Designation: E 343 – 96

Standard Test Method for Measuring Reaction Rates by Analysis of Molybdenum-99 Radioactivity From Fission Dosimeters[1]

This standard is issued under the fixed designation E 343; 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 covers the measurement of reaction rates by determining the amount of the fission product ^{99}Mo produced by the non-threshold reactions ^{241}Am(n,f), ^{235}U(n,f), and ^{239}Pu(n,f) and by the threshold reactions ^{238}U(n,f), ^{237}Np(n,f), and ^{232}Th(n,f).

1.2 These reactions produce many fission products, among which is ^{99}Mo, having a half-life of 65.94 h. Because of unresolved or interfering gamma rays when gamma-ray spectrometry is accomplished, the competing activity from other fission products requires that a chemical separation be employed to isolate the ^{99}Mo. ^{99}Mo emits gamma rays of several energies, which are easily detected and identified by a gamma-ray spectrometer.

1.3 With suitable techniques, neutron fluence rates can be measured in the range 10^7 to approximately $10^{14} n \cdot cm^{-2} \cdot s^{-1}$.

1.4 The measurement of time-integrated reaction rates with fission dosimeters by ^{99}Mo analysis is limited by the half-life of ^{99}Mo to irradiation times up to about 300 h.

1.5 The values stated in SI units are to be regarded as the standard.

1.6 *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:*

C 697 Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Plutonium Dioxide Powders and Pellets[2]

D 1193 Specification for Reagent Water[3]

E 170 Terminology Relating to Radiation Measurements and Dosimetry[4]

E 181 Test Methods for Detector Calibration and Analysis of Radionuclides[4]

E 261 Practice for Determining Neutron Fluence Rate, Fluence, and Spectra by Radioactivation Techniques[4]

E 704 Test Method for Measuring Reaction Rates by Radioactivation of Uranium-238[4]

E 705 Test Method for Measuring Reaction Rates by Radioactivation of Neptunium-237[4]

E 844 Guide for Sensor Set Design and Irradiation for Reactor Surveillance, E706(IIC)[4]

E 944 Guide for Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance (IIA)[4]

E 1005 Test Method for Application and Analysis of Radiometric Monitors for Reactor Vessel Surveillance, E706(IIIA)[4]

E 1018 Guide for Application of ASTM Evaluated Cross Section Data File, Matrix E 706 (IIB)[4]

2.2 *Other Document:*

NCRP Handbook of Radioactivity Measurements Procedures, NCRP Report No. 58.[5]

3. Terminology

3.1 *Definitions:*

3.1.1 Refer to Terminology E 170.

4. Summary of Test Method

4.1 The fission product ^{99}Mo is separated from the irradiated fission dosimeter by a solvent extraction technique. The activity of the ^{99}Mo is determined by counting the 740 or 778 keV, or both, gamma-energy peaks. This information combined with the fission yield of ^{99}Mo gives the reaction (fission) rate. When the proper cross section is used with the reaction rate, the equivalent fission rate can be determined.

5. Significance and Use

5.1 Refer to Guide E 844 for the selection, irradiation, and quality control of neutron dosimeters.

5.2 Refer to Practice E 261 for a general discussion of the measurement of neutron fluence rate and fluence. The neutron spectrum must be known in order to measure neutron fluence rates with a single detector. Also it is noted that cross sections

[1] This test method is under the jurisdiction of ASTM Committee E-10 on Nuclear Technology and Applicationsand is the direct responsibility of Subcommittee E10.05 on Nuclear Radiation Metrology.

Current edition approved Jan. 10, 1996. Published February 1996. Originally published as E 343 – 67 T. Last previous edition E 343 – 92.

[2] *Annual Book of ASTM Standards*, Vol 12.01.

[3] *Annual Book of ASTM Standards*, Vol 11.01.

[4] *Annual Book of ASTM Standards*, Vol 12.02.

[5] Available from National Council on Radiation Protection and Measurements (NCRP), 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814.

TABLE 1 Recommended Cumulative Fission Yields for ^{99}Mo Production

Fission Dosimeter	Thermal or Fast Neutron Field	Fission Yield, (%)[A,B]
^{235}U	T	6.18839 ± 1.4 %
	F	5.91653 ± 1.4 %
^{238}U	F	6.18839 ± 1.4 %
^{239}Pu	T	6.19863 ± 1.4 %
	F	5.95472 ± 2 %
^{237}Np	F	6.11547 ± 4 %
^{232}Th	F	2.95528 ± 2 %
^{241}Am	T	6.63629 ± 2.8 %
	F	5.40483 ± 6 %

[A] These ENDF/B-VI values are considered the best available data. The uncertainties are expressed as a percentage of the fission yield.

[B] England, T. R., and Rider, B. F., *ENDF-349 Evaluation and Compilation of Fission Product Yields*, Los Alamos National Laboratory, Los Alamos, NM, report LA-UR-94-3106, ENDF-349, October 1994.

are continuously being reevaluated. The latest recommended fission cross sections and details on how they can be obtained are discussed in Guide E 1018.

5.3 The reaction rate of a detector nuclide of known cross section, when combined with information about the neutron spectrum, permits the determination of the magnitude of the fluence rate impinging on the detector. Furthermore, if results from other detectors are available, the neutron spectrum can be defined more accurately. The techniques for fluence rate and fluence determinations are explained in Practice E 261.

5.4 ^{99}Mo is a radioactive nuclide formed as a result of fission. Its half-life is 65.94 h.[6] Recommended fission yields for ^{99}Mo production are given in Table 1.

5.5 Because of the short half-life and substantial fission yield,^{99}Mo is useful for short irradiation times or moderate neutron fields. Its decay constant and yield are known more accurately than those of many fission products, so it is sometimes used as a standard or basic reaction with which other measurements can be normalized.

6. Apparatus

6.1 *NaI—(Tl), or High Resolution, Gamma-Ray Scintillation Spectrometer*, using a single- or a multichannel pulse height analyzer. See Test Methods E 181.

6.2 *Balance*, providing the accuracy and precision required by the experiment.

6.3 *Separatory Funnels*, 125-mL capacity.

6.4 *Centrifuge*, clinical-type, accommodating 50-mL centrifuge tubes.

6.5 *Filter Chimney*—The filter chimney must hold a nominal 25.4-mm filter-paper disk rigidly in place during filtration. It is commercially available from many laboratory supply houses. A diagram of such an apparatus is shown in Fig. 1.

6.6 *Drying Oven*.

6.7 *Glass Filter Crucibles*, fine-porosity.

6.8 *Filter Papers*, open, rapid filtering, and fine texture retentive.

7. Reagents and Materials

7.1 *Purity of Fission Dosimeters*—High purity uranium, plutonium, neptunium, and thorium in the form of alloy wire, foil, or oxide powder are available.

7.1.1 *Target material* shall be furnished with a certificate of analysis indicating any impurity concentrations.

7.1.2 *Fission dosimeters* shall be encapsulated in hermetically sealed containers to avoid loss of materials and for health-hazard requirements. (Plutonium should be doubly sealed.)

7.1.3 In *thermal reactors threshold reaction dosimeters* (For example, ^{238}U, ^{237}Np, ^{232}Th) shall be shielded from thermal neutrons with elemental, or compounds of, cadmium, gadolinium, or boron to prevent fission production from trace quantities (>40 ppm) of ^{235}U, and ^{239}Pu and to suppress buildup of interfering fissionable nuclides, for example. ^{239}Pu in the ^{238}U dosimeter, ^{238}Np and^{238}Pu in the ^{237}Np dosimeter, and ^{233}U in the ^{232}Th dosimeter (see Guide E 844).

7.2 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[7] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.3 Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Specification D 1193.

7.4 *Ammonium Acetate Solution* (5 %)—Dissolve 40 g of ammonium acetate in 760 mL of water.

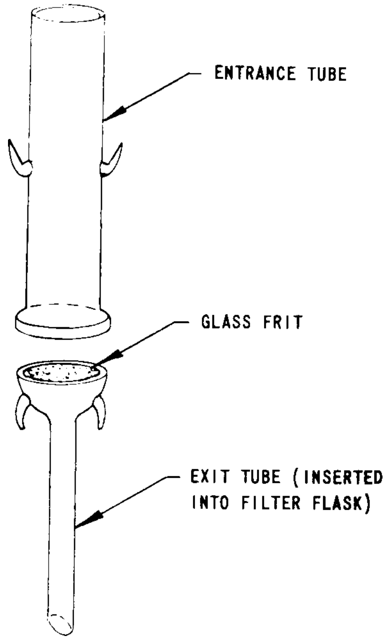

FIG. 1 Filter Chimney

[6] *Nuclear Wallet Cards*, compiled by J. K. Tuli, National Nuclear Data Center, July 1990.

[7] "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., New York, NY, and the "United States Pharmacopeia."