



Designation: ~~E266-07~~ Designation: E266 - 11

# Standard Test Method for Measuring Fast-Neutron Reaction Rates by Radioactivation of Aluminum<sup>1</sup>

This standard is issued under the fixed designation E266; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

- 1.1 This test method covers procedures measuring reaction rates by the activation reaction  $^{27}\text{Al}(n,\alpha)^{24}\text{Na}$ .
- 1.2 This activation reaction is useful for measuring neutrons with energies above approximately 6.5 MeV and for irradiation times up to about 2 days (for longer irradiations, see Practice E261).
- 1.3 With suitable techniques, fission-neutron fluence rates above  $10^6 \text{ cm}^{-2} \cdot \text{s}^{-1}$  can be determined.
- 1.4 Detailed procedures for other fast neutron detectors are referenced in Practice E261.
- 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:<sup>2</sup>

- E170 Terminology Relating to Radiation Measurements and Dosimetry
- E181 Test Methods for Detector Calibration and Analysis of Radionuclides
- E261 Practice for Determining Neutron Fluence, Fluence Rate, and Spectra 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)
- E1018 Guide for Application of ASTM Evaluated Cross Section Data File, Matrix E706 (IIB)

## 3. Terminology

### 3.1 Definitions:

- 3.1.1 Refer to Terminology E170.

## 4. Summary of Test Method

- 4.1 High-purity aluminum is irradiated in a neutron field, thereby producing radioactive  $^{24}\text{Na}$  from the  $^{27}\text{Al}(n,\alpha)^{24}\text{Na}$  activation reaction.
- 4.2 The gamma rays emitted by the radioactive decay of  $^{24}\text{Na}$  are counted (see Test Methods E181) and the reaction rate, as defined by Practice E261, is calculated from the decay rate and irradiation conditions.
- 4.3 The neutron fluence rate above about 6.5 MeV can then be calculated from the spectral-weighted neutron activation cross section as defined by Practice E261.

## 5. Significance and Use

- 5.1 Refer to Guide E844 for the selection, irradiation, and quality control of neutron dosimeters.
- 5.2 Refer to Practice E261 for a general discussion of the determination of fast-neutron fluence rate with threshold detectors.
- 5.3 Pure aluminum in the form of foil or wire is readily available and easily handled.
- 5.4  ~~$^{24}\text{Na}$  has a half-life of 14.951 h and emits gamma rays with energies of 1.368633 and 2.754028 MeV.~~

<sup>1</sup> 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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<sup>2</sup> 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.

<sup>3</sup> The boldface numbers in parentheses refer to a list of References at the end of this standard.

5.4  $^{24}\text{Na}$  has a half-life of 14.9574 h (2) and emits gamma rays with energies of 1.368626 and 2.754007 MeV (2).

5.5 Fig. 1 shows a plot of cross section versus neutron energy for the fast-neutron reaction  $^{27}\text{Al}(n,\alpha)^{24}\text{Na}$  from the IRDF2002 dosimetry cross-section library Na (3) along with a comparison to the current experimental database (4). This figure is for illustrative purposes only to indicate the range of response of the  $^{27}\text{Al}(n,\alpha)$  reaction. Refer to Guide E1018 for descriptions of recommended tabulated dosimetry cross sections.

5.6 Two competing activities,  $^{28}\text{Al}$  and  $^{27}\text{Mg}$ , are formed in the reactions  $^{27}\text{Al}(n,\gamma)^{28}\text{Al}$  and  $^{27}\text{Al}(n,p)^{27}\text{Mg}$ , respectively, but these can be eliminated by waiting 2 h before counting.

## 6. Apparatus

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 Test Methods E181 and E1005).

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

## 7. Materials

7.1 The purity of the aluminum is important. No impurities should be present that produce long-lived gamma-ray-emitting radionuclides having gamma-ray energies that interfere with the  $^{24}\text{Na}$  determination. Discard aluminum that contains such impurities or that contains quantities of  $^{23}\text{Na}$  sufficient to interfere, through thermal-neutron capture, with  $^{24}\text{Na}$  determination. The presence of these impurities should be determined by activation analysis since spectrographically pure aluminum may contain a contaminant not detectable by the emission spectrograph. If the  $^{24}\text{Na}$  content of the irradiated samples is determined from the emission rate of the 2.754028-2.754007 MeV gamma ray, the probability of interference from contaminant gamma rays is much less than if the 1.368-63331.368626 MeV gamma ray is used.

7.2 *Encapsulating Materials*—Brass, stainless steel, copper, aluminum, quartz, or vanadium have been used as primary encapsulating materials. The container should be constructed in such a manner that it will not create significant flux perturbation and that it may be opened easily, especially if the capsule is to be opened remotely (see Guide E844).

## 8. Procedure

8.1 Decide on the size and shape of aluminum sample to be irradiated. This is influenced by the irradiation space and the expected production of  $^{24}\text{Na}$ . Calculate the expected production rate of  $^{24}\text{Na}$  from the activation equation described in Section 9, and adjust sample size and irradiation time so that the  $^{24}\text{Na}$  may be accurately counted. A trial irradiation is recommended.

8.2 Determine a suitable irradiation time (see 8.1). Since  $^{24}\text{Na}$  has a 14.951 h half-life, the  $^{24}\text{Na}$  activity will approach equilibrium after a day of irradiation.

8.3 Weigh the sample.

8.4 Irradiate the sample for the predetermined time period. Record the power level and any changes in power during the irradiation, the time at the beginning and end of the irradiation, and the relative position of the monitors in the irradiation facility.

8.5 After irradiation, the sample should be thoroughly rinsed in warm water. This will remove any  $^{24}\text{Na}$  surface contamination produced during irradiation.

8.6 Check the sample for activity from cross-contamination by other irradiated materials. Clean, if necessary, and reweigh.

8.7 Analyze the sample for  $^{24}\text{Na}$  content in disintegrations per second using the gamma-ray spectrometer after the  $^{28}\text{Al}$  and  $^{27}\text{Mg}$  have decayed (1 to 2 h will usually suffice) or until the contaminant activities, if any, have decayed (see Test Methods E181 and E1005).

8.8 Disintegration of  $^{24}\text{Na}$  nuclei produces 1.368-633-MeV 1.368626-MeV and 2.754028-MeV 2.754007-MeV gamma rays with probabilities per decay of 0.999935 and 0.9986, 0.99872, respectively (2). When analyzing either gamma-ray peak, a correction for

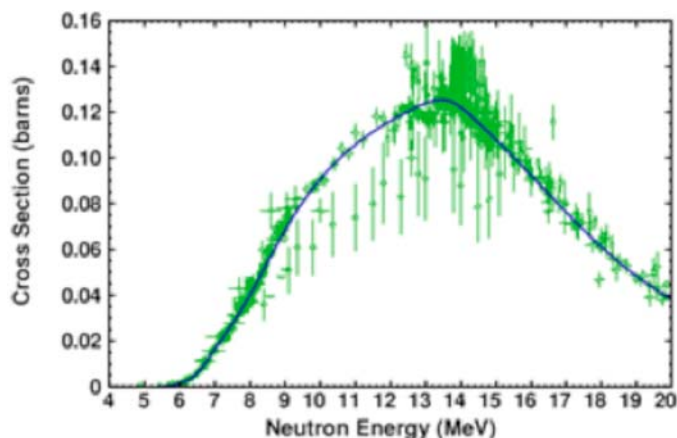


FIG. 1  $^{27}\text{Al}(n,\alpha)^{24}\text{Na}$  Cross Section with EXFOR Experimental Data