Table 1S Crystal data and structure refinement for TTDA-4est·HBr.

Empirical formula	$C_{29}H_{56}BrN_3O_8$
Formula weight	654.68
Temperature	293(2) K
Wavelength	0.71069 A
Crystal system, space group	monoclinic, P21/n (No.14)
Unit cell dimensions	a = 11.957(4) Å α = 90 deg.
	b = 11.822(3) Å β = 94.96(2) deg.
	c = 26.391(4) Å γ = 90 deg.
Volume	3716.7(16) $Å^3$
Z, Calculated density	4, 1.170 mg/m^3
Absorption coefficient	1.150 mm^{-1}
F(000)	1400
Crystal size	0.60 x 0.60 x 0.95 mm
Theta range for data collection	2.32 to 26.00 deg.
Limiting indices	$14 \geq h \geq 0$, $14 \geq k \geq 0$, $32 \geq 1 \geq -32$
Reflections collected / unique	7680 / 7315 [R(int) = 0.0215]
Completeness to theta = 26.00	99.9 %
Absorption correction	Psi-scan
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	7315 / 0 / 378
Goodness-of-fit on F^2	1.007
Final R indices [I>2sigma(I)]	R1 = 0.0378, wR2 = 0.0829
R indices (all data)	R1 = 0.1190, wR2 = 0.1152
Largest diff. peak and hole	0.239 and -0.249 $e.A^{-3}$

Summary of Data CCDC 603492

X-ray Structure Determination Details. A colorless crystal (0.60 x 0.60 x 0.95 mm) was grown when a layer of hexane was allowed to slowly diffuse into a ethyl acetate solution of TTDA-4est·HBr. The single-crystal X-ray determinations of compounds TTDA-4est·HBr with Mo Kα radiation were carried out at 293(2) K by using a Rigaku AFC7S diffractometer. Data were collected to a maximum 2θ value of 26.0°. Of the 7680 unique reflections (R_{int} = 0.0215) collected, there were 7315 with $F_o^2 > 3.0\sigma(F_o^2)$. An empirical absorption correction based on Psi scans of several reflections was applied. The structures were solved by an expanded Fourier technique. All non-hydrogen atoms were refined anisotropically. Hydrogen atoms were included (0.95 Å) but not refined.

Electronic Supplementary Information for Dalton Transactions

Table 2S Bond lengths [Å] and angles [deg] for TTDA-4est·HBr.

C(1)-C(2)	1.487(6)	C(26)-C(27)	1.503(5)
C(1)-O(1)	1.490(4)	C(26)-C(29)	1.508(5)
C(1)-C(3)	1.497(5)	C(26)-C(28)	1.514(5)
C(1)-C(4)	1.521(6)	C(2)-H(2A)	0.9600
C(5)-O(2)	1.196(4)	C(2)-H(2B)	0.9600
C(5)-O(1)	1.321(4)	C(2)-H(2C)	0.9600
C(5)-C(6)	1.524(4)	C(3)-H(3A)	0.9600
C(6)-N(1)	1.454(4)	C(3)-H(3B)	0.9600
C(7)-N(1)	1.453(4)	C(3)-H(3C)	0.9600
C(7)-C(8)	1.511(4)	C(4)-H(4A)	0.9600
C(8)-O(3)	1.331(4)	C(4)-H(4B)	0.9600
C(8)-O(4)	1.197(4)	C(4)-H(4C)	0.9600
C(9)-O(3)	1.487(4)	C(6)-H(6A)	0.9700
C(9)-C(12)	1.511(5)	C(6)-H(6B)	0.9700
C(9)-C(11)	1.513(5)	C(7)-H(7B)	0.9700
C(9)-C(10)	1.517(6)	C(7)-H(7A)	0.9700
C(13)-N(1)	1.465(4)	C(10)-H(10A)	0.9600
C(13)-C(14)	1.519(5)	C(10)-H(10B)	0.9600
C(14)-C(15)	1.509(5)	C(10)-H(10C)	0.9600
C(15)-N(2)	1.487(4)	C(11)-H(11A)	0.9600
C(16)-N(2)	1.478(4)	C(11)-H(11B)	0.9600
C(16)-C(17)	1.517(4)	C(11)-H(11C)	0.9600
C(17)-N(3)	1.461(4)	C(12)-H(12A)	0.9600
C(18)-N(3)	1.447(4)	C(12)-H(12B)	0.9600
C(18)-C(19)	1.505(5)	C(12)-H(12C)	0.9600
C(19)-O(8)	1.208(4)	C(13)-H(13A)	0.9700
C(19)-O(7)	1.321(4)	C(13)-H(13B)	0.9700
C(20)-O(7)	1.484(5)	C(14)-H(14A)	0.9700
C(20)-C(23)	1.501(8)	C(14)-H(14B)	0.9700
C(20)-C(21)	1.506(6)	C(15)-H(15A)	0.9700
C(20)-C(22)	1.510(7)	C(15)-H(15B)	0.9700
C(24)-N(3)	1.458(4)	C(16)-H(16A)	0.9700
C(24)-C(25)	1.514(4)	C(16)-H(16B)	0.9700
C(25)-O(6)	1.198(4)	C(17)-H(17A)	0.9700
C(25)-O(5)	1.341(4)	C(17)-H(17B)	0.9700
C(26)-O(5)	1.480(4)	C(18)-H(18A)	0.9700

Table 2S Bond lengths [Å] and angles [deg] for TTDA-4est·HBr (continued).

C(18)-H(18B)	0.9700		
C(21)-H(21A)	0.9600		
C(21)-H(21B)	0.9600		
C(21)-H(21C)	0.9600		
C(22)-H(22A)	0.9600		
C(22)-H(22B)	0.9600		
C(22)-H(22C)	0.9600		
C(23)-H(23A)	0.9600		
C(23)-H(23B)	0.9600		
C(23)-H(23C)	0.9600		
C(24)-H(24A)	0.9700		
C(24)-H(24B)	0.9700		
C(27)-H(27A)	0.9600		
C(27)-H(27B)	0.9600		
C(27)-H(27C)	0.9600		
C(28)-H(28A)	0.9600		
C(28)-H(28B)	0.9600		
C(28)-H(28C)	0.9600		
C(29)-H(29A)	0.9600		
C(29)-H(29B)	0.9600		
C(29)-H(29C)	0.9600		
N(2)-H(2D)	0.95(4)		
N(2)-H(2E)	0.87(3)		

C(2)-C(1)-O(1)	107.7(3)	N(2)-C(16)-C(17)	110.0(2)
C(2)-C(1)-C(3)	113.3(4)	N(3)-C(17)-C(16)	111.3(3)
O(1)-C(1)-C(3)	112.0(3)	N(3)-C(18)-C(19)	113.5(3)
C(2)-C(1)-C(4)	110.5(4)	O(8)-C(19)-O(7)	124.3(4)
O(1)-C(1)-C(4)	101.3(3)	O(8)-C(19)-C(18)	125.4(4)
C(3)-C(1)-C(4)	111.3(4)	O(7)-C(19)-C(18)	110.2(3)
O(2)-C(5)-O(1)	125.9(3)	O(7)-C(20)-C(23)	108.4(5)
O(2)-C(5)-C(6)	124.4(3)	O(7)-C(20)-C(21)	111.5(4)
O(1)-C(5)-C(6)	109.7(3)	C(23)-C(20)-C(21)	112.4(5)
N(1)-C(6)-C(5)	115.8(3)	O(7)-C(20)-C(22)	101.4(4)
N(1)-C(7)-C(8)	111.0(3)	C(23)-C(20)-C(22)	112.5(5)
O(4)-C(8)-O(3)	124.5(3)	C(21)-C(20)-C(22)	110.2(5)
O(4)-C(8)-C(7)	125.0(3)	N(3)-C(24)-C(25)	115.9(3)
O(3)-C(8)-C(7)	110.5(3)	O(6)-C(25)-O(5)	125.3(3)
O(3)-C(9)-C(12)	110.7(3)	O(6)-C(25)-C(24)	126.0(3)
O(3)-C(9)-C(11)	102.2(3)	O(5)-C(25)-C(24)	108.7(3)
C(12)-C(9)-C(11)	111.9(4)	O(5)-C(26)-C(27)	109.8(3)
O(3)-C(9)-C(10)	108.1(3)	O(5)-C(26)-C(29)	109.7(3)
C(12)-C(9)-C(10)	112.8(4)	C(27)-C(26)-C(29)	112.5(4)
C(11)-C(9)-C(10)	110.6(4)	O(5)-C(26)-C(28)	102.4(3)
N(1)-C(13)-C(14)	113.0(3)	C(27)-C(26)-C(28)	111.0(3)
C(15)-C(14)-C(13)	114.3(3)	C(29)-C(26)-C(28)	110.9(3)
N(2)-C(15)-C(14)	111.1(3)	C(6)-N(1)-C(7)	114.4(3)

C(6)-N(1)-C(13)	112.8(3)	C(5)-C(6)-H(6B)	108.3

Table 2S Bond lengths [Å] and angles [deg] for TTDA-4est·HBr (continued).

C(7)-N(1)-C(13)	113.8(3)		
C(16)-N(2)-C(15)	115.6(3)		
C(16)-N(2)-H(2D)	112.7(19)		
C(15)-N(2)-H(2D)	108(2)		
C(16)-N(2)-H(2E)	107.9(18)	N(1)-C(7)-H(7A)	109.4
C(15)-N(2)-H(2E)	108.6(18)	C(8)-C(7)-H(7A)	109.4
H(2D)-N(2)-H(2E)	103(3)	N(1)-C(7)-H(7B)	109.4
C(18)-N(3)-C(24)	114.5(3)	C(8)-C(7)-H(7B)	109.4
C(18)-N(3)-C(17)	114.1(3)	H(7A)-C(7)-H(7B)	108.0
C(24)-N(3)-C(17)	114.1(3)	C(9)-C(10)-H(10A)	109.5
C(5)-O(1)-C(1)	123.0(3)	C(9)-C(10)-H(10B)	109.5
C(8)-O(3)-C(9)	122.1(3)	H(10A)-C(10)-H(10B)	109.5
C(25)-O(5)-C(26)	122.0(3)	C(9)-C(10)-H(10C)	109.5
C(19)-O(7)-C(20)	122.2(3)	H(10A)-C(10)-H(10C)	109.5
C(1)-C(2)-H(2A)	109.5	H(10B)-C(10)-H(10C)	109.5
C(1)-C(2)-H(2B)	109.5	C(9)-C(11)-H(11A)	109.5
H(2A)-C(2)-H(2B)	109.5	C(9)-C(11)-H(11B)	109.5
C(1)-C(2)-H(2C)	109.5	H(11A)-C(11)-H(11B)	109.5
H(2A)-C(2)-H(2C)	109.5	C(9)-C(11)-H(11C)	109.5
H(2B)-C(2)-H(2C)	109.5	H(11A)-C(11)-H(11C)	109.5
C(1)-C(3)-H(3A)	109.5	H(11B)-C(11)-H(11C)	109.5
C(1)-C(3)-H(3B)	109.5	C(9)-C(12)-H(12A)	109.5
H(3A)-C(3)-H(3B)	109.5	C(9)-C(12)-H(12B)	109.5
C(1)-C(3)-H(3C)	109.5	H(12A)-C(12)-H(12B)	109.5
H(3A)-C(3)-H(3C)	109.5	C(9)-C(12)-H(12C)	109.5
H(3B)-C(3)-H(3C)	109.5	H(12A)-C(12)-H(12C)	109.5
C(1)-C(4)-H(4A)	109.5	H(12B)-C(12)-H(12C)	109.5
C(1)-C(4)-H(4B)	109.5	N(1)-C(13)-H(13A)	109.0
H(4A)-C(4)-H(4B)	109.5	C(14)-C(13)-H(13A)	109.0
C(1)-C(4)-H(4C)	109.5	N(1)-C(13)-H(13B)	109.0
H(4A)-C(4)-H(4C)	109.5	C(14)-C(13)-H(13B)	109.0
H(4B)-C(4)-H(4C)	109.5	H(13A)-C(13)-H(13B)	107.8
N(1)-C(6)-H(6A)	108.3	C(15)-C(14)-H(14A)	108.7
C(5)-C(6)-H(6A)	108.3	C(13)-C(14)-H(14A)	108.7
N(1)-C(6)-H(6B)	108.3	C(15)-C(14)-H(14B)	108.7

C(13)-C(14)-H(14B)	108.7	H(23A)-C(23)-H(23B)	109.5
H(14A)-C(14)-H(14B)	107.6	C(20)-C(23)-H(23C)	109.5
N(2)-C(15)-H(15A)	109.4	H(23A)-C(23)-H(23C)	109.5
C(14)-C(15)-H(15A)	109.4	H(23B)-C(23)-H(23C)	109.5
N(2)-C(15)-H(15B)	109.4	N(3)-C(24)-H(24A)	108.3

Table 2S Bond lengths [Å] and angles [deg] for TTDA-4est·HBr (continued).

C(14)-C(15)-H(15B)	109.4	C(25)-C(24)-H(24A)	108.3
H(15A)-C(15)-H(15B)	108.0	C(25)-C(24)-H(24B)	108.3
N(2)-C(16)-H(16A)	109.7	C(25)-C(24)-H(24B)	108.3
C(17)-C(16)-H(16A)	109.7	H(24A)-C(24)-H(24B)	107.4
N(2)-C(16)-H(16B)	109.7	C(26)-C(27)-H(27A)	109.5
C(17)-C(16)-H(16B)	109.7	C(26)-C(27)-H(27B)	109.5
H(16A)-C(16)-H(16B)	108.2	H(27A)-C(27)-H(27B)	109.5
N(3)-C(17)-H(17A)	109.4	C(26)-C(27)-H(27C)	109.5
C(16)-C(17)-H(17A)	109.4	H(27A)-C(27)-H(27C)	109.5
N(3)-C(17)-H(17B)	109.4	H(27B)-C(27)-H(27C)	109.5
C(16)-C(17)-H(17B)	109.4	C(26)-C(28)-H(28A)	109.5
H(17A)-C(17)-H(17B)	108.0	C(26)-C(28)-H(28B)	109.5
N(3)-C(18)-H(18A)	108.9	H(28A)-C(28)-H(28B)	109.5
C(19)-C(18)-H(18A)	108.9	C(26)-C(28)-H(28C)	109.5
N(3)-C(18)-H(18B)	108.9	H(28A)-C(28)-H(28C)	109.5
C(19)-C(18)-H(18B)	108.9	H(28B)-C(28)-H(28C)	109.5
H(18A)-C(18)-H(18B)	107.7	C(26)-C(29)-H(29A)	109.5
C(20)-C(21)-H(21A)	109.5	C(26)-C(29)-H(29B)	109.5
C(20)-C(21)-H(21B)	109.5	H(29A)-C(29)-H(29B)	109.5
H(21A)-C(21)-H(21B)	109.5	C(26)-C(29)-H(29C)	109.5
C(20)-C(21)-H(21C)	109.5	H(29A)-C(29)-H(29C)	109.5
H(21A)-C(21)-H(21C)	109.5	H(29B)-C(29)-H(29C)	109.5
H(21B)-C(21)-H(21C)	109.5		
C(20)-C(22)-H(22A)	109.5		
C(20)-C(22)-H(22B)	109.5		
H(22A)-C(22)-H(22B)	109.5		
C(20)-C(22)-H(22C)	109.5		
H(22A)-C(22)-H(22C)	109.5		
H(22B)-C(22)-H(22C)	109.5		
C(20)-C(23)-H(23A)	109.5		
C(20)-C(23)-H(23B)	109.5		

Table 3S Hydrogen bonds for TTDA-4est·HBr [Å and deg.].

D-H...A	d(D-H)	d(H...A)	d(D...A)	<(DHA)
N(2)-H(2D)...Br	0.95(4)	2.27(4)	3.209(3)	170(3)
N(2)-H(2E)...O(4)	0.87(3)	2.55(2)	3.035(4)	116(2)
N(2)-H(2E)...N(1)	0.87(3)	2.17(3)	2.876(4)	138(2)

Table 4S Temperature dependence of reduced transverse and longitudinal ^{17}O relaxation rates and reduced angular frequencies of solutions containing $[Gd(TTDASQ)]^-$ at 9.4 T. (c = 0.022 mol kg^{-1}, pH = 6.2)

1000K/T	$\ln(1/T_{2r})$	$\ln(1/T_{1r})$	$\Delta\omega_r/10^6$ rad s^{-1}
3.595	13.771	10.812	-0.273
3.531	13.785	10.809	-0.440
3.411	13.957	10.730	-0.524
3.224	14.021	10.039	-0.651
3.047	13.878	9.583	-0.713
2.957	13.735	9.438	-0.722
2.872	13.528	9.084	-0.709

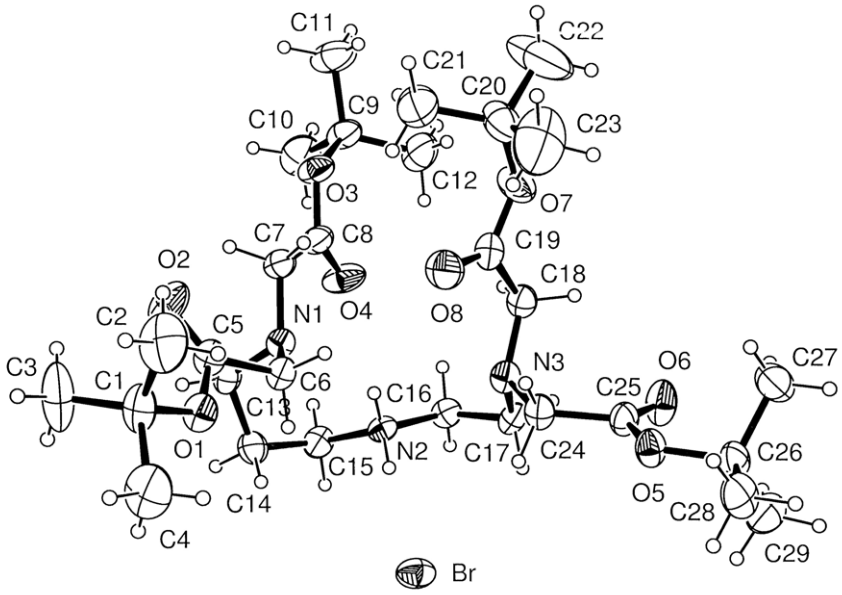

Fig. 1S Molecular view of TTDA-4est·HBr.

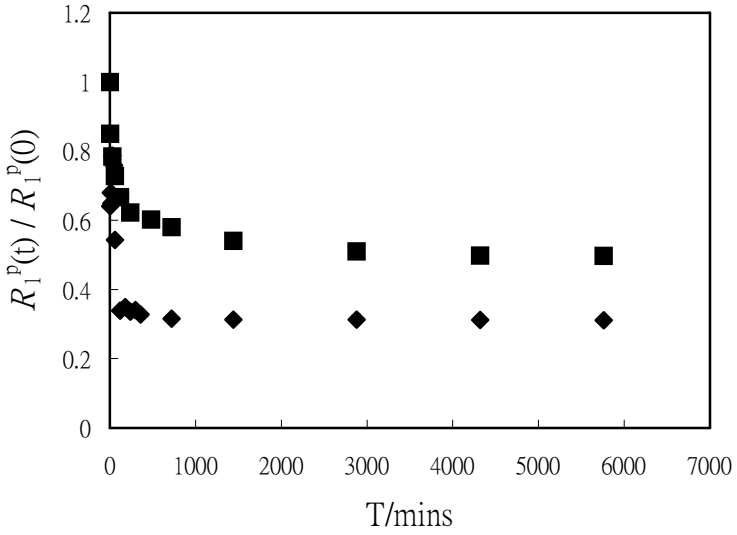

Fig. 2S The relative water proton paramagnetic longitudinal relaxation rate R_{1p} (t)/R_{1p}(0) vs. time for $[Gd(TTDASQ)]^-$(◆) and $[Gd(DTPA)]^{2-}$ (■). The solution contained Gd(III) complex(2.5 mmol dm^{-3}) and $ZnCl_2$ (2.5 mmol dm^{-3}) in phosphate buffer.

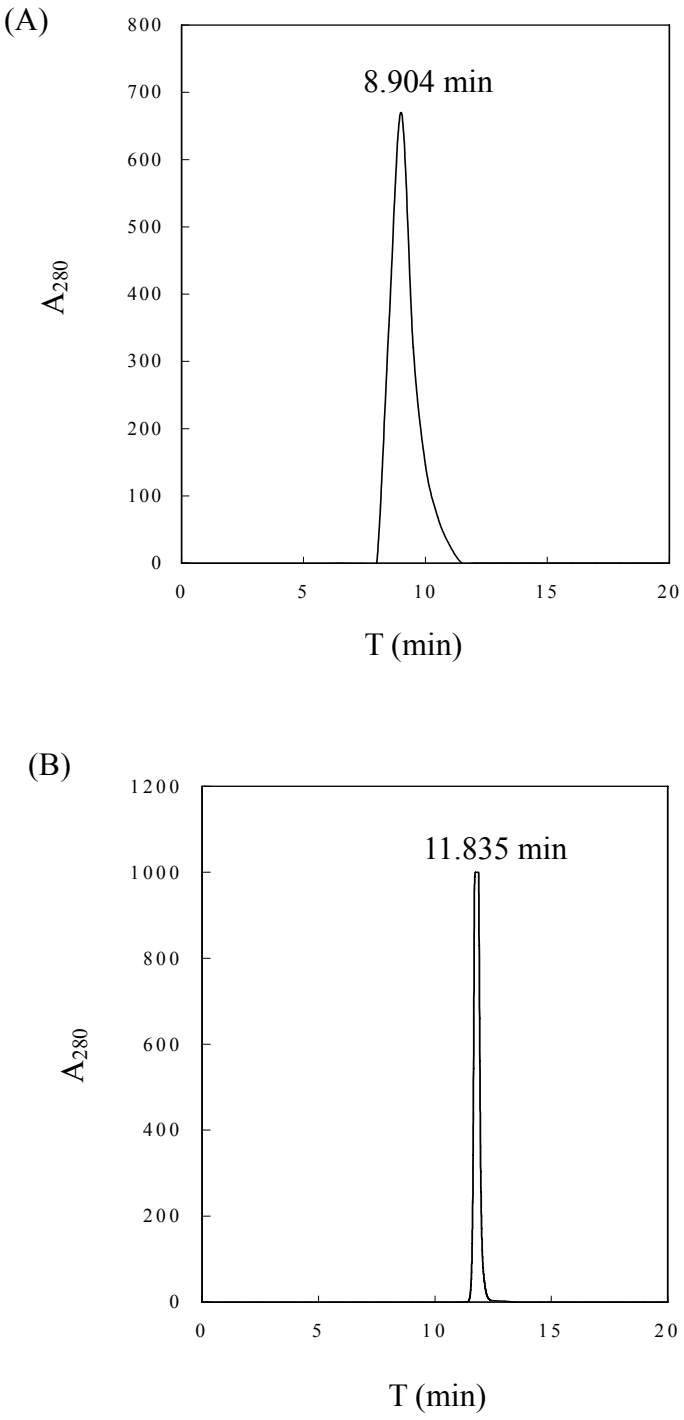

Fig. 3S The elution curve of (A) [$(TTDASQ)_n$-pro_{19}] and (B) TTDASQ on HPLC. Column: $G2000SW_{XL}$, Mobile phase: 10 mmol dm^{-3} phosphate buffer, Detector: UV 280 nm, Flow rate: 0.75 ml/min.

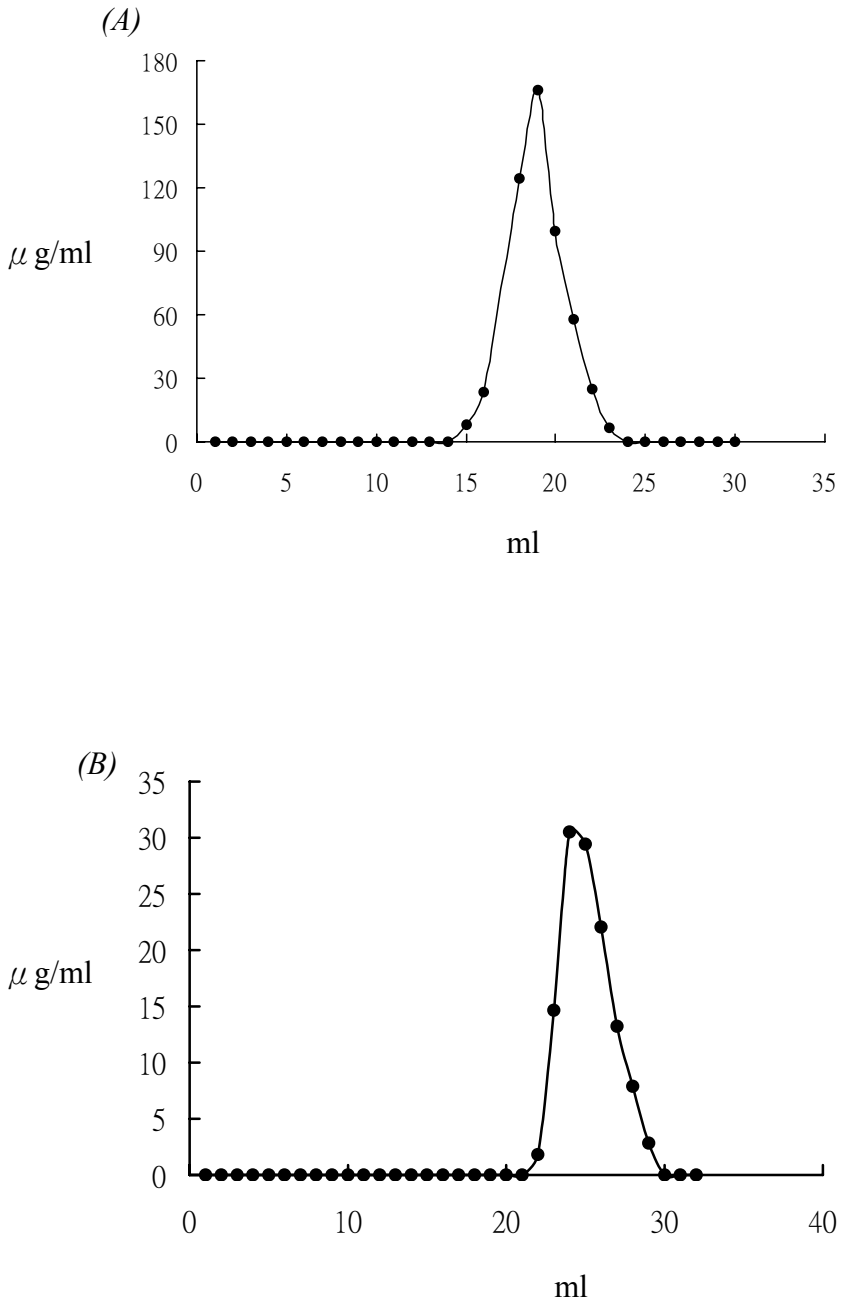

Fig. 4S The elution curve of (A) protamine (B) $(TTDASQ)_3$-pro_{19} using gradient 0~2 mol dm^{-3} NaCl as an eluent and heparin affinity column (HiTrap heparin 1 × 5ml).

S1 Variable-Temperature ^{17}O NMR Measurements. From the measured ^{17}O NMR relaxation rates and angular frequencies of the Gd^{3+} containing solutions, $1/T_1$, $1/T_2$, and ω, and of the acidified water reference, $1/T_{1A}$, $1/T_{2A}$, and ω_A, one can calculate the reduced relaxation rates and chemical shift, $1/T_{1r}$, $1/T_{2r}$, and $\Delta\omega_r$:

$$\frac{1}{T_{1r}} = \frac{1}{P_m}\left[\frac{1}{T_1} - \frac{1}{T_{1A}}\right] = \frac{1}{T_{1m} + \tau_m} \quad (1S)$$

$$\frac{1}{T_{2r}} = \frac{1}{P_m}\left[\frac{1}{T_2} - \frac{1}{T_{2A}}\right] = \frac{1}{\tau_m}\frac{T_{2m}^{-2} + \tau_m^{-1}T_{2m}^{-1} + \Delta\omega_m^2}{\left(\tau_m^{-1} + T_{2m}^{-1}\right)^2 + \Delta\omega_m^2} \quad (2S)$$

$$\Delta\omega_r = \frac{1}{P_m}(\omega - \omega_A) = \frac{\Delta\omega_m}{\left(1 + \tau_m T_{2m}^{-1}\right)^2 + \tau_m^2\Delta\omega_m^2} + \Delta\omega_{os} \quad (3S)$$

P_m is the mole fraction of bound water.

$1/T_{2m}$ are the relaxation rates in the bound water.

$\Delta\omega_m$ is the chemical shift difference between bound water and bulk water.

$$\Delta\omega_m = \frac{g_L\mu_B S(S+1)B}{3k_B T}\frac{A}{\hbar} \quad (4S)$$

where g_L is the isotropic Landé g factor ($g_L = 2.0$ for Gd^{3+})

S is the electron spin (S= 7/2 for Gd^{3+})

$A/\hbar$ is the hyperfine or scalar coupling constant

B is the magnetic field

$$\frac{1}{T_{2m}} \cong \frac{1}{T_{2sc}} = \frac{S(S+1)}{3}\left(\frac{A}{\hbar}\right)^2\left[\tau_{1S} + \frac{\tau_{2S}}{1 + \omega_S^2\tau_{2S}^2}\right] \quad (5S)$$

where $1/\tau_{is} = 1/\tau_m + 1/T_{ie}$

$\Delta H^{\neq}$ and $\Delta S^{\neq}$ are the enthalpy and entropy of activation for the exchange process :

$$\frac{1}{\tau_m} = k_{ex} = \frac{k_B T}{h}\exp\left\{\frac{\Delta S^*}{R} - \frac{\Delta H^*}{RT}\right\} \quad (6S)$$

The ^{17}O longitudinal relaxation rates in Gd^{3+} solutions are dominated by the dipole-dipole and quadrupolar mechanisms, and are given by below :

$$\frac{1}{T_{1m}} = \left[\frac{1}{15}\left(\frac{\mu_0}{4\pi}\right)^2\frac{\hbar^2\gamma_I^2\gamma_S^2}{r_{GdO}^6}S(S+1)\right]\left[6\pi_{c1} + 14\frac{\tau_{d2}}{1 + \omega_S^2\tau_{c2}}\right] + \frac{3\pi^2}{10}\frac{2I+3}{I^2(2I-1)}\chi^2\left(1 + \frac{\eta^2}{3}\right)\tau_R \quad (7S)$$

where γ_I is the nuclear gyromagnetic ratio ($\gamma_I = -3.626 \times 10^7$ rad s^{-1} T^{-1} for ^{17}O), r_{GdO} is the mean Gd^{3+}–O distance, I is the nuclear spin ($I = 5/2$ for ^{17}O), χ is the quadrupolar coupling constant, η an asymmetry parameter, and $\tau_{ci}^{-1} = \tau_m^{-1} + T_{ie}^{-1} + \tau_R^{-1}$. Using the

quadrupolar coupling constant for acidified water, $\chi (1 + \eta^2/3)^{1/2} = 7.58$ MHz, and estimating $r = 2.5$ Å[24] from the available crystal structure.

$$\tau_R = \tau_R^{298} \exp\left[\frac{E_R}{R}\left(\frac{1}{T} - \frac{1}{298.15}\right)\right] \quad (8S)$$

E_R : activation energy

The outer-sphere contribution to $\Delta\omega_r$ has a similar temperature dependence to $\Delta\omega_m$ and is given by below, where C_{os} is an empirical constant.

$$\Delta\omega_{os} = C_{os}\Delta\omega_m \quad (9S)$$

Since only one field was used for the ^{17}O study, the electronic relaxation rate, $1/T_{1e}$, was assumed to have an exponential temperature dependence, equation (10S).

$$\frac{1}{T_{1e}^{HF}} = \frac{1}{T_{1e}^{310}} \exp\left[\frac{E_{T1e}}{R}\left(\frac{1}{T} - \frac{1}{310.15}\right)\right] \quad (10S)$$