ABSTRACT

Many living organisms on Earth are strongly dependent on water, the natural liquid of the planet. A possible reason for that could be the conjecture of Ryoji Takahashi that water microdrops release negentropy through a phase transition to a phase with zero surface tension. Biological cells could make use of such a phase transition in their duty cycle. We comment on the relative merit of this conjecture, and present it in wider theoretical context.

1 Introduction

From time to time physicists are venturing in realms not very familiar to them, like biology (see two famous examples in the following). According to Dyson, the noblesse oblige principle of not writing on topics in which the author is not a master prevented many from such activities in the past. But topics of extremely broad character, like the origins of life, are literally open to everybody as soon as one knows how to ask the right questions.

In February 1943, Erwin Schrödinger gave a famous course of lectures to an audience of about four hundred at Trinity College, Dublin. One year later this course was published as the little book What is Life?. It is an influential book to this day and a masterpiece, read by all the creators of molecular biology in the fifties as well as by many more unknown people. Schrödinger's book is essentially describing the phenomenon of biological replication, and only in one chapter the other important life phenomenon of metabolism. Also the concept of negentropy is introduced.

In February 1985, Freeman Dyson delivered the Turner Lectures at Trinity College, Cambridge, published as a little book with the title Origins of Life. One will find in this book a discussion of the so-called double-origin hypothesis of life. The first beginning of life is with replication (protein) creatures and the second beginning is with creatures capable of metabolism.
We recall here the astroplankton hypothesis of Haldane\(^1\), i.e., vital units wandering through the universe, ready to start the cycle of evolution whenever conditions are favorable. The same author\(^2\) gave an estimate for the spontaneous occurrence of a bacterial virus in the primitive ocean. Such a creature has, according to Haldane, about 100 bits of negative entropy of information that could arise spontaneously in the primitive water in \(10^9\) years.

The most remarkable chemical characteristic of living matter is its optical activity. For recent progress the reader is referred to the Ciba symposium\(^3\). What we call living organisms synthesize themselves from molecular subunits of one enantiomorph alone. This surprising fact was already known to Pasteur. In his lectures, as early as 1860, he popularized the idea that biosyntheses involve a chiral force. After the discovery of parity violation in weak interactions (1956), and especially after people became aware of the electroweak unification scheme (1970), there were speculations tracing the origin of biochiral forces to the electroweak parity violation\(^4\). However, it has to be clearly stated that electroweak energy difference between the enantiomers of an amino acid corresponds to an excess of \(10^9\) molecules of the stable form in a total of \(10^{24}\), i.e., one part in \(10^{17}\). This is only an extremely weak "signal" onto the background of many random fluctuations in more important factors, like circularly polarized light, that could determine which enantiomer is formed. However, recently, Prof. Salam\(^5\) proposed an enhancement mechanism of the chiral electroweak signal by means of a phase transition into a condensed Bose-like mode. See also the comments of Chela-Flores\(^6\), and a forthcoming work of Salam\(^7\).

In the widely interdisciplinary problem of the origins of life it is very difficult to step out from the domain of speculations into the domain of firmly established experiments.

In the following we shall discuss a new point of view on the strong correlations among the life forms on Earth and the water liquid. It is based on the works of Ryoji Takahashi\(^8\) on the negentropy of micron size drops of water. This negentropy is related to the surface tension coefficient of water drops. Laplace's equation and Maxwell's third thermodynamic relation are the key features in stating the negentropy property of water microdrops when their volume is increased. To explain thermodynamically the liquid phenomena in the micron region, which have been observed by reflected scanning electron microscopy (SEM), Takahashi introduced the hypothesis of a new phase of water, the super water. The scope of this short paper is to comment on the results of Takahashi.

### 2 Normal water

At the molecular level, water is an extremely unusual substance. It has two types of intermolecular forces - the hydrogen bond and the hydrophobic effect. Although of low molecular weight, water has unexpectedly high melting and boiling points and latent heat of vaporization. Besides, liquid water exhibits the famous density maximum at 4°C, and it is heavier than its solid phase (ice). Usually one assumes that the strong
intermolecular bonds formed in ice persist into the liquid state and that they must be strongly orientation-dependent since water adopts a tetrahedral coordination; more exactly the average number of nearest neighbors is 4.5. For more details on the cluster structure of water the interested reader may consult the recent paper of Benson and Siebert. Other unusual properties are the very low compressibility and curious solubility features, both as a solute and as a solvent. Liquid water possesses high molecular dipole moment and high dielectric constant, which, unlike any typical polar liquid, is actually increasing when water freezes into ice, and is still increasing at —70°C.

3 Super water

The surface tension of microdrops of water was investigated by means of reflected scanning electron microscopy (SEM) and very interesting phenomena were reported ten years ago by Takahashi. He investigated the creation of microdrops by the dehydration of hydrated metaphosphoric acid used as specimen when the surface of the specimen underwent bombardment of the electron beam. The imaging current was as low as $10^{-10}$ A with a beam diameter less than 100 Å and the voltage was lowered in steps down to 5 kV. The irradiation of the surface was done for 3 to 15 s. At high voltages the surface develops craters, but at low voltages the change of the surface is a local rise in the form of a microdrop without any crater. This means that the beam ionizes locally the included water and the pressure is increased in a narrow region under the surface, giving birth to a microdrop according to Laplace's formula. In other words, the SEM experimental conditions are just at the threshold of molecular surface tension phenomena. Since the surface tension is due to attractive forces between molecules acting over tens of Å, the surface tension concept is still in its range of validity for drops of micron sizes. At low values of the voltage the ionization is diminished and consequently the droplets should increase continuously in size. Surprisingly, the experimental result is different. At low accelerating voltages (from 5 kV to 8 kV) the size of the droplet is almost independent of the voltage and of the size of the specimen. The interpretation of Takahashi is to postulate the existence of a minimum drop in any liquid, a fact he claims to be universal. Moreover, by employing Gibbs-Helmholtz equation he claims that in the one micron region there exists a phase transition to a super-lubricant phase of water for which the surface tension is naught. The Gibbs-Helmholtz equation gives the surface energy of a plane liquid per unit area $u$ as follows:

$$ u = \frac{T}{T} - \frac{\gamma}{dT} $$

or since the second term is just the surface entropy per unit area changed in sign:

$$ u = \frac{T}{T} + s $$

A zero $\gamma$ implies both $u$ and $s$ zero. Such a limiting case describes a liquid which is able to freely deform itself without any change in volume, i.e., the best lubricant. Takahashi
estimated the minimum diameter of water droplets at which the normal-super water transition takes place to be 1 μm. As the short range attractive forces drop to naught in the super phase the binding is provided by the electromagnetic attractive forces, being less than that of normal water. In the surface of the super water the electromagnetic forces exerted on charged particles are balanced at each point in the tangent plane.

It is this normal-super water transformation that was thought responsible by Takahashi of the negentropy cycle of living cells. These living devices accumulate entropy by metabolic processes. The excess entropy is however compensated by the negentropy of a pressure induced transformation to super water. A conclusion to be drawn from this explanation is that the size of a one-cell organism should be larger than the minimum diameter of normal-super water transition.

4 Negentropy of water microdrops

In 1989 Takahashi[8] calculated the Laplace pressure in water droplets of various sizes in the micron range in saturated moisture based on the Landolt-Börnstein data of γ of 1956. According to Takahashi, the P-T curves represent the equilibrium between the normal and the super phases. Within equilibrium conditions Maxwell’s third thermodynamic relation is fulfilled:

\[
\frac{\partial S}{\partial V} = (\frac{\partial P_L}{\partial T})_V
\]  

\[ (3) \]

\( P_L \) is the Laplace pressure. At small diameters and for room temperatures, \((\partial P_L/\partial T)_V \) is negative. Thus, from Maxwell’s relation, it follows that when normal water turns into super water a negative entropy is produced in the transition. This negative entropy of the normal-super water transition could be used by biological cells in their attempt to avoid the second law of thermodynamics. Another requirement is to create a negative increment of pressure in the cell in order to drive the phase transition to super water. The cell might do that by controlling electrically the osmotic pressure. In the p-V plane this results in a pressure induced transformation in which a work is given out. This clearly requires entropy. The argument of Takahashi is that the biological cell produces, by metabolism, just the amount of entropy required to compensate the negentropy of super water transformation.

5 Conclusions

We presented some comments on the Takahashi model of the so-called normal-super phase transition in water microdrops and its application to the engine biological cell - microdrop. As soon as one assumes the existence of a normal to super water phase transformations with a negative latent heat, one may consider the problem of the related negative entropy (negentropy). This is what Takahashi has done. Even though the model looks very ambiguous, it is apparently supported by some experimental evidence, and in spite of the fact that other explanations of the SEM data are possible, it gives a rather
challenging interpretation of the Schrödinger negentropy.

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References


