
**Water quality — Application of
inductively coupled plasma mass
spectrometry (ICP-MS) —**

**Part 2:
Determination of selected elements
including uranium isotopes**

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*Qualité de l'eau — Application de la spectrométrie de masse avec
plasma à couplage inductif (ICP-MS) —*

*Partie 2: Dosage des éléments sélectionnés y compris les isotopes
d'uranium*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html

The committee responsible for this document is ISO/TC 147, *Water quality*, Subcommittee SC 2, *Physical, chemical and biochemical methods*.

This second edition cancels and replaces the first edition (ISO 17294-2:2003), which has been technically revised.

ISO 17294 consists of the following parts, under the general title *Water quality — Application of inductively coupled plasma mass spectrometry (ICP-MS)*:

- *Part 1: General guidelines*
- *Part 2: Determination of selected elements including uranium isotopes*

Introduction

When applying this part of ISO 17294, it is necessary in each case, depending on the range to be tested, to determine if and to what extent additional conditions are to be established.

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Water quality — Application of inductively coupled plasma mass spectrometry (ICP-MS) —

Part 2:

Determination of selected elements including uranium isotopes

WARNING — Persons using this part of ISO 17294 should be familiar with normal laboratory practice. This part of ISO 17294 does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to ensure compliance with any national regulatory conditions.

IMPORTANT — It is absolutely essential that tests, conducted in accordance with this part of ISO 17294, be carried out by suitably qualified staff.

1 Scope

This part of ISO 17294 specifies a method for the determination of the elements aluminium, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, caesium, calcium, cerium, chromium, cobalt, copper, dysprosium, erbium, gadolinium, gallium, germanium, gold, hafnium, holmium, indium, iridium, iron, lanthanum, lead, lithium, lutetium, magnesium, manganese, mercury, molybdenum, neodymium, nickel, palladium, phosphorus, platinum, potassium, praseodymium, rubidium, rhenium, rhodium, ruthenium, samarium, scandium, selenium, silver, sodium, strontium, terbium, tellurium, thorium, thallium, thulium, tin, tungsten, uranium and its isotopes, vanadium, yttrium, ytterbium, zinc and zirconium in water (for example, drinking water, surface water, ground water, waste water and eluates).

Taking into account the specific and additionally occurring interferences, these elements can also be determined in digests of water, sludges and sediments (for example, digests of water as described in ISO 15587-1 or ISO 15587-2).

The working range depends on the matrix and the interferences encountered. In drinking water and relatively unpolluted waters, the limit of quantification (xLQ) lies between 0,002 µg/l and 1,0 µg/l for most elements (see [Table 1](#)). The working range typically covers concentrations between several pg/l and mg/l depending on the element and pre-defined requirements.

The quantification limits of most elements are affected by blank contamination and depend predominantly on the laboratory air-handling facilities available on the purity of reagents and the cleanliness of glassware.

The lower limit of quantification is higher in cases where the determination suffers from interferences (see [Clause 5](#)) or memory effects (see ISO 17294-1:2004, 8.2).

Table 1 — Lower limits of quantification (xLQ) for unpolluted water

Element	Isotope often used	Limit of quantification ^a µg/l	Element	Isotope often used	Limit of quantification ^a µg/l	Element	Isotope often used	Limit of quantification ^a µg/l
Ag	¹⁰⁷ Ag	0,5	Hf	¹⁷⁸ Hf	0,1	Ru	¹⁰² Ru	0,1
	¹⁰⁹ Ag	0,5	Hg	²⁰² Hg	0,05	Sb	¹²¹ Sb	0,2
Al	²⁷ Al	1	Ho	¹⁶⁵ Ho	0,1		¹²³ Sb	0,2
As	⁷⁵ As ^c	0,1	In	¹¹⁵ In	0,1	Sc	⁴⁵ Sc	5
Au	¹⁹⁷ Au	0,5	Ir	¹⁹³ Ir	0,1	Se	⁷⁷ Se ^c	1
B	¹⁰ B	1	K	³⁹ K ^c	5		⁷⁸ Se ^c	0,1
	¹¹ B	1	La	¹³⁹ La	0,1		⁸² Se	1
Ba	¹³⁷ Ba	3	Li	⁶ Li	10	Sm	¹⁴⁷ Sm	0,1
	¹³⁸ Ba	0,5		⁷ Li	1	Sn	¹¹⁸ Sn	1
Be	⁹ Be	0,1	Lu	¹⁷⁵ Lu	0,1		¹²⁰ Sn	1
Bi	²⁰⁹ Bi	0,5	Mg	²⁴ Mg	1	Sr	⁸⁶ Sr	0,5
				²⁵ Mg	10		⁸⁸ Sr	0,3
Ca	⁴³ Ca	100	Mn	⁵⁵ Mn	0,1	Tb	¹⁵⁹ Tb	0,1
	⁴⁴ Ca	50		⁹⁵ Mo	0,5	Te	¹²⁶ Te	2
	⁴⁰ Ca	10	Mo	⁹⁸ Mo	0,3	Th	²³² Th	0,1
Cd	¹¹¹ Cd	0,1		Na	²³ Na	10	Tl	²⁰³ Tl
	¹¹⁴ Cd	0,5	Nd	¹⁴⁶ Nd	0,1	²⁰⁵ Tl		0,1
Ce	¹⁴⁰ Ce	0,1		Ni	⁵⁸ Ni	0,1	Tm	¹⁶⁹ Tm
Co	⁵⁹ Co	0,2	⁶⁰ Ni		0,1	U		²³⁸ U
Cr	⁵² Cr ^c	0,1	P	³¹ P	5		²³⁵ U	10 ⁻⁴
	⁵³ Cr	5		²⁰⁶ Pb	0,2		²³⁴ U	10 ⁻⁵
Cs	¹³³ Cs	0,1	Pb	²⁰⁷ Pb	0,2	V	⁵¹ V	0,1
Cu	⁶³ Cu	0,1		²⁰⁸ Pb	0,1		W	¹⁸² W
	⁶⁵ Cu	0,1		Pd	¹⁰⁸ Pd	0,5		¹⁸⁴ W
Dy	¹⁶³ Dy	0,1	Pr		¹⁴¹ Pr	0,1		Y
Er	¹⁶⁶ Er	0,1	Pt	¹⁹⁵ Pt	0,5	Yb	¹⁷² Yb	0,2
Fe	⁵⁶ Fe ^c	5	Rb	⁸⁵ Rb	0,1		¹⁷⁴ Yb	0,2
	Ga	⁶⁹ Ga	0,3	Re	¹⁸⁵ Re	0,1	Zn	⁶⁴ Zn
⁷¹ Ga		0,3	¹⁸⁷ Re		0,1	⁶⁶ Zn		1
Gd	¹⁵⁷ Gd	0,1	Rh	¹⁰³ Rh	0,1	⁶⁸ Zn		1
	¹⁵⁸ Gd	0,1	Ru	¹⁰¹ Ru	0,2	Zr	⁹⁰ Zr	0,2
Ge	⁷⁴ Ge	0,3						

^a Depending on the instrumentation, significantly lower limits can be achieved.

^b In order to avoid incorrect results due to the varying isotop ratios in the environment, the signal intensities of ²⁰⁶Pb, ²⁰⁷Pb and ²⁰⁸Pb shall be added.

^c In order to reach these limits, depending on interferences, the use of a collision/reaction cell is recommended

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3696, *Water for analytical laboratory use — Specification and test methods*

ISO 5667-1, *Water quality — Sampling — Part 1: Guidance on the design of sampling programmes and sampling techniques*

ISO 5667-3, *Water quality — Sampling — Part 3: Preservation and handling of water samples*

ISO 8466-1, *Water quality — Calibration and evaluation of analytical methods and estimation of performance characteristics — Part 1: Statistical evaluation of the linear calibration function*

ISO 15587-1, *Water quality — Digestion for the determination of selected elements in water — Part 1: Aqua regia digestion*

ISO 15587-2, *Water quality — Digestion for the determination of selected elements in water — Part 2: Nitric acid digestion*

ISO 17294-1:2004, *Water quality — Application of inductively coupled plasma mass spectrometry (ICP-MS) — Part 1: General guidelines*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 17294-1 and the following apply.

3.1

limit of application

lowest concentration of an analyte that can be determined with a defined level of accuracy and precision

4 Principle

Multi-element determination of selected elements, including uranium isotopes, by inductively coupled plasma mass spectrometry (ICP-MS) consists of the following steps:

- introduction of a measuring solution into a radiofrequency plasma (for example, by pneumatic nebulization) where energy transfer processes from the plasma cause desolvation, decomposition, atomization and ionization of elements;
- as an additional option, collision and reaction cell technology may be to overcome several interferences (see [5.1](#));
- extraction of the ions from plasma through a differentially pumped vacuum interface with integrated ion optics and separation on the basis of their mass-to-charge ratio by a mass spectrometer (for instance a quadrupole MS);
- transmission of the ions through the mass separation unit (for instance, a quadrupole) and detection, usually by a continuous dynode electron multiplier assembly, and ion information processing by a data handling system;
- quantitative determination after calibration with suitable calibration solutions.

The relationship between signal intensity and mass concentration is usually a linear one over a broad range (usually over more than several orders of magnitude).

The method to be used for determination of uranium isotopes is described in [Annex A](#). With instruments equipped with a magnetic sector field, higher mass resolution spectra can be obtained. This can help to separate isotopes of interest from interfering species.

5 Interferences

5.1 General

In certain cases, isobaric and non-isobaric interferences can occur. The most important interferences in this respect are coinciding masses and physical interferences from the sample matrix. For more detailed information, see ISO 17294-1.

Common isobaric interferences are given in [Table 2](#) (for additional information, see ISO 17294-1). It is recommended that different isotopes of an element be determined in order to select an isotope

that does not suffer from interference. If there are none that meet this requirement, a mathematical correction has to be applied. For the determination of uranium isotopes, the specific procedure detailed in [Annex A](#) has to be followed.

Small drifts or variations in intensities should be corrected by the application of the internal standard correction. In general, in order to avoid physical and spectral interferences, the mass concentration of dissolved matter (salt content) should not exceed 2 g/l (corresponding to a conductivity of less than 2 700 µS/cm).

NOTE With the use of collision and reaction cell technology, it is possible to overcome several interferences. As the various options and parameters of those techniques cannot be described in detail in this part of ISO 17294, the user is responsible for demonstrating that the chosen approach is fit for purpose and achieves the necessary performance.

5.2 Spectral interferences

5.2.1 General

For more detailed information on spectral interferences, see ISO 17294-1:2004, 6.2.

5.2.2 Isobaric elemental

Isobaric elemental interferences are caused by isotopes of different elements of the same nominal mass-to-charge ratio and which cannot be separated due to an insufficient resolution of the mass spectrometer in use (for example, ¹¹⁴Cd and ¹¹⁴Sn).

Element interferences from isobars may be corrected for taking into account the influence from the interfering element (see [Table 3](#)). In this case, the isotopes used for correction shall be determinable without any interference and with sufficient precision. Possible proposals for correction are often included in the instrument software.

Table 2 — Important isobaric and polyatomic interferences

Element	Isotope	Inter-element interferences caused by isobars and doubly charged ions	Interferences caused by polyatomic ions
Ag	¹⁰⁷ Ag ¹⁰⁹ Ag	—	ZrO NbO, ZrOH
As	⁷⁵ As	—	ArCl, CaCl
Au	¹⁹⁷ Au	—	TaO
B	¹⁰ B	—	—
	¹¹ B	—	BH
Ba	¹³⁸ Ba	La ⁺ , Ce ⁺	—
Be	⁹ Be	—	¹⁸ O ₂
Ca	⁴³ Ca	—	CNO
	⁴⁴ Ca	—	COO
Cd	¹¹¹ Cd	—	MoO, MoOH, ZrOH
	¹¹⁴ Cd	Sn ⁺	MoO, MoOH
Co	⁵⁹ Co	—	CaO, CaOH, MgCl
Cr	⁵² Cr	—	ArO, ArC, ClOH
	⁵³ Cr	Fe ⁺	ClO, ArOH,
Cu	⁶³ Cu	—	ArNa, POO, MgCl
	⁶⁵ Cu	—	SOOH

NOTE In the presence of elements in high mass concentrations, interferences can be caused by the formation of polyatoms or doubly charged ions which are not listed above.

Table 2 (continued)

Element	Isotope	Inter-element interferences caused by isobars and doubly charged ions	Interferences caused by polyatomic ions
Eu	¹⁵¹ Eu	—	BaO
	¹⁵³ Eu	—	BaO
Fe	⁵⁴ Fe	—	³⁷ Cl ¹⁶ O ¹ H+ ⁴⁰ Ar ¹⁴ N
	⁵⁶ Fe	—	⁴⁰ Ar ¹⁶ O+ ⁴⁰ Ca ¹⁶ O+
	⁵⁷ Fe	—	⁴⁰ Ar ¹⁶ O ¹ H+ ⁴⁰ Ca ¹⁶ O ¹ H+ ⁴⁰ Ar ¹⁷ O+
Ga	⁶⁹ Ga	Ba ⁺⁺	CrO, ArP, ClOO
Ge	⁷⁴ Ge	Se ⁺	ArS, ClCl
In	¹¹⁵ In	Sn ⁺	—
Ir	¹⁹³ Ir	—	HfO
Mg	²⁴ Mg	—	CC
	²⁵ Mg	—	CC
Mn	⁵⁵ Mn	—	NaS, ArOH, ArNH
Mo	⁹⁸ Mo	Ru ⁺	—
Ni	⁵⁸ Ni	Fe ⁺	CaO, CaN, NaCl, MgS
	⁶⁰ Ni	—	CaO, CaOH, MgCl, NaCl
Pd	¹⁰⁸ Pd	Cd ⁺	MoO, ZrO
Pt	¹⁹⁵ Pt	—	HfO
Re	¹⁸⁷ Re	Os ⁺	—
Ru	¹⁰² Ru	Pd ⁺	—
Sb	¹²³ Sb	Te ⁺	—
Sc	⁴⁵ Sc	—	COO, COOH
Se	⁷⁷ Se	—	CaCl, ArCl, ArArH
	⁷⁸ Se	Kr ⁺	ArAr, CaCl
	⁸² Se	Kr ⁺	HBr
Sn	¹²⁰ Sn	Te ⁺	—
V	⁵¹ V	—	ClO, SOH, ClN, ArNH
W	¹⁸⁴ W	Os ⁺	—
Zn	⁶⁴ Zn	Ni ⁺	AlCl, SS, SOO, CaO
	⁶⁶ Zn	Ba ⁺⁺	PCL, SS, FeC, SOO
	⁶⁸ Zn	Ba ⁺⁺ , Ce ⁺⁺	FeN, PCL, ArS, FeC, SS, ArNN, SOO

NOTE In the presence of elements in high mass concentrations, interferences can be caused by the formation of polyatoms or doubly charged ions which are not listed above.

Table 3 — Examples for suitable isotopes with their relative atomic masses and formulae for correction

Element	Recommended isotope and inter-element correction	
As	⁷⁵ As	-3,127 (⁷⁷ Se - 0,815 ⁸² Se) or
	⁷⁵ As	-3,127 (⁷⁷ Se + 0,322 0 ⁷⁸ Se)
Ba	¹³⁸ Ba	-0,000 900 8 ¹³⁹ La - 0,002 825 ¹⁴⁰ Ce
Cd	¹¹⁴ Cd	-0,026 84 ¹¹⁸ Sn
Ge	⁷⁴ Ge	-0,138 5 ⁸² Se
In	¹¹⁵ In	-0,014 86 ¹¹⁸ Sn
Mo	⁹⁸ Mo	-0,110 6 ¹⁰¹ Ru

Table 3 (continued)

Element	Recommended isotope and inter-element correction	
Ni	^{58}Ni	$-0,048\ 25\ ^{54}\text{Fe}$
Pb	^{208}Pb	$+^{207}\text{Pb} + ^{206}\text{Pb}$
Se	^{82}Se	$-1,009\ ^{83}\text{Kr}$
Sn	^{120}Sn	$-0,013\ 44\ ^{125}\text{Te}$
V	^{51}V	$^{51}\text{V} -3,127\ (^{53}\text{Cr} -0,113\ 4\ ^{52}\text{Cr})$
W	^{184}W	$-0,001\ 242\ ^{189}\text{Os}$

5.2.3 Polyatomic interferences

Polyatomic ions are formed by coincidence of plasma gas components, reagents and sample matrix (for example, interference of the relative mass ^{75}As by $^{40}\text{Ar}^{35}\text{Cl}$ and $^{40}\text{Ca}^{35}\text{Cl}$). Examples for correction formulae are given in [Table 3](#) and information on the magnitude of interferences are stated in [Table 4](#). This interference is of particular relevance for several elements (for example, As, Cr, Se, V).

It is recommended that the analyst checks the magnitude of this interference regularly for the particular instrument.

In the case of mathematical corrections, it shall be taken into account that the magnitude of interference depends both on the plasma adjustment (for example, oxide formation rate) and on the mass concentration of the interfering element, which will usually be a variable component of the sample solution.

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5.3 Non-spectral interferences (standards.iteh.ai)

For detailed information on non-spectral interferences, see ISO 17294-1:2004, 6.3.

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Table 4 — Important interferences by solutions of Na, K, Ca, Mg, Cl, S, P ($\rho = 100\ \text{mg/l}$) and Ba ($\rho = 1\ 000\ \mu\text{g/l}$)

Element	Isotope	Simulated mass concentration ^a $\mu\text{g/l}$	Type of interference
As	^{75}As	1,0	ArCl
Co	^{59}Co	0,2 to 0,8	CaO, CaOH
Cr	^{52}Cr	1,0	ClOH
		1,0	ArC
	^{53}Cr	5,0	ClO
Cu	^{63}Cu	1,0 to 3,0	ArNa
		1,0 to 1,6	POO
	^{65}Cu	2,0	ArMg
		2,0	POO
		2,0	SOOH
Ga	^{69}Ga	1,0 to 25	Ba ⁺⁺
		0,3	ArP
		1,0	ClOO
	^{71}Ga	0,2 to 0,6	ArP

^a Indicates the magnitude of interference without corrective measures. User should check the interferences and decide how to reduce or eliminate them.