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Chapter 1 : Phase transition - Wikipedia

The physics of phase transitions is an important area at the crossroads of several fields that play central roles in materials sciences. In this second edition, new developments had been included which came up in the states of matter physics, in particular in the domain of nanomaterials and atomic.

A typical phase diagram. The dotted line gives the anomalous behavior of water. A small piece of rapidly melting solid argon simultaneously shows the transitions from solid to liquid and liquid to gas. Comparison of phase diagrams of carbon dioxide red and water blue explaining their different phase transitions at 1 atmosphere A eutectic transformation, in which a two component single phase liquid is cooled and transforms into two solid phases. The same process, but beginning with a solid instead of a liquid is called a eutectoid transformation. A peritectic transformation, in which a two component single phase solid is heated and transforms into a solid phase and a liquid phase. A spinodal decomposition , in which a single phase is cooled and separates into two different compositions of that same phase. Transition to a mesophase between solid and liquid, such as one of the " liquid crystal " phases. The transition between the ferromagnetic and paramagnetic phases of magnetic materials at the Curie point. The transition between differently ordered, commensurate or incommensurate , magnetic structures, such as in cerium antimonide. The martensitic transformation which occurs as one of the many phase transformations in carbon steel and stands as a model for displacive phase transformations. Changes in the crystallographic structure such as between ferrite and austenite of iron. Order-disorder transitions such as in alpha- titanium aluminides. The dependence of the adsorption geometry on coverage and temperature, such as for hydrogen on iron The emergence of superconductivity in certain metals and ceramics when cooled below a critical temperature. The transition between different molecular structures polymorphs , allotropes or polyamorphs , especially of solids, such as between an amorphous structure and a crystal structure, between two different crystal structures, or between two amorphous structures. Quantum condensation of bosonic fluids Boseâ€"Einstein condensation. The superfluid transition in liquid helium is an example of this. The breaking of symmetries in the laws of physics during the early history of the universe as its temperature cooled. Isotope fractionation occurs during a phase transition, the ratio of light to heavy isotopes in the involved molecules changes. When water vapor condenses an equilibrium fractionation , the heavier water isotopes 18O and 2H become enriched in the liquid phase while the lighter isotopes 16O and 1H tend toward the vapor phase. This condition generally stems from the interactions of a large number of particles in a system, and does not appear in systems that are too small. It is important to note that phase transitions can occur and are defined for non-thermodynamic systems, where temperature is not a parameter. In these types of systems other parameters take the place of temperature. For instance, connection probability replaces temperature for percolating networks. At the phase transition point for instance, boiling point the two phases of a substance, liquid and vapor , have identical free energies and therefore are equally likely to exist. Below the boiling point, the liquid is the more stable state of the two, whereas above the gaseous form is preferred. It is sometimes possible to change the state of a system diabatically as opposed to adiabatically in such a way that it can be brought past a phase transition point without undergoing a phase transition. The resulting state is metastable , i. This occurs in superheating , supercooling , and supersaturation , for example. Ehrenfest classification[edit] Paul Ehrenfest classified phase transitions based on the behavior of the thermodynamic free energy as a function of other thermodynamic variables. First-order phase transitions exhibit a discontinuity in the first derivative of the free energy with respect to some thermodynamic variable. Second-order phase transitions are continuous in the first derivative the order parameter , which is the first derivative of the free energy with respect to the external field, is continuous across the transition but exhibit discontinuity in a second derivative of the free energy. The magnetic susceptibility , the second derivative of the free energy with the field, changes discontinuously. Under the Ehrenfest classification scheme, there could in principle be third, fourth, and higher-order phase transitions. For instance, in the ferromagnetic transition, the heat capacity diverges to infinity. The same phenomenon is also seen in superconducting phase transition. Modern classifications[edit] In the modern classification scheme, phase transitions are divided into two broad categories, named similarly to the Ehrenfest classes: During such a transition, a system either absorbs or releases a fixed and typically large amount of energy per volume. During this process, the temperature of the system will stay constant as heat is added: Familiar examples are the melting of ice or the boiling of water the water does not instantly turn into vapor , but forms a turbulent mixture of liquid water and vapor bubbles. Imry and Wortis showed that quenched disorder can broaden a first-order transition. That is, the transformation is completed over a finite range of temperatures, but phenomena like supercooling and superheating survive and hysteresis is observed on thermal cycling. They are characterized by a divergent susceptibility, an infinite correlation length, and a power-law decay of correlations near criticality. Examples of second-order phase transitions are the ferromagnetic transition, superconducting transition for a Type-I superconductor the phase transition is second-order at zero external field and for a Type-II superconductor the phase transition is second-order for both normal-stateâ€"mixed-state and mixed-stateâ€"superconducting-state transitions and the superfluid transition. In contrast to viscosity, thermal expansion and heat capacity of amorphous materials show a relatively sudden change at the glass transition temperature [7] which enables accurate detection using differential scanning calorimetry measurements. Lev Landau gave a phenomenological theory of second-order phase transitions. Apart from isolated, simple phase transitions, there exist transition lines as well as multicritical points , when varying external parameters like the magnetic field or composition. Several transitions are known as infinite-order phase transitions. They are continuous but break no symmetries. The most famous example is the Kosterlitzâ€"Thouless transition in the two-dimensional XY model. Many quantum phase transitions , e. The liquidâ€"glass transition is observed in many polymers and other liquids that can be supercooled far below the melting point of the crystalline phase. This is atypical in several respects. It is not a transition between thermodynamic ground states: Glass is a quenched disorder state, and its entropy, density, and so on, depend on the thermal history. Therefore, the glass transition is primarily a dynamic phenomenon: Some theoretical methods predict an underlying phase transition in the hypothetical limit of infinitely long relaxation times. This continuous variation of the coexisting fractions with temperature raised interesting possibilities. On cooling, some liquids vitrify into a glass rather than transform to the equilibrium crystal phase. This happens if the cooling rate is faster than a critical cooling rate, and is attributed to the molecular motions becoming so slow that the molecules cannot rearrange into the crystal positions. Extending these ideas to first-order magnetic transitions being arrested at low temperatures, resulted in the observation of incomplete magnetic transitions, with two magnetic phases coexisting, down to the lowest temperature. First reported in the case of a ferromagnetic to anti-ferromagnetic transition, [12] such persistent phase coexistence has now been reported across a variety of first-order magnetic transitions. These include colossal-magnetoresistance manganite materials, [13] [14] magnetocaloric materials, [15] magnetic shape memory materials, [16] and other materials. The relative ease with which magnetic fields can be controlled, in contrast to pressure, raises the possibility that one can study the interplay between Tg and Tc in an exhaustive way. Phase coexistence across first-order magnetic transitions will then enable the resolution of outstanding issues in understanding glasses. Critical points[edit] In any system containing liquid and gaseous phases, there exists a special combination of pressure and temperature, known as the critical point , at which the transition between liquid and gas becomes a second-order transition. Near the critical point, the fluid is sufficiently hot and compressed that the distinction between the liquid and gaseous phases is almost non-existent. This is associated with the phenomenon of critical opalescence , a milky appearance of the liquid due to density fluctuations at all possible wavelengths including those of visible light. Symmetry[edit] Phase transitions often involve a symmetry breaking process. For instance, the cooling of a fluid into a crystalline solid breaks continuous translation symmetry: Typically, the high-temperature phase contains more symmetries than the low-temperature phase due to spontaneous symmetry breaking , with the exception of certain accidental symmetries e. An example of an order parameter is the net magnetization in a ferromagnetic system undergoing a phase transition. From a theoretical perspective, order parameters arise from symmetry breaking. When this happens, one needs to introduce one or more extra variables to describe the state of the system. For example, in the ferromagnetic phase, one must provide the net magnetization , whose direction was spontaneously chosen when the system cooled below the Curie point. However, note that order parameters can also be defined for non-symmetry-breaking transitions. Some phase transitions, such as superconducting and ferromagnetic, can have order parameters for more than one degree of freedom. In such phases, the order parameter may take the form of a complex number, a vector, or even a tensor, the magnitude of which goes to zero at the phase transition. There also exist dual descriptions of phase transitions in terms of disorder parameters. These indicate the presence of line-like excitations such as vortex - or defect lines. Relevance in cosmology[edit] Symmetry-breaking phase transitions play an important role in cosmology. It has been speculated by Lee Smolin and Benjamin and Jeremy Bernstein that, in the hot early universe , the vacuum i. As the universe expanded and cooled, the vacuum underwent a series of symmetry-breaking phase transitions. This transition is important to understanding the asymmetry between the amount of matter and antimatter in the present-day universe see electroweak baryogenesis. Progressive phase transitions in an expanding universe are implicated in the development of order in the universe, as is illustrated by the work of Eric Chaisson [20] and David Layzer.

Chapter 2 : Membrane Phase Transitions - Physics LibreTexts

A different sort of phase transition also has a critical role to play in the formation of those drink-related examples of condensation, namely the solid-to-liquid transition of melting ice.

The singularities at two certain critical times that the measured function exhibited indicate that dynamical quantum phase transitions occurred at these times. While most studies in this field have focused on matter that is in thermal equilibrium with its environment, many phenomena occurring in nature involve matter out of equilibrium. Rainer Blatt from the Austrian Academy of Sciences and the University of Innsbruck, Austria, and colleagues [1] have now succeeded in observing one such class of phenomenaâ€"dynamical quantum phase transitionsâ€"in a quantum many-body spin system. These transitions are similar to those that take place when ice melts or water evaporates, but they are not driven by external factors such as temperature. Instead, they are triggered by internal changes in a nonequilibrium quantum system as it evolves in time. Matter studied in labs equilibrates quickly with the environment with which it typically interacts. The environment is usually held at some temperature, so matter in the lab equilibrates at this temperature. By contrast, artificially engineered quantum matter made up of many atoms or ions at temperatures close to absolute zero, such as an atomic Bose-Einstein condensate, is generally thermally isolated from the environment and can be easily taken out of equilibrium. This feature of engineered quantum matter has made it both the focus and motivator of recent research on nonequilibrium matter. In particular, recent theoretical work [2] put forward a new class of phenomena that nonequilibrium quantum many-body systems may exhibit. The authors of this study noted an analogy between the evolution operatorâ€"a mathematical operator that describes the evolution of the wave function of a quantum systemâ€"and the partition function, which describes the statistical properties of a system in thermal equilibrium with the environment. In this analogy, the role of time in the evolution of a thermally isolated quantum system is equivalent to that of the inverse of the temperature in a system in thermal equilibrium. This equivalence has been known and widely used since the early days of quantum mechanics [3]. But the study pointed out a previously unexplored consequence of the analogy: These dynamical quantum phase transitionsâ€"as the authors dubbed this class of nonequilibrium phenomenaâ€"would manifest themselves in discontinuous behavior of the system at certain critical times. These researchers [2] explored this notion in the much-studied one-dimensional transverse-field Ising model, a chain of interacting quantum spins in a transverse magnetic field [4]. This model is known to undergo a standard quantum phase transition between its ordered and disordered spin phases as parameters in the model that describe the spin-spin interactions are changed [5]. This transition occurs in thermal-equilibrium conditions. This is exactly what Blatt and colleagues observed in their experimental study of a quantum many-body spin system. The result comes on the heels of a series of studies that realized the transverse-field Ising model using a chain of ultracold ions [6 , 7]. Obtained in this way, the model features long-range interactions between the ions, in contrast to the short-range interactions that characterize the original transverse-field Ising model. The team created this modified version of the transverse-field Ising model using a linear string of up to 10 calcium ions. They first prepared the string in the ordered spin state, in which all ion spins point in the same direction. They then suddenly switched on interactions among the spins such that the chain, if it were in equilibrium, would be in a disordered state in which the spins are randomly oriented. This sudden change drove the system out of equilibrium. Next, the system was allowed to evolve freely in time. Finally, the team measured the probability that either all the spins pointed in the same original direction some time after the switch, or they all pointed in the opposite direction. Theorists have predicted [8] that the evolution of this probability in time would be singular that is, not a smooth function of time at certain critical times as a consequence of dynamical phase transitions expected in this system. The probability measured by Blatt and co-workersâ€"or more accurately the so-called rate function, which is closely related to the probabilityâ€"displays exactly these singularities in time Fig. Meanwhile, two papers posted on the arXiv have also described experimental searches for dynamical phase transitions [9 , 10]. One of the papers reported a somewhat different signature of dynamical phase transitions in a system of ultracold atoms in an optical lattice

[9]. And the other reported additional signatures of dynamical phase transitions in a transverse-field Ising chain made of 53 ions [10]. Clearly, researchers are actively on the hunt for dynamical quantum phase transitions. It remains to be seen whether they are as ubiquitous and as rich in their properties as their equilibrium counterparts. Yet, a predicted class of nonequilibrium phenomena has been brought to the experimental realm. This may well be the beginning of an exciting chapter in the study of nonequilibrium matter. This research is published in Physical Review Letters. Biercuk, and John J. He works in condensed-matter physics and many-body theory, with an emphasis on applications to ultracold atomic systems. His recent interests include superconductivity with cold atoms, topological states of matter and the quantum Hall effect, and out-of-equilibrium phenomena.

Chapter 3 : thermodynamics - Order of phase transitions - Physics Stack Exchange

biology biophysics microbiology phase transitions physics statistical physics At first glance, the movie didn't seem like much: a chaotic swarm of E. coli bacteria twiddling this way and that in a petri dish, seemingly at random.

References The membranes that provide structure and definition to cellular compartments are composed of dynamic and heterogeneous lipids whose varying chemical properties allow for their function. Relevant Properties of Lipid Phases Membranes composed of a lipid bilayer can exist in either the liquid or gel phase, depending on the strength of interaction between the molecules. The two phases are quite different in their physical properties and biological relevance. Head groups in the liquid phase are loosely packed with rotational freedom, giving rise to a larger area per molecule at room temperature than observed in the gel phase[1]. In the liquid phase, phospholipid molecules can move freely in the X and Y axis, but distance between the bilayers the Z axis direction is shorter in than in the gel phase, as would be expected due to the kinks in the hydrophobic tails[2]. The presence of gel phase domains within the bilayer can inhibit the lateral diffusion of liquid phase molecules[3]. This gives the gel phase a longer Z axis, or length, because the acyl chains are more rigid and straight. Tightly packed head groups result in a lower area per molecule at room temperature than in the liquid phase[1]. Magnetization is an example of a second order phase transition process. During phase transition, the temperature stays constant while heat is added to the system[4]. Plotting heat flow versus temperature shows intuitively the energy required for phase transition, with an integral of the curved area representing the free energy of the process: This phenomenon occurs only in first and not second order phase transitions[5]. Characteristics of Phase Transitions The close packing of the gel phase is accomplished in part by the long and straight acyl chains. These chains are kept straight and rigid by the trans orientation of the alkane chain. During phase transitions, the acyl chain portion of the phospholipid hydrophobic tail undergoes a trans-gauche isomerization produces kinks, a shorter and skewed tail, and leads to less efficient packing[6]. Biologically relevant membranes exist as complex mixtures of different lipids with varying melting temperatures. As a fraction of the membrane reaches its phase transition temperature Tm a mixed phase will exist with a heterogenous mixture of liquid and gel phases. Should a sufficient amount of mixed phase exist, a substantial amount of lipid molecules may become exposed to an aqueous environment as the liquid phase molecules will be shorter in the Z axis than the gel phase, making the membrane thinner and exposing a portion of the hydrophobic tails of adjacent phospholipid molecules. Thus, the disparity of phase transition temperatures in complex lipid mixtures of a lipid bilayer can be thought of as a driving force for phase separation and microdomain formation[7]. Forces Driving Phase Transition Lipids undergo temperature specific phase transitions from liquid crystalline to gel phase. The specific temperature at which this transition occurs is referred to as Tm and varies depending on the specific molecule. Lipid molecules with longer acyl chains tend to have higher Tm than shorter tailed phospholipids because the longer tail provides more opportunity for Van der Waals interactions to occur between two adjacent molecules, lowering over all energy and requiring more thermal energy to reach the point of phase transition and making the phospholipid more likely to exist in the gel phase[5]. Double bonding within the acyl chain also affects Tm[8]. Unsaturated lipids have a lower Tm whereas saturated lipids have a higher Tm. In addition to the degree of unsaturation or number of double bonds, the position of the double bond in the acyl chain also affects phase behavior[7]. In addition to the acyl tail, the lipid headgroup also influences phase behavior. The size of the headgroup is thought to have a strong influence on Tm. Glycocylated head groups have been shown to exhibit less hydrogen bonding than normal phosphatidylcholine resulting in a more fluid and flexible membrane[9]. Somewhat related, the surrounding pH and the hydration of the membrane can also affect Tm, with lower pH and higher hydration state resulting in a higher Tm for the same lipid composition by affecting the hydrogen bonding between the lipid components[10]. DSC works by measuring the amount of heat energy required to raise the temperature of the sample. By slowly ramping the temperature of the sample and accurately measuring temperature change, DSC can determine phase transition phases. By conducting a DSC scan in both directions, hysteresis can be identified. Fourier transform infrared spectroscopy FTIR is a powerful technique that can provide a wealth of information about lipid structure, membrane organization and phase behavior[13]. FTIR detects the absorbance of IR type light emission, which at certain wavelengths is absorbed by different carbon-carbon bonds. From FTIR absorbance spectra, information about lipid conformation can be extrapolated. For example, the phase transition from gel to liquid phase represent change from a more ordered to a more disordered state; the disordered state provides for more rotational and vibrational freedom of the lipid molecules, which is accompanied by a broadening of the IR absorbance of the higher energy molecule[14]. It has been used to find Tm of intact cells, including human platelets[15]. In addition, protein movement through the membrane can be impaired, or a protein could be restricted to a lipid environment in which it does not optimally function. Effect of headgroup interactions. The Journal of Membrane Biology, Longo, Obstructed diffusion in phase-separated supported lipid bilayers: Archive for History of Exact Sciences, Olmsted, Effect of hydrophobic mismatch on phase behavior of lipid membranes. Glomset, Effect of acyl chain unsaturation on the packing of model diacylglycerols in simulated monolayers. J Lipid Res, Hincha, Effects of the sugar headgroup of a glycoglycerolipid on the phase behavior of phospholipid model membranes in the dry state. Inniss, Thermal analysis of bacteria by differential scanning calorimetry: Biochim Biophys Acta, McElhaney, Membrane lipid phase transitions and phase organization studied by Fourier transform infrared spectroscopy. Correlation with cold-induced activation. Journal of Cellular Physiology, Nat Rev Mol Cell Biol, Moscarello, Alteration of lipid-phase behavior in multiple sclerosis myelin revealed by wide-angle x-ray diffraction. J Clin Invest,

Chapter 4 : Transition | atomic physics | www.nxgvision.com

The study of phase transitions is at the very core of structural condensed-matter physics, to the point that one might consider all we have learned in the previous lectures as a mere preparation for the last one.

Innovative thinking about a global world Monday, December 19, Menon and Callender on the physics of phase transitions In an earlier post I considered the topic of phase transitions as a possible source of emergent phenomena link. Philosophical questions raised by phase transitions" link. Menon and Callender provide a very careful and logical account of three ways of approaching the physics of phase transitions within physics and three versions of emergence conceptual, explanatory, ontological. The piece is technical but very interesting, with a somewhat deflating conclusion if you are a fan of emergence: We have found that when one clarifies concepts and digs into the details, with respect to standard textbook statistical mechanics, phase transitions are best thought of as conceptually novel, but not ontologically or explanatorily irreducible. Menon and Callendar review three approaches to the phenomenon of phase transition offered by physics: Thermodynamics describes the behavior of materials gases, liquids, and solids at the macro level; and statistical mechanics and renormalization group theory are theories of the micro states of materials intended to allow derivation of the macro behavior of the materials from statistical properties of the micro states. They describe this relationship in these terms: Statistical mechanics is the theory that applies probability theory to the microscopic degrees of freedom of a system in order to explain its macroscopic behavior. The tools of statistical mechanics have been extremely successful in explaining a number of thermodynamic phenomena, but it turned out to be particularly difficult to apply the theory to the study of phase transitions. Mathematically, phase transitions are represented by nonanalyticities or singularities in a thermodynamic potential. Def 1 An equilibrium phase transition is a nonanalyticity in the free energy. To explain the method, we return to our stalwart Ising model. This gives us a new Ising system with a longer distance between lattice sites, and possibly a different coupling strength. Let K be the coupling strength of the original system and R be the relevant transformation. The transformation defines a flow on parameter space. The key difficulty that has been used to ground arguments about strong emergence of phase transitions is now apparent: In theory physicists would like to hold that statistical mechanics provides the micro-level representation of the phenomena described by thermodynamics; or in other words, that thermodynamic facts can be reduced to derivations from statistical mechanics. However, the definition of a phase transition above specifies that the phenomena display "nonanalyticities" -- instantaneous and discontinuous changes of state. It is easily demonstrated that the equations used in statistical mechanics do not display nonanalyticities; change may be abrupt, but it is not discontinuous, and the equations are infinitely differentiable. So if phase transitions are points of nonanalyticity, and statistical mechanics does not admit of nonanalytic equations, then it would appear that thermodynamics is not derivable from statistical mechanics. Similar reasoning applies to renormalization group theory. This problem was solved within statistical mechanics by admitting of infinitely many bodies within the system that is represented or alternatively, admitting of infinitely compressed volumes of bodies ; but neither of these assumptions of infinity is realistic of the material world. So are phase transitions "emergent" phenomena in either a weak sense or a strong sense, relative to the micro-states of the material in question? The strongest sense of emergence is what Menon and Callender call ontological irreducibility. Ontological irreducibility involves a very strong failure of reduction, and if any phenomenon deserves to be called emergent, it is one whose description is ontologically irreducible to any theory of its parts. Batterman argues that phase transitions are emergent in this sense Batterman It is not just that we do not know of an adequate statistical mechanical account of them, we cannot construct such an account. Phase transitions, according to this view, are cases of genuine physical discontinuities. But Menon and Callender give a compelling reason for thinking this is misleading. They believe that phase transitions constitute a conceptual novelty with respect to the resources of statistical mechanics -- phase transitions do not correspond to natural kinds at the level of the micro-constitution of the material. But they argue that this does not establish that the phenomena cannot be explained or derived from a micro-level description. So phase transitions are not emergent according to the explanatory or ontological understandings of that idea. The nub of the issue comes down to how we construe the idealization of statistical mechanics that assumes that a material consists of an infinite number of elements. This is plainly untrue of any real system gas, liquid, or solid. The fact that there are boundaries implies that important thermodynamic properties are not "extensive" with volume: But the way in which the finitude of a volume of material affects its behavior is through the effects of novel behaviors at the edges of the volume. And in many instances these effects are small relative to the behavior of the whole, if the volume is large enough. Does this fact imply that there is a great mystery about extensivity, that extensivity is truly emergent, that thermodynamics does not reduce to finite N statistical mechanics? We suggest that on any reasonably uncontentious way of defining these terms, the answer is no. We know exactly what is happening here. Just as the second law of thermodynamics is no longer strict when we go to the microlevel, neither is the concept of extensivity. But this assumption can also be seen as an idealization, corresponding to a physical system that is undergoing changes at different rates under different environmental conditions. What thermodynamics describes as an instantaneous change from liquid to gas may be better understood as a rapid process of change at the molar level which can be traced through in a continuous way. The fact that some systems are coarse-grained has an interesting implication for this set of issues link. The interesting implication is that while it is generally true that the micro states in such a system entail the macro states, the reverse is not true: Rather, many possible micro states correspond to a given macro state. The conclusion they reach is worth quoting: Phase transitions are an important instance of putatively emergent behavior. Unlike many things claimed emergent by philosophers e. Here we have focused on the case for emergence built from physics. And if one goes past textbook statistical mechanics, then an argument can be made that they are not even conceptually novel. In the case of renormalization group theory, consideration of infinite systems and their singular behavior provides a central theoretical tool, but this is compatible with an explanatory reduction. They show that the phenomena of phase transitions as described by classical thermodynamics are compatible with being reduced to the dynamics of individual elements at the micro-level, so phase transitions are not ontologically emergent. Are these arguments relevant in any way to debates about emergence in social system dynamics? The direct relevance is limited, since these arguments depend entirely on the mathematical properties of the ways in which the micro-level of physical systems are characterized statistical mechanics. But the more general lesson does in fact seem relevant:

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The Physics of Phase Transitions Conc ad ations Pierr a a d Pa 2d d Pa d The Physics of Phase Transitions. The Physics of Phase Transitions. P. Papon J. Leblond P.H.E.

This amphipathic structure leads phospholipid molecules to spontaneously form bilayers when placed in water, as the phospholipids are driven to orient their head groups towards water and shield their fatty acid tails from it via the hydrophobic effect. While these bilayers tend to exist in a fluid phase under physiological conditions, their component phospholipids can undergo phase transitions under the correct environmental conditions. Lipid Phases Lipids can exist in a number of phases, which are summarized below. The Liquid Disordered Phase The liquid disordered phase, as its name implies, is a highly fluid state in which individual lipids can move laterally across the surface of the membrane relatively unhindered. Liquid-disordered bilayers are often characterized by irregular packing of individual lipid molecules, as well as the presence of kinks in unsaturated fatty acids. These kinks effectively reduce the surface area accessible to other fatty acid chains, weakening Van der Waals interactions. A depiction of the liquid-disordered phase, with a cross-sectional view to the left, and a top view at right illustrating packing irregularity. Note the irregular orientation of the fatty acid tails, indicating a high degree of fluidity. The Gel Phase Figure 2: Faller At temperatures below Tm melting temperature , lipid bilayers enter a solid-like phase known as the gel phase. Fatty acids with kinks often undergo trans isomerization, allowing the chains to be fully extended and strengthening Van der Waals interactions. Stronger Van der Waals interactions lead to tighter, more ordered lipid packing, impeding lateral movement across the surface of the membrane. The Liquid Ordered Phase The liquid ordered phase represents something of a hybrid of the liquid disordered and gel phases. Sufficiently high membrane sterol concentration combined with the relative rigidity of sterol molecules leads to tighter packing of liquid phase membranes, while separating gel phase lipids. The Ripple Phase At intermediate temperatures, the bilayer arranges itself such as to form a series of ripples along the surface, with a chain packing structure similar to the gel phase. Recent research suggests that the tilt of membrane lipids relative to the surface of the membrane plays a critical role in ripple formation. The Pseudocrystalline phase At low temperatures, lipid head-group interactions can facilitate the packing of membrane lipids into a highly ordered superlattice. Faller Factors Affecting Lipid Phase Transitions The primary factor driving most phase transitions is the temperature of the environment. However, Tm can vary between lipids due to differing structural properties. Furthermore, some phase transitions, such as the liquid-ordered phase transition, more strongly depend on environmental conditions other than temperature. Chain Length Longer fatty acid chains have higher surface areas than smaller ones, resulting in stronger Van der Waals interactions between long lipid chains. Tabulation of Tm and enthalpy data for lipids of differing lengths. Unlike chain length, however, increasing unsaturation reduces the Tm of the lipid by reducing the accessible surface area of the fatty acid tail by forming kinks that prevent nearby tails from packing together as tightly. This weakens inter-lipid Van der Waals interactions, and lowers the Tm of the lipid. The positioning of double bonds in the fatty acid chain influences the degree to which Tm is loweredâ€”with double bonds closer to the middle of the chain producing larger kinks, thereby decreasing Tm more than double bonds located closer to either end of the chain. Sterols Sterols, such as cholesterol, play a large role in modulating the fluidity of membranes. Sterols areâ€”compared to neighboring phospholipidsâ€”small, rigid molecules that are largely hydrophobic, with the exception of a single hydroxyl group. The accumulation of sterols in a lipid bilayer causes tighter packing of fatty acid tails in liquid phase lipids and separates gel phase lipids. Membrane Protein Concentration High local concentrations of membrane-associated proteins can decrease the Tm of sections of membrane through steric interactions between crowded proteins. If such a membrane system is cooled, the longer, more saturated lipids will undergo the transition to the gel phase before other shorter, less saturated lipids, as their Tm will be reached first. This results in the formation of patches of long, saturated, gel-phase lipids in the membrane. Protein Aggregation Phase separation between lipids surrounding integral membrane proteins can briefly expose the hydrophobic residues of the middle of the protein to water. Illustration of phase separation-driven protein aggregation. Different lipid types indicated by differently-shaped head groups are sorted together through the process of phase separation, which can result in aggregation of membrane proteins through the hydrophobic effect. Membrane Leakage The differential rates of phase transition between lipids composing a membrane can lead to packing defects as gel-phase fatty acid chains straighten out, forming a short-lived gap between the now gel-phase chains and neighboring, still-liquid chains. Such gaps can allow cytoplasmic contents to leak out of the cell until they are plugged via lateral diffusion of neighboring lipids. References Benalcazar, Wladimir A. University of Illinois, Urbana-Champaign. University of California, Davis. 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Chapter 6 : Quantum phase transition - Wikipedia

Second-order phase transitions of matter take place at characteristic temperatures (or pressures), but unlike first-order transitions they occur throughout the entire volume of a material as soon as that temperature (called the critical point) is reached.

Share via Email Even a watched kettle will induce a phase transition eventually Photograph: This one was from Malcolm Fairbairn and was mainly about Dark Matter. So the observations which betray its presence are all indirect. In general they depend upon its gravitational influence. From a particle-physics point of view it is also mysterious because it does not seems to be made of any of the particles we know about in our Standard Model. One very powerful indirect constraint on Dark Matter comes from considering the development of the universe shortly after the big bang. When the universe was hot and dense enough, the assumed Dark Matter particles would have participated in the cosmic mosh-pit, being scattered, annihilated and produced along with everything else. As the universe expanded and cooled, at some point they decoupled, disengaged - drifted towards the bar, if you like - but are still hanging around, distorting the behaviour of the other dancers. The distribution of galaxies, and the cosmic microwave background , depend on Dark Matter. Therefore measurements of them provide further evidence for its existence, and constrain its nature. I love the way physics allows us to make that kind of connection - in this case, between the distribution of stars in the night sky and the possible existence of a new fundamental particle. Such connections typically require a broad array of apparently disparate pieces of physics. In this case one of the most important links in the chain is thermodynamics - the study of how heat and temperature change, and how they make other things change. Much of thermodynamics was worked out around the industrial revolution, because the phase transition of boiling water is the driving force behind steam engines. If you add energy to water, the temperature will in general increase steadily. However, at degrees celsius, that behaviour changes quite dramatically. The temperature stops increasing, even if you carry on adding energy. But the volume or the pressure, if the water is in a boiler will suddenly increase as the water undergoes a phase transition from liquid to gas. The pressure can be used to drive an engine. Once the water has boiled, the temperature will start going up again. In simple terms, it is when particles acquire mass; quite a dramatic change. As Malcolm descibed in his seminar, this is a bit of a problem for cosmologists, because of another piece of physics which gets dragged in. It is quite difficult to come up with models of the Big Bang which can produce all the matter we see around us, and no antimatter. To make protons and neutrons, without making equal numbers of anti-protons and anti-neutrons, a dramatic shift is required somewhere as the universe cools. The favourite way of achieving this is by having a first-order electroweak phase transition. Which is now ruled out in the Standard Model thanks to the Higgs boson being too heavy, and smoothing out that phase transition into a continuous one. This is one reason why people like Malcolm are coming up with theoretical extensions of the Standard Model which would both provide a suitable Dark Matter particle, and allow the electroweak phase transition to be first order. It is also one of the reasons the hunt for Dark Matter is so exciting, and in fact difficult, since some of these constraints imply it might be even harder to find than we thought. But it is also pleasing to remember that it goes both ways. The physics that was worked out while struggling to make better steam engines for the industrial revolution now allows us to connect the Big Bang, the behaviour of galaxies, the abundance of matter compared to antimatter, the Higgs boson and Dark Matter; all via the thermodynamics of the early universe. See here for more on derivatives. Another reason knowing that number is interesting. Jon Butterworth has written a book about being involved in the discovery of the Higgs boson, Smashing Physics , available here. Some interesting events where you might be able to hear him talk about it etc are listed here.

Chapter 7 : Aggregat states and phase transitions - Heat - Physics Equipment - Physics

The observation of dynamical quantum phase transitions in an interacting many-body system breaks new ground in the study of matter out of thermal equilibrium. Understanding matterâ€"a collection of many interacting constituents, such as *atoms and electronsâ€”is a major endeavor in physics. While.*

Chapter 8 : Physics - Viewpoint: Quantum Phase Transitions Go Dynamical

The term phase transition (or phase change) is most commonly used to describe transitions between solid, liquid, and gaseous states of matter, as well as plasma in rare cases. A phase of a thermodynamic system and the states of matter have uniform physical properties.

Chapter 9 : The Main Phase Transition - Physics LibreTexts

Mixtures of surfactant or amphiphilic molecules and solvents are known to display a large number of lyotropic mesophases. Although the physics of thermotropic liquid crystals has been vastly discussed in the literature, lyotropic mesophases have been much less explored.