SYNTHESIS OF NOVEL BISPHENOL-BIPHENANTHROLINE-BASED MOLECULAR TWEEZERS

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Received: 13.04.2015, Accepted: 18.09.2015
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Abstract

A molecular "dugdugi" B derived from 1,10-phenanthroline was synthesized and characterized by using NMR, EIMS and UV studies. Bisphenol was alkylated with 1,3-dibromopropane and reacted with 4-[1H-imidazol-4,5-[f][1,10]phenanthrolin-2-yl]phenol to obtain B. 30 μmol.1 solution of B was prepared in 10 % DMF in ethanol and was stirred for 30 min with 30 μL.1 ethanolic solution of Co2+, Cr3+, Cu2+, Fe2+, Mn2+, Ni2+, Ag+, and Zn2+, all nitrates. Chemosensor B switched-on in the presence of Fe3+ by showing pink color while it remained turn-off in the presence of other metals. The UV spectra of the molecular "dugdugi" showed a peak at 279 nm which shifted to 290 nm after interacting with Fe3+. A new peak also appeared at 524 nm.

Keywords: Fe3+ chemosensor, imidazole, naked-eye chemosensors, molecular switch

MOLEKÜLER CIMBIZLAMAYA DAYALI YENİ BİR BISPENOL-BIPHENANTHROLINE SENTEZİ

ÖZET

1,10-phenantrolin‘den elde edilen "dugdugi" B molekülü sentezlenedi ve NMR, EIMS ve UV kullanılarak yapısı aydınlatıldı. Bisfenol B’yi elde etmek için 1,3-dibromopropan kullanarak alkilendi ve 4-[1H-imidazol-4,5-[f][1,10]phenanthrolin-2-yl]phenol ile reaksiyona sokuldu. Molekül B’nin 30 μmolL-1 çözeltisi %10 DMF içeren etanolde hazırlanı, ve etanol ile hazırlamış 30 μL-1 Co2+, Cr3+, Cu2+, Fe2+, Mn2+, Ni2+, Ag+, ve Zn2+ çözeltisi ile 30 dakika karıştırıldı. Kemosensor B, Fe3+ varlığında pembe renk vererek çalışırken, diğer metallerin varlığında ayırt edici bir renk gözlenmedi. "Dugdugi" nin moleküler UV spektrumunda 279 nm’de bulunan pik Fe3+ ile etkileşirülince 290 nm’ye kaydı. Ayrıca, 524 nm’de yeni bir pik oluştuğu görüldü.

Anahtar Kelimeler: Fe3+ Kemosensör, İmidazol, Çapık Gözle Kemosensör, Moleküler Anahtar

1 Introduction

Chemosensors and switches are promising candidates for the realization of innovative materials for information technology.[1] Molecular sensors[2-4] can sense metal cations,[5-7] anions,[8-10] amino acids,[11] pesticides,[12, 13] proteins[14] etc. Schiff bases are reported as high sensitive and reversible chemosensor for gas phase HCl.[15] Metal pollution is of great concern due to their toxicity.[16] Development of suitable probes for sensing metal ion induced changes has assumed greater significance. Number of chemosensors have been reported for Zn2+,[17-19] Cr2+,[17, 18] Cu2+,[18] Ag+,[20, 21] Hg2+,[20, 22] Mg2+,[23] Cr3+,[24] Cr6+,[25] Pb2+,[26] Al3+,[27] etc. Simplest form of metal detection is based on color change - also called naked-eye detection.[28-30] Despite the extensive work on chemosensors, fewer chemosensors for Fe3+ are reported.[31-33] Extensive efforts are going on to develop sensitive and selective Fe3+ chemosensors.[34-38] Fluorescence spectrometry is a sensitive technique for detection of metals having lower concentrations. However, due to its paramagnetic nature, fluorescent detection of Fe3+ is marred by quenching.

Colorimetric sensors [39, 40] containing combination of a receptor and a chromophore are more promising, requires less labor and inexpensive equipment than closely related fluorescent sensors. Up to now, a number of naked-eye sensors for transition metal ions have been reported[41, 42] but surprisingly, the reported Fe3+ selective fluorescent sensors are relatively rare despite the widespread applications of Fe3+[43]

Figure 1. Monkey’s drum (dugdugi) above and molecular dugdugi below
A molecular "dugdugi" is a molecule that is similar to the "dugdugi" of a monkey-charmer also called monkey’s drum. Dugdugi (Urdu language) has two goatskin drumheads that are tensioned with a threaded length of string, such that its pitch may be raised by squeezing the bunched strings at the dugdugi’s waist. A monkey charmer plays the drum by right-left movement. Our synthesized molecule is symmetrical and can be divided in two equal halves if cut from the middle—same as a "dugdugi" (Figure 1). Herein we report the synthesis of a naked-eye chemosensor for Fe³⁺ with efficient detection limit of up to >1 μmol L⁻¹ concentrations. Nitrates of Co²⁺, Cr³⁺, Cu²⁺, Fe³⁺, Mn²⁺, Ni²⁺, Ag⁺, and Zn²⁺ were mixed with chemosensor 8. The solution containing Fe³⁺ turned pink while other metals did not show any color change to naked eye. The same behavior was also observed in the UV-visible spectrum. The Fe³⁺ sensing properties were tested in 10 % DMF in ethanol with a concentration of 30 μmol L⁻¹.

2 Result and Discussion

2.1 Synthesis

Our target fluorogenic chemo-sensor 8 was synthesized in four steps. The first step was to elaborate flexible alkyl chain to the starting bisphenol 1. The dialkylation of bisphenol 1 was carried out with the help of 1,3-dibromopropene 2. The bisphenol was stirred with potassium carbonate at 50 °C (Scheme 1) which gave a greenish solution of the bisphenoxide ions. The reaction temperature was increased to 60 °C and excess of 1,3-dibromopropene was added. Excess of dibromopropene avoided the formation of undesired cyclophanes and bromsubstituted alkylated bisphenol 3 was obtained in excellent yield.

![Scheme 1. Alkylation of bisphenol](image1)

After having the flexible dialkylated bisphenol 3 in hand, our next requirement for the synthesis of target fluorescent compound 8 was to synthesize such a precursor which is fluorogenic and must contain the functional group to substitute the bromines of 3 and to achieve the desired chemosensor molecule 8. For this purpose compound 7 was chosen as a fluorogenic precursor for the chemosensor 8.

![Scheme 2. Oxidation of 1,10-phenanthroline](image2)

Hydroxy-derivative of 1,10-phenanthroline 7 was synthesized according to literature procedure 45. 1,10-Phenanthroline 4 was first oxidized to 1,10-phenanthroline-5,6-dione 5. Phenanthroline 4 and KBr were taken in an ice cold flask. 10 mL of concentrated H₂SO₄ and 5 mL HNO₃ were added slowly with stirring at 0 °C and refluxed for 3 h (Scheme 2). The color of mixture was changed to yellow and was poured into 500 mL of ice water and sodium hydroxide was added slowly to make the pH 4. The aqueous phase was extracted three times with dichloromethane and dried over Na₂SO₄. The solvent was evaporated under vacuum and required dione 5 was obtained with 96 % yield. The product was crystallized out from ethanol. 1,10-phenanthroline-5,6-dione 5 and 4-hydroxybenzaldehyde 6 were dissolved in glacial acetic acid. After stirring for 5 minutes at room temperature, ammonium acetate was added. Temperature was increased to 100 °C and then stirred at this temperature for three hours (Scheme 3). After the desired time, the mixture was poured in 50 mL of ice cold water and neutralized with ammonium hydroxide solution. Kept in freezer at -20 °C for overnight and then filtered, washed with water and then acetone successively. Our required product 7 was obtained as yellow powder in 65 % yield. The compound was dried under vacuum at 50 °C for 24 h.

![Scheme 3. Synthesis of phen-imidazole](image3)

The highly fluorescent precursor 7 was then subjected to the last step of our target synthesis; it was dissolved in DMF and was added K₂CO₃ to stirrer for 40 min at 60 °C. Now the bromsubstituted dialkylated bisphenol 3 was added into the reaction mixture and the temperature was increased to 80 °C (Scheme 4). After 3 h TLC showed the completion of reaction and formation of highly polar product. The hot reaction mixture was poured in the ice water which gave yellow ppts which was washed with brine, ethanol and finally with acetone. The ppt was then dried under vacuum for 24 h and was characterized by NMR, EI-MS and ESI-MS as our required fluorogenic chemosensor 8. Figure 3 shows the ¹HNMR spectra of compound 8.

2.2 UV studies

The UV spectrum of molecular "dugdugi" 8 was obtained in 10 % DMF in ethanol with concentration of 30 μmol L⁻¹. The compound showed λmax at 279 nm and no peak was observed in the range of 800 to 350 nm. The molecular "dugdugi" was screened with different metals i.e. Co²⁺, Cr³⁺, Cu²⁺, Fe³⁺, Mn²⁺, Ni²⁺, Ag⁺, and Zn²⁺ through UV-visible spectroscopy for their sensing properties for these metals. Compound 8 was mixed in 1:1 ration with the stated metals with concentration of 30 μM and stirred in a 10 mL conical flask for 30 minutes. The flask having Fe³⁺ showed pinkish color while the solutions containing other metals did not show any color (Figure 2).

All these metal solutions were subjected for UV-visible studies. The spectrum of the solution containing Fe³⁺ showed a peak at 524 nm while the molecular "dugdugi" with other metals did not show a peak in that region as shown in figure 4.
Said NADEEM, Burhan KHAN, Muhammad R. SHAH, Mehmet Ali ÖZLER
Mugla Journal of Science and Technology, Vol 1, No 2, 2015, Pages 1-5

3 Experimental

3.1 Preparation of solutions
Stock solutions of 1 mM of nitrates of Co$^{2+}$, Cr$^{3+}$, Cu$^{2+}$, Fe$^{3+}$, Mn$^{2+}$, Ni$^{2+}$, Ag$^+$, and Zn$^{2+}$ were prepared in ethanol. For analytical study, 30 μM solutions were prepared by dilution with 10 % of DMF in ethanol. Stock solution of compound 8 was also prepared in 10 % DMF in ethanol with concentration of 1 mM which was diluted to 30 μM by 10 % DMF in ethanol for analytical studies.

3.2 UV-visible studies
UV-Visible spectra were obtained by using Perkin-Elmer’s LAMBDA 35 UV/Vis Systems spectrophotometer in the range of 800-200 nm. 30 μM of chemosensor 8 was stirred with different metals (30 μM) for 30 min followed by UV-visible analysis.

3.3 Synthesis
3.3.1 4,4′-bis(3-bromoproxy)-1,1′-biphenyl (3)
500 mg (2.69 mmol) of 4,4′-biphenol 1 was taken in 50 mL round bottom flask in 30 mL acetone. 1.1 g (8.09 mmol) of K$_2$CO$_3$ was added and stirred for 40 minutes at 40°C. 1,3-dibromopropane 2 was added in excess and then reaction mixture was stirred at 60 °C for 4 h. Solvent was evaporated and the crude product was extracted in triplicate with dichloromethane from aqueous phase. The organic phase was dried with MgSO$_4$ and purified on column chromatography by using silica gel as stationary phase and 20 % ethyl acetate in hexane as eluent. The compound was obtained as colorless flat crystals which were submitted for XRD studies. EIMS m/e: 428.1; 1HNMR 300 MHz CDCl$_3$: 7.46 (d, 4H, $J = 8.7$ Hz), 6.94 (d, 4H, $J = 8.7$ Hz), 4.13 (t, 4H, $J = 6$ Hz, -CH$_2$), 3.61 (t, 4H, $J = 6.3$ Hz), 2.32 (pent, 4H, $J = 6.3$ Hz).
3.3.2 1,10-phenanthroline-5,6-dione (5): 1 g (5.5 mmol) of 1,10-phenanthroline and 1 g (8.4 mmol) of KBr were taken in an ice cold flask. 10 mL of concentrated H\textsubscript{2}SO\textsubscript{4} and 5 mL HNO\textsubscript{3} were added slowly with stirring at 0 °C. The mixture was then refluxed for 3 h. The color of mixture changed to yellow and was poured into 500 mL of ice water and sodium hydroxide was added slowly to make the pH 4. The aqueous phase was extracted three times with DCM and dried with Na\textsubscript{2}SO\textsubscript{4}. The solvent was evaporated under vacuum and 1.5 g of target compound was obtained with 96 % yield. The product was crystalized out from ethanol. M. p. 234 °C and was stirred at 524 nm.

4 Conclusion

We have successfully synthesized 1,10-phenanthroline-based chemosensor molecules against Fe\textsuperscript{3+} by showing pink color while it remained turn-off in the presence of other metals. The UV spectra of the molecular "dugdugi" showed a peak at 279 nm which shifted to 290 nm after interacting with Fe\textsuperscript{3+}. A new peak also appeared at 524 nm.

5 Acknowledgment

We are thankful to the TUBITAK (The Scientific and Technological Research Council of Turkey) for financial support (Program# 2216), HEJ Research Institute of Chemistry ICCBS Karachi University Pakistan and Chemistry department of Akdeniz University, Antalya, Turkey.

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Said NADEEM, Burhan KHAN, Muhammad R. SHAH, Mehmet Ali ÖZLER

Mugla Journal of Science and Technology, Vol 1, No 2, 2015, Pages 1-5


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