NON-STATISTICAL NATURE AND HIGH-SPIN SELECTIVITY OF THE $^{10}B(^{14}N,^{12}C)^{12}C$ REACTION

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Excitation functions of the two-nucleon transfer reaction $^{10}B(^{14}N,^{12}C)^{12}C$ to ground states and three excited states have been measured at a very forward angle of 2.9° (LAB) over the range E_{CM}=5-32 MeV, corresponding to ^{24}Mg excitation energies from 34-61 MeV. The experiments were performed for low energies at the Bochum Dynamitron tandem and above 10 MeV (CM) at the Heidelberg Emperor. Low-energy ^{12}C ions have been identified with a cylindrical ΔE-E ionization-chamber annular-detector telescope of large solid angle.

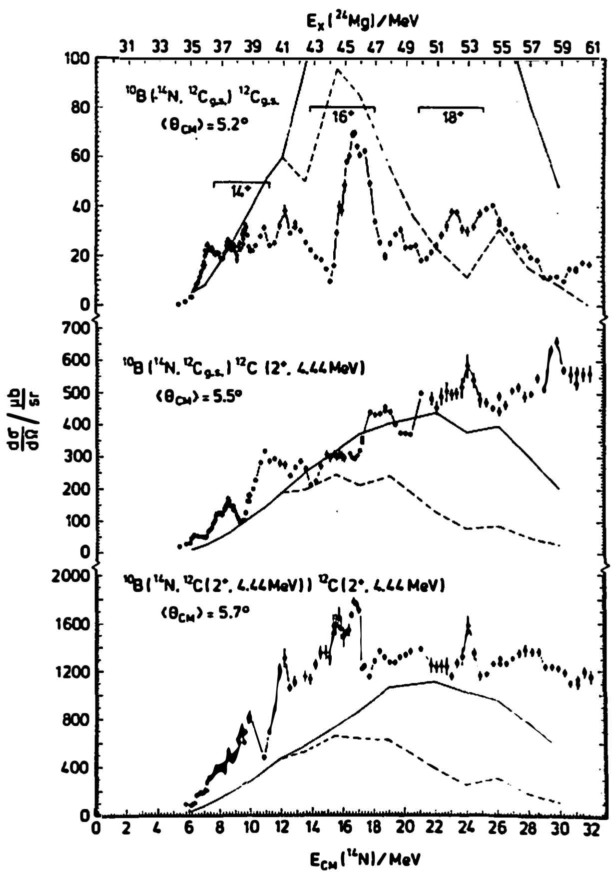

Fig.1: $^{10}B(^{14}N,^{12}C)^{12}C$ excitation functions and Hauser-Feshbach calculations.

The weakly fluctuating cross sections presented in Fig.1 show some indications of correlated structures and two resonance-like effects near $E_x(^{24}Mg)$=45 and 52 MeV, which are correlated in energy with high-spin molecular resonances found in ^{12}C+^{12}C inelastic excitation [1] (the positions and

J^{π} values of which are indicated by brackets in Fig.1). The resonant structure at 45 MeV, which is found to be correlated with the (16^{+}?) member of the $^{12}C+^{12}C$ molecular band, appears also strongly in the total cross section of $^{12}C(^{12}C,^{10}B)^{14}N$ [2] and in $^{14}N+^{10}B$ fusion data [3]. It clearly belongs to the most pronounced heavy-ion resonances ever seen.

With optical-model parameters obtained from best fits of ^{10}B $+^{14}N$ elastic scattering measured at 20^{o}, 30^{o}, 40^{o} and energies $E_{CM}(^{14}N)$=12-32 MeV, statistical-model calculations have been performed. The results shown in Fig.1 (lines without dots) differ in the Yrast-cutoff parameter assumed for the compound nucleus ^{24}Mg (r_o^C=1.5 and 1.3 fm for solid and dashed curve, respectively). Evidently, the statistical model fails to describe the data above 41 MeV excitation, i.e. slightly above the Coulomb barrier. In particular, relative cross sections are not reproduced at all. The discrepancy is increasing with energy and with excitation energy of decay channel and is found to be rather independent of parameter choice. It is especially pronounced for the $^{12}C(g.s.)+^{12}C(4_1^+,14.1$ MeV) cross sections (not shown here), for which the kinematical conditions for a large transfer probability given by Brink [4] are well satisfied. The observed strong deviation of statistical theory from experiment is interpreted as evidence for a direct-reaction contribution with strength depending on energy and reaction channel.

From the statistical model also partial cross sections for the $^{10}B(^{14}N,^{12}C)^{12}C$ reaction have been calculated for energies of proposed molecular resonances ($J^{\pi}=14^{+},16^{+},18^{+},20^{+}$). These $\sigma(J)$ distributions are displayed in Fig.2 (open circles denote partial-cross-section distributions of the entrance channel (reduced by a factor 10^{-3}), full dots, full squares, and open squares those of the three reaction channels $^{12}C(g.s.)+^{12}C(g.s.)$, $^{12}C(g.s.)+^{12}C(2_1^+)$, $^{12}C(2_1^+)+^{12}C(2_1^+)$, respectively). One notices that angular-momentum matching is quite similar for the three channels. Therefore, by observing these fission-like decay channels simultaneously, any structural effects should clearly be exhibited. This is an advantage of $^{10}B+^{14}N$ reactions compared to the inverse [2], by which the resonant $^{12}C+^{12}C$ inelastic channels are not accessible.

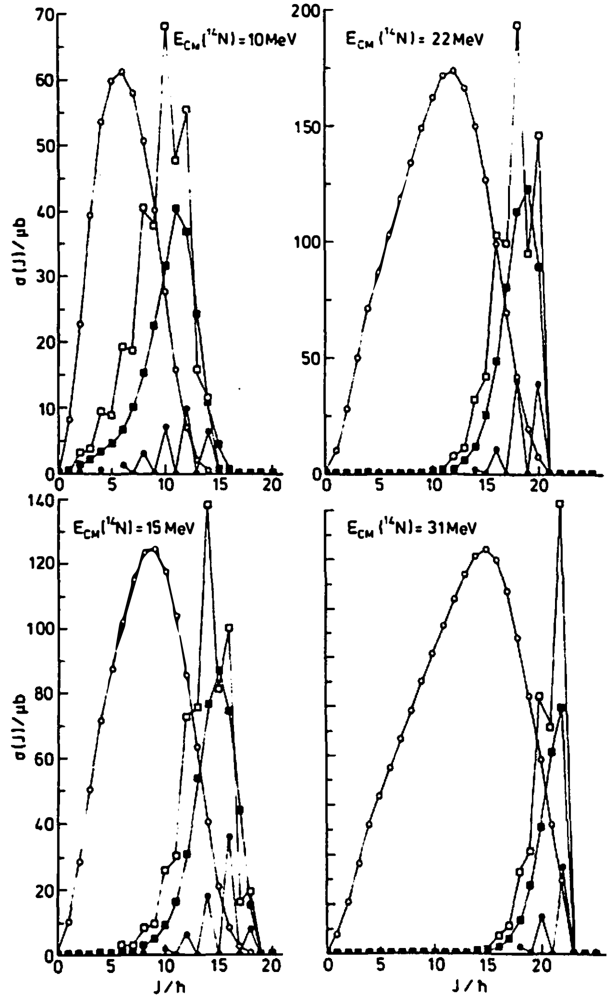

Fig.2 shows also that due to the large mismatch between entrance and exit channel a narrow ℓ window results, the width of which decreases drastically with increasing energy. Since the overlap of ℓ distributions is increasing with energy, the ℓ matching of the reaction is improving considerably at high excitation. Consequently, at high energies the $^{10}B(^{14}N,^{12}C)^{12}C$ reaction is supposed to preferentially excite high-spin resonances.

Similar conclusions can be drawn from the Band-Crossing model which suggests a crossing of the $^{12}C+^{12}C$ elastic band with the spin-aligned $^{10}B+^{14}N$ channel near $J_{cross}=21\,\hbar$ (this readily explains why the $^{10}B+^{14}N$ resonance at 45 MeV does not decay into the kinematically equivalent $^{11}B+^{13}N$ channel [5] for which one finds $J_{cross}=37\,\hbar$).

__Fig.2:__ Partial cross section distributions for the $^{10}B(^{14}N,^{12}C)^{12}C$ reaction.

In Fig.3, the ℓ_{graz} trajectory for $^{10}B+^{14}N$ is plotted (thin straight line) as calculated with an optical-model potential. It crosses the experimentally defined $^{12}C+^{12}C$ molecular band (thick straight line) at about 23 ħ (somewhat higher than the aligned component). Again it is demonstrated that the aligned $^{10}B+^{14}N$ band with its reduced slope causes ℓ matching of the $^{10}B(^{14}N,$

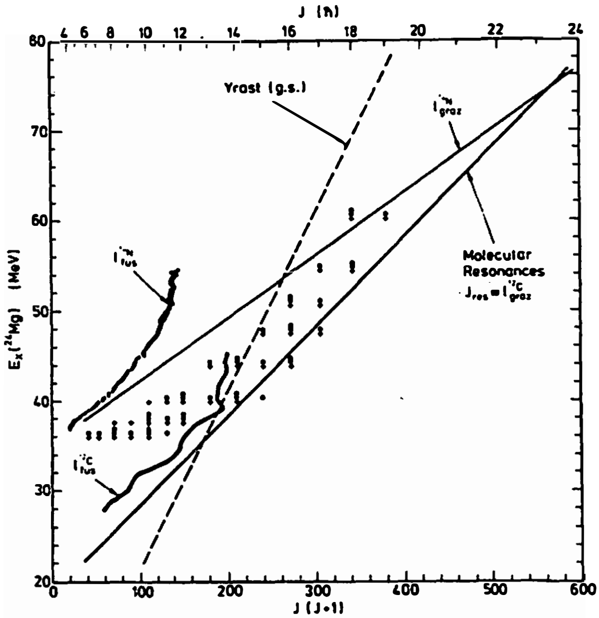

Fig. 3: Trajectories for the critical ℓ from fusion cross sections, for ℓ_{graz} of $^{10}B+^{14}N$ and for the positions of molecular resonances. The point-like symbols indicate the regions of large reaction contributions from $^{10}B(^{14}N,^{12}C)^{12}C$.

$^{12}C)^{12}C$ reaction at high energies. Besides critical angular momentum trajectories deduced from total fusion cross sections of $^{14}N+^{10}B$ and $^{12}C+^{12}C$ [3], Fig. 3 shows also the regions of maximum contribution of the first three channels of the $^{10}B(^{14}N,^{12}C)^{12}C$ reaction (obtained from the calculations of Fig. 2). Above 41 MeV excitation the reaction excites preferentially high-spin states close to the ^{24}Mg Yrast line. Clearly, the reaction 'penetrates' deeply into the region of surface transparency above the bending of fusion cross sections, where the number of open channels is a minimum and direct-reaction contributions are expected to dominate.

We conclude that the observation of the 45 MeV resonance most strongly in the g.s. transition and much less pronounced in the double-excitation channel is unexpected and seems to indicate formation of a rather cold, rapidly spinning nucleus, supporting the recently proposed "Saturn-ring" model of heavy-ion resonances [6].

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