Solvent-free synthesis of novel styrenesulfonamide derivatives and evaluation of their antibacterial activity

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Novel *N*-aryl-styrenesulfonamide derivatives have been prepared from styrenesulfonyl chloride and a variety of amines under solvent-free conditions and their *in vitro* anti-bacterial activities against *Staphylococcus aureus* and *Escherichia coli* have been determined.

Keywords: solvent-free synthesis, styrenesulfonamide, antibacterial activity

Sulfonamides have a rich chemical and biological history and are important functional groups in medicinal chemistry because of their widespread chemical and biological activities.[1] The sulfonamides are synthetic antimicrobial agents with a wide spectrum encompassing most gram-positive and many gram-negative organisms.[2] These drugs were the first efficient treatment to be employed systematically for the prevention and cure of bacterial infections. Sulfonamides feature in other classes of pharmaceuticals such as anti-inflammatory,[3] anti-fungal[4] and anti-viral agents.[5] So there is considerable interest in devising mild and environmentally friendly methods for the synthesis of these compounds.

Styrene is used in everything from food containers and packaging materials to cars, boats and computers. Styrene also occurs in the environment and is found in many common foods, such as coffee, strawberries, peanut and cinnamon. Styrene derivatives are known to play an important role in biological systems, for example styrenesulfonamide acts as a carbonic anhydrase inhibitor,[6] and compounds containing a β-nitro styrene moiety are anti-microbial, anti-cancer[7,8] and anti-platelet agents.[9]

In an extension of our research on the synthesis and biological activity of sulfonamide derivatives,[10–12] we report here an efficient method for the synthesis of novel (*E*)-styrenesulfonamides *via* the condensation of amines with *trans*-β-styrenesulfonyl chloride under solvent-free conditions at room temperature. Also, the *in vitro* anti-bacterial activity of the synthesised compounds was evaluated.

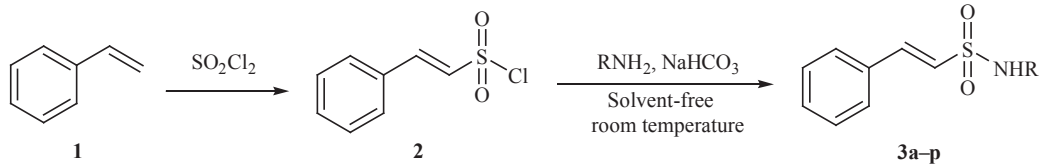
Results and discussion

The synthetic route of the target compounds **3a**–**p** is outlined in Scheme 1. The chlorosulfonation of styrene to *trans*-β-styrenesulfonyl chloride **2** was achieved with a literature method[13] using sulfuryl chloride at 60 °C for 8 h. It was obtained in 85% yield with high purity and was used in the next step without purification. Based upon our previous studies of solvent-free reactions,[14–18] the synthesis of (*E*)-styrenesulfonamides **3a**–**p** was achieved by simply stirring a mixture of *trans*-β-styrenesulfonyl chloride **2** and an amine in the presence of $NaHCO_3$ at room temperature for varying periods of 5 to 70 min. After completion of the reaction, which was monitored by TLC, the desired solid styrenesulfonamide was easily isolated in high purity by the addition of water and simple filtration. The products, which were oils, were isolated by solvent extraction using ethyl acetate. Some of them were purified by column chromatography.

In the IR spectrum of all the products, a sharp peak was seen around 1615 cm^{-1} due to the C=C of the styrene moiety. In the ^1H NMR spectrum of compound **3d**, two doublet peaks at 6.84 and 7.50 ppm with a coupling constant of 15.2 Hz were present which indicated that the vicinal protons on the double bond of the styrenesulfonamides were in the (*E*)-configuration. Similar peaks were seen in the spectra of the other products, but were not always so well resolved, confirming that in all products the styrene double bond is in the (*E*)-configuration.

Several structurally and electronically diverse amines were reacted with *trans*-β-styrenesulfonyl chloride and the results are summarised in Table 1. As the results show, all of the reactions proceeded efficiently, and the desired sulfonamides were obtained in good to excellent yield in short to moderate reaction times. It was observed that electronic factors play an effective role in these reactions. Aromatic amines substituted with electron-donating groups such as alkyl and alkoxy reacted faster than compounds that have electron-withdrawing groups (entries 2–6). Aromatic amines with weak electron-withdrawing groups like Cl and Br showed relatively good reactivity with high yield (entries 7–9). A heterocyclic amine was also reacted and the corresponding sulfonamide was produced in high yield (entry 12).

The antimicrobial screenings of the styrenesulfonamide derivatives were undertaken using agar well diffusion assays against selected strains of Gram-positive (*Staphylococcus aureus* ATCC6538) and Gram-negative (*Escherichia coli* ATCC 35218) bacteria. The diameters of the zones of inhibition for compounds **3a**–**p** are listed in Table 1 and compared with those of reference standards ampicillin and chloramphenicol. Solutions of the test compounds and the reference drugs were dissolved in DMSO to a concentration of 4 mg mL^{-1}. The highest



Scheme 1

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Table 1 Yields/reaction times for the preparation of styrenesulfonamides **3a**–**p** from a variety of amines **1** (Scheme 1) and their antibacterial activities[a]

Entry	Amine	Product	Time/min	Yield/%[b]	*S. aureus* (ATCC6538)	*E. coli* (ATCC35218)
1	$PhNH_2$	**3a**	70	75	13	<5
2	MeO-4-$C_6H_4NH_2$	**3b**	15	85	14	6
3	MeO-2-$C_6H_4NH_2$	**3c**	25	75	12	6
4	Me-4-$C_6H_4NH_2$	**3d**	30	85	10	<5
5	Me-2-$C_6H_4NH_2$	**3e**	40	75	12	6
6	2,4-Me_2-$C_6H_4NH_2$	**3f**	30	70	9	<5
7	Br-4-$C_6H_4NH_2$	**3g**	40	75	24	10
8	Cl-3-$C_6H_4NH_2$	**3h**	40	75	14	6
9	Cl-2-$C_6H_4NH_2$	**3i**	60	70	12	6
10	2,4-Cl_2-$C_6H_4NH_2$	**3j**	60	65	12	6
11	NO_2-m-$C_6H_4NH_2$	**3k**	90	60	12	<5
12	6-Me-2-pyridylamine	**3l**	40	70	8	8
13	HO-*p*-$C_6H_4NH_2$	**3m**	10	50	12	7
14	HO-*o*-$C_6H_4NH_2$	**3n**	7	65	22	10
15	Cyclohexylamine	**3o**	60	60	<5	<5
16	Piperazine	**3p**[c]	20	60	<5	<5
17		Ampicillin			28	15
18		Chloramphenicol			19	22

[a]Effectiveness was classified into four zones on the basis of the diameter of zone of inhibition: less than 5 mm (poor activity); 6–10 mm (moderate activity); 11–15 mm (good activity); and above 16 mm (very good activity). Each value is an average of three independent determinations.
[b]Isolated yield.
[c]Product is a bis-styrene sulfonamide derivative.

antibacterial activity against *S. aureus* was observed for the (*E*)-*N*-(2-hydroxyphenyl)-2-phenylethenesulfonamide **3n** and (*E*)-*N*-(4-bromophenyl)-2-phenylethenesulfonamide **3g**, so it is possible to conclude that the presence of bromine or *o*-hydroxyl groups on the amine moiety leads to an increase of the inhibitory effect. (*E*)-*N*-cyclohexyl-2-phenylethenesulfonamide **3o** and 1,4-bis(styrylsulfonyl)piperazine **3p** have the weakest activity against the Gram-positive bacteria strain. These results show that styrenesulfonamides derived from aliphatic amines are less active than those from aromatic amine. The *in vitro* efficacy of these new styrenesulfonamides against the Gram-negative bacteria was much lower than that against Gram-positive bacteria. Indeed, most compounds, except **3g**, **l**–**n** were essentially inactive.

In conclusion, this report describes a general and efficient method for the synthesis of a series of novel styrenesulfonamide derivatives. The procedure is quite general for a wide range of amines, including less nucleophilic and sterically hindered anilines. This protocol has advantages in terms of its low cost and the availability of the reagents, short reaction times, high chemoselectivity, and easy work-up. The synthesised compounds showed good antibacterial activity against two strains of gram-positive bacteria but generally were much less active against gram-negative bacteria.

Experimental

All chemicals were purchased from Merck or Fluka. NMR spectra were obtained on a Bruker 400 MHz FT spectrometer (^{1}H NMR at 400 Hz, ^{13}C NMR at 100 Hz) in $CDCl_3$ or DMSO-d_6 using TMS as internal standard. Chemical shifts (δ) are given in ppm and coupling constants (J) in Hz. IR spectra were recorded on a PerkinElmer VIR spectrophotometer. Plate chromatography was performed using silica gel. All reactions were conducted open to the atmosphere and the yields refer to the isolated products.

Synthesis of trans-*β-styrenesulfonyl chloride* (**2**): To a stirred mixture of DMF (1 mL) at 0 °C, sulfuryl chloride (1.25 mL, 15 mmol) was added dropwise. The mixture was stirred for 45 min at room temperature. Then styrene (0.97 mL, 7.5 mmol) was added and the mixture heated to 60 °C. The progress of the reaction was monitored by TLC. After completion of the reaction (8 h), cold water was poured into the mixture and it was extracted with CH_2Cl_2. The organic phase was washed with saturated NaCl (2 × 20 mL) and dried. The product was obtained as an oil. R_f = 0.55 (20% ethyl acetate, 80% *n*-hexane); IR (KBr, cm^{-1}) 1602 (C=C), 1375, 1164 (SO_2).

Synthesis of styrenesulfonamides; general procedure

A mixture of *trans*-β-styrenesulfonyl chloride **2** (2 mmol), $NaHCO_3$ (2 mmol) and an amine (2 mmol) was stirred at room temperature and the progress of the reaction was monitored by TLC. (The reaction time required for the formation of each product is listed in Table 1.) After completion of the reaction, water (15 mL) was added and many of the desired solid sulfonamides **3a**, **c**, **e**, **f**, **j**, **m** and **p** were easily isolated by simple filtration and washing with additional water (3 × 10 mL). For sulfonamides that were oils **3b**, **d**, **g**, **h**, **i**, **k**, **l**, **n** and **o**, the mixture was extracted with ethyl acetate (3 × 25 mL) and the combined extracts washed with water (20 mL), dried and evaporated under reduced pressure. For the purification of sulfonamides **3j**, **k**, **m** and **n** column chromatography was used with (40% ethyl acetate 60% n-hexane for **3j**; 100% ethyl acetate for **3k** and **3m**; 20% ethyl acetate 80% n-hexane for **3n**). The IR, ^{1}H and ^{13}C NMR of all of the products, which were novel were recorded and their elemental analyses determined.

*(E)-*N*,2-Diphenylethenesulfonamide* (**3a**): Light yellow powder, m.p. 105–107 °C; R_f = 0.33 (20% ethyl acetate, 80% n-hexane); IR (KBr, cm^{-1}) 3266 (NH), 1602 (C=C), 1339, 1146 (SO_2); ^{1}H NMR ($CDCl_3$) δ (ppm) 6.69 (1H$_{vinyl}$, d, *J* = 15.2 Hz), 6.92 (1H$_{N-H}$, s), 7.00 (1H$_{arom}$, t, *J* = 7.2 Hz), 7.07–7.13 (2H$_{arom}$, m), 7.15–7.20 (2H$_{arom}$, m), 7.21–7.29 (5H$_{arom}$, m), 7.38 (1H$_{vinyl}$, d, *J* = 15.2 Hz); ^{13}C NMR ($CDCl_3$) δ (ppm) 121.0, 124.3, 125.2, 128.4, 129.1, 129.5, 131.1, 132.3, 136.5, 143.1. Anal. calcd for $C_{14}H_{13}NO_2S$: C, 64.84; H, 5.05; N, 5.40; found: C, 64.72; H, 5.12; N, 5.36%.

*(E)-*N*-(4-Methoxyphenyl)-2-phenylethenesulfonamide* (**3b**): Oil; R_f = 0.36 (40% ethyl acetate, 60% n-hexane); IR (KBr, cm^{-1}) 3266 (NH), 1612 (C=C), 1330, 1146 (SO_2); ^{1}H NMR ($CDCl_3$) δ (ppm)

3.79 ($3H_{OMe}$, s), 6.80–6.87 ($2H_{arom}$, $1H_{vinyl}$, $1H_{N-H}$, m), 7.21 ($2H_{arom}$, d, J = 8.0 Hz), 7.36–7.44 ($5H_{arom}$, $1H_{vinyl}$, m); ^{13}C NMR ($CDCl_3$) δ (ppm) 50.7, 121.8, 125.6, 128.1, 129.7, 130.9, 131.5, 132.2, 133.5, 135.6, 142.9. Anal. calcd for $C_{15}H_{15}NO_3S$: C, 62.26; H, 5.23; N, 4.84; found: C, 62.31; H, 5.29; N, 4.78%.

*(*E*)-*N*-(2-Methoxyphenyl)-2-phenylethenesulfonamide* (**3c**): Grey powder, m.p. 106–108 °C; R_f = 0.41 (20% ethyl acetate, 80% n-hexane); IR (KBr, cm^{-1}) 3254 (NH), 1605 (C=C), 1337, 1149 (SO_2);^{1}H NMR ($CDCl_3$) δ (ppm) 3.86 ($3H_{OMe}$, s), 6.79 ($1H_{vinyl}$, d, J = 15.2 Hz), 6.87 ($1H_{arom}$, d, J = 8.0 Hz), 6.96 ($2H_{arom}$, t, J = 7.8 Hz), 7.01 ($1H_{N-H}$, s), 7.10 ($1H_{arom}$, t, J = 7.6 Hz), 7.37–7.45 ($5H_{arom}$, m), 7.49 ($1H_{vinyl}$, d, J = 15.2 Hz), 7.56 ($1H_{arom}$, d, J = 7.6 Hz); ^{13}C NMR ($CDCl_3$) δ (ppm) 55.8, 110.6, 120.4, 121.2, 124.3, 125.2, 125.9, 128.3, 129.0, 130.9, 132.4, 142.7, 149.3. Anal. calcd for $C_{15}H_{15}NO_3S$: C, 62.26; H, 5.23; N, 4.84; found: C, 62.20; H, 5.19; N, 4.80%.

(E)-2-Phenyl-N-p-*tolylethenesulfonamide* (**3d**): Oil; R_f = 0.33 (20% ethyl acetate, 80% n-hexane);IR (KBr, cm^{-1}) 3264 (NH), 1615 (C=C), 1332, 1146 (SO_2); ^{1}H NMR ($CDCl_3$) δ (ppm) 2.32 ($3H_{Me}$, s), 6.84 ($1H_{vinyl}$, d, J = 15.2 Hz), 6.97 ($1H_{N-H}$, br), 7.11–7.19 ($4H_{arom}$, m), 7.36–7.46 ($5H_{arom}$, m), 7.50 ($1H_{vinyl}$, d, J = 15.2 Hz); ^{13}C NMR ($CDCl_3$) δ (ppm) 20.9, 121.8, 124.3, 128.4, 129.1, 130.0, 131.0, 132.4, 133.7, 135.3, 142.9. Anal. calcd for $C_{15}H_{15}NO_2S$: C, 65.91; H, 5.53; N, 5.12; found: C, 65.84; H, 5.58; N, 5.06%.

*(*E*)-2-Phenyl*-N-o-*tolylethenesulfonamide* (**3e**): Cream powder, m.p. 126–128 °C; R_f = 0.44 (80% ethyl acetate, 20% n-hexane); IR (KBr, cm^{-1}) 3278 (NH), 1612 (C=C), 1327, 1146 (SO_2); ^{1}H NMR ($CDCl_3$) δ (ppm) 2.23 ($3H_{CH3}$, s), 6.27 ($1H_{N-H}$, S), 6.75 ($1H_{vinyl}$, d, J = 15.2 Hz), 7.01–7.05($1H_{arom}$, m), 7.11 ($2H_{arom}$, d, J = 7.2), 7.18–7.20 ($1H_{arom}$, m), 7.31–7.33 ($2H_{arom}$, m), 7.34–7.36 ($3H_{arom}$, m), 7.39 ($1H_{vinyl}$, d, J = 15.2 Hz); ^{13}C NMR ($CDCl_3$) δ (ppm) 8.0, 123.4, 124.6, 126.1, 127.2, 128.3, 128.7, 129.1, 130.7, 131.0, 132.3, 134.4, 142.7. Anal. calcd for $C_{15}H_{15}NO_2S$: C, 65.91; H, 5.53; N, 5.12; found: C, 65.82; H, 5.49; N, 5.18%.

*(*E*)-*N*-(2,4-Dimethylphenyl)-2-phenylethenesulfonamide* (**3f**): Light yellow powder, m.p. 140–141 °C; R_f = 0.53 (20% ethyl acetate, 80% n-hexane); IR (KBr, cm^{-1}) 3279 (NH), 1615 (C=C), 1326, 1147 (SO_2); ^{1}H NMR ($CDCl_3$) δ (ppm) 2.31 (6H, s), 6.30 ($1H_{N-H}$, s), 6.85 ($1H_{vinyl}$, d, J = 15.2 Hz), 6.99–7.05 ($2H_{arom}$, m), 7.28–7.34 ($1H_{arom}$, m), 7.39–7.48 ($5H_{arom}$, $1H_{vinyl}$, m);^{13}C NMR ($CDCl_3$) δ (ppm) 18.1, 20.9, 124.7, 124.8, 127.7, 128.3, 129.1, 131.0, 131.6, 131.7, 132.5, 136.4, 142.3. Anal. calcd for $C_{16}H_{17}NO_2S$: C, 66.87; H, 5.96; N, 4.87; found: C, 66.82; H, 5.90; N, 4.89%.

*(*E*)-*N*-(4-Bromophenyl)-2-phenylethenesulfonamide* (**3g**): Oil; R_f = 0.45 (20% ethyl acetate, 80% n-hexane); IR (KBr, cm^{-1}) 3248(NH), 1611 (C=C), 1329, 1147 (SO_2); ^{1}H NMR ($CDCl_3$) δ (ppm) 6.84 ($1H_{vinyl}$, d, J = 15.6 Hz), 7.13–7.18 ($2H_{arom}$, m), 7.39–7.46 ($6H_{arom}$, $1H_{N-H}$, m), 7.53 ($1H_{vinyl}$, d, J = 15.6 Hz); ^{13}C NMR ($CDCl_3$) δ (ppm) 118.4, 122.5, 123.8, 128.5, 129.1, 131.3, 132.0, 132.5, 135.6, 143.7. Anal. calcd for $C_{14}H_{12}BrNO_2S$: C, 49.72; H, 3.58; N, 4.14; found: C, 49.79; H, 3.61; N, 4.12%.

*(*E*)-*N*-(3-Chlorophenyl)-2-phenylethenesulfonamide* (**3h**): Oil; R_f = 0.35 (20% ethyl acetate, 80% n-hexane); IR (KBr, cm^{-1}) 3257 (NH), 1618 (C=C), 1323, 1147 (SO_2); ^{1}H NMR ($CDCl_3$) δ (ppm) 6.85 ($1H_{vinyl}$, d, J = 15.6 Hz), 7.11–7.16 ($2H_{arom}$, m), 7.25 ($1H_{arom}$, t, J = 8.0 Hz), 7.29–7.38 ($1H_{arom}$, $1H_{N-H}$, m), 7.38–7.48 ($5H_{arom}$, m), 7.58 ($1H_{vinyl}$, d, J = 15.2 Hz); ^{13}C NMR ($CDCl_3$) δ (ppm) 118.4, 120.4, 123.8, 125.1, 128.5, 129.1, 130.5, 131.3, 132.0, 135.1, 137.9, 143.8. Anal. calcd for $C_{14}H_{12}ClNO_2S$: C, 57.24; H, 4.12; N, 4.77; found: C, 57.20; H, 4.09; N, 4.71%.

*(*E*)-*N*-(2-Chlorophenyl)-2-phenylethenesulfonamide* (**3i**): Oil; R_f = 0.43 (20% ethyl acetate, 80% n-hexane); IR (KBr, cm^{-1}) 3280 (NH), 1613 (C=C), 1336, 1151 (SO_2); ^{1}H NMR ($CDCl_3$) δ (ppm) 6.83 ($1H_{vinyl}$, d, J = 15.6 Hz), 7.11–7.17 ($2H_{arom}$, m), 7.25 ($1H_{arom}$, t, J = 8.1 Hz), 7.30–7.35 ($1H_{arom}$, $1H_{N-H}$, m), 7.37–7.49 ($5H_{arom}$, m), 7.59 ($1H_{vinyl}$, d, J = 15.6 Hz); ^{13}C NMR ($CDCl_3$) δ (ppm) 119.0, 120.4, 123.7, 125.1, 128.4, 129.0, 130.5, 131.3, 132.0, 135.2, 137.8, 143.9. Anal. calcd for $C_{14}H_{12}ClNO_2S$: C, 57.24; H, 4.12; N, 4.77; found: C, 57.29; H, 4.19; N, 4.74%.

*(*E*)-*N*-(2,4-Dichlorophenyl)-2-phenylethenesulfonamide* (**3j**): Light yellow needles; m.p. 121–124 °C; R_f = 0.46 (20% ethyl acetate, 80% n-hexane); IR (KBr, cm^{-1}) 3270 (NH), 1616 (C=C), 1334, 1153 (SO_2); ^{1}H NMR ($CDCl_3$) δ (ppm) 6.78 ($1H_{vinyl}$, d, J = 15.2 Hz), 6.87 ($1H_{N-H}$, br), 7.27 ($1H_{arom}$, d, J = 7.4 Hz), 7.40–7.48 ($6H_{arom}$, m), 7.51 ($1H_{vinyl}$, d, J = 15.2 Hz), 7.62 ($1H_{arom}$, d, J = 8.8); ^{13}C NMR ($CDCl_3$) δ (ppm) 123.2, 123.7, 125.8, 126.7, 128.3, 128.5, 129.2, 129.4, 131.0, 131.4, 132.0, 132.1, 143.8. Anal. calcd for $C_{14}H_{11}Cl_2NO_2S$: C, 51.23; H, 3.38; N, 4.27; found: C, 51.26; H, 3.36; N, 4.31%.

*(*E*)-*N*-(3-Nitrophenyl)-2-phenylethenesulfonamide* (**3k**): Oil; R_f = 0.64 (40% ethyl acetate, 60% n-hexane); IR (KBr, cm^{-1}) 3269 (NH), 1615 (C=C), 1347, 1148 (SO_2); ^{1}H NMR ($CDCl_3$) δ (ppm) 6.86 ($1H_{vinyl}$, d, J = 15.6 Hz), 7.33–7.48 ($5H_{arom}$, $1H_{vinyl}$, m), 7.59–7.62 ($2H_{arom}$, m), 7.92 ($1H_{arom}$, d, J = 8.0 Hz), 8.11–8.13 ($1H_{arom}$, m), 8.33 ($1H_{N-H}$, br). Anal. calcd for $C_{14}H_{12}N_2O_4S$: C, 55.25; H, 3.97; N, 9.21; found: C, 55.28; H, 4.01; N, 9.18%.

*(*E*)-*N*-(6-Methylpyridin-2-yl)-2-phenylethenesulfonamide* (**3l**): Oil; R_f = 0.63 (100% ethyl acetate); IR (KBr, cm^{-1}) 3241 (NH), 1607 (C=C), 1362, 1116 (SO_2); ^{1}H NMR ($CDCl_3$) δ (ppm) 2.52 ($3H_{Me}$, s), 6.74 ($1H_{arom}$, d, J = 7.2 Hz), 6.96 ($1H_{vinyl}$, d, J = 15.2 Hz), 7.14–7.23 ($1H_{N-H}$, $1H_{arom}$, m), 7.40–7.44 ($3H_{arom}$, m), 7.48–7.52 ($2H_{arom}$, m), 7.59–7.65 ($1H_{vinyl}$, $1H_{arom}$, m); ^{13}C NMR ($CDCl_3$) δ (ppm) 23.6, 112.3, 120.5, 125.6, 128.4, 129.3, 132.5, 133.4, 135.7, 142.9, 149.5, 153.6. Anal. calcd for $C_{14}H_{14}N_2O_2S$: C, 61.29; H, 5.14; N, 10.21; Found: C, 61.34; H, 5.09; N, 10.25%.

*(*E*)-*N*-(4-Hydroxyphenyl)-2-phenylethenesulfonamide* (**3m**): Yellow mustard needles; m.p. 173 °C; R_f = 0.76 (100% ethyl acetate); IR (KBr, cm^{-1}) 3392 (OH), 3206 (NH), 1614 (C=C), 1317, 1140 (SO_2); ^{1}H NMR (DMSO) δ (ppm) 6.67 ($2H_{arom}$, d, J = 7.2 Hz), 7.01 ($2H_{arom}$, d, J = 7.2 Hz), 7.15 ($1H_{vinyl}$, d, J = 15.2 Hz), 7.28 ($1H_{vinyl}$, d, J = 15.2 Hz), 7.38–7.69 ($5H_{arom}$, $1H_{N-H}$, m), 9.52 ($1H_{OH}$, s); ^{13}C NMR (DMSO) δ (ppm) 115.4, 124.0, 126.1, 126.2, 128.4, 128.9, 130.6, 132.5, 140.4, 140.5. Anal. calcd for $C_{14}H_{13}NO_3S$: C, 61.07; H, 4.76; N, 5.09; found: C, 61.37; H, 4.45; N, 5.14%.

*(*E*)-*N*-(2-Hydroxyphenyl)-2-phenylethenesulfonamide* (**3n**): Oil; R_f = 0.66 (100% ethyl acetate); IR (KBr, cm^{-1}) 3251 (OH, NH), 1601 (C=C), 1330, 1145 (SO_2); ^{1}H NMR (DMSO) δ (ppm) 6.37 ($1H_{N-H}$, b), 6.72 ($1H_{vinyl}$, d, J = 15.6 Hz), 6.80 ($1H_{arom}$, dt, J_1 = 7.6, J_2 = 1.2), 6.86 ($1H_{arom}$, dd, J_1 = 8.0, J_2 = 1.2), 7.04 ($1H_{arom}$, dt, J_1 = 7.6, J_2 = 1.2), 7.16 ($1H_{arom}$, dd, J_1 = 8.0, J_2 = 1.2), 7.19 ($1H_{OH}$, s), 7.30–7.39 ($5H_{arom}$, $1H_{vinyl}$, m); ^{13}C NMR ($CDCl_3$) δ (ppm) 111.2, 116.9, 121.3, 123.2, 125.3, 128.0, 128.4, 128.5, 129.1, 131.2, 143.7, 149.9. Anal. calcd for $C_{14}H_{13}NO_3S$: C, 61.07; H, 4.76; N, 5.09; found: C, 61.44; H, 4.46; N, 5.08%.

*(*E*)-*N*-Cyclohexyl-2-phenylethenesulfonamide* (**3o**): Oil; R_f = 0.28 (20% ethyl acetate, 80% n-hexane); IR (KBr, cm^{-1}) 3283 (NH), 1602 (C=C), 1322, 1143 (SO_2); ^{1}H NMR ($CDCl_3$) δ (ppm) 1.25–1.34 ($4H_{CH2-}$, m), 1.50–1.60 ($2H_{CH2-}$, m), 1.66–1.75 ($4H_{CH2-}$, m), 3.16–3.28 ($1H_{CH-}$, m), 6.84 ($1H_{vinyl}$, d, J = 15.6 Hz), 7.40–7.43 ($4H_{arom}$, m), 7.47 ($1H_{N-H}$, s), 7.48–7.51 ($1H_{arom}$, $1H_{vinyl}$, m); ^{13}C NMR ($CDCl_3$) δ (ppm) 24.8, 25.2, 34.3, 52.7, 126.6, 128.2, 129.1, 130.6, 132.8, 140.4. Anal. calcd for $C_{14}H_{19}NO_2S$: C, 63.32; H, 7.26; N, 5.28; found: C, 63.39; H, 7.19; N, 5.31%.

1,4-Bis(styrylsulfonyl)piperazine (**3p**): Light brown powder, m.p. 253–256 °C; R_f = 0.64 (40% ethyl acetate, 60% n-hexane); IR (KBr, cm^{-1}) 1606 (C=C), 1155, 1335 (SO_2); ^{1}H NMR (DMSO) δ (ppm) 3.50 (8H, t, J = 5.6 Hz), 6.89 ($2H_{vinyl}$, d, J = 15.2 Hz), 7.45–7.51 ($10H_{arom}$, m), 7.76 ($2H_{vinyl}$, d, J = 15.2 Hz); ^{13}C NMR (DMSO) δ (ppm) 44.9, 122.2, 127.0, 128.8, 129.0, 130.9, 132.5. Anal. calcd for $C_{20}H_{22}N_2O_4S_2$: C, 57.39; H, 5.30; N, 6.69; found: C, 57.42; H, 5.25; N, 6.71%.

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