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THERMODYNAMIC PARAMETERS OF SOLUBILITY OF 1-CYCLOHEXYL-2-METHYL-5-PHENYL-1*H*-PYRROLE-3-CARBOXYLIC ACID IN ORGANIC SOLVENTS

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The temperature dependence of the solubility of 1-cyclohexyl-2-methyl-5-phenyl-1*H*-pyrrole-3-carboxylic acid in methyl acetate, ethyl acetate, acetonitrile, 1-butanol, 2-butanol, 1-propanol, 2-propanol was used to calculate the enthalpy and entropy of their dissolution. The nature of the interaction between solvents and the dissolved substance is determined. The temperature dependences of the solubility of 1-cyclohexyl-2-methyl-5-phenyl-1*H*-pyrrole-3-carboxylic acid in various solvents are presented. Taking into account the enthalpy and entropy of melting recalculated to 298.15 K, the enthalpies and entropies of mixing were calculated.

Keywords: solubility; enthalpy of dissolution, enthalpy of mixing, enthalpy of melting, pyrrole-3-carboxylic acid, polysubstituted pyrroles.

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1. Introduction

Analysing the worldwide trends in the pharmaceutical industry, it was noted that substances with a pyrrole fragment are increasingly attracting attention as biologically active compounds due to their antioxidant, anti-inflammatory and antibacterial effects in the composition of medicines. The high reactivity is explained by the aromatic structure of the pyrrole, which interacts with various electrophilic agents [1]. The interest in these substances arises in other areas of human activity, such as scientific and industrial, for example, as part of dyes, catalysts, semiconductors and batteries, which helps to switch to a cleaner form of energy [2, 3]. The widespread use is explained by the presence of various substituents in the pyrrole ring, which, by changing the structure of the substance in space, also change its properties. Pyrrole compounds themselves are found in biologically active structures, such as hemoglobin, chlorophyll, or cytochrome.

In this paper, we will discuss the interaction between solvents and solute, which is the basis of purification methods, namely recrystallization from solution [4] and synthesis of compounds of this class. The study of the interaction of substances with solvents that

serve as reaction media is a scientific novelty to facilitate the production of precision-pure final substances in the pharmaceutical industry. Thus, when choosing a solvent, its chemical inertness to a given substance, light volatility and non-toxicity are taken into account when used correctly. Therefore, the thermodynamic parameters of the interaction between the solvent and the solute are necessary for technological calculations of the energy balances of the synthesis, purification and processing.

2. Purpose of the study and experimental

To determine the thermodynamic parameters of the solubility of 1-cyclohexyl-2-methyl-5-phenyl-1*H*-pyrrole-3-carboxylic acid in methyl acetate, ethyl acetate, acetonitrile, 1-butanol, 2-butanol, 1-propanol, 2-propanol.

1-Cyclohexyl-2-methyl-5-phenyl-1*H*-pyrrole-3-carboxylic acid **5** was synthesized as shown in Figure 1.

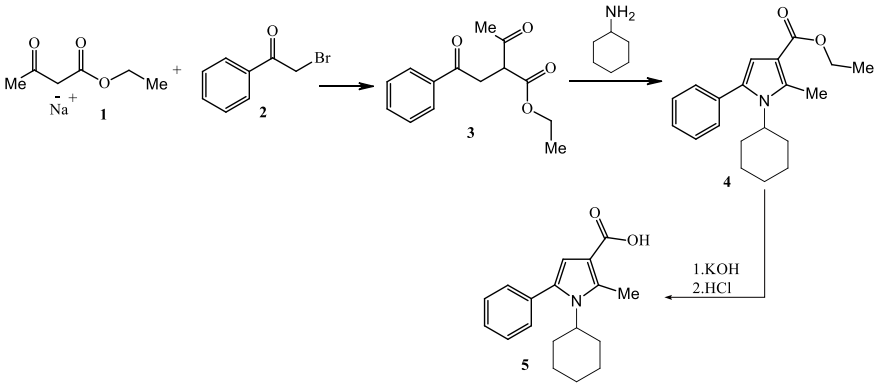

Fig. 1. Scheme of the synthesis of 1-cyclohexyl-2-methyl-5-phenyl-1*H*-pyrrole-3-carboxylic acid **5**

In the first step, ethyl 2-acetyl-4-oxo-4-phenylbutanoate **3** was obtained. To a suspension of crushed metallic sodium (0.03 mol) in 40 ml of toluene under constant cooling and vigorous stirring was added 0.044 mol of ethyl acetoacetate, after which the mixture was stirred for three days at room temperature. After cooling to 283 K, 0.03 mol of phenacyl bromide **2** was added to the mixture, after which the mixture was stirred at 283 K for another 1 h and at room temperature for 1 day. The reaction mixture was filtered from sodium bromide, the toluene was evaporated at 30 mm Hg, the residue was distilled in vacuum, B.p. 175–177 °C/2 mm Hg. Yield 6.35 g (86 %).

In the second step, 2.14 g (0.02 mol) of cyclohexylamine was added to a mixture of 5.00 g (0.02 mol) of ethyl 2-acetyl-4-oxo-4-phenylbutanoate **3** in 30 ml of glacial acetic acid. The mixture was boiled for 2.5 hours, then cooled, diluted in 100 ml of water, extracted with methylene chloride, washed with water, and dried with sodium sulfate for 2 hours. The methylene chloride was distilled off, and a solution of 2.24 g (0.04 mol) of KOH in 20 mL of ethanol was added to the crude ester **3**. The reaction mixture was heated for 15 min, cooled to room temperature, after which 50 ml of water was added and acidified with 1:1 dilute hydrochloric acid under stirring. The resulting light yellow precipitate of acid **5** was recrystallised from ethanol. Yield 4.62 g (79 %).

The structure of 1-cyclohexyl-2-methyl-5-phenyl-1*H*-pyrrole-3-carboxylic acid **5** was confirmed by ^{1}H and ^{13}C NMR spectra:

^{1}H NMR (500 MHz, DMSO-d_6), δ: 11.66 (br.s, 1H), 7.43 (t, J = 7.3 Hz, 2H), 7.37

(t, *J* = 7.3 Hz, 1H), 7.30 (d, *J* = 7.0 Hz, 2H), 6.27 (s, 1H), 3.98 (tt, J = 12.7, 3.6 Hz, 1H), 2.66 (s, 3H), 2.03–1.46 (m, 8H), 1.16–1.08 (m, 2H).

^{13}C NMR (151 MHz, DMSO-*d*6), δ: 166.23, 135.47, 133.49, 133.26, 129.61, 128.36, 127.61, 112.37, 110.13, 57.02, 31.69, 25.91, 24.73, 12.80.

The solvents selected for the study represent different classes of compounds, and an important characteristic is their relatively low boiling point. Thus, methyl acetate and ethyl acetate are among the most common and affordable solvents, easy to work with and low toxicity. Acetonitrile has a nitrile moiety, and all the bonds present are provided by dipole-dipole and dispersion interactions. It was used to determine the behavior of the substance under study in an environment without hydrogen bonds. Representatives of lower alcohols, such as 1-propanol and 2-propanol, which are less toxic than methanol and exhibit similar properties as ethanol and are readily available. From the higher alcohols, the first representatives were selected, which have a low boiling point compared to other representatives of the homologous series, such as the boiling point of 1-butanol is 390.85 K and 1-pentanol is 411 K.

The solvents used for the study were manufactured by Merck (acetonitrile CAS 75-05-8; methyl acetate CAS 79-20-9; ethyl acetate CAS 71-43-2; 1-propanol CAS 71-23-8; 2-propanol CAS 67-63-0; 1-butanol CAS 71-36-3; 2-butanol CAS 78-92-2). With the content of the main component ≥99.9 %, which are intended for chromatographic studies.

The temperature dependence of the solubility of the studied acid was determined by the gravimetric method [5–10].

The acid was dissolved in sealed glass round-bottomed vessels equipped with a Teflon stirrer, thermometer and sampling hole, which were subjected to immersion in a temperature-controlled thermostat with an accuracy of ±0.1 K. The stirrer rotation was 30–40 rpm. The saturation of the solutions was carried out for 48 hours without stirring and 2 hours with constant stirring. The experiments were performed by changing the temperature regime, i.e., after increasing the temperature, it was reduced and vice versa. In this way, we tried to obtain results that would neutralize the environmental conditions. The absence of a hysteresis loop on the solubility temperature dependence curve confirms the achievement of a state close to equilibrium. The amount of solvent in the flask was enough to keep the dissolved substance in excess and to allow for easy sampling.

Samples of the solutions were taken in series of three samples, transferred to pre-weighed sealed heat-resistant glass vials with lids, with subsequent solvent removal in an oven at a temperature of 363–373 K. After solvent removal, the vials were sealed, cooled in a desiccator and weighed. The weighing was carried out at a room temperature of 296±2 K using pre-calibrated and verified balances, with a weighing accuracy of ±0.0002 g.

3. Results and discussion

Table 1 shows the results of the acid dissolution experiments, including the mass of solute (m_2), the mole fraction of solubility (X_2) and the temperature (T) at which the solubility was determined. The linear equations obtained using the least squares method are presented in the form of the Schrader's equation:

$$lnX_2 = -\Delta_{sol}H/RT + \Delta_{sol}S/R, \quad (1)$$

where $\Delta_{sol}H$ and $\Delta_{sol}S$ – enthalpy and solubility entropy. Hereinafter, the errors of all values are given for a significance level of 0.95.

Table 1

Temperature dependence of the solubility of 1-cyclohexyl-2-methyl-5-phenyl-1*H*-pyrrole-3-carboxylic acid in organic solvents

T , K	m_1, г	m_2, г	$X_2 \cdot 10^3$	T, K	m_1, г	m_2, г	$X_2 \cdot 10^3$	T, K	m_1, г	m_2, г	$X_2 \cdot 10$
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Methyl acetate											
278.65	1.1698	0.0277	6.14	294.25	1.5818	0.0576	9.43	301.05	2.3541	0.1028	11.29
278.65	1.2759	0.0314	6.39	294.25	1.4986	0.0562	9.71	301.05	2.0049	0.0876	11.29
278.65	1.5378	0.0370	6.25	294.25	1.8999	0.0721	9.82	301.05	1.7869	0.0775	11.21
284.95	1.5985	0.0468	7.60	295.45	1.6958	0.0663	10.12	302.25	1.5226	0.0702	11.91
284.95	1.1166	0.0317	7.36	295.45	2.2873	0.0894	10.12	302.25	1.5579	0.0722	11.96
284.95	1.0193	0.0289	7.36	295.45	2.0747	0.0818	10.21	302.25	1.5582	0.0721	11.94
289.75	1.8247	0.0602	8.55	297.15	1.7065	0.0690	10.45	303.75	1.0260	0.0489	12.32
289.75	2.1558	0.0708	8.51	297.15	1.9841	0.0804	10.49	303.75	1.0514	0.0502	12.34
289.75	1.3733	0.0458	8.63	297.15	1.2980	0.0525	10.46	303.75	0.9819	0.0470	12.36
290.95	1.8805	0.0632	8.71	298.25	2.0648	0.0820	10.27	304.75	2.1808	0.1064	12.59
290.95	1.6377	0.0556	8.80	298.25	1.8488	0.0728	10.19	304.75	1.9223	0.0957	12.85
290.95	1.6247	0.0554	8.84	298.25	1.9402	0.0770	10.27	304.75	1.6608	0.0826	12.83
ln X_2=(3,12±0,24)–(2284±72)*1/T											
Ethyl acetate											
278.95	1.6881	0.0532	9.70	284.65	1.2569	0.0463	11.32	293.65	1.9033	0.0877	14.13
278.95	1.8416	0.0585	9.77	284.65	1.1378	0.0419	11.33	294.45	1.3255	0.0625	14.44
278.95	1.7546	0.0561	9.84	286.35	1.1593	0.0450	11.93	294.45	1.1096	0.0520	14.38
280.25	1.4748	0.0479	10.00	286.35	1.0295	0.0403	12.01	294.45	1.5912	0.0747	14.40
280.25	1.5898	0.0518	10.03	286.35	1.2883	0.0504	12.03	297.55	1.4121	0.0730	15.81
280.25	1.3446	0.0436	9.99	287.95	1.6863	0.0663	12.09	297.55	1.3456	0.0693	15.77
281.95	1.8340	0.0633	10.62	287.95	1.8446	0.0725	12.07	297.55	1.2386	0.0645	15.92
281.95	2.1508	0.0742	10.61	287.95	1.5747	0.0624	12.18	299.05	0.9667	0.0516	16.31
281.95	2.8016	0.0958	10.52	293.65	1.6041	0.0740	14.14	299.05	1.1694	0.0622	16.26
284.65	1.6664	0.0616	11.35	293.65	2.3539	0.1085	14.13	299.05	1.8026	0.0956	16.23
ln X_2=(2.98±0.16)–(2125±45)*1/T											
Acetonitrile											
281.05	1.7037	0.0047	0.40	296.55	1.3483	0.0062	0.67	305.95	1.8549	0.0122	0.96
281.05	1.5741	0.0042	0.39	296.55	1.7743	0.0083	0.67	313.55	1.9400	0.0152	1.13
281.05	1.3127	0.0035	0.39	299.05	1.5191	0.0076	0.72	313.55	1.7540	0.0138	1.14
286.65	2.0450	0.0068	0.48	299.05	1.6583	0.0084	0.73	313.55	1.6515	0.0131	1.15
286.65	1.8149	0.0061	0.48	299.05	1.0765	0.0054	0.73	317.45	1.8039	0.0158	1.27
286.65	2.2132	0.0075	0.49	301.35	1.7039	0.0098	0.83	317.45	2.2785	0.0205	1.30
290.15	1.6120	0.0060	0.54	301.35	2.0065	0.0114	0.82	317.45	2.0902	0.0189	1.30
290.15	1.3793	0.0052	0.54	301.35	2.2079	0.0128	0.84	319.25	1.2232	0.0117	1.39
290.15	1.0355	0.0039	0.55	305.95	2.3023	0.0148	0.93	319.25	1.9762	0.0189	1.38
296.55	1.1469	0.0053	0.68	305.95	2.5883	0.0167	0.93	319.25	1.8835	0.0183	1.41
ln X_2=(2.62±0.19)–(2942±56)*1/T											
1-Propanol											
276.85	1.4824	0.0138	1.97	285.35	1.8327	0.0303	3.49	290.25	2.2565	0.0523	4.89
276.85	1.3641	0.0128	1.99	285.35	1.3589	0.0225	3.51	292.75	1.5536	0.0425	5.76
276.85	1.4411	0.0136	1.99	286.95	1.0253	0.0186	3.83	292.75	1.4965	0.0417	5.87
280.95	1.5550	0.0186	2.53	286.95	1.0167	0.0182	3.78	292.75	1.4543	0.0393	5.70
280.95	0.9864	0.0121	2.58	286.95	1.0249	0.0183	3.77	294.15	2.1276	0.0656	6.50
280.95	0.9892	0.0121	2.59	288.55	1.8138	0.0356	4.15	294.15	1.5824	0.0488	6.50
284.55	1.5407	0.0231	3.17	288.55	2.0030	0.0397	4.18	294.15	1.4815	0.0454	6.45
284.55	1.6417	0.0244	3.14	288.55	2.1251	0.0418	4.15	300.05	1.3103	0.0587	9.40
284.55	1.5804	0.0234	3.13	290.25	2.1674	0.0505	4.92	300.05	2.0053	0.0905	9.48
285.35	2.3512	0.0387	3.47	290.25	2.4552	0.0581	5.00	300.05	1.8233	0.0832	9.58
ln X_2=(14.29±0.52)–(5693±149)*1/T											
2-Propanol											
273.45	0.9045	0.0077	1.80	282.15	1.6771	0.0210	2.64	294.05	1.2618	0.0260	4.36
273.45	2.2464	0.0194	1.83	284.05	1.8780	0.0264	2.97	294.05	0.9096	0.0192	4.46
273.45	1.3461	0.0115	1.80	284.05	1.9096	0.0264	2.92	296.95	1.5609	0.0370	5.00
276.85	1.0842	0.0103	2.01	284.05	1.3819	0.0189	2.88	296.95	1.9245	0.0463	5.08
276.85	1.8615	0.0177	2.02	286.25	2.2685	0.0355	3.31	296.95	1.4793	0.0356	5.07
276.85	1.8250	0.0173	2.01	286.25	2.1694	0.0336	3.27	300.05	1.9056	0.0532	5.89
280.95	1.2955	0.0151	2.47	286.25	1.6204	0.0250	3.26	300.05	1.7065	0.0472	5.83

End of table 1

1	2	3	4	5	6	7	8	9	10	11	12
280.95	0.6147	0.0072	2.50	291.05	1.0860	0.0201	3.91	300.05	1.1996	0.0331	5.82
280.95	1.1989	0.0142	2.50	291.05	1.7517	0.0322	3.88	300.95	1.3985	0.0416	6.27
282.15	1.7403	0.0213	2.59	291.05	1.6237	0.0304	3.95	300.95	1.2742	0.0379	6.27
282.15	1.4752	0.0183	2.62	294.05	1.1341	0.0236	4.39	300.95	1.7292	0.0512	6.23
ln X_2=(7.22±0.25)–(3712±73)*1/T											
1-Butanol											
279.15	1.0468	0.0240	5.96	286.85	1.0755	0.0337	8.13	293.45	1.8508	0.0743	10.39
279.15	1.0253	0.0236	5.97	289.65	1.3931	0.0490	9.12	293.45	1.4038	0.0582	10.74
279.15	1.3860	0.0321	6.01	289.65	1.1554	0.0405	9.10	294.05	1.4322	0.0588	10.63
282.25	1.2508	0.0330	6.85	289.65	1.1406	0.0397	9.02	294.05	0.9253	0.0384	10.73
282.25	1.4251	0.0374	6.83	290.45	1.6374	0.0588	9.31	294.05	1.5200	0.0617	10.50
282.25	1.4726	0.0383	6.76	290.45	1.0083	0.0365	9.38	294.95	1.0707	0.0450	10.87
285.05	1.1598	0.0337	7.55	290.45	1.0378	0.0380	9.47	294.95	1.0772	0.0453	10.88
285.05	0.9150	0.0263	7.46	292.05	0.7709	0.0292	9.81	294.95	1.2161	0.0504	10.72
285.05	1.2622	0.0368	7.57	292.05	1.7673	0.0673	9.86	295.45	0.7516	0.0318	10.95
286.85	1.4649	0.0457	8.09	292.05	1.4241	0.0538	9.79	295.45	1.0026	0.0420	10.84
286.85	1.3255	0.0422	8.25	293.45	1.2593	0.0504	10.37	295.45	1.0608	0.0448	10.91
ln X_2=(6.00±0.24)–(3101±71)*1/T											
2-Butanol											
279.15	1.2862	0.0368	7.42	287.05	1.3767	0.0451	8.51	294.05	1.5584	0.0583	9.70
279.15	1.6622	0.0471	7.35	287.05	1.3073	0.0428	8.48	294.05	1.2776	0.0480	9.72
279.15	1.4973	0.0424	7.34	287.05	1.3730	0.0454	8.58	294.05	1.3413	0.0507	9.80
282.25	1.3183	0.0395	7.77	289.65	1.5866	0.0557	9.11	294.95	1.2785	0.0489	9.91
282.25	1.4414	0.0428	7.71	289.65	1.7648	0.0615	9.03	294.95	1.1656	0.0443	9.84
282.25	1.3897	0.0415	7.74	289.65	1.5726	0.0547	9.02	294.95	1.4650	0.0560	9.90
285.05	1.5548	0.0491	8.19	293.45	1.2666	0.0465	9.52	297.65	1.5256	0.0612	10.38
285.05	1.4310	0.0453	8.21	293.45	1.1130	0.0410	9.56	297.65	1.3431	0.0541	10.43
285.05	1.6206	0.0511	8.17	293.45	1.1678	0.0432	9.59	297.65	1.4382	0.0575	10.36
ln X_2=(0,68±0,12)–(1562±36)*1/T											

Since the studied substance decomposes during melting, we could not experimentally determine the enthalpy of melting ($\Delta_{fus}H$) and will use one of the described analytical methods [12; 13]. According to this method, the specific value of the melting entropy ($\Delta_{fus}S_{Tfus}$) is a constant value within a certain class of organic substances. Thus, for substances with an aryl fragment $\Delta_{fus}S_{Tfus}$ = 0.383±0.054 J/(g·K); with pyrrole, imidazole and pyrazole fragments $\Delta_{fus}S_{Tfus}$ = 0.460±0.032 J/(g·K); with an aryl furan fragment $\Delta_{fus}S_{Tfus}$ = 0.323±0.027 J/(g·K). However, the substance under study belongs to substances with an arylpyrrole fragment for which the value $\Delta_{fus}S_{Tfus}$ (J/(g·K)) in [11; 12] is not specified, therefore, a review of literature sources was conducted, the results of which revealed that $\Delta_{fus}H$ 3-(1,5-diphenylpyrrol-2-yl)-propanoic acid is 43.6±1.2 kJ/mol at 442.4 K [13], 3-(5-phenylpyrrol-2-yl)-propanoic acid melts at a temperature of 416.45 K and $\Delta_{fus}H$ = 28.71±0.78 kJ/mol [14]. According to the above methodology, the specific value of $\Delta_{fus}S_{Tfus}$ for compounds with an aryl pyrrole fragment will be 0.329±0.013 J/(g·K).

The molecular weight of the test substance **5** is 283.37 g/mol, T_{fus} = 500.7 K (based on the results of the melting of the substance in the capillary), the value of the molar change in the entropy of melting of the substance under study can be estimated as:

$$\Delta_{fus}S=(0.329\pm0.013)\cdot283.37=93.2\pm3.7 \text{ (J/(mol·K))}.$$

Using the equation $\Delta_{fus}S_{Tfus}=\Delta_{fus}H_{Tfus}/T_{fus}$ calculate the value of the enthalpy of fusion:

$$\Delta_{fus}H_{500,7}=(93.2\pm3.7)\cdot500.7=46.7\pm1.9 \text{ (kJ/mol)}.$$

The enthalpy and entropy of melting to 298.15 K were recalculated using the equations given in [13] $\Delta_{fus}S_{298,15}$=57.4±4.0 J/(mol·K); $\Delta_{fus}H_{298,15}$=32.7±2.0 kJ/mol.

Table 2 shows the results of calculating the thermodynamic parameters of the dissolution process at 298.15 K.

Table 2

Thermodynamic functions of solubility of 1-cyclohexyl-2-methyl-5-phenyl-1*H*-pyrrole-3-carboxylic acid in organic solvents at 298.15 K

Solvent	X_2	$\Delta_{sol}H$, kJ/mol	$\Delta_{sol}S$, J/(mol·K)	$\Delta_{mix}H$, kJ/mol	$\Delta_{mix}S$, J/(mol·K)
Methyl acetate	0.0107	18.99±0.60	25.9±2.0	–13.7±2.1	–31.5±4.5
Ethyl acetate	0.0158	17.67±0.37	24.8±1.3	–15.0±2.0	–32.6±4.2
Acetonitrile	0.0007	24.46±0.56	21.8±1.6	–8.2±2.1	–35.6±4.3
1-Propanol	0.0082	47.3±1.2	118.8±4.3	14.6±2.3	61.2±5.9
1-Butanol	0.0123	25.79±0.59	49.9±2.0	–6.9±2.9	–7.5±4.5
2-Propanol	0.0054	30.86±0.61	60.0±2.1	–1.8±2.8	2.6±4.5
2-Butanol	0.0105	12.99±0.30	5.6±1.0	–19.7±2.0	–51.8±4.1

The results of the study of the thermodynamic parameters of the solubility of 1-cyclohexyl-2-methyl-5-phenyl-1*H*-pyrrole-3-carboxylic acid in organic solvents are given in Table 2 for the values of $\Delta_{mix}H$ and the $\Delta_{mix}S$ are negative values, except for 1-propanol, since the destruction of primary bonds in solvents and the test acid requires less energy than is released during the formation of new ones. Moreover, for 2-propanol, the values of the thermodynamic parameters of mixing are not significantly less than zero, so the new bonds formed are stronger than the original ones. The highest value of the entropy of mixing is observed in a solution for 1-propanol, due to the formation of hydrogen bonds between the polar hydroxyl group in the alcohol and the carbonyl group in the substance under study. The negative values of enthalpy of mixing in solutions of 1- and 2-butanol are associated with the nature of higher alcohols, since an increase in the length of the hydrocarbon radical causes a decrease in polarity, which directly affects the value of the enthalpy of mixing.

4. Conclusions

The temperature dependences of the solubility of 1-cyclohexyl-2-methyl-5-phenyl-1*H*-pyrrole-3-carboxylic acid in methyl acetate, ethyl acetate, acetonitrile, 1-butanol, 2-butanol, 1-propanol and 2-propanol were determined, and the thermodynamic parameters of their solubility and mixing (solvation) were calculated. The obtained data are consistent with the previously reported studies and do not contradict the nature of the interaction between hydroxyl and carbonyl groups.

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ТЕРМОДИНАМІЧНІ ПАРАМЕТРИ РОЗЧИННОСТІ 1-ЦИКЛОГЕКСИЛ-2-МЕТИЛ-5-ФЕНІЛ-1*H*-ПІРОЛ-3-КАРБОНОВОЇ КИСЛОТИ В ОРГАНІЧНИХ РОЗЧИННИКАХ

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За температурною залежністю розчинності 1-циклогексил-2-метил-5-феніл-1*H*-пірол-3-карбонової кислоти в метилацетаті, етилацетаті, ацетонітрилі, 1-бутанолі, 2-бутанолі, 1-пропанолі, 2-пропанолі розраховано величини ентальпії та ентропії їх розчинення. Визначено характер взаємодії між розчинниками та розчиненою речовиною. Наведено температурні залежності розчинності 2-метил-5-феніл-1-циклогексил-пірол-3-карбонової кислоти в розчинниках різної природи. З урахуванням ентальпії та ентропії плавлення, перерахованої до 298,15 К, розраховано ентальпії та ентропії змішування.

Завдяки дослідженням термодинамічних параметрів розчинності 1-циклогексил-2-метил-5-феніл-1*H*-пірол-3-карбонової кислоти в органічних розчинниках з'ясовано, що значення $\Delta_{mix}H$ та $\Delta_{mix}S$ є від'ємними (за винятком 1-пропанолу та 1-бутанолу), оскільки на розрив первинних зв'язків між молекулами розчинників та досліджуваної речовини затрачено менше енергії, ніж виділено за утворення нових. Причому у 2-пропанолі значення термодинамічних параметрів змішування не є суттєво меншими від нуля, тому утворені нові зв'язки є міцнішими за вихідні. Найвище значення ентропії змішування простежували для 1-пропанолу, що пояснено утворенням водневих зв'язків між полярною гідроксильною групою у спирті та карбонільною групою у досліджуваній речовині. Щодо значень термодинамічних параметрів процесу змішування досліджуваної кислоти в 1-бутанолі та 2-бутанолі, то ці значення дещо нижчі порівняно з ентальпіями змішування у 1- та 2-пропанолах, що пов'язано з природою вищих спиртів, оскільки збільшення довжини вуглеводневого радикала сприяє зменшенню полярності, що безпосередньо впливає на величину ентропії змішування.

Ключові слова: розчинність, ентальпія розчинення, ентальпія змішування, ентальпія плавлення, пірол-3-карбонова кислота, полізаміщені піроли.

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