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The Coherent and Thermal Photons Radiation in the Enzyme

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ABSTRACT

This paper presents the theoretical states of radiation field in the mechanism of enzyme, for state of thermal and coherent radiation by concept of the quantum mechanics. For illustrating the energy and distribution of photon, we used simple concepts of the radiation field in the enzyme. We try to present the thermal radiation and coherent radiation happened in the biological microscopic system especially in the enzyme, and show that, these radiations could break the hydrogen bond pairs in the enzyme (substrate) at high temperature (above 323K) and show its effects on the relative activity of the enzyme.

KEYWORDS: Quantum Mechanics; Photon Radiation; Biophoton; Enzyme; Biological Physics.

La radiación de fotones coherentes y térmicos en la enzima

RESUMEN

Este artículo presenta los estados teóricos del campo de radiación en el mecanismo de la enzima, para el estado de radiación térmica y coherente por concepto de la mecánica cuántica. Para ilustrar la energía y la distribución del fotón, utilizamos conceptos simples del campo de radiación en la enzima. Tratamos de presentar la radiación térmica y la radiación coherente que se produjo en el sistema microscópico biológico, especialmente en la enzima, y mostramos que estas radiaciones podrían romper los pares de enlaces de hidrógeno en la enzima (sustrato) a alta temperatura (por encima de 323K) y mostrar sus efectos sobre la actividad relativa de la enzima.

PALABRAS CLAVE: Mecánica Cuántica; Radiación de fotones; Biofotón; Enzima; Física Biológica

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Introduction

Understanding the photon radiation happening in the biological system with respect to its effects on the biological systems is gaining an increased attention these days (Mayburov, 2009; Niggli, 2014; Mayburov, 2015).

There, biophoton describes photons in low frequency which are produced by a biological system. Biological physics and applying physical law in the biological system is more benefitial for both the academic knowledge and experimental framework. Living cells use a wide variety of cellular mechanisms for doing their activities. They do this at proper place at proper time.

The basic design idea of these nano-machines is based on the quantum physics, and in the quantum physics view, the enzyme is one kind of nano-machines. The enzyme plays an important role to explain how cells and proteins work inside a biological system. In a living system, there are various kinds of enzymes, however, the type of operation of all kinds of enzymes is usually the same (Cooper, 2000). In this paper, we would like to illustrate that the radiation state happens in the enzyme when the substrate binds to the active site.

Different types of enzymes have different classifications based on the kind of reactions they catalyze. We selected the enzyme worked on the temperature between 293K-353K i.e. before any reactions between the enzyme and the substrate, that enzyme's temperature is 293k. When the substrate binds to the enzyme (active site), the temperature is raised to 353k. In this case we probe the energy of each photon by two variables (the temperature and the frequency).

It is more benefitial to spend more time to know about DNA helix, because any living system is made up of DNA or RNA, and almost every cell in a human's body has DNA. DNA is made up of base pairs. The configuration of DNA is made of two long strands that called a double helix. The structure of the double helix is bonding many elements like C, O, N, H, etc. (Watson & Crick, 1993; Park & Lakes, 2007; Sheu et al., 2003). Those elements bond to each other and make the DNA double helix. The important bond in DNA double helix is hydrogen bond, the hydrogen bond is the heart of any biological structure. In this paper, we focus on the formation of hydrogen bonds in the alpha-helix and beta-sheet secondary structures. (Fig. 1)

In addition, hydrogen bonds are often playing the central role in the function of the catalytic active sites in the enzyme (Sneppen, & Zocch, 2005).

In Sec. 1, we show the description of the entire system (enzyme) and the type of operation. In Sec. 2, follows our design in the quantum thermal radiation for the temperature state. In Sec. 3, calculates the photon probability and the energy of photon in the coherent radiation. Finally, in sec 4, we numerically solve our model.

1. Enzyme and Operation (Model)

Enzymes are the organic particles living inside the cell. Enzymes accelerate the rate of all chemical reactions. They are vital for the life and serve the body, for example aiding in digestion and metabolism (Briegel & Popescu, 2013).

The enzyme and the substrate can bind to each other by two ways: the lock-and-key (Fig 2) and the induced-fit model, these two theories explain how enzymes work. This research focused on the lock-and-key model and in this model, the substrate and active site of the enzyme has the same configuration. When the substrate is binding to the active site, the chemical reactions start to effect the substrate and change it to product. Then the product leaves the active site of the enzyme and it goes on to catalyze the other reactions (Kaplan, 2010).

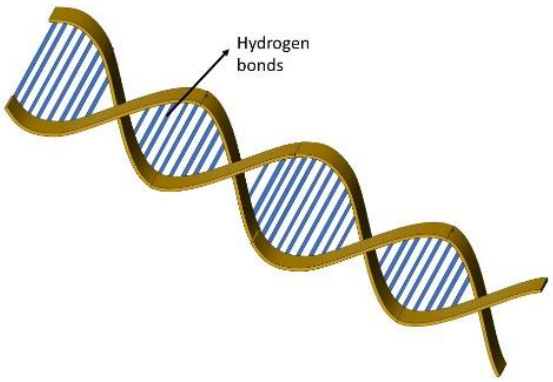

Figure 1: DNA helix is made up of the base pairs. These pairs have complex structures and are made up of particular elements like C, O, N, H, etc. Hydrogen is the most important element in these structures.

As mentioned, the human body is made up of many elements like sodium, potassium, calcium, magnesium, and hydrogen. These elements have electrical charges, called ions. All of our cells and sub-cells are made up of these elements. The electrical charge in our body has

studded in the bioelectric field (Elson & Haas, 2011). The enzyme is made up of some of these elements. It is convenient to suppose that the enzyme has electrical charge.

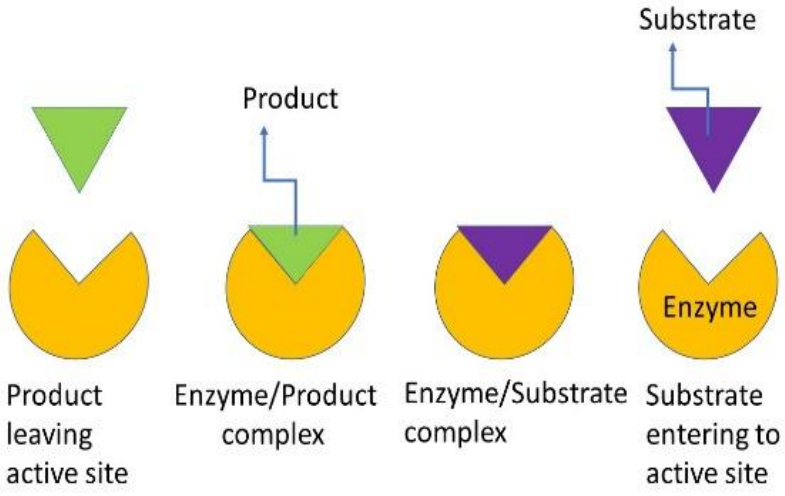

Figure 2: The enzyme has an active site in which the substrate could bind. A chemical reaction happens between the substrate and the enzyme when the substrate and the enzyme bind to each other, and due to the chemical reaction, the temperature rises. Then the chemical reaction causes the substrate convert to product and this product leaves the enzyme.

In the microscopic view, while the substrate and the enzyme are binding (enzyme/substrate complex), we supposed, the subsystem is made up of the alpha-helix and beta-sheet secondary structures and the hydrogen bond always oscillates with a high frequency, it is advantageous to ask how much free energy is related to the hydrogen bonds between these ranges 0.1-0.3 nm. The range of the order-of-magnitude for these ranges is 0.15-5.07 kJ/mol (Garrett & Grisham, 1997; Haynie, 2008; Van Der Spoel et al. 2006; Markovitch, & Agmon, 2007; Yakovchuk et al. 2006).

An important factor for the enzyme activity is *relatively activity*, which is the ratio between the activity of the enzyme and the activity of the temperature control, and it is expressed in percentage.

Before we introduce the thermal radiation and coherent radiation, let think about why we should focus on these two specific radiations. Biophotons are photons of light that are produced by a biological system. These photons lie down in the ultraviolet and low visible light ranges.

The emission of the biophotons is either non-thermal or thermal depending on the type of cells we select (Greffet et al., 2002; Bajpai, 1999), moreover, near the thermal source, we can also find the coherent radiation. Due to these reasons, we measure and find the energy of photons in both radiations. and the term of biophotons used here should not be confused with the Biophotonic Field, which studies the general interaction of light with the biological systems.

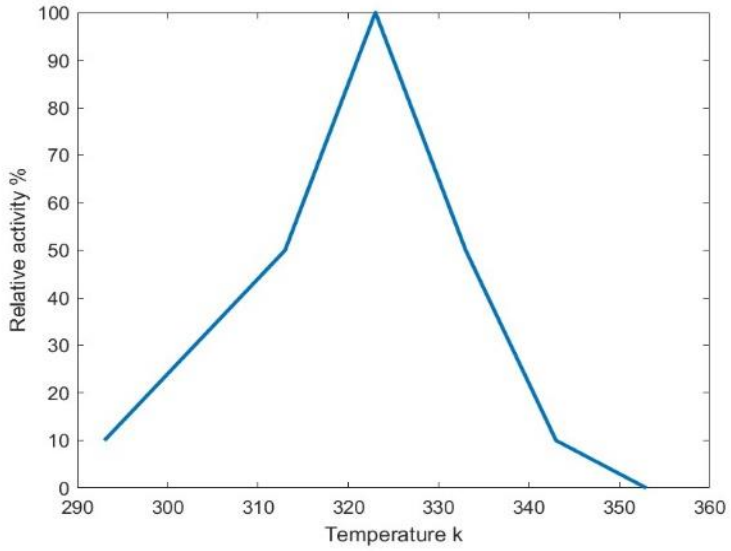

Figure 3: The effects of the temperature stress on the enzymatic relatively activity. The enzymatic activity starts below 20% at temperature 293k, when the substrate and the enzyme bind to each other; due to chemical reaction between the substrate and the enzyme, the temperature rises slightly. However, the enzymatic activity rises dramatically, the enzymatic activity at 323k is 100%. The enzymatic relatively activity rapidly decreases when the temperature rises above 323k. (De Freitas et al., 2014).

2. Thermal Radiation

This paper supposes that the interaction between the enzyme and the substrate stimulate photons with respect to changing temperature. The chemical reaction between the substrate and enzyme causes a rise in the temperature of the subsystem (enzyme/substrate complex), and it causes a change in the temperature of the nearest electron in the structure of the enzyme and then the substrate (electron) could emit the photon.

We suppose that, these photons are absorbed by the substrate with the fix frequency □ and given the state of polarization. The energy of photon is given by $E = \hbar$□, otherwise

the electron can diffuse n photons, the total energy of photons could be written by $E = n\hbar$ where $\hbar$ is plank's constant, and those photons are attracted by the substrate.

As mentioned, if the subsystem emits n of these photons, the energy essentially equals to $E = n\hbar$. The probability of photon is proportional to Boltzmann factor $E \sim e^{\frac{-\varepsilon}{kT}}$, where k is Boltzmann's constant and T is the temperature. We can write the probability of this system as follows:

$$P_n(E) = Ae^{-B\hbar n} \qquad (1)$$

where $B = \frac{1}{kT}$ and A is a normalizing factor. The radiation inside the substrate (cavity) can be regarded by the oscillator, and the energy inside the oscillator can be written by $E = \hbar\left(n + \frac{1}{2}\right)$. To determine what A is, we note that the sum of all probabilities must be equals to 1.

$$\sum_{n=0}^{\infty} P(E_n) = A\sum_{n=0}^{\infty} e^{-E_n/KT} = A\sum_{n=0}^{\infty} e^{-n\hbar\omega/KT} = 1. \qquad (2)$$

The above sum can be written in this form $\sum X = 1 + X^1 + X^2 + \cdots$, where $X = e^{-B\hbar}$ This series, called binomial expansion of $\frac{1}{1-x}$ (Beloussov, 2003). Hence $A = 1 - x = 1 - e^{-B\hbar}$, then

$$P_n(E) = Ae^{-B\hbar n} \qquad (3)$$

$$P_n(E) = (1 - e^{-B\hbar n})e^{-B\hbar n} \qquad (4)$$

The average number of photons with frequency and given polarization can be calculated in this form:

$$\langle n\rangle = \frac{1}{e^{B\hbar\square} - 1} \qquad (5)$$

For obtaining thermal energy of photon, we should multiply thermal average number of photons times with the energy per photon. This relation is known as the Planck distribution function:

$$\langle E_n\rangle = \hbar\square\langle n\rangle = \frac{\hbar\square}{e^{\hbar\square/KT} - 1} \qquad (6)$$

The factor $e^{B\hbar\square}$ can be very large or very small, depending on frequency and temperature. In this case, we have chosen $\hbar\square \gg KT$ and if we called $\langle n\rangle = \underline{n}$, photon distribution can be written by:

$$P_n = \frac{\underline{n}^n}{(\underline{n} + 1^{n+1})} \qquad (7)$$

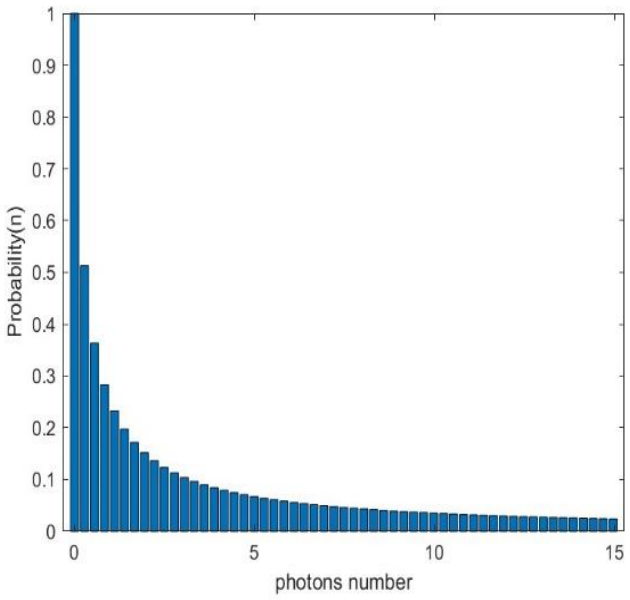

Figure 4: Photon distribution for thermal radiation of $P_n = \frac{\underline{n}^n}{(\underline{n}+1^{n+1})}$. It can be found that n = 0 has always the largest probability and the distribution falls off monotonically with increasing n.

The energy density is given by $u(\square, T)d\square dT = \frac{\hbar}{\pi^2 C^3}\frac{\square^3 d\square dT}{e^{B\hbar\square}-1}$. This energy density is very close to Stefan-Boltzmann law in the thermal radiation. However in the enzyme, the

temperature and the frequency are changed by the linear combination and it is the reason for the extra integral in the energy density.

The opposite side of the thermal radiation is the coherent radiation. In this subsystem, we modeled the oscillator coherent states.

3. Coherent Radiation

The main difference between the coherent and the thermal radiation is the wave phase. In fact, in thermal radiation the source emission wave is in the random phases *however* in the coherent source, waves are in the *same phases*. In the coherent thermal state, we should introduce displacement operator and density operator in phase-space.

The density matrix of the coherent thermal state is represented by:

$$\rho(\alpha,\beta) = \frac{D(\alpha)e^{-Bn\hbar}D^{+}(\alpha)}{\sum_{n=0}^{\infty} e^{-Bn\hbar}} \qquad (8)$$

where $D(\alpha)$ is the displacement operator generating the coherent state $D(\alpha)|0\rangle = |\alpha\rangle$ with the complex amplitude α

$$|\alpha\rangle = e^{-\frac{1}{2}|\alpha|^2 \sum_{r=0}^{\infty} \frac{\alpha^r}{\sqrt{r!}}|r\rangle} \qquad (9)$$

where $|r\rangle$ is photon number operator. Photon distribution (probability) of the coherent radiation can be calculated by

$$P_n = |\langle n|\alpha\rangle|^2 = e^{-\bar{n}}\frac{\bar{n}^n}{\bar{n}!} \qquad (10)$$

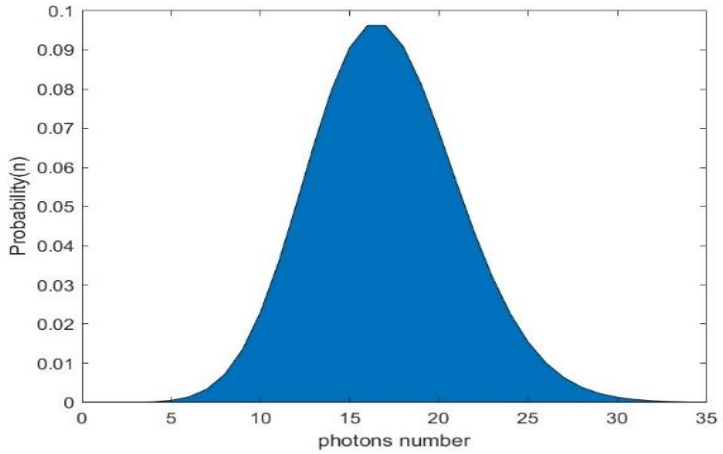

Figure 5: Photon distribution for the coherent radiation $P_n = e^{-\bar{n}}\frac{\bar{n}^n}{\bar{n}!}$ is Poissonian distribution.

4. Result and Discussion

We suppose that the enzyme emits photons with particular energy, and this energy depends on the specific frequency and temperature, i.e. if the enzyme seats on temperature T_1 then it emits the photon with the specific frequency $\square_1$ and in temperature T_2 emits $\square_2$. We will determine the energy of these photons for the thermal and coherent radiations. The energy to break the hydrogen bond of the alpha helices in isolated molecule is 4.79-5.57 KJ/mol, and the associated energy for this molecule in the water environment is 1.58-1.93 KJ/mol (Sheu et al., 2003).

We calculated, the maximum and the minimum content of the photon's energy respected to the thermal radiation that is 1.9 – 2.29 KJ/mol as shown in Fig. 6. As we mentioned in section I, many cells follow either the coherent or thermal radiation state. For thermal radiation of cell (enzyme), the energy of photon lies down between 1.9KJ/mol at temperature 294K and 2.3KJ/mol at temperature 360K.

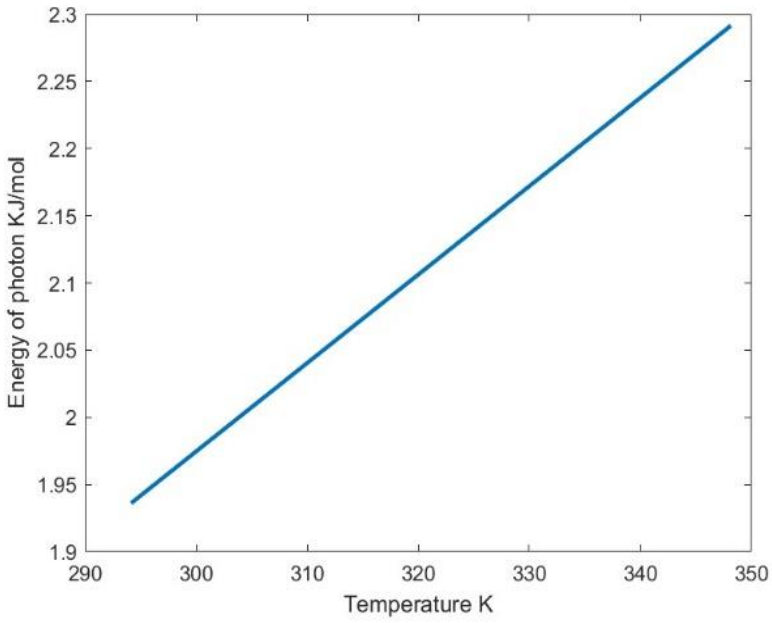

Figure 6: The minimum energy of photon is 1.9KJ/mol at temperature 294K, and the maximum energy of photon is 2.2915 KJ/mol at 358K without applying attenuation coefficient for the enzyme. The attenuation coefficient is a very small number depending on the enzyme classification. The energy of photon at 294K does not have enough power to break down the hydrogen bond, however when the temperature arises at 325K, the energy of photon is able to break the weakest hydrogen bond. At temperature 350K, the energy of photon can break all hydrogen bonds in the alpha helix in the water environment.

If we assume the alpha helix in the water environment follows the thermal equilibrium states, then at temperature 325K, the energy of photons can break down the hydrogen bond in the DNA alpha helices.

The energy of photons for the coherent radiation (squeeze state) Fig. 7 is between 3.87-4.73 KJ/mol. If we suppose that the hydrogen bond of the alpha helices in the isolated molecule follows the coherent radiation then the energy for breaking the hydrogen bond stands at 4.79-5.57 KJ/mol. However, we know that the distance between the hydrogen bond plays an important role for finding the energy bond. If we suppose that the hydrogen bond pair is 0.1nm, then the energy for the hydrogen bond in the isolated molecule is reduced to ~ 4.9KJ/mol for the stronger bond (Mitchell & Price, 1990).

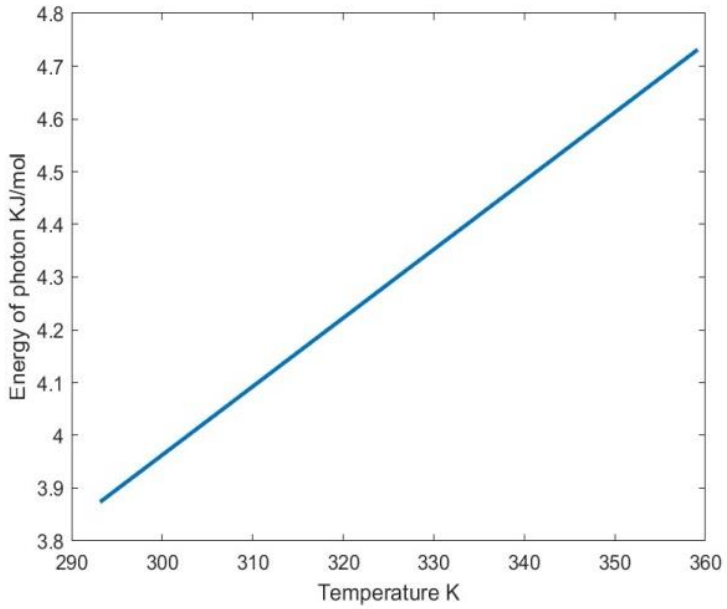

Figure 7: The minimum energy of the photon is 3.87 KJ/mol at temperature 294K, and the maximum energy of photon is 4.73 KJ/mol at temperature 358K.

It is found that the relative activity of the enzyme was shown in Fig. 3, when the temperature rises above 323k, the activity decreased dramatically. It may be because the enzyme starts to deform the shape and this deformation causes disconnection of the substrate and the enzyme. Regarding the radiation of the enzyme, it is reasonable to assume that the photons radiated by the enzyme can break down the pair of DNA helices, and these photons might play an important role to decrease the relative activity.

In the coherent modes, we could guess that after temperature 325K, the photons have enough energy for breaking down the weakest hydrogen bonds. When the temperature rises

above 325K, the energy of photons rises similarly, and thus these photons can break all the hydrogen bonds in the alpha helix. The photons radiated by the enzyme directly affects the relative activity of the enzyme.

Conclusion

In this paper, we supposed when the enzyme and substrate are binding to each other due to a chemical reaction, the temperature in the enzyme changes. Due to change of the temperature, the enzyme emits photons with respect to the thermal and coherent radiation. After calculating the energy of photons for both types of the radiations and comparing it with the DNA helix, we understood when the temperature sits at 293k, the energy of each photon could not break these bonds. However when the temperature rises above 293k, the energy of photon increases and it can break down the hydrogen bonds. By these results we noticed that the photons radiated by the enzyme plays a role for decreasing the relative activity in the enzyme.

The DNA helix is made up of the base pairs. These pairs have complex structures which are made up of the particular elements like C, O, N, H, etc. In this paper, we focus on hydrogen bond in the alpha-helix. The hydrogen energy bonding in the alpha-helix is between 1.58-1.93 KJ/mol for the water environment and 4.19-4.9 for the isolated mode. We assume when the enzyme's temperature rises above 325K, the photons emitted by the enzyme at this temperature can break the base pairs of DNA. In the other hand, as we observed in Fig 3, the relative activity starts to decrease when the temperature rises more than 293k. It is more benefital to mention that the enzyme begins to denature itself in high temperature. However, if the enzyme could not denature itself, these photons are able to break the connection between the enzyme and the product.

Conflict of Interests Statement

The authors declare that there is no conflict of interests.

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