

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/24308621>

ChemInform Abstract: Azacrown–Oxabridged Macrocycles: A Novel Hybrid Fluorogenic Chemosensor for Transition and Heavy Metal Ions

ARTICLE *in* CHEMICAL COMMUNICATIONS · JUNE 2009

Impact Factor: 6.83 · DOI: 10.1039/b820479a · Source: PubMed

CITATIONS

21

READS

20

3 AUTHORS, INCLUDING:



Faiz Ahmed Khan

Indian Institute of Technology Hyderabad

110 PUBLICATIONS 1,663 CITATIONS

SEE PROFILE



Kalyan Sadhu

Indian Institute of Technology Roorkee

20 PUBLICATIONS 199 CITATIONS

SEE PROFILE

Electronic Supplementary Information (ESI)

Azacrown-Oxabridged Macrocycle: A Novel Hybrid Fluorogenic Chemosensor for Transition and Heavy Metal Ions

Faiz Ahmed Khan,* Karuppasamy Parasuraman and Kalyan Kumar Sadhu

Department of Chemistry, Indian Institute of Technology, Kanpur 208016, India.

Contents

General methods and experimental procedures: **S3 – S6**

Copies of ^1H and ^{13}C spectra: **S7 – S11**

Table S1. Absorption maxima and corresponding molar extinction coefficients (ϵ), total fluorescence quantum yields (ϕ_F) and corresponding enhancement factor in MeCN in presence of various ionic inputs for **L1** : **S12**

Figure S1. The absorption spectral changes of **L1** in the presence of alkali, alkaline earth metal and the transition metal ions in dry acetonitrile : **S13**

Figure S2. The absorption spectral changes of **L1** in dry acetonitrile upon addition of increasing equivalent of Zn^{2+} : **S13**

Figure S3. Plot for association constant determination of 1: 1 **L1**: Zn^{2+} complex. : **S14**

Figure S4. Fluorescence spectral changes of **L1** with the addition of Hg^{2+} in dry acetonitrile solution. and determination of association constant **S14**

Figure S5. Fluorescence spectral changes of **L1** with the addition of Ag^+ in dry S15 acetonitrile solution. and determination of association constant :**S15**

Figure S6. Fluorescence spectral changes of **L1** with the addition of Co^{2+} in dry acetonitrile solution. and determination of association constant :**S15**

Figure S7. Fluorescence spectral changes of **L1** with the addition of Cu^{2+} in dry acetonitrile solution. and determination of association constant :**S16**

Figure S8. ^1H -NMR of the compound **L2**. : **S16**

Table S2. Absorption maxima and corresponding molar extinction coefficients (ϵ), total fluorescence quantum yields (ϕ_F) and corresponding enhancement factor in acetonitrile in presence of various ionic inputs for **L2** : **S17**

Figure S9. The absorption spectral changes of **L2** in presence of an alkali, alkaline earth metal and the transition metal ions in dry acetonitrile : **S18**

Figure S10. Fluorescence spectra of the **L2** alone and in the presence of different ionic inputs in acetonitrile. : **S18**

Figure S11: X-ray crystal structure of the **L1**. : **S19**

Figure S12: X-ray crystal structure of the **L1+Na⁺**. : **S19**

Experimental for data collection and structure solution : **S20**

Figure S13. Fluorescence response of **L1** in the presence Zn^{2+} and other metal ion mixtures in acetonitrile. $[\text{L1}] = 1.9 \times 10^{-7} \text{ M}$, $[\text{M}^{n+}] = 1.9 \times 10^{-5} \text{ M}$. $\lambda_{\text{ex}} = 350 \text{ nm}$. : **S20**

Figure S14. A truth table for the inhibit (INH) logic gate : **S20**

Table S3. Selected bond length and bond angle for the Na^+ coordination environment in the **L1+Na⁺** complex. : **S21**

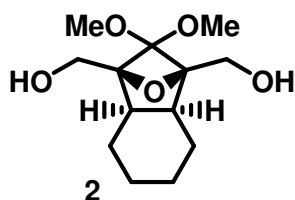
General Methods:

Melting points were recorded on JSGW melting point apparatus and are uncorrected. IR spectra were recorded as KBr pellets (solids) or thin films (liquids). ^1H NMR and proton-decoupled ^{13}C NMR spectra were recorded at 400 and 100 MHz, respectively. Data are reported as follows: (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet; coupling constant(s) in Hz.). TLC was performed on silica gel coated on microscopic slides. Visualization of spots was effected by exposure to iodine or spraying with 4% ethanolic H_2SO_4 and charring. Samples for NMR were made in CDCl_3 ; tetramethylsilane was used as the internal standard. X-ray data were collected on a Bruker SMART APEX diffractometer. The structures were solved using SIR-92¹ and refined using SHELXL-97².

UV – Visible spectra were recorded on a JASCO V-570 spectrophotometer at 293 K and it was the average of three measurements. The deviation found for molar absorption coefficient in the last digit only. Steady-state Fluorescence spectra were obtained using a Perkin-Elmer LS 50B Luminescence spectrophotometer at 293 K with excitation and emission band-pass, 5 nm; $\lambda_{\text{ex}} = 350$ nm. Steady-state Fluorescence anisotropy data were obtained using a Perkin-Elmer LS 55 Fluorometer at 293 K with slit width 5nm and integration time 40 sec. Quantum Yield of the all the compounds were determined by comparing the corrected ϕ_{FT} spectrum with that of anthracene ($\phi_{\text{F}} = 0.297$) in ethanol³ taking the area under the total emission. The solid-state emission spectra were recorded using a Fluorolog3, model FL3-22, SPEX spectrometer excited at 350 nm with a 450 W Xenon lamp at a band pass of 2 nm and the integration time was kept at 0.2 sec.

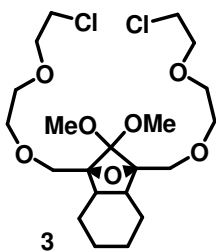
Experimental Procedures:

Compound: 2



To a flame dried 50 mL round bottom flask charged with diester **1** (1.59 gm, 5.08 mmol) in 14 mL dry THF NaBH₄ (1.12 gm, 5.95 mmol) was added under argon atmosphere and refluxed for 21 h. Reaction mixture was cooled to room temperature and added ice pieces to quench excess NaBH₄ and diluted with water (20 mL), extracted with ethyl acetate (7 mL x 4) and organic layer washed with water (3 mL x 2), dried over Na₂SO₄, filtered and concentrated afforded the thick liquid which on drying under vacuum yields the colorless solid (1.259 gm). Yield: 96%; mp: 112–114 °C. ¹H NMR (400 MHz, CDCl₃): δ 3.81 (q, *J* = 12.7 Hz, 4H), 3.44 (s, 3H), 3.26 (s, 3H), 2.3 (br, 2H), 2.24 (s, 2H), 1.63 (s, 2H), 1.3 (s, 6H); ¹³C NMR (100 MHz, CDCl₃): δ 108.4 94.5 (2C), 59.1 (2C), 52.2, 51.1, 39.5 (2C), 17.9 (2C), 17.4 (2C); IR (KBr): 3300, 2800, 1450, 1170 cm⁻¹; Anal. Calcd. for C₁₃ H₂₂ O₅: C 60.45, H 8.58; Found: C 60.43, H 8.55.

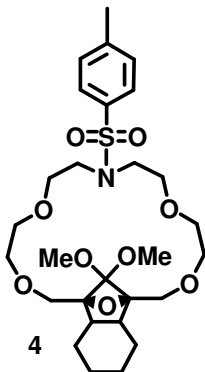
Compound: 3



To a ice cold solution of diol **2** (500 mg, 1.94 mmol), bis(2-chloroethyl) ether (15 mL) and tetra-*n*-butylammonium hydrogen sulfate (1.32 gm, 3.88 mmol), 50% NaOH solution was added drop wise over 10 min. and the reaction mixture was stirred at room temperature for 48 h under argon atmosphere. 25 mL distilled water followed by 25 mL dichloromethane were added and stirred for 2 min. organic layer was separated and the aqueous layer was extracted by dichloromethane (5 mL x 4), combined organic layer was washed with water (3 mL), brine solution (3 mL) and dried over Na₂SO₄, filtered and concentrated. The product was purified by silica gel column chromatography using 20–30 % ethyl acetate / hexane as eluent afforded 772 mg thick liquid. Yield: 85%, ¹H NMR (400 MHz, CDCl₃): δ 3.79 – 3.51 (m, 20H), 3.46 (s, 3H), 3.27 (s, 3H), 2.39 – 2.33 (m, 2H), 1.69 – 1.67 (m, 2H), 1.47 – 1.32 (m, 6H); ¹³C NMR (100 MHz, CDCl₃): δ 105.7, 94.0 (2C), 71.2 (2C), 70.9 (2C), 70.3 (2C), 65.1 (2C), 51.8,

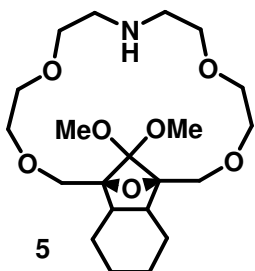
51.6, 42.6 (2C), 39.9 (2C), 18.1 (2C), 17.3 (2C); IR (Neat): 2940, 1454, 1120 cm^{-1} ; Anal. Calcd. for $\text{C}_{21} \text{H}_{36} \text{Cl}_2 \text{O}_7$: C 53.50, H 7.70; Found: C 53.52, H 7.67.

Compound: 4



Compound **3** (1.24 gm, 2.63 mmol), anhydrous K_2CO_3 (2.9 gm, 20.98 mmol) and p-toluenesulfonamide (540 mg, 3.15 mmol) were taken in dry acetonitrile (20 mL) and refluxed for 63 h under argon atmosphere. 25 mL water followed by 25 mL of dichloromethane was added, stirred for 2 min. Organic layer was separated and the aqueous layer was extracted with dichloromethane (4 mL x 5), washed with water (3 mL) and brine solution (3 mL), dried over Na_2SO_4 , filtered and concentrated. The product was purified by silica gel column chromatography using 40–50 % ethyl acetate / hexane as eluent afforded 802 mg of pale yellowish thick liquid. Yield: 57%, ^1H NMR (400 MHz, CDCl_3): δ 7.64 (d, J = 8 Hz, 2H), 7.22 (d, J = 8.3 Hz, 2H), 3.94 – 3.16 (m, 23H), 3.12 (s, 3H), 2.35 (s, 3H), 2.1 – 2.08 (m, 2H), 1.6 – 1.58 (m, 2H), 1.29 – 1.28 (m, 6H); ^{13}C NMR (100 MHz, CDCl_3): δ 143.2, 136.2, 129.6 (2C), 127.2 (2C), 107.6, 94.4 (2C), 71.2 (2C), 70.7 (2C), 70.1 (2C), 67 (2C), 52.5, 51, 49.9 (2C), 40.85 (2C), 21.5, 18.2 (2C), 18.02 (2C); IR (Neat): 2937, 1598, 1342, 1117 cm^{-1} ; Anal. Calcd. for $\text{C}_{28} \text{H}_{43} \text{N O}_9 \text{S}$: C 59.03, H 7.61, N 2.46; Found: C 59.05, H 7.64, N 2.47.

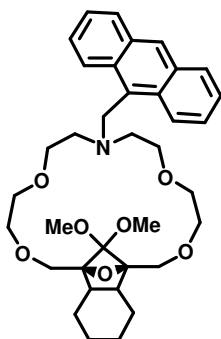
Compound: 5



In a flame dried 50 mL two neck round bottom flask charged with naphthalene (495 mg, 386 mmol), sodium metal (111 mg, 4.82 mmol) in dimethoxyethane (6 mL) was stirred at room temperature 1.5 h (until the deep greenish color develop), cooled to -55 to -60 $^{\circ}\text{C}$ and added compound **4** (275 mg, 0.483 mmol) dissolved in 2 mL of dimethoxyethane drop wise via septum over 5 min and allow to warm to -10 $^{\circ}\text{C}$ and stirred for about 2 h (TLC). Reaction mixture was quenched with water at the same temperature and diluted with water (10 mL), extracted with dichloromethane (4 mL x 5). The organic layer washed with 1M HCl (4 mL x 5) and resultant aqueous layer was

basified (pH = 10) with NaOH pellet at 0 – 5 °C which upon extracted with dichloromethane (4 mL x 5). Organic layer washed with water (2 mL), brine solution (2 mL) dried over Na₂SO₄, filtered and concentrated. The product was purified by neutral alumina column chromatography using 30–40 % ethyl acetate / hexane as eluent afforded 152 mg thick liquid. Yield: 76%, ¹H NMR (400 MHz, CDCl₃): δ 3.87 – 3.49 (m, 16H), 3.37 (s, 3H), 3.19 (s, 3H), 2.78 (t, *J* = 4.9 Hz, 4H), 2.15 (s, 2H), 1.61 (s, 2H), 1.29 – 1.27 (m, 6H); ¹³C NMR (100 MHz, CDCl₃): δ 107.3, 94.4 (2C), 71.3 (2C), 70.5 (2C), 69.9 (2C), 66.1 (2C), 52.5, 51.2, 49.7 (2C), 40.2 (2C), 18.1 (2C), 17.8 (2C); IR (Neat): 3421, 2934, 1634, 1456 cm⁻¹; Anal. Calcd. for C₂₁ H₃₇ N O₇: C 60.70, H 8.98, N 3.37; Found: C 60.67, H 8.98, N 3.35.

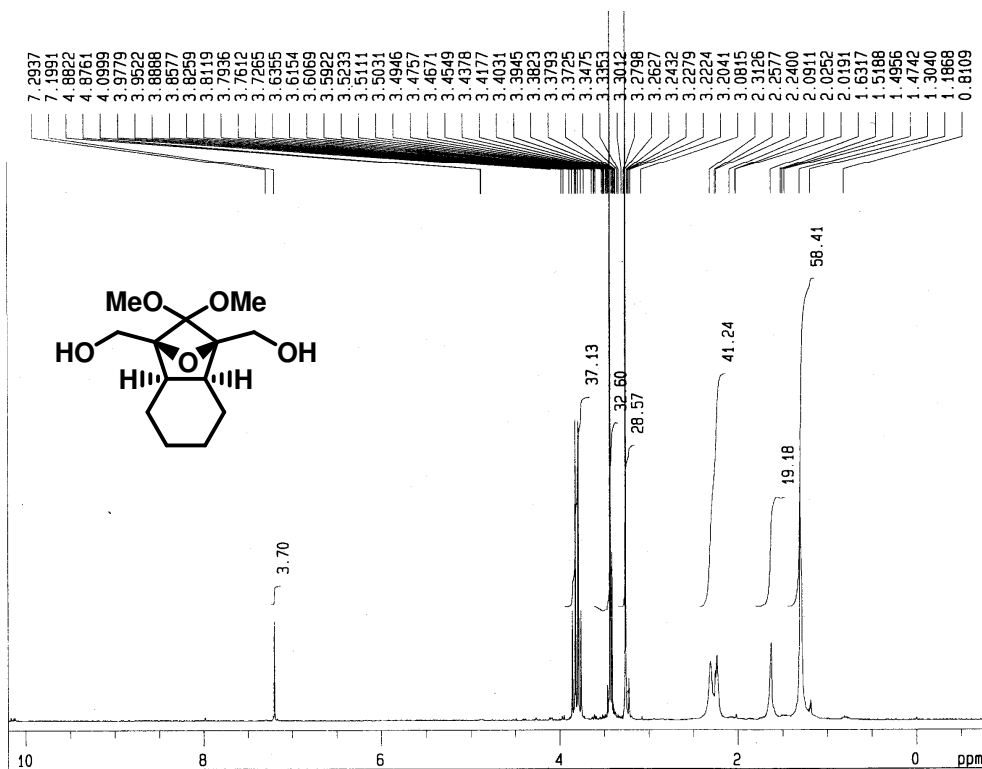
Compound L1



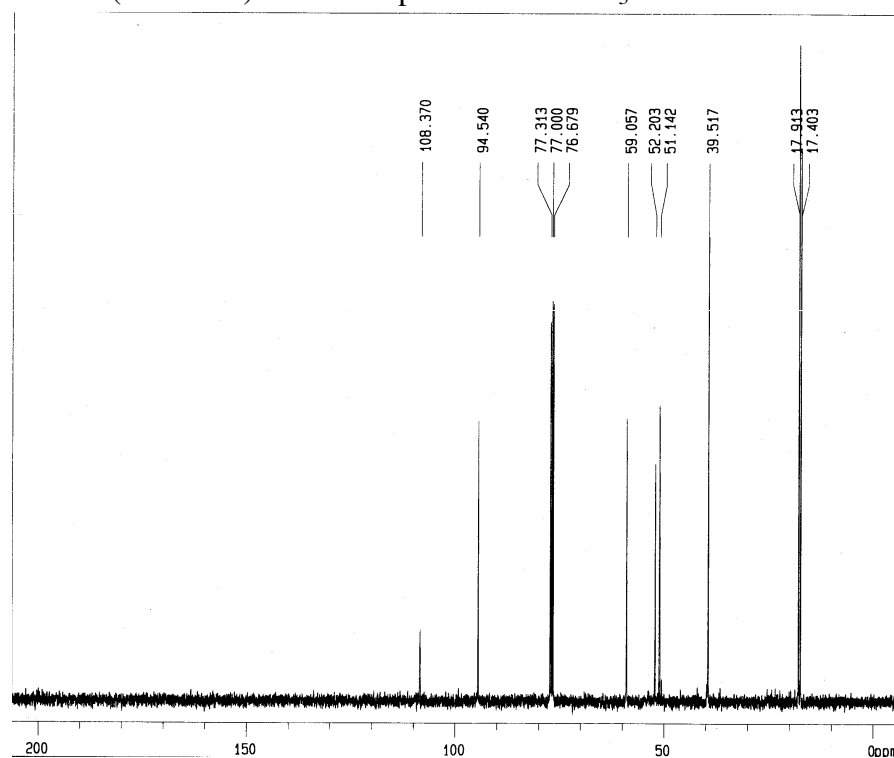
In a flame dried 50 mL round bottom flask compound **5** (100 mg, 0.24 mmol), 9-bromomethyl anthracene (98 mg, 0.361 mmol), K₂CO₃ (83 mg, 0.6 mmol) and KI (30 mg, 0.18 mmol) were taken in N,N-dimethylformamide (10 mL) and heated to 80 °C for 8 h. Reaction mixture cooled to room temperature diluted with water (10 mL), extracted with ethyl acetate (4 mL x 3), washed with water (2 mL), brine solution (2 mL), dried over Na₂SO₄, filtered and concentrated.

The product was purified by basic alumina column chromatography using 20 % ethyl acetate / hexane as eluent afforded 110 mg pale yellowish solid. Yield: 79%, mp: 120 °C; ¹H NMR (400 MHz, CDCl₃): δ 8.53 (d, *J* = 8.8 Hz, 2H), 8.37 (s, 1H), 7.9 (d, *J* = 8.3 Hz, 2H), 7.49 – 7.4 (m, 4H), 4.59 (s, 2H), 3.91 – 3.46 (m, 16H), 3.36 (s, 3H), 3.19 (s, 3H), 2.9 – 2.82 (m, 4H), 2.19 – 2.17 (m, 2H), 1.74 – 1.67 (m, 2H), 1.36 (m, 6H); ¹³C NMR (100 MHz, CDCl₃): δ 131.3 (2C), 130.3 (2C), 128.8 (2C), 127.4 (2C), 125.5 (2C), 125.3 (2C), 124.7 (2C), 107.3, 94.5 (2C), 71.0 (2C), 70.4 (2C), 69 (2C), 66.3 (2C), 54.3 (2C), 52.4, 52.4, 51.1, 40.5 (2C), 18.2 (2C), 17.9 (2C); IR (KBr): 2800, 1440, 1330, 1080 cm⁻¹; Anal. Calcd. for C₃₆ H₄₇ N O₇: C 71.38, H 7.82, N 2.31; Found: C 71.41, H 7.85, N 2.32.

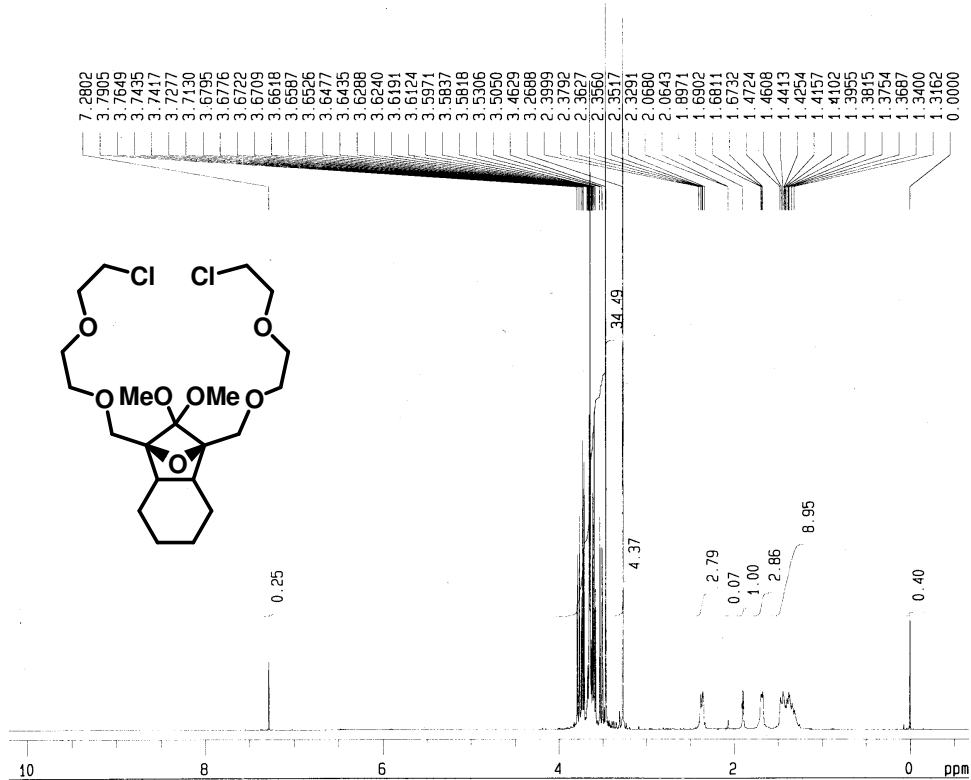
Copies of ¹H and ¹³C spectra:



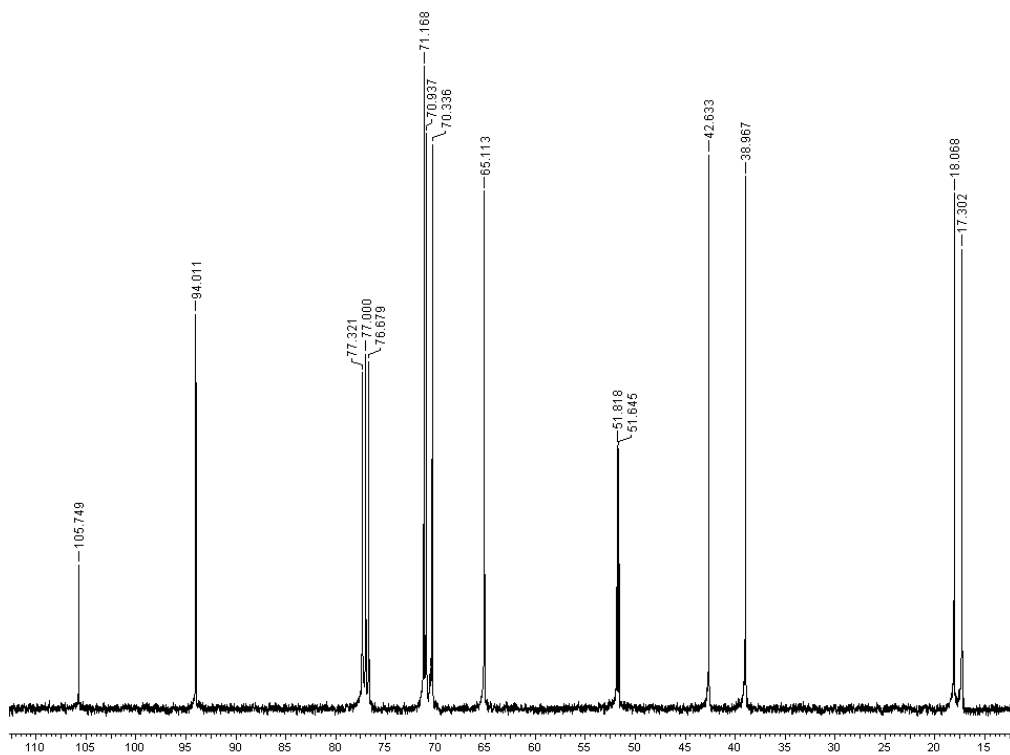
¹H NMR (400 MHz) of the compound **2** in CDCl₃



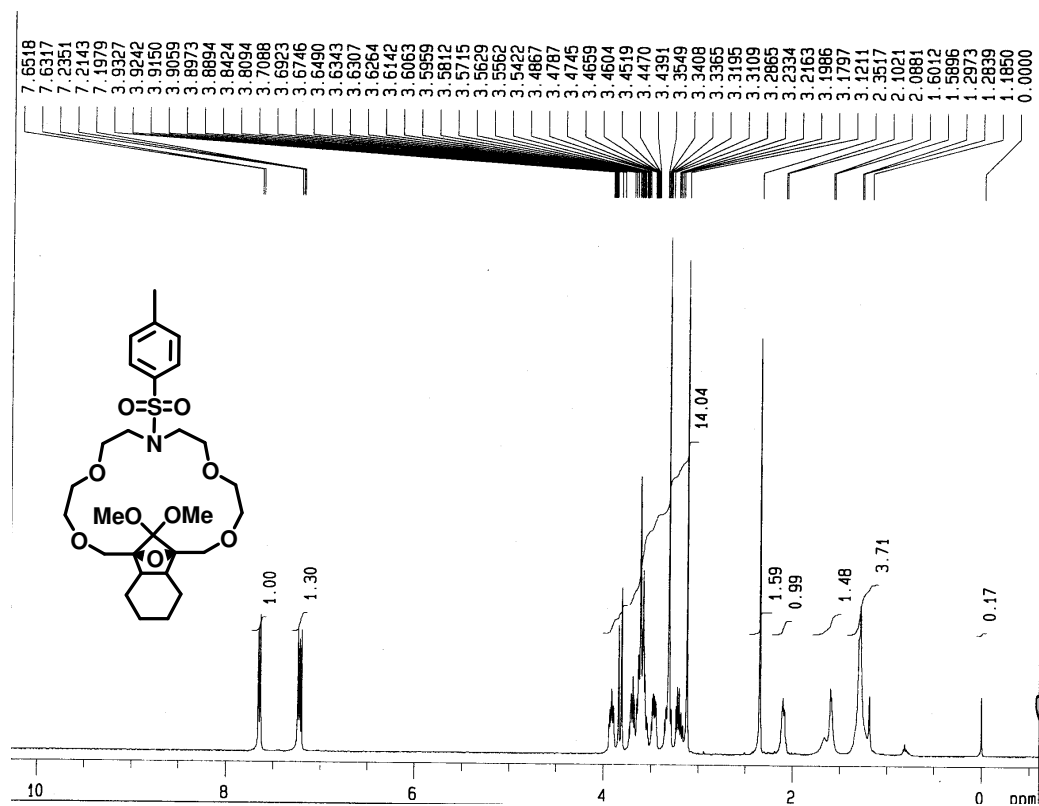
¹³C NMR (100 MHz) of the compound **2** in CDCl₃



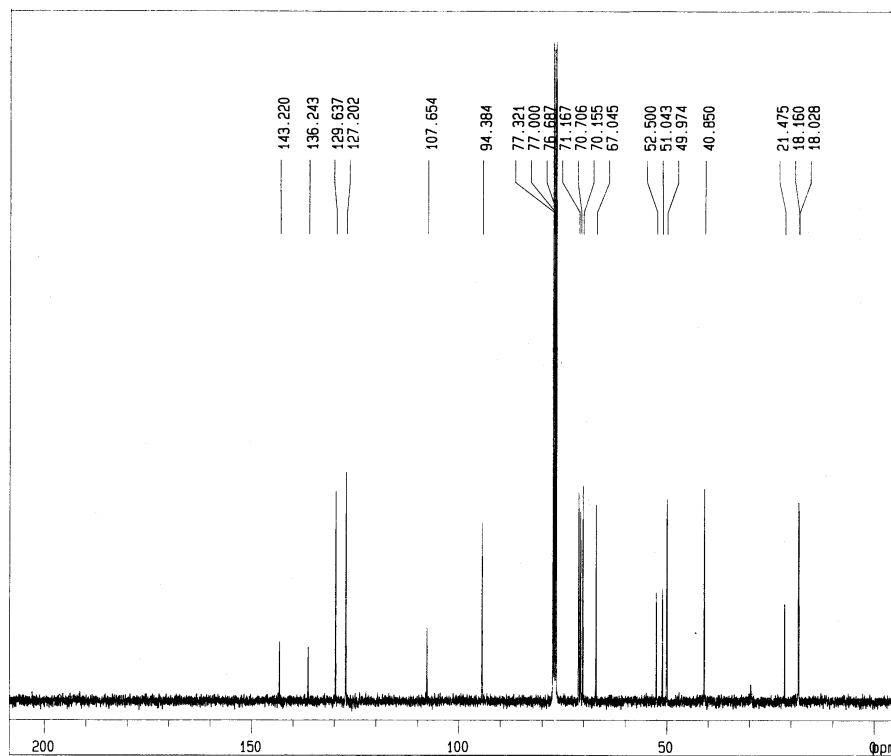
¹H NMR (400 MHz) of the compound **3** in CDCl₃



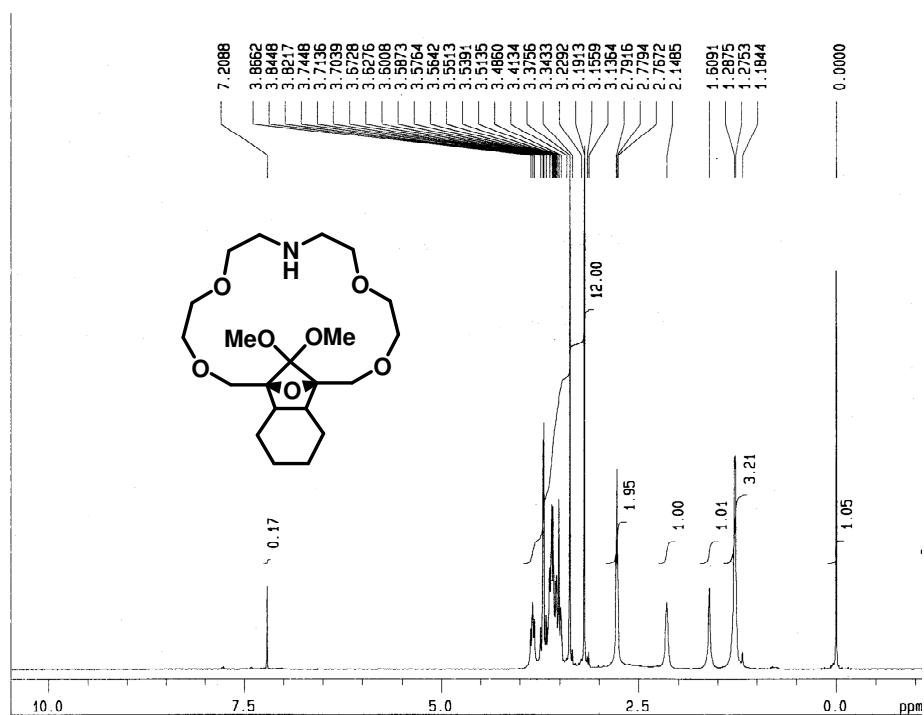
¹³C NMR (100 MHz) of the compound **3** in CDCl₃



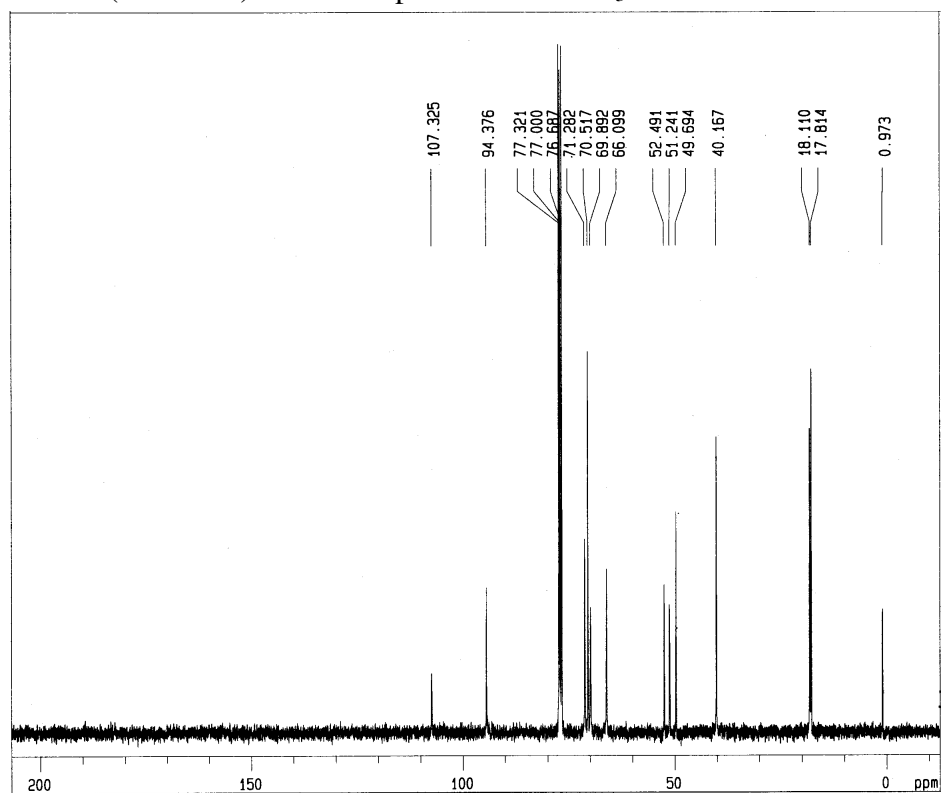
¹H NMR (400 MHz) of the compound **4** in CDCl₃



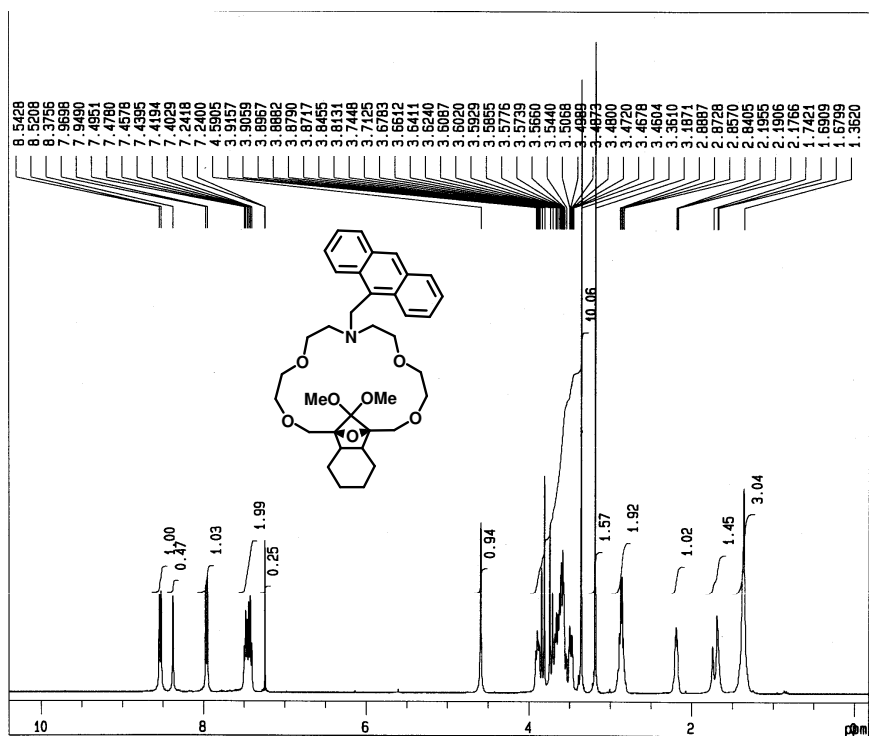
¹³C NMR (100 MHz) of the compound **4** in CDCl₃



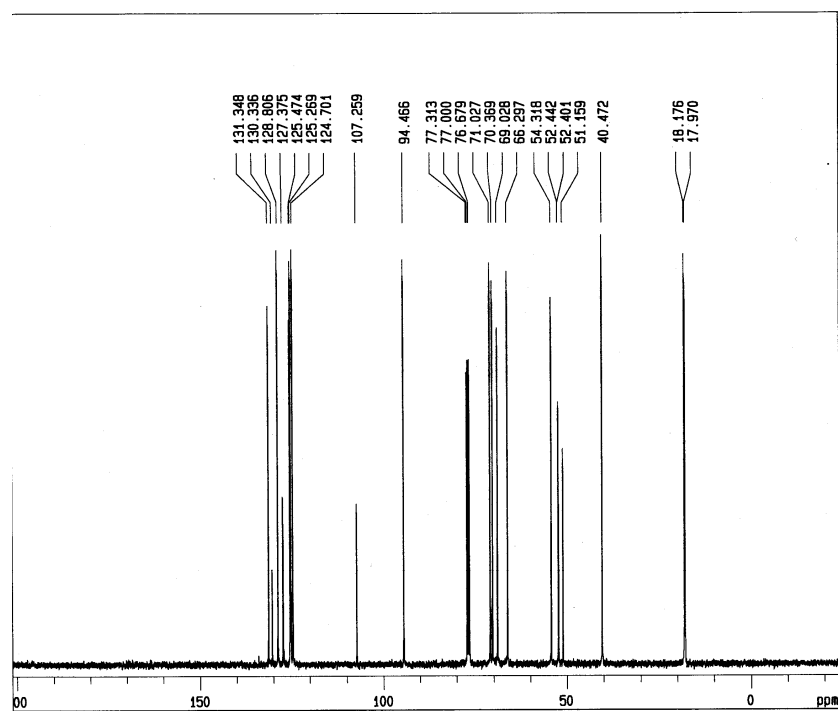
¹H NMR (400 MHz) of the compound **5** in CDCl₃



¹³C NMR (100 MHz) of the compound **5** in CDCl₃



¹H NMR (400 MHz) of the compound **L1** in CDCl₃



¹³C NMR (100 MHz) of the compound **L1** in CDCl₃

Table S1: Absorption maxima and corresponding molar extinction coefficients (ϵ), total fluorescence quantum yields (ϕ_F) and corresponding enhancement factor in MeCN in presence of various ionic input for **L1**. $[\mathbf{L1}] = 1 \times 10^{-5}$ M, $[\mathbf{M}^{n+}] = 1 \times 10^{-3}$ M.

S.No.	Ionic Input	Band position, nm (ϵ , $\text{dm}^3 \text{mol}^{-1} \text{cm}^{-1}$)	Quantum Yield (ϕ_F)	FE
1	L1	386 (8159) 366 (8956) 348 (5788) 332 (2939)	0.004	1
2	Li(I)	386 (7852) 365 (8521) 349 (5367) 331 (2295)	0.007	2
3	Na(I)	386 (7787) 367 (8509) 347 (5567) 332 (2468)	0.006	2
4	K(I)	385 (7873) 365 (8503) 347 (5332) 331 (2327)	0.022	6
5	Mg(II)	388 (5944) 369 (7410) 350 (5109) 336 (2377)	0.094	24
6	H ⁺	389 (5249) 369 (6825) 351 (5215) 336 (2752)	0.029	7
7	TEA	385 (7901) 365 (8510) 347 (5329) 332 (2369)	0.007	2
8	Mn(II)	389 (6146) 369 (7595) 353 (5365) 336 (2680)	0.102	26
9	Co(II)	387 (6365) 367 (7722) 350 (5483) 335 (2844)	0.110	28
10	Ni(II)	387 (6129) 369 (7516) 350 (5231) 333 (2401)	0.078	20
11	Cu(II)	389 (5746) 369 (7042) 352.5 (5194) 335 (3085)	0.104	26
12	Zn(II)	390 (6317) 369 (7560) 352 (5512) 336 (2439)	0.393	98
13	Ag(I)	388 (6328) 369 (7777) 350 (5699) 335 (3038)	0.228	57
14	Cd(II)	389 (7283) 369 (8614) 353 (5816) 336 (2721)	0.075	19
15	Hg(II)	389 (6107) 371 (7322) 352 (5355) 336 (2941)	0.277	69
16	Pb(II)	391 (6215) 370 (6931) 353 (4871) 338 (2189)	0.005	1

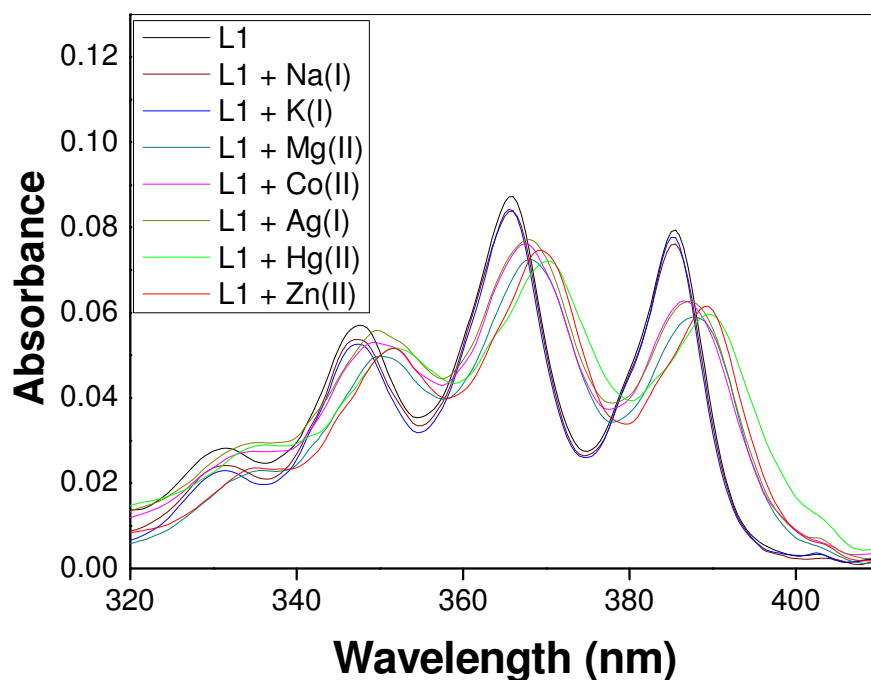


Figure S1: The absorption spectral changes of **L1** in the presence of alkali, alkaline earth metal and the transition metal ions in dry acetonitrile. $[L1] = 1 \times 10^{-5} \text{ M}$, $[M^{n+}] = 1 \times 10^{-3} \text{ M}$.

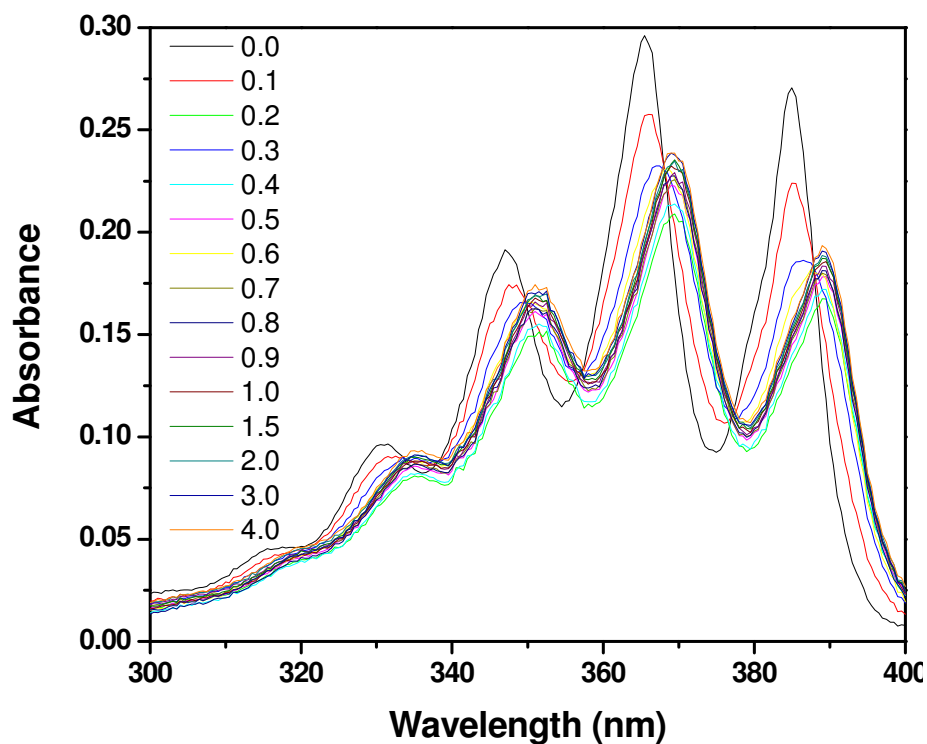


Figure S2. The absorption spectral changes of **L1** in dry acetonitrile ($1 \times 10^{-5} \text{ M}$) upon addition of increasing equivalent of Zn^{2+}

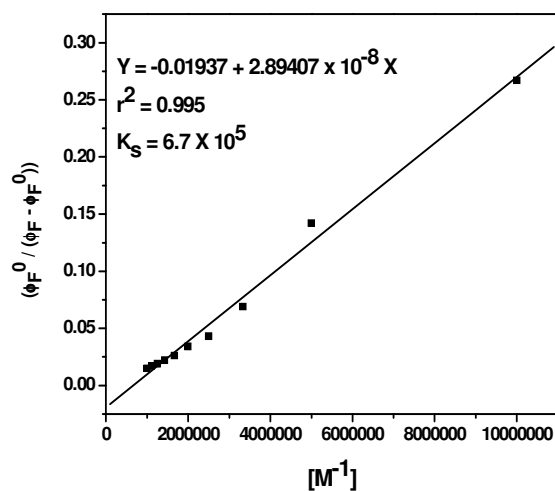


Figure S3. Plot for association constant determination of 1:1 **L1**: Zn^{2+} complex. $\lambda_{\text{ex}} = 350$ nm.

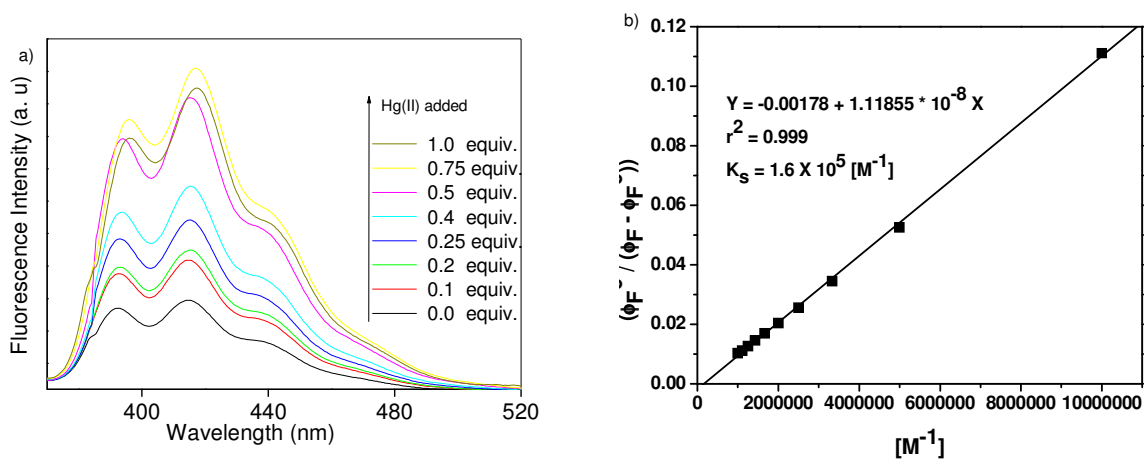


Figure S4. (a) Fluorescence spectral changes of **L1** (1×10^{-7}) with the addition of Hg^{2+} in dry acetonitrile solution. (b) Plot for association constant determination.

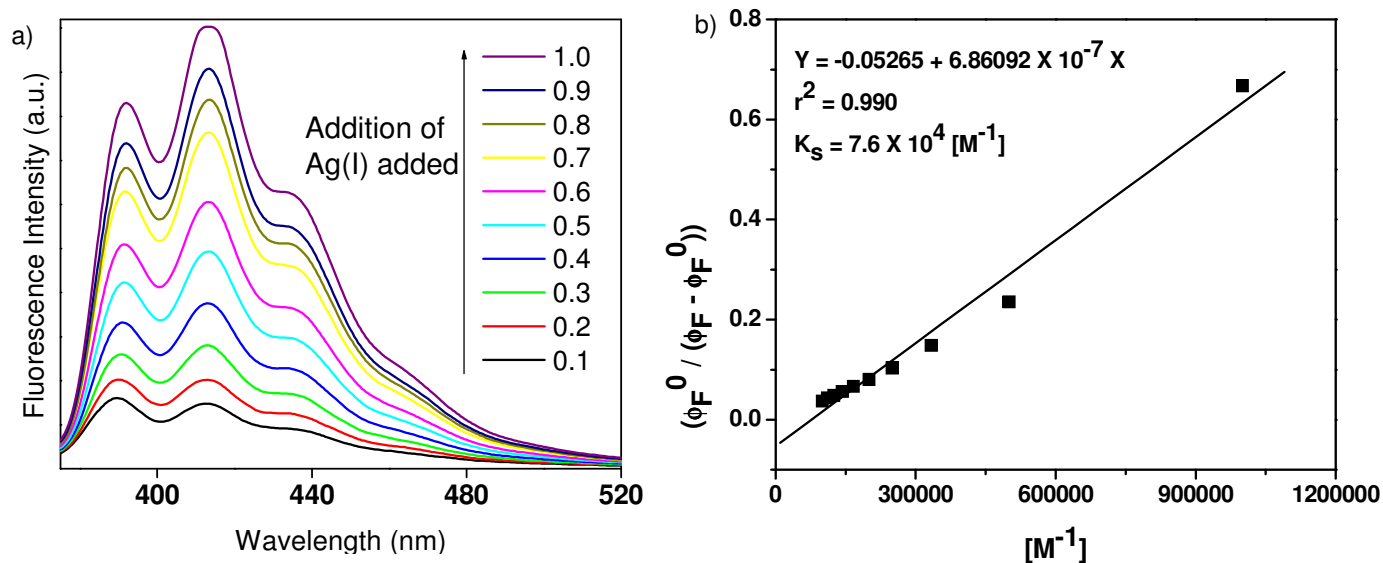


Figure S5. (a) Fluorescence spectral changes of **L1** (1×10^{-7}) with the addition of Ag^+ in dry acetonitrile solution. (b) Plot for association constat determination

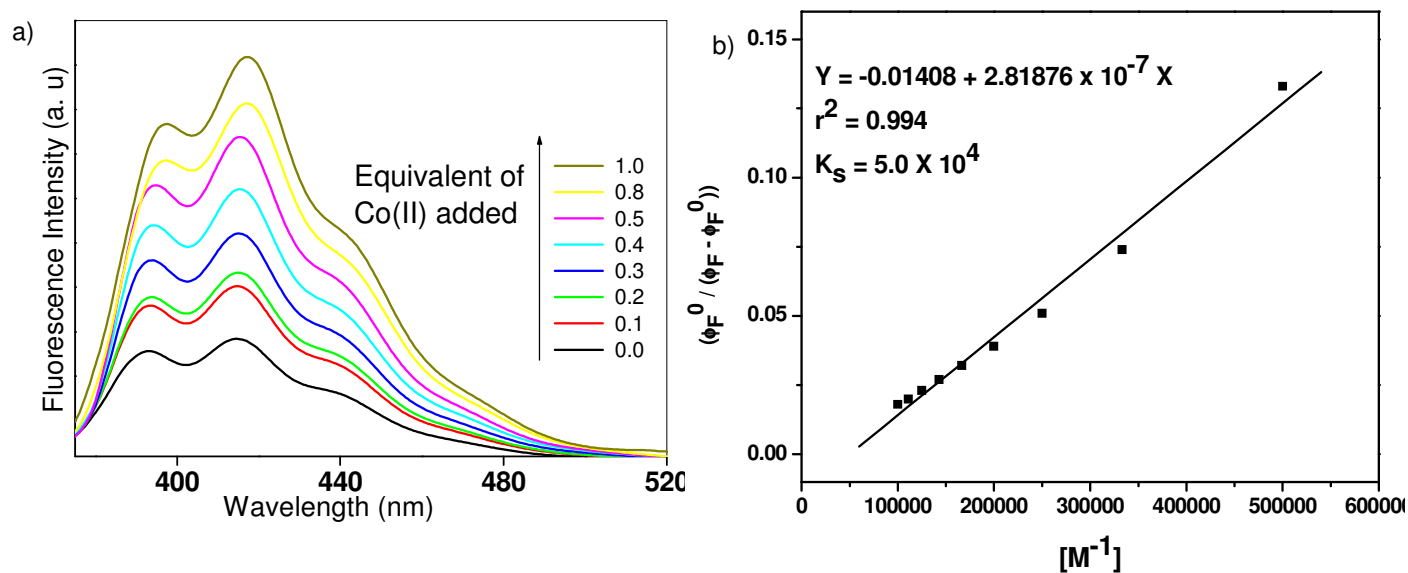


Figure S6. (a) Fluorescence spectral changes of **L1** (1×10^{-7}) with the addition of Co^{2+} in dry acetonitrile solution. (b) Plot for association constat determination

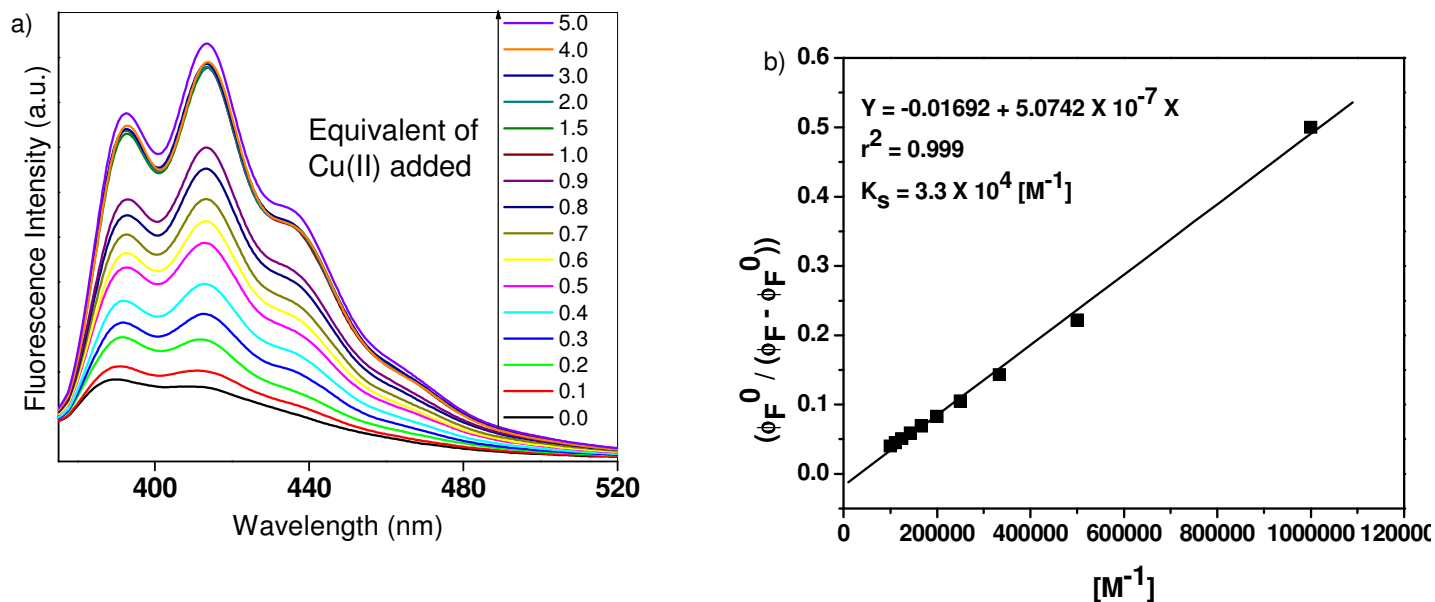


Figure S7. (a) Fluorescence spectral changes of **L1** (1 × 10⁻⁷) with the addition of Cu²⁺ in dry acetonitrile solution. (b) Plot for association constant determination

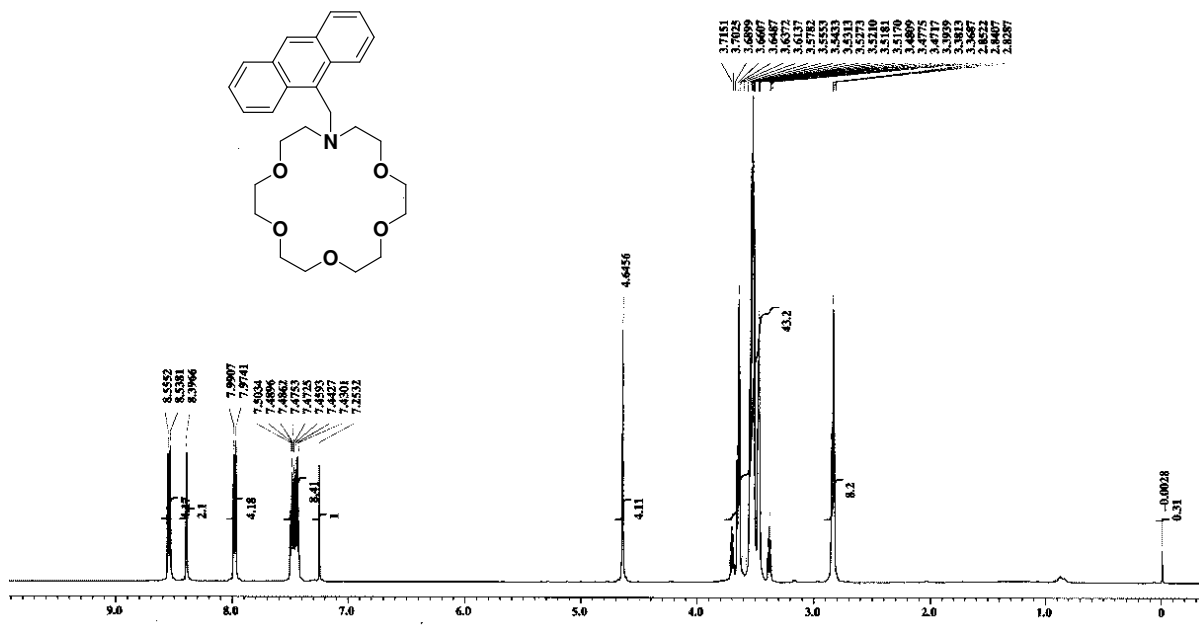


Figure S8. ¹H-NMR (500 MHz, CDCl₃) of the compound **L2**⁴

Table S2: Absorption maxima and corresponding molar extinction coefficients (ϵ), total fluorescence quantum yields (ϕ_F) and corresponding enhancement factor in MeCN in presence of various ionic input for **L2**. $[\mathbf{L2}] = 1 \times 10^{-5}$ M, $[\mathbf{M}^{n+}] = 1 \times 10^{-3}$ M.

S.No.	Ionic Input	Band position, nm (ϵ , $\text{dm}^3 \text{mol}^{-1} \text{cm}^{-1}$)	Quantum Yield (ϕ_F)	FE
1	L2	385 (9191) 365 (9901) 347 (6224) 331 (2847)	0.006	1
2	Li(I)	385 (9092) 365 (9808) 348 (6491) 331 (2870)	0.006	1
3	Na(I)	385 (8702) 366(9472) 348 (6059) 331 (2937)	0.007	1.2
4	K(I)	386(8131) 365 (8841) 348 (5494) 331 (2483)	0.008	1.3
5	Mg(II)	390 (6780) 370 (8349) 352 (6287) 335 (3147)	0.09	15
6	H ⁺	390 (6793) 371 (8470) 352 (6329) 337 (3015)	0.14	23
7	Mn(II)	390 (6631) 368 (8223) 352 (6173) 336 (3086)	0.08	13
8	Co(II)	391 (6743) 369 (8479) 352 (6488) 336 (3283)	0.12	20
9	Ni(II)	390 (6372) 370 (7953) 353 (5958) 335 (2896)	0.11	18
10	Cu(II)	390 (6008) 369 (7522) 353 (5611) 337 (2967)	0.12	20
11	Zn(II)	390 (6823) 372 (8345) 352 (6322) 335 (3086)	0.06	10
12	Ag(I)	390 (6954) 370 (8591) 354 (6441) 336 (3186)	0.12	20
13	Cd(II)	390 (7145) 372 (8598) 353 (6434) 337 (3215)	0.12	20
14	Hg(II)	390 (7119) 371 (8708) 353 (6450) 336 (3161)	0.13	22
15	Pb(II)	390 (6940) 371 (8356) 352 (6398) 336 (3069)	0.05	8

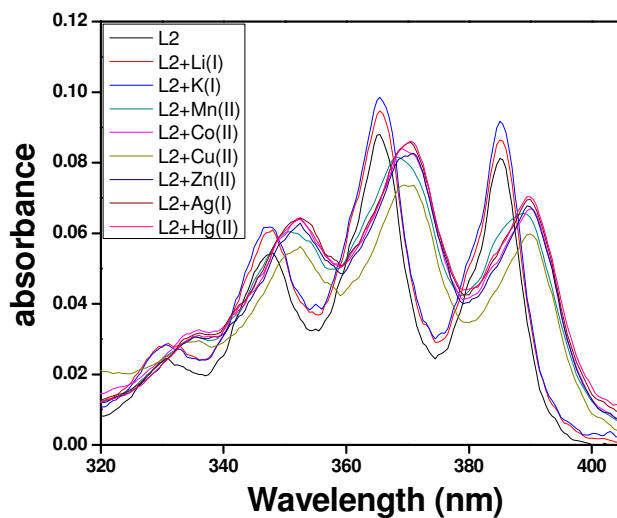


Figure S9. The absorption spectral changes of **L2** in the presence of alkali, alkaline earth metal and the transition metal ions in dry acetonitrile. $[\text{L2}] = 1 \times 10^{-5} \text{ M}$, $[\text{M}^{n+}] = 1 \times 10^{-3} \text{ M}$.

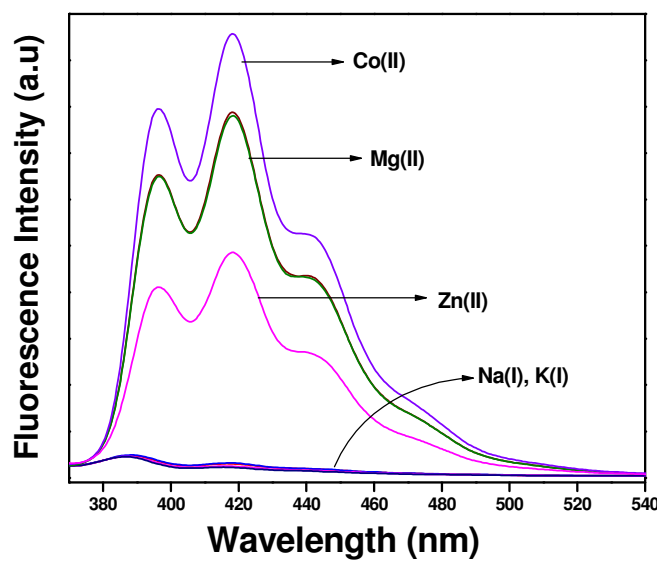


Figure S10. (a) Fluorescence spectra of the **L2** alone and in the presence of different ionic inputs in acetonitrile. $[\text{L2}] = 1.9 \times 10^{-7} \text{ M}$, $[\text{M}^{n+}] = 1.9 \times 10^{-5} \text{ M}$. $\lambda_{\text{ex}} = 350 \text{ nm}$.

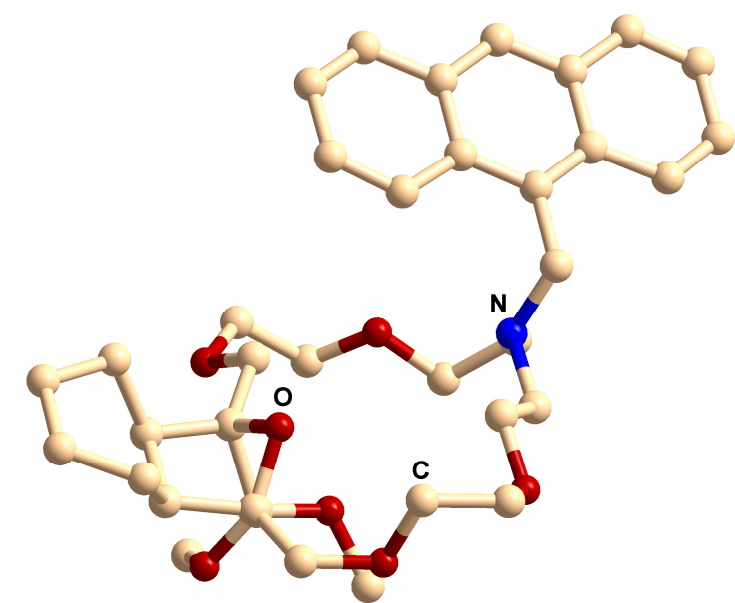


Figure S11: X-ray crystal structure of the **L1**. Hydrogen atoms are omitted for clarity.

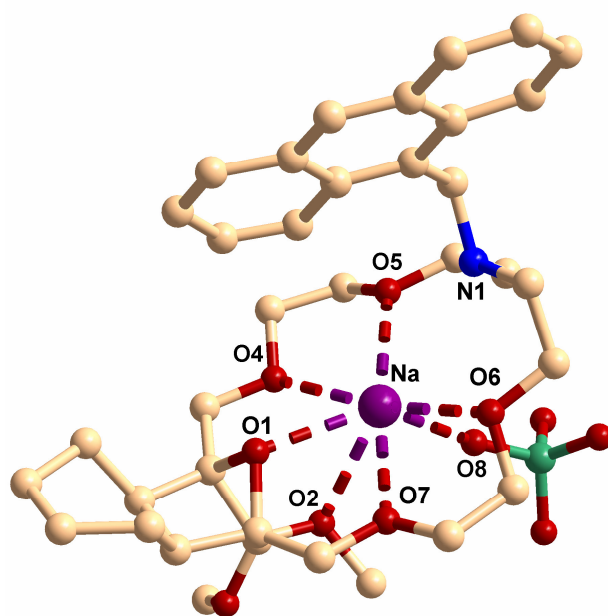


Figure S12: X-ray crystal structure of the **L1+Na⁺**. Hydrogen atoms are omitted for clarity.

Experimental for data collection and structure solution:

All data were collected on a Bruker SMART APEX diffractometer. The structure was solved using SIR-92 and refined using SHELXL-97. Single crystal of **L1** was recrystallised from the acetonitrile solution and data was collected at 100 k; **L1**+Na⁺ was recrystallised from acetonitrile-diethyl ether solution and data was collected at 100 k.

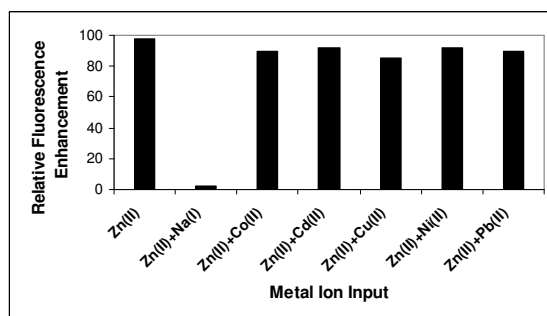


Figure S13. Fluorescence response of **L1** in the presence Zn²⁺ and other metal ion mixtures in acetonitrile. [**L1**]= 1.9 x10⁻⁷ M, [Mⁿ⁺] = 1.9x10⁻⁵ M. λ_{ex} = 350 nm.

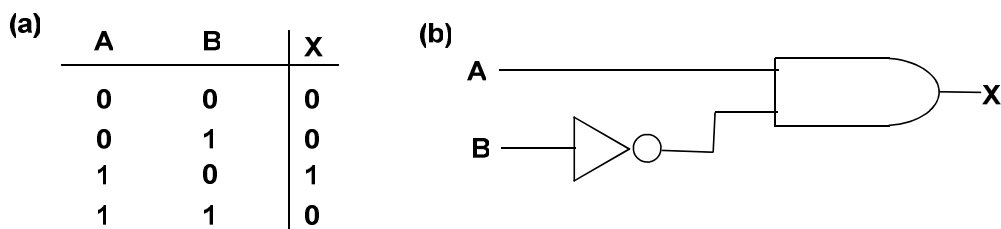


Figure S14

- (a) A truth table for the inhibit (INH) logic gate; inputs A and B correspond to the Zn²⁺ and Na⁺ respectively; X [fluorescence emission], is the output signal.
- (b) The INH gate represented using a conventional gate notation; an active output signal (fluorescence emission) is obtained when A = 1 and B = 0.

Table S3. Selected bond length (Å) and angles (°) for the Na⁺ coordination environment in **L1**+Na⁺ complex.

Bond distances (Å)

O5...Na = 2.537(3)

O7...Na = 2.550(3)

O6...Na = 2.703(3)

O2...Na = 2.702(3)

O1...Na = 2.534(2)

O4...Na = 2.571(3)

O8...Na = 2.433(3)

Bond angles (°)

O8..Na..O1 = 139.84(10)

O8..Na..O5 = 81.93(9)

O1..Na..O5 = 120.17(9)

O8..Na..O7 = 96.83(10)

O1..Na..O7 = 65.30(7)

O5..Na..O7 = 172.41(9)

O8..Na..O4 = 103.33(10)

O1..Na..O4 = 65.59(8)

O5..Na..O4 = 63.72(8)

O7..Na..O4 = 123.74(9)

O8..Na..O2 = 78.06(8)

O1..Na..O2 = 62.06(7)

O5..Na..O2 = 118.53(8)

O7..Na..O2 = 68.26(8)

O4..Na..O2 = 65.64(8)

O8..Na..O6 = 83.72(9)

O1..Na..O6 = 113.56(8)

O5..Na..O6 = 110.89(8)

O7..Na..O6 = 61.53(7)

O4..Na..O6 = 169.89(9)

O2..Na..O6 = 123.54(9)

References:

- 1) Altomare, A.; Gascarano, G.; Giacovazzo, C.; Guagliardi, A. *J. Appl. Cryst.* **1993**, 26, 343-350.
- 2) Sheldrick, G. M. SHELXL97, Program for the Refinement of Crystal Structures, University of Göttingen, Germany, **1997**.
- 3) Birks, J. B. *Photophysics of aromatic molecules*; Wiley-Interscience: New York, **1970**.
- 4) For synthesis compound **L2**, see *J. Org. Chem.* **1986**, 51, 4974.