EXTENDED DIRECT-SEMIDIRECT MECHANISM AND THE ROLE OF MULTISTEP PROCESSES IN FAST-NUCLEON RADIATIVE CAPTURE

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Author(s):
F. S. Dietrich, Lawrence Livermore National Laboratory, Livermore, CA 94551 USA

M.B. Chadwick, T-2, MS-B283, Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545, USA

A. K. Kerman, Massachusetts Institute of Technology, Cambridge, MA 02139 USA

Submitted to:

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EXTENDED DIRECT-SEMI DIRECT MECHANISM AND THE
ROLE OF MULTISTEP PROCESSES IN FAST-NUCLEON
RADIATIVE CAPTURE

F. S. DIETRICH¹, M. B. CHADWICK², and A. K. KERMAN³

¹Lawrence Livermore National Laboratory, Livermore, CA USA
²Los Alamos National Laboratory, Los Alamos, NM USA
³Massachusetts Institute of Technology, Cambridge, MA USA

We have recently developed an extension of the direct-semidirect (DSD) radiative
capture model to unstable final states and have confirmed its utility in explaining the
spectrum of γ rays from capture of polarized 19.6-MeV protons on ⁸⁹Y [1]. It was found
that the extended DSD model, supplemented by a Hauser-Feshbach contribution, suc-
cessfully explains the observed γ spectra, angular distributions, and analyzing powers,
without requiring additional mechanisms, such as precompound or multistep emission,
or nucleon-nucleon bremsstrahlung. In this contribution we show that the model also
successfully explains data at higher energies (34 MeV incident protons), and that there
is no need for additional contributions other than Hauser-Feshbach at this energy as
well.

The extended DSD model treats capture to unbound final states and also to bound
single-particle states that damp into a compound system. An optical (complex) poten-
tial is used to describe the propagation of the captured particle. For capture to unbound
states, the cross section for inclusive γ emission is the sum of two terms, σ = σ₁ + σ₂.
σ₂ is the usual DSD cross section with the final-state bound wave function replaced
by a continuum (optical) wave function. The first term, which is dominant, describes
damping of the captured particle into the compound system:

σ₁ ∝ ∫ d²r W(r) |⟨r |Gⁿ(+)H₂|Ψ_{kin}ⁿ⟩|².

Schematically, the incident particle, after capture by the DSD mechanism via the op-
erator H₂, is propagated by the Green’s function Gⁿ(+) to the position r, where it is
absorbed by the final-state imaginary potential W. Details of this as well as the unsta-
ble bound final-state case may be found in [1].

Application of this model to the γ spectrum in the ⁸⁹Y(p,γ) reaction at 19.6 MeV,
reported in [1], is shown at the left in Fig. 1. We have performed new calculations
at higher energy (34 MeV protons), and have compared them with the spectra and angular distributions measured in [2] on targets of natural Cu, Ag, and Au. An example of the results, for the \( \gamma \) spectrum from Cu, is shown in the right-hand part of the figure. In both cases the DSD calculation is shown by a solid line, and a Hauser-Feshbach calculation by a dashed line. The 34-MeV calculations were very similar to those at 19.6 MeV as described in [1]. In both cases, the sum of DSD and Hauser-Feshbach calculations adequately describes the measured spectra. Although not shown, the angular distributions are also well described.

There are no significant deficiencies in the comparison with experiment that indicate a need for multistep processes or other additional reaction mechanisms. These results suggest that such processes, if present, are required only at significantly higher energies than reported here. This conclusion applies only to radiative capture of nucleons; precompound and multistep treatments are likely to be essential for gamma emission with complex projectiles and heavy ions, since a detailed quantum mechanical model is not currently practical and available.

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References


Figure 1: Measured and calculated \( \gamma \) spectra from radiative proton capture on \(^{89}\text{Y}\) at 19.6 MeV and Cu at 34 MeV; see text for details.