

Physics 127b: Statistical Mechanics

Landau Theory of Second Order Phase Transitions

Order Parameter

Second order phase transitions occur when a new state of *reduced symmetry* develops continuously from the disordered (high temperature) phase. The ordered phase has a *lower symmetry* than the Hamiltonian—the phenomenon of *spontaneously broken symmetry*. There will therefore be a number (sometimes infinite) of equivalent (e.g. equal free energy) symmetry related states. These are macroscopically different, and so thermal fluctuations will not connect one to another in the thermodynamic limit. To describe the ordered state we introduce a *macroscopic order parameter* that describes the *character* and *strength* of the broken symmetry.

Examples

1. **Ising ferromagnet:** the Hamiltonian is invariant under all $s_i \rightarrow -s_i$, whereas the low temperature phase has a spontaneous magnetization, and so is not. A convenient order parameter is the total average spin $S = \sum_i \langle s_i \rangle$ or the magnetization $M = \mu S$. This reflects the nature of the ordering: (under the transformation $s_i \rightarrow -s_i$ we have $S \rightarrow -S$) and goes to zero continuously at T_c .
2. **Ising antiferromagnet on a simple cubic lattice:** the ordering is the staggered magnetization $N = \sum_i (-1)^i \langle s_i \rangle$ where alternate sites are labelled even or odd.
3. **Heisenberg ferromagnet:** now the Hamiltonian is invariant under any rotation of *all* the spins together. The ordering is characterized by a *vector* order parameter. A convenient choice is again the total spin $\vec{S} = \sum_i \langle \vec{s}_i \rangle$ or magnetization.
4. **Heisenberg antiferromagnet on a simple cubic lattice:** the staggered magnetization is now a vector $\vec{N} = \sum_i (-1)^i \langle \vec{s}_i \rangle$.
5. **Superfluid:** the broken symmetry is the invariance of the (quantum) Hamiltonian under a phase change of the wave function. Since for a charge system a gauge transformation also changes the quantum phase, this is also known as broken gauge symmetry. The order parameter can be thought of as the one particle wave function into which the particle Bose condense, multiplied by the number of condensed atoms. This picture is good for a non- or weakly interacting system. For a strongly interacting system a better definition is the “expectation value of the particle annihilation operator” $\langle \psi(\vec{r}) \rangle$.
6. **Solid:** has broken translational and rotational symmetry, and a convenient order parameter is the amplitude of the density wave. In three dimensions the liquid-solid transition is always first order, but in two dimensions may be second order.
7. **Nematic liquid crystal:** consists of long molecules which align parallel to one another at low temperatures, although the position of the molecules remains disorder as in a liquid. The liquid becomes anisotropic, and a second rank tensor characterizes the strength of the anisotropy and can be used as the order parameter.

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An Introduction to Thermal Physics Daniel V. Schroeder, 2021 This is a textbook for the standard undergraduate level course in thermal physics sometimes called thermodynamics or statistical mechanics Originally published in 1999 it quickly gained market share and has now been the most widely used English language text for such courses as taught in physics departments for more than a decade Its clear and accessible writing style has also made it popular among graduate students and professionals who want to gain a better understanding of thermal physics The book explores applications to engineering chemistry biology geology atmospheric science astrophysics cosmology and everyday life It includes two appendices reference data an annotated bibliography a complete index and 486 homework problems

Materials Interaction with Femtosecond Lasers Bernd Bauerhenne, 2021-10-25 This book presents a unified view of the response of materials as a result of femtosecond laser excitation introducing a general theory that captures both ultrashort time non thermal and long time thermal phenomena It includes a novel method for performing ultra large scale molecular dynamics simulations extending into experimental and technological spatial dimensions with ab initio precision For this it introduces a new class of interatomic potentials constructed from ab initio data with the help of a self learning algorithm and verified by direct comparison with experiments in two different materials the semiconductor silicon and the semimetal antimony In addition to a detailed description of the new concepts introduced as well as giving a timely review of ultrafast phenomena the book provides a rigorous introduction to the field of laser matter interaction and ab initio description of solids delivering a complete and self contained examination of the topic from the very first principles It explains step by step from the basic physical principles the underlying concepts in quantum mechanics solid state physics thermodynamics statistical mechanics and electrodynamics introducing all necessary mathematical theorems as well as their proofs A collection of appendices provide the reader with an appropriate review of many fundamental mathematical concepts as well as important analytical and numerical parameters used in the simulations

The Publishers' Trade List Annual, 1977

Molecular Physical Chemistry for Engineering Applications Florin Emilian Daneş, Silvia Daneş, Valeria Petrescu, Eleonora-Mihaela Ungureanu, 2021-07-06 This textbook introduces the molecular side of physical chemistry It offers students and practitioners a new approach to the subject by presenting numerous applications and solved problems that illustrate the concepts introduced for varied and complex technical situations The book offers a balance between theory tools and practical applications The text aims to be a practical manual for solving engineering problems in industries where processes depend on the chemical composition and physical properties of matter The book is organized into three main topics I the molecular structure of matter II molecular models in thermodynamics and III transport phenomena and mechanisms Part I presents methods of analysis of the molecular behavior in a given system while the following parts use these methods to study the equilibrium states of a material system and to analyze the processes that can take place when the system is in a state of non

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Nuclear Science Abstracts ,1957 *Forthcoming Books* Rose Arny,2001

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