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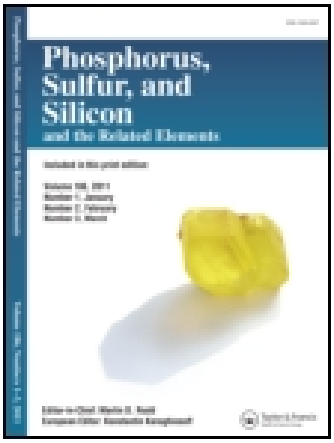

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Synthesis and Biological Evaluation of Diastereomeric (E and Z) Sulfides, Sulfones, Sulfide-Sulfones, and Disulfones

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SYNTHESIS AND BIOLOGICAL EVALUATION OF DIASTEREOMERIC (*E* AND *Z*) SULFIDES, SULFONES, SULFIDE-SULFONES, AND DISULFONES

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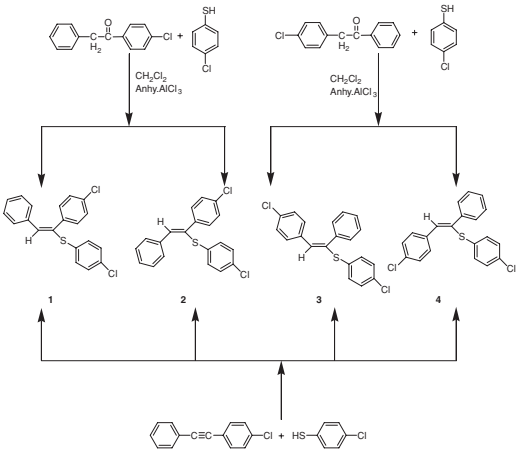
GRAPHICAL ABSTRACT



Abstract *The addition of* p-*chlorobenzenethiol to benzyl p-chlorophenylketone resulted in the formation of a mixture of diastereomers* (E)- *and* (Z)-*1*-p-*chlorophenyl-2-phenyl-1*-p-*chlorophenylthioethylene* (***1*** *and* ***2***). *These compounds, upon reaction with bromine in acetic acid, yielded a mixture of* (E)- *and* (Z)-*1-bromo-2*-p-*chlorophenyl-1-phenyl-2*-p-*chlorophenylthioethylenes* (***5a*** *and* ***5b***). *Oxidation of* ***5a*** *and* ***5b*** *affords* (E)- *and* (Z)-*1-bromo-2*-p-*chlorophenyl-1-phenyl-2*-p-*chlorophenylsulfonylethylenes* (***6a*** *and* ***6b***), *which upon reaction with the p-chlorobenzenethiol gave* (E)- *and* (Z)-*1*-p-*chlorophenyl-1*-p-*chlorophenylsulfonyl-2-phenyl-2*-p-*chlorophenylthioethylenes* (***7a*** *and* ***7b***). *Oxidation of* ***7a*** *and* ***7b*** *yielded* (E)- *and* (Z)-*1,2-bis(*p-*chlorophenylsulfonyl)-2-phenyl-1-p-chlorophenylethylenes* (***8a*** *and* ***8b***). *The final products,* ***8a*** *and* ***8b***, *were also synthesized from a mixture of diastereomers,* (E)- *and* (Z)-*2-p-chlorophenyl-1-phenyl-1-p-chlorophenylthioethylenes* (***3*** *and* ***4***), *yielding the intermediates* ***9a*** *and* ***9b***, ***10a*** *and* ***10b***, *and* ***11a*** *and* ***11b***. *The configurations of these compounds were established by elemental analysis, IR,* ^{1}*H NMR, and mass spectra, and by their preparation from the*

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corresponding phenylketones and p-chlorophenylphenylacetylene. All these new compounds exhibited pronounced in vitro antibacterial and antifungal activities.

Supplemental materials are available for this article. Go to the publisher's online edition of Phosphorus, Sulfur, and Silicon and the Related Elements *to view the free supplemental file.*

Keywords Antimicrobial activity; disulfones; (*E*)- and (*Z*)-isomers, sulfide-sulfones; sulfides; sulfones

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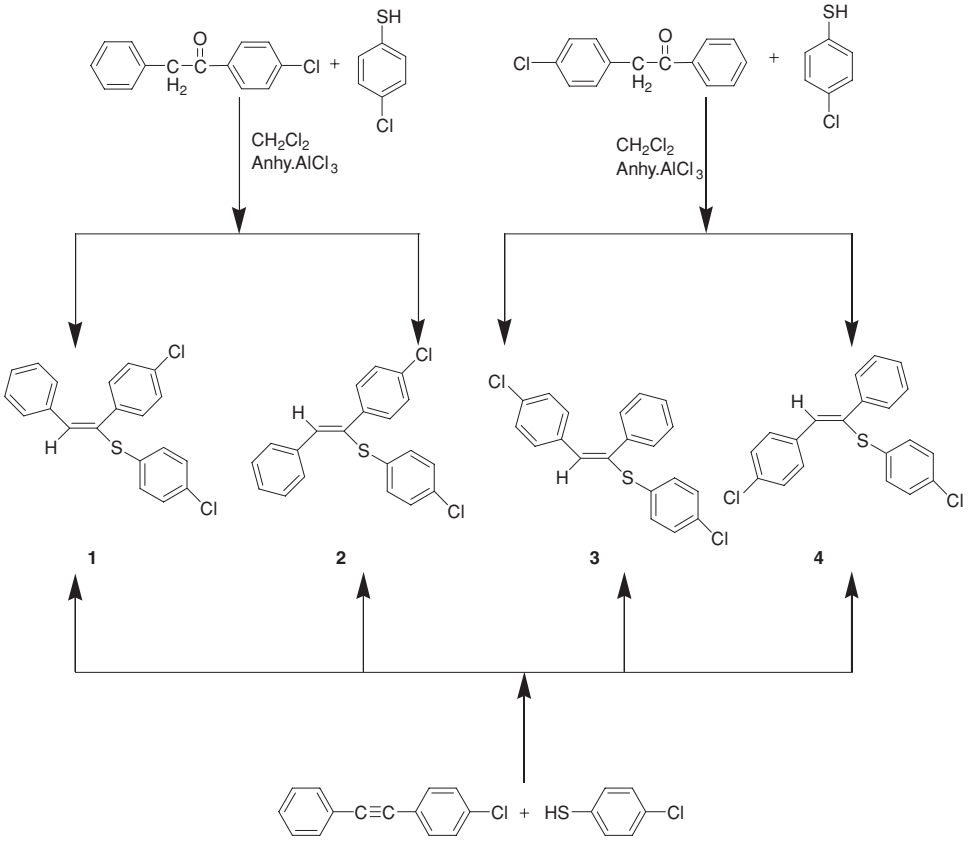
INTRODUCTION

Sulfones, an important class of synthetic intermediates, are used for C-C bond formation and stereo-controlled functional group transformations.[1–3] Dimethylsulfone or methylsulfonylmethane is one of the best and safest drugs[4] for the relief of arthritis,[5] inflammation, lupus, and other debilitating and disabling pain conditions, and is also effective in ameliorating the symptoms of gastrointestinal upset.[6] The biological studies on sulfones revealed that they can be used in chemotherapy, agriculture, dyes, and detergents.[7] Vinyl sulfones have been known for their synthetic utility in organic chemistry, easily participating in 1,4-addition reactions. This functional group has also recently been shown to potently inhibit a variety of enzymatic processes, providing unique properties for drug design and medicinal chemistry.[8] Divinyl sulfones and hydroxydiethyl sulfones are used to give crease-resistant finishes, while other sulfones are used as fuel additives, plasticizers, and anti-icing additives.[9] The recently originated unsaturated disulfones revealed from their biological studies that they can be used as effective fungicides.[7] There are several reports in the literature for synthesis of sulfones, but not much information is available for the synthesis of disulfones. We report the synthesis and biological evaluation of diastereomeric (*E* and *Z*) sulfides, sulfones, sulfide-sulfones, and disulfones.

DISCUSSION

Benzylphenyl ketone is known to react with benzenethiol, forming a mixture of (*E*)- and (*Z*)-1-phenylthiostilbenes in which the (*E*)-isomer predominates.[10] Similarly, the reaction of *p*-chlorobenzenethiol with benzyl *p*-chlorophenylketone in the present investigation gave a mixture of (*E*)- and (*Z*)-1-*p*-chlorophenyl-2-phenyl-1-*p*-chlorophenylthioethylenes (**1** and **2**) in which the (*E*)-isomer was in major proportion. On the other hand, the reaction of *p*-chlorobenzenethiol with *p*-chlorobenzylphenylketone gave a mixture of (*E*)- and (*Z*)-2-*p*-chlorophenyl-1-phenyl-1-*p*-chlorophenyl thioethylenes (**3** and **4**) in which the (*E*)-isomer predominated (Scheme 1).

Only a pair of (*E*)- and (*Z*)-1-arylthiostilbenes are known to be formed by the addition of arenethiols to diphenylacetylene.[11] But the addition of *p*-chlorobenzenethiol to *p*-chlorophenylphenylacetylene in the present study resulted in the formation of two pairs of diastereomeric (*E*)- and (*Z*)-1-*p*-chlorophenyl-2-phenyl-1-*p*-chlorophenylthioethylenes (**1** and **2**), and (*E*)- and (*Z*)-2-*p*-chlorophenyl-1-phenyl-1-*p*-chlorophenylthioethylenes (**3** and **4**) (Scheme 1). The formation of two pairs of diastereomeric (*E*)- and (*Z*)-isomers is expected because the dissimilar acetylenic carbons in *p*-chlorophenylphenylacetylene can be attacked independently by the thio radical, and the addition can be both *cis* and *trans*. The *cis*-addition of thiol leads to (*E*)-isomers, and the *trans*-addition leads to (*Z*)-isomers. They were separated by fractional distillation under reduced pressure. The (*E*)-isomers **1**



Scheme 1

and **3** were the major products compared to their respective (Z)-isomers **2** and **4**. The addition of thiols to acetylenes was reported to yield primarily the *cis*-addition products, and the *trans*-addition products were obtained in minor proportion.[12–15] Thus, the predominant occurrence of the (*E*)-isomers **1** and **3** in the present investigation may be, in part, due to their steric preference over the corresponding (*Z*)-isomers **2** and **4**.

The synthesis of the four isomers was subsequently verified by the reaction of *p*-chlrophenylphenylacetylene with *p*-chlorobenzenethiol. Of the four isomers formed in the mixture, both the diastereomers **3** and **4** were in a higher proportion when compared to the diastereomers **1** and **2**. This may be attributed to the stabilities of the intermediate radicals involved (Scheme 2). Thus, the formation of compounds **3** and **4** involves the intermediate radical **I**, and those of **1** and **2** involve the intermediate radical **II**. The radical **I** is expected to be more stable than **II** due to the contribution of a greater number of resonance structures. The (*E*)-isomers **1** and **3** obtained from ketone have the same melting point, and there is no depression in the mixed melting point. Also, the (Z)-isomers **2** and **4** have the same melting point with no change of mixed melting point. The IR spectra of all the isomers formed following the two methods were identical.

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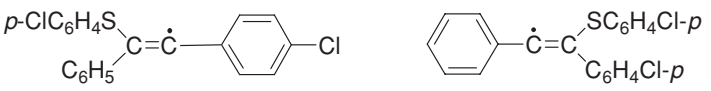

I II

Scheme 2

The reaction of **1** and/or **2** with Br_2 in AcOH at room temperature gave a mixture of **5a** and **5b** (Scheme 3). They were separated by fractional crystallization from methanol. Compound **5a** was in a major proportion (64%), while **5b** was a minor product (32%). This is expected because of the formation of a carbocation (Scheme 4).

The carbocations **I** and **II** are interconvertable by rotation of a central carbon–carbon single bond. The expulsion of a proton from carbocation **I** results in the formation of (*Z*)-isomer (**5a**), and the expulsion of a proton from carbocation **II** gives (*E*)-isomer (**5b**). In carbocation **I**, the *p*-ClC_6H_4S group is gauche to H on the adjacent carbon, whereas in carbocation **II** the *p*-ClC_6H_4S group is gauche to C_6H_5. Since the formation of the (*Z*)-isomer involves a more stable carbocation (**I**) than the (*E*)-isomer, the (*Z*)-isomer forms in a major proportion. The identity of compound (**5a**) has been confirmed as the (*Z*)-isomer.

Compound **5a** upon irradiation with UV light[14] gave **5b**. Oxidation of **5a** and **5b** afforded (*E*)- and (*Z*)-1-bromo-2-*p*-chlorophenyl-1-phenyl-2-*p*-chlorophenylsulfonyl ethylenes (**6a** and **6b**), respectively. Compounds **6a** and **6b** when heated with sodium salt of *p*-chlorobenzenethiol yielded (*E*)- and (*Z*)-1-*p*-chlorophenyl-1-*p*-chlorophenylsulfonyl-2-phenyl-2-*p*-chlorophenylthioethylenes (**7a** and **7b**) with retention of configuration.[16] Oxidation of **7a** and **7b** afforded **8a** and **8b,** respectively (Scheme 3). The stereoisomers **3** and **4** also yielded the final compounds **8a** and **8b** (Scheme 5).

The characterization data of all the newly synthesized compounds are presented in Table 1. In the IR region, $\nu_{c=c}$ mode was not observed for all sulfide-sulfones and bis-sulfones. This may be attributed to the tetrasubstituted nature of the compounds.[17] The strong bands at 1175 and 1356 cm^{-1} in bis-sulfones were assigned to ν_{as} SO_2 and ν_s SO_2 modes, and the bands observed in sulfide-sulfones and bis-sulfones at 1086 cm^{-1} were assigned to $\nu_{c\text{-}c}$ (aryl) mode.[18] Because the compounds **1** through **4** are trisubstituted ethylenes, the ^1H NMR spectra chemical shifts (included in the Supplemental Materials, available online) are used,[19] rather than coupling constants, to differentiate between (*E*)- and (*Z*)-isomers. The chemical shifts of vinyl protons of *cis*-(*E*)-thioethylenes **1** and **3** occur at a lower field strength (δ 7.29 and 7.39) than their corresponding *trans*-(*Z*)-thioethylenes **2** and **4** (δ 6.96 and 7.02). A similar observation was made with monosulfides by Hussain et al.,[20] wherein all aromatic hydrogens resonated as multiplets at δ 6.99–8.00. The electron impact mass spectral data of some (*E*)- and (*Z*)-monosulfides, bromosulfones, sulfide-sulfones, and disulfones are presented as Supplemental Materials, available online. A notable feature observed in the spectra of (*E*)- and (*Z*)-bromosulfides, bromosulfones, sulfide-sulfones, and disulfones is the absence of molecular ion peaks, and this may be due to the thermal decomposition of the sample during vaporization.[12]

Antimicrobial Activity

The data related to antibacterial and antifungal activities are presented as Supplemental Materials (Tables S1 and S2).

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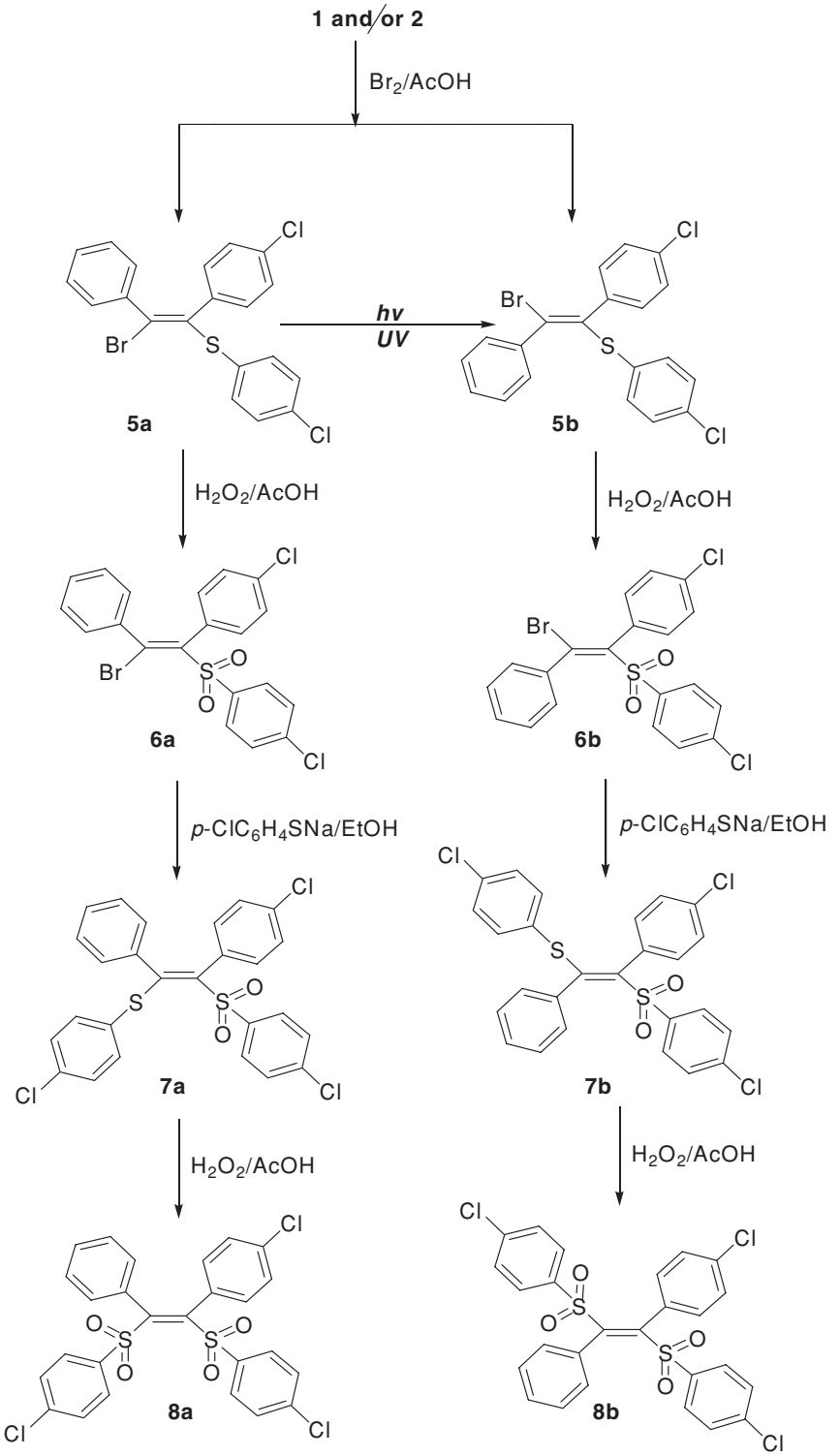
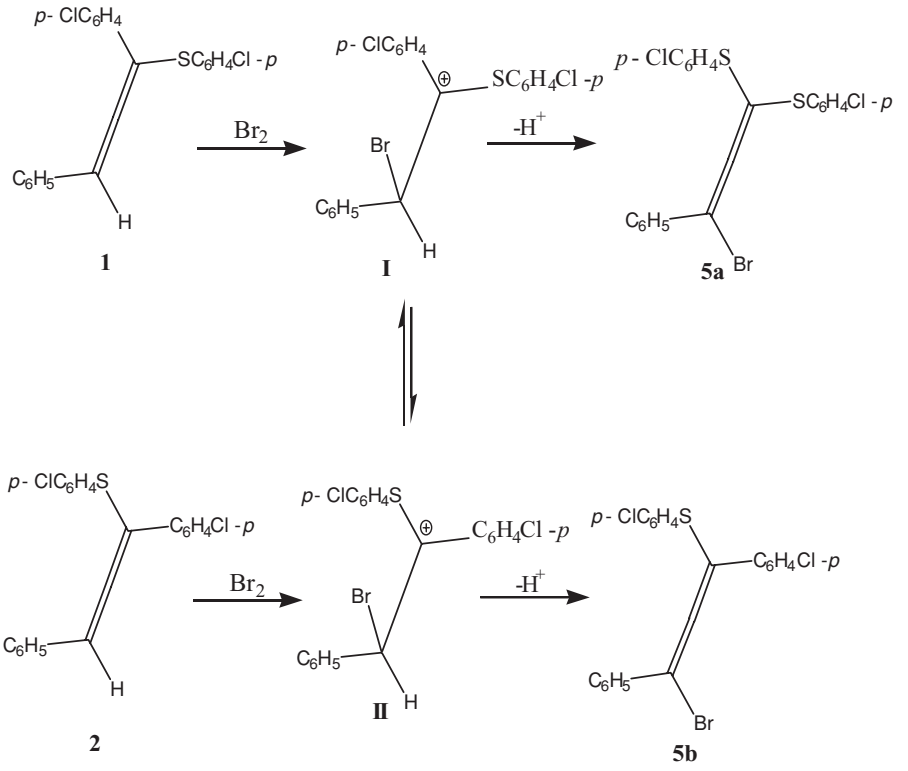


Scheme 3



Scheme 4

EXPERIMENTAL

All melting points were determined in open capillary tubes on Mel-Temp apparatus (Laboratory Devices, Cambridge, MA, USA), and are uncorrected. Infrared spectra (ν_{max} in cm^{-1}) were recorded as KBr pellets on a Perkin-Elmer 283 double beam spectrophotometer. ^1H NMR spectra were recorded on an ABX 400 MHz spectrophotometer operating at 400 MHz for ^1H NMR, using DMSO-d_6 as solvent. The ^1H NMR chemical shifts were referenced to tetramethylsilane (TMS).

General Procedure for the Preparation of 1 and 2 from Benzyl *p*-Chlorophenyl Ketone or 3 and 4 from *p*-Chlorobenzyl Phenyl Ketone

A solution of benzyl *p*-chlorophenyl ketone (23 g, 100 mmol) or *p*-chlorobenzylphenylketone and *p*-chlorobenzenethiol (23 g, 159 mmol) in methylene chloride (100 mL) were taken in a 250 mL conical flask fitted with an air-condenser guarded with a calcium chloride tube. The solution was stirred at room temperature, and anhydrous aluminium chloride (4.53 g, 34 mmol) was added in small portions over a period of 10 min. The reaction mixture became turbid as the reaction proceeded. After the addition, the mixture was further stirred for another 60 min and was poured into water (75 mL). The resulting mixture was extracted with methylene chloride (100 mL), and the

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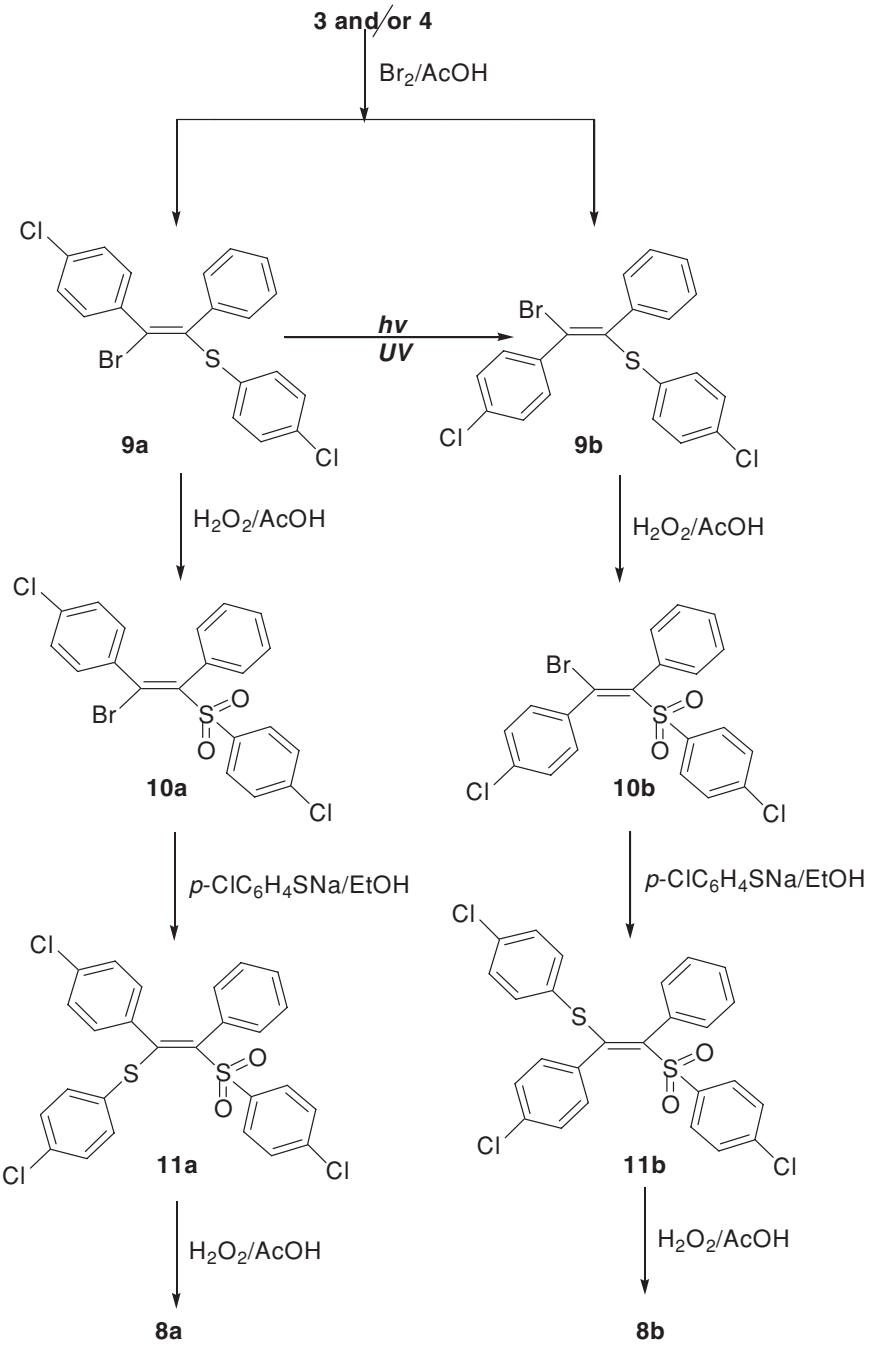

extract was washed with brine solution (100 × 2 mL), 2% sodium hydroxide solution (100 × 2 mL), and water (250 mL). The organic layer was dried over anhydrous $MgSO_4$, and the solvent was evaporated to give the solid, which was recrystallized from acetic acid (**1** or **3**). The yields varied from 65–71%.

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Table 1 Characterization data of all synthesized compounds

Compound	Mp°C	Molecular formula	Found (%)/(Cal)			IR (KBr/neat) cm^{-1}			^{1}H NMR $CDCl_3$		
			C	H	S	$\nu_{c=c}$	$\nu_{s\text{-aryl}}$	ν_{so2}	=CH	Ar-H (m)	*m/z* (M^++1)
1	110–112	$C_{20}H_{14}Cl_2S$	67.23 (67.28)	3.95 (3.98)	8.97 (8.88)	1654	1098	—	7.29	7.12–7.89	358
2	78–80	$C_{20}H_{14}Cl_2S$	67.23 (67.28)	3.98 (3.98)	8.99 (8.88)	1674	1099	—	6.96	7.23–7.99	358
3	139–140	$C_{20}H_{14}Cl_2S$	67.27 (67.28)	3.99 (3.98)	8.96 (8.88)	1672	1098	—	7.39	6.99–7.86	358
4	172–174	$C_{20}H_{14}Cl_2S$	67.27 (67.28)	4.01 (3.98)	8.96 (8.88)	1679	1099	—	7.02	7.14–7.65	358
5a	112–114	$C_{20}H_{13}BrCl_2S$	55.07 (55.18)	3.00 (3.08)	7.35 (7.34)	1698	1103	—	—	7.11–7.89	—
5b	120–121.5	$C_{20}H_{13}BrCl_2S$	55.10 (55.18)	3.00 (3.08)	7.38 (7.34)	1696	1099	—	—	7.01–7.73	—
6a	175–176.5	$C_{20}H_{13}BrCl_2O_2S$	51.31 (51.28)	2.80 (3.88)	6.85 (6.85)	1696	1087	1308 1148	—	7.23–7.97	—
6b	155–157	$C_{20}H_{13}BrCl_2O_2S$	51.33 (51.28)	2.87 (3.88)	6.84 (6.85)	1691	1089	1311 1156	—	7.13–7.89	—
7a	232–234	$C_{26}H_{17}Cl_3O_2S_2$	58.71 (58.75)	3.22 (3.20)	12.06 (12.07)	—	1086	1309 1152	—	7.03–7.99	—
7b	202–204	$C_{26}H_{17}Cl_3O_2S_2$	58.70 (58.75)	3.25 (3.20)	12.11 (12.07)	—	1085	1313 1147	—	6.99–8.00	—
8a	272–273	$C_{26}H_{17}Cl_3O_4S_2$	55.38 (55.35)	3.05 (3.05)	11.37 (11.42)	—	1087	1356 1175	—	7.10–7.98	—
8b	243–245	$C_{26}H_{17}Cl_3O_4S_2$	55.39 (55.35)	3.11 (3.05)	11.39 (11.42)	—	1089	1354 1162	—	7.11–8.00	—
9a	155–157	$C_{20}H_{13}BrCl_2S$	55.09 (55.18)	3.04 (3.08)	7.36 (7.34)	1699	1104	—	—	7.06–7.88	—
9b	167–168	$C_{20}H_{13}BrCl_2S$	55.10 (55.18)	3.00 (3.08)	7.38 (7.34)	1696	1099	—	—	7.01–7.73	—
10a	136–138	$C_{20}H_{13}BrCl_2O_2S$	51.33 (51.28)	2.81 (3.88)	6.87 (6.85)	1685	1086	1318 1138	—	7.13–7.96	—
10b	205–207	$C_{20}H_{13}BrCl_2O_2S$	51.34 (51.28)	2.86 (3.88)	6.85 (6.85)	1692	1090	1317 1129	—	7.09–7.99	—
11a	241–243	$C_{26}H_{17}Cl_3O_2S_2$	58.76 (58.75)	3.23 (3.20)	12.05 (12.07)	—	1095	1329 1163	—	7.13–7.99	—
11b	198–199	$C_{26}H_{17}Cl_3O_2S_2$	58.75 (58.75)	3.25 (3.21)	12.10 (12.07)	—	1086	1317 1156	—	7.01–8.00	—

The acetic acid solution obtained after separating **1** or **3** on evaporation of the solvent gave **2** or **4** as solid, which upon recrystallization with 95% ethanol yielded needle-shaped crystals. The yields varied from 35–39%.

Reaction of *p*-Chlorobenzenethiol with *p*-Chlorophenylphenylacetylene

A solution of *p*-chlorophenylphenylacetylene (21.24 g, 100 mmol) in n-heptane (150 mL) was heated to reflux, and *p*-chlorobenzenethiol (21.63 g, 150 mmol) was added to the above solution. The reaction mixture was refluxed for 24 h. The solution was washed successively with 2% sodium hydroxide solution (100 × 2 mL) and water (250 mL), and dried over anhydrous calcium chloride. The residue left after the evaporation of the solvent was subjected to fractional distillation under reduced pressure to get four fractions.

The first fraction was collected at 180–182°C/30 mm Hg, which upon cooling gave a solid of 7.05 g (19.8%). It was recrystallized from 95% ethanol to give needle-shaped crystals of (*E*)-1-*p*-chlorophenyl-2-pheny-1-*p*-chlorophenylthioethylene (**1**), mp 110–112°C. There was no change in melting point of this compound when mixed with **1** prepared earlier from benzyl *p*-chlorophenylketone.

The second fraction was collected at 188–190°C/30 mm, which upon cooling became a pasty mass, and upon treatment with petroleum spirit gave a solid of 16.92 g (47.4%). It was recrystallized from 95% ethanol to give colorless crystals of (*E*)-2-*p*-chlorophenyl-1-phenyl-1-*p*-chlorophenylethylne (**3**), mp 139–140°C. No change in melting point of this compound was observed upon mixing with **3** synthesized earlier from *p*-chlorobenzylphenylketone.

The third fraction was collected at 195–197°C/30 mm, which upon cooling gave a solid of 4.96 g (13.7%). It was recrystallized from methanol to give (*Z*)-1-*p*-chlorophenyl-2-phenyl-1-*p*-chlorophenylthioethylene (**2**) with a mp of 78–80°C. When mixed with **2** prepared earlier from benzyl *p*-chlorophenylketone, there was no change in melting point of this compound.

The fourth fraction was collected at 198–200°C/30 mm, which upon cooling gave a pasty mass, and upon trituration with n-hexane yielded a solid of 3.25 g (8.9%). It was recrystallized from ethyl acetate to give (*Z*)-2-*p*-chlorophenyl-1-phenyl-1-*p*-chlorophenylthioethylene (**4**), mp 172–174°C. The melting point of this compound also did not depress on admixture with **4** prepared earlier from benzyl *p*-chlorophenylketone.

General Procedure for the Bromination of (1 or 2) to (5a and 5b), or (3 or 4) to (9a and 9b)

1 or **2** or **3** or **4** (9.54 g, 26 mmol) was dissolved in glacial acetic acid (100 mL) in a 250 mL conical flask fitted with a mechanical stirrer. The stirrer was set in motion, and a solution of bromine (4.37 g, 26 mmol) in glacial acetic acid (15 mL) was added dropwise. Decolorization was observed during addition, and stirring was continued for 24 h. The solid separated was filtered and recrystallized from 95% ethanol. The yields varied from 59–63%. The filtrate from the above reaction mixture after separating the **5b** or **9b** upon dilution with water gave **5a** or **9a** as a solid, which was recrystallized from 95% ethanol. The yields ranged from 35–39%.

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General Procedure for the Oxidation of 5a to 6a or 5b to 6b or 9a to 10a or 9b to 10b

A solution of **5a** or **5b** or **9a** or **9b** (4.03 g, 9 mmol) in glacial acetic acid (60 mL) was taken in a 100 mL round-bottomed flask fitted with a reflux condenser. The solution was heated to boiling, then 30% hydrogen peroxide (50 mL) was added dropwise and refluxed for 2 h. The product that separated upon cooling was collected, filtered, and recrystallized from 95% ethanol. The yields varied from 80–98%.

General Procedure for the Conversion of 6a to 7a or 6b to 7b or 10a to 11a or 10b to 11b

p-Chlorobenzenethiol (0.77 g, 5 mmol) was added to an ethanolic solution of sodium ethoxide, which was prepared from sodium (0.12 mg, 5 mmol) dissolved in absolute ethanol (10 mL). This solution was then added to a hot solution of **6a** or **6b,** or **10a** or **10b** (2.37 g, 5 mmol) in absolute ethanol (200 mL) contained in a 500 mL round-bottomed flask fitted with a reflux condenser protected with calcium chloride guard tube. The mixture was refluxed for 24 h. The colorless product that separated upon cooling was filtered and recrystallized three times from 95% ethanol. They yields ranged from 38–69%.

General Procedure for the Oxidation of 7a or 7b or 11a or 11b to (*E*)- and (*Z*)-1,2-Bis-(*p*-chlorophenylsulfonyl)-1-*p*-chlorophenyl-2-phenyl Ethylene (8a and 8b)

A solution of **7a** or **7b**, or **11a** or **11b** (1.07 g, 2 mmol) in glacial acetic acid (50 mL) was taken in a 100 mL round-bottomed flask fitted with a reflux condenser. The solution was heated to boiling, and 30% hydrogen peroxide (10 mL) was added slowly. The solution was refluxed for 1 h, and the colorless crystals that separated upon cooling were filtered and recrystallized from 95% ethanol. The yields varied from 88–95%.

Spectroscopic Data

Spectral data for **5b**, **6b**, **7b**, and **8b** are found as Figures S1–S4 in the Supplementary Materials.

(*E*)-1-*p*-chlorophenyl-2-phenyl-1-*p*-chlorophenylthioethylene (1). ^{1}H NMR (400 MHz, $CDCl_3$)**:** δ 7.12–7.14 (m, 4H), 7.29 (s, 1H), 7.32–7.41 (m, 5H), 7.55–7.58 (d, 2H), 7.83–7.89 (d, 2H). LCMS: (m/z) 356 (M^++1), 212, 213, 215, 143, 111.

(*Z*)-1-*p*-Chlorophenyl-2-phenyl-1-*p*-chlorophenylthioethylene (2). ^{1}H NMR (400 MHz, $CDCl_3$)**:** δ 6.96 (s, 1H), 7.23–7.32 (d, 2H), 7.35–7.39 (m, 5H), 7.63–7.68 (m, 4H), 7.92–7.99 (d, 2H). LCMS**:** (m/z) 356 (M^++1), 212, 213, 215, 143, 111.

(*E*)-2-*p*-Chlorophenyl-1-phenyl-1-*p*-chlorophenylthioethylene (3). ^{1}H NMR (400 MHz, $CDCl_3$)**:** δ 6.99 (d, 2H), 6.99–7.01 (d, 2H), 7.08 (d, 2H), 7.26–7.31 (m, 5H), 7.39 (s, 1H). 7.86 (d, 2H). LCMS**:** (m/z) 356 (M^++1), 212, 213, 215, 143, 111.

(*Z*)-2-*p*-Chlorophenyl-1-phenyl-1-*p*-chlorophenylthioethylene (4). ^{1}H NMR (400 MHz, $CDCl_3$)**:** δ 7.02 (s, 1H), 7.14–7.20 (m, 4H), 7.11–7.18 (d, 2H), 7.38–7.44 (m, 5H), 7.57–7.65 (d, 2H). LCMS**:** (m/z) 356 (M^++1), 212, 213, 215, 143, 111.

(*E*)-1-Bromo-2-*p*-chlorophenyl-1-phenyl-2-*p*-chlorophenylthioethylene (5b). ^{1}H NMR (400 MHz, $CDCl_3$)**:** δ 7.01–7.12 (m, 5H), 7.14 (d, 2H), 7.17 (d, 2H),

7.26–7.35 (d, 2H), 7.62–7.73 (d, 2H). LCMS**:** (m/z) 291, 293, 295, 212, 214, 176, 143, 111.

(*E*)-1-Bromo-2-*p*-chlorophenyl-1-phenyl-2-*p*-chlorophenylsulfonylethylene (6b). ^{1}H NMR (400 MHz, $CDCl_3$)**:** δ 7.13 (d, 2H), 7.25 (d, 2H), 7.29-7.38 (m, 5H), 7.42 (d, 2H), 7.89 (d, 2H). LCMS**:** (m/z) 291, 293, 295, 212, 214, 176, 175, 143, 111.

(*E*)-1-*p*-Chlorophenyl-2-phenyl-1-*p*-chlorophenylsulfonyl-2-*p*-chlropenylthioethylene (7b). NMR (400 MHz, $CDCl_3$)**:** δ 6.99–7.04 (d, 2H), 7.13–7.24 (m, 5H), 7.43 (d, 2H), 7.67–789 (m, 4H), 7.83–7.89 (d, 2H), 7.93–8.00 (d, 2H). LCMS**:** (m/z) 359, 358, 357, 356, 355, 321, 320, 319, 212, 214,177, 176, 175, 143, 111.

(*E*)-1,2-Bis(*p*-chlorophenylsulfonyl)-1-*p*-chlorophenyl-2-phenylethylene (8b). ^{1}H NMR (400 MHz, $CDCl_3$)**:** δ 7.11 (d, 2H), 7.18 (d, 2H), 7.26 (d, 2H), 7.32 (d, 2H), 7.36-7.48 (m, 5H), 7.47 (d, 2H), 7.87 (d, 2H), 8.00 (d, 2H). LCMS**:** (m/z) 387, 357, 323, 212, 177, 176, 175, 139, 111, 105.

Antimicrobial Activity

All the compounds synthesized (**1** through **11b**) were screened for their antibacterial activity against human pathogenic bacteria *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Escherichia coli*, *Streptococcus faecalis*, and *Propionibacterium acnes*. The minimum inhibition concentration (MIC) of each compound was determined using the tube dilution method.[21] DMF was used as a blank and ciprofloxacin as a standard. The compounds were also screened for their antifungal activity against *Candida albicans* and *Aspergillus niger* using the fungicide clotrimazole in DMF[22] as a standard.

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