On the Effect of Lengthening Circadian Rhythm by Heavy Water

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The problem of time sensor of biological clock (BC) attracts interest of many scientists, and a great number of experiments are being conducted to study the influence of various physical and chemical factors on functioning of BC. Special attention is drawn to studying the influence of heavy water (D_2O) on functioning of BC that always leads to lengthening of circadian rhythms (CR). This work presents theoretical consideration of lengthening of CR, when hydrogen (H_2) in water is replaced by deuterium (D_2), that is based on spacial difference of energy levels with similar principle quantum numbers.

The problem of the mechanism of time sensor (TS) of biological clock (BC), or biorhythms of periods close to periods of geophysical factors, attracts attention of scientists for a long time. The most thoroughly experimentally studied are circadian rhythms (CR) i.e. rhythms with a period close to 24 hours. And in a range of data about physical and chemical factors unfluence on CR there is a special case for the effects of D_2O on the rhythms. In [3, 4] it is noticed "that at present D_2O is the only matter, which always leads to lengthening of endogenous rhythms", and it is underlined, that theoretical interpretation of "the effect of heavy water" is based on the theory of reactions' absolute speeds, neglecting mass effects. However, the principle difference of H_2O and D_2O is the difference of masses of hydrogen and deuterium nuclei.

Consideration of the mass difference permits qualitave explanation of the lengthening of CR in biological objects, where H_2O is partially or completely replaced by D_2O.

Let's consider spacial distribution of energy levels of the same principle quantum number in atoms of hydrogen and deuterium. Taking into account the masses of the nuclei energy levels are separated by the distance.

$$r_{nH} = \frac{\alpha}{4\pi} \times \frac{1}{R_H} \times n^2 \qquad \text{in a hydrogen atom, and}$$

$$r_{nH} = \frac{\alpha}{4\pi} \times \frac{1}{R_D} \times n^2 \qquad \text{in a deuterium atom}$$

where α is fine structure constant, R_H and R_D are Rydberg constants for hydrogen and deuterium, respectively, n – the main quantum number [4].

In comparison with the similar levels of hydrogen atom in an atom of deuterium energy levels of the same principle quantum number are spatially shifted towards the nucleus by the value of

$$\Delta r = n^2 \times \frac{\alpha}{4\pi} \times \left(\frac{1}{R_H} - \frac{1}{R_D}\right)$$

Accepting that $\alpha = 7.397535 \times 10^{-3}$, $R_H = 109677.576$ cm^{-1} and $R_D = 109707.419$ cm^{-1}, for $n = 1$, we have $r_1 = 1.3937 \times 10^{-12}$ cm. For example for $n = 10$, $r_{10} = 1.3937 \times 10^{-10}$ cm.

It is natural to assume, that the lower the energy threshold through which biochemical processes run in bio-objects the higher the sensitivity of the objects to the spatial shift of energy levels caused by the replacement of H_2 by D_2.

Thus, from above mentioned it follows that lengthening of CR by adding D_2O is caused by decreasing the possibility of biochemical processes running through the appropriate energy levels in deuterium atoms, which, being caused by mass difference, are spatially shifted towards the nucleus in comparison with analogous levels in hydrogen.

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