

Supporting Information

Bis-triazolyl indoleamines as unique “off-approach-on” chemosensors for copper and fluorine

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S1. Experimental section

General

All chemicals and reagents are of high commercially available grade, and used as received. ^1H and ^{13}C NMR spectra were recorded on a Bruker AM-300 or a Bruker AM-400 spectrometer using tetramethyl silane (TMS) as the internal standard ($\delta = 0$). Mass spectra were recorded on a Finnigan MAT-95 mass spectrometer. High performance liquid chromatograms (HPLC) were performed with Agilent 1100. Silica gel 60 H (200-300 mesh) manufactured by Qingdao Haiyang Chemical Co. (China) was used for chromatography. All UV-vis absorption spectra were measured on a Varian Cary 500 UV-vis spectrophotometer and fluorescence spectra measured on a Varian Cary Eclipse Fluorescence spectrophotometer.

Synthesis of **b**

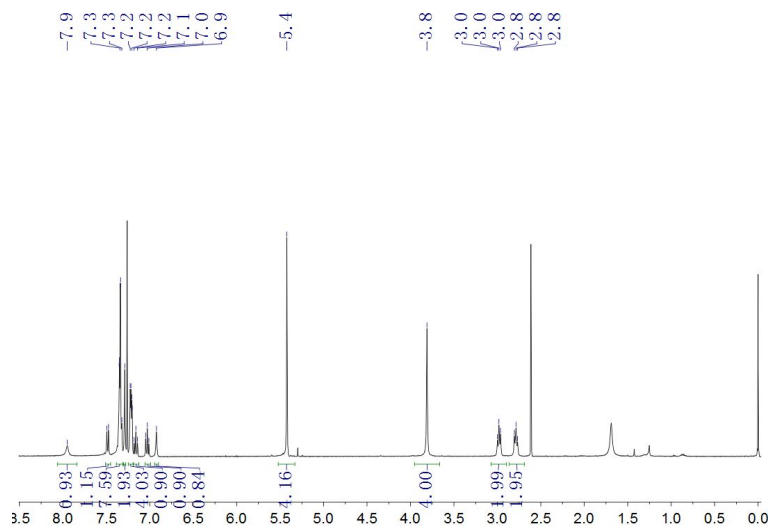
A mixture of tryptamine **a** (960 mg, 6 mmol), K_2CO_3 (2.5 g, 18 mmol) and propargyl bromide (1.1 ml, 12 mmol) in acetone (10 ml) was heated to reflux and stirred for 12 h. Then the mixture was filtered; the filtrate was concentrated and then washed with water and extracted with hexane to afford **b** (1.4 g, quantitative). *N,N*-diprop-2-yn-1-yltryptamine (**b**). ^1H NMR (300 MHz, CDCl_3): δ 2.30 (t, $J = 2.20$ Hz, 2H), 2.88-3.08 (m, 4H), 3.51-3.67 (m, 4H), 7.04 (d, $J = 1.46$ Hz, 1H), 7.11-7.28 (m, 2H), 7.35 (d, $J = 8.06$ Hz, 1H), 7.67 (d, $J = 7.69$ Hz, 1H), 8.07 (br s 1H); EI-MS (70 eV, m/z): 236 (M^+ , 8%), 106 (100%).

General protocol for the synthesis of compounds 1-3

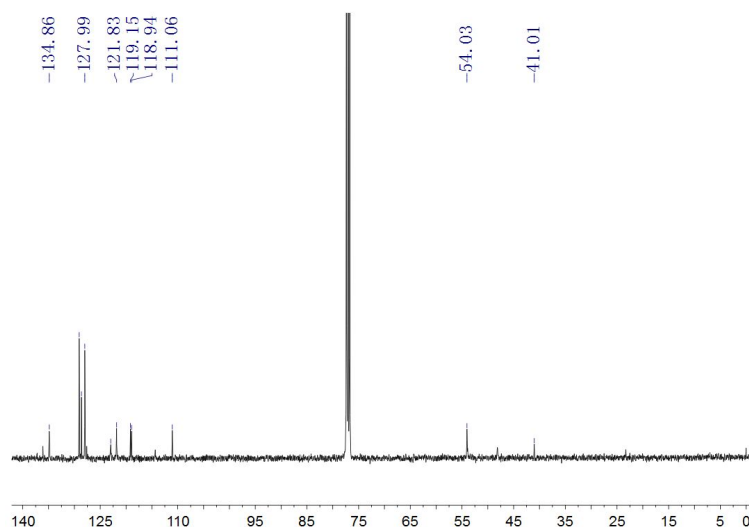
To a stirred solution of NaN_3 (136 mg, 2.1 mmol) in anhydrous DMSO (0.5 ml), the organic halide (2.4 mmol) was added and the mixture was stirred overnight. Water was then added followed by solid sodium ascorbate (35 mg, 0.2 mmol), **b**, and 1 M aqueous solution of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (46 mg, 0.2 mmol). The mixture was stirred overnight, and then water was added slowly until the product precipitated completely from the solution. The precipitate was collected, filtered with continuous washing by water, and then dried over anhydrous Na_2SO_4 .

Bis-triazolyl indole (1). ^1H NMR (400 MHz, CDCl_3): δ 2.98 (t, $J = 7.2$ Hz, 2H), 2.79 (t, $J = 7.3$ Hz, 2H), 3.81 (s, 4 H), 5.42 (s, 4 H), 6.92 (s, 1 H), 7.03 (t, $J = 7.5$ Hz, 1H), 7.16 (t, $J = 7.6$ Hz, 1H), 7.22 (dd, $J = 6.7, 2.8$ Hz, 4 H), 7.29 (s, 2 H), 7.31-7.37 (m, 7 H), 7.49 (d, $J = 7.9$ Hz, 1 H), 7.95 (s, 1 H); ^{13}C NMR (100 MHz, CDCl_3): δ 136.1, 134.9, 129.1, 128.6, 128.0, 127.6, 123.0, 121.8, 121.8, 119.2, 118.9, 111.1, 54.0, 48.2, 41.0, 23.3; HR-ESI-MS m/z : $[\text{M} + \text{H}]^+$ calcd. for $\text{C}_{24}\text{H}_{31}\text{N}_8\text{O}_4$ 495.2468, found 495.2472. HPLC ($t_{\text{R}} = 4.2$ min over 10 min of 100% MeOH, purity 100%).

^1H NMR of **1**:

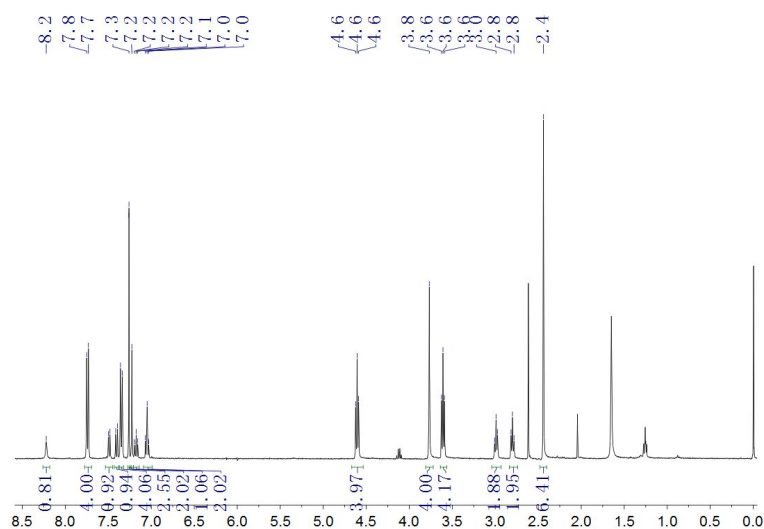


^{13}C NMR of **1**:

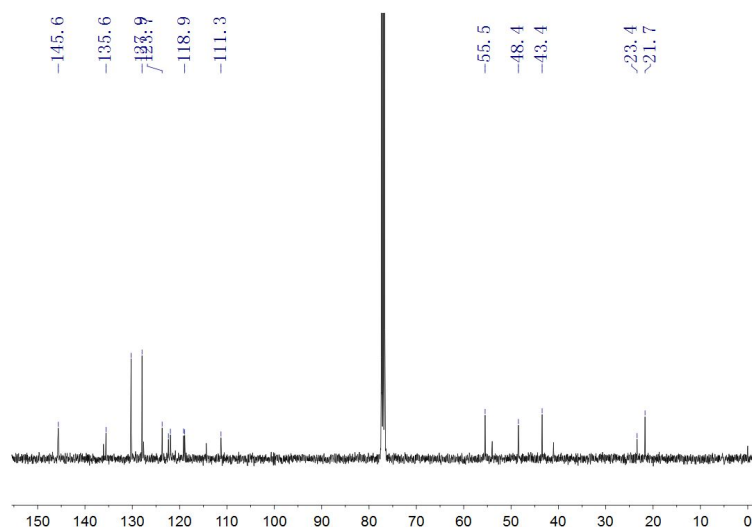


Bis-triazolyl indole (2). ^1H NMR (400 MHz, CDCl_3): δ 2.44 (s, 6 H), 2.80 (t, $J = 6.9$ Hz, 2H), 2.99 (t, $J = 6.8$ Hz, 2H), 3.60 (t, $J = 6.9$ Hz, 4 H), 3.77 (s, 4 H), 4.60 (t, $J = 6.9$ Hz, 4 H), 7.05 (t, $J = 7.5$ Hz, 1H), 7.18 (t, $J = 7.6$ Hz, 1 H), 7.23 (s, 2 H), 7.34 (d, $J = 8.3$ Hz, 4 H), 7.40 (d, $J = 8.1$ Hz, 1H), 7.48 (d, $J = 7.6$ Hz, 1 H), 7.73 (d, $J = 8.3$ Hz, 4 H), 8.22 (s, 1 H); ^{13}C NMR (100 MHz, CDCl_3): δ 145.6, 135.6, 127.9, 123.7, 118.9, 114.4, 111.3, 55.5, 54.0, 48.4, 43.4, 41.0, 23.4, 21.7; HR-ESI-MS m/z : $[\text{M} + \text{H}]^+$ calcd. for $\text{C}_{34}\text{H}_3\text{N}_8\text{O}_4\text{S}_2$ 687.2536, found 687.2538. HPLC ($t_{\text{R}} = 4.2$ min over 10 min of 100% MeOH, purity 98.9%).

^1H NMR of **2**:

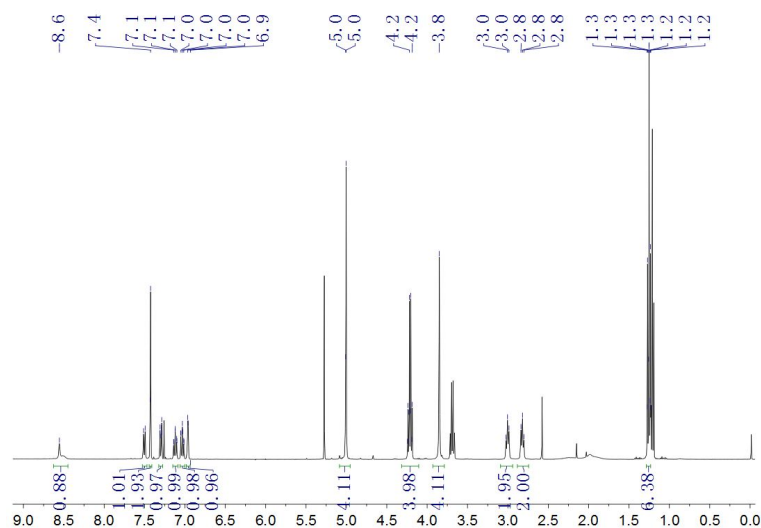


^{13}C NMR of **2**:

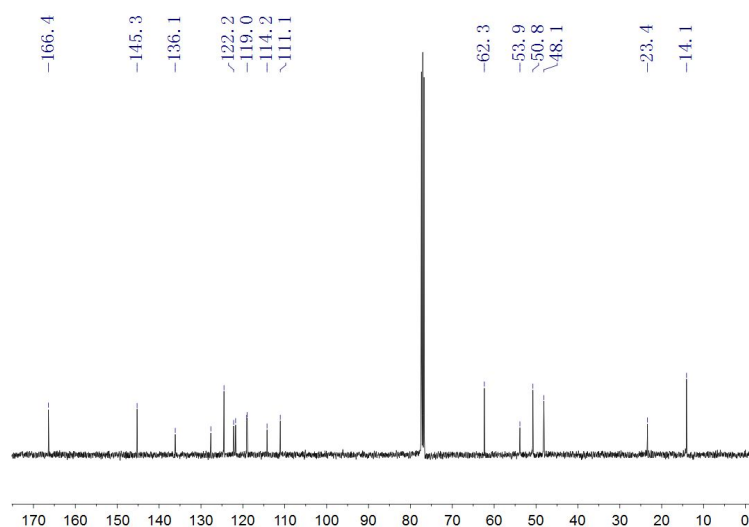


Bis-triazolyl indole (3). ^1H NMR (400 MHz, CDCl_3): δ 1.22-1.28 (m, 6 H), 2.77-3.07 (m, 4 H), 3.85 (s, 4 H), 4.16-4.26 (m, 4 H), 5.00 (s, 4 H), 7.03 (m, $J = 8.0, 7.0, 1.0$ Hz, 1H), 6.95 (t, $J = 10.5$ Hz, 1H), 7.16-7.08 (m, 1H), 7.35-7.27 (m, 1H), 7.45-7.40 (m, 2H), 7.50 (d, $J = 7.9$ Hz, 1 H), 8.53 (d, $J = 16.9$ Hz, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ 166.4, 145.3, 136.1, 124.5, 122.2, 121.7, 119.1, 119.0, 114.2, 111.1, 62.3, 53.9, 50.8, 48.1, 23.4, 14.1; HR-ESI-MS m/z : $[\text{M} + \text{H}]^+$ calcd. for $\text{C}_{30}\text{H}_{31}\text{N}_8$ 503.2672, found:503.2674. HPLC ($t_{\text{R}} = 4.0$ min over 10 min of 100% MeOH, purity 99.1%).

^1H NMR of **3**:



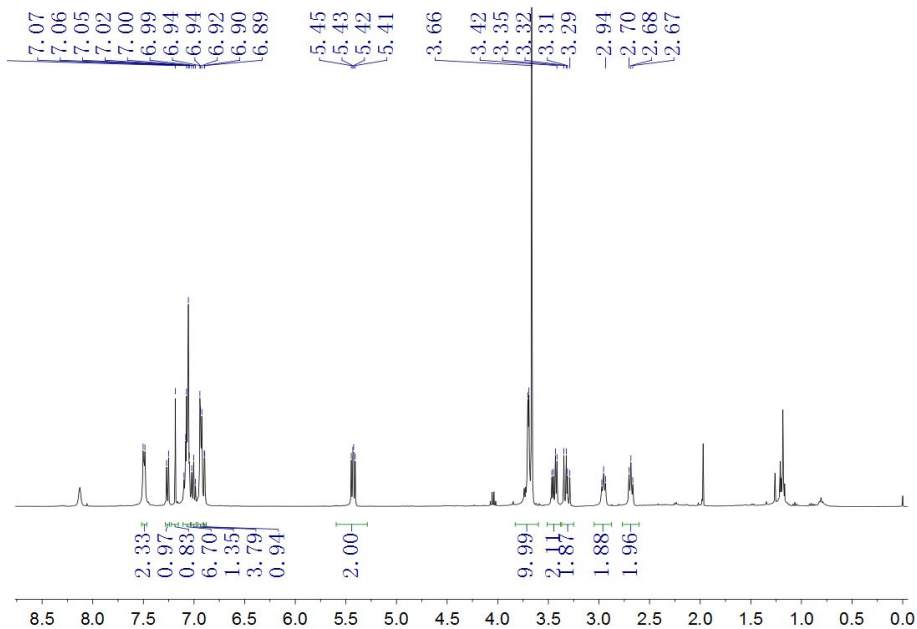
^{13}C NMR of **3**:



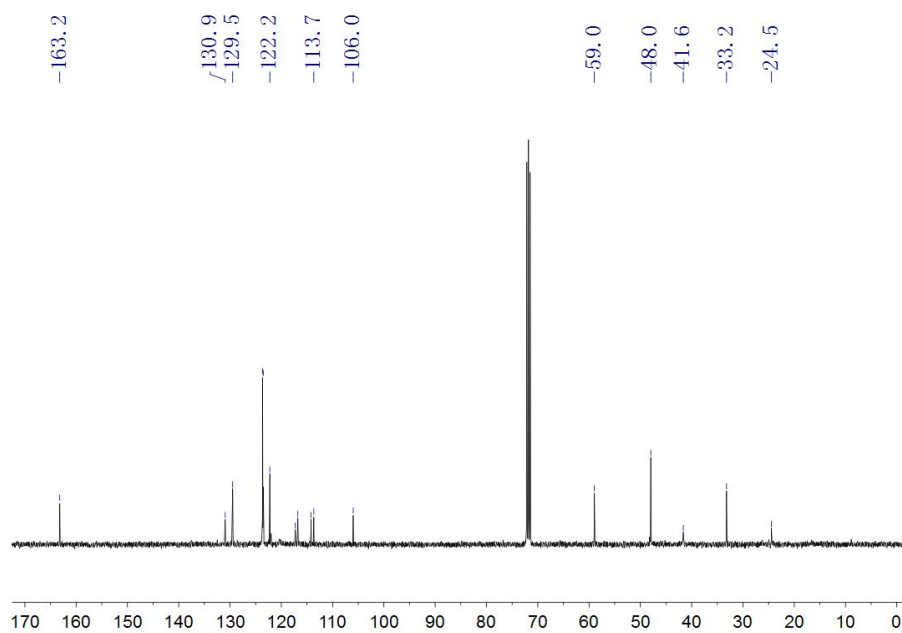
Synthesis of compound 4

To a solution of **b** (103.9 mg, 0.4 mmol) and **c** (168.9 mg, 0.9 mmol) in CH₂Cl₂ (5 ml)/H₂O (5 ml), were added CuSO₄·5H₂O (220 mg, 0.9 mmol) and sodium ascorbate (348.7 mg, 1.8 mmol). The resulting mixture was stirred at room temperature overnight. Then the mixture was washed with water and brine, and extracted with CH₂Cl₂. The combined organic layer was dried over MgSO₄, filtered and then concentrated in vacuum. The resulting residue was purified by column chromatography on silica gel (petroleum ether/EtOAc = 2:1) to afford compound **4** (170.8 mg, 60%). ¹H NMR (400 MHz, CDCl₃) δ 7.49 (d, *J* = 10.2 Hz, 2H), 7.26 (d, *J* = 8.1 Hz, 1H), 7.19 (s, 1H), 7.10-7.02 (m, 7H), 7.00 (t, *J* = 11.0, 3.9 Hz, 1H), 6.93 (dd, *J* = 7.3, 1.9 Hz, 4H), 6.90 (d, *J* = 1.9 Hz, 1H), 5.43 (dd, *J* = 9.4, 6.0 Hz, 2H), 3.70-3.66 (m, 10H), 3.47-3.42 (m, 2H), 3.33 (dd, *J* = 14.1, 9.5 Hz, 2H), 2.95 (t, *J* = 7.4 Hz, 2H), 2.68 (t, *J* = 7.5 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃): δ 163.2, 130.9, 129.5, 123.6, 123.5, 122.2, 117.3, 116.8, 114.2, 113.7, 106.0, 59.0, 48.0, 41.6, 33.2, 24.5; HR-ESI-MS *m/z*: [M + H]⁺ calcd. for C₃₆H₃₈N₈O₄ 647.3094, found: 647.3099. HPLC (*t*_R = 4.5 min over 10 min of 100% MeOH, purity 95.2%).

^1H NMR of **4**:



^{13}C NMR of **4**:



Spectroscopic measurements

The fluorescence measurements were carried out on a Varian Cary Eclipse Fluorescence spectrophotometer by using a path length of 10 mm with excitation at 282 nm by scanning the emission spectra between 300 nm and 500 nm. The bandwidth for both excitation and emission spectra was 5 nm.

Solutions of the chemosensors (100 μM) were prepared in DMSO. Stock solutions of 20 mM of $\text{Cd}(\text{ClO}_4)_2$, $\text{Co}(\text{ClO}_4)_2$, $\text{Zn}(\text{ClO}_4)_2$, $\text{Ba}(\text{ClO}_4)_2$, $\text{Mg}(\text{ClO}_4)_2$, KClO_4 , NaClO_4 , $\text{Mn}(\text{ClO}_4)_2$, $\text{Pd}(\text{ClO}_4)_2$, $\text{Pb}(\text{ClO}_4)_2$, $\text{Ca}(\text{ClO}_4)_2$, AgClO_4 , $\text{Ni}(\text{ClO}_4)_2$, $\text{Hg}(\text{ClO}_4)_2$, $\text{Cu}(\text{ClO}_4)_2$, and those of 20 mM of KF, KCl, KBr and KI were prepared in deionized water. Stock solutions of 20 mM of TBAF, TBACl, TBABr and TBAI were prepared in DMSO. For a typical experiment measuring the ion sensing activity of the sensors, 15 μL of each diluted metal solution was added into the test solution (3 mL). For the fluorescence recovery experiment, 15 μL of each diluted metal solution was first added into the test solution (3 mL), incubated for 2 min, followed by addition of 15 μL of the diluted halide anion solution. For the titration experiments of ligands with Cu^{2+} , 0-90 μL of diluted $\text{Cu}(\text{ClO}_4)_2$ solutions were added into the test solution (3 mL). As for the titration experiment of copper-ligand complex for F^- , 0-90 μL of diluted KF (or TBAF) solutions were added into the solution (3 mL).

S2. Fig. S1-Fig. S6

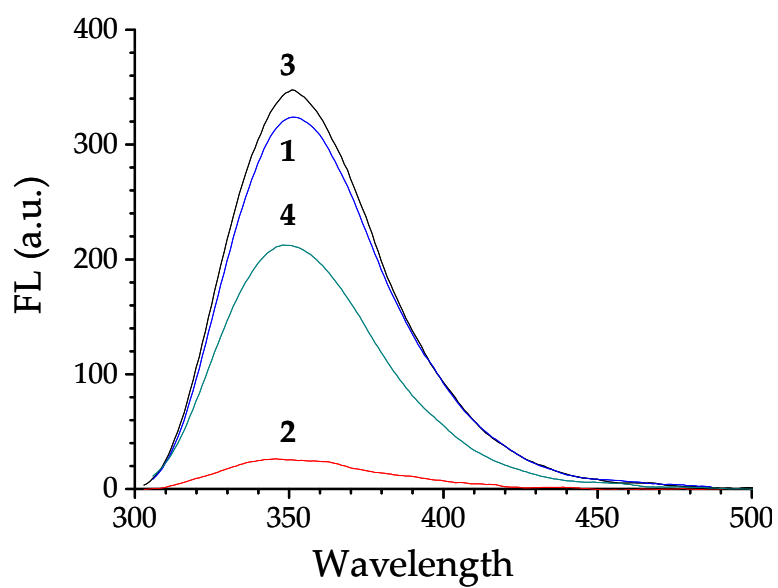


Figure S1. The stacked fluorescence spectra of compounds **1-4** (100 μ M) in DMSO ($\lambda_{\text{ex}} =$
282 nm).

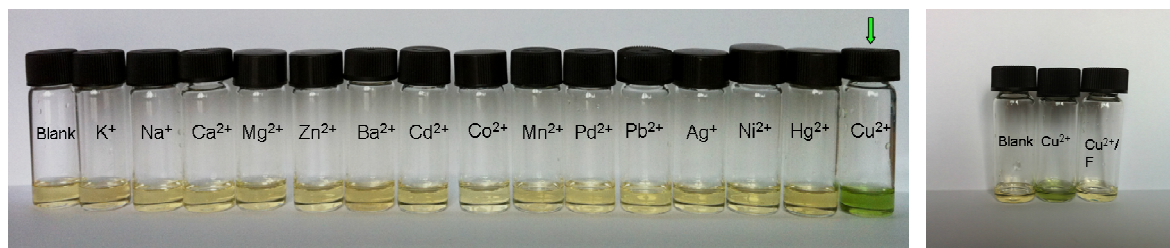


Figure S2. The colorimetric change of ligand **1** in DMSO (10 mM) in the absence (blank) or presence of various ions (10 mM).

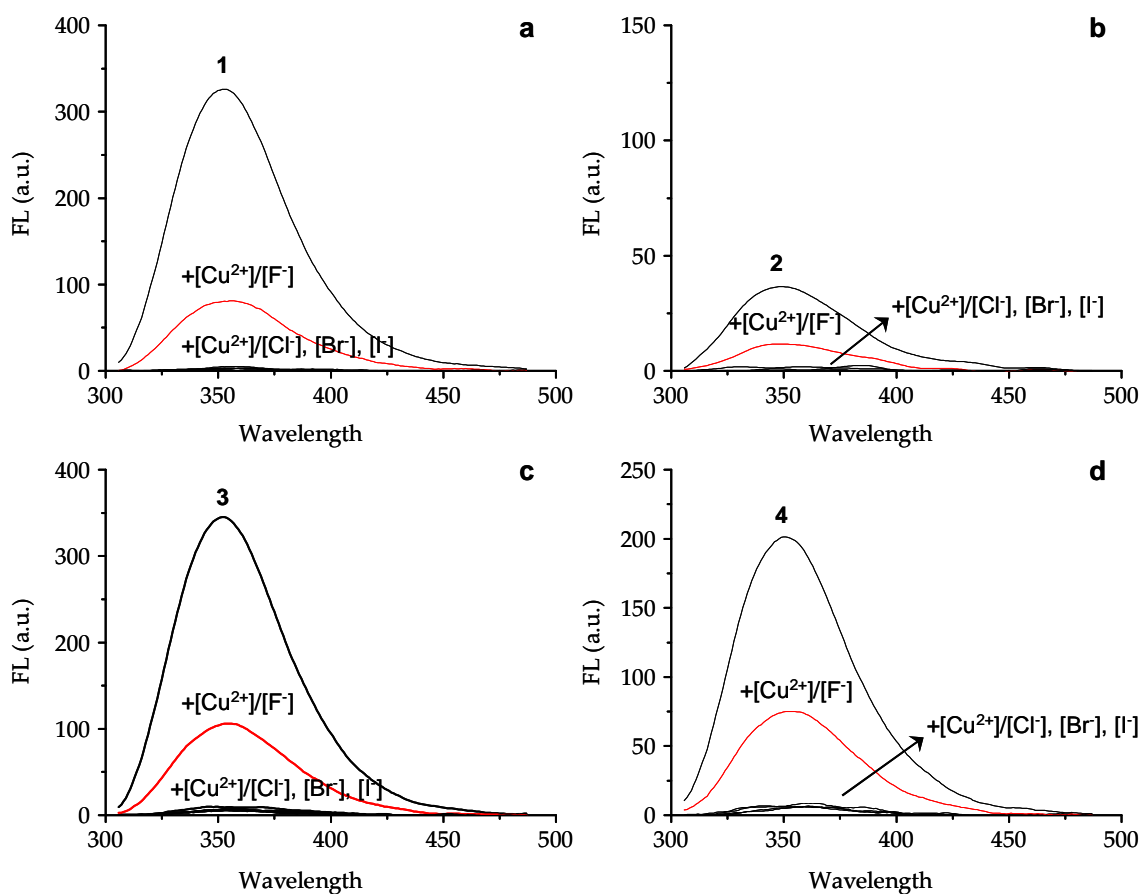


Figure S3. The stacked fluorescence spectra of complex (a) **1**-Cu²⁺, (b) **2**-Cu²⁺, (c) **3**-Cu²⁺ and (d) **4**-Cu²⁺ in DMSO ($\lambda_{\text{ex}} = 282 \text{ nm}$) in the absence (the bottom line) and presence of various halides (100 μM in water).

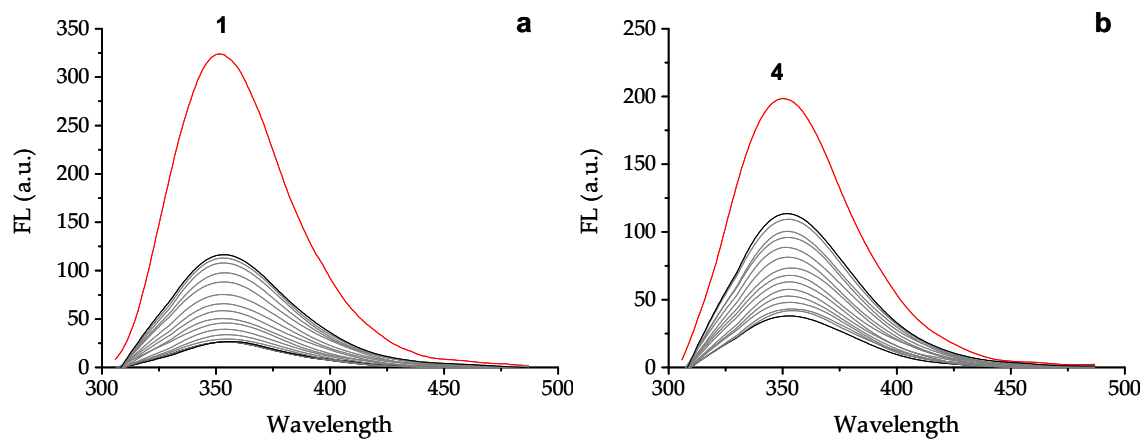


Figure S4. The stacked fluorescence spectra of complex (a) **1**-Cu²⁺ and (b) **4**-Cu²⁺ in DMSO ($\lambda_{\text{ex}} = 282$ nm) in the absence (the bottom line) and presence of increasing TBAF (in DMSO).

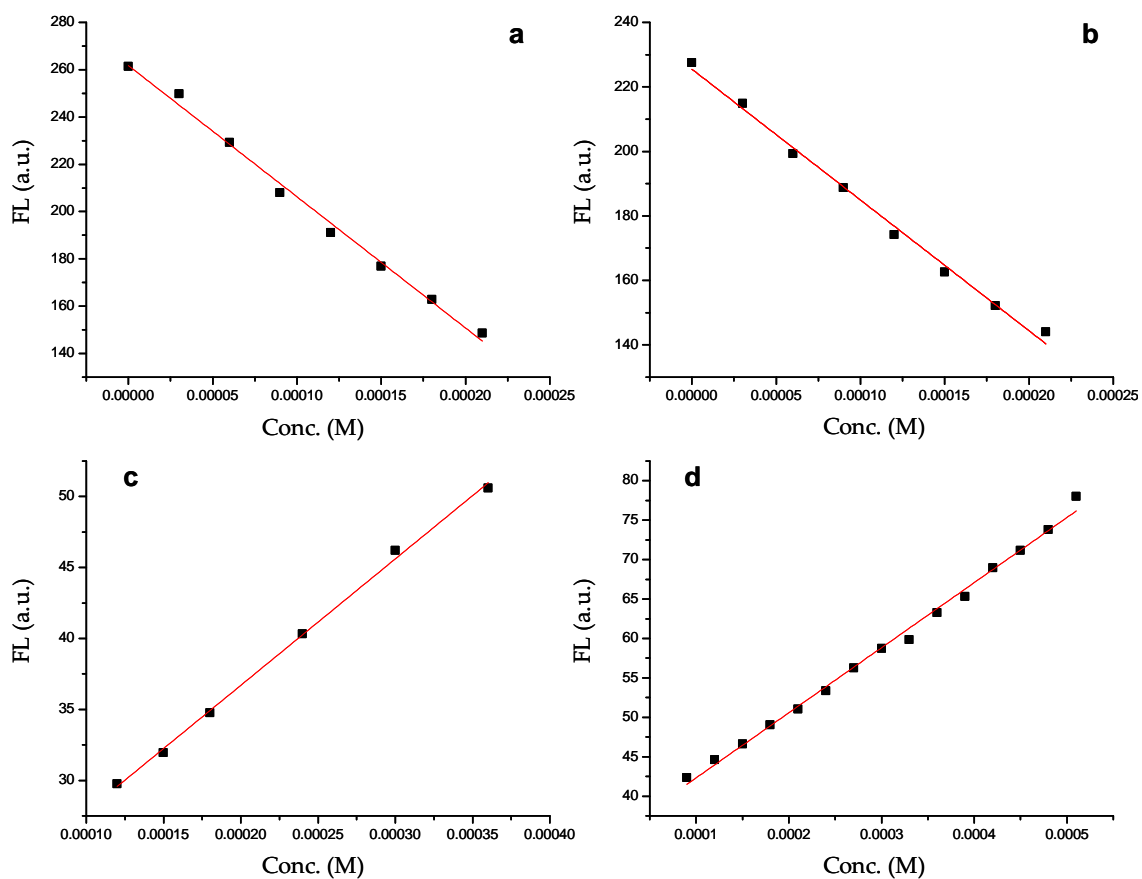


Figure S5. Linear range of (a) **1** and (b) **2** in the presence of increasing [Cu²⁺], and of (c) **1**-Cu²⁺ and (d) **4**-Cu²⁺ in the presence of increasing [F⁻] in DMSO ($\lambda_{\text{ex}} = 282 \text{ nm}$).

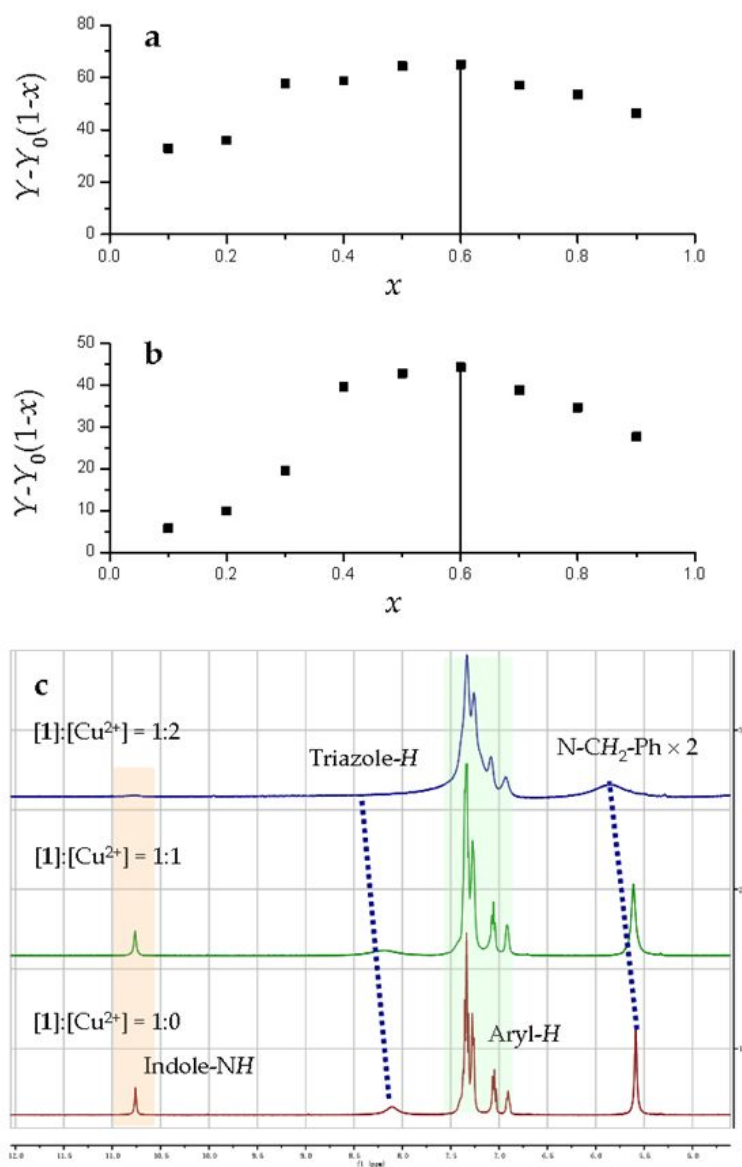


Figure S6. Job's plot of (a) **1**-Cu²⁺ complex, and (b) **4**-Cu²⁺ complex; (c) Partial stacked ¹H NMR titration spectra of **1** (DMSO-*d*₆) in the presence of increasing [Cu²⁺].