



# Standard Test Methods for Iodide and Bromide Ions in Brackish Water, Seawater, and Brines<sup>1</sup>

This standard is issued under the fixed designation D 3869; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 These test methods<sup>2</sup> cover the determination of soluble iodide and bromide ions, or both, in brackish water, seawater, and brines. Four test methods are given as follows:

1.1.1 *Test Method A for both Iodide and Bromide Ions*—Volumetric, for concentrations from 0.2 to 2000 mg/L iodide and from 5 to 6500 mg/L bromide (Sections 7-14).

1.1.2 *Test Method B for Iodide Ion*—Colorimetric, for concentrations from 0.2 to 2000 mg/L iodide (Sections 15-23).

1.1.3 *Test Method C for Iodide Ion*—Selective electrode, for concentrations from 1 to 2000 mg/L iodide (Sections 24-31).

1.1.4 *Test Method D for Bromide Ion*—Colorimetric, for concentrations from 40 to 6500 mg/L bromide (Sections 32-40).

1.2 Test Method A is intended for use on all brackish waters, seawaters, and brines that contain appreciable amounts of iodide or bromide ions or both. Test Methods B, C, and D, because of their rapidity and sensitivity, are recommended for the analysis of brackish waters, seawaters, and brines in the field and in the laboratory.

1.3 Samples containing from 0.2 to 2000 mg/L of iodide or 5 to 6500 mg/L of bromide may be analyzed by these methods.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applica-*

*bility of regulatory limitations prior to use.* For specific precautionary statements, see 19.2 and 36.2.

## 2. Referenced Documents

### 2.1 ASTM Standards:

D 1129 Terminology Relating to Water<sup>3</sup>

D 1193 Specification for Reagent Water<sup>3</sup>

D 2777 Practice for Determination of Precision and Bias of Applicable Methods of Committee D-19 on Water<sup>3</sup>

D 3370 Practices for Sampling Water from Closed Conduits<sup>3</sup>

E 60 Practice for Photometric and Spectrophotometric Methods for Chemical Analysis of Metals<sup>4</sup>

E 200 Practice for Preparation, Standardization, and Storage of Standard and Reagent Solutions for Chemical Analysis<sup>5</sup>

E 275 Practice for Describing and Measuring Performance of Ultraviolet, Visible, and Near Infrared Spectrophotometers<sup>6</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in these test methods, refer to Terminology D 1129.

## 4. Significance and Use

4.1 Identification of a brackish water, seawater, or brine is determined by comparison of the concentrations of their dissolved constituents. The results are used to evaluate the origin of the water, determine if it is a possible pollutant or determine if it is a commercial source of a valuable constituent such as iodine or bromine.

## 5. Reagents

5.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specification of the Committee

<sup>1</sup> These test methods are under the jurisdiction of ASTM Committee D-19 on Water and are the direct responsibility of Subcommittee D19.05 on Inorganic Constituents in Water.

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<sup>2</sup> Additional information is contained in the following references:

Collins, A. G., *Geochemistry of Oilfield Waters*, Elsevier, New York, N. Y., 1975, 496 pp.

American Petroleum Institute, API Recommended Practice for Analysis of Oilfield Waters, Subcommittee on Analysis of Oilfield Waters, API RP, 45 2nd ed, 1968, 49 pp.

Hoke, S. H., Fletcher, G. E., and Collins, A. G., "Fluoride and Iodide Selective Electrodes Applied to Oilfield Brine Analysis." US Department of Energy, Report of Investigations, BETC/RI-78/7, 1978.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 11.01.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 03.05.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 15.05.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 03.06.

on Analytical Reagents of the American Chemical Society,<sup>7</sup> where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 *Purity of Water*— Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Specification D 1193, Type III.

## 6. Sampling

6.1 Collect the sample in accordance with Practices D 3370.

## TEST METHOD A—VOLUMETRIC FOR IODIDE AND BROMIDE

## 7. Scope

7.1 This test method is applicable to brackish waters, seawaters, and brines, and is recommended for such waters containing appreciable amounts of iodide or bromide, or both. The test method can be used for concentrations as high as 2000 mg/L iodide and 6500 mg/L bromide.

## 8. Summary of Test Method

8.1 Iodide in the sample is oxidized with bromine to iodate in a buffered solution, the excess bromine is decomposed with sodium formate, and the iodate reacts with added iodide to form iodine which is titrated with sodium thiosulfate.

8.2 Iodide and bromide are oxidized to iodate and bromate, respectively, with hypochlorite. The excess hypochlorite is destroyed with sodium formate, leaving iodate and bromate to react with added iodide to liberate iodine which is titrated with sodium thiosulfate.

8.3 The bromide concentration is calculated by difference between the iodide and combined iodide and bromide determinations.

## 9. Interferences

9.1 Iron, manganese, and organic matter can interfere (Note 1). They are removed by precipitation and filtration. Remaining traces of iron are masked with fluoride.

NOTE 1—Brines containing surfactants can cause emulsion problems, in which case a suitable emulsion breaker can be used.

## 10. Apparatus

10.1 *Mechanical Bottle Shaker*.

10.2 *Bottles*, 200-mL, for use on mechanical shaker.

10.3 *Pipets*.

10.4 *Hot-Water Bath*, thermostatically controlled to  $\pm 1^\circ\text{C}$ .

10.5 *Erlenmeyer Flasks*, 250-mL.

## 11. Reagents

11.1 *Acetic Acid*, glacial.

11.2 *Ammonium Molybdate Solution*—Dissolve 2 g of ammonium molybdate in water and dilute to 100 mL.

11.3 *Bromine Water (Saturated)*—Add to 250 mL of water slightly more liquid bromine (8 to 10 mL) than will dissolve on shaking. Store in a glass-stoppered amber bottle.

11.4 *Calcium Carbonate* ( $\text{CaCO}_3$ ), powdered.

11.5 *Calcium Oxide* ( $\text{CaO}$ ), anhydrous powdered.

11.6 *Hydrochloric Acid* (1 + 1)—Add 1 volume of HCl (sp gr 1.19) to 1 volume of water.

11.7 *Hydrochloric Acid* (1 + 3)—Add 1 volume of HCl (sp gr 1.19) to 3 volumes of water.

11.8 *Hydrochloric Acid* (1 + 199)—Add 1 volume of HCl (sp gr 1.19) to 199 volumes of water.

11.9 *Methyl Red Indicator Solution* (0.1 g/L)—Dissolve 0.01 g of water-soluble methyl red in water and dilute to 100 mL.

11.10 *Potassium Fluoride* ( $\text{KF}\cdot 2\text{H}_2\text{O}$ )—crystalline.

11.11 *Potassium Iodide* (KI), crystals, free of iodates when tested in accordance with American Chemical Society (ACS) specifications.

11.12 *Sodium Acetate Solution* (275 g/L)—Dissolve 275 g of sodium acetate trihydrate ( $\text{NaC}_2\text{H}_3\text{O}_2\cdot 3\text{H}_2\text{O}$ ) in water, to dilute to 1 L, and filter.

11.13 *Sodium Chloride* ( $\text{NaCl}$ ), crystals, which, in addition to satisfying ACS specifications, must be free of iodide, iodate, bromide, and bromate.

11.14 *Sodium Formate Solution* (500 g/L)—Dissolve 50 g of sodium formate ( $\text{NaCHO}_2$ ) in hot water and dilute to 100 mL. This solution must be freshly prepared.

11.15 *Sodium Hypochlorite Solution*—Use a fresh commercial sodium hypochlorite or bleach solution containing approximately 5 %  $\text{NaClO}$ .

11.16 *Sodium Thiosulfate Solution* (0.1 N)—Prepare and standardize as directed in Practice E 200.

11.17 *Sodium Thiosulfate Solution* (0.01 N)—With a calibrated pipet transfer 25 mL of the 0.1 N  $\text{Na}_2\text{S}_2\text{O}_3$  solution into a 250-mL volumetric flask. Dilute to the mark with water that has been freshly boiled and cooled then mix well. This solution shall be prepared not more than 2 days before it is to be used.

11.18 *Starch Indicator Solution*—Make a paste of 6 g of arrowroot or soluble iodometric starch with cold water. Pour the paste into 1 L of boiling water. Add 20 g of KOH, mix thoroughly, and allow to stand for 2 h. Add 6 mL of glacial acetic acid. Mix again and add sufficient HCl (sp gr 1.19) to adjust the pH to 4.0. Store in a glass-stoppered bottle. Starch solution prepared in this manner will remain chemically stable for at least 1 year.

11.18.1 If a proprietary starch indicator powder is used, it shall be so indicated in reporting the results of the analysis.

## 12. Procedure

12.1 To remove iron, manganese, and organic matter from the sample, add exactly 100 mL of sample to a bottle. Add 1 g of calcium oxide, stopper, and place the mixture in a shaker for 1 h. Allow the mixture to stand overnight and filter on a dry folded filter, discarding the first 20 mL that come through. Brines with specific gravities less than 1.009 may be filtered without standing overnight. Prepare a blank in the same manner.

<sup>7</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. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

12.2 Transfer an aliquot of the filtrate containing 1 to 2 mg of iodide to a 250-mL Erlenmeyer flask. Add sufficient water to provide a total volume of 75 mL.

12.3 Add 3 drops of methyl red indicator. Add HCl (1 + 199) dropwise until the mixture is just slightly acid.

12.4 Add 10 mL of sodium acetate solution, 1 mL of glacial acetic acid, 4 mL of bromine water, and allow to stand for 5 min.

12.5 Add 2 mL of sodium formate solution, blow out any bromine vapor from the neck of the flask, and wash down the sides with water.

12.6 When the solution is completely colorless, add 0.2 g of KF and 0.5 g of KI. Mix until dissolved and add 15 mL of HCl (1 + 1).

12.7 For final treatment and titration of the sample, proceed as directed in (12.13).

12.8 To determine the combined iodide and bromide, transfer an aliquot of the filtrate (12.1) containing 1 to 2 mg of bromide to a 250-mL Erlenmeyer flask. Add sufficient water to make the total volume 75 mL.

12.9 If necessary add sufficient NaCl to produce a 3-g chloride content. Add, in order, 10 mL of sodium hypochlorite solution and approximately 0.4 g of CaCO<sub>3</sub> (or enough so that approximately 0.1 g will remain after the next step).

12.10 Adjust the pH of the solution with HCl (1 + 3) to a pH between 5.5 and 6.0. Heat at 90°C for 10 min. (A small amount of undissolved CaCO<sub>3</sub> should remain at this point.)

12.11 Remove the flask and cautiously add 10 mL of sodium formate solution, return the flask to the water bath, and keep the contents hot for 5 min more. Observe the timing closely. Rinse down the inside of the flask with a few millilitres of water and allow the solution to cool to room temperature. Do not use a water bath.

12.12 Add 3 drops of ammonium molybdate solution, 0.5 g of KF (if iron is present), 0.5 g of KI, mix until dissolved, and acidify with 15 mL of HCl (1 + 1).

12.13 Titrate the sample (12.7) for iodide or the sample (12.12) for combined iodide and bromide with 0.01 N sodium thiosulfate solution using starch indicator. Disregard any return of blue color after the endpoint.

### 13. Calculation

13.1 Calculate the concentration of iodide and bromide ions in milligrams per litre as follows:

13.2 *Iodide:*

$$C = E - D$$

where:

*C* = corrected millilitres of Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> solution,  
*E* = millilitres of Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>, sample solution, and  
*D* = millilitres of Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> blank solution.

$$I^-, \text{ mg/L} = \frac{CN}{S} \times 21150$$

where:

*N* = normality of Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> solution, and  
*S* = millilitres of sample.

**TABLE 1 Determination of Precision and Bias of Iodide Ions, Volumetric Methods**

Amount Added, mg/L	Amount Found, mg/L	S <sub>O</sub>	S <sub>T</sub>	±Bias	Statistically Significant (95 % Confidence Level)
12.1	11.4	1	1	-5.78	yes
116.3	112.5	2	3	-3.27	yes
771	743	12	15	+2.63	no
1375	1282	40	73	-6.76	yes

13.3 *Bromide:*

$$C = E - D$$

$$Br^-, \text{ mg/L} = \frac{CN}{S} \times 13320 - X$$

where:

*X* = concentration of I<sup>-</sup> as determined above.

### 14. Precision and Bias <sup>8</sup>

14.1 The overall precision (*S<sub>T</sub>*) and single-operator precision (*S<sub>O</sub>*) of this test method within their designated ranges vary with the quantity being tested in accordance with Table 1 and Table 2.

14.2 The bias of the test method determined from recoveries of known amounts of iodide and bromide in a series of prepared standards are given in Table 1 and Table 2.

NOTE 2—The precision and bias estimates are based on the interlaboratory study on four artificial brine samples containing various amounts of iodide, bromide, and interfering ions as shown in Table 3. Two analysts in each of three laboratories performed duplicate determinations on each of 2 days. Practice D 2777 was used in developing these precision and bias estimates.

14.3 Precision and bias for this test method conforms to Practice D 2777-77, which was in place at the time of collaborative testing. Under the allowances made in 1.5 of D2777-86, these precision and bias data do meet existing requirements for interlaboratory studies of Committee D-19 test methods.

### TEST METHOD B—COLORIMETRIS FOR IODIDE

#### 15. Scope

15.1 This test method <sup>2</sup> covers the colorimetric determination of iodide in brackish water, seawater, and brines where concentrations range from 0.2 to 2000 mg/L.

#### 16. Summary of Test Method

16.1 Iodide in the sample is oxidized with nitrous acid and extracted into carbon tetrachloride. The concentration is proportional to the intensity of the purple color measured at 517 nm.

<sup>8</sup> Supporting data are available from ASTM Headquarters. Request RR:D19-1061.

**TABLE 2 Determination of Precision and Bias of Bromide Ions, Volumetric Method**

Amount Added, mg/L	Amount Found, mg/L	$S_o$	$S_T$	$\pm$ Bias	Statistically Significant (95 % Confidence Level)
30.3	31.7	1	5	+4.62	yes
534	531	15	25	-0.56	no
1286	1249	23	182	-2.88	no
5734	5688	65	227	-0.80	no

**TABLE 3 Composition of Artificial Brine Samples**

Sample No.	mg/L			
	1	2	3	4
I	12.1	116.3	771	1 375
Br	30.3	534	1 286	5 734
Na	9 500	65 000	31 000	75 000
K	300	1 400	2 000	5 000
Ca	550	1 000	700	2 000
Mg	1 200	1 200	500	250
Ba	30	650	300	300
Cl	19 000	107 000	52 000	121 000

## 17. Interference

17.1 Hydrocarbons that might interfere with the spectrophotometric measurement can be removed from the sample by a carbon tetrachloride extraction.

17.2 Hydrogen sulfide can interfere and is removed by boiling an acidified sample.

## 18. Apparatus

18.1 Spectrophotometer or filter photometer having a light path of approximately 10 mm for use at 517 nm. Filters, when required, shall be green, have a narrow-band pass, and a maximum transmittance at or about this wavelength. Photometers and photometric practices prescribed in this method shall conform to Practice E 60. Spectrophotometers shall conform to Practice E 275.

18.2 *Chemical (Filters) Funnel*, approximate inside diameter of top of funnel 45 mm.

18.3 *Separatory Funnel*, 125-mL capacity, borosilicate glass with a TFE-fluorocarbon stopcock and a linear high-density polyethylene stopper.

18.4 *Volumetric Flask*, 50-mL capacity, borosilicate glass, with a linear high-density polyethylene stopper.

18.5 *Filter Paper*, rapid qualitative, 70-mm diameter.

18.6 *Buret*, precision-bore, micro, 10-mL capacity with a TFE-fluorocarbon stopcock.

## 19. Reagents

19.1 *Bromphenol Blue Indicator Solution* (1 g/L)—Dissolve 0.1 g of water-soluble bromphenol blue in water and dilute to 100 mL.

19.2 *Carbon Tetrachloride* ( $CCl_4$ ). **Warning**—Avoid inhalation and conduct all manipulation in a well-ventilated hood.

19.3 *Hydrochloric Acid* (1 + 1)—Add 1 volume of HCl (sp gr 1.19) to 1 volume of water.

19.4 *Iodide Solution, Standard* (1 mL = 0.25 mg  $I^-$ )—Dry about 3 g of potassium iodide (KI) crystals for 6 h at 105°C. Any large crystals should be crushed before drying, but not

ground in a mortar for a long time. Dissolve 0.3270 g of the KI in water and dilute to exactly 1 L in a volumetric flask.

19.5 *Potassium Nitrite Solution* (100 g  $KNO_2/L$ )—Dissolve 10 g of  $KNO_2$  in water and dilute to 100 mL.

## 20. Calibration

20.1 Using a microburet, to five 125-mL separatory funnels add respectively 0.0 (blank), 2.0, 4.0, 6.0, and 8.0-mL aliquots of standard iodide solution. Add sufficient water to bring the volume in each funnel to about 50 mL.

20.2 Follow 21.2-21.7.

20.3 Prepare a calibration curve by plotting absorbance against milligrams of iodide.

## 21. Procedure

21.1 From the sample that is free of hydrocarbons and hydrogen sulfide, pipet an aliquot containing less than 2.5 mg of iodide into a separatory funnel and adjust the volume with water to 50 mL.

21.2 Add 3 drops of bromphenol blue solution.

21.3 Swirl the mixture and add HCl (1 + 1) dropwise until the indicator turns yellow (pH 5).

21.4 Add 10 mL of carbon tetrachloride, 1 mL of potassium nitrite solution, and mix by shaking the contents vigorously, relieving the pressure occasionally. (A violet color in the carbon tetrachloride phase indicates the presence of iodide in the sample).

21.5 After the phases have separated drain the carbon tetrachloride phase through a dry filter paper into a 50-mL volumetric flask.

21.6 Repeat the extraction with two more 10-mL portions of carbon tetrachloride and drain through the same filter paper into the same volumetric flask (21.5).

21.7 Dilute the combined extracts to 50 mL with carbon tetrachloride. Measure the absorbance at 517 nm in a 10 nm transmittance cell using the blank extract as a reference (see 20.3). The iodine- $CCl_4$  solution is fairly stable. However, avoid undue delay unless precautions are taken to prevent evaporation of the  $CCl_4$ .

## 22. Calculation

22.1 From the analytical curve (see 20.3) determine the milligrams of iodide corresponding to the absorbance obtained for each sample.

22.2 Calculate the concentration of iodide ion in the sample, in milligrams per litre, as follows:

$$I^-, \text{ mg/L} = \frac{M \times 1000}{S}$$

where:

$M$  = milligrams of iodide from curve, and

$S$  = millilitres of sample.

## 23. Precision and Bias <sup>8</sup>

23.1 The overall precision ( $S_T$ ) and single-operator precision ( $S_o$ ) of this test method within their designated ranges vary with the quantity being tested in accordance with Table 4.

**TABLE 4 Determination of Precision and Bias of Iodide Ions, Colorimetric Method**

Amount Added, mg/L	Amount Found, mg/L	S <sub>O</sub>	S <sub>T</sub>	±Bias	Statistically Significant (95 % Confidence Level)
12.1	12.1	1	1	0.0	yes
116.3	119.2	10	15	+2.49	no
771	786	58	63	+1.94	no
1375	1488	160	225	+8.22	yes

23.2 The bias of the test method determined from recoveries of known amounts of iodide in a series of prepared standards are given in Table 4.

NOTE 3—The precision and bias estimates are based on an interlaboratory study on four artificial brine samples containing various amounts of iodide and interfering ions as shown in Table 5. Two analysts in each of four laboratories performed duplicate determinations on each of two days. Practice D 2777 was used in developing these precision and bias estimates.

23.3 Precision and bias for this test method conforms to Practice D 2777-77, which was in place at the time of collaborative testing. Under the allowances made in 1.5 of D2777-86, these precision and bias data do meet existing requirements for interlaboratory studies of Committee D-19 test methods.

### TEST METHOD C—SELECTIVE ELECTRODE FOR IODIDE

#### 24. Scope

24.1 This test method is applicable to all brackish waters, seawaters, and brines containing from 1 to 2000 mg/L iodide.

#### 25. Summary of Test Method

25.1 The iodide-selective electrode and the reference electrode are placed in the solution and the potential recorded. Additional potential readings are taken after each of two standard additions. The electrode slope is determined from potential measurements of two iodide solutions of known concentration. The iodide concentration of the unknown sample is then calculated.

#### 26. Interferences

26.1 Ions commonly found in brines that interfere with the method are Cl<sup>-</sup>, Br<sup>-</sup>, and S<sup>=</sup>. The maximum allowable ratio of interfering ion to iodide is as follows:<sup>2</sup> Cl<sup>-</sup>, 10<sup>6</sup>; Br<sup>-</sup>, 5 × 10<sup>3</sup>; S<sup>=</sup>, <10<sup>-6</sup>. Sulfide interference can be eliminated by buffering the sample at pH 6 or lower.

#### 27. Apparatus

27.1 *Millivoltmeter (Accurate to ± 0.1 mV) or Specific Ion Meter.*

27.2 *Iodide Selective Electrode, reference electrode.*

27.3 *Pipets, microlitre, various sizes (100 to 1000 µL) with disposable polypropylene tips.*

27.4 *Volumetric Flask, 50-mL capacity, borosilicate glass.*

#### 28. Reagents

28.1 *Iodide Solution, Standard (1 mL = 1 mg I<sup>-</sup>)—Dissolve 1.308 g of KI in water and dilute to 1 L (see 19.4).*

**TABLE 5 Composition of Artificial Brine Samples**

Sample No.	mg/L			
	1	2	3	4
I	12.1	116.3	771	1 375
Na	9 500	65 000	31 000	75 000
K	300	1 400	2 000	5 000
Ca	550	1 000	700	2 000
Mg	1 200	1 200	500	250
Ba	30	650	300	300
Cl	19 000	107 000	52 000	121 000

28.2 *Ionic Strength Adjuster—Dissolve 42.5 g of NaNO<sub>3</sub> in water and dilute to 100 mL.*

#### 29. Procedure

29.1 Pipet 500 µL of the sample and 1 mL of ionic strength adjuster into a 50-mL volumetric flask. Dilute to the mark and transfer solution to a 100-mL beaker. Place electrodes in the solution to a depth of 30 mm. Stir the solution and record the potential across the two electrodes when the drift in potential is less than 0.1 mV/min. For high iodide levels this condition may be reached in less than 1 min; however, it may require several minutes for low levels. At this point, add iodide standard such that the change in potential is about 50 mV. After the potential has stabilized, record the mV reading. For the second addition, add the same volume of iodide standard and record the corresponding potential. For brines with low specific gravity smaller dilutions can be made to obtain greater sensitivity at low iodide levels.

29.2 In order to determine the slope of the electrode, it is necessary to measure the respective electrode potentials of two iodide solutions of known concentration.

#### 30. Calculation

30.1 Calculate the slope of the electrode as follows:

$$\text{Slope} = \frac{E_B - E_A}{\log [B] - \log [A]}$$

where:

*A and B* = two iodide solutions of known concentration (mg/L),

*E<sub>A</sub>* = electrode potential of Solution A, mV, and

*E<sub>B</sub>* = electrode potential of Solution B, mV.

NOTE 4—The slope of the electrode should meet the manufacturer's specifications.

30.2 The concentration of iodide in the sample can be calculated as follows:<sup>9</sup>

$$A = \frac{Xf}{\text{antilog} \left( \frac{\Delta E}{\text{slope}} \right) - 1}$$

where:

<sup>9</sup> Rix, C. J., Bond, A. M., and Smith, J. D., "Direct Determination of Fluoride in Sea Water with a Fluoride Selective Ion Electrode by a Method of Standard Additions," *Analytical Chemistry*, ANCHA, Vol 48, 1976, p. 1236.

$X$  = change in concentration upon addition of standard (mg I<sup>-</sup> added/50 mL of solution),  
 $f$  = dilution factor (50 mL/mL of sample), and  
 $\Delta E$  = the change in potential resulting from addition of standard.

From the above procedure, two  $A$  values can be calculated and averaged for each sample.

### 31. Precision and Bias <sup>8</sup>

31.1 The overall precision ( $S_T$ ) and single-operator precision ( $S_o$ ) of this test method within their designated ranges vary with the quantity being tested in accordance with Table 6.

31.2 The bias of the test method determined from recoveries of known amounts of iodide in a series of prepared standards are given in Table 6.

NOTE 5—The precision and bias estimates are based on an interlaboratory study on four artificial brine samples containing various amounts of iodide and interfering ions as shown in Table 7. Two analysts in each of four laboratories and one analyst in one laboratory performed duplicate determinations on each of two days. Also, one analyst in one laboratory performed duplicate determinations on one day. Practice D 2777 was used in developing these precision and bias estimates.

31.3 Precision and bias for this test method conforms to Practice D 2777-77, which was in place at the time of collaborative testing. Under the allowances made in 1.5 of D2777-86, these precision and bias data do meet existing requirements for interlaboratory studies of Committee D-19 test methods.

## TEST METHOD D—COLORIMETRIC FOR BROMIDE

### 32. Scope

32.1 This test method is applicable to all brackish waters, seawaters, and brines with bromide concentrations ranging from 40 to 6500 mg/L.

### 33. Summary of Test Method

33.1 Bromides are oxidized to bromine in acid solution by chromium trioxide. The bromine is extracted into carbon tetrachloride and measured spectrophotometrically.

### 34. Interferences

34.1 This test method is free of interference from iodide and chloride. No other interferences are known in oilfield waters.

### 35. Apparatus

35.1 *Photometer*—Spectrophotometer or filter photometer having a light path of approximately 10 mm for use at 417 nm. Filters, when required, shall be blue, have a narrow-band pass, and a maximum transmittance at or about this wavelength. Photometers and photometric practices prescribed in this test method shall conform to Practice E 60. Spectrophotometers shall conform to Practice E 275.

35.2 *Separatory Funnel*, 250-mL capacity, borosilicate glass with a TFE fluorocarbon stopcock and stopper.

35.3 *Pipets*, various sizes, borosilicate glass.

35.4 *Filter Paper*, rapid.

**TABLE 6 Determination of Precision and Bias of Iodide Ions, Selective Electrode**

Amount Added, mg/L	Amount Found, mg/L	$S_o$	$S_T$	$\pm$ Bias	Statistically Significant (95 % Confidence Level)
12.1	12.4	1	3	+ 2.48	yes
116.3	126.4	7	12	+ 8.68	yes
771	814	30	50	+ 5.57	yes
1375	1464	34	90	+ 6.47	yes

**TABLE 7 Composition of Artificial Brine Samples**

Sample No.	mg/L			
	1	2	3	4
I	12.1	116.3	771	1 375
Na	9 500	65 000	31 000	75 000
K	300	1 400	2 000	5 000
Ca	550	1 000	700	2 000
Mg	1 200	1 200	500	250
Ba	30	650	300	300
Cl	19 000	107 000	52 000	121 000

35.5 *Graduated Cylinder*, 25-mL capacity, borosilicate glass with a ground-glass stopper.

### 36. Reagents

36.1 *Bromide Solution, Standard* (1 mL = 1 mg Br<sup>-</sup>)—Dissolve 1.4893 g of dry potassium bromide in water and dilute to 1 L in a volumetric flask.

36.2 *Carbon Tetrachloride* (CCl<sub>4</sub>)—**Warning:** Avoid inhalation and conduct all manipulation in a well-ventilated hood.

36.3 *Chromium Trioxide* (CrO<sub>3</sub>).

36.4 *Sulfuric Acid* (1 + 1)—Slowly add 1 volume of H<sub>2</sub>SO<sub>4</sub>(sp gr 1.84) to 1 volume of water while mixing and cooling the solution.

### 37. Calibration

37.1 Prepare a series of standards containing up to 400 mg/L of bromide.

37.2 Follow 38.1-38.6.

37.3 Prepare an analytical curve by plotting absorbance against milligrams of bromide.

### 38. Procedure

38.1 Pipet up to 25 mL of sample into a 250-mL separatory funnel equipped with a TFE-fluorocarbon stopcock.

38.2 Cautiously add 1 volume of H<sub>2</sub>SO<sub>4</sub> (1 + 1) to 1 volume of sample to bring the H<sub>2</sub>SO<sub>4</sub> concentration of the solution to 9 N and cool.

38.3 To the cooled solution add 15 mL of CCl<sub>4</sub>, 2 g of CrO<sub>3</sub> and shake well.

38.4 Drain the CCl<sub>4</sub> layer through a rapid filter paper into a graduated cylinder fitted with a ground-glass stopper, taking care that none of the aqueous layer is allowed to drain into the cylinder.

38.5 Repeat the extraction with 5-mL portions of CCl<sub>4</sub> until that layer is no longer colored. Adjust the final volume of CCl<sub>4</sub> to 25 mL, stopper, and mix well.

38.6 Measure the absorbance at 417 nm against CCl<sub>4</sub>(measurements must be made immediately following extraction).

### 39. Calculation

39.1 From the analytical curve (see 38.3) determine the milligrams of bromide corresponding to the absorbance for each sample.

39.2 Calculate the concentration of bromide in the sample, in milligrams per litre, as follows:

$$\text{Br}^-, \text{mg/L} = \frac{B}{S} \times 1000$$

where:

$B$  = milligrams of bromide from curve and

$S$  = millilitres of sample.

### 40. Precision and Bias <sup>8</sup>

40.1 The precision of the test method within its designated range may be expressed as follows:

$$S_T = 0.092X - 2.47$$

$$S_o = 0.061X - 0.092$$

where:

$S_T$  = overall precision,

$S_o$  = single-operator precision, and

$X$  = concentration of bromide determined, mg/L.

40.2 The bias of the test method determined from recoveries of known amounts of bromide in a series of prepared standards are given in Table 8.

NOTE 6—The above precision and bias estimates are based on an interlaboratory study of bromide and interfering ions as shown in Table 9. One analyst in each of two laboratories and two analysts in each of three laboratories performed duplicate determinations on each of two days.

**TABLE 8 Determination of Precision and Bias of Bromide Ions, Colorimetric Method**

Amount Added, mg/L	Amount Found, mg/L	$S_o$	$S_T$	$\pm$ Bias	Statistically Significant (95 % Confidence Level)
30.3	29.5	2	0	-2.64	yes
534	491	30	46	-8.05	yes
1286	1407	86	127	+9.41	yes
5734	6204	378	568	+8.20	yes

**TABLE 9 Composition of Artificial Brine Samples**

Sample No.	mg/L			
	1	2	3	4
Br	30.3	534	1 286	4 737
Na	9 500	65 000	31 000	75 000
K	300	1 400	2 000	5 000
Ca	550	1 000	700	2 000
Mg	30	650	300	300
Cl	19 000	107 000	52 000	121 000

Practice D 2777 was used in developing these precision and bias estimates.

40.3 Precision and bias for this test method conforms to Practice D 2777-77, which was in place at the time of collaborative testing. Under the allowances made in 1.5 of D2777-86, these precision and bias data do meet existing requirements for interlaboratory studies of Committee D-19 test methods.

### 41. Keywords

41.1 brackish; brine; bromide ion; colorimetric; iodide ion; selective electrode

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