First Observation of the (4He, 8B) Reaction

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The (4He, 8B) reaction on 27Al and 66Zn targets has been studied at E~ = 109 MeV, the first observation of this reaction. Five groups appear in the first 4 MeV of excitation in the 23Ne spectrum, with laboratory differential cross sections ranging from 35 to 384 nb/sr at θlab = 8°. Individual levels in 62Co were not resolved in the exposure on the 66Zn target. However, 8B events were observed which are tentatively attributed to the 66Zn(α, 8B)62Co reaction, since contributions from plausible target contaminants can be eliminated on the basis of Q value. The observed yield at 8° indicates a laboratory cross section of 540 nb/sr summed over the first 4.6 MeV of excitation in 62Co.

1. Introduction

One of the methods which has often been used to determine the masses of nuclides away from the line of stability is the direct observation of reactions which remove several nucleons of the same kind from the target. For example, such reactions as (3He, 6He) and (4He, 8He), which involve the transfer of neutrons, have been extensively used to measure the masses of light and medium-weight neutron-deficient nuclides.

For various experimental reasons, much less work has been done using reactions which transfer several protons, although multiple-proton transfer reactions induced by heavy ions have been observed in a few cases [1–3]. Among the possible light-ion induced reactions, the (4He, 8B) reaction, which removes three protons and a neutron from the target, could in principle be used to study several presently unknown neutron-rich nuclides, beginning at A ≈ 45. However, the (4He, 8B) reaction suffers from some serious experimental disadvantages as a vehicle for mass measurements. In comparison with the aforementioned neutron-transfer reactions, the contributions to line widths from target thickness are greatly increased by the difference in charge between the projectile and ejectile. This difficulty is exacerbated by the large negative Q values, typically at least −30 MeV on neutron-rich targets. In addition, the transfer of an odd number both of protons and neutrons leads to odd-odd residual nuclei with their more complicated level schemes, when the more abundant even-even targets are used. Still, given a reasonable cross section, the (4He, 8B) reaction might be expected to yield some useful information about certain nuclides which are difficult to reach in any other way.

To our knowledge, the (4He, 8B) reaction has never previously been observed, although an unsuccessful attempt to measure the mass of 56Mn via the 64Ni(4He, 8B)60Mn reaction has been reported [4]. In the present communication, we present some data for the (4He, 8B) reaction on 27Al and 66Zn targets, at a bombarding energy of 109 MeV. Neither of the residual nuclides, 23Ne and 62Co, is of interest from a mass measurement point of view, since each mass is well known. However, the Q values for these reactions (−32.5 MeV and −27.8 MeV for the aluminum and zinc targets respectively) are roughly comparable to those for some neutron-rich targets of interest. In addition, the low-lying level structure of 23Ne is fairly well known, so that some insight may be gained into the selectivity of the reaction. The purpose of this paper is to provide an approximate guide to the yield which might be expected in mass measurement experiments under similar conditions.

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**Fig. 1.** A two-dimensional display of energy loss ($\Delta E_2$) versus the energy ($E$) measured at the spectrograph focal plane, for events induced by 109 MeV $\alpha$ particles incident on an $^{27}$Al target. Note that relative to the remainder of the figure, the vertical scale in the region containing the $^8$B group (upper right) is expanded by a factor of 100, while it is compressed by a factor of 16 in the vicinity of the intense $^4$He group.

2. Experimental Procedure

Measurements were made of $^8$B spectra at $\theta_{lab} = 8^\circ$, from $^{27}$Al and $^{66}$Zn targets bombarded with 109.0 MeV alpha particles at the Indiana University Cyclotron Facility. The aluminum target consisted of two stacked, self-supporting foils totaling 413 $\mu$g/cm$^2$ in thickness. The zinc target was fabricated by evaporating $^{66}$Zn, 765 $\mu$g/cm$^2$ thick and enriched to 98.8% onto a 30 $\mu$g/cm$^2$ carbon backing.

The $^8$B ejectiles were momentum-analyzed in a magnetic spectrograph and detected in a position-sensing gridded ionization chamber placed at the focal plane of the spectrograph. The solid angle subtended by the spectrograph aperture was 3.3 msr. The design of the ionization chamber was based on one developed at Argonne [5]. The essential feature of such a detector is that the position sensing wire proportional counters and the electrodes used for differential energy loss measurements are all contained in the same gas volume, separated by grids from the region in which the incident ions are stopped. The parameters measured included an initial position measurement ($X_1$), two sequential differential energy loss measurements ($\Delta E_1$), and ($\Delta E_2$), a second position measurement ($X_2$), and the energy ($E$). These parameters were recorded in event mode and simultaneously sorted on-line. The two position measuring elements each consisted of a single-wire proportional counter using a carbon-coated quartz fiber. Positions along the fiber were determined using the Borkowski-Kopp rise-time scheme [6]. A third proportional counter mounted at the rear of the detector was used to veto passing particles.

The measured values of $E$ and either of the $\Delta E$ signals, together with knowledge of the spectrograph setting $Bp_0$, were sufficient to cleanly and unambiguously distinguish the $^8$B ions from other species. Redundant information from the other $\Delta E$ measurement and the second position measurement $X_2$ was also available for background rejection; however, a display of $\Delta E_2$ vs. $E$ showed the background in the vicinity of the $^8$B group to be quite small under actual operating conditions. A two-dimensional display of $\Delta E_2$ vs. $E$ obtained during a run on the aluminum target is shown in Fig. 1.

3. Results and Discussion

3.1. The $^{27}$Al($^4$He, $^8$B)$^{23}$Ne Reaction

In Fig. 2, we show a spectrum from the $^{27}$Al($^4$He, $^8$B)$^{23}$Ne reaction at $\theta_{lab}=8^\circ$, obtained from the first of the two position measurements ($X_1$). This spectrum is a composite of two overlapping settings of the spectrograph magnetic field, with events from the second exposure shifted in position to compensate for the different field setting. The range of $Q$ values covered extends from approximately 2.5 MeV above the ground state energy to 4.5 MeV of excitation in $^{23}$Ne, or from $Q=-30$ to $-37$ MeV. Although no special effort was made to calibrate the spectrograph and beam analysis magnets for this particular experiment, the ground state peak appeared within 150 keV of its calculated position, as-

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**Fig. 2.** A spectrum observed for the $^{27}$Al($^4$He, $^8$B)$^{23}$Ne reaction at $8^\circ$. The positions of known states in $^{23}$Ne are indicated by arrows. The ordinate represents the number of counts observed per 2,500 $\mu$C integrated charge, in order to adjust for differing beam exposure in different parts of the spectrum.