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Investigating the variation of elastic alpha scattering cross sections in the A $\approx$ 100 region

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Abstract. The elastic scattering cross sections for the reactions ^{110,116}Cd$(\alpha,\alpha)^{110,116}$Cd at energies above and below the Coulomb barrier are measured to provide a sensitive test for the alpha-nucleus optical potential parameter sets. The potentials under study are a basic prerequisite for the prediction of α-induced reaction cross sections, e.g. for the calculation of stellar reaction rates in the astrophysical p- or γ-process. Moreover, the variation of the elastic alpha scattering cross sections along the $Z = 48$ isotopic and $N = 62$ isotonic chain is investigated by the study of the ratios of the of ^{110,116}Cd$(\alpha,\alpha)^{110,116}$Cd scattering cross sections at $E_{c.m.} \approx 15.6$ and 18.8 MeV and the ratio of the ^{110}Cd$(\alpha,\alpha)^{110}$Cd and ^{112}Sn$(\alpha,\alpha)^{112}$Sn reaction cross sections at $E_{c.m.} \approx 18.8$ MeV, respectively. These ratios are sensitive probes for the alpha-nucleus optical potential parameterizations.

1. Motivation

In several astrophysical applications — such as modeling the nucleosynthesis in explosive scenarios like γ process — the reaction rates are taken from statistical model calculations [1]. These calculations utilize global alpha-nucleus optical potential (which combines a Coulomb term with a complex nuclear potential, composed of real and imaginary parts) parameter sets. Considerable efforts have been devoted in recent years to improve the knowledge of the alpha-nucleus optical potential [2, 3, 4, 5, 6, 7]. The extensive use of the statistical model calculations requires experimental tests for these parameter sets. One possible way of testing the different potential parameterizations is to carry out alpha elastic scattering experiments and compare the measured angular distributions to the corresponding predictions from the global potential parameterizations.

Furthermore, a global alpha-nucleus optical potential must be able not only to provide a correct prediction for the elastic scattering cross section but also to describe the variation of the angular distributions along isotopic and isotonic chains. This is especially important for explosive nucleosynthesis scenarios where reaction rates on large number of reactions involving thousands of nuclei have to be taken into account. The reliability of the potential parameterizations can be tested by measuring the elastic scattering cross sections on several nuclei along isotopic and

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isotonic chains and use the ratio of the Rutherford normalized cross sections as a very sensitive observable for the quality of α-nucleus potentials.

2. Experimental approach

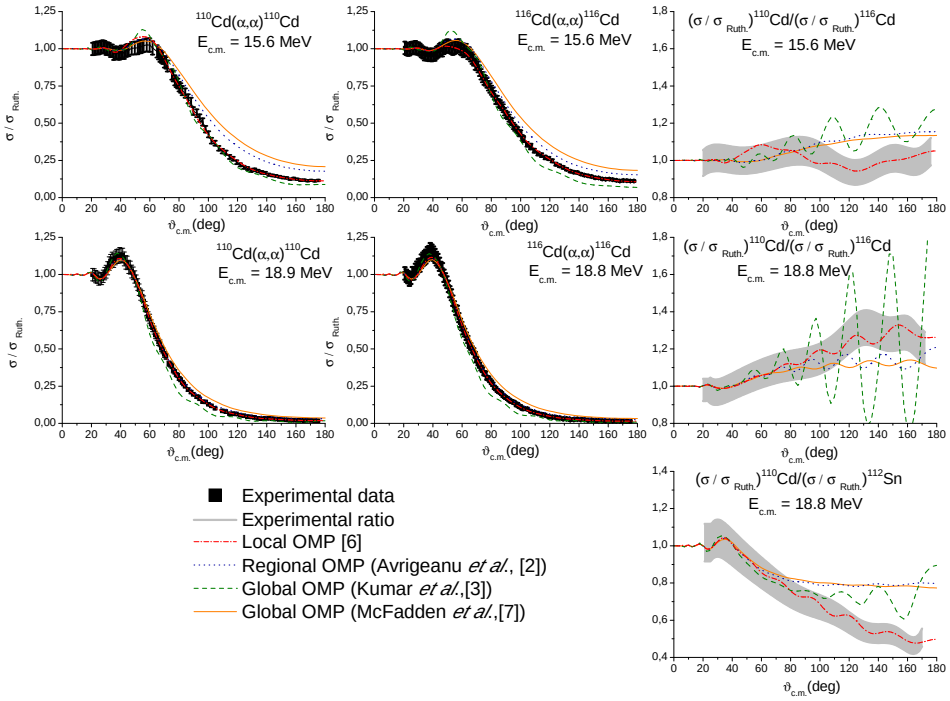


Figure 1. Rutherford-normalized elastic scattering cross sections of the ^{110,116}Cd$(\alpha,\alpha)^{110,116}$Cd reactions at E$_{c.m.}$ $\approx$ 15.6 and 18.8 MeV and experimental ratio (gray area with taken into account the experimental uncertainties) of the measured scattering cross sections at $\approx$ 15.6 MeV and 18.9 MeV versus the angle in center-of-mass frame. The cross sections of the ^{112}Sn$(\alpha,\alpha)^{112}$Sn are taken from [4]. The lines correspond to the predictions using a local[7], a regional [2] and global [3, 8] optical model parameter sets (OMP).

The experiment was carried out at the cyclotron laboratory of ATOMKI, Debrecen (further details on the experimental procedure can be found in [7]). The targets were produced by evaporating highly enriched ($\geq$ 95%) ^{110,116}Cd onto thin carbon foils ($\approx$ 20 μg/cm^2). The target thickness was determined via alpha particle energy loss measurement using radioactive sources and was found to be approximately 200 μg/cm^2. The energies of the alpha beam were 16.14 and 19.46 MeV with typical beam currents of 150-200 pnA. Six ion implanted silicon detectors with active areas of 50 mm^2 mounted on two rotatable turntables were used to measure the angular distributions. In addition, two detectors were mounted at a larger distance on the wall of the scattering chamber at fixed angles ϑ=$\pm$15° left and right to the beam axis. These detectors were used as monitor detectors during the whole experiment to normalize the measured angular distribution and to determine the precise position of the beam on the target.

3. Results and discussion

Complete angular distributions between 20° and 175° were measured at energies of $E_{lab.}$ = 16.14 and 19.46 MeV in 1° (20° $\leq \vartheta \leq$ 100°) and 2.5° (100° $\leq \vartheta \leq$ 175°) steps. On the left side of Figure 1. the Rutherford-normalized cross sections of the ^{110,116}Cd$(\alpha,\alpha)^{110,116}$Cd reactions can be seen. Whereas the Rutherford normalized cross sections cover only about two orders of magnitude between the highest (forward angles at $E_{lab.}$ = 16.14 MeV) and the lowest cross sections (backward angles at $E_{lab.}$ = 19.46 MeV), the underlying cross sections cover more than four orders of magnitude. Over this huge range of cross sections almost the same accuracy of about 4-5% total uncertainty could be achieved. This error is mainly caused by the uncertainty of the determination of the scattering angle in the forward region and from the statistical uncertainty in the backward region.

The behavior of the elastic alpha scattering cross sections along the Cd isotopic (Z=48) chain at $E_{c.m.} \approx$ 15.6 and 18.8 MeV and along the N=62 isotonic chain at $E_{c.m.} \approx$ 18.8 MeV is investigated in this work. Although there are small differences in the center-of-mass energies ($\leq$ 120 keV), the ratios of the Rutherford normalized cross sections are well defined because the dominating $1/E^2$ dependence of the scattering cross section is taken into account during Rutherford normalization. Therefore, the ratios of Rutherford normalized cross sections are a very sensitive test for local, regional and global alpha-nucleus potential parameterizations.

It is found that the ratio of the normalized scattering cross sections shows an oscillation pattern at backward angles (right side of Fig. 1). The large number of experimental points and the low uncertainties on all data sets provide a unique probe to understand the evolution of the alpha nucleus potential along the Cd isotopic chain. In the present work the local potential derived in [7] and the following open access regional and global alpha nucleus optical potential parameterizations are considered: the recent regional potential of Avrigeanu *et al.* [2], the global potential of Kumar *et al.* [3] and the global potential of McFadden and Satchler [8]. No regional or global parameterization can describe correctly the amplitude and the phase of the oscillation pattern of the experimental data at backward angles. This fact indicates that the available theoretical alpha nucleus optical potential parameterizations have to be further improved.

4. Acknowledgments

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