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Designation: C1637 - 06 C1637 - 13

## Standard Test Method for the Determination of Impurities in Plutonium Metal: Acid Digestion and Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) Analysis<sup>1</sup>

This standard is issued under the fixed designation C1637; 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 ( $\varepsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This Test Method covers the determination of 58 trace elements in plutonium (Pu) metal. The Pu sample is dissolved in acid, and the concentration of the trace impurities are determined by Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS).

1.2 This Test Method is specific for the determination of trace impurities in Pu metal. It may be applied to other types of Pu materials, such as Pu oxides, if the samples are dissolved and oxidized to the Pu(IV) state. However, it is the responsibility of the user to evaluate the performance of other matrices.

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

1.4 This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this method to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use of this standard.

## 2. Referenced Documents

- 2.1 ASTM Standards:<sup>2</sup>
- C757 Specification for Nuclear-Grade Plutonium Dioxide Powder, Sinterable
- 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
- C1168 Practice for Preparation and Dissolution of Plutonium Materials for Analysis
- 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. Summary of Test Method

3.1 A sample of Pu metal is dissolved in a small volume of 6 M hydrochloric acid (HCl). Then, 10 M nitric acid (HNO<sub>3</sub>)/0.03 M hydrofluoric acid (HF) is added to the dissolved Pu to oxidize the Pu to the Pu(IV) state. An aliquot of the original sample is taken and diluted with 1 % HNO<sub>3</sub> by volume to a prescribed volume. Aliquots from a second dilution of the original sample are used to prepare run batch dilutions that are analyzed for trace impurities by ICP-MS.<sup>3</sup>

#### 4. Significance and Use

4.1 This test method may be run together with Test Method C1432 to analyze for trace impurities in Pu metal. Using the technique described in this test method and the technique described in Test Method C1432 will provide the analyst with a more

 <sup>&</sup>lt;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 Jan. 1, 2006Jan. 1, 2013. Published February 2006January 2013. Originally approved in 2006. Last previous edition approve in 2006 as D1637
 – 06. DOI: 10.1520/C1637-06.

 $<sup>^{2}</sup>$  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>&</sup>lt;sup>3</sup> "Inductively Coupled Plasma – Mass Spectrometry Using the VG Elemental Plasma Quad," Actinide Analytical Chemistry Procedures, Los Alamos National Laboratory, ANC102 R.1.2, LA-UR-05-7605, 2004.

thorough verification of the impurity concentrations contained in the Pu metal sample. In addition, Test Method C1432 can be used to determine impurity concentrations for analytes such as Ca, Fe, Na, and Si, which have not been determined using this test method.

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4.2 This test method can be used on Pu matrices in nitrate solutions.

4.3 This test method has been validated for use on materials that meet the specifications described in Specification C757 and Test Methods C758 and C759.

4.4 This test method has been validated for all elements listed in Table 1.

#### 5. Interferences

5.1 Ions from doubly charged (2+) species are formed in the ICP-MS. The actinide related spectral interferences are from actinide 2+ and actinide-oxide 2+. The spectral interferences are observed at 120.5 and 127.5 atomic mass unit (amu), when analyzing plutonium-239.

5.2 Spectral interferences from the argon plasma and the acid used to transport the sample to the plasma. These spectral interferences occur between 12 and 80 amu.

5.3 Ions from plutonium cause a matrix related signal suppression. Signal suppression increases as the Pu concentration increases. In order to minimize signal suppression effects from Pu, samples are diluted so that the concentration of Pu in the analyzed aliquot is less than 500  $\mu$ g/mL. Three internal standards are added to samples to correct for matrix related signal suppression and signal drift. Scandium, rhodium and thulium are used as internal standards. Analytes at the low end of the mass range (below 75 amu) are referenced to scandium. Rhodium is a reference for analytes at the middle of the mass range (76-138) and all analytes at the high end of the mass range are referenced to thulium (139-238 amu).

#### 6. Apparatus

6.1 An ICP-MS instrument with a quadrupole mass spectrometer and a electron multiplier that operates at 1 amu resolution is used for this determination. The instrument can also be a magnetic sector instrument or a time of flight instrument.

6.2 The ICP-MS is interfaced to a glovebox. The torch box, and the analyzer region of the mass spectrometer are glovebox enclosed, since Pu containing materials come in direct contact with these sections of the instrument. Methods for enclosing plasma spectroscopic sources so that hazardous materials can be analyzed safely are described in ASTM STP 951.<sup>4</sup>

6.3 Graduated 14 mL disposable plastic round bottom tubes and caps or similar.

6.4 Electronic pipettes.

#### 7. Reagents and Materials

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7.1 Ultra high purity acids shall be used for sample dissolution and calibration standards preparation unless otherwise noted.<sup>5</sup>

7.2 *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 specification are available.<sup>6</sup>

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

Note 1-The molarity of 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.

7.4 Hydrochloric Acid (HCl, 11.3 M), concentrated HCl.

7.5 *Hydrochloric Acid* (HCl, 6 M), Add 531 mL of concentrated HCl (11.3 M) to less than 450 mL of water and dilute to 1 liter with water.

7.6 Nitric Acid (HNO<sub>3</sub>, 15.8 M)— concentrated nitric acid.

7.7 *Nitric Acid*, 1 % by volume— One volume of concentrated nitric acid (HNO<sub>3</sub>, 15.8 M) brought to one hundred volumes with water.

7.8 Hydrofluoric Acid (HF, 28.3 M), concentrated HF.

<sup>5</sup> "The ULTREX II (J. T. Baker) and INSTRUMENT QUALITY (Seastar Chemicals) lines of ultra high purity acids have been found satisfactory for this purpose."

<sup>&</sup>lt;sup>4</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 951*, ASTM, 1986.

<sup>&</sup>lt;sup>6</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.

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#### TABLE 1 Impurity Elements, Mean Percent Recoveries and Percent Relative Standard Deviations

Beryllium       22       96.46       8.14         Boron       22       98.30       7.58         Aluminium       22       99.43       8.96         Phosphorus       22       99.43       8.96         Titanium       22       99.43       8.96         Variadium       22       99.44       7.83         Variadium       22       97.29       3.90         Manganese       22       95.82       4.36         Cobell       22       95.82       4.36         Cobell       22       96.66       3.70         Jine       22       98.16       4.54         Arsenic       22       91.18       8.67         Selenium       22       98.80       4.16         Yttium       22       98.80       3.46         Yttium       22       98.80       3.41         Niobidium       22       97.82       3.81         Molybdenum <sup>4</sup> 21       98.30       3.42         Niobidium       22       97.82       3.81         Molybdenum <sup>4</sup> 21       98.33       3.42         Niobidium       22       97.69       2.49		r	Percent Relative Star	idard Deviations	
Lithium 22 93.66 7.26 Beryllum 22 96.46 8.14 Boron 22 98.48 6.97 Magnesium 22 98.63 7.86 Auminium 22 99.66 8.62 Prosphorus 22 99.43 Vanadium 22 99.25 2.44 Vanadium 22 99.25 2.44 Vanadium 22 99.25 2.44 Chromium 22 99.25 2.44 Chromium 22 99.25 9.24 Silver 22 96.78 3.39 Zine 22 96.78 3.39 Zine 22 96.78 3.39 Zine 22 96.78 3.39 Zine 22 96.66 3.70 Germanium 22 96.66 3.70 Germanium 22 96.66 3.70 Germanium 22 98.16 4.54 Arsenie 22 101.15 8.00 Rubidium 22 100.24 5.36 Stronthum 22 98.80 4.16 Yitrium 22 98.80 3.18 Zine 22 98.80 3.18 Silver 21 97.82 3.81 Molybdenum 22 98.80 3.18 Zine 22 97.82 3.65 Molybdenum 22 97.82 3.65 Molybdenum 22 97.82 3.65 Molybdenum 22 97.69 2.49 Silver 21 106.56 4.22 Cadmium 22 97.69 2.49 Silver 21 107.65 6.21 Haldium 22 97.65 6.21 Haldium 22 97.65 6.21 Fillum 22 98.81 3.77 Fillum 22 98.81 3.77 Fillum 22 98.83 3.99 Antinony 22 97.65 6.21 Fillum 22 98.81 3.77 Fillum 22 98.81 3.77 Fillum 22 98.83 3.77 Fillum 22 98.81 2.20 Fillum 3.77 Fillum 22 98.81 2.20 Fillum 3.77 Fillum 22 98.81 2.20 Fillum 3.77 Fillum 22 98.81 2.21 Fillum 3.77 Fillum 22 98.81 2.20 Fillum 3.77 Fillum 22 98.81 2.20 Fillum 3.77 Fillum 22 98.81 2.20 Fillum 3.77 Fillum 3.77 Fi		Element	N	Mean R, %	RSD, %
Beryllium         22         96.46         8.14           Boron         22         98.48         6.97           Magnesium         22         99.66         8.62           Prosphorus         22         99.25         8.44           Vanadium         22         99.25         8.44           Vanadium         22         99.25         8.44           Vanadium         22         99.25         8.44           Vanadium         22         99.25         8.45           Coronium         22         96.24         4.35           Nickel         22         96.76         3.98           Zinc         22         98.16         4.56           Arsenic         22         101.15         8.00           Germanium         22         98.07         3.81           Molybdenum         22         98.07         3.81           Molybdenum         22         98.30         2.41           Palladum         22         97.82         3.81           Molybdenum         22         97.83         3.84           Molybdenum         22         97.85         3.94           Anthenum         22					
Boron         22         98.48         6.97           Aluminium         22         99.66         8.62           Phosphorus         22         99.25         2.44           Vanadium         22         99.25         2.44           Vanadium         22         99.25         2.44           Vanadium         22         99.25         2.44           Vanadium         22         99.26         3.80           Chromium         22         99.54         3.60           Cobalt         22         99.73         3.90           Zinc         22         99.73         3.93           Zinc         22         99.66         3.70           Germanium         22         101.15         8.00           Rubidium         22         101.15         8.00           Rubidium         22         98.81         4.16           Yttrium         22         98.82         3.85           Molybdenum <sup>4</sup> 21         98.32         2.14           Nickel         22         98.32         2.14           Paladum         22         98.33         3.72           Indium         22         98.03					
Magnesium       22       98.30       7.58         Aluminium       22       99.43       8.96         Titanium       22       99.43       8.96         Titanium       22       99.44       7.38         Chromium       22       97.29       3.90         Manganese       22       95.48       3.46         Cobalt       22       95.78       3.98         Nickel       22       95.78       3.98         Zinc       22       94.24       4.12         Copper       22       96.66       3.70         Germanium       22       98.16       4.54         Arsenic       22       101.38       8.67         Selenium       22       100.24       5.86         Strontium       22       98.89       4.16         Yttrium       22       98.22       3.81         Jobjbdenum <sup>A</sup> 21       98.32       2.14         Nobjbdenum <sup>A</sup> 21       98.32       2.14         Palladium       22       97.69       2.83         Molybdenum <sup>A</sup> 21       98.36       2.41         Nicobium       22       97.63       3.7					
Aluminium       22       99.66       8.62         Phosphorus       22       99.25       2.44         Vanadium       22       99.25       2.44         Vanadium       22       99.26       2.44         Vanadium       22       99.28       3.90         Manganese       22       95.48       3.46         Cobalt       22       95.78       3.90         Zinc       22       96.66       3.70         Germanium       22       98.16       4.54         Arsenic       22       101.15       8.00         Rubidium       22       102.4       5.36         Strontium       22       98.89       4.16         Yttrum       22       98.07       3.81         Molybdenum <sup>4</sup> 21       99.36       2.90         Yttrum       22       98.32       2.96         Noibybdenum <sup>4</sup> 21       98.32       2.90         Paladuim       22       97.69       2.49         Silver       22       97.69       2.49         Silver <sup>A</sup> 21       106.56       2.90         Silver <sup>A</sup> 21       106.56       2.90<					
Phosphorus       22       99.43       8.66         Vanadium       22       92.25       2.44         Vanadium       22       97.48       3.48         Chromium       22       95.28       3.48         Cobalt       22       95.78       3.98         Nickel       22       95.78       3.98         Zinc       22       94.24       4.12         Copper       22       94.24       4.12         Copper       22       98.16       4.54         Arsenic       22       101.38       8.67         Selenium       22       100.24       5.86         Strontium       22       98.16       3.41         Niobium       22       98.89       4.16         Yttium       22       98.89       4.16         Yttium       22       97.62       3.81         Noibiberum <sup>4</sup> 21       98.32       2.14         Palladium       22       97.69       2.49         Silver <sup>4</sup> 21       106.56       4.26         Cadmium       22       97.69       3.44         Noibiberum <sup>4</sup> 21       96.05       3.72     <					
Titanum       22       99.25       2.44         Vanadium       22       97.29       3.90         Marganese       22       97.29       3.90         Cobalt       22       95.92       4.35         Nickel       22       96.78       3.98         Zinc       22       96.76       3.98         Zinc       22       96.66       3.70         Germanium       22       101.15       8.00         Rubidum       22       101.15       8.00         Rubidum       22       98.07       3.81         Molybdenum       22       98.07       3.81         Molybdenum       22       98.32       2.49         Vitrium       22       98.32       2.44         Niobium       22       98.07       3.81         Molybdenum       21       98.32       2.49         Silver       22       96.03       3.72         Indium       22       98.32       2.44         Paladuim       22       96.03       3.72         Indum       22       96.03       3.72         Indum       22       96.03       3.72					
Vanadium       22       94.44       7.38         Chromium       22       95.48       3.46         Cobait       22       95.48       3.46         Cobait       22       95.78       3.98         Zinc       22       96.78       3.98         Zinc       22       96.66       3.70         Germanium       22       101.38       8.67         Selenium       22       101.38       8.67         Selenium       22       98.89       4.16         Yttrium       22       98.89       4.16         Yttrium       22       98.89       4.16         Yttrium       22       98.89       4.16         Yttrium       22       96.92       3.65         Molybdenum       22       97.68       2.49         Nibbium       22       97.69       2.49         Silver <sup>4</sup> 21       106.56       4.26         Cadmium       22       97.69       2.49         Silver <sup>4</sup> 21       106.56       4.26         Cadmium       22       97.99       3.68         Silver <sup>4</sup> 21       100.10       6.66					
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Manganese         22         95.48         3.46           Cobalt         22         96.78         3.98           Zinc         22         96.78         3.98           Zinc         22         94.24         4.12           Copper         22         98.16         4.54           Arsenic         22         101.38         8.67           Selenium         22         100.24         5.36           Stronthum         22         98.09         4.16           Yttrium         22         98.07         3.81           Niobium         22         97.82         3.81           Molybdenum         22         97.82         3.81           Molybdenum         22         97.69         2.49           Silver         21         106.56         4.26           Cadmium         22         97.69         2.49           Silver <sup>A</sup> 21         106.56         4.26           Cadmium         22         97.69         3.64           Autinony         22         97.69         3.64           Cadmium         22         97.57         3.94           Autinony         22         97.32<					
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Nickel         22         96.78         3.98           Zinc         22         94.24         4.12           Copper         22         96.66         3.70           Germanium         22         101.15         8.60           Arsenic         22         101.15         8.00           Rubidium         22         100.15         8.67           Selenium         22         98.89         4.16           Yttrium         22         98.89         4.16           Yttrium         22         98.89         4.16           Yttrium         22         98.32         3.65           Molybdenum         22         97.82         3.81           Molybdenum <sup>A</sup> 21         98.36         2.90           Ruthenium         22         97.82         3.81           Molybdenum <sup>A</sup> 21         106.56         4.26           Cadmiun         22         97.82         3.94           Antimony         22         97.81         3.94           Antimony         22         97.92         3.66           Cadmiun         22         97.92         3.68           Lanthanum         22					
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Copper         22         96.66         3.70           Germanium         22         101.13         8.67           Selenium         22         101.15         8.00           Rubidium         22         100.24         5.36           Strontium         22         98.89         4.16           Yitrium         22         98.907         3.81           Zirconium         22         98.92         3.65           Molybdenum         22         97.82         3.81           Molybdenum         22         97.82         3.81           Molybdenum         22         97.82         3.81           Molybdenum         22         97.69         2.49           Silver         22         97.69         2.49           Silver         22         97.69         2.49           Silver <sup>4</sup> 21         106.56         4.26           Cadmium         22         96.03         3.72           Tin         22         96.03         3.72           Tin         22         96.05         6.21           Torium         22         96.05         6.21           Torium         22         96					
Germanium         22         98.16         4.54           Arsenic         22         101.38         8.67           Selenium         22         100.24         5.36           Strontium         22         98.89         4.16           Yttrium         22         98.07         3.81           Zirconium         22         98.07         3.81           Niobium         22         98.92         3.65           Molybdenum <sup>A</sup> 21         98.36         2.90           Ruthenium         22         97.62         2.84           Palladium         22         97.69         2.49           Silver         22         106.16         4.26           Cadmium         22         97.69         2.49           Silver <sup>A</sup> 21         106.56         4.26           Cadmium         22         97.55         3.94           Tin         22         98.01         3.57           Tin         22         98.01         3.62           Cadmium         22         97.99         3.88           Lanthanum         22         97.57         3.72           Praeseodymium         22					
Arsenic       22       101.35       8.67         Selenium       22       101.15       8.00         Rubidium       22       100.24       5.36         Strontium       22       98.89       4.16         Yitnium       22       98.89       4.16         Yitnium       22       98.89       4.16         Yitnium       22       98.92       3.65         Molybdenum       22       97.82       3.81         Molybdenum       22       97.82       3.81         Molybdenum       22       97.69       2.49         Silver       22       97.69       2.49         Silver       21       106.56       4.26         Cadmium       22       96.03       3.72         Indium       22       98.01       3.57         Tin       22       96.03       3.72         Indium       22       98.01       3.57         Tin       22       98.01       3.57         Tellurium       22       98.01       3.57         Tellurium       22       98.31       3.84         Cerium       22       97.57       3.72 <t< td=""><td></td><td>Copper</td><td></td><td>96.66</td><td>3.70</td></t<>		Copper		96.66	3.70
Selenium         22         101.15         8.00           Rubidium         22         100.24         5.36           Strontium         22         98.89         4.16           Yttrium         22         98.87         3.81           Zirconium         22         96.92         3.65           Molybdenum         21         98.36         2.90           Ruthenium         22         97.82         3.81           Molybdenum <sup>4</sup> 21         98.32         2.14           Palladium         22         97.69         2.49           Silver <sup>4</sup> 21         106.56         4.26           Cadmium         22         96.03         3.72           Indium         22         96.03         3.72           Indium         22         100.10         6.86           Cadesium         22         100.10         6.86           Caesium         22         97.97         3.72           Praeseodymium         22         97.97         3.72           Praeseodymium         22         97.43         3.00           Neodymium         22         97.43         3.02           Gadolinium		Germanium		98.16	4.54
Rubidium         22         100.24         5.36           Strontium         22         98.89         4.16           Yttrium         22         98.07         3.81           Niobium         22         98.10         3.41           Niobium         22         97.82         3.81           Molybdenum <sup>A</sup> 21         98.36         2.90           Ruthenium         22         97.69         2.49           Silver         21         106.56         4.26           Cadmium         22         96.03         3.72           Indium         22         97.25         3.84           Antimony         22         97.99         3.84           Ceium         22         97.99         3.84           Ceium         22         97.92         3.02           Praeseodymium         22         97.62         3.72           Indunium         22         97.62		Arsenic	22	101.38	8.67
Rubidium         22         100.24         5.36           Strontium         22         98.89         4.16           Yttrium         22         98.07         3.81           Niobium         22         98.10         3.41           Niobium         22         97.82         3.81           Molybdenum <sup>A</sup> 21         98.36         2.90           Ruthenium         22         97.69         2.49           Silver         21         106.56         4.26           Cadmium         22         96.03         3.72           Indium         22         97.25         3.84           Antimony         22         97.99         3.84           Ceium         22         97.99         3.84           Ceium         22         97.92         3.02           Praeseodymium         22         97.62         3.72           Indunium         22         97.62		Selenium	22	101.15	8.00
Strontium       22       98.807       3.81         Yttrium       22       98.10       3.41         Niobium       22       96.92       3.65         Molybdenum       22       97.82       3.81         Molybdenum <sup>A</sup> 21       98.36       2.90         Ruthenium       22       97.82       3.81         Molybdenum <sup>A</sup> 21       98.32       2.14         Palladium       22       97.69       2.49         Silver       22       105.14       7.88         Silver <sup>A</sup> 21       106.56       4.26         Cadmium       22       98.01       3.57         Tin       22       98.01       3.57         Tin       22       97.05       6.21         Antimony       22       98.01       8.84         Cadesium       22       98.31       3.84         Caesium       22       97.57       3.72         Praeseodymium       22       97.52       3.34         Antimony       22       97.52       3.34         Lanthanum       22       97.52       3.56         Samarium       22       97.53       3.34<					
Ytrium       22       98.07       3.81         Zirconium       22       98.10       3.41         Niobium       22       96.92       3.65         Molybdenum <sup>A</sup> 21       98.36       2.90         Puthenium       22       98.32       2.14         Palladium       22       97.68       2.49         Silver       22       106.56       4.26         Cadmium       22       96.03       3.72         Indium       22       98.01       3.57         Tin       22       98.01       3.57         Tellurium       22       98.01       3.64         Caesium       22       97.57       3.72         Tellurium       22       97.57       3.72         Praeseodymium       22       97.53       3.00         Redoinium       22       97.57       3.72					
Zirconium       22       98.10       3.41         Niobidenum       22       96.92       3.65         Molybdenum <sup>A</sup> 21       98.36       2.90         Ruthenium       22       98.32       2.14         Palladium       22       98.32       2.14         Palladium       22       98.69       2.49         Silver       22       96.03       3.72         Indium       22       96.03       3.72         Indium       22       96.03       3.72         Indium       22       96.05       6.21         Tin       22       100.10       6.86         Cassium       22       100.10       6.88         Carium       22       97.59       3.68         Lanthanum       22       97.57       3.72         Praeseodymium       22       97.52       3.94         Neodymium       22       97.57       3.72         Praeseodymium       22       97.57       3.72         Praeseodymium       22       97.43       3.02         Gadolinium       22       97.62       2.72       3.56         Samarium       22 <td< td=""><td></td><td></td><td></td><td></td><td></td></td<>					
Niobium         22         96.92         3.65           Molybdenum <sup>A</sup> 21         98.32         2.90           Ruthenium         22         98.32         2.14           Palladium         22         97.69         2.49           Silver         22         105.14         7.88           SilverA         21         106.66         4.26           Cadmium         22         96.03         3.72           Indium         22         96.05         6.21           Indium         22         95.05         6.21           Tin         22         95.05         6.21           Tellurium         22         97.99         3.68           Caesium         22         97.32         3.02           Tellurium         22         97.32         3.02           Praeseodymium         22         97.43         3.02           Gadolinium         22         97.62         2.76           Noby         22         97.62         2.43           Lanthanum         22         97.62         2.76           Gadolinium         22         97.62         2.76           Dysprosium         22					
Molybdenum         22         97.82         3.81           Molybdenum <sup>A</sup> 21         98.36         2.90           Ruthenium         22         97.69         2.49           Silver         22         105.14         7.89           Silver <sup>A</sup> 21         106.56         4.26           Cadmium         22         96.03         3.72           Indium         22         98.01         3.57           Tin         22         98.01         3.57           Tin         22         98.01         6.86           Caesium         22         98.01         6.86           Caesium         22         98.31         3.84           Cerium         22         98.31         3.84           Cerium         22         98.31         3.84           Cerium         22         97.57         3.72           Praeseodymium         22         97.57         3.72           Praeseodymium         22         97.83         3.34           Europium         22         97.62         3.65           Samarium         22         97.62         84.5         2.72           Dysprosium					
Molybdenum <sup>A</sup> 21         98.36         2.90           Ruthenium         22         97.69         2.49           Silver         22         105.14         7.88           Silver <sup>A</sup> 21         106.66         4.26           Cadmium         22         96.03         3.72           Indium         22         95.05         6.21           Tin         22         95.05         6.21           Tellurium         22         96.03         3.72           Indium         22         95.05         6.21           Tellurium         22         97.59         3.84           Antimony         22         97.99         3.68           Lanthanum         22         98.31         3.84           Cerium         22         97.57         3.72           Praeseodymium         22         97.43         3.00           Neodymium         22         97.43         3.02           Gadolinium         22         97.63         2.20           Horimum         22         97.62         2.22           Vstoribim         22         97.63         2.20           Hodomium         22					
Ruthenium         22         98.32         2.14           Palladium         22         97.69         2.49           Silver         22         105.14         7.88           Silver <sup>A</sup> 21         106.56         4.26           Cadmium         22         96.03         3.72           Indium         22         98.01         3.57           Tin         22         95.05         6.21           Tellurium         22         100.10         6.86           Caesium         22         97.99         3.68           Lanthanum         22         97.32         3.00           Neodymium         22         97.32         3.00           Neodymium         22         97.32         3.00           Neodymium         22         97.43         3.02           Gadolinium         22         97.62         2.72           Dysprosium         22         98.61         2.21           Vaterolium         22         98.61         2.21           Opino         22         98.61         2.21           Yaterolium         22         98.61         2.21           Qadolinium         22					
Palladium22 $97.69$ 2.49Silver22105.147.88Silver <sup>A</sup> 21106.564.26Cadmium2296.033.72Indium2296.033.57Tin2295.056.21Tellurium22100.106.86Caesium2297.993.68Lanthanum2297.993.68Lanthanum2297.323.00Neodymium2297.323.00Neodymium2297.433.02Gadolinium2297.433.02Gadolinium2297.622.72Dysprosium2298.612.20Holmium2298.612.20Holmium2298.652.29Ytterbium2298.652.29Ytterbium2298.652.29Ytterbium2293.423.72Lutetium <sup>A</sup> 2197.793.72Hafnium2298.652.29Ytterbium2298.652.29Ytterbium2298.652.29Ytterbium2298.612.21Erbium2298.833.70Findium2299.753.28Gold2299.753.28Gold2299.753.28Gold2299.753.28Gold2299.753.28Gold22100.573.93 <td></td> <td></td> <td></td> <td></td> <td></td>					
Silver       22       105.14       7.88         Silver <sup>A</sup> 21       106.56       4.26         Cadmium       22       96.03       3.72         Indium       22       98.01       3.57         Tin       22       100.10       6.86         Caesium       22       100.10       6.86         Caesium       22       97.99       3.84         Carium       22       98.31       3.84         Cerium       22       98.31       3.84         Cerium       22       98.31       3.84         Cerium       22       97.39       3.00         Neodymium       22       97.32       3.00         Neodymium       22       97.32       3.00         Qadolinium       22       97.43       3.02         Gadolinium       22       98.83       2.20         Holmium       22       98.61       2.21         Dysprosium       22       98.61       2.21         Holmium       22       98.61       2.21         Holmium       22       98.61       2.21         Trataum       21       97.79       3.72      <					
SilverA21106.564.26Cadmium2296.033.72Indium2298.013.57Indium2298.013.57Tin2297.253.94Antimony22100.106.86Caesium22101.816.93Barium2297.993.68Lanthanum2298.313.84Cerium2297.323.00Neodymium2297.323.00Neodymium2297.433.02Gadolinium2297.433.02Gadolinium2298.182.20Holmium2298.182.21Terbium2298.162.21Etropium2298.612.21Etropium2298.612.21Etropium2297.065.00Lutetium2297.553.28Indium2297.553.28Indium2293.843.21Tantalum2293.892.43Lutetium2293.883.70Itantalum2293.883.70Platinum2293.883.70Platinum2293.883.70Platinum2293.883.70Platinum2293.883.71Ical Lutetium <sup>A</sup> 2193.892.43Indium2293.883.70Platinum2293.883.70 <td></td> <td></td> <td></td> <td></td> <td></td>					
Cadmium         22         96.03         3.72           Indium         22         98.01         3.57           Tin         97.55         3.94           Antimony         22         95.05         6.21           Tellurium         22         100.10         6.86           Caesium         22         97.57         3.64           Barium         22         98.31         3.84           Cerium         22         97.32         3.00           Neodymium         22         97.32         3.00           Neodymium         22         97.32         3.00           Neodymium         22         97.43         3.02           Gadolinium         22         97.43         3.02           Gadolinium         22         97.52         2.20           Vistandards.teh and         Terbium         22         98.18         2.20           Vistandards.teh and         Terbium         22         98.16         2.21           Upsprosium         22         97.56         2.29         7.76         5.00           Utetium         22         97.56         2.29         7.72         3.72           Holmium					
Indium       22       98.01       3.57         Tin       22       97.25       3.94         Antimony       22       97.25       3.94         Antimony       22       100.10       6.86         Caesium       22       97.99       3.66         Barium       22       98.91       3.84         Cerium       22       98.31       3.84         Cerium       22       98.31       3.84         Cerium       22       97.32       3.00         Neodymium       22       97.32       3.00         Neodymium       22       97.43       3.02         Gadolinium       22       97.62       8.45       2.72         Dysprosium       22       98.18       2.20         Holmium       22       98.61       2.21         Erbium       22       98.65       2.29         Ytterbium       22       98.05       2.20         Holmium       22       97.62       3.42         Lutetium <sup>4</sup> 21       97.79       3.72         Ytterbium       22       98.65       2.29         Ytterbium       22       93.42       3					
Tin2297.253.94Antimony2295.056.21Tellurum22100.106.86Caesium2297.993.68Lanthanum2298.313.84Cerium2297.573.72Praeseodymium2297.323.00Neodymium2297.323.00Neodymium2297.433.02Gadolinium2297.433.02Gadolinium2297.628.45Zentorium2297.628.45Samarium2297.628.45Cadolinium2297.628.45Zentorium2297.628.45Vistandards. teh2298.182.20Holmium2298.612.21Erbium2298.612.21Erbium2297.692.43Lutetium <sup>A</sup> 2197.793.72Hafnium2293.423.21Tantalum <sup>A</sup> 2193.892.43Lutetium <sup>A</sup> 2193.892.43Tungsten2299.753.28Iridium2299.753.28Iridium2299.753.28Iridium2299.753.28Indiget21100.573.93Gold22101.205.35Gold22101.205.35Gold22100.573.93Gold22100.99 <t< td=""><td></td><td>Cadmium</td><td></td><td>96.03</td><td>3.72</td></t<>		Cadmium		96.03	3.72
Tin2297.253.94Antimony2295.056.21Tellurum22100.106.86Caesium2297.993.68Lanthanum2298.313.84Cerium2297.573.72Praeseodymium2297.323.00Neodymium2297.323.00Neodymium2297.433.02Gadolinium2297.433.02Gadolinium2297.628.45Zentorium2297.628.45Samarium2297.628.45Cadolinium2297.628.45Zentorium2297.628.45Vistandards. teh2298.182.20Holmium2298.612.21Erbium2298.612.21Erbium2297.692.43Lutetium <sup>A</sup> 2197.793.72Hafnium2293.423.21Tantalum <sup>A</sup> 2193.892.43Lutetium <sup>A</sup> 2193.892.43Tungsten2299.753.28Iridium2299.753.28Iridium2299.753.28Iridium2299.753.28Indiget21100.573.93Gold22101.205.35Gold22101.205.35Gold22100.573.93Gold22100.99 <t< td=""><td></td><td>Indium 🔹</td><td>22</td><td>98.01</td><td>3.57</td></t<>		Indium 🔹	22	98.01	3.57
Antimony       22       95.05       6.21         Tellurium       22       100.10       6.86         Caesium       22       101.81       6.93         Barium       22       97.99       3.68         Lanthanum       22       98.31       3.84         Cerium       22       97.57       3.72         Praeseodymium       22       97.57       3.00         Neodymium       22       97.32       3.00         Neodymium       22       97.43       3.02         Gadolinium       22       97.43       3.02         Gadolinium       22       97.62       2.72         Dysprosium       22       98.18       2.20         Holmium       22       98.61       2.21         Dysprosium       22       98.61       2.21         Lutetium       22       98.61       2.21         Holmium       22       98.61       3.72 </td <td></td> <td></td> <td>22 22</td> <td></td> <td></td>			22 22		
Tellurium       22       100.10       6.86         Caesium       22       97.99       3.68         Barium       22       97.99       3.68         Lanthanum       22       97.31       3.84         Cerium       22       97.32       3.00         Neodymium       22       97.43       3.02         Gadolinium       22       97.62       8.45       2.72         Dysprosium       22       98.18       2.20         Holmium       22       98.61       2.21         Hoimium       22       98.65       2.29         Ytterbium       22       97.06       5.00         Lutetium <sup>4</sup> 21       97.79       3.72         Hafnium       22       93.42       3.21         Tantalum       22       93.42       3.21         Tantalum <sup>4</sup> 21       97.75       3.28         Tidium       22       93.89<					
Caesium       22       97.99       3.68         Barium       22       97.99       3.68         Lanthanum       22       98.31       3.84         Cerium       22       97.97       3.72         Praeseodymium       22       97.32       3.00         Neodymium       22       97.32       3.00         Neodymium       22       97.43       3.02         Gadolinium       22       97.43       3.02         Gadolinium       22       97.62       2.72         Opsprosium       22       98.61       2.20         Vistandards       22       98.61       2.21         Dysprosium       22       98.61       2.21         Dysprosium       22       98.65       2.29         Ytterbium       22       97.66       5.00         Lutetium       22       97.06       5.00         Lutetium       22       93.42       3.21         Tantalum <sup>A</sup> 21       97.79       3.72         Hafnium       22       99.75       3.28         Tindum <sup>A</sup> 21       93.89       2.43         Tungsten       22       99.75					
Barium         22         97.99         3.68           Lanthanum         22         98.31         3.84           Cerium         22         97.57         3.72           Praeseodymium         22         97.32         3.00           Neodymium         22         97.32         3.00           Neodymium         22         97.22         3.56           Samarium         22         98.39         3.34           Europium         22         97.43         3.02           Gadolinium         22         97.43         3.02           Gadolinium         22         97.62         2.72           Dysprosium         22         97.62         2.72           Dysprosium         22         98.18         2.20           Holmium         22         98.61         2.21           Erbium         22         98.05         2.29           Ytterbium         22         97.06         5.00           Lutetium <sup>A</sup> 21         97.79         3.72           Hafnium         22         100.32         3.95           Tantalum <sup>A</sup> 21         93.42         3.21           Tantalum <sup>A</sup> <t< td=""><td></td><td></td><td></td><td></td><td></td></t<>					
Lanthanum 22 98.31 3.84 Cerium 22 97.57 97.37 Praeseodymium 22 97.22 3.56 Samarium 22 98.39 3.34 Europium 22 98.39 3.34 Europium 22 97.43 3.02 Gadolinium 22 97.43 3.02 Gadolinium 22 97.43 3.02 Gadolinium 22 97.43 3.02 Gadolinium 22 97.43 3.02 Ystandards.itch 22 98.61 2.21 Erbium 22 98.61 2.21 Erbium 22 98.65 2.29 Ytterbium 22 99.59 2.43 Lutetium <sup>A</sup> 21 97.79 3.72 Hafnium 22 93.42 3.21 Tantalum 22 93.42 3.21 Tantalum <sup>A</sup> 21 97.79 3.72 Hafnium 22 93.42 3.21 Tantalum <sup>A</sup> 21 93.89 2.43 Lutetium <sup>A</sup> 21 93.89 2.43 Tungsten 22 96.29 3.54 Rhenium 22 99.75 3.28 Iridium 23 99.75 3.28 Iridium 24 99.75 3.28 Iridium 25 99.75 3.					
Cerium2297.57 $3.72$ Praeseodymium22 $97.32$ $3.00$ Neodymium22 $97.32$ $3.66$ Samarium22 $97.22$ $3.66$ Samarium22 $97.43$ $3.02$ Gadolinium22 $97.43$ $3.02$ Gadolinium22 $97.62$ $8.45-18$ Zere27.62 $97.62$ $8.45-18$ Vistandards.iteh22 $98.61$ $2.21$ Dysprosium22 $98.61$ $2.21$ Erbium22 $98.61$ $2.21$ Erbium22 $99.59$ $2.43$ Lutetium22 $99.59$ $2.43$ Lutetium <sup>A</sup> 21 $97.79$ $3.72$ Hafnium22 $93.42$ $3.21$ Tantalum <sup>A</sup> 21 $93.89$ $2.43$ Tungsten22 $96.29$ $3.54$ Rhenium22 $99.75$ $3.28$ Iridium22 $99.75$ $3.28$ Iridium22 $99.75$ $3.28$ Iridium22 $99.75$ $3.28$ Iridium22 $90.75$ $3.93$ Gold22 $100.57$ $3.93$ Gold22 $100.57$ $3.93$ Gold22 $101.20$ $5.35$ Gold22 $101.68$ $5.54$ Bismuth22 $100.70$ $5.43$ Thorium22 $100.70$ $5.43$ Thorium22 $103.30$ $6.89$					
Praeseodymium22 $97.32$ $3.00$ Neodymium22 $97.22$ $3.56$ Samarium22 $98.39$ $3.34$ Europium22 $97.43$ $3.02$ Gadolinium22 $97.43$ $3.02$ Gadolinium22 $97.62$ $2.72$ Dysprosium22 $98.61$ $2.21$ Holmium22 $98.61$ $2.21$ Erbium22 $98.61$ $2.21$ Hutetium22 $98.65$ $2.29$ Ytterbium22 $97.66$ $5.00$ Lutetium <sup>A</sup> 21 $97.79$ $3.72$ Hafnium22 $93.42$ $3.21$ Tantalum <sup>A</sup> 21 $97.79$ $3.72$ Hafnium22 $93.42$ $3.21$ Tantalum <sup>A</sup> 21 $97.79$ $3.72$ Hafnium22 $99.75$ $3.28$ Iridium22 $100.57$ $3.93$ Gold22 $101.20$ $5.35$ Gold22 $101.20$ $5.54$ Bismuth22 $100.70$ $5.43$ Thorium22 $103.30$ $6.89$					
Neodymium22 $97.22$ $3.56$ Samarium22 $98.39$ $3.34$ Europium22 $97.43$ $3.02$ Gadolinium22 $97.43$ $3.02$ Gadolinium22 $97.43$ $3.02$ Terbium22 $97.62$ $87.62$ Dysprosium22 $98.18$ $2.20$ Holmium22 $98.61$ $2.20$ Holmium22 $98.65$ $2.29$ Ytterbium22 $98.65$ $2.29$ Ytterbium22 $99.59$ $2.43$ Lutetium <sup>A</sup> 21 $97.79$ $3.72$ Hafnium22 $93.42$ $3.21$ Tantalum <sup>A</sup> 21 $97.79$ $3.72$ Hafnium22 $99.59$ $2.43$ Tungsten22 $99.75$ $3.28$ Iridium22 $99.75$ $3.28$ Iridium22 $99.88$ $3.70$ Platinum22 $99.88$ $3.70$ Platinum22 $100.57$ $3.93$ Gold22 $101.20$ $5.35$ Gold22 $101.20$ $5.35$ Gold22 $100.99$ $5.02$ Lead22 $100.70$ $5.43$ Thorium22 $100.70$ $5.43$			CU <sup>22</sup> ent		
Samarium       22       98.39       3.34         Europium       22       97.43       3.02         Gadolinium       22       97.43       3.02         Gadolinium       22       97.62       88.45-18       2.72         Dysprosium       22       98.61       2.21         Holmium       22       98.61       2.21         Holmium       22       98.65       2.29         Ytterbium       22       97.66       5.00         Lutetium <sup>A</sup> 21       97.79       3.72         Hafnium       22       93.42       3.21         Tantalum <sup>A</sup> 21       97.79       3.72         Hafnium       22       93.42       3.21         Tantalum <sup>A</sup> 21       97.79       3.72         Hafnium       22       93.42       3.21         Tantalum <sup>A</sup> 21       93.89       2.43         Tungsten       22       99.75       3.28         Iridium       22       99.75       3.28         Gold       22       100.57       3.93         Gold       22       101.58       5.54         Gold       22       100.57 </td <td></td> <td></td> <td></td> <td></td> <td></td>					
Europium         22         97.43         3.02           Gadolinium         22         100.04         2.78           Ystandards.iteh         22         98.18         2.20           Dysprosium         22         98.18         2.20           Holmium         22         98.61         2.21           Erbium         22         98.61         2.21           Erbium         22         98.65         2.29           Ytterbium         22         97.66         5.00           Lutetium <sup>A</sup> 21         97.79         3.72           Hafnium         22         93.42         3.21           Tantalum <sup>A</sup> 21         97.79         3.72           Hafnium         22         93.42         3.21           Tantalum <sup>A</sup> 21         93.89         2.43           Tungsten         22         93.42         3.28           Iridium         22         93.75         3.28           Iridium         22         99.75         3.28           Iridium         22         99.88         3.70           Platinum         22         100.57         3.93           Gold         22					
Gadolinium22100.042.78Vistandards.iteh.aicTerbium2297.6284.52.72Dysprosium2298.182.20Holmium2298.612.21Erbium2298.052.29Ytterbium2299.592.43Lutetium2297.065.00Lutetium <sup>A</sup> 2197.793.72Hafnium2293.423.95Tantalum2293.423.21Tantalum2299.753.28Iridium2299.753.28Iridium2299.753.28Iridium2299.883.70Platinum2299.883.70Platinum22100.573.93Gold22101.205.35Gold <sup>A</sup> 21100.095.02Lead22101.585.54Bismuth22100.705.43Thorium22103.306.89					
Astandards.itch allTerbium and and sist2297.6288.452.72Dysprosium2298.182.20Holmium2298.612.21Erbium2298.052.29Ytterbium2299.592.43Lutetium2297.065.00Lutetium <sup>A</sup> 2197.793.72Hafnium2293.423.21Tantalum2293.423.21Tantalum <sup>A</sup> 2193.892.43Tungsten2299.753.28Iridium2299.753.28Iridium2299.883.70Platinum22100.573.93Gold22101.205.35Gold <sup>A</sup> 21100.095.02Lead22101.585.54Bismuth22100.705.43Thorium22103.306.89					
Dysprosium         22         98.18         2.20           Holmium         22         98.61         2.21           Erbium         22         98.05         2.29           Ytterbium         22         99.59         2.43           Lutetium         22         97.06         5.00           Lutetium <sup>A</sup> 21         97.79         3.72           Hafnium         22         93.42         3.21           Tantalum <sup>A</sup> 21         93.89         2.43           Tungsten         22         96.29         3.54           Rhenium         22         96.29         3.54           Rhenium         22         99.75         3.28           Iridium         22         99.75         3.28           Iridium         22         99.75         3.28           Iridium         22         99.75         3.28           Iridium         22         100.57         3.93           Gold         22         101.20         5.35           Gold <sup>A</sup> 21         100.09         5.02           Lead         22         101.58         5.54           Bismuth         22         103.					
Dysprosium         22         98.18         2.20           Holmium         22         98.61         2.21           Erbium         22         98.05         2.29           Ytterbium         22         97.06         5.00           Lutetium         22         97.06         5.00           Lutetium <sup>A</sup> 21         97.79         3.72           Hafnium         22         93.42         3.21           Tantalum         22         93.42         3.21           Tantalum         22         93.42         3.21           Tantalum <sup>A</sup> 21         93.89         2.43           Tungsten         22         99.75         3.28           Iridium         22         99.75         3.28           Iridium         22         99.88         3.70           Platinum         22         100.57         3.93           Gold         22         101.20         5.35           Gold         22         101.20         5.35           Gold         22         101.20         5.35           Gold         22         101.20         5.54           Bismuth         22         101.58		Terbium ctanda	de/sist/c226c2c1c	362 97.62 00	245-18-2.72
Holmium22 $98.61$ $2.21$ Erbium22 $98.05$ $2.29$ Ytterbium22 $99.59$ $2.43$ Lutetium22 $97.06$ $5.00$ Lutetium <sup>A</sup> 21 $97.79$ $3.72$ Hafnium22 $100.32$ $3.95$ Tantalum22 $93.42$ $3.21$ Tantalum <sup>A</sup> 21 $93.89$ $2.43$ Tungsten22 $96.29$ $3.54$ Rhenium22 $99.75$ $3.28$ Iridium22 $99.88$ $3.70$ Platinum22 $99.88$ $3.70$ Platinum22 $100.57$ $3.93$ Gold22 $101.20$ $5.35$ Gold <sup>A</sup> 21 $100.41$ $3.96$ Thallium22 $101.58$ $5.54$ Bismuth22 $100.70$ $5.43$ Thorium22 $103.30$ $6.89$		Dysprosium	22		2.20
Erbium2298.052.29Ytterbium2299.592.43Lutetium2297.065.00Lutetium <sup>A</sup> 2197.793.72Hafnium22100.323.95Tantalum <sup>A</sup> 2193.423.21Tantalum <sup>A</sup> 2193.892.43Tungsten2296.293.54Rhenium2299.753.28Iridium2299.883.70Platinum22100.573.93Gold22101.205.35Gold <sup>A</sup> 21100.413.96Thallium22101.585.54Bismuth22101.585.54Bismuth22100.705.43Thorium22103.306.89			22		
Ytterbium       22       99.59       2.43         Lutetium       22       97.06       5.00         Lutetium <sup>A</sup> 21       97.79       3.72         Hafnium       22       100.32       3.95         Tantalum       22       93.42       3.21         Tantalum <sup>A</sup> 21       93.89       2.43         Tungsten       22       96.29       3.54         Rhenium       22       99.75       3.28         Iridium       22       99.88       3.70         Platinum       22       100.57       3.93         Gold       22       101.20       5.35         Gold <sup>A</sup> 21       100.41       3.96         Thallium       22       101.58       5.54         Bismuth       22       101.58       5.54         Bismuth       22       103.30       6.89					
Lutetium         22         97.06         5.00           Lutetium <sup>A</sup> 21         97.79         3.72           Hafnium         22         100.32         3.95           Tantalum         22         93.42         3.21           Tantalum <sup>A</sup> 21         93.89         2.43           Tungsten         22         96.29         3.54           Rhenium         22         99.75         3.28           Iridium         22         99.88         3.70           Platinum         22         100.57         3.93           Gold         22         100.57         3.93           Gold         22         100.57         3.93           Gold         22         101.20         5.35           Gold <sup>A</sup> 21         100.41         3.96           Thallium         22         100.99         5.02           Lead         22         101.58         5.54           Bismuth         22         100.70         5.43           Thorium         22         103.30         6.89					
Lutetium <sup>A</sup> 21         97.79         3.72           Hafnium         22         100.32         3.95           Tantalum         22         93.42         3.21           Tantalum <sup>A</sup> 21         93.89         2.43           Tungsten         22         96.29         3.54           Rhenium         22         99.75         3.28           Iridium         22         99.88         3.70           Platinum         22         100.57         3.93           Gold         22         101.20         5.35           Gold <sup>A</sup> 21         100.41         3.96           Thallium         22         100.99         5.02           Lead         22         101.58         5.54           Bismuth         22         100.70         5.43           Thorium         22         103.30         6.89					
Hafnium22100.323.95Tantalum2293.423.21Tantalum <sup>A</sup> 2193.892.43Tungsten2296.293.54Rhenium2299.753.28Iridium2299.883.70Platinum22100.573.93Gold22101.205.35Gold <sup>A</sup> 21100.413.96Thallium22101.585.54Bismuth22100.705.43Thorium22103.306.89					
Tantalum2293.423.21TantalumA2193.892.43Tungsten2296.293.54Rhenium2299.753.28Iridium2299.883.70Platinum22100.573.93Gold22101.205.35GoldAA21100.413.96Thallium22100.595.02Lead22101.585.54Bismuth22100.705.43Thorium22103.306.89					
Tantalum <sup>A</sup> 21         93.89         2.43           Tungsten         22         96.29         3.54           Rhenium         22         99.75         3.28           Iridium         22         99.88         3.70           Platinum         22         100.57         3.93           Gold         22         101.20         5.35           Gold <sup>A</sup> 21         100.41         3.96           Thallium         22         100.09         5.02           Lead         22         101.58         5.54           Bismuth         22         100.70         5.43           Thorium         22         103.30         6.89					
Tungsten         22         96.29         3.54           Rhenium         22         99.75         3.28           Iridium         22         99.88         3.70           Platinum         22         100.57         3.93           Gold         22         101.20         5.35           Gold <sup>A</sup> 21         100.41         3.96           Thallium         22         100.59         5.02           Lead         22         101.58         5.54           Bismuth         22         100.70         5.43           Thorium         22         103.30         6.89					
Rhenium         22         99.75         3.28           Iridium         22         99.88         3.70           Platinum         22         100.57         3.93           Gold         22         101.20         5.35           Gold <sup>A</sup> 21         100.41         3.96           Thallium         22         100.09         5.02           Lead         22         101.58         5.54           Bismuth         22         100.70         5.43           Thorium         22         103.30         6.89					
Iridium         22         99.88         3.70           Platinum         22         100.57         3.93           Gold         22         101.20         5.35           Gold <sup>A</sup> 21         100.41         3.96           Thallium         22         100.09         5.02           Lead         22         101.58         5.54           Bismuth         22         100.70         5.43           Thorium         22         103.30         6.89					
Platinum         22         100.57         3.93           Gold         22         101.20         5.35           Gold <sup>A</sup> 21         100.41         3.96           Thallium         22         100.09         5.02           Lead         22         101.58         5.54           Bismuth         22         100.70         5.43           Thorium         22         103.30         6.89					
Gold22 $101.20$ $5.35$ Gold <sup>A</sup> 21 $100.41$ $3.96$ Thallium22 $100.09$ $5.02$ Lead22 $101.58$ $5.54$ Bismuth22 $100.70$ $5.43$ Thorium22 $103.30$ $6.89$		Iridium		99.88	
Gold22 $101.20$ $5.35$ Gold <sup>A</sup> 21 $100.41$ $3.96$ Thallium22 $100.09$ $5.02$ Lead22 $101.58$ $5.54$ Bismuth22 $100.70$ $5.43$ Thorium22 $103.30$ $6.89$		Platinum			
Gold <sup>A</sup> 21         100.41         3.96           Thallium         22         100.09         5.02           Lead         22         101.58         5.54           Bismuth         22         100.70         5.43           Thorium         22         103.30         6.89					
Thallium22100.095.02Lead22101.585.54Bismuth22100.705.43Thorium22103.306.89					
Lead22101.585.54Bismuth22100.705.43Thorium22103.306.89					
Bismuth         22         100.70         5.43           Thorium         22         103.30         6.89					
Thorium 22 103.30 6.89					
Uranium 22 104.14 9.11					
		Uranium	22	104.14	9.11

<sup>A</sup> Without Outlying Value

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

7.10 Stock solutions, traceable to a national standards organization, of multielement spike solutions are available from commercial vendors. The stock solutions of multielement spike solutions can also be prepared in-house.