**Abstract**

The inclusion of volatile organic compounds of various  classes in the permethylated *β*-cyclodextrine in an oligomeric solution of polyethylene glycol was investigated by the inverse gas-liquid chromatography (GLC) methods and by Voronoi crystal-method. It was established that the "guest-master" complexation process is influenced by the geometrical structure of the guest molecules, their chirality and enthropy factors.

**Introduction**

Recently water-soluble polymers (polyethylene glycol, polyvinylpyrrolidone, sodium carboxymethylcellulose, etc.) became widely used to increase the effectiveness of the binding of medical substances to cyclodextrines [...]  A synergy effect is observed when polymers and cyclodextrines are used together: solubility of a medical substance becomes higher than its total solubility in the original polymer and pure cyclodextrines or their derivatives [ ]. Special attention is given to the polyethylene glycol for its good solubility in water environments, low toxicity and low cost [...]. Therefore the study of the complexation of model organic compounds of various classes with cyclodextrines in the polyethylene glycol solution is important.

The purpose of this work is the study of the binding ability of the permethylated *β*-cyclodextrine with hydrophobic and hydrophilic volatile organic compounds of various classes in the polyethylene glycol-400, as well as the interpretation of the obtained results based on the calculated constants of sustainability and the thermodynamic functions of complexation. The studied system is a convenient model to better understand the inclusive complexation with cyclodextrines in water-soluble polymers.

**Theoretical Consideration**

Sorption redistribution of the volatile compound (sorbate) between the liquid and gas phases in an infinitely diluted solution with *V,T = const*was characterized by the distribution constant:

, (1)

where the  *CL* , *CG* are the sorbate molarity in liquid and gas phases.

The *KC* value was calculated based on the experimental data obtained by the GLC method according to the equation:

   *KC =* ∙ *ρL* , (2)

where   is the sorbate specific retention volume at the column temperature, *ρL* - the density of the liquid stationary phase.

  The standard molar changes of the internal energy *ΔspU0* (heat *QV*) and of the entropy *ΔSPS0* during the sorption of the volatile compound by the liquid phase in the researched temperature interval were calculated based on the linear dependence:

   *C =*- +  +1 (3)

 Thermodynamic justification of such calculations for a small temperature interval in the model system of the permanent volume is given in the work of [...]. The  *Δsp* and  *ΔSP* values correspond to the internal energy and entropy changes (average values) during the sorbate transition from the ideal gas phase with the standard (infinitely low) concentration of *CG* =1 into the infinitely diluted solution in the liquid phase with concentration *CL* =1 (based on 1 mol of the sorbated substance).

  The change of the thermodynamic sorption functions due to the insertion of *Me-β-CD* into the polymer matrix was characterized by the relation of the distribution constants in the stationary phase with a macro cycle and without it (*KC /* ), and by the values:

   Δ(*Δsp*) = *Δsp* - *Δsp* , (4)

   *Δ*(*ΔSP*= *Δsp* *-* *Δsp*, (5)

  To calculate "sorbate-macro cycle" binding (sustainability) constants known model representations [...] were used. They are based on the assumption that the structure of the solvent does not change before and after the introduction of the macro cyclic additives and using the asymmetric choice system of the standard state: *γi* →1 where *Ci→0;*  *i* - guest, master. In small concentrations of the master in a solution the formed complexes have 1:1 composition and the sustainability constant is calculated from the following equation:

   *KC =*  *∙* (1 + *K1 ∙*  ), (6)

where *∙*  is molarity.

  Since for the condensed phase *ΔG**ΔF*[ ], Gibbs energy change, enthalpy, and entropy at complexation in the solution is calculated based on the known equations [...]:

 *ΔG\* = - RT lnK1*  (7)

  *ΔG\* = ΔH\* - TΔS\* .* (8)

where  *ΔH\** = Δ(*Δsp*) is the difference between the  *Δsp* values obtained on the columns with macro cycle and without it ( equation 4).

**Results and Discussion**

The "guest-master" type of complexation was studied in the polyethylene glycol environment with an average molecular mass of 400 (PEG-400). It is known from the literature that linear polymers of medium polarity, including PEG, are not inclined to form supramolecular structures resembling beads with a polymer molecule being the thread and  cyclodextrines acting as beads. Unsubstituted cyclodextrins are more likely to form "molecular beads". Thus, polymeric systems containing substituted cyclodextrins have a higher probability that the cavities will remain sufficiently empty for the guest inclusion. Therefore, *гептакис-*(2,3,6-три-О-метил) -*β-*cyclodexstrine (permethylated  *β-CD* , *Ме-β-CD*) was used as a macro cyclic agent (master). Works of [...] have shown that *Me-β-CD* forms stable complexes with a number of medicinal substances.

*Me-β-CD* is a *β-CD* derivative where 7 of the hydrogen atoms of the primary and 14 hydrogen atoms of the secondary hydroxyl groups are replaced by the methyl group. Twenty volatile  organic hydrophobic and hydrophilic compounds (VOC) with acyclic and cyclic molecule structures, including optical isomers of terpene hydrocarbons class, (+)- and (-)- limonene, (+)- and (-)- camphene were used as guests.

Molecular characteristics of the researched compounds are shown in the table 1: molecular mass *Mr*, polarizability *α*, dipole moment , molecular volume *Vm*, and second moment of inertia *G3.*  The same table includes lipophilic (hydrophobic) coefficients, and *logP*  of the researched compounds.

*Table 1*

*Molecular characteristics and lipophilicity of the researched compounds*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Substance** | **Mr** | **α , Å3** | **µ, D** | **Vm, Å3** | **G3** | **log P** |
| **1** | **Циклогексан** | **84,16** | **9.626** | **0** | **162** | **0,0836** | **2,67** |
| **2** | **Бензол** | **78,11** | **9.842** | **0** | **128** | **0,0952** | **1,97** |
| **3** | **Толуол** | **92,14** | **10.370** | **0,3725** | **154** | **0,0993** | **2,49** |
| **4** | **Этилбензол** | **106,17** | **12.150** | **0,3264** | **180** | **0,1016** | **2,93** |
| **5** | ***о*-Ксилол** | **106,17** | **12.157** | **0,6375** | **183** | **0,0988** | **3,00** |
| **6** | ***м*-Ксилол** | **106,17** | **12.179** | **0,3853** | **182** | **0,1034** | **3,00** |
| **7** | ***п*-Ксилол** | **106,17** | **12.329** | **0,0050** | **182** | **0,1072** | **3,00** |
| **8** | **Пропанол-1** | **60,1** | **6.485** | **1,8437** | **115** | **0,0874** | **0,36** |
| **9** | **Бутанол-1** | **74,12** | **8.309** | **1,8636** | **139** | **0,0919** | **0,81** |
| **10** | **Пентанол-1** | **88,15** | **9.100** | **1,8677** | **164** | **0,0993** | **1,25** |
| **11** | **Пропанол-2** | **60,1** | **5.796** | **1,9291** | **114** | **0,0861** | **0,25** |
| **12** | **2-Метилпропанол-1** | **74,1** | **8.294** | **1,7783** | **137** | **0,0861** | **0,73** |
| **13** | **2-Метилпропанол-2** | **74,1** | **8.359** | **1,8795** | **136** | **0,0836** | **0,54** |
| **14** | **Циклогексанон** | **98,1** | **9.346** | **3,39** | **163** | **0,0838** | **1,49** |
| **15** | **Тетрагидрофуран** | **72,11** | **6.200** | **2,2968** | **123** | **0,0848** | **0,53** |
| **16** | **1.4-Диоксан** | **88,1** | **7.224** | **0,0048** | **132** | **0,0867** | **-0,09** |
| **17** | **(+)-Лимонен** | **136** | **16.011** | **0,5777** | **238** | **0,1002** | **3,22** |
| **18** | **(-)-Лимонен** | **136** | **16.011** | **0,5777** | **238** | **0,1002** | **3,22** |
| **19** | **(+)-Camphene** | **136** | **15.334** | **0,5793** | **233** | **0,0850** |  **2,86** |
| **20** | **(-)-Camphene** | **136** | **15.334** | **0,5793** | **233** | **0,0850** |  **2,86** |

The α and µ values are calculated by Gaussian 09 software package by  density functional theory method using hybrid functionality B3LYP in the 6-311G basis. Lipophilic coefficients *logP*are calculated by the additive scheme using the MarvinSketch software package. Molecular volume *Vm*  and the second moment of inertia G3 characterizing the deviation of the guest molecules' shape from a sphere were calculated using the Voronoi crystal-method (Voronoi approach) utilizing ToposPro software. The same method was applied to calculate the cavity volume of the *Me-β-CD* (3700 3) molecule. It has exceeded the cavity volume of the unsubstituted *β-CD* (244 3) and the volume of molecules of all researched guests (114-238 3).

***Change of the thermodynamic functions of the VOC sorption redistribution in the "gas-liquid" system due to complexation***

  The inverse GLC method has been applied in the study of the VOC sorption redistribution between the gas and liquid phases on the columns with a "pure" PEG-400 (matrix) and with a mixed stationary phase "PEG-400 - *Mu-β-CD(10% masses)".*

  The sorption thermodynamic functions: constant distribution of the *KC*, internal energy *Δsp*and entropy *ΔSP* at the sorption from the gas phase of the researched VOC on the column with the *Me-β-CD,* are presented in table 2. The same table contains *KC* / Δ(*Δsp*), *Δ*(*ΔSP*values demonstrating changes of the thermodynamic functions of sorption redistribution due to inclusion of the *Me-β-CD* additive into the matrix.

*Table 2*

*Distribution constants, thermodynamic functions of sorption of the researched compounds from the gas phase by the system "PEG-400-Me-β-CD" and changes of these values due to addition of the  Me-β-CD into PEG-400*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No.** | **Sorbate** | **PEG-400 - Me-β-CD** |  | ***(spU0),*** **kJ/mol** | ***(sp*S0), kJ/mol** |
| **, 90°C** | ***spU0*****kJ/mol** | **-*sp*S0,****J/mol·K** |
| **1** | **Циклогексан** | **16.6** | **17.8±1.7** | **34±2** | **0.79** | **1,6** | **3** |
| **2** | **Бензол** | **51.4** | **24.2±2.2** | **42±3** | **1.42** | **2,6** | **10** |
| **3** | **Толуол** | **92.4** | **31±1.6** | **56±6** | **1.45** | **-1,9** | **-2** |
| **4** | **Этилбензол** | **154.6** | **31.7±1.5** | **53±2** | **1.30** | **4,6** | **16** |
| **5** | ***о*-Ксилол** | **226.8** | **30.2±2.9** | **46±5** | **1.33** | **7,6** | **24** |
| **6** | ***м*-Ксилол** | **197.1** | **30.8±3.4** | **49±6** | **1.52** | **5,7** | **20** |
| **7** | ***п*-Ксилол** | **172.7** | **27.9±2.6** | **42±4** | **1.37** | **8,5** | **27** |
| **8** | **Пропанол-1** | **124.6** | **37.1±1.4** | **70±2** | **1.43** | **-3,6** | **-6** |
| **9** | **Бутанол-1** | **227.5** | **42.2±1.4** | **80±2** | **1.31** | **-0,3** | **1** |
| **10** | **Пентанол-1** | **394.3** | **45.4±1.0** | **83±5** | **1.15** | **1,8** | **7** |
| **11** | **Пропанол-2** | **62.2** | **35.8±1.1** | **73±1** | **1.40** | **-8,3** | **-21** |
| **12** | **2-Метилпропанол-1** | **157.5** | **41.5±2.6** | **79±4** | **1.36** | **-2,8** | **-5** |
| **13** | **2-Метилпропанол-2** | **54.7** | **36.7±2.3** | **76±3** | **1.55** | **-13,7** | **-34** |
| **14** | **Циклогексанон** | **522.4** | **35.3±3.0** | **54±4** | **1.22** | **5,7** | **17** |
| **15** | **Тетрагидрофуран** | **44.3** | **31.2±3.3** | **62±4** | **1.19** | **-9,9** | **-25** |
| **16** | **1.4-Диоксан** | **136.9** | **32.6±2.0** | **57±9** | **1.35** | **-3,2** | **-6** |
| **17** | **(+)-Лимонен** | **231.1** | **37.8±0.5** | **67±1** | **1.40** | **0,4** | **4** |
| **18** | **(-)-Лимонен** | **212.7** | **36.1±1.2** | **63±2** | **1.29** | **2,1** | **8** |
| **19** | **(+)-Камфен** | **121.7** | **34.5±0.6** | **64±1** | **1.19** | **-8,1** | **-21** |
| **20** | **(-)-Камфен** | **113.8** | **33.1±0.6** | **60±1** | **1.11** | **-6,7** | **-17** |

Data presented in table 2 demonstrate that adding *Me-β-CD* to PEG-400 leads to an increase in the constant of the interphase redistribution for 19 compounds. For these compounds *KC*/ which indirectly indicates their bonding with *Me-β-CD* in PEG-400. For cyclohexane *KC* / .

The increase of the distribution constant for limonene and camphene optical isomers happens selectively which provides enantioselectivity of the "PEG-400 - *Me-β-CD*" system in gas-liquid chromatography. For the (+) and (-)- limonenes the increase of the distribution constant is observed in all temperature ranges (fig. 1). For the (+) and (-)-camphenes the increase of the distribution constant due to bonding with the macro cycle takes place only at relatively low temperatures. At temperatures *t*1100C a reduction of the constant is observed (fig. 2). 2-метилпропанол-2 and тетрагидрофуран behave similarly to camphenes. For these compounds a reduction of the distribution constant is observed at temperatures *t*1100C  (*KC*/).

|  |
| --- |
|  |
| *Fig. 1. Limonene isomer distribution constant dependence lnKC on the inverse temperature: 1 - PEG-400, (+) and (-) - isomers; 2 and 3 - "PEG-400 - Me-β-CD"; 2 - (-) -isomer, 3 (+) - isomer.* |
|  |
| *Fig. 2. Camphene isomer distribution constant dependence lnKC on the inverse temperature: 1 - PEG-400, (+) and (-)-isomers; 2 and 3 - "PEG-400 - Me-β-CD"; 2 - (-) -isomer, 3 (+) -isomer.* |

Enantioselectivity factor for limonene optical isomers defined by the equation

*α+/-* =   (9)

amounted to 1.09, and 1.07 for camphene isomers at 90 *°* temperature. Increased sorption of (+)-isomers comparing to (-)-isomers for these hydrophobic compounds is due to the greater heat of sorption of (+)-isomers ( approximately 1.5 kJ/mol, table 2).

Based the equation ( )

 *ln(KC* /)= -  + , ( )

where the differences   Δ(*Δsp*) and *Δ*(*Δsp* demonstrate the contributions of sorbate-macro cycle complexation to the thermodynamic parameters of sorption (table 2). Fig.3 demonstrates the ratio between the Δ(*Δsp*) и *Δ*(*Δsp* values for the researched compounds.



*Fig. 3.* Δ(*Δsp*) *dependence on Δ*(*Δsp* *(the numbering of the points corresponds to table 2).*

Fig. 3 shows that for the 19 researched compounds, for which there is an increase in the sorption constant (*KC*/), there is a linear dependence of Δ(*Δsp*) upon *Δ*(*Δsp* with a high value of the coefficient of determination (*R2*=0,997). This dependence includes both, the compounds with the exothermic effect of complexation and molecule localization (0 and*Δ*(*Δsp*0), as well as the compounds with the endothermic effect of complexation and increased molecular mobility (*Δ*(*Δsp*0 и *Δ*(*ΔSP*0). The point (1) for cyclohexane does not fit in the overall compensation dependence. Considering this and the fact that for cyclohexane *KC*/, it can be argued that its bonding with *Me-β-CD* in a PEG-400 solution is unlikely. Existing compensatory dependence (Fig.3) shows presence of some common binding mechanism of hydrophobic and hydrophilic guests with *Me-β-CD* in the PEG-400 solution regardless of the thermal effect знака (direction?) of the binding process (Δ(*Δsp*)

***Determination of stability constants of inclusion complexes and thermodynamic parameters of complexation***

Model representations from the works of [..] were used to calculate binding constants and thermodynamic parameters of the process. Since we used a low concentrated solution of *Me-β-CD* in PEG-400 (0.076 mol/l, 900C) and infinitely small concentration of guests, the stability constant calculation was done based on equation (6) assuming formed complexes had stoichiometric composition 1:1. Stability constants *К1*  at 900 and 1100C temperatures are presented in table 3.

*Table 3*

*Stability constants of Me-β-CD complexes in PEG-400 for the researched VOCs and thermodynamic parameters of complexation*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **No.** | **Sorbates** | ***К1*, 90 оС** | ***К1*, 110 оС** | ***ΔH\**,** **kJ/mol** | ***ΔG\**, 90 оС****kJ/mol** | ***ΔS\**, 90 оС****J/mol·K** |
| **2** | **Бензол** | **5,8** | **6,7** | **3,7** | **-5,3** | **22** |
| **3** | **Толуол** | **6,6** | **6** | **-1,9** | **-5,7** | **10** |
| **4** | **Этилбензол** | **5,1** | **6,7** | **4,9** | **-4,9** | **26** |
| **5** | ***о*-Ксилол** | **5,8** | **8,6** | **7,8** | **-5,3** | **36** |
| **6** | ***м*-Ксилол** | **6,5** | **8,7** | **5,9** | **-5,6** | **31** |
| **7** | ***п*-Ксилол** | **5,7** | **8,9** | **8,7** | **-5,3** | **38** |
| **8** | **Пропанол-1** | **6,2** | **5,1** | **-2,2** | **-5,5** | **5** |
| **9** | **Бутанол-1** | **4,4** | **4,4** | **-0,2** | **-4,5** | **11** |
| **10** | **Пентанол-1** | **2,6** | **3,1** | **0,1** | **-2,9** | **13** |
| **11** | **Пропанол-2** | **5,0** | **2,6** | **-7,4** | **-4,9** | **-9** |
| **12** | **2-Метилпропанол-1** | **5,9** | **5,1** | **-5,1** | **-5,4** | **7** |
| **13** | **2-Метилпропанол-2** | **6,2** | **0,5** | **-11,6** | **-5,5** | **-23** |
| **14** | **Циклогексанон** | **2,4** | **4,1** | **5,0** | **-2,6** | **23** |
| **15** | **Тетрагидрофуран** | **3,4** | **0,8** | **-11,9** | **-3,7** | **-17** |
| **16** | **1,4-Диоксан** | **4,8** | **3,9** | **-2,3** | **-4,7** | **4** |
| **17** | **(+)-Лимонен** | **4,9** | **5,1** | **-0,8** | **-4,8** | **14** |
| **18** | **(-)-Лимонен** | **3,8** | **4,5** | **0,9** | **-4,0** | **17** |
| **19** | **(+)-Камфен** | **2,2** | **0,2** | **-8,8** | **-2,4** | **-16** |
| **20** | **(-)-Камфен** | **1,4** | **0** | **-7,4** | **-1,0** | **-16** |

Calculated values *К1*  for hydrophobic and hydrophilic guests are between 1.4 and 6.6 l/mol (900C) and they are significantly lower than *К1* values  for terpenes and arenes in low-molecular polar solvents.  For example, in our work for the (+)-limonene *К1*=3.8 , for (-)-limonene *К1*=2.2 l/mol (900C), whereas for the ()-limonens value *К1*=8.8 l/mol  (600C) in binding with *β-CD* in glycerin [..]. *К1* value for the arenes in our work is significantly lower than in the work of the […] where binding with *β-CD* was studied in a water solution (250C). This seems to be related to the fact that solvophobic effect in low molecular polymer solvents (water, glycerin) is stronger relative to hydrophobic compounds than in PEG-400 which molecules contain two hydroxyl groups at the ends of the oligomeric chain.

Table 3 shows that at 900C temperature relatively high values of binding constants *К1* are observed for both the hydrophilic (Propanol-1, 2-метилпропанол-2) and for the hydrophobic compounds (толуол, *мета*-ксилол). In the homologous row of arenes the *К1* value increases through the transition from бензол to толуол and then decreases for этилбензол (fig.4).



*Fig. 4. "Binding constant-molecular volume" diagram in the "PEG-400 - Me-β-CD" system, 900С.*

In the row of n-alkanes *С3 – С5* (points 8, 9, and 10) *К1* value decreases with the growth of the molecule volume (*Vm*) and, accordingly, polarizability (α) and hydrophoby (*logP*). However, enatiomers of bicyclic terpene camphene (points 17 and 18) with high hydrophoby (*logP*=2.86) have binding constant values closer to the binding constant values of the hydrophilic butanols (*logP*=0.81) (point 9). For close values of *Vm*, α and   for isomeric butanols (points 9, 12, 13) *К1*  values increase with growth of branching of the hydrocarbon radical in the row butanol-12-метилпропанол-1→2-метилпропанол-2.

To explain the achieved results we used both the experimentally obtained data on the change of the thermodynamic sorption functions at the point of inclusion into the liquid phase of the macrocycle Δ(*Δsp*) и *Δ*(*Δsp*, and data on the thermodynamic parameters of complexation (*ΔG\*,ΔH\*,ΔS\**) calculated using model representations. Special attention was given to the enthalpy of complexation *ΔH\*=*Δ(*Δsp*) that is directly determined through GLC research. As it was demonstrated above (Fig. 3) total compensation dependence includes compounds with both exothermic and endothermic effect of complexation. The first group (compounds with the exothermic effect of complexation) includes 9 compounds, both hydrophilic (пропанол-1, пропанол-2, 2-метил-пропанол-1, 2-метил-пропанол-2, тетрагидрофуран, 1,4-диоксан) and hydrophobic (толуол, (+)- и (-)–camphenes). The maximum exothermic contribution due to binding with *Me-β-CD* is observed for 2-метилпропанола-2 (*ΔH\*=-*11.6 kJ/mol) and for тетрагидрофурана (*ΔH\** = -11,9 kJ/mol), table 3. The second group (compounds with the endothermic effect of complexation) consists of 8 compounds, predominantly hydrophobic: бензол, этилбензол, изомеры ксилола, пентанол-1, циклогексан (-)-limonene. The maximum endothermic effect is seen for n*-*ксилола ( *ΔH\** = +8,7 kJ/mol). The two compounds (butanol-1 and (+), limonene) are characterized by practically athermic effect of complexation (points 9 and 17 on Fig.3) whose driving force is the enthropy factor. The value *ΔH\** indirectly describes the guest interaction with *Me-β-CD*. Analysis of the obtained data demonstrated that the enthalpy of complexation (*ΔH\*)*poorly correlates with guests' molecular parameters (*Vm*, α and ) and their hydrophoby (*logP* ). It is known the flatter is the adsorbate molecule the higher are the heats of adsorption on a homogeneous and flat carbon surface (graphitized thermal soot). This is due to the particular nature of dispersive attractive forces that dramatically decrease with the increase in the distance from an attractive surface. We assumed that with the inclusion of guest molecules in *Me-β-CD* cavity an opposite relationship must be observed. In other words, the higher is the molecule’s sphericity and posibility of contacts with the "walls" of a semi-polar cavity and methoxy groups located at the entrance to the cavity, the greater must be the heat of inclusion. It is known that the higher is the "sphericity" of the molecule’s shape the less is the value of the second moment of inertia of *G3* molecule calculated using crystal-chemical methods.

  Figure 5 shows a relationship between - *ΔH\**and *G3.*



Fig.5. Enthalpy complexation – the second moment of molecule inertia (the point numbers correspond to Table 2).

 It can be observed that the left part of the Figure 5 (region *I*) contains 8 points representing hydrophobic and hydrophilic compounds, for which the inclusion of their molecules in *Me-β-CD* cavity is accompanied by the exothermic heat effect (*ΔH\**). For these compounds having quite different volumes of molecules, from propanol-2 (1143) to camphene (233 3), cleardownward trend of |*ΔH\*|* is observed as anisometricity of guest molecules (*G3*) increases. Cyclohexanone’s behavior differs from that of the compounds of group *I*. For smaller *G3* values (0.0838) endothermic binding effect with *Me-β-CD* is observed, presumably, due to a small number of contacts with the cavity because of low conformational mobility. Region *II* contains compounds with more anisometric molecular structure (*G3*). Their entry into the cavity occurs athermally or with the endothermic effect. It is known that in athermal polymeric systems, as well as in polymeric systems with endothermic mixing, the increase of the system’s entropy is a driving force for low molecular weight component dissolution, and it increases with temperature rising. This is precisely why increase in *K1* binding constant for group II compounds is observed with rising temperature (Table 3).

   Thus...

**EXPERIMENT**

**Materials**

*Ме-β-CD* was supplied by Sigma Aldrich. The Chromaton NAW (…….. mesh) for GC was product of …. The model compounds (+) - and (-) – limonene, (+) - and (-) – camphene were supplied by …. All other model compounds were of the analytical reagent grade and were used without further purification.

 Steel columns (1x3 mm) were packed with Chromaton NAW, which was coated with PEG-400 (matrix column) and *Ме-β-CD* (10% mass) dissolved in PEG-400.

**Gas-Chromatography Experiment**

  The experiment was carried out using the "ЛХМ" gas chromatograph with flame-ionization detector. Chromatographic measurements of retention time *tR* of model compounds were carried out under isothermal conditions at temperatures ranging from 80 to 1400C with a 10 °C interval. For each compound *tR* value at researched temperature was determined no less than three times. The \_\_\_ integrator and \_\_\_ software were used to register peaks and the retention time of the researched compounds. Methane was used to determine the hold-up time *tM.* The carrier-gas speed at the column exit did not exceed 20 ml/min. Using small samples of volatile compounds the specific retention volume at column temperature was identified based on the equation:

    =    , (7)

where *FC*  is the volumetric flow rate of the carrier-gas at the column exit at the researched temperature, *WS* is the liquid stationary phase mass, *j*- mobile phase compressibility correction factor. Errors in determining  did not exceed 3%. In order to calculate the distribution constant *Кс* using the experimentally found  values (equation 2) the density of the stationary liquid phase *ρL* needs to be known. Temperature dependencе of the PEG-400 density was obtained using the work of [..]. The density of the mixed stationary phase was calculated based on the x-ray density of an ideally built *Me-β-CD* crystal [..*..*] assuming there is no volume change after mixing PEG-400 with *Me-β-CD.*

**CULCULATION OF GEOMETRICAL PARAMETRS OF MOLECULES BY VORONOI APPROUCH**

Geometrical parameters of guest molecules and of the macrocycle were calculated using the crystal-chemical method based on Voronoi partitioning. Within this approach the geometrical parameters of molecules are calculated from the geometry of the Voronoi molecular polyhedra that is a collection of polyhedra, built for the molecule's atoms. *Vm* volumesand the second moment of inertia *G3*  of the guest molecules are calculated on the basis of the averaged volume and *G3* values of the  molecular polyhedra in the corresponding crystal structures. Information on the crystal structures containing guest molecules was obtained from the Cambridge Structure Database. The calculation of the molecular polyhedra and their geometric characteristics was conducted using ToposPro [..], crystal-chemical analysis software. *Me-β-CD* cavity's parameters calculations were done by the [..] method.

**Conclusion**

The inverse GLC method was used to determine the thermodynamic functions of inclusive binding of volatile hydrophobic and hydrophilic guests with the permethylated *β*-cyclodextrine in PEG-400. For only 9 out of the 20 researched guests the guest-master binding process takes place with a weak exothermal effect (*Н\**0) and the molecule localization in the cavity (*S\**0).  For the rest of the compounds binding occurs athermally or with an endothermal effect  (*Н\**0), indicating the dominant role of the entropy factor in the guest-master complexation in PEG-400. It has been established that the strength of the guest-master inclusive binding is dependent more on the molecule geometry than on their electronic structure and volume. With an increase in *G3,* the molecule second moment of inertia,  and, respectively, an increase in the anisometricity of the guest molecule shape, inclusion complexes strength decreases.

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