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Selective fluorometric "Turn-off" sensing for Hg²⁺ with pyrazoline compound and its application in real water sample analysis

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Abstract

In this study, a new pyrazoline derivative (4-(3-phenyl-3a,4-dihydroindeno[1,2c]pyrazol-2(3H)-yl)benzenesulfonamide, K1) was described as fluorescent probe for fluorometric detection of Hg^{2+} . This fluorescence probe had a high selectivity only toward Hg^{2+} ion in the 19 metal ions (Li⁺, Na⁺, K⁺, Ag⁺, Mg²⁺, Ca²⁺, Ba²⁺, Cd²⁺, Zn²⁺, Cu²⁺, Hg²⁺, Cr²⁺, Pb²⁺, Cr²⁺, Pb²⁺, Cr²⁺, Fe^{2+} , Mn^{2+} , Co^{2+} , Fe^{3+} , Al^{3+} and Cr^{3+}). It was observed that Hg^{2+} ions significantly decrease the fluorescence intensity of K1, but the fluorescence intensity of K1 did not changed in the presence of the other metal ions. Limit of detection (LOD) value was calculated as 0.16 µM for Hg^{2+} while the binding constant was calculated as $4.69 \times 10^5 M^{-2}$ via fluorescence measurements. The values obtained by this study were very good compared to our previous Hg²⁺ sensor study which was realized with a different pyrazoline compound. The interaction between of **K1** and Hg²⁺was not interfered by the presence of other metal ions. In addition, the type of interaction was reversible. It was found that the relative standard deviations (RSD) of three measurements were less than 15% with the real sample tests performed in the tap water and its response time was less than 0.5 min. In conclusion, the new pyrazoline derivative K1 is a highly selective and sensitive fluorescence probe for the detection of Hg^{2+} ion and it has a great chance for practical application.

Keywords: Pyrazoline; Fluorometric; Turn off; Hg²⁺ ions.

1. Introduction

Detection of heavy metal ions is very important since they cause serious damage to the environment and human health. Mercury is one of the most toxic and polluting heavy metal used in many industrial products such as batteries, paints and electrical equipment. Therefore, it causes pollution in the atmosphere and surface waters. As a result, it has serious damage to the central nervous system and endocrine system in human through the food chain [1]. So, selective and sensitive detection studies for Hg^{2+} are quite important.

In recent years, the detection of Hg^{2+} ions by using new fluorescence probes is a very popular research area since fluorometric detection is a very sensitive, low-costly method in addition to getting the response quickly and compared to traditional methods such as highperformance liquid chromatography (HPLC), inductively coupled plasma mass spectrometry (ICP-MS) and atomic absorption/emission spectrometry (AAS/AES) [2]. Organic dyes such as rhodamine, fluorescein and coumarin derivatives are fluorescence probes commonly used in detection of Hg^{2+} ions [3-5]. So, it is an attractive and important field development of new fluorometric sensors for the detection of Hg^{2+} ion.

Pyrazoline derivatives are among the outstanding compounds since they are non-toxic bioactive compounds in addition to their strong fluorescence properties. Therefore, these compounds have widely been used as fluorometric ion sensor [6], hole-transport material in optoelectronic applications [7]. They are also interesting and attractive pharma core in medicinal chemistry since they have wide range of bioactivities such as anticancer and carbonic anhydrase inhibiting properties [8-10]. In recent years, ion detection studies with pyrazoline derivatives have become widespread due to their high selectivity and sensitivity [11].

In the present study, we have been investigated the effects of nineteen metal ions (Li⁺, Na⁺, K⁺, Ag⁺, Mg²⁺, Ca²⁺, Ba²⁺, Cd²⁺, Zn²⁺, Cu²⁺, Hg²⁺, Cr²⁺, Pb²⁺, Fe²⁺, Mn²⁺, Co²⁺, Fe³⁺, Al³⁺ and Cr³⁺) on the absorption and fluorescence properties of the novel pyrazoline derivative compound **K1** having the chemical structure 4-(3-phenyl-3a,4-dihydroindeno[1,2-c]pyrazol-

2(3H)-yl)benzenesulfonamide by using UV-Vis absorption and steady-state fluorescence measurements. These obtained results presented that **K1** is a sensor with high selectivity and sensitivity for the detection of Hg²⁺ compared to the other relevant metal ions. Real sample test realized for the possibility application of **K1** to determine practical use.

2. Experimental

2.1. Materials

Ethanol and LiCl, NaCl, AgCH₃COO, MgCl₂.6H₂O, CaCl₂.2H₂O, BaCl₂.2H₂O, CdCl₂, ZnCl₂.H₂O, CuCl₂.2H₂O, HgCl₂, CrCl₂, Pb(CH₃COOH)₂.3H₂O, FeSO₄.7H₂O, MnCl₂.4H₂O, CoCl₂.6H₂O, FeCl₃, AlCl₃ and CrCl₃ as the metal ion sources and ethylene diamine tetra acetic acid (EDTA) were obtained from Sigma and pH buffer solutions purchased from Fluka. Stock solution of freshly synthesized [12] and prepared **K1** was solved in ethanol at $1.0x10^{-3}$ M. Certain amount of **K1** in aqueous solution was made ready from its stock solution by evaporating ethanol. For all measurements, the final concentration of **K1** was 10 µM. All the experiments were performed at room temperature.

2.2. Apparatus

For **K1**, ¹H and ¹³C NMR spectra were recorded on Varian 400 and Bruker 400 instruments in DMSO-d₆. UV-Vis absorption and fluorescence spectra of **K1** were recorded with Perkin Elmer Lambda 35 UV/VIS Spectrophotometer and Shimadzu RF-5301PC spectrofluorophotometer, respectively. For the steady-state fluorescence measurements, sample solutions were excited at 350 nm and fluorescence intensities were recorded between 360 nm and 650 nm. FTIR measurements of the samples of **K1** were recorded with Vertex 80/80v FTIR spectrometer [13].

Fluorescence quantum yields of samples were calculated by using Parker-Rees equation.

$$\emptyset_{s} = \emptyset_{r} \left(\frac{D_{s}}{D_{r}} \right) \left(\frac{\eta_{s}^{2}}{\eta_{r}^{2}} \right) \left(\frac{1 - 10^{-OD_{r}}}{1 - 10^{-OD_{s}}} \right)$$
(1)

where *D* is the integrated area under the corrected fluorescence spectrum, *n* is the refractive index of the solution, and *OD* is the optical density at the excitation wavelength (λ_{exc} = 350 nm). The subscripts *s* and *r* refer to the sample and reference solutions, respectively [14]. Quinine sulphate in 0.5 M H₂SO₄ solution was used as the reference. The fluorescence quantum yield of quinine sulphate is 0.54 in 0.5 M H₂SO₄ solution [15].

2.3. Synthesis of 4–(3-Phenyl)-3a,4-dihydro-3H-indeno[1,2-c]pyrazol-2-yl) benzenesulfonamide (K1)

The compound **K1** was synthesized and characterized as described in our previous study [12]. The synthesis of the compound **K1** has been summarized in Scheme 1. Briefly, aqueous solution of sodium hydroxide (10% w/v, 10 mL) was added into the ethanol (6 mL) solution of 1-indanone (20 mmol) and benzaldehyde (20 mmol). Then, to obtain the starting compound chalcone the mixture was stirred overnight at room temperature and then it was poured on icewater (100 mL) in the beaker. The mixture was neutralized with hydrochloric acid (10% w/v, 10 mL). The colored precipitate formed was filtered and crystallized from water ethanol to obtain chalcone compound **1**. Chemical structure of the compound **1** was confirmed by ¹H NMR, ¹³C NMR, HRMS and the literature reported melting points of the compound. Data are not presented here. The solution of 2–(benzylidene)-2,3-dihydro-1*H*-inden-1-one (**1**, 1.00 mmol) and 4-hydrazinobenzensulfonamide hydrochloride (1.10 mmol) in ethanol (50 mL) was heated (100°C, 200 Watt, 3 barr, 20 min). Reaction was monitored by TLC. When the reaction was stopped, the volume of the reaction mixture was concentrated to the half and the precipitate

formed was filtered, washed with cold ethanol, and dried. Then compound was purified by crystallization from ethanol to obtain **K1**. Chemical structure of the compound **K1** was confirmed by ¹H NMR, ¹³C NMR, and HRMS. M.p. 243–246°C. Yield: 8.4% ¹H NMR (400 MHz, CDCl₃, ppm) δ 7.76 (d, 1H, Ar-H, *J*=8.4 Hz), 7.67 (d, 2H, Ar-H, *J*=9.1 Hz), 7.34–7.19 (m, 6H, Ar-H), 7.03 (bs, 4H, Ar-H), 5.59 (d, 1H, C₃ -H, *J*=10.9 Hz), 4.28–4.21 (m, 1H, C_{3a} -H), 2.91 (dd, 1H, C₄ -H_a, *J*=15.9, 8.7 Hz), 2.17 (dd, 1H, C₄ -H_b, *J*=15.9, 7.6 Hz); ¹³C NMR (100 MHz, CDCl₃, ppm) δ 163.9, 151.7, 148.1, 134.3, 131.0, 130.7, 129.8, 128.9, 128.4, 128.3, 127.9, 127.3, 126.6, 122.9, 112.5, 67.5, 55.2, 29.9; Mass spectrum: 390.12 (M⁺ +1); HRMS (ESI-MS) Calc.: 390.1276 for C₂₂ H₂₀ N₃ O₂ S [M+H]⁺, found: 390.1281.

2.4. The sensing of metal ion

 $1.0x10^{-2}$ M stock solutions of all metal ions (Li⁺, Na⁺, K⁺, Ag⁺, Mg²⁺, Ca²⁺, Ba²⁺, Cd²⁺, Zn²⁺, Cu²⁺, Hg²⁺, Cr²⁺, Pb²⁺, Fe²⁺, Mn²⁺, Co²⁺, Fe³⁺, Al³⁺ and Cr³⁺) were prepared in pure water. Then, 10 µL of metal ion solution was added to 5 ml water solution of **K1** having 10 µM concentration at room temperature. The spectroscopic changes of **K1** were recorded by absorption and fluorescence measurements. In addition, special series of water solutions of Hg²⁺ ion with different concentrations (0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 4.0, 6.0, 8.0, 10, 20, 30, and 40 µM) were also prepared since only Hg²⁺ decreased the fluorescence intensity of **K1** among 19 metal ions. The absorption and fluorescence measurements were taken for each solution containing Hg²⁺ ions. The detection limit for Hg²⁺ was determined with the fluorescence data. For this purpose, 3s/k equation was used. Where s is the standard deviation of blank, k is the slope of the fit line in fluorescence titration experiment. Moreover, the following Benesi-Hildebrand equation was used to calculate the binding constant:

$$\frac{1}{F - F_0} = \frac{1}{K_A (F_{max} - F_0) [M^+]^n} + \frac{1}{F_{max} - F_0}$$
(2)

where F_0 , F, and F_{max} are the fluorescent intensity of molecule in which F_0 is in the absence of metal ion, F is at a certain concentration of metal ion, F_{max} is at a complete interaction concentration of metal ion. [M⁺] is the concentration of Hg²⁺, n is the binding stoichiometry for dye and metal ion [16].

2.5. Testing real sample

Tap water was used for real sample tests. After filtration, 2.5 ml of tap water was put into 5 ml volumetric flask containing 10 μ M **K1**. Then 5 μ l, 10 μ l and 15 μ l stock solutions of Hg²⁺ were added on **K1** solution. The mixture was diluted to 5 ml with distilled water and the fluorescence spectra were recorded between 360 nm and 650 nm at 350 nm excitation wavelength.

3. Result and Discussion

3.1. The photo-physical behavior of K1 and the effect of metal ions

The **K1** studied here was synthesized according to literature procedure [12] and it was summarized in Scheme 1.

The optical behavior of the **K1** in water was determined by taking UV-Vis absorption and fluorescence spectra (Fig. 1). The **K1** exhibited two absorption bands at 278 nm and 363 nm and relatively high intensity fluorescence band at 464 nm (Fig. 1).

The effects of several alkali, alkaline-earth and heavy/transition metal ions (Li⁺, Na⁺, K⁺, Ag⁺, Mg²⁺, Ca²⁺, Ba²⁺, Cd²⁺, Zn²⁺, Cu²⁺, Hg²⁺, Cr²⁺, Pb²⁺, Fe²⁺, Mn²⁺, Co²⁺, Fe³⁺, Al³⁺, and Cr³⁺) on the optical properties of the **K1** were studied. For this, solutions containing 20 μ M metal ions were added into the **K1** (10 μ M) aqueous solution. Then, at room temperature absorption and fluorescence measurements were taken for the solutions mentioned above. It was observed that the absorption spectrum of the **K1** did not changed in the presence of the metal ions (Fig. 2). However, the fluorescence intensity of **K1** significantly decreased only in

the presence of Hg^{2+} ion (Fig. 3a). As shown in Fig. 3b, the color of the solution changed in the presence of Hg^{2+} ion, while other metal ions did not cause a significant change in solution color.

The fluorescence quantum yields of **K1** in the presence and absence of metal ions were calculated by using Eq. (1) (Table 1). The calculated fluorescence quantum yield value of **K1** in the presence of Hg^{2+} ion was 0.05. This value was 8.6 times smaller than the value in pure water. This reduction in the quantum yield of **K1** supported that Hg^{2+} reduced the fluorescence intensity of **K1**. The calculated fluorescence quantum yield values of the **K1** in the presence of other metal ions rather than Hg^{2+} were almost the same with the value of **K1** in pure water (0.43).

3.2. Detection of Hg²⁺ by using K1

In order to detect mercury ions, the fluorescence intensity of **K1** (10 μ M) was determined in the presence of Hg²⁺ ions in different concentrations (0-40 μ M) (Fig. 4). As shown in Fig. 4, while the fluorescence band maximum (λ_{max}) was not changed compared to pure water's (464 nm); the fluorescence intensity of **K1** decreased as Hg²⁺ ion concentration increased. This finding was in accordance with the literature [2, 17]. The linear relationship between the fluorescence intensity of **K1** and the Hg²⁺ ion concentration was presented in Fig. 5. The detection limit (LOD) of Hg²⁺ was determined as 0.16 μ M by using Fig. 5. LOD value was very low in the present study compared to our previous Hg²⁺ sensor study which was realized with a different pyrazoline compound [11]. Having low LOD value is a very good parameter for the development of fluorescence sensor.

Job's plot analysis was used to determine the stoichiometry of interaction between **K1** and Hg^{2+} . The interaction ratio between **K1** and Hg^{2+} was found as 2:1 according to the results obtained (Fig. 6). The binding constant of Hg^{2+} was calculated as 4.69×10^5 M⁻² with the slope of graph which was drawn using Eq. (2). This value is greater than the Hg^{2+} sensor studies in the literature [18, 19]. This is also good parameter for this type of fluorescence sensor studies.

This value was also higher than our previous report obtained with a different pyrazoline compound [12].

Competition studies were carried out to determine the selectivity of **K1** against Hg^{2+} . For this purpose, fluorescence measurements of **K1** solutions were taken by adding Hg^{2+} ion in the presence of competitive metal ions (Li⁺, Na⁺, K⁺, Ag⁺, Mg²⁺, Ca²⁺, Ba²⁺, Cd²⁺, Zn²⁺, Cu²⁺, Cr^{2+} , Pb²⁺, Fe²⁺, Mn²⁺, Co²⁺, Fe³⁺, Al³⁺ and Cr³⁺). As seen in Fig. 8, the presence of competitive ions in the medium did not affect the selectivity of **K1** to Hg^{2+} ion. This is a very good result for the selective detection of Hg^{2+} ion without interaction with other ions.

Reversible behavior is a preferable property for the fluorescence sensors. Reversible behavior of **K1** against Hg^{2+} ion was investigated by fluorescence measurements using EDTA. When EDTA was added to the **K1** solution in the presence of Hg^{2+} ion, it was observed that **K1** could return to the fluorescence intensity in the absence of Hg^{2+} (Fig. 9). This result showed that **K1** was a sensor with recycling capability via Hg^{2+} "OFF" and EDTA "ON" system. It means that **K1** is a reversible fluorescence sensor.

Shortness of response time (SRT) of a sensor is one of the important features that was desired. So, the change in the interaction of **K1** and Hg^{2+} ion with time was evaluated (Fig. 10). It was found that the fluorescence intensity of **K1** decreased within 0.5 minute (min) and then remained fixed from 1 min to 10 min. The rapid and stable response of **K1** to Hg^{2+} ion is a very important result for the detection of Hg^{2+} ion in fluorescence sensor studies. Although, SRT is an important parameter, it was not considered in studies in this area [20-22]. So, this study makes a valuable contribution to the fluorescence sensor studies by this respect.

3.3. pH profiles of K1

The effect pH on the Hg^{2+} detection with **K1** was evaluated at different pH values (pH 2-12) by taken fluorescence spectra (Fig. 11). As shown in Fig. 11, the fluorescence intensity

of **K1** decreased in the presence of Hg^{2+} ions in the pH range of 7-12. This result shows that this new sensor can be used for neutral water samples and biological applications at physiological pH.

3.4. Hg²⁺ ion sensing mechanism

FTIR measurements were used to determine the interaction between **K1** and Hg^{2+} . The FTIR spectra for **K1** (black color, Fig. 12) and **K1**+Hg²⁺ (red color, Fig. 12) were given in Fig. 12. According to Fig. 12, the **K1** gave the peaks at 1310 (C-N stretching vibration), 1429 (C-C stretching vibration), 1736 (C=N stretching vibration), 2915 (C-H stretching vibration), and 3439 (N-H stretching vibration) cm⁻¹. In the presence of Hg²⁺, the peaks at 1310 (C-N stretching vibration) and 3439 (N-H stretching vibration) cm⁻¹ disappeared. This suggested that the decrease in fluorescence intensity of **K1** was due to electrostatic interactions between **K1** and Hg²⁺ ions. The proposed interaction mechanism for **K1** and Hg²⁺ was shown in Scheme 2.

To determine the interaction mode of Hg^{2+} metal ions with **K1**, ¹H NMR titration was also performed in the absence and presence of Hg^{2+} in DMSO-d₆ (Fig. 13). According to ¹H NMR of the **K1** without Hg^{2+} , proton signals of SO₂NH₂ group was seen at 7.00 ppm as a singlet. With increasing amount of Hg^{2+} , the appearance of the proton signals of the SO₂NH₂ changed. It was observed that proton of the SO₂NH₂ group of the **K1** and shifted to upfield and its shape changed to a broad singlet from sharp singlet while its intensity was decreasing. This supports suggested the interaction mechanism of the **K1** with Hg^{2+} (Scheme 2) by FTIR.

3.5. Real sample tests

The real sample performance of our novel sensor **K1** was investigated. In our experimental design for this purpose it was used tap water and pure water mixture in 1:1 volume ratio. Three **K1** solutions at 10 μ M were prepared by using this water mixture. After that 10 μ M, 20 μ M and 30 μ M Hg²⁺ ions were added into **K1** solutions which have constant

concentration as 10 μ M. then the fluorescence measurements were taken and the results were presented in Table 2. Hg²⁺ concentrations were detected as 7.3 μ M, 21.9 μ M and 29.5 μ M for 10 μ M, 20 μ M and 30 μ M Hg²⁺ solutions, respectively. The relative standard deviation (RSD) of three measurements was less than 15%. Recovery was between 72.7% and 109.6%. These results are quite satisfactory for the analytical applications of **K1**.

3.6. Comparison with other Hg²⁺ sensors

The comparison of the fluorescent sensor K1 used in our study with other Hg^{2+} sensors in the literature were given in Table-3. The value of the detection limit obtained in this study was found to be significantly better than many studies in literature and also our previous study's [1, 2, 11, 22-29].

4. Conclusions

In this study, the ability of new pyrazoline derivative **K1** to be a metal ion sensor was investigated. Based on this target, the effects of 19 different metal ions on the optical behavior of **K1** were studied in pure water by using UV-Vis absorption and steady-state fluorescence measurements. The fluorescence intensity of **K1** only changed significantly in the presence of Hg^{2+} ion, while other metal ions had no effect on the absorption spectrum of **K1**. So, the next part of our studies was continued with Hg^{2+} ion. The LOD value for Hg^{2+} ion was calculated as 0.16 µM using the linear reduction of fluorescence intensity of **K1** depending on increasing concentrations of Hg^{2+} ion. This value was found to be quite low compared to many other studies reported including in our previous study. Interaction ratio of **K1** and Hg^{2+} was determined as 2:1 by Job's method. The interaction between of **K1** and Hg^{2+} did not interfere from the presence of other metal ions and the type of interaction was reversible. The interaction mechanism of Hg^{2+} with **K1** was estimated with the FT-IR measurements. Real sample experiments were performed in tap water for possible practical application of **K1**. In conclusion, the new pyrazoline derivative K1 is a highly selective and sensitive fluorescence probe for the detection of Hg^{2+} ion and it has a great chance for practical application.

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FIGURE and SCHEME CAPTIONS

Scheme 1. The general synthesis and molecular structure of K1.

Fig. 1. Absorption and fluorescence spectra of **K1** in water (λ_{exc} =350 nm).

Fig. 2. Absorption spectra of K1 in the absence and presence of 20 µM metal ions in water.

Fig. 3. (a) Fluorescence spectra of K1 in the absence and presence of 20 μ M metal ions in water (λ_{exc} =350 nm). (b) Photographs of K1 in the presence of metal ions under UV. B; includes only K1 while the others contain K1 and a metal ion.

Fig. 4. Fluorescence spectra of K1 with the increasing concentration of Hg²⁺ (λ_{exc} =350 nm).

Fig. 5. Change fluorescence intensity of K1 with the increasing concentration of Hg^{2+} .

Fig. 6. Job's plot of **K1** with Hg^{2+} in water.

Fig. 7. Benesi-Hildebrand plot based on a 1:2 association stoichiometry between Hg^{2+} and K1.

Fig. 8. Metal ion selectivity profiles of K1 in the presence of various metal ions in water. Red bars represent the fluorescence intensity of K1 in the presence of 20 μ M of metal ion. Blue bars represent the fluorescence intensity in the presence of various metal ions after the addition of Hg²⁺.

Fig. 9. Fluorescence spectra of K1 in the presence of 20 μ M Hg²⁺ ion and EDTA in water (λ_{exc} =350 nm).

Fig. 10. Fluorescence enhancing profile of addition Hg^{2+} (20 μ M) to K1 (10 μ M) in water from 0.5 min to 10 min.

Fig. 11. Fluorescence (at 464 nm) of **K1** (10 μ M) and **K1** (10 μ M) + Hg²⁺ (20 μ M) at different pH (2-12).

Fig. 12. FTIR spectra of K1 and Hg^{2+}

Scheme 2. The proposed mechanism of interaction between K1 and Hg²⁺

Fig. 13. ¹H NMR spectra of **K1** (10 μ M); **K1** (10 μ M) + Hg²⁺ (20 μ M) in DMSO-d₆



Reagents and conditions. (i) aq. NaOH 10%, EtOH, r.t, 12 h; (ii) 4hydrazinobenzensulfonamide hydrochloride, EtOH, 100 °C, 200 Watt, 3 barr, 20'.





Fig. 1.



Fig. 2.



Fig. 3b.



Fig. 4.













Fig. 8.









Fig. 11.



Fig. 12.



Scheme 2.





TABLES

Table 1. The fluorescence quantum yield values of K1 in the absence and presence of 20 μ M metal ions in water.

Table 2. Determination of Hg^{2+} contents in tap water samples (n=3).

Table 3. Comparison of some Hg²⁺ selective chemosensors.

Table 1.

Media	Φ_{f}	Media	Φ_{f}
Pure water	0.43	Cu ²⁺	0.25
Na ⁺	0.33	Hg ²⁺	0.05
Li ⁺	0.33	Cr ²⁺	0.28
K ⁺	0.31	Pb ²⁺	0.28
Ag^+	0.32	Fe ²⁺	0.21
Mg^{2+}	0.31	Mn ²⁺	0.22
Ca ²⁺	0.31	Co ²⁺	0.31
Ba ²⁺	0.31	Fe ³⁺	0.21
Cd ²⁺	0.32	Al ³⁺	0.27
Zn ²⁺	0.35	Cr ³⁺	0.30

Table 2.

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Samples	Hg ²⁺ spiked (µM)	Hg ²⁺ found (µM)	Recovery (%)	RSD (%)		
1	10	7.3	72.7	11.0		
2	20	21.9	109.6	5.6		
3	30	29.5	98.3	2.1		

Table 3.

Ref	Binding Constant (M ⁻¹)	Detection Limit (µM)	Sensing Ions	Response Time (min)
[1]	4.19×10^{5}	0.18	Hg^{2+}	-
[2]	-	0.50	Hg^{2+}	-
[11] (Our previous work)	$8.06 ext{x} 10^4$	14.54	Hg^{2+}	1.0
[22]	3.00x10 ⁹	0.39	Hg ²⁺	C
[24]	$2.5 imes 10^4$	2.00	Ag^+, Hg^{2+}	/
[25]	$4.71 \times 10^{-10} \text{ M}$	0.33	Hg ²⁺	-
[26]	-	1.21	Hg ²⁺ , I ⁻	-
[27]	$1.7 imes 10^4$	10.00	Hg ²⁺	-
[28]	-	0.53	Cu ²⁺ ,Hg ²⁺	-
[29]	1.61×10^{4}	1.84	Cu ²⁺ ,Hg ²⁺	-
K1 (This work)	4.69x10 ⁵ M ⁻²	0.16	Hg ²⁺	0.5

Highlights

- A new pyrazoline derivative (**K1**) was synthesized for Hg²⁺ ion sensing based on fluorometric detection.
- The possibility of practical uses of **K1** as selective fluorometric "turn-off" was reported.
- **K1** seemed a highly selective and sensitive fluorescence probe for the detection of Hg²⁺ ion.

GRAPHICAL ABSTRACT

