Rainbow Elastic Scattering of ^{16}O on ^{12}C at 300 MeV

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An experiment was performed with a 300 MeV ^{16}O beam on a ^{12}C target to study the elastic scattering beyond the nuclear rainbow angle. Its aims were to extend the measurements to very large angles, and attempt to uniquely identify the elastic scattering potential (see e.g. [1] and refs. therein). Experimental evidence for refractive phenomena, first in alpha scattering, then in the elastic scattering of light ions lead to the hope that more information about the internal regions of colliding nuclei can be gained which will provide a unique nucleus-nucleus potential and, from there, constraints on various folding model interactions and even on the compressibility of cold nuclear matter.

The experiment was carried out with a beam from the K500 superconducting cyclotron. The beam analysis system (BAS) was used to control the energy and angular spread of the beam and the MDM magnetic spectrometer was used to analyze the scattered particles. The experimental setup and the analysis were similar to those used in our previous experiments at somewhat lower energies [2]. A self-supported carbon foil 1 mg/cm^2 thick was used as the target. The scattered particles were detected in the focal plane of the spectrometer by a large detector [3] with an entrance window 43cmx10cm. It determined the position along the dispersive direction with resistive wires at four different depths in the detector, the specific energy loss in the ionization chamber and the residual energy in a NE102A plastic scintillator behind it. The ionization chamber was filled with a mixture of butane and alcohol vapors flowing through it at 62 torr. A new plastic scintillator detector, designed for these heavy ions was built for this experiment. Measurements were made with the magnetic fields set for the transport of the fully stripped elastically scattered ^{16}O ions at angles between 4 and 39 deg. (spectrometer setting). We also measured the ^{12}C ions at forward angles to assess the importance of the elastic alpha exchange ^{12}C(^{16}O,^{12}C)^{16}O reaction mechanism, indistinguishable from the elastic scattering at complementary backward angles. At smaller angles, an acceptance window of 4° (horizontal) x 1° (vertical) (1.25 mrad) was used, which was replaced at larger angles and for the transfer reaction with a larger a 4°x4° (5 mrad) window. RAYTRACE reconstruction was done as part of the data analysis. The position in the wire closest to the focal plane and the position in wires 1 and 4 were used to reconstruct the focal plane position and the scattering angle. This particular experiment was run with the spectrometer near its saturation limits. Also, due to the kinematics of the reaction, the focal plane migrates rapidly from the back of the detector to its front, and even into the spectrometer, as the angle increases. This migration, the fast oscillations in the angular distribution that required a very good angular resolution, and the large overall drop in the cross section as the measuring angle increased, were the main challenges in the experiment and in the data analysis. In the end we succeeded to determine the angular distribution for elastic scattering over the angular range $2_{c.m.}$=6°–85° and 158°–175° (from transfer). The cross sections measured span more than seven orders of magnitude (Fig. 1). The good angular resolution of the experiment (less than 0.2°) allowed us to divide the full 4° opening of the spectrometer acceptance window into 0.25° bins at forward angles. We used 0.5° binning at the most backward angles. At small angles the energy resolution was around 800 keV, but it degraded at larger angles due mainly to kinematical broadening coupled to the angular spread in the beam.

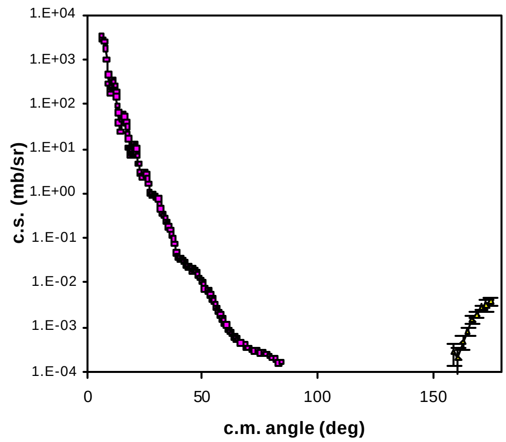

Figure 1. Angular distribution measured for elastic scattering ^{16}O (300 MeV) + ^{12}C (forward angles) and for the alpha exchange reaction $^{12}C(^{16}O,^{12}C)^{16}O$ (backward angles).

The angular distribution features the characteristic Fraunhoffer diffraction pattern at forward angles followed by a very clear and prominent refractive pattern at larger angles with two clear Airy minima around 40 and 70 degrees (Figure 2). The cross section measured for the transfer reaction is very small, in the microbarn/sr region and below, and shows that the alpha exchange mechanism contributes little, if at all, to the elastic scattering measured at forward angles. It results that the interpretation of any of the structures observed in the angular distribution as the result of interference between the direct elastic scattering amplitude and the exchange reaction amplitude can be excluded. The data in Figure 2 are proof that rainbow scattering appears in the scattering of these light nuclei and their analysis in terms of an optical model potential is in progress. Previous evidence for rainbow scattering was seen in the symmetrical systems $^{12}C+^{12}C$ and $^{16}O+^{16}O$ and in the same system at lower energy [4].

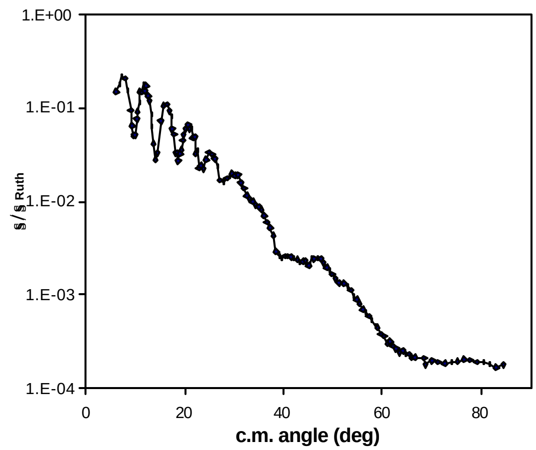

Figure 2. The cross section divided by the Rutherford c.s. The Airy minima are clearly seen.

It is interesting to notice that other reaction channels are more strongly populated (projectile stripping channels mostly) than alpha exchange, with selectivity for states lying high in the continuum, at excitation energies as high as 20 MeV. Excited states were populated in ^{15}O, ^{14}O, ^{15}N, ^{16}N and several other projectile stripping channels. These excitations will be a challenge to understand.

References

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