Designation: E246 – 01 (Reapproved 2005)

Standard Test Methods for Determination of Iron in Iron Ores and Related Materials by Dichromate Titration[1]

This standard is issued under the fixed designation E246; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover the determination of total iron in iron ores, concentrates, and agglomerates in the concentration range 30 to 95 % iron.

1.2 The test methods in this standard are contained in the sections indicated as follows:

Test Method A—Iron by the Hydrogen Sulfide Reduction Dichromate Titration Method (30 to 75 % Fe)

Test Method B—Iron by the Stannous Chloride Reduction Dichromate Titration Method (35 to 95 % Fe)

Test Method C—Iron by the Silver Reduction Dichromate Titration Method (35 to 95 % Fe)

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific hazards statements are given in Section 5 and in special "Warning" paragraphs throughout these test methods.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1193 Specification for Reagent Water
E50 Practices for Apparatus, Reagents, and Safety Considerations for Chemical Analysis of Metals, Ores, and Related Materials
E276 Test Method for Particle Size or Screen Analysis at No. 4 (4.75-mm) Sieve and Finer for Metal-Bearing Ores and Related Materials
E877 Practice for Sampling and Sample Preparation of Iron Ores and Related Materials for Determination of Chemical Composition
E882 Guide for Accountability and Quality Control in the Chemical Analysis Laboratory

3. Significance and Use

3.1 The determination of the total iron content is the primary means for establishing the commercial value of iron ores used in international trade.

3.2 These test methods are intended as referee methods for the determination of iron in iron ores. It is assumed that all who use these methods will be trained analysts capable of performing common laboratory procedures skillfully and safely. It is expected that work will be performed in a properly equipped laboratory and that proper waste disposal procedures will be followed. Appropriate quality control practices must be followed, such as those described in Guide E882.

4. Apparatus, Reagents, and Instrumental Practices

4.1 *Apparatus*—Specialized apparatus requirements are listed in the "Apparatus" Section in each test method.

4.2 *Reagents*:

4.2.1 *Purity of Reagents*—Unless otherwise indicated, all reagents used in these test methods shall conform to the reagent grade specifications of the American Chemical Society.[3] Other grades may be used provided it is first ascertained that they are of sufficient purity to permit their use without adversely affecting the expected performance of the determination, as indicated in the "Precision and Bias" Section. Reagent water shall conform to Type II as described in Specification D1193.

5. Hazards

5.1 For precautions to be observed in the use of certain reagents and equipment in this test method refer to Practices E50.

6. Sampling and Sample Preparation

6.1 Collect and prepare the test sample in accordance with Practice E877.

6.2 The test sample shall be pulverized to pass a No. 100 (150-μm) sieve in accordance with Test Method E276. To

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[1] These test methods are under the jurisdiction of ASTM Committee E01 on Analytical Chemistry for Metals, Ores, and Related Materials and are the direct responsibility of Subcommittee E01.02 on Ores, Concentrates, and Related Metallurgical Materials.

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[2] 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.

[3] *Reagent Chemicals, American Chemical Society Specifications,* American Chemical Society, Washington, DC, www.chemistry.org. For suggestions on the testing of reagents not listed by the American Chemical Society, see the *United States Pharmacopeia and National Formulary,* U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD, http://www.usp.org.

facilitate decomposition some ores, such as specular hematite, require grinding to pass a No. 200 (75-µm) sieve.

TEST METHOD A—IRON BY THE HYDROGEN SULFIDE REDUCTION DICHROMATE TITRATION METHOD

7. Scope

7.1 This test method covers the determination of total iron in iron ores, concentrates, and agglomerates in the concentration range from 30 to 75 %.

8. Summary of Test Method

8.1 The sample is dissolved in hydrochloric acid. The insoluble residue is removed by filtration, ignited, and treated for the recovery of iron, and added to the main solution. To this solution containing all of the iron, sulfuric acid is added and the solution evaporated to fumes to expel chlorides. The salts are dissolved in water, the solution heated to boiling, and the iron reduced by a rapid stream of hydrogen sulfide. The precipitated sulfides are filtered and washed with an acid-sulfide wash solution until free of iron. The filtrate is then boiled to expel the hydrogen sulfide, cooled, and titrated with potassium dichromate solution, using sodium diphenylamine sulfonate as the indicator.

9. Interferences

9.1 None of the elements normally found in iron ores interfere with this test method. These include vanadium, copper, and small amounts of molybdenum, which occasionally occur in iron ores.

10. Apparatus

10.1 *Hydrogen Sulfide Generator*—Hydrogen sulfide shall be obtained from a cylinder of the compressed gas or from a Kipp generator. A consistent flow of 1 L/min shall be maintained and the gas passed through a water trap to remove any salts.

10.1.1 *Warning*—Hydrogen sulfide is extremely toxic. All procedures involving its use must be performed in an efficient fume hood. Refer to Hazards section in Practices E50.

10.2 *Crucibles*, platinum, 25-mL capacity.

11. Reagents and Materials

11.1 *Ferrous Ammonium Sulfate Solution (approximately 0.10 N)*—Dissolve 40 g of ferrous ammonium sulfate ($FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$) in sulfuric acid (1 +19). Transfer to a 1-L flask and dilute to volume with the same acid. When the sample solution is ready for titration, standardize the $FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$ solution against the standard potassium dichromate (0.1000 *N*), as described in 12.5. Calculate the millilitres of standard potassium dichromate equivalent to 1 mL of the $FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$ solution.

11.2 *Potassium Dichromate, Standard Solution (0.1000 N)*—Transfer 4.9031 g of primary standard grade potassium dichromate ($K_2Cr_2O_7$); previously ground in an agate mortar, and dried at 105 to 110°C, to a 1-L volumetric flask. Dissolve in water and dilute to 1 L. If preferred, this solution may be prepared from reagent grade $K_2Cr_2O_7$, by purifying the salt twice by recrystallizing from water, drying at 110°C, pulverizing in an agate mortar, and drying at 180°C to constant weight. The titer of this solution shall be confirmed by means of standard sample similar in type and composition to the test sample.

11.3 *Potassium Permanganate Solution (25 g/L)*—Dissolve 25 g of potassium permanganate ($KMnO_4$) in water and dilute to 1 L.

11.4 *Sodium Diphenylamine Sulfonate Indicator Solution*—Dissolve 0.3 g of sodium diphenylamine sulfonate in 100 mL of water. Store in a dark-colored bottle.

11.5 *Sodium Pyrosulfate* ($Na_2S_2O_7$).

11.6 *Sulfuric Acid-Hydrogen Sulfide Wash Solution*—Add 20 mL of concentrated sulfuric acid (H_2SO_4, sp gr 1.84) to 900 mL water, cool, dilute to 1 L, and pass a rapid stream of H_2S through it for at least 10 min.

12. Procedure

12.1 Transfer approximately 0.50 g of the test specimen to a small weighing bottle previously dried at about 105°C. Dry the bottle and contents for 1 h at 105 to 110°C (Note 1). Cap the bottle and cool to room temperature in a desiccator. Momentarily release the cap to equalize the pressure and weigh the capped bottle and sample to the nearest 0.1 mg. Repeat the drying and weighing until there is no further weight loss. Transfer the test specimen to a 250-mL beaker and reweigh the capped bottle to the nearest 0.1 mg. The difference between the two weights is the weight of the sample taken for analysis.

NOTE 1—Most ores yield their hygroscopic moisture at this temperature. If a drying temperature other than that specified is required, this shall be determined by mutual agreement between manufacturer and purchaser.

12.2 *Decomposition of the Sample*—Moisten the sample with a few millilitres of water and add 25 mL of HCl. Cover the beaker and heat, maintaining a temperature below boiling until most of the dark particles are dissolved and no further attack is apparent. Add 5 mL of HNO_3 and digest for another 15 min. Remove from the source of heat, wash the sides and cover of the beaker, and dilute to 50 mL with warm water. Filter the insoluble residue on a fine-texture paper. Wash the residue with warm HCl (1 + 50) until the yellow color of ferric chloride is no longer observed and then with warm water six to eight times. Collect the filtrate and washings in a 600-mL beaker and reserve as the main solution (Note 2). Place the paper and residue in a platinum crucible. Char the paper at a low temperature, then ignite at 950°C. Allow the crucible to cool, moisten the residue with H_2SO_4 (1 + 1), add about 5 mL of HF, and heat gently to remove silica and H_2SO_4 (Note 3). Cool the crucible, add 3 g of $Na_2S_2O_7$, and heat until a clear melt is obtained. Cool, place the crucible in a 250-mL beaker, add about 25 mL of water and 5 mL of HCl, and warm to dissolve the melt. Rinse and remove the crucible. Add the solution and washings to the main solution.

NOTE 2—If the residue is small in amount and perfectly white, the filtration, and treatment of the residue may be omitted without causing significant error.

NOTE 3—The treatment of the residue depends upon the nature of the minerals present. Many ores require only an H_2SO_4–HF treatment to decompose the residue.

TABLE 1 Precision Data

Sample	Number of Laboratories	Iron Found %	Repeatability		Reproducibility	
			s_r	R_l (2.8 s_r)	s_R	R_2 (2.8 s_R)
Seine River Ore	9	57.52	0.125	0.35	0.126	0.35
Knob Lake Ore	9	58.45	0.097	0.27	0.136	0.38
NBS 27d (64.96 % Fe)	6	65.01	0.057	0.16	0.085	0.24
Chilean Iron Ore	9	66.11	0.102	0.29	0.172	0.48
Pooled standard deviations[A]			0.101		0.137	

[A] Weighted by degrees of freedom, n for s_r and (n – 1) for s_R where n = number of laboratories.

12.3 *Reduction*—To the combined solution add 10 mL of H_2SO_4 (1 + 1) and evaporate to copious fumes of SO_3 (Note 4). Cool, dilute to approximately 100 mL with water, and heat to boiling. Add dropwise $KMnO_4$ solution until the permanganate color persists. Dilute the solution to 250 mL and again heat to boiling for several minutes. Remove from the source of heat and pass a rapid stream of H_2S through the solution for 15 min. (**Warning—**Hydrogen sulfide is extremely toxic. All procedures involving its use must be performed in an efficient fume hood. Refer to Hazards section in Practices E50.) Digest at 60°C for 15 min and filter through a medium-texture paper, collecting the filtrate in a 500-mL Erlenmeyer flask. Wash the precipitated sulfides thoroughly with the H_2SO_4–H_2S wash solution. Add 10 mL of H_2SO_4 (1 + 1) to the solution in the flask and add glass beads to prevent bumping. Boil for 10 min to expel H_2S (lead acetate test paper) and continue boiling for an additional 10 min (Note 5). Remove from the source of heat, cover the flask with a small watch glass, and cool in running water to 20°C.

NOTE 4—If the sample contains much calcium, prolonged fuming with H_2SO_4 may lead to the formation of salts that are difficult to dissolve. Therefore, in the presence of considerable calcium, fume just long enough to expel the chlorides and nitrates. Cool, wash the sides of the beaker with water, and again evaporate to light fumes.

NOTE 5—If the sample contains an appreciable amount of molybdenum, further precipitation may occur in the filtrate when boiling out the H_2S. The effect of residual molybdenum is not significant and may be neglected.

12.4 *Titration*—Add to the cooled solution 5 mL of H_3PO_4 and 5 drops of the sodium diphenylamine sulfonate indicator solution. Dilute to 350 mL and titrate with the standard $K_2Cr_2O_7$ solution to a distinct purple end point.

12.5 *Determination of Blank*—Determine the blank value of the reagents concurrently with the test determination, using the same amount of all reagents and following all the steps of the procedure. Immediately before titrating with the $K_2Cr_2O_7$ solution add 1.0 mL, accurately measured, of the $FeSO_4·(NH_4)_2SO_4·6H_2O$ solution. In another beaker place 350 mL of cold H_2SO_4 (1 + 9) and add an accurately measured 1 mL of the $FeSO_4·(NH_4)_2SO_4·6H_2O$ solution. Add 5 mL of H_3PO_4 and 5 drops of the sodium diphenylamine sulfonate indicator solution and titrate with the $K_2Cr_2O_7$ solution. Record this titration and subtract from the titration of the blank solution to obtain the corrected blank.

NOTE 6—In the absence of iron, the diphenylamine sulfonate indicator does not react with the $K_2Cr_2O_7$ solution. The addition of the $FeSO_4·(NH_4)_2SO_4·6H_2O$ is, therefore, necessary to promote indicator response in the blank solution. A correction must be made in terms of its equivalent in millilitres of $K_2Cr_2O_7$ solution.

13. Calculation

13.1 Calculate the percentage of iron as follows:

$$\text{iron, \%} = [(A - B) \times C/D] \times 100 \tag{1}$$

where:

A = millilitres of $K_2Cr_2O_7$ required for titration of the sample,
B = millilitres of $K_2Cr_2O_7$ required for titration of the blank,
C = iron equivalent of the $K_2Cr_2O_7$, g/mL, and
D = grams of sample used.

14. Precision and Bias

14.1 *Precision*—From six to nine laboratories analyzed four iron ore samples to determine iron. The replication made by the different laboratories ranged from 2 to 4, averaging 3 replicates. The data was studied by the interlaboratory test procedure of Practice E691-87 modified by weighting certain sums to accommodate the unequal replication.[4] Table 1 shows a summary of these results. From pooled standard deviations, the overall between-laboratory reproducibility coefficient, R, was calculated as being 0.38.

14.2 The agreement of the determination of iron in the NBS Standard Reference Material with the certified value shows no evidence of bias, well within a 95 % confidence level (R_2 = 0.24).

TEST METHOD B—IRON BY THE STANNOUS CHLORIDE REDUCTION DICHROMATE TITRATION METHOD

15. Scope

15.1 This test method covers the determination of total iron in iron ores, concentrates, and agglomerates in the concentration range from 35 to 95 %.

16. Summary of Test Method

16.1 This test method provides two alternative dissolution procedures.

16.2 *Acid Decomposition*—The sample is dissolved in hydrochloric acid. The insoluble residue is removed by filtration, ignited, treated for the recovery of iron, and added to the main solution.

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[4] Supporting data giving the results of cooperative testing have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:E16-63, dated April 23, 1968, with an amendment, dated July 27, 1993.

16.3 *Decomposition by Fusion*—The sample is fused with a mixture of sodium carbonate and sodium peroxide. The melt is leached with water. For samples containing more than 0.1 % of vanadium or molybdenum, or both, the solution is filtered and the insoluble residue is dissolved in hydrochloric acid. For other samples the leachate is acidified with hydrochloric acid.

16.4 *Reduction of the Iron*—Most of the iron is reduced with stannous chloride, followed by the addition of a slight excess of titanium (III) chloride solution. The excess titanium (III) is then oxidized in the hot solution with perchloric acid. The solution is cooled and the reduced iron is titrated with a standard potassium dichromate solution using sodium diphenylamine sulfonate as the visual endpoint indicator.

17. Interferences

17.1 This test method covers the analysis of iron ores containing less than 0.1 % copper. In the case of iron ores containing molybdenum or vanadium, or both, these elements are removed by water leach and filtration of the cooled sodium carbonate/sodium peroxide fusion melt. Other elements normally found in iron ores do not interfere.

18. Apparatus

18.1 *Crucibles*, platinum, 25- to 30-mL capacity.

18.2 *Crucibles*, zirconium, 25- to 30-mL capacity.

18.3 *Weighing Spatula*, of a nonmagnetic material or demagnetized stainless steel.

19. Reagents

19.1 *Iron (III) Ammonium Sulfate (approximately 0.1N)*—Dissolve 40 g of iron (II) ammonium sulfate [$FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$] in H_2SO_4 (1+19). Transfer to a 1-L volumetric flask, dilute to volume with the same acid, and mix. Standardize against standard potassium dichromate solution using diphenylamine sulfonate as indicator.

19.2 *Potassium Dichromate, Standard Solution (0.1N)*—Pulverize about 6 g of potassium dichromate ($K_2Cr_2O_7$) reagent in an agate mortar, dry in an air-bath at 140°C for 3 to 4 h, and cool to room temperature in a desiccator. Dissolve 4.9031 g of the dry reagent in water and dilute the solution with water to exactly 1 L in a volumetric flask. Record the temperature at which this dilution was made.

19.3 *Potassium Permanganate Solution* ($KMnO_4$), 25 g/L.

19.4 *Potassium Pyrosulfate Fine Powder* ($K_2S_2O_7$).

19.5 *Sodium Carbonate Anhydrous Powder* (Na_2CO_3).

19.6 *Sodium Diphenylaminesulfonate Solution*—Dissolve 0.2 g of the reagent ($C_6H_5NC_6H_4 \cdot SO_3Na$) in water and dilute to 100 mL. Store the solution in a brown glass bottle.

19.7 *Sodium Hydroxide Solution* (NaOH), 20 g/L.

19.8 *Sodium Peroxide* (Na_2O_2), dry powder. (**Warning—**Use proper safety practices and equipment when performing sodium peroxide fusions.)

19.9 *Sulfuric Phosphoric Acid Mixture*—Pour 150 mL of phosphoric acid (6.12) into about 400 mL of water. While stirring, add 150 mL of sulfuric acid (6.20). Cool in a water bath and dilute with water to 1 L.

19.10 *Tin (II) Chloride Solution (100 g/L)*—Dissolve 100 g of crystalline tin (II) chloride ($SnCl_2 \cdot 2H_2O$) in 200 mL of hydrochloric acid by heating the solution in a water bath. Cool the solution and dilute the water to 1 L. This solution should be stored in a brown glass bottle with the addition of a small quantity of granular or mossy tin metal.

19.11 *Titanium (III) Chloride Solution (2 %)*—Dissolve 1 g of titanium sponge (99.5 % min. purity) in about 30 mL of hydrochloric acid in a covered beaker by heating on a steam bath. Cool the solution and dilute with water to 50 mL. Prepare fresh as needed. (If preferred, dilute 1 volume of commercial titanium (III) chloride solution (about 15 % w/v) with 7 volumes of hydrochloric acid (1+1)).

20. Procedure

NOTE 7—If the procedure is based on acid decomposition, use 20.1. If the procedure is based on an alkaline fusion followed by the filtration of the leached melt, (samples containing more than 0.1 % vanadium or molybdenum, or both), use 20.2. If the procedure is based on an alkaline fusion, followed by acidification of the leached melt (samples containing less than 0.1 % of molybdenum or vanadium, or both), use 20.3. (**Warning—**Use proper safety practices and equipment when performing sodium peroxide fusions.)

20.1 *Acid Decomposition*:

20.1.1 Weigh approximately 0.40 g of sample into a small weighing bottle previously dried at about 105°C (Note 8). Dry the bottle and contents for 1 h at 105 to 110°C. Cap the bottle and cool to room temperature in a desiccator. Momentarily release the cap to equalize the pressure and weigh the capped bottle and sample to the nearest 0.1 mg. Repeat the drying and weighing until there is no further weight loss. Transfer the samples to a 250-mL beaker and reweigh the capped bottle to the nearest 0.1 mg. The difference between the two weights is the weight of the sample taken for analysis.

NOTE 8—For samples of iron content greater than 68 %, weigh approximately 0.38 g.

20.1.2 Carry a reagent blank through all steps of the procedure.

20.1.3 Add 30 mL of hydrochloric acid, cover the beaker with a watch glass, and heat the solution gently without boiling until no further attack is apparent. Wash the watch glass and dilute to 50 mL with warm water. Filter the insoluble residue on a close-texture paper. Wash the residue with warm hydrochloric acid (1+50), until the yellow color or iron (III) chloride is no longer observed, then wash with warm water six to eight times. Collect the filtrate and washings in a 400-mL beaker. Start to evaporate this solution.

20.1.4 Place the filter paper and residue in a platinum crucible, dry, and ignite at 750 to 800°C. Allow the crucible to cool, moisten the residue with sulfuric acid (1+1), add about 5 mL of hydrofluoric acid, and heat gently to remove silica and sulfuric acid. Add to the cold crucible 2 g of potassium pyrosulfate, heat gently at first, then strongly until a clear melt is obtained. Cool, place the crucible in a 250-mL beaker, add about 25 mL of water and about 5 mL of hydrochloric acid, and warm to dissolve the melt. Remove and wash the crucible.

20.1.5 Adjust the solution to slight alkalinity with ammonia solution. Heat to coagulate the precipitate, filter on a coarse-texture paper, and wash several times with hot water. Discard the filtrate.