THRESHOLD STATES AND NUCLEAR ORBITING MOLECULES

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The threshold state[1] is a resonant state coincident in energy with the fragmenting threshold of the nucleus into two clusters and it decays preferentially in its threshold channel. Consequently, it follows from these two properties that the threshold state has a large anomalous radius. These properties suggest a molecular picture of the threshold state. On the other hand, the nuclear orbiting molecule[2] is defined by the following two properties: (1) orbiting molecules (consisting of two touching nuclei) are organized in rotational bands, $E = E_o + (\hbar^2/2\mathcal{J})I(I+1)$, the lowest spin resonance I=0 being located at the Coulomb threshold E_o, ($\mathcal{J}$ - moment of inertia of the orbiting system), and (2) their spreading width $\Gamma^\downarrow$ is proportional to the level density $\rho(E,I)$ of the compound system. (The molecular configurations are experimentally observed if $\Gamma^\downarrow$ is relatively small; otherwise the structure is washed out). The aim of this paper is to relate the R-matrix description of the threshold state to the nuclear orbiting model.

The spatial extended threshold state can be described in R-matrix theory by the compression factor β [3]; it corresponds to renormalizing the wave function to include the channel region outside the turning point. The minimum value of the β-factor defines the position of the threshold state. In the limit of heavy fragmentation of the nucleus, $\eta >> 0$, (η - Coulomb parameter), the minimum of β is found to be at the energy

$$E = E_o + (\hbar^2/2ma^2)L(L+1) + (\hbar^2/2ma^2)[-4\eta - L(L+1)/2\eta + \ldots]$$

(a - channel radius, L - orbital angular momentum). As the moment of inertia $\mathcal{J}$ is larger than ma^2, it can prove that energies of the threshold state and the orbiting molecule are nearly equal for symmetric fragmentation of the heavier system A>4. Numerical analysis of threshold states and orbiting clusters supports the above conclusion.

A second postulate of the orbiting cluster model is that of damping width. In order to explain the presence or absence of orbiting molecules according to the nature of its constituents, it is assumed that the damping width $\Gamma^\downarrow$ is proportional to the level density of the compound system. In the following we present an R-matrix evaluation for the damping width of threshold states, and conclude that the threshold-state spreading width $\Gamma^\downarrow$ is proportional to the strength function of the threshold channel. The threshold state is a high excited state embedded in a background of statistical levels; however, it is not dissolved in statistical levels. The mechanism which prevents the decay of the threshold level in the background of inner compound levels is the spatial extension, outside the channel radius, of the threshold level. The threshold-level parameters, including its resonant denominator, are renormalized in terms of the β-factor. It is proved that the threshold-level spreading

width is proportional to the imaginary part of the threshold channel background collision matrix, $\Gamma^{\downarrow} \sim \mathrm{Im}\, U^{B}_{nn}$, which is up to a factor just the strength function of the threshold channel, or even the level density of the reaction system. If the strength function is modulated by doorway components, then an intermediate structure of the threshold state has to be observed. This result is very similar to the damping-width postulate of orbiting molecules.

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