



**International
Standard**

ISO 4937

**Steel and iron — Determination of
chromium content — Potentiometric
or visual titration method**

*Aciers et fontes — Détermination du chrome — Méthode par
titrage potentiométrique ou visuel*

**Second edition
2024-12**

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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 document 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).

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For an explanation of the voluntary nature of standards, 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 1, *Methods of determination of chemical composition*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 459/SC 2, *Methods of chemical analysis for iron and steel*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 4937:1986), which has been technically revised.

The main changes are as follows:

- introduction of an optional electrode;
- re-assessment of the precision data;
- re-confirmation of upper limit of vanadium content in test portions for visual titration.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Steel and iron — Determination of chromium content — Potentiometric or visual titration method

1 Scope

This document specifies a method for the determination of chromium in steel and iron by potentiometric or visual titration.

The method is applicable to chromium contents between 0,25 % (mass fraction) and 35 % (mass fraction). If vanadium is present, the visual titration is applicable only to test portions containing less than 3 mg of vanadium.

NOTE The visual titration can be applicable to test portion containing between 3 mg and 6 mg of vanadium.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 385, *Laboratory glassware — Burettes*

ISO 648, *Laboratory glassware — Single-volume pipettes*

ISO 1042, *Laboratory glassware — One-mark volumetric flasks*

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

ISO 14284, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

4 Principle

Dissolution of a test portion with appropriate acids.

Oxidation of chromium in an acid medium to chromium(VI) by ammonium peroxydisulfate in the presence of silver sulfate. Reduction of manganese(VII) by hydrochloric acid.

Reduction of chromium(VI) by an ammonium iron(II) sulfate standard solution.

In the case of potentiometric detection, determination of the equivalence point by measurement of the potential variation when the ammonium iron(II) sulfate standard solution is being added.

In the case of visual detection, titration the excess of ammonium iron(II) sulfate by a potassium permanganate standard solution which also acts as the indicator.

5 Reagents

During the analysis, unless otherwise stated, use only reagents of recognized analytical grade and only grade 2 water as specified in ISO 3696.

5.1 Urea.

5.2 Perchloric acid, ρ approximately 1,67 g/ml.

5.3 Hydrofluoric acid, ρ approximately 1,15 g/ml.

5.4 Phosphoric acid, ρ approximately 1,70 g/ml.

5.5 Nitric acid, ρ approximately 1,40 g/ml.

5.6 Hydrochloric acid, ρ approximately 1,19 g/ml, diluted 1 + 1.

5.7 Hydrochloric acid, ρ approximately 1,19 g/ml, diluted 1 + 10.

5.8 Sulfuric acid, ρ approximately 1,84 g/ml, diluted 1 + 1.

5.9 Sulfuric acid, ρ approximately 1,84 g/ml, diluted 1 + 5.

5.10 Sulfuric acid, ρ approximately 1,84 g/ml, diluted 1 + 19.

5.11 Silver sulfate, 5 g/l.

5.12 Ammonium peroxydisulfate $[(\text{NH}_4)_2\text{S}_2\text{O}_8]$, 500 g/l.

Prepare this solution immediately before use.

5.13 Manganese sulfate $(\text{MnSO}_4 \cdot \text{H}_2\text{O})$, 4 g/l.

5.14 Manganese sulfate, 100 g/l.

5.15 Potassium permanganate, 5 g/l.

5.16 Sodium nitrite, 3 g/l.

Prepare this solution immediately before use.

5.17 Sulfamic acid $(\text{NH}_2\text{SO}_3\text{H})$, 100 g/l.

This solution remains stable for one week only.

5.18 Potassium permanganate, standard solution.

5.18.1 Preparation of the solution

Dissolve 3,2 g of potassium permanganate in 1 000 ml of water. After storage in complete darkness for 2 weeks, filter through a thick fritted filter without washing. Keep the solution in a coloured glass bottle and avoid contact with organic matter.

5.18.2 Standardization of the solution

Boil 250 ml of sulfuric acid (5.10) in a 600 ml beaker for 10 min and allow to cool. Weigh, to the nearest 0,000 1 g, 0,300 0 g of sodium oxalate $[\text{Na}_2(\text{COO})_2]$ previously dried at 105 °C and cooled in a desiccator.

Dissolve the salt in the boiled sulfuric acid (5.10). Add 39 ml to 40 ml of potassium permanganate solution (5.18.1) at a rate of 25 ml/min to 35 ml/min, stirring gently. The violet colour of the permanganate will disappear in approximately 45 s. Heat to 70 °C to 75 °C and complete the titration.

Towards the end, titrate very slowly and allow each drop to become colourless before adding the next.

To determine the blank test, titrate 250 ml of sulfuric acid (5.10), as described above, concurrently.

The concentration (ρ_2) of the potassium permanganate standard solution, expressed as milligrams of chromium per millilitre, is given by the Formula (1).

$$\rho_2 = \frac{300,0 \times 1,733}{6,700 \times (V_1 - V_0)} \quad (1)$$

where

- V_1 is the volume, in millilitres, of potassium permanganate solution (5.18.1) used for titrating sodium oxalate;
- V_0 is the volume, in millilitres, of potassium permanganate solution (5.18.1) used for titrating the blank test of sulfuric acid (5.10);
- 6,700 is the molar mass of sodium oxalate divided by 20;
- 1,733 is the mass, in milligrams, of chromium(VI) corresponding to 1 ml of the potassium dichromate standard reference solution (5.20);
- 300,0 is the mass, in milligrams, of sodium oxalate weighed.

5.19 Ammonium iron(II) sulfate $[\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}]$, standard solution in sulfuric acid medium.

1 ml of this solution corresponds to about 2 mg of chromium.

5.19.1 Preparation of the solution

Dissolve 46 g of ammonium iron(II) sulfate hexahydrate in about 500 ml of water, add 110 ml of sulfuric acid (5.8), allow to cool, dilute to 1 000 ml with water and mix.

5.19.2 Potentiometric standardization of the solution (to be carried out just before use)

Transfer 30,0 ml of the potassium dichromate standard reference solution (5.20), into a 600 ml beaker, add 45 ml of sulfuric acid (5.9) and make up to about 400 ml with water.

Titrate according to the conditions specified in 8.3.3.1.

The corresponding concentration (ρ_1) of ammonium iron(II) sulfate solution (5.19.1), expressed in milligrams of chromium per millilitre, is given by the Formula (2).

$$\rho_1 = \frac{30,0 \times 1,733}{V_2} \quad (2)$$

where

- V_2 is the volume, in millilitres, of ammonium iron(II) sulfate solution (5.19.1) used for the standardization ;
- 30,0 is the volume, in millilitres, of the potassium dichromate standard reference solution (5.20) taken for the standardization;
- 1,733 is the mass, in milligrams, of chromium corresponding to 1 ml of the potassium dichromate standard reference solution (5.20).

5.19.3 Visual standardization of the solution (to be carried out just before use)

Take 25,0 ml of ammonium iron(II) sulfate solution (5.19.1) and add 325 ml of sulfuric acid (5.10).

Titrate with the potassium permanganate standard solution (5.18) until a slight violet colour persists.

To determine the blank test, titrate a mixture of 25 ml of water and 325 ml of sulfuric acid (5.10) with the potassium permanganate standard solution (5.18).

The corresponding concentration (ρ'_1) of the ammonium iron(II) sulfate standard solution (5.19), expressed in milligrams of chromium per millilitre, is given by the Formula (3).

$$\rho'_1 = \rho_2 \times \frac{V_3 - V_0}{25,0} \quad (3)$$

where

- ρ_2 is the concentration of the potassium permanganate standard solution (5.18), expressed as milligrams of chromium per millilitre;
- V_3 is the volume, in millilitres, of the potassium permanganate standard solution (5.18) used to oxidize 25 ml of ammonium iron(II) sulfate solution (5.19.1);
- V_0 is the volume, in millilitres, of the potassium permanganate standard solution (5.18) used for titrating the blank test of sulfuric acid (5.10);
- 25,0 is the volume, in millilitres, of ammonium iron(II) sulfate solution (5.19.1) used for the standardization.

5.20 Potassium dichromate, standard reference solution.

Weigh, to the nearest 0,000 1 g, 4,903 1 g of potassium dichromate previously dried at 150 °C to constant mass and cooled in a desiccator.

Dissolve in water, transfer quantitatively to a 1 000 ml one-mark volumetric flask, dilute to the mark with water and mix.

1 ml of this standard reference solution contains 1,733 mg of Cr.

6 Apparatus

All volumetric glassware shall be class A, in accordance with ISO 385, ISO 648 or ISO 1042 as appropriate.

Ordinary laboratory apparatus and the following shall be used.

6.1 Potentiometric titration device, which permits a difference in potential to be measured with platinum-saturated calomel electrodes or platinum-Ag/AgCl electrodes.

7 Sampling and sample preparation

Sampling and sample preparation shall be carried out in accordance with ISO 14284 or appropriate national standards for steel and cast iron.

8 Procedure

WARNING — Perchloric acid vapour can cause explosions in the presence of ammonia, nitrous fumes or organic matter in general. All evaporations shall be carried out in fume cupboards suitable for use with perchloric acid.

8.1 Test portion

According to the presumed chromium content, weigh, to the nearest 0,001 g, the following mass (m) of the test portion:

- for chromium contents between 0,25 % (mass fraction) and 2 % (mass fraction): approximately 2 g;
- for chromium contents between 2 % (mass fraction) and 10 % (mass fraction): approximately 1 g;
- for chromium contents between 10 % (mass fraction) and 25 % (mass fraction): approximately 0,5 g;
- for chromium contents between 25 % (mass fraction) and 35 % (mass fraction): approximately 0,25 g.

8.2 Blank test

In parallel with the determination and following the same procedure, carry out a blank test using the same quantities of all reagents as used for the determination, but omitting the test portion.

8.3 Determination

8.3.1 Preparation of the test solution

8.3.1.1 Unalloyed steel and iron

Place the test portion (8.1) in a 600 ml beaker, add 60 ml of sulfuric acid (5.9) and 10 ml of phosphoric acid (5.4), and heat to dissolve, then oxidize with 15 ml of nitric acid (5.5). Heat until dense white fumes are given off, allow to cool and then add 100 ml of water.

To accelerate the dissolution of a test portion which has a high silicon content, a few drops of hydrofluoric acid (5.3) may be added.

The dissolution procedures may be incomplete for particular samples (for example samples with high contents of carbon). In such cases, a fusion of the residue is required, and the product of this fusion shall be added to the test solution.

8.3.1.2 Chromium and/or nickel alloyed steel and iron

Place the test portion (8.1) in a 600 ml beaker, add 25 ml of hydrochloric acid (5.6) and heat to dissolve, then oxidize with 15 ml of nitric acid (5.5). If dissolution proves to be particularly difficult, add 1 ml to 2 ml of hydrofluoric acid (5.3). Then add 20 ml of sulfuric acid (5.8) and 10 ml of phosphoric acid (5.4), and heat until dense white fumes appear.

After cooling, add a further 15 ml of nitric acid (5.5) to the fuming solution, if necessary making further additions, until the carbides have completely decomposed. Continue fuming to remove completely oxides of nitrogen then allow to cool and add 100 ml of water.

The dissolution procedures may be incomplete for particular samples (for example samples with high contents of chromium and carbon). In such cases, a fusion of the residue is required and the product of this fusion shall be added to the test solution.

8.3.1.3 Steel containing tungsten

Place the test portion (8.1) in a 600 ml beaker, add 25 ml of hydrochloric acid (5.6) then 20 ml of sulfuric acid (5.8) and 10 ml of phosphoric acid (5.4) and heat until effervescence has ceased. If dissolution proves to be particularly difficult, add 1 ml to 2 ml of hydrofluoric acid (5.3). Oxidize with 15 ml of nitric acid (5.5) then heat until dense white fumes appear.

After cooling, add a further 15 ml of nitric acid (5.5) to the fuming solution, if necessary making further additions, until the carbides have completely decomposed. Continue fuming to remove completely oxides of nitrogen then allow to cool and add 100 ml of water.

The dissolution procedures may be incomplete for particular samples (for example samples with high contents of chromium and carbon). In such cases a fusion of the residue is required, and the product of this fusion shall be added to the test solution.

8.3.1.4 High alloyed steel and iron, or steel and iron with high silicon content

Place the test portion (8.1) in a 750 ml conical flask, and add 20 ml of hydrochloric acid (5.6), 10 ml of nitric acid (5.5) and 1 ml of hydrofluoric acid (5.3).

When effervescence has ceased, add 30 ml of perchloric acid (5.2). Heat until white fumes are given off, cover with a watch-glass and continue to heat until the alloy is completely dissolved (the white fumes being retained in the flask). Allow to cool.

Add 30 ml of water, boil for 5 min, and allow to cool. Transfer quantitatively into a 600 ml beaker and add 20 ml of sulfuric acid (5.8), 10 ml of phosphoric acid (5.4) and 70 ml of water.

The dissolution procedures may be incomplete for particular samples (for example samples with high contents of chromium and carbon). In such cases a fusion of the residue is required, and the product of this fusion shall be added to the test solution.

8.3.2 Oxidation of chromium and preparation for titration

If necessary, to remove graphite, filter the test solution through a cellulose-pulp-lined filter and wash with sulfuric acid (5.10). Dilute to about 350 ml with warm water, and add 20 ml of silver sulfate (5.11) and 10 ml of ammonium peroxydisulfate (5.12). Cover the beaker with a watch-glass and boil for 10 min. The violet colour of the permanganic acid will be observed. If the test portion contains only a very small amount of manganese, add about 5 ml of manganese sulfate (5.13), so that the permanganic acid is visible.

Then, decompose the permanganic acid by adding to the solution, after it has been brought to the boil, firstly 15 ml of hydrochloric acid (5.7), then, after about 3 min, if necessary a further amount of hydrochloric acid (5.7), drop by drop, until the violet colour disappears. The addition of hydrochloric acid (5.7) shall be made after complete oxidation, visible by the violet colour-formation of the permanganic acid. Boil for 10 min until the odour from the chlorine compounds formed disappears. In the case of a visual titration (8.3.3.2), after the decomposition of the permanganic acid and after boiling for 10 min, it is necessary to add 4 ml of manganese sulfate (5.14), then boil for a further 3 min. Cool rapidly to room temperature.

8.3.3 Titration

8.3.3.1 Potentiometric titration

8.3.3.1.1 In the absence of vanadium

Place the electrodes of the potentiometric device (6.1) into the beaker containing the solution (8.3.2) to be titrated.

Agitate, preferably with an electromagnetic stirrer, and add from a burette the ammonium iron(II) sulfate standard solution (5.19) until a potential drop occurs. Titrate slowly around this point. Let V_4 be this volume in millilitres.

With the platinum-saturated calomel electrodes or platinum-Ag/AgCl electrodes, the potential drop is of the order of 300 mV and the equivalence point occurs between 700 mV and 900 mV.

If the chromium amount in the solution is less than 40 mg, use a 20 ml burette, and if the chromium amount in the solution is more than 40 mg, use a 50 ml burette.

8.3.3.1.2 In the presence of vanadium

Titrate as indicated in 8.3.3.1.1. In this case, the vanadium is measured along with the chromium. Let V_5 be this volume in millilitres. The vanadium titrated with the chromium is oxidized by potassium permanganate (5.15). To oxidize the vanadium alone, measure the oxidation potential with the platinum-saturated calomel electrodes or platinum-Ag/AgCl electrodes while potassium permanganate (5.15) is being added. Add potassium permanganate (5.15) drop by drop until a potential of 1 000 mV to 1 160 mV is obtained.

Maintain this potential for 2 min, after which, either

- eliminate the excess of potassium permanganate by the addition of about 10 ml of sodium nitrite (5.16); about a minute later add 3 g of urea (5.1); wait for the potential to become stabilized at around 800 mV, agitate and titrate as indicated in 8.3.3.1.1; or
- eliminate the excess potassium permanganate by the addition, drop by drop, of sodium nitrite (5.16) until the potential stabilizes at around 770 mV; add 5 ml of sulfamic acid (5.17) (potential 780 mV); then add 30 ml of phosphoric acid (5.4), agitate and titrate as indicated in 8.3.3.1.1.

Let V_6 be this volume in millilitres.

8.3.3.2 Visual titration

Whilst stirring, add from a burette accurately known amounts of the ammonium iron(II) sulfate standard solution (5.19) until the colour of the solution changes from orange-yellow to bluish-green. Add 5 ml of the ammonium iron(II) sulfate standard solution (5.19) in excess and continue to stir for 5 s.

Let V_7 be this volume in millilitres.

Titrate immediately the excess ammonium iron(II) sulfate with the potassium permanganate standard solution (5.18). Take as the end point of titration, the beginning of the slight permanent darkening of the pale green colour, which is very clear and well-defined to an experienced operator.

Let V_8 be this volume in millilitres.

Add a further 2 drops of the potassium permanganate standard solution (5.18). The violet shade due to excess potassium permanganate shall persist for at least 5 min.

9 Expression of results

9.1 Method of calculation

9.1.1 Potentiometric titration

9.1.1.1 In the absence of vanadium

The chromium content w_{Cr} , expressed as a percentage by mass, is given by [Formula \(4\)](#):

$$w_{Cr} = \frac{(V_4 - V_0) \times \rho_1}{m \times 1000} \times 100 = \frac{(V_4 - V_0) \times \rho_1}{m \times 10} \quad (4)$$

where

- V_0 is the volume, expressed in millilitres, of the ammonium iron(II) sulfate standard solution ([5.19](#)) used for titrating the blank test ([8.2](#));
- V_4 is the volume, expressed in millilitres, of the ammonium iron(II) sulfate standard solution ([5.19](#)) used for titrating the chromium ([8.3.3.1.1](#));
- ρ_1 is the corresponding concentration of the ammonium iron(II) sulfate standard solution ([5.19](#)), expressed as milligrams of chromium per millilitre;
- m is the mass, expressed in grams, of the test portion ([8.1](#)).

9.1.1.2 In the presence of vanadium

The chromium content w_{Cr} , expressed as a percentage by mass, is given by [Formula \(5\)](#):

$$w_{Cr} = \frac{(V_5 - V_6) \times \rho_1}{m \times 1000} \times 100 = \frac{(V_5 - V_6) \times \rho_1}{m \times 10} \quad (5)$$

where

- V_5 is the volume, expressed in millilitres, of the ammonium iron(II) sulfate standard solution ([5.19](#)) used for titrating the chromium and the vanadium ([8.3.3.1.2](#));
- V_6 is the volume, expressed in millilitres, of the ammonium iron(II) sulfate standard solution ([5.19](#)) used for titrating the vanadium ([8.3.3.1.2](#));
- ρ_1 is the corresponding concentration of the ammonium iron(II) sulfate standard solution ([5.19](#)), expressed as milligrams of chromium per millilitre;
- m is the mass, expressed in grams, of the test portion ([8.1](#)).

9.1.2 Visual titration

The chromium content w_{Cr} , expressed as a percentage by mass, is given by [Formula \(6\)](#):

$$w_{Cr} = [(V_7 \times \rho'_1) - (V_8 \times \rho_2)] \times \frac{100}{m \times 1000} = \frac{(V_7 \times \rho'_1) - (V_8 \times \rho_2)}{m \times 10} \quad (6)$$

where

- V_7 is the volume, expressed in millilitres, of the ammonium iron(II) sulfate standard solution (5.19) added to reduce the chromium (8.3.3.2);
- V_8 is the volume, expressed in millilitres, of the potassium permanganate standard solution (5.18) used for the back titration (8.3.3.2);
- ρ'_1 is the corresponding concentration of the ammonium iron(II) sulfate standard solution (5.19), expressed as milligrams of chromium per millilitre;
- ρ_2 is the corresponding concentration of the potassium permanganate standard solution (5.18), expressed as milligrams of chromium per millilitre;
- m is the mass, expressed in grams, of the test portion (8.1).

9.2 Precision

A planned trial of this method was carried out by eleven laboratories at ten levels of chromium, each laboratory making two determinations at each level.

The test samples used are listed in Table A.1.

The results obtained were treated statistically according to ISO 5725-2.

The data obtained showed a logarithmic relationship between chromium content and repeatability limit (r) and reproducibility limit (R) of the test results as summarized in Table A.2 (potentiometric titration) and Table A.3 (visual titration).

The graphical presentations of these relationships are given in Figures B.1 and B.2.

The smoothed precision data, expressed as a percentage (mass fraction), shown in Table 1 (potentiometric titration) and Table 2 (visual titration) were calculated from the relationships between the chromium content mean values and repeatability limit and reproducibility limit experimental data (see Annex A and Annex B).

NOTE 1 Both determinations were carried out under repeatability conditions as defined in ISO 5725-1, i.e. one operator, same apparatus, identical operating conditions and a minimum period of time.

NOTE 2 When revising the present document, the precision data were re-evaluated. This new statistical treatment has led to the retention of three samples (containing between 3 mg and 6 mg of vanadium in the test portion) for the visual titration method, after the removal of one outlier laboratory's data (see Table A.3).

Table 1 — Precision data of potentiometric titration (smoothed values)

Chromium content % (mass fraction)	Repeatability limit % (mass fraction) r	Reproducibility limit % (mass fraction) R
0,250	0,010	0,011
0,500	0,015	0,017
1,00	0,023	0,028
2,50	0,042	0,053
5,00	0,064	0,086
10,0	0,100	0,138
15,0	0,128	0,183
20,0	0,154	0,223
25,0	0,177	0,261
35,0	0,219	0,329

Table 2 — Precision data of visual titration (smoothed values)

Chromium content % (mass fraction)	Repeatability limit % (mass fraction) <i>r</i>	Reproducibility limit % (mass fraction) <i>R</i>
0,250	0,010	0,024
0,500	0,016	0,036
1,00	0,026	0,055
2,50	0,048	0,097
5,00	0,076	0,149
10,0	0,121	0,228
15,0	0,159	0,293
20,0	0,192	0,350
25,0	0,223	0,401
35,0	0,279	0,493

10 Test report

The test report shall include at least the following information:

- a) all information necessary for the identification of the sample, the laboratory and the date of analysis or of the test report;
- b) method used by reference to this document, i.e. ISO 4937:2024;
- c) results and unit in which they are expressed;
- d) any unusual features noted during the determination;
- e) any operation not specified in this document, or any optional operation which might have influenced the results.

Annex A (informative)

Additional information on the international interlaboratory precision tests

The detailed results of chromium contents obtained from the international interlaboratory precision tests are shown in [Table A.2](#) (potentiometric titration) and [Table A.3](#) (visual titration).

[Tables 1](#) and [2](#) were derived from the results of the international interlaboratory precision tests carried out in 1983-1984 on ten steel and cast iron samples in four countries involving eleven laboratories.

Table A.1 — Test samples used for the precision test

Sample	Chemical composition % (mass fraction)								
	Cr	C	Si	Mn	Mo	Ni	V	W	Co
IRSID 102-1	0,261	0,389	0,281	0,367	1,2	4,4	-	-	-
BAM 182-1	0,591	0,790	0,368	0,389	-	0,152	0,177	-	-
IRSID 110-1	1,54	0,987	0,446	0,367	-	0,378	0,259	-	-
IRSID 210-1	3,92	0,762	0,200	0,250	8,15	-	1,650	1,54	0,185
IRSID 276-1	5,29	0,364	0,985	0,368	1,47	0,178	0,541	-	-
IRSID 201-1	12,33	0,291	0,843	0,363	-	0,202	0,02 ^a	-	-
IRSID 279-2	15,64	0,088	0,516	0,258	-	1,603	0,02 ^a	-	-
CTIF A	19,5	2,5	0,45	0,655	1,4	1,2	0,02 ^a	-	-
IRSID B ^a	27,0	0,02 ^a	0,27 ^a	0,115 ^a	0,016 ^a	0,15 ^a	0,014 ^a	-	0,32 ^a
NBS 890	32,4	2,91	0,67	0,62	0,018	0,397	0,45	-	-

^a non certified value.

Table A.2 — Experimental data obtained from the precision test (potentiometric titration)

Sample	Chromium content % (mass fraction)		Experimental precision data % (mass fraction)	
	Certified	Found	Repeatability limit <i>r</i>	Reproducibility limit <i>R</i>
IRSID 102-1	0,261	0,277	0,009	0,013
BAM 182-1	0,591	0,593	0,019	0,021
IRSID 110-1	1,54	1,542	0,034	0,034
IRSID 210-1	3,92	3,916	0,048	0,055
IRSID 276-1	5,29	5,289	0,080	0,080
IRSID 201-1	12,33	12,406	0,078	0,196
IRSID 279-2	15,64	15,633	0,144	0,157
CTIF A	19,5	19,258	0,199	0,311
IRSID B	(27,0)	27,164	0,183	0,247
NBS 890	32,4	32,474	0,193	0,327

Table A.3 — Experimental data obtained from the precision test (visual titration)

Sample	Chromium content % (mass fraction)		Experimental precision data % (mass fraction)	
	Certified	Found	Repeatability limit <i>r</i>	Reproducibility limit <i>R</i>
IRSID 102-1	0,261	0,265	0,020	0,032
BAM 182-1	0,591	0,591	0,011	0,042
IRSID 110-1	1,54	1,550	0,028	0,053
IRSID 276-1	5,29	5,272	0,087	0,127
IRSID 201-1	12,33	12,358	0,107	0,224
IRSID 279-2	15,64	15,590	0,115	0,234
CTIF A	19,5	19,285	0,221	0,370
IRSID B	(27,0)	27,109	0,280	0,477
NBS 890	32,4	32,409	0,358	0,677

NOTE When revising the present document, the precision data were reevaluated. Visual titration method can be applicable to test portions containing between 3 mg and 6 mg of vanadium. Sample IRSID 210-1 contains more than 6 mg of vanadium in the test portion. The data of sample IRSID 210-1 have been omitted in [Table A.3](#) and [Figure B.2](#).

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