Synthesis of New Heteroaromatic Nitrogen Ligands: Pyrimido-[4",5":4',5']-thieno[3',2':4,5]thieno[3,2-*d*]pyrimidines and 1,2,3-Triazine[4",5":4',5']thieno[3',2':4,5]thieno[3,2-*d*]-1,2,3-triazines

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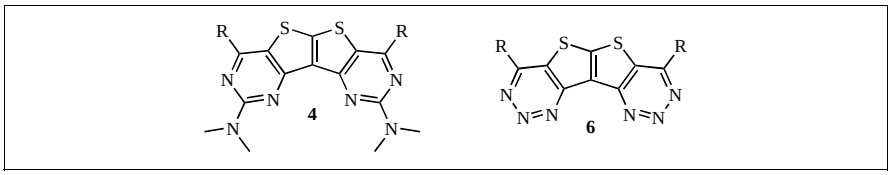

An efficient one-pot access for the synthesis of the previously unreported tetracyclic fused pyrimido-[4",5":4',5']thieno[3',2':4,5]thieno[3,2-*d*]pyrimidine (**3**) and 1,2,3-triazine[4",5":4',5']thieno-[3',2':4,5]thieno-[3,2-*d*]-1,2,3-triazine (**5**) heteroaromatic nitrogen ligands is described. The title compounds **3** and **5** were obtained from 3,4-diaminothieno[2,3-*b*]thiophene-2,5-dicarbonitrile and phosgeniminium chloride and sodium nitrite/HCl, respectively. Substituted condensed thieno[2,3-*b*]thiophene derivatives **4** and **6** were synthesized by nucleophilic displacement of the chloroderivatives **3** and **5**.

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Introduction.

Nitrogen-containing rings are among the most useful heterocycles and their utility has been widely demonstrated [1]. Heteroaromatic nitrogen ligands have attracted strong interest because they have found applications in several important research and technological fields such as supramolecular chemistry [2], asymmetric homogeneous and heterogeneous catalysis [3], photosensitisation [4], DNA binding [5], use as diagnostic agents and drugs [6], antitumor compounds [7], and other applications in electrooptical and photonic devices [8].

Thieno[2,3-*b*]thiophenes [9], structurally related to isoelectronic naphthalene and 10π-pentalene dianion are of potential interest as π-electron donors in several current applications [10]. Substituted thieno[2,3-*b*]thiophenes and their preparation methods are known since the 1950's. These compounds have been studied and developed for different purposes in the pharmaceutical field and have been tested as, depending on the nature of the substituents, potential antiviral [11], antibiotic [12], antiglaucoma [13], analgesic and antipyretic drugs [14]. Condensed thiophene derivatives and polithiophenes have received much attention as potential conducting polymers [15], electron acceptors [16], hydrogen-poor heterocycles [17], organic conductors and superconductors [18], photosensitive receptors [19] and materials for non-linear optics [20].

Thienopyrimidines, which are well known bioisosteres of quinazolines, are of great importance because of their remarkable effects on the central nervous system as well as a wide variety of other biological activities [21]. During the last years we have been interested in the synthesis of substituted heterocycles containing the thienopyrimidine and thienotriazine systems with the aim of finding different compounds with antiallergic, antiinflammatory and analgesic activities [22] and we have also reported a new class of donor-receptor combined π-conjugated compounds [23].

In this paper we report the preparation and structural confirmation of derivatives of the unreported tetracyclic pyrimido[4",5":4',5']thieno[3',2':4,5]thieno[3,2-*d*]pyrimidine (**3, 4**) and 1,2,3-triazine[4",5":4',5']thieno[3',2':4,5]-thieno[3,2-*d*]-1,2,3-triazine (**5, 6**) systems. A literature scan revealed that very little has so far been published on these compounds and, to our knowledge, only three reports have been reported [24].

Results and Discussion.

Our strategy for the synthesis of these compounds was based on the disconnection illustrated in Figure 1. Inspection of the retrosynthetic pathway displayed in

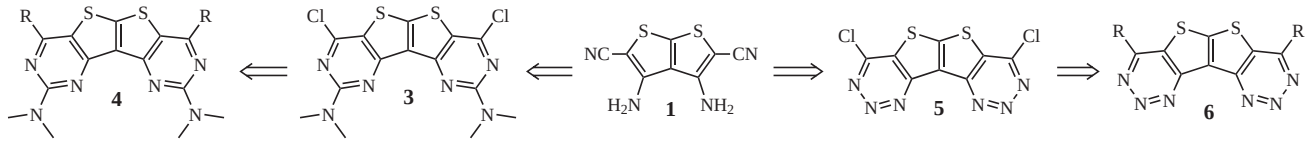


Figure 1. Retrosynthetic pathway for the heteroaromatic ligands

Figure 1, clearly indicates that the heterocyclic β-enaminonitrile 3,4-diaminothieno[2,3-*b*]thiophene-2,5-dicarbonitrile (**1**), would be an ideal starting point for the synthesis of these functionalizated tetraheterocyclic skeletons.

For the synthesis of 1,2,3-triazine[4",5":4',5']thieno-[3',2':4,5]thieno[3,2-*d*]-1,2,3-triazines (compounds **5** and **6**), we started with the α,β-aminonitrile (**1**) (Figure 1) that, by diazotization, gave the condensed chlorotriazine **5**, which underwent normal halide displacement with a variety of nucleophiles to yield compounds **6**. For the preparation of pyrimido[4",5":4',5']thieno[3',2':4,5]thieno-[3,2-*d*] pyrimidines (compounds **3** and **4**), we used a synthetic procedure based on the use of β-enaminonitriles and phosgeniminium chloride that allows the introduction of two substituents, R and $N(CH_3)_2$, on the heterocycle. Thus, substituent dimethylamino is introduced during the formation of the pyrimidine ring. Substituent R is introduced in the last step by means of an aromatic nucleophilic substitution of a chloro-substituent.

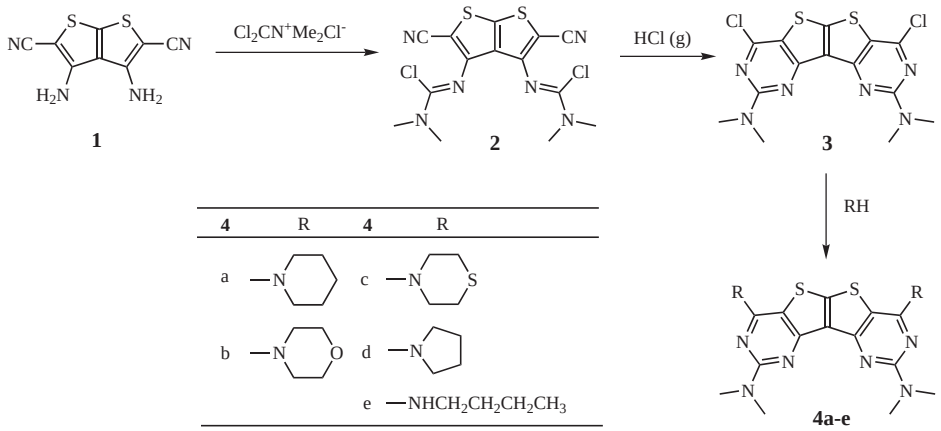
We considered this methodology would be attractive due to its conciseness and utilization of readily synthesized or commercially available starting materials.

Aromatic *ortho*-amino cyano compounds are well established as versatile starting materials for the synthesis of a variety of heterocyclic compounds [25]. Phosgeniminium salts are valuable synthons for heterocyclic synthesis and have proved to be very useful one carbon atom reagents, condensing with many types of nucleophiles and having, due to the presence in their molecule of three mobile chlorine atoms, greater synthetic potential than corresponding Vilsmeier-Haack, Arnold and Mannich reagents [26]. In particular, cyclization reactions of aromatic *o*-aminonitriles with *N*,*N*-dimethyldichloromethylene iminium chloride (Viehe's salt), a well-known multiple electrophilic one carbon atom synthon, provide a convenient access to a number of fused pyrimidine derivatives [27]. The starting 3,4-diaminothieno[2,3-*b*]thiophene-2,5-dicarbonitrile (**1**) was readily obtained by a slight modification of a previously described one pot procedure using K_2CO_3/DMF as the condensation promoter [28].

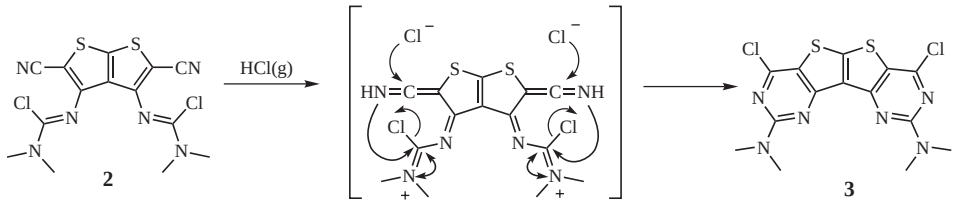
The title dithienodipyrimidine compounds (**3**) and (**4**) were prepared *via* synthetic 2-chloroamidine intermediate (**2**) (Scheme 1).

In our scheme, the conversion of **1** into **2** involves the introduction of one additional carbon atom. In this way, 3,4-diaminothieno[2,3-*b*]thiophene-2,5-dicarbonitrile (**1**), was made to react with *N*,*N*-dimethyldichloromethylene iminium chloride in refluxing 1,2-dichloethane affording the amide halide intermediate (**2**) which underwent smooth cyclization to the corresponding fused thieno-pyrimidine (**3**) *via* reaction with dry hydrogen chloride. Direct one-pot synthesis using α,β-enamononitrile (**1**) and phosgeniminium salt in refluxing 1,2-dichloroethane for 2 hours and subsequent treatment with hydrogen chloride provided the fused dichloroderivative (**3**) in 70% yield. Nucleophilic displacement reaction of the chloride bearing groups in the tetracyclic compound (**3**) resulted in the formation on the corresponding substituted products (**4**) in good yields. Structural elucidation of compounds **2**, **3** and **4** was accomplished from their analytical and spectroscopic data. The mass spectra showed the expected molecular ion peak and the IR spectrum of **2** exhibited a strong absorption band at ν = 1650 cm^{-1} due to the imino groups and presented the characteristic signal al ν = 2210 cm^{-1} (CN), while the decoupled ^{13}C NMR spectrum showed one signal at δ = 113.9 due to the carbon atom in the cyano groups. After cyclization, the IR spectrum of compounds (**3**) and (**4**) did not include those types of characteristic signals. The most salient features of the ^1H NMR and ^{13}C NMR spectra are summarized under Experimental.

Scheme 1



Scheme 2

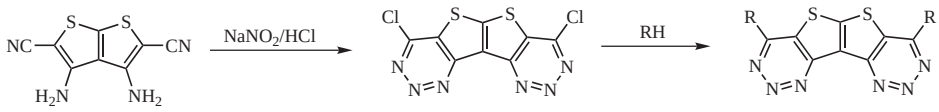


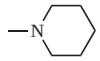
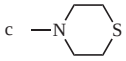
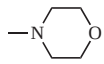
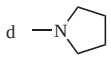
Phosgeniminium salts are known to undergo condensation with CH-acidic compounds such as ketones, carboxylic acids and chlorides, nitriles, and amides to give amide halides [29], able to react further with nucleophiles and to produce, through either inter- or intramolecular processes, various types of functionalized 5-, 6- and 7-membered ring systems [30]. Amide chlorides have been similarly obtained from enamines [31], fulvenes [32], barbituric acid derivatives [33] and pyridopyrimidines [34] by reaction with dichloromethyleniminium salts. In addition, phosgeniminium salts do not react with the nitrile group unless it is sufficiently activated or the salts are previously transformed into chloroiminium chlorides by means of dry hydrogen chloride. Since the intermediate adduct (**2**) was isolated the reaction can be assumed to proceed as described in Scheme 2 [35].

The preparation of thienotriazines (**6**) was accomplished in good yields by intramolecular condensation of a diazonium ion with an adjacent nucleophilic function. This procedure has proven useful in the synthesis of various five- and six-membered ring nitrogen heterocycles. A good example [36] of the application of this method is the preparation, using a cyanide group as the nucleophile, of 4-chloro-1,2,3-triazines. We found in fact that the diazotization of α,β-enaminonitrile (**1**) constitutes a direct and very convenient route to the title ring system (**6**). The tetracyclic dithieno-1,2,3-triazines (**6**) were prepared as shown in Scheme 3, by starting from the key 3,4-diaminothieno[2,3-*b*]thiophene-2,5-dicarbonitrile (**1**). Diazotization of **1** with sodium nitrite in HCl afforded the dichloro-substituted ditriazine (**5**), which produced the 1,2,3-triazine[4",5":4',5']thieno[3',2':4,5]thieno[3,2-*d*]-1,2,3-triazines (**6**) in moderate yields by halide displacement with the appropriate secondary amine as a nucleophile. The molecular formula of compounds **5** and **6** are supported by elemental analyses and mass spectra which gave the expected molecular ion peaks.

In summary, we have succeeded in developing an efficient one-pot procedure for the synthesis to previously unreported tetracyclic dithienodipyrimidine (**3**) and dithienodi-1,2,3-triazine (**5**) starting from the key 3,4-diaminothieno[2,3-*b*]thiophene-2,5-dicarbonitrile (**1**) and phosgeniminium chloride and sodium nitrite in HCl, respectively. Nucleophilic displacement reaction of the chloride bearing groups in the tetracyclic compounds **3** and **5** resulted in the formation on the corresponding thienopyrimidines (**4**) and thienotriazines (**6**) bearing various substituents on the pyrimidine and triazine rings, respectively. These substituted fused heterocyclic compounds can be useful in medicinal chemistry since the thieno, pyrimido, and 1,2,3-triazine moieties display a broad range of biological activities and have been widely used as pharmaceuticals. On the other hand, the new condensed thiophene heteroaromatic nitrogen ligands can form complexes with transition metals and these complexes have broad applications to supramolecular science.

Scheme 3



6	R	**6**	R
a		c	
b		d	
		e	—NHCH$_2$CH$_2$CH$_2$CH$_3$

EXPERIMENTAL

Melting points were determined on a Bibby SMP3 apparatus and are uncorrected. All reagents used were commercial grade chemicals from freshly opened containers. IR spectra were recorded as potassium bromide disks on a Bruker vector 22FT-IR. ^{1}H and ^{13}C NMR spectra TMS as internal standard) were recorded on a Bruker AC 200F spectrometer (δ units are given in ppm). Compounds **4a-e** and **6a-e** are very insoluble in most habitual NMR solvents and ^{13}C NMR spectra could not be obtained. Mass spectra were obtained on a VG-QUATTRO spectrometer. Reactions and products were monitored by means of thin layer-chromatography using Kieselgel 60F-254 (Merck, Germany) pre-coated aluminium sheets (50 x 100 mm, layer thickness 0.2 mm). Microanalyses for C, H, N, and S were performed by the elemental analyses general services of the University of A Coruña.

3,4-Diaminothieno[2,3-*b*]thiophene-2,5-dicarbonitrile (**1**).

The starting dicarbonitrile (**1**) was prepared by a slight modification of a previous procedure described in the literature [27]. To a mixture of dried potassium carbonate (6.22 g, 45 mmol) in ethanol (10 mL), malononitrile (1,00 g, 15 mmol) in ethanol (5 mL) was added, followed by carbon disulfide (1.35 g, 22.5 mmol), which was added dropwise under vigorous stirring. The reaction mixture was cooled to 5 ºC for 30 minutes and bromoacetonitrile (3.60 g, 30 mmol) in ethanol (3 mL) was added. The reaction mixture was stirred for 6 hours at room temperature and poured into 200 mL of cold water. The precipitate was collected and the obtained solid product was washed several times with water. The crude 3,4-diaminothieno[2,3-*b*]thiophene-2,5-dicarbonitrile was purified by flash chromatography using CH_2Cl_2/AcOEt (8:2 v/v) as eluent to yield **1** (2.40 g, 74%), mp > 300º (decomp.) (lit. 250-253º); ir (KBr): 3366, 3316, 3218 (NH_2), 2203 (CN) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 6.82 (br s, 4H, NH_2). ^{13}C nmr (DMSO-d_6): δ 78.3, 115.9, 125.73, 146.81, 150.37; ms (FAB): m/z 221 (MH^+, 41), 220 (MH^+ - 1, 70), 193 (21).

Anal. Calcd for $C_8H_4N_4S_2$: C, 43.62; H, 1.83; N, 25.43; S, 29.11. Found: C, 43.79; H, 1.85; N, 25.42; S, 28.94.

3,4-Bis(chlorodimethylaminomethylenamino)thieno[2,3-*b*]thiophene (**2**).

A mixture of **1** (0.1 g, 0.45 mmol) and phosgeniminium chloride (0.18 g, 1.09 mmol) in 1,2-dichloroethane (5 mL) was heated at reflux until all starting material has disappeared as checked by tlc. The solvent was removed under reduced pressure and the resulting solid was purified by flash chromatography using hexane/dichloromethane (1:9, v/v) as eluent to obtain **2** (0.14 g, 80%), mp 212-213º; ir (KBr): 2210(CN), 1650 (C=N) cm^{-1}; ^{1}H nmr (CD_3Cl): δ 3.20 (s, 12 H, $N(CH_3)_2$); ^{13}C nmr (DMSO-d_6): δ 40.1, 96.6, 113.9 (CN), 132.8, 141.4, 143.1; ms (EI): m/z 363 (M^+ - Cl, 42), 345 (M^+ -2HCN, 7), 329 (M^+ -2Cl, 13), 149 (100).

Anal. Calcd for $C_{14}H_{12}Cl_2N_6S_2$: C, 42.11; H, 3.03; N, 21.05; S, 16.06. Found: C, 41.93; H, 2.97; N, 21.17; S, 16.23.

2,9-Bis(dimethylamino)-4,7-dichloropyrimido[4'',5'':4',5']thieno-[3',2':4,5]thieno[3,2-*d*]pyrimidine (**3**).

Method A.

A stream of dry hydrogen chloride was passed through a mixture of **2** (0.72 g, 1.72 mmol) in 1,2-dichloroethane (20 mL) for 3 hours. The reaction mixture was allowed to stand overnight at room temperature. The precipitate was collected and washed with water and 1,2-dichloroethane. The resulting solid purified by flash chromatography using hexane/dichloromethane (3:7, v/v) as eluent to afford **3** (0.55 g, 76%), mp > 300º (decomp.); ir (KBr): 1650 (C=N) cm^{-1}; ^{1}H nmr (CD_3Cl): δ 3.34 (s, 12 H, $N(CH_3)_2$); ms (FAB): m/z 399 (MH^+, 20), 355 (25), 327 (18%), 311 (11), 191 (100); ^{13}C nmr spectrum could not be obtained due to poor solubility.

Anal. Calcd for $C_{14}H_{12}Cl_2N_6S_2$: C, 42.11; H, 3.03; N, 21.05; S, 16.06. Found: C, 42.06; H, 2.96; N, 21.14; S, 15.97.

Method B.

A mixture of **1** (0.1 g, 0.45 mmol) and phosgeniminium chloride (0.18 g, 1.09 mmol) in 1,2-dichloroethane (5 mL) was heated at reflux for 24 hours. A stream of dry hydrogen chloride was passed through the mixture for 2 hours and the reaction mixture was allowed to stand overnight at room temperature. The resulting solid purified by flash chromatography using hexane/dichloromethane (3:7, v/v) as eluent to obtain **3** (0.15 g, 83%).

General Procedure for the Reaction of 2,9-Bis(dimethylamino)-4,7-dichloropyrimido[4'',5'':4',5']thieno[3',2':4,5]thieno[3,2-*d*]-pyrimidine (**3**) with Amines.

A suspension of dichloroderivative (**3**) (15 mg, 0.04 mmol) and the appropriate amine (0.09 mmol) in DMSO (3 mL) was heated at reflux until all starting material had disappeared as checked by tlc. It was cooled to room temperature and the mixture was poured into saturated NaCl solution (50 mL). The resulting solid was collected and washed several times with water, ethanol, hot acetone and hot dimethylsulfoxide to give **4a-e** in analytical pure form. ^{13}C nmr spectra of compounds **4** could not be obtained due to poor solubility.

2,9-Bis(dimethylamino)-4,7-dipiperidinopyrimido[4'',5'':4',5']-thieno[3',2':4,5]thieno[3,2-d]pyrimidine (4a).

This compound was obtained in 83% yield, mp 260 ºC (decomp.); ir (KBr): 2930, 2851, 1556, 1539, 1514 cm^{-1}; ^{1}H nmr (CD_3Cl): δ 1.72 (m, 12 H, $CH_2CH_2CH_2$), 3.29 (s, 12H $N(CH_3)_2$), 3.82 (m, 8H, NCH_2); ms (FAB): m/z 498 (MH^+ + 1, 27), 497 (MH^+, 100), 483 (33).

Anal. Calcd for $C_{24}H_{32}N_8S_2$: C, 58.03; H, 6.49; N, 22.56; S, 12.91. Found: C, 57.76; H, 6.65; N, 22.38; S, 13.20.

2,9-Bis(dimethylamino)-4,7-dimorpholinopyrimido[4'',5'':4',5']-thieno[3',2':4,5]thieno[3,2-*d*]pyrimidine (**4b**).

This compound was obtained in 92% yield, mp > 300º C (decomp.); ir (KBr): 2957, 2918, 2892, 2852, 1561, 1534, 1513 cm^{-1}; ^{1}H nmr (CD_3Cl): δ 3.29 (s, 12H $N(CH_3)_2$), 3.86 (m, 16H, CH_2O); ms (FAB): m/z 503 (MH^+ + 2, 22), 501 (MH^+, 100), 217 (25).

Anal. Calcd for $C_{22}H_{28}N_8O_2S_2$: C, 52.78; H, 5.64; N, 22.38; S, 12.81. Found: C, 52.97; H, 5.34; N, 22.09; S, 13.14.

2,9-Bis(dimethylamino)-4,7-dithiomorpholinopyrimido[4'',5'':4',5']-thieno[3',2':4,5]thieno[3,2-*d*]pyrimidine (**4c**).

This compound was obtained in 72% yield, mp 255º (decomp.); ir (KBr): 2909, 2851, 2780, 1562, 1535, 1512 cm^{-1}; ^{1}H nmr (CD_3Cl): δ 2.76 (m, 8H, CH_2S) 3.29 (s, 12H $N(CH_3)_2$), 4.20 (m, 8H, CH_2N); ms (FAB): m/z 534 (MH^+ + 1, 28), 533 (MH^+, 100), 531 (23), 459 (17), 133 (15).

Anal. Calcd for $C_{22}H_{28}N_8S_4$: C, 49.60; H, 5.30; N, 21.03; S, 24.07. Found: C, 49.81; H, 4.98; N, 21.36; S, 23.85.

2,9-Bis(dimethylamino)-4,7-dipyrrolidinopyrimido[4'',5'':4',5']-thieno[3',2':4,5]thieno[3,2-*d*]pyrimidine (**4d**).

This compound was obtained in 78% yield, mp > 300º (decomp.); ir (KBr): 2920, 2859, 2778, 1547, 1519 cm $^{-1}$; ^{1}H nmr (CD_3Cl): δ 2.01 (m, 8H, CH_2CH_2), 3.28 (s, 12H $N(CH_3)_2$), 3.83 (m, 8H, CH_2N); ms (FAB): m/z 469 (MH^+, 70), 327 (10), 133 (33).

Anal. Calcd for $C_{22}H_{28}N_8S_2$: C, 56.38; H, 6.02; N, 23.91; S, 13.68. Found: C, 56.47; H, 6.11; N, 24.07; S, 13.35.

2,9-Bis(dimethylamino)-4,7-butylaminopyrimido[4'',5'':4',5']-thieno[3',2':4,5]thieno[3,2-*d*]pyrimidine (**4e**).

This compound was obtained in 77% yield, mp > 300º (decomp.); ir (KBr): 3325 (NH), 2957, 2927, 2870, 1633, 1589, 1557, 1377, 1366 cm $^{-1}$; ms (FAB): m/z 475 (MH^+ + 2, 27), 473 (MH^+, 100), 429 (8), 386 (5), 133 (35). Signals in the ^{1}H nmr spectrum are unobservable because of poor solubility.

Anal. Calcd for $C_{22}H_{32}N_8S_2$: C, 55.90; H, 6.82; N, 23.71; S, 13.57. Found: C, 56.29; H, 6.44 ; N, 24.10; S, 13.17.

4,7-Dichloro-1,2,3-triazino[4'',5'':4',5']thieno[3',2':4,5]thieno-[3,2-*d*]-1,2,3-triazine (**5**).

To an ice-cooled solution the α,β-enaminonitrile (**1**) (1.00 g, 4.54 mmol) in 1:1 (v/v HCl/AcOH) (150 mL) was added dropwise a solution of sodium nitrite (1.25 g, 18.16 mmol) in water (5 mL). The solution was stirred at room temperature for 8 hours, and the mixture was poured into water (400 mL). The resulting solid was collected by filtration and purified by flash chromatography on silica gel using dichloromethane as eluent to give **5** (0.96 g, 67%), mp 229-230º; ir (KBr): 1536 (C=N) cm^{-1}; ms (FAB): m/z 315 (MH^+, 4), 197 (11), 181 (13), 167 (189, 149 (100). Signals in the ^{1}H nmr and ^{13}C nmr spectra are unobservable because of poor solubility.

Anal. Calcd for $C_8Cl_2N_6S_2$: C, 30.49; N, 26.67; S. 20.35. Found: C, 30.68; N, 26.43; S, 20.51.

General Procedure for the Reaction of 4,7-Dichloro-1,2,3-triazino[4'',5'':4',5']thieno[3',2':4,5]thieno[3,2-*d*]-1,2,3-triazine (**5**) with Amines.

To a suspension of dichlorotriazine (**5**) (30 mg, 0.095 mmol) in DMF (3 mL) was added the appropriate amine (0.23 mmol). The mixture was stirred at room temperature until starting material has disappeared as checked by tlc (1-2 hours). The crude precipitated product was collected by filtration and washed several times with hot DMF until **6a-e** are obtain in analytical pure form. ^{13}C nmr spectra of compounds **6a-d** could not be obtained due to poor solubility.

4,7-Dipiperidino-1,2,3-triazino[4'',5'':4',5']thieno[3',2':4,5]thieno-[3,2-d]-1,2,3-triazine (**6a**).

This compound was obtained in 70% yield, mp 265-266º; ir (KBr): 2936, 2856, 1550 cm^{-1}; ^{1}H nmr (pyridine-d_5): δ 1.60 (m, 12H), 3.98 (m, 8H, CH_2N); ms (FAB): m/z 413 (MH^+, 100), 385 (MH^+ - N_2, 50), 357 (23).

Anal. Calcd for $C_{18}H_{20}N_8S_2$: C, 52.41; H, 4.89; N, 27.16; S, 15.55. Found: C, 52.16; H, 4.91; N, 27.13; S, 15.80.

4,7-Dimorpholino-1,2,3-triazino[4'',5'':4',5']thieno[3',2':4,5]thieno-[3,2-*d*]-1,2,3-triazine (**6b**).

This compound was obtained in 83% yield, mp 290º (decomp.); ir (KBr): 2963, 2903, 2866, 1545, 1534 cm^{-1}; ^{1}H nmr (pyridine-d_5): δ 3.87 (m, 8H, CH_2N), 4.10 (m, 8H, CH_2O); ms (FAB): m/z 417 (MH^+, 5), 392 (60), 317 (85), 288 (100).

Anal. Calcd for $C_{16}H_{16}N_8O_2S_2$: C, 46.14; H, 3.87; N, 26.90; S, 15.40. Found: C, 46.50; H, 3.68; N, 26.58; S, 15.77.

4,7-Dithiomorpholino-1,2,3-triazino[4'',5'':4',5']thieno[3',2':4,5]-thieno[3,2-*d*]-1,2,3-triazine (**6c**).

This compound was obtained in 60% yield, mp 280º (decomp.); ir (KBr): 2910, 1547, cm^{-1}; ^{1}H nmr (pyridine-d_5): δ 2.84 (m, 8H, CH_2S), 4.38 (m, 8H, CH_2N); ms (FAB): m/z 449 (MH^+, 9), 392 (9), 288 (100), 245 (23).

Anal. Calcd for $C_{16}H_{16}N_8S_4$: C, 42.84; H, 3.59; N, 24.98; S, 28.59. Found: C, 42.49; H, 3.91; N, 25.36; S, 28.24.

4,7-Dipyrrolidino-1,2,3-triazino[4'',5'':4',5']thieno[3',2':4,5]thieno-[3,2-*d*]-1,2,3-triazine (**6d**).

This compound was obtained in 74% yield, mp 270º (decomp.); ir (KBr): 2968, 2947, 2926, 2872, 1571, 1530 cm^{-1}; ^{1}H nmr (pyridine-d_5): δ 1.83 (m, 8H, CH_2CH_2), 3.85 (m, 8H, CH_2N); ms (FAB): m/z 385 (MH^+, 100), 357 (30), 329 (16), 314 (10), 244 (26).

Anal. Calcd for $C_{16}H_{16}N_8S_2$: C, 49.98; H, 4.19; N, 29.14; S, 16.68. Found: C, 50.23; H, 4.32; N, 28.88; S, 16.57.

4,7-Dibutylamino-1,2,3-triazino[4'',5'':4',5']thieno[3',2':4,5]thieno-[3,2-*d*]-1,2,3-triazine (**6e**).

This compound was obtained in 73% yield, mp 295º (decomp.); ir (KBr): 3239, 3158 (NH), 2958, 2931, 2872, 1604 cm^{-1}; ms (FAB): m/z 389 (MH^+, 6), 391 (45), 149 (100). ^{1}H nmr spectrum could not be obtained due to poor solubility.

Anal. Calcd for $C_{16}H_{20}N_8S_2$: C, 49.46; H, 5.19; N, 28.84; S, 16.51. Found: C, 49.15; H, 4.89; N, 29.14; S, 16.82.

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REFERENCES

[1a] N. Matzanke, R. J. Gregg, and S. M. Weinreb, *Org. Prep. Proced. Int.*, **30**, 1 (1998); [b] F. Palacios, C. Alonso, P. Amezua, and G. Rubiales, *J. Org. Chem.*, **67**, 1941 (2002), and references therein; [c] G. Jones, Comprehensive Heterocyclic Chemistry, ed. by A. R. Katritzky, C. W. Rees, A. J. Boulton, and A. McKillop, Pergamon, Oxford, 1984, Vol. **2**; (d) A. R. Renslo and R. L. Danheiser, *J. Org. Chem.*, **63**, 7840 (1998).

[2] J. M. Lehn, Supramolecular Chemistry, Concepts and Perspectives, VCH, Weinheim, 1995.

[3] G. Chelucci and R. P. Thummel, *Chem. Rev.*, **102**, 3129 (2002).

[4a] A. Islam, H. Sugihara, and H. Arakawa, *J. Photochem. Photobiol.*, **158**, 131 (2003); [b] M. Grätzel, *Prog. Photovolt. Res. Appl.*, **8**, 171 (2000).

[5a] L.-N Ji, X.-H Zou, and J.-G Liu, *Coord. Chem. Rev.*, **216-217**, 513 (2001); [b] D. R. McMillin and K. M. McNett, *Chem. Rev.*, **98**, 1201 (1998); [c] D. S. Sigman, A. Mazumder, and D. M. Perrin, *Chem. Rev.*, **93**, 2295 (1993).

[6] P. Caravan, J. J. Ellison, T. J. McMurry, and R. B. Lauffer, *Chem. Rev.*, **99**, 2293 (1999).

[7] M. J. Clarke, *Coord. Chem. Rev.*, **203**, 209 (2003).

[8a] K. Kalyanasundaram and M. Grätzel, *Coord. Chem. Rev.*, **177**, 347 (1998); [b] S. M. Baxter, W. E. Jones, E. Danielson, L. Worl, G. Strouse, J. Younathan, and T. Meyer, *Coord. Chem. Rev.*, **111**, 47 (1991).

[9a] C. V. Bird, G. W. H. Cheeseman, Eds. Comprehensive Heterocyclic Chemistry, Vol. **IV**, Pergamon, London, 1984, p. 1037; [b] V. P. Litvinov and Y. A. L. Gol'dfarb, in Chemistry of thienothiophenes, Advanced Heterocyclic Chemistry, ed. by A. R. Katritzky and A. J. Boulton, Academic Press, New York, 1976, vol. **19**, p. 123.

[10a] P. V. Bedworth, Y. Cai, A. Jen, and S. R. Marden, *J. Org. Chem.*, **61**, 2242 (1996); [b] D. M. Burland, R. D. Miller, and C. A. Walsh, *Chem. Rev.*, **94**, 31 (1994); [c] K. Takahashi and M. Ogiyama, *J. Chem. Soc., Chem. Commun.*, 1196 (1991); [d] F. Garnier, *Angew. Chem. Int. Ed. Engl.*, **28**, 513 (1989).

[11] D. Peters, A. B. Hörnfeldt, and S. Gronowitz, *J. Heterocyclic Chem.*, **27**, 2165 (1990).

[12] S. Kukolja, S. E. Draheim, B. J. Graves, D. C. Hunden, J. L. Pfeil, R. D. G. Cooper, J. L. Ott, and F. T. Couter, *J. Med. Chem.*, **28**, 1896 (1995).

[13] J. D. Prugh, G. D. Hartman, P. J. Mallorga, B. M. McKeever, S. R. Michelson, M. A. Murcko, H. Schwam, R. L. Smith, J. M. Sondey, J. P. Springer, and M. F. Surgrue, *J. Med. Chem.*, **35**, 1805 (1991).

[14] J. L. Fabre, D. Farge, and C. James, German Patent 2,703,624 (1976); *Chem. Abstr.*, 1976, **87**, 168000v (1976).

[15] S. Musmanni and J. P. Ferraris, *J. Chem. Soc., Chem. Commun.*, 172 (1993).

[16] D. Lorcy, K. D. Robinson, Y. Okuda, J. L. Atwood, and M. P. Cava, *J. Chem. Soc., Chem. Commun.*, 345 (1993).

[17] K. Yui, H. Ishida, Y. Aso, T. Otsubo, F. Ogura, A. Kawamoto, and J. Tanaka, *Bull. Chem. Soc. Jpn.*, **62**, 1547 (1989).

[18] O. Kobayashi, *Phosphorus, Sulfur, Silicon & Relat. Elem.*, **43**, 187 (1989).

[19] H. Hayata, A. Hirano, and H. Hirose, *Jpn. Kokai Tokkyo Koho*, JP, 1992, 043338, 761; *Chem. Abstr.*, **118**, 263832k (1992).

[20] R. A. Ham and D. Bloor, Eds. Organic Materials for Non-linear, The Royal Society of Chemistry, Cambridge, Special Publication No. 91, 1991.

[21a] Y. A. Ibrahim, A. H. Elwahy, and A. M. Kadry, *Adv. Heterocyclic Chem.*, **65**, 235 (1996); [b] G. Varvounis and T. Giannopoulos, *Adv. Heterocyclic Chem.*, **66**, 193 (1996).

[22a] J. M. Quintela, C. Peinador, L. M. González, R. Riguera, I. Rioja, M. C. Terencio, A. Ubeda, and M. J. Alcaraz, *J. Med. Chem.*, **42**, 4720 (1999); [b] J. M. Quintela, C. Peinador, L. González, I. Devesa, M. L. Ferrándiz, M. J. Alcaraz, and R. Riguera, *Bioorg. Med. Chem.*, **11**, 863 (2003), and references therein.

[23a] W. Ong, J. Grinstaff, D. Sobransingh, R. Toba, J. M. Quintela, C. Peinador, and A. Kaifer, *J. Am. Chem. Soc.*, **127**, 3353 (2005); [b] R. Toba, J. M. Quintela, C. Peinador, E. Román, and A. Kaifer, *Chem. Commun.*, 857 (2001); [c] E. Román, M. Chas, J. M. Quintela, C. Peinador, and A. Kaifer, *Tetrahedron*, **58**, 699 (2002); [d] R. Toba, J. M. Quintela, C. Peinador, E. Román, and A. Kaifer, *Chem. Commun.*, 1768 (2002).

[24a] A. Khodairy, H. Abdel-Ghany, *Phosphorus, Sulfur, Silicon & Relat. Elem.*, **162**, 259 (2000); [b] A. Artyomov, L. A. Rodinovskaya, A. M. Shestopalov, and V. P. Litvinov, *Tetrahedron*, **52**, 1011 (1996); [c] A. K. El-Shafei, A. M. M. El-saghier, A. Sultan, and A. M. Soliman, *Phosphorus, Sulfur, Silicon & Relat. Elem.*, **72**, 73 (1992).

[25] L. M. Deck and E. P. Papadopoulos, *J. Heterocyclic Chem.*, **37**, 675 (2000) and references cited therein.

[26] For a review see: Z. Janousek and H. G. Viehe, in Iminium Salts in Organic Chemistry, Advances in Organic Chemistry: Chemistry of Dichlorometileniminium Salts (Phosgeniminium Salts) , ed. by H. Böhme and H. G. Viehe, John Wiley and Sons, Inc., New York, 1976, Vol. **9**, p. 343.

[27] For a review see: J. M. Quintela, C. Peinador, M. J. Moreira, and R. Alvarez-Sarandés, *Recent. Res. Devel. In Organic Chem.*, **2**, 409 (1998).

[28] A. Comeln and G. Kirsch, *J. Heterocyclic Chem.*, **38**, 1167 (2001).

[29] D. Bartholomew and I. T. Kay, *Tetrahedron Lett.*, 2827 (1979).

[30a] H. Kokel, *J. Heterocyclic Chem.*, **31**, 8445 (1994); [b] B. Kokel, *J. Heterocyclic Chem.*, **31**, 1185 (1994); [c] R. Neidlein and Zh. Wang, *Synth. Commun.*, **27**, 1223 (1997); [d] J. Morris, G. P. Luke, and D. Wishka, *J. Org. Chem.*, **61**, 3218 (1996); [e] C. H. M. Marsow, *Tetrahedron*, **48**, 3659 (1992); [f] J. Liebscher, *Synthesis*, 655 (1988).

[31] W. Kantlehner, *Adv. Org. Chem.*, **9**, 65 (1979).

[32] K. Hafner and H. P. Krimmer, *Angew. Chem.*, **92**, 202 (1980).

[33] B. Kokel, C. Lespagnol, and H. G. Viehe, *Bull. Soc. Chim. Belg.*, **89**, 651 (1980).

[34] I. Bitter, B. Pete, I. Hermecz, G. Tóth, K. Simon, M. Czugler, and Z. Mészáros, *Tetrahedron Lett.*, 2891 (1982).

[35] B. Kokel, G. Menichi, and M. Hobar-Habart, *Tetrahedron Lett.*, 1557 (1984).

[36] J. R. Beck and J. A. Yahner, *J. Org. Chem.*, **41**, 1733 (1976).