



HANDBOOK
of
ENVIRONMENTAL CONTROL
VOLUME I: AIR POLLUTION



HANDBOOK
of
ENVIRONMENTAL CONTROL
VOLUME I: AIR POLLUTION

EDITORS

Richard G. Bond, M.S., M.P.H.
*Director, Division of
Environmental Health
University of Minnesota*

Conrad P. Straub, Ph.D.
*Director, Environmental Health
Research and Training Center
University of Minnesota*

COORDINATING EDITOR

Richard Prober, Ph.D.
*Associate Professor of Engineering
Case Western Reserve University*



A DIVISION OF
THE **CHEMICAL RUBBER** CO.
18901 Cranwood Parkway • Cleveland, Ohio 44128

HANDBOOK OF ENVIRONMENTAL CONTROL

VOLUME I: AIR POLLUTION

This book presents data obtained from authentic and highly regarded sources. Reprinted material is quoted with permission, and sources are indicated. A wide variety of references are listed. Every reasonable effort has been made to give reliable data and information, but the editors and the publisher cannot assume responsibility for the validity of all materials or for the consequences of their use.

© 1972 by THE CHEMICAL RUBBER CO. All rights reserved. This book, or any parts thereof, may not be reproduced in any form without written consent from the publisher. Printed in the United States of America.

International Standard Book Number (ISBN)

Complete Set 0-87819-270-0

Volume I 0-87819-271-9

Library of Congress Catalog Card Number 72-92118



HANDBOOK SERIES

- Handbook of Chemistry and Physics, 53rd edition
- Standard Mathematical Tables, 20th edition
- Handbook of tables for Mathematics, 4th edition
- Handbook of tables for Organic Compound Identification, 3rd edition
- Handbook of Biochemistry, selected data for Molecular Biology, 2nd edition
- Handbook of Clinical Laboratory Data, 2nd edition
- Manual for Clinical Laboratory Procedures, 2nd edition
- Manual of Nuclear Medicine Procedures, 1st edition
- Handbook of Laboratory Safety, 2nd edition
- Handbook of tables for Probability and Statistics, 2nd edition
- Fenaroli's Handbook of Flavor Ingredients, 1st edition
- Handbook of Analytical Toxicology, 1st edition
- Manual of Laboratory Procedures in Toxicology, 1st edition
- Handbook of tables for Applied Engineering Science, 2nd edition
- Handbook of Chromatography, 1st edition
- Handbook of Environmental Control, 1st edition
- Handbook of Food Additives, 2nd edition
- Handbook of Radioactive Nuclides, 1st edition
- Handbook of Lasers, 1st edition
- Handbook of Microbiology, 1st edition
- Handbook of Engineering in Medicine and Biology, 1st edition
- *Handbook of Marine Sciences, 1st edition
- *Handbook of Material Science, 1st edition
- *Handbook of Spectroscopy, 1st edition
- *Atlas of Spectral Data and Physical Constants for Organic Compounds, 1st edition

*Currently in preparation.

MATHEMATICS AND STATISTICS

William H. Beyer, Ph.D.

University of Akron

Brian Girling, M.Sc., F.I.M.A.

The City University, London

Samuel M. Selby, Ph.D., Sc.D.

Hiram College

MICROBIOLOGY

Allen I. Laskin, Ph.D.

Esso Research and Engineering Co.

Hubert Lechevalier, Ph.D.

Rutgers University

ORGANIC CHEMISTRY

Saul Patai, Ph.D.

Hebrew University of Jerusalem

Zvi Rappoport, Ph.D.

Hebrew University of Jerusalem

RADIOLOGICAL SCIENCES

Yen Wang, M.D., D.Sc. (Med.)

University of Pittsburgh

SPECTROSCOPY

Jeanette Grasselli, M.S.

Standard Oil Company (Ohio)

W. M. Ritchey, Ph.D.

Case Western Reserve University

James W. Robinson, Ph.D.

Louisiana State University

TOXICOLOGY

Irving Sunshine, Ph.D.

Cuyahoga County Coroner's Office, Ohio

CRITICAL REVIEW JOURNALS

ANALYTICAL CHEMISTRY

Louis Meites, Ph.D.

Clarkson College of Technology

BIOCHEMISTRY

Gerald Fasman, Ph.D.

Brandeis University

BIOENGINEERING

David G. Fleming, Ph.D.

Case Western Reserve University

CLINICAL SCIENCES

Willard R. Faulkner, Ph.D.

Vanderbilt University Medical Center

John W. King, M.D., Ph.D.

Cleveland Clinic Foundation

ENVIRONMENTAL SCIENCES

Richard G. Bond, M.S., M.P.H.

University of Minnesota

Conrad P. Straub, Ph.D.

University of Minnesota

FOOD AND NUTRITION

Thomas E. Furia

CIBA-GEIGY Corp.

MACROMOLECULAR SCIENCE

Eric Baer, Ph.D.

Case Western Reserve University

Phillip Geil, Ph.D.

Case Western Reserve University

Jack Koenig, Ph.D.

Case Western Reserve University

MICROBIOLOGY

Allen I. Laskin, Ph.D.

Esso Research and Engineering Co.

Hubert Lechevalier, Ph.D.

Rutgers University

RADIOLOGICAL SCIENCES

Yen Wang, M.D., D.Sc. (Med.)

University of Pittsburgh

SOLID STATE SCIENCES

Richard W. Hoffman, Ph.D.

Case Western Reserve University

Donald E. Schuele, Ph.D.

Bell Telephone Laboratories

TOXICOLOGY

Leon Golberg, D.Phil., D.Sc.

Albany Medical College of

Union University

PREFACE TO VOLUME I: AIR POLLUTION

In this, the first volume of the *Handbook of Environmental Control*, the editors have attempted to bring together in tabular form the data needed to provide an approach to a solution to environmental problems in air pollution. Data are provided on contaminants and pollutants in ambient air and from various industrial operations. Control measures found valuable are identified. Broadly speaking, the data are grouped as follows: basic data, sampling and monitoring, effects of air pollutants, emission sources, and control measures.

We hope that this handbook can provide answers to the following kinds of questions:

1. About specific problems that exist, that may exist, or that could exist in the future.
2. About a problem in a general way or by analogy or by extrapolation.
3. About new and innovative approaches that can be developed from the use of building blocks of specific data.

This volume on air pollution should be of use to workers within the broad scope of the disciplines of environmental management, including ecology, earth sciences, resources, recreation, and environmental design and protection. In addition, because of the extension of awareness and concern about the environment, students in the above areas and other professions, such as law, business, political science, and sociology, will find the volume a source of ready information.

Minneapolis, Minnesota
August 1972

R.G. BOND
C.P. STRAUB

ADVISORY BOARD

Callis H. Atkins

Assistant Surgeon General (Retired)
U.S. Public Health Service
Washington, D.C.

Jack W. Carlson

Assistant to the Director for Planning and
Economic Affairs
Office of Management and Budget
Washington, D.C.

Chris A. Hansen

Vice President
Georgetown University
Washington, D.C.

Howard E. Heggstad

Leader, Air Pollution Laboratory
U.S. Department of Agriculture
Beltsville, Maryland

Jesse Lunin

U.S. Department of Agriculture
Agricultural Research Service
Beltsville, Maryland

Vernon G. MacKenzie

Assistant Surgeon General (Retired)
U.S. Public Health Service
Washington, D.C.

James K. Rice

President, Cyrus William Rice Division
NUS Corporation
Pittsburgh, Pennsylvania

Frederick Sargent II

School of Public Health
University of Texas at Houston
Houston, Texas

James H. Steele

School of Public Health
University of Texas at Houston
Houston, Texas

David G. Stephan

Director, Program Management Division
Office of Research and Monitoring
Environmental Protection Agency
Washington, D.C.

James H. Sterner

School of Public Health
University of Texas at Houston
Houston, Texas

Meredith H. Thompson

Assistant Commissioner, Division of
Environmental Health
New York State Health Department
Albany, New York

Kenneth Watson

Director of Environmental Control
Kraftco, Inc.
Glenview, Illinois

Richard L. Woodward

Vice President
Camp, Dresser, and McKee, Inc.
Boston, Massachusetts

James W. Wright

Chief, Vector Biology and Control
World Health Organization
Switzerland

TABLE OF CONTENTS

Preface to the Environmental Control Series viii

Preface to Volume I: Air Pollution ix

SECTION 1 THE ATMOSPHERE AND AIR POLLUTANTS

- 1.1 Atmospheric Data 3
- 1.2 Air Pollutant Properties 5
- 1.3 Air Pollution Variables 47
- 1.4 Surveys 61
- 1.5 Sampling and Analysis 80

SECTION 2 EFFECTS OF AIR POLLUTION

- 2.1 Biological Effects on Humans 121
 - 2.1.1 Human Physiology 133
 - 2.1.2 Air Pollution Episodes 149
- 2.2 Biological Effects on Animals 155
- 2.3 Biological Effects on Plant Life 168
- 2.4 Economic Effects and Damage to Materials 190

SECTION 3 EMISSION SOURCES

- 3.1 General Emission Sources 203
- 3.2 Fuel Properties Related to Pollution Emissions 215
- 3.3 General Emission Factors 224
- 3.4 Industrial Emission Factors 236
 - 3.4.1 Iron and Steel Industry 242
 - 3.4.2 Foundry Operations 254
 - 3.4.3 Nonferrous Metals Industries 257
 - 3.4.4 Sulfuric Acid Manufacturing 262
 - 3.4.5 Chemical Industry (Excluding Sulfuric Acid) 267
 - 3.4.6 Portland Cement Manufacturing 271
 - 3.4.7 Glass, Ceramics, and Mineral-Wool Industries 275
 - 3.4.8 Petroleum Industry 276
 - 3.4.9 Asphalt Industries 278
 - 3.4.10 Food Industries 279
 - 3.4.11 Clothing Industries 282
 - 3.4.12 Pulp and Paper Industry 284
- 3.5 Stationary Combustion Emission Factors 285
- 3.6 Transportation Emissions 323
- 3.7 Traffic vs. Emissions Study 349
- 3.8 Interstate Air Pollution Study 358

SECTION 4 AIR POLLUTION CONTROL MEASURES

- 4.1 Air Quality Criteria 375
- 4.2 Sample Regulations and Ordinances 388
- 4.3 Air Pollution Control Equipment 415
 - 4.3.1 Mechanical Collectors 429
 - 4.3.2 Filters 433
 - 4.3.3 Wet Collectors 442
 - 4.3.4 Electrical Precipitators 448
 - 4.3.5 Gas Adsorption Devices 453
 - 4.3.6 Absorption Devices 458
 - 4.3.7 Incinerators, Afterburners, and Exhaust Systems 467
- 4.4 Industrial Controls
 - 4.4.1 Iron and Steel Industry 476
 - 4.4.2 Foundry Operations 483
 - 4.4.3 Nonferrous Metals Industries 488
 - 4.4.4 Sulfuric Acid Manufacture 493
 - 4.4.5 Chemical Industry (Excluding Sulfuric Acid Manufacture) 496
 - 4.4.6 Portland Cement, Lime Plants 505
 - 4.4.7 Glass, Ceramics, and Mineral-Wool Industries 508
 - 4.4.8 Petroleum Industry 518
 - 4.4.9 Asphalt Industry 529
 - 4.4.10 Food Industries 534
 - 4.4.11 Industrial Ovens 539
 - 4.4.12 Resin and Varnish 545
- 4.5 Applications of Air Pollution Controls for Stationary Combustion 546

Conversion Factors 559

Index 567

Section I

The Atmosphere and Air Pollutants

1.1 Atmospheric Data

Pages 3–4

1.2 Air Pollutant Properties

Pages 5–46

1.3 Air Pollution Variables

Pages 47–60

1.4 Surveys

Pages 61–79

1.5 Sampling and Analysis

Pages 80–117

1.1 ATMOSPHERIC DATA

1.1-1 COMPONENTS OF THE ATMOSPHERE

1.1-1A AVERAGE COMPOSITION OF DRY AIR

For most applications the following accepted values for the average composition of the atmosphere are adequate. These values are for sea level or any land elevation. Proportions remain essentially constant to 50 000 ft altitude.

Gas	Molecular weight	Percentage by volume, mol fraction	Percentage by weight
Nitrogen	N ₂ = 28.016	78.09	75.55
Oxygen	O ₂ = 32.000	20.95	23.13
Argon	Ar = 39.944	0.93	1.27
Carbon dioxide	CO ₂ = 44.010	0.03	0.05
		100.00	100.00

For many purposes the percentages 79% N₂–21% O₂ by volume and 77% N₂–23% O₂ by weight are sufficiently accurate, the argon being considered as nitrogen with an adjustment of molecular weight to 28.16.

Other gases in the atmosphere constitute less than 0.003% (actually 27.99 parts per million by volume), as given in the following table.

1.1-1B MINOR CONSTITUENTS OF DRY AIR

Gas	Molecular weight	Parts per million	
		By volume	By weight
Neon	Ne = 20.183	18.	12.9
Helium	He = 4.003	5.2	0.74
Methane	CH ₄ = 16.04	2.2	1.3
Krypton	Kr = 83.8	1.	3.0
Nitrous oxide	N ₂ O = 44.01	1.	1.6
Hydrogen	H ₂ = 2.0160	0.5	0.03
Xenon	Xe = 131.3	0.08	0.37
Ozone	O ₃ = 48.000	0.01	0.02
Radon	Rn = 222.	(0.06 × 10 ⁻¹²)	

Minor constituents may also include dust, pollen, bacteria, spores, smoke particles, SO₂, H₂S, hydrocarbons, and larger amounts of CO₂ and ozone, depending on weather, volcanic activity, local industrial activity, and concentration of human, animal, and vehicle population. In certain enclosed spaces the minor constituents will vary considerably with industrial operations and with occupancy by humans, plants, or animals.

The above data do not include water vapor, which is an important constituent in all normal atmospheres.

Source: *Handbook of Tables for Applied Engineering Science*, R.E. Bolz and G. L. Tuve, Eds., The Chemical Rubber Co., Cleveland, O., 1970, p. 533.

1.1-2 U.S. STANDARD ATMOSPHERE

To 300 000 ft; 45° North Latitude, July

SYMBOLS:

Z , ft = geometric altitude, feet
 Z , m = geometric altitude, meters
 H , ft = geopotential altitude, feet
 t , °F = temperature, degrees Fahrenheit
 t , °C = temperature, degrees Celsius
 P , in. Hg = pressure, inches of mercury.
 For atmospheres multiply by
 0.033 421 0. For psia multiply
 by 0.491 154

ρ , English = density. For lb_m/ft³ multiply by 10⁻³
 ρ , metric = density. For kg/m³ multiply by 10⁻³
 V_s , fps = speed of sound, ft/sec. For m/sec multiply
 by 0.3048
 μ = viscosity. For lb_m/ft sec multiply by 10⁻⁵
 For g/cm sec (poises) multiply by 10⁻⁵ and
 by 14.882
 k = thermal conductivity. For Btu/sec ft °R
 multiply by 10⁻⁵. For W/cm °K multiply
 by 10⁻⁵ and by 62.306

Z , ft	H , ft	Z , m	t , °F	t , °C	P , in. Hg	ρ , English	ρ , metric	V_s , fps	μ	κ
0	0	0	73.5	23.1	29.93	74.4	1 192.	1.132	1.228	.417
1,000	1,000	305	70.7	21.4	28.89	72.2	1,157	1,129	1.223	.415
2,000	2,000	610	68.0	20.0	27.89	70.1	1,123	1,126	1.218	.413
3,000	3,000	915	65.2	18.4	26.91	68.0	1,090	1,123	1.213	.411
4,000	3,999	1,220	62.4	16.9	25.96	65.9	1,057	1,120	1.209	.409
5,000	4,999	1,525	59.7	15.4	25.05	63.9	1,025	1,117	1.204	.407
6,000	5,998	1,830	57.0	13.9	24.16	62.0	994	1,114	1.199	.405
7,000	6,998	2,135	53.9	12.2	23.30	60.1	964	1,111	1.193	.403
8,000	7,997	2,440	50.4	10.2	22.46	58.4	936	1,107	1.187	.401
9,000	8,996	2,745	46.9	8.3	21.65	56.6	908	1,103	1.180	.398
10,000	9,995	3,050	43.4	6.3	20.86	55.0	881	1,100	1.174	.396
11,000	10,994	3,355	40.0	4.4	20.09	53.3	855	1,096	1.168	.393
12,000	11,993	3,660	36.6	2.6	19.35	51.7	829	1,092	1.162	.391
13,000	12,992	3,965	33.2	.7	18.63	50.1	803	1,088	1.155	.389
14,000	13,991	4,270	29.8	-1.2	17.94	48.6	779	1,085	1.149	.386
15,000	14,990	4,575	26.5	-3.1	17.26	47.1	755	1,081	1.143	.384
16,000	15,988	4,880	23.1	-4.9	16.61	45.6	731	1,077	1.137	.381
17,000	16,986	5,185	19.7	-6.8	15.97	44.2	708	1,073	1.130	.379
18,000	17,984	5,490	16.4	-8.7	15.36	42.8	686	1,070	1.124	.377
19,000	18,983	5,795	13.0	-10.6	14.77	41.4	664	1,066	1.118	.374
20,000	19,981	6,100	9.61	-12.5	14.19	40.1	643	1,062	1.111	.372
21,000	20,979	6,405	6.02	-14.4	13.63	38.8	622	1,058	1.105	.369
22,000	21,977	6,710	2.44	-16.4	13.10	37.6	602	1,054	1.098	.367
23,000	22,975	7,015	-1.14	-18.4	12.57	36.4	583	1,050	1.091	.364
24,000	23,972	7,320	-4.72	-20.4	12.07	35.2	564	1,046	1.084	.361
25,000	24,970	7,625	-8.31	-22.4	11.58	34.0	545	1,042	1.077	.359
26,000	25,968	7,930	-11.9	-24.4	11.11	32.9	527	1,037	1.070	.356
27,000	26,965	8,235	-15.5	-26.4	10.65	31.8	510	1,033	1.063	.353
28,000	27,962	8,540	-19.0	-28.3	10.21	30.7	492	1,029	1.056	.351
29,000	28,960	8,845	-22.6	-30.4	9.79	29.7	476	1,025	1.049	.348
30,000	29,957	9,150	-26.2	-32.3	9.38	28.7	460	1,021	1.043	.346
32,000	31,951	9,760	-33.3	-36.3	8.60	26.7	428	1,012	1.029	.340
34,000	33,945	10,370	-40.4	-40.2	7.87	24.9	399	1,004	1.014	.335
36,000	35,938	10,980	-47.6	-44.2	7.19	23.1	371	995	1.000	.330
38,000	37,931	11,590	-54.7	-48.2	6.56	21.5	344	987	.986	.325
40,000	39,923	12,200	-61.8	-52.1	5.98	19.9	319	978	.972	.319
45,000	44,903	13,725	-71.5	-57.5	4.71	16.1	258	966	.952	.312
50,000	49,880	15,250	-71.5	-57.5	3.70	12.7	203	966	.952	.312
55,000	54,855	16,775	-71.5	-57.5	2.91	9.95	159	966	.952	.312
60,000	59,828	18,300	-68.8	-56.0	2.29	7.78	125	969	.957	.314
65,000	64,798	19,825	-65.6	-54.2	1.81	6.08	97.5	973	.964	.316
70,000	69,766	21,350	-62.3	-54.4	1.43	4.77	76.4	977	.970	.319
75,000	74,731	22,875	-59.0	-50.6	1.13	3.75	60.3	981	.977	.321
80,000	79,694	24,400	-55.8	-48.8	.898	2.95	47.2	985	.984	.324
85,000	84,655	25,925	-52.5	-46.9	.714	2.33	37.3	989	.990	.326
90,000	89,613	27,450	-48.7	-44.8	.569	1.84	29.4	994	.998	.329
100,000	99,523	30,500	-37.3	-38.5	.364	1.14	18.3	1,008	1.021	.337
125,000	124,255	38,125	-4.6	-20.3	.126	.368	5.90	1,046	1.084	.361
150,000	148,929	45,750	29.3	-1.50	.047	.129	2.06	1,084	1.148	.386
175,000	173,544	53,375	32.5	.28	.019	.0503	.807	1,088	1.154	.388
200,000	198,100	61,000	-1.2	-18.4	.0071	.0205	.329	1,050	1.091	.364
250,000	247,039	76,250	-116.2	-82.3	.0007	.0028	.0444	909	.857	.278
300,000	295,746	91,500	-156.6	-104.8	.00004	.0002	.0025	855	.770	.247

Source: U.S. Standard Atmosphere Supplements, U.S. Government Printing Office, 1966.

1.2 AIR POLLUTANT PROPERTIES

Air pollution is the presence in the ambient air of one or more contaminants, which can be naturally occurring or man-made. The quantities, characteristics, and duration of these contaminants are, or may tend to be, injurious to human, plant, and animal life or may interfere with the enjoyment of life or use of property.

1.2-1 CLASSIFICATION OF AIR POLLUTANTS

Major classes	Subclasses	Typical members
Inorganic gases	Oxides of nitrogen (NO_x) Oxides of sulfur (SO_x) Other inorganics	Nitrogen dioxide, nitric oxide Sulfur dioxide, sulfuric acid Ammonia, carbon monoxide, chlorine, hydrogen fluoride, hydrogen sulfide, ozone
Organic gases	Hydrocarbons Aldehydes, ketones Other organics	Benzene, butadiene, butene, ethylene, isooctane, methane Acetone, formaldehyde Acids, alcohols, chlorinated hydrocarbons, peroxyacyl nitrates, polynuclear aromatics
Aerosols	Solid particulate matter Liquid particulates	Dusts, smoke Fumes, oil mists, polymeric reaction-products

Source: *Environmental Biology*, P.L. Altman and D.S. Dittmer, Eds., Federation of American Societies for Experimental Biology, Bethesda, Md., 1966.

1.2-2 CHEMICAL AND PHYSICAL PROPERTIES OF POTENTIAL POLLUTANTS

ABBREVIATIONS USED:

A—specific gravity with reference to air = 1
 abs—absolute
 al—alcohol
 °C—Celsius degrees (all temperatures in Table 1.2-2 are in the Celsius system)
 c—cold
 cryst—crystal
 d—decomposes or decomposed
 d h—decomposes hot
 dil—dilute
 expl—explodes
 h—hot
 insol—insoluble
 ign—ignites
 m—meta position
 n—normal
 o—ortho position
 p—para position

prim—primary
 sol—soluble
 s abs—soluble in absolute alcohol
 s h—soluble hot
 sl d—slightly decomposed
 sl s—slight or slightly soluble
 subl—sublimes
 v—very
 v s—very soluble
 v s h—very soluble hot
 v sl—very slight or very slightly
 v sl s—very slightly soluble
 ∞—soluble in all proportions
 -O 800 loses an atom of oxygen at 800°C
 α—alpha form or position
 β—beta form or position
 ω—omega position

TABLE 1.2-2A

Element, compound, or other substance	Chemical formula	Specific gravity or density	Solubility in 100 parts	
			Water	Alcohol
Acetaldehyde (ethanal)	CH ₃ ·CHO	0.783 ^{1.3} / ₄ [°]	∞	∞
Acetic acid (ethanoic acid)	CH ₃ ·COOH	1.049 ^{2.0} / ₄ [°]	∞	∞
Acetic anhydride	(CH ₃ CO) ₂ O	1.082 ^{2.0} / ₄ [°]	12 c; d h	∞
Acetone (propanone)	CH ₃ ·CO·CH ₃	0.792 ^{2.0} / ₄ [°]	∞	∞
Acetylene tetrachloride (sym-tetrachloroethane)	Cl ₂ CH·CHCl ₂	1.600 ^{2.0} / ₄ [°]	insol	∞
Acrolein (acrylic aldehyde)	CH ₂ :CH·CHO	0.841 ^{2.0} / ₄ [°]	40	sol
Acrylonitrile (vinyl cyanide)	CH ₂ :CH·CN	0.811 ^{2.0} / ₄ [°]	sol	—
Allyl ether (diallyl ether)	(CH:CH·CH ₂) ₂ O	0.826 ^{2.0} / ₄ [°]	0.3	∞
Ammonia	NH ₃	0.817 ^{-7.9} / ₄ [°]	89.9 ⁰ / ₄ [°] 7.4 ^{9.6} / ₄ [°]	14.8 ^{2.0} / ₄ [°]
Amyl acetate (iso) (common amyl acetate)	CH ₃ CO ₂ ·(CH ₂) ₄ ·CH: (CH ₃) ₂	0.876 ^{1.5} / ₄ [°]	0.25 ^{1.5} / ₄ [°]	∞
Amyl alcohol (prim iso) (2-methyl-butanol-4)	(CH ₃) ₂ CH·CH ₂ CH ₂ OH	0.813 ^{1.5} / ₄ [°]	2 ^{1.4} / ₄ [°]	∞
n-Amyl butyrate	C ₂ H ₅ CH ₂ CO ₂ (CH ₂) ₄ ·CH ₃	0.871 ^{1.5} / ₄ [°]	0.05 ^{5.0} / ₄ [°]	∞
n-Amyl formate	HCO ₂ ·C ₅ H ₁₁	0.902 ⁴ / ₄ [°]	v sl s	∞
n-Amyl nitrite	C ₅ H ₁₁ ·O·NO	0.853 ^{2.0} / ₄ [°]	sl s	∞
Aniline (aminobenzene)	C ₆ H ₅ ·NH ₂	1.022 ^{2.0} / ₄ [°]	3.6 ^{1.8} / ₄ [°]	∞
Arsenic (black)	As ₄	4.7 ^{2.0} / ₄ [°]	insol	—
Arsenic trichloride (butter of arsenic)	AsCl ₃	liq 2.163	d	—

1.2-2 CHEMICAL AND PHYSICAL PROPERTIES OF POTENTIAL POLLUTANTS (Continued)

TABLE 1.2-2A

Element, compound, or other substance	Chemical formula	Specific gravity or density	Solubility in 100 parts	
			Water	Alcohol
Arsine (arsenous hydride)	AsH ₃	2.695(A)	20 cc	—
Asbestos	—	—	—	—
Barium peroxide	BaO ₂	4.958	v sl s	—
Benzene (benzol)	C ₆ H ₆	0.879 ²⁰ / ₄	0.07 ²⁰	∞
Benzoyl chloride	C ₆ H ₅ ·CO·Cl	1.212 ²⁰ / ₄	d	abs al
Benzyl amine (ω-aminotoluene)	C ₆ H ₅ ·CH ₂ ·NH ₂	0.982 ²⁰ / ₄	∞	d h ∞
Beryllium	Be	—	—	—
Bromine	Br ₂	3.2 ⁰ / ₄	3.13 ³⁰	sol
Bromobenzene (phenyl bromide)	C ₆ H ₅ Br	1.495 ²⁰ / ₄	insol	sol
Bromoethane (ethyl bromide)	C ₂ H ₅ ·Br	1.460 ²⁰ / ₄	1.06 ⁰ 0.9 ³⁰	∞
Bromoethylene (vinyl bromide)	CH ₂ :CH·Br	1.529 ¹⁴ / ₀	insol	∞
Bromopropane (propyl bromide)	CH ₃ ·CH ₂ ·CH ₂ ·Br	1.353 ²⁰ / ₄	0.25 ²⁰	∞
ω-Bromotoluene (benzyl bromide)	C ₆ H ₅ ·CH ₂ ·Br	1.443 ¹⁷ / ₀	insol; sl d	∞
Bromoxylene (bromo- <i>o</i> -xylene[3])	Br·C ₆ H ₃ ·(CH ₃) ₂	1.365 ²⁰ / ₄	insol	—
1,3-Butadiene (erythrene)	CH ₂ :CH·CH:CH ₂	0.621 ²⁰ / ₄	insol	∞
Butane (diethyl)	CH ₃ ·CH ₂ ·CH ₂ ·CH ₃	liq 0.60 ⁰	15 cc ¹⁷ / ₇₇₂	1 883 ¹⁷ / ₇₇₃
<i>n</i> -Butanol	C ₂ H ₅ ·CH ₂ ·CH ₂ OH	0.810 ²⁰ / ₄	91 ⁵ / ₀	∞
2-Butanone (methyl ethyl ketone)	CH ₃ ·CO·C ₂ H ₅	0.805 ²⁰ / ₄	37	∞
1-Butene (butylene)	C ₂ H ₅ ·CH:CH ₂	liq 0.6 ⁹ / ₀	insol	v s
<i>n</i> -Butyl acetate	CH ₃ CO ₂ ·(CH ₂) ₃ ·CH ₃	0.882 ²⁰ / ₀	0.7	∞
<i>n</i> -Butyl cellosolve	C ₄ H ₉ ·O·CH ₂ CH ₂ OH	0.903 ²⁰ / ₀	∞	∞
<i>n</i> -Butyl formate	HCO ₂ ·(CH ₂) ₃ ·CH ₃	0.911 ⁰ / ₀	v sl s	∞
Butyl ether (<i>n</i> -dibutyl ether)	(C ₂ H ₅ ·CH ₂ ·CH ₂) ₂ O	0.769 ²⁰ / ₀	<0.05	∞
<i>n</i> -Butyl nitrite	C ₄ H ₉ ·O·NO	0.911 ⁰ / ₀	—	∞
Cacodyl oxide (cacodylic oxide)	[(CH ₃) ₂ As] ₂ O	1.486 ¹⁵ / ₀	sl s	sol
Cadmium	Cd	8.65 ²⁰ / ₀	insol	—
Carbon dioxide	CO ₂	solid 1.56 ⁻⁷⁹ / ₀	179.7 cc ⁰ / ₀ 90.1 cc ²⁰ / ₀	—
Carbon disulfide	CS ₂	liq 1.261 ²² / ₀	0.2 ⁰ 0.014 ⁵⁰ / ₀	∞
Carbon monoxide	CO	liq 0.814 ⁻¹⁹⁵ / ₄	0.004 4 ⁰	sol
Carbon tetrachloride	CCl ₄	1.595 ²⁰ / ₄	0.001 8 ⁵⁰ / ₀ 0.097 ⁰ 0.08 ²⁰ / ₀	∞

1.2-2 CHEMICAL AND PHYSICAL PROPERTIES OF POTENTIAL POLLUTANTS (Continued)

TABLE 1.2-2A

Element, compound, or other substance	Chemical formula	Specific gravity or density	Solubility in 100 parts	
			Water	Alcohol
Cellosolve (2-ethoxy-ethanol-1)	$C_2H_5 \cdot O \cdot (CH_2)_2 OH$	$0.931 \frac{20}{4}^{\circ}$	∞	∞
Cellosolve acetate	$CH_3CO_2C_4H_9O$	$0.975 \frac{20}{4}^{\circ}$	22	∞
Chlorine	Cl_2	liq $1.56 \frac{33.6}{4}^{\circ}$	$1.46^{\circ} g$ $310 cc^{100}$	—
Chlorine dioxide (chlorine peroxide)	ClO_2	$2.4^{11} (A)$	$2\ 000 cc^4$	expl
Chlorine monoxide	Cl_2O	$2.9 (A)$	$20\ 000 cc^{00}$	expl
Chloroacetone	$Cl \cdot CH_2 \cdot CO \cdot CH_3$	1.162^{16}°	∞	∞
Chlorobenzene (phenyl chloride)	$C_6H_5 \cdot Cl$	$1.107 \frac{20}{4}^{\circ}$	insol	∞
2-Chlorobutadiene (chloroprene)	$CH_2 : CCl : CH : CH_2$	$0.958 \frac{20}{4}^{\circ}$	sl s	∞
<i>o</i> -Chlorodiphenyl (chlorobiphenyl)	$Cl \cdot C_6H_4 \cdot C_6H_5$	—	insol	—
Chloroform (trichloromethane)	$CHCl_3$	1.489^{20}°	0.82^{20}°	∞
Chloronaphthalenes (see penta- and trichloronaphthalenes)				
1-Chloro-1-nitropropane	$C_2H_5 \cdot CH(Cl)NO_2$	$1.209 \frac{20}{4}^{\circ}$	$<0.8^{20}^{\circ}$	—
Chloropicrin (nitrochloroform)	$NO_2 \cdot CCl_3$	$1.651 \frac{24.8}{4}^{\circ}$	0.17^{18}°	37 cc 80% al
Chloropropane (<i>n</i> -propyl chloride)	$CH_3 \cdot CH_2 \cdot CH_2Cl$	$0.890 \frac{20}{4}^{\circ}$	0.27^{20}°	∞
3-Chloropropene-1 (allyl chloride)	$CH_2 : CH \cdot CH_2Cl$	$0.938 \frac{20}{4}^{\circ}$	<0.1	∞
ω -Chlorotoluene (benzyl chloride)	$C_6H_5 \cdot CH_2 \cdot Cl$	$1.100 \frac{20}{4}^{\circ}$	insol	∞
Chlorovinylchloro- arsine (Lewisite)	$ClCH : CH \cdot AsCl_2$	$1.888 \frac{20}{4}^{\circ}$	insol	—
Chloroxylene (<i>o</i> -xylylchloride)	$Cl \cdot C_6H_3(CH_3)_2$		insol	∞
Chromic acid (chromium trioxide)	CrO_3	2.70	164.9^{90}	sol
<i>o</i> -Cresol	$CH_3 \cdot C_6H_4 \cdot OH$	$1.048 \frac{20}{4}^{\circ}$	2.5	∞^{30}°
<i>m</i> -Cresol	$CH_3 \cdot C_6H_4 \cdot OH$	$1.034 \frac{20}{4}^{\circ}$	0.5	∞
<i>p</i> -Cresol	$CH_3 \cdot C_6H_4 \cdot OH$	$1.035 \frac{20}{4}^{\circ}$	1.8	∞^{36}°
Cyanogen	C_2N_2	liq $0.866^{-17.2}^{\circ}$	$450 cc^{20}^{\circ}$	$2\ 300 cc^{20}^{\circ}$
Cyanogen bromide	$Br \cdot CN$	2.015^{20}°	sol	sol
Cyanogen chloride	$Cl \cdot CN$	1.222^{00}°	$2\ 500 cc^{20}^{\circ}$	$10\ 000 cc^{20}^{\circ}$
Cyclohexane (benzene hexahydride)	$CH_2 \cdot (CH_2)_4 \cdot CH_2$	$0.779 \frac{20}{4}^{\circ}$	insol	∞
Cyclohexanol (hexahydrophenol)	$CH_2 \cdot (CH_2)_4 \cdot CHOH$	$0.962 \frac{20}{4}^{\circ}$	3.6^{20}°	sol
Cyclohexanone (pimelin ketone)	$CH_2 \cdot (CH_2)_4 \cdot CO$	$0.947 \frac{19}{4}^{\circ}$	sol	sol
Cyclohexene (benzene tetrahydride)	$CH_2(CH_2)_3 \cdot CH : CH$	$0.810 \frac{20}{4}^{\circ}$	v sl s	v s