Investigation of States in $^{17}$F by the $^{15}$N($^3$He, $n$)$^{17}$F Reaction*

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The absolute differential cross sections for several levels in the $^{15}$N($^3$He, $n$)$^{17}$F reaction were measured at laboratory scattering angles from 0 to 140 degrees using neutron time-of-flight techniques. Angular distributions were obtained at effective helium bombarding energies of 3.8 and 4.8 MeV. A new state was identified at $5.18 \pm 0.02$ MeV excitation energy which is probably the analogue of the 5.217 MeV state in $^{18}$O. Spectroscopic factors were obtained for the low-lying states using distorted wave method calculations.

1. Introduction

The mirror nuclei $^{17}$O and $^{17}$F have been the object of extensive experimental and theoretical investigations because of the simplicities expected from a single nucleon outside the doubly magic closed shell nucleus $^{16}$O. Although a number of the low-lying levels display the large reduced width characteristic of a single particle state, the true situation is more complex as other low excitation states apparently mix many particle-hole configurations. Of particular interest in the present investigation was the sixth excited state of $^{17}$O ($E_x = 5.22$ MeV) for which no counterpart in $^{17}$F had been reported in the literature until recently [1–3]. With the exception of the sixth excited state of $^{17}$O the energy level parameters [4] of $^{17}$O and $^{17}$F nearly coincide through the first twelve excited states (6 MeV excitation energy). The 5.22 MeV state of $^{17}$O is weakly excited in the $^{16}$O($d$, $p$)$^{17}$O reaction [5], but is moderately excited in the $^{15}$N($^3$He, $p$)$^{17}$O [6], $^{14}$N($\alpha$, $p$)$^{17}$O [7], $^{13}$C($^6$Li, $d$)$^{17}$O and $^{13}$C($^7$Li, $t$)$^{17}$O [8] reactions. It has such a small neutron width ($\Gamma < 0.1$ keV) that it is not observed in the $^{16}$O($n$, $n'$)$^{16}$O reaction [9] and displays no stripping pattern in the $^{16}$O($d$, $p$)$^{17}$O reaction [5]. Since the 5.22 MeV state in $^{17}$O is moderately populated in the $^{15}$N($^3$He, $p$)$^{17}$O reaction, the $^{15}$N($^3$He, $n$)$^{17}$F reaction should be a promising way to observe the mirror state. If the cross sections were of

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the same order of magnitude in the mirror reactions, it would be experimentally possible to identify the neutrons resulting from the population of the mirror state in $^{17}F$. Such a state was identified in $^{17}F$ at $5.18 \pm 0.02$ MeV [1]. The results of three recent experiments [1–3] give a more precise value of $5.213 \pm 0.010$ MeV. (The excitation energy will henceforth be quoted as 5.21 MeV in this paper.)

Further justification for performing the present measurement was to study other states in $^{17}F$. Many of the states had only been identified as compound nucleus (CN) states in the $^{16}O(p, p)^{16}O$ elastic scattering reaction [10]. The present measurement confirms their existence and excitation energy assignments. The $^{15}N(^{3}He, n)^{17}F$ reaction should preferentially populate $2p - 1h$ states in $^{17}F$. The character of $^{17}O$ states has been extensively investigated, and an investigation of the mirror analog states is useful, since the mirror state configurations should be similar.

2. Experimental Method

Pulsed singly-charged helions were obtained from the University of Virginia CN Van de Graaff accelerator and bunched with a Mobley magnet bunching system. Neutron spectra were obtained using time-of-flight techniques. Details of the experimental apparatus and procedures are given elsewhere [11].

The neutron detector consisted of a 12.7 cm diameter by 3.8 cm thick cell of NE 213 liquid scintillator coupled to a RCA model 4522 photomultiplier tube. Pulse shape discrimination was used to differentiate between neutron and $\gamma$-ray induced pulses. The low energy neutron bias was set at a pulse height equivalent to that produced by the 60 keV photopeak of $^{241}Am$. The absolute efficiency of the neutron detector was determined with the computer program DETEFF [12] and was checked with efficiencies determined from measurements of the $^{2}H(d, n)$ $^{3}He$ reaction using gas targets of known thicknesses and the known absolute differential cross sections [13]. Both neutron and $\gamma$-ray spectra were recorded and stored on magnetic tape enabling a check of the $n-\gamma$ discrimination.

The $N_2$ gas was contained in a cylindrical cell 2 cm long by 0.95 cm diameter. The gas was separated from the high vacuum by a 2.3 $\mu$m Mo foil. The gas cell is described in more detail elsewhere [14]. Data were taken with and without gas, and the background runs were subtracted to obtain the neutron spectra from the $N_2$ gas. The only observed neutron spectra from impurities other than $^{14}N$ were occasional small peaks from $^{12}C$ and $^{16}O$. The $N_2$ gas was enriched to greater than 96.5% $^{15}N$ and was used at a pressure of approximately 60 Torr.