Cold Helium, a Microcosm of the World

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Helium is unique among elements. Even at 0 Deg. K., it does not completely solidify until a 26 atm Pressure is also applied. We perform the obvious, compelling calculation**:** (26 atm Pressure) times (the jurisdictional Volume of a solidified helium atom); and we explore implications. That strange squeezed product, (P x V), implies an equivalent 'stealth' energy and also a stealth temperature times Boltzmann's constant. We note that a weak 2**.**72 Deg. K 'CMB' photon would seem to knock a zero-viscosity liquid helium atom, i.e., at 2**.**18 Deg. K or less, into its warmer viscous state. We consider the reverse; and contemplate helium as a microcosm of the world**.** Zero-viscosity helium flow is difficult to detect -- somewhat like the aether wind and aether drag. But a superflu-ID is not superflu-OUS, (i.e., it is not 'suPERfluous' – as Einstein wrongly termed 'aether'). We note that Helium-II acts much like outer space and Helium-I acts more like earth's typical elements. Also, the heat of vaporization of helium seems exactly six times its heat of fusion. We crudely explore implications of all the above.

1. Preface: This paper employs such techniques as thought experiments, allegorical comments, and use of generalizations instead of 'splitting hairs'; but I think the reader will find it worth it. This paper is shortened version of the 1-10-2007 original, and more like the short presentation at the NPA 2007 Conference.

2. Introduction: When most elements approach 0 Deg. K, they freeze and a tensile strength arises. That tensile strength is the epitome of impediment to flow, somewhat like an infinite viscosity! But as pressurized helium approaches 0 Deg. K; it strongly resists freezing and it maintains a great pro-spacing counter-pressure, like a trampoline or levitating magnetic train. So that opposite behavior hints at a possible opposite of infinite viscosity for helium; thus a minimum impediment to flow -- perhaps a zero viscosity!

Introduction -- optional: It has long been noted that the product**:** (**Mass** of helium atom) x (**Velocity** of a typical liquid helium atom) x (**Spacing** between liquid helium atoms) is of such small resultant, (angular momentum value), as to rival *Planck's* constant '***h***', i.e., that small '***h***' angular momentum value. That is the small 'realm,' or micro-world, in which an electron seems to orbit a proton without friction.

Where is helium's anti-solidifying, 26atm counter-pressure, coming from -- when it is at 0 Deg. K? From some rogue 'pro-spacing foam' with energy, in the crevices between the fairly close-packed helium 'billiard balls'? How much crevice space and nearby layers are occupied by such pro-spacing foam, compared to the space occupied by the 'Van der Waals' equivalent helium balls themselves? A 1/1 ratio or 2/1 ratio, or more? What center-to-center and ball-to-ball spacings are maintained before helium finally thoroughly solidifies at 0 Deg. K?

Optional Historical Comments: Helium was first successfully liquefied by K. Onnes in 1908. A few years later, he also discovered superconductivity by cooling solid mercury. That unimpeded electron travel was discovered while many physicists still resisted the idea of an unimpeded flow of bodies through aether—an aether as strong as steel! That was also a little before Bohr's model of an unimpeded electron's orbit around a hydrogen nucleus.

In my opinion, Onnes' work hinted at the possibility of a helium zero-viscosity, i.e., superfluidity. A student of Onnes, W. H. Keesom, finally solidified helium in 1926 at about 25 atm pressure. I think that further hinted at a possible existence of a zero-viscosity helium, and apparently so did others, before P. L. Kapitsa discovered it in 1938. That superfluidity discovery was well before1964 when Penzias and Wilson discovered CMB. (All three received Nobel prizes at the same time in 1978 for their good respective works.) I think their works are ultimately somewhat related, but Penzias and Wilson apparently did not know of Kapitsa's work. Figuratively speaking, Kapitsa had materially restored at least one 'superflu-id' to our universe after Einstein had originally declared the aether 'superflu-ous', for his own work. (In doing that, I think that Einstein had, in a sense, temporarily wrongly left our universe without any superfluid.)

3. Related DATA; and the Calculation of Solid Helium's Pressure x Volume, etc:

Let us now calculate the product (Pressure times Volume) for a typical solidified helium atom**:**

Helium's solidifying **Pressure is 26 atm = 2.63x 10^6 N/m^2** . (1)

At nearly 0 Deg. K, from slight pressure up to about 25 atm pressure; there exists a special nearly zero viscosity (phase 2) liquid helium. That stuff has a density of roughly 150 kg/m^3. And then, say, by increasing pressure up to about 26 atm; it transitions through a combination liquid and solid phase, and reaches roughly a 190 kg/m^3 density of pure, solidified helium**.** [1] Since the mass of a helium atom is about 4 times that of a hydrogen atom; each helium atom has a mass of about 6**.**68 x 10^{-27} kg. So we divide the mass of one helium atom (6**.**68 x 10^{-27} kg) by solid helium's density (190 kg/cu. m) to get the jurisdictional volume of space accorded each helium atom in the solid..

Jurisdictional Volume of solidified helium atom = 3.51 x 10^{-29} m^3. (2a)
Ref. Helium atom's **Van der Waals ball volume** = **1.15 x 10^{-29}** m^3. (2b)

Optional Note: The product (PxV) is a key factor in enthalpy and thermodynamics. An energy would seem to be held-back, gathered-in or confined. And that energy, perhaps is related to solid helium's pressure times a helium atom's Van der Waals volume, or non-Van der Waals volume, or both. And those may relate to a [(PxV)/k] temperature, and that temperature relate to a viscosity transition temperature, or another 'critical' temperature transition point, or heat of vaporization. ((See 'Special Note 1', an inch below (9c).))

((Unless otherwise stated, my empirical data is found in *Wikipedia*, Ref. [2]; and my Van der Waals ball volume in (2b) was calculated from a Van der Waals radius also found *there*.))

Solid helium's Pressure x Volume = (2.63×10^{6} N/ m^2) x (3.51×10^{-29} m^3) = 9.24×10^{-23} rogue joules (or N-m), and we will regard that as a rough initial estimate of rogue energy in each atom in solidified helium!

Solid helium's **Pressure x Volume = 9.24 x 10** $^{-23}$ **N meter**/atom (3)

Using Bolzmann's constant, (k) = 1.38×10^{-23} J/Deg. K, and the ideal gas law, (P)(V) = (k)(T), and (3) above; we can roughly calculate a sort of hidden, rogue temperature equivalent for solid helium:

Stealth (hidden) Solid Helium **Temperature = 6.7 Deg. K** (4a)

Now, regarding the actual empirical data for cold helium, we have the following**:**

Critical point Temperature for Helium = **5.19 Deg.K** (4b)

(and that happens to occur at pressure = 227,000N/sq. m. For comparisons, 1 atm is about 101,000 N/sq. m)

Now, suppose we could roughly estimate liquid helium's specific heat per atom (at constant volume) as being 3/2 times Boltzmann's constant 'k'. We can then roughly estimate an accumulation of heat (based on specific heat and temperature rising) by multiplying (5.19 Deg.K) x (2.07×10^{-23} joules/atom Deg. K.). So starting at 0 Deg. K, we have roughly**:**

To reach critical Temp., est. **Heat Accumulation** = **10.7x10** $^{-23}$ **J**/atom (5a)

If we had used [(**5**/3)k], associated with constant pressure, instead of [(**3**/2)k], associated with constant volume; we would obtain **17.8x10** $^{-23}$ **J**/atom instead of 10.7×10^{-23} **J**/atom for that (5a) estimate above.

Note that (5a) is based many rough assumptions, but there is considerable variances to those assumptions. [3] One example is the sharp specific heat increase as liquid helium is cooled toward 2.18 Deg. K. Graphically its trace appears like the Greek symbol 'lambda', and it is known as the lambda transition point from non-zero viscosity to zero viscosity. Some scientists find that a concept that Einstein helped developed after his 'GRT' (the 'Bose-Einstein condensate') helps them mentally to address helium, etc. Still, during helium's cooling; helium expands during that lambda transition – despite the existence of that wording, 'Bose-Einstein condensate'.

Incidentally, technically speaking, some aspects of even Helium-II behavior are interpreted as its possessing a very slight viscosity, even though minuscule.

We note that for ideal gases; we have, ideally, for one atom**:** PV = (2/3) (Kinetic Energy of an atom). So, using (3) above for PV; we now estimate for the kinetic energy equivalent of a solid helium atom's (P x V)**:**

Kinetic Energy equivalent for solid helium atom **=** **13.7 x 10** $^{\mathbf{-23}}$ **J**/atom (5b)
((That is interesting to compare with (5a) above, or (9b) below.)) Now, back to empirical facts**:**

Max.**Temperature** for Phase-II (zero-viscosity) Helium = **2.18 Deg.K** (6a)

Universe's **Microwave Background Radiation (CBR) = 2.72 Deg.K** (6b)
(Note: that is more commonly called the **C**osmic **B**ackground **R**adiation)

When a black-body emits its very wide frequencies of radiation, Wein's law gives the light wavelength around which the greatest light radiation intensity is generated. (I.e., that is the radiation wavelength around which there will be a greater intensity than around much longer or much shorter wavelengths.) That means that even though a short wavelength photon may be more energetic than a longer one; there will likely be a lot fewer of them than the longer wavelengths. That Wein's displacement law can be given in the following simplified form, Ref. [4]**:**

Wavelength region of most intensity = 0.00290 Deg. K-m / body Temp. in Deg. K.
Substituting 2.72 Deg. K for the body Temp. photon equivalent above, we have:

Wavelength vicinity of **CBR** where radiation greatest **=** **0.00107 m** (7)
(that corresponds to Freq. = 2.8 x 10 ^{11} Hz.) Let *h* denote Planck's constant.

Then a typical CBR Photon **Energy** = *h* x Freq. = **18.5 x 10** $^{\mathbf{-23}}$ **joule** (8)

Helium's heat of fusion = 2.29 x 10 $^{-23}$ joule/atom (9a)
Its heat of vaporization = 13.8 x 10 $^{-23}$ joule/atom (9b)
Heats of fusion + vaporization = **16.1 x 10** $^{\mathbf{-23}}$ joule/atom (9c)

A reminder here -- there may be some inaccuracies in the above assumptions, etc.; but I think my assumptions, etc., are sufficiently accurate to support my limited interpretations and conclusions near the end of my paper.

Special **Note 1:** We note the following approximate ratio relationship even though it may be, at most, only a weak `cause-effect relationship**:** A helium atom's Van der Waals (ball) volume, i.e., 1.15 x 10 $^{-29}$ m ^{3}., is to a solidified helium atom's jurisdictional volume, i.e., 3.51 x 10 $^{-29}$ m ^{3}., --- as liquid helium's max. zero-viscosity temperature, 2.18 Deg. K, is to a solidified helium atom's (P x V)/ (k) equivalent temperature, i.e., 6.7 Deg. K See ref. (2a, 2b), (3), (4a), and (6a) above.

We note that solid helium's non-Van der Waals volume is about twice helium's Van der Waals 'ball' volume. Based on Van der Waals sized balls, that represents a much looser packing than even expected of inefficient simple 'cubic' packing where balls would touch. But solid helium displays a hexagonal 'bcc' array, which would be an efficient packing if balls actually did touched. Based on Van der Waals sized helium and neon atoms, respectively; calculations would show that solid helium has a much looser (non-touching) packing associated with it, than cold solid neon does. Based on a neon atom's Van der Waals ball volume; we calculate that solid neon achieves much more efficient packing than simple 'cubic' packing; and, in fact, it is rather close to very efficient 'face-centered cubic' packing where balls, indeed, touch. (In fact, solid neon has face-centered cubic packing.)

Special **Note 2:** Toward the other end of the periodic table, there exist metals with high density and very high tensile strength, such as tungsten (W) and molybdenum (Mo). When they solidify, they lose a certain amount of heat per volume, and that relates somewhat to their heat of fusion. That is a sort of negative energy per volume, and it has the same 'dimensions' as tensile strength. Let us remember that a suction also developed when a gas (with a kinetic energy equivalent) was removed from Guericke's hemispheres. The suction between Guericke's hemispheres, of course, was a suction pressure and is equal to (2/3) times the kinetic energy of gas removed. For metals W and Mo; their tensile strength equals approximately 85% and 65%.respectly times the heat per volume removed, respectively, to solidify them. [5] Those 85% and 65% values can be compared with 66**.**7% for Guericke's gas equivalent. The percent values are not drastically different, especially since tensile strength measurements are generally very inexact, anyway.

Note that those high metal tensile strengths, however, do not manifest themselves until things are cooled to near room temperature. I.e., metals, of course, exhibit almost no strength when still at their near-melting high temperature; so the above is as if the metals could store a latent 'IOU' or UOI in their memories. Perhaps the bookkeeping accounting is, in effect, kept by some equipartition of energy mechanism in those metals.

4. Summary and Conclusions

Unlike other elements, helium does not solidify at dozens of degrees above 0 Deg. K or higher. In fact helium does not even solidify at 0 Deg. K until a huge (26 atm) pressure is also applied. **That helium's solidifying requirement, (pressure x volume** per atom **= $\mathbf{9.24 \times 10^{-23}}$** N-m**), provides many helpful hints and implications; and that is the first major theme of this paper!**

(Maybe there is involved in cold helium's behaviors some non-traveling spin energy or vibrational degrees of freedom -- actions related to equipartition of energy, or yet something else? And/or perhaps a potential energy gained and kinetic energy lost.)

The 9**.**24 x 10 $^{-23}$ N-m of solid helium (pressure x volume) corresponds with an ideal gas kinetic energy equivalent of about **13.7 x 10** $^{\mathbf{-23}}$ Joule/atom (or a rather low ~ **6.7 Deg K** temperature). In fact, helium's critical point temperature is **5.19 Deg. K**. And the accumulated heat capacity storage can be roughly estimated to be very roughly **10.7x10** $^{\mathbf{-23}}$ joules/helium atom, when that critical temperature is reached. So the (pressure x volume) value of solid helium does provide a rough guide as to where some of helium's unique energy and temperature values likely will be found. In this case, below which, cold helium may display its unique, special behavior! (Also note that 5b is not very far different than 9b or 9c.)

We conclude that the **(pressure x volume**) consideration, although very crude, **hints at several important other experimental values** and correlates very roughly with them.

The **second major theme** of this paper is that **low temperature helium is a microcosm of the universe!** When helium's is cooled to about a degree below the 2**.**72 Deg. K temperature of CBR, it has nearly zero viscosity, like space does. When cold helium is heated a few degrees above that 2**.**72 Deg. K, it behaves more like the other ordinary elements on earth. Again, cold helium exhibits a diversity of behavior like that of the universe, as if it is a 'microcosm of the world'!

Actually, CBR does exhibit a very slight (minuscule) viscosity-like effect on bodies moving through it. Although very cold helium and CBR-infested space would seem to be very different stuff; we can perhaps say this**:** "Not only are 'CBR' and cold helium's behaviors somewhat alike; but, in a sense, very cold helium **dances** with space temperature; and indirectly **dances** with the distant stars!

However, that is a subtle interaction; and I would **not** conclude, as Ernst Mach did, that "When the subway jerks, it is the fixed stars that throw you down"! [6]

Optional: We must maintain the distinction between primary features, like momentum and mass, that are present, but sometimes not detectable by our instruments; versus subtle, but secondary changes induced, so that our instruments can finally detect, the primary features that were always present. (Such as momentum and mass). The drastically different behaviors, manifested between Helium I and II, but brought about with only small changes in temperature, serve as an example as to why scientist need to be careful about their interpretations and conclusions. Thus, I would quote Shakespeare, and urge Mach adherents to consider that, "The fault, dear Brutus, is not in the Stars, but in ourselves that we are underlings".

My **third** major theme is this**: The difficulty in detecting an 'aether wind' or its causing an impediment to photon travel doesn't prove that seemingly empty space has no mass, no aether, and no energy. I.e., not any more than, the difficulty in detecting the flow of zero-viscosity cold Helium-II proves that helium has no mass, no existence, and no hidden** $\mathbf{mc^2}$ **energy**. Nor that super-conductivity (the frictionless flow of electrons through certain cold metals) proves that the metal bulk is not there.

Neither the reality of superfluid Helium II (nor the possibility of aether's somewhat similar behavior) should be regarded as 'suPERfluous', i.e., to use that Einstein 'misnomer', (superfluous). [7] Had Einstein stuck with the original Latin term, 'superfluus' or 'superfluere'; he would have very early, most futuristically and amazingly, described what would be discovered about 33 years later, i.e., the superfluidity of Helium II. But I think Einstein strayed too far from the original geometry of the 'Latin' word, 'superfluus'; (and I think he also strayed too far from Euclidian geometry, and from classic notions of time and space).

5. Closing Remarks and Speculation

We note that Helium's heat of vaporization (9b) is almost exactly *Six* times helium's heat of fusion (9a). I calculated that based on hopefully accurate data from 'Wikipedia'. But I don't know if that *'exactly*, or *almost exactly*, *Integer Six*' is mostly co-incidental? Most noble elements, and many molecular compounds, have corresponding data not very far from '*Six*', but yet far from exactly *'Six'*. That is just one aspect of cold helium that may invite further study by experts in theoretical and experimental science, and perhaps even invite the development of more precise data.

Perhaps solid and cold helium is somewhat like a Grove, which the part-time poet Brockes wrote about, in his short poem, In den angenehmen Buschen**:** "In den angenehmen Buschen, wo sich Licht and Schatten mischen," **…..** ("In the pleasant grove, where light and shadow mingle **….**"). [8] I.e., my theme that there may be more to be inferred about the universe from helium than from most other elements.

(Speaking of cosmopolitanism or cosmology; it is interesting to note that helium was first discovered on the Sun, not the earth.)

Notes and References:

[1] D. G. Henshaw, "Structure of Solid Helium by Neutron Diffraction", Phys. Rev. 109, 328-330 (1958); Note, although more precise data might be found in more recent publications; I sometimes select references more accessible through the Internet.
[2] Wikipedia, Helium
[3] **http://hyperphysics.phy-astr.gsu.edu/hbase/lhel.html**, Liquid helium, superfluidity, ('HyperPhysics website' hosted by the Dept. of Physics and Astronomy, Georgia State University.) Or go to just http://hyperphysics.phy-astr.gsu (and scroll down the index provided to right until the word 'superfluid' appears, and click it.)
[4] **http://www.straightdope.com/mailbag/mspacetemp.html**, (Note, ref. selected for rapid Internet accessibility and simplicity.)
[5] C. R. Littmann, A Simplified Approach to Metal Tensile Strength Using Concepts of Guericke and Venturi", article 2-20-2001 at **http://causeeffect.org**
[6] Milo Wolff, "Spin, the Origin of the Natural Laws, and the Binary Universe", Frontier Perspectives, Center for Frontier Sciences at Temple University, Vol. 10, No. 2, Fall 2001.

[7] Einstein's used the term 'superfluous' in his 1905 paper, On the Electrodynamics of Moving Bodies, see last sentence of his second paragraph, For Einstein's paper, see **http://www.fourmilab.ch/etexts/einstein/specrel/www/** Einstein's original paper, in German, uses the word 'uberflussig' instead of 'uberfluten'. See dictionary at **http://www.ultralingua.com/onlinedictionary/** for translation of uberflussig.
[8] An old vinyl recording, Seraphim 'Mono 60015', and jacket, translating Brockes' refrain.