



Rigidity Symmetry Line for Liquid and Solid States

Article: research presented at Joint European Thermodynamics Conference (JETC-2023) Salerno, Italy.

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Abstract: A single Gibbs phase, that includes triple-point liquid, extends over the whole fluid density range to temperatures (T) above the Boyle temperature (T_B). Below T_B , above the critical temperature T_c , predominantly gas and liquid phases are bounded by a narrow 2-state colloid-like supercritical mesophase defined by percolation transition lines, within which the density derivative of pressure, rigidity ($\omega = [dp/d\rho]_T$) is constant. The Boyle line, defined by $p/p_c(T) = RT$, i.e., by a cancellation of all the virial terms, decreases linearly with T until it intersects a 1st-order liquid-crystal coexistence transition near the triple point. For all densities below the Boyle line, an alternative cluster expansion with equilibrium constants shows that there is substantial cancellation of all higher virial coefficients $b_n > b_1$. The Boyle line is related to a rigidity symmetry line defined by $(dp/d\rho_\infty)(T) = RT$. Whereas the Boyle line interpolates at 0 K to a perfect classical crystalline (FCC) ground state, the rigidity symmetry line, interpolates to an amorphous ground state at a lower density closer to random loose packing of atomic spheres as $T \rightarrow 0$. The rigidity symmetry line is linear until it intersects the 1st-order gas-liquid condensation transition just below T_c (around 140 K for argon). The rigidity symmetry line arises from the corresponding state equivalence of the variance of density fluctuations of the ideal gas as $\rho \rightarrow 0$, and determined at finite ρ by clusters in a percolating gas void, whereas the liquid-side symmetry is determined by the variance of density fluctuations of molecular size voids in one percolating cluster. The solid density ground state constants at $T \rightarrow 0$ K could be useful physical constants in the development of analytic thermodynamic property equations of state.

Keywords: Boyle line; rigidity symmetry; rigidity line, percolation lines, spinodal lines, ground states; cluster physics

1. Introduction

JETC-2023 coincides with the 150th anniversary of the birth of classical thermodynamics, whence J. W. Gibbs (Figure 1) published his description of thermodynamic properties and transitions between different phases as state functions on 2-dimensional, e.g., temperature T and pressure p , surfaces [1].

This year also marks 150 years since the renowned PhD thesis of van der Waals [2] (Figure 2) in which he introduced the concepts of a theoretical equation of state $p(V,T)$ for pressures of a gas at fixed volume (V) and temperature (T), based upon his hypothesis that there exists a singularity described by the node of a cubic equation, on commemorative stamp Figure 2. His equation-of-state defines a critical temperature T_c , pressure p_c , and singular volume V_c at the “critical point”. For all $T > T_c$ and all $p > p_c$, there is no delineation between gas and liquid states in van der Waals “continuity” hypothesis.

Rigidity And Symmetry Rigidity And Symmetry

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Rigidity and Symmetry Robert Connelly, Asia Ivić Weiss, Walter Whiteley, 2014-06-11 This book contains recent contributions to the fields of rigidity and symmetry with two primary focuses to present the mathematically rigorous treatment of rigidity of structures and to explore the interaction of geometry algebra and combinatorics Contributions present recent trends and advances in discrete geometry particularly in the theory of polytopes The rapid development of abstract polytope theory has resulted in a rich theory featuring an attractive interplay of methods and tools from discrete geometry group theory classical geometry hyperbolic geometry and topology Overall the book shows how researchers from diverse backgrounds explore connections among the various discrete structures with symmetry as the unifying theme The volume will be a valuable source as an introduction to the ideas of both combinatorial and geometric rigidity theory and its applications incorporating the surprising impact of symmetry It will appeal to students at both the advanced undergraduate and graduate levels as well as post docs structural engineers and chemists *Handbook of Geometric Constraint Systems Principles* Meera Sitharam, Audrey St. John, Jessica Sidman, 2018-07-20 The Handbook of Geometric Constraint Systems Principles is an entry point to the currently used principal mathematical and computational tools and techniques of the geometric constraint system GCS It functions as a single source containing the core principles and results accessible to both beginners and experts The handbook provides a guide for students learning basic concepts as well as experts looking to pinpoint specific results or approaches in the broad landscape As such the editors created this handbook to serve as a useful tool for navigating the varied concepts approaches and results found in GCS research Key Features A comprehensive reference handbook authored by top researchers Includes fundamentals and techniques from multiple perspectives that span several research communities Provides recent results and a graded program of open problems and conjectures Can be used for senior undergraduate or graduate topics course introduction to the area Detailed list of figures and tables About the Editors Meera Sitharam is currently an Associate Professor at the University of Florida's Department of Computer Information Science and Engineering She received her Ph D at the University of Wisconsin Madison Audrey St John is an Associate Professor of Computer Science at Mount Holyoke College who received her Ph D from UMass Amherst Jessica Sidman is a Professor of Mathematics on the John S Kennedy Foundation at Mount Holyoke College She received her Ph D from the University of Michigan *Handbook of Discrete and Computational Geometry* Csaba D. Toth, Joseph O'Rourke, Jacob E. Goodman, 2017-11-22 The Handbook of Discrete and Computational Geometry is intended as a reference book fully accessible to nonspecialists as well as specialists covering all major aspects of both fields The book offers the most important results and methods in discrete and computational geometry to those who use them in their work both in the academic world as researchers in mathematics and computer science and in the professional world as practitioners in fields as diverse as operations research molecular biology and robotics Discrete geometry has contributed significantly to the

growth of discrete mathematics in recent years This has been fueled partly by the advent of powerful computers and by the recent explosion of activity in the relatively young field of computational geometry This synthesis between discrete and computational geometry lies at the heart of this Handbook A growing list of application fields includes combinatorial optimization computer aided design computer graphics crystallography data analysis error correcting codes geographic information systems motion planning operations research pattern recognition robotics solid modeling and tomography

Symmetry in Geometry and Analysis, Volume 1 Michael Pevzner,Hideko Sekiguchi,2025-02-09 Symmetry in Geometry and Analysis is a Festschrift honoring Toshiyuki Kobayashi The three volumes feature 35 selected contributions from invited speakers of twin conferences held in June 2022 in Reims France and in September 2022 in Tokyo Japan These contributions highlight the profound impact of Prof Kobayashi's pioneering ideas groundbreaking discoveries and significant achievements in the development of analytic representation theory noncommutative harmonic analysis and the geometry of discontinuous groups beyond the Riemannian context among other areas over the past four decades The first volume of the Festschrift includes a survey article on Kobayashi's innovative contributions to Mathematics emphasizing their influence and introducing new perspectives across various fields Original articles contained in Volume 1 focus on differential geometry with symmetries as well as algebraic and geometric aspects of representation theory of reductive Lie groups and related topics Contributions are by Velleda Baldoni Dan Barbasch Leticia Barchini Sigiswald Barbier Yves Benoist Sam Claerebout Michael Eastwood Wee Teck Gan William M Goldman Roger Howe Kazuki Kannaka Toshihisa Kubo Hung Yean Loke Jia Jun Ma Reiko Miyaoka Kento Ogawa Takayuki Okuda Yoshiki Oshima Paul mile Paradan Annegret Paul Michael Pevzner Yiannis Sakellaridis Atsumi Sasaki Gordan Savin Hideko Sekiguchi Binyong Sun Yuichiro Tanaka Koichi Tojo Peter Trapa Mich le Vergne Joseph A Wolf Kayue Daniel Wong and Chen Bo Zhu The Mathematical Work of Toshiyuki Kobayashi is available open access under a Creative Commons Attribution 4.0 International License via link.springer.com *Frameworks, Tensegrities, and Symmetry* Robert Connelly,Simon D. Guest,2022-01-27 This introduction to the theory of rigid structures explains how to analyze the performance of built and natural structures under loads paying special attention to the role of geometry The book unifies the engineering and mathematical literatures by exploring different notions of rigidity local global and universal and how they are interrelated Important results are stated formally but also clarified with a wide range of revealing examples An important generalization is to tensegrities where fixed distances are replaced with cables not allowed to increase in length and struts not allowed to decrease in length A special feature is the analysis of symmetric tensegrities where the symmetry of the structure is used to simplify matters and allows the theory of group representations to be applied Written for researchers and graduate students in structural engineering and mathematics this work is also of interest to computer scientists and physicists *Computational Kinematics* Federico Thomas,Alba Perez Gracia,2013-10-17 Computational kinematics is an enthralling area of science with a rich spectrum of problems at the junction of mechanics robotics computer science

mathematics and computer graphics The covered topics include design and optimization of cable driven robots analysis of parallel manipulators motion planning numerical methods for mechanism calibration and optimization geometric approaches to mechanism analysis and design synthesis of mechanisms kinematical issues in biomechanics construction of novel mechanical devices as well as detection and treatment of singularities The results should be of interest for practicing and research engineers as well as Ph D students from the fields of mechanical and electrical engineering computer science and computer graphics

Job Security and Flexibility Emil Dinga, Monica Florica Dutcas, Gabriela-Mariana Ionescu, 2023-06-20 This book examines the relationship between job security and job flexibility Through an innovative conceptual approach the concept of job flexicurity is presented to highlight the labour market dynamics between job flexibility and employee security The dynamics of labour market mechanisms are placed within ideas of rigidity security flexibility and plasticity to explore the interplay between different employee considerations Particular attention is given to the Romanian labour market with an empirical case study that expands upon the ideas discussed This book aims to analyse how job security and flexibility impact worker well being and happiness It will be relevant to students and researchers interested in labour economics and the job market

Perspectives on Statistical Thermodynamics Yoshitsugu Oono, 2017-12-14 This original text develops a deep conceptual understanding of thermal physics highlighting the important links between thermodynamics and statistical physics and examining how thermal physics fits within physics as a whole from an empirical perspective The first part of the book is devoted to elementary mesoscopic topics such as Brownian motion which leads to intuitive uses of large deviation theory one of the pillars of modern probability theory The book then introduces the key concepts behind statistical thermodynamics and the final part describes more advanced and applied topics from thermal physics such as phase transitions and critical phenomena This important subject is presented from a fresh perspective and in a highly pedagogical manner with numerous worked examples and relevant cultural side notes throughout making it ideal as either a textbook for advanced thermal physics courses or for self study by undergraduate and graduate students in physics and engineering

Application of Group Theory to Symmetric Structures Ichiro Ario, Machi Zawidzki, 2024-04-11 Ario and Zawidzki show readers how to handle symmetric structures in engineering using group theoretic bifurcation theory as a mathematical tool for the finite element analysis of symmetric structures They guide the reader from the initial mathematical concepts through to application examples Readers will gain a solid theoretical grounding in group theory and strong working knowledge of the use of computational frameworks for structural analysis using mathematical representations of symmetry and physical symmetry First the authors elaborate an outline of symmetric structures in engineering and then describe the representation of symmetry and group theory They then discuss block diagonalization theory and finite element analysis models This provides readers with the base knowledge needed for Chapter 6 which is based on numerical analysis examples of invariant static FEM model systems and dynamic model systems of the dihedral group This unique approach is a vital

method that will enable readers to reduce the time and computation needed for accurate analysis so that they can better design such structures The focus on finite element methods and practical examples and case studies throughout provides a strong practical foundation for anyone studying or working in this field The book is a valuable resource for undergraduate and postgraduate students on various courses such as civil and mechanical engineering architecture structural engineering applied mathematics and physics Additionally it describes vital practical solutions for structural engineers structural system manufacturers fabricators of prefabricated elements and developers of computational mechanics and so on

Spin Glass Theory And Far Beyond: Replica Symmetry Breaking After 40 Years Patrick Charbonneau, Enzo Marinari, Giorgio Parisi, Federico Ricci-terseghi, Gabriele Sicuro, Francesco Zamponi, Marc Mezard, 2023-07-26

About sixty years ago the anomalous magnetic response of certain magnetic alloys drew the attention of theoretical physicists It soon became clear that understanding these systems now called spin glasses would give rise to a new branch of statistical physics As physical materials spin glasses were found to be as useless as they were exotic They have nevertheless been recognized as paradigmatic examples of complex systems with applications to problems as diverse as neural networks amorphous solids biological molecules social and economic interactions information theory and constraint satisfaction problems This book presents an encyclopaedic overview of the broad range of these applications More than 30 contributions are compiled written by many of the leading researchers who have contributed to these developments over the last few decades Some timely and cutting edge applications are also discussed This collection serves well as an introduction and summary of disordered and glassy systems for advanced undergraduates graduate students and practitioners interested in the topic

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