Europium(III) Macrocyclic Complexes with Alcohol Pendant Arms as Chemical Exchange Saturation Transfer (CEST) Agents

Electronic Supplementary Information

Mark Woods,[†±] Donald E. Woessner,[∞] Piyu Zhao,[±] Azhar Pasha,[±] Meng-Yin Yang,[‡] Olga Vasalitiy,[±] Janet R. Morrow,[‡]* A. Dean Sherry[±∞]*

[†] Macrocyclics, 2110 Research Row, Suite 425, Dallas, TX 75235, USA.

[±] Department of Chemistry, University of Texas at Dallas, P.O. Box 830668, Richardson, TX 75083, USA.
E-mail: sherry@utdallas.edu

[∞] Department of Radiology & the Advanced Imaging Research Center, University of Texas Southwestern Medical Center, Harry Hines Boulevard, Dallas, TX 75235, USA.
E-mail: dean.sherry@utsouthwestern.edu

[‡] Department of Chemistry, State University of New York at Buffalo, Amherst, NY 14260, USA.
E-mail: jmorrow@buffalo.edu

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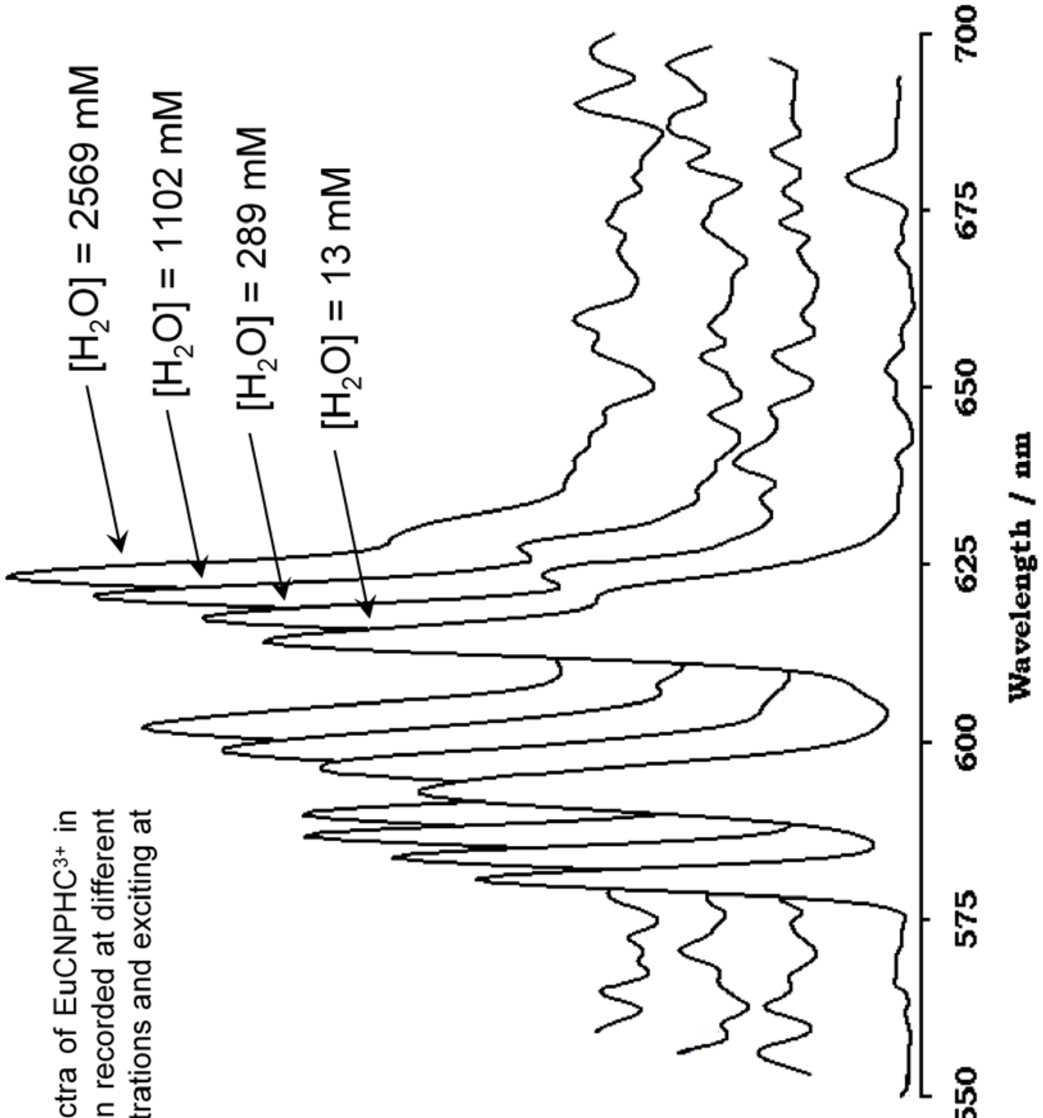
Electronic Supplementary Information Sheet 1



Emission spectra of EuCNPHC^{3+} in MeCN solution recorded at different water concentrations and exciting at 397 nm.

Electronic Supplementary Information Sheet 2

H_2O molecules per EuL	T_1 / ms						
	Hydroxyl Protons			Eu-OH_2	Bulk H_2O	Amide NH	
	19 ppm	16 ppm	14 ppm			-1 ppm	-2 ppm
0.18	39	39	39	—	102	—	39
6.93	40	40	39	—	165	—	—
14.35	40	40	39	—	232	—	—
21.80	Broad	Broad	Broad	—	274	—	—
29.25	Broad	Broad	Broad	—	334	—	—
44.18	Broad	Broad	Broad	—	444	—	—
59.12	—	—	—	—	573	—	—
74.05	—	—	—	—	678	—	—

Table 1. The experimentally determined T_1 values of the exchanging protons in the $EuCNPHC^{3+}$ complex. Peaks that had exchange broadened to an extent that T_1 could not be reliably measured are denoted "broad" and dashed entries indicate that the peak could not be seen or sufficiently resolved to measure T_1.

Electronic Supplementary Information Sheet 3

Equations used for fitting the 6 exchanging pool system $EuCNPHC^{3+}$

The six pools of protons are designated by A, B, C, D, E, and F. Each of them is characterized by equilibrium Z magnetization designated by M_0^i where i is one of the designations. M_0^i is directly proportional to the number of protons in pool i. Also, each pool is characterized by:

M_x^i , M_y^i , and M_z^i , the X, Y, and Z magnetizations at any time

ω_i , the Larmor frequency of pool i, in rad s^{-1}

T_{1i} , the spin-lattice relaxation time, in seconds

T_{2i} , the transverse relaxation time, in seconds.

Two other parameters that appear in the equations are the NMR spectrometer settings:

ω , the irradiation frequency of the spectrometer

ω_1 , the strength of the irradiation, in rad s^{-1} [equal to $2\pi B_1$, where B_1 is in Hz] .

Protons of pool A can exchange with pools B, C, D, E, and F but protons of pools B, C, D, E, and F do not exchange with other.

In the differential equations given below, the exchange rates for protons leaving pools B, C, D, E, and F and entering pool A are

$$C_{ba} = 1/\tau_b \quad (1)$$

$$C_{ca} = 1/\tau_c \quad (2)$$

$$C_{da} = 1/\tau_d \quad (3)$$

$$C_{ea} = 1/\tau_e \quad (4)$$

$$C_{fa} = 1/\tau_f \quad (5)$$

in which τ_i is the average lifetime of a proton in pool i. The principle of detailed balance gives us the exchange rates for protons to leave pool A and enter each of the other pools:

$$C_{ab} = (M_0^b / M_0^a)\, C_{ba} \quad (6)$$

$$C_{ac} = (M_0^c / M_0^a)\, C_{ca} \quad (7)$$

$$C_{ad} = (M_0^d / M_0^a)\, C_{da} \quad (8)$$

$$C_{ae} = (M_0^e / M_0^a)\, C_{ea} \quad (9)$$

$$C_{af} = (M_0^f / M_0^a)\, C_{fa} \quad (10)$$

and then, the rate for protons to leave pool A is

$$C_a = C_{ab} + C_{ac} + C_{ad} + C_{ae} + C_{af}$$

In order to simplify the equations, some of the parameters are lumped into new parameters:

$$k_{1a} = 1/ T_{1a} + C_a \quad (11)$$

$$k_{2a} = 1/ T_{2a} + C_a \quad (12)$$

$$k_{1b} = 1/ T_{1b} + C_{ba} \quad (13)$$

$$k_{2b} = 1/ T_{2b} + C_{ba} \quad (14)$$

$$k_{1c} = 1/ T_{1c} + C_{ca} \quad (15)$$

$$k_{2c} = 1/ T_{2c} + C_{ca} \quad (16)$$

$k_{1d} = 1/ T_{1d} + C_{da}$ (17)

$k_{2d} = 1/ T_{2d} + C_{da}$ (18)

$k_{1e} = 1/ T_{1e} + C_{ea}$ (19)

$k_{2e} = 1/ T_{2e} + C_{ea}$ (20)

$k_{1f} = 1/ T_{1f} + C_{fa}$ (21)

$k_{2f} = 1/ T_{2f} + C_{fa}$ (22)

The time dependencies of the various magnetizations while irradiated by the RF pulse are given by the solution of the following set of 18 coupled differential equations:

$$dM_x^a/dt = -k_{2a} M_x^a + C_{ba} M_x^b + C_{ca} M_x^c + C_{da} M_x^d + C_{ea} M_x^e + C_{fa} M_x^f + (\omega - \omega_a) M_y^a \quad (23)$$

$$dM_x^b/dt = C_{ab} M_x^a - k_{2b} M_x^b + (\omega - \omega_b) M_y^b \quad (24)$$

$$dM_x^c/dt = C_{ac} M_x^a - k_{2c} M_x^c + (\omega - \omega_c) M_y^c \quad (25)$$

$$dM_x^d/dt = C_{ad} M_x^a - k_{2d} M_x^d + (\omega - \omega_d) M_y^d \quad (26)$$

$$dM_x^e/dt = C_{ae} M_x^a - k_{2e} M_x^e + (\omega - \omega_e) M_y^e \quad (27)$$

$$dM_x^f /dt = C_{af} M_x^a - k_{2f} M_x^f + (\omega - \omega_f) M_y^f \quad (28)$$

$$dM_y^a/dt = (\omega_a - \omega) M_x^a - k_{2a} M_y^a + C_{ba} M_y^b + C_{ca} M_y^c + C_{da} M_y^d + C_{ea} M_y^e$$

$$+ C_{fa} M_y^f - \omega_1 M_z^a$$
(29)

$$dM_y^b/dt = (\omega_b - \omega) M_x^b + C_{ab} M_y^a - k_{2b} M_y^b - \omega_1 M_z^b$$
(30)

$$dM_y^c/dt = (\omega_c - \omega) M_x^c + C_{ac} M_y^a - k_{2c} M_y^c - \omega_1 M_z^c$$
(31)

$$dM_y^d/dt = (\omega_d - \omega) M_x^d + C_{ad} M_y^a - k_{2d} M_y^d - \omega_1 M_z^d$$
(32)

$$dM_y^e/dt = (\omega_e - \omega) M_x^e + C_{ae} M_y^a - k_{2e} M_y^e - \omega_1 M_z^e$$
(33)

$$dM_y^f /dt = (\omega_f - \omega) M_x^f + C_{af} M_y^a - k_{2f} M_y^f - \omega_1 M_z^f$$
(34)

$$dM_z^a/dt = \omega_1 M_y^a - k_{1a} M_z^a + C_{ba} M_z^b + C_{ca} M_z^c + C_{da} M_z^d + C_{ea} M_z^e$$
$$+ C_{fa} M_z^f + M_0^a / T_{1a}$$
(35)

$$dM_z^b/dt = \omega_1 M_y^b + C_{ab} M_z^a - k_{1b} M_z^b + M_0^b / T_{1b}$$
(36)

$$dM_z^c/dt = \omega_1 M_y^c + C_{ac} M_z^a - k_{1c} M_z^c + M_0^c / T_{1c}$$
(37)

$$dM_z^d/dt = \omega_1 M_y^d + C_{ad} M_z^a - k_{1d} M_z^d + M_0^d / T_{1d}$$
(38)

$$dM_z^e/dt = \omega_1 M_y^e + C_{ae} M_z^a - k_{1e} M_z^e + M_0^e / T_{1e}$$
(39)

$$dM_z^f /dt = \omega_1 M_y^f + C_{af} M_z^a - k_{1f} M_z^f + M_0^f / T_{1f}$$
(40)