

Supplementary Information

S1: Experimental procedures

General

NMR spectra were recorded at ambient temperature, on a Bruker Avance-500 (^1H , ^1H -H COSY, 500.13 MHz; ^{13}C , 135-DEPT, 125.77 MHz). All ^{13}C spectra are ^1H broadband decoupled. Chemical shifts (δ) are expressed in ppm and J values are given in Hz. ^1H and ^{13}C NMR spectra were referenced internally to Me_4Si (for **1** and the *t*-butyl ester derivative of L^1H_3 in CDCl_3), or TSP- d_4 (for L^1H_3 in D_2O). Mass spectrometry was performed using a Kratos Profile HV3 mass spectrometer in "Liquid Secondary Ionisation Mass Spectrometry" mode (employing glycerol as a matrix) or a MassLynx 4.0 SP4, SCN 519 Q-TOF mass spectrometer employing an electrospray source in positive ion (ES^+) mode. Melting points were obtained on an Electrothermal Eng. Ltd. digital melting point apparatus, and are uncorrected. A Carlo Erba 1108 Elemental Analyser was used for C, H and N microanalyses. TLC was performed on pre-coated silica plates (Whatman Al Sil G/UV, 250 μm layer) in the solvent system stated. Column chromatography was performed over Fluka silica gel 60 (63-200 μm particle diameter). Reagents were used as purchased. Solvents DMF, diethyl ether and methanol respectively were either used as the HPLC grade material or dried and stored in accordance with established procedures.¹ All other solvents and materials were used as purchased.

Syntheses

1,4,7-Tris(carbo-[1,1-dimethyl]ethoxymethyl)-1,4,7,10-tetraazacyclododecane, HBr salt (**1**, DO3A-*tert*-butyl ester, HBr salt) was prepared as a white solid from cyclen according to the method of Schultze and Bulls.²

Respective correlations are denoted "resp." Room temperature is denoted "rt". Major and minor multiplets are denoted "maj" and "min" respectively, singlets as "s" and multiplets as "m" with additional "br" notation if broad. Phthalimido functions are

denoted "Phth" and aromatic *C* and *H*'s therein are denoted "*o*, *m*, *ipso*" relative to imido-substituted positions.

1,4,7-tris(carboxymethyl)-10-(3-[phthalimido]propyl)-1,4,7,10-

tetraazacyclododecane (L^1H_3); An anhydrous DMF suspension (5 cm³) of DO3A-*tert*-butyl ester HBr salt **1** (1.49 g, 2.5 mmol), *N*-(3-bromopropyl)phthalimide (0.80 g, 3.0 mmol) and anhydrous K₂CO₃ (0.83 g, 6.0 mmol) was vigorously stirred under anhydrous conditions at rt for 12 days. The mixture was then decanted into dichloromethane (100 cm³), washed with deionised water (6x100 cm³) and sat'd brine (100 cm³), and the organic phase was dried over MgSO₄. Evaporation *in vacuo* yielded an immobile straw-coloured glass which was subjected to column chromatography (eluent - CH₂Cl₂/MeOH 7:1 v/v; desired fractions, ¹H-NMR; TLC - R_f 0.70), leaving the 1,4,7-tris(carbo-[1,1-dimethyl]ethoxymethyl)-10-(3-[phthalimido]propyl)-1,4,7,10-tetraazacyclododecane intermediate as a hygroscopic oil (1.1320 g) which was subjected to the deprotection procedure below: δ_H(CDCl₃): 1.41, 1.42, 1.44, 1.46 [27H, 4x s, CH₃'s (^tBu)]; 1.83 [2H, m, CH₂CH₂CH₂ (linker)]; 1.90-3.60 [24H, br. m, PhthNCH₂ (linker), and 11x NCH₂ (DO3A segment)]; 3.68 (maj), 3.80 (min) [2H, 2x t, CH₂N (linker)]; 7.74-7.76 and 7.83-7.87 [2H, 2x m, ArH (Phth)]; also 5.31 [~0.8H, 0.4x CH₂Cl₂]; δ_C(CDCl₃): 25.71 [CCH₂C (linker)]; 27.82, 27.92, 28.10, 28.14 [CH₃'s, ^tBu]; 35.51, 36.11 [NCH₂'s (linker)]; ~48.70, 50.33, 50.45, 51.83, 52.51, 53.46, 55.76, 56.76br. [NCH₂'s (DO3A segment)]; 81.76, 81.91, 82.34, 82.74 [CMe₃'s, ^tBu]; 123.26, 123.43, 123.66, 125.29, 128.22, 129.03, 134.14, 134.18 [*o,m*-ArC]; 131.91, 131.93 [*ipso*-ArC]; 168.15, 169.79, 170.16, 172.78 [C=O's]. **ES-MS: 702.31 (100%, [MH⁺])**

A stirred dichloromethane solution (5 cm³) of the *t*-butyl ester of L^1H_3 was charged with trifluoroacetic acid (40 cm³) and the reaction mixture was stirred under N₂ at rt for 4½ h. The mixture was evaporated *in vacuo* (70°C), azeotroped twice with acetone (2x 10 cm³), and the residue was redissolved in acetone (5 cm³). Dropwise addition of diethyl ether (~ 25 cm³) to the vigorously stirred solution precipitated a white solid

which was isolated, washed with diethyl ether and dried in vacuo (~ 60°C, ½ h) to yield **L¹H₃** as a cream-white solid (603.2 mg, 28% from **1**): mp 114-115°C dec: (Found: C, 41.32; H, 4.87; N, 8.14. Calc'd. for C₂₅H₃₅N₅O₈.2½CF₃COOH.3H₂O: C, 41.23; H, 4.98; N, 8.01%): δ_H(D₂O, solvent suppression): 2.18 [2H, br m., CH₂CH₂CH₂]; 3.00-3.04, 3.05-3.08 and 3.13-3.17 (8H, 3x br.m) and 3.36-3.38br.m, 3.39,3.42, 3.45, 3.49, 3.60, 3.63 (14H, 1x br.m, 6x s) [22H total, 11x NCH₂ (DO3A segment)]; 3.76 [2H, t, PhthNCH₂ (linker)]; 4.04 [2H, s, NCH₂ (linker)]; 7.82 [4H, s, ArH (Phth)]; also 2.22 [s, trace, CH₃]; δ_C(D₂O): 25.35 [CCH₂C (linker)]; 37.65 [NCH₂'s (linker)]; 50.97, 51.22, 52.74, 54.36, 54.84, 55.75, 58.27 [NCH₂'s (DO3A segment)]; 115.65, 117.97, 120.30, 122.61 [CF₃]; 126.26, 133.97, 137.64 [ArC, (Phth)]; 165.64, 165.92, 172.13, 173.24, 177.00 [C=O's]; also 33.04; ES-MS: 556.3613 (45%, [MNa⁺]); 534.3680 (100%, [MH⁺]).

1,4,7-tris(carboxymethyl)-10-(3-[phthalimido]propyl)-1,4,7,10-tetraazacyclododecane, Terbium complex ([TbL¹(H₂O)].1¼ CF₃COOH.5H₂O); Aqueous suspension (3 cm³) of ligand **L¹H₃** (50.3 mg, 0.0576 mmol) and Tb₂(CO₃)₃.xH₂O (22.6 mg, 0.0288 mmol; Tb 40.4%w/w) was stirred at 50°C for 18 h, filtered, and the filtrate azeotroped *in vacuo* with 2-propanol (2x10 cm³) and acetone (2x10 cm³) at 60°C. Addition of acetone (3 cm³) and diethyl ether (1 cm³) yielded a precipitate which was isolated by filtration and washed with diethyl ether. Air-drying on the apparatus left Tb(III) complex as a white solid (38.7 mg, 73% from **L¹H₃**): mp 196-200°C dec: (Found: C, 35.64; H, 4.34; N, 7.90. Calc'd for C₂₅H₃₂N₅O₈Tb.1¼ CF₃COOH.5H₂O: C, 35.81; H, 4.69; N, 7.59%); MS (ES+): 712.2479 (5%, [MNa⁺]) 690.2637 (18%, [MH⁺]); 534.3210 (100%, [LigandH⁺]).

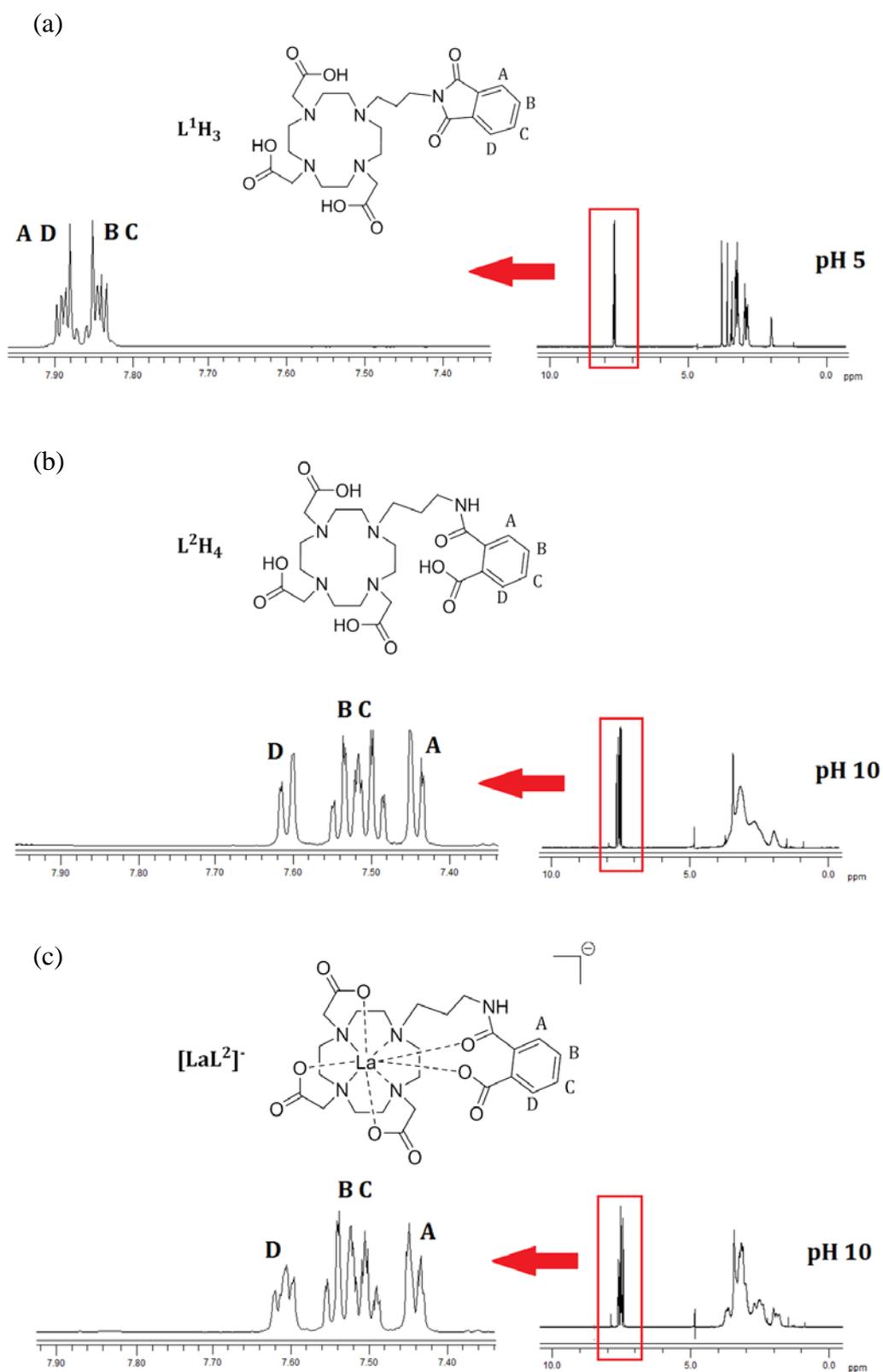


Fig. S1. 1H NMR spectra recorded at (a) pH 5 and pH 10 (b) and (c) on coordination with La^{3+} demonstrating structural changes on proposed during the hydrolysis of L^1 to L^2

Luminescence studies

Absorption spectra were recorded on a Perkin Elmer EZ301 Spectrophotometer UV/Vis spectrometer with luminescence cells with a path length of 0.2 cm. Luminescence lifetime measurements were recorded on a Perkin-Elmer LS50B spectrometer at 298 K with no external regulation. The phosphorescent lifetime was measured by recording the decay at the maximum of the emission spectra. The signals were analysed to be single-exponential. The instrument settings were as follows: cycle time = 200 ms, a flash count of 5, a gate time of 5 ms, integration time of 1s and excitation and emission slit widths of 2.5 nm. The number of coordinated water molecules present in solution q were determined from lifetime measurements by using the equation of Parker and co-workers ($q = A_{Ln}(1/\tau_{H_2O} - 1/\tau_{D_2O} - \alpha_{Ln})$ with $A_{Tb} = 5$ ms, $A_{Eu} = 1.2$ ms, $\alpha_{Tb} = 0.06$ ms⁻¹, and $\alpha_{Eu} = 0.25$ ms⁻¹).³

Quantum yields Q have been calculated by using the equation $Q_x/Q_r = A_r(\tilde{\nu}) \cdot n_x^2 \cdot D_x / A_s(\tilde{\nu}) \cdot n_r^2 \cdot D_r$, in which x refers to the sample, r to the reference, A to the absorbance, $\tilde{\nu}$ to the excitation wavenumber used, n to the refractive index, and D to the integrated emitted intensity. The tris(dipicolinate) complexes [Tb(dpa)₃]³⁻ ($\Phi = 26.5\%$, 6.5×10^{-5} M in tris buffer 0.1M) was used as references for the determination of the quantum yields of the Tb-containing samples.⁴ The consistency of data was checked by measuring the quantum yield of the tris(dipicolinate) complexes against rhodamine B ($Q_{abs} = 65\%$ in absolute ethanol).⁵

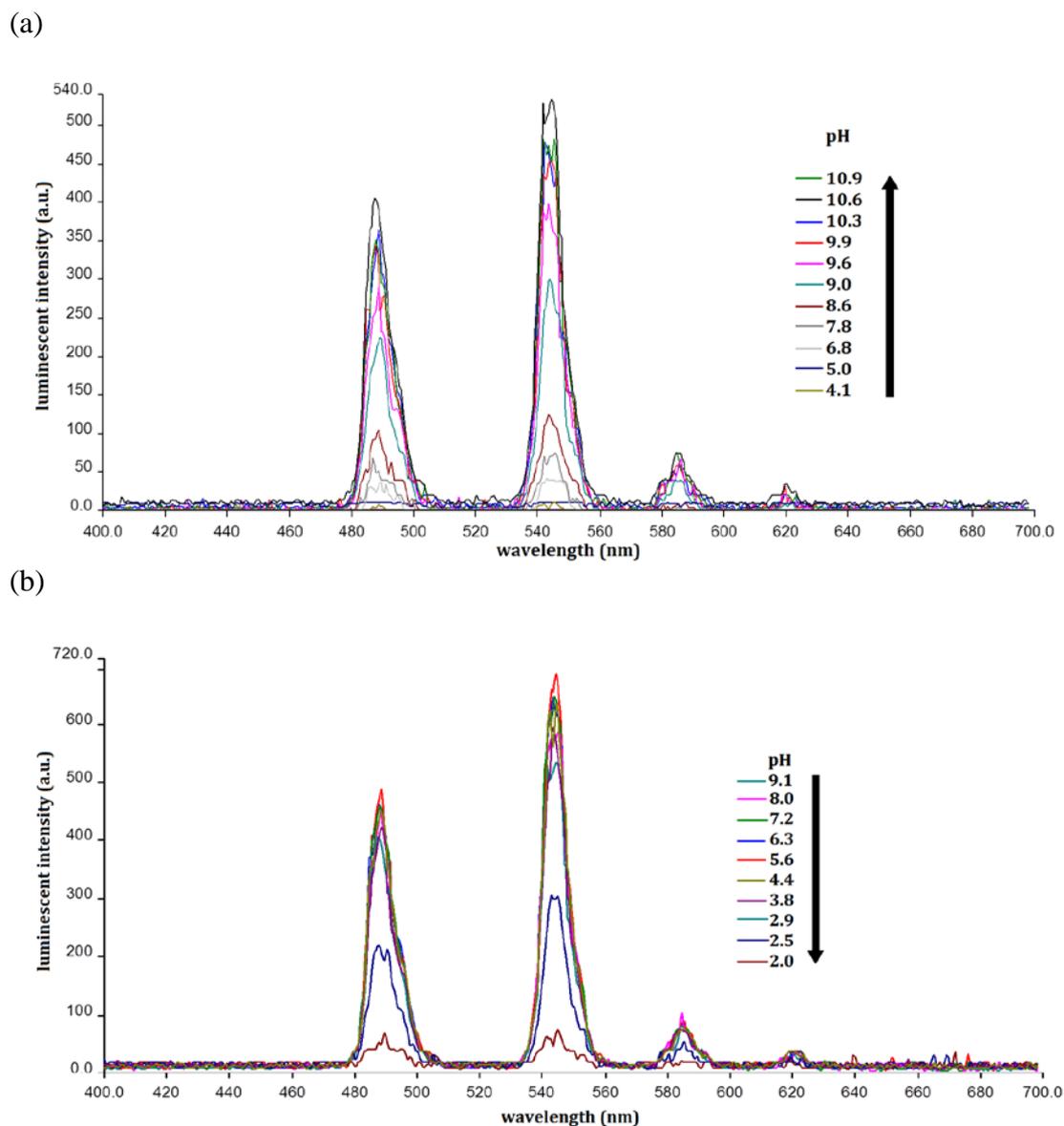


Fig S2. Overlay of luminescence spectra obtained for [TbL₂]⁻ as a function of pH on addition of (a) base and (b) acid ($\lambda_{\text{exc}} = 272 \text{ nm}$).

References

1. A.I. Vogel, *Vogel's Textbook of Practical Organic Chemistry* (5th Edn); B.S. Furniss; A.J. Hanniford, A.J.; P.W.G. Smith; A.R. Tatchell, Eds.; Longman Scientific and Technical, co-published with John Wiley and Sons, New York, 1989.
2. L. Schultze and A.R. Bulls, *WO Pat* 96/28433 (19.09.96).

3. A. Beeby, I. M. Clarkson, R. S. Dickens, S. Faulkner, D. Parker, L. Royle, A. S. de Sousa, G. J. A. Williams, M. Woods, *J. Chem. Soc. Perkin Trans. 2*. 1999, 493-503
4. A.-S. Chauvin, F. Gumy, D. Imbert. J.-C Bünzli, *Spectrosc. Lett.* 2004, 37, 517-532; A.-S. Chauvin, F. Gumy, D. Imbert. J.-C Bünzli, *Spectrosc. Lett.* 2007, 40, 193-193
5. R. F. Kubin, A. N. Fletcher, *J. Fluorescence*, 1982, 27, 455-462