ENHANCEMENT OF CERTAIN CROSS SECTIONS - AN EVIDENCE FOR NUCLEAR MOLECULES?

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The nuclear molecules have usually been associated with the observation of resonance structure in the excitation functions. Here I want to draw attention to an other aspect of molecular states, the enhancement of cross sections for certains channels. As pointed out previously for the ^{12}C + ^{12}C reaction[1], the molecular states should decay with large probability to (1) the elastic channel,(2) the ^{8}Be + ^{16}O channel, reached by α-particle transfer, and (3) the α + ^{20}Ne channel, reached by two α-particle transfers, since ^{12}C could be considered as an α-α-α cluster configuration. The measurements at subbarrier energies actually show substantial enhancement with respect to the statistical evaporation in the α + ^{20}Ne channel and the recent measurements[2] demonstrated a very large enhancement for the ^{8}Be + ^{16}O cross section, in no way attributable to a direct α-transfer mechanism.

Table 1. The α transfer reactions from ^{9}Be.

Reaction	Final nucleus bound states (MeV)*	Q_0 (MeV)+	Ref.	Observed†
^{9}Be + ^{9}Be	^{13}C 3.09, 3.68, 3.85	8.18	3	(a)
^{9}Be + ^{10}Be	^{14}N 2.31, 3.95..(6)..7.03	9.15	4	(a)
^{9}Be + ^{11}B	^{15}N 5.27..(13)...10.01	8.52	5	(a)
^{9}Be + ^{12}C	^{16}O 6.13, 6.92, 7.12	4.70	6	(b)
^{9}Be + ^{13}C	^{17}O 0.87 3.06, 3.84	3.89	5	(a)
^{9}Be + ^{16}O	^{20}Ne 1.63, 4.25	2.26	7	(c)
^{9}Be + ^{18}O	^{22}Ne 1.28...(45)...9.32	7.20	8	(c)

* Listed are the bound states, deexciting by γ-ray emission. In the case of many bound states the number of unlisted states is shown in parenthesis. The underlining denotes observation of enhanced cross section.

\+ The reaction Q value for the (^{9}Be, ^{5}He) α-transfer leading to the ground state is listed. The Q value for the αn channel is 0.89 MeV larger.

† (a) Enhancement not attributable to the direct α transfer process.
(b) No evidence.
(c) Enhancement attributable to the direct α transfer process.

A good case for investigation of the cluster transfer via molecular states are the reactions involving ^{9}Be, an n-α-α cluster nucleus. Table 1 presents the systems for which the cross sections have been measured at sub-barrier energies by the γ-ray detection method. As ^{9}Be has a loosely bound neutron (S_n = 1.67 MeV) and a loosely bound α particle (S_α = 2.53 MeV), the cross sections for the direct transfer of a neutron or an α particle are large for the reactions with Q ≈ 0. For most of the α transfer reactions, resulting in the αn channel, the reaction Q values are, however, large and the process can not be attributed to the direct transfer mechanism but it is indicative of an α transfer in a molecular mode.

It is interesting to note that only the more symmetrical systems (^{9}Be + ^{9}Be, ^{9}Be + ^{10}B, ^{9}Be + ^{11}B) show realy large enhancement in the αn cross section. An other observation pointing in the same direction is the enhancement observed[9] at subbarrier energies for the ^{13}C + ^{13}C → αα + ^{18}O reaction, wich could arise by a transfer of a neutron and an α-particle in a molecular mode. Moreover, the enhancement observed[10] in the subbarrier fusion cross section of ^{16}O + ^{16}O with respect to that of ^{12}C + ^{20}Ne is perhaps also attributable to the symmetry of the system and the molecular state formation.

A theoretical investigation of molecular-state-formation probability for the symetrical systems versus the asymetrical ones would be very useful.

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