CONF-750303--10

CROSS SECTIONS FOR THE PRODUCTION OF LOW ENERGY PHOTONS BY NEUTRON INTERACTIONS WITH FLUORINE AND TANTALUM*

J. K. Dickens, G. L. Morgan, and F. G. Perey
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

Differential cross sections for the production of low energy photons (< 240 keV) by neutron interactions in fluorine and tantalum have been measured for neutron energies between 0.1 and 20 MeV. Photons were detected at 92° using an intrinsic germanium detector. Incident neutron energies were determined by time-of-flight techniques for a white source spectrum.

(Cross sections, neutron-induced low-energy photons, fluorine, tantalum)

Introduction

A previous paper at this conference[1] has presented measurements of cross sections for neutron induced gamma radiation in a number of elements. These data, obtained with a NaI detector and covering photon energies as low as 300 keV, are generally adequate for most applications. However, for several nuclides, the cross sections for production of lower energy photons may be quite large and constitute a significant fraction of the total photon production. In particular applications such as neutron-induced heating and ionization, the production of low energy gamma rays, conversion electrons and associated x-rays in these nuclides will be important.

Fluorine in the form of LiF is a possible constituent of a CTR blanket. It occurs as well in insulating material such as teflon. Tantalum is used in reactor control rods, heavy metal shields, and electronic components. We have therefore measured cross sections for the production of 96, 110, and 197 keV gamma rays from fluorine and for the K x-rays and several of the discrete gamma rays from tantalum over the neutron energy range from 0.1 to 20 MeV.

Experimental Procedure

A schematic diagram of the experimental arrangement is shown in Fig. 1. This is basically the same as used in Ref. 1, except that a Ge detector was used instead of a shielded NaI crystal.

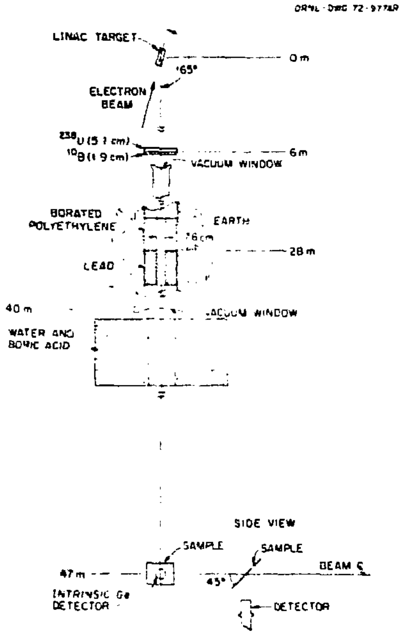

Figure 1. Experimental Facility Showing Neutron Source, Collimators, Sample and Detector.

Neutrons were produced at the tantalum target of the Oak Ridge Electron Linear Accelerator (ORELA). The samples consisted of 30 cm x 30 cm sheets of teflon (.0177 molecules/barn) or tantalum (.0007 atoms/b) oriented 45° with respect to the incident beam at a distance of 47 m from the neutron source. The neutron beam was defined by a 7.6-cm-diameter collimator located 28 m from the neutron source. A filter of uranium at 5 m reduced the intensity of the gamma flash. Overlap from adjacent linac bursts was prevented by a filter of ^{10}B.

The detector, 200 mm² intrinsic germanium, was located at 92° with respect to the incident beam. It is important to note that this detector was specially constructed without the usual teflon insulating materials.

For each event occurring in the detector, the pulse of the event and its time of occurrence after the electron burst were recorded. These data were stored in two ways. In the first, the data were placed in a two-parameter array on a fast computer disk (a 2048 channel pulse height spectrum of each of 200 time-of-flight channels). In addition, digital windows were used to select prominent lines (or adjacent regions for background determination) for storage in a series of 1024 channel time-of-flight spectra. This technique permitted retention of all the pulse height information as well as high resolution in the incident neutron energy for dominant lines. Figure 2 shows a typical pulse height spectrum for the teflon sample obtained by integrating the two-parameter data over a range of time-of-flight.

The neutron flux was determined as in Ref. 1 using organic scintillators. The efficiency of the Ge detector was measured using a set of calibrated sources (^{241}Am, ^{57}Co, ^{152}Eu). Because the low counting rate required a rather close and therefore extended geometry, considerable effort and testing were employed to ensure that the flux weighted efficiency and solid angle were accurately determined.

Backgrounds due to scattered neutrons were checked by acquiring data with a carbon slab (.01 atoms/barn) at the sample position. These were found to be negligible.

Absolute cross sections were derived from either of the two data sets described above by normalizing peak areas to neutron flux, detector efficiency and sample thickness. Corrections were applied for self-absorption in the sample.

Results

Fluorine. Figures 3 and 4 show the results for the 110, 197, and 96 keV photons from fluorine. Tables of numerical values as well as comparisons with previous data are available elsewhere.[2] It should be

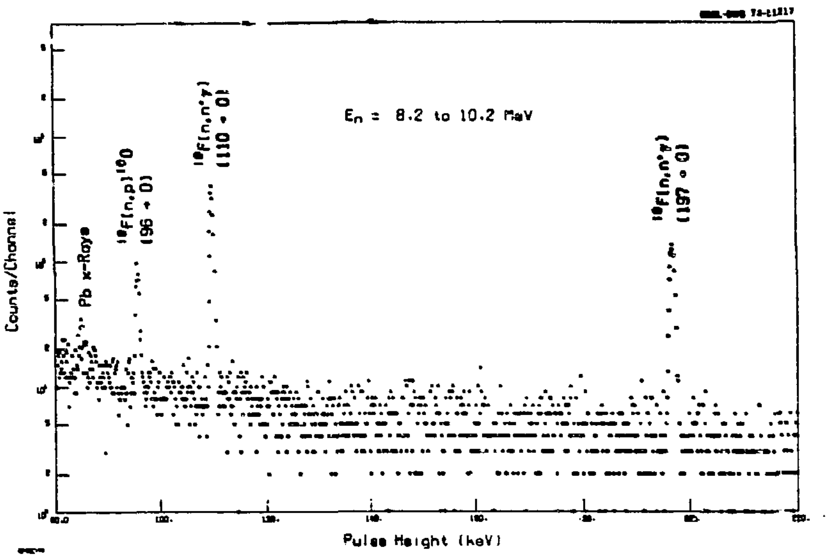

Figure 2. A typical pulse height spectrum from the teflon sample. The lead x-rays originate in the detector collimator.

noted that the 197 keV gamma-ray results from the decay of a level in ^{19}F having a lifetime of 129 ns. This causes a slewing in the time-of-flight measurement which at neutron energies greater than 5 MeV distorts the energy dependence of the cross section. The dashed curve in Fig. 4 indicates the shape of the cross section after correction for this effect.

Tantalum. The total cross section for the production of K-series x-rays in tantalum is shown in Fig. 5. These results were obtained by analyzing each of four lines separately, then summing the differential cross sections and multiplying by 4π. Checking the relative intensities of the separate lines with the tabulated values[3] verified the internal consistency of the data.

Figure 6 shows a typical result for one of the several low-energy gamma rays from tantalum. Close examination of the pulse height spectrum shows this line to be two unresolved photons, one from the 136 → 0 transition, the other from the 619 → 482 transition. Because the 136 keV level is partially fed by transitions originating at the level of 615 keV, which has a 20 μs lifetime, some time slewing is also present in these data.

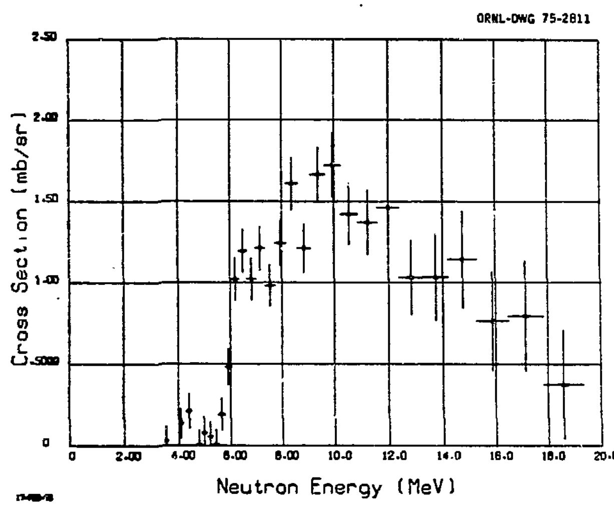

Figure 3. Differential cross section at 92° for the 96 keV gamma ray from the $^{19}F(n,p)^{19}O$ (96 keV) reaction.

References

*Research sponsored by the Defense Nuclear Agency at Oak Ridge National Laboratory, operated by the Union Carbide Corporation for the Energy Research and Development Administration.

1. G. T. Chapman, J. K. Dickens, T. A. Love, G. L. Morgan, and E. Newman, preceeding paper.

2. J. K. Dickens and G. L. Morgan, Production of Low-Energy Gamma Rays by Neutron Interactions with Fluorine for Incident Neutron Energies between 0.1 and 20 MeV, ORNL-TM-4823 (1975).

3. C. M. Lederer, J. M. Hollander, and I. Perlman, Table of Isotopes, 6th edition, Wiley, New York (1967).

ORNL-DWG 75-2817

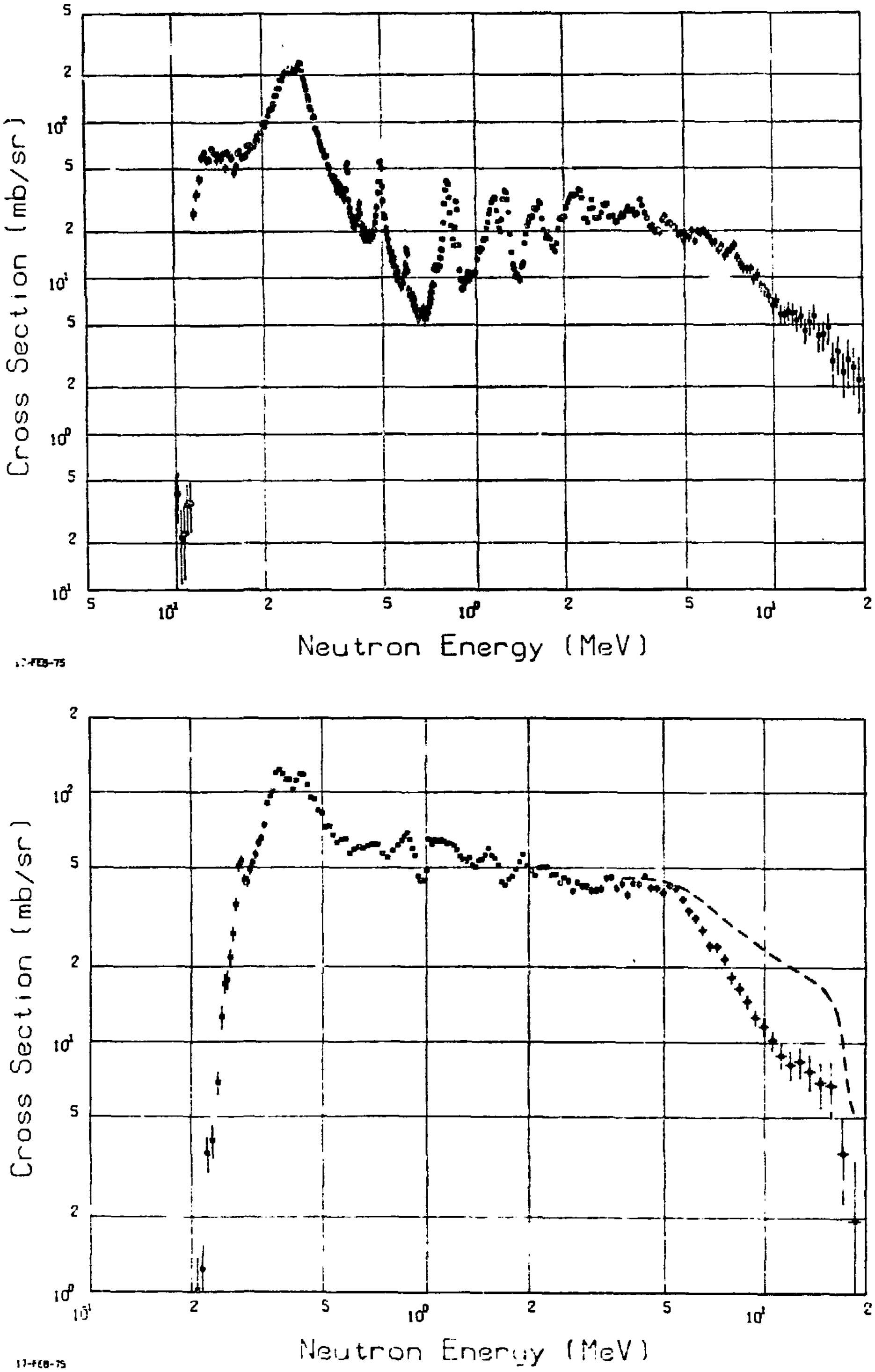

Figure 4. Differential cross section at 92° for the 110 and 197 keV gamma rays from fluorine. The dashed curve is an approximate correction for the 129 ns lifetime of the 197-keV level.

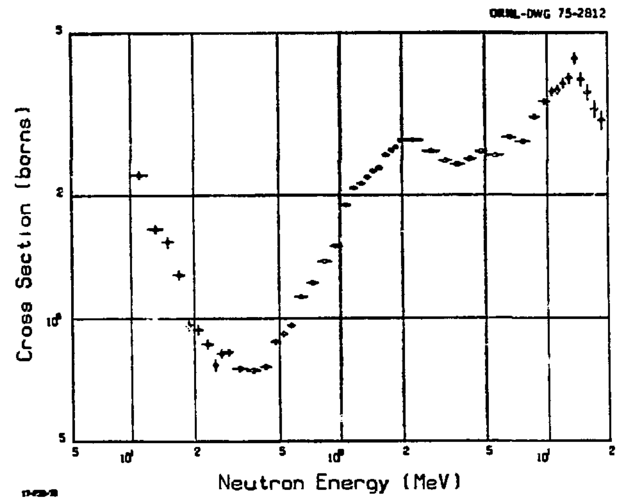

Figure 5. Total K x-ray Production cross section for tantalum.

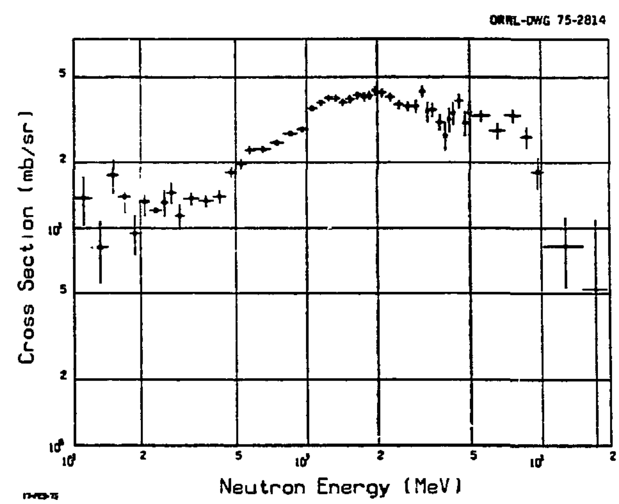

Figure 6. Differential Cross Section at 92° for 136 keV gamma rays from tantalum.