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SMD/SMC-MODEL FOR NUCLEAR DATA EVALUATION

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Abstract: Aconsistent full-scale description of neutron emission spectra including equilibrium, pre-equilibrium, direct processes as well as multiple particle emission is presented. Excitation of non-collective and collective modes are considered. Calculations are performed without any parameter fit.

(statistical multistep direct and compound reactions, nuclear data evaluation, double-differential neutron emission cross sections)

A simple reaction model for statistical multistep direct (SMD) and compound (SMC) processes was derived /1,2/ from Green's function formalism and random matrix physics. The SMD/SMC-model predicts neutron and proton (first-chance) emission spectra without any parameter fit as a sum of SMD and SMC cross sections. The latter results from

$$\frac{d\sigma_{ab}^{SMC}(E_a)}{dE_b}$$

$$= \sigma_a^{SMC}(E_a) \sum_{n=3} \frac{\tau_n}{h} \left[\Gamma_{nb}^{(0)}\uparrow + \Gamma_{nb}^{(-)}(E_b)\uparrow\right]$$

where the mean life-time τ_n is a solution to the (time-integrated t=0 ... ∞) master equation. Here, a and b refer to the particle type (neutron or proton). Using $\overline{I^2}\,\rho(E_b)$ for the bound-unbound mean squared matrix element which enters the escape widths $\Gamma_{nb}^{(\Delta n)}\uparrow$ all matrix elements $\overline{I^2}$ within the SMC-model cancel exactly. $\rho(E_b)$ is the single particle state density in the nuclear volume $V_N = 4\pi R^3/3$ and $R = 1.4\ A^{1/3}$ fm. The value σ_a^{SMC} is chosen as the OM reaction crose section diminished by all SMD contributions.

Within the SMD-model besides non-collective particle-hole excitations (ex) also collective vibration modes (vib) are considered. Below 30 MeV we restrict ourselves to one-step and two-step processes, (SMD) = (1) + (2) where

$$(1) = (ex) + (vib)$$
$$(2) = (2ex) + 2(exvib) + (2vib)$$

which are denoted according to the sequence of exciton and phonon excitations. More explicitly, we have (for neutron inelastic scattering)

$$\frac{d\sigma^{(\alpha)}(E_a)}{dE_b} = \left(\frac{mV_S}{2\pi h^2}\right)^2 4\pi(\alpha)\left(\frac{E_b}{E_a}\right)^{1/2}$$

where (α) should be replaced by

$$(ex) = \overline{I^2}(2_S+1)g^2\ U/2$$

$$(vib) = \sum_\lambda \beta_\lambda (2\lambda+1)^{-1} V_o{}^2 \delta(U-\omega_\lambda)/4\pi$$

and similar expressions for two-step processes. Here, the value $\overline{I^2} = 190\ A^{8/3}$ was obtained /2/ from OM reaction cross section. Adopting $V_S = V_N(KR)^{-2}$ interactions located on the nuclear surface are simulated. In (vib) only two low-lying phonons ($\lambda^\pi = 2^+$ and 3^-) are taken into account. Phonon energies $\omega_{2,3}$ and deformation parameter β are used from nuclear tables /5,6/, whereas β_3 was approximated by $(0.007\ \omega_3)^{1/2}$. $V_O \cong 48$ MeV is the potential depth. The δ-functions are replaced by Gaussians of width 1 MeV.

The SMC-model was generalized /4/ to multiple particle emission (MPE). Neutron and proton emission spectra including first-chance, second-chance, etc. emissions as well as angular distributions are calculated /4/ by code EXIFON for medium and heavy nuclei at incidence energies betw-en 5 and 26 MeV. Ignoring shell and pairing effects we use g = A/13 MeV^{-1} (except for 208-Pb and 209-Bi where at 14 MeV: g = 8 MeV^{-1}). Results for (n,xn) are depicted in Figs. 1 to 3. Despite of the great simplicity of the SMD/SMC plus MPE model it is successful in reproducing experimental data /7-9/. More details and reactions are presented in Ref. 4.

Conclusions: (i) The ratio at SMD to SMC increases with incident energy and is about 1 at 30 MeV. (ii) The one-step contribution dominates; it is about 18 % (30 %) of the OM reaction cross section at 14 (27) MeV. Otherwise for the two-step contributions we have 3 % (10 %) at 14 (26) MeV. The ratios are independent of mass number. (iii) Whereas (ex) increases (vib) decreases with energy; both are of same order at 10 MeV.

REFERENCES

1. H. Kalka: in Proc. of ICTP Workshop on Applied Nucl. Theory, Trieste, 1988
2. H. Kalka: submitted to Phys. Rev. C
3. H. Kalka, D. Seeliger, F.A. Zhivopistsev: Z. Phys. A329, 331 (1988)

4. H. Kalka, M. Torjman, D. Seeliger: submitted to Phys. Rev. C
5. S. Raman et al.: At. Data and Nucl. Data Tables 36, 1 (1987)
6. A. Bohr, B.R. Mottelson: Nuclear Structure II, NY., 1975
7. A. Pavlik, H. Vonach: IRK-Report, 1988, unpublished
8. A. Marcinkowski et al.: Nucl. Sci. Eng. 83, 13 (1983)
9. G.N. Lovchikova et al.: FEI Obninsk, USSR

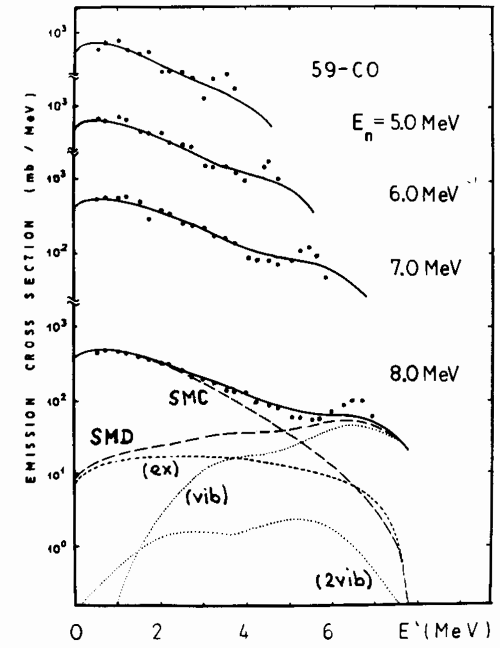

Fig. 1 Neutron emission spectra for 59-CO + n at incidence energies between 5 MeV and 8 MeV. experiment [9]; theoretical curves: full line-total emission spectrum calculated by EXIFON, (vib)-direct one-step vibrational excitation, (2vib)-direct two-step vibrational excitation, (ex)-direct pasticle-hole excitation, SMD-sum over all direct contributions, SMC-multistep compound contribution including equilibrium emission

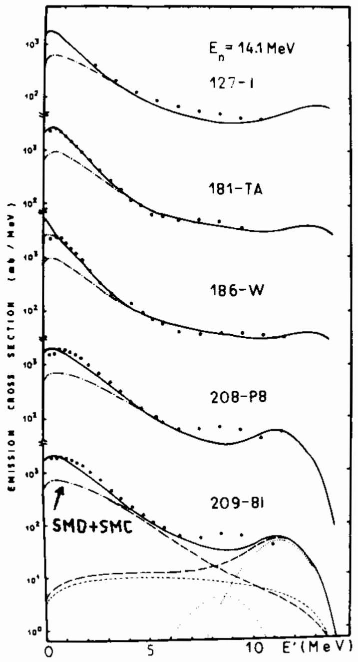

Fig. 2 Neutron emission spectra at 14 MeV incidence energy; experiment [7]; theoretical curves: as fig. 1

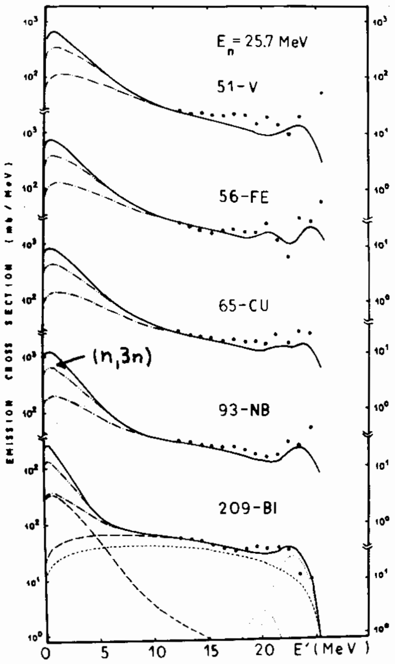

Fig. 3 Neutron emission spectra at 25.7 MeV incidence energy; experiment [8], theoretical curver: as fig. 1