INFLUENCE OF THE RING SHAPE OF DIFFERENT CYCLODEXTRINS ON COMPLEXATION PROPERTIES

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ABSTRACT

The complexation properties of various cyclodextrins depend on their ring size and the molecular shape of the guest molecules, but also on the hydrophobicity of the interior. Convenient systems for the characterization of the environment (solvation shell or complexing host molecules) are alkylaminomethyl-naphthols, molecules with an intramolcular hydrogen bond allowing proton transfer, which is extremely sensitive to solvation phenomena.

1. INTRODUCTION

The complexation of guest molecules by various cyclodextrins is characterized by the association constant K and the corresponding thermodynamical parameters ΔG, ΔH and ΔS. The equilibrium constant K can be estimated from electron absorption spectra at various concentration ratios, or from n.m.r. experiments, but also from solubility enhancement measurements [1-3]. The constant K depends on the shape of the interior of the CDs due to steric interactions as well as on the hydrophobicity of the molecular surface of the hosts cavity. This surface property may be estimated by molecular calculations, but a quantitative experimental description of the electrostatic influence of the CD ring on a guest molecule appears from the measurement of a convenient model system e.g. the intramolecular proton transfer equilibrium in dialkylaminomethyl-naphthols. This type of compounds was also used

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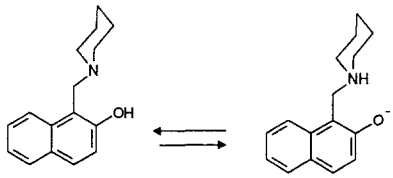
extensively as a model for intramolecular hydrogen bonding and related proton transfer [4-6], because of the confirmed stoichiometry of the molecules and the easy synthetic access to various derivatives, which allows to modify the properties of the hydrogen bond. The proton transfer equilibrium of these substances is established between a neutral intramolecularly hydrogen bonded structure, where the proton remains at the oxygen atom of the naphthol component, and a zwitterionic, more polar structure with the proton located at the nitrogen atom of the basic component.



This proton transfer equilibrium is highly sensitive to solvent effects, which can be monitored by electron absorption spectroscopy. Complexation of 1-piperidinylmethyl-2-naphthol (P2N) by different cyclodextrins in aqueous solution shifts the proton transfer equilibrium of P2N in direction to the nonpolar structure in such a way, that a characterization of the host cavity can be given more quantitatively [7]. Additionally the naphthol residue of these compounds allows the investigation of the CD complexes in excited state by steady state and time dependent fluorescence spectroscopy. The complete scheme of the elementary steps of the inclusion of P2N into cyclodextrins is given in Figure 1.

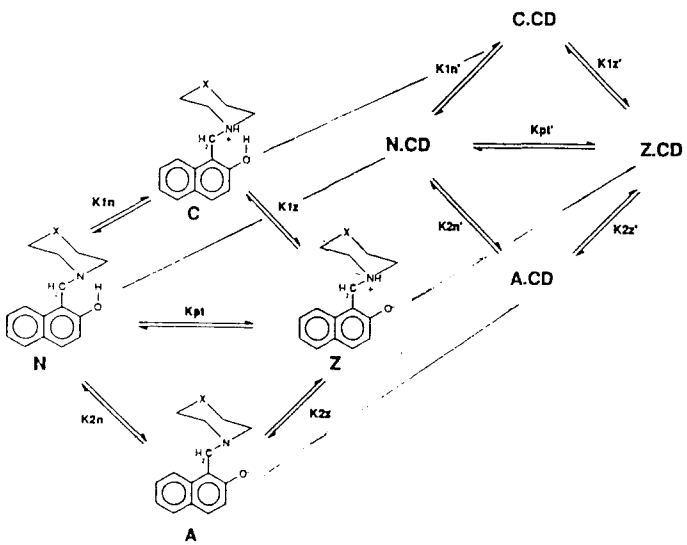


Figure 1: Complete reaction scheme of the inclusion complexation of the condensation products of naphthols with cyclic amines.

2. RESULTS AND DISCUSSION

The proton transfer equilibrium can be monitored by electron absorption spectroscopy, the absorption spectra of the anion and the zwitterionic structures are similar, also the neutral and the cationic form. In the reaction scheme (Figure 1) the proton transfer constant K_{PT} can be therefore estimated easily. The overall equlibrium constant K can be determined by various methods. The pH dependence of the electron absorption spectrum of pure P2N, and of some association complexes is given in Figure 2.

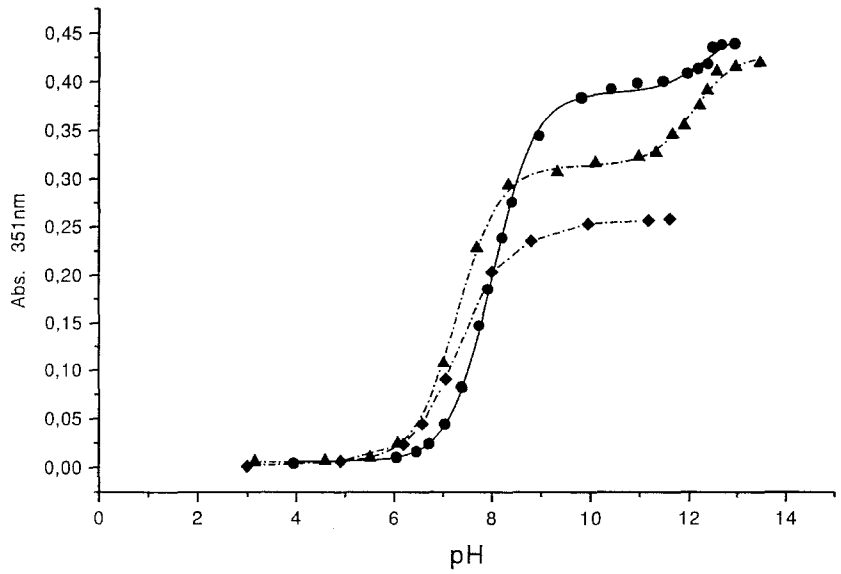


Figure 2: pH dependence of the electron absorption spectrum of P2N at 351nm. Full circles indicate P2N in pure water, squares P2N-β-cyclodextrin association complexes, triangles P2N-γ-cyclodextrin inclusion complexes.

In Figure the pH dependence of the electron absorption spectrum of P2N is monitored at 351nm. The first deprotonation step occurs round pH = 8, the second higher than pH = 12. The plateau between these two pK values indicates the proton transfer equilibrium. In pure water the equilibrium is shifted towards the zwitterionic structure (full circles), the inclusion into the β-cyclodextrin cavity diminishes the amount of zwitterionis (squares), γ-cyclodextrin does not show such a strong shift as as β-cyclodextrin, because the larger interior of this compound diminishes the association affinity of the small molecule P2N. The molecular

surfaces do not fit completely and this lack in complementarity results in a decreased association constant. The association constants of various cyclodextrins with P2N are given in Table 1 together with the proton transfer constants K_{PT}.

Table 1: Overall association constants (K) of P2N with various cyclodextrins and proton transfer constants (K_{PT}) of P2N included in different cyclodextrins

Cyclodextrin	K [(mol/l)$^{-1}$]	K_{PT}
β-CD	332	1.8
Dimethyl-β-CD	454	0.9
Hydroxypropyl-β-CD	362	1.1
γ-CD	56	3.1
Hydroxypropyl-γ-CD	70	3.3

For P2N the proton transfer constant K_{PT} (9,5 in pure water) is decreased in the inclusion complexes due to the hydrophobic interior. The association constant K for the considered β-cyclodextrins association complexes is influenced by the hydrophobicity of the host compounds too, a tendency which can be also observed for the proton transfer constant. The association constants for the γ-cyclodextrins are remarkably smaller and again the proton transfer constant is significantly larger.

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