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Elastic and inelastic scattering of $^{13}C + ^{18}O$ versus $^{12}C + ^{18}O$ and $^{13}C + ^{16}O$

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Abstract

Complete angular distributions of the $^{13}C + ^{18}O$ elastic and inelastic scattering were measured at the energy $E_{lab}(^{18}O) = 105$ MeV ($E_{c.m.} = 44.03$ MeV). These and the $^{13}C + ^{18}O$ scattering data taken from the literature at the energies $E_{c.m.} = 6.29$–13.94 MeV were analyzed within the optical model and coupled-reaction-channels methods. Sets of Woods–Saxon $^{13}C + ^{18}O$ optical potential parameters were obtained. The $^{13}C + ^{18}O$ scattering data and deduced potential parameters are compared with those for $^{12}C + ^{18}O$ and $^{13}C + ^{16}O$ previously measured and analyzed. The $^{13}C + ^{18}O$ elastic scattering is well described by potential scattering over its complete angular range. The $^{13}C + ^{18}O$ inelastic-scattering data were well described over the entire angular range as arising from collective excitations of the states in the target and projectile nuclei.

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1. Introduction

While the elastic scattering of light heavy-ions has been studied experimentally and theoretically for fifty years, there are still no generally accepted techniques to determine scattering properties of systems that differ in either energy or mass number away from systems where previous measurements have been made. The advent of intense beams of unstable nuclei have greatly expanded the experimental possibilities and also our ability to understand nuclear potentials as a function of binding energies and internal structures of the interacting nuclei. The study of isotopic effects in the scattering of stable "$i\alpha + j$n" systems such as ^{12}C + ^{18}O, ^{13}C + ^{18}O and ^{14}C + ^{18}O has the potential to provide predictions for the scattering of unstable systems such as ^{15,16}C + ^{17,16}O, ^{13,12}C + ^{19,20}O. In the past, isotopic effects were studied in the ^{12}C + ^{18}O and ^{12}C + ^{16}O scattering at energies $E_{\rm c.m.} = 12.9$–56 MeV [1]. These studies demonstrated the different contributions of transfer reactions in these scatterings at large angles as well as differences in their absorptive potentials. For example, the ^{12}C + ^{16}O absorption potential has a quasi-molecular form at energies $E_{\rm c.m.} < 50$ MeV, that is absent in the ^{12}C + ^{18}O scattering. The quasi-molecular form was found also in a recent study of the energy dependence of the ^{13}C + ^{16}O scattering at energies $E_{\rm c.m.} = 6.3$–57.9 MeV [2].

In the present work, the results of the elastic and inelastic scattering of ^{13}C + ^{18}O at the energy $E_{\rm lab}(^{18}{\rm O}) = 105$ MeV are presented. The use of inverse kinematics in the present experiment makes it possible to measure both forward and backward angle data simultaneously. The present ^{13}C + ^{18}O elastic and inelastic scattering data were then combined with previously measured data at the energies $E_{\rm lab}(^{18}{\rm O}) = 15$, 20, 24 MeV [3], 31 MeV [4] and $E_{\rm lab}(^{13}{\rm C}) = 24$ MeV [5] in optical model (OM) and coupled-reaction-channels (CRC) analyses to obtain parameters of the ^{13}C + ^{18}O scattering potential at a range of energies. Special attention was given to understanding the large angle scattering data, where a significant difference with previous ^{13}C + ^{16}O data was found.

The paper is organized as follows. Section 2 describes the experimental procedure and results of the measurements. Results of the ^{13}C + ^{18}O elastic and inelastic scattering data analysis, energy dependence of the ^{13}C + ^{18}O potential parameters and the ^{13}C + ^{16,18}O isotopic effects are given in Section 3. Summary and conclusions can be found in Section 4.

2. Experimental procedure

Angular distributions for the ^{13}C(^{18}O, X) reactions were measured at the energy $E_{\rm lab}(^{18}{\rm O}) = 105$ MeV using a ^{18}O beam from the Warsaw University cyclotron C-200P. The beam energy spread on the target was about 0.5%. A selfsupporting 500 μg/cm^2 foil of carbon with 90% enriched ^{13}C was used as a target. The reaction products were detected by the silicon $\Delta E(E)$–E-telescopes. The details of the detectors and data accumulation system are given in Ref. [1].

Typical $\Delta E(E)$-spectra measured with the Si telescope composed of a 67 μm ΔE-detector and a 1 mm E-detector are presented in Fig. 1. One can see that individual elements were well resolved and the isotopes of oxygen and carbon were also resolved.