Cucurbituril derivatives as oxygen carriers

Supporting Information

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# Binding constant extraction

For a model where a cucurbituril can bind one O2 molecule at most, called 1:1 model, the law of mass action $K=\frac{\left[O\_{2}@C\right]}{\left[O\_{2}\right]\left[C\right]}$ (1)

and the law of conservation of matter $\left[C\_{0}\right]=\left[C\right]+\left[O\_{2}@C\right]$ (2)

stand, where [C], [O2@C] and [C0] are the free, binding one O2 guest, and total host concentrations, respectively. In the regime where exchange is far faster than relaxation rate R1, R1 is a weighted average of a diamagnetic component R1d where the host C does not bind O2, and a paramagnetic component R1p where an O2-C binding occurs. Thus, R1 verifies the following equation: $R\_{1}=\frac{1}{1+K\left[O\_{2}\right]}R\_{1d}+\frac{K\left[O\_{2}\right]}{1+K\left[O\_{2}\right]}R\_{1p}$ (3)

This equation has been fitted against the O2 concentration, obtained from the product of O2 pressure above the solution and the solubility value of 0.18 mM/bar.1 The reverse of the relative errors on fitted R1 values have been used as weights for the fitting of K.

In the model where two O2 molecules, but not only one, called 2:1 model, are encapsulated, equations (1), (2) and (3) become:

$K=\frac{\left[O\_{2}@C\right]}{\left[O\_{2}\right]^{2}\left[C\right]}$ (4)

$\left[C\_{0}\right]=\left[C\right]+\left[\left(O\_{2}\right)\_{2}@C\right]$ (5)

$R\_{1}=\frac{1}{1+K\left[O\_{2}\right]^{2}}R\_{1d}+\frac{K\left[O\_{2}\right]^{2}}{1+K\left[O\_{2}\right]^{2}}R\_{1p}$ (6)

R1 values of Hax of **3** as a function of [O2] are then used as inputs for a nonlinear least squares fitting procedure (*nls* function from the R software), adjusting K, R1d and R1p in both 1:1 and 2:1 models.

(1) Garcia, H. E.; Gordon, L. I. Oxygen Solubility in Seawater: Better Fitting Equations. *Limnol. Oceanogr.* **1992**, *37* (6), 1307–1312.

# **Figure S1** - Inductively coupled plasma mass spectrometry

Titration of potassium in CB[5] **1** and (HO)10CB[5] **3** by ICP-MS, in collision cell mode (KED) mode. The calibration is performed by diluting a certified K standard (diamonds and solid line). (a) The 0.35 mM solution of CB[5] 1, diluted by a factor 1000, indicates a potassium concentration of the non-diluted solution of 0.67 mM (circle and dashed lines). (b) The 1.27 mM solution of (HO)10CB[5], diluted by a factor 10000, indicates a potassium concentration of the non-diluted solution of 5.9 mM.





# Figure S2 - electrospray ionization mass spectra

Positive ion electrospray ionization mode mass spectra (ESI-MS) of (a) CB[5] **1**, (b) Me10CB[5] **2** and (c) OH10CB[5] **3**.

**CB[5]**

**M=830 Da**

M+Na+

M+K+

M+NH4+

**a)**

**Me10CB[5]**

**M=970 Da**

M+K+

M+Na+

M+NH4+

**b)**

**OH10CB[5]**

**M=990 Da**

**c)**

# Figure S3 – 1H NMR of (OH)10CB[5] 3 in DMSO-d6

2.7 mM (OH)10CB[5] **3** in DMSO-d6.



1. 1H NMR spectra with weak (blue) and strong (red) diffusion filters. The red spectrum is scaled to the blue spectrum by taking Hax signals as reference. The DMSO 1H residual signal (main signal is cut, but 13C satellites are observed) and the signal of NH4+ show a high diffusion coefficient, unlike signals assigned to methylene protons of (OH)10CB[5] and signals tentatively assigned to alkyl amines.



1. **NOESY spectrum** with a mixing time of 0.35 second, a recycling delay of 1 second, at 11.7 T. 1D spectrum with recycling delay is displayed above with assignment.

# Figure S4 – 1H relaxation rates of (OH)10CB[5] 3

Fits of the relaxation rate R1, in s-1, against the inversion-recovery delay for each proton of OH10CB[5] **3** in D2O solution and the residual protons of solvent, at 293 K. Error bars stand for one standard deviation. The poor precision on the signals of Heq \* comes from a partial overlap with the dominant HDO signal.



# Figure S5 – relaxation rates of 1, 2 and 3

Relaxation rates R1, in s-1, measured for protons of CB[5] **1**, Me10CB[5] **2** and (OH)10CB[5] **3**, in D2O solution, at 293 K. Color codes: blue, under ca. 1 bar of O2; orange, degassed NMR tubes. Error bars stand for one standard deviation. For a better readability, values are given for HDO signal.



# Table S1 - Full-width half maximum of the Hax 1H signals of the three cucurbiturils under study, at 293 K

Full-width half maximum, in s-1, directly measured on the spectra unless otherwise stated, for signals assigned to Hax protons of CB[5] **1** and Me10CB[5] **2** either degassed or under 1 bar of oxygen and, for **2** and **3**, also with 155 mM NaCl. O2 solubility at 293 K is 0.26 mM/bar in pure water and 0.25 mM/bar in a 150 mM NaCl water solution, according to Garcia et Gordon, Limnol Oceanogr 1992;37:1307, already cited in the main text. **3\*** and **3°** stand for signals sensitive and not sensitive to the presence of O2, respectively, as identified in Figure 2.

|  |  |  |  |
| --- | --- | --- | --- |
| **Molecule** | **NaCl concentration, mM** | **O2 concentration, mM** | **Hax** |
| CB[5] **1** | 0 | Degassed sample | 2.8 |
| CB[5] **1** | 0 | 0.26 | 3.3 |
| Me10CB[5] **2** | 0 | Degassed sample | 3.4 |
| Me10CB[5] **2** | 0 | 0. 26 | 16 |
| OH10CB[5] **3°** | 0 | Degassed sample | 2.3 |
| OH10CB[5] **3°** | 0 | 0. 26 | 3.0 |
| OH10CB[5] **3\*** | 0 | Degassed sample | 2.5 |
| OH10CB[5] **3\*** | 0 | 0. 26 | 10.4 |
| Me10CB[5] **2** | 155 | Degassed sample | 3.1 |
| Me10CB[5] **2** | 155 | 0. 25 | 5.1 |
| OH10CB[5] **3°** | 155 | Degassed sample | 3.0 |
| OH10CB[5] **3°** | 155 | 0. 25 | 3.9 |
| OH10CB[5] **3\*** | 155 | Degassed sample | 4.3 |
| OH10CB[5] **3\*** | 155 | 0. 25 | 15.7 a |

a: this value results from a fit using PeakFit software.

# Table S2 - Full-width half maximum of OH10CB[5] 3, in a 0.15 M NaCl solution, at 310 K

Full-width half maximum, in s-1, directly measured on the spectra unless otherwise stated, for signals assigned to Hax protons marked by a star or a circle in Figure 3, *i.e.* those of OH10CB[5] **3** sensitive or not to O2 binding. In these conditions, O2 solubility is estimated to 0.18 mM Garcia et Gordon, Limnol Oceanogr 1992;37:1307.

|  |  |  |
| --- | --- | --- |
| **O2 concentration, mM** | **Hax \*** | **Hax °** |
| Degassed sample | 2.7 | 3.5 |
| 0.0012 | 2.7 | 3.6 |
| 0.0033 | 3.0 | 3.7 |
| 0.0049 | 2.9 | 3.4 |
| 0.0112 | 5.0 | 3.2 |
| 0.0133 | 8.3 | 4.8 |
| 0.0287 | 9.7 | 4.1 |
| 0.0731 | 13.5 a | 3.7 |
| 0.1800 | 14.5 b and 21.0 b,c | 3.3 and 3.9 a |
| 0.9326 | 39.0 b | 3.6 |

a: this value results from a fit using PeakFit software.

b: values estimated from measurement of the line-width of the doublet, then subtracting the known J coupling of 16 Hz.

c: from 2 distinct samples.