R matrix analysis of ^{22}Ne states populated in the $^{18}O(\alpha,\alpha)$ resonant elastic scattering

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It is well known [1] that low energy $^{18}O+\alpha$ interaction may play an important role in astrophysical processes. The $^{18}O(\alpha,\gamma)$ reaction synthesizes ^{22}Ne, the main neutron source for the weak s process, and the reaction $^{18}O(\alpha,n)^{21}Ne$ has been proposed as a weak neutron source in a reaction chain to produce ^{19}F in TP-AGB stars. A few years ago detailed measurements of the excitation functions for the $^{18}O(\alpha,n_0)$ and $^{18}O(\alpha,n_1)$ reactions were performed in the astrophysically important region of 10.6 -11.5 MeV ^{22}Ne excitation energy [1].

Simultaneously properties of ^{22}Ne states populated in the $^{18}O(\alpha,\alpha)$ resonant interaction are of interest for cluster development in neon region and, specifically, to better understand extra neutron influence on alpha cluster structure [2]. It is also important from the perspective of a comparison of alpha cluster properties in mirror resonant reactions $^{18}O+\alpha$ and $^{18}Ne+\alpha$. The measurements for the $\alpha+^{18}O$ elastic scattering were made in a broad energy interval and high energy resolution in two old works [3,4] and in a inverse kinematics publication [5]. None of these data were analyzed in the framework of R matrix theory.

We performed new measurements of the $\alpha+^{18}O$ elastic scattering in the inverse kinematics setup at lower energy than in the reference [5] to observe the states at a lower excitation energy at better conditions, and we made the first R matrix analysis of the available data on the $\alpha+^{18}O$ resonant elastic scattering in the energy region 11-15 MeV excitation energy in ^{22}Ne. Here we report on R matrix analysis of the oldest data [3] for the 11.5-12.5 MeV excitation region in ^{22}Ne, a part of a broader investigation of the $\alpha+^{18}O$ resonant interaction.

In future publications, together with an analysis of a higher excitation region in ^{22}Ne, we consider new requirements for enhanced theoretical predictions important for high excitation region of high density of states and several decay modes. We also intend to outline the merits and restrictions of different experimental approaches in resonant studies of nuclear structure at these conditions.

The data [3] were obtained at the ^{4}He beam of the ORNL 5.5-MV Van de Graaff well over half a century ago. The elastic scattering of alpha particles from $\alpha+^{18}O$ interaction was observed at θcm. = 90.0°, 125.3°, 140.7°, 152.3°, and 164.4°. The angles 90.0°, 125.3°, and 140.7° correspond, respectively, to the zeros of Legendre polynomials of odd order, order two, and order three. The authors [3] normalized data at the lowest energy of alpha particles of 2.40 MeV to the Rutherford-plus-hard-sphere scattering cross sections and claimed 6% counting statistics. The experimental data were analyzed in Ref. [3] using the single level [5] and two-level [6] approximations.

We used multilevel, multichannel R matrix code, AZURE [7], to fit the experimental data [3]. The resonances in the investigated excitation region in ^{22}Ne decay by alpha particles back to the ground state in ^{18}O and by neutrons to the ground $5/2^+$ state and to the $½^+$ first excited state in ^{17}O. Data [1,4] showed that both states in ^{17}O might be populated with comparable probability by these decays. We have included in the analysis only n decay to the ground state in ^{17}O to restrict the number of free parameters of the fit. However, we checked the influence of an inclusion of the second n channel to the fit of several strong resonances. We did not observe any important changes in the fit of the elastic scattering of alpha particles due to distribution of the reduced widths between two neutron decay channels. A stronger influence to neutron yield was observed. However, there are available data only on the total neutron yield for this excitation region in ^{22}Ne [8], and these data evidently less detailed and less precise than the excitation functions for alpha particle scattering. Therefore, we used data on the neutron yield [8] only as a final test of the analysis and did not include these data in the fit.

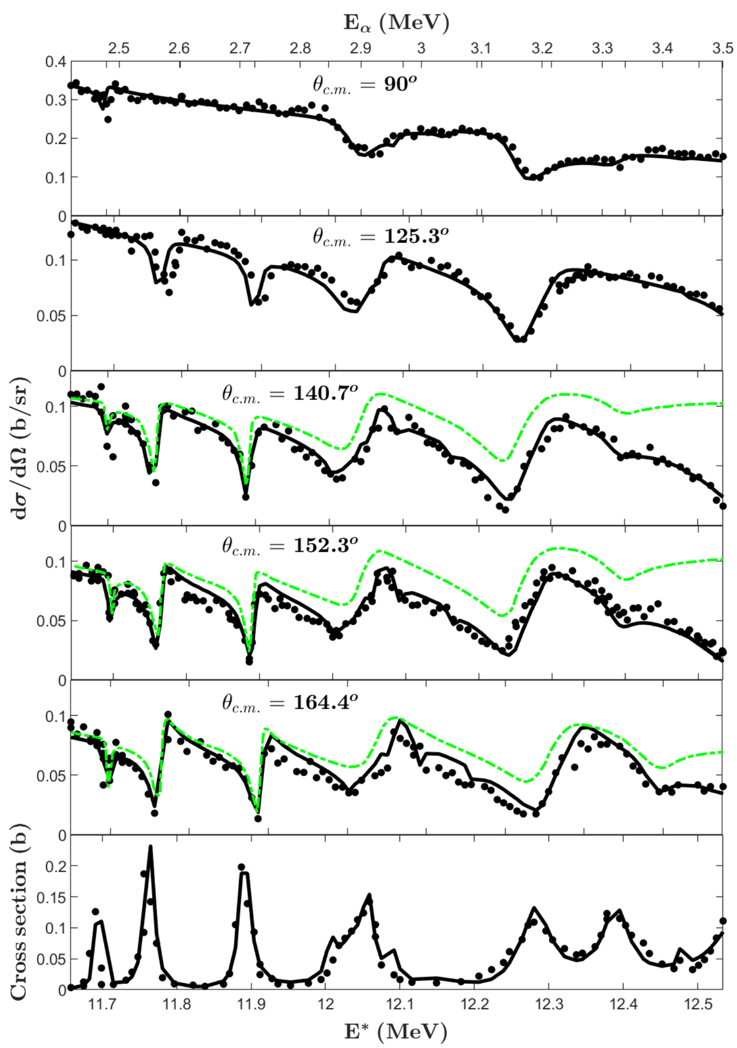

Fig. 1. R matrix fit of the excitation functions for the α+^{18}O elastic scattering [3] and the total 18O(α,n) reaction [8] (the lowest panel). The dash line shows a previous fit [3].

Fig.1 presents fit of the present work to the data [3]. Though the authors [3] claimed the data normalization at the lowest energies, we found that an additional scaling by 7% of the experimental data at 125.3° and 152.3° improves overall fit including the lowest energies.

An analysis of development of alpha cluster structure from ^{19}F and ^{20}Ne [9-11] to $^{21,22}Ne$ shows that the changes depend upon the nuclear parity of the state. We are looking for explanations in the frameworks of cluster or shell models, however, no reliable answer has been found yet.

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