A Strange Thing Called Love: In the view of Thermodynamics

ABSTRACT

In this article, an attempt is made to explore Thermodynamics of love based on the standard laws of thermodynamics namely Zeroth, First, and Second laws. In doing so, the human is considered as two entities based on the size or form: Physical/ 'Bulk' replicated as an engine and neurological resembled to an active species or a radical. Considering the proposed human thermodynamics table from the standpoint of chemical kinetics, it is interpreted that love is a form of energy and it gets transferred from one object to another supported by the second law of thermodynamics that change in entropy is either zero or positive but not negative. A practical illustration was made earlier by a short film on the same theme wherein a person falls in love with nine girls and the time comes when he is supposed to choose 'the one'.

INTRODUCTION

Thermodynamics of love has been an emerging field of interest in the recent years. Earlier studies represented human as a molecule (Jean Sales), point atom (Humphry Davy), human atom (Erich Fromm), particle (Joel de Rosnay), and element (William Fairburn). The current model (table 1) firstly divides the human as two separate entities (based on the 'form' as physical and neurological) and then tries to apply a *thermodynamic equivalent* for each.

Table 1: Human Thermodynamics table

Variable	Thermodynamic equivalent
Human body (physical)	Engine
Human body (neurological) – '*mind*'	Radical/ion
Money	Internal energy (state function)
Residence time/Activity span/Activation	Work (Path function)
Love	Heat (Path function)
Measure of love	Entropy
Transferability – '*change of mind state*'	Change in entropy

In one of his recent works on human thermodynamics, American electro-chemical engineer Libb Thims tried to establish a molecular formula for human that comprised a total of 26 elements wherein the primary elements where C, H, and O [1]. This work along with the known fact that a major amount of gas exhaled by human body [2] being O_2, H_2O vapor and CO_2 (with trace amounts of H_2, CO) suggests that the human physical body be modeled as an 'engine'.

Human body ≈ engine

An engine works on the principle of combustion of reactant mixture wherein a fuel (typically hydrocarbons) is mixed at high temperature/pressure with oxidizer (air or O_2) in a chamber forming products that includes CO_2, H_2O, and other by-products (depending on the initial and working conditions like pressure, temperature, and species concentration). Combustion in general can be expressed by the following chemical reaction model.

Fuel + oxidizer -> CO_2 + H_2O + (other by-products) + heat release ---------- (1)

A similar analogy is made in the current model wherein *fuel* is the compounds having 'C', 'H', and/or other elements present in the body and the *oxidizer* is the inhaled air (79% N_2, 21% O_2 neglecting other trace amounts of impurities) and the *products* being standard products of combustion (O_2, H_2O vapor and CO_2) as mentioned earlier.

*Note that as 'O' which acts as an oxidizer in real world is already present in the human body, the authors claim that there is a continues/never-ending (all through its life-span) combustion process happening in the human body which needs external oxygen to 'sustain' this combustion fire. In addition, this claim is supported by the idea that such a fire is the source of digestion phenomenon in any living-being including human body.

Apart from engine operation, its maintenance and repairs can be analogized to the hygiene living and medications that the body undertakes.

Human mind ≈ Radical/Ion [R*]

Although people whom we call the 'people' seem to exist as what we 'see' from outside, there is some other 'formless' form lying inside them. In this context, the analogy of body to engine is

made based on the interpretation that the physical body is purely 'maintained and driven' by the *mind*. An illustration can be a man (mind) driving a car (body) or the flow of current lighting up the bulb. This latter example is what hints the analogy of human mind to a radical/ion or a collection of these.

Basic definitions of radical and ion:

"*Radicals (often referred to as free radicals) are atoms, molecules, or ions with unpaired electrons or an open shell configuration. Free radicals may have positive, negative, or zero charge. With some exceptions, these unpaired electrons cause radicals to be highly chemically reactive."* [3]

As seen from the above definition, a radical consists of very high chemical reactivity and in-fact the presence of radicals is what makes combustion process to prolong until all the reactants are burnt to products releasing heat. A general chemical kinetic model for any combustion process may be represented by the following reaction mechanism. Interested readers on this subject can refer to C.K. Law's work [4].

$$R \rightarrow R^{*} \text{---------- (2)}$$

$$R^{*} \rightarrow P \text{---------- (3)}$$

where R – Reactant, R^{*} - Radical, and P - Product

This whole process of combustion is what makes an engine to run and absence of such radicals will hinder running of engine (due to no combustion)! Similarly the body works or moves as long as there is presence of mind. Having said so, it should be made clear about the word 'presence'. An extensive amount of research was made in the past and continues on 'conscious' and 'sub-conscious' mind [5-7]. So when it is mentioned as 'absence of mind', it should be understood as say the 'un-conscious' mind. Hence by representing human mind as a radical, the current model highlights *the highly reactive nature of mind almost all the time*. The intention of saying 'almost' instead of saying 'all the time' is to include those instances wherein people do attain so called peace of mind or a state of equilibrium like seen in meditation, yoga exercises

etc. Such a behavior of mind can be interpreted by the additional feature that a radical has. This feature can be represented by the following equation

$$R^{*} + R^{*} \rightarrow Q \text{---------- (4)}$$

where Q – arbitrary compound having no reactivity.

Hence there is a possibility of two highly reactive radicals to combine forming compounds with low or least reactivity. Even this reaction scheme is seen in combustion chemical kinetics wherein some radicals combine themselves forming a low or zero reactive compounds [4].

Money ≈ Internal energy [U]

Money is a state function (one which doesn't depend on path). It is a monetary variable which purely gives the information as to 'how much' one possess irrespective of "in what way" was that earned. In this context, the means of earning can be included in 'life' (which will be discussed shortly) leaving 'money' variable as a *state function*.

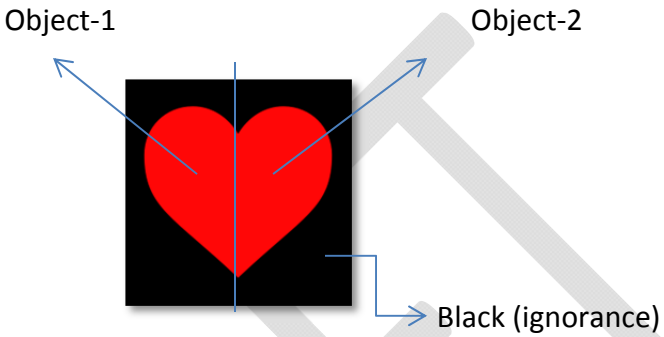
Residence time ≈ Work [W]

Having interpreted human as two separate entities - body and mind, the amount of work done by either of these depends on the residence time: Durability of body and Gibbs free energy of active radical. The former is something straightforward that as long as the body is in good or at-least threshold condition, a non-zero work is possible. The latter case needs further explanation since it is a natural tendency of humans to hardly understand something non-physical or at a nano-scale. Coming back to the radical analogy for mind, work is done by an active radical as until it dissociates or depletes due to corresponding chemical reactions as mentioned earlier (eqn-4), the body comes to rest.

On the whole, as the amount of work done depends on 'activity span' of either body or mind, residence time is considered a *path function*.

Love ≈ Heat [Q]

It is a common notion seen in the world to represent love with a 'heart shaped symbol filled with red color'. While the 'heart' shape articulates heart, bonding, and other perceptions, the 'red' color says blood, passion etc. This latter perception of passion is what hints to compare love with heat.



(http://en.wikipedia.org/wiki/Heart)

Fig 1 A heart shape in a dark background wherein 'darkness' represents ignorance

As seen from fig 1, love is symbolized as "two objects which/who were initially in ignorance (de-activated) as shown by the black background when 'come across' (again replicating movement of radicals, mean-free path etc.) each other, gets activated shown by a change in color to red. Hence 'red' in the current model is interpreted as *life or activation*.

THERMODYNAMICS OF LOVE

On an elementary level, heat exists due to molecular level vibrations and collisions in an object. This again highlights the current proposal that love is formed due to chemical reactions among radicals belonging to the same object or between radicals of two different objects. This latter statement may be related to prior works of Surya Pati and Libb Thims (based on works of John Gottman's *Why marriages succeed or* fail) wherein these works demonstrated human relations with chemical reactions

Libb thims: A + B → A≡B (bond formation)

Surya Pati: A + B → AB

Further interpretation of love to heat is based on the first law of thermodynamics,

$$\delta W = dU + \delta Q \text{----------} \quad (5)$$

where W – Residence time; U – Money; Q – Love;

This is a modified form of original First law in that work here is a combination of analogous heat and internal energy unlike conventional definition that heat is a vectorial summation of work and energy. In other words, the current analogous variables reproduce first law with different 'sign convention' as used in first law of thermodynamics.

-> No life or more technically no activation ($\delta W=0$) implies no money and no love (w.r.t to that particular object. For an instance, one may be having lots of love to his/her parents. But once the activation is lost i.e. expired, though they may have love on the object (him/her), it does not have an option to take-in that love i.e. love is not taken by him/her. If there is no residence time, there is no radical and its movement, and hence there is no love.

-> As money is decreased, to retain activation, love should be increased.

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Measure of love ≈ Entropy [S]

According to Zeroth law of thermodynamics, "*Systems are said to be in thermal equilibrium if they have no net exchange of heat*". The law implies that thermal equilibrium between systems is a transitive relation, which introduces the definition of an empirical physical parameter, called temperature. The temperatures are equal for all systems in thermal equilibrium.

A similar interpretation is made with current systems in that these systems (people are of interest in the current discussion) are in 'equilibrium' if they have no exchange of love. For an instance, consider a situation wherein a person needs to form a group to participate in an event. If that person has a friend/lover/relative etc. (to whom he shares his love) in the constructed team, he tries to be more inclined to that person knowingly or unknowingly which

is not the characteristic of equilibrium. On contrary, if the same person forms a team whom he met for the first time in that hall, there can be two possibilities (assuming he is not talking to only one girl!!!).

Case-1: He may not be showing any interest on the rest.

Case-2: He may be contributing equally to the group (the rest).

In the above two cases, he is in 'equilibrium' with the rest.

Such a discussion based on Zeroth law introduces the next analogy for a 'measure of Love' to entropy.

'A measure of love' in the current model is ideated from the interpretation made from the Zeroth law. But coincidentally, such an evaluating parameter was suggested by American physicist John Hokikian that "Human beings can be classified into low-entropic and high-entropic people." [8]. However, entropy in the current model is a measure of love. Taking back to the analogy of radical and its movement and corresponding consequence of love as covered in previous sections of this article, entropy is related to that of a radical. All radicals do not lead to same results. Some radicals while undergoing chemical reactions get destroyed due to wall collisions/surface reactions. Others successfully turn into products. Taking this context to a larger scale, all human beings do not contain same radicals nor do they contain radicals with same energy levels. So depending on whether radicals are excited, whether these radicals are active until products are formed and other such factors, different objects may possess different measures of love.

Transferability of love ≈ Change in entropy [dS]

After explaining the intent of measure of love**,** the authors would like to discuss the last, in-fact the most crucial variable for the current study – Transferability of love. In the previous discussions, the relation between love and mind (which is represented by radical content) was covered to certain extent. Also it was mentioned that love is analogous to heat; measure of love is analogous to entropy. Now a change in entropy is taken as an analogy for transfer of

love from one object to another. All through our discussion, it was mentioned that a radical is a non-stabilized matter by its nature. Hence by highlighting this fact that mind is always moving (non-stabilized), the authors would like to continue with their argument on "Transfer of love from one girl to another".

As the love on something changes, so does the transferability for a given measure of love for a particular object. As the love on something decreases, transferability of love on that object is more.

For an instance, let a person X like apples. Once he had enough number of them, and is still provided with extra apples, his love on them starts reducing and finally may reach threshold (starting point of "hate"). While his love on apples is reducing, his measure of transferability increases (he may start to "look" for something else. Note that *seeking* nothing is also something in this context). On the other hand, for a reversible process i.e if there is no change in love (again this is an idealized case as we do have such a case in thermodynamics), then obviously there is no transferability (dS = 0)

This illustration applies to anything (moving such as human or immovable objects like furniture). This is where the concept of "transfer of love from one girl to other" comes into picture.

Exploring second law of thermodynamics on entropy and its change,

1) If the change in entropy is greater than zero, then the process is irreversible (which is seen in nature).

Interpretation: If the love on something/someone reduces, the transferability is greater than zero.

$$dS = \delta Q/T;$$

where T – Surrounding temp. in which the radical resides/reacts.

In the above context, T may be considered for instance as the temperature of body/brain. This is said so in order highlight that the current study is more emphasized on the change in love measure and transferability rather than change in temperature.

2) If the change in entropy is equal to zero, then the process is reversible.

Interpretation: If there is no transferability in love, then it is a reversible process (idealized). That means, the source or system is either a machine or a person who doesn't really have love/hate towards anything!!! (Refer to eqn. 4).

*Going back to first law (eqn. 5), when $\delta Q = 0$, then $\delta W = dU$ (money). So living (a state of activation) was meant only for earning which is what a machine does (although it may not give money always!!!), it provides output that only depends on input.

3) A negative change in entropy is not possible.

Interpretation: Even when the case of love on something to increase is considered, transferability on that thing/person stays at what it was before or may reduce in absolute values (S) but the change in transferability (dS) stays positive.

*Last statement in this discussion can be justified by the *never-ending flow of thoughts in mind (except when in deep sleep which we are not interested in dealing with the current laws)*.

This directly ties to the Second Law of Thermodynamics, which states that "The entropy of the Universe is increasing".

$$dS >= 0$$

Therefore transferability of love is always increasing in the real-world"

Hence comes the proposal that,

"Love is a form of energy which gets transferred from one girl to another"

Finally, a video was made by the authors on the same concept with the title as "A strange thing called love" [9]. The plot of this video is that a man falls in love with nine girls and that day comes when he is supposed to make a decision on choosing 'the one'. Surprisingly in the early 1800's, Johann Wolfgang von Goethe published a book named "Elective affinities" based on a similar concept of love and marriage relations among two couples. It is a pure co-incidence and

the current authors actually didn't know about it until they started preparing this article. As an auxiliary data, readers may refer to [9] this short film based on which the current article sprouted!!!

CONCLUSION

Different human thermodynamic variables were chosen and proper relations were established among them on the basis of standard laws of thermodynamics. Further, the second law was explored in the context of love and after certain interpretations, it was concluded that love is a form of energy and transferability of love is always increasing.

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REFERENCES

[1] Thims, Libb. (2008). *The Human Molecule*

[2] http://en.wikipedia.org/wiki/Breathing

[3] http://en.wikipedia.org/wiki/Radical

[4] Combustion Physics by C.K.Law, Cambridge University Press, Sep 11, 2006.

[5]**Theory of mind—evolution, ontogeny, brain mechanisms and psychopathology** Review Article
Neuroscience & Biobehavioral Reviews, *Volume 30, Issue 4*, *2006*, *Pages 437-455*
Martin Brüne, Ute Brüne-Cohrs

[6]**Decision making under stress: A selective review** Review Article
Neuroscience & Biobehavioral Reviews, *Volume 36, Issue 4*, *April 2012*, *Pages 1228-1248*
Katrin Starcke, Matthias Brand

[7] **Causes and consequences of mind perception** Review Article
Trends in Cognitive Sciences, *Volume 14, Issue 8*, *August 2010*, *Pages 383-388*
Adam Waytz, Kurt Gray, Nicholas Epley, Daniel M. Wegner

[8] Hokikian, Jack. (2002). *The Science of Disorder: Understanding the Complexity, Uncertainty, and Pollution in Our World* (pg. 48).

[9] http://www.youtube.com/watch?v=9JtbxjGT89k&feature=player_embedded

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