INTERNATIONAL

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Standard Test Method for Measuring Fast-Neutron Reaction Rates by Radioactivation of Titanium[1]

This standard is issued under the fixed designation E 526; 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 $^{46}Ti(n,p)\,^{46}Sc$ + $^{47}Ti(n, np)^{46}Sc$.

NOTE 1—Since the cross section for the (n,np) reaction is relatively small for energies less than 12 MeV and is not easily distinguished from that of the (n,p) reaction, this test method will refer to the (n,p) reaction only.

1.2 The reaction is useful for measuring neutrons with energies above approximately 4.4 MeV and for irradiation times up to about 250 days (for longer irradiations, see Practice E 261).

1.3 With suitable techniques, fission-neutron fluence rates above 10^9 $cm^{-2}\cdot s^{-1}$ 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 E 261.

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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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 170 Terminology Relating to Radiation Measurements and Dosimetry

E 181 Test Methods for Detector Calibration and Analysis of Radionuclides

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

E 262 Test Method for Determining Thermal Neutron Reaction and Fluence Rates by Radioactivation Techniques

E 844 Guide for Sensor Set Design and Irradiation for Reactor Surveillance, E706 (IIC)[2] E 706(IIC)

E 944 Guide for Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance, E 706 (IIA)

E 1005 Test Method for Application and Analysis of Radiometric Monitors for Reactor Vessel Surveillance, E706 (IIIA)[2] E 706(IIIA)

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

3. Terminology

3.1 *Definitions*:

3.1.1 Refer to Terminology E 170.

4. Summary of Test Method

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

4.2 The gamma rays emitted by the radioactive decay of ^{46}Sc are counted in accordance with Methods E 181 and the reaction rate, as defined by Test Method E 261, 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 E 261.

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[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* , Vol 12.02.volume information, refer to the standard's Document Summary page on the ASTM website.

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 Test Method E 261 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 1675°C, and can be obtained with satisfactory purity.

5.4 ^{46}Sc has a half-life of ~~83.81~~83.79 days.[3] The ^{46}Sc decay[4] emits a 0.8893 MeV gamma 99.984 % of the time and a second gamma with an energy of 1.1205 MeV 99.987 % of the time.

5.5 The isotopic content of natural titanium recommended for ^{46}Ti is ~~8.012%.~~8.25 %.[3]

5.6 The radioactive products of the neutron reactions $^{47}Ti(n,p)^{47}$~~Sc(T½ = 3.35 d) and~~Sc ($\tau_{1/2}$ = 3.3492 d) and $^{48}Ti(n,p)^{48}$~~Sc(T½ = 1.82 d), might interfere with the analysis of~~Sc ($\tau_{1/2}$ = 43.67 h), might interfere with the analysis of ^{46}Sc.

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

5.8 ^{46}Ti and ^{46}Sc have cross sections for thermal neutrons of ~~0.60~~0.59 and 8 barns, respectively[5]; 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 ^{46}Sc or measure the thermal-neutron fluence rate and calculate the burn-up.

5.9 Fig. 1 shows a plot of cross section versus neutron energy for the fast-neutron reactions of titanium which produce ^{46}~~Sc (that is,~~Sc [that is, $^{Nat}Ti(n,X)^{46}$~~Sc).~~Sc]. Included in the plot is the $^{46}Ti(n,p)$ reaction~~and the~~[6] and the $^{47}Ti(n,np)$ contribution to the ^{46}Sc production,[7] normalized (at 14.7 MeV)[8] ~~normalized (to 14.7 MeV) per~~per ^{46}Ti atom. This figure is for illustrative purposes only to indicate the range of response of the $^{46}Ti(n,p)$ reaction. Refer to Guide E 1018 for descriptions of recommended tabulated dosimetry cross sections.

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 E 181 and E 1005.

[3] Nuclear Wallet Cards, National Nuclear Data Center, prepared by Jagdish K. Tuli, ~~July 1990.~~April 2005.

[4] Evaluated Nuclear Structure Data File (ENSDF), maintained by the National Nuclear Data Center (NNDC), Brookhaven National Laboratory, on behalf of the International Network for Nuclear Structure Data Evaluation.

~~[5] Isotopic Compositions of the Elements 1983, International Union of Pure and Applied Chemistry, Vol. 56, Pergamon Press, 1984.~~

[5] Nuclear Data retrieval program NUDAT, a computer file of evaluated nuclear structure and radioactive decay data, which is maintained by the National Nuclear Data Center (NNDC), Brookhaven National Laboratory (BNL), on behalf of the International Network for Nuclear Structure Data Evaluation, which functions under the auspices of the Nuclear Data Section of the International Atomic Energy Agency (IAEA). The URL is http://www.nndc.bnl.gov/nudat2/indx_sigma.jsp.

~~[6] Chart of the Nuclides, Knolls Atomic Power Laboratory, 14th Ed, April 1988.~~

[6] "International Reactor Dosimetry File (IRDF-2002)," International Atomic Energy Agency, Nuclear Data Section, Technical Reports Series No. 452, 2006, Document available from URL http://www-nds.iaea.org/irdf2002/docs/irdf-2002.pdf.

~~[7] "International Reactor Dosimetry File (IRDF-90)," assembled by N. P. Kocherov, et al., International Atomic Energy Agency, Nuclear Data Section, IAEA–NDS–141, Rev 0, August 1990.~~

[7] Zolotarev, K. I., Ignatyuk, A. V., Mahokhin, V. N., Pashchenko, A. B., RRDF-98, Russian Reactor Dosimetry File, Rep. IAEA-NDS-193, Rev. 1, IAEA, Vienna, 2005. URL is http://www-nds.ipen.br/ndspub/libraries2/rrdf98/

~~[8] ENDF/B-V Dosimetry Tape 531-G, Mat. No. 6427 (22-Ti-46), October 1979.~~

[8] Meadows, J. W., Smith, D. L., Bretscher, M. M., and Cox, S. A., "Measurement of 14.7 MeV Neutron-Activation Cross Sections for Fusion," *Annals of Nuclear Energy*, Vol 1, No. 9, 1987 .

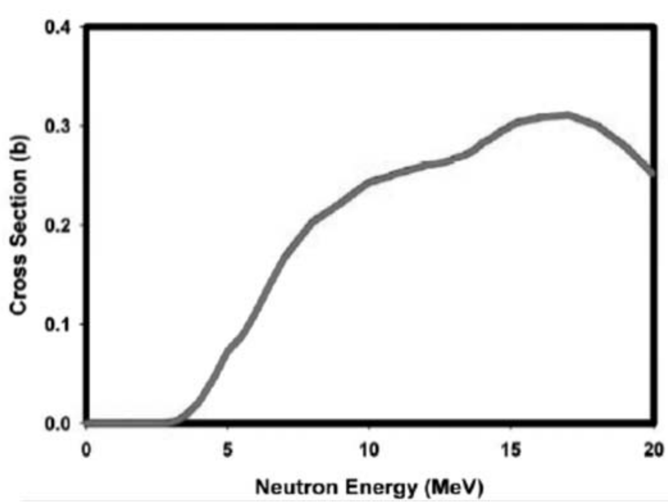

FIG. 1 $^{Nat}Ti(n,X)^{46}Sc$ Cross Section (Normalized per Ti-46 Atom)