



Designation: E1297 – 08

Standard Test Method for Measuring Fast-Neutron Reaction Rates by Radioactivation of Niobium¹

This standard is issued under the fixed designation E1297; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes procedures for measuring reaction rates by the activation reaction $^{93}\text{Nb}(n,n')^{93\text{m}}\text{Nb}$.

1.2 This activation reaction is useful for monitoring neutrons with energies above approximately 0.5 MeV and for irradiation times up to about 30 years.

1.3 With suitable techniques, fast-neutron reaction rates for neutrons with energy distribution similar to fission neutrons can be determined in fast-neutron fluences above about 10^{16} cm^{-2} . In the presence of high thermal-neutron fluence rates ($>10^{12} \text{ cm}^{-2} \cdot \text{s}^{-1}$), the transmutation of $^{93\text{m}}\text{Nb}$ due to neutron capture should be investigated. In the presence of high-energy neutron spectra such as are associated with fusion and spallation sources, the transmutation of $^{93\text{m}}\text{Nb}$ by reactions such as $(n,2n)$ may occur and should be investigated.

1.4 Procedures for other fast-neutron monitors are referenced in Practice E261.

1.5 Fast-neutron fluence rates can be determined from the reaction rates provided that the appropriate cross section information is available to meet the accuracy requirements.

1.6 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:²

D1193 Specification for Reagent Water

¹ This test method is under the jurisdiction of ASTM Committee E10 on Nuclear Technology and Applications and is the direct responsibility of Subcommittee E10.05 on Nuclear Radiation Metrology.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E170 Terminology Relating to Radiation Measurements and Dosimetry

E181 Test Methods for Detector Calibration and Analysis of Radionuclides

E185 Practice for Design of Surveillance Programs for Light-Water Moderated Nuclear Power Reactor Vessels

E261 Practice for Determining Neutron Fluence, Fluence Rate, and Spectra by Radioactivation Techniques

E262 Test Method for Determining Thermal Neutron Reaction Rates and Thermal Neutron Fluence Rates by Radioactivation Techniques

E844 Guide for Sensor Set Design and Irradiation for Reactor Surveillance, E 706 (IIC)

E944 Guide for Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance, E 706 (IIA)

E1005 Test Method for Application and Analysis of Radiometric Monitors for Reactor Vessel Surveillance, E 706 (IIIA)

E1006 Practice for Analysis and Interpretation of Physics Dosimetry Results for Test Reactors, E 706 (II)

E1018 Guide for Application of ASTM Evaluated Cross Section Data File, Matrix E706 (IIB)

3. Terminology

3.1 *Definitions*—The definitions stated in Terminology E170 are applicable to this test method.

4. Summary of Test Method

4.1 High purity niobium is irradiated in a neutron field producing radioactive $^{93\text{m}}\text{Nb}$ from the $^{93}\text{Nb}(n,n')^{93\text{m}}\text{Nb}$ reaction. The metastable state decays to the ground state by the virtual emission of 30 keV gamma rays that are all internally converted giving rise to the actual emission of orbital electrons followed by X rays.

4.2 Sources of the irradiated niobium are prepared for X ray or liquid scintillation counting.

4.3 The X rays emitted as a result of the decay of $^{93\text{m}}\text{Nb}$ are counted, and the reaction rate, as defined in Practice E261, is calculated from the decay rate and irradiation conditions.

4.4 The neutron fluence rate may then be calculated from the appropriate spectral-weighted neutron activation cross section as defined by Practice E261.

5. Significance and Use

5.1 Refer to Practice E261 for a general discussion of the determination of decay rates, reaction rates, and neutron fluence rates with threshold detectors (1-29).³ Refer to Practice E1006, Practice E185 and Guide E1018 for the use and application of results obtained by this test method.(34-36)

5.2 The half-life of ^{93m}Nb is 5730 ± 220 days (30) and has a K X-ray emission probability of 0.1099 ± 0.0025 per decay (30). The K_{α} and K_{β} X-rays of niobium are at 16.5213–16.152 and 18.618–18.953 keV, respectively. The recommended $^{93}\text{Nb}(n,n')^{93m}\text{Nb}$ cross section comes from the IRDF-90 cross section compendium (31), was drawn from the RRDF-98 cross section evaluations (37) and is shown in Fig. 1.

5.3 Chemical dissolution of the irradiated niobium to produce very low mass-per-unit area sources is an effective way to obtain consistent results. The direct counting of foils or wires can produce satisfactory results provided appropriate methods and interpretations are employed. It is possible to use liquid scintillation methods to measure the niobium activity provided the radioactive material can be kept uniformly in solution and appropriate corrections can be made for interfering activities.

5.4 The measured reaction rates can be used to correlate neutron exposures, provide comparison with calculated reaction rates, and determine neutron fluences. Reaction rates can be determined with greater accuracy than fluence rates because of the current uncertainty in the cross section versus energy shape.

5.5 The $^{93}\text{Nb}(n,n')^{93m}\text{Nb}$ reaction has the desirable properties of monitoring neutron exposures related to neutron damage of nuclear facility structural components. It has an energy response range corresponding to the damage function of steel

and has a half-life sufficiently long to allow its use in very long exposures (up to about 40 years). Monitoring long exposures is useful in determining the long-term integrity of nuclear facility components.

6. Interferences

6.1 Pure niobium in the forms of foil and wire is available and easily handled as a metal. When thin niobium is irradiated, it may become brittle and fragile, thus requiring careful handling or encapsulation to prevent damage or loss of the niobium. Refer to Guide E844 for the selection, irradiation, and quality control of neutron dosimeters.

6.2 There are some distinct advantages and limitations to three measurement techniques identified in 5.3. It is the responsibility of the user to evaluate these and determine the optimum technique for the situation.

6.2.1 Low mass source X-ray spectrometry advantages include sufficient energy resolution to eliminate other X-ray emissions, stable long life sources, reduced interference fluorescence due to other radionuclides, small and precise background corrections, and minimal X-ray source self-absorption corrections. Limitations are low counting efficiency, complex source preparation, and use of hazardous chemicals.

6.2.2 Direct X-ray spectrometry of metal (foil or wire) sources has the advantages of simple source preparation, stable long life sources, sufficient energy resolution to eliminate other X-ray emissions, small and precise background corrections, and no use of hazardous chemicals. Limitations are low counting efficiency, large X-ray source self-absorption corrections, larger corrections for interference fluorescence due to the other radionuclides, and source geometry control.

6.2.3 Liquid scintillation counting advantages include very high detection efficiency, reproducible source preparation, and no source self absorption corrections. Limitations include specialized calibration techniques to reduce interference from

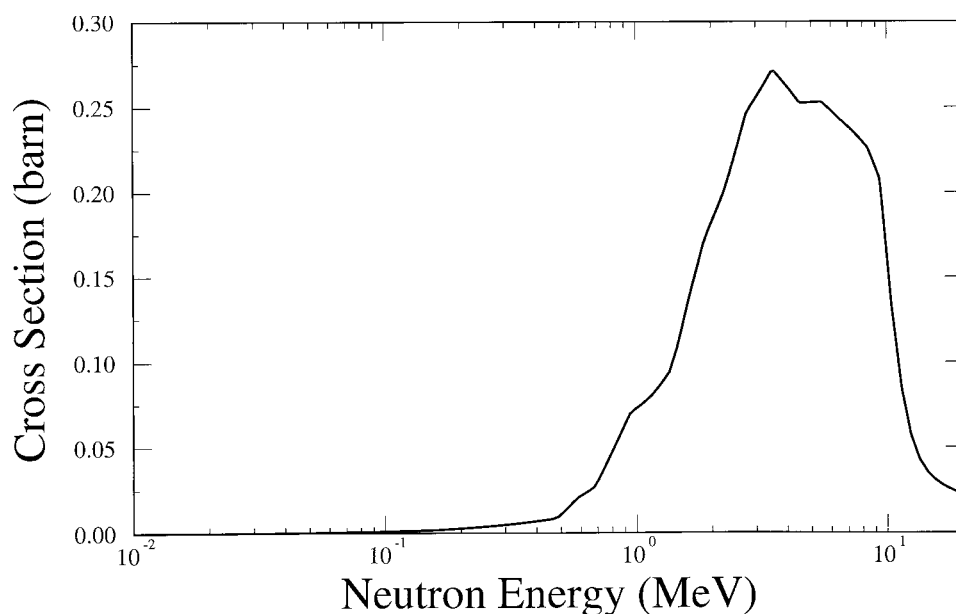


FIG. 1 IRDF-90 Cross Section Versus Energy for the $^{93}\text{Nb}(n,n')^{93m}\text{Nb}$ Reaction

³ The boldface numbers in parentheses refer to the list of references at the end of this test method.