**The fairytale about the old and young twin and its thermodynamic solution**

**(“Twin paradox” after 100 years)**

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**Abstract** The year *2011 is the international year of chemistry, and it is exactly 100 years past after the P. Langevin promotion of “twin paradox” problem.* T*he hundred year old problem still demands its solution. Twin paradox, established by a physicist, has been representing a nightmare for philosophers, physicists, chemists and biologists until these days. After a hundred years, it is time to try to close this page in long history of misunderstanding of the special relativity. Chemical and relativistic thermodynamics, biological and medical facts and chemical kinetics of the metabolic reactions are the base for the analysis of the twin paradox problem. Entropy can be taken as a measure of cell age or even human age according to [1-5]. So Entropy invariance strongly suggests that both twins should be the same age. Further, the extent of the metabolic reactions is also Lorentz invariant according to [6], so both twins should have same intensity of metabolic reaction and consequently should be the same age. If the Lorentz-Fitzgerald contraction according to [7-12] is apparent, artificial, virtual phenomenon that actually does not exist in reality, then relativistic volume contraction according to [13] is also apparent, so there can’t be any relativistic mole concentration which could have influence on the dynamics of metabolic reactions. The second possible mechanism of the length contraction influence on the kinetics of chemical reactions is the changed reaction surface according to [14], so if the length contraction is apparent then there can’t be any change in reaction surface and any influence of it on the dynamics of chemical reactions*. *If there is no relativistic temperature transformation according to [15-21], then there can’t be any influence of temperature change (in both directions) on the kinetics of chemical reactions. Since pressure is Lorentz invariant according to [22], there is no change of pressure during relativistic movement. So it can’t affect the metabolic reaction rate. The only possible influence of relativity on the chemical reaction rate is time dilatation. However time flow does not cause the aging process [6], so time dilatation cannot have any influence on it. So, after detailed analysis, it is concluded that there is no twin paradox in reality. Both twins will be exactly in same thermodynamic state and biological age. The traveler twin will notice time dilatation, but this relativistic effect has no influence on the aging process.*

**Key words** *Special relativity, twin paradox, aging, entropy, extent of the reaction, metabolic reaction rate*

1. **Introduction**

Origin of the now iconic unsolved story about twin paradox lay in Einstein’s words: "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." [23] In 1911, P. Langevin gave a "striking example" by describing the story of a traveler making a trip at v→ c. The traveler remains in a projectile for one year of his time, and then reverses direction. Upon return, the traveler will find that he has aged two years, while 200 years have passed on Earth [24]. To be clear, this is the picture presented to the public: „Consider a space ship traveling from Earth to the nearest star system outside of our solar system: a distance *d* = 4.45 light years away, at a speed *v* = 0.866*c*. The Earth-based mission control reasons about the journey this way: the round trip will take *t* = 2*d* / *v* = 10.28 years in Earth time, *i.e.* everybody on earth will be 10.28 years older when the ship returns (*Notice underlined, suggested logical connection between time flow and aging*)[[1]](#footnote-1). The amount of time as measured on the ship's clocks and the aging of the travelers during their trip will be reduced by the factor, the reciprocal of the Lorentz factor. In this case \epsilon = 0.500 \, and the travelers will have aged only 0.500×10.28 = 5.14 years when they return“.

So the logic behind this paradox is

*Syllogism A*

1. Time passes slower under relativistic conditions
2. Time passing causes aging of living organism

→Aging of a living organism is slower under relativistic conditions.

And second

*Syllogism B*

1. Time pass usually under usual Earth condition
2. Time passing causes aging of living organism

→Aging of living organism is usual under usual Earth condition.

*Comparing the A and B*

1. Aging of a living organism is slower under relativistic condition
2. Aging of living organism is usual under usual Earth condition

Take us to the twin paradox problem. Traveler twin returns after trip and met his older twin brother. Is it just logic (or logical mistake) leading us to that conclusion or the problem is more complex? At the beginning, second premise in both syllogisms is wrong, time passing does not cause the aging process. There is not such theory in biology or gerontology [6]. However there are few relativistic effects that potentially may have some influence on the aging process. So let’s start from the origin of the problem. Special theory of relativity was published in 1905. One, but not the only consequence of relativistic motion is time dilatation given as

Second relativistic consequence important for this analysis is relativistic length contraction given as

In that case length contraction must cause volume contraction given as

Volume contraction than causes relativistic molarity (change in mole concentration of a substance in a solution) according to Ohsumi [25], given as

Concept of relativistic molarity, time dilatation and relativistic length and therefore volume contraction lead us to some conclusions

1. Change in molar concentration (if it is real) may cause change in reaction kinetics according to Goulberg-Waage law.
2. The second mechanism of length contraction influence on the kinetics of the chemical reaction is the changed surface according to Veitsman.[14]
3. The third mechanism affection of the chemical reaction rate is influence of time dilatation on it.

At the end, one more relativistic effect may affect chemical reaction rate. Temperature has great influence on the chemical reaction rate (Arrhenius equation), so if there is relativistic temperature transformation, then also is possible change in reaction rate. So according to Planck and early Einstein [36]

Or according to late Einstein and Ott [26]

According to Planck’s transformation the system (including biological system) appears colder so Planck and Einstein transformation change the chemical reaction rate in one direction. According to Ott transformation the system appears hotter, so Ott transformation changes the reaction rate in exactly opposite direction. 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.”[38] 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.”[39] 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 spectrum.”[16] The conclusion that: “all thermodynamic relations become Lorentz-invariant” have been made by some authors.[18] At the end:” one has to conclude that the temperature is invariant with Lorentz transformations.”[20] “There is no universal relativistic temperature transformation“claims E. Bormashenko 2007.[19] In the Avramov paper we 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”. It is generally accepted that pressure is Lorentz invariant according to [22], there is no change of pressure during relativistic movement. So it can’t affect the metabolic reaction rate. Physicist tries to solve twin paradox on the many different ways. “It is pointed out that a complete resolution of the twin paradox demands that the travelling twin takes into account the gravitational effect upon the rate of time when he predicts the ageing of his brother“[27]. So the problem is really complex and its solution demands multidisciplinary access. The year 2011 is the year of chemistry, and it is exactly 100 years past after the promotion of twin paradox. The aim of this paper is to revisit and reconsider the problem and shed more light on it.

1. **Theoretical analysis**

“Aging process is the accumulation of changes in an organism or object over time” [28]. This change is visible as a change in thermodynamic, biological and physical state. The change is in accordance with thermodynamics, caused by the Second Law, and they have some dynamics connected with the chemical kinetics. Let’s say the other way; Aging process is continuous, consecutive change of the state of the biological system caused by the law of thermodynamics. Note that this definition does not include time because the time plays no role in aging process. Aging is spontaneous process. The opposite process has never been seen. Correlation with entropy increase is evident. It is possible to analyze aging process at various levels (molecular, sub cellular, cellular, and level of the tissue, organs and organism, population) [29].There are few proposes concerning the mechanism of aging. Entropy increase and entropy generation during life seems to be in good accordance with the second law of thermodynamics [30]. “The findings of macrothermodynamics (supramolecular thermodynamics) of quasi-closed systems and the published data about the variation of the chemical composition of living organisms in ontogeny confirm the thermodynamic tendency of aging processes. According to the thermodynamic theory, the specific value of the Gibbs function of the formation of supramolecular structures of the organism tends to a minimum. That tendency explains the variation of supramolecular and chemical composition and the morphology of tissues during aging „ [31]. „The homeostatic controls which order our existence are energy dependent. As energies diminish, homeostasis as order deteriorates; aging proceeds and life is threatened” [32]. “The aging process occurs because the changed energy states of bimolecular renders them inactive or malfunctioning“[33]. Some opinions are more chemical. “Through rational thinking and critical analysis, we conclude that the accumulation of irreparable damages and alternations caused by spontaneous biological side-reactions seems to be the essential and profound nature of higher animals' aging mechanisms.” [34] So in any case process of aging is correlated with change in some thermodynamic properties like Entropy or chemical reaction extent. The fact is that accumulation of some deposed chemicals ( lipofuscin also called the aging pigment [35] ) in the cell, and irreparable damages on the cellular structures are consequence of the reaction going on in cell or organism. Damage on the tissue is consequence of some physical or chemical cause. So to make thing easier our focus will be on the cellular aging. The entropy of the cell increase during life until it reaches maximum value in the moment of death. During life continuously lipofuscin is deposed in cell so the name for it, aging pigment originates from that fact. Every chemical reaction including deposition of lipofuscin, or telomere shortening or free radicals caused reaction goes on under rules of thermodynamics and chemical kinetics. Increase of chemical reaction rate or in extent of the reaction cause more rapid chemical and therefore aging process. That means that in that case more lipofuscin will be deposed in cell or telomere shortening must be more evident.

Every change in the chemical reaction kinetics reflects on the state of the cell which we can observe as level of aging process. So the crucial condition for the Twin Paradox is existence of a difference in the state of the two (biological) systems. Same state means same age. Does the state of the system depend on the observer? Certainly not! The state depends only on the physical laws. Note that the basic relativity principle say: scientific investigations generally assume that laws of nature are the same regardless of the person measuring them. So Lorentz invariant physical laws mean same state. Fundamental logic leads us to conclude that two observers in K and K’ (one of them is in relatively rest while the other is in relativistic movement) must notice only one state of an object. Same state means same age, because the age is just visualization of the state. Same age means that Twin paradox is impossible even the clocks of the two observers show different time. Time flow does not cause change in the systems state. To be more plastic, 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 ob server situated in the system K’, and the candle will not change its shape. The observer in K 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 transformation the observer in K should see the candle melt (even though it is unlit). The absurd situation will appear if the ob server situated in K’ arrives to the ob server in K, 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[6]. So, both observers must visualize the same state of the thermodynamic system in one space-time point.

It is possible to use Entropy as a measure of aging according to [6, 29-34]. Entropy is the function of state, not time according to [6]. 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 short cut (without time dilatation), the state of the system after completing the road should be the same. The fact is that when two twins reach the same space-time point (point B) than the state parameters are equal for both observers in K and K’. 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. Let’s put it on the other way, Entropy change is Lorentz invariant as Planck suggested in theorem of the entropy invariance [36]. In that case both twins should have the same value of entropy in the same space time point after returning, so they are exactly the same thermodynamic, biological and metabolic age.

Entropy is a state function, so it can’t be Lorenz covariant. The Planck’s theorem of entropy invariance, as well as Ott, and many other authors such as Bomarshenko [19] and Popovic [13, 21] confirm the entropy invariance. Entropy is given as

is Boltzman constant. Where *W* is the probability given as

In relativistic conditions the equation above becomes

is Lorentz invariant claim Bomarshenko [40] so . Now, if S=S’, and kB=kB’ , then

W=W’

Explanation for this will be given later in part which analyze the possible influence of Lorentz-Fitzgerald contraction on the aging process.

Further, let’s take one of the reaction characteristic for aging process for example free radicals, or telomere shortening or some of the reaction mentioned above. If the extent of those reactions 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 the reaction is defined as:

where, is a stoichiometry coefficient.

Relativistic transformation of the extent is given as:

Since,

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 color of hair. To make picture more clear consider a system in which we have an irreversible reaction, with a solid phase being deposited. Such an example could be a solution containing Ba2+ and CrO42- ions, together with urea dissolved in water at low pH. The solution is being heated to around 90 ºC. At that temperature urea hydrolyses and releases ammonia

This reaction is irreversible, because at 90 ºC the solubility of CO2 in water is very small, and it escapes from the solution as a gas. As the ammonia is released it reacts with hydrogen ions in water and raises the pH. The higher the pH the more BaCrO4 sediments. So the quantity of the sediment indicates the extent of the first reaction. The quantity of the sediment characterizes the state of the system. Both observer in K and K’ must notice the same state of the system, so they see the same quantity of sediment, which means the same extent of reaction.

Now let’s analyze the possible influence of Lorentz-Fitzgerald contraction on the aging process. Ohsumi [25] predict that as a consequence of length and volume contraction appears relativistic molarity. In that case it is quite reasonable to expect its influence on the kinetics of the chemical (and metabolic) reaction according to Guldberg-Waage law. Let’s use equation of state in form which relates mole fraction and molarity according Popovic [37]

where is the mole fraction of the substance A, and [A] is mole concentration of the substance A.

It is generally accepted that pressure is Lorentz invariant [22,36]. According to [13,15-21] there is no relativistic temperature transformation so , and . The mole fraction according to conservation law isn’t affected by relativity, so . In that case

So there is no real relativistic mole concentration, which confirms opinion published in [7-12]. Popovic [13,37] suggest the solution by taking the effective volume in calculation. If there is no real change in mole concentration then there is no influence of it on the dynamics of the chemical and metabolic reaction, and consequently on aging process. It also means that there is no change in reaction surface, so there can’t be any variation in surface chemical reaction rates proposed by Veitsman [14].

Let us consider a system which includes an autoclave with oleic acid and hydrogen gas. The reaction is hydrogenation of unsaturated oleic acid.

CH3(CH2)7CH=CH(CH2)7COOH + H2 → CH3(CH2)16COOH

This reaction happens at 175 °C to 200 °C. Catalyst is nickel (also possible with platinum or palladium).

Einstein predicts rigid body which measured at rest is ball shaped, takes the form of rotational ellipsoid when it moves, observed from K, its axis are

R , R, R (X,Y,Z)

While, Y and Z dimensions of the ball (or any other rigid body, regardless of its shape) are not modified as a consequence of motion, the X dimension looks shortened. So the higher the v, the smaller the X[41] Notice that Einstein considered length contraction as a real process. The changed surface of the catalysator Ni must have influence on the dynamics of the reaction because the changed fractional coverage. The observer in K will see the hydrogenation process, and because of that he will see stearic acid forming as sediment. The observer at K’ will see the same process and same thermodynamic state of the system, and consequently same quantity of stearic acid in same space-time point. We can conclude that the dynamics of the hydrogenisation was not changed and because of that we conclude that no change in surface is performed.

Temperature may have great influence on the dynamics of the chemical and metabolic reactions. Possible change (caused by relativistic movements=relativistic temperature transformation) in systems temperature may have influence on this dynamics. 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 consist 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. According to Ott’s transformations, the observer in K 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 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 + O2 =2HgO

For Lavoisier moving in K’ the temperature would remain the same, so he wouldn’t notice any red oxide of mercury would form 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. 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. Further,

Thermodynamic system consisted of Zn and HCl. The reaction is going as:

Zn + 2 HCl → Zn(Cl)2 + H2↑

The hydrogen molecules evaporate from the system. If the observer at K’ is at room temperature he will see certain reaction rate and a certain quantity of hydrogen evaporating. At the same time, the observer at K should see (if temperature is not invariant) a different reaction rate according to Arrhenius equitation, and a different quantity of hydrogen released from the system. As this process is irreversible, the observer will never see the opposite process. Therefore, an absurd situation will appear if the second observer arrives to the first one at K. At the same space-time point, two observers would see different quantities of Zn, HCl, Zn, Cl2 and H2.

Phenomenological consideration above leads us to conclude that there is no relativistic temperature transformation. The same states plenty of papers published in last 30 years [13,15-21,37-40].

It is generally accepted that pressure is Lorentz invariant according to [22], there is no change of pressure during relativistic movement. So it can’t affect the metabolic reaction rate.

At the end, Time dilatation can have some influence on calculated chemical reaction rate, but has no influence on the state of the system and consequently age of the biological system. Reason for that is fact that time flow do not cause anything, especially not thermodynamic process, and consequently aging process because it is primary thermodynamic process caused by the fundamental natural laws such as second law of thermodynamics.

1. **conclusions**

There is no twin paradox because none of the factors that may have some influence on the aging dynamics is actually present. The time dilatation plays no role in aging process. Aging is thermodynamic phenomenon and it represents continuously, consecutive change of the state of the biological system caused by the rise of Entropy.

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1. Author’s remark [↑](#footnote-ref-1)