PROTON-CAPTURE GAMMA RAYS FROM NITROGEN-13†

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From a recent experiment in this laboratory (Shute *et al.* 1962) on the elastic scattering of protons from ^{12}C, resonance levels ($E_{^{13}N}$, J^{π}) of ^{13}N were obtained at the laboratory bombarding energies (E_p) shown in Table 1. To confirm these results, an investigation of the yield and angular distribution of gamma rays from the reaction $^{12}C(p,\gamma_0)^{13}N$ and $^{12}C(p,\gamma_1)^{13}N$ was undertaken. Accordingly, the theoretical angular distributions, $W(\theta)$, for the gamma ray (γ_0) to the ground state of $^{13}N(\frac{1}{2}^-)$ and also for the gamma ray (γ_1) to the 1st excited state of $^{13}N(\frac{1}{2}^+)$ were evaluated on the assumptions that overlap of levels in ^{13}N is small and lowest order multipoles are involved. As angular distributions are parity insensitive, these were found to be identical for the two gamma rays expected. The simpler of these angular distributions are also shown on the table. The expected angular distributions indicate that 90° is a suitable angle for yield curves.

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Attempted detection of these gamma rays was by means of a 5 in. diameter and 6 in. thick sodium-iodide crystal with matched photomultiplier, the whole being enclosed in a 4 in. lead shield containing a 2 in. collimating aperture. After amplification, the pulses were analysed in a T.M.C. 256-channel pulse-height analyser. Pile-up effects were minimized by the use of a new clipping-line termination (Garwin and Penfold 1960).

The spectra obtained showed the intense 4·43 MeV gamma ray produced from the inelastic scattering of protons to the 1st excited state in ^{12}C. This was used as a calibration point and established the energy scale for the expected capture gamma rays. A weak peak at about 6·5 MeV was observed and its magnitude was consistent with neutron production from the reaction ^{13}C(p,n)^{13}N with subsequent radiative capture of the neutrons in the iodine of the crystal. The ^{13}C arises from the 1% abundance of this isotope in natural carbon.

TABLE 1

LEVEL PARAMETERS OF ^{13}N AND UPPER LIMITS TO ^{12}C(p,γ)^{13}N CROSS SECTIONS

E_p (MeV)	$E_{^{13}\mathrm{N}}$ (MeV)	$J\pi$	$W(\theta)$	σ(p,p′) (mbn/st)	σ(p,γ_0) (μbn/st)	σ(p,γ_1) (μbn/st)
6·6	8·0	3/2+	5—3 cos² (θ)	4	<2	<4
7·53	8·89	1/2−	isotropic	16	<2	<10
8·17	9·48	3/2−	5—3 cos² (θ)	19	<2	<2
9·14	10·38	7/2−	complex	24	<2	<2

No evidence for the presence of either γ_0 or γ_1 was found and as the detector efficiency is approximately known at these energies (Nordhagen 1961) a limit was placed on the differential cross sections, σ(p,γ_0) and σ(p,γ_1), by a simple comparison with the known differential cross section, σ(p,p′) for inelastic scattering (McKenna and Shute 1961; Adams *et al.* 1962). These limits are shown in Table 1.

These results are in agreement with the Houston work of Reich, Phillips, and Russell (1956), who investigated the region below these resonances. However, there is a marked disagreement with the work of Cohen (1955). In this latter experiment an activation technique was used in which ^{13}N activity was counted; although a substantial correction for the production of ^{13}N from the ^{13}C(p,n)^{13}N reaction was included, the cross section obtained was about 2 orders of magnitude greater than that reported here. As the experiment reported here did not have the same bombardment energies and target techniques as Cohen's, a similar activation experiment to his is now in progress in this laboratory.

A confirmation of the discrepancy is also given by the inelastic scattering experiment of the Florida group, Adams *et al.* (1962), who noted the absence of gamma rays higher in energy than the 4.43 MeV ray being investigated. However, their limits of detection are an order of magnitude higher than the present ones.

When the activation experiment is completed, an attempt will be made to lower these limits of detection by the use of isotopically enriched targets, lower beam currents, faster electronics, or more extensive shielding. Moreover, no comparison with predictions for radiative widths obtained from the ^{13}N models described in the elastic scattering paper (Shute *et al.* 1962) will be made until then.

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