Tetrahedron 70 (2014) 2563–2569

Contents lists available at ScienceDirect

Tetrahedron

journal homepage: www.elsevier.com/locate/tet

Solvent-dependent Baylis–Hillman reactions for the synthesis of 3-benzyl-3-hydroxyoxindoles and benzo-δ-sultams

Mehdi Ghandi [a,*], Shahzad Feizi [a,b], Farhood Ziaie [b], Behrouz Notash [c]

[a] School of Chemistry, College of Science, University of Tehran, Tehran, PO Box 14155 6455, Iran
[b] Agricultural, Medical and Industrial Research School (AMIRS), Karaj, PO Box 31485498, Iran
[c] Department of Chemistry, Shahid Beheshti University, G. C. Evin, Tehran, PO Box 1983963113, Iran

ARTICLE INFO

Article history:
Received 1 December 2013
Received in revised form 9 February 2014
Accepted 17 February 2014
Available online 27 February 2014

Keywords:
Baylis–Hillman reaction
Benzo-δ-sultams
3-Benzyl-3-hydroxy-*N*-methyloxindoles

ABSTRACT

We have developed a solvent-dependent method for the preparation of novel benzo-δ-sultam and 3-benzyl-3-hydroxy-*N*-methyloxindole scaffolds. A variety of 3-(methoxy(phenyl)methyl)-1-methyl-1*H*-benzo-[*c*][1,2]thiazine 2,2-dioxides and 3-benzyl-3-hydroxy-1-methylindolin-2-ones were obtained in moderate to high yields via DBU-catalyzed Baylis–Hillman reaction of a number of (*E*)-*N*-(2-formylphenyl)-*N*-methyl-2-phenylethenesulfonamides in DMF and MeOH, respectively. The proof of the structures relies on analytical investigation and X-ray crystallography. Whereas reaction of (*E*)-*N*-(2-formylphenyl)-*N*-methyl-2-phenylethenesulfonamides in MeOH presumably proceeds through intramolecular Baylis–Hillman/dehydration, 3-hydroxy-*N*-methyloxindoles seem to have been generated via intramolecular Baylis–Hillman/1,3-H shift/oxidation/intramolecular cyclization tandem sequences in DMF.

1. Introduction

A base-catalyzed reaction of carbon electrophiles with the activated alkenes (alkynes) or electron-deficient Michael-accepting components, known as Baylis–Hillman (BH) reaction, is an efficient process going cleanly under very mild conditions, affording a highly functionalized adduct.[1] Considerable progress has been achieved in developing effective catalysts such as DBU,[2] DABCO,[3] DMAP,[4] PR_3,[5] Et_3N,[6] quinuclidine,[7] and imidazole.[8] The BH reaction was discovered in 1972.[9] Recent attention has been focused on intramolecular versions of the BH reaction.[10] Such reactions in principle can provide carbocyclic or heterocyclic compounds in different ring sizes with functionality.[11]

Sulfonamides have a rich chemical and biological history and are an important class of compounds in drug discovery due to their extensive chemical and biological activities.[12] Significant interest has been directed toward cyclic sulfonamides, also known as sultams. Although not found in nature, sultams are known as privileged structures in drug discovery due to their diverse biological properties.[13] Examples include the ampiroxicam (COX-2) anti-inflammatory agent,[14] calpain inhibitor 1,[15] benzodithiazine dioxides displaying anti-HIV-1 activity,[16] and antiepileptic agent sulthiame (Fig. 1a).[17] On the other hand, oxindole natural products have been the subject of excellent reviews.[18] In particular, the 3-substituted-3-hydroxy-2-oxindole scaffold as a sub-class of oxindole natural products is known to be at the core of several natural products with different biological activities (Fig. 1b).[19]

To the best of our knowledge, there has been no report in the literature on the intramolecular BH reaction of an electron-deficient Michael-accepting electrophile tethered to a phenyl ring by a sulfonamide link. Our own interest in the BH reaction[20] prompted us to explore the synthesis of benzo-δ-sultam template as the structurally related analogue of COX-2 (see Fig. 1a). Herein, we report the synthesis of novel 3-benzyl-3-hydroxy-1-methylindolin-2-one and benzo-δ-sultam scaffolds using a solvent-dependent DBU-catalyzed BH reaction.

2. Results and discussion

Vinyl sulfonamides **1a**–**g** were initially prepared using the previously reported procedure.[21] Vinyl sulfonamide **1a** served for our early exploration of intramolecular BH chemistry. Whereas reaction of **1a** in CH_2Cl_2, MeCN, H_2O, and PhMe was almost inefficient toward BH reaction, upon addition of DBU (100 mol %, 0.10 M) (entries 1–4, Table 1), 3-benzyl-3-hydroxy-1-methylindolin-2-one (**2a**)[22] was identified as the sole product in 20 and 25% yield in DMF within 36 and 72 h, respectively (entries 5 and 6, Table 1). Changing the base concentration from 0.10 to 0.25, 0.50, and 0.75 M increased the product yield to 42, 52, and 83%, respectively (entries 7–9, Table 1). Since no reaction progress

* Corresponding author. Tel.: +98 21 61112250; fax: +98 21 66495291; e-mail addresses: meh.ghandi@gmail.com, ghandi@khayam.ut.ac.ir (M. Ghandi).

0040-4020/$ – see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.tet.2014.02.038

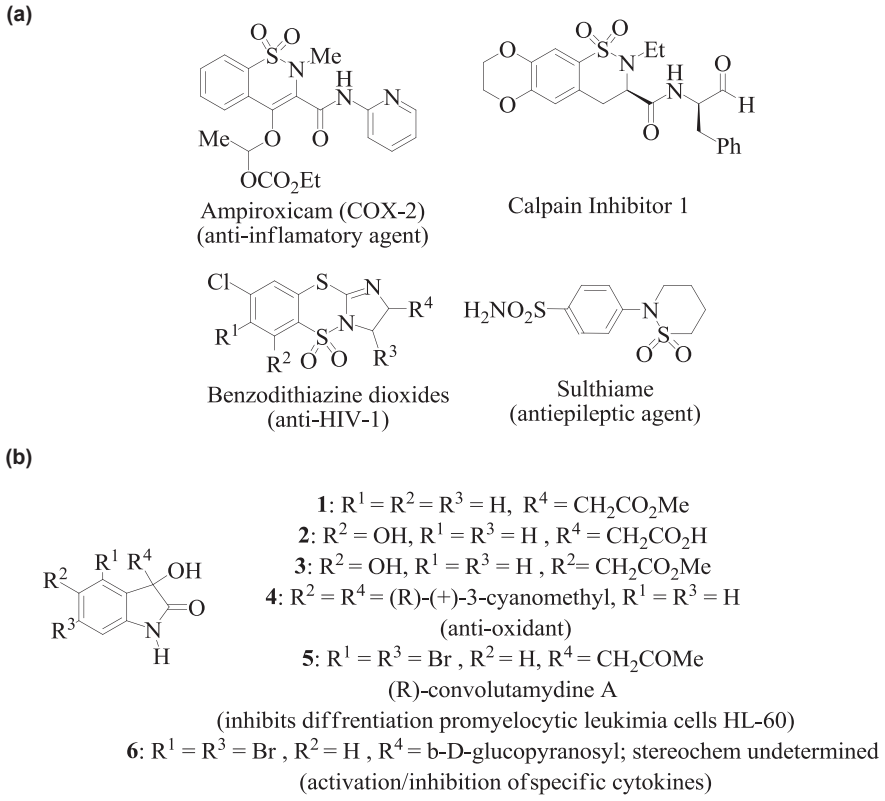
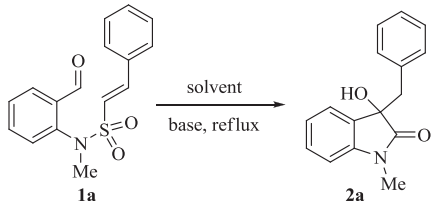


Fig. 1. Biologically active (a) six-membered sultams, (b) simple 3-alkyl-3-hydroxyoxindoles.

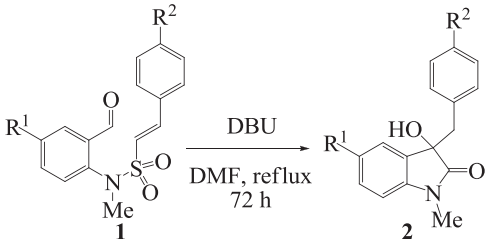
Table 1
Effect of solvent and base on the BH reaction of **1a**



Entry	Solvent (base, M)	Time (h)	Yield[a] (%)
1	CH_2Cl_2 (DBU, 0.10)	36	(–)
2	MeCN (DBU, 0.10)	36	(–)
3	H_2O (DBU, 0.10)	36	(–)
4	PhMe (DBU, 0.10)	36	(–)
5	DMF (DBU, 0.10)	36	(20)
6	DMF (DBU, 0.10)	72	(25)
7	DMF (DBU, 0.25)	72	(42)
8	DMF (DBU, 0.50)	72	(52)
9	DMF (DBU, 0.75)	72	(83)
10	DMF (DBU, 0.00)	72	(–)
11	DMF (DABCO, 0.10)	36	(15)
12	DMF (DABCO, 0.25)	72	(25)
13	DMF (DABCO, 0.50)	72	(35)
14	DMF (DABCO, 0.75)	72	(42)
15	DMF (NEt_3, 0.25–0.75)	72	(–)

[a] Isolated yield.

Table 2
Products **2a**–**g** obtained from DBU-catalyzed BH reaction of **1a**–**g** in DMF



Entry	R^1	R^2	Yield (%)
1	H	H	**2a** (83)
2	H	Cl	**2b** (85)
3	H	Br	**2c** (80)
4	Me	H	**2d** (85)
5	Me	Cl	**2e** (80)
6	OMe	H	**2f** (85)
7	OMe	Cl	**2g** (72)

occurs in the absence of DBU in DMF (entry 10, Table 1), the key role of DBU in promoting BH reaction is concluded. Whereas utilization of DABCO was partially effective in affording **2a** (entries 11–14, Table 1), triethylamine in 0.25–0.75 M was almost ineffective at promoting cyclization of vinyl sulfonamide **1a** (entry 15, Table 1).

Products **2b**–**g** were then obtained when this new method was applied to a range of vinyl sulfonamides **1b**–**g** (Table 2). The structures of **2a**–**g** were deduced by elemental analysis, MS, IR, ^{1}H NMR, and ^{13}C NMR spectroscopy. For example, part of the ^{1}H NMR spectrum of **2d** exhibited two sharp and one broad singlets at δ 2.31, 2.96, and 3.58 due to Me, MeN, and OH together with a ABq at δ 3.13 and 3.28 (J=12.9 Hz) for CH_2Ph. The ^{1}H-decoupled ^{13}C NMR spectrum of **2d** showed 15 distinct signals including a characteristic signal at δ 178.1 due to C=O group, in agreement with the proposed structure. Unambiguous evidence for the proposed structure of **2d** was finally obtained by single-crystal X-ray-diffraction analysis (Fig. 2).[23]

It has been reported that the BH reaction is second order in aldeyde.[24] Therefore, effect of decreasing the amount of solvent on rate enhancement is rationalized. That the reaction proceeds

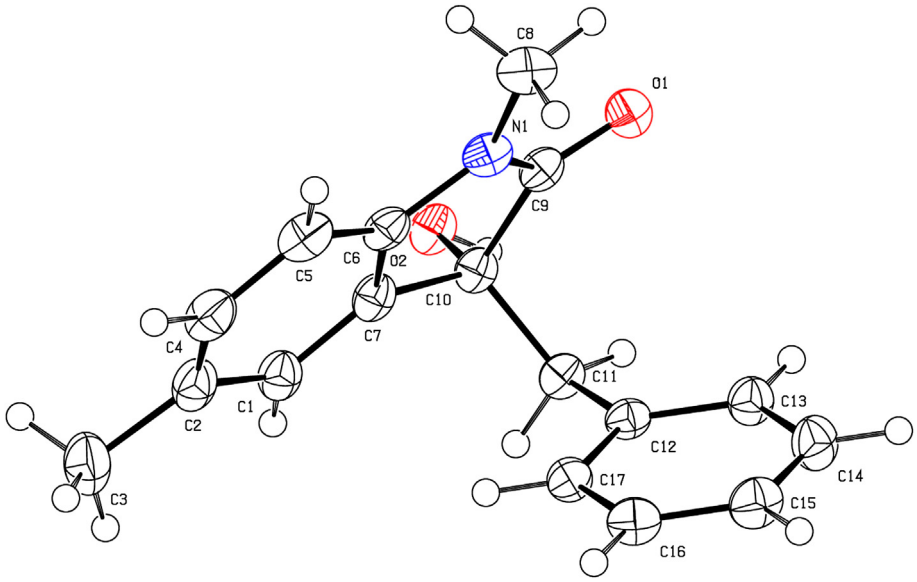


Fig. 2. X-ray crystal structure of compound **2d**.

efficiently in DMF may be due to unique solvation of the polar transition state in this solvent.

Whereas DBU has a high pK_a[25] but is also sterically hindered, a feature that usually results in severely reduced rates. Observation of the high rate increase with DBU indicates that, in this specific case, the basicity of the amine is more important than its steric hindrance. As indicated in Fig. 3a, the stabilization of the generated β-ammonium-α-carbanion sulfonamide intermediate from DBU through conjugation seems to be a more likely explanation for the origin of the increased reactivity of DBU.[26] In contrast, DABCO not only has lower pK_a,[27] but also lacks such conjugation stability (Fig. 3b).

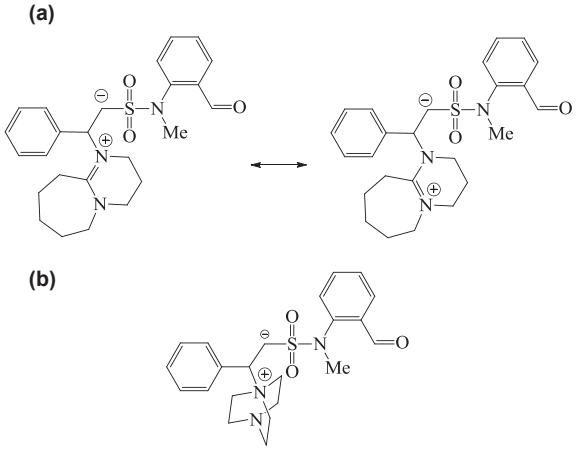
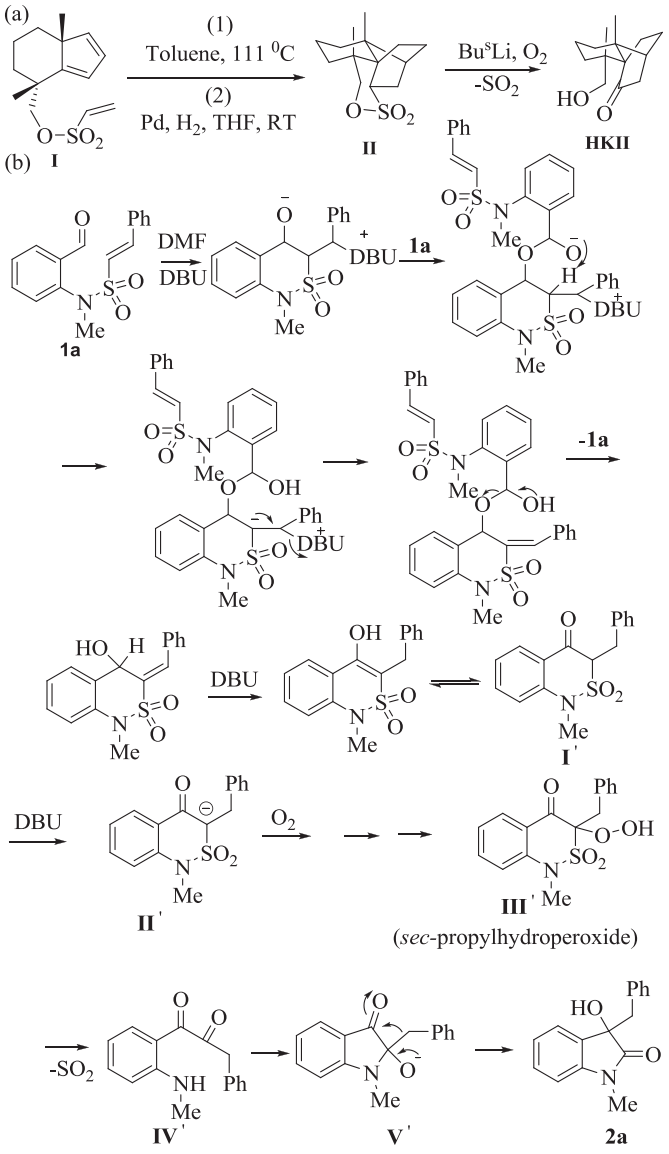


Fig. 3. (a) Stabilization of the β-ammonium-α-carbanion sulfonamide obtained from DBU, (b) similar β-ammonium-α-carbanion sulfonamide obtained from DABCO.

The formation of **2a**–**g** with extrusion of a SO_2 group was a surprising outcome. Our surprise was tempered when a literature search disclosed that the sultone **II** obtained from cyclopentadiene sulfonate **I** has undergone similar oxidative ring fission to hydroxyketone **HKII** with extrusion of a SO_2 group in reaction with molecular oxygen (Scheme 1a).[28] As such, the in situ generated sultam **I′** from sulfonamide **1a**[20] has similarly undergone DBU-catalyzed reaction with molecular oxygen, probably through the initially generated anion **II′** and implication of the *sec*-propyl



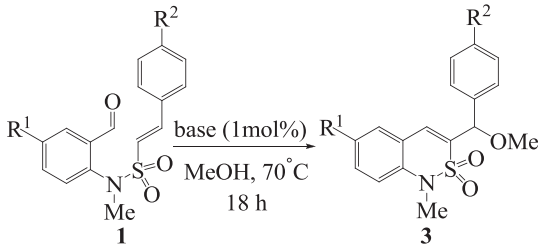
Scheme 1. (a) Oxidative ring fission of saltone **II** to hydroxylketone **HKII**, (b) suggested mechanism for the formation of 3-benzyl-3-hydroxyoxinole **2a** from **1a**.

hydroperoxide **III**′ in a series of steps, affording the aminoketone **IV**′ (Scheme 1b). In contrast to hydroxyketone **II** (see Scheme 1a), and upon intramolecular cyclization, aminoketone **IV**′ is finally converted to **2a** (Scheme 1b).

To highlight the effect of molecular oxygen, reaction of vinyl sulfonamide **1a** with DBU was carried out under argon atmosphere. A complex mixture of products obtained amongst, which **2a** was not identified. This experiment clearly indicates the key role of molecular oxygen on the formation of **2a**.

When vinyl sulfonamides **1a**–**g** were treated with an equimolar amount of DBU in MeOH, benzo-δ-sultams **3a**–**g** were identified as the sole products (Table 3). The structures of **3a**–**g** were deduced by elemental analysis, MS, IR, ^{1}H NMR, and ^{13}C NMR spectroscopy. For example, part of the ^{1}H NMR spectrum of **3f** exhibited four singlets at δ 3.43, 3.48, 3.79, and 5.48 due to MeN, MeO, MeO, and CHPh. The ^{1}H-decoupled ^{13}C NMR spectrum of **3f** revealed 16 distinct signals in agreement with the proposed structure. Unambiguous evidence for the proposed structure of **3f** was finally obtained by single-crystal X-ray-diffraction analysis (Fig. 4).[29]

Table 3
Products **3a**–**g** obtained from base-catalyzed BH reaction of **1a**–**g** in MeOH

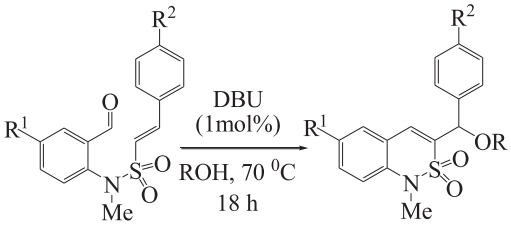


Entry	Base	R^1	R^2	Product (yield, %)
1	DBU	H	H	**3a** (90)
2	DBU	H	Cl	**3b** (85)
3	DBU	H	Br	**3c** (88)
4	DBU	Me	H	**3d** (91)
5	DBU	Me	Cl	**3e** (82)
6	DBU	OMe	H	**3f** (98)
7	DBU	OMe	Cl	**3g** (88)
8	K_2CO_3	OMe	Cl	**3g** (30)
9	NaOMe	OMe	Cl	**3g** (35)

To our delight, reaction of **1g** either with K_2CO_3 or NaOMe in MeOH also afforded product **3g** although in lower yields (entries 8 and 9, Table 3). These results clearly indicate the implication of MeO^- in DBU-catalyzed BH reaction of **1g**–**3g** in MeOH.

Notably, the BH reaction of a number of (*E*)-*N*-(2-formylphenyl)-*N*-methyl-2-phenylethenesulfonamides in EtOH afforded the corresponding 3-(ethoxy(phenyl)methyl)-1-methyl-1*H*-benzo[*c*][1,2]thiazine 2,2-dioxides (entries 1–4, Table 4). Almost no progress in the BH reactions was observed either in isopropanol or cyclohexanol (entries 5 and 6, Table 4).

Table 4
Effect of EtOH, isopropanol and cyclohexanol on DBU-catalyzed BH reaction of **1**



Entry	R^1	R^2	ROH	Yield (%)
1	OMe	H	EtOH	**3h** (90)
2	H	Cl	EtOH	**3i** (88)
3	OMe	Cl	EtOH	**3j** (84)
4	Me	H	MeCH(OH)Me	**3k** (–)
5	OMe	H	$C_6H_{11}OH$	**3l** (–)

The suggested mechanism for the formation of **3a** is shown in Scheme 2. The in situ generated MeO^- via acid–base reaction of MeOH with DBU promotes the intramolecular BH reaction, affording intermediates **M**, **M**′, and **M**″. The oxindole **3a** is finally obtained through elimination of the hemiacetal group rather than the traditional reaction to BH adduct. The pseudoaromatic character, if any, of **3a** may be the driving force for this process. This mechanism was proposed on the basis of our previously reported work as well as the one reported by Ciganek who showed that NaOMe in THF could mediate the coupling of methyl acrylate with aromatic aldehydes.[30]

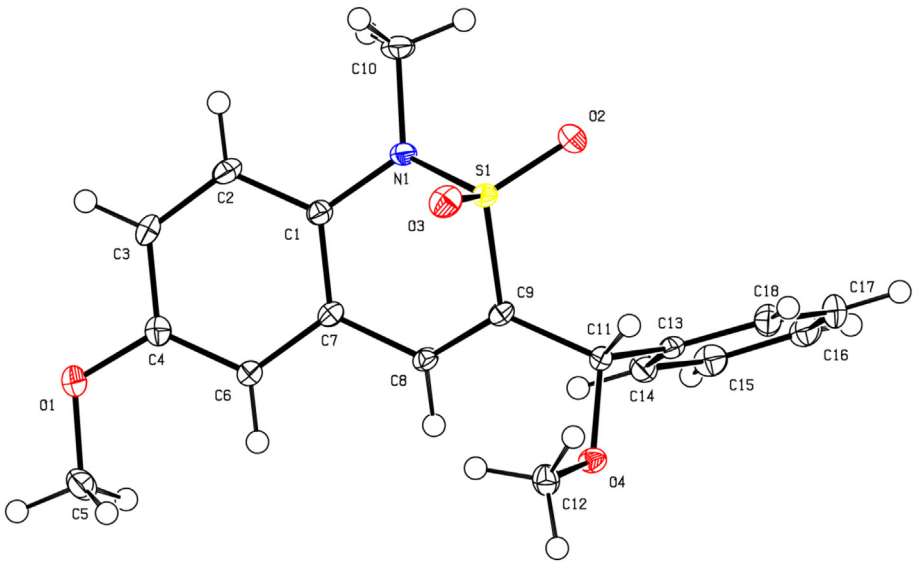
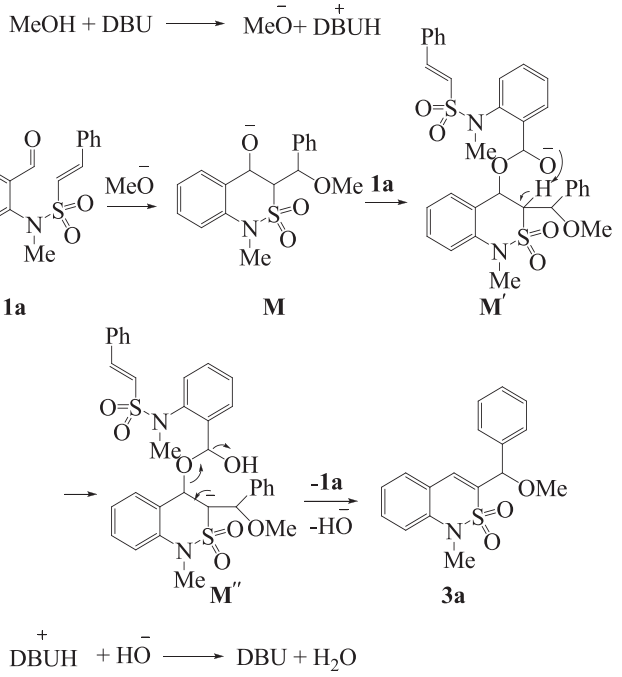


Fig. 4. X-ray crystal structure of compound **3f**.



Scheme 2. Mechanistic rationalization for the formation of compound **3a**.

In conclusion, a number of solvent-dependent BH reactions were carried out in this work for the synthesis of novel oxindole and benzo-δ-sultam scaffolds. Whereas the DBU-catalyzed BH reaction of (*E*)-*N*-(2-formylphenyl)-*N*-methyl-2-phenylethenesulfonamides exhibited 3-benzyl-3-hydroxy-1-methylindolin-2-one scaffolds in moderate to good yields in DMF, reactions in MeOH afforded novel benzo-δ-sultams in high yields. These new structures broaden the synthesis of interesting scaffolds and many of them may represent interesting pharmacophores.

To the best of our knowledge, no method of using an intramolecular BH reaction in the synthesis of novel oxindole and benzo-δ-sultams scaffolds is found in literature.

3. Experimental section

3.1. General information

^{1}H NMR, ^{13}C NMR, MS, and elemental analysis were measured with conventional spectrometers. All solvents were purified and dried by following standard procedures unless otherwise stated.

3.2. Synthesis of 3-benzyl-3-hydroxy-1-methyl-1,3-dihydro-indol-2-one derivatives 2a–g

General procedure: To a stirring solution of DBU (0.453 g, 300 mol %) in DMF (3 mL) was added (*E*)-*N*-(2-formylphenyl)-*N*-methyl-2-phenylethenesulfonamide (**1a**–**g**) (1.0 mmol) and the mixture was heated at 150 °C for 72 h. The progress of the reaction was followed by TLC. After completion, CH_2Cl_2 (20 mL) and H_2O (20 mL) were added and the mixture was neutralized with 5% HCl. The organic phase was separated, and the aqueous phase was extracted with CH_2Cl_2 (3×10 mL). After drying the combined organic phases with anhydrous Na_2SO_4, the solvent was removed under reduced pressure. The residue was purified by column chromatography (SiO_2, gradiantly hexane/ethyl acetate, 5:1, 3:1) to afford products **2a**–**g**.

*3.2.1. 3-Benzyl-3-hydroxy-1-methyl-1,3-dihydro-indol-2-one (**2a**).* White solid (0.209 g, 83%); mp 156–158 °C; IR (KBr) ν_{max} 3378, 1694, 1614, 1086, 746 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ_H 6.94–7.27 (8H, m), 6.65 (1H, d, *J*=7.8 Hz), 3.29 (1H, d, *J*=13.0 Hz), 3.12 (1H, d, *J*=13.0 Hz), 3.01 (3H, s), 2.87 (1H, br s) ppm; ^{13}C NMR (75 MHz, $CDCl_3$) δ_C 178.1, 143.1, 134.0, 130.2, 129.5, 129.3, 127.7, 126.8, 124.5, 122.9, 108.2, 76.6, 44.8, 25.9 ppm; *m*/*z* (EI, 70 eV) 253 (22, M$^+$), 162 (100), 161 (84), 91 (48), 77 (38), 65 (38%). Anal. Calcd for $C_{16}H_{15}NO_2$: C, 75.87; H, 5.97; N, 5.53. Found: C, 75.87; H, 5.83; N, 5.47%; R_f (25% EtOAc/hexane) 0.14.

*3.2.2. 3-(4-Chloro-benzyl)-3-hydroxy-1-methyl-1,3-dihydro-indol-2-one (**2b**).* White solid (0.243 g, 85%); mp 169–171 °C; IR (KBr) ν_{max} 3324, 1693, 1615, 1084, 745 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 7.13–7.15 (3H, m), 6.97–7.00 (2H, m), 6.76–6.79 (2H, m), 6.54 (1H, d, *J*=9.3 Hz), 4.16 (1H, br s), 3.30 (1H, d, *J*=12.9 Hz, part of ABq), 3.15 (1H, d, *J*=12.9 Hz, part of ABq), 3.00 (3H, s) ppm; ^{13}C NMR (75 MHz, $CDCl_3$) δ_C 178.0, 156.0, 136.4, 134.1, 130.6, 130.3, 127.8, 126.8, 114.4, 111.3, 108.7, 76.6, 44.8, 26.0 ppm; *m*/*z* (EI, 70 eV) 289 (4, M$^+$+2), 288 (24, M$^+$+1), 287 (13, M$^+$), 163 (38), 162 (100), 161 (36), 125 (85), 89 (35), 77 (37%). Anal. Calcd for $C_{16}H_{14}ClNO_2$: C, 66.79; H, 4.90; N, 4.87. Found: C, 66.60; H, 4.47; N, 4.83%; R_f (25% EtOAc/hexane) 0.13.

*3.2.3. 3-(4-Bromo-benzyl)-3-hydroxy-1-methyl-1,3-dihydro-indol-2-one (**2c**).* White solid (0.264 g, 80%); mp 152–153 °C; IR (KBr) ν_{max} 3338, 1700, 1610, 1229, 1114, 752 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 7.18–7.30 (2H, m), 7.23 (2H, d, *J*=8.3 Hz), 7.07 (1H, t, *J*=7.5 Hz), 6.81 (2H, d, *J*=8.3 Hz), 6.67 (1H, d, *J*=7.5 Hz), 3.27 (1H, d, *J*=12.9 Hz, part of ABq), 3.11 (1H, d, *J*=12.9 Hz, part of ABq), 3.02 (3H, s) ppm; ^{13}C NMR (75 MHz, $CDCl_3$) δ_C 177.7, 143.1, 133.0, 131.9, 130.8, 129.8, 128.9, 124.3, 122.9, 120.9, 108.4, 77.1, 44.1, 26.0 ppm; *m*/*z* (EI, 70 eV) 284 (3, M$^+$+1), 283 (15, M$^+$), 192 (100), 149 (27), 121 (44), 91(77), 65 (22%). Anal. Calcd for $C_{16}H_{14}BrNO_2$: C, 57.85; H, 4.25; N, 4.22. Found: C, 57.68; H, 3.83; N, 4.07%; R_f (25% EtOAc/hexane) 0.14.

*3.2.4. 3-Benzyl-3-hydroxy-1,5-dimethyl-1,3-dihydro-indol-2-one (**2d**).* White solid (0.226 g, 85%); mp 143–145 °C; IR (KBr) ν_{max} 3272, 1690, 1614, 1100, 699 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ_H 7.09–7.14 (3H, m, Ar), 7.03 (1H, d, *J*=7.85 Hz, Ar), 7.00 (1H, s, Ar), 6.93 (2H, m, Ar), 6.51 (1H, d, *J*=7.8 Hz), 3.58 (1H, br s), 3.28 (1H, d, *J*=12.9 Hz, part of ABq), 3.13 (1H, d, *J*=12.9 Hz, part of ABq), 2.96 (3H, s), 2.31 (3H, s) ppm; ^{13}C NMR (125 MHz, $CDCl_3$) δ_C 178.2, 141.2, 134.5, 132.8, 129.7, 130.7, 128.1, 130.7, 127.2, 125.7, 108.3, 77.9, 45.3, 26.4, 21.5 ppm; *m*/*z* (EI, 70 eV) 267 (1, M$^+$), 176 (58), 91 (100), 65 (21%). Anal. Calcd for $C_{17}H_{17}NO_2$: C, 76.38; H, 6.41; N, 5.24. Found: C, 76.23; H, 6.56; N, 5.44%; R_f (25% EtOAc/hexane) 0.12.

*3.2.5. 3-(4-Chloro-benzyl)-3-hydroxy-1,5-dimethyl-1,3-dihydro-indol-2-one (**2e**).* White solid (0.240 g, 80%); mp 185–187 °C; IR (KBr) ν_{max} 3292 (OH), 1691, 1492, 1103, 1082, 811 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ_H 7.08 (2H, d, *J*=8.4 Hz), 7.02–7.07 (2H, m, Ar), 6.86 (2H, d, *J*=8.4 Hz), 6.54 (1H, d, *J*=7.9 Hz, Ar), 3.24 (1H, d, *J*=12.9 Hz, part of ABq), 3.19 (1H, br s, OH), 3.11 (1H, d, *J*=12.9 Hz, part of ABq), 2.96 (3H, s), 2.32 (3H, s) ppm; ^{13}C NMR (125 MHz, $CDCl_3$) δ_C 178.0, 141.1, 133.5, 132.8, 132.5, 132.0, 130.1, 129.9, 128.0, 125.4, 108.2, 77.5, 44.3, 26.2, 21.4 ppm; *m*/*z* (EI, 70 eV) 303 (25, M$^+$+2), 302 (56, M$^+$+1), 301 (47, M$^+$), 286 (37), 285 (23), 284 (100), 176 (40), 125 (16%). Anal. Calcd for $C_{17}H_{16}ClNO_2$: C, 67.66; H, 5.34; N, 4.64. Found: C, 67.20; H, 5.20; N, 4.58%; R_f (25% EtOAc/hexane) 0.13.

*3.2.6. 3-Benzyl-3-hydroxy-5-methoxy-1-methyl-1,3-dihydro-indol-2-one (**2f**).* White solid (0.240 g, 85%); mp 149–151 °C; IR (KBr) ν_{max} 3246, 1677, 1099, 697 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ_H 6.76–7.14

(7H, m), 6.53 (1H, d, J=9.3 Hz), 4.39 (1H br s), 3.73 (3H, s), 3.34 (1H, d, J=12.9 Hz, part of ABq), 3.15(1H, d, J=12.9 Hz, part of ABq), 2.97 (3H, s) ppm; ^{13}C NMR (75 MHz, $CDCl_3$) δ_C 178.0, 156.0, 136.4, 134.1, 130.5, 130.3, 127.7, 126.8, 114.4, 111.2, 108.7, 77.8, 55.8, 44.8, 26.0 ppm; m/z (EI, 70 eV) 284 (3, M^++1), 283 (15, M^+), 192 (100), 149 (27), 121 (44), 91(77), 65 (22%). Anal. Calcd for $C_{17}H_{17}NO_3$: C, 72.07; H, 6.05; N, 4.94. Found: C, 72.03; H, 6.02; N, 4.87%; R_f (25% EtOAc/hexane) 0.08.

*3.2.7. 3-(4-Chloro-benzyl)-3-hydroxy-5-methoxy-1-methyl-1,3-dihydro-indol-2-one (**2g**).* White solid (0.228 g, 72%); mp 99–101 °C; IR (KBr) ν_{max} 3315 (OH), 1701, 1213, 1088 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ_H 6.98 (2H, d, J=8.4 Hz), 6.80 (2H, d, J=8.4 Hz), 6.65–6.67 (2H, m), 6.46 (1H, d, J=9.1 Hz). 4.94 (1H, br s), 3.64 (3H, s), 3.14 (1H, d, J=12.9 Hz, part of ABq), 2.98 (1H, d, J=12.9 Hz, part of ABq), 2.88 (3H, s) ppm; ^{13}C NMR (125 MHz, $CDCl_3$) δ_C 177.9, 156.3, 136.9, 133.5, 132.9, 132.1, 131.3, 128.1, 114.4, 111.7, 108.9, 77.7, 56.2, 44.4, 26.3 ppm; m/z (EI, 70 eV) 319 (11, M^++2), 318 (6, M^++1), 317 (29, M^+), 193 (47), 192 (100), 149 (29), 125 (28), 89 (15%). Anal. Calcd for $C_{17}H_{16}ClNO_3$: C, 64.26; H, 5.08; N, 4.41. Found: C, 64.18; H, 5.07; N, 4.28%; R_f (25% EtOAc/hexane) 0.08.

3.3. Synthesis of 3-(methoxy-phenyl-methyl)-1-methyl-1*H*-benzo[*c*][1,2]thiazine 2,2-dioxide derivatives 3a–j

General procedure: To a stirring solution of DBU (0.304 g, 200 mol %) in alcohol (3 mL) was added (*E*)-*N*-(2-formylphenyl)-*N*-methyl-2-phenylethenesulfonamide derivatives **3a**–**g** (1.0 mmol) and the mixture was heated at reflux for 18 h. The progress of the reaction was followed by TLC. After completion, the solvent was removed under reduced pressure and the crude residue purified by column chromatography (SiO_2, 6:1, *n*-hexane/ethyl acetate) to afford product **3a**–**j**.

*3.3.1. 3-(Methoxy-phenyl-methyl)-1-methyl-1H-benzo[c][1,2]thiazine 2,2-dioxide (**3a**).* Yellow solid (0.283 g, 90%); mp 85–87 °C; IR (KBr) ν_{max} 2949, 1317, 1143, 753 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ_H 7.11–7.51 (9H, m), 6.91 (1H, s), 5.42 (1H, s), 3.49 (3H, s), 3.48 (3H, s) ppm; ^{13}C NMR (75 MHz, $CDCl_3$) δ_C 140.1, 137.7, 136.7, 131.8, 130.9, 130.2, 128.7, 128.6, 127.5, 122.9, 120.9, 116.2, 79.4, 57.7, 30.6 ppm; m/z (EI, 70 eV) 317 (3, M^++2), 316 (12, M^++1), 315 (58, M^+), 221 (44), 220 (100), 121 (72), 105 (37), 77 (47%). Anal. Calcd for $C_{17}H_{17}NO_3S$ C, 64.74; H, 5.43; N, 4.44. Found: C, 64.82; H, 5.21; N, 4.63%; R_f (25% EtOAc/hexane) 0.43.

*3.3.2. 3-[(4-Chloro-phenyl)-methoxy-methyl]-1-methyl-1H-benzo[c][1,2]thiazine 2,2-dioxide (**3b**).* White solid (0.296 g, 85%); mp 122–124 °C; IR (KBr) ν_{max} 2939, 1297, 1144, 1088, 828, 758 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 7.14–7.49 (8H, m), 6.97 (1H, s), 5.39 (1H, s), 3.48 (3H, s), 3.47 (3H, s) ppm; ^{13}C NMR (75 MHz, $CDCl_3$) δ_C 140.1, 136.5, 136.2, 134.4, 131.7, 131.0, 130.2, 128.9, 128.8, 122.9, 120.8, 116.2, 78.7, 57.6, 30.6 ppm; m/z (EI, 70 eV) 351 (7, M^++2), 350 (3, M^++1), 349 (18, M^+), 256 (44), 255 (26), 254 (100), 218 (33), 155 (41), 89 (24%). Anal. Calcd for $C_{17}H_{16}ClNO_3S$: C, 58.37; H, 4.61; N, 4.00. Found C, 58.53; H, 4.57; N, 4.03%; R_f (25% EtOAc/hexane) 0.42.

*3.3.3. 3-[(4-Bromo-phenyl)-methoxy-methyl]-1-methyl-1H-benzo[c][1,2]thiazine 2,2-dioxide (**3c**).* White solid (0.347 g, 88%); mp 139–142 °C; IR (KBr) ν_{max} 2936, 1297, 1143, 1092, 825, 758 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ_H 7.53 (2H, d, J=8.4 Hz), 7.35–7.46 (2H, m), 7.37 (2H, d, J=8.4 Hz), 7.14 (2H, dd, J=8.9, 7.7 Hz), 6.97 (1H, s), 5.36 (1H, s), 3.47 (3H, s), 3.46 (3H, s) ppm; ^{13}C NMR (125 MHz, $CDCl_3$) δ_C 140.6, 137.6, 136.6, 132.3, 132.1, 131.5, 130.7, 129.5, 123.4, 123.0, 121.3, 116.7, 79.2, 58.1, 31.1 ppm; m/z (EI, 70 eV) 396 (17, M^++1), 395 (88, M^+), 393 (79, M^+−2), 300 (100), 219 (51), 199 (36), 89 (44%). Anal. Calcd for $C_{17}H_{16}BrNO_3S$: C, 51.79; H, 4.09; N, 3.55. Found: C, 51.67; H, 3.94; N, 3.60%; R_f (25% EtOAc/hexane) 0.43.

*3.3.4. 3-(Methoxy-phenyl-methyl)-1,6-dimethyl-1H-benzo[c][1,2]thiazine 2,2-dioxide (**3d**).* Pale yellow solid (0.299 g, 91%); mp 127–129 °C; IR (KBr) ν_{max} 2941, 1321, 1252, 1145, 1059, 854 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ_H 7.48 (2H, d, J=8.6 Hz), 7.39 (2H, t, J=7.0 Hz), 7.35–7.37 (1H, t, J=6.2 Hz), 7.23 (1H, d, J=8.4 Hz), 7.13 (1H, s), 7.02 (1H, d, J=8.4 Hz), 6.86 (1H, s), 5.41 (1H, s), 3.47 (3H, s), 3.44 (3H, s), 2.31 (3H, s) ppm; ^{13}C NMR (125 MHz, $CDCl_3$) δ_C 138.5, 138.3, 137.2, 132.9, 132.2, 132.1, 130.8, 129.1, 128.9, 127.9, 121.4, 116.8, 79.8, 58.1, 31.3, 20.9 ppm; m/z (EI, 70 eV) 331 (1, M^++2), 330 (5, M^++1), 329 (28, M^+), 234 (100), 218 (32), 121 (35), 91 (20), 77 (35%). Anal. Calcd for $C_{18}H_{19}NO_3S$: C, 65.63; H, 5.81; N, 4.25. Found C, 65.51; H, 5.80; N, 4.28%; R_f (25% EtOAc/hexane) 0.40.

*3.3.5. 3-[(4-Chloro-phenyl)-methoxy-methyl]-1,6-dimethyl-1H-benzo[c][1,2]thiazine 2,2-dioxide (**3e**).* Yellow oil (0.297 g, 82%); IR (KBr) ν_{max} 2930, 1316, 1145, 1087, 808 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ_H 7.42 (2H, d, J=8.4 Hz), 7.37 (2H, d, J=8.4 Hz), 7.24 (1H, d, J=8.9 Hz), 7.16 (1H, s), 7.03 (1H, d, J=8.4 Hz), 6.91 (1H, s), 5.36 (1H, s), 3.46 (3H, s), 3.43 (3H, s), 2.32 (3H, s) ppm; ^{13}C NMR (75 MHz, $CDCl_3$) δ_C 138.4, 137.1, 136.7, 134.8, 133.1, 132.3, 132.1, 130.8, 129.3, 129.2, 121.3, 116.8, 79.2, 58.1, 31.3, 20.9 ppm; m/z (EI, 70 eV) 365 (21, M^++2), 364 (17, M^++1), 363 (56, M^+), 332 (37), 268 (94), 155 (100), 103 (70), 91 (83), 77 (51), 51 (43%). Anal. Calcd for $C_{18}H_{18}ClNO_3S$: C, 59.42; H, 4.99; N, 3.85. Found C, 59.41; H, 4.85; N, 3.39%; R_f (25% EtOAc/hexane) 0.55.

*3.3.6. 6-Methoxy-3-(methoxy-phenyl-methyl)-1-methyl-1H-benzo[c][1,2]thiazine 2,2-dioxide (**3f**).* Pale yellow solid (0.338 g, 98%); mp 110–112 °C; IR (KBr) ν_{max} 2929, 1309, 1247, 1139, 1058, 853 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 7.50 (2H, d, J=7.3 Hz), 7.35–7.46 (3H, m), 7.10 (1H, d, J=9.0 Hz), 7.02 (1H, dd, J=9.0, 2.7 Hz), 6.87 (1H, s), 6.84 (1H, d, J=2.7 Hz), 5.40 (1H, s), 3.79 (3H, s), 3.48 (3H, s), 3.43 (3H, s) ppm; ^{13}C NMR (75 MHz, $CDCl_3$) δ_C 155.3, 137.7, 137.6, 134.0, 131.2, 128.7, 128.5, 127.4, 122.2, 118.4, 117.9, 113.2, 79.4, 57.6, 55.6, 31.8 ppm; m/z (EI, 70 eV) 347 (9, M^++2), 346 (25, M^++1), 345 (100, M^+), 250 (87), 121 (66), 77 (34%). Anal. Calcd for $C_{18}H_{19}NO_4S$: C, 62.59; H, 5.54; N, 4.06. Found C, 62.76; H, 5.51; N, 4.03%; R_f (25% EtOAc/hexane) 0.30.

*3.3.7. 3-[(4-Chloro-phenyl)-methoxy-methyl]-6-methoxy-1-methyl-1H-benzo[c][1,2]thiazine 2,2-dioxide (**3g**).* Yellow solid (0.333 g, 88%); mp 116–118 °C; IR (KBr) ν_{max} 2942, 1311, 1252, 1143, 1082, 811 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ_H 7.43 (2H, d, J=8.5 Hz), 7.37 (2H, d, J=8.5 Hz), 7.08 (1H, d, J=9.0 Hz), 7.00 (1H, dd, J=9.0, 2.9 Hz), 6.91(1H, s), 6.85 (1H, d, J=2.9 Hz), 5.34 (1H, s), 3.78 (3H, s), 3.45 (3H, s), 3.93 (3H, s) ppm; ^{13}C NMR (125 MHz, $CDCl_3$) δ_C 155.9, 137.7, 137.0, 134.8, 134.5, 131.6, 129.3, 129.2, 122.6, 119.0, 118.5, 113.8, 112.0, 79.2, 58.1, 56.1, 32.4 ppm; m/z (EI, 70 eV) 381 (17, M^++2), 380 (9, M^++1), 379 (44, M^+), 312 (37), 284 (63), 162 (57), 155 (100), 139 (70), 91 (75%). Anal. Calcd for $C_{18}H_{18}ClNO_4S$: C, 56.91; H, 4.78; N, 3.69. Found C, 56.93; H, 4.82; N, 3.71%; R_f (25% EtOAc/hexane) 0.33.

*3.3.8. 3-(Ethoxy-phenyl-methyl)-6-methoxy-1-methyl-1H-benzo[c][1,2]thiazine 2,2-dioxide (**3h**).* White solid (0.323 g, 90%); mp 140–142 °C; IR (KBr) ν_{max} 2934, 1310, 1247, 1141, 1057, 819 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 7.33–7.53 (5H, m), 7.10 (1H, d, J=8.9 Hz), 7.01 (1H, dd, J=8.9, 2.8 Hz), 6.91 (1H, s), 6.84 (1H, d, J=2.8 Hz), 5.52 (1H, s), 3.80 (3H, s), 3.65 (2H, m), 3.42 (3H, s), 1.30 (3H, t, J=7.0 Hz) ppm; ^{13}C NMR (75 MHz, $CDCl_3$) δ_C 155.4, 138.4, 138.2, 134.1, 131.0, 128.6, 128.4, 127.4, 122.3, 118.4, 117.8, 113.2, 77.4, 65.5, 55.7, 31.8, 15.2 ppm; m/z (EI, 70 eV) 361 (8, M^++2), 360 (29, M^++1), 359 (100, M^+), 314 (77), 250 (76), 207 (17), 135 (27), 79 (14%). Anal.

Calcd for $C_{19}H_{21}NO_4S$: C, 63.49; H, 5.89; N, 3.90. Found: C, 63.18; H, 5.88; N, 3.80%; R_f (25% EtOAc/hexane) 0.38.

*3.3.9. 3-[(4-Chloro-phenyl)-ethoxy-methyl]-1-methyl-1H-benzo[c][1,2]thiazine 2,2-dioxide (**3i**).* Yellow solid (0.319 g, 88%); mp 135–136 °C; IR (KBr) ν_{max} 2973, 1309, 1219, 1143, 1087, 751 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ_H 7.36–7.48 (6H, m), 7.15 (1H, dd, J=7.8, 7.1 Hz, Ar), 7.03 (1H, s), 5.51 (1H, s, CH–O–), 3.65 (2H, m), 3.47 (3H, s), 1.30 (3H, t, J=7.0 Hz) ppm; ^{13}C NMR (75 MHz, $CDCl_3$) δ_C 140.1, 137.2, 136.6, 134.2, 131.5, 130.9, 130.2, 128.8, 128.7, 122.9, 120.9, 116.2, 76.7, 65.6, 30.5, 15.2 ppm; m/z (EI, 70 eV) 365 (16, M^++2), 364 (5, M^++1), 363 (41, M^+), 256 (89), 254 (100), 141 (85), 139 (73), 77 (67%). Anal. Calcd for $C_{18}H_{18}ClNO_3S$: C, 59.42; H, 4.99; N, 3.85. Found: C, 59.24; H, 4.98; N, 3.81%; R_f (25% EtOAc/hexane) 0.38.

*3.3.10. 3-[(4-Chloro-phenyl)-ethoxy-methyl]-6-methoxy-1-methyl-1H-benzo[c][1,2]thiazine 2,2-dioxide (**3j**).* Yellow solid (0.330 g, 84%); mp 139–140 °C; IR (KBr) ν_{max} 2971, 1304, 1247, 1142, 1089, 813 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ_H 7.45 (1H, d, J=8.5 Hz), 7.37 (1H, d, J=8.5 Hz), 6.68–7.11 (4H, m), 5.47 (1H, s), 3.80 (3H, s), 3.57–3.73 (2H, m), 3.41 (3H, s), 1.29 (3H, t, J=7.0 Hz) ppm; ^{13}C NMR (75 MHz, $CDCl_3$) δ_C 155.5, 137.7, 137.2, 134.2, 134.0, 130.9, 128.8, 128.7, 122.2, 118.5, 117.9, 113.2, 76.7, 65.6, 55.7, 31.9, 15.2 ppm; m/z (EI, 70 eV) 395 (33, M^++2), 394 (18, M^++1), 393 (73, M^+), 312 (62), 284 (100), 162 (35), 141 (47), 77 (31%). Anal. Calcd for $C_{19}H_{20}ClNO_4S$: C, 57.94; H, 5.12; N, 3.56. Found: C, 58.03; H, 5.31; N, 3.75%; R_f (25% EtOAc/hexane) 0.38.

Acknowledgements

The authors acknowledge the University of Tehran for financial support of this research.

Supplementary data

Supplementary data associated with this article can be found in the online version, at http://dx.doi.org/10.1016/j.tet.2014.02.038. These data include MOL files and InChiKeys of the most important compounds described in this article.

References and notes

1. (a) Basavaiah, D.; Reddy, B. S.; Badsara, S. S. *Chem. Rev.* **2010**, *110*, 5447–5674; (b) Basavaiah, D.; Rao, A. J.; Satyanarayana, T. *Chem. Rev.* **2003**, *103*, 811–891; (c) Langer, P. *Angew. Chem., Int. Ed.* **2000**, *39*, 3049–3052.
2. (a) Ballini, R.; Barboni, L.; Bosica, G.; Fiorini, D.; Mignini, E.; Palmieri, A. *Tetrahedron* **2004**, *60*, 4995–4999; (b) Ghosh, N. *Synlett* **2004**, 574–575; (c) Aggarwal, V. K.; Mereu, A. *Chem. Commun.* **1999**, 2311–2312; (d) Hwu, J. R.; Hakimelahi, G. H.; Chou, C.-T. *Tetrahedron Lett.* **1992**, *33*, 6469–6472.
3. (a) de Souza, R. O. M. A.; Pereira, V. L. P.; Esteves, P. M.; Vasconcellos, M. L. A. A. *Tetrahedron Lett.* **2008**, *49*, 5902–5905; (b) Shi, M.; Zhao, G.-L. *Tetrahedron* **2004**, *60*, 2083–2089; (c) Yu, C.; Hu, L. *J. Org. Chem.* **2002**, *67*, 219–223.
4. (a) Octavio, R.; de Souza, M. A.; Vasconcellos, M. L. A. A. *Synth. Commun.* **2003**, *33*, 1383–1389; (b) Rezgui, F.; El Gaied, M. M. *Tetrahedron Lett.* **1998**, *39*, 5965–5966.
5. (a) Teng, W. D.; Huang, R.; Kwong, C. K.; Shi, M.; Toy, P. H. *J. Org. Chem.* **2006**, *71*, 368–371; (b) Shi, M.; Liu, Y. H. *Org. Biomol. Chem.* **2006**, *4*, 1468–1470; (c) Ito, H.; Takenaka, Y.; Fukunishi, S.; Iguchi, K. *Synthesis* **2005**, 3035–3038; (d) Morita, K.; Kobayashi, T. *Bull. Chem. Soc. Jpn.* **1969**, *42*, 2732–2736; (e) Morita, K.; Suzuki, Z.; Hirose, H. *Bull. Chem. Soc. Jpn.* **1968**, *41*, 2815.
6. (a) Lattanzi, A. *Synlett* **2007**, 2106–2110; (b) Hill, J. S.; Isaacs, N. S. *Tetrahedron Lett.* **1986**, *27*, 5007–5010.
7. Ribiere, P.; Yadav-Bhatnagar, N.; Martinez, J.; Lamaty, F. *QSAR Comb. Sci.* **2004**, *23*, 911–914.
8. (a) Luo, S.; Wang, P. G.; Cheng, J.-P. *J. Org. Chem.* **2004**, *69*, 555–558; (b) Shi, M.; Jiang, J.-K.; Li, C.-Q. *Tetrahedron Lett.* **2002**, *43*, 127–130.
9. Baylis, A. B.; Hillman, M. E. D. German Patent 2155113, 1972; *Chem. Abstr.* **1972**, *77*, 34174q.
10. (a) Duarte, F. J. S.; Cabrita, E. J.; Frenking, G.; Santos, A. G. *Chem.—Eur. J.* **2009**, *15*, 1734–1746; (b) Krishna, P. R.; Kannan, V.; Sharma, G. V. M. *J. Org. Chem.* **2004**, *69*, 6467–6469; (c) Yeo, J. E.; Yang, X.; Kim, H. J.; Koo, S. *Chem. Commun.* **2004**, 236–237; (d) Keck, G. E.; Welch, D. S. *Org. Lett.* **2002**, *4*, 3687–3690; (e) Frank, S. A.; Mergott, D. J.; Roush, W. R. *J. Am. Chem. Soc.* **2002**, *124*, 2404–2405; (f) Black, G. F.; Dinos, F.; Fratuccello, S.; Murphy, F. J.; Nielsen, M.; Williams, H. L. *Tetrahedron Lett.* **1997**, *38*, 8561–8564; (g) Roth, F.; Gygax, P.; Frater, G. *Tetrahedron Lett.* **1992**, *33*, 1045–1048.
11. (a) Gong, J. J.; Yuan, K.; Song, H. L.; Wu, X. Y. *Tetrahedron* **2010**, *66*, 2439–2443; (b) Chen, S.-H.; Hong, B.-C.; Su, C.-F.; Sarshar, S. *Tetrahedron Lett.* **2005**, *46*, 8899–8903; (c) Aroyan, C. E.; Vasbinder, M. M.; Miller, S. J. *Org. Lett.* **2005**, *7*, 3849–3851; (d) Marino, J. P.; Nguyen, H. N. *J. Org. Chem.* **2002**, *67*, 6291–6296; (e) Yagi, K.; Turitani, T.; Shinokubo, H.; Oshima, K. *Org. Lett.* **2002**, *4*, 3111–3114; (f) Dinon, F.; Richards, E.; Murphy, P. J. *Tetrahedron Lett.* **1999**, *40*, 3279–3282; (g) Drewes, S. E.; Njamela, O. L.; Emslie, N. D.; Ramesar, N.; Field, J. S. *Synth. Commun.* **1993**, *23*, 2807–2815.
12. (a) Drews, J. *Science* **2000**, *287*, 1960–1964; (b) Scozzafava, A.; Owa, T.; Mastrolorenzo, A.; Supuran, C. T. *Curr. Med. Chem.* **2003**, *10*, 925–953.
13. (a) Horton, D. A.; Bourne, G. T.; Smythe, M. L. *Chem. Rev.* **2003**, *103*, 893–930; (b) Rayabarapu, D. K.; Zhou, A.; Jeon, K. O.; Samarakoon, T.; Rolfe, A.; Siddiqui, H.; Hanson, P. R. *Tetrahedron* **2009**, *65*, 3180–3188; (c) Rolfe, A.; Young, K.; Volp, K.; Schoenen, F.; Neuenswander, B.; Lushington, G. H.; Hanson, P. R. *J. Comb. Chem.* **2009**, *11*, 732–738.
14. Rabasseda, X.; Hopkins, S. J. *Drugs Today* **1994**, *30*, 557–561.
15. Wells, G. J.; Tao, M.; Josef, K. A.; Bihovsky, R. *J. Med. Chem.* **2001**, *44*, 3488–3503.
16. Brzozowski, F.; Saczewski, F.; Neamati, N. *Bioorg. Med. Chem. Lett.* **2006**, *16*, 5298–5302.
17. Tanimukai, H.; Inui, M.; Hariguchi, S.; Kaneko, Z. *Biochem. Pharmacol.* **1965**, *14*, 961–970.
18. (a) Marti, C.; Carreira, E. M. *Eur. J. Org. Chem.* **2003**, *12*, 2209–2219; (b) Galliford, C. V.; Scheidt, K. A. *Angew. Chem., Int. Ed.* **2007**, *46*, 8748–8758.
19. Peddibhotla, S. *Curr. Bioact. Compd.* **2009**, *5*, 20–38.
20. Ghandi, M.; Hasani Bozcheloei, A.; Nazari, S. H.; Sadeghzadeh, M. *J. Org. Chem.* **2011**, *76*, 9975–9982.
21. Ghandi, M.; Sheibani, S.; Sadeghzadeh, M.; Johari Daha, F.; Kubicki, M. *J. Iran. Chem. Soc.* **2013**, *10*, 1057–1065.
22. Munusamy, R.; Dhathathreyan, K. S.; Balasubramanian, K. K.; Venkatachalam, C. S. *J. Chem. Soc., Perkin Trans. 2* **2001**, 1154–1166.
23. The CCDC deposition number for compound **2d** is 950191. Formula: $C_{16}H_{15}NO_2$. Unit cell parameters: a=9.0171(18), b=9.0680(18), c=9.822(2), P–1.
24. (a) Price, K. E.; Broadwater, S. J.; Jung, H. M.; McQuade, D. T. *Org. Lett.* **2005**, *7*, 147–150; (b) Price, K. E.; Broadwater, S. J.; Walker, B. J.; McQuade, D. T. *J. Org. Chem.* **2005**, *70*, 3980–3987.
25. Aggarwal, V. K.; Mereu, A. *Chem. Commun.* **1999**, 2311–2312.
26. Aggarwal, V. K.; Emme, I.; Fulford, S. Y. *J. Org. Chem.* **2003**, *68*, 692–700.
27. Hine, J.; Chen, Y. J. *J. Org. Chem.* **1987**, *52*, 2091–2094.
28. Doye, S.; Hotopp, T.; Winterfeldt, E. *Chem. Commun.* **1997**, 1491–1492.
29. The CCDC deposition number for compound **3f** is 950190. Formula: $C_{17}H_{17}NO_3S$. Unit cell parameters: a=9.1990(18), b=10.209(2), c=10.616(2), P–1.
30. Ciganek, E. *J. Org. Chem.* **1995**, *60*, 4635–4637.