Fission, Total and Neutron Capture Cross Section Measurements at ORELA

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Introduction

In support of the Nuclear Criticality Predictability Program established in response to the Defense Nuclear Facility Safety Board Recommendation 93-2,1 time-of-flight (TOF) measurements of the fission cross sections of $^{233}$U in the neutron energy range from 0.36 eV to several hundred keV have been initiated at the Oak Ridge Electron Linear Accelerator (ORELA)$^2$. Also total and capture cross sections of Al, Cl, and K in the energy range from about 100 eV to several hundred keV have been measured or are under way. The goal is to derive accurate cross section representations for the materials involved in criticality calculations of fuel storage, transportation, etc., configurations. Additional high-resolution measurements of the total cross sections of $^{233}$U below a few keV neutron energy are being planned for 1998, as well as for the other involved material. Evaluated data files in ENDF-6 format will be processed into formats for use in criticality analysis and utilized in benchmark data testing. Finally the data will be submitted for inclusion in ENDF/B.

Description

Two different runs for the fission measurements on $^{233}$U were done in order to cover the whole energy range. One run using a Cd overlap filter and an accelerator burst rate of 78 pulses per second (pps) covers the energy range from about 0.36 eV to 100 eV; a high energy run at ~400 pps and using a $^{10}$B overlap filter covers energies up to 700 keV. For the measurements we used a fission chamber consisting of 21 plates of 0.127 mm thick...
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aluminum coated on both sides with 1.0 mg/cm² of $^{233}$U. The total amount of $^{233}$U (99.997% purity) was 2.11g giving a sample thickness of 0.00011956 a/b. The fission chamber was located at a distance of 81.237 m from the ORELA neutron target on flight path one (FP-1). The relative neutron flux through the fission chamber was measured with a 1 mm thick $^6$Li loaded glass scintillator located approximately 1.5 m upstream of the chamber.

Extremely high purity aluminum, natural potassium and chlorine samples were used in the present measurements. The transmission samples were mounted in the holder of a sample changer positioned at about 10 meters from the neutron target in the FP-1 beam of ORELA. Measurements were made on a thin sample and on a thick sample for the aluminum runs. Additional measurements were made for the open beam and thick polyethylene samples were used to determine the gamma-ray background. The thin sample was 0.01894 a/b and the thick sample was 0.1513 a/b as derived from weight and diameter measurements. The collimation was arranged in order to accept neutrons coming from the water moderator of the ORELA target. A pre-sample collimation limited the beam size to about 2.54 cm on the samples. The neutron detector was a 7.6 cm diameter, 1 cm thick $^6$Li glass scintillator viewed on edge by two 12.7 cm diameter photomultipliers and positioned in the beam at ~80 meters. For the chlorine transmission sample we used natural CCl₄ (thickness for chlorine 0.2075 a/b) which was compensated by the exact amount of carbon and the windows of the sample holder. In the run for the potassium we used a metallic sample which was mounted in a sealed container in the sample holder.

For the neutron capture measurements we used rectangular samples (2.54 x 5.08 cm) of high purity aluminum. These consisted again of a “thin” sample, 0.01520 a/b in thickness, and a “thick” sample of 0.04573 a/b. The capture samples and C₆D₆ gamma-ray detectors were situated at a distance of ~40 meters from the neutron target on FP-7. This capture system² has been re-engineered to minimize structural material surrounding the sample and detectors. In addition, the less neutron sensitive C₆D₆ scintillators replaced the previously used C₂F₆ scintillators. A 0.5 mm thick $^6$Li glass scintillator served as the neutron flux monitor. Pulse-height weighting was employed with the C₆D₆ detectors and normalization of the capture efficiency was carried out in a separate measurement using the “black resonance” technique³ by means of the 4.9 eV resonance from a 0.00508 cm thick gold sample.

Results

Figure 1 shows the measured fission yield of $^{233}$U in the energy range below 10 eV neutron energy and preliminary fits to the data generated by the code SAMMY⁴. With the present data it will be possible to obtain good fits to energies as high as 1.5 keV. Figure 2 shows the capture yield for the 5.906 keV resonance in aluminum. For the present data without any neutron sensitivity correction we obtain a 30% reduction in the gamma width compared to previous measurements. In Figure 3 the transmission data for the natural chlorine sample are shown.


Figure 1: $^{233}$U fission yield from data taken at ORELA and a preliminary fit to the data generated by the SAMMY code.
Figure 2: Capture data for the 5.9 keV resonance in $^{27}$Al and the SAMMY fit to the data.
Figure 3: Transmission data of the natural Chlorine sample in the energy range 1 to 35 keV (the line is an eye guide).