Second Edition

Non-Equilibrium Thermodynamics for Engineers

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World Scientific

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Second Edition

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Second Edition

This book is dedicated to our children

Preface of the Second Edition

The popularity of the first edition has promoted a revised and enlarged new print. Original chapters have been revised, especially the chapters on entropy production minimization. Two chapters concerning phase transitions and membrane transport (Chapters 9 and 10) have been added to take advantage of recent developments in surface transport. The eight lecture videos mentioned in the Preface of the First Edition are now available on iTunesU and MIT Open Academy (in collaboration with TU Delft.)[1] IUPAC notation has been introduced for symbol dimensions.

The authors were inspired by the Opinion paper issued on October 2015 by the Physical, Chemical and Mathematical Sciences Committee of Science Europe, D/2015/13.324/6, *A common scale for our common future*. The paper recommends policy makers to (quote) "guide the establishment of *exergy destruction footprints* for commodities and services". This, they argue, will enhance development of technologies with better energy efficiency.

In view of the impact such a development may have on climate issues, the teaching of non-equilibrium thermodynamics can become central, or even important. We hope that this book can help universities and schools worldwide to establish a curriculum in the field.

[1] http://theopenacademy.com/content/signe-kjelstrup

As said in the Preface of our first edition, we continue to welcome comments and feedback from users to help improve this book.

Trondheim and Stuttgart, January 2016

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Preface of the First Edition

Meeting the entropy challenge is probably more central than the issue of providing sufficient power to the world. The entropy production, not the energy used, can measure our wastes and the efficiency of work, or the limit of our activity. This book introduces non-equilibrium thermodynamics to engineers, and discusses how the theory can be useful for typical engineering problems.

The book has been written after many years of teaching the subject at the Norwegian University of Science and Technology, Trondheim, Norway, and the Technical University of Delft, Delft, The Netherlands. Early versions of the book have been used for short courses at the International Center of Thermodynamics, Istanbul, Chalmers Technical University, Gothenburg, Helsinki Technical University and Pennsylvania State University.

This book can be used in Bachelor or Master study programs after a basic course in thermodynamics, or for self study in the industry. The book requires knowledge of basic thermodynamics corresponding to that given by Smith, van Ness and Abbott in *Introduction to Chemical Engineering*, or in Moran and Shapiro's, *Fundamentals of Engineering Thermodynamics*.

To facilitate learning, exercises for the topics of the book and solutions to these, are available on the NTNU homepage.[2] Eight DVD lectures are also available there or from The Technical University of Delft.[3]

[2]http://www.chem.ntnu.no/nonequilibrium-thermodynamics/

[3]http://collegerama.tudelft.nl/mediasite/Catalog/?cid=0cbe1b45-06c6-4d03-a692-92a6dad4711d

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The authors welcome comments and suggestions that can improve future editions.

Trondheim and Stuttgart, March 2010

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Signe Kjelstrup is Professor of Physical Chemistry since 1985 at the Norwegian University of Science and Technology (NTNU), Trondheim, Norway. Until 2015, she was also a part-time Chair on irreversible thermodynamics and sustainable processes at the Technical University of Delft, The Netherlands. Her works in irreversible thermodynamics concern electrochemical cells, membrane systems and entropy production minimization in process equipment. She holds an honorary doctorate from the University of North East China, and has been a guest professor at Kyoto University, Japan, University of Barcelona, Spain. Her book on irreversible thermodynamics, coauthored with K.S. Førland and T. Førland (Wiley, 1988 and 1994, Tapir 2001), has been translated into Japanese and Chinese.

Dick Bedeaux was Professor of Physical Chemistry at the University of Leiden, The Netherlands, from 1984 to 2002, and held (from 2002 to 2011) a part-time Chair at the Norwegian University of Science and Technology (NTNU), Trondheim, Norway. He is now emeritus at both places. Bedeaux, together with Albano and Mazur, extended the theory of irreversible thermodynamics to surfaces. He has worked on curved surfaces. Bedeaux is a fellow of the American Physical Society, and the recipient of the Onsager Medal from the Norwegian University of Science and Technology. Together with Jan Vlieger he wrote the book *Optical Properties of Surfaces* (Imperial College Press, 2002, and revised edition 2004).

Eivind Johannessen holds a Dr-Ing from the Norwegian University of Science and Technology (NTNU), Trondheim, Norway, and is presently a researcher at the Norwegian Energy Company, Statoil. His doctoral thesis on the state of systems with minimum entropy production was awarded Best doctor thesis defended at Norwegian University of Technology and Science in 2004.

Joachim Gross is Professor of Thermodynamics and Thermal Process Engineering at the University of Stuttgart, Germany. His research interest is in Molecular Thermodynamics and the development of Fluid Theories. After receiving his PhD from the University of Berlin, Germany, he worked in the Conceptual Process Design group of the BASF AG in Ludwigshafen for 4 years. In 2004, he became Associate Professor at the Delft University of Technology, The Netherlands, in the Separation Technology group. In 2005, he was appointed Chair of Thermodynamics at the same university, before moving to Stuttgart in 2010.

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