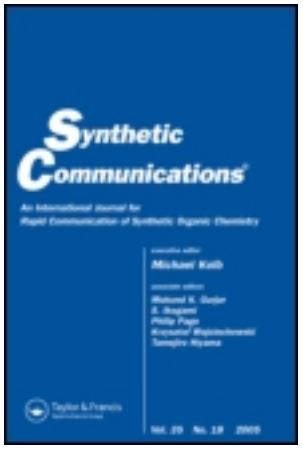

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Rearrangement of Indolinesulfonamides to Sulfones Using Polyphosphoric Acid (PPA)

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REARRANGEMENT OF INDOLINESULFONAMIDES TO SULFONES USING POLYPHOSPHORIC ACID (PPA)

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Unlike other N-alkylsulfonanilides, indolinesulfonamides hydrolyze in 98% sulfuric acid. Recent work in this laboratory has shown that rearrangement can be achieved by using polyphosphoric acid. A series of substituted indolinesulfonamides has been prepared and rearranged to their corresponding indoline arylsulfones.

Keywords: Indoline; phenylsulfonylindoline; polyphosphoric acid

INTRODUCTION

Diaryl sulfones have been shown to function as nonnucleoside reverse transcription inhibitors (NNRTIs) of HIV.[1] In an ongoing effort to prepare novel sulfones for possible use against AIDS, the 98% sulfuric acid–catalyzed rearrangement of N-alkyl benzene sulfonanilides has been successfully carried out on a large number of diarylsulfonamides with substitutents on either or both of the aromatic rings.[2] The reaction's scope was broadened to include anilines in which the nitrogen was tied back to its ring by an alkyl group, for example, tetrahydroquinoline[3] (THQ) and 2,3,4,5-tetrahydro-1*H*-1-benzazepine.[4] However, when indolinesulfonamides were treated with 98% sulfuric acid, only hydrolysis products resulted.[4] No explanation for this anomaly is forthcoming.

As part of another approach to preparing heterocyclic aryl sulfones, the reaction of benzene or toluenesulfonic acid with arenes in polyphosphoric acid (PPA) was studied. For example, when p-xylene, p-toluenesulfonic acid, and PPA were heated at 130°C, a good yield of 1,4-dimethyl-2-[(4-methylphenyl)sulfonyl]benzene resulted[5] (Fig. 1a). A similar reaction using toluenesulfonic acid and THQ failed (Fig. 1b). Suspecting that the weakly basic nitrogen atom in THQ might have interfered with the reaction, 1-(phenylsulfonyl)indoline (**3**), in which the nitrogen is protected, was used instead (Fig. 1c). A sulfone product was isolated; however, when it was analyzed by NMR, the product did not

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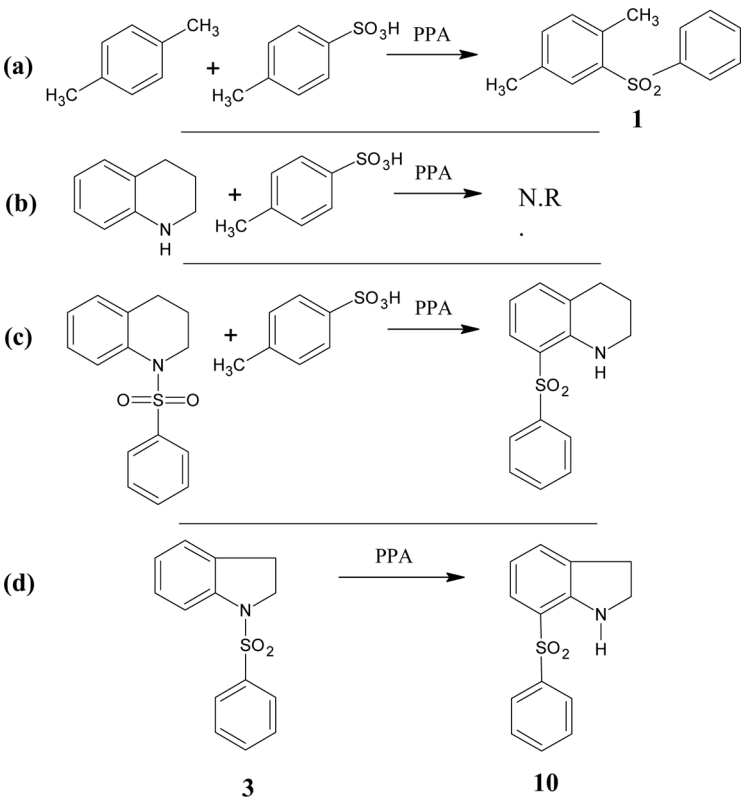


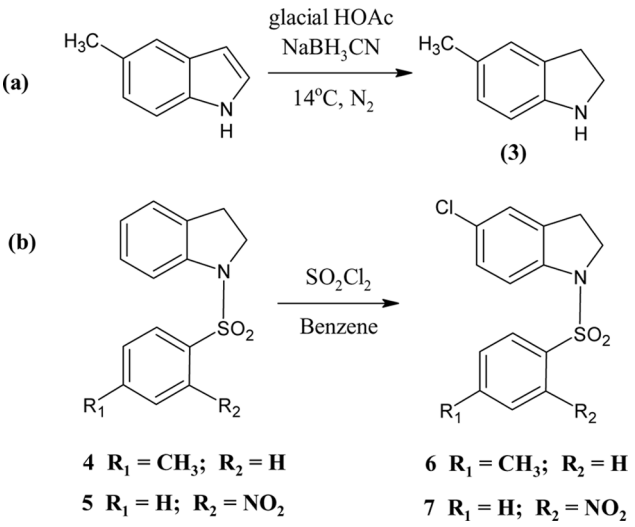
Figure 1. Background for indolinesulfonamide rearrangements.

possess the *p*-methyl group. What in fact had happened was that the benzenesulfonyl group attached to the nitrogen had migrated (rearranged) to the *o*-position on the THQ. The toluenesulfonic acid did not participate in the reaction.

Having uncovered a novel method for achieving sulfonamide rearrangements, this technique (PPA) was tried on 1-(phenylsulfonyl)indoline, (**3**). PPA and the indoline amide were heated at 100°C for periods ranging from 1 to 24 h (Fig. 1d). The hot reaction mixture was quenched in ice water, and the resulting solid was filtered and analyzed. The product of these reactions consisted of some unreacted starting material and rearranged product, 7-(phenylsulfonyl)-indoline (**10**). This article describes the synthesis and rearrangement of indoline sulfonamides.

RESULTS AND DISCUSSION

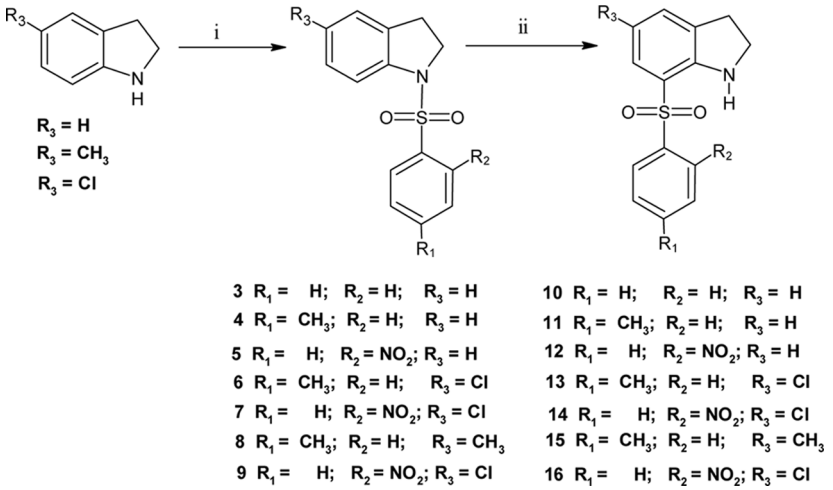
For this work, the syntheses of substituted indoline sulfones, which paralleled those prepared from terahydroquinoline and 2,3,4,5-tetrahydro-1*H*-1-benzazepine, were desired. This required the synthesis of indoline or indoline derivatives with methyl and chloro-groups on the 5-position (Scheme 1). The preparation of



Scheme 1. Syntheses of 5-substituted indoline/indolinesulfonamide.

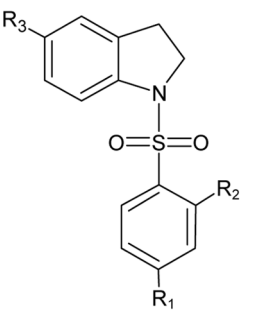
5-methylindoline[6] (**2**) was achieved by the reduction of 5-methylindole using sodium cyanoborohydride. The 5-chloroindoline amide (**6**) was prepared by chlorination of the 1-(4-methylphenylsulfonyl)indoline (**4**) using sulfuryl chloride.[4]

The indolinesulfonamides were prepared by reaction of the indolines with benzenesulfonyl chloride, *p*-tolylsulfonyl choride, or 2-nitrobenzenesulfonyl chloride to give **3–5, 8**, and **9.** This was followed by chlorination of **4** and **5**, which gave compounds **6** and **7** (Scheme 2). Of the amides, **3–5** and **8** were known, whereas for the sulfones, only **11** is known. Table 1 lists the sulfonamides and sulfones that were prepared and characterized.

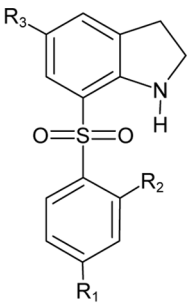


Scheme 2. (i) $R_1R_2BzSO_2Cl$, 10% NaOH, warm to 50°C; (ii) PP at 140°C for 2 h, pour into ice water.

Table 1. Preparation of sulfonamides and sulfones



Type I



Type II

No.	Type	R_1	R_2	R_3	Mp (°C)	Formula	Yield (%)
3[a]	I	H	H	H	131–132	$C_{14}H_{13}NO_2S$	95
4[b]	I	CH_3	H	H	100.5–101.5	$C_{15}H_{15}NO_2S$	72
5[c]	I	H	NO_2	H	106–107	$C_{14}H_{12}N_2O_4S$	72
6	I	CH_3	H	Cl	120–121	$C_{15}H_{14}ClNO_2S$	78
7	I	H	NO_2	Cl	158–159	$C_{14}H_{11}ClN_2O_4S$	83
8[d]	I	CH_3	H	CH_3	99–100	$C_{16}H_{17}NO_2S$	62
9	I	H	NO_2	CH_3	142–143	$C_{15}H_{14}N_2O_4S$	59
10	II	H	H	H	114–116	$C_{14}H_{13}NO_2S$	40
11[e]	II	CH_3	H	H	134–135	$C_{15}H_{15}NO_2S$	20
12	II	H	NO_2	H	141–142	$C_{14}H_{12}N_2O_4S$	33
13	II	CH_3	H	Cl	154–155	$C_{15}H_{14}ClNO_2S$	20
14	II	H	NO_2	Cl	184–185	$C_{14}H_{11}ClN_2O_4S$	50
15	II	CH_3	H	CH_3	133–134	$C_{16}H_{17}NO_2S$	33
16	II	H	NO_2	CH_3	167–168	$C_{15}H_{14}N_2O_4S$	25

[a]Compound **3** is known: Ref. 7 (mp 129.5–131).
[b]Compound **4** is known: Ref 8 (mp 100.5–101.5).
[c]Compound **5** is known: Ref. 9 (no mp reported).
[d]Compound **8** is known: Ref. 10 (mp 75–77).
[e]Compound **11** is known: Ref. 11 (mp 135–136).

EXPERIMENTAL

Chemicals were purchased from Sigma-Aldrich Chemical Co. and were used without further purification. Reactions were monitored using Analtech Inc. silica-gel 60 GF analytical thin-layer chromatography (TLC) plates and analyzed with 254-nm ultraviolet (UV) light. Silica gel for column chromatography was 60–200 mesh. Melting points were obtained with a Stanford Research Systems' Optimelt automatic melting-point device without correction. ^1H and ^{13}C NMR spectra were obtained in $CDCl_3$ (sulfonamides) and d_6-acetone (sulfones) on a Bruker Avance 400 NMR spectrometer operating at 400 MHz for ^1H and 100 MHz for ^{13}C. All infrared spectra (FT-IR) were recorded as thin films on KBr plates or in KBr pellets. All mass spectra were determined with a gas chromatography–mass spectrometry (GC-MS) instrument.

Preparation of 5-Methylindoline[6] (2)

Acetic acid (AcOH; 1 mL) and sodium cyanoborohydride (0.53 g, 8.36 mmol, 1.1 eq) were added to a vial equipped with a magnetic stir bar. The vial was chilled in a waterbath and sealed with a rubber septum. The reaction was run under nitrogen gas. 5-Methylindole (1.0 g, 7.6 mmol, 1 eq) was dissolved in AcOH (0.5 mL) and transferred to the vial via a syringe. The reaction was left stirring under nitrogen at 14°C (~2 h) and was monitored by TLC 2:1 hexane/ethyl acetate. The reaction was quenched over ice (10 × volume) and a KOH/H_2O (50% wt/vol, 5 mL) slurry. The product was extracted using ethyl acetate and dried over magnesium sulfate. It was purified by column chromatography. The product, 5-methylindoline **2** (0.60 g, 60% isolated yield), was isolated as a yellow oil. This oil was used as starting material to form the 5-methylindoline sulfonamides. No analytical data was accumulated for this intermediate.

Preparation of 1-(Phenylsulfonyl)indoline (3)

Benzenesulfonyl chloride (17.6 g, 0.1 mol) was added to a magnetically stirred solution of indoline (11.9 g, 0.1 mol) at room temperature for 30 min, followed by the addition of 10% NaOH (5 mL). The mixture was stirred for an additional 10 min while the pH was kept alkaline. The reaction mixture was allowed to sit for 30 min. The solid was collected using suction filtration and was washed with H_2O (3 × 100 mL). The solid was allowed to air dry. The crude product was recrystallized (95% EtOH) to give 1-(phenylsulfonyl)indoline **3** (24.6 g, 95%) as fine white crystals: mp 132–133°C (lit. 131–132°C); IR (thin film) 1351.77 cm^{-1} (SO_2 asym str.), 1168.30 cm^{-1} (SO_2 sym str.); ^1H (400 MHz, DMSO-d_6): δ 7.82 (d, $J = 8.0$, 2H), 7.66 (t, $J = 8.0$, 1H), 7.55 (t, $J = 8.0$, 2H), 7.50 (d, $J = 8.0$, 1H), 7.20 (t, $J = 8.0$ 1H), 7.14 (d, $J = 8.0$ 1H), 6.98 (t, $J = 8.0$, 1H), 3.90 (t, $J = 8.0$, 2H), 2.82 (t, $J = 80$, 2H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 142.11, 136.99, 134.57, 134.30, 132.98, 130.54, 130.30, 130.04, 128.38, 128.24, 127.97, 127.65, 126.32, 124.67, 115.06, 50.83, 28.08; MS m/z 259.

Preparation of 1-[(4-Methylphenyl)sulfonyl]indoline (4)

p-Toluenesulfonyl chloride (19.1 g, 0.1 mol) was gradually added with stirring to indoline (11.9 g, 0.1 mol) at room temperature, followed by the addition of 10% NaOH (5 mL). The mixture was stirred for an additional 10 min while the pH was kept alkaline. The reaction mixture was allowed to sit for 30 min. The solid was collected using suction filtration and was washed with H_2O (3 × 100 mL). The solid was allowed to air dry. The crude product was recrystallized (95% EtOH) to give 1-[(4-methylphenyl)sulfonyl]indoline **4** (19.6 g, 72%) as fine white crystals: mp 100.5–101.5°C (lit. 100.5–101.5°C); IR (KBr pellet): 1349.13 cm^{-1} (SO_2 asym str.), 1167.25 cm^{-1} (SO_2 sym str.) cm^{-1}; ^1H (400 MHz, $CDCl_3$): δ 7.68 (d, $J = 8.6$, 3H), 7.24 (m, $J = 8.6$, 3H), 7.10 (d, $J = 7.3$, 1H), 6.99 (t, $J = 7.4$, 1H), 3.93 (t, $J = 8.4$, 2H), 2.90 (t, $J = 8.4$, 2H), 2.39 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 144.45, 142.39, 132.17, 130.06, 128.10, 127.72, 125.51, 124.12, 115.41, 77.79, 77.47, 77.15, 50.35, 28.27, 21.94; MS m/z 273.

Preparation of 1-[(2-Nitrophenyl)sulfonyl]indoline (5)

o-Nitrobenzenesulfonyl chloride (22.2 g, 0.1 mol) was gradually added with stirring to indoline (11.9 g, 0.1 mol) at room temperature, followed by the addition of 10% NaOH (5 mL). The mixture was stirred for an additional 10 min while the pH was kept alkaline. The reaction mixture was allowed to sit for 30 min. The solid was collected using suction filtration and was washed with H_2O (3×100 mL). The solid was allowed to air dry. The crude product was recrystallized (95% EtOH) to give 1-[(2-nitrophenyl)-sulfonyl]indoline **5** (27.3 g, 72%) as fine white crystals: mp 106–107°C; IR (KBr pellet): 1541.69 cm^{-1} (NO_2 asym str.), 1357.84 cm^{-1} (NO_2 sym str.), 1242.94 cm^{-1} (SO_2 asym str.), 1164.20 cm^{-1} (SO_2 sym str.); ^1H (400 MHz, $CDCl_3$): δ 7.96 (d, $J = 7.8$, 1H), 7.70 (t, $J = 8.4$, 1H), 7.63 (m, $J = 8.4$, 2H), 7.48 (d, $J = 8.0$, 1H), 7.20 (m, $J = 7.5$, 8.0, 2H), 7.05 (t, $J = 7.5$, 1H), 4.20 (t, $J = 8.4$, 2H), 3.10 (t, $J = 8.4$, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.47, 134.37, 132.01, 130.67, 128.19, 125.88, 124.62, 114.92, 77.76, 77.65, 77.44, 77.13, 50.86, 28.44; MS m/z 304.

Preparation of 5-Chloro-1-[(4-methylphenyl)sulfonyl]indoline (6)

Sulfuryl chloride (5.0 g, 37 mmol) was added to a magnetically stirred solution of indoline-p-toluenesulfonamide **4** (6.19 g, 20.4 mmol) in benzene (50 mL) at room temperature. A condenser was fitted to the round-bottomed flask, and the reaction mixture was heated to reflux for 3–5 h. The reaction mixture was monitored by TLC (20:1 CH_2Cl_2/MeOH). A Dean–Stark trap was fitted to the apparatus to help remove any excess sulfuryl chloride. Excess benzene (10 mL) was added to the round-bottomed flask, and the mixture was refluxed to remove the excess sulfuryl chloride. The reaction mixture was allowed to cool, and the benzene was removed in vacuo. The product was triturated with cold methanol (20 mL) and was recrystallized (isopropyl alcohol) to give 5-chloro-1-[(4-methylphenyl)-sulfonyl]indoline **6** (4.83 g, 78%) as white needles: mp 120–121°C; IR (KBr pellet): 1161.53 cm^{-1} (SO_2 sym str.); ^1H: (400 MHz, $CDCl_3$) δ 7.67 (d, $J = 8.6$, 2H), 7.58 (d, $J = 8.6$, 1H), 7.26 (d, J = 8.6, 2H), 7.18 (d, $J = 8.6$, 1H), 7.06 (s, 1H), 3.93 (t, $J = 8.4$, 2H), 2.88 (t, $J = 8.5$, 2H), 2.40 (s, 3H); ^{13}C NMR (100 MHz): δ 144.74, 141.18, 134.13, 134.07, 130.17, 129.31, 127.70, 125.70, 116.35, 77.75, 77.43, 77.11, 50.54, 28.11, 21.96; MS m/z 308.

Preparation of 5-Chloro-1-[(2-nitrophenyl)sulfonyl]indoline (7)

Sulfuryl chloride (5.0 g, 37 mmol) was added to a magnetically stirred solution of indoline-*o*-nitrobenzenesulfonamide **5** (6.19 g, 18.3 mmol) in benzene (50 mL) at room temperature. A condenser was fitted to the round-bottomed flask, and the reaction mixture was heated to reflux for 3–5 h. The reaction mixture was monitored by TLC (20:1 CH_2Cl_2/MeOH). A Dean–Stark trap was fitted to the apparatus to help remove any excess sulfuryl chloride. Excess benzene (10 mL) was added to the round-bottomed flask, and the mixture was refluxed to draw off the excess sulfuryl chloride. The reaction mixture was allowed to cool, and the benzene was removed in vacuo. The product was triturated with cold methanol

(20 mL) and was recrystallized (isopropyl alcohol) to give 5-chloro-1-[(2-*o*-nitrophenyl)sulfonyl]indoline **7** (5.12 g, 83%) as white fine white crystals: mp 158–159°C; IR (KBr pellet): 1544.61 cm^{-1} (NO_2 asym str.), 1377.78 cm^{-1} (NO_2 sym str.), 1364.01 cm^{-1} (SO_2 asym str.), 1174.07 cm^{-1} (SO_2 sym str.); ^1H (400 MHz, $CDCl_3$): δ 7.96 (d, $J = 8.6$, 1H), 7.74 (t, $J = 8.2$, 1H), 7.66 (m, $J = 8.2$, 8.6, 2H), 7.39 (d, $J = 8.2$, 1H), 7.16 (d, $J = 8.6$, 1H) 7.15 (s, 1H), 4.10 (t, $J = 8.4$, 2H), 3.08 (t, $J = 8.4$, 2H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 140.23, 134.63, 134.08, 132.11, 129.84, 128.18, 126.05, 124.74, 115.85, 77.76, 77.44, 77.12, 51.06, 28.30; MS m/z 338.

Preparation of 5-Methyl-1-[(4-methylphenyl)sulfonyl]indoline (8)

In a vial equipped with a magnetic stir bar, 5-methylindoline **2** (0.30 g, 2.25 mmol) was added along with base (K_2CO_3/H_2O, 1 g/mL, 1 mL). Tosyl chloride (0.24 g, 2.25 mmol) was dissolved in CH_2Cl_2 and pipetted into the vial. The reaction was stirred at room temperature and was monitored by TLC (2:1 hexane/ethyl acetate, product Rf = 0.49). The product was extracted and washed with brine. The organic phase was dried over magnesium sulfate and filtered, and the solvent was removed in vacuo. The crude solid was purified by column chromatography (hexane/ethyl acetate, silica gel, gradient 0–100%). The product, 5-methyl-1-[(4-methylphenyl)sulfonyl]indoline **8** (0.40 g, 62% isolated yield) was a white powder: mp 99–100.5°C (lit.[4] 75–77°C); IR: (thin film) 1352.44 cm^{-1} (SO_2 asym str.), 1164.29 cm^{-1} (SO_2 sym str.); ^1H (400 MHz, $CDCl_3$): 7.66 (d, $J = 8.2$, 2H), 7.48 (d, $J = 8.1$, 1H), 7.23 (d, $J = 8.2$, 2H), 6.89 (d, $J = 8.1$, 1H), 6.59 (s, 1H), 3.81 (t, $J = 8.5$, 2H), 2.50 (t, $J = 8.5$, 2H), 2.32 (s, 3H), 2.24 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 144.28, 140.04, 134.42, 133.86, 132.39, 129.99, 128.60, 127.75, 125.13, 115.40, 50.50, 28.29, 92.8, 21.27; MS m/z 287.

Preparation of 5-Methyl-1-[(2-nitrophenyl)sulfonyl]indoline (9)

5-Methyl indoline **3** (0.30 g, 2.3 mmol) was added with base (10% NaOH, 1 mL) to a vial equipped with a magnetic stir bar. The 2-nitrobenzenesulfonyl chloride (0.24 g, 2.3 mmol) was dissolved in CH_2Cl_2 (5 mL) and was pipetted into the vial. The reaction was stirred at room temperature and monitored by TLC (2:1 hexane/ethyl acetate, product Rf = 0.31). The product was extracted with ethyl acetate and washed with brine. The organic phase was dried over magnesium sulfate. The solvent was removed in vacuo. The crude solid was purified by column chromatography (hexane/ethyl acetate, silica gel, gradient 0–100%). The product, 5-methyl-1-[(2-nitrophenyl)-sulfonyl]indoline **9** (0.42 g, 59% isolated yield) gave white crystals: mp 142–143°C; IR: (KBr Pellet) 1547.09 cm^{-1} (NO_2 asym str.), 1377.79 cm^{-1} (NO_2 sym str.), 1358.69 cm^{-1} (SO_2 asym str.), 1175.05 cm^{-1} (SO_2 sym str.); ^1H (400 MHz, $CDCl_3$): δ 7.93 (d, $J = 8.6$, 2H), 7.70 (t, $J = 8.2$, 1H), 7.65 (m, $J = 8.6$, 2H), 7.37 (d, $J = 8.5$, 1H), 7.01 (d, $J = 7.9$, 1H), 6.99 (s, 1H), 4.13 (t, $J = 8.3$, 2H), 3.03 (t, $J = 8.3$, 2H), 2.31 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 139.11, 136.88, 134.49, 134.23, 131.89, 130.63, 128.66, 126.51, 124.51, 114.86, 77.75, 77.43, 77.11, 50.96, 28.46; MS m/z 318.

General Procedure for the Formation of Indoline Sulfones

PPA (50 mL) was added to a 250-mL beaker equipped with a stir bar and magnetic stirrer. The PPA was heated to 130°C and was stirred vigorously until the acid became fluid. The sulfonamide (3.00 g) was added to the beaker in portions while stirring steadily. A uniform dark green color appeared in less than 1 h. The reaction was carried out for 3 h. The reaction was monitored by a thermometer (heat range 120–135°C). The hot mixture was poured into H_2O (75 mL) and was stirred vigorously to avoid clumping. The precipitate was stirred for 15 min and then was filtered through a fritted (medium porosity) funnel. Cold water (3×20 mL) was used to wash the solid. The product was dried in a vacuum oven for 2 days. The product was decolorized and purified using a Soxhlet extraction and CH_2Cl_2.

Preparation of 7-(Phenylsulfonyl)indoline (10)

Using the procedure described previously, the final compound 7-[(4-methylphenyl)sulfonyl]indoline **10** (1.2 g, 40% isolated yield) was a white powder that was intensely fluorescent under long UV light: mp 114–116°C; IR: (thin film) 3409.87 cm^{-1} (N-H str.), 1284.91 cm^{-1} (SO_2 asym str.), 1133.16 cm^{-1} (SO_2 sym str.); ^1H (400 MHz, DMSO-d_6): δ 7.94 (d, $J = 8.0$, 2H), 7.59 (d, $J = 8.0$, 2H), 7.57 (m, $J = 8.0$, 1H), 7.35 (d, $J = 8.0$, 1H), 7.18 (d, 1H), 6.58 (t, $J = 8.0$, 1H), 6.45 (s, 1H-N), 3.60 (t, $J = 5.7$, 2H), 2.92 (t, $J = 5.7$, 2H); ^{13}C NMR: (100 MHz, DMSO-d_6) δ 151.03, 142.72, 134.14, 133.44, 130.24, 130.08, 127.39, 126.59, 117.54, 117.09, 47.52, 28.53; MS m/z 259.

Preparation of 7-[(4-Methylphenyl)sulfonyl]indoline (11)

As before, the final compound 7-[(4-methylphenyl)sulfonyl]indoline **11** (0.60 g, 20% isolated yield) was a white powder that was intensely fluorescent under long UV light: mp 135°C; IR (KBr pellet): 3401.50 cm^{-1} (N−H str.), 1284.42 cm^{-1} (SO_2 asym str.) 1132.03 cm^{-1} (SO_2 sym str.); ^1H (400 MHz, acetone-d_6): δ 7.87 (d, $J = 8.6$, 2H), 7.30 (m, $J = 8.5$, 8.6, 3H), 7.21 (d, $J = 8.5$, 1H), 6.63 (t, $J = 8.1$, 1H), 6.02 (s, 1H), 3.70 (t, $J = 8.7$, 2H), 3.01 (t, $J = 8.7$, 2H), 2.41 (d, $J = 7.6$, 3H); ^{13}C NMR (100 MHz, acetone-d_6): δ 151.04, 144.26, 140.41, 132.88, 130.04, 129.37, 127.14, 126.39, 118.94, 117.05, 47.21, 29.90, 20.88; MS m/z 273.

Preparation of 7-[(2-Nitrophenyl)sulfonyl]indoline (12)

The crude product was purified by column chromatography (hexane/ethyl acetate, silica gel, gradient 0–100% ethyl acetate). This gave 7-[(2-nitrophenyl)sulfonyl]indoline **12** (0.10 g, 33% isolated yield), a white solid: mp 141–142°C; IR (KBr pellet): 3404.88 cm^{-1} (N−H str.), 1542.43 cm^{-1} (NO_2 asym str.), 1365.08 cm^{-1} (NO_2 sym str.), 1291.79 cm^{-1} (SO_2 asym str.), 1137.18 cm^{-1} (SO_2 sym str.); ^1H (400 MHz, acetone-d_6): δ 8.4 (d, $J = 8.6$, 1H), 7.95 (m, $J = 8.2$, 8.2, 8.6, 3H), 7.40 (d, $J = 8.5$, 1H), 7.26 (d, $J = 8.5$, 1H), 6.68 (t, $J = 8.6$, 1H), 6.06 (s, 1H), 3.76 (t, $J = 8.8$, 2H), 3.08 (t, $J = 8.6$, 2H); ^{13}C NMR (100 MHz, acetone-d_6): δ

135.09, 133.63, 132.60, 131.63, 130.97, 128.58, 128.23, 127.05, 126.19, 124.87, 47.48, 29.89; MS m/z 304.

Preparation of 5-Chloro-7-[(4-methylphenyl)sulfonyl]indoline (13)

The crude rearrangement product resulted in tan crystals weighing (0.88 g, 88% crude yield). The product was recrystallized from isopropyl alcohol to give 5-chloro-7-[(4-methylphenyl)sulfonyl]indoline **13** (0.200 g, 20% isolated yield), a white powder: mp 154–155°C; IR (KBr pellet): 3413.67 cm^{-1} (N−H str.), 1291.55 cm^{-1} (SO_2 asym str.), 1140.20 cm^{-1} (SO_2 sym str.); ^1H (400 MHz, acetone-d_6): δ 7.89 (d, $J = 8.6$, 2H), 7.54 (s, 1H), 7.38 (d, $J = 8.6$, 2H), 7.22 (s, 1H), 3.64 (t, $J = 8.5$, 2H), 2.88 (t, $J = 8.5$, 2H), 2.41 (s, 3H); ^{13}C NMR (400 MHz, acetone-d_6): δ 149.85, 144.77, 139.68, 135.87, 130.22, 129.48, 127.30, 125.07, 120.67, 119.03, 47.48, 47.40, 29.90, 20.93; MS m/z 308.

Preparation of 5-Chloro-1-[(2-nitrophenyl)sulfonyl]indoline (14)

The crude rearrangement product resulted in light green crystals (0.93 g, 93% crude yield). The product was purified by column chromatography (hexane/ethyl acetate, silica gel, gradient 0–100% ethyl acetate). This resulted in 5-chloro-1-[(2-nitrophenyl)sulfonyl]indoline **14** (0.500 g, 50% isolated yield) of yellow crystals: mp 184–185°C; IR (KBr pellet) 3409.51 cm^{-1} (N−H str.), 2923.67 cm^{-1} (CH_2 asym str.), 2853.77 cm^{-1} (CH_2 sym str.), 1541.55 cm^{-1} (NO_2 asym str.), 1375.32 cm^{-1} (NO_2 sym str.), 1293.56 cm^{-1} (SO_2 asym str.), 1164.83 cm^{-1} (SO_2 sym str.); ^1H (400 MHz, acetone-d_6): δ 8.40 (d, $J = 8.6$, 1H), 7.97 (m, $J = 8.4$, 3H), 7.35 (s, 1H), 7.29 (s, 1H), 6.22 (s, 1H), 3.75 (t, $J = 8.7$, 2H), 3.11 (t, $J = 8.7$, 2H); ^{13}C NMR (100 MHz, acetone-d_6): δ 150.88, 136.27, 135.64, 134.11 132.91, 131.25, 130.25, 125.84, 125.19, 120.36, 116.48, 47.60, 29.90; MS m/z 338.

Preparation of 5-Methyl-7-[(4-methylphenyl)sulfonyl]indoline (15)

The product was extracted with ethyl acetate. The organic phase was dried over magnesium sulfate, and the solvent was removed in vacuo. The crude product was purified by column chromatography (hexane/ethyl acetate, gradient 0–100% ethyl acetate). The resulting yield was 5-methyl-7-[(4-methylphenyl)sulfonyl]indoline **15** (0.10 g, 33% isolated yield), a white powder: mp 133–134°C; IR (KBr pellet): 3418.09 cm^{-1} (N−H str.), 1289.52 cm^{-1} (SO_2 asym str.), 1145.39 cm^{-1} (SO_2 sym str.); ^1H (400 MHz, acetone-d_6): δ 7.86 (d, $J = 8.3$, 2H), 7.38 (d, $J = 8.0$, 2H), 7.22 (s, 1H), 7.05 (s, 1H), 5.84 (s, 1H), 3.67 (t, $J = 8.6$, 2H), 2.97 (t, $J = 8.6$, 2H), 2.40 (s, 3H), 2.21 (s, 3H); ^{13}C NMR (100 MHz, acetone-d_6): δ 149.14, 144.17, 140.55, 133.27, 130.76, 130.00, 127.10, 126.58, 125.53, 118.69, 47.40, 29.91, 20.89, 19.93; MS m/z 287.

Preparation of 5-Methyl-7-[(2-nitrophenyl)sulfonyl]indoline (16)

The product was extracted with ethyl acetate. The organic phase was dried over magnesium sulfate, and the solvent was removed in vacuo. The crude product was

purified by column chromatography (hexane/ethyl acetate, gradient 0–100% ethyl acetate). The resulting yield was 5-methyl-7-[(2-nitrophenyl)sulfonyl]indoline **16** (0.10 g, 25% isolated yield), a yellow powder: mp 167–168°C; IR (KBr pellet): 3413.81 cm^{-1} (N−H str.), 1537.29 cm^{-1} (NO_2 asym str.), 1376.37 cm^{-1} (NO_2 sym str.), 1296.18 cm^{-1} (SO_2 asym str.), 1151.62 cm^{-1} (SO_2 sym str.); ^1H (400 MHz, acetone-d_6): δ 8.30 (d, $J = 7.9$, 1H), 7.90 (m, $J = 8.2$, 2H), 7.52 (d, $J = 7.6$, 1H), 7.19 (s, 1H), 7.14 (s, 1H), 5.88 (s, 1H), 3.72 (t, $J = 8.5$, 2H), 3.03 (t, $J = 8.6$, 2H), 2.23 (s, 3H); ^{13}C NMR (100 MHz, acetone-d_6): δ 135.09, 133.63, 132.60, 131.63, 130.97, 128.58, 128.23, 127.05, 126.19, 124.87, 47.48, 29.89, 19.93; MS m/z 318.

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