PHYSICAL CHEMISTRY

Sonochemical Transformations of Chelate and Clathrate Structures in a Low-Frequency Acoustic Field

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Low-frequency vibrations are known [1-4] to have a detrimental effect on the human body. Vibrations that harm various systems of the human organism are within the infrasonic and low-frequency audio ranges from 2 to 35 Hz [2]. The mechanism of the action of such low-frequency acoustic vibrations on biologically active structures has been poorly studied to date. In this work, a change in the state of chelate structures in a low-frequency acoustic field was detected for the first time by the example of the poly(vinylpyrrolidone)—iodine complex.

EXPERIMENTAL

The experiments were performed using absorption spectroscopy. We analyzed changes in the optical density of aqueous solutions of the poly(vinylpyrrolidone)—iodine chelate complex (povidone-iodine) under the action of low-frequency acoustic vibrations. The acting frequency range comprised the infrasonic range from 2 to 20 Hz and the low-frequency audio range to 50 Hz. The optical density of solutions was measured both before and after the action of low-frequency acoustic vibrations. A PE-5400V spectrophotometer (St. Petersburg, Russia) was used. The measurement range was 335–1100 nm. The accuracies of measuring wavelength and optical density were ± 0.5 nm and ± 0.2 , respectively.

Under the action of low-frequency vibrations, the chelate complex irreversibly discolors to white. We determined the optimal frequencies, at which the effect of low-frequency acoustic vibrations on povidone-iodine is maximal. The optimal frequencies are within the infrasonic range and are 10-12 Hz. In the experiments, the action of vibrations at the following frequencies was studied: infrasonic range, 10 Hz;

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boundary between infrasonic and audio ranges, 20 Hz; and low-frequency audio range, 25 Hz.

The experimentally determined kinetic order of acoustic chemical transformations of the chelate complex povidone-iodine is close to the first order. Table 1 presents the reaction rate constants for acoustic chemical reactions for the three frequencies at two action intensities. Table 2 compares the experimentally determined activation energy of the acoustic chemical transformation of the povidone-iodine structure with the activation energies of acoustic chemical transformations of the clathrate complexes amilojodin, amilopectojodin, and iodinolum [5–7].

RESULTS AND DISCUSSION

After the mechanism of absorption of the energy of low-frequency vibrations by clathrate compounds was studied [5-8], it was necessary to determine whether clathrates are unique species or there are other structures sensitive to low-frequency vibrations at relatively

Table 1. Rate constants $(k \times 10^4, s^{-1})$ for destabilization of iodinolum and povidone-iodine at various action intensities

Compley	Intensity, dB	Frequency, Hz		
complex		10	20	25
Iodinolum	40	5.66	4.28	2.01
	55	7.95	9.33	4.01
Povidone-iodine	40	9.78	1.12	0.78
	55	11.72	4.73	3.01

Table 2. Activation energies of acoustic chemical transformations of clathrate and chelate structures in a low-frequency acoustic field at 10 Hz and an intensity of 40 dB

Complex	Amilojodin	Amilopec tojodin	Iodino- lum	Povidone- iodine
$E \pm 2$, kJ/mol	29-31	38-41	14–16	34-36

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Fig. 1. Raman spectra of the clathrate complex iodinolum (a) before and (b) after the action of acoustic vibrations at a frequency of 10 Hz and an intensity of 55 dB.

low action intensity. It was important to find how the energy of vibrations applied from the outside is distributed. Energy consumption by biochemically active structures can be performed by several ways. The energy can be [8]:

(i) absorbed by the high-molecular weight component of a complex, which constitutes a significant part of the weight of the compound;

(ii) distributed in a certain ratio between components of a structure; (iii) spent mainly on a change in the state of the low-molecular-weight component of a biochemically active structure.

To gain insight into acoustic chemical processes and determine the mechanisms of energy transfer in acoustic chemical transformations, Raman spectra of chelate and clathrate structures were recorded with an Ntegra Spectra AFM Raman confocal SNOM/NSOM system (Russia) with a resolution of $0.4 \,\mu\text{m}$. Figures 1 and 2 present the Raman spectra of a clathrate com-