



Designation: ~~C1432–15~~ C1432 – 23

# Standard Test Method for Determination of Impurities in Plutonium: Acid Dissolution, Ion Exchange Matrix Separation, and Inductively Coupled Plasma-Atomic Emission Spectroscopic (ICP/AES) Analysis<sup>1</sup>

This standard is issued under the fixed designation C1432; 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 the determination of 25 elements in plutonium (Pu) materials. The Pu is dissolved in acid, the Pu matrix is separated from the target impurities by an ion exchange separation, and the concentrations of the impurities are determined by inductively coupled plasma-atomic emission spectroscopy (ICP-AES).

1.2 This test method is specific for the determination of impurities in 8 M HNO<sub>3</sub> solutions. Impurities in other plutonium materials, including plutonium oxide samples, may be determined if they are appropriately dissolved (see Practice C1168) and converted to 8 M HNO<sub>3</sub> solutions.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions that are provided for information only and are not considered standard. Additionally, the non-SI units of molarity and centimeters of mercury are to be regarded as standard.

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 and health~~safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use. Some specific hazards statements are given in Section 9 on Hazards.*

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:<sup>2</sup>

~~C757 Specification for Nuclear-Grade Plutonium Dioxide Powder for Light Water Reactors~~

~~C758 Test Methods for Chemical, Mass Spectrometric, Spectrochemical, Nuclear, and Radiochemical Analysis of Nuclear-Grade Plutonium Metal~~

~~C759 Test Methods for Chemical, Mass Spectrometric, Spectrochemical, Nuclear, and Radiochemical Analysis of Nuclear-Grade Plutonium Nitrate Solutions~~

~~C859 Terminology Relating to Nuclear Materials~~

~~C1128 Guide for Preparation of Working Reference Materials for Use in Analysis of Nuclear Fuel Cycle Materials~~

~~C1168 Practice for Preparation and Dissolution of Plutonium Materials for Analysis~~

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee C26 on Nuclear Fuel Cycle and is the direct responsibility of Subcommittee C26.05 on Methods of Test. Current edition approved June 1, 2015; Dec. 1, 2023. Published July 2015; January 2024. Originally approved in 1999. Last previous edition approved in 2008; 2015 as C1432–03 (2008); C1432–15. DOI: 10.1520/C1432-15.10.1520/C1432-23.

<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.

[C1215 Guide for Preparing and Interpreting Precision and Bias Statements in Test Method Standards Used in the Nuclear Industry](#)  
[D1193 Specification for Reagent Water](#)

### 3. Terminology

3.1 Except as otherwise defined herein, definitions of terms are as given in Terminology [C859](#).

### 4. Summary of Test Method

4.1 A sample of plutonium metal is dissolved in a small volume of 6 M hydrochloric acid (HCl). Then, 10 M (HNO<sub>3</sub>)/0.03 M /0.03 M hydrofluoric acid (HF) is added to the dissolved plutonium to oxidize the plutonium to the Pu (IV) state. The sample solution is loaded onto a nitrate anion exchange resin and eluted with 8 M HNO<sub>3</sub>/0.006 M HF. The rinses contain the target metallic impurities and less than 15 µg/mL Pu. The plutonium is stripped from the anion exchange resin with 0.1 M HCl. The rinses containing the metallic impurities are analyzed by ICP-AES.

### 5. Significance and Use

5.1 This test method can be used on plutonium matrices in nitrate solutions.

5.2 This test method has been validated for all elements listed in Test Methods [C757](#) except sulfur (S) and tantalum (Ta).

5.3 This test method has been validated for all of the cation elements measured in [Table 1](#). Phosphorus (P) requires a vacuum or an inert gas purged optical path instrument.

### 6. Interferences

6.1 Plutonium concentrations of less than 50 µg/mL in the final aqueous phase do not significantly affect the analytical results for most elements. Interference studies should be made to determine the degree of Pu and other elemental interferences on the target analytes; background and interelement corrections may be required.

### 7. Apparatus

7.1 An ICP-AES equipped with a Charge Injection Device (CID) detector or an ICP-AES with a spectral bandpass of 0.05 nm

**TABLE 1 Percent-Recovery and Repeatability Standard Deviation for Sixteen Spiked Samples**

Element	Wavelength/Order (nm)	Actual Conc (µg/mL)	Mean Conc (µg/mL)	Average (%R) R %	R.S.D.-RSD (%)
Aluminum	Al 396.152 {67}	2.5	2.4	95	6
Barium	Ba 455.403 {58}	2.5	2.4	95	5
Beryllium	Be 313.042 {84}	2.5	2.3	94	6
Boron	B 249.773 {106}	2.5	2.5	100	7
Cadmium	Cd 226.502 {116}	2.5	2.5	101	12
Calcium	Ca 396.847 {66}	2.5	2.6	104	20
Chromium	Cr 283.563 {93}	2.5	2.3	92	8
Cobalt	Co 228.616 {115}	2.5	2.5	101	6
Copper	Cu 324.754 {81}	2.5	2.4	97	6
Iron	Fe 259.940 {101}	2.5	2.5	101	12
Lead	Pb 220.353 {120}	2.5	3.1	122	12
Lithium	Li 670.784 {39}	2.5	2.2	87	6
Magnesium	Mg 280.270 {94}	2.5	2.4	95	6
Manganese	Mn 257.610 {102}	2.5	2.5	98	5
Molybdenum	Mo 202.030 {130}	2.5	2.6	103	10
Nickel	Ni 231.604 {114}	2.5	2.5	100	11
Silicon	Si 251.612 {104}	2.5	2.3	92	16
Sodium	Na 588.995 {45}	25.0	24.7	97	16
Strontium	Sr 421.552 {62}	2.5	2.4	95	5
Tin	Sn 189.989 {139}	2.5	2.7	109	19
Titanium	Ti 334.941 {79}	2.5	2.5	102	8
Tungsten	W 207.911 {127}	2.5	2.5	99	11
Vanadium	V 292.402 {90}	2.5	2.0	82	7
Zinc	Zn 213.856 {123}	2.5	2.5	100	8
Zirconium	Zr 339.198 {78}	2.5	2.5	101	10

0.05 nm or less is required to provide the necessary spectral resolution. The spectrometer may be either a simultaneous multielement or a sequential spectrometer. The spectrometer may be either an inert gas-path or vacuum instrument; the appropriate spectral lines should be selected for each specific instrument. Either an analog or digital readout system may be used.

7.2 The ICP-AES is interfaced to an enclosure. The torch box is contained within an enclosure, since plutonium containing materials may come in direct contact with the torch despite the substantial removal by ion exchange in 10.3. A possible setup is described in ASTM STP 951.<sup>3</sup>

7.3 Vacuum manifold set at approximately 23 cm Hg (9 in. Hg) is optional. A gravity system is also acceptable.

7.4 15 mL plastic disposable ion exchange columns.

7.5 50 mL plastic vials.

7.6 Plastic micro and macro pipettes.

7.7 1000 mL plastic volumetric flasks.

## 8. Reagents and Materials

8.1 *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 Committee on Analytical Reagents of the American Chemical Society (ACS), where such specifications are available.<sup>4</sup> Other grades could 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.

8.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean laboratory accepted demineralized or deionized water as described by Type 1 of Specification D1193.

8.3 ~~Ultra-high~~ Ultra-high purity acids shall be used for sample dissolution and calibration standards preparation unless otherwise noted.

NOTE 1—The molarity of ~~ultra-high~~ ultra-high purity acids may vary from standard ACS specifications for concentrated acids.

NOTE 2—All reagents are prepared and stored in polytetrafluoroethylene (PTFE) containers.

8.4 *Hydrochloric Acid* (HCl, 11.3 M), concentrated ~~ultra-high~~ ultra-high purity HCl.

8.5 *Hydrochloric Acid* (HCl, 6 M)—Add 531 mL of concentrated ~~ultra-high~~ ultra-high purity HCl (11.3 M) to less than 450 mL of water and dilute to 1 L with water.

8.6 *Hydrochloric Acid* (HCl, 0.1 M)—Add 8.8 mL of concentrated ~~ultra-high~~ ultra-high purity HCl (11.3 M) to water, while stirring, and dilute to 1 L with water. (Reagent grade HCl can be used in preparing this reagent.)

8.7 *Hydrofluoric Acid* (HF, 28.3 M), concentrated ~~ultra-high~~ ultra-high purity HF.

8.8 *Nitric Acid* (HNO<sub>3</sub>, 15.8 M), concentrated ~~ultra-high~~ ultra-high purity nitric acid.

<sup>3</sup> Edellson, M. C., and Daniel, J. Leland, "Plasma Spectroscopy of the Analysis of Hazardous Materials: Design and Application of Enclosed Plasma Sources," *Conference Proceedings, ASTM STP 951*, ASTM, 1986.

<sup>4</sup> *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 Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

8.9 *Nitric Acid-Hydrofluoric Acid Mixture*, 10 M HNO<sub>3</sub>/0.03 M HF—Add 1 mL of concentrated ~~ultra-high-ultra-high~~ purity HF (28.3 M) (28.3 M) to water; using a plastic pipette, while stirring, add 633 mL concentrated ~~ultra-high-ultra-high~~ purity HNO<sub>3</sub> (15.8 M) and dilute to ~~1 L~~ 1 L with water.

8.10 *Nitric Acid-Hydrofluoric Acid Mixture*, 8 M HNO<sub>3</sub>/0.006 M HF—Add 0.21 mL of concentrated ~~ultra-high-ultra-high~~ purity HF (28.3 M) to water; using a plastic pipette, while stirring, add 506 mL of concentrated ~~ultra-high-ultra-high~~ purity HNO<sub>3</sub> (15.8 M) and dilute to 1 L with water.

8.11 *Nitric Acid* (HNO<sub>3</sub>, 4 M)—Add 253 mL of concentrated ~~ultra-high-ultra-high~~ purity nitric acid (15.8 M) to water, while stirring, and dilute to 1 L with water.

8.12 *Anion Exchange Resin*, macroporous-1 (MP-1), ~~200-400-200~~ mesh - 400 mesh, either nitrate form or chloride form, high purity.<sup>5</sup>

8.13 *Stock Solutions*, traceable to a national standard, of multielement spike solutions are available from a commercial vendor. The stock solutions of multielement spike solutions can also be prepared in-house.

8.13.1 *Spike Solution 1 (SS-1)*, contains 500 µg/mL of Al, Ba, Be, Ca, Li, Mg, Sr, and Na in 0.8 M HNO<sub>3</sub>.

8.13.2 *Spike Solution 2 (SS-2)*, contains 500 µg/mL of B, Mo, Si, Sn, Ti, W, and Zr in 0.8 M HNO<sub>3</sub>.

8.13.3 *Spike Solution 3 (SS-3)*, contains 500 µg/mL of Cd, Cr, Co, Cu, Fe, Pb, Mn, Ni, V, and Zn in 0.8 M HNO<sub>3</sub>.

8.14 *Stock Solutions*, traceable to a national standard, of multielement impurity standards are available from a commercial vendor. The stock solutions of multielement standards can also be prepared in-house.

8.14.1 *Calibration Stock Solution-2 (CSS-2)*, contains 5000 µg/mL of Na in 0.8 M HNO<sub>3</sub>.

8.14.2 *Calibration Stock Solution-3 (CSS-3)*, contains 500 µg/mL of Mo, Si, Sn, Ti, W, and Zr in 0.3 M HNO<sub>3</sub>/0.1 M HF.

8.14.3 *Calibration Stock Solution-5 (CSS-5)*, contains 500 µg/mL of Al, Ba, and Sr in 0.8 M HNO<sub>3</sub>.

8.14.4 *Calibration Stock Solution-6 (CSS-6)*, contains 500 µg/mL of Be, B, Cd, Ca, Cr, Co, Cu, Fe, Li, Mg, Mn, Ni, Pb, V, and Zn in 0.8 M HNO<sub>3</sub>.

8.15 Prepare the multielement impurity standards and blanks as described in 8.15.1 – 8.15.5. All calibration standard solutions are stored in PTFE containers.

8.15.1 *Calibration Standard One High (CAL 1 HI)*—Pipette 20 mL each, of stock solutions CSS-3, and CSS-5 into a 1 L volumetric flask. Dilute to 1 L with 8 M HNO<sub>3</sub>/0.006 M HF. This standard solution contains the target analytes at a concentration of 10 µg/mL.

8.15.2 *Calibration Standard One Low (CAL 1 LO)*—Pipette 10 mL each, of stock solutions CSS-3, and CSS-5 into a 1 L volumetric flask. Dilute to 1 L with 8 M HNO<sub>3</sub>/0.006 M HF. This standard solution contains the target analytes at a concentration of 5 µg/mL.

8.15.3 *Calibration Standard Two High (CAL 2 HI)*—Pipette 20 mL each, of stock solutions CCS-2, and CSS-6 into a 1 L volumetric flask. Dilute to 1 L with 8 M HNO<sub>3</sub>/0.006 M HF. This standard solution contains the target analytes at a concentration of 10 µg/mL, except Na. Na is 100 µg/mL.

<sup>5</sup> The sole source of supply of the resin known to the committee at this time is AG MP-1 anion exchange resin, Bio-Rad, Hercules, CA. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,<sup>1</sup> which you may attend.