MedCrave Step into the World of Research

MedCrave Online Journal of Applied Bionics and Biomechanics

Mini Review

Open Access CrossMark

# Review of thermodynamics concerning phase transitions

## How to increase high temperature superconductivity via quantum entanglement

**Abstract**

We review thermodynamic 4 variables and 4 potentials, and recommend precision optics interference.

Measurement techniques for the phase transitions as follows. We consider the superconductivity as a Lambda (close to the 2nd order) phase transition phenomena. Then the quantum mechanics entanglement of two branches of superconductor wires that are made of YBCO 123 high temperature superconductor can be further increased one wire toward room temperature while still kept at zero resistance Ohm's law measured by precision Optics Phase Conjugated Interferometer.

Volume 7 Issue 1 - 2023

Harold Szu

Res. Ord. Professor, Bio-Med. Engineering, Visiting Scholar at CUA, Catholic University of America, USA

**Correspondence:** Harold H Szu, PhD (The Rockefeller U), Fellows (AIAA, INNS, AIMBE, IEEE, OSA, SPIE) Academician (RAS) (RNL. S.V. Malrosov, 135, 1999), Res Ord Prof., CUA, Wash D.C, USA, Email szuharoldh@gmail.com

**Received:** April 18, 2023 | **Published:** May 12, 2023

## Background

We know winter's ice & snow melting to summer's water & creeks, these phenomena are thermodynamically

known as ***phase transition***. It happens at constant temperature $T_0$ say $0^o C$, and constant pressure $P(T_0) = P_0$, say **1** ***ATP*** *(atmosphere pressure)*, the associated volume V changing from solid to liquid and vice versa has a ***singularity***. Phase transition of state variables is always associated with singularity of associated thermodynamic potential. Can one measure them directly?

### Review Thermodynamics

There are 4 thermodynamic variables: Pressures P, Volume **V**, Temperature **T**, and Entropy $\mathcal{S}$. There are associated 4 thermodynamic potentials[1] *Hermann* ***Helmholtz free energy*** $A \equiv U - T\mathcal{S}$, where $U$ is the **internal energy** at the absolute temperature **T** and $\mathcal{S}$ is the wasteful homogeneity called by the name of **Entropy** by Ludwig Boltzmann; moreover, the[2] Josiah W. **Gibbs** *chemical potential* $G \equiv A + PV$ [3] **enthalpy** $H = U + PV$. Altogether, we have 4 thermodynamic potential: (internal energy **U**, *Helmholtz* **A**, Gibbs **G**, enthalpy **H)** All together we have $4+4=8$ variable collected as in the following diagram:

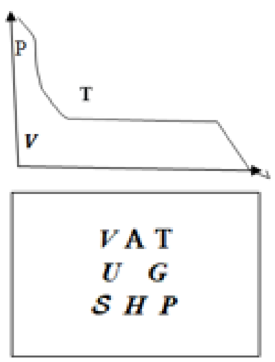


**Figure 1**

i. Tisza Square; (1960) consist of 4 potentials and 4 dynamics variable,

ii. At a constant temperature T, e.g. $0^o$C degree, snow/ ice melt down into water changes volume (in a complicate way due to ice crystal structures) as we plot here the simplest pressure versus its volume V monotonously.

Moreover, we consider 4 thermodynamic laws,

***a)*** ***zero-th*** Law (Ralph H. Fowler in the 1930s) "all heat are the same kind";

b) the **1st** Law about ***conservation of energy*** heat **Q** and work **W,**

**c) 2nd Law direction of natural processes namely increasing the Entropy,**

**d) the 3rd Law the entropy of a system at absolute zero is a well-defined constant.** Note that the **Tisza square whose** ***4 edges*** have *4* thermodynamic potentials **A, U, G, H, and** ***4 corners*** **4 thermodynamic variable** ***V, T,*** $\mathcal{S}$ ***, P.***

**Now for readers' edifice, we itemize 4 potentials and 4 variables as follows.**

Internal energy $dU = dQ - dW = Td\mathcal{S} - PdV$;

Gibb energy: $dG = -\mathcal{S}dT + VdP$;

***enthalpy*** $dH = Td\mathcal{S} + VdP$;

***Helmholtz*** $dA = -PdV - \mathcal{S}dT$;

From[1–4] follows the differential relationship expressed in partial derivative,

e.g. $T = \left(\frac{\partial U}{\partial \mathcal{S}}\right)$; $P = -\left(\frac{\partial U}{\partial V}\right)$; $V = \left(\frac{\partial G}{\partial P}\right)$; $\mathcal{S} = -\left(\frac{\partial A}{\partial T}\right)$

After the formal definitions, we return to the initial remarks about the weather phase transition, as $G = m_{ice}\, g_{ice+} + m_{water}\, g_{water}$; these two states must be at a minimum $\delta G = 0$. This completes the review of the first order phase transition theory.

The resistance of electric *currents* will suddenly disappear in a very low temperature. Question is this a phase transition? What's the associated math-physics theory? When the electrons have internal spins quantum number " s "will be spitted in inhomogeneous external magnetic field into 2 lines: $2xs = 2, s = 1/2$ in the Otto Stern & Walther Gerlach Experiments as discovered by George Uhlenbeck and Samuel Goudsmit in 1925. These electrons with half integer angular momentum are called Fermions with resistance; but when pairs of electrons with the opposite spin will attract each other, forming pairs, will have no more resistance, called superconductor. We know that is due to pair of electrons with spin up and spin down forming the pair, Bosons, as pointed out by Leon N. Cooper 1956, ((*Bardeen–Cooper–*

*Schrieffer BCS* pair at liquid Helium temperature $4^0 K$ ). P. Ehrenfest [1933] introduced the second-order type due to the "heat capacity anomaly" in liquid He latent heat.

Recent decades, there are ceramic (not conductor, but insulator) compound discover by *Paul C.W. Chu*, M.K. Wu, et al.[4] called Yttrium Bariums Copper Oxide (YBCO)1,2,3 compound where a large Barium molecule kept Cooper pairs bounded within ceramic lattice that can be still forming *Cooper pairs* beyond the liquid Nitrogen temperature $77^0 K + \rightarrow$. Question in this communication, was our understanding still correct for the phase transition phenomena? If so, can we mathematically extend Nobel Laureate *C.N. Yang* & *T.D. Lee* their 1953 theory of phase transition from the first order to the second order phase transition?

## Phase transitions

A liquid may become gas upon heating to its boiling point, resulting in an abrupt change in molecular volume. This abrupt or discontinuous change is mathematically called singularity, say the normalized *Helmholtz free energy* $\mu$ resulted in the **first order phase transition** resulted in the pressure versus volume plateau. While the pressure is kept at a constant, the molecular volume increases in gas phase. Let's first introduce Ludwig Boltzmann measure of the degree of uniformity called the entropy $\mathcal{S}$ , which is multiplied the absolute temperature T, we have obtained the "free to do work energy" called *Helmholtz free energy* $\boldsymbol{A} \equiv \mathbf{U} - \boldsymbol{\mathcal{S}}\mathbf{T}$ such that Maxwell-Boltzmann called the weighted chemical potential the fugacity:

$$z = \exp(\mu); \mu = \log z;\ \mu \equiv \frac{A}{k_B T}$$

We will consider a mathematical model proposed by C. N. Yang and T.D. Lee which reveals the singularity of the ***Grand Canonical Ensemble*** in terms of the fugacity $z \le 1$. The ***Grand Partition Function*** where the number of particles goes to the infinite $n \rightarrow \infty$ , defined by Peano algorithm

$$n = n + 1; \infty = \infty + 1.$$

A mathematical model if n-th particle partition function is uniform $Q_n \cong 1$.

$$\mathbb{Q}_{Y-L} = 1 + zQ_1 + z^2 Q_2 + z^3 Q_3 + z^4 Q_4 + \ldots = \frac{1}{1-z}; iff\ Q_n = 1, \forall n$$

Where we observe clearly the first order phase transition modeled by C.N. Yang & T.D. Lee that has a phase transition diverges at $Re[z] \rightarrow 1$.

Now, we[5] wish **to generalize Yang-Lee Model to the 2nd Order phase transition for superconductivity.**

The first classification of general types of transition between phases of matter, introduced by **Paul Ehrenfest** in **1933**, lies at a crossroads in the thermodynamically study of critical phenomena. It arose following the discovery in 1932 of a suprising new phase transition in **liquid helium**, the **"lambda transition**," when **W. H. Keesom** and coworkers in Leiden, Holland observed a **ë -shaped "jump" discontinuity in the curve giving the temperature dependence of the specific heat of helium** at a critical value. This apparent jump led Ehrenfest to introduce a classification of phase transitions on the basis of jumps in derivatives of the free energy function. This classification was immediately applied by **A. J. Rutgers** to the study of the transition from the normal to superconducting state in metals. Eduard Justi and Max von Laue soon questioned the possibility of its class of "second-order phase transitions" - of which the "lambda transition was believed to be the arche type - but **CJ. Goiter** and **H. B. G. Casimir** used an "order parameter to demonstrate their existence in superconductors. As a crossroads of study, the **Ehrenfest** classification was forced to undergo a slow, adaptive evolution during subsequent decades. During the 1940's the classification was increasingly used in discussions of liquid-gas, order-disorder, paramagnetic-ferromagnetic and normalsuper-conducting phase transitions. Already in 1944 however**,** ***Lars Onsager's*** solution of the Ising model for two-dimensional magnets was seen to possess a derivative with a logarithmic divergence rather than a jump as the critical point was approached. In the 1950's, experiments further revealed the lambda transition in helium to exhibit similar behavior. Rather than being a prime example of an Ehrenfest phase transition, the lambda transition was seen to lie outside the **Ehrenfes**t classification. The Ehrenfest scheme was then extended to include such singularities, most notably by **A. Brain Pippard in 1957**, with widespread acceptance. During the 1960's these **logarithmic infinities** were the focus of the investigation of "scaling" by **Leo Kadanoff, B. Widom** and others. By the 1970s, a radically simplified binary classification of phase transitions into "first-order" and "continuous" transitions was increasingly adopted.

**Lemma:** factorial function, **replacing** $z \rightarrow z!$ and its derivative

Let's define the Gamma function $\tilde{A}(z+1)$ which has the Laplace transform

$$\tilde{A}(z+1) \equiv \int_0^\infty t^z e^{-t} dt = z! = z(z-1)(z-2)!$$

**Theorem:**

$$\frac{dz!}{dz} = \frac{d\Gamma(z+1)}{dz} = \int_0^\infty \frac{\partial}{\partial z} t^z e^{-t}\, dt = 0$$

**Lemma:** Where use is made of the following derivative of arbitrary base" t" called "a"

$$\frac{d}{dz} a^z = a^z log\, a:$$

Lemma Prof: $\frac{da^z}{a^z} = d\ (\log a^z) = \log a\ dz;$

$$\frac{d}{dz} a^z = a^z \log a$$

**Theorem Prof:**

$$\int_0^\infty t^z\, logt\ e^{-t} dt \equiv \int_0^\infty V dU = UV - \int_0^\infty U dV = z! logt - \int_0^\infty z! \frac{1}{t} dt = 0$$

Where:

$$V = logt;\ dV = \frac{1}{t} dt$$

$$dU = t^z e^{-t} dt;\ U = \int_0^\infty t^z e^{-t}\, dt = z! = \Gamma(z+1);$$

*Q.E.D.*

$$\mathbb{Q}_{Y-L-2} = \frac{1}{1-z!} = 1 + z! + z!^2 + z!^3 + z!^4 + \ldots$$

$$\frac{d\mathbb{Q}_{Y-L-2}}{dz} = \frac{d}{dz}\frac{1}{1-z!} = -(1-z!)^{-2}\left(-\frac{dz!}{dz}\right) = \frac{1}{(1-z!)^2} * 0$$

## Measurement technique

Phase-conjugate interferometer (1982), **Patent number:** 4280764 **Abstract:** A speckle interferometer including a beam splitter, a mirror in the object beam arm, and a phase-conjugate mirror in the reference beam arm, a converging lens and a photographic film. Laser light scattered retro-reflectively from a rough surface (new app: **e.g. Ceramic YBCO123**) under investigation and passed through an imaging lens illuminates the interferometer. Fringes occur upon sandwiching a pair of exposures of the interference pattern made before and after deformation of the rough surface. The relative magnitude of the displacements from the original position at different points of the surface can be determined from the position of the fringes. **Date of Patent:** July 28, 1981, The United States of America as represented by the Secretary of the Navy, **Inventors:** Louis Sica, Jr., Harold Hwaling Szu, NRL,Wash DC. Data of the first order or the second order remain to be demonstrated in subsequent works.

**Application of Quantum entanglement to increase temperature for superconductivity:** ***Alain Aspect*** ( France 1960), ***John F. Clauser***, (California, 1980) and ***Anton Zeilinger***( Austria, 1990) have won the Nobel Prize in physics 2022 for their landmark achievements in quantum mechanics for verified the ***Quantum Entanglement Phenomena***, namely "when two particles behave as one and affect each other, even though they can be at a vast distance to one another, when millions cooper pairs of superconductor bosons are split into two branches of superconductor wires and one branch has higher temperature where Cooper pairs bosons are entangled with the other branch kept at usual superconductor temperature.

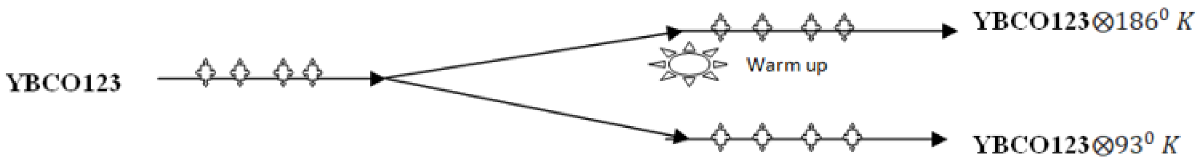


Figure 2 Schematic Diagram of Ceramic superconductor **made of Yttrium Barium Copper Oxide YBCO123operated at Paul Chu et al operated at beyond the liquid Nitrogen temperature** $93^o K +$ is further split into two branches and the Cooper pairs bosons are kept at the Quantum Mechanics Entanglement of which numerous Cooper pairs ♢ stream through will have much higher probability to be entangled with the lower temperature branch Cooper pairs ♢ and stayed in the superconductor Boson domain, while they are operated in the higher temperature close to the room temperature region that Prof. Chu has been looking for decades.

Their discoveries have added to the work of 1964, British John Stewart Bell who cannot afford publication cost and appeared in an obscure journal and died of brain hemorrhage in Geneva 1990 when he was nominated as Nobel Prize Candidate. Let's denote Alice binary particle measurements as $A_o, A_1$ and when Bob receives this particle, he chooses one of two measurements, $B_o, B_1$ which are also binary. Then, J.S. Bell of Geneva proved the celebrated inequality.

$$\langle A_o B_o \rangle + \langle A_o B_1 \rangle + \langle A_1 B_o \rangle - \langle A_1 B_1 \rangle \le 2$$

This notion that ***hidden variables*** affect interactions between particles with his well-known Bell's inequalities, whose theorem about possible hidden variable changed the scientific world's understanding of quantum mechanics. The US Patent ***4280764*** can apply the precision optics ***Phase-conjugate interferomete***r to determine/verify the phase transition from superconductor to normal conductor can happen at one place to affect the other place, due to the superconductor being a quantum system which should satisfy the quantum entanglement. In other words, we might verify that the longitudinal thermal heat can propagate faster than the transversal speed of the light.

## Acknowledgments

None.

## Funding

None.

## Conflicts of interest

The author declares no conflicts of interest.

## References

1. Jaeger G. The Ehrenfest classification of phase transitions: introduction and evolution. *Arch Hist Exact Sci*. 1998;53(1):51–81.
2. Yang CN, Lee TD. Statistical Theory of Equations of State and Phase Transitions. I. Theory of Condensation. *Phys Rev*. 1952;87:404.
3. Lee TD, Yang CN. Statistical Theory of Equations of State and Phase Transitions. II. Lattice Gas and Ising Model. *Phys Rev*. 1952;87:410.
4. Wu MK, Ashburn JR, Torng CJ, et al. Superconductivity at 93 K in a new mixed-phase Y-Ba-Cu-O compound system at ambient pressure. *Phys Rev Lett*. 1987;58(9):908–910.
5. H Szu, Nichols FW. s. j. Phys. Dept U. of Detroit (1965-66 unpublished MS Thesis).