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ACYL AND SULFONYL DERIVATIVES OF 10-AMINOALKYL-2,7-DIAZAPHENOTHIAZINES[#]

Beata Morak-Mlodawska and Krystian Pluta*

Department of Organic Chemistry, The Medical University of Silesia,
Jagiellońska 4, 41-200 Sosnowiec, Poland. E-mail: pluta@sum.edu.pl.

Abstract – Reaction of 3,3'-dinitro-4,4'-dipyridinyl disulfide (**1**) with sodium hydroxide in DMF led to 10*H*-2,7-diazaphenothiazine (**4**). *N*-Alkylation of (**4**) with phthalimidopropyl and phthalimidobutyl bromides gave phthalimidoalkyl derivatives (**5**) and (**6**) which were hydrolyzed to aminoalkyldiazaphenothiazines (**7**) and (**8**). *N*-Acylation with acetyl anhydride, benzoyl chloride, ethyl chloroformate and 2-chloroethyl isocyanate gave *N*-acyl derivatives (**9-16**). *N*-Sulfonylation with methanesulfonyl and *p*-toluenesulfonyl chlorides led to *N*-sulfonyl derivatives (**17-20**).

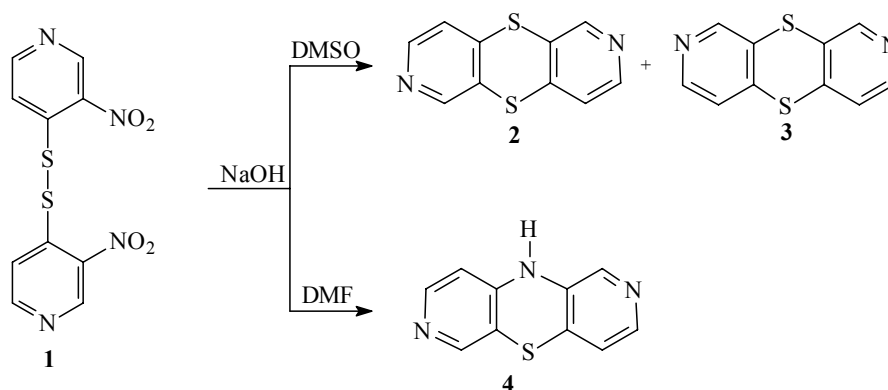
Phenothiazines form an important class of heterocyclic compounds because of significant biological activities such as antipsychotic, antihistaminic, antitussive and antiemetic, interesting chemical properties, wide and inexpensive availability.¹ Recent reports have focused interests on anticancer, antiplasmodial and antibacterial activities, reversal of multidrug resistance (MDR) and potential treatment in Alzheimer's, Creutzfeldt-Jakob and AIDS diseases of classical and new synthesized phenothiazines.²⁻¹⁰ New phenothiazines have been obtained by modifications of the parent phenothiazine structure by an introduction of a new substituent at the thiazine nitrogen atom (at position 10) or at the benzene ring (at positions 1-4 and 6-9) and by a substitution of one or two benzene rings with homoaromatic and heteroaromatic rings (most often azine rings). Motohashi and co-workers found that 10-aminopropyl- and 10-aminobutylphenothiazines (as maleates) and their selected *N*-acyl and *N*-sulfonyl derivatives exhibit promising anticancer and antibacterial activities.^{7,10-12,}

In our previous paper^{13,14} we described synthesis of new type of azaphenothiazine, 10*H*-dipyrido[3,4-*b*;-3',4'-*e*][1,4]thiazine, (named also as 10*H*-2,7-diazaphenothiazine (**4**)) and its 10-alkyl, aryl, heteroaryl and dialkylaminoalkyl derivatives. Since the syntheses of phenothiazines can proceed via the Smiles rearrangement of the S→N type, the 2,7-diazaphenothiazine structure was confirmed by X-ray analysis of 10-(3'-nitro-4'-pyridinyl) derivative.¹⁴ In continuation of these studies we worked out an efficient

synthesis of 10*H*-2,7-diazaphenothiazine (**4**) from 3,3'-dinitro-4,4'-dipyridinyl sulfide (**1**) and transformed into aminoalkyl, acylaminoalkyl and sulfonylaminoalkyl derivatives (**5-20**).

Synthesis

In one of the previous papers,¹⁵ we described reaction of 3,3'-dinitro-4,4'-dipyridinyl disulfide (**4**) (a side product in the synthesis of 4-mercapto-3-nitropyridine from the 4-chloro-3-nitropyridine) with sodium hydroxide in DMSO giving two isomeric dipyridodithiins (2,7-diazathianthrene (**2**) and 2,8-diazathianthrene (**3**), Scheme 1). As we found reductive properties of DMF in the presence of a base in relation to sodium 3-nitropyridine-4-thiolate and 4-chloro-3-nitropyridine (in the presence of sodium sulfide),^{13,14} we carried out the reaction of disulfide (**1**) in those conditions for 24 h to give 10*H*-2,7-diazaphenothiazine (**4**) in 84% yield. In our opinion the reaction proceeded through the formation of sodium 3-nitropyridine-4-thiolate which underwent cyclization to compound (**4**) under reductive action of DMF, what we observed previously.¹³



Scheme 1

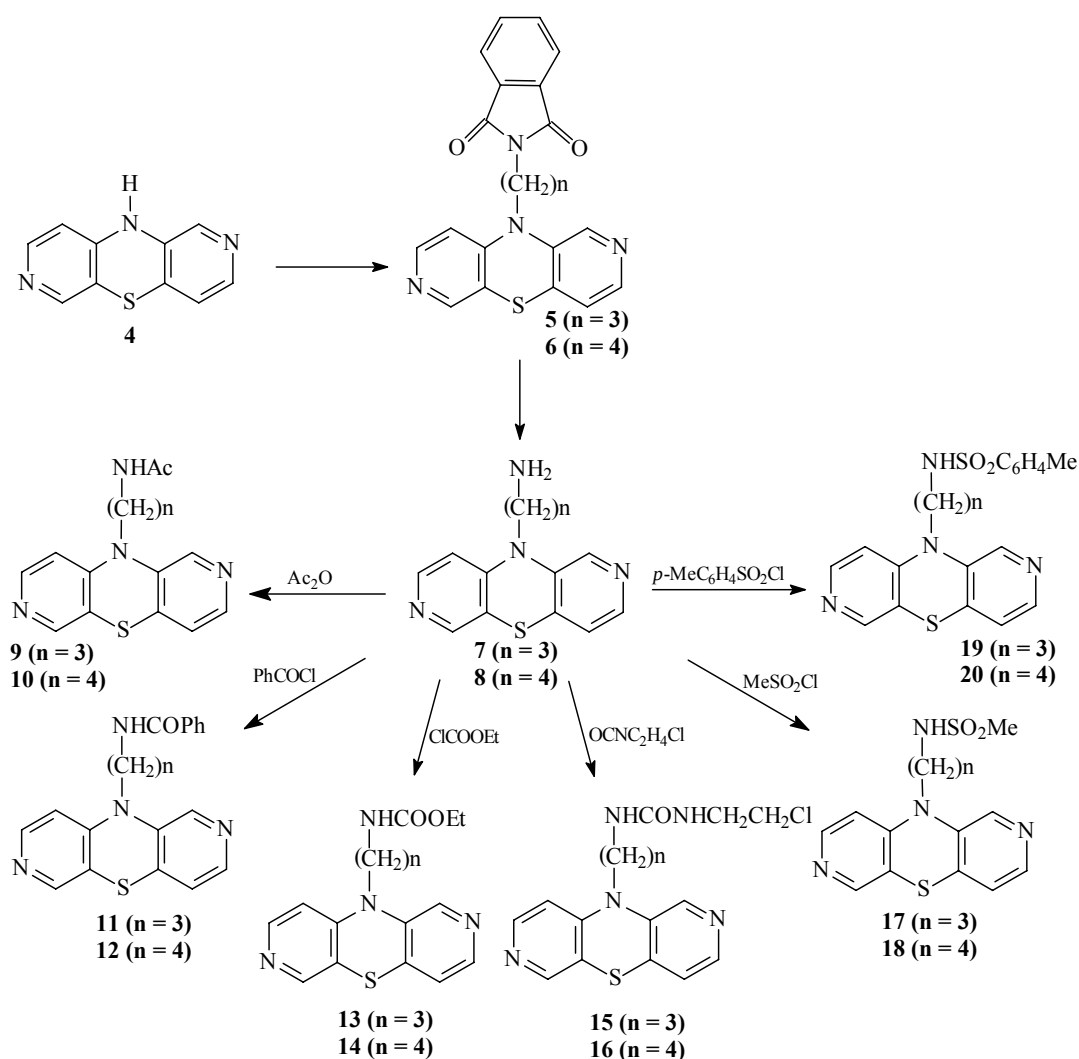
Reactions of 10*H*-2,7-diazaphenothiazine (**4**) with phthalimidopropyl and phthalimidobutyl bromides in toluene in the presence of sodium hydride gave 10-phthalimidoalkyl-2,7-diazaphenothiazines (**5**) and (**6**) (alkyl = propyl, butyl) in 70% and 76% yield, respectively (Scheme 2). Hydrolysis of compounds (**5**) and (**6**) using hydrazine led to 10-aminoalkyl-2,7-diazaphenothiazines (**7**) and (**8**) in 72% and 77% yield.

The obtained (**7**) and (**8**) were transformed into amide and sulfonamide derivatives (Scheme 2). The acetylation and benzoylation with acetyl anhydride and benzoyl chloride gave 10-acetyl- and 10-benzoylaminoalkyldiazaphenothiazines (**9-12**) in 69-80% yield. Reactions with ethyl chloroformate led to 10-ethoxycarbonyaminolalkyldiazaphenothiazines (**13**) and (**14**) in 82% and 80% yield. Reactions with 2-chloroethyl isocyanate led to the urea derivatives (**15**) and (**16**) in 68% and 71% yield. The sulfonamide derivatives were obtained in the reactions with methanesulfonyl and *p*-toluenesulfonyl chlorides giving 10-methane- and 10-*p*-toluenesulfonylaminoalkyldiazaphenothiazines (**17-20**) in 68-80% yield.

Physical and spectroscopic properties of 2,7-diazaphenothiazines

The described reactions were monitored by TLC analysis. All chromatograms of 2,7-diazaphenothiazines

showed colour changing [from yellowish to celadon (**9-14**, **17-20**), light-greenish (**7**, **8**) and intensive yellow (**5**, **6**, **15**, **16**)] during irradiation with UV lamp unlike to chromatograms of other compounds used and formed. Similar effect color [light-yellow (**5**, **6**), yellow (**9-14**, **17-20**), canary (**15**, **16**) and orange-yellow (**5**, **6**)] was observed when chromatograms of diazaphenothiazines were sprayed with a phenothiazine detection mixture (sulfuric acid-water-ethanol 1:1:8).¹⁶ In contrast to 10-diethylaminoethyl- and 10-dimethylaminopropyl-2,7-diazaphenothiazines,¹³ 10-aminopropyl and 10-aminobutyl derivatives (**7**) and (**8**) turn out to be less stable.



The ¹H NMR spectra of the obtained azaphenothiazines (**5-20**) were recorded in deuterochloroform and revealed two singlet signals and four doublet signals showing unsymmetrical structure of the diazaphenothiazine system.¹³ Since EI MS spectra showed labile the aminoalkyl chains in compounds (**5-20**), FAB MS spectra were used to determine the molecular ions.

All diazaphenothiazines (**5-20**) are diaza-analogs of the anticancer and antibacterial compounds obtained by Motohashi^{7,10-12} and show promising potential anti-inflammatory, anticancer, antihistaminic, antiviral, cardiotonic and immunomodulating activities¹⁷ and relatively low lipophilic character in comparison with

neuroleptic phenothiazines ($\log P = 3.5\text{--}5.9^{18}$). Basic compound, 10*H*-2,7-diazaphenothiazine (**4**), was tested against 57 human cancer lines in National Cancer Institute in Bethesda showing promising activity against lung, colon and renal cancers, and leukemia.^{13,19}

We report here an efficient synthesis of 10*H*-2,7-diazaphenothiazine (**4**) from 3,3'-dinitro-4,4'-dipyridinyl disulfide (**1**) in reductive conditions of DMF and its transformation into aminopropyl and aminobutyl compounds (**7**) and (**8**), and further to their *N*-acyl and *N*-sulfonyl derivatives (**9–20**).

EXPERIMENTAL

Melting points were determined in open capillary tubes on a Boetius melting point apparatus and are uncorrected. The ¹H NMR spectra were recorded on a Varian Unity-Inova-300 and a Bruker DRX spectrometers at 300 and 500 MHz in deuteriochloroform with tetramethylsilane as the internal standard. Fast Atom Bombardment mass spectra (FAB MS) were run in glycerol on a Finnigan MAT 95 spectrometer at 70 eV. The thin layer chromatography were performed on silica gel 60 F₂₅₄ (Merck 1.05735) with CHCl₃-EtOH (5:1 and 10:1 v/v) and on aluminum oxide 60 F₂₅₄ neutral (type E) (Merck 1.05581) with CHCl₃-EtOH (10:1 v/v) as eluents.

Synthesis of 10*H*-2,7-diazaphenothiazine (**4**)

A mixture of 3,3'-dinitro-4,4'-dipyridinyl disulfide (**1**) (0.31 g; 1 mmol) and sodium hydroxide (0.12 g; 3 mmol) in dry DMF (5 mL) was refluxed for 24 h under argon atmosphere. After cooling the solvent was evaporated *in vacuo* and water (10 mL) was added and neutralized with diluted hydrochloric acid to pH = 7. The resulted solid was filtered off and the filtrate was extracted with CHCl₃ (3 x 5 mL). the extracts were washed with water, dried with anhydrous sodium sulfate and evaporated *in vacuo*. The obtained residue and solid were purified by column chromatography (aluminum oxide, CHCl₃-EtOH 10:1) to give 10*H*-2,7-diazaphenothiazine (**4**) (0.17 g, 84%); mp 169–170 °C (EtOH), (lit.,¹³ mp 169–170 °C).

Synthesis of 10-phthalimidoalkyl-2,7-diazaphenothiazines (**5**) and (**6**)

To a stirred solution of 10*H*-2,7-diazaphenothiazine (**4**) (0.100 g, 0.5 mmol) in dry toluene (10 mL) NaH (0.12 g, 5 mmol, washed out with hexane) was added. The mixture was stirred for 10 min at rt, then refluxed for 1 h and a solution of *N*-(bromoalkyl)phthalimide [1.5 mmol, *N*-(3-bromopropyl)phthalimide – 0.405 g, *N*-(4-bromobutyl)phthalimide – 0.420 g] in toluene (5 mL) was added. The mixture was refluxed for 24 h. After cooling the resulted solid was filtered off, toluene was evaporated *in vacuo* and the residue was purified by column chromatography (aluminum oxide, CHCl₃) to give:

1. 10-(3'-phthalimidopropyl)-2,7-diazaphenothiazine (IUPAC name: N-[3-(10*H*-dipyrido[3,4-*b*;3',4'-*e*]-[1,4]thiazin-10-yl)propyl]phthalamide) (**5**) (0.124 g, 70%); mp 87–88 °C (EtOH). ¹H NMR (DMSO-*d*₆) δ :

1.78 (m, 2H, CH₂), 3.58 (t, $J = 6.1$ Hz, 2H, NCH₂), 3.65 (t, $J = 6.0$ Hz, 2H, NCH₂), 5.73 (d, $J = 6.8$ Hz, 1H, H-9), 6.60 (d, $J = 4.6$ Hz, 1H, H-4), 7.08 (s, 1H, H-1), 7.25 (d, $J = 6.8$ Hz, 1H, H-8), 7.48 (s, 1H, H-6), 7.68 (d, $J = 4.6$ Hz, 1H, H-3), 7.84 (m, 4H_{phthalimide}). FAB MS m/z : 389 (M+H, 95), 185 (2gly+H, 100). Anal. Calcd for C₂₁H₁₆N₄O₂S: C 64.93, H 4.15, N 14.42. Found C 64.78, H 4.21, N 14.20.

2. 10-(4'-phthalimidobutyl)-2,7-diazaphenothiazine (IUPAC name: *N*-[4-(10*H*-dipyrido[3,4-*b*;3',4'-*e*]-[1,4]thiazin-10-yl)butyl]phthalamide) (**6**) (0.153 g, 76%); mp 43-44 °C (EtOH). ¹H NMR (CDCl₃) δ : 1.71 (m, 4H, 2CH₂), 3.46 (t, $J = 6.3$ Hz, 2H, NCH₂), 3.72 (t, $J = 6.3$ Hz, 2H, NCH₂), 5.69 (d, $J = 7.2$ Hz, 1H, H-9), 6.17 (s, 1H, H-1), 6.36 (s, 1H, H-6), 6.57 (d, $J = 7.2$ Hz, 1H, H-4), 7.74 (m, 4H_{phthalimide}), 7.87 (m, 2H, H-3 and H-8). FAB MS m/z : 403 (M+1, 70), 185 (2gly+H, 100). Anal. Calcd for C₂₂H₁₈N₄O₂S: C 65.65, H 4.51, N 13.92. Found C 65.38, H 4.55, N 13.69.

Synthesis of 10-aminoalkyl-2,7-diazaphenothiazines (**7**) and (**8**)

To a solution of 10-phthalimidoalkyl-2,7-diazaphenothiazines (**5**) and (**6**) [1 mmol, 0.388 g of (**5**), 0.402 g of (**6**)] in EtOH (20 mL) 80% aqueous solution of hydrazine (0.2 mL, 5 mmol) was added. The mixture was refluxed for 2 h. After cooling the reaction mixture was acidified with conc. hydrochloric acid to pH = 2. The solution was concentrated and the resulted solid was filtered off. The filtrate was alkalized with 10% aqueous solution of sodium hydroxide and extracted with CHCl₃ (3 x 10 mL). The extracts were washed with water, dried with anhydrous sodium sulfate and evaporated *in vacuo*. The obtained residue was purified by column chromatography (aluminum oxide, CHCl₃) to give:

1. 10-(3'-aminopropyl)-2,7-diazaphenothiazine (IUPAC name: 3-(10*H*-dipyrido[3,4-*b*;3',4'-*e*]-[1,4]thiazin-10-yl)propan-1-amine) (**7**), (0.186 g, 72%), an oil. ¹H NMR (CDCl₃) δ : 1.93 (m, 2H, CH₂), 2.34 (broad s, 2H, NH₂), 2.90 (m, 2H, CH₂NH₂), 3.95 (t, $J = 6.9$ Hz, 2H, NCH₂), 6.75 (d, $J = 5.4$ Hz, 1H, H-9), 7.08 (d, $J = 4.8$ Hz, 1H, H-4), 8.06 (s, 1H, H-1), 8.11 (d, $J = 4.8$ Hz, 1H, H-3), 8.13 (s, 1H, H-6), 8.25 (d, $J = 5.4$ Hz, 1H, H-8). FAB MS m/z : 259 (M+1, 18), 202 (M-C₃H₅NH₂, 19), 185 (2gly+H, 100). Anal. Calcd for: C₁₃H₁₄N₄S: C 60.44, H 5.46, N 21.69. Found: C 60.21, H 5.58, N 21.58.

2. 10-(4'-aminobutyl)-2,7-diazaphenothiazine (IUPAC name: 4-(10*H*-dipyrido[3,4-*b*;3',4'-*e*]-[1,4]thiazin-10-yl)butan-1-amine) (**8**), (0.209 g, 77%), an oil. ¹H NMR (CDCl₃) δ : 1.89 (m, 2H, CH₂), 1.96 (m, 2H, CH₂), 2.42 (broad s, 2H, NH₂), 3.12 (m, 2H, CH₂NH₂), 3.67 (t, $J = 6.3$ Hz, 2H, NCH₂), 6.67 (d, $J = 6.0$ Hz, 1H, H-9), 6.97 (d, $J = 6.0$ Hz, 1H, H-4), 8.04-8.23 (m, 4H, H-1, H-3, H-6 and H-8). FAB MS m/z : 273 (M+1, 20), 202 (M-C₄H₇NH₂, 100). Anal. Calcd for C₁₄H₁₆N₄S: C 61.74, H 5.92, N 20.57. Found C 61.52, H 5.90, N 20.29.

Synthesis of 10-acetylaminoalkyl-2,7-diazaphenothiazines (**9**) and (**10**)

To a suspension of 10-aminoalkyl-2,7-diazaphenothiazines (**7**) and (**8**) [0.5 mmol, 0.129 g of (**7**); 0.136 g

of (**8**)] in pyridine (5 mL) acetic anhydride (1.48 mL, 1.5 mmol) was added and the mixture was stirred at rt for 2 h. After evaporation of pyridine *in vacuo* the residue was dissolved in CHCl₃ (10 mL). The solution was washed with water, dried with anhydrous sodium sulfate and evaporated *in vacuo*. The residue was purified by column chromatography (aluminum oxide, CHCl₃) to give:

1. 10-(3'-acetylaminopropyl)-2,7-diazaphenothiazine (IUPAC name: *N*-[3-(10*H*-dipyrido[3,4-*b*:3',4'-*e*]-[1,4]thiazin-10-yl)propyl]acetamide) (**9**), (0.108 g, 72%) mp 117-118 °C (EtOH). ¹H NMR (CDCl₃) δ: 2.03 (s, 3H, CH₃), 2.05 (m, 2H, CH₂), 3.40 (m, 2H, NHCH₂), 3.92 (t, *J* = 6.6 Hz, 2H, NCH₂), 6.09 (broad s, 1H, NH), 6.70 (d, *J* = 4.8 Hz, 1H, H-9), 7.01 (d, *J* = 4.4 Hz, 1H, H-4), 8.01-8.27 (m, 4H, H-1, H-3, H-6 and H-8). FAB MS *m/z*: 301 (*M*+*H*, 100), 202 (*M*+1-C₃H₅NHCOCH₃, 20). Anal. Calcd for C₁₅H₁₆N₄OS: C 59.98, H 5.37, N 18.65. Found C 59.69, H 5.31, N 18.32.

2. 10-(4'-acetylaminobutyl)-2,7-diazaphenothiazine (IUPAC name: *N*-[4-(10*H*-dipyrido[3,4-*b*:3',4'-*e*]-[1,4]thiazin-10-yl)butyl]acetamide) (**10**), (0.126 g, 80%). mp 119-120 °C (EtOH). ¹H NMR (CDCl₃) δ: 1.66 (m, 2H, CH₂), 1.84 (m, 2H, CH₂), 1.97 (s, 3H, CH₃), 3.29 (m, 2H, NHCH₂), 3.84 (t, *J* = 7.2 Hz, 2H, NCH₂), 5.62 (broad s, 1H, NH), 6.67 (d, 1H, *J* = 5.7 Hz, H-9), 7.00 (d, *J* = 4.8 Hz, 1H, H-4), 8.04-8.29 (m, 4H, H-1, H-3, H-6 and H-8). FAB MS *m/z*: 315 (*M*+1, 89), 202 (*M*+1-C₄H₇NHCOCH₃, 100). Anal. Calcd for C₁₆H₁₈N₄OS: C 61.12, H 5.77, N 17.82. Found C 60.83, H 5.71, N 17.57.

Synthesis of 10-benzoylaminoalkyl-2,7-diazaphenothiazines (**11**) and (**12**)

To a stirred solution of 10-aminoalkyl-2,7-diazaphenothiazines (**7**) and (**8**) (0.5 mmol) in a mixture of CH₂Cl₂ (5 mL) and 10% aqueous Na₂CO₃ solution (5 mL), benzoyl chloride ((0.12 mL, 1.5 mmol) was added. The solutions were stirred at rt for 12 h. The organic phase was separated and aqueous phase was extracted with CH₂Cl₂ (2 x 5 mL). The combined extracts were washed with water (10 mL) and dried with anhydrous sodium sulfate and evaporated *in vacuo*. The residue was purified by column chromatography (aluminum oxide, CH₂Cl₂) to give:

1. 10-(3'-benzoylaminoethyl)-2,7-diazaphenothiazine (IUPAC name: *N*-[3-(10*H*-dipyrido[3,4-*b*:3',4'-*e*]-[1,4]thiazin-10-yl)propyl]benzamide) (**11**), (0.128 g, 71%), an oil. ¹H NMR (CDCl₃) δ: 2.09 (m, 2H, CH₂), 3.62 (m, 2H, NHCH₂), 4.03 (t, *J* = 6.6 Hz, 2H, NCH₂), 6.38 (broad s, 1H, NH), 6.73 (d, *J* = 5.7 Hz, 1H, H-9), 6.99 (d, *J* = 4.8 Hz, 1 H, H-4), 7.41 (m 2H, *m*-C₆H₅), 7.49 (m 1H, *p*-C₆H₅), 7.68 (m 2H, *o*-C₆H₅), 8.10-8.26 (m, 4H, H-1, H-3, H-6 and H-8). FAB MS *m/z*: 363 (*M*+1, 10), 202 (*M*+1-C₃H₅NHCOC₆H₅, 8), 162 (C₃H₅NHCOC₆H₅, 49), 105 (C₆H₅CO, 100). Anal. Calcd for C₂₀H₁₈N₄OS: C 66.28, H 5.01, N 15.46. Found C 66.01, H 4.97, N 15.19.

2. 10-(4'-benzoylaminoethyl)-2,7-diazaphenothiazine (IUPAC name: *N*-[4-(10*H*-dipyrido[3,4-*b*:3',4'-*e*]-[1,4]thiazin-10-yl)butyl]benzamide) (**12**), (0.130 g, 69%), an oil. ¹H NMR (CDCl₃) δ: 1.78 (m, 2H, CH₂), 1.98 (m, 2H, CH₂), 3.52 (m, 2H, NHCH₂), 3.95 (t, *J* = 7.2 Hz, 2H, NCH₂), 6.31 (broad s, 1H, NH), 6.78

(d, $J = 5.7$ Hz, 1H, H-9), 6.95 (d, $J = 4.8$ Hz, 1H, H-4), 7.41 (m, 2H, *m*-C₆H₅), 7.51 (m, 1H, *p*-C₆H₅), 7.68 (m, 2H, *o*-C₆H₅), 8.01-8.24 (m, 4H, H-1, H-3, H-6 and H-8). FAB MS m/z : 377 (M+1, 57), 202 (M+1-C₄H₇NHCOC₆H₅, 9), 176 (C₄H₇NHCOC₆H₅, 10), 105 (C₆H₅CO, 100). Anal. Calcd for C₂₁H₂₀N₄OS: C 67.00, H 5.35, N 14.88. Found C 66.81, H 5.29, N 14.61.

Synthesis of 10-ethoxycarbonylaminoalkyl-2,7-diazaphenothiazines (13) and (14)

To a stirred solution of 10-aminoalkyl-2,7-diazaphenothiazines (7) and (8) (0.5 mmol) in a mixture of CH₂Cl₂ (5 mL) and 10% aqueous Na₂CO₃ solution (5 mL) a solution of ethyl chloroformate (0.14 mL, 1.5 mmol) in CH₂Cl₂ (3 mL) was added. The solutions were stirred at rt for 12 h. The organic phase was separated and aqueous phase was extracted with CH₂Cl₂ (2 x 5 mL). The combined extracts were washed with water (10 mL) and dried with anhydrous sodium sulfate and evaporated *in vacuo*. The residue was purified by column chromatography (aluminum oxide, CH₂Cl₂) to give:

1. 10-(3'-ethoxycarbonylaminoethyl)-2,7-diazaphenothiazine (IUPAC name: ethyl 3-(10*H*-dipyrido[3,4-*b*;3',4'-*e*][1,4]thiazin-10-yl)propylcarbamate) (13), (0.135 g, 82%), an oil. ¹H NMR (CDCl₃) δ : 1.23 (t, $J = 6.6$ Hz, 3H, CH₃), 2.05 (m, 2H, CH₂), 3.34 (m, 2H, NHCH₂), 3.95 (t, $J = 7.2$ Hz, 2H, NCH₂), 4.11 (q, $J = 6.6$ Hz, 2H, OCH₂), 4.92 (broad s, 1H, NH), 6.70 (d, $J = 5.7$ Hz, 1H, H-9), 6.98 (d, $J = 4.8$ Hz, 1H, H-4), 8.08-8.28 (m, 4H, H-1, H-3, H-6 and H-8). FAB MS m/z : 331 (M+1, 100), 202 (M+1-C₃H₆NHCOOC₂H₅, 25). Anal. Calcd for C₁₆H₁₈N₄O₂S: C 58.16, H 5.49, N 16.96. Found C 58.01, H 5.44, N 16.65.
2. 10-(4'-ethoxycarbonylaminoethyl)-2,7-diazaphenothiazine (IUPAC name: ethyl 4-(10*H*-dipyrido[3,4-*b*;3',4'-*e*][1,4]thiazin-10-yl)butylcarbamate) (14), (0.138 g, 80%), an oil. ¹H NMR (CDCl₃) δ : 1.23 (t, $J = 6.7$ Hz, 3H, CH₃), 1.78 (m, 2H, CH₂), 1.95 (m, 2H, CH₂), 3.24 (m, 2H, NHCH₂), 3.86 (t, $J = 7.1$ Hz, 2H, NCH₂), 4.10 (q, $J = 6.7$ Hz, 2H, OCH₂), 4.95 (broad s, 1H, NH), 6.70 (d, $J = 5.7$ Hz, 1H, H-9), 6.98 (d, $J = 4.8$ Hz, 1H, H-4), 8.00-8.19 (m, 4H, H-1, H-3, H-6 and H-8). FAB MS m/z : 345 (M+1, 40), 201 (M-C₄H₇NHCOOC₂H₅, 15), 202 (M+1-C₄H₇NHCOOC₂H₅, 100). Anal. Calcd for C₁₇H₂₀N₄O₂S: C 59.28, H 5.85, N 16.27. Found C 59.21, H 5.80, N 16.02.

Synthesis of 10-chloroethylureidoalkyl-2,7-diazaphenothiazines (15) and (16)

To a stirred solution of 10-aminoalkyl-2,7-diazaphenothiazines (7) and (8) (0.5 mmol) in dry EtOH (10 mL) at 0 °C 2-chloroethyl isocyanate (0.87 mL, 1 mmol) was added. The mixture was stirred at 0 °C for 0.5 h and at rt for 24 h. After evaporation of EtOH *in vacuo* the residue was purified by column chromatography (aluminum oxide, CH₂Cl₂) to give:

1. 10-chloroethylureidopropyl-2,7-diazaphenothiazine (IUPAC name: 1-[3-(10*H*-dipyrido[3,4-*b*;3',4'-*e*][1,4]thiazin-10-yl)propyl]-3-(2-chloroethyl)urea) (15), 0.124 g, 68%), mp 101-102 °C (EtOH). ¹H NMR

(DMSO- d_6) δ : 1.95 (m, 2H, CH₂), 3.36 (m, 6H, 3CH₂), 3.90 (broad s, 1H, NH), 3.96 (m, 2H, CH₂), 4.22 (broad s, 1H, NH), 6.98 (d, J = 5.4 Hz, 1H, H-9), 7.14 (d, J = 4.8 Hz, 1H, H-4), 8.03-8.27 (m, 4H, H-1, H-3, H-6 and H-8). FAB MS m/z : 365 (M+2, 4), 367 (M+4, 2) 328 (M-Cl, 2), 202 (M+H-C₃H₆NHCONHCH₂CH₂Cl, 10), 185 (2gly+H, 100). Anal. Calcd for C₁₆H₁₈ClN₅OS: C 52.82, H 4.99, N 19.25. Found: C 52.51, H 5.17, N 18.87.

2. 10-chloroethylureidobutyl-2,7-diazaphenothiazine (IUPAC name: 1-[4-(10*H*-dipyrido[3,4-*b*;3',4'-*e*]-[1,4]thiazin-10-yl)butyl]-3-(2-chloroethyl)urea) (**16**), 0.134 g, 71%), mp 104-105 °C (EtOH). ¹H NMR (CDCl₃) δ : 1.69 (m, 2H, CH₂), 1.86 (m, 2H, CH₂), 3.25 (m, 2H, CH₂), 3.52 (m, 2H, CH₂), 3.62 (t, J = 5.5 Hz, 2H, CH₂Cl), 3.88 (t, J = 7.4 Hz, 2H, NCH₂), 4.35 (broad s, 1H, NH), 4.65 (broad s, 1H, NH), 6.68 (d, J = 2.9 Hz, 1H, H-9), 6.92 (d, J = 5.6 Hz, 1H, H-4), 8.05-8.24 (m, 4H, H-1, H-3, H-6 and H-8). FAB MS m/z : 378 (M+1, 90), 201 (M-C₄H₇NHCONH-CH₂CH₂Cl, 50), 202 (M+1-C₄H₇NHCONHCH₂CH₂Cl, 100). Anal. Calcd for C₁₇H₂₀ClN₅OS: C 54.03, H 5.33, N 18.53. Found C 54.03, H 5.33, N 18.31.

Synthesis of 10-sulfonylaminoalkyl-2,7-diazaphenothiazines (**17-20**)

To a stirred solution of 10-aminoalkyl-2,7-diazaphenothiazines (**7**) and (**8**) (0.5 mmol) in a mixture of CH₂Cl₂ (5 mL) and 10% aqueous Na₂CO₃ solution (5 mL) a solution of methanesulfonyl chloride (0.12 mL, 1.5 mmol) or *p*-toluenesulfonyl chloride (0.286 g, 1.5 mmol) in CH₂Cl₂ (3 mL) was added. The solutions were stirred at rt for 12 h and 24 h, respectively. The organic phase was separated and aqueous phase was extracted with CH₂Cl₂ (2 x 5 mL). The combined extracts were washed with water (10 mL) and dried with anhydrous sodium sulfate and evaporated *in vacuo*. The residue was purified by column chromatography (aluminum oxide, CH₂Cl₂) to give:

1. 10-(3'-methanesulfonylaminopropyl-2,7-diazaphenothiazine (IUPAC name: *N*-[3-(10*H*-dipyrido[3,4-*b*;3',4'-*e*]-[1,4]thiazin-10-yl)propyl]methanesulfonamide) (**17**), (0.133 g, 79%), an oil. ¹H NMR (CDCl₃) δ : 2.09 (m, 2H, CH₂), 2.92 (s, 3H, CH₃), 3.31 (m, 2H, NHCH₂), 4.02 (t, J = 6.9 Hz, 2H, NCH₂), 5.50 (broad s, 1H, NH), 6.73 (d, J = 5.7 Hz, 1H, H-9), 7.03 (d, J = 5.1 Hz, 1H, H-4), 8.09-8.26 (m, 4H, H-1, H-3, H-6 and H-8). FAB MS m/z : 337 (M+1, 100), 202 (M+1-C₃H₅NHSO₂CH₃, 30). Anal. Calcd for C₁₄H₁₆N₄O₂S₂: C 49.98, H 4.79, N 16.65. Found C 49.71, H 4.71, N 16.42.

2. 10-(4'-methanesulfonylaminobutyl-2,7-diazaphenothiazine (IUPAC name: *N*-[4-(10*H*-dipyrido[3,4-*b*;3',4'-*e*]-[1,4]thiazin-10-yl)butyl]methanesulfonamide) (**18**), (0.140 g, 80%), an oil. ¹H NMR (CDCl₃) δ : 1.75 (m, 2H, CH₂), 1.89 (m, 2H, CH₂), 2.93 (s, 3H, CH₃), 3.18 (m, 2H, NHCH₂), 3.86 (t, J = 7.2 Hz, 2H, NCH₂), 5.02 (broad s, 1H, NH), 6.68 (d, J = 5.7 Hz, 1H, H-9), 6.99 (d, J = 4.8 Hz, 1H, H-4), 8.05-8.26 (m, 4H, H-1, H-3, H-6 and H-8). FAB MS m/z : 351 (M+1, 100), 202 (M+1-C₄H₇NHSO₂CH₃, 58). Anal. Calcd for C₁₅H₁₈N₄O₂S₂: C 51.41, H 5.18, N 15.99. Found C 51.33, H 5.11, N 15.78.

3. 10-(3'-*p*-toluenesulfonylaminopropyl-2,7-diazaphenothiazine (IUPAC name: *N*-[3-(10*H*-dipyrido[3,4-

b;3',4'-e][1,4]thiazin-10-yl)propyl]-4-methylbenzenesulfonamide) (**19**), (0.140 g, 68%), an oil. ^1H NMR (CDCl_3) δ : 2.08 (m, 2H, CH_2), 2.44 (s, 3H, CH_3), 3.32 (m, 2H, NHCH_2), 4.01 (t, $J = 6.8$ Hz, 2H, NCH_2), 4.78 (broad s, 1H, NH), 6.66 (d, $J = 5.7$ Hz, 1H, H-9), 6.96 (d, $J = 4.9$ Hz, 1H, H-4), 7.72 (m, 4H, C_6H_4), 8.03-8.12 (m, 4H, H-1, H-3, H-6 and H-8). FAB MS m/z : 413 ($M+1$, 30), 202 ($M+1-\text{C}_3\text{H}_5\text{NHSO}_2\text{C}_6\text{H}_4\text{CH}_3$, 30), 155 ($\text{SO}_2\text{C}_6\text{H}_4\text{CH}_3$, 100). Anal. Calcd for $\text{C}_{20}\text{H}_{20}\text{N}_4\text{O}_2\text{S}_2$: C. 58.23, H 4.89, N 13.58. Found C. 58.05, H 4.83, N 13.39.

4. 10-(4'-*p*-toluenesulfonylaminobutyl-2,7-diazaphenothiazine (IUPAC name: *N*-[4-(10*H*-dipyrido[3,4-*b;3',4'-e*][1,4]thiazin-10-yl)butyl]-4-methylbenzenesulfonamide) (**20**), (0.152 g, 71%), an oil. ^1H NMR (CDCl_3) δ : 1.62 (m, 2H, CH_2), 1.87 (m, 2H, CH_2), 2.40 (s, 3H, CH_3), 3.10 (m, 2H, NHCH_2), 3.79 (t, $J = 7.3$ Hz, 2H, NCH_2), 4.72 (broad s, 1H, NH), 6.64 (d, $J = 5.7$ Hz, 1H, H-9), 6.96 (d, $J = 4.8$ Hz, 1H, H-4), 7.70 (m, 4 H, C_6H_4), 8.01-8.10 (m, 4H, H-1, H-3, H-6 and H-8). FAB MS m/z : 427 ($M+1$, 100), 202 ($M+1-\text{C}_4\text{H}_7\text{NHSO}_2\text{C}_6\text{H}_4\text{CH}_3$, 30). Anal. Calcd for $\text{C}_{21}\text{H}_{22}\text{N}_4\text{O}_2\text{S}_2$: C 59.13, H 5.20, N 13.13. Found C 58.88, H 5.15, N 12.88.

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