



Designation: E526 – 17

Standard Test Method for Measuring Fast-Neutron Reaction Rates by Radioactivation of Titanium¹

This standard is issued under the fixed designation E526; 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 procedures for measuring reaction rates by the activation reactions $^{46}\text{Ti}(n,p)^{46}\text{Sc} + ^{47}\text{Ti}(n, np)^{46}\text{Sc} + ^{47}\text{Ti}(n,d)^{46}\text{Sc}$.

NOTE 1—The cross section for the $^{47}\text{Ti}(n,np+d)$ reaction is relatively small for energies less than 12 MeV and is not easily distinguished from that of the $^{46}\text{Ti}(n,p)$ reaction. This test method will apply to the composite $^{nat}\text{Ti}(n,X)^{46}\text{Sc}$ reaction that is typically used for dosimetry purposes.

1.2 The reaction is useful for measuring neutrons with energies above approximately 4.4 MeV and for irradiation times, under uniform power, up to about 250 days (for longer irradiations, or for varying power levels, see Practice E261).

1.3 With suitable techniques, fission-neutron fluence rates above $10^9 \text{ cm}^{-2}\cdot\text{s}^{-1}$ can be determined. However, in the presence of a high thermal-neutron fluence rate, ^{46}Sc depletion should be investigated.

1.4 Detailed procedures for other fast-neutron detectors are referenced in Practice E261.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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.

Current edition approved Aug. 1, 2017. Published October 2017. Originally approved in 1976. Last previous edition approved in 2013 as E526 – 08(2013). DOI: 10.1520/E0526-17.

2. Referenced Documents

2.1 *ASTM Standards:*²

E170 Terminology Relating to Radiation Measurements and Dosimetry

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E181 Test Methods for Detector Calibration and Analysis of Radionuclides

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

E456 Terminology Relating to Quality and Statistics

E844 Guide for Sensor Set Design and Irradiation for Reactor Surveillance

E944 Guide for Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance

E1005 Test Method for Application and Analysis of Radiometric Monitors for Reactor Vessel Surveillance

E1018 Guide for Application of ASTM Evaluated Cross Section Data File

3. Terminology

3.1 *Definitions:*

3.1.1 Refer to Terminologies E170 and E456.

4. Summary of Test Method

4.1 High-purity titanium is irradiated in a fast-neutron field, thereby producing radioactive ^{46}Sc from the $^{46}\text{Ti}(n,p)^{46}\text{Sc}$ activation reaction.

4.2 The gamma rays emitted by the radioactive decay of ^{46}Sc are counted in accordance with Methods E181 and the reaction rate, as defined by Test Method E261, is calculated from the decay rate and the irradiation conditions.

4.3 The neutron fluence rate above about 4.4 MeV can then be calculated from the spectral-weighted neutron activation cross section as defined by Test Method E261.

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.

5. Significance and Use

5.1 Refer to Guide E844 for the selection, irradiation, and quality control of neutron dosimeters.

5.2 Refer to Test Method E261 for a general discussion of the determination of fast-neutron fluence rate with threshold detectors.

5.3 Titanium has good physical strength, is easily fabricated, has excellent corrosion resistance, has a melting temperature of 1668°C, and can be obtained with satisfactory purity.

5.4 ⁴⁶Sc has a half-life of 83.787 (16)³ days(1).⁴ The ⁴⁶Sc decay emits a 0.889271 (2) MeV gamma 99.98374 (35) % of the time and a second gamma with an energy of 1.120537 (3) MeV 99.97 (2) % of the time.

5.5 The isotopic content of natural titanium recommended for ⁴⁶Ti is 8.25 %. (2)

5.6 The radioactive products of the neutron reactions ⁴⁷Ti(n,p)⁴⁷Sc ($\tau_{1/2} = 3.3485$ (9) d) (1) and ⁴⁸Ti(n,p)⁴⁸Sc ($\tau_{1/2} = 43.67$ h), (2) might interfere with the analysis of ⁴⁶Sc.

5.7 Contaminant activities (for example, ⁶⁵Zn and ¹⁸²Ta) might interfere with the analysis of ⁴⁶Sc. See 7.1.2 and 7.1.3 for more details on the ¹⁸²Ta and ⁶⁵Zn interference.

5.8 ⁴⁶Ti and ⁴⁶Sc have cross sections for thermal neutrons of 0.59 ± 0.18 and 8.0 ± 1.0 barns, respectively (3); therefore, when an irradiation exceeds a thermal-neutron fluence greater than about 2×10^{21} cm⁻², provisions should be made to either use a thermal-neutron shield to prevent burn-up of ⁴⁶Sc or measure the thermal-neutron fluence rate and calculate the burn-up.

5.9 Fig. 1 shows a plot of the Russian Reactor Dosimetry

³ The value of uncertainty, in parentheses, refers to the corresponding last digits, thus 14.958(2) corresponds to 14.958 ± 0.002 .

⁴ The boldface numbers in parentheses refer to a list of references at the end of this standard.

File (RRDF-2002) cross section (4) versus neutron energy for the fast-neutron reactions of titanium which produce ⁴⁶Sc [that is, ^{Nat}Ti(n,X)⁴⁶Sc]. This cross section is identical, for energies up to 20 MeV, to what is found in the latest International Atomic Energy Agency (IAEA) International Reactor Dosimetry and Fusion File, IRDFF-1.05 (5). Included in the plot is the ⁴⁶Ti(n,p) reaction and the ⁴⁷Ti(n,np) contribution to the ⁴⁶Sc production, normalized per ⁴⁶Ti atom using the natural abundances (2). This figure is for illustrative purposes only to indicate the range of response of the ^{Nat}Ti(n,p) ⁴⁶Sc reaction. Refer to Guide E1018 for descriptions of recommended tabulated dosimetry cross sections. Fig. 2 compares the cross section for the ⁴⁶Ti(N,p)⁴⁷Sc reaction to the current experimental database (6, 7). Fig. 3 compares the cross section for the ⁴⁷Ti(N, np+d) reaction to the current experimental database (6, 7).

6. Apparatus

6.1 *NaI(Tl) or High Resolution Gamma-Ray Spectrometer.* Because of its high resolution, the germanium detector is useful when contaminant activities are present. See Methods E181 and E1005.

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

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

7. Materials

7.1 *Titanium Metal*—High-purity titanium metal in the form of wire or foil is available.

7.1.1 The metal should be tested for impurities by a neutron activation technique. If the measurement is to be made in a thermal-neutron environment, scandium impurity must be low because of the reaction, ⁴⁵Sc(n, γ)⁴⁶Sc. To reduce this interference, the use of a thermal-neutron shield during irradiation would be advisable if scandium impurity is suspected. As an example, when a titanium sample containing 6 ppm scandium has been irradiated in a neutron field with equal thermal and fast-neutron fluence rates about 1 % of the ⁴⁶Sc in the sample is due to the reaction ⁴⁵Sc(n, γ)⁴⁶Sc.

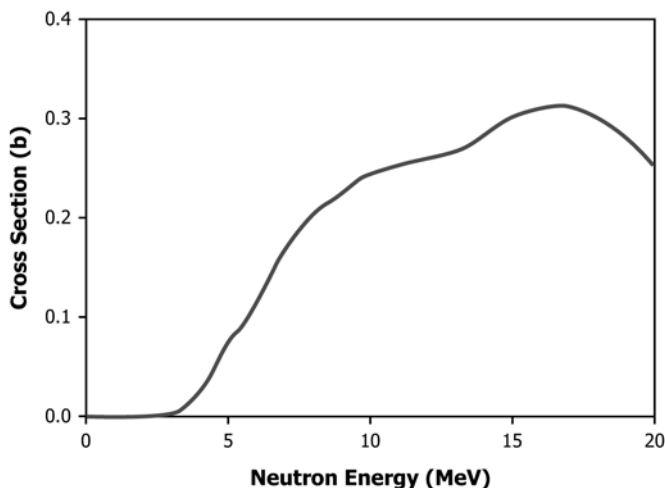


FIG. 1 ^{Nat}Ti(n,X)⁴⁶Sc Cross Section (Normalized per Ti-46 Atom Using Natural Abundance Data)

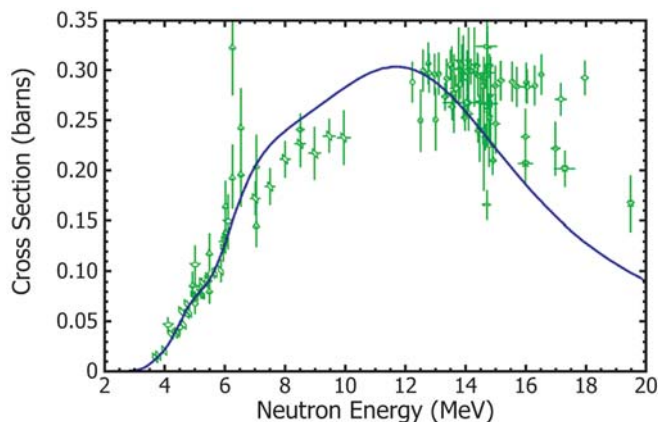


FIG. 2 ⁴⁶Ti(n,p)⁴⁶Sc Cross Section, from RRDF-2002/IRDFF-1.05, with EXFOR Experimental Data