A 1,2,3-triazole-based Chiral Fluorescence Sensor for the Sensitive Recognition of Ferric Ion

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Abstract. A chiral fluorescent sensor containing (S)-BINOL and 1, 2, 3-triazole moieties was synthesized via a nucleophilic substitution reaction and a click reaction with high total yield. The fluorescence responses of chiral compounds W1 and ferric ion were investigated by fluorescence spectra. The fluorescence emission intensity of W1 at λ = 390 nm (λex = 300 nm) was quenched quickly upon the coordination with a ferric ion while other metal ions had no obvious change.

1. Introduction
In the field of ion recognition, the detection of heavy metal ions in the ecosystem and the surrounding environment, whether it is good or bad, has always received extensive attention. As iron ion, it is one of the most important metal elements on the earth, its content occupies the fourth place in the crust, and it is widely distributed. As a trace element, it plays an important role in biological systems.

In organisms, iron ions exist as divalent iron ions (Fe²⁺) and trivalent iron ions (Fe³⁺). Studies have shown that if the content of Fe³⁺ ions in the organism is too high, it will cause the liver, heart, pancreas and other important organs to malfunction. Conversely, if the content of Fe³⁺ ions in the organism is too low, it will cause physiological disorders and cause various diseases. At the same time, because iron ions can gain and lose electrons through reduction (Fe²⁺) and oxidation (Fe³⁺), iron ions can be used as a catalytic cofactor for a variety of essential enzymes. In addition, iron is also commonly found in the natural environment, in the form of Fe²⁺ ions or Fe³⁺ ions in the liquid state, and generally in the form of iron oxide in the solid state.

At present, the detection and content determination of iron ions have basically become mature. Commonly used detection methods include ultraviolet-visible absorption spectroscopy (UV), atomic absorption spectroscopy (AAS), atomic emission spectroscopy (AES), inductively coupled plasma Body (ICP), X-ray diffraction (XRD), ion recognition, X-ray photoelectron spectroscopy (XPS), etc. These analytical techniques often require a long time, expensive instruments, demanding experimental conditions, and professional analysts. In view of the importance of Fe³⁺ ions to living organisms and the natural environment, the detection of Fe³⁺ ions has attracted widespread attention in recent years. Therefore, the design and preparation of fluorescent molecules with high selectivity, short response time, and detection of Fe³⁺ ions in living bodies or cells. The probe has important theoretical significance and application value.
2. Result and discussion

2.1 Synthesis procedures

The synthetic procedure for sensor W1 and W2 were outlined in Scheme 1. Based on the original material (S)-1,1′-binaphthol (BINOL), novel 2-positions and 2,2′-positions 1,2,3-triazole modified BINOL fluorescent sensors W1 and W2 were obtained via click reaction in this paper. According to the former literature, the propargyl derivative (S)-1 and (S)-2 were prepared from (S)-BINOL and 3-Bromopropyne. The reaction of the propargyl derivative (S)-1 and Azidoacetic acid ethyl ester was operated in THF under room temperature, with copper (II) sulfate and sodium ascorbate to obtain 1,2,3-triazole modified BINOL derivative W1 with moderate yield (83%) after further purified by column chromatography. When 2 was hydrolyzed in methanol, the yield was 83%, a new fluorescent sensor 1 was obtained. The composition of the target compounds were demonstrated by 1H NMR, 13C NMR, and ESI-MS.

![Scheme 1 Synthetic procedure of fluorescent sensor W1 and W2](image)

2.2 Fluorescence responses

In the methanol system, the selective fluorescence of W1 on Pb\(^{2+}\), Cu\(^{2+}\), Fe\(^{3+}\), Ni\(^{2+}\), Zn\(^{2+}\), Ag\(^{+}\), Al\(^{3+}\), Ba\(^{2+}\), Ca\(^{2+}\), Cr\(^{3+}\), Co\(^{2+}\), Cd\(^{2+}\), K\(^{+}\), Mg\(^{2+}\), Mn\(^{2+}\), Sr\(^{2+}\), Fe\(^{2+}\), Sn\(^{2+}\) plasma tests were carried out and the fluorescence responses were shown in Figure 1. When the excitation wavelength was set to 300 nm, when Fe\(^{3+}\) (5 eq.) was added to the fluorescent probe W1, the emission peak at 390 nm could be seen to decrease. After a simple calculation, the fluorescence quenching degree was almost 75%. When measuring cations, the emission peak at the maximum emission wavelength did not show a significant change in fluorescence. The obvious quenching fluorescence of chiral ligand W1 in excimer emission after addition of Fe\(^{3+}\) ion to the solution of W1 maybe contribute to a PET effect (Photoinduced Electron Transfer).
Similarly, in the methanol system, we need to investigate the influence of different concentration gradients of Fe$^{3+}$ on the fluorescence intensity of W1, and we conducted a fluorescence titration experiment (as shown in Figure 2). With the increase of [Fe$^{3+}$] in the system according to the gradient, the fluorescence emission peak at 390 nm is observed, and it can be seen that the fluorescence of the system exhibits a proportional decrease. When the Fe$^{3+}$ concentration in the system reaches 13 molar equivalents, there is almost no change in the fluorescence intensity, which indicates that the titration of W1 by Fe$^{3+}$ has reached saturation.

**Figure 1.** Fluorescence spectra of W1 ($2.0 \times 10^{-5}$ mol/L) upon addition of other metal ions (5 equiv) in methanol.

**Figure 2.** Fluorescence titration spectra of 1 ($2.0 \times 10^{-5}$ mol/L) with incremental addition of Fe$^{3+}$ in methanol

3. **Experimental section**

Experimental reagents used in the experiment were all buy in Energy Chemical and Shanghai Aladdin Company and used without deep purification. All solvents (99.9%, water ≤ 50 ppm) used in the synthesis were purchased from Innochem. All the analytical grade solvents were distilled before used. The optical purity was recorded by a Rudolph AUTOPOL IV automatic polarimeter. $^1$H NMR
and $^{13}$C NMR were measured on a Bruker AM-400WB spectrometer with DMSO, CDCl$_3$, D$_2$O and CD$_3$OD as solvents. The fluorescence spectrum was measured on Hitachi F-4500 fluorescence spectrophotometer, the slit width were 5.0nm and 2.5nm respectively ($\lambda$ex=300 nm).

3.1 Synthesis of (S)-2-Hydroxy-2'-propargyloxy-1,1'-binaphthyl (S)-I

To a 100 mL three-necked flask was added (S)-BINOL (5 g, 17.5 mmol), potassium carbonate (7.5 g, 52.4 mmol) in normal temperature. Add 30.0 ml of dry acetone to the three necked flask to dissolve. 3-Bromopropyne (2.1 ml, 17.5 mmol) was slowly added to the three-necked flask and agitated under in normal temperature about 5-10 min. Next, the experimental device was placed in a 55°C environment and refluxed for 8 hours. After the reaction is found to be detected by TLC, the reaction was stopped. After cooling the system to normal temperature. The reaction liquid was filtered with suction, then the whole is dried, and then light yellow powder particles are obtained. The ratio of petroleum ether to ethyl acetate was 50:1. The product was collected and dried. The product was extracted by vacuum pump for 2 hours. 4.6 g of product was obtained, and the yield was 81%. $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.91 (d, $J = 9.1$ Hz, 1H), 7.88 – 7.74 (m, 3H), 7.47 (d, $J = 9.1$ Hz, 1H), 7.37 – 7.27 (m, 2H), 7.25 – 7.11 (m, 4H), 7.04 (d, $J = 8.4$ Hz, 1H), 5.11 (s, 1H), 4.52 (t, $J = 2.2$ Hz, 2H), 4.03 (d, $J = 7.1$ Hz, 1H), 2.29 (t, $J = 2.1$ Hz, 1H), 1.94 (s, 1H), 1.18 (t, $J = 7.1$ Hz, 1H). $^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 154.0, 151.4, 134.1, 133.8, 130.8, 130.0, 129.2, 128.3, 127.4, 126.6, 125.3, 125.0, 124.8, 123.4, 117.8, 115.96 (s), 114.8, 78.9, 76.0, 60.5, 57.0.

3.2 Synthesis of W1 probe

In an eggplant shaped bottle charged with (S)-2-Hydroxy-2'-propargyloxy-1,1'-binaphthyl (324 mg, 1.0 mmol) and 2-azide ethyl acetate (230 mg, 2.0 mmol) under the protection of argon. Add 5.0 ml of dried THF to the eggplant flask at 0 °C to dissolve and stir at normal temperature for 5-10 minutes. Sodium ascorbate (396.0 mg, 2.0 mmol) and hydrated copper sulfate (250.0 mg, 1.0 mmol) were mixed with 5.0 ml in deionized water, which was slowly added into eggplant shaped bottle and stirred for 10-15 min. Next, the eggplant shaped bottle was moved to normal temperature for reaction overnight. After the reaction is found to be detected by TLC, the reaction was stopped. Deionized water of ice was added to the reaction system, then EA was used to extract three times, then saturated salt water was used to wash once, and finally anhydrous sodium sulfate was used to dry for 15 minutes, spin-dried and separated by column chromatography (PE:EA= 4:1). The product was collected and dried. The product was extracted by vacuum pump for 2 hours. 374.2 g of product was obtained, and the yield was 83%. $^1$H NMR (400 MHz, CDCl$_3$, TMS) $\delta$(ppm) 7.92 (d, $J = 9.1$ Hz, 1H), 7.86 – 7.76 (m, 3H), 7.48 (d, $J = 9.1$ Hz, 1H), 7.34 – 7.27 (m, 2H), 7.24 – 7.17 (m, 2H), 7.13 (d, $J = 8.1$ Hz, 2H), 6.95 (d, $J = 8.5$ Hz, 1H), 6.87 (s, 1H), 5.36 – 5.19 (m, 2H), 5.15 (d, $J = 13.1$ Hz, 1H), 4.92 – 4.78 (m, 2H), 4.13 (q, $J = 7.2$ Hz, 2H), 1.17 (d, $J = 7.1$ Hz, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$, TMS) $\delta$ 164.93, 153.31, 150.42, 143.73, 132.83, 129.94, 128.90, 128.72, 128.03, 127.19, 127.01, 126.27, 125.38, 124.03, 123.92, 123.56, 122.87, 122.19, 116.82, 115.04, 76.31, 75.99, 75.68, 62.57, 61.37, 49.74, 12.97.

4. Conclusions

In general, through a nucleophilic substitution reaction and a click reaction, a novel highly selective and sensitive 2-positions 1,2,3-triazole modified BINOL derivative fluorescent sensor W1 which could detect ferric ion was prepared with a total yield of 67%. Meanwhile W1 could be employed as a ferric ion specific fluorescent sensor because it demonstrated highly specificity and sensitivity in fluorescence experiments. The fluorescence quenching phenomenon is caused by the binding complex between W1 and ferric ions, and is not interfered by various metal ions.

5. Acknowledgements

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