



Designation: E 263 – 00

Standard Test Method for Measuring Fast-Neutron Reaction Rates by Radioactivation of Iron¹

This standard is issued under the fixed designation E 263; 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 reappraisal. A superscript epsilon (ε) indicates an editorial change since the last revision or reappraisal.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method describes procedures for measuring reaction rates by the activation reaction $^{54}\text{Fe} (n,p) ^{54}\text{Mn}$.

1.2 This activation reaction is useful for measuring neutrons with energies above approximately 2.2 MeV and for irradiation times up to about 3 years (for longer irradiations, see Practice E 261).

1.3 With suitable techniques, fission-neutron fluence rates above $10^8 \text{ cm}^{-2}\cdot\text{s}^{-1}$ can be determined. However, in the presence of a high thermal-neutron fluence rate (for example, $>2 \times 10^{14} \text{ cm}^{-2}\cdot\text{s}^{-1}$) ^{54}Mn depletion should be investigated.

1.4 Detailed procedures for other fast-neutron detectors are referenced in Practice E 261.

1.5 *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:

D 1193 Specification for Reagent Water²

E 170 Terminology Relating to Radiation Measurements and Dosimetry³

E 181 Test Methods for Detector Calibration and Analysis of Radionuclides³

E 261 Practice for Determining Neutron Fluence Rate, Fluence, and Spectra by Radioactivation Techniques³

E 844 Guide for Sensor Set Design and Irradiation for Reactor Surveillance, E 706(IIC)³

E 944 Guide for Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance, (IIA)³

E 1005 Test Method for Application and Analysis of Radio-

metric Monitors for Reactor Vessel Surveillance, E 706(IIIA)³

E 1018 Guide for Application of ASTM Evaluated Cross Section Data File, Matrix E 706(IIB)³

3. Terminology

3.1 Definitions:

3.1.1 Refer to ASTM Standard E 170 for definitions of terms relating to radiation measurements and neutron dosimetry.

4. Summary of Test Method

4.1 High-purity iron is irradiated in a neutron field, thereby producing radioactive ^{54}Mn from the $^{54}\text{Fe} (n,p) ^{54}\text{Mn}$ activation reaction.

4.2 The gamma rays emitted by the radioactive decay of ^{54}Mn are counted in accordance with Methods E 181 and the reaction rate, as defined by Practice E 261, is calculated from the decay rate and irradiation conditions.

4.3 Radioassay of the ^{54}Mn activity may be accomplished by directly counting the irradiated iron dosimeter, or by first chemically separating the ^{54}Mn activity prior to counting.

4.4 The neutron fluence rate above about 2.2 MeV can then be calculated from the spectral-weighted neutron activation cross section as defined by Practice E 261.

5. Significance and Use

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

5.2 Refer to Practice E 261 for a general discussion of the determination of fast-neutron fluence rate with threshold detectors.

5.3 Pure iron in the form of foil or wire is readily available and easily handled.

5.4 Fig. 1 shows a plot of cross section as a function of neutron energy for the fast-neutron reaction $^{54}\text{Fe} (n,p) ^{54}\text{Mn}$. (1)⁴ This figure is for illustrative purposes only to indicate the range of response of the $^{54}\text{Fe} (n,p) ^{54}\text{Mn}$ reaction. Refer to

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

Current edition approved Jan. 10, 2000. Published April 2000. Originally published as E 263 – 65 T. Last previous edition E 263 – 93.

² Annual Book of ASTM Standards, Vol 11.01.

³ Annual Book of ASTM Standards, Vol 12.02.

⁴ The boldface numbers in parentheses refer to the list of references located at the end of this test method.

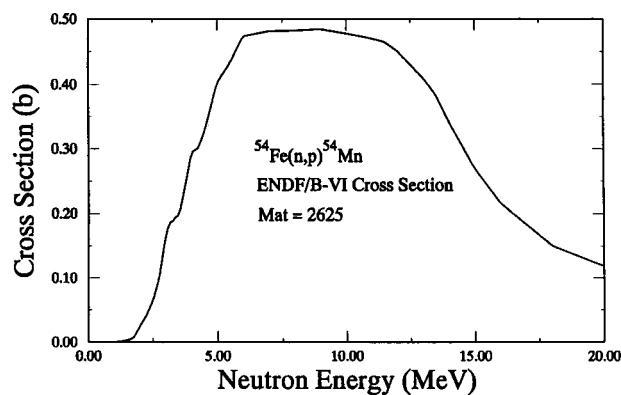


FIG. 1 ^{54}Fe (n,p) ^{54}Mn Cross Section

Guide E 1018 for descriptions of recommended tabulated dosimetry cross sections.

5.5 ^{54}Mn has a half-life of 312.12 days (2)⁴ and emits a gamma ray with an energy of 834.8 eV. (3)⁵

5.6 Competing activities from thermal or fast neutrons are 2.58-h ^{56}Mn , 44.5-d ^{59}Fe , and 5.271-y ^{60}Co . (Consult reference 2 for more precise values currently accepted for the half-lives.) Interference from ^{56}Mn can be eliminated by waiting 48 h before counting. Although chemical separation of ^{54}Mn from the irradiated iron is the most effective method for eliminating ^{59}Fe and ^{60}Co , direct counting of iron for ^{54}Mn is possible using high-resolution detector systems or unfolding or stripping techniques, especially if the dosimeter was covered with cadmium or boron during irradiation. Altering the isotopic composition of the iron dosimeter is another useful technique for eliminating interference from extraneous activities when direct sample counting is to be employed.

5.7 The vapor pressures of manganese and iron are such that manganese diffusion losses from iron can become significant at temperatures above about 700°C. Therefore, precautions must be taken to avoid the diffusion loss of ^{54}Mn from iron dosimeters at high temperature. Encapsulation in quartz, vanadium, or other materials will contain the manganese for temperatures up to about 900°C.

5.8 Sections 6, 7 & 8 that follow were specifically written to describe the method of chemical separation and subsequent counting of the ^{54}Mn activity. When one elects to count the iron dosimeters directly those portions of Sections 6, 7 & 8 that pertain to radiochemical separation should be disregarded.

NOTE 1—The following portions of this test method apply also to direct sample-counting methods: 6.1-6.3, 7.4, 7.9, 7.10, 8.1-8.5, 8.18, 8.19, and 9-12.

6. Apparatus (Note 1)

6.1 *Nal(Tl) or High-Resolution Gamma-Ray Spectrometer*, because of its high resolution, the germanium detector is useful when contaminant activities are present. See Methods E 181 and E 1005.

⁴ Reference (3) gives a value of 834.848 keV as the most precise value currently accepted for the ^{54}Mn decay gamma-ray energy.

6.2 *Precision Balance*, able to achieve the required accuracy.

6.3 *Digital Computer*, useful for data analysis (optional).

6.4 *Cylinder*, borosilicate glass, about 25-mL capacity, equipped with stopcock and funnel. This apparatus is illustrated in Fig. 2.

6.5 *Beakers*, borosilicate glass, 50 mL; *volumetric flasks*, 25 and 50 mL, and *volumetric pipets*, 1 mL.

7. Reagents and Materials (Note 1)

7.1 *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 Commerce on Analytical Reagents of the American Chemical Society, where such specifications are available.⁵ 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.

7.2 *Purity of Water*— Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Specification D 1193.

7.3 *Anion Exchange Resin*, strongly basic type, 100 to 200 mesh size.

⁵ "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 "Analytical Standards for Laboratory Chemicals," BDH Ltd., Poole, Dorset, U.K., and the "United States Pharmacopeia."

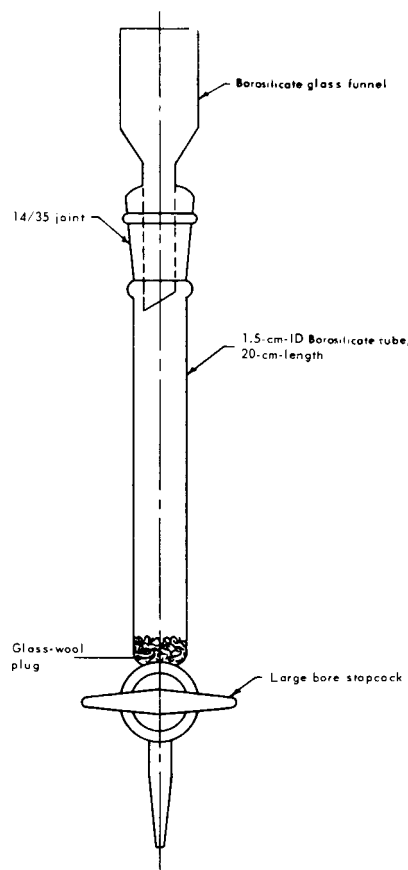


FIG. 2 Ion-Exchange Separation Apparatus