FTIR-spectroscopic studies on the hydration shell of methylated cyclodextrins

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Cyclodextrins (or cycloamyloses) are doughnut-like molecules composed of $\alpha(1\rightarrow4)$ linked D-glucose units. The inner hydrophobic cavities of these rings allows a diversified binding of guest molecules. If methylated, cyclodextrins change to be better soluble in cold water than in warm water [1], [2].

Crystals of either dimethylated (at positions O2 and O6) or trimethylated (at O2, O3 and O6) cyclodextrins obtained at 60° to 80°C contain less water molecules than those obtained from cold water (4° to 18°C), as shown by x-ray analysis [3]. The inverse solubility of methylated cyclodextrins is possibly related to molecular hydration [4].

The effect of cyclodextrins on surrounding water molecules was studied by Fourier transform infrared (FTIR) difference spectroscopy. Spectra of fully methylated β-cyclodextrin and γ-cyclodextrin in water (i.e. cycloamyloses of seven and eight units, resp.) were measured as a function of cyclodextrin concentration (100 to 400 mg/ml) and temperature (10 to 50°C).

The very strong band of the hydroxyl modes of water centred at ~3400 cm^{-1} was analysed. This band is composed of three components: an overtone bending vibration at ~3250 cm^{-1} ($2\nu2$), and two stretching vibrations at ~3450 cm^{-1} ($\nu1$) and ~3600 cm^{-1} ($\nu3$) [5]. Probing concentrated solutions of methylated cyclodextrins a markedly changed absorption has been observed arising from the water molecules in the hydration shell. Methylated cyclodextrin does not contribute to the spectral features in this wavenumber range as shown by KBr measurements. Deconvolution of the 3400 cm^{-1} band into Gaussian shaped components reveals further details, however an unequivocal assignment of these components is difficult.

Compensation of the contribution of bulk water to the difference spectrum was achieved by optimising the concentrations of the fully methylated cyclodextrins in our experimental setup. By this way, the spectral characteristics clearly indicate changes of the water structure in the surrounding of the fully methylated cyclodextrin molecules in comparison to bulk water.

[1] Saenger, W., Jacob, J., Gessler, K., Steiner, T., Hoffmann, D., Sanbe, H., Koizumi, K., Smith, S.M., and Takaha, T., *Structures of the common cyclodextrins and their larger analogues - Beyond the doughnut.* Chem. Rev., 1998. **98**(5): p. 1787-1802.

[2] Harata, K., *Structural aspects of stereodifferentiation in the solid state.* Chem. Rev., 1998. **98**(5): p. 1803-1827.

[3] Aree, T., Hoier, H., Schulz, B., Reck, G., and Saenger, W., *Novel type of thermostable channel clathrate hydrate formed by heptakis(2,6-di-O-methyl)-beta-cyclodextrin center dot 15H_2O - A paradigm of the hydrophobic effect.* Angew. Chem.-Int. Edit., 2000. **39**(5): p. 897-899.

[4] Aree, T., Uson, I., Schulz, B., Reck, G., Hoier, H., Sheldrick, G.M., and Saenger, W., *Variation of a theme: Crystal structure with four octakis(2,3,6-tri-O-methyl)-gamma-cyclodextrin molecules hydrated differently by a total of 19.3 water.* J. Am. Chem. Soc., 1999. **121**(14): p. 3321-3327.

[5] Venyaminov, S. and Prendergast, F.G., *Water (H_2O and D_2O) molar absorptivity in the 1000-4000 cm^{-1} range and quantitative infrared spectroscopy of aqueous solutions.* Anal. Biochem., 1997. **248**(2): p. 234-245.