EFFECTIVE INTERACTIONS AND REACTION DYNAMICS*

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ABSTRACT

Consideration is given to the effects of strong coupling of the nucleon elastic-scattering channel with other reaction channels. Pickup channels are found to be much more important than inelastic couplings in a coupled-channels environment. For high energies, however, the conventional optical-model potential simulates the coupling effects rather well. At lower energies (\(E \lesssim 50\) MeV), coupled-channels effects can be quite significant and the problem is made worse by difficulties regarding the treatment of intermediate channels.

INTRODUCTION

The testing of theoretically constructed effective interactions in nuclear reactions, or their extraction from cross-section data, requires a knowledge of the reaction dynamics. Calculations of nuclear-reaction cross sections rely heavily on the nuclear optical-model description of elastic scattering for the wave functions in the incident and outgoing channels and the use of the distorted-wave Born approximation (DWBA). Although it is possible to construct optical potentials from the effective interactions themselves,\(^1,2\) phenomenological potentials still provide the best fits to the data. The effective interaction then enters the calculation of inelastic-scattering or charge-exchange reactions only in the construction of the form factor.

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Numerous developments in recent years, both experimental and theoretical, have clearly shown the need for higher-order mechanisms in the reaction dynamics. Two-step processes can contribute in significant ways to both the cross sections and the shapes of the angular distributions of states of interest. Furthermore, in the common approach of coupled reaction channels (CRC), the amplitudes resulting from the back couplings to the elastic channel may destroy the fit to the elastic-scattering data given by the phenomenological optical potentials. Compensations for this must then be devised. Even though these considerations may not have much influence on the interpretation of particular data, each needs to be examined before firm conclusions are reached.

I wish to focus some attention especially on the latter issue and to look at some of its consequences. Mention has already been made of recent $^{12}\text{C}(p,p')^{12}\text{C}$ data at 122 MeV and the general success of an analysis made in terms of a realistic effective interaction.\(^2\) Unfortunately $^{12}\text{C}$ is often considered to be a somewhat intractable nucleus for realistic studies, since its large deformation and strong coupling to the $2^+$ state at 4.44 MeV are difficult to handle in reaction calculations. Thus the reaction dynamics must be given special attention. We shall also examine some nucleon elastic-scattering data from the Mo isotopes, for which the Lane model provides a description of a macroscopic effective interaction.

**ELASTIC SCATTERING AND COUPLED CHANNELS**

Proton interactions with nuclei may lead to both $(p,p')$ and $(p,d)$ reactions and these often have comparable cross sections. Since couplings to collective excitations in $(p,p')$ reactions are known to affect the results of both elastic-scattering and reaction calculations, there is good reason to suppose that couplings to pickup channels could also produce significant effects. Indeed, phenomenological studies by Mackintosh\(^3\) have demonstrated some effects quite clearly. The analysis of Coulter and Satchler\(^4\) has elucidated many of the features of such couplings.

To be specific, we consider proton interactions with $^{12}\text{C}$. In second order DWBA, it is possible to compute cross sections in the elastic channel that result from the back-coupling amplitudes for various two-step paths. Such cross sections are shown in Fig. 1 for $(p,p',p)$ and $(p,d,p)$ two-step processes proceeding through, respectively, the first $2^+$ state of $^{12}\text{C}$ and the ground state of $^{11}\text{C}$. The $(p,p',p)$ cross section had to be multiplied by 100 for display purposes. Thus it is clear that the pickup-stripping process may be far more important than the inelastic couplings implying, perhaps, that $^{12}\text{C}$ is even more intractable than was pre-