^{13}C (P,N) REACTION AS A NEW SOURCE OF FAST NEUTRONS, ESPECIALLY FOR THERAPY

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Abstract

The total neutron yield from a thick ^{13}C target, through the (p,n) reaction, has been estimated and presented in a graphical form. From this yield curve the intensity of neutrons being produced by a thick, moderately-thick or even a thin target, under known bombarding conditions, can be directly obtained. It is suggested that the ^{13}C (p,n) reaction can be used as a cheap and simple source for fast neutron production, even for therapy.

1 INTRODUCTION

Due to its extraordinary stability and low-neutron production cross section, especially under proton bombardment, natural carbon (consisting of 98.89 % ^{12}C and 1.11 % ^{13}C) is an excellent material for target-backings, beam-dumps and collimators for neutron producing reactions in cyclotrons at high beam intensities.

Based on these characteristics of carbon it is suggested that ^{13}C, where the neutron production cross section is much higher under proton bombardment than that of natural carbon, could be a useful neutron producing target. However, there is very little data available on (p,xn) cross sections on ^{13}C or neutron yields from this reaction under proton bombardment at energies higher than 10 MeV. We have used the data of Krasnov et al on the yields of ^{13}N in order to estimate the thick target total neutron production from the reaction ^{13}C (p,n) ^{13}N from threshold to up to 23 MeV, and extrapolated the results to 75 MeV in order to cover the energy range of interest in neutron therapy facilities.

2 SUGGESTED TARGET DESIGN

About 99,9 % enriched C-13 is easily available at moderate costs in powder form. Any desired thickness of enriched ^{13}C can be pressed into a groove of natural carbon-block, with no soldering or brazing required. This ^{13}N target being a conductor and having very high melting temperature should be capable of very good heat dissipation and withstanding high beam currents and thus producing more intense neutron beams. Furthermore, unlike some other neutron producing targets being currently used (such as Ba, Li, etc.) its life would be much longer as there would be no danger of it being unstuck or separated from its backing carbon-block.

3 METHOD AND EVALUATION

In the absence of any systematic direct neutron yields or cross section measurements for the ^{13}C (p,n) ^{13}N reaction above about 10 MeV, we have used the indirect method of estimating the neutron yields from this reaction from the ^{13}N yields measurements by the bombardment of natural carbon with protons of up to 23 MeV [1]. However, as there are a number of cyclotrons operating, especially for neutron therapy, at energies of up to 60-70 MeV, the estimated neutron yields have been extrapolated to 75 MeV.

4 RESULTS AND DISCUSSION

The estimated total neutron yield curve is presented in fig. 1, showing neutron yield / sec. / μA of the proton beam current. However, as this target should be capable of withstanding much higher beam currents, normally available from modern cyclotrons, much higher neutron intensities could be produced from this target. The full line is the estimate from the ^{13}N data of Krasnov et al [1], and the dashed curve is extrapolation.

From this curve the total neutron yield from a thick target at any incident energy of protons can be directly obtained. Furthermore, for a target of moderate thickness, the neutron yield can be obtained by taking the difference in the yields at energies at which the proton beam enters and leaves the target.

It will be seen from fig. 1 that at a proton energy of 23 MeV, as many as 1.4×10^9 n/sec would be produced for a proton beam current of 100 μA – which is easily obtained in many modern cyclotrons. Due to the mechanism of the nuclear reaction, most probably direct reaction, it is expected that the majority of the neutrons would be concentrated in the forward direction. This yield compares very favourably with the most commonly used Be target under proton bombardment and therefore could prove to be a simpler and cheaper alternative neutron producing target.
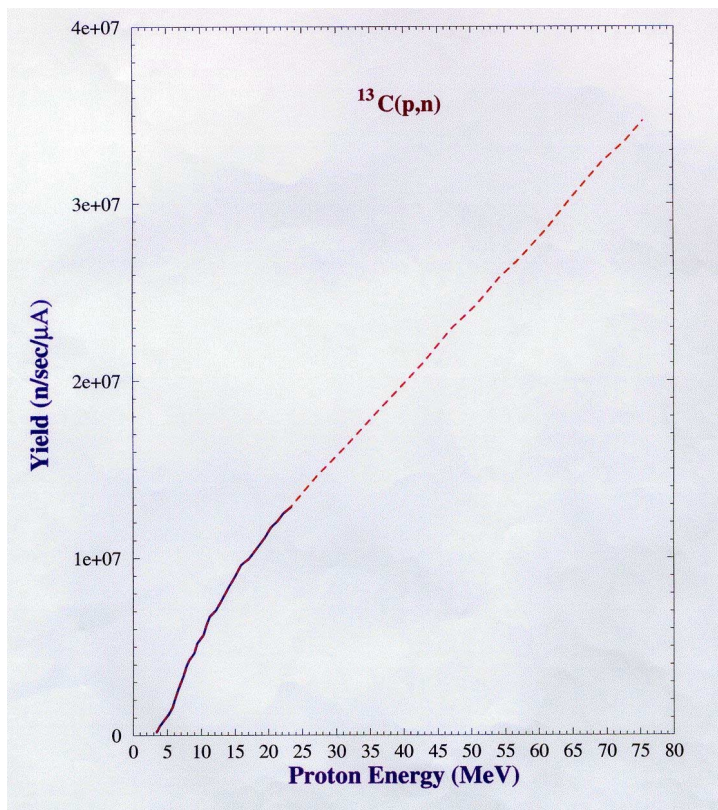
Figure 1. Total neutron production from a C-13 target under bombardment with protons. The full curve is based on ref.[1] and the dashed curve is extrapolation.

REFERENCES

[1] N. N. Krasnov, P. P. Dmitriyeva, I. O. Konstantinov and G. A. Molin, The Uses of Cyclotrons in Chemistry, Metallurgy and Biology, Ed. C. B. Amphlett, Butterworth, London (1970), p. 341.