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6. AUTHOR(S) Paul B. Savage, Ning Su, Jerald S. Bradshaw, Reed M. Izatt, Luca Prodi, Carlotta Bargossi, Marco Montalti, and Nelsi Zaccheroni				
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by

Paul B. Savage, Ning Su, Jerald S. Bradshaw, Reed M. Izatt,
Luca Prodi, Carlotta Bargossi, Marco Montalti, and Nelsi Zaccheroni

Department of Chemistry and Biochemistry,
Brigham Young University, Provo, UT 84602

March 13, 2000

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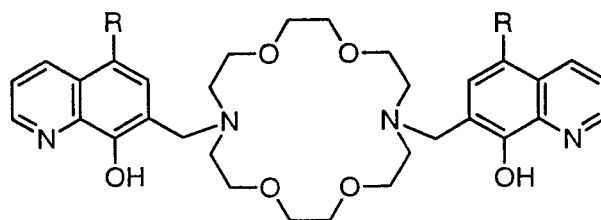
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N,N'-Bis-(8-hydroxy-5-nitroquinolin-7-ylmethyl)diazacrown-18, a Chemosensor for Mercury Ions.

Paul B. Savage, Ning Su, Jerald S. Bradshaw, Reed M. Izatt,
Luca Prodi, Carlotta Baggioni, Marco Montalti, and Nelsi Zaccheroni

Department of Chemistry and Biochemistry,
Brigham Young University, Provo, UT 84602

We have prepared and studied several series of macrocyclic ligands with appended chromophores and fluorophores for use as selective metal ion chemosensors.¹ We recently reported ligand **1** as an ion-selective chemosensor for Mg^{2+} .² We now report that replacement of the chlorine atoms on the 8-hydroxyquinoline moieties in **1** with nitro groups yields a compound (**2**)^{1a} that is an effective fluorescent chemosensor for Hg^{2+} , even in the presence of other metal cations, including Mg^{2+} , that might interfere with its detection.



1 R = -Cl
2 R = -NO₂

Few potential chemosensors for Hg^{2+} have been developed.³ Notable exceptions include the work of Czarnik and coworkers⁴ who developed an anthracene-based chemosensor that selectively responded to Hg^{2+} and Cu^{2+} in aqueous solution. Association with these ions caused fluorescence quenching of the anthracene. In contrast, chemosensor **2** responds to Hg^{2+} via a fluorescent enhancement, a feature that would reduce the likelihood of false positive signals. Recently, Rurack et al.⁵ reported a fluoroionophore for Hg^{2+} , Ag^+ and Cu^{2+} which gave significant fluorescence enhancements upon complexation with these ions in acetonitrile. However, in water/acetonitrile mixtures, fluorescence of the metal ion complexes was significantly attenuated. In aqueous media, a medium in which ion-sensing applications would likely be carried out, **2** displays a strong fluorescent response to Hg^{2+} .

As reported for other lariat ethers containing hydroxyquinoline derivatives, **2** was able to complex a large variety of metal ions. In particular, in methanol-water (1:1 vol:vol)⁶ solutions, it formed stable 1:1 complexes with Hg^{2+} , Cu^{2+} , Cd^{2+} , Zn^{2+} , Ni^{2+} , and Mg^{2+} . Much lower association constants in this solvent ($\log K_a < 2.5$) were observed with the other alkaline earth ions, whereas no complexation was detected ($\log K_a < 1.5$) for alkali metal ions.

Analogous to previous observations,² the complexation process caused strong changes in the absorption spectrum of **2** upon addition of an increasing amount of Hg^{2+} (Figure 1). In particular, blue shifts, an intensity decrease of the band at 440 nm, and a concomitant appearance of a new band at 265 nm were observed. More importantly, changes were also observed in the fluorescence spectrum of **2** upon metal ion complexation. Complexes with Cu^{2+} and Ni^{2+} were not luminescent as expected because these metal ions provide

pathways for energy- and electron-transfer processes which cause fluorescence quenching. A small increase of the luminescence intensity was detected upon addition of Cd^{2+} (with an enhancement factor, $\text{EF} = 3.0$; $\lambda_{\text{max}} = 466 \text{ nm}$), Zn^{2+} ($\text{EF} = 3.4$; $\lambda_{\text{max}} = 467 \text{ nm}$), or Mg^{2+} ($\text{EF} = 1.7$; $\lambda_{\text{max}} = 470 \text{ nm}$). A much higher luminescence increase ($\text{EF} = 12$; $\lambda_{\text{max}} = 476 \text{ nm}$) was observed for Hg^{2+} (Figure 2).

From the changes observed in the absorption and luminescence spectra, we were able to determine association constants of **2** in methanol-water (1:1 vol:vol) with Mg^{2+} ($1.2 \times 10^5 \text{ M}^{-1}$) and Ni^{2+} ($3.6 \times 10^5 \text{ M}^{-1}$), while with Zn^{2+} , Cu^{2+} , Cd^{2+} , and Hg^{2+} only a lower limit ($1 \times 10^8 \text{ M}^{-1}$) could be measured. However, competition experiments performed at neutral pH with **2** in the presence of one equivalent of Zn^{2+} and Cd^{2+} , showed that Hg^{2+} ions could replace these ions with high efficiency, leading to the formation of the luminescent mercury complex (Figure 3). This result indicated that the association constant with the latter ion was likely at least two orders of magnitude higher than those with zinc and cadmium. In contrast, only a partial recovery of the luminescent band was obtained when one equivalent of Hg^{2+} was added to the **2**- Cu^{2+} complex suggesting that **2** has similar affinities for copper and mercury. Nevertheless, interference due to the presence of copper ions, which do not form a luminescent complex with **2**, can be observed only when saturation of **2** occurs; otherwise, all of the mercury is complexed, giving its characteristic luminescence. Finally, no interference was observed while performing titrations with Hg^{2+} in a complex matrix containing alkali, and earth alkali metal ions present in hundred-fold excess.

References.

1. (a) Su, N.; Bradshaw, J. S.; Zhang, X. X.; Song, H.-C.; Savage, P. B.; Xue, G.-P.; Krakowiak, K. E.; Izatt, R. M. *J. Org. Chem.* **1999**, *64*, 8855. (b) Su, N.; Bradshaw, J. S.; Savage, P. B.; Krakowiak, K. E.; Izatt, R. M.; DeWall, S. L.; Gokel G. W. *Tetrahedron* **1999**, *55*, 9737. (c) Su, N.; Bradshaw, J. S.; Savage, P. B.; Krakowiak, K. E.; Izatt, R. M. *J. Org. Chem.* **1999**, *64*, 3825. (d) Yang, Z.; Bradshaw, J. S.; Zhang, X. X.; Savage, P. B.; Krakowiak, K. E.; Dalley, N. K.; Su, N.; Bronson, T.; Izatt, R. M. *J. Org. Chem.* **1999**, *64*, 3162. (e) Su, N.; Bradshaw, J. S.; Savage, P. B.; Krakowiak, K. E.; Izatt, R. M. *J. Heterocyclic Chem.* **1999**, *36*, 771. (f) Bordunov, A. V.; Bradshaw, J. S.; Pastushok, V. N.; Zhang, X. X.; Kou, X.; Dalley, N. K.; Yang, Z.; Savage, P. B.; Izatt, R. M. *Tetrahedron* **1997**, *53*, 17595.
2. Prodi, L.; Bolletta, F.; Montalti, M.; Zaccheroni, N.; Savage, P.B.; Bradshaw, J.S.; Izatt, R.M. *Tetrahedron Lett.* **1998**, *39*, 5451.
3. (a) de Silva, A. P.; Gunaratne, H. Q. N.; Gunnlaugsson, T.; Huxley, A. J. M.; McCoy, C. P.; Rademacher, J. T.; Rice, T. E. *Chem. Rev.* **1997**, *97*, 1515. (b) *Fluorescent Chemosensors for Ion and Molecule Recognition*, Czarnik, A.W., ed., A.C.S.: Washington, D. C., 1992. (c) Prodi, L.; Bolletta, F.; Montalti, M.; Zaccheroni, N. *Coord. Chem. Rev.* in press. (d) Bargossi, C.; Fiorini, M.C.; Montalti, M.; Prodi, L.; Zaccheroni, N. *Coord. Chem. Rev.* in press.
4. Yoon, J.; Ohler, N. E.; Vance, D. H.; Aumiller, W. D.; Czarnik, A. W. *Tetrahedron Lett.* **1997**, *38*, 3845.
5. Rurack, K.; Kollmannsberger, M.; Resch-Genger, U.; Daub, J. *J. Am. Chem. Soc.* **2000**, *122*, 968.
6. The behavior of **2** in the presence of metal cations was measured in methanol-water (1:1 vol:vol) due to the low solubility of **2** in water. Nevertheless, the ion selectivities of **2** are expected to be the same in water as they are in the mixed aqueous solvent system (for an example of ion selectivities of macrocycles in methanol-water mixtures compared to selectivities in water see: Zhang, X. X.; Izatt, R. M.; Krakowiak, K. E.; Bradshaw, J. S. *Inorg. Chim. Acta* **1997**, *254*, 43).

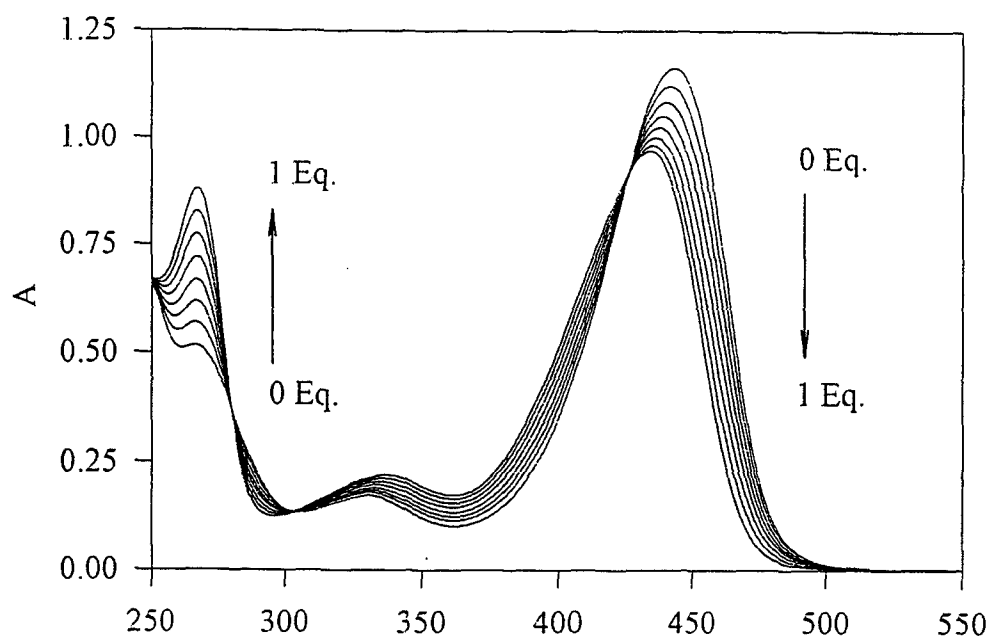


Figure 1: Absorption spectra of **2** ($2.5 \times 10^{-5} M$) in methanol-water (1:1 vol:vol) with increasing amounts of Hg^{2+} ions.

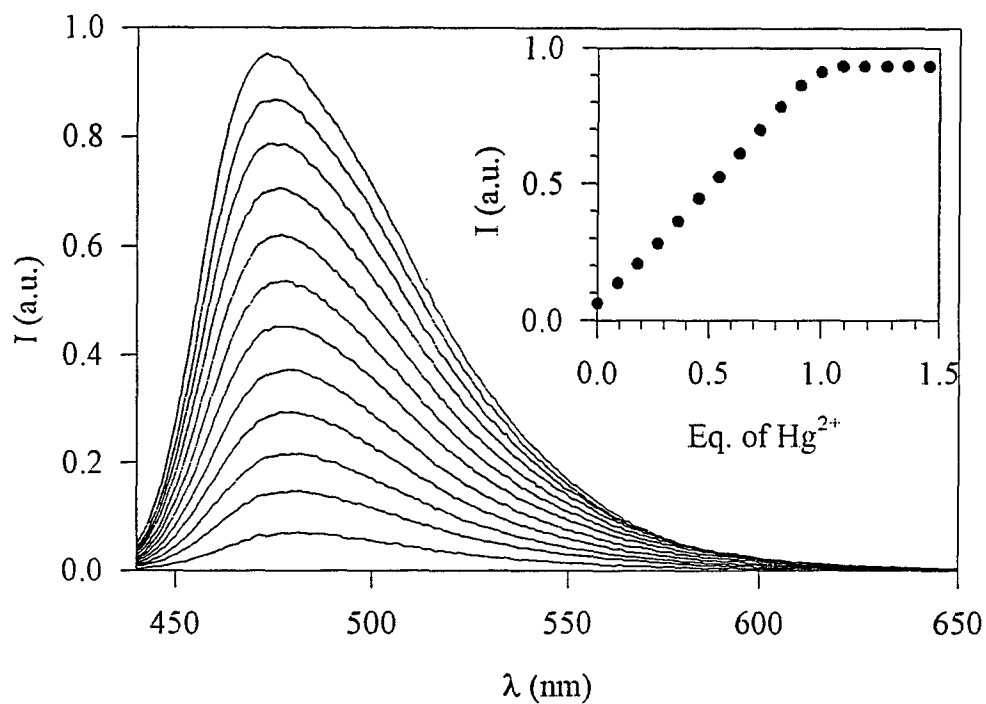


Figure 2: Fluorescence spectra ($\lambda_{\text{exc}} = 423 \text{ nm}$) of **2** ($2.5 \times 10^{-5} \text{ M}$) in methanol-water (1:1 vol:vol) with increasing amounts of Hg^{2+} ions. Inset: Fluorescence intensity values ($\lambda_{\text{exc}} = 423 \text{ nm}$, $\lambda_{\text{em}} = 476 \text{ nm}$) vs. equivalents of added Hg^{2+} .

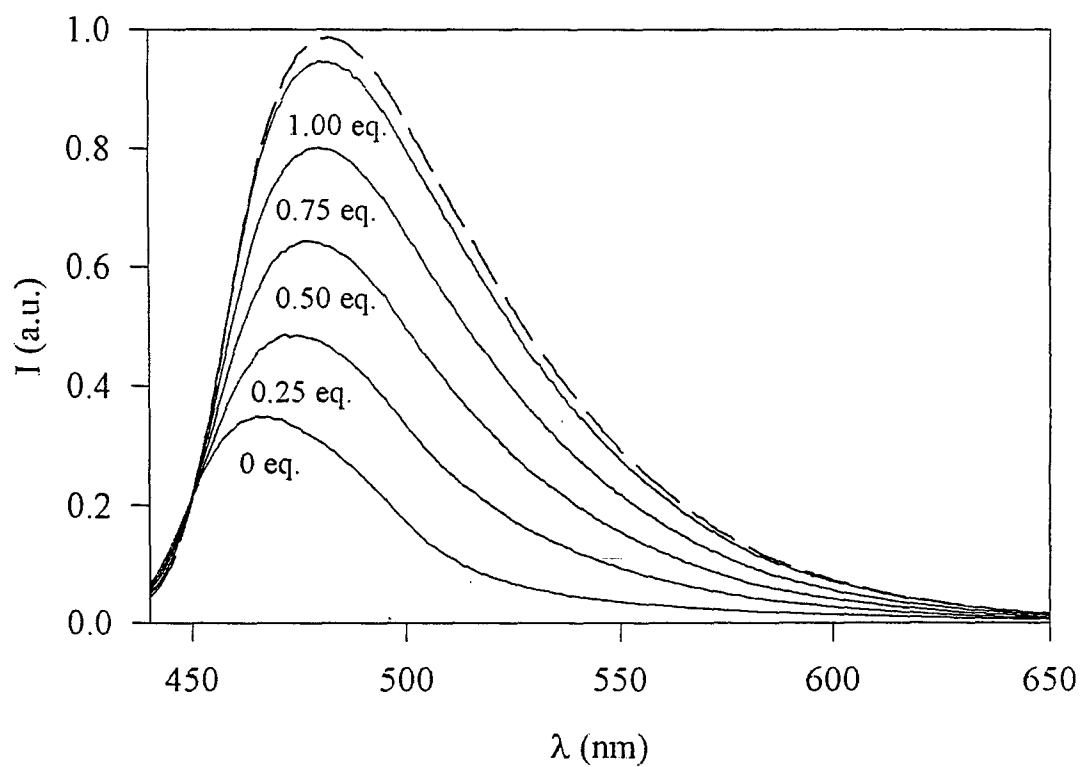


Figure 3: Fluorescence spectra of **2** in the presence of one equivalent of Cd^{2+} and Zn^{2+} upon addition of increasing amounts of Hg^{2+} (dashed line corresponds to the complex (**2** - Hg^{2+}) without other metal ions).