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Excitation of ^{14}C by 45 MeV ^{11}B ions

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Abstract

Angular distributions of the $^{11}B + ^{14}C$ elastic scattering and inelastic scattering for transitions to a few excited states of ^{14}C were measured at $E_{lab}(^{11}B) = 45$ MeV over the full angular range. The data were analyzed within the coupled-channels method. Contributions from one- and two-step transfer reactions were found to be negligible. Quadrupole deformation of the ^{14}C ground state was deduced to be negative, the deformation of the 8.318 MeV (2^+) state was found to be similar to that of the ground state. The single particle model calculations reproduced the experimental data for transition to the 6.094 (1^-) state of ^{14}C much better than the collective model analysis. The fit to this experimental data set was improved when we took into account reorientation of ^{11}B in its ground state and considerably enlarged the radius of the potential binding the neutron to the ^{13}C core. The same

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procedure was tested against the experimental data for transition to the $1/2^+$ (3.089 MeV) excited state of ^{13}C, populated in the ^{11}B + ^{13}C scattering at $E_{\text{lab}}(^{11}\text{B}) = 45$ MeV, with the similar effect.

Keywords: NUCLEAR REACTIONS ^{14}C(^{11}B, ^{11}B), (^{11}B, ^{14}C), $E = 45$ MeV; measured $\sigma(E, \theta)$ deduced optical model parameters. ^{14}C levels deduced deformation parameters, single-particle structure. Coupled-channels analysis.

1. Introduction

Inelastic nucleus–nucleus scattering is a useful tool to study the macroscopic characteristics of nuclei, such as deformation parameters, as well as the microscopic structure of their ground and excited states. Nowadays this question especially concerns nuclei beyond the line of β-stability. For instance, structure of neutron-rich carbon isotopes is recently widely discussed [1–5]. Therefore, the experimental investigation of heavy ion scattering from carbon isotopes, which is the subject of this work, is of particular interest.

The theoretical calculations of Kanada-En'yo and Horiuchi [1], performed in the framework of the antisymmetrized molecular dynamics (AMD) model, predict oblate shapes for the distributions of protons for the even–even carbon isotopes, but different shapes for the neutron distributions depending on the neutron number. The neutron shapes vary from oblate in ^{12}C, ^{18}C, ^{20}C, ^{22}C, spherical in ^{14}C to prolate in ^{10}C, ^{16}C. A sign of the quadrupole deformation of the carbon isotopes is determined by the summary configuration of the proton and neutron distributions. The oblate + oblate, oblate + prolate and oblate + spherical proton and neutron distributions would lead, probably, to negative (^{12}C, ^{18}C, ^{20}C, ^{22}C), positive or negative (^{10}C, ^{16}C) and negative (^{14}C) quadrupole deformations, respectively. However, a positive quadrupole deformation of ^{14}C was found from d(pol) + ^{14}C [6], α + ^{14}C [7] and ^{3}He + ^{14}C [8] inelastic scattering. New experimental data for the ^{11}B + ^{14}C elastic and inelastic scattering at $E_{\text{lab}}(^{11}\text{B}) = 45$ MeV, measured recently at the Warsaw Cyclotron U-200P and analyzed within the coupled-channels method in this work, open an additional possibility to answer the question about the sign of the ^{14}C quadrupole deformation.

Another interesting question is connected with a possible halo nature of the 1^- (6.094 MeV) excited state of ^{14}C, for which a root-mean-square (rms) radius for the valence neutron of 4.57 ± 0.30 fm was obtained [9], 1.84 times larger than the size of the ^{13}C core. Another example of an excited halo state is the $1/2^+$ (3.089 MeV) state of ^{13}C [10]. Its halo properties were predicted in [11]. Moreover, in the paper [12] the rms radius of the last neutron orbital 5.04 ± 0.75 fm was calculated using asymptotic normalization coefficients (ANC) extracted from the ^{12}C(d, p)^{13}C$_{1/2^+}$ experimental cross sections.

In this paper we present the results of a collective model as well as a single particle model analysis of ^{11}B + ^{14}C elastic and inelastic scattering at $E_{\text{lab}}(^{11}\text{B}) = 45$ MeV for transitions to the ground states of ^{11}B and ^{14}C as well as to the 6.094 MeV (1^-), 7.012 MeV (2^+) and 8.318 MeV (2^+) excited states of ^{14}C. The structure of the ground and excited states of ^{14}C is discussed. We also performed an analysis of recently published experimental data for ^{13}C excitation to its $1/2^+$ (3.089 MeV) state, populated in the ^{11}B + ^{13}C