

ЗАКОНОМЕРНОСТИ ИЗМЕНЕНИЯ ТЕРМОДИНАМИЧЕСКИХ ПАРАМЕТРОВ ПРИ ОБРАЗОВАНИИ КОМПЛЕКСОВ УРАЦИЛА С НЕКОТОРЫМИ АРОМАТИЧЕСКИМИ АМИНОКИСЛОТАМИ В БУФЕРНОМ РАСТВОРЕ ПРИ pH 7,4

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Возрастающий интерес к физико-химическим исследованиям оснований нуклеиновых кислот и их производных обусловлен главным образом их биологическим и фармацевтическим значением. Несмотря на увеличение данных о взаимодействии ДНК с протеинами, молекулярный механизм распознавания частиц в образующихся комплексах изучен еще недостаточно. Изучение природы и сил, стабилизирующих структуры нуклеиновых кислот и их комплексов с другими молекулами, имеет не только фундаментальное значение, но и может найти практическое применение. В данной работе мы обсудили взаимодействие модельных соединений нуклеиновых кислот и протеинов на примере комплексов урацила с ароматическими аминокислотами: L-гистидином, L-триптофаном и L-фенилаланином в водных буферных растворах с физиологическим значением pH 7,4. Используются имеющиеся литературные данные по термодинамическим, объемным и теплоемкостным свойствам указанных систем. Растворение изучаемых реагентов в воде вызывает изменение кислотности среды, что сопровождается сдвигом равновесия ионных форм и таутомеров и приводит к изменению их реакционной способности. Полученные характеристики процесса комплексообразования при фиксированном значении pH заметно отличаются от результатов, полученных для водного раствора без использования буфера. Проведено обобщение данных по изменению термодинамических параметров (констант равновесия, энергии Гиббса, энтальпии, энтропии, кажущегося молярного объема и кажущейся молярной теплоемкости) при образовании комплексов между урацилом и ароматическими аминокислотами в зависимости от их физико-химических свойств. Установлена зависимость термодинамических параметров образования комплексов от кислотно-основных свойств аминокислот как характеристики электронной плотности на карбоксилатной группе. Изменения стандартной кажущейся молярной теплоемкости и стандартного кажущегося молярного объема урацила при добавлении аминокислот коррелируют с гидрофобностью добавляемых аминокислот.

Ключевые слова: термодинамика, комплексообразование, растворы, урацил, L-гистидин, L-триптофан, L-фенилаланин

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**REGULARITIES OF CHANGES IN THERMODYNAMIC PARAMETERS INDUCED
BY THE COMPLEXES FORMATION OF URACIL WITH SOME AROMATIC AMINO ACIDS
IN A BUFFER SOLUTION AT PH 7.4**

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The increasing interest in the physicochemical studies of nucleic acid bases and their derivatives is due mainly to their biological and pharmaceutical importance. Despite increasing data on the interaction of DNA with proteins, the molecular mechanism of recognition of particles in the resulting DNA-protein complexes is not well understood yet. The investigation of the nature and the forces that stabilize nucleic acid structures and their complexes with other molecules is not only of fundamental significance but may also find practical applications. In this paper, we discussed the interaction of model compounds of nucleic acids and proteins using the example of complexes of uracil with aromatic amino acids: L-histidine, L-tryptophan, and L-phenylalanine in aqueous buffer solutions with physiological value of pH to be 7.4. The available literature data on the thermochemical, volume, and heat capacity properties of these systems were used. It should be noted that a change in the acidity of the medium induces a shift in the equilibrium of ionic forms, tautomers, and this leads to a variation in the reactivity of the reagents. The obtained characteristics of the complex formation process differ markedly from the results obtained for an aqueous solution without the use of buffer. A generalization of data on the change in thermodynamic parameters (equilibrium constants, Gibbs energy, enthalpy, entropy, apparent molar volume, and apparent molar heat capacity) under the formation of uracil complexes with above aromatic amino acids depending on their physicochemical properties is given. The dependence of the thermodynamic parameters of the formation of complexes on the acid-base properties of amino acids as a characteristic of the electron density on the carboxylate group has been established. Changes in the standard apparent molar heat capacity and in the standard apparent molar volume of uracil under the addition of amino acids correlate with the hydrophobicity of the added amino acids.

Key words: thermodynamics, complex formation, solutions, uracil, L-histidine, L-tryptophan, L-phenylalanine

INTRODUCTION

Nucleic acids and proteins are complex molecules and hence, the study of model compounds which represent various groups and subunits in the biopolymers, throw light on the exact nature of interactions [1-3]. The study of interactions between peptides and nucleic acids and their monomer units - amino acids and nucleic acid bases - is a fundamental problem in biology. It is known that biosynthesis of the protein molecule proceeds with participation of the specific sRNA molecules fixing the positions of the corresponding amino acids. The molecular recognition of every amino acid is determined by the pecu-

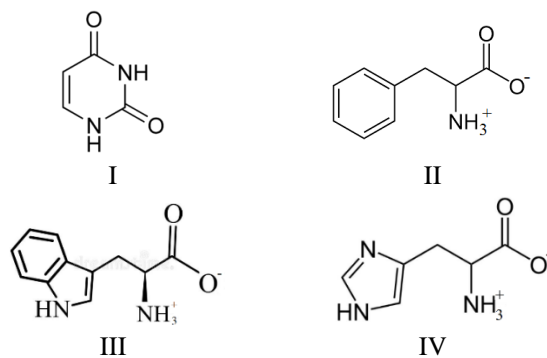
liar sequence of the nucleotides in sRNA. Thermodynamic investigations elucidate the nature and driving forces of these processes.

Two possible mechanisms for the interaction of nucleic bases with amino acids (or amino acid residues in proteins) are discussed in the literature. One of them is the formation of hydrogen bonds. Active sites of nucleic bases are NH groups involved in heterocycles, acting as H-donors, as well as carbonyl oxygen atoms, capable of being H-acceptors [4-7]. In amino acids, the terminal charged groups NH_3^+ and COO^- are potentially active. In peptides, amide fragments $\text{O}=\text{C}-\text{NH}$ can exhibit activity. In [7] the B3LYP method was used to simulate the formation of

H-bonds of nucleic bases with amino acid residues involved in proteins through two sp^2 C-H bonds of aromatic side groups of phenylalanine, tyrosine, and tryptophan. Although the lengths of the marked $CH\cdots O=C$ bonds of the order of 2.8 Å lie outside the criterion for H-bond formation. The possibility of participation in the formation of H-bonds of the NH groups of the side indole fragment of tryptophan and the imidazole fragment of histidine was noted. The bond lengths $NH\cdots O=C$ in these cases are 1.98-2.47 Å and 1.95-2.72 Å, respectively.

Stacking or π - π interaction between conjugated electron systems of nucleic bases and aromatic side groups of amino acids is the second possible interaction mechanism [8,9]. For the case of the most favorable mutual arrangement of aromatic groups, the stacking interaction energies amounted to -20 kJ mol⁻¹ for Ur:Phe, up to -26 kJ mol⁻¹ for Ur:His, and up to -34 kJ mol⁻¹ for Ur:Trp according to the results of the MP2 method. The given values refer to the interaction in the gas phase and do not include the contribution of the partial dehydration of the interacting molecules.

In this paper, we have discussed the interactions of uracil (Ura, I) with L-histidine (His, II), L-tryptophan (Trp, III) and L-phenylalanine (Phe, IV) in aqueous buffer solutions (with pH = 7.4) using available literature data on thermochemical, volume and heat capacity properties [10-16]. The chemical structures of above solutes are shown in the scheme.



Scheme. Molecular structures of chemicals
Схема. Молекулярные структуры химических веществ

Based on a comparison of the known results for the above systems, we analyze the patterns in the thermodynamic parameters of the complexes formed between the reagents, as well as the patterns of changes in the physicochemical properties of multi-component systems under the influence of complexation in buffer media.

EXPERIMENTAL PART

We used the values of reaction constant, enthalpy and entropy for the formation of molecular

complexes of uracil with a series of aromatic amino acids (histidine, phenylalanine and tryptophan) in a phosphate buffer medium at pH = 7.4, which are given in works [10-12]. The data were obtained by calorimetry (isoperibol ampoule solution calorimeter) and UV-spectroscopy (Spectrometer Specord M40, Germany). The data on the apparent molar values of volume and heat capacities [13-15] obtained from measurements with a DMA 5000 M density meter (Anton Paar) and a SKAL-1 microdifferential scanning calorimeter (Pushchino, Russia) confirmed the occurrence of the complex formation process in ternary mixtures [Ura + (His, Phe, Trp) + bufer].

The obtained characteristics of the process differ markedly from the results obtained for an aqueous solution without the use of buffer [17]. Aqueous solutions of various amino acids and nucleic acid bases are characterized by different pH values. A change in the acidity of the medium induces a shift in the equilibrium of ionic forms, tautomers, and this leads to a variation in the reactivity of the reagents. That is why the data measured under such conditions are not suitable for comparing results in a series of amino acids or nucleic acid bases.

RESULTS AND DISCUSSION

In this work, we have made an attempt to generalize the available thermodynamic parameters of complex formation of uracil with aromatic amino acids at pH = 7.4, summarized in Table 1.

Table 1
Thermodynamic parameters of complex formation of uracil with aromatic amino acids in a phosphate buffer medium at 298.15 K

Таблица 1. Термодинамические параметры образования комплексов между урацилом и ароматическими аминокислотами в фосфатной буферной среде при 298,15 К

Amino acids	$\lg K_r^{**}$	$\Delta_r G^{**}$	$\Delta_r H^{**}$	$T\Delta_r S^{**}$
histidine	3.98	-22.7	-2.68	20.0
tryptophan	4.89	-27.9	-22.7	5.1
phenylalanine	4.13	-23.6	-14.6	9.0

Data from refs. [10-12]

*The mole ratio of amino acid and uracil in complexes is 1:2; unit of K_r is kilogram² (buffer solution) mol⁻²

**Unit is kJ mol⁻¹

The stoichiometry of the resulting amino acid : uracil complexes was 1:2 in all cases considered. In the process of formation of above complexes, the enthalpy effect dominates over the entropy one. Thermodynamic and physico-chemical properties of amino acids given in Table 2 were used to establish the patterns of interactions between the uracil and the aromatic amino acids, whose molecules contain various structure side chains, under buffer solution conditions.

Table 2

Some physico-chemical properties of amino acids at 298.15 K

Таблица 2. Некоторые физико-химические свойства аминокислот при 298,15 К

Amino acids	$pK_1(\text{COOH})$	$pK_2(\text{NH}_3^+)$	Hydrophobicity***
His *	1.82	9.17	-3.20
Trp *	2.37	9.39	-0.90
Phe **	2.20	9.09	2.80

* From Ref. [18] **From Ref. [12] ***From Ref. [19]

The acid dissociation constants K_1 and K_2 ($pK = -\lg K$) characterize the ability of COOH and NH_3^+ amino acid groups to donate a proton, these values are proportional to the electron density on oxygen and nitrogen atoms. A decrease in the dissociation constant of the COOH group of amino acids (an increase in pK_1) indicates an increase in the electron density on the oxygen atom, while the ability of the ionized COO^- group to act as an H-bond acceptor increases. This should lead to an increase in the exothermic effect of the process and stabilization of the complex formed with the participation of this group. On the contrary, an increase in the electron density on the nitrogen atom should decrease the ability of the amino acid NH_3^+ group to act as an H-bond donor. As expected, a regular relationship was found between the thermodynamic parameters of complex formation and the dissociation constants of COOH groups of pK_1 amino acids, that it shown in Fig. 1.

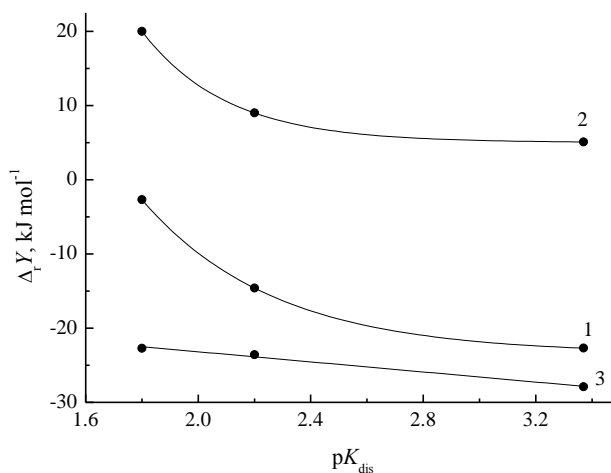


Fig. 1. Dependence of the standard thermodynamic parameters in the reaction of formation of complexes of uracil with aromatic amino acids on the acid dissociation constant of the carboxyl group of the amino acid: 1 – enthalpy change Δ_rH ; 2 – change in the entropy factor $T\Delta_rS$; 3 – Gibbs energy change Δ_rG , $T=298.15$ K

Рис. 1. Зависимость стандартных термодинамических параметров в реакции образования комплексов урацила с ароматическими аминокислотами при 298,15 К от константы кислотной диссоциации карбоксильной группы аминокислоты: 1 – изменение энтальпии Δ_rH ; 2 – изменение энтропийного фактора $T\Delta_rS$; 3 – изменение энергии Гиббса Δ_rG , $T=298,15$ К

The increase in pK_1 values in the series of amino acids from 1.82 for histidine to 2.37 for tryptophan is accompanied by an increase in the complexation reaction constant $\lg K_r$ from 3.98 to 4.89. In this case, the negative values of changes in the Gibbs energy Δ_rG are altered (from -22.7 to -27.9 kJ mol^{-1}), the exothermic effect of the reaction increases (from -2.68 to -22.7 kJ mol^{-1}), and the favorable entropy effect $T\Delta_rS$ is going down (from 20.0 to 5.1 kJ mol^{-1}). The observed trend may be related to the change in the electron density on the oxygen atoms of the COO^- group of amino acids, as indicated above. The enthalpy effect in the series of considered amino acids undergoes the greatest changes as it is most dependent on the electronic effects in the complexes. The manifestation of a monotonic dependence of $\lg K_r$, Δ_rG , Δ_rH , and $T\Delta_rS$ on pK_1 is an argument in favor of hydrogen bonding of uracil with the carboxylate group of amino acids of the $\text{NH}\cdots\text{OOC}$ type. On the contrary, no monotonic dependence on dissociation constants of NH_3^+ group of amino acids is observed; therefore, the formation of H-bonds of uracil with amino group is not obvious.

The $\lg K_r$ values of Ura complexes increase in the order $\text{His} \rightarrow \text{Phe} \rightarrow \text{Trp}$. The similar favorable (more negative) trends were also observed for the Δ_rG and Δ_rH values obtained, while the entropy of complexation became more favorable (more positive) for the series of $\text{Trp} \rightarrow \text{Phe} \rightarrow \text{Trp}$. The stacking effect can influence the thermodynamic parameters of complex formation. As it is known [9], the stacking interactions between the natural nucleobases and the aromatic amino acids increase in the following order $\text{Phe} < \text{His} \approx \text{Tyr} < \text{Trp}$. It was found that the increase in pK_2 values in the series of amino acids from 9.09 for Phe, 9.16 for His to 9.38 for Trp is consistent with their ability to stacking effect. In case of Ura, the more stability of $\text{Trp}:2\text{Ura}$ complex and larger enthalpy change accompanying binding of Ura to Trp as compared with Phe and His results apparently from the additional process of the stacking interaction between the indole ring of Trp molecule and the pyrimidin ring of Ura molecule.

The process of formation of molecular complexes affects the thermodynamic and physicochemical properties of aqueous solutions of uracil with the addition of amino acids. There are a number of works that present data on the change in the apparent isobaric molar heat capacity of uracil in a buffer solution under the influence of additions of histidine [15], phenylalanine [14], and tryptophan [13]. The obtained results of extrapolation of concentration dependences of the apparent isobaric molar heat capacities of uracil at infinite dilution in a buffer solution of various amino acids are given in Table 3 as the

standard (at infinite dilution) apparent isobaric molar heat capacities of Ura (${}^{\circ}C_p$) in the studied solutions for each amino acid.

Table 3
Standard apparent molar heat capacities (${}^{\circ}C_p / \text{J K}^{-1} \text{mol}^{-1}$) of uracil in an aqueous buffer solution and an aqueous buffer solution of amino acids at different temperatures
Таблица 3. Стандартные кажущиеся молярные теплоемкости (${}^{\circ}C_p / \text{Дж K}^{-1} \text{моль}^{-1}$) урацила в водном буферном растворе и водном буферном растворе аминокислоты при разных температурах

T, K	Ura	Ura+His	Ura+Phe	Ura+Trp
288.15	449.42	452.34	-	-
293.15	449.55	453.04	446.62	-
298.15	449.73	453.71	447.10	449.41
303.15	450.10	454.22	447.64	-
308.15	450.52	454.76	-	-
313.15	450.92	455.29	448.65	-
323.15	-	-	450.16	-

Data from refs. [13-15]

As can be seen, the ${}^{\circ}C_p$ values of uracil in the buffer solution increase in case of the addition of His, and those fall when Phe or Trp are added. At the same time, the trend of temperature dependences of ${}^{\circ}C_p$ remains; the values of $\partial {}^{\circ}C_p / \partial T$ change slightly for the systems studied. Therefore, the difference between the values of ${}^{\circ}C_p$ for uracil in the buffer solution of amino acids and in the buffer without the additives, $\Delta_{\text{tr}}({}^{\circ}C_p)$, also increases with temperature, as shown in Fig. 2.

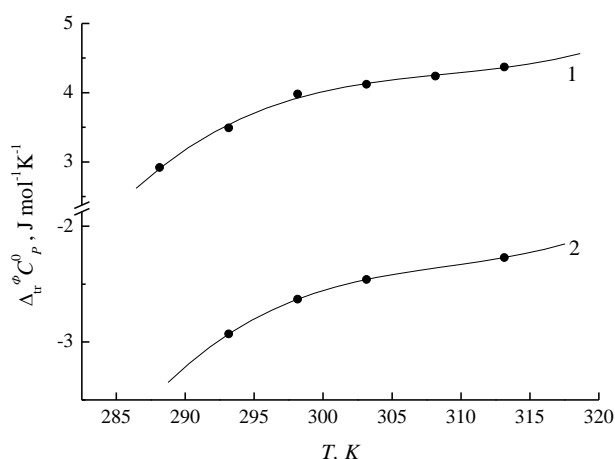


Fig. 2. Changes in the standard apparent isobaric heat capacity of uracil in a buffer solution with the addition of histidine (1) and phenylalanine (2) at different temperatures

Рис. 2. Изменения кажущейся изобарной теплоемкости урацила в буферном растворе при добавках гистидина (1) и фенилаланина (2) при различных температурах

It should be noted, that positive $\Delta_{\text{tr}}({}^{\circ}C_p)$ values suggest that the Ura solution in (amino acid +

buffer) are more structured than in the buffer solvent. As it is known [20, 21], the complex formation between Ura and amino acid leads to a loss of some degree of freedom, which gives a negative contribution to $\Delta_{\text{tr}}({}^{\circ}C_p)$, and to dehydration of the solutes which gives a positive contribution to $\Delta_{\text{tr}}({}^{\circ}C_p)$. The apparent isobaric heat capacity is a comprehensive property that is very sensitive to changes in both the stability of the resulting complexes and changes in the hydration shells of the interacting particles. The penetration of the amino acid zwitterion into the hydration shell of uracil induces a change in structure of its hydration shell and the mobility of water molecules in the environment of uracil. In addition to the changes caused by the H-bonding of the COO^- amino acid group, attention should be paid to the influence of their side groups: a hydrophilic fragment of imidazole in His and more hydrophobic fragments of indole and phenyl in Trp and Phe, respectively. These groups are not directly involved in the formation of the complex with uracil. However, the influence of side groups can lead to additional effects of destructuring (in the case of hydrophilic fragments) or making structure of the uracil hydration shell (in the case of hydrophobic fragments). In this regard, one can expect a dependence of the apparent heat capacity of uracil in amino acid solutions on the hydrophobicity of amino acids. As shown in Fig. 3, there is indeed a correlation between changes in the standard apparent molar heat capacity of uracil in a buffer solution and the hydrophobicity of the added amino acids. Here we have applied the Kyte and Doolittle hydrophobicity scale [18], which is widely used in protein chemistry.

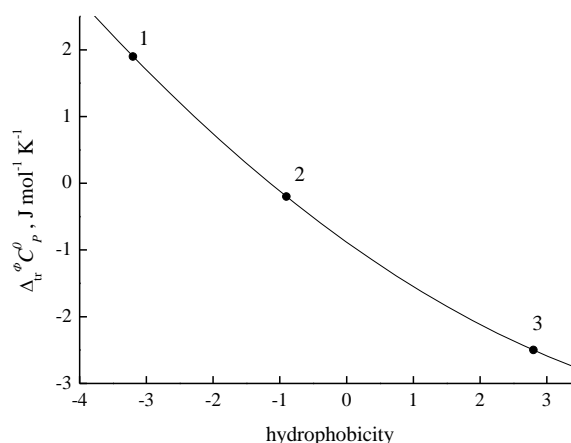


Fig. 3. Change in the standard apparent isobaric heat capacity of uracil in a buffer solution with the addition of amino acids as a function of amino acid hydrophobicity according to the scale [18], pH=7.4, T=298.15 K: 1 – His; 2 – Trp; 3 – Phe

Рис. 3. Изменение стандартной кажущейся изобарной теплоемкости урацила в буферном растворе при добавках аминокислот как функция гидрофобности аминокислот по шкале [18]; pH=7,4, T=298.15 K: 1 – His; 2 – Trp; 3 – Phe

The addition of phenylalanine, as the most hydrophobic of the considered amino acids, causes the greatest decrease in the apparent molar heat capacity of uracil, although the formation of the complex in this case is characterized by less favorable $\Delta_r G$ value compared to the tryptophan complex (Table 1). The addition of histidine containing a hydrophilic imidazole fragment in the side chain leads to an increase in ${}^\circ C_p$, which is typical for processes accompanied by greater disorder than in systems containing Phe and Trp. The most favorable entropy factor in case of His, $T\Delta_r S=20.0 \text{ kJ mol}^{-1}$, confirms this conclusion.

Analysis of the volumetric parameters from works [13-15] summarized in Table 4 allow to conclude that there are marked changes in the standard apparent molar volume of uracil in buffer solution when various amino acids are added.

Table 4

Standard apparent molar volumes (${}^\circ V_2 \times 10^6 / \text{m}^3 \text{mol}^{-1}$) of uracil in an aqueous buffer solution and their changes ($\Delta_{tr}({}^\circ V_2) \times 10^6 / \text{m}^3 \text{mol}^{-1}$) with amino acid additions at different temperatures

Таблица 4. Стандартные кажущиеся молярные объемы (${}^\circ V_2 \times 10^6 / \text{m}^3 \text{моль}^{-1}$) урацила в водном буферном растворе и их изменение ($\Delta_{tr}({}^\circ V_2) \times 10^6 / \text{m}^3 \text{моль}^{-1}$) при добавках аминокислот при разных температурах

T, K	${}^\circ V_2 \cdot 10^6$	$\Delta_{tr}({}^\circ V_2) \cdot 10^6$		
	Ur*	Ur+His	Ur+Phe	Ur+Trp
288.15	55.8±0.3	1.7		-
293.15	57.2±0.1		0.9	-
298.15	58.1±0.2	1.9	0.5	1.6
303.15	60.0±0.2	2.4	0.9	-
308.15	61.5±0.2	4.1		-
313.15	62.8±0.2	6.2	2.0	-
323.15	65.1±0.1		2.5	-

* From Refs. [14, 15]

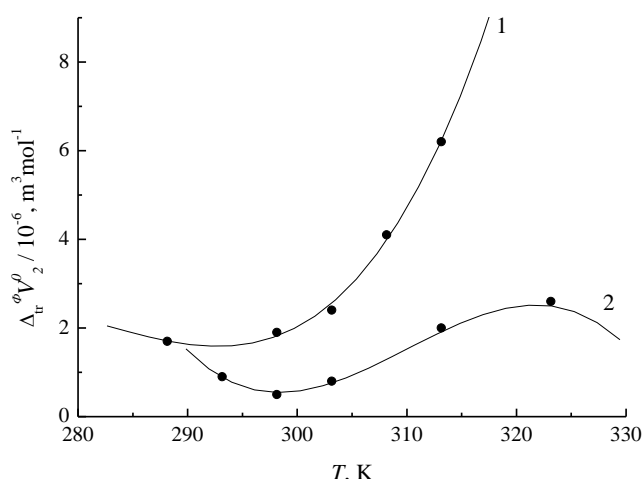


Fig. 4. Changes in the standard apparent molar volume ($\Delta_{tr}({}^\circ V_2)$) of uracil in a buffer solution with the addition of histidine (1) and phenylalanine (2) at different temperatures

Рис. 4. Изменение стандартного кажущегося молярного объема ($\Delta_{tr}({}^\circ V_2)$) урацила в буферном растворе при добавках гистидина (1) и фенилаланина (2) при различных температурах

The standard apparent volume of uracil in a buffer solution increases almost linearly with temperature; this trend is usually associated with thermal destruction of the water structure. The plots of the apparent molar volumes of transfer of Ura, $\Delta_{tr}({}^\circ V_2)$, from buffer to buffer solutions of amino acid (His, Phe, Trp) versus temperature are given in Fig. 4. Fig. 4 clearly demonstrates, that the changes of values of $\Delta_{tr}({}^\circ V_2)$ increase non-monotonically with temperature as amino acids are added. These values are influenced not only by the thermal destruction of water, but also by hydrophilic and hydrophobic fragments of amino acids that are introduced into the hydration shell of uracil. It follows from the results that the apparent molar volume of uracil in the composition of amino acid complexes changes more sharply with temperature than the volume of free uracil. The volume parameters of uracil also show a dependence on the hydrophobicity of the added amino acids.

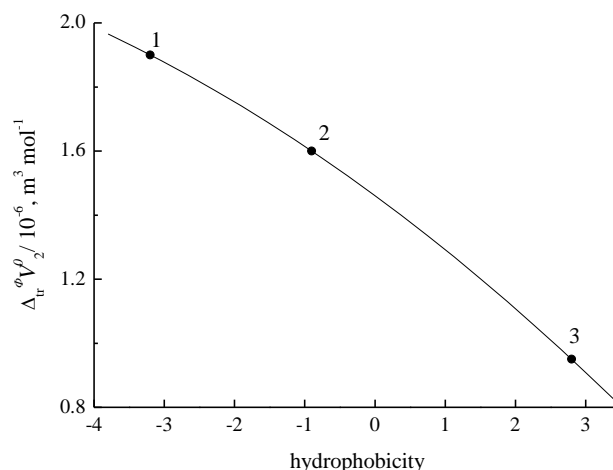


Fig. 5. Changes in the standard apparent molar volume ($\Delta_{tr}({}^\circ V_2)$) of uracil in buffer solution with the addition of amino acids as a function of the hydrophobicity of amino acids according to the scale [18], pH=7.4, T=298.15 K: 1 – His; 2 – Trp; 3 – Phe
Рис. 5. Изменение стандартного кажущегося молярного объема ($\Delta_{tr}({}^\circ V_2)$) урацила в буферном растворе при добавках аминокислот как функция гидрофобности аминокислот по шкале [18], pH=7,4, T=298.15 K: 1 – His; 2 – Trp; 3 – Phe

As shown in Fig. 5, the addition of the most hydrophobic amino acid, phenylalanine, induces the smallest change in the standard apparent molar volume of uracil. Conversely, the addition of histidine, which has a side hydrophilic fragment in the structure and is characterized by the lowest hydrophobicity index [18] produces the maximum increase in the standard apparent molar volume of uracil.

As the solutes studied consists of both hydrophilic and hydrophobic groups, so there is a competition among various interactions occurring among solute and co-solute molecules in buffer solutions. The following types of interactions are possible in the

studied systems: (I) hydrophilic-ionic interactions among polar groups of nucleic acid base and charged end groups of zwitterions of the co-solute (amino acids); (II) hydrophilic-hydrophilic interactions between polar groups of Ura and amino acids; (III) hydrophobic-ionic interactions of the non-polar parts of Ura with the zwitterions of amino acids, and (IV) hydrophobic-hydrophobic interactions between the non-polar parts of the studied solutes. The first and second types of interactions will contribute positively, whereas the third and fourth type will contribute negatively to $\Delta_{tr}(\Phi V_2)$ values according to co-sphere overlap model [R.W. Gurney, *Ionic Processes in Solution*, McGraw Hill, New York, 195]. The positively observed $\Delta_{tr}(\Phi V_2)$ values for the studied systems indicate that (ionic + hydrophilic) and hydrophilic-hydrophilic (types (I) and (II)) interactions dominate over other (types (III) and (IV)) interactions. Thus, it can be suggested that overall structural order is enhanced in Ura buffer solutions under the addition of amino acid (His, Phe, Trp).

CONCLUSIONS

This study was undertaken in order to clarify the issue of the influence of the acid-base properties and hydrophobicity of amino acid molecules on the thermodynamic parameters and physicochemical characteristics of the process of complex formation between aromatic amino acids (His, Phe, Trp) and uracil under condition of physiological pH 7.4 value of media. A regular relationship has been established between the thermodynamic parameters of complex formation and the dissociation constants of COOH groups of amino acids, pK_1 . Thus, quantities of $\lg K_r$, $\Delta_r G$, $\Delta_r H$, and $T\Delta_r S$ are most dependent on the electronic effects in the complexes. It can be approved that an increase in the electron density on the oxygen atoms of the COO⁻ group of amino acids promotes the

formation of hydrogen bonds between uracil and the carboxylate group of amino acids according to the NH...OOC type. In ternary systems of (Ura + amino acid + buffer) the stability constants ($\lg K_r$) values of Ura complexes increase in the order His → Phe → Trp. The more stability of Trp:2Ura complex and larger enthalpy change accompanying binding of Ura to Trp as compared with Phe and His results from the additional process of the stacking interaction between the indole ring of Trp molecule and the pyrimidin ring of Ura molecule.

The influence of side groups nature in amino acid molecules on values of $\Delta_{tr}\Phi C_p$ and $\Delta_{tr}(\Phi V_2)$ reveals in the additional effects of destructuring (in the case of hydrophilic fragments) or making structure of the uracil hydration shell (in the case of hydrophobic fragments) in buffer solutions. The correlation between changes in the standard apparent molar heat capacity of uracil in a buffer solution containing amino acid and the hydrophobicity of the added amino acids (His, Phe, Trp) was obtained. The decreases in the standard apparent molar heat capacity and in the standard apparent molar volume of uracil in buffer systems with amino acids have been detectable, when the hydrophobicity of the added amino acids increases in the order: His < Trp < Phe.

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The authors declare the absence a conflict of interest warranting disclosure in this article.

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