Asian Journal of Chemistry; Vol. 27, No. 12 (2015), 4373-4378

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2015.19128

Synthesis and Antimicrobicidal Activity of Phenothiazinophanes: A New Class of Permanent Fluorescence Sensing Stilbenophanes

RAJAGOPAL KANAGALATHA[1], PERUMAL RAJAKUMAR[2,*], C.S. SENTHAMIL SELVI[3] and NATARAJAN MOHAN[3]

[1]Department of Chemistry, Government Arts College (Autonomous), Salem-636 007, India
[2]Department of Organic Chemistry, University of Madras, Guindy Campus, Chennai-600 025, India
[3]Center of Advanced Studies in Botany, University of Madras, Guindy Campus, Chennai-600 025, India

*Corresponding author: E-mail: perumalrajakumar@gmail.com

Received: 24 February 2015; *Accepted*: 21 April 2015; *Published online*: 29 August 2015; AJC-17474

The synthesis, characterization and antimicrobicidal activity of phenophiazinophane and chiral phenothiazinophanes are described. The synthesized compounds also exhibits excellent fluorescent sensing properties.

Keywords: Stilbenophanes, Phenothiazine, Fluorescence Sensing, Antimicrobicidal activity.

INTRODUCTION

Supramolecular systems with fluorescence tag play an important role in biology[1], phenothiazine based supramolecules finds application in electronics and optoelectronics[1-8] including light-emitting diodes[2-4], photovoltanic cells[4-6], thin film transistors[7] and in electrochromic cells[8]. Though phenothiazine based oligomers have been reported earlier[9], very few phenothiazine based cyclophanes have been reported recently[10]. Phenothiazine is a well-known heterocyclic compound with several biological properties[11] including antiviral[12], antiparasitic[13], antiparkinsonian[14], anticonvulsant[15], antihistaminic[16] as well as anthelmintic[17] activities. The presence of phenothiazine unit in cyclophane exhibits unusual photoluminescence and electrochemical properties[18]. We wish to report the synthesis and antibacterial activity of phenothiazinophanes (**1-8**) which exhibits excellent fluorescent sensing properties also.

EXPERIMENTAL

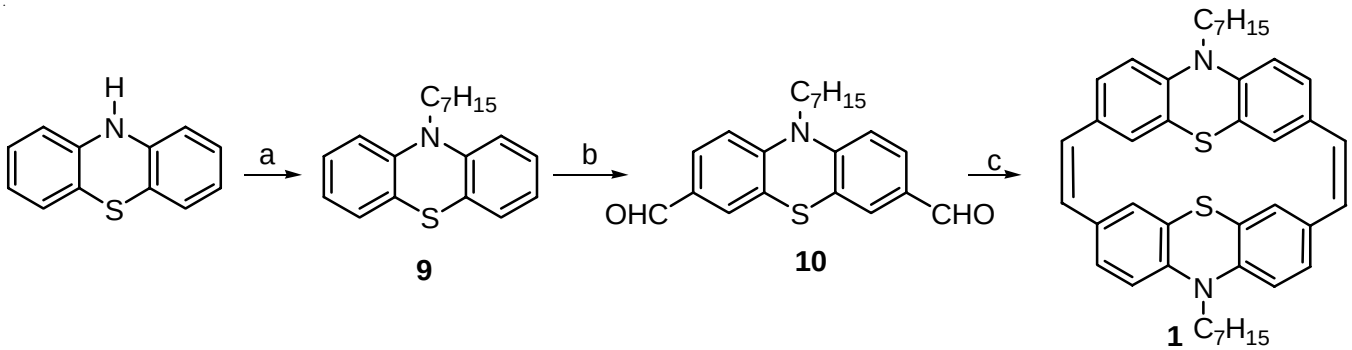
Herein, we focus the synthesis and antibacterial activity of phenothiazine based fluorescent stilbenophanes (**1-5**) using McMurry coupling[19] and chiral phenothiazinophanes (**6-8**) using high dilution method[20]. Our strategy was to first build the basic phenothiazine structure and then to extend the study with *N*-alkylated compounds which are capable of imparting red-emitting properties to the cyclophane and to investigate their antimicrobial efficacy towards various bacteria such as *S. aureus, S. pneumoniae, E. coli, K. pneumonia, P. vulgaris, S. typhi, S. Flexner* as well as with various fungai such as *Candida albicans, Rhizoctonia solani* and *Fusarium oxysporum.*

Synthetic pathway leading to the preparation of phenothiazinophane (**1**) was shown in **Scheme-I**. *N*-Heptyl phenothiazine dialdehyde (**10**) on treatment with low valent Ti coupled intermolecularly to form phenothiazinophane (**1**) in 26 % yields. The structure was further confirmed by ^{1}H NMR, ^{13}C NMR, QIT mass spectral data and elemental analysis[19].

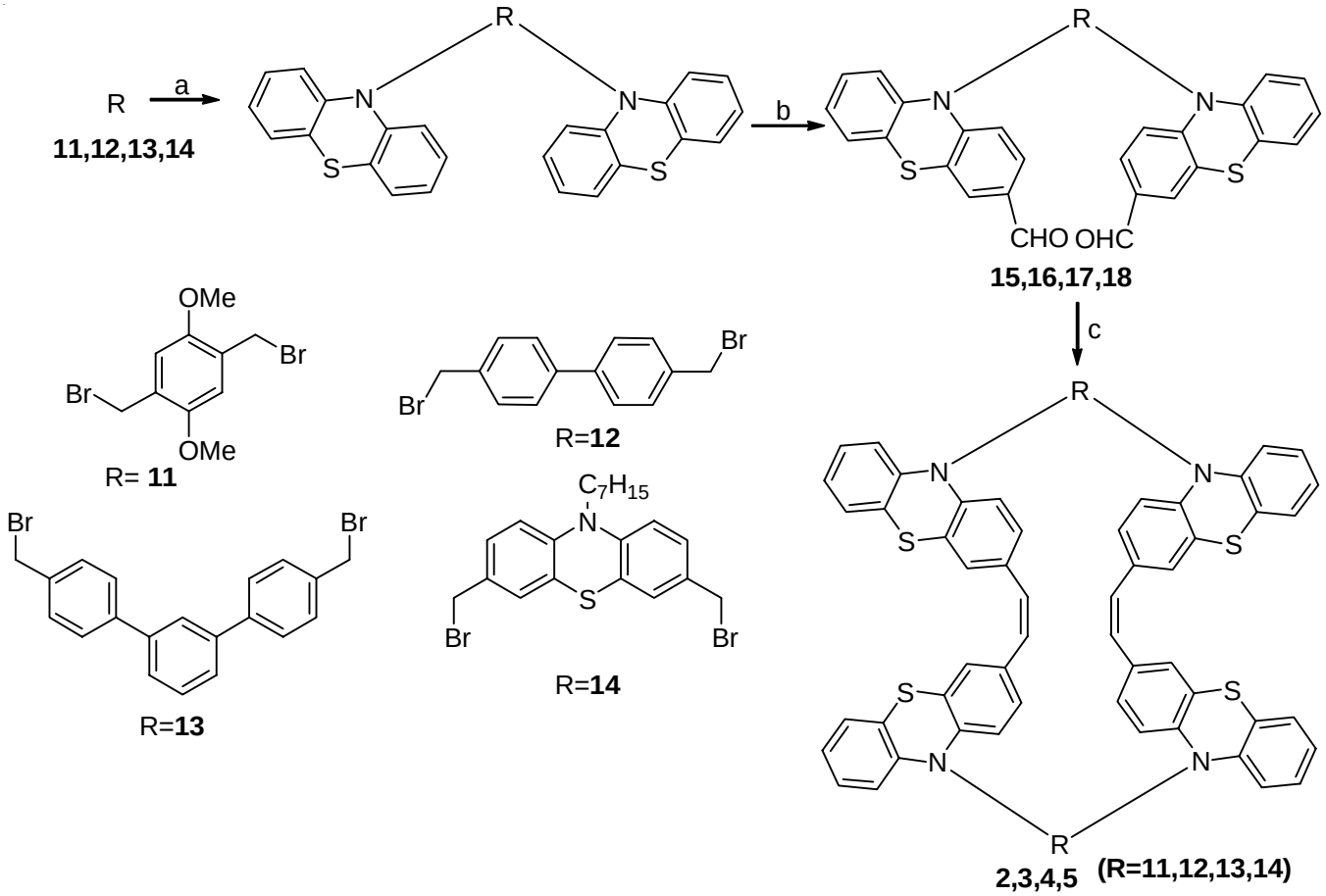
The synthetic pathway leading to phenothiazinophanes **2**, **3**, **4** and **5** is outlined in **Scheme-II**. Phenothiazinophane **2, 3, 4** and **5** were synthesized by using similar methodology from the correspounding dialdehyde **15, 16, 17** and **18**[19]. Treatment of dialdehyde **15, 16, 17** and **18** with low valent Ti coupled intermolecularly to form phenothiazinophane **2**, **3**, **4** and **5** in 28, 25, 19 and 19 % yields, respectively. The structure was further confirmed by ^{1}H NMR, ^{13}C NMR and mass spectral data and elemental analysis[19].

Our attention was foused on the synthesis of chiral phenothiazinophanes (**6-8**) incorporating optically active (*S*)-BINOL moiety as a spacer unit. The synthetic pathway leading to chiral phenothiazinophanes is outlined in the **Scheme-III**.

Antibacterial activity: The antibacterial activity of the compound against human pathogens was evaluated by the agar diffusion method. About 1 mL of inoculam of each test pathogen was added to the molten NA medium and poured into sterile petriplates under aseptic conditions. After solidification, a 5 mm well was made in the center of each plate using a sterile cork borer. Each compound was dissolved in 10 % DMSO to get different concentrations and filter sterilized using 0.25 µm



Scheme-I: (a) 1 bromoheptane, DMSO, rt, 48 h, **9** (92 %); (b) DMF, $POCl_3$, 1,2-dichloroethane, 90 °C, 48 h, **10** (62 %); (c) $TiCl_4$, (20 equiv.), Zn (40 equiv.), pyridine, reflux over night, **1** (26 %)



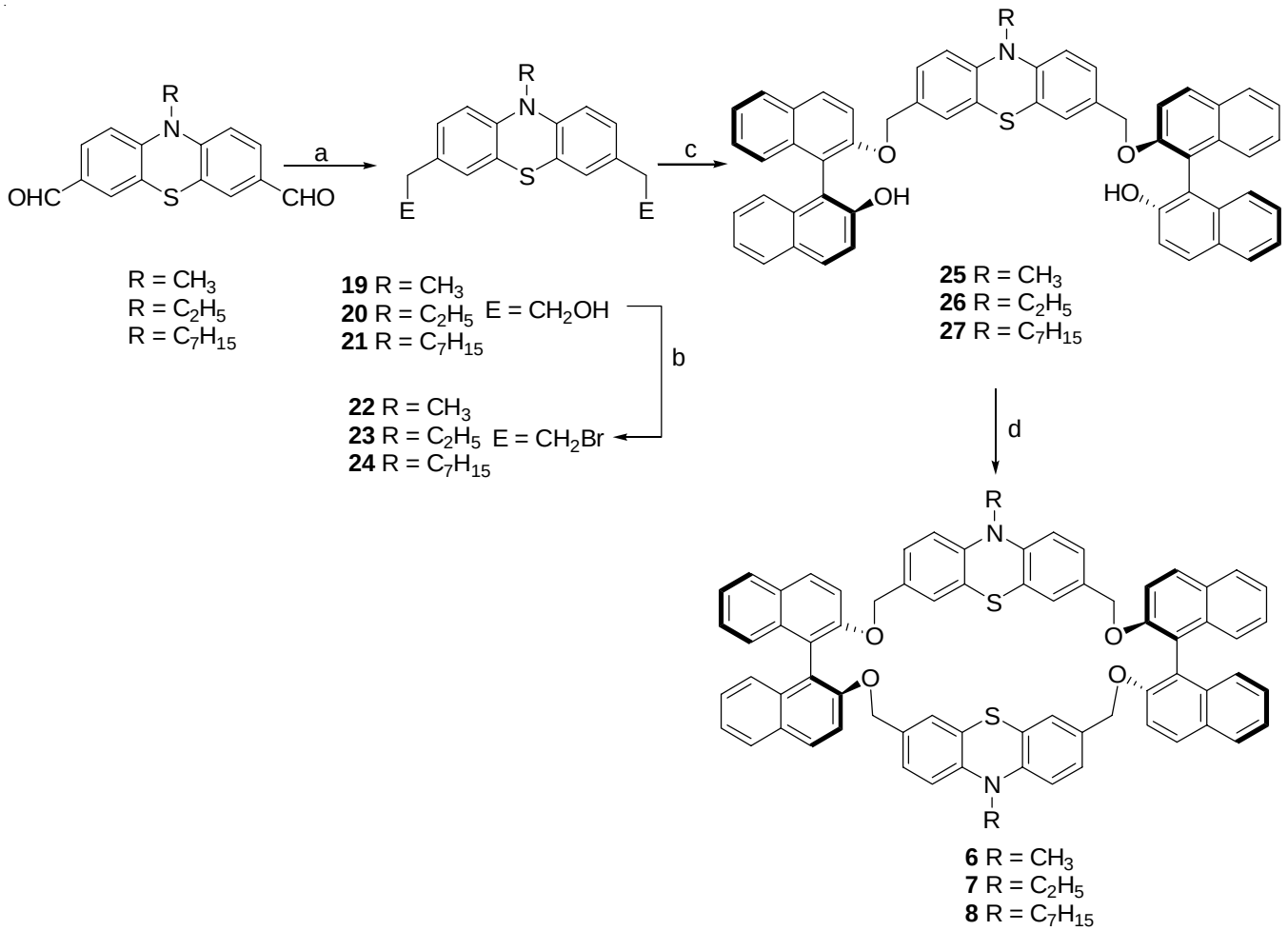
Scheme-II: (a) 1 bromoheptane, DMSO, rt, 48 h, **9** (78 %), (88 %), (98 %), (59 %); (b) DMF, $POCl_3$, 1,2-dichloroethane, 90 °C, 48 h, **15** (52 %), **16** (62 %), **17** (58 %), **18** (63 %); (c) $TiCl_4$, (20 equiv.), Zn (40 equiv.), THF, pyridine, reflux over night, **2** (28 %), **3** (25 %), **4** (19 %), **5** (19 %)

filter paper. Each well received 25 µL solution of each compound and the plates were incubated at room temperature. Sterile DMSO (10 %) was used as control. After 48 h, the appearance of inhibition zone around the well was observed.

Antifungal activity: The antifungal activity of the phenothiazinophanes was studied by agar diffusion test using potato dextrose agar (PDA). Mycellal discs of fungal of pathogens were cut from 5 and 7 days old culture and placed in one edge of potato dextrose agar plates. A well was made on the opposite edge of the plate using sterile cork borer and 50 µL suspension of 10 % DMSO dissolved phenothiazinophane at 50 µg/mL concentration was placed in respective well. Sterile DMSO (10 %) served as control. The zone of inhibition was observed after 5-7 days.

Spectral data

Precyclophane (25): Yield 64 %. m.p.: 128-130 °C. $[\alpha]_D$-119.42 (c 0.2, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$); δ = 7.70 -7.55 (m, 8H), 7.57-7.62 (m, 8H), 7.50-7.54 (m, 4H), 7.35-7.43 (m, 4H), 7.32 (s, 4H), 6.42-6.62 (m, 4H), 4.32 (s, 4H), 2.87 (t, 3H, *J* = 6.5 Hz). ^{13}C NMR (100 MHz, $CDCl_3$); 132.1, 132.0, 131.6, 131.2, 130.7, 130.4, 128.3, 128.0, 127.9, 127.5, 127.1, 126.8, 126.3, 126.1, 125.8, 125.4, 125.1, 124.7, 124.5, 124.1, 122.9, 119.9, 115.3, 114.0, 113.8, 112.4, 54.9, 13.4.



Scheme-III: (a) EtOH/THF (1:1), $NaBH_4$, 0 °C, 5 h, **19** (81 %), **20** (78 %), **21** (62 %); (b) 48 % HBr in H_2O, $CHCl_3$, 0 rt, 3 h, **22** (81 %), **23** (79 %), **24** (86 %); (c) (S) BINOL, K_2CO_3, dry acetone, rt, 48 h, **25** (64 %), **26** (52 %), **27** (56 %); (d) K_2CO_3, dry acetone, high dilution condition, rt, 120 h, **6** (25 %), **7** (20 %), **8** (18 %)

MS: *m/z* = 809 [M+]. Anal. calcd. for $C_{55}H_{39}NSO_4$: C, 81.58; H, 4.82; N, 1.73; Found: C, 81.16; H, 4.87; N, 1.78.

Precyclophane (26): Yield 52 %. m.p.: 168-170 °C. $[\alpha]_D$-120.05 (c 0.2, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$); δ = 7.68 -7.72 (m, 8H), 7.59-7.63 (m, 8H), 7.50-7.55 (m, 4H), 7.47 (d, 2H, *J* = 7.2 Hz), 7.41 (d, 2H, *J* = 7.2 Hz), 7.30 (s, 2H), 6.69 (d, 2H *J* = 8.1 Hz), 6.64 (d, 2H, *J* = 8.1 Hz), 4.62 (s, 4H), 2.11 (q, 2H, *J* = 7.2 Hz), 0.33 (t, 3H, *J* = 7.2 Hz). ^{13}C NMR (100 MHz, $CDCl_3$); 132.4, 132.2, 131.4, 131.0, 130.8, 130.5, 128.7, 128.3, 128.0, 127.5, 127.1, 126.5, 126.3, 125.8, 125.3, 125.1, 124.3, 124.1, 122.4, 120.0, 119.4, 116.8, 115.7, 114.2, 113.4, 112.8, 55.3, 32.2, 13.0. MS: *m/z* = 823 [M+]. Anal. calcd. for $C_{56}H_{41}NSO_4$: C, 81.65; H, 4.98; N, 1.70; Found: C, 81.21; H, 5.03; N, 1.75.

Precyclophane (27): Yield 56 %. m.p.: 182-184 °C. $[\alpha]_D$-123.14 (c 0.2, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$); δ = 7.62 -7.75 (m, 8H), 7.52-7.58 (m, 8H), 7.42-7.49 (m, 4H), 7.29-7.32 (m, 4H), 6.98 (s, 2H), 6.70 (d, 2H, *J* = 8.2 Hz), 6.67 (d, 2H, *J* = 8.2 Hz), 4.32 (s, 4H), 3.75 (t, 3H, *J* = 6.5 Hz), 1.23-1.31 (m, 10H), 0.84 (t, 3H, *J* = 6.5 Hz). ^{13}C NMR (100 MHz, $CDCl_3$); 151.8, 151.4, 151.1, 150.7, 141.6, 141.2, 140.8, 140.5, 139.4, 137.0, 136.8, 136.6, 128.1, 128.0, 127.4, 127.2, 126.9, 126.7, 123.7, 123.6, 123.3, 123.0, 122.9, 120.1, 119.6, 119.7, 55.2, 40.3, 31.8, 30.0, 29.0, 23.8, 22.6, 14.1. MS: *m/z* = 894 [M+]. Anal. calcd. for $C_{61}H_{51}NSO_4$: C, 81.97; H, 5.71; N, 1.56; Found: C, 81.57; H, 5.76; N, 1.61.

Cyclophane (6): Yield 25 %. m.p.: 157-159 °C. $[\alpha]_D$-115.00 (c 0.2, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$); δ = 7.79-7.82 (m, 8H), 7.70-7.76 (m, 8H), 7.53-7.68 (m, 8H), 7.52 (s, 2H), 7.39-7.42 (m, 4H), 7.29-7.34 (m, 4H), 4.82 (d, 2H *J* = 2.1 Hz), 4.45 (d, 2H, *J* = 2.1 Hz), 2.69 (t, 6H, *J* = 2.1 Hz), 2.69 (t, 6H, *J* = 6.5 Hz). ^{13}C NMR (100 MHz, $CDCl_3$); 155.8, 155.4, 152.7, 152.3, 151.6, 151.2, 140.9, 140.8, 140.5, 140.4, 136.7, 136.2, 135.8, 134.9, 134.4, 130.7, 130.8, 128.4, 128.5, 127.3, 126.9, 126.7, 126.4, 126.2, 125.3, 125.2, 124.4, 122.8, 119.8, 118.3, 117.5, 116.2, 54.9, 13.7. MS: *m/z* = 1047 [M+]. Anal. calcd. for $C_{70}H_{50}N_2S_2O_4$: C, 80.61; H, 4.79; N, 2.68; Found: C, 81.16; H, 4.84; N, 2.73.

Cyclophane (7): Yield 20 %. m.p.: 182-184 °C. $[\alpha]_D$-119.13 (c 0.2, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$); δ = 7.64-7.70 (m, 8H), 7.60-7.63 (m, 8H), 7.57 (d, 2H, *J* = 3.8 Hz), 7.54 (d, 2H, *J* = 3.8 Hz), 7.52 (d, 2H, *J* = 3.6 Hz), 7.49 (d, 2H, *J* = 3.6 Hz), 7.46 (s, 2H), 7.40(s, 2H), 7.39 (d, 2H *J* = 7.8 Hz), 7.37 (d, 2H, *J* = 7.8 Hz), 7.34 (d, 2H, *J* = 7.8 Hz), 7.30 (d, 2H, *J* = 7.8 Hz), 4.78 (d, 4H, *J* = 2.4 Hz), 4.51 (d, 4H, *J* = 2.4 Hz), 2.01 (q, 4H, *J* = 7.3 Hz)0.30 (t, 6H, *J* = 7.3 Hz). ^{13}C NMR (100 MHz, $CDCl_3$); 155.2, 155.1, 152.9, 152.4, 151.5, 151.1, 140.8, 140.7, 140.5, 140.2, 139.6, 136.2, 135.8, 134.2, 134.0,

130.8, 130.0, 128.4, 128.3, 127.4, 126.7, 126.6, 125.1, 124.5, 122.9, 119.5, 117.7, 116.7, 115.9, 115.3, 114.9, 113.7, 55.9, 55.4, 31.9, 13.8. MS: *m/z* = 1075 [M+]. Anal. calcd. for $C_{72}H_{54}N_2S_2O_4$: C, 80.44; H, 5.02; N, 2.60; Found: C, 80.05; H, 5.07; N, 2.65.

Cyclophane (8): Yield 18 %. m.p.: 167-169 °C. $[\alpha]_D$-121.31 (c 0.2, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$); δ = 7.69-7.72 (m, 8H), 7.62-7.67 (m, 8H), 7.56 (d, 2H, *J* = 3.8 Hz), 7.53 (d, 2H, *J* = 3.8 Hz), 7.49 (d, 2H, *J* = 3.8 Hz), 7.47 (d, 2H, *J* = 3.8 Hz), 4.54 (s, 2H), 7.43 (s, 2H), 7.41 (d, 2H, *J* = 7.2 Hz), 7.39 (d, 2H, *J* = 7.2 Hz), 7.35 (d, 2H, *J* = 7.2 Hz), 7.33 (d, 2H, *J* = 7.2 Hz), 4.89 (d, 4H, *J* = 2.3 Hz), 4.62 (d, 4H, *J* = 2.3 Hz), 3.92 (t, 4H, *J* = 6.5 Hz), 1.27-1.30 (m, 20H), 0.82 (t, 6H, *J* = 7.3 Hz). ^{13}C NMR (100 MHz, $CDCl_3$); 151.3, 151.2, 150.9, 150.5, 140.8, 139.2, 139.0, 137.0, 136.7, 136.5, 132.1, 131.9, 130.0, 129.2, 129.1, 128.3, 128.1, 127.5, 127.3, 127.2, 127.1, 126.9, 124.0, 123.8, 123.7, 123.5, 123.3, 123.2, 122.8, 120.0, 119.8, 114.1, 55.7, 55.70, 32.9, 32.8, 32.6, 31.9, 29.7, 29.4, 14.1. MS: *m/z* = 1215 [M+]. Anal. calcd. for $C_{82}H_{74}N_2S_2O_4$: C, 81.05; H, 6.09; N, 2.30; Found: C, 80.61; H, 6.41; N, 2.35.

RESULTS AND DISCUSSION

O-Alkylation of optically pure (*S*) BINOL with N-ethyl (2,7-bromomethyl) phenothiazine **23** in dry acetone in the presence of K_2CO_3 gave the chiral precyclophane **26** in 52 % yield. The IR spectrum of precyclophane showed an absorption band at 3321 cm^{-1} due to the free –OH group present in the BINOL moiety. The ^{1}H NMR spectrum of chiral precyclophane **26** displayed at a triplet at δ 0.32 (*J* = 7.2 Hz) for methyl protons and quartet at δ 2.11 (*J* = 7.2 Hz) for methylene protons. The *O*-methylene protons appeared as a singlet at δ 4.62 in addition to aromatic protons. The ^{13}C NMR spectrum the precyclophane **26** showed the aliphatic and methylene carbon at δ 13.0, 32.2 and δ 53.0 respectively, in addition to the aromatic carbons. The QIT mass spectrum of **26** showed the molecular ion peak at *m/z* 823. Similar methodology was used to synthesize the precyclophane **25** and **27** in 64 %, 56 % yield and completely characterized from spectral and analytical data.

The cyclization of one equivalent of precyclophanes (**6, 7** and **8**) with one equivalent of dibromides **22/23/24** in dry acetone in K_2CO_3 under high dilution gave chiral phenothiazinophanes **6/7/8** in 25, 20 and 18 % yields respectively. The ^{1}H NMR spectrum of phenothiazinophane **7** showed a six-proton in triplet at δ 0.30 (*J* = 7.3 Hz) for methyl protons and four protons quartet at δ 2.01 (*J* = 7.3 Hz) for methylene protons present in the aliphatic unit. The *O*-methylene protons appeared as two doublet at δ 4.51 and δ 4.73 (*J* = 2.4 Hz) and two sets of four doublet at δ 7.30, 7.34 (*J* = 7.8 Hz) and δ 7.34, 7.40 (*J* = 7.8 Hz) for phenothiazine protons respectively and two singlet at δ 7.40, δ 7.46 for phenothiazine moiety in addition to the BINOL protons at δ 7.49-δ 7.70. ^{13}C NMR spectrum of **7** showed ethyl carbon at δ 13.8, δ 31.9 and *O*-methylene carbon appeared at δ 55.4 and δ 55.9 in addition to the aromatic carbon. The QIT mass spectrum of **7** showed the molecular ion peak at *m/z* 1075. The structure was also confirmed from elemental analysis. Further, the structure of chiral cyclophanes **6** and **8** were also confirmed from ^{1}H NMR, ^{13}C NMR and FAB-MS and elemental analysis.

Absorption and fluorescence studies on phenothiazinophanes (1-8): The absorption spectra of the phenothiazinophanes **1-5** and **6-8** showed maxima (λ_{max}) around 285-316 nm and 278-542 nm. The photoluminescence emission spectra of the phenothiazinophane showed around λ_{max} 525-537 nm and 523-542 nm. All the phenothiazinophanes are emitted in greenish-yellow region in $CHCl_3$ solvent medium. Phenothiazinophane **5** showed UV-visible absorption at 316 nm in $CHCl_3$ and the same solution emitted in the greenish-yellow region when excited at 537 nm (Fig. 1a). Addition of trifluoro acetic acid to the fluorescence solution of phenothiazinophane **5** (1×10^{-4}, pH = 5) did not change the λ_{max} absorption maxmia of the phenothiazinophane **5** but a slight decrease in the intensity was observed (Fig. 1b) up to pH = 5. After pH = 5, further addition of trifluoro acetic acid did not cause any change in the intensity of the fluorescence spectra for phenothiazinophane **5**. This shows that phenothiazinophane **5** in general can function as permanent fluorescence sensing material even under highly acidic conditions. The absorption and emission bands are very broad, without any vibrational structure. The breath of the absorption and emission bands can be attributed to the decreased planarity of the molecules caused by large steric interaction within the molecules[21]. The photoluminescence emission of phenothiazinophanes **1-8** exhibited red shifts (bathochromic shifts). The UV-visible absorption and photoluminescence emission spectral properties of phenothiazinophanes **1-8** are summarized in Table-1.

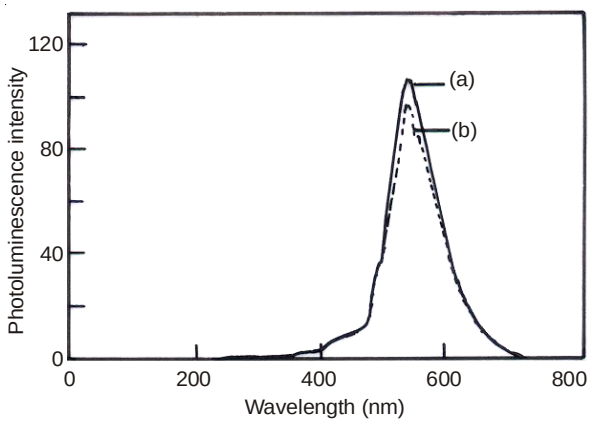


Fig. 1. Photoluminescence emission spectrum of phenothiazinophane **5** in $CHCl_3$ (1×10^{-5} M) (a) $CHCl_3$ medium. (b) $CHCl_3$ and TFA (pH = 5)

TABLE-1
OPTICAL PROPERTIES OF PHENOTHIAZINOPHANES **1-5**

Phenothiazinophane	λ_{max} (nm)[a]	
	Absorption	Emission
1	301	534
2	292	525
3	295	530
4	289	533
5	316	537
6	315	542
7	292	523
8	287	519

[a]All the spectra were recorded at 1×10^{-5} M in $CHCl_3$

Microbicidal efficacy: The bactericidal activity of the phenothiazinophanes were **1-8** assayed against bacteria

TABLE-2
ANTIBACTERIAL ACTIVITY OF THE COMPOUNDS **1-8**

Phenothiazenophanes	Concentration (µg/mL)	Zone of inhibition (mm)						
		S. aureus	*S. pneumoniae*	*E. coli*	*K. pneumoniae*	*P. vulgaris*	*S. typhi*	*S. filxneri*
1	10	9.3	7.5	6.3	8.4	7.6	9.2	8.3
	25	11.7	13.6	13.2	13.4	13.6	11.5	13.5
	50	17.6	17.5	18.7	16.6	20.6	20.2	15.2
2	10	8.1	9.4	7.6	9.1	11.0	9.4	9.8
	25	10.5	13.0	12.1	14.4	13.4	13.5	11.1
	50	15.4	17.7	15.8	16.7	20.2	18.6	15.4
3	10	9.4	9.4	10.7	10.7	11.4	10.2	11.2
	25	16.7	15.2	13.2	14.4	13.8	14.7	13.7
	50	17.3	21.0	18.1	17.0	20.5	18.1	19.1
4	10	9.5	12.0	13.2	9.2	11.4	12.2	10.0
	25	15.7	11.4	10.5	13.4	15.8	14.5	13.5
	50	19.1	14.8	15.3	16.5	21.2	21.3	20.1
5	10	11.5	10.1	11.5	9.2	9.0	11.0	8.6
	25	18.3	22.5	15.2	17.5	13.4	14.5	10.4
	50	25.4	26.8	21.9	23.4	17.4	18.8	13.3
6	10	9.2	10.2	10.0	9.2	9.0	10.5	9.2
	25	15.4	12.6	13.7	15.5	14.5	11.2	12.5
	50	22.8	13.7	16.3	19.7	17.7	16.4	18.8
7	10	9.2	9.0	8.4	9.2	9.0	11.4	10.0
	25	11.5	11.5	10.8	13.5	10.5	13.3	11.2
	50	17.7	14.7	15.3	17.0	18.3	17.7	15.7
8	10	8.0	8.2	9.2	7.0	9.0	11.2	10.4
	25	14.4	13.6	12.8	14.5	15.5	13.8	13.3
	50	15.9	17.4	14.3	18.9	18.7	20.3	18.0

Escherichia coli, Klebsiella pneumonia, Proteus vulgaris, Salmonella typhi, Shigella flexneri, Staphylococcus aureus and *Streptococcus pneumoniae* by disc agar diffusion method[22]. Phenothiazinophanes **1** and **8** exhibited good zone of inhibition compared to other stilbenophanes. It was observed that the zone of inhibition was found to increases with increase in phenothiazine moiety, because phenothiazinophane **5** shows good antibacterial activity then other phenothiazinophanes. The inhibition zone of phenothiazinophanes for each concentration against all the test bacteria is depicted in the Table-2. Stilbenophane **5** in the concentration of 10, 25 and 50 µg/mL showed a zone finhibition of 10.1, 22.5 and 26.8 mm in diameter, respectively in *Streptococcus pneumoniae*.

Similarly, these phenothiazinophanes **1-8** inhibited the three fungal pathogens namely *Candida albicans* (human pathogen), *Rhizoctonia solani and Fusarium oxysporum* (plant pathogen). Among five stilbenophanes tested, phenothiazinophanes **1** and **5** showed good activity against fungal pathogens particularly *Fusarium oxysporum*. Phenothiazinophane **5** showed good zone of inhibition of 18.6, 26.8 and 29.9mm in diameter in the concentration of 50, 100 and 150 µg/mL respectively. The inhibition zone of phenothiazinophanes for each concentration against the entire test fungal is depicted in Table-3.

TABLE-3
ANTIBACTERIAL ACTIVITY OF THE COMPOUND **1-8**

Phenothia-zenophanes	Conc. (µg/mL)	Zone of inhibition (mm)		
		C. albicans	*R. solani*	*F. oxysporum*
1	50	14.2	11.0	16.4
	100	17.5	15.2	19.3
	150	21.7	19.3	24.7
2	50	6.5	8.6	8.9
	100	9.6	12.7	12.6
	150	11.8	15.8	16.8
3	50	9.0	6.8	8.6
	100	12.8	11.2	14.0
	150	14.3	13.9	17.9
4	50	5.8	9.7	7.5
	100	9.8	11.9	13.8
	150	11.6	13.8	18.6
5	50	18.5	15.2	18.6
	100	24.6	20.6	26.8
	150	26.9	24.8	29.9
6	50	13.2	7.0	9.8
	100	15.0	10.8	12.0
	150	20.6	13.0	17.0
7	50	9.0	10.0	9.0
	100	13.6	13.8	13.5
	150	15.0	18.0	19.8
8	50	8.9	9.0	10.2
	100	15.0	16.5	15.9
	150	16.8	21.6	19.3

Conclusion

In general, phenothiazinophanes **1-8** exhibited good microbiocidal activity against all the seven human pathogenic bacteria and three fungal pathogens. Phenothiazinophane **5** showed excellent inhibition against the test bacteria and fungal when compared with other phenothiazinophanes. The increase inhibition activity of phenothiazinophane **5** could be due to increase in number of phenothiazine moiety.

ACKNOWLEDGEMENTS

The authors thank DST, FIST, New Delhi, India for NMR spectral data and CDRI, Lucknow, India for spectral data. The authors also thank CSIR, New Delhi, India for financial assistance and one of the athours (RKL) thanks CSIR New Delhi, India for SRF.

REFERENCES

1. M. Sakamoto, A. Ueno and H. Mihara, *Chem. Commun.*, 1741 (2000).
2. (a) A.J. Heeger, *Angew. Chem. Int. Ed.*, **40**, 2591 (2001); (b) A.G. Mac Diarmid, *Angew. Chem. Int. Ed.*, **40**, 2581 (2001).
3. (a) M.T. Bernius, M. Inbasekaran, J. O'Brien and W. Wu, *Adv. Mater.*, **12**, 1737 (2000); (b) A. Kraft, A.C. Grimsdale and A.B. Holmes, *Angew. Chem. Int. Ed.*, **37**, 402 (1998).
4. (a) X. Zhang, A.S. Shetty and S.A. Jenekhe, *Macromolecules*, **32**, 7422 (1999); (b) M.M. Alam and S.A. Jenekhe, *Chem. Mater.*, **14**, 4775 (2002).
5. (a) J.J.M. Halls, C.A. Walsh, N.C. Greenham, E.A. Marseglia, R.H. Friend, S.C. Moratti and A.B. Holmes, *Nature*, **376**, 498 (1995); (b) A.C. Arias, J.D. MacKenzie, R. Stevenson, J.J.M. Halls, M. Inbasekaran, E.P. Woo, D. Richards and R.H. Friend, *Macromolecules*, **34**, 6005 (2001).
6. H. Antoniadis, B.R. Hsieh, M.A. Abkowitz, S.A. Jenekhe and M. Stolka, *Synth. Met.*, **62**, 265 (1994).
7. (a) A. Babel and S.A. Jenekhe, *J. Phys. Chem. B*, **107**, 1749 (2003).; (b) A. Babel and S.A. Jenekhe, *Macromolecules*, **36**, 7759 (2003).
8. (a) S.A. Sapp, G.A. Sotzing and J.R. Reynolds, *Chem. Mater.*, **10**, 2101 (1998); (b) F. Fungo, S.A. Jenekhe and A.J. Bard, *Chem. Mater.*, **15**, 1264 (2003).
9. N.S. Cho, J.-H. Park, S.-K. Lee, J. Lee, H.-K. Shim, M.-J. Park, D.-H. Hwang and B.-J. Jung, *Macromolecules*, **39**, 177 (2006).
10. H. Bauer, F. Stier, C. Petry, A. Knorr, C. Stadler and H.A. Staab, *Eur. J. Org. Chem.*, **2001**, 3255 (2001).
11. P.J. Raval and R.K. Desai, *ARKIVOV*, 21 (2005).
12. R. Ddhibom and T. Fkstramd, *Arch. Int. Pharmacodyn.*, **159**, 70 (1996).
13. C.S. Weil, *Biomertics*, **8**, 249 (1952).
14. B.N. Harpen, *J. Am. Med. Assoc.*, **129**, 1419 (1945).
15. J.D. Genzer, M.N. Lewis, F.H. McMillan and J.A. King, *J. Am. Chem. Soc.*, **75**, 2506 (1953).
16. L.J. Dushay, *Rev. Can. Biol.*, **20**, 321 (1961).
17. J.R. Douglass, N.F. Baker and M.W. Longwest, *Am. J. Vet. Res.*, **17**, 318 (1956).
18. (a) R.T. Lai, E.F. Fabrizio, L. Lu, S.A. Jenekhe and A. Bard, *J. Am. Chem. Soc.*, **123**, 9112 (2001); (b) D. Sun, S.V. Rosokha and J.K. Kochi, *J. Am. Chem. Soc.*, **126**, 1388 (2004).
19. P. Rajakumar and R. Kanagalatha, *Tetrahedron Lett.*, **48**, 8496 (2007).
20. P. Rajakumar and R. Kanagalatha, *Tetrahedron*, **62**, 9735 (2006).
21. M.S. Nair, U. Sudhir, S. Joly and N.P. Rath, *Tetrahedron*, **55**, 7653 (1999).