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Electrogenerated base-promoted synthesis of *N*-benzylic rhodanine and carbamodithioate derivatives

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Electrogenerated magnesium-associated cyanomethyl anions/bases obtained from the electrochemical reduction of acetonitrile and the oxidation of a sacrificial magnesium rod were successfully used to promote the addition of carbon disulfide to primary benzylic amines. Alkylation with ethyl 3-bromopropionate acid ester or with ethyl 2-bromoacetate acid ester yields the corresponding ring-opened carbamodithioate compounds or cyclic rhodanine derivatives, respectively. The effect of the amount of electrogenerated base on the yield of reaction was also evaluated.

Keywords: electrogenerated bases/anions; rhodanines; carbamodithioates; electrosynthesis; cyclization; heterocycles

1. Introduction

Alternative paths to environmentally unfriendly preparation methods of organic compounds gains new interest if polluting and hazardous solvents and corrosive reagents are to be avoided. Recently, an efficient and convenient one-pot multicomponent electrochemical synthesis of tetrahydrobenzo[b]pyran and 2-amino-4H-chromenes derivatives, starting, respectively, from malononitrile, aryl aldehydes and dimedone and from malononitrile, aryl aldehydes and resorcinol without the involvement of an added base were reported (*1*, *2*). Inesi and colleagues have developed a new approach for the synthesis of new families of carbonates, carbamates and oxazolinones under very mild conditions. Alcohols, amines, aminoalcohols, haloamides, carbon dioxide and strong basic species generated during the electrolysis from organic solvents are commonly known as electrogenerated bases (EGBs) (*3*–*6*). In the last two decades, numerous papers reported the generation and use of strong basic species from organic aprotic solvents such as dimethyl sulfoxide, dimethyl formamide, acetonitrile, etc., and their application in organic synthesis. One of the most striking advantages is the excellent control of the base strength depending on the choice of the solvent. Furthermore, the amount of EGB is a function of the imposed current density and the duration of the electrolysis, which can be also adjusted (*7*, *8*).

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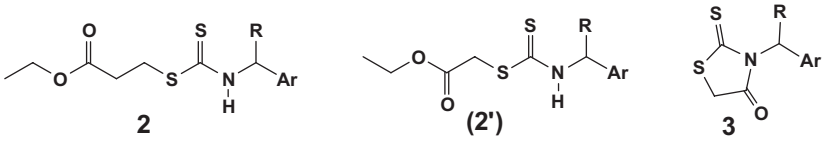
On the other hand, it is well established that the electrochemical reduction of acetonitrile with or without the addition of probases such as halobenzene, azobenzene, cyanomethyl triphenylphosphonium or arsonium cations and phenylsulfonyl acetonitrile (*9–11*) in the presence of a quaternary ammonium salt as a supporting electrolyte yields the corresponding cyanomethyl anion, a strong basic entity, with a p*K*a value of *ca.* 32 (*12*), capable of removing a weak acidic proton. In most cases, the generated anions are known to react once or several times with acetonitrile, leading to aminocrotonitrile, pyrimidine and triazine anions, which could also serve as EGBs (*13*, *14*). These anions can also react as nucleophilic entities upon subsequent addition to electrophiles, giving C- and N-functionalized products. The use of a magnesium rod as a sacrificial anode frequently leads to cyanomethyl electrogenerated species, which are stabilized as Grignard-type anions associated with the anodically generated magnesium cations. In a previous work, we established that in the case of acetonitrile as a solvent, the dimerization of the cyanomethyl anion occurred through a nucleophilic addition of the EGB to the nitrile group of the acetonitrile. The aminocrotonitrile anions led to ethyl 1-cyanoprop-1-en-2-ylcarbamodithioate as a by-product via the reaction with carbon disulfide and ethyl iodide during the synthesis of carbamodithioates (*15*).

Herein, we report the electrochemical synthesis of benzylic carbamodithioates (**2**) and (**2′**) and rhodanines (**3**), starting from various benzylic amines, carbon disulfide and bromoalkyl acid ester. These families of products may display a large spectrum of applications, such as antibacterial agents for the inhibition of RNA transcription for *Staphylococcus epidermidis* or *Staphylococcus aureus*, which are the major cause of nosocomial infections (*16*), reducing the activity of tyrosine phosphatase (PRL-3) enzyme which could be associated with colorectal cancer proliferation (*17*), and chelating agents for the coordination and detection of noble metals (*18*).

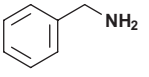
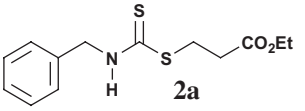
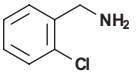
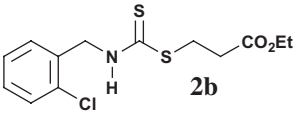
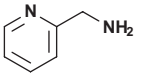
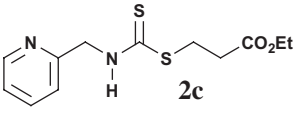
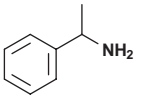
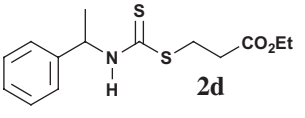
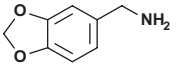
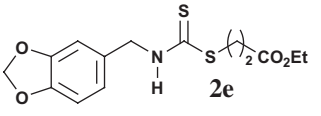
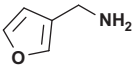
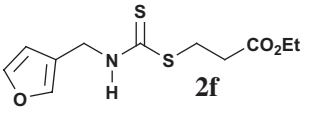
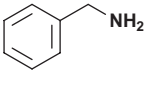
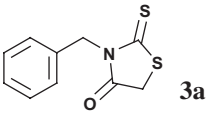
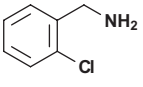
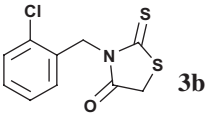
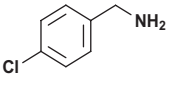
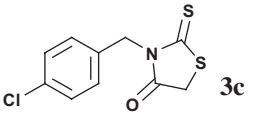
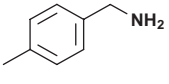
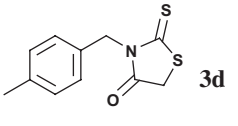
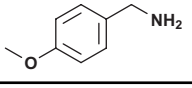
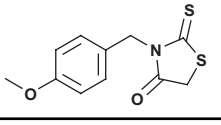


2. Results and discussion

Electrolysis of dry acetonitrile, under galvanostatic conditions, was conducted in an undivided electrochemical cell cooled at −20 °C, fitted with a magnesium rod as a sacrificial anode and a stainless steel grid cathode, maintained under an inert nitrogen atmosphere. When the desired amount of base was formed, the electrolysis of acetonitrile was stopped. The amount of EGB was calculated with respect to the quantity of amine to be used. At the end of the electrolysis, the amine was introduced, followed by the addition of carbon disulfide. The color of the solution turned to dark red immediately. Finally, the bromoalkyl acid ester was added, and the solution was allowed to reach room temperature and kept under continuous stirring overnight. Final work-up and column chromatography over silica gel afforded the products **2** and **3** (Table 1) in good yields (Scheme 1).

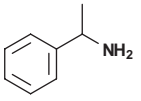
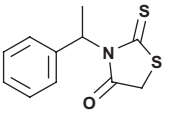
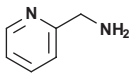
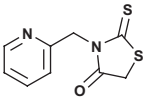
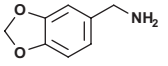
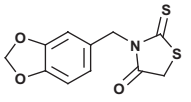
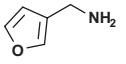
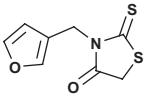
A stabilized dithiocarbamate intermediate was formed during the reaction of carbon disulfide and the amine. The EGB (cyanomethyl and aminocrotonitrile species) was essential to promote the reaction. The dithiocarbamate anion was probably stabilized by ion-pairing with magnesium cations generated during the oxidation of the sacrificial magnesium electrode. Alkylation of the intermediate with ethyl 3-bromopropionate acid ester gave only the acyclic dithiocarbamate acid ester (**2**); no cyclic products were formed, even if three to four equivalents of EGB were used with respect to the introduced amine. Instead, a complex mixture of products was obtained. In one case, the consumption of one equivalent of the EGB per mole of amine yielded acyclic intermediate

Table 1. Synthesized carbamodithioates (**2**) and rhodanines (**3**).

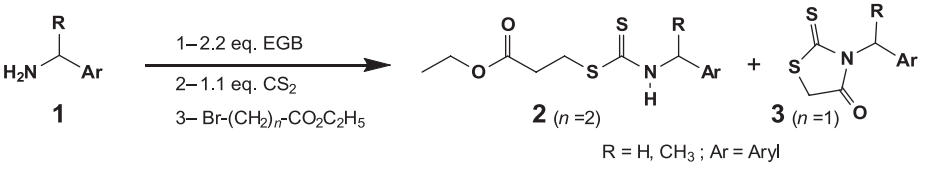
Entry	Starting amine	Electrophile	Product	Q^a	Yield[b] (%)
1		A	 **2a**	2.2	41
2		A	 **2b**	2.2	54
3		A	 **2c**	2.2	59
4		A	 **2d**	1.1	79
5		A	 **2e**	2.2	49
6		A	 **2f**	2.2	65
7		B	 **3a**	2.2	68
8		B	 **3b**	2.2	60
9		B	 **3c**	2.2	78
10		B	 **3d**	2.2	67
11		B	 **3e**	2.2	80

(*Continued*)

Table 1. Continued.

12		B	 **3f**	2.2	55
13		B	 **3g**	2.2	59
14		B	 **3h**	2.2	75
15		B	 **3i**	2.2	49

Notes: A, ethyl 2-bromopropionate; B, ethyl 2-bromoacetate. [a]The consumed quantity of electricity represents the number of faradays per mole of amine. [b]The yield was calculated in regard to the starting amine.



Scheme 1. EGB-promoted electrosynthesis of ring-opened and cyclic carbamodithioates 2 and 3.

carbamodithioates (**2′**) when a hindered amine was used (entry 12) and ethyl 2-bromoacetate acid ester was added as an alkylating agent. When the amount of base reached 2.2 equivalents of EGB, the intermediate (**2′**) readily underwent *in situ* ring closure to give product **3**. A series of products **2** and **3** were synthesized by applying the latter conditions, *i.e.* consumption of 2.2 faraday of electrons per mole of amine, to form the same amount of EGB, followed by a subsequent addition of amine, carbon disulfide and bromoalkyl acid ester (Table 1).

The improvement of the reaction yield could be probably attributed to two major factors: (i) the replacement of a divided electrochemical cell by an undivided cell allowed to avoid an important ohmic drop and thus permitted the application of higher current densities; (ii) the nature of the electrode material was also important. In fact, the oxidation of graphite carbon did not produce stabilizing cations for the electrogenerated anions/bases. It is noteworthy that when a small quantity of the same amine was used, the electrolysis time of acetonitrile was shortened and less basic species were re-protonated affording higher yields of compound **3a** (Tables 1 and 2).

The consumed amount of electrons, *i.e.* number of faradays per mole of amine being proportional to the number of mole of the EGB, affected the yield of the reaction. For this reason, benzylamine was chosen as model compound to study this influence. A standard procedure consists of the electrolysis of the acetonitrile by passing through the desired number of faradays per mole, and then benzylamine was introduced, followed half an hour later by carbon disulfide and finally ethyl 2-bromoacetate. The solution was stirred overnight and followed by a standard work-up to yield product **3a** (Table 2).

Table 2. Variation of the yield of **3a** as a function of the consumed number of faradays per mole of amine.

Entry	Q (faraday/mole)	Yield of **3a** (%)
1	0.5	67
2	1.0	76
3	1.5	82
4	1.8	84
5	2.0	86
6	2.5	88
7	3.0	90
8	4.0	94
9	5.0	96

From the obtained results, we noticed that the yield of the reaction increased with the amount of the used EGB, *i.e.* the number of faradays per mole. For an amount of the base equal to 2.0–2.5 equivalents with respect to benzylamine, the yield reached 86–88%, which was a good compromise between the reaction time and the consumed energy. In fact, when a five-fold excess of base was used per mole of amine, the yield of was only ameliorated by 8–10%.

3. Conclusion

When compared with classical synthetic methods, the present one using EGBs shows several advantages such as (i) no additional base required because of the *in situ* formation of the base, (ii) milder reaction conditions and use of cheap and readily available reagents, (iii) fair to very good yields, (iv) no hazardous chemicals and polluting by-products resulting from the addition of base or probase, (v) no sophisticated electrochemical instrumentation and cell needed, (vi) easy work-up procedure.

4. Experimental

Melting points were determined with an Electrothermal 9100 apparatus. ^{1}H NMR and ^{13}C NMR spectra were recorded using a Bruker Advance 250 or 300 MHz spectrometer in $CDCl_3$ with tetramethylsilane as an internal standard. Elemental analyses were performed by Microanalyse Service of the ICSN, Gif sur Yvette, Paris, France. All the products have been previously described (*19–24*).

4.1. *Electro-organic synthesis of ethyl 3-(benzylcarbamothioylthio)propanoate (2) and 3-benzyl-2-thioxothiazolidin-5-one (3)*

In a typical reaction, acetonitrile (90 ml) solution of tetrabutylammonium tetrafluoroborate (0.01 M) as a supporting electrolyte in an undivided cell fitted with a sacrificial magnesium rod as an anode and a stainless steel grid (20 cm^2) as a cathode was subjected to electrolysis at a constant current density ($I = 80$ mA/cm^2, 7.0 h, 2.2 faraday/mole with respect to the quantity of amine to be added). The cell was cooled to $-20\,^{\circ}$C by immersing it in Lauder refrigerating system. During the electrolysis, the system was maintained under inert atmosphere by continuous bubbling of argon. The electrolysis was stopped after the formation of 2.2 equivalents of cyanomethyl anion with respect to the amine. First, 10.0 mmol of the amine was introduced, and 1 h later, 2.2 equivalents of carbon disulfide were added, and the solution turned immediately from pale yellow to

dark red. For the second set of experiments summarized in Table 2, 5.0 mmol of benzylamine, 11.0 mmol of CS_2 and 11.0 mmol of ethyl 2-bromoacetate were used. After 1 h of stirring, 2.2 equivalents of bromoalkyl acid ester were added. The cooling bath was removed and the solution was allowed to reach room temperature and kept under continuous stirring overnight to ensure the tandem alkylation–cyclization reaction where it is possible. The excess of acetonitrile was removed in rotatory evaporator and the residue was diluted in 50 ml of water and extracted three times with 20 ml of diethyl ether. The organic layer was washed with 20 ml of water and dried over anhydrous magnesium sulfate. The solvent was removed and the residue was purified by column chromatography on silica gel 60. A mixture of ethyl acetate/hexane (3:7) was used as eluent. The resulting yellowish solid was filtered and recrystallized from chloroform. All the products are known and were characterized by ^{1}H NMR and ^{13}C NMR spectroscopy, melting point and, in some cases, elemental analysis.

4.1.1. *Ethyl 3-(benzylcarbamothioylthio)propanoate (**2a**) (19)*

Yield: 41%, m.p.: 152–153 °C; ^{1}H NMR (300 MHz, $CDCl_3$), δ (ppm): 1.28 (3H, t, $^3J_{H-H}$ = 6.2 Hz); 2.78 (2H, t, CH_2, $^3J_{H-H}$ = 7.5 Hz); 3.52 (2H, t, CH_2, $^3J_{H-H}$ = 7.4 Hz); 4.14 (2H, q, CH_2, $^3J_{H-H}$ = 6.2 Hz); 4.9 (2H, s, CH_2); 7.32–7.44 (5H, CH_{arm}); ^{13}C NMR (250 MHz, $CDCl_3$), δ (ppm): 14.2; 30.2; 34.3; 51.1; 60.9; 126.7; 127.4; 128; 128.2; 128.8; 136.3; 172.1; 197.4.

4.1.2. *Ethyl 3-(2-chlorobenzylcarbamothioylthio)propanoate (**2b**) (19)*

Yield: 54%, m.p.: 178–179 °C; ^{1}H NMR (300 MHz, $CDCl_3$), δ (ppm): 1.25 (3H, t, CH_3, $^3J_{H-H}$ = 7.1 Hz); 2.78 (2H, t, CH_2, $^3J_{H-H}$ = 6.7 Hz); 3.5 (2H, t, CH_2, $^3J_{H-H}$ = 6.7 Hz); 4.14 (2H, q, CH_2, $^3J_{H-H}$ = 7.2 Hz); 5.04 (2H, s, CH_2); 7.4 (4H, CH_{arm}); ^{13}C NMR (250 MHz, $CDCl_3$), δ (ppm): 30.3; 34.3; 48.6; 60.8; 127.1; 126.7; 127.9; 129.5; 130.7; 133.8; 171.9; 197.8.

4.1.3. *Ethyl 3-(pyridin-2-ylmethylcarbamothioylthio)propanoate (**2c**) (19)*

Yield: 43%, m.p.: 267–268 °C; ^{1}H NMR (300 MHz, $CDCl_3$), δ (ppm): 1.28 (3H, t, $^3J_{H-H}$ = 6.2 Hz); 2.78 (2H, t, CH_2, $^3J_{H-H}$ = 7.6 Hz); 3.52 (2H, t, CH_2, $^3J_{H-H}$ = 7.4 Hz); 4.14 (2H, q, CH_2, $^3J_{H-H}$ = 6.2 Hz); 4.9 (2H, s, CH_2); 8.1 (4H, CH_{arm}); ^{13}C NMR (250 MHz, $CDCl_3$), δ (ppm): 14.2; 30.2; 34.3; 51.1; 60.9; 126.7; 127.4; 128; 128.2; 128.8; 136.3; 172.1; 197.4.

4.1.4. *Ethyl 3-(1-phenylethylcarbamothioylthio)propanoate(**2d**) (19)*

Yield: 79%, m.p.: 87–88 °C; ^{1}H NMR (300 MHz, $CDCl_3$), δ (ppm): 1.24 (3H, t, $^3J_{H-H}$ = 6.1 Hz); 1.52 (2H, d, CH_3, $^3J_{H-H}$ = 7.0 Hz); 2.74 (2H, t, CH_2, $^3J_{H-H}$ = 7.1 Hz); 3.28 (2H, t, CH_2, $^3J_{H-H}$ = 6.9 Hz); 4.15 (2H, q, CH_2, $^3J_{H-H}$ = 7.0 Hz); 5.47 (1H, q, CH, $^3J_{H-H}$ = 6.8 Hz); 7.01–7.28 (5H, CH_{arm}); 6.29 (1H, br, NH); ^{13}C NMR (75 MHz, $CDCl_3$), δ (ppm): 14.5; 20.5; 31.7; 32.2; 53.6; 61.7; 128.1; 129.0; 129.9; 142.1; 172.0; 205.2; Elemental analysis (found/calculated): C: 56.61/56.53; H: 6.40/6.44; N: 4.75/4.71.

4.1.5. *Ethyl 3-(furan-2-ylmethylcarbamothioylthio)propanoate (**2e**) (19)*

Yield: 49%, m.p.: 148–149 °C; ^{1}H NMR (300 MHz, $CDCl_3$), δ (ppm): 1.27 (3H, t, CH_3, $^3J_{H-H}$ = 7.3 Hz); 2.78 (2H, t, CH_2, $^3J_{H-H}$ = 6.6 Hz); 3.56 (2H, t, CH_2, $^3J_{H-H}$ = 6.5 Hz); 4.16 (2H, q, CH_2, $^3J_{H-H}$ = 7.2 Hz); 6.98 (3H, CH_{arm}); ^{13}C NMR (300 MHz, $CDCl_3$) : δ (ppm) 14.2; 30.3; 34.7; 43.8; 60.9; 108.8; 110.6; 143.0; 149.2; 172.0; 197.4.

4.1.6. *Ethyl 3-(benzo[d][1,3]dioxol-5-ylmethylcarbamothioylthio)propanoate (**2f**) (19)*

Yield: 65%; m.p.: 155–156 °C; ^{1}H NMR (300 MHz, $CDCl_3$), δ (ppm): 1.28 (3H, t, CH_3, $^3J_{H-H} = 7.2$ Hz); 2.78 (2H, t, CH_2, $^3J_{H-H} = 6.7$ Hz); 3.58 (2H, t, CH_2, $^3J_{H-H} = 6.7$ Hz); 4.18 (2H, q, CH_2, $^3J_{H-H} = 7.2$ Hz); 5.92 (2H, s, CH_2); 6.78 (3H, CH_{arm} ^{13}C NMR (300 MHz, $CDCl_3$): δ (ppm) 14.1; 34.3; 37.8; 50.2; 61.3; 101.4; 108.5; 121.6; 129.9; 148.3; 171.9; 197.1.

4.1.7. *3-Benzyl-2-thioxothiazolidin-4-one (**3a**) (20)*

Yield: 68%, m.p.: 80–81 °C; ^{1}H NMR (250 MHz, $CDCl_3$), δ (ppm): 3.92 (2H, s, CH_2); 5.15 (2H, s, CH_2); 7.34 (5H, CH_{arm}); ^{13}C NMR (250 MHz, $CDCl_3$), δ (ppm): 35.5; 47.9; 128.5; 128.4; 129.1; 135.0; 174.7; 201.3 CI-MS: 224; HRMS: 224.0194; Elemental analysis (found/calculated): C: 54.28/54.8; H: 3.97/4.03; N: 6.19/6.27; S: 28.54/28.69.

4.1.8. *3-(2-Chlorobenzyl)-2-thioxothiazolidin-4-one (**3b**) (21)*

Yield: 60%, m.p.: 73–74 °C; ^{1}H NMR (250 MHz, $CDCl_3$), δ (ppm): 4.08 (2H, s, CH_2); 5.3 (2H,s, CH_2); 7.27 (4H, CH_{arm}); ^{13}C NMR (250 MHz, $CDCl_3$), δ (ppm): 35.5; 45.4; 126.8; 126.9; 128.8; 129.8; 131.6; 135; 173.4; 200.5.

4.1.9. *3-(4-Chlorobenzyl)-2-thioxothiazolidin-4-one (**3c**) (21)*

Yield: 78%, m.p.: 126–127 °C; ^{1}H NMR (300 MHz, $CDCl_3$), δ (ppm): 3.95 (2H, s, CH_2); 5.11 (2H, s, CH_2); 7.29 (4H, CH_{arm}); ^{13}C NMR (300 MHz, $CDCl_3$), δ (ppm): 35.4; 46.9; 128.2; 130.5; 133.1; 134.1; 173.7; 200.9.

4.1.10. *3-(4-Methylbenzyl)-2-thioxothiazolidin-4-one (**3d**) (21)*

Yield: 67%, m.p.: 71–72 °C; ^{1}H NMR (250 MHz, $CDCl_3$), δ (ppm): 2.31 (3H, s, CH_3); 3.97 (2H, s, CH_2); 5.12 (2H, s, CH_2); 7.21 (4H, CH_{arm}); ^{13}C NMR (300 MHz, $CDCl_3$), δ (ppm): 21.3; 38.6; 45.6; 128.1; 128.8; 133.5; 136.4; 171.2; 202.3.

4.1.11. *3-(4-Methoxybenzyl)-2-thioxothiazolidin-4-one (**3e**) (21)*

Yield: 80%, m.p.: 98–99 °C; ^{1}H NMR (300 MHz, $CDCl_3$), δ (ppm): 3.78 (2H, s, CH_2); 3.96 (3H, s, CH_3); 5.1 (2H, s, CH_2); 7.18 (4H, CH_{arm}); ^{13}C NMR (300 MHz, $CDCl_3$), δ (ppm): 35.4; 47.1; 55.2; 113.8; 126.9; 130.8; 159.5; 173.9; 201.1.

4.1.12. *3-(1-Phenylethyl)-2-thioxothiazolidin-4-one (**3f**) (22)*

Yield: 55%, m.p.: 109–110 °C; ^{1}H NMR (250 MHz, $CDCl_3$), δ (ppm) 1.83 (3H, d, $^3J_{H-H} = 7.2$ Hz); 3.70 (2H, s); 6.37 (1H, d, CH, $^3J_{H-H} = 7.1$ Hz); 7.32 (5H, CH_{arm}); ^{13}C NMR (250 MHz, $CDCl_3$), δ (ppm): 15; 34; 55.1; 127.5; 127.8; 128.1; 138; 173.4; 202.1. Elemental analysis (found/calculated): C: 55.72/55.67; H: 4.61/4.67; N: 5.94/5.90.

4.1.13. *3-(Pyridin-2-ylmethyl)-2-thioxothiazalidin-4-one (**3g**) (23)*

Yield: 59%, m.p.: 114–115 °C; ^{1}H NMR (300 MHz, $CDCl_3$), δ (ppm): 4.12 (2H, s, CH_2); 5.29 (2H, s, CH_2); 7.87 (4H, CH_{arm}); ^{13}C NMR (300 MHz, $CDCl_3$), δ (ppm): 38.6; 50.2; 120.9; 124.1; 139.6; 148.6; 156.1; 171.2; 202.3.

4.1.14. *3-(Benzo[d][1,3]dioxol-5-ylmethyl)-2-thioxothiazolidin-4-one (**3h**) (24)*

Yield: 75%, m.p.: 104–105 °C; ^{1}H NMR (300 MHz, $CDCl_3$), δ (ppm): 3.97 (2H, s, CH_2); 5.09 (2H, s, CH_2); 5.94 (2H, s, CH_2); 6.95 (3H, CH_{arm}); ^{13}C NMR (300 MHz, $CDCl_3$), δ (ppm): 38.6; 45.9; 101.2; 107.7; 109.2; 122.8; 134.9; 145; 146.8; 171.2; 202.3.

4.1.15. *3-(Furan-2-ylmethyl)-2-thioxothiazolidin-4-one (**3i**) (21)*

Yield: 49%, m.p.: 118–120 °C; ^{1}H NMR (300 MHz, $CDCl_3$), δ (ppm): 3.88 (2H, s, CH_2); 4.92 (2H, s, CH_2); 5.814 (2H, s, CH_2); 6.85 (3H, CH_{arm}); ^{13}C NMR (300 MHz, $CDCl_3$), δ (ppm): 37.3; 44.8; 100.6; 106.4; 108.4; 120.3; 133.6; 144.9; 147.3; 173.7; 204.7.

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References

(1) Fotouhi, L.; Heravi, M.M.; Fatehi, A.; Bakhtiari, K. *Tetrahedron Lett.* **2007,** *48*, 5379–5381.
(2) Makarem, S.; Mohammadi, A.A.; Fakhari, A.R. *Tetrahedron Lett.* **2008,** *49*, 7194–7196.
(3) Feroci, M.; Casadei, M.A.; Orsini, M.; Palombi, L.; Inesi, A. *J. Org. Chem.* **2003,** *68*, 1548–1551.
(4) Verdecchia, M.; Feroci, M.; Palombi, L.; Rossi, L. *J. Org. Chem.* **2002,** *67*, 8287–8289.
(5) Feroci, M.; Orsini, M.; Sotgiu, G.; Rossi, L.; Inesi, A. *J. Org. Chem.* **2005,** *70*, 7795–7798.
(6) Rossi, L.; Feroci, M.; Verdecchia, M.; Inesi, A. *Lett. Org. Chem.* **2005,** *2*, 731–733.
(7) Utley, J.H.P. In *Topics in Current Chemistry;* Steckhan, E., Ed.; Electrochemistry I, Vol. 142; Springer-Verlag: Berlin–Heidelberg, 1987; pp 131–165.
(8) Nielsen, M.F. In *Encyclopedia of Electrochemistry;* Bard, A.J., Stratmann M., Schäefer, H.J., Eds.; Organic Electrochemistry, Vol. 8; Wiley-VCH: Weinheim, 2004; pp 451–488.
(9) Boto, K.G.; Thomas, F.G. *Aust. J. Chem.* **1973,** *26*, 1251–1258.
(10) Shono, T.; Mitani, M. *J. Am. Chem. Soc.* **1968,** *90*, 2728–2729.
(11) Iversen, P.E.; Lund, H. *Tetrahedron Lett.* **1969,** *10*, 3523–3524.
(12) Matthews, W.S.; Bares, J.E.; Bartmess, J.E.; Bordwell, F.G.; Cornforth, F.J.; Drucker, G.E.; Margolin, Z.; McCallum, R.J.; McCollum, G.J.; Vanier, N.R. *J. Am. Chem. Soc.* **1975,** *97*, 7006–7014.
(13) Foley, J. K.; Korzeniewski, C.; Pons, S. *Can. J. Chem.* **1988,** *66*, 201–206.
(14) Otero, M.D.; Batanero, B.; Barba, F. *Tetrahedron Lett.* **2005,** *46*, 8681–8683.
(15) Toumi, M.; Raouafi, N.; Boujlel, K.; Tapsoba, I.; Picard, J.-P.; Bordeau, M. *Phosphorus, Sulfur, Silicon Relat. Elem.* **2007,** *182*, 2477–2490.
(16) Villain-Guillot, P.; Gualtieri, M.; Bastide, L.; Roquet, F.; Martinez, J.; Amblard, M.; Pugniere, M.; Leonetti, J.P. *J. Med. Chem.* **2007,** *50*, 4195–4204.
(17) Ahn, J.H.; Kim, S.J.; Park, W.S.; Cho, S.Y.; Ha, J.D.; Kim, S.S.; Kang, S.K.; Jeong, D.G.; Jung, S.-K.; Lee, S.-H.; Kim, H.M.; Park, S.K.; Lee, K.H.; Lee, C.W.; Ryu, S.E.; Choi, J.K. *Bioorg. Med. Chem. Lett.* **2006,** *16*, 2996–2999.
(18) Savvin, S.B.; Gur'eva, R.F. *Talanta* **1987,** *34*, 87–101.
(19) Fischer, U.; Kaiser, A. German patent DE 271762, Hoffman-LaRoche, 1977.
(20) Sing, W.T.; Lee, C.L.; Yeo, S.L.; Lim, S.P.; Sim, M.M. *Bioorg. Med. Chem. Lett.* **2001,** *11*, 91–94.
(21) Brown, F.C.; Bradsher, C.K.; Morgan, E.C.; Tetenbaum, M.; Wilder, P. *J. Am. Chem. Soc.* **1956,** *78*, 384–388.
(22) Kallenberg, S., *Chem. Ber.* **1919,** *52*, 2057–2071.
(23) Stephen, W.I.; Townshend, A. *J. Chem. Soc.* **1965,** 5127–5128.
(24) Burton, W.H.; Budde, W.L.; Cheng, C.-C. *J. Med. Chem.* **1970,** *13*, 1009–1012.