THE (α,p) REACTION ON ^{12}C, ^{13}C, AND ^{14}N

S.M. Aziz
Indiana University Cyclotron Facility, Bloomington Indiana 47405

J.D. Brown, L.K. Herold, K.E. Luther, A. Middleton, M.L. Pitt
Department of Physics, Princeton University, Princeton, New Jersey 08544

D. Barker
Department of Physics, Rutgers University, Piscataway, New Jersey 08854

H.S. Camarda
Department of Physics, Pennsylvania State University
University Park, Pennsylvania 16802

Recently we have studied ^{14}N, ^{15}N, ^{16}O(p,π^+) reactions, searching for 2p-1h high-spin states with configurations $|\, Target * (p_{1/2})^{-1}(d_{5/2})^2\rangle$ and $|\, Target * (p_{3/2})^{-1}(d_{5/2})^2\rangle$. These configurations lead to a maximum spin $13/2^-$ in ^{17}O, 7^+ in ^{16}N, and $15/2^-$ in ^{15}N. The reactions lead to strong states at 15.80 MeV in ^{17}O, 14.15 MeV in ^{16}N, and 21.50 MeV in ^{15}N[1]. The systematics of the states, strength, cross section shape, and analyzing power, as well as a weak coupling calculation, lead to the belief that they are the stretched states with the configuration $|\, Target * (p_{3/2})^{-1}(d_{5/2})^2\rangle$. If the spin identifications and transition structures are right, then they should not be expected to be excited by ^{12}C, ^{13}C, ^{14}N(α,p) reactions; these strongly excite states with $|\, Target * (d_{5/2})^3\rangle$ configurations. In addition, those reactions are interesting in themselves, since the high excitation energy region has not been studied in the final nuclei, ^{15}N, ^{16}N, and ^{17}O.

The experiments were run at the Princeton Cyclotron Laboratory, using E_α= 48 MeV on enriched targets. The QDDD magnetic spectrometer was used to detect protons. The energy resolution was about 30 keV. Because of the small acceptance of the spectrometer, many field settings were necessary in order to cover a broad range of excitation energy.

A melamine target was used for the ^{14}N(α,p) reaction. Figure 1 shows a typical ^{14}N(α,p)^{17}O spectrum. The spectrum is a sum of four bites (each bite covers about 2 MeV of excitation energy). The dark states are ^{15}N states, while the others, in ^{17}O, are at E_x= 10.49, 12.26, 13.58, 14.41, and 14.87 MeV. No states were found at higher excitation. The 13.58- and 14.87-MeV states are strongly excited. The 13.58-MeV state was identified in a ^{13}C(^{6}Li,d) reaction[2] as 4p-3h ($11/2^-$, $13/2^-$). The 15.78- and 17.10-MeV states seen in the ^{16}O(p,π^+) reaction are not observed in the present work.

The high-excitation energy region in ^{16}N is studied by the ^{13}C(α,p)^{16}N reaction. Excited states in that reaction are shown in Figure 2. The figure is a sum of many bites, each one covering about 1.5 MeV of excitation energy. The spectrum is similar, in general, to that of the same reaction done at E_α= 35 and 118 MeV by Hammel, et al.[3], and Andrew, et, al[4], respectively. There are two strong peaks at 11.08 and 11.70 MeV, identified as 3p-3h states with spin of 6^- and 7^-, respectively[3,4]. At higher excitation energy there are also strong states at 13.24 and 14.30 MeV. The strength of the 13.24-MeV state is comparable to those of the high-spin 11.08- and 11.70-MeV states. The

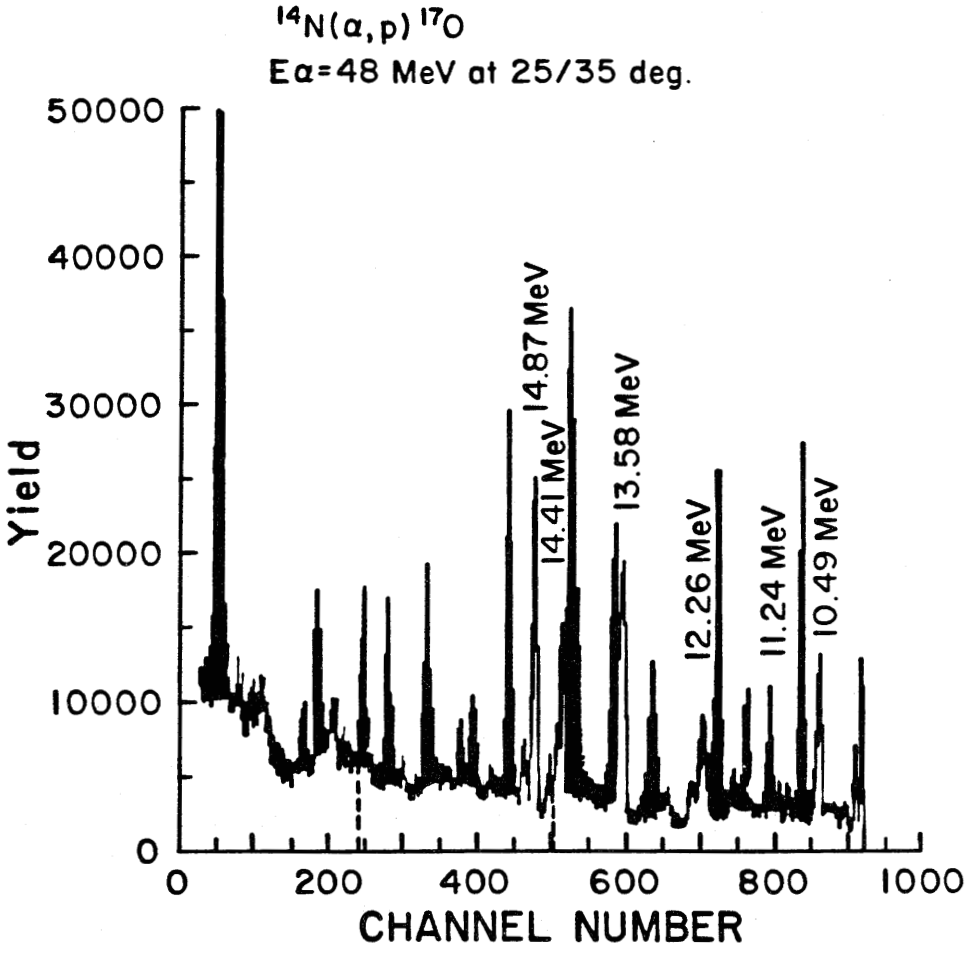

Figure 1. Energy spectrum for the $^{14}N(\alpha,p)^{17}O$ reaction. The area between channel 240 and 500 was taken at 35°.

14.30-MeV state is slightly weaker than the others. The large strength of the 13.24-MeV and 14.30-MeV states (with respect to the high-spin states, 7^- and 6^-) is surprising because it has not been observed in the other reactions[3,4]. The strength of the 13.24- and 14.30-MeV states indicates they are also 3p-3h high-spin states. There are other weak states excited at 14.84, 15.99, 16.73, and 20.89 MeV. A comparison between the two spectra $^{13}C(\alpha,p)^{16}N$ and $^{15}N(p,\pi^+)$, shows that the two states, 14.15 and 16.00 MeV, are not observed strongly in the $^{13}C(\alpha,p)^{16}N$ reaction. This agrees with the hypothesis that the 14.15-MeV and 16.00-MeV states are mostly 2p-2h with a hole in the $p_{3/2}$ shell. States with such a configuration are unlikely to be excited in $^{13}C(\alpha,p)$.

The $^{12}C(\alpha,p)^{15}N$ reaction has been studied previously[3], but not to such a high excitation energy. It was necessary to run this experiment to determine the contamination in

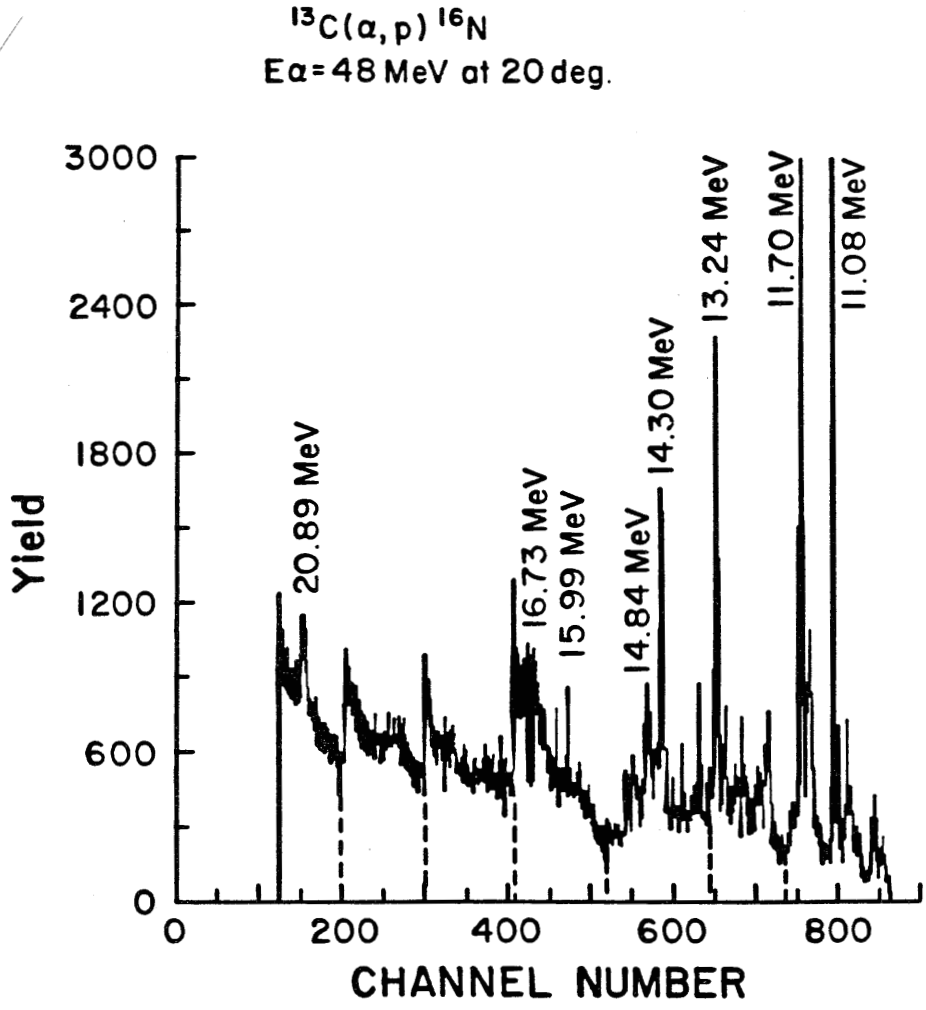

Figure 2. Energy spectrum for the $^{13}C(\alpha,p)^{16}N$ reaction.

the $^{14}N(\alpha,p)^{17}O$ reaction. The $^{12}C(\alpha,p)^{15}N$ spectrum is shown in Fig. 3. The hydrogen contaminant is around 10 MeV. There are three strong states excited at 15.38, 16.05, and 17.92 MeV and there are other weak states at higher excitation energy. The 15.38-MeV state has been identified as a 3p-4h $13/2^+$ state, but the others have not been discussed in the previous work[3]. The strength of the 16.05- and 17.92-MeV states indicates that they are also high-spin 3p-4h states. As the spectrum shows, there is a weak state at 21.6 MeV and we are not sure that it is the 21.50-MeV state seen in the $^{14}N(p,\pi^+)$ reaction.

The $^{12,13}C(\alpha,p)^{15,16}N$ reactions are done in the present work with a slightly higher beam energy than that of Hamill[3], but certain excited states (16.05- and 17.92-MeV in ^{15}N, and 13.24- and 14.30-MeV in ^{16}N) are strongly populated. This leads to the conclusion that those states are very sensitive to the beam energy involved in the reactions.

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2. M.E. Clark, K.W. Kemper, and J.D. Fox, Phys. Rev. C **18**, (1978) 1262.
3. J.J. Hamill, et al., Nucl. Phys. A**408** (1983) 21.
4. P.R. Andrews, et al., Nucl. Phys. A**459** (1986) 317.

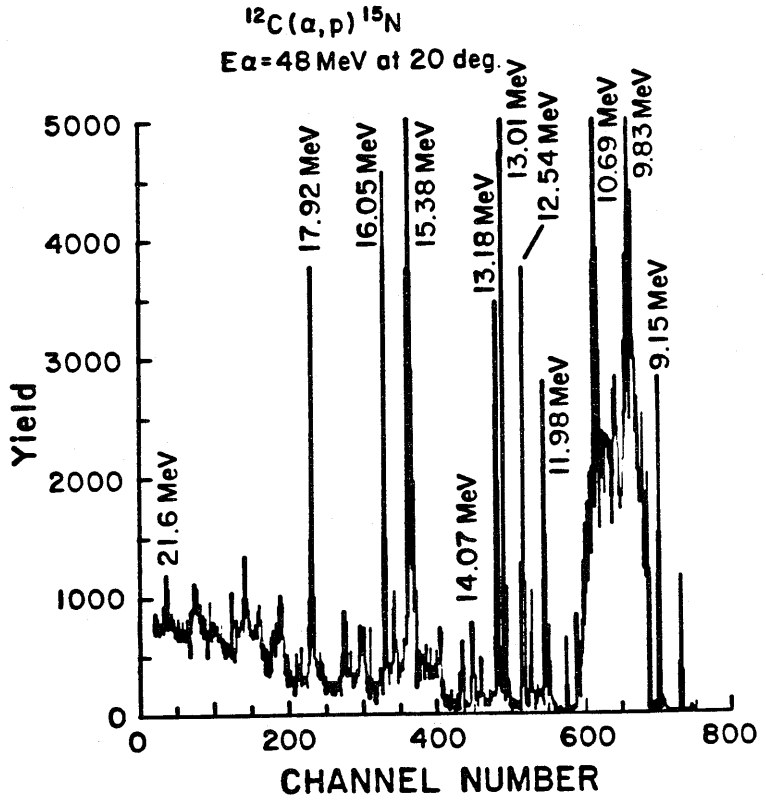

Figure 3. Energy spectrum for the $^{12}C(\alpha,p)^{15}N$ reaction.