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F. S. Dietrich and A. K. Kerman

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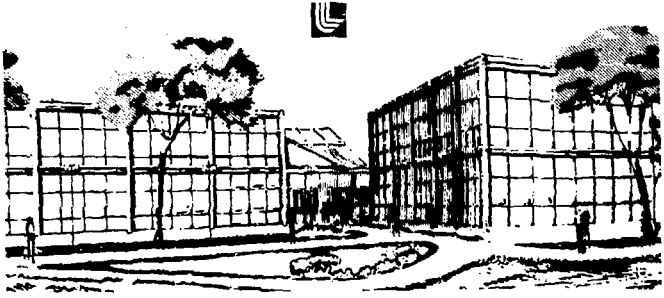

DIRECT-SEMIDIRECT AND PURE-RESONANCE MODEL CALCULATIONS OF FAST NEUTRON CAPTURE ON ^{208}Pb*

F. S. Dietrich, Lawrence Livermore Laboratory

A. K. Kerman, Massachusetts Institute of Technology

Abstract: Fast neutron capture on ^{208}Pb is calculated in a formalism in which only a giant-dipole resonance term appears explicitly. The calculations give reasonable fits to the data, and are much less sensitive to form-factor ambiguities than direct-semidirect calculations.

Attempts to calculate the magnitudes and excitation functions for fast-nucleon radiative capture in medium and heavy nuclei have almost exclusively employed the direct-semidirect (DSD) reaction model,[1] in which a slowly varying direct-capture amplitude interferes with a resonant term representing excitation of the giant-dipole resonance (GDR). This model has been fairly successful in explaining general features of experimental data. However, a difficulty with the model has been its sensitivity to assumptions about the nature of the form factor for coupling to the GDR. Sufficiently detailed information on the form factor is not available from other reactions, although the coupling is closely related to the isovector portion of the optical potential. Nevertheless, it has emerged that an adequate fit to the shapes of excitation functions requires an imaginary coupling term.[2] The strength of the imaginary coupling appears to be much larger than that found in typical optical potentials. Thus, the question naturally arises as to whether such a strong imaginary coupling represents an essential part of the reaction mechanism, or simply covers up a defect in the model.

We present here an alternative calculation of the same physical processes based on the Feshbach reaction formalism, in which the GDR is explicitly projected out of the continuum space. The assumption that the entire dipole strength of the target-plus-nucleon system resides in the GDR results in the absence of a nonresonant term, and we accordingly refer to this model as the pure-resonance model (PRM). The calculational techniques follow closely those developed for the analog-resonance problem.[3] For each incident channel, the reaction

amplitudes in the two models are

(DSD) $\langle u_b|r|\chi_i\rangle + M_\gamma\langle u_b|h'(r)|\chi_i\rangle/(E_\gamma - E_R + i\Gamma/2)$, and

(PRM) $M_\gamma[\langle u_b|h'(r)|\phi_i\rangle + \langle w_i|H(opt)|\phi_i\rangle c_i]/(E - E_R + i\Gamma/2)$.

The quantities that are identical in both techniques are the energy denominator which refers to the GDR of the target-plus-nucleon system; M_γ, the E1 decay amplitude of the GDR; u_b, the final bound wave function of the captured nucleon; and $h'(r)$, the coupling form factor. The spatially-localized particle wave function w_i of the GDR component in channel i (with amplitude proportional to c_i) is obtained by multiplying u_b by the dipole operator and projecting out occupied-state components. The c_i are obtained from the RPA version of the schematic model.[4] The continuum wave functions are solutions to $(E-H(opt))=0$ and $P(E-H(opt))P=0$ with appropriate boundary conditions, where the projection operator P which removes the GDR from the continuum space is $I-|w_i\rangle\langle w_i|$. The identity of the DSD and PRM resonance denominators results from considering the coupling interaction to all orders, rather than to first order, as has frequently been done in derivations of the DSD model. The only essential difference in the models is the treatment of the GDR component in the reaction channel, which in the PRM is determined from an explicit model calculation, but in the DSD model is obtained from an optical model which in practice has not been fitted to giant-resonance properties.

The calculations employ the Rosen optical parameters,[5] and a bound-state radius parameter 1.27 f with diffuseness 0.67 f. The real

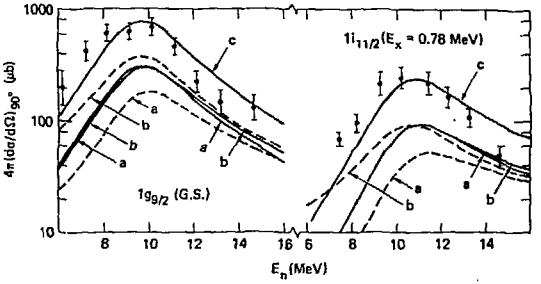

Fig. 1 Comparison of DSD and PRM calculations with data of ref. 6 for neutron capture to the ground and first excited states of ^{209}Pb. See text for significance of the curves.

and imaginary form factors were taken in a form very similar to ref. 2, with coupling strengths $V_1=W_1=96$ MeV. The normalizations of the form factors, M_γ, and the c_i assume exhaustion of the TRK sum rule with no exchange enhancement. In Fig. 1, the PRM calculations are shown with solid lines and the DSD with dashed lines. The curves (a) are for real coupling only in the form factor, whereas the imaginary coupling has been added in the curves (b). The PRM curves (c) are for real coupling as in (a), but with the structure coefficients c_i arbitrarily increased by 80%. The GDR parameters used in all the calculations are $E_R=13.43$ MeV and $\Gamma=4.07$ MeV.

Three principal features are evident in the comparison of the DSD and PRM calculations. The first is that with no imaginary coupling, the PRM calculations are much less asymmetric than the DSD. The second is that addition of an imaginary coupling has negligible effect on the PRM calculations, whereas in the DSD model the assymetry in the excitation functions may be varied rather arbitrarily by adjusting the relative strengths of the real and imaginary couplings. Finally, the magnitude but not the shape of the excitation function is sensitive to changes in the amplitudes c_i in the PRM calculations. All of these features are common to both transitions. With the exception of the curves (c), no adjustment of model parameters has been attempted; either model is capable of yielding the observed[6] peak magnitudes with plausible variation of the coupling strengths.

We conclude that the PRM model yields a reasonable description of the data, although the excitation functions are still somewhat more asymmetric than observed. Even though based on closely related assumptions, the PRM calculations are much less sensitive to poorly understood details of the coupling form factor than the DSD, and instead are more sensitive to the structure coefficients of the GDR, which may be obtained from model calculations. On the basis of these conclusions we feel that the explanation of the remaining asymmetry discrepancy is most likely to be found in an improved treatment of the neutron optical potential.

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