



A Honeywell Company

Disulfide Sulfur in Light Petroleum Distillates and LPG

UOP Method 202-14

Scope

This method is for determining disulfide sulfur in gasoline, liquefied petroleum gas (LPG), and other light petroleum distillates. Part A of the method, an acid stirring procedure, is used for low molecular weight disulfides usually found in LPG and for distillates that do not contain tertiary disulfides. Because of its rapidity, the acid stirring procedure is recommended for routine work where tertiary disulfides are not a factor. Part B of the method, an acid reflux procedure, is reserved for samples containing tertiary disulfides. This method is applicable to samples containing a disulfide sulfur concentration of 10 mass-ppm or greater.

References

ASTM Method D4052, "Density and Relative Density of Liquids by Digital Density Meter,"

www.astm.org

Hubbard, R.L., Haines, W.E., and Ball, J.S., *Anal. Chem.*, **30**, (1958)

UOP Method 163, "Hydrogen Sulfide and Mercaptan Sulfur in Liquid Hydrocarbons,"

www.astm.org

UOP Method 516, "Sampling and Handling of Gasolines, Distillate Fuels, and C₃-C₄ Fractions,"

www.astm.org

UOP Method 999, "Precision Statements in UOP Methods," www.astm.org

Outline of Method

Part A - Acid Stirring Procedure

The mercaptan sulfur content of the sample is first determined by a potentiometric titration with silver nitrate, according to UOP Method 163, "Hydrogen Sulfide and Mercaptan Sulfur in Liquid Hydrocarbons." The disulfides in the sample are reduced to mercaptans with zinc metal and acetic acid in methanol by stirring at room temperature for 30 minutes. Then the mixture is decanted and filtered quickly into a titration beaker. The reaction flask and filter paper are washed with titration solvent and the washings are added to the titration beaker. This is followed by a potentiometric titration of the solution with alcoholic silver nitrate. The mercaptan sulfur titrated is equal to the original mercaptan present plus the mercaptan sulfur resulting from the reduction of the disulfides. The

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disulfide sulfur present in the sample is determined from the difference between the mercaptan sulfur content before and after reduction.

Part B - Acid Reflux Procedure

The mercaptan sulfur content of the sample is first determined by a potentiometric titration with silver nitrate, according to UOP Method 163. The disulfides in the sample are reduced to mercaptans by refluxing in the presence of acetic acid and zinc in a reaction flask. Part of the mercaptans are vaporized, and are carried from the reaction flask with nitrogen and collected into a potassium hydroxide solution for a subsequent potentiometric titration with alcoholic silver nitrate. An aliquot is taken from the liquid in the reaction flask and is also titrated potentiometrically with silver nitrate.

The mercaptan sulfur titrated is equal to the original mercaptan present plus the mercaptan sulfur resulting from the reduction of the disulfides. The disulfide sulfur present in the sample is determined from the difference between the mercaptan sulfur content before and after reduction.

Apparatus

References to catalog numbers and suppliers are included as a convenience to the method user. Other suppliers may be used.

In addition to the equipment listed below, the apparatus specified in UOP Method 163 is also required for this method. For LPG samples, the apparatus specified in UOP Method 516, "Sampling and Handling of Gasolines, Distillate Fuels, and C₃-C₄ Fractions," is also required.

Balance, 5-kg maximum capacity, readable to 0.5 g

Balance, readable to 0.0001 g

Beakers, tall form, 300-mL, Fisher Scientific, Cat. No. 10-310-8

Boiling flask, 1000-mL, round bottom, center neck with 24/40 standard taper female joint, side neck 19/38 standard taper female joint; fitted with an inlet tube extending to the bottom of the flask for nitrogen purging, Kimble Chase Kontes, Cat. Nos. 605020-1419 and 479101-0000, respectively

Bottle, gas-washing, 250-mL, with a coarse fritted glass cylinder, Fisher Scientific, Cat. No. 03-040B

Condenser, Allihn, reflux, with 24/40 standard taper male joint to fit boiling flask, Kimble Chase Kontes, No.:431000-2430, Fisher Scientific, Cat. No. K431000-2430

Connector, with a 24/40 standard taper connector on one end, and a hose connector on other end, for top of condenser, Sigma-Aldrich, Cat. No. Z11,908-3

Desiccator, glass, Fisher Scientific, Cat. No. 08-595D

Dry ice condenser trap, Sigma-Aldrich, Cat. No. Z15,426-1

Electrode, combination glass/silver Titrode, Metrohm, Cat. No. 20948507. This electrode should be dedicated to sulfur analysis.

Flasks, Erlenmeyer, 125- and 250-mL, glass-stoppered, Fisher Scientific, Cat. Nos. 10-100D and 10-100E, respectively

Flasks, volumetric, 100- and 1000-mL, Fisher Scientific, Cat. Nos. 10-209D and 10-209H, respectively, several of each required

Flow meter, capable of measuring gas flow in the 100- to 200-mL/min range, Sigma-Aldrich, Cat. No. 20432

Funnels, glass, short-stem, Fisher Scientific, Cat. No. 10-322D, several required

Heating mantle, 1000-mL, Fisher Scientific, Cat. No. 11-473-22

Oven, laboratory drying

Pans, to hold water ice bath and dry ice bath

Pipets, volumetric, Class A, 1-, 2-, 5-, 10-, 50-, and 100-mL, Fisher Scientific, Cat. Nos. 13-650-2B, -2C, -2F, -2L, -2S, and -2U, respectively

Regulator, nitrogen, two-stage, high purity, Matheson Tri-Gas, Model 3122-580

Scotchbrite™ abrasive cleaning pads, or equivalent, local supply

Stirrer, magnetic, Fisher Scientific, Cat. No. 11-300-49S

Stirring bar, magnetic, Teflon™-covered, 8-mm x 32-mm (5/16-inch x 1.25-inch), Fisher Scientific, Cat. No. 14-511-94

Titration, potentiometric, recording, 2000-mV range, 1-mV resolution with a dispenser having a volume readout of 0.00 to 20.00 mL and 0.01% resolution, Titrand, Metrohm, Cat. No. 29040020

Tube, stainless steel, 3.2-mm (1/8-inch) OD x 300-mm (12-inch) long, local supply

Valve, needle, to fit LPG sample cylinders, local supply

Reagents and Materials

References to catalog numbers and suppliers are included as a convenience to the method user. Other suppliers may be used. References to water mean deionized or distilled water.

In addition to the reagents and materials listed below, the reagents and materials specified in UOP Method 163 are also required for this method. For LPG samples, the reagents and materials specified in UOP Method 516 are also required.

Acetic acid, glacial, Fisher Scientific, Cat. No. A38-212

Acetone, Fisher Scientific, Cat. No. A18-4

Ammonium hydroxide, concentrated, Fisher Scientific, Cat. No. A669-212

Calcium sulfate, anhydrous, Drierite, 4-mesh, Fisher Scientific, Cat. No. 07-577-1B

Chelating solution, a solution of chelating agents found effective in reducing the deterioration of sulfides and mercaptides in caustic solutions. The recommended usage is 2 mL/100 mL of caustic solution. This chelating solution is made up from the constituent chemicals:

Diethylenetriamine pentaacetic acid, sodium salt (Na₅DTPA), 40% aqueous solution, Acros Organics, Fisher Scientific, Cat. No. 40729-0010

Diethylenetriamine pentaacetic acid, sodium salt, 20 mass-% solution. Dilute diethylenetriamine pentaacetic acid, sodium salt, 40% aqueous solution, with water to make a 20 mass-% solution.

N-(2-hydroxyethyl) ethylenediaminetriacetic acid, sodium salt, (Na₃HODTA), Sigma-Aldrich, Cat. No. 16,153-5, or Acros Organics, Fisher Scientific, Cat. No. 34870-0010

N-(2-hydroxyethyl) ethylenediaminetriacetic acid, sodium salt, 20 mass-% solution. Dissolve *N*-(2-hydroxyethyl) ethylenediaminetriacetic acid, sodium salt, in water to make a 20 mass-% solution.

Ethylenediaminetetraacetic acid, sodium salt (Na₄EDTA), Sigma-Aldrich, Cat. No. E2,629-0, or, Acros Organics, Fisher Scientific, Cat. No. 14786-5000

N,N-bis(2-hydroxyethyl)glycine (Bicine), Sigma-Aldrich, Cat. No. 16,379-1, or, Acros Organics, Fisher Scientific, Cat. No. 17265-1000

Mix 1:1 by weight ethylenediaminetetraacetic acid, sodium salt, and *N,N*-bis(2-hydroxyethyl)glycine. Dissolve in water to make a 20 mass-% solution. Mix equal volumes of each of the three 20 mass-% solutions to make the final chelating solution.

Congo red, indicator test paper, Fisher Scientific, Cat. No. 14-861

Dry ice, crushed

Filter paper, coarse, 110-mm, Whatman 41, Fisher Scientific, Cat. No. 09-850C

Isooctane, pesticide grade, Fisher Scientific, Cat. No. O297-4

Methanol, certified ACS grade, Fisher Scientific, Cat. No. A412-4

Nitrogen, high purity, local supply

Potassium chloride, primary standard. NIST Standard Reference Material 999b. Before each use, oven dry at 105°C for 2.5 hours and cool in a desiccator.

Potassium hydroxide, 10 % (mass/vol), 1-L, Fisher Scientific, Cat. No. 50-823-5157

Potassium hydroxide-chelating solution. Add 10.0 ± 0.1 g of the chelating solution mixture (see below) directly to the 1-L bottle of 10% potassium hydroxide, cap and invert several times to thoroughly mix.

2-Propanol, certified ACS grade, Fisher Scientific, Cat. No. A416-4

Silver nitrate concentrate, Fisher certified grade, Fisher Scientific, Cat. No. SS73

Silver nitrate, alcoholic solution, nominally 0.1N. Quantitatively transfer the silver nitrate concentrate to a 1000-mL volumetric flask using several washes of 2-propanol. Fill to the mark with 2-propanol, cap and invert several times to thoroughly mix the contents. Standardize this solution following the stepwise instructions in *Procedure*. Mark the actual normality thus determined on the volumetric flask.

Silver nitrate, alcoholic solution, nominally 0.01N. Pipet 100 mL of the nominally 0.1-*N* alcoholic silver nitrate solution into a 1000-mL volumetric flask. Add 80 mL of water to the flask. Fill to the mark with 2-propanol, cap and invert several times to thoroughly mix the contents. The normality of this solution will be exactly one-tenth the normality of the nominally 0.1-*N* alcoholic silver nitrate solution as determined in *Procedure*. Mark this actual normality on the volumetric flask.

Sodium sulfide, 9-hydrate, Fisher Scientific, Cat. No. S425-500

Sodium sulfide, 1% solution. Dissolve 1.0 g ± 1.0 mg of sodium sulfide in 100 mL of water.

Sulfuric acid, concentrated, Fisher Scientific, Cat. No. A300-212

Sulfuric acid, dilute. Prepare by mixing equal volumes of concentrated sulfuric acid and water.

Titration solvent, oxygen free. Purge a freshly opened bottle of 2-propanol with nitrogen for 30 minutes. Add 1% by volume of concentrated ammonium hydroxide. Store under nitrogen.

Tubing, plastic, appropriate size to connect pieces of acid reflux apparatus

Water, deionized or distilled

Water ice

Water, tap

Wipers, Kimwipes Ex-L, VWR, Cat. No. 21905-026

Zinc, powder, Fisher certified grade, Fisher Scientific, Cat. No. Z5-500

Zinc, granular, 20-mesh, certified ACS grade, Fisher Scientific, Cat. No. Z15-500

Procedure

The analyst is expected to be familiar with general laboratory procedures, the technique of titration, and the equipment being used. Dispose of used supplies and samples in an environmentally safe manner according to local regulations.

Electrode Preparation and Reconditioning

Proper electrode preparation is essential to obtain reproducible and noise-free titration curves having good endpoints. The electrode should be reconditioned on a weekly basis when in use, and should be reconditioned if it is used for any titrations other than sulfur compounds. It is recommended that an electrode be dedicated to sulfur analysis. Prepare and recondition the silver-silver sulfide electrode as follows:

1. Clean the silver surface with a Scotchbrite pad. Rinse with water and dry.
2. Immerse the electrodes in a solution containing 90 mL of 2-propanol, 2 mL of ammonium hydroxide and 8 mL of 1% sodium sulfide solution.
3. Slowly titrate approximately 10 mL of 0.1N silver nitrate solution over a period of 10 minutes while stirring at a moderate speed. A film of silver sulfide will be deposited on the silver electrode.
4. Wipe the excess silver sulfide from the electrode with a wiper or a soft paper towel.
 - The electrode should be cleaned after each titration by rinsing with water.

LPG Sample Preparation

1. Obtain a sample of LPG from the process sampling point by following the instructions in UOP Method 516, including the cleaning of the 1000-mL cylinder, and transport it to the laboratory.
 - Trace sulfur applications require the use of a specially coated cylinder as described in UOP Method 516.
2. Connect a needle valve to the LPG cylinder and attach an approximately 300-mm length of 3.2-mm (1/8-inch) tubing to the outlet of the needle valve.
3. Weigh the sample cylinder to the nearest 0.5 g.
4. Add 75 mL of isooctane to a 250-mL Erlenmeyer flask.
5. Place the flask into a pan containing crushed dry ice in a hood and ground the sample cylinder and pan by attaching a length of copper wire from the valve and pan to a metal water outlet in

the hood. If the water pipes are not metal, establish a connection to another suitable ground.

6. Position the cylinder such that liquid will be withdrawn through the attached valve and that the outlet of the tubing is placed below the surface of the isooctane. Direct, slowly and carefully, a flow of LPG from the cylinder into the flask. Take approximately 200 g of sample and swirl to mix.
 - The flow may be stopped and restarted several times to control the boiling of the LPG.
7. Reweigh the cylinder to the nearest 0.5 g to determine the actual sample size taken.
8. Allow the LPG to boil off at room temperature in a fume hood.
9. Transfer the isooctane now containing the disulfides (they do not evaporate under these conditions) from the flask to a 100-mL volumetric flask.
 - This method is not appropriate for quantitation of mercaptans in LPG.
10. Wash the Erlenmeyer flask with 20 mL of isooctane and add the washings to the volumetric flask.
11. Dilute to the mark with isooctane. Cap and invert the flask several times to ensure proper mixing. This solution is hereafter referred to as the LPG-isooctane concentrate.
12. Proceed to *Sample Analysis, Part A - Acid Stirring Procedure*.

Silver Nitrate Standardization

1. Weigh approximately three 0.10 g (to the nearest 0.1 mg) portions each of dried potassium chloride into three clean, dry 300-mL tall form beakers.
2. Add approximately 100 mL of water and a stirring bar to each beaker. Drop a small piece of congo red test paper into the solution in the beakers. Add, drop by drop, dilute sulfuric acid until the solution is acidified as indicated by the congo red paper turning blue.
3. Titrate the contents of each beaker with the nominally 0.1N alcoholic silver nitrate solution, while stirring.
4. Calculate the normality of the silver nitrate solution to three significant figures using Equation 1 for each of the three titrations and average them. If the values of the three titrations are not all within 5% of each other, recheck your procedure and repeat the titrations.

$$N = \frac{A}{0.07455 B} \quad (1)$$

where:

A = mass of potassium chloride weighed into beaker, g

B = volume of silver nitrate used in titration, mL

N = normality of silver nitrate, mol of equivalent/L

0.07455 = molecular weight of the potassium chloride multiplied by 0.001, the factor to convert milliliters to liters

Sample Analysis

For the LPG-isooctane concentrate, certain gasolines and other petroleum distillates where tertiary disulfides are known not to be a factor, use *Part A - Acid Stirring Procedure*. For gasoline and petroleum distillates that are thought to contain tertiary disulfides, use *Part B - Acid Reflux Procedure*.

Part A - Acid Stirring Procedure

1. Pipet a 10 mL portion of the sample to be analyzed (LPG-isooctane concentrate or light petroleum distillate) into a 125-mL Erlenmeyer flask containing 25 mL of methanol and 1 mL of glacial acetic acid (the latter two are added by pipet).
2. Add approximately 0.5 g of powdered zinc and a Teflon-covered magnetic stirring bar.
3. Stopper the flask and stir the mixture for 30 minutes at room temperature using a magnetic stirrer.
4. Allow the zinc powder to settle and then quickly decant and filter the liquid into a 250-mL titration beaker containing a magnetic stirring bar.
5. Rinse the reaction flask three times with titration solvent, totaling 100 mL, and filter the liquid into the titration beaker.
6. Titrate potentiometrically with 0.01N alcoholic silver nitrate.
 - The sample should be titrated within five minutes of the filtration to prevent reoxidation of the mercaptans.
7. Determine the mercaptan content of the sample by potentiometrically titrating a second aliquot of sample, omitting the zinc reduction step above, by following the procedure in UOP Method 163. Record the volume of sample and silver nitrate used.
8. Determine the density of unreduced light petroleum distillate samples by ASTM D 4052 or any other appropriate method. The density of the LPG samples is not needed because they are weighed to determine sample size.

Part B - Acid Reflux Procedure

1. Pipet 150 mL of the sample into the 1000-mL boiling flask. Pipet 150 mL of glacial acetic acid and add approximately 30 g of 20-mesh zinc to the flask.
2. Connect the reflux condenser and nitrogen supply to the flask and start tap water flowing through the condenser. Purge the system with nitrogen for a few minutes to remove air and then close the nitrogen valve.
3. Set the flask in the heating mantle. Connect the outlet of the reflux condenser to a gas-washing bottle containing 50 mL of the 10% potassium hydroxide-chelating solution. Connect the outlet of the gas-washing bottle to the dry ice trap. Add dry ice to the trap.
 - The dry ice trap serves to catch light ends from the sample.
4. Turn on the heat and adjust it until the sample is refluxing at a moderate rate. Allow the sample to reflux for about 1.5 hour.
5. Open the nitrogen line and slowly nitrogen purge the reaction flask. The nitrogen purge rate should be about 140 to 190 mL/min (check with a flow meter or similar device). Continue refluxing and purging for 1.5 hour.
6. Remove the heating mantle from the boiling flask. Place an ice bath around the flask and cool for 15 minutes while continuing the nitrogen purge.
7. Disconnect the nitrogen line and remove the ice bath. Disconnect the dry ice trap, the gas-washing bottle and the reflux condenser. If there is any liquid in the dry ice trap, pour this liquid into the boiling flask.
8. Transfer the contents of the gas-washing bottle to a titration beaker. Rinse the gas-washing

bottle with a total of 50 mL of water and add the washings to the titration beaker.

9. Add 1 mL of concentrated ammonium hydroxide to the titration beaker. Titrate potentiometrically with 0.01N silver nitrate.
 - If a double inflection occurs, both hydrogen sulfide and mercaptan are present in the solution as the ammonium salts. Record both endpoints in this case.
10. Place about 40 mL of the titration solvent into another titration beaker. Pipet 50 mL of the mixture from the boiling flask into the beaker.
 - Be careful not to pull up and transfer any fine particles of zinc which might still remain in the flask.
11. Titrate potentiometrically with 0.01N alcoholic silver nitrate.
12. Determine the mercaptan content of a separate sample of the test material before reduction by following the procedure of UOP Method 163. Record the volume of sample and silver nitrate used.
13. Determine the density of the unreduced sample by ASTM D4052, "Density and Relative Density of Liquids by Digital Density Meter," or other appropriate method.

Calculations

Part A - Acid Stirring Procedure

Calculate the disulfide sulfur content in an LPG sample to the nearest mass-ppm using Equation 2.

$$\text{Disulfide Sulfur as S, mass - ppm} = \frac{3.2(10^5)N}{W} \left(A - \frac{10B}{V_1} \right) \quad (2)$$

where:

A = volume of the silver nitrate solution used to titrate the mercaptans in the reduced sample, mL

B = volume of the silver nitrate solution used to titrate the mercaptans in the separate sample of LPG-isooctane concentrate before reduction, mL

N = previously defined, Equation 1

V₁ = volume of LPG-isooctane concentrate used for titration before reduction, mL

W = weight of the original LPG sample, g

10 = sample volume, mL

3.2(10⁵) = molecular weight of sulfur, g/mol, times 10⁶ (factor to convert to mass-ppm), divided by 1000 (factor to convert mL to L), times 10 (dilution factor)

Calculate the disulfide sulfur concentration in petroleum distillates to the nearest mass-ppm using Equation 3.

$$\text{Disulfide Sulfur as S, mass - ppm} = \frac{3.2(10^4)N}{D} \left(\frac{C}{10} - \frac{E}{V_2} \right) \quad (3)$$

where:

C = volume of the silver nitrate solution used to titrate the mercaptans in the reduced sample, mL

D = density of the unreduced sample, g/mL

E = volume of the silver nitrate solution used to titrate the mercaptans in the separate sample of test material before reduction, mL

N = previously defined, Equation 1

V₂ = volume of the hydrocarbon sample titrated for original mercaptan content reduction, mL

10 = sample volume, mL

3.2(10⁴) = molecular weight of sulfur (g/mol) times 10⁶ (factor to convert to mass-ppm), divided by 1000

(factor to convert mL to L)

Part B - Acid Reflux Procedure

Calculate the disulfide sulfur concentration in petroleum distillates containing tertiary disulfides to the nearest mass-ppm using Equation 4.

$$\text{Disulfide Sulfur as S, mass - ppm} = \frac{3.2 (10^4) N}{D} \left(\frac{F}{25} + \frac{G}{150} - \frac{H}{V_3} \right) \quad (4)$$

where:

D = previously defined, Equation 3

F = volume of the silver nitrate solution used to titrate the mercaptans in the 50 mL mixture from the boiling flask, mL

G = volume of the silver nitrate solution used to titrate the contents of the gas-washing bottle, mL

H = volume of the silver nitrate solution used to titrate the mercaptans in the sample of test material before reduction, mL

N = previously defined, Equation 1

V₃ = volume of the hydrocarbon sample titrated for original mercaptan content reduction, mL

3.2 (10⁴) = previously defined, Equation 3

25 = sample volume titrated (50 mL of 1:1 by volume of sample/acetic acid), mL

150 = sample volume initially taken, mL

Note

The determination of organic sulfides using reflux and stirring methods is described in “Quantitative Determination of Organic Disulfides,” Hubbard, et al.

Precision

The precision values reported below were generated using Part A - Acid Stirring Procedure. There is insufficient data to calculate precision values for Part B - Acid Reflux Procedure. The precision statements were developed using UOP Method 999. The data for butane was not obtained using current procedures.

Repeatability and Site Precision

A nested design was carried out for disulfide sulfur in naphtha by two analysts. Each analyst carried out tests on two separate days, performing two tests each day at each of two concentrations. The total number of tests performed was 16. Using a stepwise analysis of variance procedure, the within-day and within-lab estimated standard deviations (esd) were calculated at the concentrations listed in the Table. Two tests performed by the same analyst on the same day should not differ by more than the repeatability allowable differences shown in the Table with 95% confidence. Two tests performed in one laboratory by different analysts on different days should not differ by more than the site precision differences shown in the Table with 95% confidence.

Additionally, 12 tests were performed by a single analyst on a butane sample at a single concentration level, with tests performed in duplicate over six days. The esd in the Table was calculated from the six pairs of data. Two tests performed by the same analyst on the same day should not differ by more than the allowable difference shown in the Table with 95% confidence.

The data in the Table are short-term estimates of repeatability. When the test is run routinely, a control standard and chart should be used to develop a better estimate of the long-term repeatability.

Table
Part A - Acid Stirring Procedure
Repeatability and Site Precision, mg/kg (mass-ppm)

<u>Sample Type</u>	<u>Disulfide Sulfur Concentration</u>	<u>Repeatability</u>		<u>Site Precision</u>	
		<u>Within-Day esd</u>	<u>Allowable Difference</u>	<u>Within-Lab esd</u>	<u>Allowable Difference</u>
Naphtha	14	1.0	4	1.1	4
Naphtha	85	1.7	7	3.1	12
Butane	20	2.4	8	---	---

Reproducibility

There is insufficient data to calculate the reproducibility of the test at this time.

Time for Analysis

Part A - Acid Stirring Procedure

For samples which are normally liquid, such as gasolines or other distillates, one-half hour is required for one analysis and one hour of elapsed time.

LPG samples require more time due to more complex sampling. The total time requirement is two hours per analysis with three hours elapsed time.

Part B - Acid Reflux Procedure

Two hours are required for one analysis with four hours of elapsed time.

Suggested Suppliers

Fisher Scientific, 711 Forbes Ave., Pittsburgh, PA 15219-4785, USA, 1-412-490-8300,
www.fishersci.com

Kimble Chase Kontes, 1022 Spruce St., Vineland, NJ 08362, USA, 1-856-692-8500,
www.kimble-chase.com

Matheson Tri-Gas, 166 Keystone Dr., Montgomeryville, PA 18936, USA, 1-215-641-2700,
www.mathesontrigas.com

Metrohm USA, 6555 Pelican Creek Circle, Riverview, FL 33578, USA, 1-813-316-4700,
www.metrohmusa.com

National Institute of Standards and Technology (NIST), Standard Reference Materials Group, 100
 Bureau Dr., Gaithersburg, MD 20899, USA, 1-301-975-6776, www.nist.gov

Sigma-Aldrich, 3050 Spruce St., St. Louis, MO 63103, USA, 1-314-771-5765, www.sigma-aldrich.com

VWR International, 1310 Goshen Parkway, West Chester, PA 19380, 1-610-431-1700,
www.vwr.com