DIRECT GAMMA TRANSITIONS BETWEEN RESONANCES IN $^{12}C+^{12}C$ AND THE ORBITING-CLUSTER MODEL

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In this contribution we use the orbiting-cluster model of resonances[1)] to estimate gamma-ray transition probabilities between resonances in $^{12}C+^{12}C$.

Should resonances in $^{12}C+^{12}C$ collisions be due to quasi-molecular configurations of two rotating ^{12}C nuclei, they would follow the rotational-band rule

$$E(J) = E_o + \frac{\hbar^2}{2\mathcal{J}} J(J+1) \quad , \tag{1}$$

with $\mathcal{J}_o$ the moment of inertia associated with the configuration.

In the above physical picture, relatively strong gamma transitions between subsequent levels of the band could be observed. For quadrupole transitions within the same band,

$$T(E2) = 0.526\times10^{80}\times B(E2)\times E_\gamma^5 \ s^{-1} \quad , \tag{2}$$

with B(E2) in esu^2cm^4 and E_γ in MeV. Also,

$$B(E2) = \frac{5}{16\pi} e^2 Q_o^2 |\langle J_i 2K0 | J_i 2 J_f K\rangle|^2 \quad . \tag{3}$$

The crucial model-dependent quantity is the static quadrupole moment Q_o. The configuration responsible for the resonances in $^{12}C+^{12}C$ in the orbiting-cluster model is composed of two osculating ^{12}C nuclei; such a configuration can be approximated by an ellipsoid of large deformation. We can start with a rotational ellipsoid of eccentricity $\varepsilon=\Delta R_{elong}/\langle R\rangle \approx 1$. Its quadrupole moment is approximated by

$$Q_o \approx \frac{6}{5} ZR^2\varepsilon \quad . \tag{4}$$

With $R=1.2\ A^{1/3}$ fm one obtains $Q_o \approx 1.7\times10^{-24}\ cm^2$. The corresponding reduced rate is $B(E2) \approx 6.5\times10^{-68}|\langle|\rangle|^2$ with the square bracket from expression (3).

Alternatively, one can use the expression for Q_o from the nuclear collective model

$$Q_o \approx \frac{3}{\sqrt{5\pi}} ZR^2\beta(1+0.16\beta+...) \ . \qquad (5)$$

The value of the deformation parameter β can be estimated in the orbiting-cluster model by equating the moment of inertia of the deformed ellipsoid with that deduced from the experimental $E_{exc}(^{24}Mg)$ vs $J(J+1)$ dependence of resonances in $^{12}C+^{12}C$.[1)] This comparison gives $\beta\approx2-2.5$. With $\beta\approx2$ and $R=1.2\ A^{1/3}$ fm, one obtains $Q_o \approx 2.9\times10^{-24}$ cm^2 and $B(E2) \approx 19\times10^{-68}|\langle|\rangle|^2$ esu^{2}cm^4.

The relevant quantities $|Q_o, B(E2), T(E2)|$ for the transition between the E_{CM}=25.95 MeV and 19.35 MeV resonances in $^{12}C+^{12}C$ calculated for various values of ε and β are shown in table 1.

Table 1

	Rot.ellipsoid $\varepsilon=1$	1.5	Coll.model $\beta=2$	2.5	S.p.model
Q_o (10^{-24} cm^2)	0.9	2.6	2.9	3.8	
B(E2) (10^{-68}esu^{2}cm^4)	0.8	1.7	2.3	4	0.0095
T(E2) (10^{15}s^{-1})	5	11	15	26	0.064

To calculate T(E2), we have assumed that the resonances have spins J=14 and 12, respectively[2)]. The estimated values of T(E2) are several hundred times the single-particle estimate (Weisskopf unit).

Preliminary experimental data for this transition give T(E2) of the order of 100 Weisskopf units[3)], in reasonable agreement with the above.

Two comments are appropriate on the above calculation. First, the range of validity of expressions (4) and (5) is limited to small values of ε and β; we have deliberately used them also for large values, as we are interested in a rough estimate only. Second, it is clear that the two expressions derive from different parametrizations of the same physical picture, i.e. that of a deformed ellipsoid.

References

1) N. Cindro and D. Počanić, J. Phys. G6 (1980) 359
2) R.L. McGrath et al., Bull.Am.Phys.Soc. 25 (1980) 591
3) R.M. Cormier et al., Phys.Rev.Lett. 38 (1977) 940