

NUCLEAR MOLECULAR STRUCTURE AT HIGH SPIN AND HIGH
EXCITATION ENERGY

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Experimentally the gamma-ray spectrum following heavy-ion fusion reactions is very nearly exponential between 2 MeV and approximately one neutron binding energy. At higher energies there is a pronounced enhancement in the spectrum as compared to the low-energy exponential. This feature was first reported by Newton et al.¹ who also advanced the hypothesis that the high-energy radiation observed originates from the deexcitation of the giant dipole resonance in the hot compound nucleus. Since then other experiments have confirmed that this part of the spectrum is emitted primarily very early in the decay²⁻⁴. The directional distribution of the high-energy gamma radiation following ¹²C-induced reactions on indium and terbium is, however, not consistent with the assumption that these gamma rays solely originate from the giant dipole resonance^{5,6}. For both reactions the A_2 coefficient changes sign and obtains a negative value for the low-energy part of the shoulder. This is contrary to what is expected for the giant dipole resonance in a prolate nucleus or a nucleus with oblate shape rotating around its symmetry axis. For the terbium reaction there is in fact evidence for a higher multipole component around 9 MeV.

In a recent experiment we have studied the neutron emission following 100 MeV ¹²C-induced reactions on terbium in coincidence with high-energy gamma rays. The coincident gamma-ray multiplicity was determined simultaneously. Preliminary results from the analysis of neutron spectra recorded at different angles indicate the presence of two separate neutron distributions, one corresponding to a hot source ($kT \approx 3$ MeV) moving faster than the center-of-mass and the other to a cooler source ($kT \approx 1.5$ MeV) at rest in the center-of-mass frame. The gamma-ray multiplicity associated with the "hot" neutron distribution is significantly lower than that associated with the cooler component, indicating that the appearance of the hot source is favoured at central collisions. The proportion of "hot" neutrons is considerably lower in coincidence with gamma rays with energies around 9 MeV, leading to the conclusion that these are emitted in more peripheral collisions.

The results above, indicate that the initial hypothesis by Newton et al. is unable to explain the gamma-ray emission over the whole high-energy shoulder for these reactions.

We have calculated the spectrum of vibrational and rotational excitations in the pocket of the ion-ion potential for the C-In and C-Tb systems. For the C-In system at orbital angular momentum $L \approx 15\hbar$ the three lowest vibrational levels have partial halflives longer than 10^{-19} s against tunnelling through the outer

barrier. From the transition energies and transition probabilities ($E \approx 9$ MeV, $\Gamma \approx 6 \cdot 10^{16} \text{ s}^{-1}$ for In) we obtain results for the directional distribution coefficients in qualitative agreement with the experimental results both regarding the change in sign of A_2 and a negative sign of A_4 . The measured spectrum together with the calculated gamma-ray transition rate suggest that the molecular configuration has a total life-time of approximately 10^{-20} s. Such a long life-time may at first appear surprising. However, because ^{12}C is more strongly bound than its immediate neighbours, the potential governing the drift of nucleons towards the larger mass may well have a local minimum for the entrance channel, stabilizing the molecular configuration.

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