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## Chapter 1 : Superfluid helium-4 - Wikipedia

*Microscopic Theory of Nonhomogeneous Structures [Katsnelson] on racedaydvl.com \*FREE\* shipping on qualifying offers.*

This is an open access article distributed under the Creative Commons Attribution License , which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The bundle consists of a mixture of metallic and doped semiconducting nanotubes, which have different critical transition temperatures. We investigate how a spatially averaged superconducting order parameter and the critical transition temperature depend on the fraction of the doped semiconducting carbon nanotubes in the bundle. Our simulations suggest that the superconductivity in the bundle will be suppressed when the fraction of the doped semiconducting carbon nanotubes will be less than 0. Single wall carbon nanotubes SWCNTs represent a unique class of quasioone-dimensional nanoscale systems exhibiting various interesting phenomena. Among other exciting features, it was demonstrated that individual single wall carbon nanotubes may have intrinsic superconducting properties [ 1 ]. Carbon nanotubes can also form bundles and ropes [ 4 ], with tens and hundreds of individual SWCNTs in the bundle, coupled to each other by dispersive Van der Waals forces. Generally speaking, for nanoscale systems with the quantum level spacing approaching the superconducting gap energy , the superconductivity vanishes [ 5 ]. It is expected that doping of SWCNTs in a bundle by, for example, boron, may significantly improve their superconducting properties [ 6 ]. At a proper level of doping, the Fermi level may be at a one-dimensional singularity of the energy spectrum that gives a higher density of states DOSs , that will lead to a higher critical temperature. In particular, we assume here that such kind of mechanism of doping enhanced may be much better pronounced in the case of semiconducting SWCNTs, which may have higher DOS due to lower energy of the Van Hove singularities. This is in contrast to metallic SWCNTs, where singularities in the DOS are at higher energies and can be filled at much higher doping levels only according to the Kataura plot [ 7 ]. This means that a bundle consisting of doped semiconducting nanotubes could be a much better superconductor compared to a bundle made of metallic SWCNTs. However, synthesis of SWCNTs by currently known methods usually results in a mixture of semiconducting and metallic nanotubes. Since the nanotubes after the synthesis initially are not doped or unintentionally slightly p-type doped, e. One may try to estimate a spatially averaged order parameter and the corresponding effective critical temperature for a bundle consisting of a mixture of these two types of SWCNTs. It will be also interesting to know whether it is possible to obtain the critical temperature higher than in other carbon based nanostructures, like in alkali metal doped fullerenes. Spatial variations of the superconducting order parameter are significant for nanoscale systems, including nanotubes [ 9 , 10 ]. In this work, we use a microscopic theory based on inhomogeneous Bogoliubov-de Gennes equations to establish how the superconducting properties of a bundle depend on the fraction of doped semiconducting nanotubes. The lattice can be enumerated by indexes , which correspond to the position of a nanotube , but in this work we prefer to enumerate nanotubes in a bundle using a single index through the mapping , where is the number of nanotubes in the raw. The doped semiconducting nanotubes are assumed to occupy the fraction of the sites in the bundle, and the metallic nanotubes occupy the fraction of the sites. A full three-dimensional description of a bundle taking into account the band structure and chirality of individual nanotubes would make simulations of the Bogoliubov-de Gennes equations too complex. On the other hand, assumption about the translation invariance along the longitude direction of the nanotubes would make the simulations marginally simpler, because one still needs to deal with quantum problem in three dimensions, but at the same time, this assumption would throw away the band structure difference between semiconducting and metallic nanotubes. In this study, we adopted a simplified two-dimensional picture which allows us to repeat our simulations several dozens of times for different arrangements of the nanotubes in the bundle. In the two-dimensional picture, the conduction electrons can stay in a nanotube or can hop to the neighboring nanotubes sites. In principle, there may be three different hopping

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constants, with the hopping matrix elements equal to either.

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### Chapter 2 : References: "Superconductivity and superfluidity (what was done and what was not)"

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Aperture elements 32, 36 are provided in front of the detectors 12, 38 for controlling the forward and diffracted beams incident on the detectors. As stated in this publication, the development of X-ray crystallography early in the twentieth century yielded accurate images of matter at atomic resolution. Subsequently electron microscopes have been developed and provide direct views of viruses and minute surface structures. Another type of microscope utilizing X-rays rather than light or electrons, provides a different way of examining tiny details, and considerably improves on the resolution of optical microscopes. They can also be used to map the distribution of certain chemical elements, form pictures in extremely short times, and have the potential for special capabilities such as 3-dimensional imaging. X-ray microscopy differs from conventional electron microscopy in that specimens can be kept in air and in water, whereby biological samples can be studied under conditions similar to their natural state. As further described in the above article, imaging X-ray microscopes use focusing optics to form an image magnified a few hundred times, which can then be recorded by a detector of modest resolution. The principle benefit of imaging X-ray microscopes is that the entire sample is illuminated and imaged at once, which permits rapid picture taking thereby combatting blurred images resulting from motion and minimizing radiation damage in biological samples. A micro-zone plate magnifies images of the sample on a detector. The image field is indicated at Fresnel zone plates serve as condenser and objective X-ray lenses. In the scanning X-ray microscope shown in FIG. The focused X-ray beam scans back and forth, top to bottom across the sample. The rays that penetrate at each point are measured using a proportional X-ray counter. An element which imparts a phase shift to a preselected order of diffraction of the radiation is arranged in the Fourier plane of the X-ray objective to obtain the highest possible image contrast. The specimen outside the chamber is positioned adjacent to the second surface of the substrate, and at least one X-ray detector is positioned to detect X-rays leaving the specimen. The X-ray detector is an energy dispersive type capable of selecting and recording a narrow range of peak energy and energies close to peak energy. X-rays of the selected wavelength are reflected and diffracted to produce an overlapping array of images to a detector at the second focus of elliptical diffraction mirrors. Each image corresponds to the emission from the plasma in a single spectral line. The different diffraction grating mirrors on each rotating carrier have the same surface contour, but are coated with multilayer coatings of different multilayer compositions or 2D parameter. Conditions for the formation and observation of X-ray Moire patterns in crystalline systems are discussed in "Main Crystallographic Situations for the Formation of X-ray Moire Patterns", by P. Pinsker, Springer-Verlag, Berlin. The development of X-ray microscopes has faced a number of technology problems and up to the present time it cannot be claimed that all of these problems have been solved. The established approaches can be placed in one of several categories including scanning microscopes, imaging X-ray microscopes, image converting microscopes, and X-ray holography. Scanning X-ray microscopes, like scanning electron microscopes, use a small probe beam of X-rays to produce a signal. The small size of the probe beam can be produced either by a focusing element or by a simple pinhole. Imaging X-ray microscopes are more analogous to conventional optical microscopes in that the sample is uniformly illuminated and imaged onto an area detector or film by a magnifying optical element. Image converting X-ray microscopes involve a simple contact image of the sample being recorded onto a photoresist, with the actual magnification performed by electron micrography of the developed resist. X-ray holography depends upon recording the pattern of interference between radiation scattered by the sample and a coherent reference source of X-rays. The technological limitations for these traditional approaches toward X-ray microscopy involve the difficulties of producing suitable optical elements, detectors, photoresists and sources for the X-ray wavelengths employed. X-rays interact weakly with matter, which is an advantage for many applications, but is a severe disadvantage for producing optical elements. Even producing a pinhole, as

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required for some scanning microscopes, is difficult in that the material around the pinhole must be thick enough to stop the unwanted portions of the illuminating X-ray beam. Both imaging X-ray microscopes and X-ray holography require position sensitive area detectors whose position resolution is ultimately limited by the volume of material required to completely contain the energy deposited by the X-rays upon detection. Production of coherent beams of X-rays tends to limit the total signal even from the brightest X-ray sources available. In addition to holography, X-ray coherence is required for optimal performance of Fresnel zone plates which are the most successful type of X-ray focussing element demonstrated to date. All of the above problems have been addressed with the most success in the soft X-ray regime, i. The concept of forming images through mathematical transformation is related to Hadamard Transform Imaging used in X-ray astronomy. A Hadamard transform is analogous to a Fourier transform where the former uses square-wave modulation and the latter uses sine-waves. Computed X-ray tomography is also an imaging technique that depends upon a mathematical transformation of recorded data G. Sinner, Scientific American 8 84; P. X-ray Moire patterns produced by X-ray diffraction from two or more crystals have been observed on a macroscopic scale. These patterns are used in studies of crystal defects and are observed in X-ray interferometry J. A 24 It is a further object of this invention to provide a method and apparatus for image formation based on Fourier transformation of area integrated signals produced by variable Moire fringes. It is another object of this invention to provide an imaging technique combined with production and control of Moire patterns by X-ray diffraction from crystals. It is a still further object of the invention to provide an X-ray Moire microscope for use in both a radiography mode and elemental specific microprobe mode. The above objects are achieved by the instant invention which provides an X-ray Moire Microscope XMM using a relatively large beam of X-rays having a sinusoidal intensity profile which is both well defined and variable on demand by the production of X-ray Moire patterns via X-ray diffraction from crystals. The X-ray diffraction is typically limited to photon energies greater than 2, eV and opens a new portion of the electromagnetic spectrum to microscopy. In the simplest case, X-ray diffraction from single crystals is treated by a two-beam approximation, one beam being the X-rays in the incident or forward direction and the second beam being X-rays in the diffracted direction. For single crystals these two beams are treated as a pair, since the diffracted beam can be multiple diffracted back to the forward direction. Dynamical theories of single crystal diffraction see for example, B. This bunching of the photons leads to the well known Borrmann effect anomalous X-ray transmission. Even in the case of thinner crystals, or weakly absorbing cases where the Borrmann effect is not fully developed, the X-rays will interfere to produce similar X-ray fringe structure. If the X-ray beam which has become modulated in intensity via diffraction as described above then encounters a second crystal so that the orientation or spacing of the atoms in the second crystal does not match that of the first, the superposition of the Borrmann fringes of the first and second crystal will exhibit a Moire effect, i. The spatial frequency and the phase of this Moire modulation can be varied by appropriate rotations and displacements of the crystals. For a sample in a Moire X-ray field, signals which are dependent on the X-ray intensity will be directly related to the Fourier transform of the structure of the sample. The Fourier component which is recorded is related to the spatial wavelength of the Moire pattern. By varying the Moire wavelength through a relative rotation of the crystals, and varying the phase of the Moire pattern through a translation of the crystals, a complete Fourier transform of the structure can be measured. A mathematical inversion of this measured Fourier transform would reproduce a real-space image of the structure with an arbitrary magnification included in the mathematics. In practice, a complete Fourier transform cannot be measured. Nevertheless, a discrete Fourier transform within a range of wavelengths between short and long wavelength limits results in a transformed image that has a resolution and field of view determined by the range of the Fourier transform. For the simple case where X-ray diffraction in the crystals can be treated by the two-beam approximation, a measurement involving relative rotation of displacement for the diffracting crystals generates a one-dimensional Fourier transform of the sample structure. To produce a two-dimensional image, a second set of diffracting planes may subsequently be used. Alternatively, a more complicated, two-dimensional Moire pattern can be generated by

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using multi-beam diffraction in the two Moire crystals. In the latter case, the inverse transformation from measurements to recover the real image is not strictly a Fourier transform. In the simplest case, the recorded signal is the transmitted intensity. Alternatively, the structure of a given atomic species can be determined by using a characteristic signal, such as X-ray fluorescence. The detailed dependence of the X-ray Moire patterns upon experimental factors, such as crystal thickness, crystal spacing, number of diffracting crystals, and X-ray divergence are treatable using spherical wave theory of dynamical X-ray diffraction. The highest sensitivity for an XMM would be achieved in the microprobe mode, i. Using bending magnet X-ray beamlines located at a synchrotron radiation source, one can expect on the order of photons per second to be delivered to a nm square pixel. For example, this would produce 0. Image formation at this signal rate would require lengthy integration times, but images of elements with higher area concentrations would be less tedious. Furthermore, wigglers beamlines at existing synchrotrons could increase the signal rate by a factor of 30, and undulator sources such as will be available at the Advanced Photon Source under construction at Argonne National Laboratory in the U. S. will provide another factor of 30 increase to a total gain of in signal. Additional improvements could be expected from improved detector efficiency and optimization of the crystal optics. Thus, detectible signals could be expected even for monolayer coverage with pixel sizes of a few nanometers in dimension. In accordance with the invention as shown in FIG. Crystals 14 and 16 may be silicon or germanium in the form of thin plates having a thickness appropriate to the X-ray wavelength; e. Crystals 14 and 16 are attached in a strain free manner, for example, by gentle clamping or low distortion adhesive means, to the output platforms of actuator 18 e. Actuator 18 is secured to a stable base not shown also supporting the source of X-rays and the sample under investigation. Relative rotation about an axis of rotation extending in the direction 19 is used to vary the spatial wavelength of the Moire fringe field generated as will be now described. The degree of rotation of crystals 14, 16 for a sample having a diameter of 1 mm is about 0. With the second crystal 16 disposed in substantially parallel spaced relation to the first crystal 14 at a small separation 22, an X-ray interference field is produced in the region between the crystals resulting in a second, Moire, interference field in the region after the second crystal 16 where the sample under investigation 20 is mechanically supported relative to the stable base noted above. The X-ray beam incident on crystal means 14 is modulated in intensity via diffraction as described above and then encounters second crystal means 16 having the orientation or spacing of the atoms thereof not matching those of the first crystal means 14, thereby producing superposition of the Borrmann fringes of the first and second crystal means to exhibit Moire effect in area. Mismatching of the orientation for spacing of the second crystal atoms with respect to the first crystal atoms is controlled by displacement and rotation of the crystal means 14 and 16 as described above. Crystal means 14 and 16 are also mounted for relative displacement in the direction 17 with respect to each other to vary the spacing  $d$  at 22 therebetween, so that the spatial frequency and the phase of this Moire modulation can be varied by the rotation and displacement of the crystals as described above. The displacement in direction 17 is 0. The modulated X-ray beam impinging on sample 20 results in a forward transmitted X-ray beam 26 in the incident, or forward, direction and a second beam 28 in the diffracted direction. Sample 20 may be any material whose native and thickness permit transmission of X-rays. Materials having nonhomogeneous characteristics would be of interest. The forward transmitted beam 26 passes through an aperture 30 in an X-ray opaque material element 32 onto the forward beam detector 12 which may be any of the standard electronic X-ray registration devices or counters. The diffracted beam 28 passes through an aperture 34 in an X-ray opaque material 36 and is directed onto diffracted beam X-ray detector. Elements 32 and 36 can be tungsten, lead, molybdenum, or any material having appropriate opacity. Detectors 12 and 38 are a suitable type known in the prior art and fully described in "Radiation and Measurement" by Glenn F. Signals from the detectors are used to determine transmitted intensity, for example, by counting individual X-rays with a scintillation detector, a semiconductor detector or a gas proportional counter. If available intensities are sufficiently large, then the X-ray intensity can be monitored by means of a gaseous or solid state ionization chamber whose average electrical currents are proportional to X-ray intensities. The main steps

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which are needed to obtain an image are registration of the transmitted intensity alternative registration modes are given below for each of a large number of spatial Moire wavelengths. These will be members of a discrete, uniformly spaced distribution extending over a spatial wavelength range including the size of the smallest object period deemed to be of interest. This discrete array of intensities is an array of squared moduli of the Fourier component of active absorption in the sample.

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## Chapter 3 : Superconducting Properties of 3D Low-Density Translation-Invariant Bipolaron Gas

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To be included in the collection of papers: Fizmatlit, Khalatnikov I M Ed. Reminiscences of Landau Moscow: Nauka, ; Landau. The Physicist and the Man Oxford: A Onnes H Kamerlingh Comm. Leiden 11 This paper is included as an Appendix in a more readily available paper [9] Dahl P F Superconductivity. AIP, ; J. Physics Today 49 9 40 Ginzburg V L "Research on superconductivity brief history and outlook for the future " Sverkhprovodimost: Elsevier, London F Superfluids Vol. The microscopic theory" Usp. Nauk 48 26 Translation of the main part of the paper: Acta 30 93 Cooper L N Phys. For the Russian translation see the book Low-Temperature Physics p. Inostrannaya Literatura, Ginzburg V L "On gyromagnetic and electron-inertia experiments with superconductors" Zh. Part 2 Condensed state theory, Moscow: Benjamin, ; Moscow: Mir, ; Oxford: Fizmatlit, Weinan E Phys. Birkhauser, Kirzhnits D A Usp. Nauk [Sov. Nauka, Ginsburg V "On the non-linearity of electromagnetic processes in superconductors" Journ. Sowjetunion 11 26, Yang C N Rev. Press, Russian translation of the previous edition Moscow: JETP 5 ]; Dokl. JETP 36 ] Ginzburg V L "Allowance for the effect of pressure in the theory of second-order phase transitions as applied to the case of superconductivity " Zh. Macroscopic Theory of Superconductivity, New York: Wiley, Buckel W Superconductivity Moscow: Atomizdat, Ginzburg V L "Several remarks on second-order phase transitions and microscopic theory of ferroelectrics" Fiz. Tela Leningrad 2 [Sov. JETP 67 ]; Usp. LT Part 3, Nauk 9 [Phys. Physics 39 83 ; Contemp. Physics 43 ; Edelstein V M J. Nauk 5 ; [Sov. V L Ginzburg, Moscow: JETP 25 ]; Phys. Nauk 19 [Sov. Nauk 2 1 [Sov. Nauka ; Zh. JETP 43 ]; Fiz. Tela Leningrad 19 [Sov. B 39 ; Hirschfeld P J Phys. B 37 Jezowski A et al. Acta 61 Cohn J L et al. B 45 ; Yu R C et al. S 2 , LT21 ; Sverkhprov.: JETP 56 ]; J. Nauk [Phys. Nauk 97 [Sov. Nauka, [Translated into English New York: Consultants Bureau, ] Ginzburg V L On the electrostatics of two-dimensional surface superconductors. JETP 20 ]; Phys. Nauk 95 91 ; [Sov. AIP conference proceeding Ed. D H Duglass, New York: Nauk 95 [Sov. On Physics and Astrophysics Moscow: Burean Quqntum, p. B 51 Maksimov E G J. Pedagogika, ; [Translated into English Singapore: International Educational Programme, ; Papers written by the present author or those where he is a co-author are given with titles. This was done with the only purpose of providing additional information because very little is said about some of the papers in the main text. Golubov A A et al. D M Ginsberg, Singapore:

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### Chapter 4 : Mir Publishers - books from this publisher (ISBNs begin with )

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The Journal of Chemical Physics 83, ; doi: Electrostatic energy contribution J. Reuse of AIP content is subject to the terms at: Sun, 21 Dec This model, interacting clusters and heteroclusters ICH, consists of a distribution of heteroclusters and clusters. The interaction between monomers, cluster-monomer, heterocluster-monomer, and heterocluster-heterocluster are taken into account. The method of correlation functions is extended so that configuration integral of the ICH model can be calculated. The concentration of heteroclusters is derived in terms of microscopic quantities. In the limit of no interaction between clusters and heteroclusters, the heterocluster concentration is expressed in terms of monomer concentration, the chemical potential of monomers, and the internal free energy of a heterocluster. In this limit the heterocluster concentration may also be expressed in terms of the total number of ions and the internal free energy of heteroclusters. The formation energy of a heterocluster is calculated. Although this phenomenon was observed in the last century,<sup>1</sup> the heteromolecular theory of condensation is not very well developed. The droplet model of homogeneous nucleation was extended to include the presence of ions by Thomson<sup>2</sup> and Volmer and Weber. The classical model has been improved by developing a more realistic electrostatic potential<sup>4,5</sup> and by taking into account corrections to the free energy of formation,<sup>6,7</sup> However, as has been pointed out by many authors,<sup>8</sup> the classical model is not valid for small clusters and one has to look at a cluster as a composite system with an internal structure. Within a cluster, molecules interact with one another. In the case of heteroclusters i. In order to calculate the equilibrium concentration of clusters one has to incorporate the microscopically found formation energy into the formalism developed for the continuous droplet model. As a result, the supersaturated background of monomers has been treated as a perfect gas and the interaction between clusters has been ignored. As in the case of homogeneous nucleation,<sup>16</sup> we believe that a single heterocluster model is not a sufficient model for a heteromolecular condensing system. One usually has a gaseous system with ions distributed throughout as impurities. When the system becomes supersaturated, a distribution of - Current address: The background monomers based molecules is a supersaturated imperfect gas. Here we extend the model suggested for homogeneous nucleation <sup>16</sup> to the case of heteromolecular nucleation theory, We envision a model composed of a distribution which includes concentrations of both clusters and heteroclusters of different sizes. Each cluster is a bounded system which can undergo translation of its center of mass. Each cluster has an internal structure, We allow the internal structure of a cluster and a heterocluster to be different. The internal energy of each cluster and heterocluster may be calculated from some two-body potential where this potential may be classical quantum mechanical. In our model, the monomers interact with all clusters and heteroclusters and the heteroclusters interact with each other. We have extended the method of correlation functions to handle the configuration of our model for the system of interacting clusters and heteromolecular ICH model. One of the advantages of using the correlation function method is that one does not need to use the concept of mathematical clusters. Approximate solutions for the above distribution functions are given in the Appendix. Using the method of the most probable set we have derived the equilibrium concentration of clusters and heteroclusters. This concentration depends on the monomer concentration, the free energy of the internal motion of clusters, and on the monomer-cluster, the monomer-heterocluster, and the heterocluster-heterocluster interactions, respectively. When the interactions are turned off, the equilibrium concentration of clusters becomes identical to the equilibrium concentration of clusters in the atomistic model, <sup>16,19</sup> and the equilibrium concentration of heteroclusters reduces to a form which resembles the expression used in the classical model. Heteromolecular theory of nucleation clusters depends on the total number of ions in the system and on the free energy of internal motion of heteroclusters. The formation energy of a cluster and a heterocluster is calculated from the total energy of the ICH model. These formation energies

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are expressed in terms of the internal energy of a cluster or a heterocluster, the monomer-monomer, monomer-cluster, and monomer-heterocluster interactions. In the case of no interaction these expressions depend on only the cluster or heterocluster energy and the free monomer energy. As long as the supersaturation ratio is less than the critical supersaturation, the system may be regarded as residing in a metastable state. Thus we have a gaseous system in volume  $V$  where a distribution of clusters and heteroclusters are already formed. The formation of these clusters may be expressed in terms of the following reactions: We assume that there are no free ions and there is only one sign of charge present. Here a  $k$ -mer cluster has  $k$  based molecules and  $J$ -mer heterocluster has  $J$  based molecules and an ion. The total mass of the system is fixed. The internal structure of based molecules a cluster of size one with no embedded ion can be considered if it is of any interest. The interaction among  $M$  clusters and heteroclusters in the system is denoted by  $U_{ij}$ ,  $i, j = 1, 2, \dots$ . We make the following assumptions about the interaction potential of the total Hamiltonian:  $U_{ij}$  can be expressed in terms of two-body potentials  $U_{ij} = \sum_{i,j} \phi_{ij}(r_{ij})$ . Both  $Q_k$  and  $Q_{HJ}$  may be calculated using either a classically or quantum mechanically developed two-body interaction. While the calculation of  $Q_k$  and  $Q_{HJ}$  are of great interest in themselves, we do not address this problem in the present work. We assume that the  $Q_k$  and  $Q_{HJ}$  can in principle be calculated and are available. In order to handle the configuration integral, we extend the method of correlation functions used in the homogeneous nucleation problem to ICH model. Thus, we start by defining the probability distribution in the configurational space  $e^{-\beta U}$ ,  $U = \sum_{i,j} \phi_{ij}(r_{ij})$ . An approximate solution to these equations are given in the Appendix A. We use the method of the most probable set to derive the equilibrium cluster concentrations and the heterocluster concentration. We use the method of undetermined Lagrange multipliers subject to the constraint that the total number of molecules in the system remains constant. Thus, we have  $J$ . The concentration of hetero- $J$ -mers depends on the concentration of monomers, on the internal Helmholtz free energy of a hetero- $J$ -mer and an monomer-monomer, as well as the heterocluster-monomer and heterocluster-heterocluster interactions. The concentration of  $K$ -mers, Eq. Equations 21 and 22 are general forms of cluster and heterocluster concentrations. Later we show other forms of these equations for the case of no interaction between clusters. To find the formation energy of a heterocluster of size  $J$ , we write the total energy of the system with constant number of molecules but assuming that the largest heterocluster size in the system is  $J - 1$  I-mer. As a result of formation of hetero- $J$ -mers, only the concentration of monomers and heteroclusters of size one have been changed. In this case, Eq. Substituting this approximation into Eq. V 39 40 Thus we have the concentration of hetero- $J$ -mers for the case of no interaction between clusters. Heteromolecular theory of nucleation monomers, the monomer-monomer, and the heterocluster-heterocluster interaction. For the case of no interaction between clusters we found two forms for expressing the heteroclusters concentration. The other form of the heterocluster concentration, Eq. All the new expressions for heterocluster concentration are given in terms of microscopic quantities. The last one, Eq. Similarly, we found the formation energy of a heterocluster and cluster from the total energy of the system. This was done by taking the difference of the total energy of the ICH model when heteroclusters of size  $J$  are formed and when the largest heterocluster in the system is  $J - 1$ . Dividing the formation energy of  $J$ -mers by the number of hetero- $J$ -mers, we obtained the formation energy for a hetero- $J$ -mer. This formation energy, Eq. In the limit of no interaction one gets an expression for the formation energy which depends only on the energy of free monomers, the energy of a heterocluster, and the energy of a heterocluster of size one. In our next work we will give the comparison of the ICH model to experimental and other theoretical work on heteromolecular condensation. We would like in particular to examine the effect of treating the background monomers as an imperfect gas on the heterocluster concentration and the formation energy of clusters. Diana Tussing for her aid in preparing the manuscript. One of us H. In ICH when the interaction between monomers and heteroclusters and clusters are considered, one needs to have the monomer-cluster, heterocluster-heterocluster, and the heterocluster-monomers distribution functions. Since the method we used in solving all distribution functions is the same, we give only the detail solution of the heterocluster-monomer distribution function. Taking the

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derivative of the heterocluster-monomer distribution function, Eq. Let us assume that  $M$  is small. A2 Substituting the above series into Eq. A1 and equating terms of the same order yields  $M$   $J_p$   $l$   $r$   $v$ . Heteromolecular theory of nucleation For zeroth-order differential equations [Eqs. A14 In a similar way we can find all other two-cluster distribution functions up to the first order. Wilson, Trans, R, Soc. A , ; Philos. A , ; , 2W. Edinburgh 7, 63 , 3M. Weber, Phys, Chern, A , Chern, Phys, 50, ; b J, p, Hirth and G. W, Castleman, Jr, and I. N, Tang, J, Chern. Reiss, Nucleation Phenomena, edited by A, C. Zettlemoyer Elsevier, New York, , 9e. Pal, Adv, Phys, 24, Dunning, Nucleation, edited by A, e.

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### Chapter 5 : A microscopic model for the heteromolecular theory of nucleation - [PDF Document]

*The dynamics of translations and rotations of molecular solids and liquids has been studied by using a microscopic theory. The effects of translation-rotation coupling on the depolarized Rayleigh-Brillouin spectrum are investigated in detail.*

The centrality of science and absolute values, proceedings of the 4th International Conf. Human Systems in Transition, eds. Waddington Addison-Wesley Publishing Company: USA 73 English version in preprint form: Sanfeld "Surface Thermodynamics," J. Volume I Studies on the Conceptual Foundations, eds. New York, Stengers "The New Alliance: Part One - From Dynamics to Thermodynamics: Towards a Human Science of Nature," Scientia Also in French translation, ibid. USA 74 Nauda Indian National Science Academy: Nicolis "Nonequilibrium Phase Transitions: University of Uppsala, Grecos " On the derivation of linear irreversible thermodynamics for classical fluids," Proc. Entropy and Measurement in Quantum Mechanics," Proc. USA 76 Stengers "Dynamics from Leibnitz to Lucretius," in Hermes: Literature, Science, Philosophy, ed. Lieng-Huang Lee Plenum Publ. Theoretical Physics 69 USA 78 Boulder, CO, Triumphs and Conflicts," in Albert Einstein: Poortmans University Park Press: Allen University of Texas Press: Amsterdam, USA 80 Miriam Balaban Balaban Publishers: Pahaut "The Rediscovery of Time," Zygon 19 An Overview," in Aspects of Chemical Evolution, ed. Nicolis "Self-Organization in Nonequilibrium Systems: Towards a Dynamics of Complexity," in Bifurcation Analysis, eds. Elskens "From Instability to Irreversibility," Proc. USA 83 Lefever "Immune System and Stability: Pahaut "Redescubrir el Tiempo," El Paseante 4 Katrin Meschkowski Serie Piper: Petrosky "Limits to Quantum Theory? Kawasaki, Kyoto University An Autobiography," Physicalia Magazine 9 Weaver Simon and Schuster: USA 85 Abitare la terra a cura di Mauro Ceruti e Ervin Laszlo, ed. Nicolaides Kluwer Academic Publishers: Mareschal "Velocity Correlations and Irreversibility: Elsevier Science Publishers B. Petrosky "Laws and Events: Bell, Foundations of Physics 21, No. Discussion Remarks and Comments to R. Sudarshan, Austin, Texas, September 16, , ed. Chaotic Dynamics and Transport in Fluids and Plasma, ed. Antoniou "Intrinsic irreversibility and integrability of dynamics," Physica A World Scientific Publishing Co. USA 90 Beyond the Cartesian Dualism," Origins: Brain and Self Organization, ed. Science, Research, Development 1, European Commission Polanyi Nobel Laureates Lectures, ed. Moskovits House of Anansi Press, Ltd. Lakshmikantham Walter de Gruyter, Berlin, Schurz Springer, Lecture Notes in Physics: Petrosky "Extension of classical dynamics. The case of anharmonic lattices," Gravity, Particles and Space-Time, eds. Sardanashvily World Scientific, Singapore, Santos Editorial Complutense, Madrid, Schnitman Artes Medicas, Porto Alegre, Phillips Quorum Books, Westport, Connecticut Galkowski Cambridge University Press, Cambridge Architecture and Design in America on Value, ed. Franklin Institute, B, No. Petrosky "Le vide Quantique et le dilemme hamiltonien," Le vide, eds. Petrosky "Extension of classical dynamics: Emergence of irreversibility and stochasticity," Fundamental and Applications of Complex Systems, ed. Exact solution and indirect spectroscopy. Ruffini, World Scientific, Singapore Hall Cambridge University Press, Cambridge, Ricciardelli, Presses Universitaires France, Paris Genetics in Europe Open days , Brussels, November 16, , eds. John Benjamins, Kondepudi Preface, Modern Thermodynamics: Petrosky, "Quantum transitions and dressed unstable states," Phys. A 63 Karpov "Explicit construction of a time superoperator for quantum unstable systems," Chaos, Solitons and Fractals 12 Pronko "Gamow algebras," Chaos, Solitons and Fractals 12 Petrosky "Memory effects and dressing: Ordonez "Space time formulation of quantum transitions" Phys. A 64 Petrosky "Limits to causality and delocalization in classical field theory" Evolution Equations and their Applications in Physical and Life Sciences, ed. A A 66 Ilya Prigogine on the occasion of his 85th birthday Fondation des Treilles, Tourtour, France, July published in a special issue of the International Journal of Quantum Chemistry on Complexity:

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## Chapter 6 : USA - X-ray moire microscope - Google Patents

*The symmetrical analysis of the variational equation, which describes the modulated phases of the systems with the scalar order parameter, has been carried out.*

Correspondence should be addressed to V. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. Abstract Consideration is given to thermodynamical properties of a three-dimensional Bose-condensate of translation-invariant bipolarons TI-bipolarons. The critical temperature of transition, energy, heat capacity, and the transition heat of ideal TI-bipolaron gas are calculated. The results obtained are used to explain experiments on high-temperature superconductors. Introduction The theory of superconductivity is one of the finest and oldest subject matters of condensed matter physics which involves both macroscopic and microscopic theories as well as derivation of macroscopic equations of the theory from microscopic description [ 1 ]. In this sense the theory was thought to be basically completed and its further development was to have been concerned with further details and consideration of various special cases. The situation changed when the high-temperature superconductivity HTSC was discovered [ 2 ]. Surprisingly, it was found that, in oxide ceramics, the correlation length is some orders of magnitude less than that in traditional metal superconductors while the ratio of the energy gap to the temperature of superconducting transition is much greater [ 3 ]. The current status of research can be found in books and reviews [ 4 – 18 ]. Today the main problem in this field is to develop a microscopic theory capable of explaining experimental facts which cannot be accounted for by the standard BCS theory. One might expect that development of such a theory would not affect the macroscopic theory based on phenomenological approach. With all the variety of modern versions of HTSC microscopic descriptions: In what follows such a bosonization of electrons provides the basis for the description of their superconducting condensate. The phenomenon of pairing, in a broad sense, is considered as arising of bielectron states, while, in a narrow sense, if the description is based on phonon mechanism, it is treated as formation of bipolaron states [ 19 ]. For a long time this view was hindered by a large correlation length or the size of Cooper pairs in BCS theory. For the same reason, over a long period, the superconductivity was not viewed as a boson condensate see footnote at p. A significant reason of this lack of understanding was a standard idea that bipolarons are very compact particles. It implies that a stable bound bipolaron state is formed at one node of the lattice and subsequently such small-radius bipolarons are considered as a gas of charged bosons as a variant individual SRP are formed and then are considered within BCS of creation of the bosonic states. Despite the elegance of such a picture, its actual realization for HTSC comes up against inextricable difficulties caused by impossibility to meet antagonistic requirements. On the one hand, the constant of electron-phonon interaction EPI should be large for bipolaron states of small radius to form. On the other hand, it should be small for the bipolaron mass on which the superconducting temperature depends [ 23 – 28 ] to be small too. Obviously, the HTSC theory based on SRP concept which uses any other nonphonon interaction mechanism mentioned above will run into the same problems. Alternatively, in describing HTSC one can believe that the role of a fundamental charged boson particle can be played by large-radius bipolarons LRB [ 30 – 34 ]. Historically just this assumption was made by Ogg [ 30 ] and Schafroth [ 35 ] long before the development of the SRP theory. When viewing Cooper pairs as a peculiar kind of large-radius bipolaron states, one might expect that the LRP theory should be used to solve the HTSC problem. As pointed out above, the main obstacle to consistent use of the LRP theory for explaining high-temperature superconductivity was an idea that electron pairs are localized in a small region, the constant of electron-phonon coupling should be large, and, as a consequence, the effective mass of electron pairs should be large. In the light of the latest advances in the theory of LRP and LRB, namely, in view of development of an all-new concept of delocalized polaron and bipolaron states, translation-invariant polarons TI-polarons and

bipolarons TI-bipolarons [ 36 – 42 ], it seems appropriate to consider their role in the HTSC theory in a new angle. We recall the main results of the theory of TI-polarons and bipolarons obtained in [ 36 – 42 ]. Notice that consideration of just electron-phonon interaction is not essential for the theory and can be generalized to any type of interaction. In what follows we will deal only with the main points of the theory important for the HTSC theory. The main result of papers [ 36 – 42 ] is construction of delocalized polaron and bipolaron states in the limit of strong electron-phonon interaction. The theory of TI-bipolarons is based on the theory of TI-polarons [ 36 , 37 ] and retains the validity of basic statements proved for TI-polarons. The chief of them is the theorem of analytic properties of the ground state of a TI-polaron accordingly TI-bipolaron depending on the constant of electron-phonon interaction. The main implication of this statement is the absence of a critical value of the EPI constant , below which the bipolaron state becomes impossible since it decays into independent polaron states. In other words, if there exists a value of , at which the TI-state becomes energetically disadvantageous with respect to its decay into individual polarons, then nothing occurs at this point but for and the state becomes metastable. Hence, over the whole range of variation we can consider TI-polarons as charged bosons capable of forming a superconducting condensate. Another important property of TI-bipolarons is the possibility of changing the correlation length over the whole range of depending on the Hamiltonian parameters [ 39 ]. Hence, it can be both much larger as is the case in metals and much less than the characteristic size between the electrons in an electron gas as happens with ceramics. A detailed description of the theory of TI-polarons and bipolarons and description of their various properties is given in review [ 42 ]. An outstandingly important property of TI-polarons and bipolarons is the availability of an energy gap between their ground and excited states Section 3. The paper is arranged as follows. The results of three canonical transformations, such as Heisenberg transformation, Lee-Low-Pines transformation, and that of Bogolyubov-Tyablikov are briefly outlined. Equations determining the TI-bipolaron spectrum are derived. In Section 3 we analyze solutions of the equations for the TI-bipolaron spectrum. It is shown that the spectrum has a gap separating the ground state of a TI-bipolaron from its excited states which form a quasicontinuous spectrum. The concept of an ideal gas of TI-bipolarons is substantiated. With the use of the spectrum obtained, in Section 4 , we consider thermodynamic characteristics of an ideal gas of TI-bipolarons. For various values of the parameters, namely, phonon frequencies, we calculate the values of critical temperatures of Bose condensation, latent heat of transition into the condensed state, heat capacity, and heat capacity jumps at the point of transition. In Section 5 we discuss the nature of current states in Bose-condensate of TI-bipolarons. It is shown that the transition from a currentless state to a current one is sharp. In Section 6 the results obtained are compared with the experiment. In Section 7 we consider the problems of expanding the theory which would enable one to make a more detailed comparison with experimental data on HTSC materials. In Section 8 we sum up the results obtained. Canonical Transformations Following [ 38 – 42 ], in describing bipolarons, we will proceed from Pekar-Froehlich Hamiltonian:

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## Chapter 7 : Ilya prigogine - 4

*The Channon entropy is represented as a path integral over superfield components. This allows one to describe, in addition to information growth, the memory of a system undergoing a chain of bifurcations. These keywords were added by machine and not by the authors. This process is experimental and.*

Amit Das See discussions, stats, and author profiles for this publication at: The user has requested enhancement of the downloaded file. All in-text references underlined in blue are added to the original document and are linked to publications on ResearchGate, letting you access and read them immediately.

Solute rotation in polar liquids: Related Articles Effective static and high-frequency viscosities of concentrated suspensions of soft particles J. Fluids 23, Additional information on J. Redistribution subject to AIP license or copyright; see <http://> In particular, we explore reasons behind the surprising success of the SED model in describing dipolar solute rotation in complex polar media. Relative importance of solvent viscosity and solute-solvent dipolar interaction is quantified via a self-consistent treatment for the total friction on a rotating solute where the hydrodynamic contribution is modified by the friction arising from the longer ranged solute-solvent dipolar interaction. Although the solute-solvent dipolar coupling is obtained via the Mori-Zwanzig formalism, the inclusion of solvent structure via the wave vector dependent viscosity in the hydrodynamic contribution incorporates solvent molecularity in the present theory. This approach satisfactorily describes the experimental rotation times measured using a dipolar solute, coumarin C , in protic and aprotic polar liquids, and more importantly, provides microscopic explanation for insignificant contribution of electrical interactions on solute rotation, in contrast to the substantial role played by the translational dielectric friction in the context of ionic mobility. It is also discussed on how the present theory can be suitably extended to study the rotation of a realistic solute in media other than dipolar solvents. The hydrodynamic rotational model then naturally raises the following question: We address this question here through a count for the variations in solute shape  $f$  and the consequent rigorous microscopic description of solute rotation in a dipole- changes in solute-solvent coupling  $C$ . However, the solute-solvent interactions polar solvents,<sup>7</sup> electrolyte solutions<sup>4</sup> and for biologically rel- are accounted for only via  $V_p$  , the excluded volume of the sol- evant moieties,<sup>5</sup> it completely breaks down while explaining vent due to the presence of the solute. Nee and amitsearch bose. Zwanzig<sup>15</sup> explored, within a continuum model description, b Electronic mail: This re- structure in the first solvation shell around the solute due to distribution is not instantaneous, rather takes time, thus im- solute-solvent electrostatic interactions. The through continuum dielectric constant and relaxation time. We derive an a spherical cavity. Alavi and Waldeck<sup>21</sup> carried out a signif- expression for the rotation time of a dipolar solute in a dipole- ican development of dielectric friction introducing extended lar solvent, where the relevant parameters have been obtained charge distribution model where a solute molecule is treated from microscopic considerations. Both the solute and the sol- so that the constituent atoms with individual partial charges vent are treated as point dipoles embedded in the center of are distributed in an asymmetric ellipsoidal cavity. The solute hard spheres to keep the calculation analytically tractable. Our rotation in this anisotropic model is considered in different main finding is that the solute-solvent electrical interactions directions rendering it much more realistic compared to the have marginal effects on solute rotation, allowing an over- earlier theories. The model has been able to qualitatively ex- whelming dominance of hydrodynamic friction on the aver- plain the differences in observed experimental rotation times age rotation times. In this way, we provide a molecular level of ionic and neutral fluorescent phenoxazine dyes of similar explanation for the validity of the well-known SED descrip- size in a common solvent. However, the estimated times are far less than the experimental data for the neutral resor- ufamine and cationic oxazine and thionine. Consider the case of C in acetonitrile at rotation times. In spite of realistic elements, this model re- ambient condition as a representative example. The wave ceived limited applications for two principal reasons: Using the values of  $r_0$  and solvation time and consequently, viscosity of the solvent. Now, in a

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non-polar medium of similar viscosity. Calculations for  $C$  in the aprotic solvents<sup>33,36</sup> hyd reported in Ref. The torque acting microscopic theory of the dielectric friction on solute rotation. Here,  $I$  denotes the moment of inertia of the rotating body about the axis of rotation. Static structure factor of acetonitrile at  $K$ , as a function of wave which, after using Eq. The details of this calculation have been given in our earlier work.  $M(t)$  is Using this normalized profile in Eq. Now, the Laplace transform of Eq. Insertion of this in Eq. We find the expression of the coupling hyd factor Appendix A: The solution to Eq. The total friction now becomes ing a similar behavior to  $V_{dip} k^{-2}$ . This actually reflects the long-ranged nature of the solute-solvent interaction. Now, we write down Eq. Note the difference Downloaded 04 Jan to The experimental circles and calculated triangles rotation times of  $C$  in aprotic polar solvents and alcohols, as a function of experimen- tal average solvation times. The experimental rotation times are taken from Ref. Note, the color codes used in this figure are identical to that of Fig- ure 3. We also show here the best linear fit through the experimental points by the dotted straight line. Under these circumstances, Eq. Typically in scales of the vertical axes in these two panels. In most carbonate both of which have dipole moments larger than  $4D$ . However, if the hyd tributions. We find that the rotational relaxation of a dipolar solute in a polar medium is IV. We can the long-ranged solute-solvent interaction. We thus provide a rewrite Eq. The differences between the VZH depicted in Figure 3, as a function of experimental average and our results are more significant for the alcohol solvents. From the data in Figure 4, it is clear that Interestingly, a common point of both the frameworks lies the calculated rotation times agree reasonably well with the in the inclusion of the solute-solvent interaction and the experimental values. The deviations observed in some of the solvation time to determine the dielectric friction. In the VZH cases are purely due to the limitation of the model parameters approach, the solute-solvent interaction is incorporated in used. Similar expressions can be written for the fluctuating solvent density and the solvent-solvent static correlations. This kind of modeling would be very similar to the extended charge distribution model<sup>21</sup> considered earlier. The modified treatment will affect the solute-solvent FIG. The solute here is modeled as a hard-sphere with a unit posi- the dielectric friction. However, the calculation scheme will tive charge embedded at the center. We show the data for three values of the be numerically quite intensive, loosing analytical simplicity solute radius with insignificant dependence for solutes larger than solvents. The scenario could be simplified for an uncharged multipolar solute in a non-dipolar solvent having only higher multipole moments. In such cases,<sup>57</sup> the rotational friction studies<sup>55</sup> have indicated presence of such interactions, even will be dominated by the packing of the solvent around the though effects of these interactions have not been reflected solute, as indicated by the data in Ref. Therefore, the VZH description, based directly on ferent cases where the dielectric contributions to net friction the Stokes shift values and solvation times, predicts larger may be appreciable. If, for a certain solute-solvent combina- hyd friction for alcohols than aprotic solvents. For instance, microscopic model of the interactions where in principle the the solute-solvent coupling and the average solvation times Stokes shift values can also be used. It is indeed true that, in for similar fluorescent solutes are reported to be very large in common to the VZH approach, the dielectric friction in the room temperature ionic liquids. How- some of these systems in future papers. Even in the linearized version Eq. Similar self-consistent treatment of dielectric friction, as in our calculation, done in the context of ion-transport in a polar medium to obtain the dielectric friction<sup>27</sup> shows APPENDIX A: For a univalent cationic solute of size comparable yond. Here, vent static structure factor to calculate the wave vector  $r$  and  $R$  are the position vectors of the solvent molecule and dependent viscosity and an appropriate solute-solvent the solute molecule, respectively. One can consider in that case, the can be written as<sup>11</sup> solute-solvent interaction in a general way: A4 This leads to the following expression of total friction: A15 the solute being located at the origin, we can write Eq. A12 and derive the plicating small density fluctuations, we can expand the Downloaded 04 Jan to B3 to get 13 C. McDonald, Theory of Simple Liquids, 3rd ed. Multiplying both sides of Eq. Again, multiplying both sides of Eq. We can 37 T. Solids 75 Here, CPY  $r$  denotes the hard- Lagendijk, Physica B 83, B , A , A , pendence of average rotation time observed for  $C$  in non-dipolar sol- Academic, San Diego, Downloaded 04 Jan to

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## Chapter 8 : University of Maryland

*Extension of microscopic theory of nucleation to macroscopic clusters H. R. Kobraei and B. R. Anderson-Murray State University, Murray, Kentucky*

The normal flow is balanced by a flow of the superfluid component from the cold to the hot end. At the end sections a normal to superfluid conversion takes place and vice versa. So heat is transported, not by heat conduction, but by convection. This kind of heat transport is very effective, so the thermal conductivity of He-II is very much better than the best materials. The situation is comparable with heat pipes where heat is transported via gas-liquid conversion. Theory[ edit ] Landau two-fluid approach[ edit ] L. Assuming that sound waves are the most important excitations in helium-4 at low temperatures, he showed that helium-4 flowing past a wall would not spontaneously create excitations if the flow velocity was less than the sound velocity. In this model, the sound velocity is the "critical velocity" above which superfluidity is destroyed. Helium-4 actually has a lower flow velocity than the sound velocity, but this model is useful to illustrate the concept. Landau also showed that the sound wave and other excitations could equilibrate with one another and flow separately from the rest of the helium-4, which is known as the "condensate". From the momentum and flow velocity of the excitations he could then define a "normal fluid" density, which is zero at zero temperature and increases with temperature. At the so-called Lambda temperature, where the normal fluid density equals the total density, the helium-4 is no longer superfluid. To explain the early specific heat data on superfluid helium-4, Landau posited the existence of a type of excitation he called a " roton ", but as better data became available he considered that the "roton" was the same as a high momentum version of sound. The Landau theory does not elaborate on the microscopic structure of the superfluid component of liquid helium. Their main objective is to derive the form of the inter-particle potential between helium atoms in superfluid state from first principles of quantum mechanics. To date, a number of models of this kind have been proposed: Vortex ring model[ edit ] Landau thought that vorticity entered superfluid helium-4 by vortex sheets, but such sheets have since been shown to be unstable. Lars Onsager and, later independently, Feynman showed that vorticity enters by quantized vortex lines. They also developed the idea of quantum vortex rings. Arie Bijl in the s, [26] and Richard Feynman around , [27] developed microscopic theories for the roton, which was shortly observed with inelastic neutron experiments by Palevsky. Later on, Feynman admitted that his model gives only qualitative agreement with experiment. Namely, the potential is assumed to be of the hard-sphere type. Gaussian cluster approach[ edit ] This is a two-scale approach which describes the superfluid component of liquid helium It consists of two nested models linked via parametric space. The long-wavelength part is the quantum many-body theory of such elements which deals with their dynamics and interactions. The approach provides a unified description of the phonon , maxon and roton excitations, and has noteworthy agreement with experiment: Helium-4 atoms are bosons, and their superfluidity can be understood in terms of the Bose-Einstein statistics that they obey. Specifically, the superfluidity of helium-4 can be regarded as a consequence of Bose-Einstein condensation in an interacting system. On the other hand, helium-3 atoms are fermions, and the superfluid transition in this system is described by a generalization of the BCS theory of superconductivity. In it, Cooper pairing takes place between atoms rather than electrons , and the attractive interaction between them is mediated by spin fluctuations rather than phonons. A unified description of superconductivity and superfluidity is possible in terms of gauge symmetry breaking. Superfluids, such as helium-4 below the lambda point, exhibit many unusual properties. See Helium Helium II state. A superfluid acts as if it were a mixture of a normal component, with all the properties of a normal fluid, and a superfluid component. The superfluid component has zero viscosity and zero entropy. Another fundamental property becomes visible if a superfluid is placed in a rotating container. Instead of rotating uniformly with the container, the rotating state consists of quantized vortices. That is, when the container is rotated at speeds below the first critical angular velocity, the liquid remains perfectly stationary. Once the first

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critical angular velocity is reached, the superfluid will form a vortex. The vortex strength is quantized, that is, a superfluid can only spin at certain "allowed" values. Rotation in a normal fluid, like water, is not quantized. If the rotation speed is increased more and more quantized vortices will be formed which arrange in nice patterns similar to the Abrikosov lattice in a superconductor. Practical application[ edit ] Recently in the field of chemistry, superfluid helium-4 has been successfully used in spectroscopic techniques as a quantum solvent. Referred to as superfluid helium droplet spectroscopy SHeDS , it is of great interest in studies of gas molecules, as a single molecule solvated in a superfluid medium allows a molecule to have effective rotational freedom, allowing it to behave similarly to how it would in the "gas" phase. Droplets of superfluid helium also have a characteristic temperature of about 0. Superfluids are also used in high-precision devices such as gyroscopes , which allow the measurement of some theoretically predicted gravitational effects for an example, see Gravity Probe B. The Infrared Astronomical Satellite IRAS , launched in January to gather infrared data was cooled by 73 kilograms of superfluid helium, maintaining a temperature of 1. When used in conjunction with helium-3, temperatures as low as 40 mK are routinely achieved in extreme low temperature experiments. The helium-3, in liquid state at 3. This evaporation pulls energy from the overall system, which can be pumped out in a way completely analogous to normal refrigeration techniques. Superfluid-helium technology is used to extend the temperature range of cryocoolers to lower temperatures. So far the limit is 1. Under certain conditions, fermion pairs form diatomic molecules and undergo Bose-Einstein condensation. At the other limit, the fermions most notably superconducting electrons form Cooper pairs which also exhibit superfluidity. This work with ultra-cold atomic gases has allowed scientists to study the region in between these two extremes, known as the BEC-BCS crossover. Supersolids may also have been discovered in by physicists at Penn State University. This suggested that the supersolid nature of helium-4 is not intrinsic to helium-4 but a property of helium-4 and disorder.

### Chapter 9 : Superconductivity in an Inhomogeneous Bundle of Metallic and Semiconducting Nanotubes

A. A. Katsnelson, A. I. Olemskoi, *Microscopic Theory of Nonhomogeneous Structures*, Mir publ. (Moscow), AIP (New York), , p.