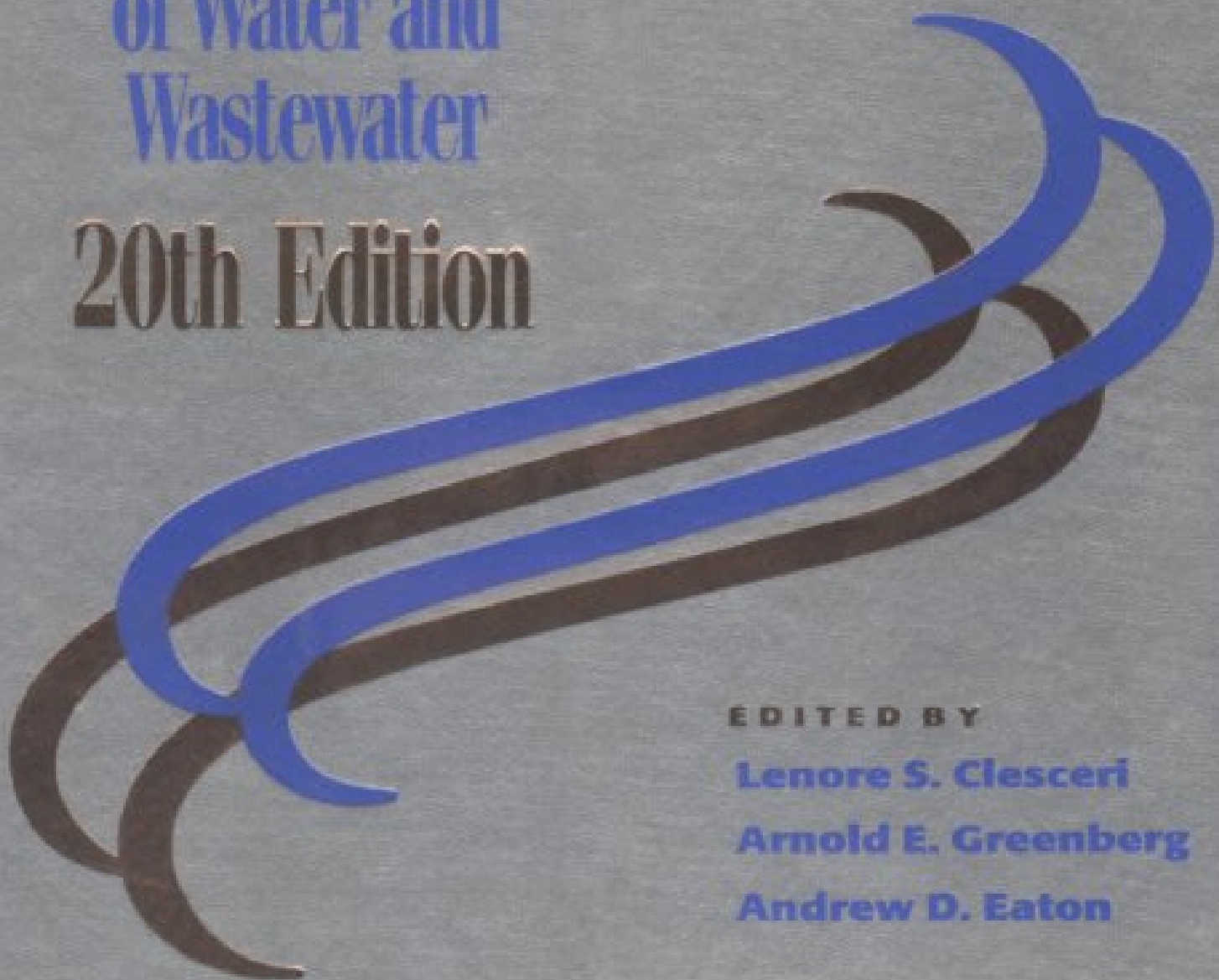


# Standard Methods

**FOR THE**  
Examination  
of Water and  
Wastewater

**20th Edition**



**EDITED BY**

**Lenore S. Clesceri**

**Arnold E. Greenberg**

**Andrew D. Eaton**

Copyright © 1917, 1920, 1923, and 1925 by  
American Public Health Association

Copyright © 1933, 1936, and 1946 by  
American Public Health Association  
American Water Works Association

Copyright © 1955 by  
American Public Health Association  
American Water Works Association  
Federation of Sewage and Industrial Waste Associations

Copyright © 1960 by  
American Public Health Association  
American Water Works Association  
Water Pollution Control Federation (formerly Federation of  
Sewage and Industrial Waste Associations)

Copyright © 1965, 1971, 1976, 1981, 1985, and 1989 by  
American Public Health Association  
American Water Works Association  
Water Pollution Control Federation

Copyright © 1992 by  
American Public Health Association  
American Water Works Association  
Water Environment Federation (formerly Water Pollution  
Control Federation)

Copyright © 1995 and 1998 by  
American Public Health Association  
American Water Works Association  
Water Environment Federation

All rights reserved. This publication is protected by copyright. No part of this publication may be reproduced in any form or by any means, including photocopying, or utilized by any information storage and retrieval system without the prior written permission of the publishers.

30M12/98

ISBN 0-87553-235-7  
ISSN 55-1979

Printed and bound in the United States of America.

Composition: Maryland Composition Company, Glen Burnie, MD

Set in: Times Roman

Printing: United Book Press, Inc., Baltimore, Maryland

Binding: United Book Press, Inc., Baltimore, Maryland

Cover Design: Jane Perini, JEP Graphics, Potomac, Maryland

## Preparation of Common Types of Desk Reagents Specified in This Book

### Acid Solutions

Prepare the following reagents by cautiously adding required amount of concentrated acid, with mixing, to designated volume proper type of distilled water. Dilute to 1000 mL and mix thoroughly.

See Table A for preparation of HCl, H<sub>2</sub>SO<sub>4</sub>, and HNO<sub>3</sub> solutions.

### Alkaline Solutions

a. *Stock sodium hydroxide*, NaOH, 15*N* (for preparing 6*N*, 1*N*, and 0.1*N* solutions): Cautiously dissolve 625 g solid NaOH in 1000 mL distilled water to form 1 L of solution. Remove sodium carbonate precipitate by keeping solution at the boiling point for a few hours in a hot water bath or by letting particles settle for at least 48 h in an alkali-resistant container (wax-lined or polyethylene) protected from atmospheric CO<sub>2</sub> with a soda lime tube. Decant the supernate for preparing dilute solutions listed in Table B. Alternatively prepare dilute solutions by dissolving the weight of solid NaOH indicated in Table B in CO<sub>2</sub>-free distilled water and diluting to 1000 mL.

Store NaOH solutions in polyethylene (rigid, heavy-type) bottles with polyethylene screw caps, paraffin-coated bottles with rubber or neoprene stoppers, or borosilicate-glass bottles with rubber or neoprene stoppers. Check solutions periodically. Protect them by attaching a tube of CO<sub>2</sub>-absorbing granular material such as soda lime or a commercially available CO<sub>2</sub>-removing agent.\* Connect at least 70 cm of rubber tubing to minimize vapor diffusion in the bottle. Replace absorption tube before it becomes exhausted. Withdraw solution by a siphon to avoid opening bottle.

\*Carbite II®, Arthur H. Thomas Co.; or equivalent.

TABLE B: PREPARATION OF UNIFORM SODIUM HYDROXIDE SOLUTIONS

Normality of NaOH Solution	Required Weight of NaOH to Prepare 1000 mL of Solution g	Required Volume of 15 <i>N</i> NaOH to Prepare 1000 mL of Solution mL
6	240	400
1	40	67
0.1	4	6.7

b. *Ammonium hydroxide solutions*, NH<sub>4</sub>OH: Prepare 5*N*, 3*N*, and 0.2*N* NH<sub>4</sub>OH solutions by diluting 333 mL, 200 mL, and 13 mL, respectively, of the concentrated reagent (sp gr 0.90, 29.0%, 15*N*) to 1000 mL with distilled water.

### Indicator Solutions

a. *Phenolphthalein indicator solution*: Use either the aqueous (1) or alcoholic (2) solution.

1) Dissolve 5 g phenolphthalein disodium salt in distilled water and dilute to 1 L.

2) Dissolve 5 g phenolphthalein in 500 mL 95% ethyl or isopropyl alcohol and add 500 mL distilled water.

If necessary, add 0.02*N* NaOH dropwise until a faint pink color appears in solution 1) or 2).

b. *Methyl orange indicator solution*: Dissolve 500 mg methyl orange powder in distilled water and dilute to 1 L.

TABLE A: PREPARATION OF UNIFORM ACID SOLUTIONS\*

Desired Component	Hydrochloric Acid (HCl)	Sulfuric Acid (H <sub>2</sub> SO <sub>4</sub> )	Nitric Acid (HNO <sub>3</sub> )
Specific gravity (20/4°C) of ACS-grade conc acid	1.174-1.189	1.834-1.836	1.409-1.418
Percent of active ingredient in conc reagent	36-37	96-98	69-70
Normality of conc reagent	11-12	36	15-16
Volume (mL) of conc reagent to prepare 1 L of:			
18 <i>N</i> solution	—	500 (1 + 1) <sup>†</sup>	—
6 <i>N</i> solution	500 (1 + 1) <sup>†</sup>	167 (1 + 5) <sup>†</sup>	380
1 <i>N</i> solution	83 (1 + 11) <sup>†</sup>	28	64
0.1 <i>N</i> solution	8.3	2.8	6.4
Volume (mL) of 6 <i>N</i> reagent to prepare 1 L of 0.1 <i>N</i> solution	17	17	17
Volume (mL) of 1 <i>N</i> reagent to prepare 1 L of 0.02 <i>N</i> solution	20	20	20

\*All values approximate.

†The *a* + *b* system of specifying preparatory volumes appears frequently throughout this manual and means that *a* volumes of the concentrated reagent are diluted with *b* volumes of distilled water to form the required solution.

# Standard Atomic Weights, 1995

[Scaled to  $A_r(^{12}\text{C}) = 12$ ]

The atomic weights of many elements are not invariant but depend on the origin and treatment of the material. The standard values of  $A_r(E)$  and the uncertainties (in parentheses, following the last significant figure to which they are attributed) apply to elements of natural terrestrial origin. The footnotes to this Table elaborate the types of variation which may occur for individual elements and which may be larger than the listed uncertainties of values of  $A_r(E)$ . Names of elements with atomic number 104 to 111 are temporary.

Name	Symbol	Atomic Number	Atomic Weight	Footnotes	Name	Symbol	Atomic Number	Atomic Weight	Footnotes
Actinium*	Ac	89			Neon	Ne	10	20.1797(6)	g, m
Aluminium	Al	13	26.981538(2)		Neptunium*	Np	93		
Americium*	Am	95			Nickel	Ni	28	58.6934(2)	
Antimony	Sb	51	121.760(1)	g	Niobium	Nb	41	92.90638(2)	
Argon	Ar	18	39.948(1)	g, r	Nitrogen	N	7	14.00674(7)	g, r
Arsenic	As	33	74.92160(2)		Nobelium*	No	102		
Astatine*	At	85			Osmium	Os	76	190.23(3)	g
Barium	Ba	56	137.327(7)		Oxygen	O	8	15.9994(3)	g, r
Berkelium*	Bk	97			Palladium	Pd	46	106.42(1)	g
Beryllium	Be	4	9.012182(3)		Phosphorus	P	15	30.973762(4)	
Bismuth	Bi	83	208.98038(2)		Platinum	Pt	78	195.078(2)	
Boron	B	5	10.811(7)	g, m, r	Plutonium*	Pu	94		
Bromine	Br	35	79.904(1)		Polonium	Po	84		
Cadmium	Cd	48	112.411(8)	g	Potassium	K	19	39.0983(1)	g
Calcium	Ca	20	40.078(4)	g	Praseodymium	Pr	59	140.90765(3)	
Californium*	Cf	98			Promethium*	Pm	61		
Carbon	C	6	12.0107(8)	g, r	Protactinium*	Pa	91	231.03588(2)	
Cerium	Ce	58	140.116(1)	g	Radium*	Ra	88		
Cesium	Cs	55	132.90545(2)		Radon*	Rn	86		
Chlorine	Cl	17	35.4527(9)	m	Rhenium	Re	75	186.207(1)	
Chromium	Cr	24	51.9961(6)		Rhodium	Rh	45	102.90550(2)	
Cobalt	Co	27	58.933200(9)		Rubidium	Rb	37	85.4678(3)	g
Copper	Cu	29	63.546(3)	r	Ruthenium	Ru	44	101.07(2)	g
Curium*	Cm	96			Samarium	Sm	62	150.36(3)	g
Dysprosium	Dy	66	162.50(3)	g	Scandium	Sc	21	44.955910(8)	
Einsteinium*	Es	99			Selenium	Se	34	78.96(3)	
Erbium	Er	68	167.26(3)	g	Silicon	Si	14	28.0855(3)	r
Europium	Eu	63	151.964(1)	g	Silver	Ag	47	107.8682(2)	g
Fermium*	Fm	100			Sodium	Na	11	22.989770(2)	
Fluorine	F	9	18.9984032(5)		Strontium	Sr	38	87.62(1)	g, r
Francium*	Fr	87			Sulfur	S	16	32.066(6)	g, r
Gadolinium	Gd	64	157.25(3)	g	Tantalum	Ta	73	180.9479(1)	
Gallium	Ga	31	69.723(1)		Technetium*	Tc	43		
Germanium	Ge	32	72.61(2)		Tellurium	Te	52	127.60(3)	g
Gold	Au	79	196.96655(2)		Terbium	Tb	65	158.92534(3)	
Hafnium	Hf	72	178.49(2)		Thallium	Tl	81	204.3833(2)	
Helium	He	2	4.002602(2)	g, r	Thorium*	Th	90	232.0381(1)	g
Holmium	Ho	67	164.93032(3)		Thulium	Tm	69	168.93421(2)	
Hydrogen	H	1	1.00794(7)	g, m, r	Tin	Sn	50	118.710(7)	g
Indium	In	49	114.818(3)		Titanium	Ti	22	47.867(1)	
Iodine	I	53	126.90447(3)		Tungsten	W	74	183.84(1)	
Iridium	Ir	77	192.217(3)		Unnilennium*	Une	109		
Iron	Fe	26	55.845(2)		Unnilhexium*	Unh	106		
Krypton	Kr	36	83.80(1)	g, m	Unniloctium*	Uno	108		
Lanthanum	La	57	138.9055(2)	g	Unnilpentium*	Unp	105		
Lawrencium*	Lr	103			Unnilquadium*	Unq	104		
Lead	Pb	82	207.2(1)	g, r	Unnilseptium*	Uns	107		
Lithium	Li	3	[6.941(2)]t	g, m, r	Ununnilium	Uun	110		
Lutetium	Lu	71	174.967(1)	g	Unununium	Uuu	111		
Magnesium	Mg	12	24.3050(6)		Uranium*	U	92	238.0289(1)	g, m
Manganese	Mn	25	54.938049(9)		Vanadium	V	23	50.9415(1)	
Mendelevium*	Md	101			Xenon	Xe	54	131.29(2)	g, m
Mercury	Hg	80	200.59(2)		Ytterbium	Yb	70	173.04(3)	g
Molybdenum	Mo	42	95.94(1)	g	Yttrium	Y	39	88.90585(2)	
Neodymium	Nd	60	144.24(3)	g	Zinc	Zn	30	65.39(2)	
					Zirconium	Zr	40	91.224(2)	g

\* Element has no stable nuclides.

t Commercially available Li materials have atomic weights that range between 6.94 and 6.99; if a more accurate value is required, it must be determined for the specific material.

g geological specimens are known in which the element has an isotopic composition outside the limits for normal material. The difference between the atomic weight of the element in such specimens and that given in the Table may exceed the stated uncertainty.

m modified isotopic compositions may be found in commercially available material because it has been subjected to an undisclosed or inadvertent isotopic fractionation. Substantial deviations in atomic weight of the element from that given in the Table can occur.

r range in isotopic composition of normal terrestrial material prevents a more precise  $A_r(E)$  being given; the tabulated  $A_r(E)$  value should be applicable to any normal material.

Source: INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY. 1996. Atomic weights of the elements, 1996, *Pure Appl. Chem.* 68:2339.

BAMDAD Engineering Data Bank, Tell: 77196009, Fax: 77194208, Web: WWW.BAMDADBANK.COM

## PREFACE TO THE TWENTIETH EDITION

### The Nineteenth and Earlier Editions

The first edition of *Standard Methods* was published in 1905. Each subsequent edition presented significant improvements of methodology and enlarged its scope to include techniques suitable for examination of many types of samples encountered in the assessment and control of water quality and water pollution.

A brief history of *Standard Methods* is of interest because of its contemporary relevance. A movement for "securing the adoption of more uniform and efficient methods of water analysis" led in the 1880's to the organization of a special committee of the Chemical Section of American Association for the Advancement of Science. A report of this committee, published in 1889, was entitled: A Method, in Part, for the Sanitary Examination of Water, and for the Statement of Results, Offered for General Adoption.\* Five topics were covered: (1) "free" and "albuminoid" ammonia; (2) oxygen-consuming capacity; (3) total nitrogen as nitrates and nitrites; (4) nitrogen as nitrites; and (5) statement of results.

In 1895, members of the American Public Health Association, recognizing the need for standard methods in the bacteriological examination of water, sponsored a convention of bacteriologists to discuss the problem. As a result, an APHA committee was appointed "to draw up procedures for the study of bacteria in a uniform manner and with special references to the differentiation of species." Submitted in 1897,† the procedures found wide acceptance.

In 1899, APHA appointed a Committee on Standard Methods of Water Analysis, charged with the extension of standard procedures to all methods involved in the analysis of water. The committee report, published in 1905, constituted the first edition of *Standard Methods* (then entitled *Standard Methods of Water Analysis*). Physical, chemical, microscopic, and bacteriological methods of water examination were included. In its letter of transmittal, the Committee stated:

The methods of analysis presented in this report as "Standard Methods" are believed to represent the best current practice of American water analysts, and to be generally applicable in connection with the ordinary problems of water purification, sewage disposal and sanitary investigations. Analysts working on widely different problems manifestly cannot use methods which are identical, and special problems obviously require the methods best adapted to them; but, while recognizing these facts, it yet remains true that sound progress in analytical work will advance in proportion to the general adoption of methods which are reliable, uniform and adequate.

It is said by some that standard methods within the field of applied science tend to stifle investigations and that they retard true progress. If such standards are used in the proper spirit, this ought not to be so. The Committee strongly desires that every effort shall be continued to improve the techniques of water analysis and especially to compare current methods with those herein recommended, where different, so that the results obtained may be still more accurate and reliable than they are at present.

Revised and enlarged editions were published by APHA under the title *Standard Methods of Water Analysis* in 1912 (Second Edition), 1917 (Third), 1920 (Fourth), and 1923 (Fifth). In 1925, the American Water Works Association joined APHA in publishing the Sixth Edition, which had the broader title, *Standard Methods of the Examination of Water and Sewage*. Joint publication was continued in the Seventh Edition, dated 1933.

In 1935, the Federation of Sewage Works Associations (now the Water Environment Federation) issued a committee report, "Standard Methods of Sewage Analysis."‡ With minor modifications, these methods were incorporated into the Eighth Edition (1936) of *Standard Methods*, which was thus the first to provide methods for the examination of "sewages, effluents, industrial wastes, grossly polluted waters, sludges, and muds." The Ninth Edition, appearing in 1946, likewise contained these methods, and in the following year the Federation became a full-fledged publishing partner. Since 1947, the work of the *Standard Methods* committees of the three associations—APHA, AWWA, and WEF—has been coordinated by a Joint Editorial Board, on which all three are represented.

The Tenth Edition (1955) included methods specific for examination of industrial wastewaters; this was reflected by a new title: *Standard Methods for the Examination of Water, Sewage and Industrial Wastes*. To describe more accurately and concisely the contents of the Eleventh Edition (1960), the title was shortened to *Standard Methods for the Examination of Water and Wastewater*. It remained unchanged in the Twelfth Edition (1965), the Thirteenth Edition (1971), the Fourteenth Edition (1976), and the Fifteenth Edition (1981).

In the Fourteenth Edition, the separation of test methods for water from those for wastewater was discontinued. All methods for a given component or characteristic appeared under a single heading. With minor differences, the organization of the Fourteenth Edition was retained for the Fifteenth and Sixteenth (1985) Editions. Two major policy decisions of the Joint Editorial Board were implemented for the Sixteenth Edition. First, the International System of Units (SI) was adopted except where prevailing field systems or practices require English units. Second, the use of trade names or proprietary materials was eliminated insofar as possible, to avoid potential claims regarding restraint of trade or commercial favoritism.

The organization of the Seventeenth Edition (1989) reflected a commitment to develop and retain a permanent numbering system. New numbers were assigned to all sections, and unused numbers were reserved for future use. All part numbers were expanded to multiples of 1000 instead of 100. The parts retained their identity from the previous edition, with the exception of Part 6000, which contained methods for the measurement of specific organic compounds. The more general procedures for organics were found in Part 5000.

\* *J. Anal. Chem.* 3:398 (1889).

† *Proc. Amer. Pub. Health AMCC.* 23:56 (1897).

‡ *Sewage Works J.* 7:444 (1935).

The Seventeenth Edition also underwent a major revision in the introductory Part 1000. Sections dealing with statistical analysis, data quality, and methods development were greatly expanded. The section on reagent water was updated to include a classification scheme for various types of reagent water. At the beginning of each of the subsequent parts of the manual, sections were included that discussed quality assurance and other matters of general application within the specific subject area, to minimize repetition in the succeeding text.

The Eighteenth Edition (1992) underwent only minor revisions in the format from the 17th edition. A number of new methods were added in each section. The 18th Edition has many of its methods cited for compliance monitoring of both drinking water and wastewater.

In the Nineteenth Edition (1995), sections were added on laboratory safety and waste management in Part 1000. Substantial changes occurred throughout, adding new methodology and revisions to many of the sections.

## The Twentieth Edition

The Twentieth Edition has maintained the trend of the Nineteenth Edition in continued renewal of Part 1000. Significant revision has occurred in the sections on data quality (1030), sampling (1060) and reagent water (1080).

In Part 2000 (physical and aggregate properties), odor (2150) has been revised to supply new tables for odor identification. The salinity (2520) formula has been made compatible with conductivity nomenclature and quality control procedures have been updated and strengthened.

Significant reworking of the introductory material has occurred in Part 3000 (metals); the introduction now includes a user guide to appropriate methods of metal analysis. A new section, inductively coupled plasma/mass spectrometry (ICP/MS), has been added. Anodic stripping voltammetry (3130) has been expanded to include zinc. The sections on ICP, sample preparation, and specific metal analyses have been revised.

Part 4000 (inorganic nonmetallic constituents) has been reviewed and includes new methods on flow injection analysis (4130), potassium permanganate (4500-KMnO<sub>4</sub>), and capillary ion electrophoresis (4140). Ozone (4500-O<sub>3</sub>) methods have been updated. Significant revisions also have been made in the nitrogen sections. Other sections have undergone minor revisions.

Part 5000 (aggregate organic constituents) has significantly revised sections on chemical oxygen demand (5220), total organic carbon (5310) (from the Nineteenth Edition supplement), and dissolved organic halogen (5320). Freon has been mostly replaced by hexane in the oil and grease section (5520).

In Part 6000 (individual organic compounds), a new section on volatile organic compounds has replaced a number of old sections and a major section on quality control has been added.

Various editorial changes were made in Part 7000 (radioactivity) and a revision in gamma-emitting radionuclides (7120) was made.

Part 8000 (toxicity testing) underwent major changes with new protocols for quality assurance (8020), P450 methodology (8070) from the Nineteenth Edition supplement, pore water test procedures (8080), protozoa (8310), rotifers (8420), *Daphnia* (8711), *Ceriodaphnia* (8712), mysids (8714), decapods (8740), echinoderm fertilization and development (8810), and fathead minnows (8911).

Other sections have been revised significantly and illustrations of many test organisms have been added.

Part 9000 (microbiological examination) has had major revisions to quality assurance and pathogenic bacteria (9260) and minor revisions in several other sections.

Part 10000 (biological examination) has undergone minor revisions. Some new figures and illustrations of organisms have been added.

## Making Reagents

Following the instructions for making reagents may result in preparation of quantities larger than actually needed. In some cases these materials are toxic. To promote economy and minimize waste, the analyst should review needs and scale down solution volumes where appropriate. This conservative attitude also should extend to purchasing policies so that unused chemicals do not accumulate or need to be discarded as their shelf lives expire.

## Selection and Approval of Methods

For each new edition both the technical criteria for selection of methods and the formal procedures for their approval and inclusion are reviewed critically. In regard to the approval procedures, it is considered particularly important to assure that the methods presented have been reviewed and are supported by the largest number of qualified people, so that they may represent a true consensus of expert opinion.

For the Fourteenth Edition a Joint Task Group was established for each test. This scheme has continued for each subsequent edition. Appointment of an individual to a Joint Task Group generally was based on the expressed interest or recognized expertise of the individual. The effort in every case was to assemble a group having maximum available expertise in the test methods of concern.

Each Joint Task Group was charged with reviewing the pertinent methods in the Nineteenth Edition along with other methods from the literature, recommending the methods to be included in the Twentieth Edition, and presenting those methods in the form of a proposed section manuscript. Subsequently, each section manuscript (except for Part 1000) was ratified by vote of those members of the Standard Methods Committee who asked to review sections in that part. Every negative vote and every comment submitted in the balloting was reviewed by the Joint Editorial Board. Relevant suggestions were referred appropriately for resolution. When negative votes on the first ballot could not be resolved by the Joint Task Group or the Joint Editorial Board, the section was rebalotted among all who voted affirmatively or negatively on the original ballot. Only a few issues could not be resolved in this manner and the Joint Editorial Board made the final decision.

The general and quality assurance information presented in Part 1000 was treated somewhat differently. Again, Joint Task Groups were formed, given a charge, and allowed to produce a consensus draft. This draft was reviewed by the Joint Editorial Board Liaison and subsequently by the Joint Editorial Board. The draft sections were sent to the Standard Methods Committee and comments resulting from this review were used to develop the final draft.

The methods presented here, as in previous editions, are believed to be the best available and generally accepted procedures for the analysis of water, wastewaters, and related materials. They

represent the recommendations of specialists, ratified by a large number of analysts and others of more general expertise, and as such are truly consensus standards, offering a valid and recognized basis for control and evaluation.

The technical criteria for selection of methods were applied by the Joint Task Groups and by the individuals reviewing their recommendations, with the Joint Editorial Board providing only general guidelines. In addition to the classical concepts of precision, bias, and minimum detectable concentration, selection of a method also must recognize such considerations as the time required to obtain a result, needs for specialized equipment and for special training of the analyst, and other factors related to the cost of the analysis and the feasibility of its widespread use.

## Status of Methods

All methods in the Twentieth Edition are dated to assist users in identifying those methods that have been changed significantly between editions. The year the section was approved by the Standard Methods Committee is indicated in a footnote at the beginning of each section. Sections or methods that appeared in the Nineteenth Edition that are unchanged, or changed only editorially in the Twentieth Edition, show an approval date of 1993 or 1994. Sections or methods that were changed significantly, or that were reaffirmed by general balloting of the Standard Methods Committee, are dated 1996 or 1997. If an individual method within a section was revised, that method carries an approval date different from that of the rest of the section.

Methods in the Twentieth Edition are divided into fundamental classes: PROPOSED, SPECIALIZED, STANDARD, AND GENERAL. None of the methods in the Twentieth Edition have the specialized designation. Regardless of assigned class, all methods must be approved by the Standard Methods Committee. The four classes are described below:

1. **PROPOSED**—A PROPOSED method must undergo development and validation that meets the requirements set forth in Section 1040A of *Standard Methods*.
2. **SPECIALIZED**—A procedure qualifies as a SPECIALIZED method in one of two ways: a) The procedure must undergo development and validation and collaborative testing that meet the requirements set forth in Sections 1040B and C of *Standard Methods*, respectively; or b) The procedure is the "METHOD OF CHOICE" of the members of the Standard Methods Committee actively conducting the analysis and it has appeared in TWO PREVIOUS EDITIONS of *Standard Methods*.
3. **STANDARD**—A procedure qualifies as a STANDARD method in one of two ways: a) The procedure must undergo development and validation and collaborative testing that meet the requirements set forth in Sections 1040B and C of *Standard Methods*, respectively, and it is "WIDELY USED" by the members of the Standard Methods Committee; or b) The procedure is "WIDELY USED" by the members of the Standard Methods Committee and it has appeared in TWO PREVIOUS EDITIONS of *Standard Methods*.
4. **GENERAL**—A procedure qualifies as a GENERAL method if it has appeared in TWO PREVIOUS EDITIONS of *Standard Methods*.

Assignment of a classification to a method is done by the Joint Editorial Board. When making method classifications, the Joint

Editorial Board evaluates the results of the survey on method use by the Standard Methods Committee that is conducted at the time of general balloting of the method. In addition, the Joint Editorial Board considers recommendations offered by Joint Task Groups and the Part Coordinator.

Methods categorized as "PROPOSED," "SPECIALIZED," and "GENERAL" are so designated in their titles; methods with no designation are "STANDARD."

Technical progress makes advisable the establishment of a program to keep *Standard Methods* abreast of advances in research and general practice. The Joint Editorial Board has developed the following procedure for effecting interim changes in methods between editions:

1. Any method given proposed status in the current edition may be elevated by action of the Joint Editorial Board, on the basis of adequate published data supporting such a change as submitted to the Board by the appropriate Joint Task Group. Notification of such a change in status shall be accomplished by publication in the official journals of the three associations sponsoring *Standard Methods*.

2. No method may be abandoned or reduced to a lower status during the interval between editions.

3. A new method may be adopted as proposed, specialized, or standard by the Joint Editorial Board between editions, such action being based on the usual consensus procedure. Such new methods may be published in supplements to editions of *Standard Methods*. It is intended that a supplement be published midway between editions.

Even more important to maintaining the current status of these standards is the intention of the sponsors and the Joint Editorial Board that subsequent editions will appear regularly at reasonably short intervals.

*Reader comments and questions concerning this manual should be addressed to: Standard Methods Manager, American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235.*

## Acknowledgments

For the work in preparing the methods for the Twentieth Edition, the Joint Editorial Board gives full credit to the Standard Methods Committees of the American Water Works Association and of the Water Environment Federation and to the Committee on Laboratory Standards and Practices of the American Public Health Association. Full credit also is given to those individuals who were not members of the sponsoring societies. A list of all committee members follows these pages. Herbert J. Brass, U.S. Environmental Protection Agency, served as a liaison from EPA to the Joint Editorial Board; thanks are due for his interest and help.

The Joint Editorial Board expresses its appreciation to Fernando M. Treviño, former Executive Director, and Mohammad N. Akhter, M.D., current Executive Director, American Public Health Association, to John B. Mannion, former Executive Director, and Jack W. Hoffbuhr, current Executive Director, American Water Works Association, and to Quincalee Brown, Executive Director, Water Environment Federation, for their cooperation and advice in the development of this publication. Steven J. Posavec, Standard Methods Manager and Joint Editorial Board Secretary, provided a variety of important services that are

vital to the preparation of a volume of this type. Ellen Meyer, Director of Publications, American Public Health Association, functioned as publisher. Judy Castagna, also with APHA, served as production manager. Special recognition for her valuable services is due to Mary Ann H. Franson, Managing Editor, who discharged most efficiently the extensive and detailed responsibilities on which this publication depends.

*Joint Editorial Board*

Lenore S. Clesceri, Water Environment Federation, Chair  
Arnold E. Greenberg, American Public Health Association  
Andrew D. Eaton, American Water Works Association

At several places in this text, a manufacturer's name or trade name of a product, chemical, or chemical compound is referenced. The use of such a name is intended only to be a shorthand reference for the functional characteristics of the manufacturer's item. These references are not intended to be an endorsement of any item by the copublishers, and materials or reagents with equivalent characteristics may be used.



## JOINT EDITORIAL BOARD

LENORE S. CLESCERI, Water Environment Federation, Chair  
ARNOLD E. GREENBERG, American Public Health Association  
ANDREW D. EATON, American Water Works Association

## PART COORDINATORS FOR THE TWENTIETH EDITION

L. Malcolm Baker, 1000  
David J. Rexing, 2000  
Marvin D. Piwoni, 3000  
Roy-Keith Smith, 4000  
Rodger B. Baird, 5000

Edward M. Glick, 6000  
James W. Mullins, 7000  
Donald J. Reish, 8000  
Eugene W. Rice, 9000  
Michael K. Hein, 10000

## COMMITTEES FOR THE TWENTIETH EDITION Joint Task Group Chairs

Jack W. Anderson, 8070, 8740  
Robert M. Bagdigian, 2510  
Edmond J. Baratta, 7500-U  
Michael J. Barcelona, 2580  
Steven M. Bay, 8810  
Terry E. Baxter, 2710  
Robert H. Bordner, 9020  
Sandra D. Canning, 9215  
Robert S. Carr, 8080  
Russell Chinn, 6640  
Malgorzata Ciszowska, 3130  
John E. Colt, 2810  
Brian J. Condikey, 3010, 3500-(all)  
Terry C. Covert, 9213  
William G. Crumpton, 10200  
Melissa S. Dale, 6200  
Brian J. Finlayson, 8714  
Robert P. Fisher, 4500-ClO<sub>2</sub>  
Guy L. Gilron, 8310  
Edward M. Glick, 6010  
Erika M. Godwin-Saad, 8712  
Nancy E. Grams, 6232  
Joseph C. Greene, 8111  
John Gute, 5520  
Michael K. Hein, 10010  
Thomas R. Holm, 4500-S<sup>2-</sup>  
Nancy H. Hall, 9222  
Edward W.D. Huffman, 5310  
Donald G. Huggins, 8750  
Cordelia Hwang, 6251  
Walter Jakubowski, 9711  
Clarence G. Johnson, 5220  
William R. Kammin, 3125  
Lawrence H. Keith, 1060  
Donald J. Klemm, 10500  
Bart Koch, 6040  
Joseph A. Krewer, 2570  
Wayne G. Landis, 8711  
Desmond F. Lawler, 2560

Raymond D. Letterman, 2130  
Albert A. Liabastre, 1090  
James P. Malley, Jr., 5910  
Wayne L. McCulloch, 8010  
Gordon A. McFeters, 9212  
Thomas Mikel, 8610  
David W. Moore, 8020  
Nelson P. Moyer, 9260  
James W. Mullins, 7010, 7020, 7040, 7110, 7120  
Kenneth E. Osborn, 1030  
Gilbert E. Pacey, 4500-Cl<sup>-</sup>, -F<sup>-</sup>, -NO<sub>3</sub><sup>-</sup>, -P, -SiO<sub>2</sub>,  
-SO<sub>4</sub><sup>2-</sup>  
Carol Palmer, 9223  
Stephen H. Pia, 7500-Rn  
Kerwin Rakness, 4500-O3  
Donald J. Reish, 8200, 8510, 8710, 10900  
Eugene W. Rice, 9060, 9221, 9225  
Ann E. Rosecrance, 1020, 6020  
Ernest A. Sanchez, 7030  
Eric M. Silberhorn, 8921  
Miles M. Smart, 10400  
Roy-Keith Smith, 4140, 4500-N  
Terry W. Snell, 8420  
R. Kent Sorrell, 6610  
Scott Stieg, 4130, 4500-Br<sup>-</sup>, -CN<sup>-</sup>, -Cl<sup>-</sup>, -F<sup>-</sup>, -N,  
-NH<sub>3</sub>, -NO<sub>3</sub><sup>-</sup>, -N<sub>org</sub>, -P, -SiO<sub>2</sub>, -S<sup>2-</sup>, -SO<sub>4</sub><sup>2-</sup>  
Irwin H. Suffet, 2150, 2170  
James P. Swigert, 8910  
James M. Symons, 5320  
Jonathan Talbott, 3030  
David W. Tucker, 3020  
Philip A. Vella, 4500-KMnO<sub>4</sub>  
Wuncheng Wang, 8211, 8220  
Robert G. Wetzel, 10300  
Brannon H. Wilder, 2540  
George T.F. Wong, 4500-I, -I<sup>-</sup>, -IO<sub>3</sub><sup>-</sup>  
Theresa M. Wright, 4120  
Roger A. Yorton, 2350  
James C. Young, 5210

## Standard Methods Committee and Joint Task Group Members

John C. Adams	William H. Bouma
V. Dean Adams	Theresa M. Bousquet
Rose Adams-Whitehead	Celine Boutin, 8220
Katherine T. Alben	George T. Bowman, 1020, 5210
Timothy G. Albers	William C. Boyle, 2580
George W. Alford	Wayne T. Boyles
Trisha M. Alford	Lloyd W. Bracewell
Martin J. Allen	Susan M. Bradford
Osman M. Aly	Herbert J. Brass
Brian S. Anderson	Julie C. Brewen
Deanna K. Anderson, 3500-(all)	Anthony Bright, 3500-(all)
Jack W. Anderson, 8740	Udo A. Th. Brinkman
Clifford G. Annis, 1060	Karl O. Brinkmann, 5310, 5320
Neal E. Armstrong, 8111	Christine R. Brisbin
Prem N. Arora	Paul W. Britton, 1030
John A. Arrington, 2130, 2150	Michael H. Brodsky, 1020, 9020
Edward F. Askew	John K. Brokaw, 9020, 9213, 9222
Donald B. Aulenbach, 4500-NH <sub>3</sub> , -N, -S <sup>2-</sup>	DeeAnne L. Bryant
Barry M. Austern	Michael L. Bryant
Guy M. Aydlett	Bernard Bubnis, 4500-KMnO <sub>4</sub>
Robert M. Bagdigian, 2510	Anthony Bucciferro, 6200
Rodger B. Baird	Mark R. Burkhardt
L. Malcolm Baker	Gary A. Burlingame, 2170
Donald M. Baltz, 10600	Dennis T. Burton, 8010, 8712
Jarmila Banovic, 5320	Billie C. Byrom, 2710
Edmond J. Baratta, 7500-U	Richard A. Cahill, 3500-(all)
Michael J. Barcelona, 2580	Ervine A. Callin
Susan J. Barker	Devon A. Cancilla, 6252
John R. Barnett, 3125	Sandra D. Canning, 9215, 10300
Thomas O. Barnwell, 5210	Robert E. Carlson
Terry E. Baxter, 2710	Robert S. Carr, 8080, 8810
Steven M. Bay, 8810	Isabel C. Chamberlain, 3125
David C. Beckett, 10500	Peter M. Chapman, 8510, 8610, 10500
John W. Beland	Daniel D. Chen, 2710
Dannelle H. Belhateche	Russell Chinn, 6251, 6640
Peter G. Bell, 10900	Leonard L. Ciaccio
Daniel F. Bender, 1020, 1090	Malgorzata Ciszewska, 3130
Larry D. Benefield, 2150	James A. Clark, 9221, 9225
E. F. Benfield, 8750, 10900	Alois F. Clary, 3500-(all)
Loren A. Berge, 7500-Rn	Lenore S. Clesceri, 8070
Paul S. Berger, 9221, 9222	Philip A. Clifford
Sharon G. Berk, 8310	Dean Cliver
Paul M. Berthouex	Colin E. Coggan, 8711
Robert R. Bidigare, 10200	Robert S. Cohen
Star F. Birch	Larry David Cole, 2150
Jeffrey A. Black, 8010, 8921	David E. Coleman
H. Curt Blair	Tom E. Collins, 6040
Linda R. Blish, 9222	John E. Colt
David R. Blye	Brian J. Condike, 3010, 3500-(all)
Ronald J. Boczkowski	Don P. Cook
Debra K. Bolding, 1020	Robert C. Cooper
Robert H. Bordner, 9020, 9060, 9222	Harold S. Costa, 2540
Robert I. Botto	C. Richard Cothorn, 7500-Rn

**JOINT EDITORIAL BOARD AND COMMITTEE MEMBERS**

Terry C. Covert, 9020, 9060, 9213, 9223, 9225, 9260  
 Nilda B. Cox, 1020, 3020  
 Kathryn M. Craig, 8712, 9215  
 Eric W. Crofts  
 Wendell H. Cross  
 William G. Crumpton, 10010, 10200  
 Rob Cuello, 8020  
 D. Roy Cullimore  
 Rick C. Dage, 5310  
 Melissa S. Dale, 6200  
 Kathryn E. Darula  
 Ernst M. Davis, 10200  
 Richard E. DeBlois, 4500-KMnO<sub>4</sub>  
 Gary L. DeKock, 1060  
 Ricardo DeLeon, 9711  
 Joseph J. Delfino  
 Rachel A. DeMunda  
 Steven K. Dentel, 2710  
 Fred L. DeRoos  
 Gil Dichter  
 Paul A. Dinnel, 8810  
 John H. Dorsey, 10900  
 Margaret E. Doss  
 Arley T. Dubose  
 Alfred P. Dufour  
 David B. Dusenbery, 8420  
 Hamish C. Duthie, 10300  
 Bernard J. Dutka, 8712  
 Stephen C. Edberg, 9221, 9225  
 David L. Edelman  
 Carleton P. Edmunds, 1060  
 Craig E. Edwards  
 James K. Edzwald, 5710, 5910  
 James D. Eggert  
 Lawrence W. Eichler  
 Gunnar Ekedahl, 1020  
 William M. Ellgas  
 G. Keith Elmund, 1020, 9020  
 Mohamed Elnabarawy, 8712, 8910  
 Robert P. Esser, 10010  
 Otis Evans  
 William S. Ewell, 8510, 8712, 8921  
 Melly L. Fabro, 6200  
 Patricia Snyder Fair, 5310, 6251, 6252  
 Samuel D. Faust  
 Jonathan M. Feero  
 Peter Feng, 9260  
 Larry E. Fidler, 2810  
 Brian J. Finlayson, 8714  
 Dwayne F. Fischer  
 Bradford R. Fisher, 4130, 4500-Br<sup>-</sup>, -CN<sup>-</sup>, -Cl<sup>-</sup>, -F<sup>-</sup>,  
 -N, -NH<sub>3</sub>, -NO<sub>3</sub><sup>-</sup>, -N<sub>org</sub>, -P, -SiO<sub>2</sub>, -S<sup>2-</sup>, -SO<sub>4</sub><sup>2-</sup>,  
 6232  
 Robert P. Fisher, 4500-ClO<sub>2</sub>  
 Ellen P. Flanagan, 9212, 9215, 9222  
 Mary E. (Libby) Ford  
 G. Shay Fout  
 Kim R. Fox  
 Donna S. Francy, 9020  
 Martin S. Frant, 4500-S<sup>2-</sup>  
 Paul R. Fritschel, 3030  
 John L. Fronk  
 Roger S. Fujioka  
 Kensuke Fukushi  
 Leo C. Fung, 4500-O<sub>3</sub>  
 Elly M. Gabrielian, 3030  
 Anthony M. Gaglierd  
 Wallace E. Garthright  
 Eduardo Gasca  
 John C. Geldenhays  
 Edwin E. Geldreich, 9222  
 Stephen R. Gelman, 2710, 5210  
 Carl J. George, 10600  
 Vincent A. Geraci  
 Charles P. Gerba, 9060  
 Thomas V. Gerlinger, 8510  
 Mriganka M. Ghosh  
 Sambhunath Ghosh  
 Robert D. Gibbons, 1030  
 Guy L. Gilron, 8310  
 James M. Gindelberger, 1030, 4500-ClO<sub>2</sub>  
 Thomas S. Gittelman, 2150, 2170, 6040  
 Edward M. Glick, 6010  
 Erika M. Godwin-Saad, 8712  
 Margaret M. Goldberg, 3130  
 L. Gordon Goldsborough, 8220, 10300  
 Maria M. Gomez-Taylor  
 C. Ellen Gonter, 3500-(all)  
 Steven Lee Goodbred, 8211  
 William L. Goodfellow, 8010, 8020, 8712  
 Lome R. Goodwin, 4500-S<sup>2-</sup>  
 Gilbert Gordon, 4500-O<sub>3</sub>, -KMnO<sub>4</sub>, -ClO<sub>2</sub>  
 Joseph W. Gorsuch, 8711, 8712  
 Richard W. Gossett  
 Randy A. Gottler  
 Joseph P. Gould  
 Willie O.K. Grabow  
 Jill T. Gramith, 4500-O<sub>3</sub>  
 Nancy E. Grams, 1030, 6232  
 Michael A. Grant  
 Robert E. Grant, 9223  
 William B. Gray  
 Joseph C. Greene, 8111  
 John M. Gregson  
 Peter M. Grohse, 3500-(all)  
 Zoe A. Grosser  
 Donald R. Grothe, 8010  
 Maria Cecilia B. Gueco  
 Robert J. Gussman, 5520, 8712  
 John Gute, 5520  
 Kim H. Haag, 8211  
 David W. Haddaway, 3020

- Grant J. Haffely  
Stephen W. Hager  
Gary E. Hahn  
Paul B. Hahn, 7500-Rn, 7500-U  
Bruce A. Hale, 6040  
Nancy H. Hall, 9020, 9060, 9213, 9221, 9222, 9223, 9225  
Scott Hall, 8712, 8921  
Erika E. Hargesheimer, 2560  
Karen Sue Harlin  
Danial L. Harp  
Jay H. Harris  
Daniel P. Hautman  
Kenneth R. Hayes  
Robert S. Hedin  
Michael K. Hein, 10010  
Robert Henry, 3125  
Charles D. Hertz  
Paul J. Hickey, 9213, 9222  
Anita K. Highsmith  
Brian H. Hill  
David R. Hill  
Kenneth M. Hill, 6610  
Daniel C. Hillman, 3500-(all), 4500-Cl<sup>-</sup>, -F<sup>-</sup>, -NO<sub>3</sub><sup>-</sup>, -P, -SiO<sub>2</sub>, -SO<sub>4</sub><sup>2-</sup>  
Vernon F. Hodge, 7500-Rn  
Jimmie W. Hodgeson, 6251  
Robert C. Hoehn, 4500-ClO<sub>2</sub>, 5710  
George C. Holdren  
Albert C. Holler, 3500-(all)  
Thomas R. Holm, 2580, 4500-S<sup>2-</sup>  
Robert W. Hoist, 8111, 8220  
John Homa, 10600  
Wayne B. Huebner, 4500-ClO<sub>2</sub>  
Edward W.D. Huffman  
Donald G. Huggins, 8750, 10900  
Amy Hughes, 3500-(all)  
Jane Staveley Hughes, 8111  
Yung-Tse Hung  
Christon J. Hurst, 9711  
Cordelia J. Hwang, 6251  
Veronica Y. Inouye  
Billy G. Isom, 8712, 10500  
Peter E. Jackson  
R. Wayne Jackson, 1090, 9213  
Walter Jakubowski, 9060, 9711  
Carol Ruth James, 2170  
Colin R. Janssen, 8420, 8712  
Lois B. Jassie  
Karen F. Jenkins  
S. Rod Jenkins, 2710  
J. Charles Jennett, 3500-(all)  
James N. Jensen, 2350  
John O. Jensen, 2810  
Clarence G. Johnson, 5220  
Isabel C. Johnson  
Karla Alicia Johnson  
Stephen W. Johnson, 2510  
Donald L. Johnstone, 9212, 9213  
Lesla H. Julian  
Swiatoslav W. Kaczmar  
Larry J. Kaeding  
Sabry M. Kamhawy, 4500-NH<sub>3</sub>, -N<sub>org</sub>, 5210  
William R. Kammin, 3125  
Louis A. Kaplan, 5310, 9060  
David J. Kaptain, 3113  
Lawrence A. Kapustka, 8220  
Shreekant V. Karmarkar  
Irwin J. Katz  
Paul W. Keck  
Carolyn W. Keefe, 4500-NH<sub>3</sub>, -N<sub>org</sub>  
Floyd D. Kefford  
Lawrence H. Keith, 1030, 1060  
Nabih P. Kelada  
Paul J. Kemp  
William J. Kenney, 5210  
Lee G. Kent  
Edwin J. Keppner  
Zoltan Kerekes, 2580  
Robert J. Kieber  
David Eugene Kimbrough, 3030  
Joe M. King, 8111, 8220  
H.M. Kingston, 3030  
Riley N. Kinman  
Nancy E. Kinner, 7500-Rn  
James P. Kizer, 2150  
Harvey Klein  
Donald J. Klemm, 10010, 10500, 10600, 10900  
Margaret M. Knight  
Bart Koch, 5710, 6040  
William F. Koch, 2510  
Nimi Kocherlakota, 3030  
Frederick C. Kopfler  
Laura B. Kornstein, 9260  
Wolfgang Korth, 6040  
Christine M. Kosmowski, 2540  
Pamela A. Kostle  
Joseph A. Krewer, 2570  
Jim Krol, 4140  
Mark J. La Guardia  
Timothy I. Ladd, 9215  
Lawrence E. LaFleur  
Janet O. Lamberson  
Wayne G. Landis, 8711  
Dennis D. Lane, 2570  
Russell W. Lane, 2510  
Johan Langewis  
John M. Larkin  
Desmond F. Lawler, 2560  
Norman E. LeBlanc  
Mark W. LeChevallier, 9212, 9215, 9222, 9711  
G. Fred Lee

- Richard F. Lee, 8740  
 Joseph A. LeMay, 8712, 8921  
 Larry Y. C. Leong  
 Steven I. Lerman  
 Raymond D. Letterman, 2130  
 Carrie M. Lewis, 2560  
 Michael A. Lewis, 8211  
 Philip A. Lewis, 10500  
 Ronald F. Lewis  
 Albert A. Liabastre, 1020, 1090  
 Wenta Liao, 6640  
 Alvin Lieberman, 2130  
 Truman S. Light  
 Shundar Lin, 2150, 9212, 9221, 9222  
 Christopher B. Lind  
 Stanford L. Loeb, 10300  
 Raymond J. Lovett, 3113  
 Suzanne M. Lussier, 8714  
 Richard G. Luthy  
 Gerald L. Mahon, 2150  
 James P. Malley, 5910  
 Bruce E. Manning  
 Joseph P. Marcinko  
 Craig G. Markell  
 Harold G. Marshall, 10200  
 Bradley K. Martell  
 H. Frank Martin  
 Willy J. Masschelein, 4500-O<sub>3</sub>  
 John J. Mathewson  
 Owen B. Mathre, 4130, 4500-Br-, -CN<sup>-</sup>, -Cl<sup>-</sup>, -F<sup>-</sup>,  
 -N, -NH<sub>3</sub>, -NO<sub>3</sub><sup>-</sup>, -N<sub>org</sub>, -P, -SiO<sub>2</sub>, -S<sup>2-</sup>, -SO<sub>4</sub><sup>2-</sup>  
 Wayne L. McCulloch, 8010  
 Gordon A. McFeters, 9060, 9212, 9222  
 Daniel A. McLean, 1020, 3020  
 Lilia M. McMillan, 2570  
 Nancy E. McTigue, 2560  
 Morten C. Meilgaard, 2150, 2170  
 John M. Melack  
 Johan Menting, 4120  
 P. Lawrence Meschi, 5310  
 James W. Messer  
 Scott J. Mickelson, 1060  
 Thomas Mikel, 8610  
 Donald G. Miller, 5220  
 James R. Millette, 2570  
 Roger A. Minear, 3500-(all)  
 Christine L. Moe, 9213  
 David W. Moore, 8020, 8510  
 Marlene O. Moore, 3500-(all)  
 William N. Moore  
 Robert E. Morcock, 8020, 8711, 8750, 8910  
 Maria T. Morsillo, 2350  
 Richard A. Mosher  
 Christina M. Mott  
 Nelson P. Moyer, 9060, 9260, 9711  
 Terry I. Mudder  
 James W. Mullins, 1020, 7010, 7020, 7040, 7110, 7120  
 J. Vincent Nabholz, 8712, 8910  
 Diane E. Nacci, 8810  
 Mary C. Nahm  
 Brian A. Nelsen, 9222  
 Marcia Kelly Nelson, 8211  
 Dennis Neuin, 3030  
 Michael C. Newman, 8420  
 Michael C. Nichols, 1090  
 Stanley A. Nichols, 10400  
 William T. Nivens  
 Teresa Norberg-King, 8921  
 William D. Norton, 9711  
 James R. Nugent, 2150, 9212  
 James W. O'Dell, 4500-Cl<sup>-</sup>, -F<sup>-</sup>, -NO<sub>3</sub><sup>-</sup>, -P, -SiO<sub>2</sub>,  
 -SO<sub>4</sub><sup>2-</sup>, 5310  
 Patrick W. O'Keefe  
 Lisa M. Obermeyer, 2170  
 Gregg L. Oelker, 3500-(all)  
 Oladele A. Ogunseitan  
 James D. Oliver, 9260  
 Kenneth E. Osborn, 1020, 1030  
 Janet G. Osteryoung, 3130  
 Jonalea V. Ostlund, 3020  
 Gilbert E. Pacey, 4500-Cl<sup>-</sup>, -F<sup>-</sup>, -NO<sub>3</sub><sup>-</sup>, -P, -SiO<sub>2</sub>,  
 -SO<sub>4</sub><sup>2-</sup>  
 Carol J. Palmer, 9223, 9260  
 Mark A. Palmieri, 8711  
 Sunil P. Pande  
 Kemon J. Papacosta, 2130  
 Thomas W. Parker  
 David F. Parkhurst  
 Christine Paszko, 9260  
 Marlene Patillo, 5210  
 James J. Pauer  
 Raymond A. Paus  
 Pierre Payment  
 James H. Peck, 10400  
 Richard K. Peddicord  
 S. Kusum Perera, 3500-(all), 7500-Rn  
 Guido Persoone, 8420  
 Carol E. Pesch, 8510  
 Dianne M. Phelan  
 Elizabeth A. Phillips  
 Twila S. Phillips  
 Stephen H. Pia, 7500-Rn  
 Molly Pickett  
 John T. Pivinski, 3020, 5220  
 Marvin D. Piwoni  
 Misha Plam, 2510, 5310  
 James J. Pletl, 8010, 8740  
 Russell H. Plumb, 8020, 8111  
 James G. Poff, 3500-(all)  
 James M. Polisini, 8712  
 Billy B. Potter  
 T.B.S. Prakasam

- Theresa A. Prato, 6640  
 James R. Pratt, 8310  
 Michele Prevost  
 Fred T. Price  
 Norma L. Puckett  
 William E. Purcell, 2540  
 Shane S. Que Hee, 6252  
 James G. Quinn  
 Robert L. Quinn  
 Ansar A. Qureshi, 9215  
 Michael L. Rabeneck  
 Kerwin L. Rakness, 4500-O<sub>3</sub>  
 Neil M. Ram, 5710  
 William B. Randolph, 9020  
 Stephen J. Randtke, 4500-NH<sub>3</sub>, -N<sub>org</sub>  
 William R. Ray  
 Donald J. Reasoner, 9212, 9215  
 David A. Reckhow  
 Richard Reding  
 Lang Allen Reeves, 4120  
 Donald J. Reish, 8070, 8080, 8200, 8510, 8710, 8714,  
 10010, 10900  
 Vincent H. Resh, 8750, 10900  
 David J. Rexing  
 F. Ribas  
 Eugene W. Rice, 9060, 9221, 9225  
 T. J. Richards, 6200  
 Merrilee Ritter  
 Morris H. Roberts, 8610, 8714, 8740, 8810, 10500  
 Andrew Robertson, 10200  
 William J. Robertson  
 Robert S. Rodgers, 3130  
 Francois Rodigari, 6040  
 Peggy A. Roefer, 9215  
 Stephen C. Roesch, 2570  
 Bruce M. Roll, 9223  
 Joan B. Rose, 9711  
 Ann E. Rosecrance, 1020, 1030, 6020  
 Bernard Rosenberg  
 Joel A. Rosenfield  
 William D. Rosenzweig  
 James O. Ross, 3125  
 James L. Royer  
 William J. Rue, 8010  
 Charles C. Russell  
 Peggy A. Ryker, 9020, 9222  
 Michael J. Sadar  
 Robert S. Safferman  
 Ana M. Sancha  
 Ernest A. Sanchez, 7030  
 Eileen Q. Sanders, 9020  
 William A. Saner, 6200  
 Syed A. Sattar  
 Frances Y. Saunders, 4500-ClO<sub>2</sub>  
 Larry P. Scanlan  
 Frank W. Schaefer  
 Nova A. Scheller, 6252  
 Don W. Schloesser, 10500  
 Jeffrey A. Schloss  
 Charles J. Schmidt  
 Michael R. Schock  
 Elizabeth A. Schroeder  
 Michael J. Scilimenti, 6252  
 James H. Scott, 1020, 1090  
 Frank E. Scully  
 Alberta J. Seierstad  
 Pierre Servais  
 Virendra Sethi  
 Roland L. Seymour  
 Mesut Sezgin, 2710  
 M. Shahamat, 9260  
 Bernard F. Shema  
 Joseph H. Sherrard  
 Eric M. Silberhorn, 8921  
 Mark R. Simpson, 6040  
 Jeffrey G. Skousen, 3500-(all)  
 Alena Sládečková, 10300  
 Robert Slater, 6200  
 Miles M. Smart, 10010, 10400  
 Lynn P. Smith, 9212, 9222  
 Roy-Keith Smith, 4140, 4500-N  
 Stuart A. Smith  
 Kent W. Smothers  
 Terry W. Snell, 8420  
 Holger T. Sommer  
 William C. Sonzogni  
 Reginald J. Soracco  
 R. Kent Sorrell, 6610  
 Neil G. Spokes  
 Kailash C. Srivastava  
 Ravindra M. Srivastava  
 Ricky A. Stackhouse  
 Robert F. Stalzer  
 Jon Standridge, 9223  
 Lisa M. Stanley  
 Judy A. Starcevich, 8610, 9222  
 Ronald E. Stetler  
 Mic H. Stewart  
 Scott Stieg, 4130, 4500-Br<sup>-</sup>, -CN<sup>-</sup>, -Cl<sup>-</sup>, -F<sup>-</sup>, -N,  
 -NH<sub>3</sub>, -NO<sub>3</sub><sup>-</sup>, -N<sub>org</sub>, -P, -SiO<sub>2</sub>, -S<sup>2-</sup>, -SO<sub>4</sub><sup>2-</sup>  
 Irwin H. Suffet, 2150, 2170  
 Makram T. Suidan  
 Bernard F. Sullivan  
 Lynne M. Sullivan  
 Harry V. Summers, 7030  
 Paul T. Sutcliffe  
 John W. Sweeney, 2810  
 Robert A. Sweeney, 10200  
 Charles D. Sweeny  
 James P. Swigert, 8211, 8910  
 James M. Symons, 5320, 5710  
 Francis Szrom

## JOINT EDITORIAL BOARD AND COMMITTEE MEMBERS

Henry H. Tabak, 5210  
Adib F. Tabri  
Spence R. Tait, 1100  
Jonathan Talbott, 3030  
Theodore S. Tanaka, 2130, 2560  
Mark E. Tatro, 3030  
William A. Telliard  
Patti L. TenBrook, 8610, 8712, 8810  
Jerry J. Thoma  
Jeff Throckmorton  
John E. Tobiasson, 2560  
R. Yucel Tokuz  
Peter J. Trincherro, 10600  
Yu-Li Tsai  
David W. Tucker, 3020  
Jack R. Tuschall  
Mark M. Ultis, 3030  
Richard F. Unz  
Edward T. Urbansky  
George S. Uyesugi, 7500-Rn  
Schalk W. van der Merwe  
Pamela Owens Varner  
Ronald G. Velarde, 10900  
Philip A. Vella, 4500-KMnO<sub>4</sub>  
Rock J. Vitale  
Christian J. Volk  
Hsiao-Chiu Wang  
Lawrence K. Wang, 1100, 4500-O<sub>3</sub>  
Mu Hao S. Wang  
Wuncheng Wang, 8211, 8220  
Yi Y. Wang  
Barnaby J. Watten, 2810  
George R. Watzlaf  
David E. Weber, 8220  
Melissa A. Weekley, 3030  
Charles A. Weisberg  
Aaron D. Weiss, 3030  
Warren C. Westgarth  
Robert G. Wetzel, 10010, 10300, 10400  
James L. Whitlock, 8712, 10600

Donald O. Whittemore  
Ray C. Whittemore, 5210  
Michael D. Wichman, 3500-(all)  
Luann Wiedenmann  
Mark R. Wiesner, 2560  
Monte R. Wilcoxon  
Brannon H. Wilder, 2130, 2540  
Fred P. Williams  
Theodore J. Williams, 9215  
John A. Winter, 9020  
Ted W. Witten  
Marek Wojciechowski, 3130  
Ruth E. Wolf, 3030, 3125  
Roy L. Wolfe, 9215  
George T.F. Wong, 4500-I, -I<sup>-</sup>, -IO<sub>3</sub><sup>-</sup>  
Mark W. Wood  
Ty R. Woodin  
Richard E. Woodling  
Jack Q. Word, 8510, 8740, 8810, 10900  
Kevin L. Worley  
Theresa M. Wright, 4120, 4130, 4500-Br<sup>-</sup>, -CN<sup>-</sup>,  
-Cl<sup>-</sup>, -F<sup>-</sup>, -N, -NH<sub>3</sub>, -NO<sub>3</sub><sup>-</sup>, -N<sub>org</sub>, -P, -SiO<sub>2</sub>, -S<sup>2-</sup>,  
-SO<sub>4</sub><sup>2-</sup>  
John L. Wuepper, 3500-(all)  
Robert K. Wyeth, 1030  
Mark Wyzalek, 1060  
Yuefeng Xie, 4140, 6251  
Harumi Yamada, 6252  
George Yamate, 2570  
In Che Yang  
William A. Yanko, 9020, 9260  
Dennis A. Yates  
Thomas L. Yohe  
Roger A. Yorton, 2350, 5910  
James C. Young, 5210  
Ling-Su Zhang, 4500-I, -I<sup>-</sup>, -IO<sub>3</sub><sup>-</sup>  
Carol A. Ziel, 9212, 9222, 9225  
Cindy A. Ziernicki, 3125  
Melvin C. Zimmerman