



Designation: C758 – 18

Standard Test Methods for Chemical, Mass Spectrometric, Spectrochemical, Nuclear, and Radiochemical Analysis of Nuclear-Grade Plutonium Metal¹

This standard is issued under the fixed designation C758; 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 These test methods cover procedures for the chemical, mass spectrometric, spectrochemical, nuclear, and radiochemical analysis of nuclear-grade plutonium metal to determine compliance with specifications.

1.2 The analytical procedures appear in the following order:

	Sections
Dissolution Procedure	2
Plutonium by Controlled-Potential Coulometry	3
Plutonium by Amperometric Titration with Iron (II)	2
Plutonium by Ceric Sulfate Titration Test Method	3
Plutonium by Diode Array Spectrophotometry	3
Uranium by Arsenazo I Spectrophotometric Test Method	8 – 10
Thorium by Thorin Spectrophotometric Test Method	11 – 13
Iron by 1,10-Phenanthroline Spectrophotometric Test Method	14 – 16
Iron by 2,2-Bipyridyl Spectrophotometric Test Method	17 – 23
Impurities by ICP-AES	
Chloride by the Thiocyanate Spectrophotometric Test Method	24 – 26
Fluoride by Distillation-Spectrophotometric Test Method	27–28
Nitrogen by Distillation-Nessler Reagent Spectrophotometric Test Method	29–30
Carbon by the Direct Combustion-Thermal Conductivity Test Method	31 – 33
Sulfur by Distillation-Spectrophotometric Test Method	34 – 36
Isotopic Composition by Mass Spectrometry	37 and 38
Plutonium-238 Isotopic Abundance by Alpha Spectrometry	
Americium-241 by Extraction and Gamma Counting	39 – 41
Americium-241 by Gamma Counting	3
Gamma-Emitting Fission Products, Uranium, and Thorium by Gamma-Ray Spectroscopy	42 – 49
Rare Earths by Copper Spark Spectrochemical Test Method	50 – 52
Tungsten, Niobium (Columbium), and Tantalum by Spectrochemical Test Method	53 – 55
Sample Preparation for Spectrographic Analysis for Trace Impurities	56 – 60

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

¹ These test methods are under the jurisdiction of ASTM Committee C26 on Nuclear Fuel Cycle and are the direct responsibility of Subcommittee C26.05 on Methods of Test.

Current edition approved Sept. 1, 2018. Published October 2018. Originally approved in 1973. Last previous edition approved in 2010 as C758 – 04 (2010). DOI: 10.1520/C0758-18.

² Discontinued as of February 10, 1998.

³ Discontinued as of November 15, 1992

1.4 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. For specific safeguard and safety hazards statements, see Section 6.

1.5 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.

2. Referenced Documents

2.1 ASTM Standards:⁴

- C697 Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Plutonium Dioxide Powders and Pellets
- C698 Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Mixed Oxides ((U, Pu)O₂)
- C759 Test Methods for Chemical, Mass Spectrometric, Spectrochemical, Nuclear, and Radiochemical Analysis of Nuclear-Grade Plutonium Nitrate Solutions
- C852/C852M Guide for Design Criteria for Plutonium Gloveboxes
- C859 Terminology Relating to Nuclear Materials
- C1009 Guide for Establishing and Maintaining a Quality Assurance Program for Analytical Laboratories Within the Nuclear Industry
- C1068 Guide for Qualification of Measurement Methods by a Laboratory Within the Nuclear Industry
- C1108 Test Method for Plutonium by Controlled-Potential Coulometry
- C1128 Guide for Preparation of Working Reference Materials for Use in Analysis of Nuclear Fuel Cycle Materials

⁴ 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.

- C1156 Guide for Establishing Calibration for a Measurement Method Used to Analyze Nuclear Fuel Cycle Materials
- C1165 Test Method for Determining Plutonium by Controlled-Potential Coulometry in H₂SO₄ at a Platinum Working Electrode
- C1168 Practice for Preparation and Dissolution of Plutonium Materials for Analysis
- C1206 Test Method for Plutonium by Iron (II)/Chromium (VI) Amperometric Titration (Withdrawn 2015)⁵
- C1210 Guide for Establishing a Measurement System Quality Control Program for Analytical Chemistry Laboratories Within the Nuclear Industry
- C1235 Test Method for Plutonium by Titanium(III)/Cerium(IV) Titration (Withdrawn 2005)⁵
- C1268 Test Method for Quantitative Determination of ²⁴¹Am in Plutonium by Gamma-Ray Spectrometry
- C1297 Guide for Qualification of Laboratory Analysts for the Analysis of Nuclear Fuel Cycle Materials
- C1307 Test Method for Plutonium Assay by Plutonium (III) Diode Array Spectrophotometry
- C1415 Test Method for ²³⁸Pu Isotopic Abundance By Alpha Spectrometry
- C1432 Test Method for Determination of Impurities in Plutonium: Acid Dissolution, Ion Exchange Matrix Separation, and Inductively Coupled Plasma-Atomic Emission Spectroscopic (ICP/AES) Analysis
- D1193 Specification for Reagent Water

3. Terminology

3.1 For definitions of terms used in this test method but not defined herein, refer to Terminology C859.

4. Significance and Use

4.1 These test methods are designed to show whether a given material meets the purchaser's specifications.

4.1.1 An assay is performed to determine whether the material has the specified plutonium content.

4.1.2 Determination of the isotopic content of the plutonium is made to establish whether the effective fissile content is in compliance with the purchaser's specifications.

4.1.3 Impurity content is verified by a variety of methods to ensure that the maximum concentration limit of specified impurities is not exceeded. Determination of impurities is also required for calculation of the equivalent boron content (EBC).

4.2 *Fitness for Purpose of Safeguards and Nuclear Safety Applications*—Methods intended for use in safeguards and nuclear safety applications shall meet the requirements specified by Guide C1068 for use in such applications.

5. Reagents and Materials

5.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all test methods. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemi-

cal Society, where such specifications are available.⁶ Other grades may be used, provided it is first ascertained that the reagent is of sufficient high purity to permit its use without lessening the accuracy of the determination.

5.2 *Purity of Water*—Unless otherwise indicated, reference to water shall be understood to mean reagent water conforming to Specification D1193.

6. Safety Hazards

6.1 Since plutonium bearing materials are radioactive and toxic, adequate laboratory facilities, gloved boxes, fume hoods, etc., along with safe techniques, must be used in handling samples containing these materials. A detailed discussion of all the precautions necessary is beyond the scope of these test methods; however, personnel who handle these materials should be familiar with such safe handling practices as are given in Guide C852/C852M and in Refs. (1-3).⁷

7. Sampling

7.1 In the absence of ASTM test methods for sampling plutonium metal, alternative techniques are recommended (3-6).

7.2 Cognizance shall be taken of the fact that various impurities can be introduced into samples during the process of sampling. The particular impurities introduced are a function of the method of sampling (for example, iron and alloying elements in drill turning, oxygen or components of cooling oil, or both, from lathe turnings, etc.). It is necessary for the purchaser and the seller to recognize this possibility for contamination during sampling and mutually agree on the most suitable method.

7.3 Sample size shall be sufficient to perform the following:

7.3.1 Quality verification tests at the seller's plant,

7.3.2 Acceptance tests at the purchaser's plant, and

7.3.3 Referee tests in the event these become necessary.

7.4 All samples shall be identified clearly by the seller's button number and by the lot number, and all pieces of metal in that lot shall be identified clearly by the lot number and the piece number.

7.4.1 A lot is defined as a single button, fraction of a button, or multiple castings from a single melt of plutonium metal. Buttons, fractions of buttons, or multiple castings are usually supplied in pieces of not less than 50 g. All pieces shall be identified positively as coming from a particular button, fraction of a button, or casting.

7.4.2 A lot shall normally not be less than 1800 g of plutonium, except as necessary to meet some special requirement. The maximum size of a lot will depend on equipment size of the producer and criticality considerations.

⁵ The last approved version of this historical standard is referenced on www.astm.org.

⁶ *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Foundary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

⁷ The boldface numbers in parentheses refer to the list of references at the end of these test methods.

DISSOLUTION PROCEDURE

(This practice is replaced by Standard Practice **C1168**).

PLUTONIUM BY CONTROLLED-POTENTIAL COULOMETRY

(This test method was discontinued in 1992 and replaced by Test Method **C1165**)

PLUTONIUM BY CONTROLLED-POTENTIAL COULOMETRY

(With appropriate sample preparation, controlled-potential coulometric measurement as described in Test Method **C1108** may be used for plutonium determination.)

PLUTONIUM BY AMPEROMETRIC TITRATION WITH IRON(II)

(This test method was discontinued in 1992 and replaced by Test Method **C1206**)

PLUTONIUM BY CERIC SULFATE TITRATION TEST METHOD

(This test method is replaced by Test Method **C1235**.)

TEST METHOD FOR PLUTONIUM ASSAY BY PLUTONIUM(III) DIODE ARRAY SPECTROPHOTOMETRY

(With appropriate sample preparation, the measurement described in Test Method **C1307** may be used for plutonium determination.)

URANIUM BY ARSENAZO I SPECTROPHOTOMETRIC TEST METHOD

8. Scope

8.1 This test method covers the determination of uranium in the range from 300 to 3000 $\mu\text{g/g}$ of plutonium.

9. Summary of Test Method

9.1 Plutonium metal dissolved in 6 *N* HCl is reduced to Pu(III) with hydroxylamine hydrochloride. The uranium and plutonium are separated by anion exchange; then the uranium is determined by measuring the absorbance of the U(VI)-Arsenazo I complex in a 1-cm cell at a wavelength of 600 nm *versus* a reagent blank.

10. Procedure

10.1 Transfer an aliquot of sample solution, prepared in accordance with Practice **C1168**, that contains approximately 70 mg of plutonium, to a 50-mL beaker and add 1 mL of nitric acid (sp gr 1.42) and heat to boiling. Proceed with the determination of uranium in accordance with the appropriate sections of Test Methods **C759**.

NOTE 1—Since the sample starts as plutonium metal and is then dissolved in acid and diluted to volume and an aliquot of this solution taken for the uranium determination, the following equation for calculating the uranium concentration must be substituted for the equation given in 28.1 of Test Methods **C759**:

$$R = (Y - B)D/AW \quad (1)$$

where:

R = micrograms U per gram Pu,

A, B = constants in linear calibration equation,
 D = dilution factor = V/E

where:

V = volume in which sample solution was diluted, mL, and
 E = volume of aliquot of V used for uranium determination, mL,

where:

W = weight of test portion of Pu metal sample, g, and
 $Y = a - b$ = corrected absorbance of sample,

where:

a = absorbance of sample solution, and
 b = average absorbance of duplicate calibration blanks.

THORIUM BY THORIN SPECTROPHOTOMETRIC TEST METHOD

11. Scope

11.1 This test method covers the determination of thorium in the range from 10 to 150 $\mu\text{g/g}$ of plutonium in nuclear-grade plutonium metal.

12. Summary of Test Method

12.1 To an acid solution of plutonium metal, lanthanum is added as a carrier and is precipitated along with thorium as insoluble fluoride, while the plutonium remains in solution and is decanted after centrifugation of the sample. The thorium and lanthanum fluoride precipitates are dissolved in perchloric acid and the absorbance of the thorium-Thorin complex is measured at a wavelength of 545 nm *versus* a reference solution. The molar absorptivity of the colored complex is of 15 600 for thorium concentration in the range from 5 to 70 $\mu\text{g Th}/10 \text{ mL}$ of solution.

13. Procedure

13.1 Transfer an aliquot of solution of plutonium metal, prepared in accordance with Sections 6 and 7 of these test methods, that contains from 10 to 70 μg of thorium and no greater than 500 mg of plutonium, into a 20-mL beaker.

13.2 Determine the thorium concentration in accordance with the appropriate sections of Test Methods **C759**.

NOTE 2—Since the starting sample is plutonium metal the following equation for calculating the thorium concentration must be substituted for the equation given in 49.3 of Test Methods **C759**:

$$\text{Th, } \mu\text{g/g of Pu} = (Y - B)D/AW \quad (2)$$

where:

A, B = constants in the linear calibration equation,
 W = sample weight, g,
 D = dilution factor = V/E

where:

V = volume to which dissolved plutonium metal is diluted, mL, and
 E = volume of aliquot of V taken for determination, mL,

$Y = a - b$ = corrected absorbance of sample solution

where:

- a = absorbance of sample solution, and
 b = average absorbance from the duplicate reagent blanks
 (see section 47.2.1 of Test Methods **C759**).

IRON BY 1,10-PHENANTHROLINE SPECTROPHOTOMETRIC TEST METHOD

14. Scope

14.1 This test method covers the determination of microgram quantities of iron in nuclear-grade plutonium metal.

15. Summary of Test Method

15.1 Ferric iron is reduced to ferrous iron with hydroxylamine hydrochloride. Solutions of 1,10-phenanthroline and acetate buffer are added and the pH adjusted to 3.5 to 4.5. The absorbance of the red-orange complex $[(C_{12}H_8N_2)_3Fe]^{+2}$ is read at 508 nm against a sample blank containing all of the reagents except the 1,10-phenanthroline.

16. Procedure

16.1 Dissolve a sample of plutonium metal in HCl as described in Test Method **C1206**.

16.2 Determine the iron content in accordance with the appropriate sections of Test Methods **C759**.

NOTE 3—Since the starting sample is plutonium metal, the following equation must be substituted for the equation given in Section 57 of Test Methods **C759** in order to calculate the iron concentration of the sample:

$$Fe, \mu\text{g/g Pu} = CD/W \quad (3)$$

where:

- C = micrograms of Fe from calibration curve,
 W = sample weight, g, and
 D = dilution factor = V/A

where:

- V = volume to which dissolved sample is diluted, and
 A = aliquot of V that was used for iron determination.

IRON B 2,2'-BIPYRIDYL SPECTROPHOTOMETRIC TEST METHOD

17. Section

17.1 This test method covers the determination of iron in the concentration range from 20 to 100 μg for samples of nuclear-grade plutonium metal.

18. Summary of Test Method

18.1 The plutonium metal is dissolved in HCl, the solution is buffered with sodium acetate, and the iron(II) as α,α' -dipyridyl complex is extracted into chloroform and the absorbance measured at 520 nm against distilled water.

19. Apparatus

- 19.1 *Spectrophotometer*, visible range.
 19.2 *Extraction Bottles*, glass-stopped, 125-mL volume.
 19.3 *Pipets*, 10 and 25-mL, automatic dispensing.

20. Reagents and Materials

20.1 *Chloroform*.

20.2 *2,2'-Bipyridyl Solution*, 2 % aqueous solution.

20.3 *Hydrochloric Acid (1 + 1)*—Add 500 mL of HCl (sp gr 1.19), to 500 mL of water.

20.4 *Iron, Standard Solution (50 $\mu\text{g/mL}$)*—To prepare, dissolve 1.000 g of pure iron metal in 25 mL of HCl (6 *N*), cool, and dilute to 1 L with water (**Note 5**). Pipet 25 mL of the iron solution, 1.00 mg/mL, into a 500-mL flask, add 10 mL of 6 *N* HCl, and dilute to volume with water. This solution contains 50 μg of iron/mL.

20.5 *Reagent Composite*—Mix 250 mL of reducing solutions, 250 mL of α,α' -dipyridyl solution, 50 mL of wetting agent, and 500 mL of sodium acetate buffer solutions (**Note 4**).

20.6 *Reducing Solution*—Dissolve 108 g of hydroxylamine hydrochloride in water, add 600 mL of glacial acetic acid, and dilute to 2 L with water.

20.7 *Sodium Acetate Buffer Solutions*—Dissolve 2270 g (5 lb) of sodium acetate in 8 L of water.

20.8 *Wetting Agent*—Dilute 20 mL of concentrate to 2 L with water.⁸

NOTE 4—This composite solution is stable for 25 h.

NOTE 5—Heat slowly and cover beaker with watchglass to prevent loss of iron during dissolution.

21. Procedure

21.1 Weigh, in duplicate, samples of plutonium metal that contain from 25 to 75 μg of iron, transfer to 125-mL extraction bottles, and dissolve the metal in 1 mL of 6 *N* HCl.

21.2 Add 20 mL of composite reagent, mix thoroughly, and allow 30 min for ferric iron to be reduced.

21.3 Adjust the solution to pH 4.3 with sodium acetate solution.

21.4 Add 25 mL of chloroform from an automatic dispensing pipet. Invert the bottle 20 to 25 times but do not shake vigorously.

NOTE 6—Take care to avoid forming an emulsion.

21.5 Separate the chloroform phase and measure the absorbance against distilled water at a wavelength of 520 nm.

21.6 Determine a reagent blank using all reagents but omitting the sample.

21.7 Prepare a calibration curve, or calculate micrograms of iron per absorbance unit, by processing a series of solutions containing various amounts of iron standard from 5 to 200 μg of iron in accordance with the procedure outlined in **21.1 – 21.5**.

22. Calculation

22.1 Calculate the iron content of the sample as follows:

$$Fe, \mu\text{g/g} = (A - A_1)F/W \quad (4)$$

⁸ Tergitol, a trademark of Union Carbide Corp., is a satisfactory wetting agent.