Supplementary Material (ESI) for Organic & Biomolecular Chemistry

Synthesis and fluorescence of the new environment-sensitive fluorophore 6-chloro-2,3-naphthalimide derivative

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Supporting Information

Table of contents

General methods. Melting points were determined on a capillary point apparatus equipped with a digital thermometer and are uncorrected. NMR spectra were recorded in $CDCl_3$ or DMSO-d_6 with TMS for ^1H (300 MHz) and ^{13}C (75 MHz) as an internal reference. An elemental analysis was performed on a Carlo Erba-1106 instrument. Absorption spectra were recorded on a Lambda-25 (Perkin Elmer). ε was denoted molar extinction coefficient. It was calculated by using Eq.1

$$\varepsilon = \frac{A}{bc} \qquad \text{Eq. 1}$$

Fluorescence spectra were recorded on FluoroMax-3 jobin Yuon Horiba Spectrofluoremeter. All emission spectra of the compounds were detected on the same instrument.

Φ denotes quantum yield for fluorescence. It was obtained by comparison of the integrated area of the corrected emission spectra of sample with that of a solution of naphthalene in cyclohexane, which has a quantum efficiency of 0.23. The concentration of naphthalene was adjusted to give the same absorbance, which is around 0.1 as the sample at the excitation wavelength. Fluorescence quantum yield was calculated using Eq. 2

$$\theta_{\text{sample}} = \frac{Astd}{Asample} \times \frac{Fsample}{Fstandart} \times \frac{n_{sample}^2}{n_{std}^2} \times \theta_{std} \qquad \text{Eq. 2}$$

Experimental details for 7-9, 11-13, 20

3-(4-Chlorophenyl)-acrylic acid (7)

A mixture of *p*-chlorobenzaldehyde (3.75 g, 2.5 mmol) and malonic acid (2.6 g, 2.5 mmol) and pyridine (0.1 mL) were refluxed in ethanol (30 mL) for 24 h. The residue was washed with methanol to give the almost pure 3-(4-chlorophenyl)-acrylic acid **(7)** (4.4g, 86%). The acid was recrystallized from methanol. mp 247-248 ^{0}C (lit.,[1] 250-252 ^{0}C). ^{1}H NMR (300 MHz, DMSO-d_6): δ (12.48 (br s, 1H), 7.72 (d, J = 7.4 Hz, 2H), 7.57 (d, J= 15.9 Hz, 1H), 7.46 (d, J = 7.4 Hz, 2H), 6.55 (dd, J = 15.9 Hz, J = 1.1 Hz, 1H) ^{13}C NMR (75 MHz, DMSO-d_6): δ 167.5, 142.5, 134.7, 133.2, 129.9, 128.9, 120.1.

2,3-Dibromo-3-(4-chlorophenyl)-propionic acid (8)

Bromine (4.4 g, 2.8 mmol) in CCl_4 (5 mL) was added to 3-(4-chlorophenyl)-acrylic acid **(7)** (4.52 g, 2.5 mmol) in CCl_4 (20 mL). The mixture was refluxed for 5 h and the solvent and excess bromine was concentrated under vacuum to give the pure 2,3-dibromo-3-(4-chlorophenyl)-propionic acid **(8)** (7.88 g, 92%). The compound was recrystallized from carbon tetrachloride to obtain white crystals. mp 198-199 ^{0}C (lit.,[2] 194-195 ^{0}C). ^{1}H NMR (300 MHz, DMSO-d_6): δ 13.8 (br s, 1H), 7.69 (d, J= 8.4 Hz, 2H), 7.4 (d, J = 8.4 Hz, 2H), 5.59 (d, J = 11.7 Hz, 1H), 5.34 (d, J = 11.7 Hz, 1H).^{13}C NMR (75 MHz, DMSO-d_6): δ 169.0, 137.5, 133.6, 130.4, 128.7, 50.6, 47.0.

3-(4-Chlorophenyl)-2-propynoic acid (9)

A solution of 2,3-dibromo-3-(4-chlorophenyl)-propionic acid **(8)** (3.5 g, 10 mmol) in 25% potassium hydroxide in methanol (100 mL) was heated under reflux for 2 h. The solvent was evaporated under vacuo till dryness and the residue was dissolved in water and acidified. The precipitated acid was filtered off and washed with water and dichloromethane to give pure 3-(4-chlorophenyl)-2-propynoic acid **(9)** (1.57 g, 85%). mp 192-193 ^{0}C (lit.,[3] 192-194 ^{0}C). ^{1}H NMR

(300 MHz, DMSO-d_6): δ 7.65 (d, J = 8.5 Hz, 2H), 7.56 (d, J = 8.5 Hz, 2H). ^{13}C NMR (75 MHz, DMSO-d_6): δ 155.5, 135.5, 134.4, 129.6, 119.4, 85.7, 80.7.

6-Chloronaphtho[2,3-*c*]furan-1,3-dione (11) Propiolic acid **(10)** (20 mg, 3 mmol) was added to 3-(4-chlorophenyl)propioloyl chloride **(13)** (500 mg, 2.5 mmol) in dry benzene (30 mL) and the mixture was heated under reflux for 24 h. The solvent was evaporated and the residue with ether to give the 6-chloronaphtho[2,3-*c*]furan-1,3-dione **(11)** (490 mg, 85%). mp 219-220 ^{0}C (lit.,[4] 220 ^{0}C). ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.54 (s, 1H), 8.47 (s, 1H), 8.15 (s, 1H), 8.10 (d, J= 8.8 Hz, 1H), 7.76 (dd, J = 8.1 Hz, J = 2.0 Hz, 1H).^{13}C NMR (75 MHz, DMSO-d_6): δ 163.3, 136.4, 135.1, 134.1, 132.5, 130.8, 129.1, 127.5, 126.7, 126.5. Anal. Calcd for $C_{12}H_5ClO_3$: C, 61.96; H, 2.17; Found C, 61.86; H, 1.96%.

6-Chloro-4-(4-chlorophenyl)naptho[2,3-*c*]furan-1,3-dione (12)

3-(4-Chlorophenyl)-2-propynoic acid **(9)** (660 mg, 3.7 mmol) and propiolic acid **(10)** (1.52 g, 21.7 mmol) were refluxed in acetic anhydride (5 mL) for 24 h. The precipitate was treated with chloroform and the solvent was evaporated to give a mixture of compounds 6-chloro-4-(4-chlorophenyl)naptho[2,3-*c*]furan-1,3-dione (12) and 6-chloronaphtho[2,3-*c*]furan-1,3-dione **(11)** which were separated by column chromatography on eluting with dichloromethane:hexane (8:2) to obtain 6-chloro-4-(4-chlorophenyl)naptho[2,3-*c*]furan-1,3-dione **(12)** in 55% and 6-chloronaphtho[2,3-*c*]furan-1,3-dione **(11)** in 31% yield. mp 262-263 ^{0}C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.58 (s, 1H), 8.13 (d, J = 8.4 Hz, 1H), 7.83 (s, 1H), 7.76 (d, J = 8.4 Hz, 1H), 7.59 7.76 (d, J = 8.4 Hz, 2H), 7.35 (d, J = 8.4 Hz, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.2, 161.3, 140.8,

137.2, 136.4, 135.6, 134.3, 131.8, 131.0, 130.9, 130.7, 128.9, 127.1, 127.0, 125.9, 123.4. Anal. Calcd for $C_{18}H_8Cl_2O_3$: C, 63.00; H, 2.35; Found C, 62.71; H, 2.65%.

3-(4-Chlorophenyl)propioloyl chloride (13)

A solution of 3-(4-chlorophenyl)propiolic acid **(9)** (500 mg, 2.8 mmol) with thionyl chloride (1.4 g, 11.2 mmol) in dichloromethane (25 mL) was heated under reflux for 16 h and the solvent was evaporated under vacuo to give 510 mg of 3-(4-chlorophenyl)propioloyl chloride **(13)** in 93% yield. mp 66-67 ^{0}C (lit.,[5] 68-69 ^{0}C). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.35 (dd, *J* = 8.1 Hz, 2H), 7.81 (d, *J*= 8.1 Hz, 2H). ^{13}C NMR (75MHz, $CDCl_3$): δ 148.7, 138.2, 134.2, 128.7, 120.4, 91.8, 84.0.

2-(7-chloro-3-(diisopropylcarbamoyl)-2-naphthamido)acetic acid (20)

Diisopropyl amine (260 mg, 2.56 mmol) was added into a solution of 2-(6-chloro-1,3-dioxo-1*H*-benzo[*f*]isoindol-2(3*H*)-yl)acetic acid **(15)** (500 mg, 1.7 mmol) in DMF (10 mL) and refluxed for 1 h. The solution was cooled and 2-(7-chloro-3-(diisopropylcarbamoyl)-2-naphthamido)acetic acid **(20)** precipitated and was washed with dichloromethane. mp 243-245 ^{0}C. (460 mg, 79%). ^{1}H NMR (300 MHz, DMSO-d_6): δ 8.54 (s, 1H), 8.48 (s, 1H), 8.40 (s, 1H), 8.24 (d, *J* = 8.7 Hz, 1H), 7.80 (d, *J* = 8.7 Hz, 1H), 4.0 (s, 2H), 3.23-3.19 (m, 2H), 1.14 (d, *J* = 5.9 Hz, 12H). ^{13}C NMR (75 MHz, DMSO-d_6): δ 169.9, 168.6, 167.3, 136.0, 133.9, 133.6, 132.4, 129.7, 129.2, 129.0, 128.5, 124.2, 123.5, 45.9, 42.1, 19.0.

UV absorption spectra and fluorescence emission spectra for 19, 23 and 24

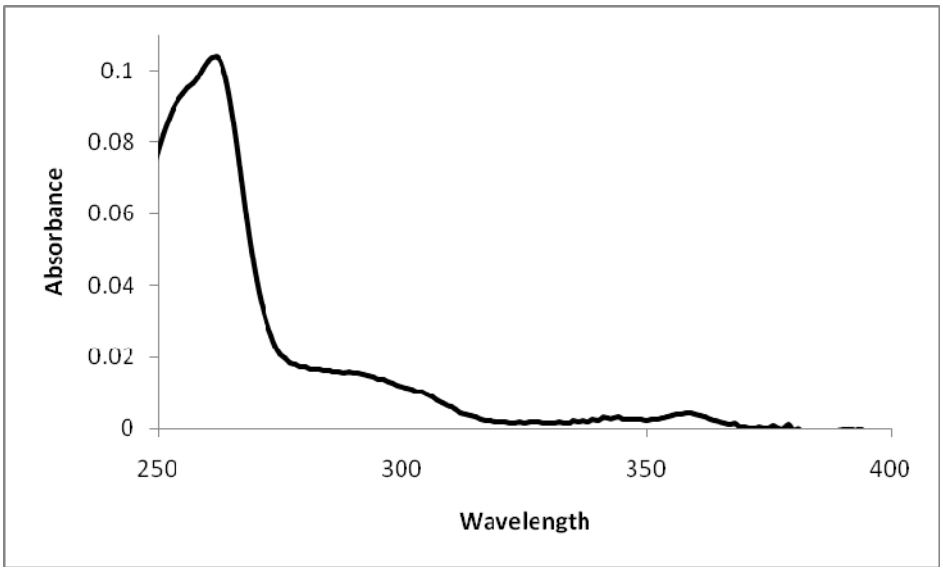

Figure 1. UV absorption spectrum of **19** (1.89 μM) in methanol

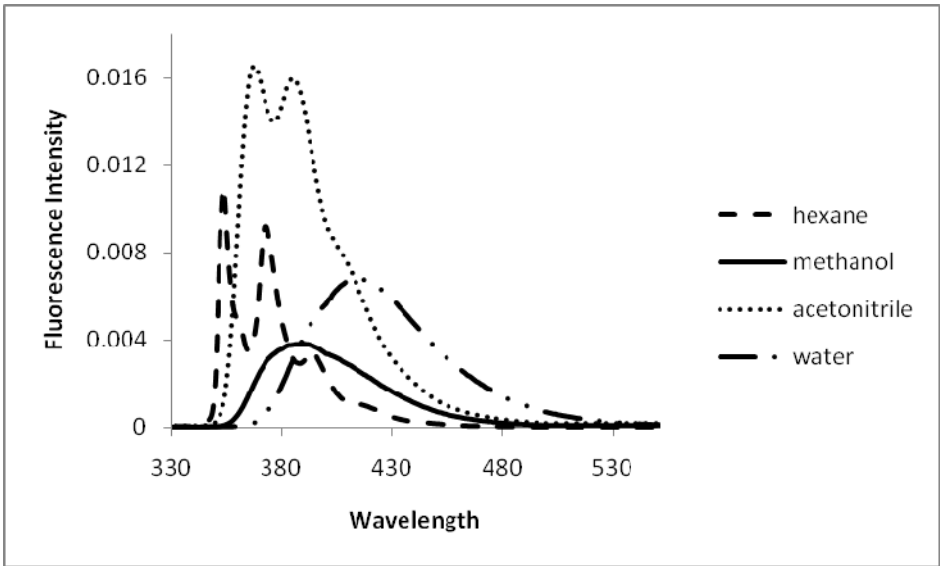

Figure 2. Emission spectrum of **19** in different solvents

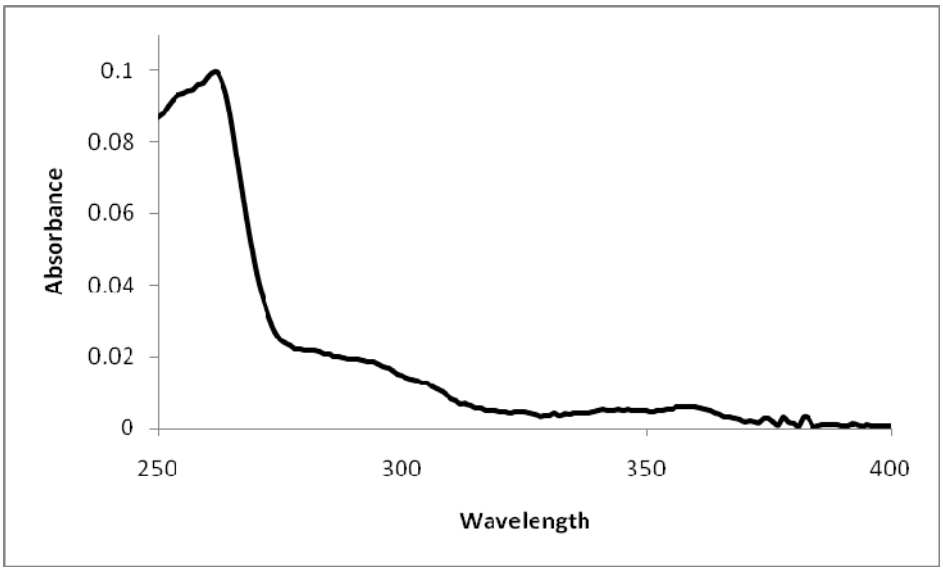

Figure 3. UV spectrum of **23** (3.16 μM) in methanol

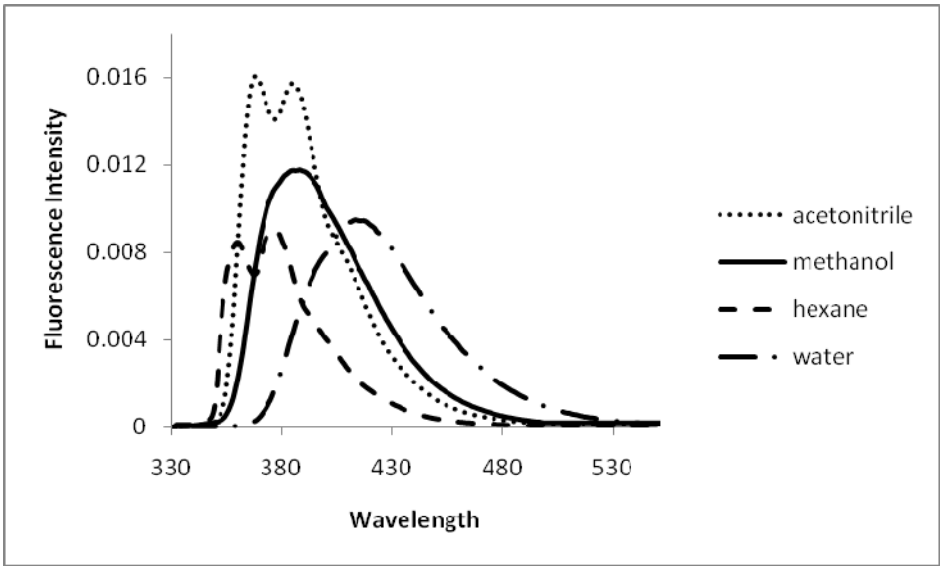

Figure 4. Emission spectrum of **23** in different solvents

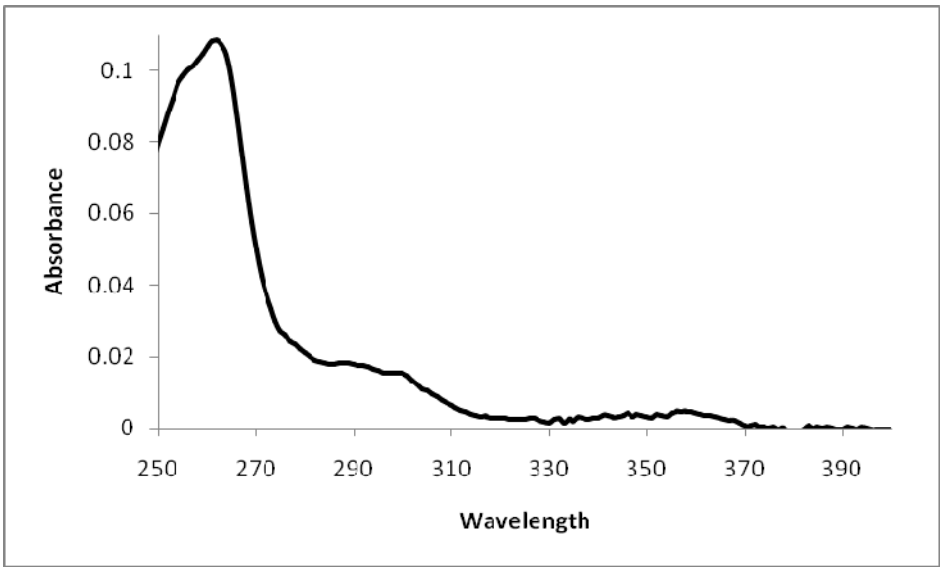

Figure 5. UV absorption spectrum of **24** (1.19 μM) in methanol

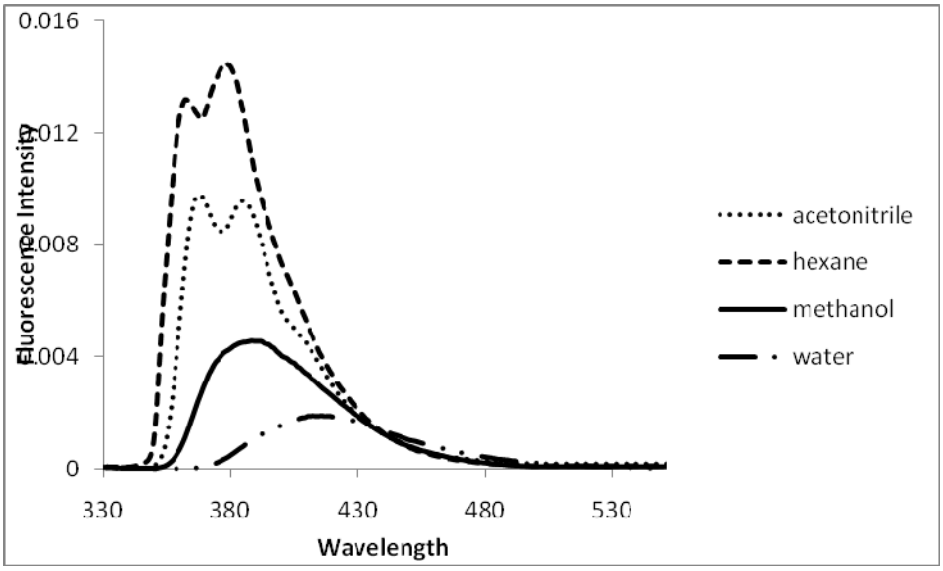

Figure 6. Emission spectrum of **24** in different solvents

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