Study of (e, e' Φ) Reaction on ^9Be (I.
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Study of (e,e' α) Reaction on ⁹Be

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The (e,e' α) cross section has been measured at energy transfers from 10.0 to 28.4 MeV and a momentum transfer of 99 MeV/c, using a 197 MeV continuous electron beam. The cross section rapidly increases with decreasing energy at angles smaller than 25°, while it appears flat at larger angles. The forward-peaked angular distribution was observed below 18 MeV, and the forward peak shrinks at higher energies. An amount of α particles from decay of ³He is estimated.

§ 1. Introduction

There has been a growing interest in the study of neutron-halo and neutron-skin structure. Very recently, the RI Beam Factory project has started at RIKEN to explore this subject. The nucleus ¹¹Be is known as a neutron-halo nucleus [1], and there are several microscopic and macroscopic attempts at describing Be isotopes in a unified framework of two α particles and extra neutrons. The ⁹Be nucleus is the simplest isotope, which has one extra neutron, and is known to have a typical α+α+n cluster structure. Therefore the nucleus has already been investigated in various models.

The photo-disintegration of ⁹Be is categorized in three separate mechanisms: (1) threshold to 5 MeV, where sharp resonances correspond to direct excitations of the unpaired neutron; (2) 5-18 MeV, where weak coupling of the unbound neutron to ⁹Be dominates; (3) above 18 MeV, where a core is excited. The photo-nuclear reaction has been investigated in the (γ, n) [2-5], (γ, p) [6], (γ, d) [6], (γ, t) [6] and (γ, ³He) [6] channels. However, no (γ, α) cross section has been measured, presumably because the decayed α particles of ⁵He that partly overlap on the spectrum make the analysis difficult. The threshold of the (γ, α) reaction is 2.53 MeV; this is the only charged-particle emission channel below 16 MeV. The cross section is expected to be large enough for measurement.

The residual nucleus ⁵He of the ⁹Be (e,e' α) reaction is same as the ⁶Li (e,e'p) reaction, which we investigated several years ago [7]. However, the missing energy spectra of both reactions may be different from each other, because they reflect their reaction mechanisms. We measured ⁹Be (e,e' α) cross section at eleven angles at transferred energies between 10.0 and 28.4 MeV as a test experiment.

§ 2. Experimental procedure

The experiment was performed using a 197 MeV continuous electron beam from a stretcher-
booster ring (STB). Electrons scattered with a 1.8 mg/cm² thick natural beryllium foil were analyzed with a magnetic spectrometer (LDM) at 30°. Missing energies were set at two energies: phase 1 (10.0 ~ 21.0 MeV), phase 2 (17.6 ~ 28.4 MeV). Corresponding momentum transfers are 98.60 MeVc for phase 1 and 99.10 MeVc for phase 2. Ejected α particles were measured with eleven SSD counter telescopes composed of two surface-barrier type SSD's (one 50 μm SSD + one 1 mm SSD at eight angles, and two 1 mm SSD's at three angles), out-of the scattering plane (φ α = 90°). The solid angle of the telescopes is 4.8 msr. Due to insufficient machine time, no measurement between 90° and 180° was made in this run.

§ 3. Results and Discussion

Figure 1 shows missing energy spectra at the momentum transfer direction: a peak at 2.5 MeV corresponds to α particle emission leaving the residual nucleus at the ground state of ³He. A tail toward higher missing energies is observed in the spectrum for the lower energy transfer region; more structures can be seen in the spectrum for the higher energy transfer region. Considering a resolution of the experiment, events below E m = 7 MeV were treated as α events.

![Fig.1](image)

Fig.1. Missing energy spectra at 0°. A peak at 2.5 MeV corresponds to (e,e' α) reaction.

A transferred energy dependence of the differential (e,e' α) cross sections is shown in Fig.2. At forward angles, the cross section becomes larger as the energy decreases; while no such rise can be seen at backward angles. Angular dependence of the differential cross section is shown in Fig.3. At low energies, a strong forward peaking is observed; data at backward angles are lacking because energies of the α particles are lower than the threshold energy of the detectors there.

In the (e,e' α) ³He reaction, the residual nucleus ³He decays into n + α; this α particles partly overlap on the α particles of the (e,e' α) ³He reaction. Simulated missing energy spectra of both α particles are demonstrated in Fig.4. In this calculation several assumptions were made:

1) The angular distribution of the ³Be (e,e' α) ³He reaction has a forward-backward symmetry in the center of mass system; Legendre parameters has been obtained by fitting the measured angular
distributions with even-order Legendre functions up to \( l = 4 \).

(2) The angular distribution of the \( \alpha \) particle due to \( \alpha + \alpha + n \) decay of \(^{5}\text{He}\) is isotropic in the center of mass system.

The lowest peak in Fig.4 corresponds to \( \alpha \) particles from the \(^{9}\text{Be} \ (e,e' \alpha) \) \(^{5}\text{He}\) reaction; the higher missing-energy part of two-peaked structure corresponds to decay products of \(^{5}\text{He}\). Alpha-particles emitted toward the detector direction make the lower peak, while those to the opposite direction do the higher peak. The structure changes slowly at other angles. The two-peaked structure shifts toward higher missing-energies as the transferred energy \( \omega \) increases. The missing energy spectra folded in the regime of the measurements are shown in Fig.5, where the structure is smeared in resolution (1 MeV FWHM). A tail in higher energy part for \( \omega = 10 \sim 21 \) MeV in Fig.1 is reproduced in this

![Graphs showing angular distributions](image)

**Fig.2.** The \(^{9}\text{Be} \ (e,e' \alpha,\omega) \) differential cross sections.
simulation. In case $\omega = 17.6 \sim 28.4$ MeV, the part $E_m > 10$ MeV cannot be reproduced in the simulation although the measured spectrum has large statistical errors. It may be a contribution of $\alpha$ particles from the $^9$Be $(e,e'\alpha)$ reaction.

We wish to thank the accelerator group and the computer group for their assistance during the measurements.

Fig.3. Angular distributions of the $^9$Be $(e, e'\alpha)$ reaction.
Fig. 4. Simulated missing energy spectra of the $^8$Be ($e, e' \alpha$) reaction (a peak at $E_m = 2.5$ MeV) and the $\alpha$ emission from $^8$He (two-peaked part at higher missing energies).

Fig. 5. Simulated missing energy spectra folded in the regime of the measurements, which are smeared with a resolution of 1 MeV FWHM.
References