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Complete List of Authors:	Zhang, You-Ming; NW Normal Univ, Han, BingBing; NW Normal Univ Northwest Normal University Lanzhou, CN 730070 0 Mao, PengPeng; NW Normal Univ Northwest Normal University Lanzhou, CN 730070 0 Chen, JinFa; NW Normal Univ Northwest Normal University Lanzhou, CN 730070 0 Yao, Hong; College of Chemistry and Chemical Engineering, Northwest Normal University LanZhou, Wei, Tai-Bao; College of Chemistry and Chemical Engineering, Northwest Normal University LanZhou,, Lin, Qi; Key Laboratory of Eco-Environment-Related Polymer Materials, Ministry of Education of China; Key Laboratory of Polymer Materials of Gansu Province; College of Chemistry and Chemical Engineering, Northwest Normal University,, ;
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2. Author names and affiliations:

You-Ming Zhang:

Key Laboratory of Eco-Environment-Related Polymer Materials, Ministry of Education of China, Key Laboratory of Polymer Materials of Gansu Province, College of Chemistry and Chemical Engineering, Northwest Normal University, Lanzhou 730070, P. R China. E-mail: zhangnwnu@126.com

Bing-Bing Han:

Key Laboratory of Eco-Environment-Related Polymer Materials, Ministry of Education of China, Key Laboratory of Polymer Materials of Gansu Province, College of Chemistry and Chemical Engineering, Northwest Normal University, Lanzhou 730070, P. R China. E-mail: 1272154952@qq.com

Peng-Peng Mao

Key Laboratory of Eco-Environment-Related Polymer Materials, Ministry of Education of China, Key Laboratory of Polymer Materials of Gansu Province, College of Chemistry and Chemical Engineering, Northwest Normal University, Lanzhou 730070, P. R China. E-mail: 547113294@qq.com

Jin-Fa Chen:

Key Laboratory of Eco-Environment-Related Polymer Materials, Ministry of Education of China, Key Laboratory of Polymer Materials of Gansu Province,

College of Chemistry and Chemical Engineering, Northwest Normal University,
Lanzhou 730070, P. R China. E-mail: 1121026344@qq.com

Hong Yao

Key Laboratory of Eco-Environment-Related Polymer Materials, Ministry of
Education of China, Key Laboratory of Polymer Materials of Gansu Province,
College of Chemistry and Chemical Engineering, Northwest Normal University,
Lanzhou 730070, P. R China. E-mail: yhxzbz@126.com

Tai-Bao Wei

Key Laboratory of Eco-Environment-Related Polymer Materials, Ministry of
Education of China, Key Laboratory of Polymer Materials of Gansu Province,
College of Chemistry and Chemical Engineering, Northwest Normal University,
Lanzhou 730070, P. R China. E-mail: weitaibao@126.com

Qi Lin

Key Laboratory of Eco-Environment-Related Polymer Materials, Ministry of
Education of China, Key Laboratory of Polymer Materials of Gansu Province,
College of Chemistry and Chemical Engineering, Northwest Normal University,
Lanzhou 730070, P. R China. E-mail: linqi2004@126.com

3. Corresponding author:

You-Ming Zhang, E-mail: zhangnwnu@126.com

Qi Lin, E-mail: linqi2004@126.com

A novel fluorescent sensor based on 4-(diethylamino)-2-(hydroxy)-phenyl imine functionalized naphthalimide for highly selective and sensitive detection of CN⁻ and Fe³⁺

You-Ming Zhang, Bing-Bing Han, Peng-Peng Mao, Jin-Fa Chen, Hong Yao, Tai-Bao Wei, and Qi Lin

Key Laboratory of Eco-Environment-Related Polymer Materials, Ministry of Education of China, Key Laboratory of Polymer Materials of Gansu Province, College of Chemistry and Chemical Engineering, Northwest Normal University, Lanzhou, Gansu 730070, P. R China

Corresponding authors: You-Ming Zhang (E-mail: zhangnwnu@126.com) and Qi Lin (E-mail: linqi2004@126.com).

Abstract:

In this work, a novel sensor molecule **HB1** based on 4-(diethylamino)-2-(hydroxy)-phenyl imine functionalized naphthalimide derivative was successfully designed and synthesized. Interestingly, the **HB1** showed fluorescence identification ability for CN^- in DMSO/ H_2O (8 : 2, v/v) solution. After addition of CN^- into the **HB1** solution, the fluorescence intensity of **HB1** solution could be enhanced obviously. The anti-disturbance experiments demonstrated that other anions couldn't interfere in the detection of CN^- . On the other hand, the **HB1** enable dual-channel (absorption and fluorescence) detection of Fe^{3+} in DMSO solution. With the addition of various metal ions into the **HB1** solution, only Fe^{3+} induced the fluorescence emission of **HB1** solution quenching and the color changing, and other metal ions couldn't interfere in the detection of Fe^{3+} . The LODs (limits of lowest detection) of **HB1** for CN^- and Fe^{3+} were 6.30×10^{-8} M and 3.95×10^{-8} M, respectively. Importantly, the real samples experiment was carried out by detecting CN^- in bitter almonds. Meanwhile, ion test strips based on **HB1** were fabricated, which could act as convenient and efficient test kits for detecting CN^- and Fe^{3+} .

Key words: sensor molecule, naphthalimide derivative, real samples, test kits.

Introduction

In the field of supramolecular chemistry, the study of cyanide anion (CN^-) sensors has been a hotspot.¹⁻³ The cyanide anion (CN^-) is a kind of highly toxic substance,⁴ whose maximum permissive level in drinking water is set at $1.9 \mu\text{M}$ by the World Health Organization (WHO).⁵ Cyanide is widespread used in a number of industrial processes such as gold mining, electroplating, metallurgy and the synthesis of fibers and resins.⁶⁻⁸ The accidental release of cyanide may result a fearful environmental disaster and severe health hazard for human and living beings.⁹⁻¹⁰ However, CN^- exists widely in industrial waste water and some food such as germination potatoes, bitter almonds and cassava.¹¹⁻¹⁴ Thus, the design and synthesis of optical sensors for specific detection of CN^- have been an important task.¹⁵⁻¹⁷ Over the past few years, optical sensing strategies for CN^- adopted in some literatures, such as hydrogen-bonding interactions,¹⁸ nucleophilic addition,¹⁹⁻²⁰ and deprotonation.²¹

Iron ion (particularly Fe^{3+}), which has special chemical properties and plays a crucial role in the process of the majority biochemical reactions.²² In the human body, the lack of Fe^{3+} may cause a lot of diseases such as anemia liver damage, hemochromatosis and Parkinson's disease.²³ The Fe^{3+} could also catalyze numerous physiological processes of growth of living cells and metabolism.²⁴ Therefore, exploring some high efficient methods to detect cyanide are extraordinarily crucial.²⁵⁻²⁷ Compared with ion chromatography,²⁸ flow injection analysis²⁹ and titration analysis detection methods,³⁰ fluorescence method is simple, low cost and widely used.³¹⁻³³

In view of these and as part of our research interest in ions recognition,³⁴⁻³⁸ herein, we reported a novel sensor molecule (**HB1**) based on 4-(diethylamino)-2-(hydroxy)-phenyl imine functionalized naphthalimide derivative (Scheme 1). Interestingly, the sensor molecule **HB1** could not only fluorescence detection CN^- in DMSO/ H_2O (8 : 2, v/v) solution but also dual-channel (absorption and fluorescence) detection of Fe^{3+} in DMSO solution with high selectivity and sensitivity. Additionally, the practical experiments were also carried out to detect CN^- in bitter almonds. Even more significantly, test strips based on **HB1** were used to detect CN^- and Fe^{3+} which exhibits good selectivity.

Experimental

Materials and methods

Fresh double distilled water was used throughout the experiment. All other reagents and solvents were commercially available in analytical grade and were used without further purification. ^1H NMR (600 MHz) and ^{13}C NMR (151 MHz) spectra were recorded on a Mercury-600 BB spectrometer. ^1H chemical shifts are reported in ppm downfield from tetramethylsilane (TMS, δ scale with the solvent resonances as internal standards). UV-Visible spectra were acquired on a Shimadzu UV-2550 spectrometer. Photoluminescence spectra were obtained on a Shimadzu RF-5301PC fluorescence spectrophotometer. Melting points were measured on an X-4 digital melting-point apparatus. The infrared spectra were obtained on a Digilab FTS-3000 FTIR spectrophotometer. Scanning electron microscopy (SEM) images of the xerogels were investigated using JSM-6701F instrument.

(Insert Scheme 1)

Synthesis of compound **M**

1, 8-naphthalic anhydride (1.98g, 10 mmol), para-phenylenediamine (2.16 g, 20 mmol) and DMF (30 mL) were added to a 100 mL round-bottom flask. Then the reaction mixture was stirred at 140 °C for 24h. After the reaction was completed, the obtained precipitate was filtered, washed thrice with hot absolute ethanol, and then recrystallized with DMF and H_2O to give yellow brown product **M** (2.79 g, yield 97%). Mp: 195-197 °C. ^1H NMR (600 MHz, $\text{DMSO}-d_6$) δ /ppm: 8.46-8.44 (m, 4H), 7.88-7.84 (m, 2H), 6.93-6.92 (d, $J = 8.5$ Hz, 2H), 6.64-6.62 (d, $J = 8.5$ Hz, 2H), 5.24 (s, 2H). ^{13}C NMR (151 MHz, $\text{DMSO}-d_6$) δ /ppm: 164.37, 148.95, 134.63, 131.84, 131.10, 129.61, 128.15, 127.61, 123.16, 114.16. HR-MS m/z : calcd for $\text{C}_{18}\text{H}_{13}\text{N}_2\text{O}_2$ [**M** + H] $^+$: 289.0977; found: 289.1392.

Synthesis of compound **HB1**

Compound **M** (2.88 g, 10 mmol), 4-(diethylamino)salicylaldehyde (1.93 g, 10 mmol) and catalytic amount of CH_3COOH (2 mL) were added to absolute ethanol (30 mL). The mixture was stirred at 140 °C under reflux conditions for 18 h. After cooling to room temperature, the precipitate was filtrated and then washed thrice with hot absolute ethanol. Finally, it was recrystallized with DMF- H_2O to get yellow product **HB1** (3.61 g, yield 78 %). Mp: 200-203 °C. ^1H NMR (600 MHz, $\text{DMSO}-d_6$) δ /ppm: 13.55 (s, 1H), 8.75 (s, 1H), 8.51-8.49 (d, $J = 7.7$ Hz, 4H), 7.92-7.88 (m, 2H), 7.43-7.34 (m, 5H), 6.34-6.32 (d, $J = 2.5$ Hz, 1H), 6.08 (s, 1H), 3.41-3.37 (m, 4H), 1.13-1.10 (t, $J = 7.0$ Hz, 6H). ^{13}C NMR ($\text{DMSO}-d_6$, 151 MHz), δ /ppm: 164.20, 163.77, 162.51, 152.10, 148.69, 134.86, 134.77, 131.18, 130.50, 127.66, 123.09, 121.56, 119.92, 114.14,

109.06, 104.38, 97.29, 44.39, 13.01. HR-MS m/z : calcd for $C_{29}H_{26}N_3O$ [**HB1** + H] $^{+}$: 464.1974; found: 464.2551.

Results and discussion

First, the recognition profiles of sensor **HB1** toward various anions (F^{-} , Cl^{-} , Br^{-} , I^{-} , AcO^{-} , $H_2PO_4^{-}$, HSO_4^{-} , ClO_4^{-} , CN^{-} , and SCN^{-}) were investigated by fluorescence spectroscopy. In the fluorescence spectra, the maximum emission of **HB1** appeared at 467 nm in DMSO/ H_2O (8 : 2, v/v) solution while excitation at 390 nm. As shown in Fig. 1, when 5 equiv. of CN^{-} were added to DMSO/ H_2O (8 : 2, v/v) solution of sensor **HB1**, the fluorescence intensity of sensor **HB1** increased rapidly and other anions could not induce the similar response. Therefore, the sensor **HB1** showed specific fluorescence selectivity for CN^{-} in DMSO/ H_2O (8 : 2, v/v) solution.

(Insert Fig. 1)

To further evaluate the sensing nature of **HB1** for CN^{-} , fluorescence emission titration experiments were carried out (Fig. 2). With the addition of CN^{-} (0-0.2 equiv.) to DMSO/ H_2O (8 : 2, v/v) solution of **HB1**, the fluorescence intensity of **HB1** enhanced gradually and then reached saturation. Furthermore, the detection limit for CN^{-} according to the fluorescent spectra changes calculated on the basis of $3\delta/S^{39}$ was 6.30×10^{-8} M (Fig. S7), which indicated that the **HB1** could detect CN^{-} at very low concentrations in the environment. The LODs (limits of lowest detection) of **HB1** for CN^{-} is much better than some reported fluorescent sensors for CN^{-} (Table S1).

(Insert Fig. 2)

In order to validate the selectivity of sensor **HB1** for CN^{-} , the anti-interference tests were conducted using F^{-} , Cl^{-} , Br^{-} , I^{-} , AcO^{-} , $H_2PO_4^{-}$, HSO_4^{-} , ClO_4^{-} , and SCN^{-} . As a result, no significant interferences upon the addition of other anion ions towards CN^{-} sensing (Fig. 3), suggesting that the present **HB1**-based sensing system possessed excellent selectivity for fluorescence detection of CN^{-} in DMSO/ H_2O (8 : 2, v/v) solution.

(Insert Fig. 3)

The sensing mechanism of sensor **HB1** to CN^{-} was investigated by the 1H NMR titrations, IR, HR-MS and SEM. As shown in Fig. 4, with the addition of different equivalents CN^{-} into

DMSO- d_6 solution of **HB1**, the proton of -OH become broaden and then completely disappeared due to the deprotonation of sensor **HB1**. At the same time, the -CH=N peak at 8.76 ppm gradually decreased due to destroy the hydrogen bonding between -OH and -CH=N groups. In the IR spectra (Fig. S8) of **HB1**, the vibration band at 3315 cm^{-1} could be attributed to the vibrational absorption peak of -OH. After the **HB1** reacted with CN^- , the vibrational absorption peak of -OH group disappeared due to deprotonation and other protons on **HB1** didn't shift. In the HR-MS spectra of **HB1**- CN^- (Fig. S9), an equimolar of **HB1** and CN^- exhibited a peak at $m/z = 486.2814$, corresponding to [**HB1** + Na - H], which similarly indicated that **HB1** lost one proton on addition of CN^- . In the SEM images (Fig. S10), the micromorphology of powder **HB1** showed overlapped rugate layer structure; however, after addition of 0.2 equiv. of CN^- , the overlapped rugate layer structure will be destroyed and changed to amorphous structure. Thus, a possible mechanism for the formation of **HB1**- CN^- was proposed in Scheme 2. Additionally, the UV-vis experiments were used to verify the above consequences. As shown in Fig. S11, after addition of CN^- to the solution of **HB1**, there was a significant color change and accompanied by an absorption peak blue shifted.

In order to further confirm the detection mechanism of **HB1** toward CN^- , we diffused some stronger bases (e.g. NaOH, $\text{NH}_3 \cdot \text{H}_2\text{O}$) into the **HB1** solution (DMSO/ H_2O = 8 : 2, v/v). As shown in Fig. S12, upon the addition of 0.2 equiv. NaOH into the **HB1** solution, the fluorescence intensity of this system increased obviously. Meanwhile, we added 0.2 equiv. $\text{NH}_3 \cdot \text{H}_2\text{O}$ into the **HB1** solution, the fluorescence intensity of the system was also slightly enhanced. These results indicated that the sensor **HB1** detection of CN^- by deprotonating the phenol. In contrast, in order to overcome the influence of some strong bases, we added the sensor **HB1** into the mixture solution of DMSO and HEPES buffer solution (pH = 7.0) to detect CN^- and Fe^{3+} . As shown in Fig. S13, after addition of 0.2 equiv. CN^- into the **HB1** solution, the fluorescence emission of **HB1** shows enhancement, which indicated that the **HB1** could also detection of CN^- in DMSO/ H_2O (v/v = 8/2) HEPES buffer solution at pH = 7.0. In addition, we added 0.2 equiv. NaOH and $\text{NH}_3 \cdot \text{H}_2\text{O}$ into the **HB1** solution, respectively. As a result, there were no significant changes in the fluorescence intensity of the mixture solution. Therefore, buffer solution helps to eliminate the interference of stronger bases when using the **HB1** to detect CN^- .

(Insert Fig. 4 and Scheme 2)

Then, we carefully investigated the cation-response properties by diffused various metal ions (Fe^{3+} , Ca^{2+} , Ba^{2+} , Co^{2+} , Ni^{2+} , Cd^{2+} , Pb^{2+} , Zn^{2+} , Cu^{2+} , Mg^{2+} , and Hg^{2+}) into the **HB1** in DMSO solution. In the fluorescence spectra (Fig. 5), the maximum emission of **HB1** appeared at 474 nm while excitation at 390 nm. After addition of 2.0 equiv. of Fe^{3+} into the DMSO solution of sensor **HB1**, the fluorescence emission of **HB1** solution quenched rapidly. Meanwhile, in the UV-vis spectra (Fig. S14), after 2.0 equiv. of Fe^{3+} was added to the **HB1** solution, there was a significant color change from yellow to dark, and accompanied by a strong and broad absorption peak blue shifted from 346 nm to 338 nm. However, other metal ions could not induce the similar response, which indicated the **HB1** could dual-channel detection of Fe^{3+} in DMSO solution.

(Insert Fig. 5)

To evaluate the sensing nature of **HB1** for Fe^{3+} , the fluorescence and UV-vis titrations with increasing amounts of Fe^{3+} were carried out. With the addition of Fe^{3+} to the DMSO solution of **HB1**, the emission peak at 474 nm decreased gradually (Fig. 6). In addition, the intensity of UV-vis absorption peak at 346 nm enhanced gradually (Fig. S15). The fluorescence intensity and UV-vis absorption reached saturation when the quantity of Fe^{3+} was 3.52 equiv. and 10.08 equiv. respectively. According to the fluorescent and UV-vis titration spectra changes, the fluorescence and UV-vis detect limits of **HB1** for Fe^{3+} were 3.95×10^{-8} M and 6.14×10^{-6} M, respectively (Fig. S15 and S16). The fluorescence detection limit of **HB1** for Fe^{3+} is much better than some reported fluorescent sensors for Fe^{3+} (Table S2).

We provided table S1 and S2 to prove the better sensitivity of sensor **HB1** toward CN^- and Fe^{3+} compare with other sensors. However, not all of these sensors have similar structure and detect CN^- or Fe^{3+} by similar detection mechanism. The most important reason why we chose these sensors is to confirm the sensor **HB1** has lower LOD for CN^- or Fe^{3+} in solution compare to other sensors. For example, as shown in ref S2, the receptor **1** using the same deprotonation mechanism to detect CN^- and the LOD for CN^- is about 2.3×10^{-7} M. As shown in ref S8, the chemosensor **Asp-NI** using the same coordination mechanism to detect Fe^{3+} and the LOD for Fe^{3+} is about 4.97×10^{-7} M.

(Insert Fig. 6)

To further exploit the selectivity of sensor **HB1** for Fe^{3+} , the anti-interference experiments were conducted using Ca^{2+} , Ba^{2+} , Co^{2+} , Ni^{2+} , Cd^{2+} , Pb^{2+} , Zn^{2+} , Cu^{2+} , Mg^{2+} , and Hg^{2+} . As a result, none of these interferences caused any significant changes in the fluorescent spectra (Fig. 7) and the UV-vis absorption spectra in DMSO solution (Fig. S17). Because **HB1** could detect CN^- and Fe^{3+} at the same time, it is necessary to examine the detection ability of **HB1** in the presence of CN^- and Fe^{3+} . Therefore, we added the anti-interference experiments again. As shown in Fig. S18, with the addition of CN^- into the mixed solution of **HB1** and Fe^{3+} , the quenched fluorescence could be opened again, meanwhile, the color of the solution recovered. This may be due to the common effect of CN^- and Fe^{3+} .

(Insert Fig. 7)

The recognition mechanism of **HB1** toward Fe^{3+} was carefully investigated via IR, Job's plot and SEM. In the IR spectra (Fig. S19) of **HB1**, the two vibration bands at 3332 cm^{-1} and 1666 cm^{-1} could be attributed to the vibrational absorption peaks of $-\text{OH}$ and $-\text{CH}=\text{N}$ respectively, after **HB1** reacted with Fe^{3+} , the vibrational absorption peak of $-\text{OH}$ group disappeared due to deprotonation of the phenol. At the same time, the vibration absorption peak of $-\text{CH}=\text{N}$ shifted to 1643 cm^{-1} due to the coordination of Fe^{3+} with the nitrogen atom of $-\text{CH}=\text{N}$ group. These results indicated that the **HB1** could complex with Fe^{3+} via "O" and "N" heteroatoms in a "O- Fe^{3+} -N" manner. Moreover, the 1:1 stoichiometry of **HB1** and Fe^{3+} was confirmed by the Job's plot (Fig. S20). The SEM (Fig. S10) images demonstrated that the powder of **HB1** showed overlapped rugate layer structure. After addition of Fe^{3+} to **HB1**, the overlapped rugate layer structure was destroyed and changed to bulk structure, which could be attributed to Fe^{3+} formed hydrogen bond with **HB1**. Thus, a possible mechanism for the formation of **HB1**- Fe^{3+} was proposed in Scheme 3.

(Insert Scheme 3)

According to our research, the sensor **HB1** could dissolve in DMSO solution; however, it couldn't dissolve in CH_3OH , $\text{CH}_3\text{CH}_2\text{OH}$ and CH_3CN solution. In the process of experiments, we use $\text{Fe}(\text{ClO}_4)_3 \cdot 6\text{H}_2\text{O}$ and NaCN as the source of Fe^{3+} and CN^- respectively, and all of them could dissolve in water solution. In addition, the concentration of Fe^{3+} was $4 \times 10^{-3}\text{ M}$ and CN^- was $1 \times 10^{-2}\text{ M}$, so they could dissolve in DMSO solution. Importantly, if we use mixture solvent

(DMSO/H₂O), the **HB1** couldn't dual-channel (absorption and fluorescence) detect Fe³⁺. Therefore, we investigated the selectivity of sensor **HB1** for Fe³⁺ in DMSO solution. Meanwhile, the **HB1** could also fluorescence detection of CN⁻ in DMSO solution. However, we found that if we use mixture solvent (DMSO/H₂O, 8 : 2, v/v), the **HB1** could also fluorescence detection of CN⁻. Because aqueous systems have greater value and significance, the CN⁻ experiments were carried out in mixture solvent.

To investigate the practical application of sensor **HB1**, test strips based on **HB1** were prepared and then utilized to sense CN⁻ and Fe³⁺. Because bitter almonds usually contain CN⁻ in them, they were selected as the real samples. Ten grams of bitter almonds were crushed and pulverized in mortar. Then, H₂O (30 mL) and NaOH (0.05 g) were added into the sample. The obtained mixture was vigorously stirred for 15 minutes at room temperature. The CN⁻-containing solution was obtained by filtration. As shown in Fig. 8a, when writing on the test papers with a writing brush dipped in CN⁻ solution, a light-blue writing image appeared under 365 nm UV lamp. Meanwhile, when writing on the test papers with a writing brush dipped in Fe³⁺ solution, a dark writing image appeared under the 365 nm UV lamp. In addition, when we blend the solution of real sample with **HB1**, a similar light-blue fluorescence appeared which indicated that the **HB1** could efficient detection of CN⁻ in bitter almonds (Fig. 8b).

Compare to other sensors, the sensor **HB1** could be easier prepared and the synthesis process was simple. Additionally, the **HB1** contain imine and hydroxyl groups as recognition site, which could act as a good ions binding site through hydrogen-bonding interactions. Importantly, the sensor **HB1** could fluorescence detection of CN⁻ and dual-channel (absorption and fluorescence) detection of Fe³⁺ with high selectivity and sensitivity. The LODs of **HB1** for Fe³⁺ and CN⁻ are much better than some reported fluorescent sensors for Fe³⁺ or CN⁻. Interestingly, ion test strips based on **HB1** were fabricated, which could act as convenient and efficient test kits to detect CN⁻ and Fe³⁺ for "in-the-field" measurement. More importantly, the practical experiments were also carried out by detecting CN⁻ in bitter almonds.

(Insert Fig. 8)

Conclusions

In summary, we prepared a novel sensor molecule **HB1** based on 4-(diethylamino)-2-(hydroxy)-phenyl imine functionalized naphthalimide derivative. Interestingly, the **HB1** could not only fluorescence detection of CN^- in DMSO/ H_2O (8 : 2, v/v) solution but also dual-channel (absorption and fluorescence) detection of Fe^{3+} in DMSO solution with high selectivity and sensitivity. Meanwhile, ion test strips based on the sensor **HB1** were fabricated, which served as convenient and efficient CN^- and Fe^{3+} test kits. Importantly, the practical experiments were carried out by detecting CN^- in bitter almonds. We believe that this work may stimulate the further development of new sensors possessing excellent performance and exploring new arena especially in the realm of ions detection and separation.

Conflicts of interest

The authors declare no competing financial interests

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Figures captions

Scheme 1. Synthetic route to compound **HB1**.

Fig. 1. Fluorescence emission spectra ($\lambda_{\text{ex}} = 390 \text{ nm}$) of **HB1** in the presence of various anions in DMSO/H₂O (8 : 2, v/v) solution. Inset: Photograph showing the change in color of the **HB1** in DMSO/H₂O (8 : 2, v/v) solution after addition of various anions under 365 nm UV lamp.

Fig. 2. Fluorescence emission titration spectra ($\lambda_{\text{ex}} = 390 \text{ nm}$) of **HB1** ($2 \times 10^{-4} \text{ M}$) upon addition of CN⁻ (0.1 M) in DMSO/H₂O (8 : 2, v/v) solution.

Fig. 3. Competitive test for the fluorescence responses ($\lambda_{\text{ex}} = 390 \text{ nm}$) of **HB1** to CN⁻ in the presence of various anions in DMSO/H₂O (8 : 2, v/v) solution.

Fig. 4. Partial ¹H NMR spectra of **HB1** upon addition of CN⁻ (0-1.0 equiv.) in DMSO-*d*₆ solution.

Scheme 2. A possible mechanism of **HB1** response to CN⁻.

Fig. 5. Fluorescence emission spectra ($\lambda_{\text{ex}} = 390 \text{ nm}$) of **HB1** in the presence of various metal ions in DMSO solution. Inset: Photograph showing the change in color of **HB1** in DMSO solution after addition of various metal ions under 365 nm UV lamp.

Fig. 6. Fluorescence titration spectra ($\lambda_{\text{ex}} = 390 \text{ nm}$) of **HB1** ($2 \times 10^{-4} \text{ M}$) upon addition of Fe³⁺ (0.1 M) in DMSO solution.

Fig. 7. Competitive test for the fluorescence responses ($\lambda_{\text{ex}} = 390 \text{ nm}$) of **HB1** to Fe³⁺ in the presence of various metal ions in DMSO solution.

Scheme 3. A possible mechanism of **HB1** response to Fe³⁺.

Fig. 8. (a) Fluorescence changes of the test strips of **HB1** with writing CN⁻ and Fe³⁺ solution under 365 nm UV lamp; (b) Fluorescence changes of **HB1** response to bitter almonds under 365 nm UV lamp.

Scheme 1. Synthetic route to compound **HB1**.

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Fig. 2. Fluorescence emission titration spectra ($\lambda_{\text{ex}} = 390 \text{ nm}$) of **HB1** ($2 \times 10^{-4} \text{ M}$) upon addition of CN^- (0.1 M) in DMSO/ H_2O (8 : 2, v/v) solution.

Fig. 3. Competitive test for the fluorescence responses ($\lambda_{\text{ex}} = 390 \text{ nm}$) of **HB1** to CN^- in the presence of various anions in DMSO/ H_2O (8 : 2, v/v) solution.

Fig. 4. Partial ^1H NMR spectra of **HB1** upon addition of CN^- (0-1.0 equiv.) in $\text{DMSO}-d_6$ solution.

Scheme 2. A possible mechanism of **HB1** response to CN^- .

Fig. 5. Fluorescence emission spectra ($\lambda_{\text{ex}} = 390 \text{ nm}$) of **HB1** in the presence of various metal ions in DMSO solution. Inset: Photograph showing the change in color of **HB1** in DMSO solution after addition of various metal ions under 365 nm UV lamp.

Fig. 6. Fluorescence titration spectra ($\lambda_{\text{ex}} = 390 \text{ nm}$) of **HB1** ($2 \times 10^{-4} \text{ M}$) upon addition of Fe^{3+} (0.1 M) in DMSO solution.

Fig. 7. Competitive test for the fluorescence responses ($\lambda_{\text{ex}} = 390 \text{ nm}$) of **HB1** to Fe^{3+} in the presence of various metal ions in DMSO solution.

Scheme 3. A possible mechanism of **HB1** response to Fe^{3+} .

Fig. 8. (a) Fluorescence changes of the test strips of **HB1** with writing CN^- and Fe^{3+} solution under 365 nm UV lamp; (b) Fluorescence changes of **HB1** response to bitter almonds under 365 nm UV lamp.