LETTERS TO THE EDITOR

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Communications should not in general exceed 600 words in length.

Cross Section of the Reaction $N^{15}(p,\alpha)C^{12}$

Of the four reactions in the "carbon cycle" which is assumed to supply the energy in ordinary stars,[1] the three $p-\gamma$ reactions have been investigated and their cross sections measured. The reaction $C^{12}(p,\gamma)N^{13}$ has been studied by Roberts and Heydenburg,[2] $C^{13}(p,\gamma)N^{14}$ by Dee, Curran and Petržílka,[3] and $N^{14}(p,\gamma)O^{15}$ by Curran and Struthers.[4]

This letter is a report of the measurement of the last reaction of the cycle;[5] *viz.*, $N^{15}(p,\alpha)C^{12}$. The experimental arrangements were the same as used in the previously reported work on the deuteron disintegration of nitrogen.[6] The protons striking the aluminum foil separating the target gas from the cyclotron tank had an energy of 0.70_5 Mev. According to the measurements of Parkinson, Herb, Bellamy and Hudson[7] the stopping power of aluminum for protons between 0.7 and 0.4 Mev is about 8 percent less than for Po alphas which were used for calibrating the foils. Therefore the foil used, of 0.86_8 cm air equivalent according to the calibration, had an actual equivalent of 0.80 cm air (15°C, 760 mm). The target of 30 percent N^{14} and 70 percent N^{15} had a thickness of 0.046 cm of air at 0°C, 760 mm Hg. The energy of the protons in the center of the target chamber was then 0.36 Mev. The ionization chamber with a collimating face subtended 0.0088 steradians of the total solid angle about the target volume.

In order to be certain that the $N^{15}(p,\alpha)C^{12}$ reaction was the one taking place the range of the alphas was measured and found to be 2.5_7 cm (15°C, 760 mm). The range to be expected from the Q value, 4.79 Mev, calculated from mass values is 2.37 cm. From the Q value observed by Burcham and Smith,[5] *viz.*, 5.00 Mev, a range of 2.50 cm would be expected. This is a sufficiently good check considering the uncertainty in the value for the proton energy. A target of N^{14} alone gave no alphas. This last fact and the reasonable check of the range make it virtually certain that the alphas came from the $N^{15}(p,\alpha)C^{12}$ reaction.

The yield was obtained by taking a number distance curve with a thyratron bias low enough to count all alpha-particles having 3 mm or more of their range in the ionization chamber. The current of protons ($\sim 0.3\mu$a) striking the target was integrated by means of a circuit described by Herb, Kerst and McKibben.[8] The total yield in 4π solid angle was 2.3×10^{-8} alpha per proton at 0.36 Mev with a target containing 3.78×10^{19} N^{15} atoms/cm³ at 0°C, 760 mm Hg and 0.046 cm thick (air equivalent at 0°C, 760 mm). From these figures the cross section of the $N^{15}(p,\alpha)C^{12}$ reaction is calculated to be 1.3×10^{-26} cm² at 0.36 Mev.

Theoretically, we may safely assume that the p,α reaction is by far the most probable reaction which can be caused by the collision of a proton with N^{15}. Then its cross section should be[9]

$$\sigma = \pi \lambda\!\!\!^{-2} 2\pi\kappa b e^{-2G} S, \qquad (1)$$

where $\lambda\!\!\!^{-}$ is the wave-length of the incident protons, κ the absolute value of its "wave number" at the surface of the nucleus, b the range of the nuclear forces, e^{-2G} the Gamow penetrability factor, and S a factor taking into account the effect of orbital momenta different from zero. For 0.36 Mev, we have $\lambda\!\!\!^{-} = 7.6\times 10^{-13}$ cm, $2\pi\kappa b = 1.7_5$ and $e^{2G} = 430$, assuming a nuclear radius $R = 1.5\times 10^{-13}\times 16^{\frac{1}{3}} = 3.8\times 10^{-13}$ cm which corresponds to a barrier height of 2.6 Mev. S can be calculated from the rules given by Bethe[10] and comes out about 1.25. Therefore the theoretical cross section from (1) is 0.9×10^{-26} cm², in very satisfactory agreement with the rather rough experimental value.

For a comparison with other astrophysical reactions, it may be most convenient to calculate the "effective width" Γ used in reference 1 Eq. (11). From the measured cross section we obtain $\Gamma = 1.0\times 10^{7}$ ev which classes $N^{15}(p,\alpha)C^{12}$ among the most probable nuclear reactions. The lifetime of a N^{15} nucleus at the center of the sun is then only about 20 years, provided no resonance effects influence the cross section. Moreover, the branching ratio between the reactions $N^{15}(p,\alpha)C^{12}$ and $N^{15}(p,\gamma)O^{16}$ is probably of the order 10^6 rather than 10^4 as assumed in reference 1 (p. 446), which means that in each completed carbon cycle only about one nucleus in a million is lost to the cycle. An account of the astrophysical consequences will be published in the *Astrophysical Journal.*

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