Annulation of eight-to ten-membered oxaza rings to the benzo[b]thiophene system by intramolecular nucleophilic displacement

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Abstract
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Annulation of Eight- to Ten-membered Oxaza Rings to the Benzo[b]thiophene System via Intramolecular Nucleophilic Displacement

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Concise synthetic routes to 2H-benzo[b]thieno[3,2-b][1,5]oxazocin-6(3H)-one, and the new benzo[b]thieno[3,2-b][1,5]oxazonin-7(2H)-one and 2H-benzo[b]thieno[3,2-b][1,5]oxazecin-8(3H)-one systems, have been developed based on intramolecular nucleophilic displacement in the key ring forming step.

Introduction

Although much progress has been made in the synthesis of N,O-containing fused medium ring systems, many opportunities for new systems remain.1 Such compounds are of inherent chemical interest and are also of significance as novel scaffolds for pharmaceutical development,2-4 particularly 8-membered systems.5-9

As part of some structure-pharmacological activity studies on benzo[b]thiophene-based potentiators of the action of serotonin, we required systems in which amide functionality at the 2-position of the benzo[b]thiophene was incorporated in a semi-flexible ring system, while retaining an electronegative group at the 3-position. Fused medium sized [1,5]-oxaza systems 1 (Scheme 1) were thus considered as synthetic targets.

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N-Substituted 3-hydroxy derivatives of the fused eight-membered ring system 1a are known (although not the parent lactam 1a itself), and were made by lactamisation in the final medium ring forming step.[10] Lactam formation also featured in approaches to the recently described 10-methoxy and 10-benzyloxy derivatives of 1a which had some inhibitory activity against protein kinase D, an enzyme involved in a number of important cellular processes.[11] The fused nine- and ten-membered ring systems 1b and 1c respectively have not been described previously, although representatives with isomeric [1,4]- and [1,5]-oxaza fused skeletons have been reported.[12] It is of interest to note that the fused 7-membered ring analogue (1, n=1) and bio-active derivatives (cell adhesion and HIV inhibitors) have been reported and were accessed by lactamisation at the final step.[13,14]

Our new ring construction approach to the systems of type (1a-c) involved an alternative and versatile O-CH₂ bond formation by nucleophilic displacement at saturated carbon in the final cyclisation step. The results of this work are presented in this paper.

Results and Discussion

The essential precursors for the ultimate cyclisation reaction were the bromo amides 7a-c, which could be accessed via the alcohols 6b, 6e and 6f in a series of steps from the readily available acid chloride 2, prepared in turn from the reaction of cinnamic acid with thionyl chloride in the presence of pyridine[15] (Scheme 1). Substitution of the 3-chloro group in acid chlorides of type 2 is readily achieved by a nucleophilic addition/elimination sequence.[16] Thus reaction of 2 with sodium methoxide gave the 3-methoxy substituted methyl ester 3,[17] from which the corresponding acid 4 [17] could be obtained by standard alkaline hydrolysis. Amide derivatisation was then achieved via dicyclohexylcarbodiimide-mediated reaction of methyl β-alinate 5 (Y=COOCH₃, n = 2) with the acid 4 in the case of 6a, and with the commercially available acetal 5 (Y=CH(OCH₂CH₃)₂, n=3) or the alcohol 5 (Y=CH₂OH, n= 4), to afford 6c and 6f respectively. These transformations proceeded in good yield and structural assignments followed from the spectral data and methods of preparation.
With the procedure for the n=2 series further terminal functional group manipulation via hydride reduction of 6a to the primary alcohol 6b was necessary, while in the n=3 series, the acetal intermediate 6c was hydrolysed to the aldehyde 6d and then reduced to the required alcohol precursor 6e. In the case of 6a an uncommon reduction of the ester functionality with sodium borohydride was involved leaving the amide group intact. There is some precedent for such reductions (see for example \cite{18,19}) and in this case there may be some increased susceptibility of the ester carbonyl group to hydride attack as a result of intramolecular H-bonding the amide N-H group. Reaction of the alcohols 6b, 6e and 6f with boron tribromide resulted in O-demethylation with a concomitant primary alcohol to bromide transformation to give the respective bromides 7a-c in good yields.

The key intramolecular nucleophilic displacement reaction to realise the fused medium ring derivatives 1a-c then proceeded smoothly on treatment of 7a-c in each case with sodium hydride in THF to generate the active 3-oxide nucleophile followed by bromide ion loss. Structural confirmations of the annulated eight- to ten-membered ring products rested on high resolution mass spectral data and the $^1$H- and $^{13}$C-NMR spectra. In the $^{13}$C NMR the presence of the lactam carbonyl group was consistent with signals in the region of $\delta$166-178. Stereochemically stable rotational isomers in the medium ring products are possible by analogy with the related bioisosteric naphthalene-ring fused oxaza systems \cite{7-9}, and some tentative evidence was seen for these in 1a-c on the basis of the NMR spectra.

Although somewhat more severe conditions were required to form the eight- and ten-membered fused lactams compared with the nine-membered congener, yields were still good. In all cases, delocalization of the negative charge on the 3-oxide through the 2,3-benzo[b]thiophene bond to the amide carbonyl group would presumably weaken the C=N resonance contribution to the amide and allow for rotation to the cisoid amide form. Suitable positioning of the CH$_2$-Br moiety would thus be realised for a subsequent favourable exo-tet intramolecular nucleophilic displacement process. In no case was evidence seen for competing macro ring formation (16-, 18- and 20-membered rings) through dimerisation, nor for any smaller ring products which could result from amide anion formation; the preferential formation of the oxide anion would be expected based on the likely greater acidity of the 3-OH group. An analogous ring formation strategy, but
involving chloride ion displacement by a phenoxide ion, was employed to access the benz-fused eight-membered ring derivative, 8-chloro-4,5-dihydro-2H-1,5-benzoxazocin-6(3H)-one. \(^{[20]}\)

![Chemical structure and reaction scheme showing the synthesis of the fused medium ring derivatives 1a - 1c.]

**Scheme 1.** Synthesis of the fused medium ring derivatives 1a - 1c.

**Conclusion**

A concise and efficient route based on O-CH\(_2\) bond formation in the final ring forming step allowed smooth access to benzo[b]thiophene-fused [1,5]-N,O containing medium ring systems. Extension of this methodology to prepare a range of heteroaromatic and aromatic ring fused, medium-sized oxaza heterocyclic systems should be feasible.
Experimental

Methods and Materials

All melting points (uncorrected) were determined on a Reichert hot stage apparatus. Infrared spectra (IR) were recorded on a Bio Rad Fourier Transform Infrared Spectrometer FTS-7 as mulls in nujol unless otherwise stated and the absorption bands are described as strong (s), medium (m) or weak (w).

$^1$H and $^{13}$C NMR spectra were determined at 399.9 MHz and 100.1 MHz, respectively, with a Varian Unity-400 spectrometer. All the spectra were measured in CDC$_3$ unless otherwise stated. Mass spectra (MS) were obtained using Vacuum General 12-12, Vacuum General Quattro and MAT-44 spectrometers by the direct insertion technique with an electron beam energy of 70 eV and a source temperature of 200°C. The peak intensities, in parentheses, are expressed as the percentage abundance. High resolution MS were run by Dr X. Song of the School of Chemistry, University of Sydney or Dr N. Davies, Central Science Laboratory, University of Tasmania. Elemental microanalyses of samples were performed by the Queensland Microanalytical Service, Department of Chemistry, University of Queensland. Analytical t.l.c. was performed on Merck silica gel F$_{254}$ silica on aluminium sheets. Column chromatography was performed under medium pressure using Merck silica gel unless otherwise indicated. All solvent ratios are v/v.

All extracts were dried over anhydrous sodium sulfate prior to being evaporated under reduced pressure. THF was freshly distilled from sodium wire in the presence of benzophenone under nitrogen. Other commercial chemicals and reagents were used as received.

Synthesis

3-Chloro-benzo[b]thiophene-2-carbonyl chloride 2

Thionyl chloride (11.1 mL, 90 mmol) was added to a solution of (E)-cinnamic acid (4.5 g, 30 mmol) in toluene (50 mL) containing pyridine (0.5 mL, 3 mmol), and, after addition, the mixture was heated at reflux for 60 h. The reaction mixture was filtered and the filtrate was concentrated under vacuum. The residue was chromatographed on a short
column (2% ethyl acetate/hexane) to give a crude product, which was recrystallized from 
CH₂Cl₂ to afford the acid chloride 2 (4.5 g, 64%) as yellow needles, mp 114-116 °C 

Methyl 3-methoxy-benzo[b]thiophene-2-carboxylate 3

Methanol (0.9 ml, 22.2 mmol) was added dropwise to a suspension of sodium hydride 
(860 mg, 60% content, 21.5 mmol) in THF (15 mL) at room temperature under nitrogen. 
After stirring for 1 h, a solution of the acid chloride 2 (1.7 g, 7.4 mmol) in THF (15 ml) 
was added dropwise. The reaction mixture was heated at reflux overnight and then 
allowed to cool to room temperature before being quenched with a saturated NH₄Cl 
solution. The mixture was extracted with ethyl acetate (3 x 30 mL). The combined 
extracts were washed with brine (20 mL), and dried. Removal of the solvent afforded the 
ester 3 (1.46 g, 89%) as colourless crystals, mp 110-112 °C (Lit.[17] mp 64.5-65.5 °C). 
ν max/cm⁻¹ 1718 (s, C=O), 1593 (m). δH 8.08 (m, 1H), 7.92 (m, 1H), 7.60 (m, 2H), 4.10 (s, 
3H), 3.9 (s, 3H). m/z (EI+) 222 (100%, M⁺), 207 (10), 191 (60), 176 (45).

3-Methoxy-benzo[b]thiophene-2-carboxylic acid 4

A mixture of the ester 3 (1 g, 4.5 mmol) and sodium hydroxide (1 M, 5 mL) in 
methanol (25 mL) was stirred overnight. The solvent was removed and the residue 
dissolved in water (5 mL) and neutralized with hydrochloric acid (1 M) to give a 
precipitate. Filtration under vacuum afforded the acid 4 (0.9 g, 97%) as colourless 
crystals, mp 250 °C (dec.) (Lit.[17] mp 176-177 °C). ν max/cm⁻¹ 1686 (m, C=O). 
δH 8.08 (m, 1H), 7.92 (m, 1H), 7.60 (m, 2H), 4.10 (s, 3H). m/z (EI+) 208 (M⁺, 97), 164 
(15), 149 (40).

N-(3-Methoxy-benzo[b]thien-2-oyl)-β-alanine methyl ester 6a

A solution of β-alanine methyl ester (5, Y=COOCH₃, n=2; 150 mg, 1.4 mmol) in DMF 
(? mL) was added to a solution of the acid 4 (208 mg, 1 mmol), 1,3-
dicyclohexylcarbodiimide (206 mg, 1 mmol) and 1-hydroxybenzotriazole (150 mg, 1.1 
mmol) in DMF (10 mL). The reaction mixture was stirred overnight. The solvent was 
removed under vacuum and the residue was column chromatographed (20%, then 40%
ethyl acetate/hexane) to give the ester 6a (230 mg, 79%) as colourless crystals, m.p. 61-62 °C. ν_max/cm⁻¹ (film) 3387 (m, NH), 1732 (s, COOCH₃), 1641 (s, ArCONH), 1535 (s). δ_H 8.10 (br.s, 1H), 7.82-7.80 (m, 2H), 7.43-7.39 (m, 2H), 4.10 (s, 3H), 3.75 (dt, J 6.0, 6.8, 2H), 3.72 (s, 3H), 2.68 (t, J 6.0, 2H). δ_C 172.9, 161.6, 150.5, 137.8, 132.4, 126.6, 124.3, 123.6, 123.5, 122.0, 61.9, 51.7, 48.8, 34.8. m/z (ESI+) 316 (M+Na+, 100), 294 (MH⁺, 10). m/z (HRMS; EI+) M+•. Calc. for C₁₄H₁₅NO₄S: 293.0722, found 293.0728.

N-(3'-Hydroxypropyl)-3-methoxy-benzo[b]thiophene-2-carboxamide 6b

An excess of sodium borohydride (20 mg, 0.8 mmol) was added to a solution of the methyl ester 6a (140 mg, 0.48 mmol) in ethanol (5 ml) and the mixture was stirred overnight. A saturated ammonium chloride solution was added and the aqueous mixture was extracted with ethyl acetate (3x10 ml). The extract was washed with brine (10 ml), dried and evaporated to afford a crude product, which was chromatographed (60% ethyl acetate/hexane) to yield the alcohol 6b (125 mg, 98%) as colourless crystals, mp 64-66°C. ν_max/cm⁻¹ (film) 3379 (s, broad, OH, NH), 3060 (w), 2878 (w). 1626 (s, C=O), 1542 (s) cm⁻¹. δ_H 7.84-7.80 (m, 3H), 7.46-7.41(m, 2H), 4.13 (s, 3H), 3.74 (t, J 5.6, 2H), 3.67 (dt, J₁ 6.4, J₂ 6.0, 2H), 1.85-1.82 (m, 2H). δ_C 162.8, 150.7, 137.8, 132.3, 126.7, 124.4, 123.5, 122.9, 122.0, 61.9, 59.5, 36.5, 32.1. m/z (ESI+) 266 (MH+, 100). m/z (HRMS; EI+) M+•. Calc. for C₁₃H₁₅NO₃S: 265.0773, found 265.0776.

N-(3'-Bromopropyl)-3-hydroxy-benzo[b]thiophene-2-carboxamide 7a

An excess of boron tribromide (0.25 mL) was added dropwise to a solution of the alcohol 6b (100 mg, 0.38 mmol) in CH₂Cl₂ (5 mL) at -78°C under nitrogen. The dry-ice bath was then removed and the reaction mixture stirred overnight. The reaction was quenched with water and the reaction mixture extracted with CH₂Cl₂ (3 x15 mL). The combined extracts were washed with brine (10 ml), dried and evaporated. Column chromatography of the residue (60% ethyl acetate/hexane) afforded the bromo derivative 7a (80 mg, 69%) as a white powder, mp 135-136 °C. ν_max/cm⁻¹ 3349 (w, NH), 1611 (m, C=O). δ_H 7.94 (d, J 8.0, 1H), 7.71 (d, J 8.0, 1H), 7.48 (dt, J₁ 1.2, J₂ 8.0, 1H), 7.42 (dt, J₁ 1.2, J₂ 8.0, 1H), 5.78 (br.s, 1H), 3.63 (dt, J₁ 6.4, J₂ 6.4, 2H), 2.21 (quintuplet, J 6.4, 2H). δ_C 167.1, 158.9, 136.2, 131.2, 128.5, 124.7, 123.0, 122.9,
4,5-Dihydro-2H-benzo[b]thieno[3,2-b][1,5]oxazocin-6(3H)-one 1a

Sodium hydride (10 mg, 0.4 mmol) was added to a solution of the bromide 7a (30 mg, 0.1 mmol) in THF (10 ml) under nitrogen. After stirring for 2 h, no reaction was observed by t.l.c. analysis (20% ethyl acetate/hexane). The reaction mixture was then heated at reflux for 2 h and quenched with water. The mixture was extracted with ethyl acetate (3 x 15 ml) and the combined extracts were washed with brine (10 ml), and dried. The solvent was evaporated to furnish a crude product, which was subjected to column chromatography (methanol: ethyl acetate:hexane 10:80:100) to give the cyclized compound 1a (15 mg, 68%) as a yellow powder, mp 196-197°C. ν max/cm⁻¹ 1626 (s, C=O). δ H 7.98-7.94 (m, 1H), 7.62-7.59 (m, 1H), 7.42 (dt, J 1 1.2, J 2 8.0, 1H), 7.28 (dt, J 1 1.2, J 2 8.0, 1H), 4.49-4.40 (m, 2H), 3.60-3.56 (m, 2H), 2.22-2.16 (m, 2H). δ C 178.5, 162.8, 140.6, 134.7, 129.6, 124.2, 123.5, 123.3, 90.0, 66.3, 37.5, 21.2. m/z (EI+) 233 (M+•, 55). m/z (HRMS; EI+) M+•. Calc. for C₁₂H₁₁NO₂S: 233.0511, found 233.0479. Anal. Calc. for C₁₂H₁₁NO₂S.H₂O: C 57.36, H 5.21, N 5.57. Found: C 57.59, H 4.66, N 5.67 %.

N-(3'-Methoxy-benzo[b]thien-2'-oyl)-4-aminobutanal 6d

A mixture of the acid 4 (208 mg, 1 mmol), 1,3-dicyclohexylcarbodiimide (206 mg, 1 mmol), 1-hydroxybenzotriazole (150 mg, 1.1 mmol) and 4-aminobutanal diethyl acetal 5 (Y=CH(OCH₂CH₃)₂, n=3; 0.3 ml, 1.74 mmol) in THF (15 mL) was stirred overnight. The reaction was quenched with water and the aqueous mixture extracted with ethyl acetate (3 x 15 mL). The combined extracts were washed with brine and dried. Removal of the solvent gave a residue, which was chromatographed (20% ethyl acetate/hexane) to give the partially characterised acetal intermediate 6c (300 mg, 85%) as colourless crystals, mp 110-111°C. ν max/cm⁻¹ 3387 (m, NH), 3065 (w), 1648 (s), 1534. δ H 7.80-7.78 (m, 2H), 7.54 (br.s, 1H), 7.43-7.40 (m, 2H), 4.53 (t, J 4.8 Hz, 1H), 4.10 (s, 3H), 3.65 (q, J 7.2, 4H),
3.55-3.48 (m, 4H), 1.74-1.72 (m, 2H), 1.21 (t, J 7.2, 6H). m/z (EI) 322 (M+• - Et, <1), 305 (3), 259 (20), 224 (30), 191(100), 176 (60). m/z (HRMS; EI+) M+•. 351.1489. 

C_{18}H_{25}NO_{4}S requires 351.1504. The acetal 6c (70 mg, 0.2 mmol) in acetone (10 ml) was then treated with a few drops of 1M hydrochloric acid at room temperature and stirred overnight. The solvent was removed and the residue was chromatographed (40% ethyl acetate/hexane) to give the aldehyde 6d (55 mg, 100%) as an oil.

ν_{max}/cm^{-1} 3387 (s, NH), 3060 (w), 1725 (s, CHO), 1641 (s, ArCONH), 1527 (s). δ_{H} 9.80 (t, J 0.8 , 1H), 7.82-7.80 (m, 2H), 7.60 (br.s, 1H), 7.43-7.40 (m, 2H), 4.10 (s, 3H), 3.50 (dt, J1 7.2 , J2 6.8, 2H), 2.60 (t, J 6.8, 2H), 2.02 (t, J 6.8, 2H), 1.98 (t, J 6.8, 2H). δ_{C} 201.6, 162.1, 150.4, 137.9, 132.4, 126.7, 124.5, 123.7, 122.1, 108.3, 61.97, 41.4, 38.9, 29.7. m/z (EI) 277 (M+•, 8), 249 (5), 191 (100). m/z (HRMS, EI+) M+• 277.0769. C_{14}H_{15}NO_{3}S requires 277.0773.

N-(4’-Hydroxybutyl)-3-methoxy-benzo[b]thiophene)-2-carboxamide 6e

An excess of sodium borohydride (20 mg, 0.8 mmol) was added to a solution of the aldehyde 6d (55 mg, 0.2 mmol) in ethanol (10 mL) and the mixture was allowed to stir overnight. The reaction was quenched with a saturated NH_{4}Cl solution and the mixture extracted with ethyl acetate (3x10 mL). The combined extracts were washed with brine (10 mL) and dried. Removal of the solvent gave the alcohol 6e (55 mg, 100%) as colourless crystals, mp 139-140°C. ν_{max}/cm^{-1} (film) 3243 (s, broad, OH), 1641 (s, C=O), 1535 (s). δ_{H} 7.82 (dd, J1 2, J2 6.8, 2H), 7.59 (br.s, 1H), 7.42-7.40 (m, 2H), 4.10, (s, 3H), 3.74 (t, J 6.0, 2H), 3.55 (dt, J1 6.8, J2 6.4, 2H), 1.73-1.70 (m, 4H). δ_{C} 162.0, 151.0, 139.1, 132.5, 126.7, 124.5, 124.0, 123.7, 122.0, 62.3, 61.9, 39.0, 30.1, 26.50. m/z (ESI+) 280 (MH+, 100), 191 (10). m/z (HRMS; EI+) M+• 279.0929. C_{14}H_{17}NO_{3}S requires 279.0929.

N-(4’-Bromobutyl)-3-hydroxy-benzo[b]thiophene-2-carboxamide 7b

Boron tribromide (0.2 ml) was added dropwise to a solution of the alcohol 6e (100 mg, 0.36 mmol) in CH_{2}Cl_{2} (10 mL) at -78°C under nitrogen. The dry ice bath was then removed and the reaction mixture stirred overnight. The reaction was quenched with water and the mixture extracted with CH_{2}Cl_{2} (3x10 mL). The combined extracts were
washed with brine (10 mL) and dried. Chromatography of the residue (10% ethyl acetate/hexane) afforded the bromide 7b (105 mg, 90%) as a grey powder, mp 87-88°C. ν max/cm⁻¹ 3354 (w, NH), 1626 (m, C=O), 1586 (s). δ H 7.94 (dd, J₁ 0.8 , J₂ 8.0 , 1H), 7.72 (dd, J₁ 0.8 , J₂ 8.0 , 1H), 7.49 (dt, J₁ 1.2 , J₂ 8.0 , 1H), 7.42 (dt, J₁ 1.2 , J₂ 8.0 , 1H), 5.60 (br.s, 1H), 3.5 (dt, J₁ 7.2 , J₂ 6.8 , 2H), 3.47 (t, J 6.4, 2H), 1.99-1.95 (m, 2H), 1.85-1.81 (m, 2H). δ C 166.9, 158.9, 136.1, 131.2, 128.5, 124.7, 122.9, 102.5, 38.6, 33.1, 29.8, 28.3. m/z (EI+) 327, 329 (M⁺, 15). m/z (HRMS; EI+) M⁺ 326.9926. C₁₃H₁₄⁷⁹BrNO₂S requires 326.9929.

3,4,5,6-Tetrahydro-benzo[b]thieno[3,2-b][1,5]oxazonin-7(2H)-one 1b

Sodium hydride (10 mg, 0.4 mmol) was added to a solution of the bromide 7b (40 mg, 0.12 mmol) in THF (20 mL) under nitrogen. After stirring overnight, water was added to stop the reaction. The reaction mixture was extracted with ethyl acetate (3x15 mL). The extracts were washed with brine (10 mL), and dried. The solvent was evaporated to furnish, after column chromatography (15% ethyl acetate/hexane) of the residue, the cyclized compound 1b (28 mg, 70%) as colourless crystals, mp 95-96°C. ν max/cm⁻¹ 1621 (w, C=O), 1565 (s). δ H 7.99-7.96 (m, 1H), 7.75-7.73 (m, 1H), 7.48 (dt, J₁ 1.2 , J₂ 8.0, 1H), 7.41 (dt, J₁ 1.2 , J₂ 8.0 , 1H), 3.84-3.80 (m, 4H), 2.01-1.98 (m, 4H). δ C 166.6, 160.9, 137.9, 130.8, 128.1, 124.3, 122.8, 122.4, 101.6, 76.6, 47.0 (C3,4,5). m/z (EI+) 247 (M•+, 69). m/z (HRMS; EI+) M•• 247.0670. C₁₃H₁₃NO₂S requires 247.0667. Anal. Calc. for C₁₃H₁₃NO₂S: C 63.14, H 5.30, N 5.66. Found: C 63.55, H 5.80, N 5.19 %.

N-(5'-Hydroxypentyl)-3-methoxy-benzo[b]thiophene-2-carboxamide 6f

A mixture of the acid 4 (208 mg, 1 mmol), 1,3-dicyclohexylcarbodiimide (206 mg, 1 mmol), 1-hydroxybenzotriazole (150 mg, 1.1 mmol) and 5-aminopentan-l-ol in DMF (10 mL) was stirred overnight. The solvent was removed under high vacuum, and the residue was chromatographed (30% ethyl acetate/hexane) to afford the alcohol 6f (240 mg, 80%) as colourless crystals, mp 68-69°C. ν max/cm⁻¹ (film) 3463 (m, OH), 3387 (m, NH), 1634 (s, C=O), 1535 (s). δ δ T 7.83-7.80 (m, 2H), 7.53 (br.s, 1H), 7.42-7.39 (m, 2H), 4.1 (s, 3H), 3.67 (t, J 6.4, 2H), 3.50 (dt, J₁ 7.2 , J₂ 6.8 , 2H), 1.76 (br.s, 1H), 1.66-1.68 (m, 4H), 1.52-1.49 (m, 2H). δ C 161.8, 150.0, 137.7, 132.4, 126.6, 124.4, 123.6, 121.9, 124.2, 62.5,
61.9, 39.3, 32.3, 29.6, 23.1. \( m/z \) (ESI-) 292 (M-1, 65); (ESI+) 316 (MNa+, 100), 294 (MH+, 22). \( m/z \) (HRMS; EI+) M+• 293.1090. \( C_{15}H_{19}NO_3S \) requires 293.1086.

\( N-(5'-Bromopenty1)-3-hydroxy-benzo[b]thiophene-2-carboxamide 7c \)

An excess of boron tribromide (0.2 mL) was added dropwise to a solution of the alcohol \( 6f \) (100 mg, 0.34 mmol) in \( CH_2Cl_2 \) (10 mL) at -78°C under nitrogen. After addition, the dry ice bath was removed and the reaction mixture stirred overnight. The reaction was quenched with water and the mixture was extracted with \( CH_2Cl_2 \) (3x10 mL). The combined extracts were washed with brine (10 mL) and dried. Chromatography of the residue (15% ethyl acetate/hexane) yielded the bromide \( 7c \) (100 mg, 86%) as pink crystals, mp 94-95°C. \( \nu_{\text{max}}/\text{cm}^{-1} \) 3356 (m, NH), 1610 (s, C=O), 1550 (m). \( \delta_H \) 7.93 (dd, \( J_1 \) 0.8, \( J_2 \) 8.0, 1H), 7.71 (dd, \( J_1 \) 0.8, \( J_2 \) 8.0, 1H), 7.48 (dt, \( J_1 \) 1.2, \( J_2 \) 8.0, 1H), 7.40 (dt, \( J_1 \) 1.2, \( J_2 \) 8.0, 1H), 5.60 (br.s, 1H), 3.46 (dt, \( J_1 \) 7.2, \( J_2 \) 6.8, 2H), 3.42 (t, \( J \) 6.4, 2H), 1.95-1.49 (m, 6H). \( \delta_C \) 166.9, 158.7, 136.1, 131.2, 128.4, 124.6, 122.9, 122.8, 102.4, 39.3, 33.5, 32.1, 28.9, 25.3. \( m/z \) (ESI-) 340, 342 (M-1, 95), 79, 81 (89). \( m/z \) (HRMS; EI+) M+• 341.0079. \( C_{14}H_{16}^{79}BrNO_2S \) requires 341.0085.

\( 4,5,6,7\)-Tetrahydro-2H-benzo[b]thieno[3,2-b][1,5]oxazecin-8(3H)-one 1c

An excess of sodium hydride (10 mg, 0.4 mmol) was added to a solution of the bromide \( 7c \) (68 mg, 0.2 mmol) in THF (20 mL). After stirring for 1 hour, no reaction occurred. The reaction mixture was heated at reflux for 1 hour, then quenched with water. The mixture was extracted with ethyl acetate (3x10 mL). The combined extracts were washed with brine (10 mL) and dried. The solvent was evaporated and the residue was chromatographed (15% ethyl acetate/hexane) to give the cyclized compound \( 1c \) (42 mg, 81%) as pink crystals, mp 69-70°C. \( \nu_{\text{max}}/\text{cm}^{-1} \) 1573 (m), 1527 (m), \( \delta_H \) 7.98-7.96 (m, 1H), 7.72-7.70 (m, 1H), 7.47-7.45 (m, 1H), 7.42-7.39 (m, 1H), 3.86-3.83 (m, 4H), 2.08 (br.s, 1H), 1.72-1.70 (m, 6H). \( \delta_C \) 167.0, 161.8, 137.3, 130.8, 128.4, 124.4, 122.8, 122.1, 101.2, 46.1 (2C), 26.2 (2C), 24.5. \( m/z \) (EI+) 261 (M+•, 65), 176 (94). \( m/z \) (HRMS; EI+) M+• 261.0787. \( C_{14}H_{15}NO_2S \) requires 261.0824. Anal. Calc. for \( C_{14}H_{15}NO_2S \): C 64.34, H 5.79, N 5.36. Found: C 64.15, H 5.97, N 5.36 %.
Supplementary Material

NMR and mass spectra are available on the Journal’s website.

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References


