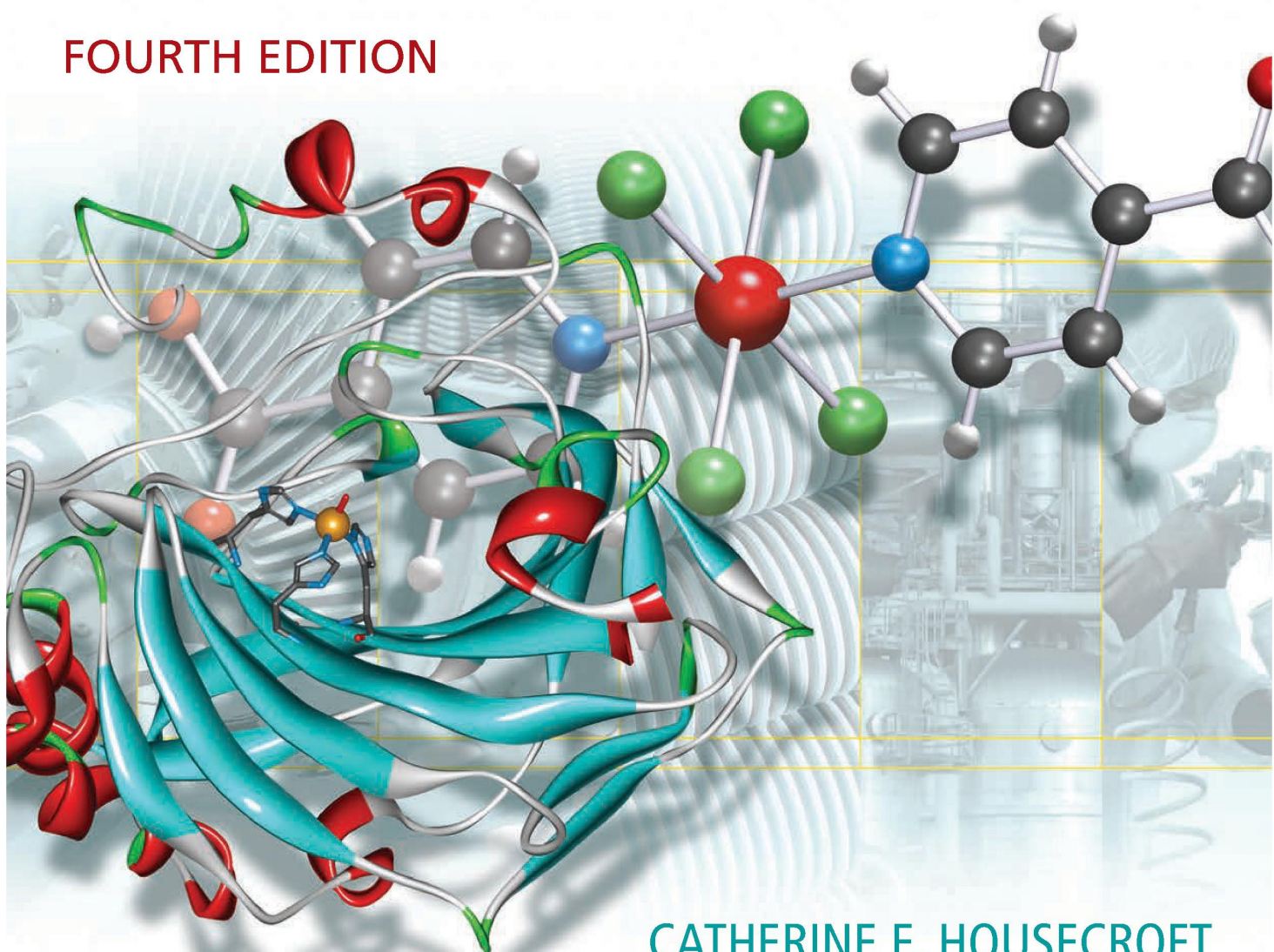


INORGANIC CHEMISTRY

FOURTH EDITION



CATHERINE E. HOUSECROFT
AND ALAN G. SHARPE

ALWAYS LEARNING

PEARSON

UM00005301

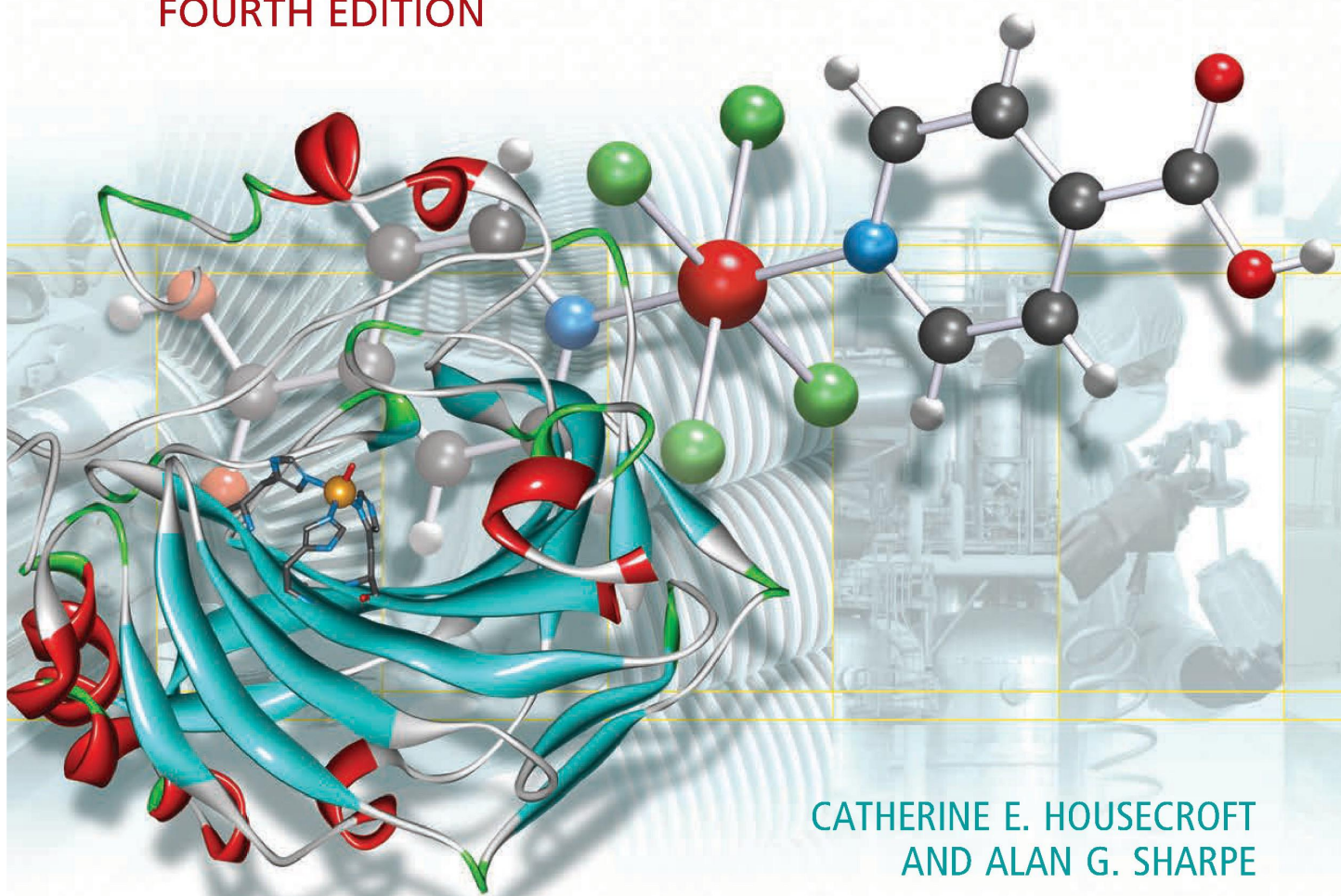
NOVARTIS EXHIBIT 1572

Novartis v. Regents, IPR2023-01347

Page 1 of 4

INORGANIC CHEMISTRY

FOURTH EDITION



CATHERINE E. HOUSECROFT
AND ALAN G. SHARPE

PEARSON

Harlow, England • London • New York • Boston • San Francisco • Toronto • Sydney • Auckland • Singapore • Hong Kong
Tokyo • Seoul • Taipei • New Delhi • Cape Town • São Paulo • Mexico City • Madrid • Amsterdam • Munich • Paris • Milan

UM00005302

NOVARTIS EXHIBIT 1572

Novartis v. Regents, IPR2023-01347

Page 2 of 4

Pearson Education Limited

Edinburgh Gate
Harlow
Essex CM20 2JE
England

and Associated Companies throughout the world

Visit us on the World Wide Web at:
www.pearson.com/uk

First published 2001

Second edition 2005

Third edition 2008

Fourth edition published 2012

© Pearson Education Limited 2001, 2012

The rights of Catherine E. Housecroft and Alan G. Sharpe to be identified as authors of this work have been asserted by them in accordance with the Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without either the prior written permission of the publisher or a licence permitting restricted copying in the United Kingdom issued by the Copyright Licensing Agency Ltd, Saffron House, 6–10 Kirby Street, London EC1N 8TS.

All trademarks used herein are the property of their respective owners. The use of any trademark in this text does not vest in the author or publisher any trademark ownership rights in such trademarks, nor does the use of such trademarks imply any affiliation with or endorsement of this book by such owners.

ISBN: 978-0-273-74275-3 (Print)

ISBN: 978-0-273-74278-4 (PDF)

British Library Cataloguing-in-Publication Data

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

Library of Congress Cataloging-in-Publication data

Housecroft, Catherine E., 1955-

Inorganic chemistry / Catherine E. Housecroft and Alan G. Sharpe. -- 4th ed.
p. cm.

Includes index.

ISBN 978-0-273-74275-3 -- ISBN 978-0-273-74276-0 (solution manual) 1.

Chemistry, Inorganic--Textbooks. I. Sharpe, A. G. II. Title.

QD151.3.H685 2012

546--dc23

2012001442

10 9 8 7 6 5 4 3

15

Typeset in 10/12.5pt Times by 73

Printed and bound by Grafos S.A., Arte sobre papel, Barcelona, Spain

9.2 Relative permittivity

Before beginning a discussion of non-aqueous solvents, we must define the *relative permittivity*, also referred to as the *dielectric constant*, of a substance. In a vacuum, the Coulombic potential energy of a system of two unit electronic charges is given by eq. 9.1 where ϵ_0 is the (absolute) permittivity of a vacuum ($8.854 \times 10^{-12} \text{ F m}^{-1}$), e is the charge on the electron ($1.602 \times 10^{-19} \text{ C}$) and r is the separation (in metres) between the point charges.

$$\text{Coulombic potential energy} = \frac{e^2}{4\pi\epsilon_0 r} \quad (9.1)$$

If a material is placed between the charges, the force is reduced by an amount that depends upon the *relative permittivity* of the material. The new Coulombic potential energy is given by eq. 9.2 where ϵ_r is the relative permittivity of the material. Since it is a *relative* quantity, ϵ_r is dimensionless.

$$\text{Coulombic potential energy} = \frac{e^2}{4\pi\epsilon_0\epsilon_r r} \quad (9.2)$$

For example, at 298 K, ϵ_r of water (the dielectric constant) is 78.7 but, as Fig. 9.1 shows, ϵ_r varies with temperature. A value of 78.7 can be considered to be a 'high' value and from eq. 9.2, we see that in aqueous solution, the force between two point charges (or two ions) is considerably reduced compared with that in a vacuum. Thus we can consider a dilute aqueous solution of a salt to contain well-separated, non-interacting ions.

Table 9.1 lists dielectric constants for water and a range of common organic solvents. The *absolute* permittivity of

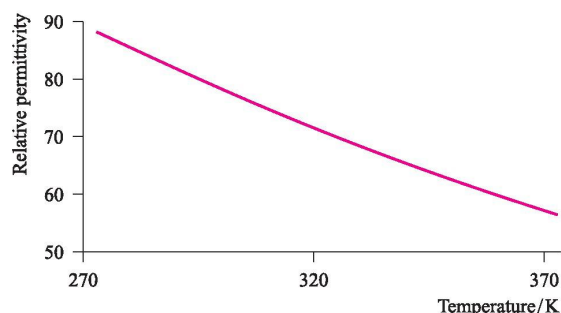


Fig. 9.1 Variation in the relative permittivity (dielectric constant) of water as a function of temperature.

a solvent is found using eq. 9.3, but it is usual to discuss solvent properties in terms of the relative values.

$$\text{Absolute permittivity of a material} = \epsilon_0\epsilon_r \quad (9.3)$$

Table 9.1 also gives the dipole moment (μ) of each solvent. In general, the trend in values of dipole moments follows that in values of the relative permittivities for solvents having related structures. Ion–solvent interactions are favoured (e.g. to facilitate the dissolution of an ionic salt) by using a solvent with a large dipole moment, but for maximum effect, the solvent molecule should also be small, and both ends of it should be able to interact with the ions in the same way that water interacts with cations through the oxygen atoms (see Fig. 7.5) and with anions through the hydrogen atoms. Thus, ammonia ($\epsilon_r = 25.0$, $\mu = 1.47 \text{ D}$) is a better solvent (see Section 9.6) for ionic salts than dimethylsulfoxide or nitromethane, even though these have ϵ_r values of 46.7 and 35.9, and dipole moments of 3.96 and 3.46 D, respectively.

Table 9.1 Relative permittivity (dielectric constant) values at 298 K (unless otherwise stated) for water and selected organic solvents.

Solvent	Formula [†]	Relative permittivity, ϵ_r	Dipole moment, μ / debye
Formamide	HC(O)NH ₂	109 (293 K)	3.73
Water	H ₂ O	78.7	1.85
Acetonitrile	MeCN	37.5 (293 K)	3.92
<i>N,N</i> -Dimethylformamide (DMF)	HC(O)NMe ₂	36.7	3.86
Nitromethane	MeNO ₂	35.9 (303 K)	3.46
Methanol	MeOH	32.7	1.70
Ethanol	EtOH	24.3	1.69
Dichloromethane	CH ₂ Cl ₂	9.1 (293 K)	1.60
Tetrahydrofuran	C ₄ H ₈ O (structure 9.2)	7.6	1.75
Diethyl ether	Et ₂ O	4.3 (293 K)	1.15
Benzene	C ₆ H ₆	2.3	0

[†] Me = methyl; Et = ethyl.