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A novel turn-on Schiff-base fluorescent sensor for Aluminum (III) ions in living cells

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(E)-4-methoxy-N-(8-methylquinoline-2-yl)methylene)aniline (L) was successfully synthesized and characterized. The complexation behavior of L with different metal ions was studied on UV-Vis absorption spectra and fluorescent spectra. Results showed that the sensor (L) exhibited 38-fold enhancements in fluorescence at 517 nm after adding 10 equiv. of Al^{3+} ion. Such fluorescent responses could be detected by naked eye under a UV-lamp at 365 nm. The complex solution (L-Al^{3+}) showed reversibility with EDTA and the complex was 1:1 ratio according to Job's plot and electrospray ionization mass spectra (ESI-MS). A photoinduced electron transfer (PET) mechanism was considered to be operational for fluorescence enhancement. The detection limit of Al^{3+} was calculated to be $1.2 \times 10^{-7} \text{ M}$, a satisfying level to detect Al^{3+} in the micromolar scale. Importantly, the chemosensor L could be used to detect and quantify Al^{3+} in living cells. Therefore, this sensor has the ability to be a practical system for monitoring Al^{3+} concentrations in biological.

1. Introduction

Aluminum is the third most abundant element in the earth's crust. Due to acidic rain and human activities, Al^{3+} exists widely in the environment. Al^{3+} affects the activity of gastrointestinal enzymes and excess Al^{3+} is toxic in the central nervous system.¹⁻³ The World Health Organization (WHO) recommends an average daily human intake of Al^{3+} of around 3-10 mg/kg and the tolerable weekly dietary intake as 7 mg/kg body weight. Excessive exposure of the human body to Al^{3+} leads to many diseases such as Alzheimer's disease and Parkinson's disease, bone softening, smoking related diseases and chronic renal failure.⁴⁻⁸ Up to now, many measurement technologies have been developed to sensitively and reliably detect Al^{3+} such as atomic absorption spectrometry, inductively coupled plasma-atomic emissions spectrometry and inductively coupled plasma-mass spectrometry.⁹ Compared to these approaches, the fluorescent probes for detecting Al ions has attracted great interests of researchers due to attention due to its several outstanding advantages such as low cost, simplicity, high sensitivity and sensitivity.

Since there is a close association between Al^{3+} and human health, the investigation of Al^{3+} detection has attracted increasing attention.¹⁰ In recent years, data showed that forty percent of children in China had aluminum intake exceeding the limitation of the WHO recommended allowance.¹¹ Therefore, development of sensitive molecular signaling systems especially for aluminum ion have become increasingly

important.^{12,13} To date, a good number of Schiff-base compounds have been reported very recently as a sensor for the detection of aluminum metal ion using fluorescence spectroscopy.¹⁴⁻²³ Wu et al. reported commercially available compound, 2-hydroxy-1-naphthaldehyde, as a highly sensitive and selective fluorescent sensor for Al^{3+} for the first time in 2012.²⁴ After that, a number of Schiff-bases have been synthesized over the couple of years employing 2-hydroxy-1-naphthaldehyde as the aldehyde and have been applied as the chemosensors for the detection of aluminum ion.²⁵⁻²⁹

Based on this knowledge, herein, a simple, high selectivity and high sensitivity Al^{3+} sensor has been designed, synthesized. We report aluminum (III) sensing behavior of (E)-4-methoxy-N-(8-methylquinoline-2-yl)methylene)aniline (L) (Scheme 1). It has been prepared from the Schiff-base condensation between 8-hydroxyquinoline-2-carbaldehyde and anisidine. L has been characterized by different spectroscopic techniques.

2. Experimental

2.1. Materials and instrumentation

All reagents were purchased commercially of grade quality and without any further purification. The (E)-4-methoxy-N-(8-methylquinoline-2-yl)methylene)aniline (L) was synthesized in the laboratory. Double-distilled water was used throughout the experiments. ¹H NMR spectra were measured on a Bruker 500 MHz instrument using TMS as an internal standard. UV-Vis absorption spectra were determined on a U-3900 spectrophotometer. Fluorescence spectra were recorded with a Hitachi F-4600 spectrophotometer equipped with quartz cuvettes of 1 cm path length. MS spectra were measured on a Shimadzu GC-17A, QP-5000 GC/MS spectrometer. FT-IR

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spectra were recorded with a NICOLET 6700 spectrophotometer.

2.2. Synthesis and characterization

2.2.1. The synthesis of 8-hydroxyquinoline-2-carbaldehyde (L1). A2-methylquinoline-8-ol (3.2g, 20mmol) was dissolved in dioxane (90mL), and SeO_2 (2.8 g, 24.8mmol) was added to this solution. The mixture was stirred at 80°C for 24h and then cooled to room temperature. The precipitate was filtered off. The solvents were evaporated to give the crude product, which was purified by flash chromatography on silica gel (5:1 petroleum ether/ethyl acetate as eluent) to give a yellow solid L1 (3.28 g, 18.96mmol, 95%). ^1H NMR (500 MHz, CDCl_3) δ 10.23 (s, 1H), 8.33 (d, $J = 8.0$ Hz, 1H), 8.15 (s, 1H), 8.07 (d, $J = 8.3$ Hz, 1H), 7.62 (d, $J = 7.9$ Hz, 1H), 7.44 (d, $J = 7.4$ Hz, 1H).

2.2.2. The synthesis for (E)-4-methoxy-N-(8-methylquinoline-2-yl)methyleneaniline (L). 8-hydroxyquinoline-2-carbaldehyde (0.692g, 4mmol) was dissolved in ethanol (30mL); then anisidine (0.492g, 4mmol) was added to the solution. The solution was refluxed for 4h under stirring. The solution was cooled to room temperature and the solvent was evaporated under pressure to obtain yellow crude. It was purified by recrystallization in ethanol to give the light yellow solid L (0.689g, 2.52mmol, 62%). ^1H NMR (500 MHz, DMSO) δ 9.95 (s, 1H), 8.82 (s, 1H), 8.41 (d, $J = 8.6$ Hz, 1H), 8.26 (d, $J = 8.6$ Hz, 1H), 7.51 (t, $J = 7.8$ Hz, 1H), 7.45 (d, $J = 8.9$ Hz, 3H), 7.16 (d, $J = 7.5$ Hz, 1H), 7.05 (d, $J = 8.8$ Hz, 2H), 3.81 (s, 3H). ^{13}C NMR (126 MHz, DMSO) δ 159.71, 158.98, 154.63, 153.51, 143.89, 139.14, 137.65, 130.24, 129.76, 123.82, 119.15, 118.74, 115.58, 113.04, 56.30. ESI-mass (m/z): $[\text{L} + \text{H}]^+$: calcd:279.31. obsd: 279.27. Anal. Calcd for $\text{C}_{17}\text{H}_{14}\text{N}_2\text{O}_2$: C, 73.37; H, 5.07; N, 10.07 Found: C, 73.29; H, 4.99; N, 10.01.

2.3. Analysis

The receptor could be dissolved in methanol. The stock solution for the different metal salts of Na^+ , K^+ , Ca^{2+} , Mg^{2+} , Ba^{2+} , Al^{3+} , Fe^{3+} , Pb^{2+} , Mn^{2+} , Co^{2+} , Ni^{2+} , Sr^{2+} , Zn^{2+} , Sn^{2+} , Cd^{2+} , Hg^{2+} , Cr^{3+} , Ce^{3+} and Ag^+ were prepared in water.

2.4. Job's plot measurements

Receptor 1 (1.39mg, 0.005mmol) was dissolved in methanol (5mL). 20, 18, 16, 14, 12, 10, 8, 6, 4 and $2\mu\text{L}$ of the receptor solution were taken and transferred to vials. Each vial was diluted with methanol to make a total volume of 1.976mL. $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$ (0.005 mmol) was dissolved in water (1 mL), respectively. 0, 2, 4, 6, 8, 10, 12, 14, 16, 18 and $20\mu\text{L}$ of the Al^{3+} solution were added to each diluted receptor solution. Each vial had a total volume of 2mL. After shaking the vials for a few minutes, fluorescence spectra were taken at room temperature.

2.5. Benesi-Hildebrand plot

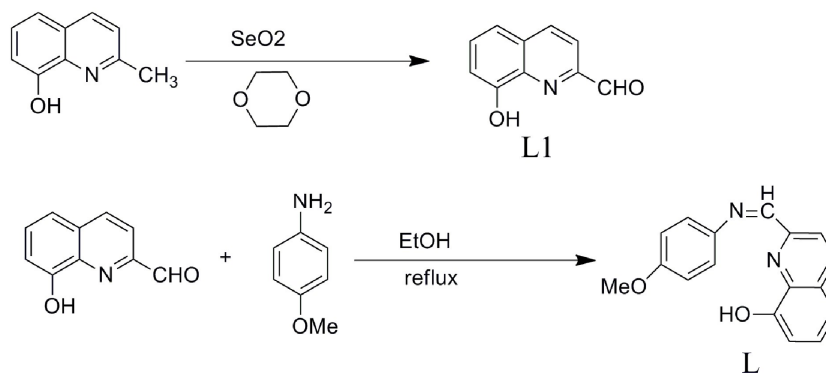
The binding constant value was determined from the fluorescence intensity data using a modified Benesi-Hildebrand equation where F_0 , F and F_{max} are emission intensities of L in absence of Al^{3+} , intermediate Al^{3+} concentration and concentration of Al^{3+} of complete interaction respectively; the plot of $(F_{\text{max}} - F_0)/(F - F_0)$ vs $1/[\text{Al}^{3+}]$ (FigS. 5) was the Benesi-Hildebrand plot

2.6. PH study

PH buffer solution (20mM) preparation: 2.384g HEPES and 4.25g NaNO_3 were dissolved in pure water (500ml volumetric flask), then use the 1mol/L HCl and 1mol/L NaOH to adjust pH value 7. The compound L (10Mm in methanol) and Al^{3+} (10mM in water) were prepared in cuvette, then adjust PH value (3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0) with 1mol/L HCl and 1mol/L NaOH (2mL, constant volume with buffer).

2.7. Cell imaging studies

The living HeLa cells were provided by XiangYa Central Experiment Laboratory of Central South University (China).



Scheme1. The synthetic routes of compound L

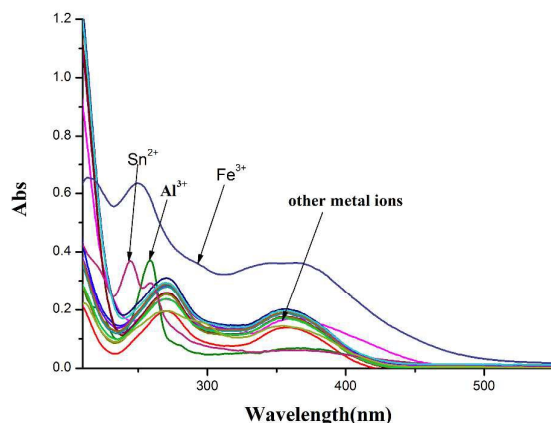


Fig.1 UV-Vis absorption spectra of compound L (10 μM) in the absence and presence of different metal ions (10 equiv.) such as Al^{3+} , Fe^{3+} , Ba^{2+} , Ag^+ , Cd^{2+} , Co^{2+} , Sr^{2+} , Hg^{2+} , K^+ , Pb^{2+} , Mg^{2+} , Na^+ , Ca^{2+} , Ni^{2+} , Mn^{2+} , Sn^{2+} , Cr^{3+} , Ce^{3+} and Zn^{2+} at room temperature.

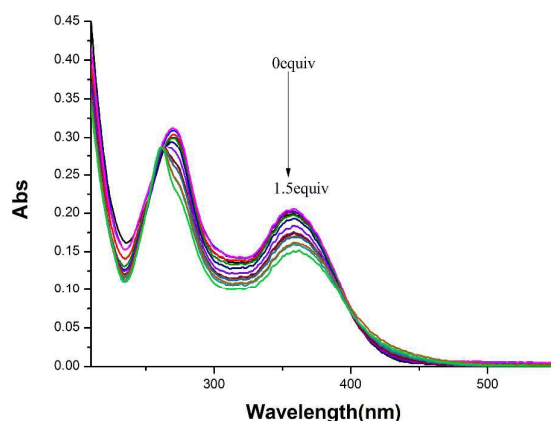


Fig.2 UV-Vis absorption spectra of compound L (10 μM) upon the titration of Al^{3+} (0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.4, 1.5, equiv.) at room temperature

Hela cells were incubated with 10 μM of L in the culture medium at 37°C for 30 min and washed with phosphate-buffered saline (PBS) followed by the addition of (0, 5, 10, 20 and 40 μM) Al^{3+} ions. Bright field and fluorescent images were captured at 20× magnification in Olympus microscope (1×70) using Camedia software (Chicago, MI, USA) (E-20P 5.0 Megapixel)

3. Results and Discussion

3.1. UV-Vis studies of compound L.

UV-Vis absorption spectra of compound L in the presence of the various metal ions Na^+ , K^+ , Ca^{2+} , Mg^{2+} , Ba^{2+} , Al^{3+} , Fe^{3+} , Pb^{2+} , Mn^{2+} , Co^{2+} , Ni^{2+} , Sr^{2+} , Zn^{2+} , Sn^{2+} , Cd^{2+} , Hg^{2+} , Ag^+ , Cr^{3+} and Ce^{3+} were recorded in an alcoholic medium (CH_3OH) using a U-3900 spectrophotometer. As seen in Fig. 1, the absorption spectrum of compound L exhibited two broad absorption bands at 271 nm and 358 nm. The position of absorption bands remained unchanged over the various metal ions except Sn^{2+} and Al^{3+} ions. Due to the complexation of Al^{3+} and L, a new

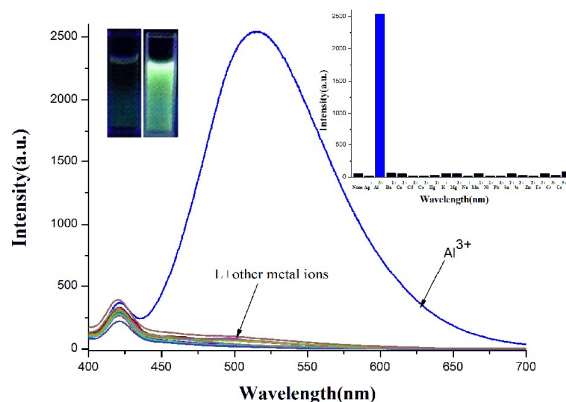


Fig.3 Fluorescence emission spectra of L (10 μM) in methanol in the presence of different metal ions (10 equiv.) such as Al^{3+} , Fe^{3+} , Ba^{2+} , Ag^+ , Cd^{2+} , Co^{2+} , Sr^{2+} , Hg^{2+} , K^+ , Pb^{2+} , Mg^{2+} , Na^+ , Ca^{2+} , Ni^{2+} , Mn^{2+} , Sn^{2+} , Cr^{3+} , Ce^{3+} and Zn^{2+} . Excitation wavelength was at 373 nm. Inset (left): Fluorescence intensity of compound L with Al^{3+} at 517 nm. Inset (right): The fluorescence intensity of different metal ions at 517 nm.

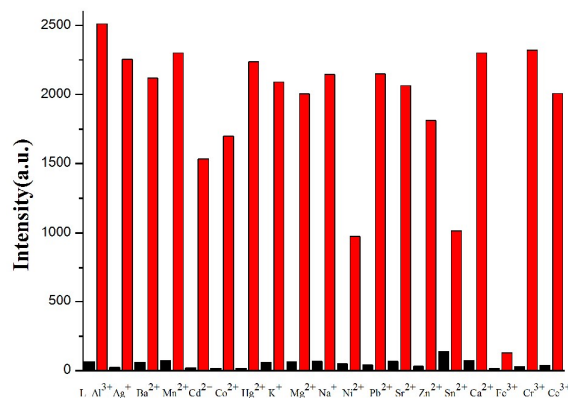


Fig.4 Selectivity of L for Al^{3+} ions in the presence of other competitive metal ions (10 equiv.) in methanol. Excitation wavelength and emission maximum are 373 nm and 517 nm respectively. Black bars represent fluorescent intensity after the addition of 10 equiv. of the appropriate metal ions (Fe^{3+} , Ba^{2+} , Ag^+ , Cd^{2+} , Co^{2+} , Mn^{2+} , Sn^{2+} , Hg^{2+} , K^+ , Pb^{2+} , Mg^{2+} , Na^+ , Ca^{2+} , Ni^{2+} , Sr^{2+} , Cr^{3+} , Ce^{3+} and Zn^{2+}) in a 10 μM solution of L. Red bars represent the subsequent addition of same equiv. of Al^{3+} ions in each of the samples.

absorption band at 258 nm was formed with Al^{3+} , and the absorption intensity at 358 nm tends to decrease.

The binding properties of L with Al^{3+} were studied by UV-Vis titration in methanol solution (Fig. 2). Upon addition of increasing amounts of Al^{3+} (0–1.5 equiv.), while the absorption bands at 271 and 358 nm decreased gradually, the absorption band at 271 nm shifted to 258 nm. The blue-shifted absorption indicated that the proton at phenol was not deprotonated.³⁰ Moreover, there were clearly two isosbestic points at 256 and 396 nm, and the presence of two different isosbestic points for the sensor L suggested the formation of a complex L-Al^{3+} .³¹

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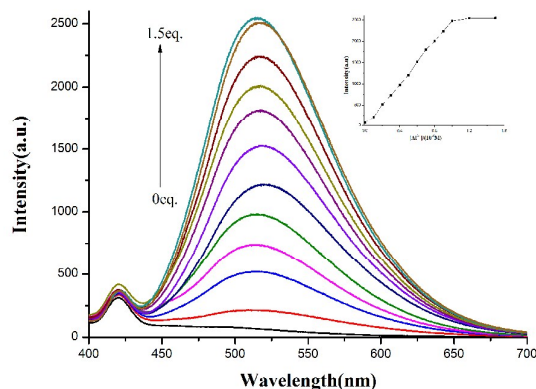


Fig.5. Fluorescence emission spectra at 517nm of L upon addition of Al^{3+} (0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2 and 1.5equiv.) with an excitation of 373nm. Inset: Fluorescence emission spectra of L upon addition of Al^{3+} (0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2 and 1.5equiv.) with an excitation of 373nm and an emission of 517nm.

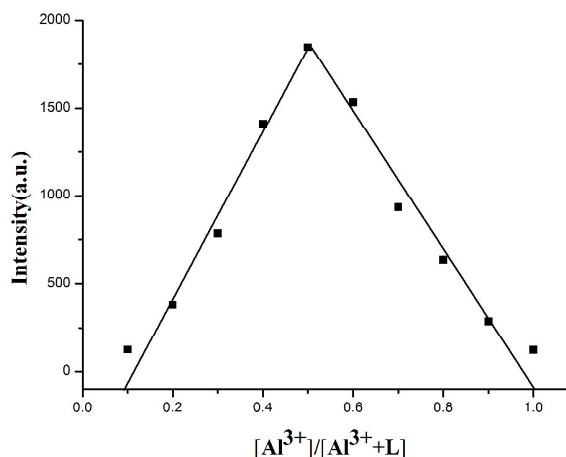


Fig.6. Job's plot of L according to the method for continuous variations, indicating the 1:1 stoichiometry for L-Al^{3+} (the total concentration of L and Al^{3+} is $20\mu\text{M}$).

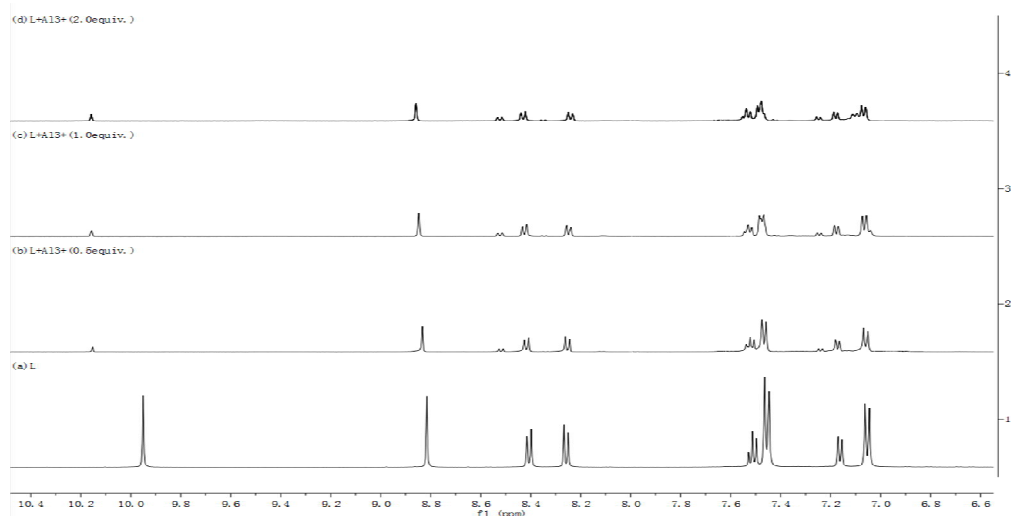


Fig.7. ^1H NMR (500MHz) spectra of L with Al^{3+} (0.0-2.0eq.) in DMSO

3.2. Fluorescence studies of compound L

3.3.1. Selectivity of compound L for Al^{3+} over other metal ions

For an excellent chemosensor, high selectivity is a matter of necessity. To confirm the selectivity of sensor L, The fluorescence behavior of (E)-4-methoxy-N-(8-methylquinoline-2yl)methylene)aniline (L) was investigated using a Hitachi F-4600 spectrophotometer upon the addition of various metal ions. Quinoline Schiff base L did not show any significant emission band alone at 517nm when the excitation wavelength was at 373nm. After the addition of Na^+ , K^+ , Ca^{2+} , Mg^{2+} , Ba^{2+} , Fe^{3+} , Pb^{2+} , Mn^{2+} , Co^{2+} , Ni^{2+} , Sr^{2+} , Zn^{2+} , Sn^{2+} , Cd^{2+} , Hg^{2+} , Ag^+ , Cr^{3+} and Ce^{3+} (Fig. 3), compound

L exhibited no significant fluorescent enhancement. Only in the case of Al^{3+} ions compound L exhibit a more than 38-fold fluorescent enhancement, the quantum yields of L and its metal complex L-Al^{3+} were 0.016 and 0.62 respectively (Fig. 4).

Interferences of cations were studied by treating L with 10 equiv. of Al^{3+} in the presence of 10 equiv. of other metal ions. As shown in Fig. 4, the response of compound L for Al^{3+} is not affected by competing metal ions (except Fe^{3+} . L and Fe^{3+} could form a stable chelate complex Lead to the fluorescence quenching), the fluorescent response of L-Al^{3+} is observed to be relatively reduced in the presence of Ni^{2+} and Sn^{2+} ions but is clearly detectable. From the results above, it was concluded that compound L had high selectivity and specificity for Al^{3+} over other metal ions.

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3.3.2. Fluorescence titration of compound L with Al^{3+}

Sensitivity of L for aluminum ions was examined with the fluorescence titration of different concentration of Al^{3+} ions (0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2 and 1.5 equiv.) at 517 nm (Fig. 5); the point which primarily indicates 1:1 stoichiometric complexation between compound L and Al^{3+} ions. The detection limit of L in recognizing Al^{3+} was found to be $1.2 \times 10^{-7} \text{ M}$ with the fluorescence titration spectra, which was lower than some reported Al^{3+} selective fluorescent sensors.^{32–36} It demonstrated that the detection limit was low enough for this sensor to detect and control Al^{3+} in environmental and biological systems (Table. S1).^{37–41}

3.3. Binding mode of compound L and Al^{3+}

A proposed binding mode of L with Al^{3+} ions has been shown in Fig. 5 (inset), which primarily demonstrates 1:1 stoichiometric complexation between sensor L and Al^{3+} . These results are further confirmed by applying the emission Job's plot method. The maximum fluorescence intensity appears at 0.5 mole fraction of Al^{3+} that indicated a 1:1 complexation between quinoline Schiff base L and Al^{3+} ions (Fig. 6). Furthermore, from the electrospray ionization mass spectra (ESI-MS) (Fig. S4), a peak was observed at 335.59 $[\text{L} + \text{Al}^{3+} + \text{CH}_3\text{OH} - 2\text{H}^+]^+$, which further supported 1:1 binding stoichiometry between L and Al^{3+} .

3.3.1. ^1H NMR titration

In order to determine the coordination site, ^1H NMR spectra experiments were performed in the presence of Al^{3+} ions, with 0 to 2 equivalent of Al^{3+} added in compound L. As shown in Fig. 7, chemical shift changes were observed in the spectrum as the $\text{HC}=\text{N}$ proton signal of L at 8.82 ppm shifted to downfield at 8.86 ppm. Meanwhile, the hydroxyl hydrogen at 9.96 ppm shifted to downfield at 10.16 ppm with almost disappearance of the proton signal. The proton signals of the quinoline and benzene groups have been shifted, while a significant shift has been

observed in the para-position hydrogen of nitrogen in the quinoline group. These spectrum changes demonstrated that nitrogen in the imine group, oxygen in the hydroxyl group and nitrogen in the quinoline group participated in complexation with Al^{3+} ions.

3.3.2. Calculations of association constants and detection limit

Association constants of L-Al^{3+} was calculated with the Benesi-Hildebrand equation through fluorescence titration:^{42–44} (Fig. S5)

$$\frac{1}{F - F_0} = \frac{1}{K_a \times (F_{\max} - F_0) \times [\text{Al}^{3+}]} + \frac{1}{F_{\max} - F_0} \quad (1)$$

In this equation F is the fluorescence intensity at 517 nm at any given Al^{3+} concentration, F_0 is the fluorescence intensity at 517 nm in the absence of Al^{3+} , and F_{\max} is the maximal fluorescence intensity at 517 nm in the presence of Al^{3+} in solution. Data were fitted linearly as shown in Fig. 8. The association constant (K_a) for Al^{3+} binding in sensor L was determined to be $2.4 \times 10^4 \text{ M}^{-1}$. The detection limit (DL) of Al^{3+} using L was determined from the follow equation: $\text{DL} = K \times \text{SD} / S$, where $K = 3$; SD is the standard deviation of the blank solution; S is the slope of the calibration curve. $\text{DL} = 1.2 \times 10^{-7} \text{ M}$, which exhibits good selectivity of L with aluminium ions.

3.3.3. The reversibility and the influence of solvents

The reversibility of sensor L was measured by the titration of EDTA with $(\text{L} + \text{Al}^{3+})$. The fluorescent intensity was quenched thoroughly after addition of EDTA (1.0 equiv.) (Fig. 9). Fluorescence emission intensity due to L-Al^{3+} probe returned to a lower level for sensor L indicating regeneration of free chemosensors L, quenching in fluorescent intensity.

The effect of the different solvents THF, DMSO, DMF, DCM, acetonitrile, ethanol and methanol on the detection of Al^{3+} by L was explored. It can be seen (Fig. 10) that the fluorescence was changed due to different binding modes with different solvents and the best result was observed with methanol.

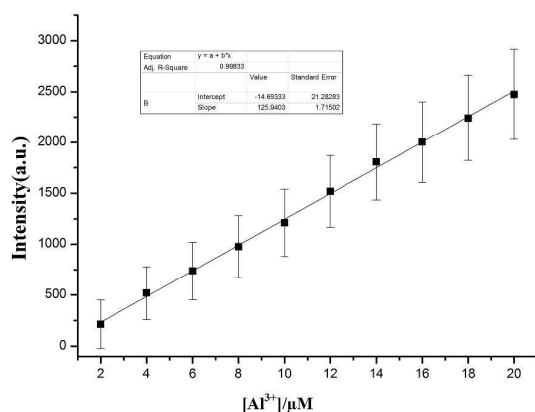


Fig. 8. Plot of fluorescence intensity variation upon varying the concentration of Al^{3+} ion from 2–20 μM with an excitation of 373 nm and an emission of 517 nm

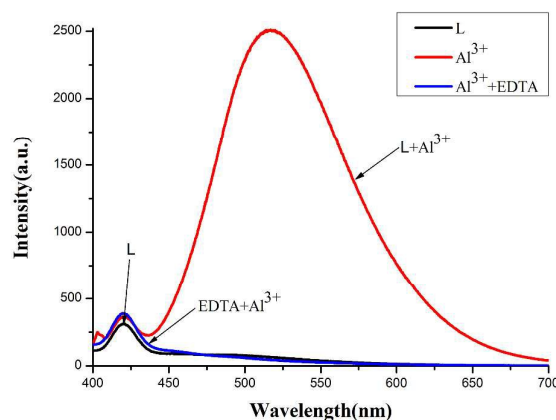


Fig. 9. Fluorescent emission spectra of compound L (10 μM) in the presence of Al^{3+} ion (1.0 equiv.) or EDTA (1.0 equiv.) in methanol.

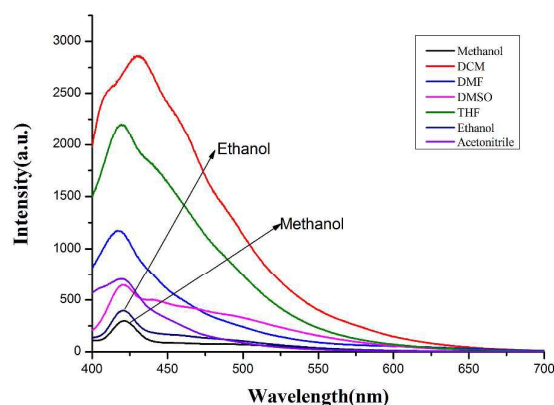
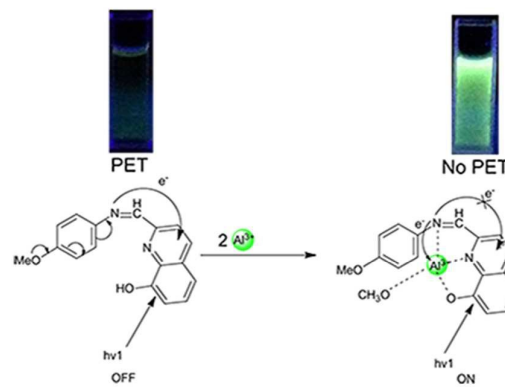


Fig.10. Effects on fluorescent intensity of L in different solvents Methanol, DMSO, DMF, DCM, Ethanol, THF and Acetonitrile.



Scheme.2 Proposed scheme of the fluorescence enhancement mechanism of compound L and Al^{3+} .

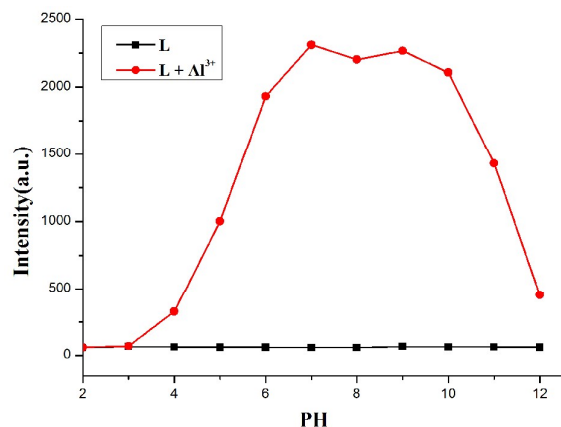


Fig. 11. Fluorescence intensity of L and L in the presence of Al^{3+} at various pH values

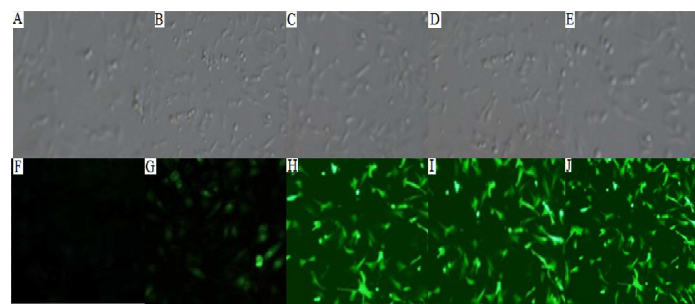


Fig.12. Representative fluorescence images of HeLa cells incubated with $10\mu\text{M}$ L and $0\mu\text{M}$ (A and F), $5\mu\text{M}$ (B and G), $10\mu\text{M}$ (C and H), $20\mu\text{M}$ (D and I), $30\mu\text{M}$ (E and J) Al^{3+} respectively. The top images (A, B, C, D, and E) were observed using a light microscope and the bottom images were taken using a fluorescence microscope. The scale bar is $20\mu\text{m}$.

3.4. Sensing mechanism

As the recognition unit, Schiff bases have been widely used for the development of fluorescence sensors based on various sensing mechanisms. In this case, The Off–On properties of sensor L may operate by the photoinduced electron transfer (PET) mechanism. In the Off state, when the UV-light was created, the lone pair of electrons from $\text{CH}=\text{N}$ unit to the quinoline fluorophore quenches the fluorescence. In the presence of Al^{3+} , the lone pair of electrons on the nitrogen atom is perturbed by the coordination of Al^{3+} , which consequently suppressed the quenching process, resulting in fluorescence enhancement (On-state). This suggests that the PET is the suitable mechanism to explain the fluorescence Off–On for L after binding to Al^{3+} .

3.5. Fluorescence imaging of intracellular L and Al^{3+}

The effect of pH in the range of pH 3.0–12.0 on emission intensity of L was examined both in absence and in the presence of Al^{3+} ion. It can be clearly seen from Fig. 11, that emission intensity of L was significantly high in the pH region of 6.0–10.0

compared to that of L in absence of Al^{3+} ion. Thus, L may be a suitable sensor to image Al^{3+} in living cell under the physiological conditions. To further demonstrate the potential of L to monitor Al^{3+} in living matrices, the Al^{3+} imaging behavior of the sensor L was studied by fluorescence microscopy using the HeLa cell. HeLa cell were first incubated with various concentrations of Al^{3+} (0, 5, 10, 20 and $40\mu\text{M}$) and then exposed to L ($10\mu\text{M}$) for 30 min at 37°C , and images were taken (Fig. 12). The fluorescence emission might be due to the complex formation between Al^{3+} and the sensor L. These results confirm that L can be a suitable and biocompatible sensor to detect Al^{3+} in living cells.

3.6. Determination of the fluorescence quantum yield

The quantum yield ϕ of the sensor 1 and $1+\text{Al}^{3+}$ complex^{45, 46} were calculated by

$$\phi_x = \phi_s (F_x/F_s)(A_s/A_x)(\eta_x/\eta_s) \quad (2)$$

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Here, x and s indicate the unknown and standard samples, ϕ = quantum yield, F = is the integrated fluorescence intensity, A = absorbance, and n = refractive index of the solvent (Rhodamine B is used as standard in ethanol [$\phi = 0.69$]). The quantum yield of **L** is 0.016, and on complexation with Al^{3+} , the value is significantly increases to 0.62.

4. Conclusion

In conclusion, we have highly selective and sensitive Al^{3+} fluorescence sensor (E)-4-methoxy-N-(8-methylquionlin-2yl)methylene)aniline (**L**). The fluorescence emission intensity of sensor **L** is remarkably enhanced more than 38-fold after the addition of aluminum ions and the association constant (K_a) and the detection limit (DL) were calculated to be $2.4 \times 10^{-4} M^{-1}$ and $1.2 \times 10^{-7} M$ respectively. Moreover, the sensor **L** is attributed to the formation of a 1:1 complex by Job's plot and electrospray ionization mass spectrometry (ESI-MS). The outstanding property of **L** is that the selectivity to Al^{3+} ions is not subject to interference by other mixed metal ions and the fluorescent nature of **L**- Al^{3+} complex goes to "turn-On" in the presence of Al^{3+} . It has been applied in biological system to study living cell imaging. Therefore, Al^{3+} ions can be easily detected by fluorescent sensor **L** through the fluorescence spectrum in biological system.

Acknowledgment

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A novel turn-on Schiff-base fluorescent sensor for Aluminum (III) ions in living cells

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The quinoline Schiff base L did not show any significant emission band alone when the excitation wavelength was at 373 nm. After addition other metal ions (Fig.1) exhibit no any significant fluorescent enhancement and only in case of Al^{3+} ions, compound L exhibits a more than 38-fold fluorescent enhancement. Therefore, it was concluded that compound L had high selectivity for Al^{3+} over other metal ions.

