Chemistry in Action

Chemistry in Action

Michael Freemantle

M
MACMILLAN

© Michael Freemantle 1987

All rights reserved. No reproduction, copy or transmission of this publication may be made without written permission.

No paragraph of this publication may be reproduced, copied or transmitted save with written permission or in accordance with the provisions of the Copyright, Designs and Patents Act 1988, or under the terms of any licence permitting limited copying issued by the Copyright Licensing Agency, 90 Tottenham Court Road, London W1P 9HE.

Any person who does any unauthorised act in relation to this publication may be liable to criminal prosecution and civil claims for damages.

First published 1987 by
THE MACMILLAN PRESS LTD
Houndmills, Basingstoke, Hampshire RG21 2XS
and London
Companies and representatives
throughout the world

ISBN 978-0-333-37310-1   ISBN 978-1-349-18541-2 (eBook)
DOI 10.1007/978-1-349-18541-2

A catalogue record for this book is available
from the **British Library**.

Reprinted (with corrections) 1987, 1989, 1990, 1991, 1992, 1993

CONTENTS

Preface	viii
Acknowledgements	ix
1 ATOMIC STRUCTURE	1
1.1 Sub-atomic particles	3
1.2 The electronic structure of atoms	12
1.3 Radioactivity	25
2 CHEMICAL BONDS	55
2.1 The nature of chemical bonds	56
2.2 The influence of bonding on size, shape, structure and properties	72
3 GASES, LIQUIDS AND SOLIDS	85
3.1 Gases and liquids	87
3.2 Solids	103
4 STOICHIOMETRY	119
4.1 Stoichiometry and nomenclature	122
4.2 Stoichiometric calculations	132
5 ENERGETICS	147
5.1 Thermodynamics	150
5.2 Enthalpies	155
5.3 Energy and structure	168
5.4 Energy sources	185
6 PHASE EQUILIBRIA	201
6.1 Equilibria and phases	203
6.2 Multicomponent systems	210
6.3 Colligative properties, colloids and chromatography	228
7 CHEMICAL EQUILIBRIA	247
7.1 The equilibrium constant	250
7.2 Manufacture of ammonia and sulphuric acid	257

8	IONS	271
8.1	Acids and bases	274
8.2	Salts, solubility and stability	287
9	CHEMICAL KINETICS	307
9.1	Rates of chemical reactions	309
9.2	Reaction mechanisms and catalysis	323
10	ELECTROCHEMISTRY	345
10.1	Conduction	347
10.2	Redox	354
10.3	Electrolysis	361
10.4	Electrochemical cells	368
10.5	Applications of electrochemistry	376
11	PERIODICITY	395
11.1	Periodicity	397
12	HYDROGEN AND WATER	419
12.1	Hydrogen	422
12.2	Water	432
13	THE s-BLOCK METALS	449
13.1	Structure and properties of the metals	451
13.2	Compounds formed by the s-block metals	458
13.3	Occurrence, manufacture and uses	470
14	THE d-BLOCK ELEMENTS	493
14.1	Structure and properties of the d-block elements	496
14.2	Chemistry of seven d-block elements	504
14.3	Occurrence, extraction and uses	513
15	GROUPS III TO VI	533
15.1	Aluminium and the Group III elements	536
15.2	Group IV	546
15.3	Group V: nitrogen and phosphorus	561
15.4	Group VI: oxygen and sulphur	579
16	THE HALOGENS AND THE NOBLE GASES	595
16.1	The halogens	598
16.2	Halogen compounds	603
16.3	Occurrence, manufacture and uses	611
16.4	The noble gases	622
17	FUNDAMENTALS OF ORGANIC CHEMISTRY	629
17.1	Organic chemistry	634
17.2	Molecular geometry of organic compounds	654
17.3	Reaction mechanisms in organic chemistry	663
18	HYDROCARBONS	677
18.1	Aliphatic hydrocarbons	680
18.2	Arenes	695
18.3	Occurrence, production and uses	707

19 FUNCTIONAL GROUPS	727
19.1 Organic halogen compounds	730
19.2 Alcohols, phenols and ethers	740
19.3 The carbonyl group	755
19.4 Amines and related compounds	782
20 NATURAL PRODUCTS AND POLYMERS	801
20.1 Amino acids, peptides and proteins	804
20.2 Carbohydrates and nucleic acids	813
20.3 Fats, oils and other natural products	828
20.4 Polymers	838
APPENDICES	853
ANSWERS TO NUMERICAL PROBLEMS	861
INDEX	865

PREFACE

Chemistry in Action aims to provide a modern, comprehensive and systematic treatment of the core chemistry required to advanced level standard. The content is based on a rigorous analysis of the most recently available syllabuses of the following examining boards: AEB, UCLES, JMB, L, NISEC, OLE, O & C and SUJB. It also covers all the inter-board common core in chemistry published by the GCE Boards in a booklet entitled *Common Cores at Advanced Level* (1983).

The book is structured and written in a style that gives easy access to the theory and knowledge of chemistry needed by 'A' level students: learning objectives, summaries and examination questions are included to help guide the student through his or her studies. The book is also designed to stimulate and sustain the interest of the student in chemistry. Numerous examples of 'chemistry in action' in both developed countries and the developing world are included to demonstrate the importance and relevance of chemistry in industry, society, the environment, history and literature.

Each chapter begins with a short article or extract from a magazine, journal or book. The aim of this is not only to show the broad relevance of chemistry but also to draw the student into the chapter. The learning objectives which follow relate to the entire chapter. The chapter is then split into several sections, each of which is devoted to a major topic. Summaries are provided at the end of each section and examination questions at the end of each chapter. The answers to these questions (given at the end of the book) are my sole responsibility. Boxed items and photographs have two main functions. First, they provide examples of 'chemistry in action'. Secondly, they are included to stimulate the interest of the student.

The content of the book develops in a conventional manner. The first 10 chapters are devoted to physical chemistry. The chapters on inorganic chemistry follow the order of the groups in the Periodic Table – moving from left to right. The final four chapters are devoted to organic chemistry.

The chemical nomenclature, symbols and terminology used in this book are based on the recommendations of the Association of Science Education published in *Chemical Nomenclature, Symbols and Terminology for Use in School Science* (Third Edition, 1985).

I would like to thank Denise Johnston-Burt for providing the initial inspiration for this book and also Mary Waltham and her colleagues at Macmillan Education for their continuous support and hard work throughout the various stages of the book. Finally, I would like to thank my family for their encouragement and understanding whilst I was writing it.

November, 1986

Michael Freemantle

ACKNOWLEDGEMENTS

The author and publishers wish to thank the following who have kindly given permission for the use of copyright material:

The Associated Examining Board, Joint Matriculation Board, Northern Ireland Schools Examination Council, Oxford and Cambridge Schools Examination Board, Scottish Examination Board, Southern Universities' Joint Board, University of Cambridge Local Examinations Syndicate, University of London School Examinations Board, University of Oxford Delegacy of Local Examinations and the Welsh Joint Education Committee for questions from past examination papers.

The Association for Science Education for an extract and tables from *Chemical Nomenclature, Symbols and Terminology for Use in School Science*, Third edition, 1985.

Bell & Hyman Ltd for a diagram from *Fifth Form Chemistry* by K. H. Farrah, 1966 and from *Modern Physical Chemistry* by G. F. Liptrot, J. J. Thompson and G. R. Walker, 1982.

The Bodley Head for an extract from *Ulysses* by James Joyce.

Chemistry International for 'Chemistry's Cornucopia' by Sir George Porter, 1986, Vol. 8, No. 1; 'Periodicity' by Norman E. Holden, 1984, No. 6; and an extract from 'What's in a Name', 1985, Vol. 7, No. 5.

Chatto & Windus Ltd for '*Dulce et Decorum Est*' from *The Collected Poems of Wilfred Owen* edited by C. Day Lewis.

Longman Group Ltd for figures from *Chemistry: Facts, Patterns and Principles* by Kneen, 1972, Addison Wesley.

Methuen & Co. for adapted figure from *Chain Reactions: An Introduction* by F. S. Dainton, 1956.

New Internationalist Publications Ltd for material from October (1984) and January (1980) editions of *New Internationalist*.

New Scientist for 'Understanding the Electron' by L. Milgrom and I. Anderson (27.10.83) and 'The Poor World Needs Chemists' by M. Freemantle (28.4.83); and for 'The Dead Sea' by D. Neev and K. O. Emery, *Science Journal*, December, 1966.

Newsweek, Inc for 'The Physics of Chemistry' by S. Begley (2.11.81) and an extract from 'Snow's Flaky Little Secrets' by S. Begley and J. Carey (16.1.84).

The Observer for 'Superbugs Start to Buzz' by J. McLoughlin (13.9.81) and an extract from 'Chaos = Gas' by J. Wain (10.10.82).

The Royal Society for a figure from British Library R&D Report No. 5626, *A Study of the Scientific Information System in the United Kingdom*, 1981.

The Royal Society of Chemistry for extracts from: 'Neither Le Chatelier's nor a Principle?' by J. and V. Gold, Sept. 1984; 'Hydrocarbons' by J. Brooks, May, 1983; 'The Firework Industry' by R. Lancaster; and 'Bhopal's Poison Gas Tragedy — Could it Happen in Britain?', Feb., 1985, all from *Chemistry in Britain*. Also for extracts from: 'Two British Women Chemists' by G. W. Rayner-Canham, July, 1983; and 'Trimethylamine — A Pungent Experience' by G. R. Willey, Nov., 1985, all from *Education in Chemistry*.

Times Newspapers Ltd for 'The Universe Strikes Back' (27.5.84) by B. Silcock and 'Crystal but not so Clear' (18.12.83) by B. Silcock from *The Sunday Times*.

World Bank for data from *World Development Report* 1985(6), Oxford University Press, New York, 1985(6).

Academic Press for the figure from Brooks, J.(ed.), *Organic Maturation Studies and Fossil Fuel Exploration* (1981).

The author and publishers wish to acknowledge, with thanks, the following photographic sources:

Aerofilms; Albright and Wilson, Australia; Author/IUPAC photographs; Basingstoke and District Hospital; BBC Hulton Picture Library; Courtesy of BDH Chemicals Ltd, Dorset; Biomedicinska Centrum, Uppsala, Sweden; Biophoto Associates; Niels Bohr Institutet, Copenhagen; Courtesy of British Airways; British Nuclear Fuels Ltd; Jim Brownbill; Camera Press, London; J. Allan Cash; CERN; CIBA GEIGY Ltd; FAO photographs J. Van Acker; G. de Sabatino; E. Kennedy; F. Mattioli; F. Botts; Michael Freemantle; Fife News; International Labour Office; ISC Chemicals Ltd; IUPAC; Kinetico/Indusfoto; Lilly Industries Ltd; Museum of Science and Industry, Manchester; NASA; Nobelstiftelsen; OXFAM; Popperfoto; RTZ Photographic Library; Science Photo Library, London; Shell Photographic Service; Snamprogetti Ltd; Courtesy of SRI-Asia; Alan Thomas; Courtesy of the Tourist Office, Lyon, France; UAC International; UNESCO photographs W. Behreuat; K. Chernush; Paul Almasy; J. H. A. Kleijo; D. Roger; Leon Herschtritt; Sunil Jonah; M. Serrailier; F. Boissonnet; UNICEF photographs Sennett; Jacques Danois; Arild Vollan; United Nations; WHO photographs J. Mohr; A. S. Kochar; R. de Silva; K. E. Mott; T. Kelly; P. Larsen; P. Pittet; W. Wiese.

The publishers have made every effort to trace the copyright holders, but if they have inadvertently overlooked any, they will be pleased to make the necessary arrangements at the first opportunity.