LAYING THE GHOST OF TWIN PARADOX

by

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Someone's true age is not written in his ID, but in his biomarkers. Aging process is not caused by time passing, but by thermodynamically laws. Entropy, extent of metabolic reaction, and temperature are Lorentz invariant, so these facts make twin paradox impossible because there is no way for one twin to age slower than the other even if the time in his frame is dilated. Entropy is the function of state, not time. So as much as standard thermodynamics concerns, the path between two points in space is equivalent to the path between two states. Whether the point B is reached by moving faster using the longer way (with time dilatation), or slower by using shortcut (without time dilatation), the state of the system after completing the road should be the same. This is supported by the fact that when two twins reach the same space-time point (point B) in which the state parameters are the same. If we use entropy as an age parameter, then both twins have the same entropy value and are exactly the same biological age. Therefore, the twin paradox is a logical mistake based on wrong first premise. Bergson symmetry is not necessary any more to explain the impossibility of twin paradox.

Key words: *twin paradox, aging, extent of the reaction, entropy, temperature, Arrhenius equation, special theory of relativity*

Introduction

Special theory of relativity was published 1905. The root of twin paradox lays in Einstein's words (1911): "If we placed a living organism in a box ... one could arrange that the organism, after any arbitrary lengthy flight, could be returned to its original spot in a scarcely altered condition, while corresponding organisms which had remained in their original positions had already long since given way to new generations. For the moving organism the lengthy time of the journey was a mere instant, provided the motion took place with approximately the speed of light." In 1911, Langevin made this concept more vivid and comprehensible by his now-iconic story. He replaced the microorganisms with the twins, one of whom is an astronaut and the other a homebody. The logical base for the twin paradox is the everyday experience, that the aging process follows the time flow. So if less time has passed in Einstein's box, the aging process for the organism in the box runs slower as well. So the organism in the box must be younger than his twin on Earth. The twin paradox concept was the subject of analysis in philosophy, physics, biology, and chemistry.

The whole nature including living organisms must obey the general laws of nature. Living organisms have certain entropy; their metabolism obeys the laws of chemical thermodynamics and chemical kinetics.

Relativistic contraction of space is given as:

$$x \quad x\sqrt{1 \quad \frac{v^2}{c^2}} \tag{1}$$

Consequence of relativistic space contraction is relativistic volume:

$$V \quad V\sqrt{1 \quad \frac{v^2}{c^2}} \tag{2}$$

Consequence of relativistic volume is relativistic molar concentration [1] given as:

$$[A] \quad \frac{[A]}{\sqrt{1 \quad \frac{v^2}{c^2}}} \tag{3}$$

In 1907 Planck [2] suggested theorem of the invariance of entropy:

$$S' = S_0$$

Also, together with Einstein-Plank suggested relativistic temperature transformation:

$$T \quad T_0\sqrt{1 \quad \frac{v^2}{c^2}} \tag{4}$$

it means that a moving body appears colder. His temperature transformation was accepted for almost fifty years.

In 1952 Einstein suggested new transformation:

$$T \quad \frac{T_0}{\sqrt{1 \quad \frac{v^2}{c^2}}} \tag{5}$$

These are the laws which Ott proposed some years later (1963), and independently of Einstein´s results. So in 1963, Ott [3], deduced exactly the opposite (to the Planck-Einstein 1907) transformation law:

$$\begin{aligned} T &\quad \frac{T_0}{\sqrt{1 \quad \frac{v^2}{c^2}}} \\ V &\quad V_0\sqrt{1 \quad \frac{v^2}{c^2}} \\ p' &= p_0 \end{aligned} \tag{6}$$

Ott also supposes the entropy as a Lorentz invariant, like other authors did. Ott's result contradicts the previous affirmations because in this treatment the accelerating body appears hotter. "Entropy is an invariant" also claim [4].

A few years later, Landsberg [5, 6] stated that temperature should be Lorentz invariant but, years later, he revised the problem by saying that it is impossible to obtain a general transformation of the temperature [7].

After that, many papers dealing with thermodynamics have shown with "a simple experiment is described, using a constant-volume gas thermometer at rest with a body to show that the ideal-gas scale is Lorentz invariant. The statement that thermodynamic temperature is Lorentz invariant is then equivalent to the requirement that the thermodynamic temperature scale and the ideal-gas scale should be identical in all frames of reference” [8]. Some papers are explicit: “Since any valid Lorentz transformation of temperature must be able to deal with black-body radiation, it is concluded that a universal and continuous temperature transformation does not exist” [9]. Also “The non-existence of a relativistic temperature transformation is due to the fact that an observer moving in a heat reservoir cannot detect a blackbody radiation spectrum” [10]. The conclusion that: “all thermodynamic relations become Lorentz-invariant” have been made by some authors [11]. At the end:” one has to conclude that the temperature is invariant with Lorentz transformations” [12]. So:

$$T' = T_0 \tag{7}$$

“There is no universal relativistic temperature transformation” claims Bormashenko [13]. “Particularly, we found the temperature and pressure transformations, given by $T' = T$ and $p' = [1 - (v^2/c^2)]\, p$, respectively”.

In the Avramov [12] paper one can find another conclusion: ”If temperature is invariant with speed, then entropy with respect to the Boltzmann constant is not. This put serious problems on the statistical physics”. So:

$$S' = T_0\sqrt{1 \quad \frac{v^2}{c^2}} \tag{8}$$

The set of relativity transformation laws for the volume V, temperature T, and pressure p is made by Avramov:

$$V' = V_0\sqrt{1 \quad \frac{v^2}{c^2}}$$

$$p' = p_0 \tag{9}$$

$$T' = T_0$$

So Boyle’s law must be Lorentz covariant. Some authors have different opinion: “The obvious relativistic transformation $p = p_0$ is not needed” [14].

On the other hand, process in isolated system cannot be in same time both isothermal and isobaric in isolated system.

Popovic [15] claims: ”Chemical reaction rate constant is Lorenz invariant.”

Ohsumi [1] claims: ”Special-relativistic rate equation which expresses an effect of a relative velocity are identical in form to the classical equation”. Even today some papers state that the twin paradox exists [16, 17, 18, 19], for example:

– This paradox is not a paradox in the true sense of a paradox but a reflection of a misunderstanding of the problem and the Principle of Relativity ... the problem is asymmetric hence leading to the same conclusion that the traveling twin will age less than the stay at home [18].
– As in the classical twin paradox, an observer at rest relative to the preferred (local) inertial frame measures the longest proper time between any two events on his or her world line; moving observers always measure less [19].

Phenomenological consideration

There are some logical indications that twin paradox is impossible. System that we accelerate contains an observer, and a candle. The candle is unlit. In the process of acceleration the temperature remains the same for the observer situated in the system K', and the candle will not change its shape. The observer in K_0 according to Planck's relativistic temperature should see the candle crack, and fall to pieces because of the cold, if we use Ott's relativistic temperature the observer in K_0 should see the candle melt (even though it is unlit). The absurd situation will appear if the observer situated in *K'* arrives to the observer in K_0, in the same space/time three observers (one in *K'*, Planck, and Ott) will see three different shapes of candle and three different value of entropy.

Historia magistra vitae est. We will use one experiment from history of chemistry to show that temperature is Lorentz invariant. Let us take for example Lavoisier experiment.

Thermodynamic system comprises retort with Hg and cylinder with air. Lavoisier doesn't heat the retort, but the whole system in which he is experimenting is moving at relativistic speed. If we use Ott's transformations, the observer in K_0 would notice that the temperature in *K'* is rising, and red oxide of mercury would form on the surface of the mercury in the retort. When no more red powder was formed, observer in K_0 would notice that about one-fifth of the air had been used up and that the remaining gas did not support life or burning. The reaction he would notice is $2Hg + O_2$ $2HgO$.

For Lavoisier moving in K' the temperature would remain the same, so he wouldn't notice any red oxide of mercury formed on the surface of the mercury in the retort, nor any change of the gas volume in the cylinder. An absurd situation would appear when the observer in *K'* arrives to K_0. At the same space-time point, one observer would see red oxide of mercury, while the other one would see none of it. One observer would see one gas volume, while the other one would see a different volume.

Theoretical analysis

The twin paradox is based on the folowing syllogisms:

- Both twins age because of time passage.
- Time passes slower at relativistic speeds.
- The twin that moves at relativistic speed ages slower than the one that relatively rests.
- *Conditio sine qua non* for the twin paradox is the slowed aging process for the moving twin.

Erarre humanum est. The twin paradox is a logical mistake. The mistake is in the first premise. Time passage does not cause the aging process. So, what does cause aging? To answer in outline form:

Metabolic damage
- Free radicals
- Glycation

Cellular senescence & death
- Telomere shortening
- Declining & inadequate DNA repair & autophagy
- Declining & inadequate anti-oxidant defense
- Defective cell cycle control, proteasomes, lysosomes & heat shock proteins

Toxic & non-toxic garbage accumulation
- Protein cross-linking & aggregation
- Advanced glycation end-products (AGEs)
- Atherosclerotic and amyloid plaques
- Inflammatory cytokines
- Lipofuscin
- Cortisol
- Heavy (transition) metals
- DDT, PCBs, *etc*.

Aging is not caused by time passage. The aging process is followed, rather than caused by time passage. Biomarkers would be better predictors of biological age than the passage of time (chronological age). There is no theory of aging that proposes time flow to be the cause of aging. So, even with time dilatation, the aging process is not affected.

Aging is a thermodynamics process. As a fact physicists don't age or die, they simply increase their entropy. In fact the entropy really does increase during life.

"The aging process occurs because the changed energy states of bimolecular renders them inactive or malfunctioning" [20], so "Aging and illness have other dimensions than just disease. Our view of ourselves will become more whole and in enlarging consonance with universal law. It relates matter and energy in the framework of time. Entropy, *time's arrow*, gives direction. Energy, rendered coherent through the metabolism of biology, acts to retard dissipation as entropy. The homeostatic controls which order our existence are energy dependent. As energies diminish, homeostasis as order deteriorates; aging proceeds and life is threatened" [21]. "Entropy generated over the lifespan of average individuals (natural death) was found to be 11.404 kJ/K per kg of body mass" [22]. Twin paradox cannot exist if the both twins have numerically the same value of entropy generated over the lifespan of average individuals (for example, 11.404 kJ/K per kg of body mass). So accepting the entropy invariance theorem we conclude that entropy generation of both twins is identical. In that case there is no paradox. The both twins are exactly the same age. So, biomarkers and entropy are the real parameters of age, not the passage of time (chronological age).

Equilibrium constant

For the reaction:

$$A \quad B \leftrightarrows C \quad D \tag{10}$$

equilibrium constant is given as:

$$K \quad \frac{k_1}{k_2} \quad \frac{[C][D]}{[A][B]} \tag{11}$$

and then relativistic equilibrium constant is given as:

$$K \quad \frac{k_1}{k_2} \quad \frac{[C]\,[D]}{[A]\,[B]} \tag{12}$$

Having in mind that:

$$[A] \quad \frac{[A]}{\sqrt{1 \quad \frac{v^2}{c^2}}}, \quad [B] \quad \frac{[B]}{\sqrt{1 \quad \frac{v^2}{c^2}}}, \quad [C] \quad \frac{[C]}{\sqrt{1 \quad \frac{v^2}{c^2}}}, \quad [D] \quad \frac{[D]}{\sqrt{1 \quad \frac{v^2}{c^2}}},$$

leads to

$$K = K' \tag{13}$$

Equilibrium constant is Lorenz invariant.

Equilibrium constant is given as:

$$K \quad \frac{[C][D]}{[A][B]}$$

For ideal gas we can write:

$$K \quad \frac{P_C P_D}{P_A P_B}$$

or using the moll fraction:

$$K \quad \frac{\chi_C \chi_D}{\chi_A \chi_B}$$

then

$$K \quad \frac{\chi_C \chi_D}{\chi_A \chi_B}$$

As the mol fraction is not affected by the effects of the relativity $\chi = \chi'$ it comes that $K = K'$. K is Lorenz invariant.

Gibbs energy

If

$$\Delta G = -RT \log K \tag{14}$$

then the relativistic transformation is given as:

$$\Delta G' = -R'T' \log K' \tag{15}$$

Having in mind, $K = K'$, $R = R'$, $T = T'$, so:

$$\Delta G = \Delta G' \quad (15)$$

Gibbs energy is Lorenz invariant.

Activation energy

If it is:

$$\ln \frac{K}{\Delta T} \quad \frac{E_a}{RT^2}$$

$$\ln \frac{K}{\Delta T} \quad \frac{E_a}{R\,T^{\ 2}} \tag{16}$$

Since $T = \quad T'$, $K = K'$, $T = T'$

$$E_a \quad E_a \tag{17}$$

Activation energy is Lorenz invariant.

Enthalpy

If it is:

$$H = E_a - RT \tag{18}$$

$$H' = E_a' - R'\,T' \tag{19}$$

Since $E_a = E_a$, $R = R'$, $T = T'$

$$H = \quad H' \tag{20}$$

Entropy

If it is:

$$\Delta S \quad \frac{\Delta H}{\Delta T} \tag{21}$$

$$\Delta S \quad \frac{\Delta H}{\Delta T} \tag{22}$$

Since $H = \quad H'$, $T = \quad T'$

$$S = \quad S' \tag{23}$$

Entropy change is Lorentz invariant as Planck suggested in theorem of the invariance of entropy [2]. In that case both twins have the same value of entropy in the same space time point after returning, so they are exactly the same biological and metabolic age. So there is no paradox. Entropy is the function of state, not time. So as much as standard thermodynamics concerns, the path between two points in space is equivalent to the path between two states. Whether the point B is reached by moving faster using the longer way (with time dilatation), or slower by using shortcut (without time dilatation), the state of the system after completing the road should be the same. This is supported by the fact that when two twins reach the same space-time point (point B) in which the state parameters are the same. So, one of those parameters is entropy. If we use entropy as an age parameter, then for both of the twins there are no differences in neither in entropy nor in age.

Further, let's take one of the reaction characteristic for aging process *i. e*. free radicals, or telomere shortening or some of the reaction mentioned above. If the extent of the reaction is Lorentz invariant it seems that both twins after returning must have aged in the same extent. It means that characteristic reaction for aging will be at the same point for both twins.

The extent of reaction

The extent of reaction is defined as:

$$\xi \quad \frac{\Delta n}{\nu_A} \tag{24}$$

where, ν_A is a stoichiometry coefficient.

Relativistic transformation of the extent is given as:

$$\xi \quad \frac{\Delta n}{\nu_A} \tag{25}$$

Since, $\Delta n = \Delta n'$

$$\xi' = \xi \tag{26}$$

The extent of the reaction is Lorenz invariant.

In that case both twins will have same extent of metabolic reaction including dose that cause aging listed above, so nobody gets older. It means that both observers are registering the same extent. For example the both observers will see, and have, the same gray collor of hair.

Further, if temperature is Lorentz invariant. [5, 7, 9-12, 15] then, according to Arrhenius equation reaction rate constant must be also Lorentz invariant as shown in [15]. In that case dynamic of chemical reaction is going on simultaneously in both twins. Both twins will have exactly the same number of gray hair.

Conclusions

Both thermodynamic and biological views strongly suggest that there is no twin paradox. Aging process is going on independently of time because it is not caused by time passing, but by the chemical thermodynamics laws. Aging process is followed, not caused by time passing.

Entropy, extent of the reaction, reaction rate constant, Gibbs energy and equilibrium constant are Lorentz invariant.

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