CONF-791058--54

PHOTONEUTRON LEAKAGE FROM THE W(γ,n) REACTION AT RADIATION THERAPY CENTERS

MASTER

by

R.J. Holt, H.E. Jackson, and J.R. Specht

Prepared for

International Conference

on

Nuclear Cross Sections for Technology

Knoxville, Tennessee

October 22-26, 1979

UofC-AUA-USDOE

ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

Operated under Contract W-31-109-Eng-38 for the

U. S. DEPARTMENT OF ENERGY

PHOTONEUTRON LEAKAGE FROM THE W(γ,n) REACTION AT RADIATION THERAPY CENTERS

R. J. Holt, H. E. Jackson and J. R. Specht
Argonne National Laboratory
Argonne, Illinois 60439, USA

The energy spectrum of photoneutrons from W(γ,n) was observed for an electron energy of 10 MeV by using the ANL high-current electron linac and a neutron time-of-flight spectrometer.

[W(γ,n), photoneutron energy spectrum for E_e = 10 MeV, E_n = 0.3 - 3.6 MeV]

Introduction

There are a number of radiation therapy facilities which rely upon 10-MeV electron linacs or betatrons. The heads of these accelerators typically contain tungsten bremsstrahlung converters, beam hardeners and photon collimators. Of course, heavy elements such as W or Pb have large photoneutron production cross sections and at energies of $\gtrsim$ 10 MeV a sizeable neutron background can be generated from these elements. Unfortunately, it is extremely difficult to determine the dose equivalent of the leakage neutrons. The primary difficulty is that most neutron detection schemes at these facilities measure only the neutron fluence and not the energy spectrum of the neutrons. Then, it is common practice to assume that the neutron spectrum has the same shape as a fission spectrum, typically that of ^{252}Cf. McCall et al.[1] have demonstrated that this is a poor assumption. This is especially true since the primary neutron spectrum is distorted in its energy dependence by the accelerator head shielding which is usually in the form of W, Fe or Pb. In principle, this spectrum can be calculated using a Monte Carlo technique,[2] provided that the primary neutron spectrum is known. However, the problem is compounded by the fact that there is not a complete set of photoneutron spectra even for the case of W. For example, there were no W(γ,n) data for an electron energy of 10 MeV. For these reasons we have observed the photoneutron energy spectrum for W(γ,n) at angles of 90° and 135° throughout the neutron energy range 0.3 to 3.8 MeV for an electron energy of 10.0 MeV.

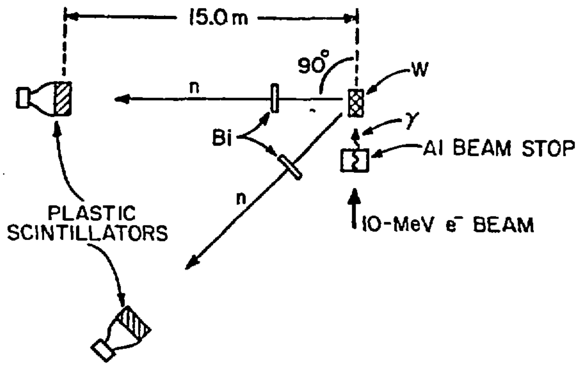

Fig. 1. Schematic diagram of experimental arrangement.

Experiment

Since we are only concerned with the spectral shape of the W(γ,n) cross section, the experimental method is relatively simple. An energy-analyzed, 10.0 MeV beam of electrons with a pulse width of 4 ns and a rate of 800 Hz was focused onto an Al electron beam stop and bremsstrahlung converter as shown in Fig. 1. The bremsstrahlung photons irradiated a sample of W powder (10.93 g/cm^3) which was encased in a thin-walled Al can. Photoneutrons from the W then traveled through two 15-m flight paths which were at angles of 90° and 135° with respect to the photon beam axis. The neutrons were detected in plastic scintillators (2.5-cm thick x 20 cm x 5.1 cm) located at the end of each flight path. The neutron energies were measured with a time-of-flight method. The shapes of the forward-produced thick target bremsstrahlung for Al and W are nearly identical, so that no significant shape error was introduced by using an Al converter. The target thickness in the photon beam direction was 0.18 g/cm^2 and 0.036 g/cm^2 in the neutron direction at 90°. The neutron detector efficiency and effects of Bi γ-flash filter were unfolded from the measured spectra. The final results are shown in Fig. 2 for a reaction angle of 90°.

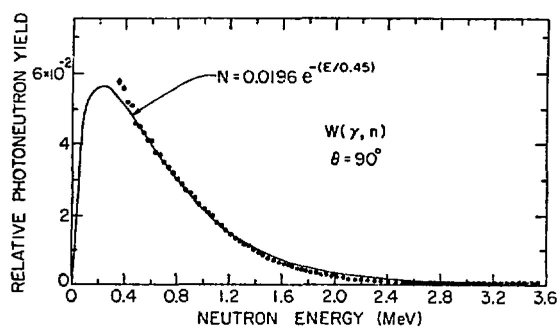

Fig. 2. Relative yield of photoneutrons from the W(γ,n) reaction at 90° for a 10-MeV electron beam.

Results

The spectrum shown in Fig. 2 was averaged and plotted in 30-keV increments. The spectrum can be relatively well-represented by a Maxwellian with a temperature of 0.45 MeV as shown in Fig. 2. The curv in the figure was calculated with the expression

$$N = N_o e^{-E/0.45}$$

where N_o = 0.0196. The constant term N_o, of course, has no significance since we have determined only the spectral shape for the W(γ,n) reaction.

There are currently two methods for determining the dose equivalent from this primary spectra. In both methods one must determine the neutron fluence and the contribution from thermal neutrons. The first method, "brute-force," would be to determine with a Monte Carlo technique the spectral shape after transmission through the head shielding. The second method, "cookbook," was developed by McCall et al.[1] He observed that to a very good approximation one only needs to know the behavior of neutrons with the average energy of the neutron spectrum in order to determine the dose equivalent. We have found the average energy from the Maxwellian shape of the present spectrum to be $\bar{E}$ = 0.67 MeV. Once this is known a simple procedure is described in Ref. 1 to obtain the dose equivalent.

It is expected that the present work will lead to more accurate determinations of neutron dose equivalent of leakage neutrons from 10-MeV electron accelerators.

Acknowledgments

We thank R. C. McCall for bringing this problem to our attention and for useful discussions. This work was performed under the auspices of the United States Department of Energy.

References

1. R. C. McCall, T. M. Jenkins and R. A. Shore, in Proc. of the Fifth International Conference on Small Accelerators, 1979, preprint.

2. R. C. McCall and W. P. Swanson, in Proc. of the Conf. on Neutrons from Electron Accelerators, 1979, preprint.