AN INTRODUCTION TO

INDUSTRIAL CHEMISTRY

2nd Edition

Edited by C A Heaton

an introduction to Industrial Chemistry

Second Edition

Edited by CR Heaton

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Also edited by C. A. Heaton

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The Chemical Industry (a complementary volume)

Contents: Editorial introduction C. A. Heaton. Polymers J. P. Candlin. Dyestuffs E. N. Abrahart. The chlor-alkali, sulphur, nitrogen and phosphorus industries D. R. Browning. The pharmaceutical industry C. W. Thornber. Agrochemicals C. A. Heaton. Biological catalysis and biotechnology M. K. Turner. The future C. A. Heaton. References Index

Preface to First Edition

The chemical industry is a major, growing influence on all our lives, encompassing household commodities and utensils, industrial materials and components, medicines and drugs, and the production of chemicals has become an essential factor in the economy of any industrialized nation. The scientists and engineers responsible for the efficient operation of the industry must have a sound knowledge not only of the physical and chemical principles, but also of the economic and environmental aspects and the cost-effective use of energy.

This book provides an introduction to these topics and includes detailed discussion of catalysis and petrochemicals. It is written as a basis from which students of chemistry and chemical engineering will be able to build an understanding and appreciation of the industry.

Acknowledgements

An undertaking of this nature requires teamwork and it is a pleasure to acknowledge the efforts and cooperation of the contributors. Thanks are also due to the publishers for their help and advice at all times. Finally, I wish to thank my wife Joy for typing part of the MS and for the support which she and our children, Susan and Simon, have given.

C.A.H.

Preface to Second Edition

The first edition of this book has been very well received and the few minor criticisms made by reviewers were largely answered by the publication of the complementary book—The Chemical Industry by C. A. Heaton (referred to as Volume 2)—which was in preparation at the time. This covers each of the major sectors of the chemical industry. They are designed to be used as a two volume set and the contents of Volume 2 are listed on page ii of this volume. We have, however, taken the opportunity in this second edition to add two new chapters: Chapter 1, Introduction to the chemical industry which gives both an overview of the industry and a lead into other chapters, and Chapter 9, Chlor-alkali products which provides a balance on the inorganic side to the Petrochemicals chapter on the organic side, plus leading into Chapter 3 of Volume 2 (The chlor-alkali, sulphur, nitrogen and phosphorus industries). Almost all statistics and tables have been updated as have references and bibliographies, where appropriate, and it is a pleasure to record that this has been done by the original team of authors. The new edition also reflects the changed situation of the industry which is currently riding high, in contrast to the recession when the first edition was written. Issues which have become more topical during the last few years, mostly environmental concerns, are also given increased coverage.

We hope you enjoy reading this new edition and find it both informative and interesting.

C.A.H.

Note

Where reference is made to West Germany this is because no figures were available for the newly combined Germany at the time of printing.

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Conversion factors

Mass

```
1 tonne (metric ton) = 1000 kilograms = 2205 pounds
= 0.984 tons
1 ton = 1016 kilograms = 2240 pounds
= 1.016 tonnes
```

Volume

```
1 litre = 0.220 gallons (U.K. or Imperial) = 1 cubic metre
```

1 gallon = 4.546 litres

1 gallon = 1.200 U.S. gallons = 0.00455 cubic metres

1 barrel = 42 U.S. gallons = 35 gallons = 0.159 cubic metres

(Densities of crude oil vary, but 7.5 barrels per tonne is an accepted average figure.)

1 cubic metre = 35.31 cubic feet

1 cubic foot = 0.02832 cubic metres

Pressure

```
1 atmosphere = 1.013 bar = 14.696 pounds per square inch
= 1.013 \times 10^5 newtons per square metre
= 1.013 \times 10^5 pascal
```

Temperature

Degrees Centigrade = 0.556 (degrees Fahrenheit - 32) Degrees Fahrenheit = 1.80 (degrees Centigrade) + 32 Degrees Kelvin = degrees Centigrade + 273

Energy

1 therm = 100 000 British thermal units 1 British thermal unit = 0.252 kilocalories = 1.055 kilojoules 1 kilocalorie = 4.184 kilojoules 1 kilowatt hour = 3600 kilojoules = 859.8 kilocalories = 3412 British thermal units.

Power

1 horsepower = 0.746 kilowatts

1 kilowatt = 1.34 horsepower

Nomenclature of organic compounds

Common or trivial name	Systematic (or IUPA name	C) Structure
(a) Classes of compound	ls	
Paraffin Cycloparaffins or Naphthenes Olefins Acetylenes Methacrylates	Alkane Cycloalkanes Alkenes Alkynes 2-Methylpropenoates	$\begin{array}{c} -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ $
(b) Individual compound	ls	3
Ethylene Propylene	Ethene Propene	$CH_2 = CH_2$ $CH_3CH = CH_2$
Styrene	Phenylethene	CH=CH ₂
Acetylene Isoprene	Ethyne 2-Methylbuta-1, 3-diene	$H-C \equiv C-H$ $CH_2 = C-CH = CH_2$ CH_3
Ethylene oxide	Oxirane	CH_2 CH_2
Propylene oxide	1-Methyloxirane	CH3-CH-CH2
Methyl iodide Methyl chloride Methylene dichloride Chloroform Carbon tetrachloride Vinyl chloride Ethylene dichloride Allyl chloride	Iodomethane Chloromethane Trichloromethane Tetrachloromethane Chloroethene 1, 2-Dichloroethane 3-Chloropropene	$\begin{array}{c} \text{CH}_3\text{I} \\ \text{CH}_3\text{Cl} \\ \text{CH}_2\text{Cl}_2 \\ \text{CHCl}_3 \\ \text{CCl}_4 \\ \text{CH}_2 = \text{CH} - \text{Cl} \\ \text{ClCH}_2\text{CH}_2\text{Cl} \\ \text{CH}_2 = \text{CH} - \text{CH}_2 - \text{Cl} \end{array}$

Chloroprene	2-Chlorobuta-1, 3-diene	CH ₂ =C-CH=CH ₂
Epichlorohydrin	1-Chloromethyloxirane	CICH2CH—CH2
Ethylene glycol Propargyl alcohol Allyl alcohol iso-Propanol	Ethane-1, 2-diol Prop-2-yn-1-ol Prop-2-en-1-ol 2-Propanol	HOCH ₂ CH ₂ OH H−C≡C−CH ₂ OH CH ₂ =CH−CH ₂ OH CH ₃ CHCH ₃
Glycerol	Propane-1, 2, 3-triol	OH HOCH ₂ —CH—CH ₂ OH
sec-Butanol	2-Butanol	OH CH ₃ CHCH ₂ CH ₃
		OH CH₂OH
Pentaerythritol	2, 2-Di (hydroxymethyl) propane-1, 3-diol	HOCH ₂ —C—CH ₂ OH CH ₂ OH
Lauryl alcohol Acetone Methylisobutyl ketone	Dodecanol Propanone 4-Methylpentan-2-one	CH ₂ OH CH ₃ (CH ₂) ₁₀ CH ₂ OH CH ₃ COCH ₃ CH ₃ COCH ₂ CHCH ₃
Formaldehyde Acetaldehyde Chloral Propionaldehyde Acrolein Butyraldehyde Formic acid Methyl formate Acetic acid Acetic anhydride Peracetic acid Vinyl acetate Acrylic acid Dimethyl oxalate Propionic acid Methyl methacrylate	Methanal Ethanal 2, 2, 2-Trichloroethanal Propanal Propenal Butanal Methanoic acid Methyl methanoate Ethanoic acid Ethanoic anhydride Perethanoic acid Ethenyl ethanoate Propenoic acid Dimethyl ethanedioate Propanoic acid Methyl 2-methylpropenoate	CH ₃ HCHO CH ₃ CHO CH ₃ CHO CH ₃ CCHO CH ₃ CH ₂ CHO CH ₂ =CHCHO CH ₂ =CHCHO HCO ₂ H HCO ₂ CH ₃ CH ₃ CO ₂ H (CH ₃ CO) ₂ O CH ₃ CO ₃ H CH ₂ =CHO ₂ CCH ₃ CH ₂ =CH-CO ₂ H CO ₂ CH ₃ CO ₂ CH ₃ CH ₃ CO ₂ H CO ₂ CH ₃ CH ₃ CO ₂ H CO ₂ CH ₃ CH ₃ CO ₂ CH

7411	NOMENCEATURE OF ORGANIC COM	OCINES
Maleic acid	cis-Butenedioic acid	H_C_CO2H H_C_CO2H
Maleic anhydride	cis-Butenedioic anhydride	H C - C O
Citric acid	2-Hydroxypropane-1,2,3- tricarboxylic acid	CH_2CO_2H $HO-C-CO_2H$ CH_2CO_2H
Methyl laurate Stearic acid Acrylonitrile Adiponitrile Urea Ketene	Methyl dodecanoate Octadecanoic acid Propenonitrile Hexane-1, 6-dinitrile Carbamide Ethenone	CH_2CO_2H $CH_3(CH_2)_{10}CO_2CH_3$ $CH_3(CH_2)_{16}CO_2H$ $CH_2=CH-CN$ $NC-(CH_2)_6-CN$ H_2NCONH_2 $CH_2=C=O$
Toluene	Methylbenzene	€H ₃
Aniline	Phenylamine	NH ₂
Cumene	iso-Propylbenzene	CH ₃ CH ₃
Benzyl alcohol	Phenylmethanol	CH ₂ OH
o-Xylene	1,2-Dimethylbenzene	CH ₃
m-Xylene	1, 3-Dimethylbenzene	CH ₃
p-Xylene	1,4-Dimethylbenzene	CH ₃
Phthalic acid	Benzene-1, 2-dicarboxylic acid	СО ₂ Н СО ₂ Н

Isophthalic acid	Benzene-1, 3-dicarboxylic acid	CO2H CO2H
Terephthalic acid	Benzene-1, 4-dicarboxylic acid	CO₂H CO₂H
o-Toluic acid	2-Methylbenzoic acid	СО ₂ Н СН ₃
p-Toluic acid	4-Methylbenzoic acid	CO₂H CH₃
p-Tolualdehyde	4-Methylbenzaldehyde	€H ₃
Benzidine	4,4'-Biphenyldiamine	H_2N NH_2
Furfural	2-Formylfuran	ОСНО

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