Resonant elastic scattering of ^{14}O on α particles studied with the TexAT active target

M. Barbui,[1] E. Aboud,[1] S. Ahn,[1] J. Bishop,[1] V.Z. Goldberg,[1] J. Hooker,[1] C.H. Hunt,[1] H. Jayatissa,[1]
Tz. Kokalova,[2] E. Koshchiy,[1] S. Pirrie,[2] E. Pollacco,[3] B.T. Roeder,[1] A. Saastamoinen,[1]
S. Upadhiayula,[1] C. Wheldon,[2] and G.V. Rogachev[1,4]
[1]*Cyclotron Institute, Texas A&M University, MS3366 College Station, Texas 77843*
[2]*School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom*
[3]*IRFU, CEA, Saclay, Gif-Sur-Ivette, France*
[4]*Department of Physics&Astronomy, Texas A&M University, College Station, Texas 77843*

Isospin symmetry is an important concept in nuclear structure that has been extensively studied for many decades. It is well established that isospin is a good quantum number (with some exceptions) for nucleon degrees of freedom. However, applicability of this symmetry to cluster degrees of freedom is not obvious. The goal of this work is to explore if isospin symmetry still holds for alpha-cluster states by comparing the alpha-cluster states in ^{18}Ne with those in the mirror nucleus ^{18}O that were previously measured by Avila et al. [1]. The Coulomb shift in resonances of mirror pair nuclei can be used to probe the cluster structure of these states. For example, Baba and Kimura [3] performed an AMD calculation on the mirror pair ^{14}C-^{14}O to study molecular orbits in positive parity states. They found three types of configurations: the triangular, π-bond linear chain, and σ-bond linear chain. The excitation energy difference between ^{14}C and ^{14}O is very small for the π-bond linear chain while it is large for the σ-bond linear chain. This large energy shift is interpreted as Thomas-Ehrman shift in the σ-bond linear chain. Nakao et al. [4] studied the Coulomb shift in the mirror pair ^{18}O-^{18}Ne using the Orthogonality Condition Model. This calculation predicts suppressed excitation energy for the 0^+ resonant levels in ^{18}Ne and a larger alpha width compared to ^{18}O. This is also explained as Thomas-Ehrman effect.

In this work we studied the reaction ^{14}O+alpha using the TexAT active target [2] at Cyclotron Institute of Texas A&M University. The ^{14}O beam was produced using Momentum Achromat Recoil Separator (MARS) with the reaction ^{14}N(p,n)^{14}O. The ^{14}N primary beam with energy of 11 MeV/nucleon was delivered by the K500 Cyclotron. The energy of the ^{14}O beam was 61.8 MeV and the intensity was about 10^4pps.

Alpha particles were detected by the front-wall silicon detectors and identified using the energy loss in the last section of the active detector together with the residual energy deposited in the silicon. The interaction point inside the gas volume was obtained after reconstructing the trajectories of the incoming beam, the alpha particle and the recoiling ^{14}O. This information was used to select only the events corresponding to elastic scattering and rejecting the inelastic scattering events. The excitation function of ^{18}Ne was measured in the detectors placed at 5º, 9º, 12º, and 15ºfrom the center of the entrance window. The corresponding differential cross sections are shown in Figure 1. The experimental cross sections were analyzed using the R-Matrix approach. Since the mirror nucleus ^{18}O has been already studied [1] we started the R-Matrix calculation with the parameters used to describe ^{18}O and we manually varied them to obtain the best reproduction of the experimental data. The result is shown by the blue line in Fig. 1. Although the statistics is low 50 resonances were identified with a reduced χ^2 of about 9 between experimental and calculated values. An almost complete correspondence between the levels in ^{18}O and

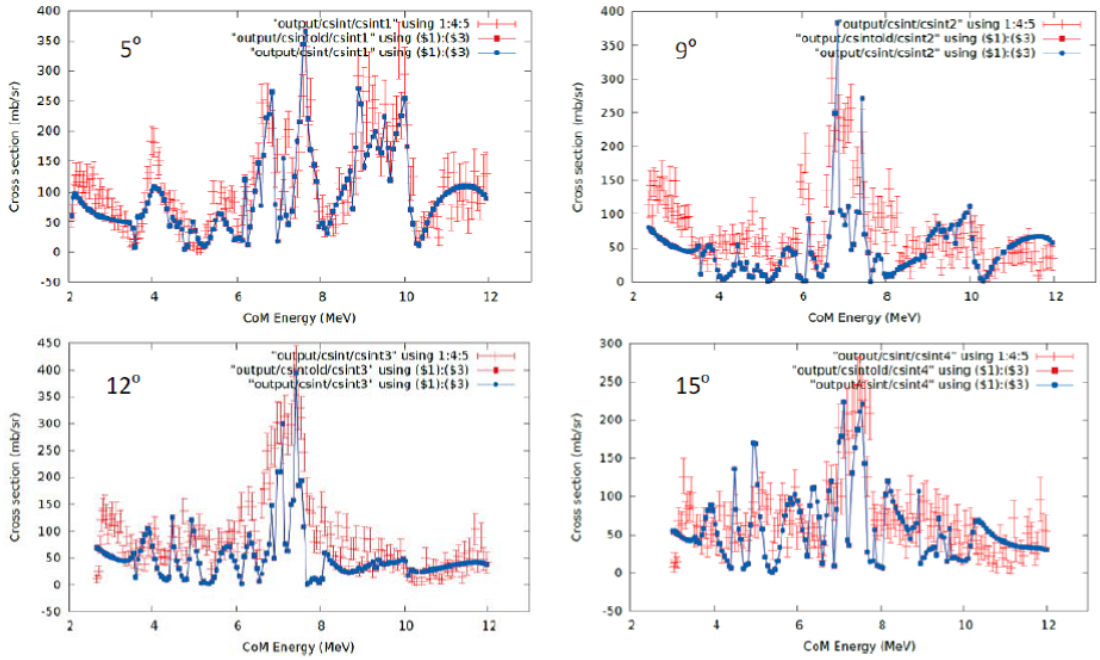

Fig. 1. ^{18}Ne excitation function measured at different angles (red points). The blu line shows the result of the R-matrix calculation.

^{18}Ne was found. This R-Matrix calculation was performed considering only the alpha exit channel, since there are no experimental data available for the p and p_1 channels in the energy range of interest. The dimensionless reduced alpha width and the excitation energy shift were calculated for all the corresponding levels in ^{18}Ne and ^{18}O. It is interesting to note that the states with the largest reduced alpha width in ^{18}Ne correspond to states with a large reduced alpha width in ^{18}O, signaling a pronounced alpha cluster structure of these states. The present R-matrix analysis does not show the drop of about 600 keV predicted by Nakao in the excitation energy of the 0^+_4 state in ^{18}Ne, but the width of the state is large (3.4 MeV). We also observe the tail of another 0^+ state at 2.2 MeV above the alpha threshold that is not seen in ^{18}O.

Calculation of the energy and width of the states in ^{18}O and ^{18}Ne have been performed using a simple potential model. These calculations are not able to reproduce at the same time the observed excitation energy shift and width of the states.

Further analysis work will be done to try to incorporate the p and p_1 exit channels in the R-Matrix calculation as well as a fit of the most significant resonances to improve the χ^2.

Comparison with the Monte Carlo shell model calculations performed by A. Volya will be also done.

[1] M.L. Avila *et al.*, Phys. Rev. C **90**, 024327 (2014).
[2] E. Koshchiy *et al.*, Nucl. Instrum. Methods Phys. Res. **A957**, 163398 (2020).
[3] T. Baba and M. Kimura, Phys. Rev. C **99**, 021303(R) (2019).
[4] M. Nakao *et al.*, Phys. Rev. C **98**, 054318 (2018).