}Cr$(ground-state) cross section [panel (g), Fig. 1], the oscillation near 80° is not well reproduced. Using the same potentials, the fit to the cross section for stripping to the first excited state of ^{53}Cr ($l=1$, $j=\frac{1}{2}$) is well reproduced, including the strong dip at 130°. Potentials using surface absorption in the deuteron channel improve the cross-section fit for the ground-state transition, but then the fit to P_p^r is quite poor.

This investigation has shown that it is possible to obtain potentials which describe at the same time the elastic scattering cross section and polarization as well as the reaction vector analyzing power and proton polarization. The reasons for the success of these particular optical-model potentials is not well understood. More work needs to be done to determine the relationship between the optical-model parameters and proton-polarization predictions.

The authors gratefully acknowledge the help of J. Escudie and J. Faivre in the ^{53}Cr(p,d)^{52}Cr experiment. We would also like to thank Dr. P. Kunz for supplying the computer program for the DWBA calculations.

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*Work supported in part by the U. S. Atomic Energy Commission.

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WHY DOES ^{56}Ni DECAY SO SLOWLY?*

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The decay of the doubly magic nucleus ^{56}Ni to the lowest 1^+ state of ^{56}Co proceeds about a hundred times slower than the shell model predicts. The explanation is that the lowest 1^+ state of ^{56}Co is mostly a two-particle, two-hole state. The giant spin-isospin resonance lies at a higher energy.

The ground state of the doubly magic nucleus ^{56}Ni decays by K capture to the lowest 1^+ state of ^{56}Co, which has an excitation energy of 1.72 MeV. The transition rate is characterized by a $\log_{10}ft$ which is[1] about 5 – not a usual value for an allowed Gamow-Teller transition.

We first point out that a shell-model calculation of this decay gives a unique answer provided the following assumptions are made: (a) ^{56}Ni is a doubly closed shell. (b) The lowest 1^+ state of ^{56}Co is a one-particle, one-hole (1p-1h) state.

The only 1p-1h state with spin 1 is $[f_{7/2}^{-1}(\pi)f_{5/2}(\nu)]$. This state can be called the giant spin-isospin state, since precisely this state results when one operates with the Gamow-Teller operator, $\sum_i \sigma_i t_{+i}$,