

METHOD 9030B

ACID-SOLUBLE AND ACID-INSOLUBLE SULFIDES: DISTILLATION

1.0 SCOPE AND APPLICATION

1.1 The distillation procedure described in this method is designed for the determination of sulfides in aqueous, solid waste materials, or effluents.

1.2 This method provides only a semi-quantitative determination of sulfide compounds considered "acid-insoluble" (e.g., CuS and SnS₂) in solid samples. Recovery has been shown to be 20 to 40% for CuS, one of the most stable and insoluble compounds, and 40 to 60% for SnS₂ which is slightly more soluble.

1.3 This method is not applicable to oil or multiphasic samples or samples not amenable to the distillation procedure which can be analyzed by Method 9031.

1.4 Method 9030 is suitable for measuring sulfide concentrations in samples which contain between 0.2 and 50 mg/kg of sulfide.

1.5 This method is not applicable for distilling reactive sulfide. Method 9034 or Method 9215 may be used to quantify the concentration of sulfide from the reactivity test. Refer to Chapter Seven, Section 7.3.4.1 for the determination of reactive sulfide.

1.6 This method measures total sulfide which is usually defined as the acid-soluble fraction of a waste. If, however, one has previous knowledge of the waste and is concerned about both soluble sulfides such as H₂S, and metal sulfides, such as CuS and SnS₂, then total sulfide is defined as the combination of both acid-soluble and acid-insoluble fractions. For wastes where only metal sulfides are suspected to be present, only the acid-insoluble fraction needs to be performed.

2.0 SUMMARY OF METHOD

2.1 For acid-soluble sulfide samples, separation of sulfide from the sample matrix is accomplished by the addition of sulfuric acid to the sample. The sample is heated to 70°C and the hydrogen sulfide (H₂S) which is formed is distilled under acidic conditions and carried by a nitrogen stream into zinc acetate gas scrubbing bottles where it is precipitated as zinc sulfide.

2.2 For acid-insoluble sulfide samples, separation of sulfide from the sample matrix is accomplished by suspending the sample in concentrated hydrochloric acid by vigorous agitation. Tin(II) chloride is present to prevent oxidation of sulfide to sulfur by the metal ion (as in copper(II)), by the matrix, or by dissolved oxygen in the reagents. The prepared sample is distilled under acidic conditions at 100°C under a stream of nitrogen. Hydrogen sulfide gas is released from the sample and collected in gas scrubbing bottles containing zinc(II) and a strong acetate buffer. Zinc sulfide precipitates.

2.3 The sulfide in the zinc sulfide precipitate is quantified titrimetrically by Method 9034 or by ion selective electrode, Method 9215.

3.0 INTERFERENCES

3.1 Aqueous samples must be taken with a minimum of aeration to avoid volatilization of sulfide or reaction with oxygen, which oxidizes sulfide to sulfur compounds that are not detected.

3.2 Reduced sulfur compounds, such as sulfite and hydrosulfite, decompose in acid, and may form sulfur dioxide. This gas may be carried over to the zinc acetate gas scrubbing bottles and subsequently react with the iodine in the determinative step to yielding false high values. The addition of formaldehyde into the zinc acetate gas scrubbing bottles removes this interference. Any sulfur dioxide entering the scrubber will form an addition compound with the formaldehyde which is unreactive towards the iodine in the acidified mixture. This method shows no sensitivity to sulfite or hydrosulfite at concentrations up to 10 mg/kg of the interferant.

3.3 Interferences for acid-insoluble sulfides have not been fully investigated. However, sodium sulfite and sodium thiosulfate are known to interfere in the procedure for soluble sulfides. Sulfur also interferes because it may be reduced to sulfide by tin(II) chloride in this procedure.

3.4 The iodometric method suffers interference from reducing substances that react with iodine, including thiosulfate, sulfite, and various organic compounds.

3.5 The insoluble method should not be used for the determination of soluble sulfides because it can reduce sulfur to sulfide, thus creating a positive interference.

4.0 APPARATUS AND MATERIALS

4.1 Gas evolution apparatus as shown in Figure 1.

4.1.1 Three neck flask - 500-mL, 24/40 standard taper joints.

4.1.2 Dropping funnel - 100-mL, 24/40 outlet joint.

4.1.3 Purge gas inlet tube - 24/40 joint, with coarse frit.

4.1.4 Purge gas outlet - 24/40 joint reduced to 1/4 in. tube.

4.1.5 Gas scrubbing bottles - 125-mL, with 1/4 in. o.d. inlet and outlet tubes. Impinger tube must be fritted.

4.1.6 Tubing - 1/4 in. o.d. polytetrafluoroethylene (PTFE) or polypropylene. Do not use rubber.

NOTE: When analyzing for acid-insoluble sulfides, the distillation apparatus is identical to that used in the distillation procedure for acid-soluble sulfides except that the tubing and unions downstream of the distillation flask must be all PTFE, polypropylene or other material resistant to gaseous HCl. The ground glass joints should be fitted with PTFE sleeves to prevent seizing and to prevent gas leaks. Pinch clamps should also be used on the joints to prevent leaks.

- 4.2 Hot plate stirrer.
- 4.3 pH meter.
- 4.4 Nitrogen regulator.
- 4.5 Flowmeter.
- 4.6 Top-loading balance - capable of weighing 0.1 g.

5.0 REAGENTS

5.1 Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, 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 Reagent water. All references to water in this method refer to reagent water, as defined in Chapter One.

5.3 Zinc acetate solution for sample preservation (2N), $\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$. Dissolve 220 g of zinc acetate dihydrate in 500 mL of reagent water.

5.4 Sodium hydroxide (1N), NaOH. Dissolve 40 g of NaOH in reagent water and dilute to 1 liter.

5.5 Formaldehyde (37% solution), CH_2O . This solution is commercially available.

5.6 Zinc acetate for the scrubber

5.6.1 For acid-soluble sulfides: Zinc acetate solution (approximately 0.5M). Dissolve about 110 g zinc acetate dihydrate in 200 mL of reagent water. Add 1 mL hydrochloric acid (concentrated), HCl, to prevent precipitation of zinc hydroxide. Dilute to 1 liter.

5.6.2 For acid-insoluble sulfides: Zinc acetate/sodium acetate buffer. Dissolve 100 g sodium acetate, $\text{NaC}_2\text{H}_3\text{O}_2$, and 11 g zinc acetate dihydrate in 800 mL of reagent water. Add 1 mL concentrated hydrochloric acid and dilute to 1 liter. The resulting pH should be 6.8.

5.7 Acid to acidify the sample

5.7.1 For acid-soluble sulfides: Sulfuric acid (concentrated), H_2SO_4 .

5.7.2 For acid-insoluble sulfides: Hydrochloric acid (9.8N), HCl. Place 200 mL of reagent water in a 1-liter beaker. Slowly add concentrated HCl to bring the total volume to 1 liter.

5.8 Nitrogen.

5.9 Tin(II) chloride, SnCl₂, granular.

5.10 Sodium hydroxide (6N), NaOH. Dissolve 240 g of sodium hydroxide in 1 liter of reagent water.

5.11 Hydrochloric acid (6N), HCl. Place 51 mL of reagent water in a 100 mL Class A volumetric flask. Slowly add concentrated HCl to bring the total volume to 100 mL.

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

6.1 All samples must have been collected using a sampling plan that addresses the considerations discussed in Chapter Nine of this manual.

6.2 All aqueous samples and effluents must be preserved with zinc acetate and sodium hydroxide. Use four drops of 2N zinc acetate solution per 100 mL of sample. Adjust the pH to greater than 9 with 6N sodium hydroxide solution. Fill the sample bottle completely and stopper with a minimum of aeration. The treated sample is relatively stable and can be held for up to seven days. If high concentrations of sulfide are expected to be in the sample, continue adding zinc acetate until all the sulfide has precipitated. For solid samples, fill the surface of the solid with 2N zinc acetate until moistened. Samples must be cooled to 4°C and stored headspace free.

6.3 Sample Preparation

6.3.1 For an efficient distillation, the mixture in the distillation flask must be of such a consistency that the motion of the stirring bar is sufficient to keep the solids from settling. The mixture must be free of solid objects that could disrupt the stirring bar. Prepare the sample using one of the procedures in this section then proceed with the distillation step (Section 7.0).

6.3.2 If the sample is aqueous, shake the sample container to suspend any solids, then quickly decant the appropriate volume (up to 250 mL) of the sample to a graduated cylinder, weigh the cylinder, transfer to the distillation flask and reweigh the cylinder to the nearest milligram. Be sure that a representative aliquot is used, or use the entire sample.

6.3.3 If the sample is aqueous but contains soft clumps of solid, it may be possible to break the clumps and homogenize the sample by placing the sample container on a jar mill and tumble or roll the sample for a few hours. The slurry may then be aliquotted and weighed as above to the nearest milligram then diluted with reagent water up to a total volume of 250 mL to produce a mixture that is completely suspended by the stirring bar.

6.3.4 If the sample is primarily aqueous, but contains a large proportion of solid, the sample may be roughly separated by phase and the amount of each phase measured and weighed to the nearest milligram into the distillation flask in proportion to their abundance in the sample. Reagent water may be added up to a total volume of 250 mL.

As a guideline, no more than 25 g dry weight or 50 g of sludge can be adequately suspended in the apparatus.

6.3.5 If the sample contains solids which absorb water and swell, limit the sample size to 25 g dry weight. Otherwise, the solids will restrict the fluid motion and lower the recovery.

6.3.6 If the sample contains solid objects that cannot be reduced in size by tumbling, the solids must be broken manually. Clay-like solids should be cut with a spatula or scalpel in a crystallizing dish. If the solids can be reduced to a size that they can be suspended by the stirring bar, the solid and liquid can be proportionately weighed.

6.3.7 Non-porous harder objects, for example stones or pieces of metal, may be weighed and discarded. The percent weight of non-porous objects should be reported and should be used in the calculation of sulfide concentration if it has a significant effect on the reported result.

7.0 PROCEDURE

For acid-soluble sulfide samples, proceed to Sec. 7.1.

For acid-insoluble sulfide samples, proceed to Sec. 7.2.

7.1 Acid-Soluble Sulfide

7.1.1 In a preliminary experiment, determine the approximate amount of sulfuric acid required to adjust a measured amount of the sample to pH less than or equal to 1. The sample size should be chosen so that it contains between 0.2 and 50 mg of sulfide. Place a known amount of sample or sample slurry in a beaker. Add reagent water until the total volume is 200 mL. Stir the mixture and determine the pH. Slowly add sulfuric acid until the pH is less than or equal to 1. Discard this preliminary sample.

CAUTION: Toxic hydrogen sulfide may be generated from the acidified sample. This operation must be performed in the hood and the sample left in the hood until the sample has been made alkaline or the sulfide has been destroyed. From the amount of sulfuric acid required to acidify the sample and the mass or volume of the sample acidified, calculate the amount of acid required to acidify the sample to be placed in the distillation flask.

7.1.2 Prepare the gas evolution apparatus as shown in Figure 1 in a fume hood.

7.1.2.1 Prepare a hot water bath at 70°C by filling a crystallizing dish or other suitable container with water and place it on a hot plate stirrer. Place a thermometer in the bath and monitor the temperature to maintain the bath at 70°C.

7.1.2.2 Assemble the three neck 500-mL flask, fritted gas inlet tube, and exhaust tube. Use PTFE sleeves to seal the ground glass joints. Place a PTFE coated stirring bar into the flask.

7.1.2.3 Place into each gas scrubbing bottle 10 ± 0.5 mL of the 0.5M zinc acetate solution, 5.0 ± 0.1 mL of 37% formaldehyde and 100 ± 5.0 mL reagent water.

7.1.2.4 Connect the gas evolution flask and gas scrubbing bottles as shown in Figure 1. Secure all fittings and joints.

7.1.3 Carefully place an accurately weighed sample which contains 0.2 to 50 mg of sulfide into the flask. If necessary, dilute to approximately 200 mL with reagent water.

7.1.4 Place the dropping funnel onto the flask making sure its stopcock is closed. Add the volume of sulfuric acid calculated in Section 7.1.1 plus an additional 50 mL into the dropping funnel. The bottom stopcock must be closed.

7.1.5 Attach the nitrogen inlet to the top of the dropping funnel gas shut-off valve. Turn on the nitrogen purge gas and adjust the flow through the sample flask to 25 mL/min. The nitrogen in the gas scrubbing bottles should bubble at about five bubbles per second. Nitrogen pressure should be limited to approximately 10 psi to prevent excess stress on the glass system and fittings. Verify that there are no leaks in the system. Open the nitrogen shut-off valve leading to the dropping funnel. Observe that the gas flow into the sample vessel will stop for a short period while the pressure throughout the system equalizes. If the gas flow through the sample flask does not return within a minute, check for leaks around the dropping funnel. Once flow has stabilized, turn on magnetic stirrer. Purge system for 15 minutes with nitrogen to remove oxygen.

7.1.6 Heat sample to 70°C. Open dropping funnel to a position that will allow a flow of sulfuric acid of approximately 5 mL/min. Monitor the system until most of the sulfuric acid within the dropping funnel has entered the sample flask. Solids which absorb water and swell will restrict fluid motion and, therefore, lower recovery will be obtained. Such samples should be limited to 25 g dry weight.

7.1.7 Purge, stir, and maintain a temperature of 70°C for a total of 90 minutes from start to finish. Shut off nitrogen supply. Turn off heat.

7.1.8 Quantify the sulfide in the scrubber solution by Method 9034 or by Method 9215.

7.2 Acid-Insoluble Sulfide

7.2.1 As the concentration of HCl during distillation must be within a narrow range for successful distillation of H₂S, the water content must be controlled. It is imperative that the final concentration of HCl in the distillation flask be about 6.5N and that the sample is mostly suspended in the fluid by the action of the stirring bar. This is achieved by adding 50 mL of reagent water, including water in the sample, 100 mL of 9.8N HCl, and the sample to the distillation flask. Solids which absorb water and swell will restrict fluid motion and, therefore, lower recovery will be obtained. Such samples should be limited to 25 g dry weight. Other samples can range from 25 to 50 g.

7.2.2 If the matrix is a dry solid, weigh a portion of the sample such that it contains 0.2 to 50 mg of sulfide. The solid should be crushed to reduce particle size to 1 mm or less. Add 50 mL of reagent water.

7.2.3 If the matrix is aqueous, then a maximum of 50 g of the sample may be used. No additional water may be added. As none of the target compounds are volatile, drying the sample may be preferable to enhance the sensitivity by concentrating the sample. If less than 50 g of the sample is required to achieve the 0.2 to 50 mg of sulfide range for the test, then add reagent water to a total volume of 50 mL.

7.2.4 If the matrix is a moist solid, the water content of the sample must be determined (Karl Fischer titration, loss on drying, or other suitable means) and the water in the sample included in the total 50 mL of water needed for the correct HCl concentration. For example, if a 20 g sample weight is needed to achieve the desired sulfide level of 0.2 to 50 mg and the sample is 50% water then 40 mL rather than 50 mL of reagent water is added along with the sample and 100 mL of 9.8N HCl to the distillation flask.

7.2.5 Weigh the sample and 5 g SnCl_2 into the distillation flask. Use up to 50 mL of reagent water, as calculated above, to rinse any glassware.

7.2.6 Assemble the distillation apparatus as in Figure 1. Place 100 ± 2.0 mL of zinc acetate/sodium acetate buffer solution and 5.0 ± 0.1 mL of 37% formaldehyde in each gas scrubbing bottle. Tighten the pinch clamps on the distillation flask joints.

7.2.7 Make sure the stopcock is closed and then add 100 ± 1.0 mL of 9.8N HCl to the dropping funnel. Connect the nitrogen line to the top of the funnel and turn the nitrogen on to pressurize the dropping funnel headspace.

7.2.8 Set the nitrogen flow at 25 mL/min. The nitrogen in the gas scrubbing bottles should bubble at about five bubbles per second. Purge the oxygen from the system for about 15 minutes.

7.2.9 Turn on the magnetic stirrer. Set the stirring bar to spin as fast as possible. The fluid should form a vortex. If not, the distillation will exhibit poor recovery. Add all of the HCL from the dropping funnel to the flask.

7.2.10 Heat the water bath to the boiling point (100°C). The sample may or may not be boiling. Allow the purged distillation to proceed for 90 minutes at 100°C . Shut off nitrogen supply. Turn off heat.

7.2.11 Quantify the sulfide in the scrubber solution by Method 9034 or by Method 9215.

8.0 QUALITY CONTROL

8.1 All quality control data must be maintained and available for reference or inspection for a period of three years. This method is restricted to use by or under supervision of experienced analysts. Refer to the appropriate section of Chapter One for additional quality control guidelines.

8.2 A reagent blank should be run once in twenty analyses or per analytical batch, whichever is more frequent.

8.3 Check standards are prepared from water and a known amount of sodium sulfide. A check standard should be run with each analytical batch of samples, or once in twenty samples. Acceptable recovery will depend on the level and matrix.

8.4 A matrix spiked sample should be run for each analytical batch or twenty samples, whichever is more frequent, to determine matrix effects. If recovery is low, acid-insoluble sulfides are indicated. A matrix spiked sample is a sample brought through the whole sample preparation and analytical process.

9.0 METHOD PERFORMANCE

9.1 Accuracy - Accuracy for this method was determined by three independent laboratories by measuring percent recoveries of spikes for both clean matrices (water) and actual waste samples. The results are summarized below.

For Acid-Soluble Sulfide

Accuracy of titration step only

Lab A 84-100% recovery

Lab B 110-122% recovery

Accuracy for entire method for clean matrices (H₂O)

Lab C 94-106% recovery

Accuracy of entire method for actual waste samples

Lab C 77-92% recovery

Spiking levels ranged from 0.4 to 8 mg/L

For Acid-Insoluble Sulfide

The percent recovery was not as thoroughly studied for acid-insoluble sulfide as it was for acid-soluble sulfide.

Accuracy of entire method for synthetic waste samples

Lab C 21-81% recovery

Spiking levels ranged from 2.2 to 22 mg/kg

9.2 Precision

For Acid-Soluble Sulfide

Precision of titration step only

Lab A CV% 2.0 to 37

Lab B CV% 1.1 to 3.8

Precision of entire method for clean matrices (H₂O)

Lab C CV% 3.0 to 12

Precision of entire method for actual waste samples

Lab C CV% 0.86 to 45

For Acid-Insoluble Sulfide

Precision of entire method with synthetic wastes

Lab C CV 1.2 to 42

9.3 Detection Limit - The detection limit was determined by analyzing seven replicates at 0.45 and 4.5 mg/L. The detection limit was calculated as the standard deviation times the student's t-value for a one-tailed test with n-1 degrees of freedom at 99% confidence level. The detection limit for a clean matrix (H₂O) was found to be between 0.2 and 0.4 mg/L.

10.0 REFERENCES

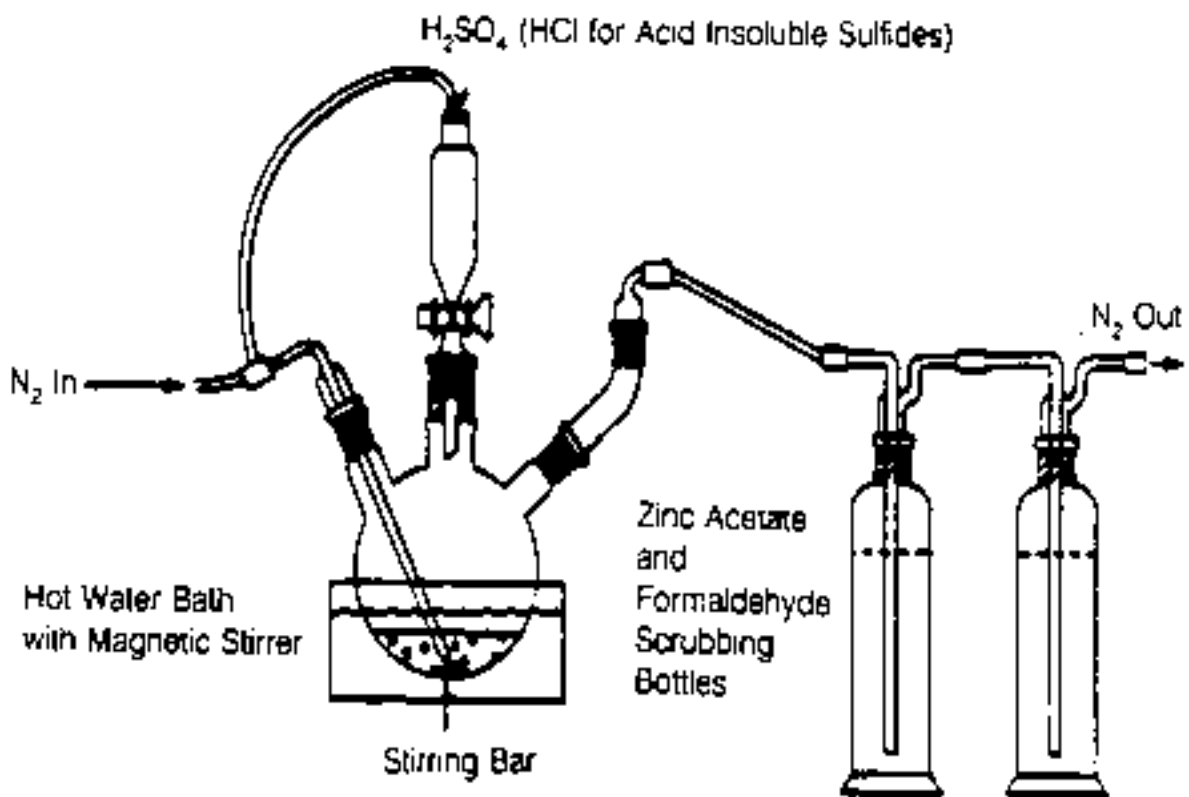
1. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, 2nd ed.; U.S. Environmental Protection Agency. Office of Solid Waste and Emergency Response. U.S. Government Printing Office: Washington, DC, 1982, revised 1984; SW-846.
2. Methods for Chemical Analysis of Water and Wastes; U.S. Environmental Protection Agency. Office of Research and Development. Environmental Monitoring and Support Laboratory. ORD Publication Offices of Center for Environmental Research Information: Cincinnati, OH, 1979; EPA-600/4-79-020.
3. CRC Handbook of Chemistry and Physics, 66th ed.; Weast, R., Ed.; CRC: Boca Raton, FL, 1985.
4. Standard Methods for the Examination of Water and Wastewater, 16th ed.; Greenberg, A.E.; Trussell, R.R.; Clesceri, L.S., Eds.; American Water Works Association, Water Pollution Control Federation, American Public Health Association: Washington, DC, 1985; Methods 427, 427A, 427B, and 427D.
5. Andreae, M.O.; Banard, W.R. Anal. Chem. 1983, 55, 608-612.
6. Barclay, H. Adv. Instrum. 1980, 35(2), 59-61.
7. Bateson, S.W.; Moody, G.J.; Thomas, J.P.R. Analyst 1986, 111, 3-9.
8. Berthage, P.O. Anal. Chim. Acta 1954, 10 310-311.
9. Craig, P.J.; Moreton, P.A. Environ. Technol. Lett. 1982, 3, 511-520.
10. Franklin, G.O.; Fitchett, A.W. Pulp & Paper Canada 1982, 83(10), 40-44.
11. Fuller, W. In Cyanide in the Environment; Van Zyl, D., Ed.; Proceedings of Symposium; December, 1984.

12. Gottfried, G.J. "Precision, Accuracy, and MDL Statements for EPA Methods 9010, 9030, 9060, 7520, 7521, 7550, 7551, 7910, and 7911"; final report to the U.S. Environmental Protection Agency (EMSL-CI); Biopheric.
13. Kilroy, W.P. Talanta 1983, 30(6), 419-422.
14. Kurtenacher, V.A.; Wallak, R. Z. Anorg. U. Allg. Chem. 1927, 161 202-209.
15. Landers, D.H.; David, M.B.; Mitchell, M.J. Int. J. Anal. Chem 1983, 14, 245-256.
16. Opekar, F.; Brukenstein, S. Anal. Chem. 1984, 56, 1206-1209.
17. Ricklin, R.D.; Johnson, E.L. Anal. Chem. 1983, 55, 4.
18. Rohrbough, W.G.; et al. Reagent Chemicals. American Chemical Society Specifications, 7th ed.; American Chemical Society: Washington, DC, 1986.
19. Snedecor, G.W.; Ghnan, W.G. Statistical Methods; Iowa State University: Ames, IA, 1980.
20. Umaña, M.; Beach, J.; Sheldon, L. "Revisions to Method 9010"; final report to the U.S. Environmental Protection Agency on Contract No. 68-01-7266; Research Triangle Institute: Research Triangle Park, NC, 1986; Work Assignment No. 1.
21. Umaña, M.; Sheldon, L. "Interim Report: Literature Review"; interim report to the U.S. Environmental Protection Agency in Contract No. 68-01-7266; Research Triangle Institute: Research Triangle Park, NC, 1986; Work Assignment No. 3.
22. Wang, W.; Barcelona, M.J. Environ. Inter. 1983, 9, 129-133.
23. Wronski, M. Talanta 1981, 28, 173-176.
24. Application Note 156; Princeton Applied Research Corp.: Princeton, NJ.
25. Guidelines for Assessing and Reporting Data Quality for Environmental Measurements; U.S. Environmental Protection Agency. Office of Research and Development. U.S. Government Printing Office: Washington, DC, 1983.
26. Fed. Regist. 1980, 45(98), 33122.
27. The Analytical Chemistry of Sulfur and Its Compounds, Part I; Karchmer, J.H., Ed.; Wiley-Interscience: New York, 1970.
28. Methods for the Examination of Water and Associated Materials; Department of the Environment: England, 1983.
29. "Development and Evaluation of a Test Procedure for Reactivity Criteria for Hazardous Waste"; final report to the U.S. Environmental Protection Agency on Contract 68-03-2961; EAL: Richmond, CA.

30. Test Method to Determine Hydrogen Sulfide Released from Wastes; U.S. Environmental Protection Agency. Office of Solid Waste. Preliminary unpublished protocol, 1985.

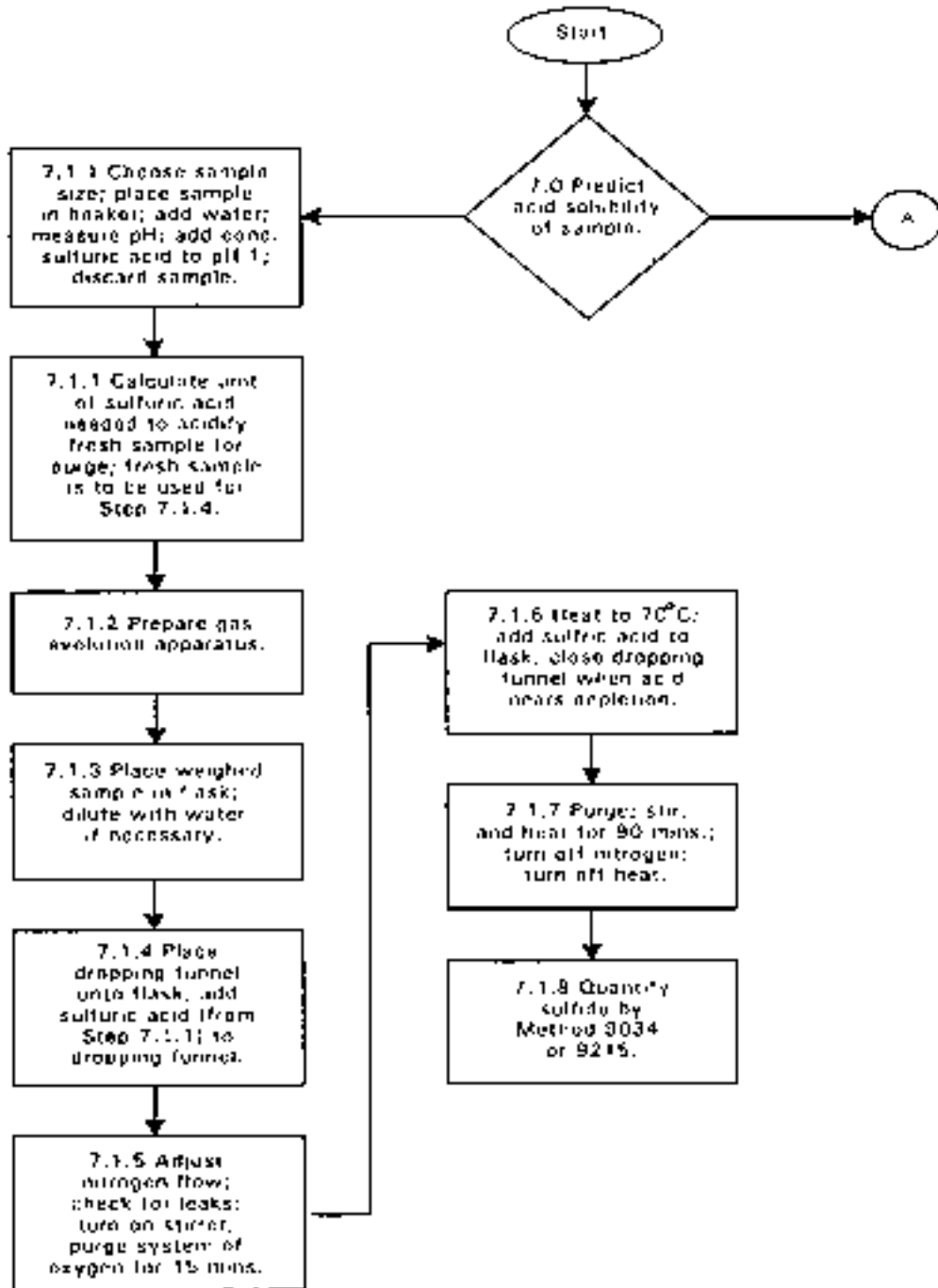
31. 1985 Annual Book of ASTM Standards, Vol. 11.01; "Standard Specification for Reagent Water"; ASTM: Philadelphia, PA, 1985; D1193-77.

FIGURE 1.
GAS EVOLUTION APPARATUS

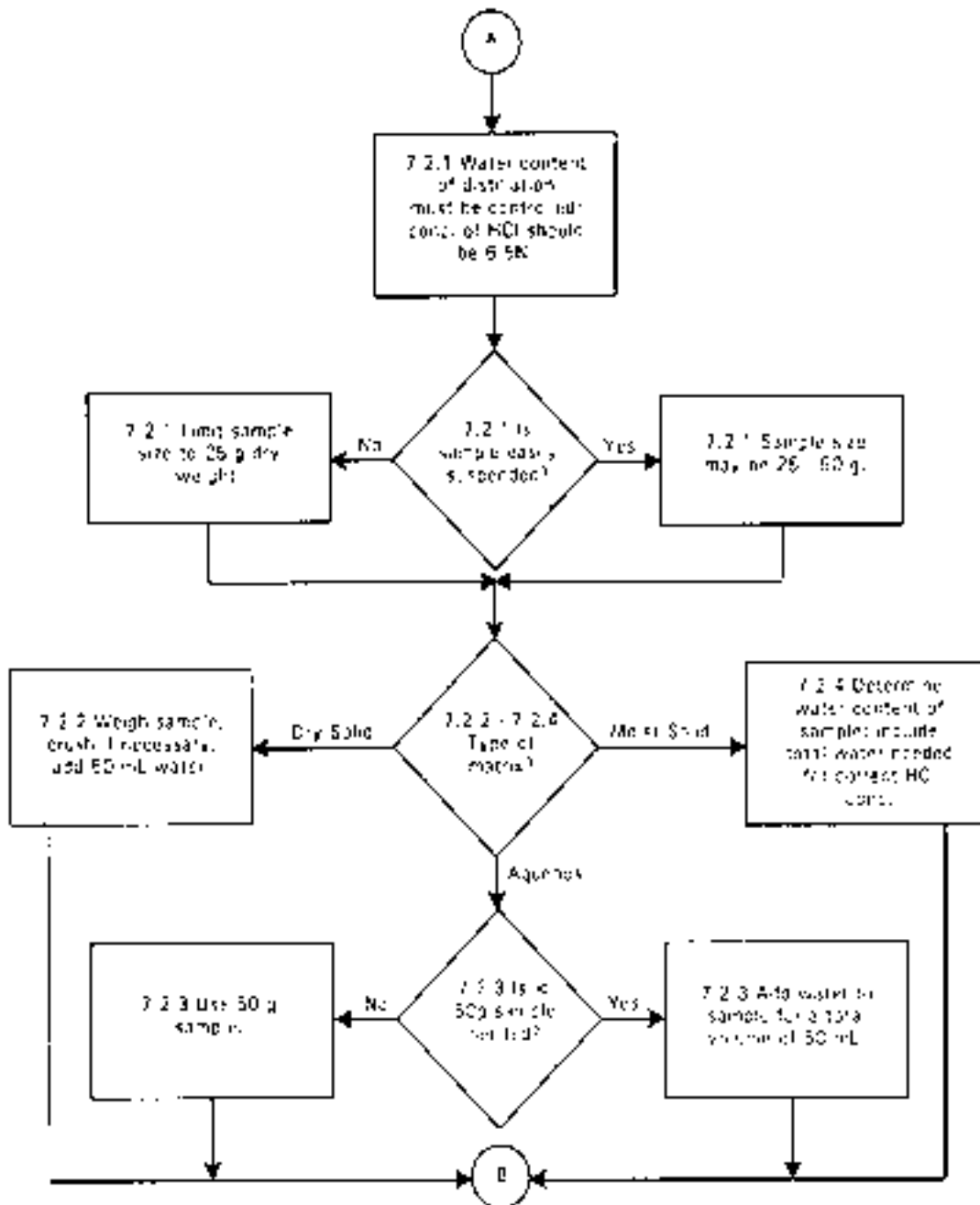


METHOD 9030B

ACID-SOLUBLE AND ACID-INSOLUBLE SULFIDES: DISTILLATION



METHOD 9030B
(Continued)



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(Continued)

