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On the resonant behavior of the $^{16}O + ^{15}N$ system

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Abstract

The $^{16}O + ^{15}N$ reaction products have been studied by the γ-ray detection method in the CM energy range 15.5 to 36.1 MeV and by the kinematical coincidence method at energies ranging from $E_{CM} = 20.6$ to 33.5 MeV. The γ-ray yield excitation function of the ^{16}O 3^- inelastic channel shows the existence of resonant structures. Two structures with ~ 1.6 MeV width are observed in the large angle elastic scattering excitation function, they are correlated with the resonances seen in the inelastic channel. Angular momentum assignments were made from the elastic backward angular distributions.

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It is now well established that resonant behavior is a relatively common feature of reactions between light-heavy ions. In particular, it has been shown that the observation of resonances is favourised for systems with a small number of open reaction channels (NOC) [1]. For lighter systems, this concerns the reactions involving closed or almost closed shell nuclei. The results obtained from ^{14}C induced reactions [2] provide a good confirmation of this prediction. Under these considerations, other good candidates to display resonant behavior are the ^{15}N induced reactions. The calculated NOC as a function of grazing angular momentum for the $^{16}O + ^{15}N$ collision predict a pronounced minimum [1], consistent

with the surface transparency of the interaction that emerged from the elastic scattering excitation functions measured at several angles by Siemssen et al. [3].

In this note, we report on various aspects of the $^{16}O + ^{15}N$ reaction which was studied through two different but complementary experimental approaches. The reaction was first studied [4] by the "inclusive" γ-ray detection technique at bombarding energies ranging from 30 to 70 MeV by steps of 1 MeV up to 48 MeV, by steps of 0.5 MeV above and with a 165 $\mu g/cm^2$ Ta_2O_5 oxygen target. In a second experiment, an "exclusive" study of the same reaction was performed [5] using the kinematical coincidence technique at bombarding energies between 40 and 65 MeV by steps of 1 MeV and with a self-supporting nominally 35 $\mu g/cm^2$ thick Al_2O_3 target. The ^{15}N ion beams were delivered by the Strasbourg MP Tandem. The fragments from the binary channels have been identified through their detection in coincidence between two position sensitive detectors covering the laboratory angles 21° to 50° and −70° to −42°, respectively. This allowed us to obtain angular distributions, at each incident energy and for an extensive angular range, i.e. $\theta_{CM} = 40°$ to 130° for the elastic channel. The excitation function of the elastic channel at large angles $\theta_{CM} = 90° - 129°$ is shown in Fig. 1. Two prominent stuctures, with a width of $\Gamma \sim 1.6$ MeV are observed at $E_{CM} = 22.7$ and 26.8 MeV, these strucures are also seen in the γ-ray yield excitation function of the inelastic channel, displayed in the same figure, corresponding to the excitation of the 6.13 MeV (3^-) level of ^{16}O. According to the Band Crossing Model [6], this correlation is due to the strong coupling between the elastic channel (elastic band) and the inelastic one (inelastic band) in that bombarding energy range. At higher energies, the model predicts that the structures should remain essentially in the inelastic channels in agreement with our data.

A comparison of the elastic angular distributions "on-resonance" at large angles, where the contribution from the elastic transfer of a proton between two ^{16}O cores is expected to dominate, with $P_L^2(\cos\theta)$ functions is given in Fig. 2. The $L = 16$ and 18 forms fit rather well the data and these assignments can thus be made to the resonances at $E_{CM} = 22.7$ and 26.8 MeV, respectively. It is interesting to note that the L-values and the energies of the two

resonances are in excellent agreement with a deep potential description of resonances in the $^{16}O + ^{16}O$ interaction [7] predicting $L = 16$ and 18 resonances at energies very close to those observed experimentally ($E_{CM} = 22.3$ and 26.5 MeV) in the reaction channels [8]. These dominant even L-values and the analogy between $^{16}O + ^{15}N$ and $^{16}O + ^{16}O$ are the result of the parity dependent effects [9] shown to be important in collisions between almost identical nuclei and also observed recently for resonances reported in $^{14}C + ^{12}C$ and $^{14}C + ^{16}O$ [2].

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FIGURES

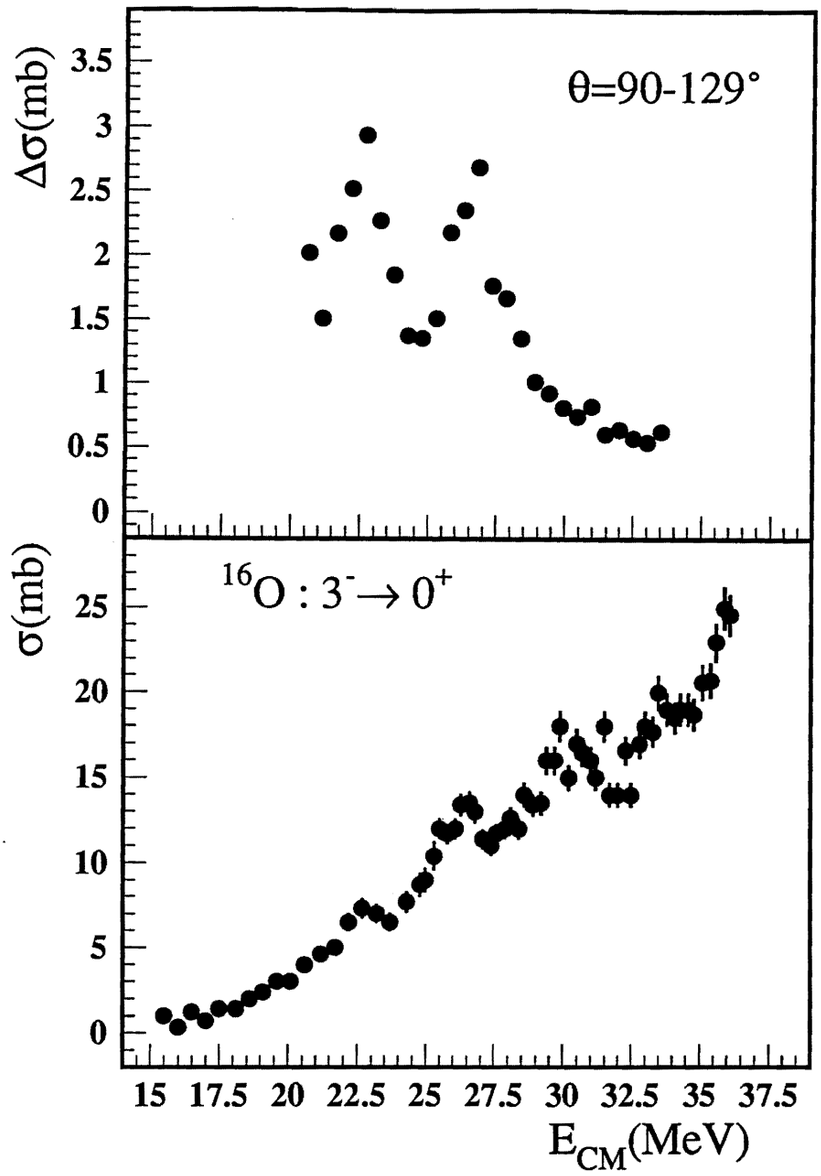

FIG. 1. $^{16}O+^{15}N$ reaction: Excitation functions of the elastic channel at large angles $90° - 129°$ (top) and of the inelastic channel, feeding the 6.13 MeV level of ^{16}O from γ-ray yield measurements (bottom).

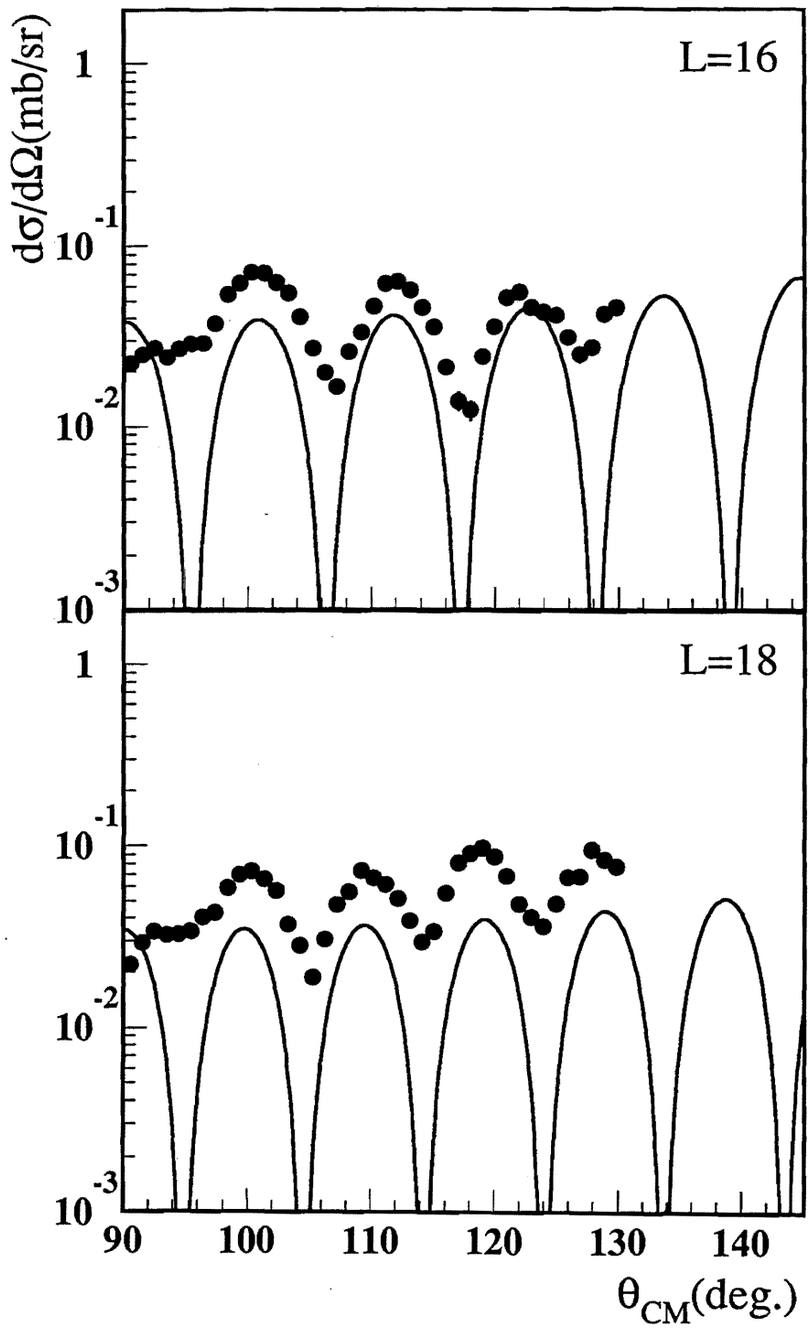

FIG. 2. Backward elastic angular distributions of the $^{16}O + ^{15}N$ reaction for the two resonances. Comparison with the $P_L^2(\cos\theta)$ forms with $L = 16$ (at $E_{CM} = 22.7\,\mathrm{MeV}$) and $L = 18$ (at $E_{CM} = 26.8\,\mathrm{MeV}$).