



Standard Test Methods for Water in Halogenated Organic Solvents and Their Admixtures¹

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 These test methods describe the use of the Karl Fischer (KF) titration for determination of water in halogenated organic solvents and mixtures thereof. Water concentrations from 2 to 1000 ppm can be determined in these solvents. Two test methods are covered as follows:

1.1.1 *Test Method A, Water Determination Using a Coulometric KF Titrator*—The coulometric test method is known for its high degree of sensitivity (typically $< 10 \mu\text{g H}_2\text{O}$) and should be the test method of choice if water concentrations are typically below 50 ppm or if only small amounts of sample are available for water determinations. This test method requires the use of equipment specifically designed for coulometric titrations.

1.1.2 *Test Method B, Water Determination Using a Volumetric KF Titrator*—The volumetric test method is a more traditional approach to KF water determinations. Although titrators are specifically designed for KF volumetric determinations, many automatic titrators on the market can be adapted to perform KF titrations.

1.2 Either of these test methods can be used to determine typical water concentrations (15 to 500 ppm) found in halogenated solvents.

1.3 These test methods recommend the use of commercially available Karl Fischer titrators and reagents.

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 applicability of regulatory limitations prior to use.* For specific precautionary statements, see Sections 11 and 15.

2. Referenced Documents

2.1 ASTM Standards:

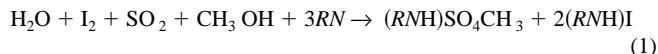
¹ These test methods are under the jurisdiction of ASTM Committee D26 on Halogenated Organic Solvents and Fire Extinguishing Agents and are the direct responsibility of Subcommittee D26.04 on Test Methods.

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E 203 Test Method for Water Using Karl Fischer Titration²

3. Summary of Test Methods

3.1 In the Karl Fischer reaction, water will react with iodine in the presence of sulfur dioxide, alcohol, and an organic base according to the following equation:



where RN = organic base.

3.2 When the volumetric titration test method is used for this determination, the halogenated sample is added to a KF solvent that usually consists of sulfur dioxide and an amine dissolved in anhydrous methanol. This solution is titrated with an anhydrous solvent containing iodine. The iodine titrant is first standardized by titrating a known amount of water.

3.3 In the coulometric titration test method, the sample is injected into an electrolytic cell where the iodine required for the reaction with water is produced by anodic oxidation of iodide. With this technique, no standardization of reagents is required.

3.4 In both test methods, the end point is determined amperometrically with a platinum electrode that senses a sharp change in cell resistance when the iodine has reacted with all of the water in the sample.

4. Significance and Use

4.1 High water concentrations can have a detrimental effect on many uses of halogenated solvents.

4.1.1 Water can cause corrosion and spotting when solvents are used for metal cleaning.

4.1.2 Water can reduce the shelf life of aerosol formulations.

4.1.3 Water can inhibit desired reactions when solvents are used in formulations.

5. Interferences

5.1 Certain compounds or classes of compounds interfere with the accurate determination of water by the Karl Fischer

² *Annual Book of ASTM Standards*, Vol 15.05.

test method. They include aldehydes, ketones, free halogens, ferric salts, and strong oxidizing and reducing agents.

5.2 Free halogens can oxidize the iodate in the KF reagents to form iodine; this causes erroneously low water values.

5.3 A more detailed discussion of KF interferences can be found in Test Method E 203 and other sources.^{3,4}

6. Apparatus

6.1 *Coulometric Titrator*,⁵ (for Test Method A only) consisting of a single or dual bath electrolytic cell, dual platinum electrode, magnetic stirrer, and control unit.

6.2 *Volumetric Titrator*,⁵ (for Test Method B only) consisting of a titration cell, dual platinum electrode, magnetic stirrer, dispensing buret, and control unit.

6.3 *Syringes*, 2, 5, 10, or 20-mL sizes.

6.4 *Syringe*, 5- μ L size.

6.5 *Silicon Rubber Blocks or Silicon Rubber Septa*.

6.6 *Drying Oven*, air circulating.

6.7 *Desiccator*.

6.8 *Analytical Balance*, capable of weighing to ± 0.01 g.

7. Reagents

7.1 *Anode Reagent*, for dual bath titration (for Test Method A only), use reagent recommended by manufacturer of titrator.

7.2 *Cathode Reagent*, for dual bath titration (for Test Method A only), use reagent recommended by manufacturer of titrator.

7.3 *Single Bath Reagent*, (for Test Method A only), use reagent recommended by manufacturer of titrator.

7.4 *Karl Fischer Volumetric Titrant*,⁴ (for Test Method B only) typically consists of a mixture of an organic amine, sulfur dioxide, and iodine dissolved in a non-hydroscopic solvent(s). Reagents with titers of 1.00, 2.00, and 5.00 mg of H₂O/mL can be commercially obtained.

7.5 *Karl Fischer Solvent*,⁴ (for Test Method B only) typically consists of a mixture of an organic amine and sulfur dioxide dissolved in anhydrous methanol.

NOTE 1—Pyridine was the organic amine that was traditionally used in Karl Fisher reagents, however, pyridine-free formulations are now available and preferred by most KF instrument manufacturers for use with their equipment. Pyridine-free reagents are said to be less toxic, less odorous, and more stable than pyridine types.

8. Sampling

8.1 Since halogenated solvents normally contain low concentrations of water, care must be taken to eliminate the introduction of water from sampling equipment and atmospheric moisture.

8.2 Without taking the proper sampling precautions, more error is typically introduced into the determination of water through sampling techniques than in the titration process itself.

³ Mitchell, J., Jr. and Smith, D. M., *Aquametry—A Treatise on Methods for the Determination of Water, Part III—The Karl Fischer Reagent*, 2nd ed., J. Wiley and Sons, Inc., New York, NY, 1977.

⁴ *Hydranal—Eugen Scholz Reagents for Karl Fischer Titration*, 4th ed., by Riedel-deHaen Aktiengesellschaft (US Distributor—Crescent Chemical Co., Inc.).

⁵ Automatic coulometric and volumetric titrators are manufactured by many different companies. Models that have been found satisfactory for this purpose are available from Fisher Scientific, EM Science, Metrohm, Mettler, Photovolt, Mitsubishi, and others.

8.3 Dry sample bottles and closures in an oven at 110°C for several hours. Place caps on the bottles immediately after removing from the oven.

8.4 Transfer solvent to the bottles as quickly as possible. Adjust the liquid level to come within 1 in. of the top of the bottle. Immediately place the cap on the bottle and tighten.

8.5 When removing a portion of sample from the bottle for KF analysis, use pipets or syringes that have been thoroughly dried. Replace the cap on the bottle immediately.

8.6 If more than one portion of sample is to be taken from the bottle or if the sample is to be retained for further water analysis, it is a good practice to blanket the top of the bottle with dry nitrogen when removing the sample. If septum cap closures are being used, dry nitrogen can be introduced with a syringe at the same time a portion of the sample is being removed with a second syringe.

TEST METHOD A—WATER DETERMINATION USING A COULOMETRIC KF TITRATOR

9. Summary of Test Method

9.1 The dual bath coulometric titration cell consists of a sealed vessel containing both an anode and cathode compartment. The anodic compartment usually contains a solution consisting of sulfur dioxide, iodide, and an amine in a methanol/chloroform solvent. The cathodic compartment contains similar reagents optimized for cathodic reduction.

9.2 When a sample containing water is injected into the anode compartment, the electrolytic cell generates its own supply of iodine from the iodide present. The iodine reacts stoichiometrically with the water and the completion of the reaction is detected with a platinum sensing electrode. The coulombs of electricity required to generate the necessary amount of iodine is then translated by the microprocessor in the control unit into the amount of water that was present in the sample.

9.3 The single bath coulometric titration cell consists of a sealed vessel filled with single bath reagent and dual platinum electrodes. When a sample containing water is injected into the vessel, the electrolytic cell generates its own supply of iodine from the iodide present in the single bath reagent. The iodine reacts stoichiometrically with the water and the completion of the reaction is detected by a platinum sensing electrode. The coulombs of electricity required to generate the necessary amounts of iodine is then translated by the microprocessor in the control unit into the amount of water that was present in the sample.

10. Verification of Instrument Accuracy

10.1 Coulometric titrators do not have a titrant that needs to be standardized since the iodine is being generated on demand by the titration cell. However, occasional checks of the instrument accuracy are recommended. This can be done by titrating a known amount of water and comparing this amount with the amount of water reported by the titrator.

10.2 Use a 5- μ L syringe to inject exactly 3.0 μ L of water into the titration cell. Once the titration is complete, the titrator should report a value of 3000 μ g (3.0 mg) H₂O. The deviation from this value should not be larger than 10 %. If the value is

larger than 10 %, consult the instrument manual or manufacturer to determine the cause.

10.3 Alternatively, standard solutions containing known amounts of water dissolved in either methanol or a non-hygroscopic solvent are available from reagent suppliers for accuracy verification. A known volume of this solution is titrated and the reported amount of water is compared with the theoretical amount stated by the supplier.

11. Precautions

11.1 Amounts of coulomatic reagents usually recommended for addition to the reaction cell typically have the capacity to react with approximately 100 to 200 mg of water. These reagents must be replaced when they are depleted.

11.2 Coulomatic reagents are hygroscopic and must be stored in tightly capped containers to reduce the absorption of atmospheric moisture.

11.3 Since the titrator automatically generates iodine to keep the reaction vessel in a dehydrated state, it is important to keep the cell sealed to prevent introduction of excess atmospheric moisture that will decrease reagent life.

11.4 The total amount of solution in the anode compartment can affect the KF reaction. Typically, the total volume of sample liquids that are added to the reaction cell should not exceed 50 % of the original reagent in the compartment. If the reagents become too dilute, the stoichiometry and rate of the Karl Fischer reaction can be adversely affected. This fact should be considered when using large sample sizes.

11.5 Follow the recommended maintenance procedures of the instrument manufacturer.

12. Procedure

12.1 Set up the coulometric titrator according to the manufacturer's instructions, and add the proper amount of coulomat reagents to the anode and cathode compartments of the titration cell.

12.2 The cell solutions must be anhydrous prior to introduction of the sample. This is accomplished by either pretitrating the cell contents or by adding a small amount of an iodine/methanol solution until a faint brownish coloration appears. Following the procedure recommended by the instrument manufacturer is suggested.

12.3 The amount of halogenated solvent that is injected into the cell depends on the quantity of water in the solvent. Table 1 lists recommended sample sizes for anticipated water concentrations.

12.4 Thoroughly clean and dry the sampling syringe. One method is to dry it in an oven and desiccate before use.

12.5 Fill the syringe to the desired level with sample and draw back the plunger so that no sample remains in the needle.

TABLE 1 Recommended Sample Amount for Coulometric Titration

Water Content, ppm	Sample Weight, g
1000	0.5
500	0.5
100	1.0
50	2.0
10	5.0
1	10

12.6 Cover the syringe needle with a silicone rubber block or piece of silicone rubber septa to further prevent evaporation or spillage during the weighing process.

12.7 Transfer the filled syringe to an analytical balance and weigh the syringe and contents to the nearest 0.01 g.

12.8 Remove the silicone block and insert the needle into the titration cell septum. Inject the sample slowly, taking care not to touch the needle to the surface of the anode solution. While the syringe is still inside the cell, draw any remaining sample that may remain in the syringe needle back into the barrel and remove the needle from the cell.

12.9 Place the silicone block back onto the tip of the needle and reweigh the empty syringe. The weight difference between the first and second weighings will be the amount of sample injected into the titration cell.

12.10 The make and model of the titrator being used will determine the actual steps performed to carry out the titration process. In most cases, all that is required is pressing a *start titration* or *run* key on the instrument keyboard either just prior to or just after the sample injection.

12.11 Once the titration is complete, the amount of water (μg or mg) that was found in the solvent will appear on the instrument's digital display. Most instruments will also calculate concentrations (ppm or %) if the sample weight is keyed into the instrument's control panel.

13. Calculation

13.1 Calculate the water content of the solvent as follows:

$$\text{ppm H}_2\text{O} = \frac{\mu\text{g H}_2\text{O found}}{\text{grams of solvent injected}} \quad (2)$$

TEST METHOD B—WATER DETERMINATION USING A VOLUMETRIC KF TITRATOR

14. Summary of Test Method

14.1 The volumetric titration cell consists of a sealed glass vessel containing a dual platinum electrode. To the cell, a suitable solvent (usually methanol based) is added. The sample is injected into the cell, the mixture is stirred thoroughly and titrated with a Karl Fischer reagent. This reagent typically contains an organic amine, sulfur dioxide, and iodine dissolved in a non-hygroscopic solvent such as xylene. The iodine reacts stoichiometrically with the water, and the completion of the reaction is detected with the platinum electrode.

15. Precautions

15.1 It is important to keep the cell sealed to prevent introduction of excess atmospheric moisture that will decrease reagent life.

15.2 The total amount of solution in the titration cell can affect the KF reaction. Typically, the total volume of sample liquids that are added to the cell should not exceed 100 % of the original solvent in the cell. If the reagents become too dilute the stoichiometry and rate of the Karl Fischer reaction can be adversely affected.

15.3 All solvents and reagents should be protected from atmospheric moisture. Drying tubes containing molecular sieves should be used on all storage containers.

15.4 Good stirring action in the titration cell is needed to mix the solution very rapidly during the titration in order for

the electrode to determine the correct end point.

15.5 Follow the recommended maintenance procedures of the instrument manufacturer.

16. Standardization of Titrant

16.1 Since the exact water equivalence of a titrant must be known for accurate moisture determinations, its titer should be checked on a regular basis.

16.2 Non-methanol-based titrants are more stable than their methanol-based counterparts and are therefore recommended for the determination of low moisture contents typically encountered in halogenated solvents.

16.3 To determine the titer, use a 5- μ L syringe to inject exactly 3.0 μ L of water into the titration cell containing solvent that has been pre-titrated to remove residual moisture. When the titration is complete, perform the following calculation:

$$\begin{aligned} & 3.0 \text{ mg H}_2\text{O/mL of titrant consumed} \\ & = \text{mg/mL H}_2\text{O equivalent of titrant} \end{aligned} \quad (3)$$

16.4 Alternatively, standard solutions of either methanol or non-hygroscopic solvents that have known amounts of water added to them are available from reagent suppliers for titer standardization.

17. Procedure

17.1 Set up the volumetric titrator according to the manufacturer's instructions.

17.2 Fill the cleaned and dry titration cell with an appropriate amount of solvent. The minimum amount required will be enough to cover the electrode ends and the titrant buret tip.

17.3 Select a stirring speed that is sufficient to create a well-defined vortex with the solvent.

17.4 Pre-titrate the solvent so that all the moisture has been removed prior to introduction of the sample.

17.5 The amount of halogenated solvent injected into the cell depends on the quantity of water in the solvent. Table 2 lists recommended sample sizes for anticipated water concentrations and various titrant concentrations.

NOTE 2—In most cases, a titrant with a capacity of 1 or 2 mg H₂O/mL will be most appropriate for determining water content in halogenated solvents.

17.6 Thoroughly clean and dry the sampling syringe. One method is to dry in an oven and desiccate before use.

17.7 Fill the syringe to the desired level with sample and draw back the plunger so that no sample remains in the needle.

17.8 Cover the syringe needle with a silicone rubber block or piece of silicone rubber septa to further prevent evaporation or spillage during the weighing process.

17.9 Transfer the filled syringe to an analytical balance and weigh the syringe and contents to the nearest 0.01 g.

17.10 Remove the silicone block and insert the needle into the titration cell septum. Inject the sample slowly, taking care not to touch the needle to the surface of the anode solution. While the syringe is still inside the cell, draw any sample that remains in the syringe needle back into the barrel and remove the needle from the cell.

17.11 Place the silicone block back onto the tip of the needle and reweigh the empty syringe. The weight difference between the first and second weighings will be the amount of sample injected into the titration cell.

17.12 The make and model of the titrator being used will determine the actual steps performed to carry out the titration process. In most cases, all that is required is pressing a *start titration* or *run* key on the instrument keyboard either just prior to or just after the sample injection.

17.13 Once the titration is complete, the amount of water (μ g or mg) that was found in the solvent will appear on the instrument's digital display. Most instruments will also calculate concentrations (ppm or %) if the sample weight is keyed into the instrument's control panel.

18. Calculation

18.1 Calculate the water content of the solvent as follows:

$$\text{ppm H}_2\text{O} = \mu\text{g H}_2\text{O found/grams of solvent injected} \quad (4)$$

19. Precision and Bias ⁶

19.1 *Precision of Test Method A, Coulometric:*

19.1.1 At levels of water below 200 ppm the coulometric test method can be expected to have a precision (one standard deviation) of less than 2 ppm. For levels near 1000 ppm water, the precision is about 15 ppm.

19.2 *Precision of Test Method B, Volumetric:*

19.2.1 At levels of water below 200 ppm the volumetric test method can be expected to have a precision (one standard deviation) of 3 ppm or less. For levels near 1000 ppm water, the precision is about 10 ppm.

19.3 *Bias*—The bias of these test methods cannot be determined due to the lack of stable standards of water in the solvents. The solvents readily pick up moisture making it nearly impossible to maintain a consistent standard.

20. Keywords

20.1 coulometric Karl Fischer titration; halogenated organic solvents; Karl Fischer test method—water content; moisture content; solvents; volumetric Karl Fischer titration; water content

⁶ Research reports are available from ASTM Headquarters. Request RR:D26-1004 and RR:D26-1009.

TABLE 2 Recommended Sample Amount for Volumetric Titration

Water Content, ppm	5 mg H ₂ O/mL Titrant, g	2 mg H ₂ O/mL Titrant, g	1 mg H ₂ O/mL Titrant, g
1000	2.5 to 10	1 to 10	0.5 to 5
500	5 to 20	2 to 20	1 to 10
100	20	10 to 20	5 to 20
50	...	20	10 to 20
10	...	20 or more	20 or more



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