HYBRID-MODEL CALCULATIONS OF THE NUCLEON REMOVAL BY 80-164 MeV PROTONS FROM MEDIUM-MASS NUCLEI

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The experimental results of the nucleon removal by medium energy protons[1)] have been compared with those of the hybrid model[2)] in which the nucleon-nucleus interaction is visualized as proceeding through a pre-equilibrium phase followed by nuclear evaporation. In the first phase the initial few-quasi-particle (exciton) state evolves to more complex states through successive two-body residual interactions which increase the exciton number by two. The probability for pre-equilibrium emission of a neutron or proton is calculated at each step using the state densities and the relative rates of emission of particles into the continuum as compared to the rate of intra-nuclear transitions for the particles. The latter is deduced from the nuclear mean free paths which are calculated either from the imaginary part of the optical potential or from nucleon-nucleon scattering cross section corrected for effects of the Pauli principle. The evaporation process is governed by particle binding energies, the inverse reaction cross sections and the ratio of final-state level densities to the initial ones.

Initial comparisons of experimental results were with the commonly-used single pre-equilibrium emission version of the model[3)]. This model explains qualitative features of the production cross sections for 80 and even 100 MeV but fails at the higher energies. The most serious discrepancy of this model is that it overpredicts the average number of nucleons removed, <ΔA>, as shown in Figure 1 by the curve marked HYBRID.

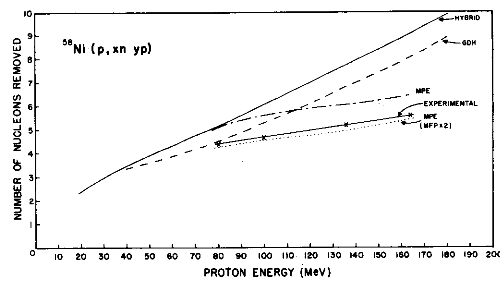

Figure 1.

The first refinement of the hybrid model considered was the geometry-dependent hybrid model (GDH)[3)]. Here the effect of the diffuse nuclear surface is taken into account by making the mean free path longer for higher (surface) partial waves as compared to the lower partial waves of the reaction cross section. Though this extension is justified by the well-established Wood-Saxon form of the nucleon-nucleus scattering potential and relatively stronger absorption of lower partial waves, the increase of <ΔA> with energy predicted by this model is still too steep. (See the curve labelled GDH in Figure 1).

The second refinement of the model allows multiple pre-equilibrium emission (MPE)[4], i.e. pre-equilibrium emission from nuclei with mass numbers A-1, A-2,... where A is the mass number of the target plus the incident proton. The evolution of the reaction is followed in a two-dimensional space of energy vs exciton number. As shown in Fig. 1 this model predicts the correct slope of <ΔA> with energy over the 80-164 MeV range with mean free paths calculated from nucleon-nucleon scattering. The predicted <ΔA> is one mass unit higher than the experimental values, precisely the amount that the GDH calculations differed from the simple hybrid model. The geometry dependence is not yet incorporated into the MPE code, but can be partially simulated by increasing the mean free path for all partial waves. An increase by a factor of two reproduces the energy dependence of <ΔA>, labelled in Fig. 1 by MPE (MFPx2).

In Figure 2, production cross sections predicted by the MPE (MFPx2) and simple hybrid models are compared with the ^{58}Ni + p(164 MeV) experimental cross sections for population of Co, Fe, Mn and Cr isotopes. A calculation embodying both the multiple pre-equilibrium emission and the geometry-dependent effects has a good chance of explaining the data in a quantitative manner.

We wish to thank Professor M. Blann and Dr. A. Mignerey for making their codes available and for discussing the results of the calculations with us.

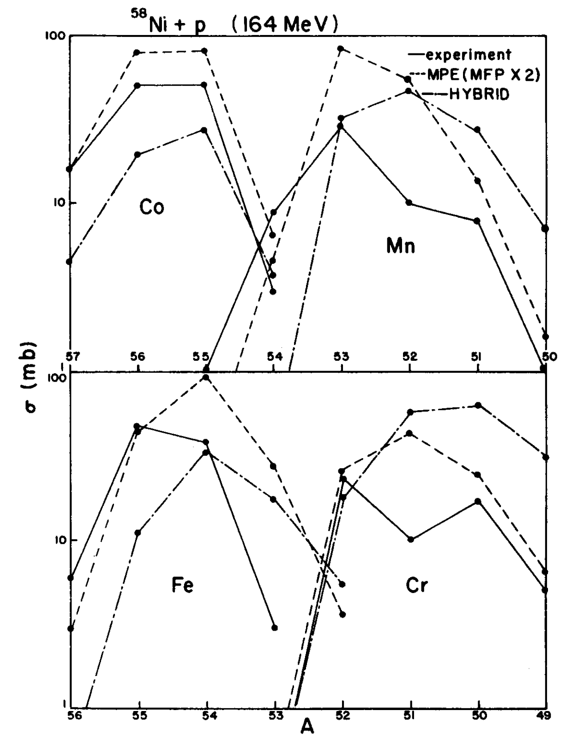

Figure 2.

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1) M. Sadler, J. Jastrzebski, A. Nadasen, P.P. Singh, L.L. Rutledge, T. Chen and R.E. Segel; Systematics in the Interaction of Intermediate Energy Protons with Medium Mass Nuclei, this Annual Report.

2) M. Blann, Ann. Rev. Nuc. Sci. 25 (1975) 123, Phys. Rev. Lett. 27 (1971) 337, 28 (1972) 757.

3) Computer code ALICE, obtained from M. Blann, Univ. of Rochester.

4) Computer code EVAHYB, obtained from M. Blann, Univ. of Rochester, and A. Mignerey, Argonne National Laboratory.