An Alternative Synthesis of 2-Alkylidene-3,4-dihydro-2*H*-1,4-benzoxazines by Intramolecular Gold-Catalyzed Hydroalkoxylation of 2-(Prop-2-yn-1-ylamino)phenols

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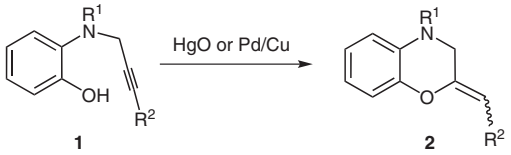
Abstract: An efficient gold-catalyzed procedure to synthesize 2-alkylidene-3,4-dihydro-2*H*-1,4-benzoxazines has been developed starting from 2-alkynyl-substituted phenols. This is an intramolecular hydroalkoxylation reaction on alkynes tethered to a phenol moiety that represents a valuable alternative to the already reported transition-metal-catalyzed procedures.

Key words: transition metals, heterocycles, alkynes, phenols, fused-ring systems

3,4-Dihydro-2*H*-1,4-benzoxazine derivatives have attracted considerable interest due to the presence of their skeleton in several naturally occurring substances,[1] often endowed with pharmacological properties.[2] Among them, 2-alkylidene-substituted compounds **2** are versatile building blocks to prepare more complex structures due to the presence of the exocyclic C=C bond. Interesting synthetic approaches for compounds **2** have been reported using transition-metal-catalyzed cyclization of 2-alkynyl-substituted phenols **1** (Scheme 1).[3]



Scheme 1 Transition-metal-catalyzed cyclization of 2-alkynyl-substituted phenols **1**

Transition-metal-catalyzed intramolecular reactions involving a C≡C bond have been recognized since some decades as useful processes to prepare heterocyclic products.[4] In this context, homogeneous gold catalysis has emerged in organic synthesis as a powerful tool due to its unique ability to activate unsaturated carbon–carbon bonds toward the attack of many nucleophiles in mild conditions.[5]

As part of our continuing interest in transition-metal catalysis as a route to heterocycles,[6] we were interested in developing a new and alternative approach for the synthesis of 2-alkylidene-3,4-dihydro-2*H*-1,4-benzoxazines using mild conditions. Hence, the feasibility of the intramolecular hydroalkoxylation of alkynes **1** in the presence of gold-catalysts was investigated and the results are reported herein.

Initially, the 2-(prop-2-yn-1-ylamino)phenol (**1a**), easily prepared in good yield from 2-aminophenol and propargyl bromide in ethanol as solvent, was submitted to gold-catalyzed reactions in different conditions (Table 1). Treatment of **1a** with gold(III) chloride alone or in the presence of silver triflate in acetonitrile at reflux resulted in the recovery of starting material **1a** together with the formation of small amounts of 8-hydroxyquinoline (**3**), arising from a 6-*endo*-dig hydroarylation (Table 1, entries 1, 2). When the reaction was performed in dichloromethane as solvent no cyclization products were observed (entry 3). The use of $NaAuCl_4 \cdot 2H_2O$ in acetonitrile afforded **3** in high yields (entry 4). By performing the reaction with gold(I) salts in different solvents no trace of cyclized products was detected (entries 5–7). Conversely, working in the presence of gold(I) chloride (5 mol%) and potassium carbonate (10 mol%) as a co-catalyst in acetonitrile at reflux, the desired 1,4-benzoxazine **2a** was obtained as 6-*exo*-dig cyclization product in satisfactory yield, with a very small amount of **3** (entry 8).

To test the effectiveness of potassium carbonate as a co-catalyst its reaction with other gold(I) catalytic systems was tried, but lower yields of compound **2a** were observed (entries 9, 10). The use of potassium carbonate with gold(III) chloride afforded **2a** in lower yield increasing the amount of **3** (entry 11). To rule out the hypothesis that potassium carbonate was solely responsible for the formation of **2a**, substrate **1a** was refluxed in acetonitrile for 24 hours with potassium carbonate (10% mol) in the absence of any type of gold catalyst, recovering only starting material (entry 12).

Next the scope of the gold-catalyzed cyclization under the conditions of Table 1, entry 8 was explored. A number of 2-alkynyl-substituted phenol derivatives **1**, that were completely cyclized in 1–24 hours, are collected in Table 2. Firstly, column chromatography of the crude mixture arising from the reaction of the nitrogen-unsubstituted compound **1a** gave the 2-methylene-3,4-dihydro-

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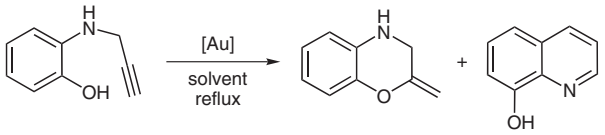
Table 1 Optimization of Reaction Conditions for the Hydroalkoxylation of **1a**



1a **2a** **3**

Entry	Catalytic system[a,b]	Solvent	Reaction product (%)[c]		
			1a	**2a**	**3**
1	$AuCl_3$	MeCN	90	–	10
2	$AuCl_3$, AgOTf	MeCN	80	–	20
3	$AuCl_3$	CH_2Cl_2	100	–	–
4	$NaAuCl_4 \cdot 2H_2O$	MeCN	20	–	80
5	AuCl	MeCN	100	–	–
6	AuCl	1,4-dioxane	100	–	–
7	PPh_3AuCl, AgOTf	MeCN	100	–	–
8	AuCl, K_2CO_3	MeCN	–	90	10
9	PPh_3AuCl, $AgBF_4$, K_2CO_3	MeCN	60	40	–
10	PPh_3AuCl, AgOTf, K_2CO_3	MeCN	55	45	–
11	$AuCl_3$, K_2CO_3	MeCN	60	20	20
12	K_2CO_3	MeCN	100	–	–

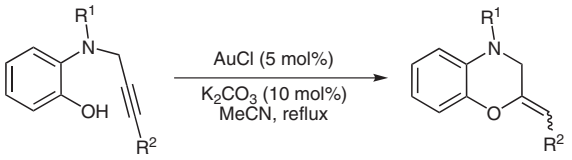
[a] Au catalyst is used in 5 mol%.
[b] K_2CO_3 is used in 10 mol%.
[c] Ratio determined by HPLC.

2*H*-1,4-benzoxazine (**2a**) in 72% yield (Table 2, entry 1). Benzoyl- and acetyl-substituted substrates **1b** and **1c** behave in a similar manner leading to the formation of the corresponding cyclized products (entries 2 and 3). Tosyl-substituted compound **1d** gave rise to **2d** with the fastest rate and highest yield (entry 4).

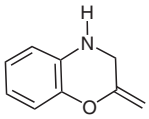
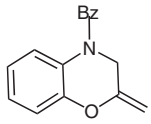
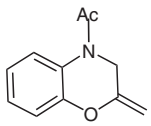
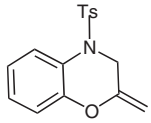
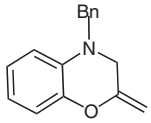
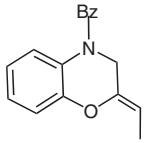
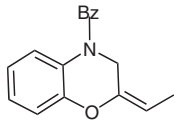
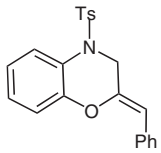
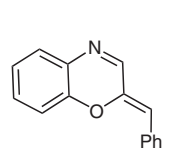
The presence of a benzyl group on the nitrogen atom did not affect the reaction outcome, giving the corresponding 1,4-benzoxazine in 65% yield (entry 5). Conversely, substrates having a disubstituted C≡C bond underwent cyclization only in the presence of gold(III) chloride in *N*,*N*-dimethylformamide at 95 °C (entries 6 and 7). Under these conditions, compound **1f** led to a clear mixture of (*Z*)- and (*E*)-2,3-dihydro-4*H*-1,4-benzoxazines **2f** in good yields with the *Z*-isomer as the major product. The behavior of **1g** was surprisingly different from **1f**, resulting in a tarry mixture that provided only the *Z*-diastereoisomer in 35% yield along with a 5% of the highly conjugated (*Z*)-**4** lacking the tosyl group. The stereochemistry of the (*Z*)- and (*E*)-**2f** as well as of (*Z*)-**2g** and (*Z*)-**4** were assigned by NOE measurements.

A proposed mechanism for the gold-catalyzed heterocyclization is shown in Scheme 2. After deprotonation, the triple bond of the phenol derivatives **1** coordinates with the gold species. The generated π-alkyne complexes **5** undergo intramolecular nucleophilic attack by phenoxide group affording the vinylgold intermediates **6**. Finally, protonolysis of the gold–carbon bond from **6** affords the 1,4-benzoxazines **2** with regeneration of the gold catalyst.

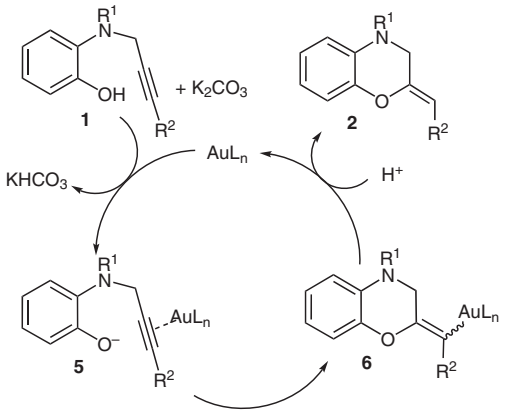
Table 2 Reaction Scope for Hydroalkoxylation of 2-(Prop-2-yn-1-ylamino)phenols



1 **2**

Entry	Substrate	R^1	R^2	Time (h)	Product (yield)
1[a]	**1a**	H	H	8	 **2a** (72%)
2	**1b**	Bz	H	8	 **2b** (63%)
3	**1c**	Ac	H	5	 **2c** (61%)
4	**1d**	Ts	H	1	 **2d** (91%)
5	**1e**	Bn	H	5	 **2e** (65%)
6[b]	**1f**	Bz	Me	2	 (*Z*)-**2f** (51%)  (*E*)-**2f** (32%)
7[b]	**1g**	Ts	Ph	24	 (*Z*)-**2g** (36%)  (*Z*)-**4** (7%)

[a] After column chromatography, 8% of **3** was isolated.
[b] $AuCl_3$ (5 mol%) in DMF at 95 °C.



Scheme 2 Proposed mechanism for the formation of compounds **2**

In summary, a valuable gold-catalyzed procedure to cyclize 2-(prop-2-yn-1-ylamino)phenols affording 2-alkylidene-3,4-dihydro-2*H*-1,4-benzoxazines was described. Intramolecular hydroalkoxylations have been already used as fruitful and atom-economy route for the synthesis of various oxygenated heterocycles.[8] In this context, this reaction represents an alternative to other metal-catalyzed routes to build the 1-4-benzoxazine skeleton and leads to the formation of products having an exocyclic C=C bond, which might allow further functionalizations in order to provide more complex structures.

Chemicals were purchased from Aldrich. ^{1}H NMR and ^{13}C NMR spectra were recorded at 600 MHz on an INOVA AS600 Variant. Chemical shifts (δ) are given as ppm relative to the residual solvent peak ($CDCl_3$ 7.25 ppm/77 ppm). Mass spectra were determined on an HPLC-MS LCQ-Advantage Thermo Finnigan instrument. Protonated molecular mass ion peaks were determined on an HPLC-MS Agilent Technologies 6140 with ESI source for electrospray ionization. Elemental analyses were executed on PerkinElmer CHN Analyzer Series II 2400. Column chromatography was performed on a Merck silica gel 60 (mesh size 63–200 μm).

Alkynes 1a,e; General Procedure

Propargyl bromide (9.16 mmol) was slowly added to a solution of the respective 2-aminophenol (45.8 mmol) in EtOH (130 mL). The mixture was stirred for 4 d at r.t. The solvent was evaporated under reduced pressure. The residue was washed with *t*-BuOMe (100 mL) and the precipitate was filtered off. The solution was evaporated under reduced pressure and the residue was purified by flash column chromatography (cyclohexane–EtOAc, 75:25).

2-(Prop-2-yn-1-ylamino)phenol (1a)

Yield: 75%; pale yellow solid; mp 96–97 °C (*i*-Pr_2O).

IR (Nujol): 2132, 3305, 3388, 3495 cm^{-1}.

^{1}H NMR (599 MHz, $CDCl_3$): δ = 2.25 (t, *J* = 2.3 Hz, 1 H), 3.96 (d, *J* = 2.3 Hz, 2 H), 4.56 (br s, 2 H, D_2O exch), 6.69–6.74 (m, 1 H), 6.76–6.82 (m, 1 H), 6.84–89 (m, 1 H), 6.91–6.99 (m, 1 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 34.4 (t), 71.6 (q), 81.3 (s), 114.2 (d), 114.8 (d), 119.7 (d), 121.7 (d), 135.6 (s), 144.6 (s).

HPLC-MS (ESI): *m*/*z* = 148.17 [MH^+].

Anal. Calcd for C_9H_9NO: C, 73.45; H, 6.16; N, 9.52. Found: C, 73.61; H, 5.90; N, 9.44.

These data are consistent with the partially reported literature values.[3a,7]

2-[Benzyl(prop-2-yn-1-yl)amino]phenol (1e)

Yield: 72%; red oil.

IR (Nujol): 2112, 3312, 3392 cm^{-1}.

^{1}H NMR (599 MHz, $CDCl_3$): δ = 2.33 (t, *J* = 2.3 Hz, 1 H), 3.58 (d, *J* = 2.3 Hz, 2 H), 4.16 (s, 2 H), 4.70 (br s, 1 H, D_2O exch), 6.88 (t, *J* = 7.7 Hz, 1 H), 6.94 (d, *J* = 8.2 Hz, 1 H), 7.11 (t, *J* = 7.7 Hz, 1 H), 7.21–7.29 (m, 1 H), 7.32–7.38 (m, 4 H), 7.41 (d, *J* = 7.6 Hz, 1 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 42.7 (t), 57.2 (t), 73.8 (d), 78.8 (s), 114.1 (d), 119.8 (d), 124.0 (d), 127.1 (d), 127.7 (d), 128.5 (d), 128.5 (d), 129.3 (d), 129.3 (d), 136.8 (s), 137.0 (s), 151.9 (s).

HPLC-MS (ESI): *m*/*z* = 238.29 [MH^+].

Anal. Calcd for $C_{16}H_{15}NO$: C, 80.98; H, 6.37; N, 5.90. Found: C, 81.14; H, 6.20; N, 5.96.

These data are consistent with the partially reported literature values.[3a]

Alkynes 1b–d,f,g; General Procedure

To a stirred solution of **1a** (985 mg, 6.7 mmol) (for the preparation of **1f**,**g**, the corresponding but-2-yn-1-yl and 3-phenylprop-2-yn-1-yl substituted aminophenols were used) and pyridine (2.7 mL) in anhyd CH_2Cl_2 (68 mL) was slowly added a solution of the appropriate acyl chloride (7.1 mL) in anhyd CH_2Cl_2 (6.7 mL) at 0 °C. The mixture was allowed to r.t. and stirred at this temperature for 3 h. The organic phase was washed with aq 2 N HCl (3 × 16 mL), then with a 5% aq $NaHCO_3$ (2 × 20 mL), and finally with H_2O (2 × 30 mL). The organic phase was dried (Na_2SO_4), filtered, and the solvent evaporated under reduced pressure. The crude residue was triturated with *t*-BuOMe (20 mL). The solid obtained was collected by filtration and dried in an oven at 40 °C.

***N*-(2-Hydroxyphenyl)-*N*-(prop-2-yn-1-yl)benzamide (1b)**

Yield: 71%; white solid; mp 156–158 °C (CH_2Cl_2–acetone).

IR (Nujol): 2133, 1698, 3290, 3325 cm^{-1}.

^{1}H NMR (599 MHz, $CDCl_3$): δ = 2.32 (br s, 1 H), 4.58 (br s, 2 H), 6.09 (br s, 1 H, D_2O exch), 6.77 (br s, 1 H), 6.94–7.02 (m, 2 H), 7.27–7.39 (m, 6 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 38.6 (t), 72.8 (d), 79.0 (s), 116.9 (d), 121.1 (d), 127.8 (d), 127.9 (d), 127.9 (d), 129.6 (d), 129.7 (d), 129.7 (d), 130.0 (s), 130.3 (d), 134.5 (s), 151.8 (s), 171.5 (s).

HPLC-MS (ESI): *m*/*z* = 252.27 [MH^+].

Anal. Calcd for $C_{16}H_{13}NO_2$: C, 76.48; H, 5.21; N, 5.57. Found: C, 76.27; H, 5.43; N, 5.75.

These data are consistent with the partially reported literature values.[3a]

***N*-(2-Hydroxyphenyl)-*N*-(prop-2-yn-1-yl)acetamide (1c)**

Yield: 76%; white solid; mp 158–159 °C (*i*-Pr_2O).

IR (Nujol): 2120, 1675, 3296 cm^{-1}.

^{1}H NMR (599 MHz, $CDCl_3$): δ = 1.89 (s, 3 H), 2.27 (t, *J* = 2.3 Hz, 1 H), 4.48–4.56 (m, 2 H), 6.69 (br s, 1 H, D_2O exch), 6.98 (t, *J* = 7.5 Hz, 1 H), 7.07 (d, *J* = 8.2 Hz, 1 H), 7.16–7.25 (m, 1 H), 7.32–7.41 (m, 1 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 22.0 (q), 37.5 (t), 72.6 (d), 79.0 (s), 117.5 (d), 121.2 (d), 128.4 (s), 129.0 (d), 130.5 (d), 152.6 (s), 171.8 (s).

HPLC-MS (ESI): *m*/*z* = 190.21 [MH^+].

Anal. Calcd for $C_{11}H_{11}NO_2$: C, 69.83; H, 5.86; N, 7.40. Found: C, 69.81; H, 6.01; N, 7.23.

These data are consistent with the partially reported literature values.[3a]

N-(2-Hydroxyphenyl)-4-methyl-N-(prop-2-yn-1-yl)benzenesulfonamide (1d)
Yield: 80%; pale yellow solid; mp 165–166 °C (*i*-Pr_2O).

IR (Nujol): 2135, 3266, 3415 cm^{-1}.

^1H NMR (599 MHz, $CDCl_3$): δ = 2.21 (t, *J* = 2.4 Hz, 1 H), 2.44 (s, 3 H), 4.39 (d, *J* = 1.3 Hz, 2 H), 6.54 (s, 1 H, D_2O exch), 6.66–6.75 (m, 2 H), 7.02–7.11 (m, 1 H), 7.19–7.27 (m, 3 H), 7.59 (d, *J* = 8.2 Hz, 2 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 21.6 (q), 41.7 (t), 74.1 (d), 77.5 (s), 117.4 (d), 120.4 (d), 125.7 (s), 128.1 (d), 128.4 (d), 128.4 (d), 129.4 (d), 129.4 (d), 130.5 (d), 133.8 (s), 144.5 (s), 154.4 (s).

HPLC-MS (ESI): *m*/*z* = 302.36 [MH^+].

Anal. Calcd for $C_{16}H_{15}NO_3S$: C, 63.77; H, 5.02; N, 4.65. Found: C, 63.92; H, 4.83; N, 4.69.

N-(But-2-yn-1-yl)-N-(2-hydroxyphenyl)benzamide (1f)
Yield: 82%; white solid; mp 142–143 °C (*i*-Pr_2O).

IR (Nujol): 2208, 1715, 3275 cm^{-1}.

^1H NMR (599 MHz, $CDCl_3$): δ = 1.81 (t, *J* = 2.3 Hz, 3 H), 4.48–4.59 (m, 2 H), 6.72 (br s, 1 H, D_2O exch), 6.87–6.96 (m, 2 H), 7.06–7.26 (m, 5 H), 7.35–7.41 (m, 2 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 3.58 (q), 39.0 (t), 74.3 (s), 80.8 (s), 117.0 (d), 120.7 (d), 127.7 (d), 127.7 (d), 127.8 (d), 127.8 (d), 129.5 (d), 129.8 (d), 130.0 (s), 130.0 (d), 134.8 (s), 152.2 (s), 171.6 (s).

HPLC-MS (ESI): *m*/*z* = 266.30 [MH^+].

Anal. Calcd for $C_{17}H_{15}NO_2$: C, 76.96; H, 5.70; N, 5.28. Found: C, 76.99; H, 5.83; N, 5.21.

N-(2-Hydroxyphenyl)-4-methyl-N-(3-phenylprop-2-yn-1-yl)benzenesulfonamide (1g)
Yield: 63%; pale yellow solid; mp 168 °C (*i*-Pr_2O).

IR (Nujol): 2215, 3324 cm^{-1}.

^1H NMR (599 MHz, $CDCl_3$): δ = 2.41 (s, 3 H), 4.63 (br s, 2 H), 6.63 (s, 1 H, D_2O exch), 6.72–6.79 (m, 1 H), 6.84 (dd, *J* = 8.0, 1.3 Hz, 1 H), 7.09 (dd, *J* = 8.2, 1.3 Hz, 1 H), 7.21–7.33 (m, 8 H), 7.65 (d, *J* = 8.2 Hz, 2 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 21.6 (q), 42.7 (t), 82.9 (s), 85.9 (s), 117.4 (d), 120.4 (d), 122.0 (s), 126.1 (s), 128.2 (d), 128.2 (d), 128.5 (d), 128.5 (d), 128.6 (d), 129.4 (d), 129.4 (d), 130.5 (d), 130.5 (d), 131.5 (d), 131.5 (d), 134.2 (s), 144.3 (s), 154.5 (s).

HPLC-MS (ESI): *m*/*z* = 378.45 [MH^+].

Anal. Calcd for $C_{22}H_{19}NO_3S$: C, 70.00; H, 5.07; N, 3.71. Found: C, 70.18; H, 4.81; N, 3.52.

Hydroalkoxylation of Alkynes 1; General Procedure
To a solution of **1a–e** (3.98 mmol) in anhyd MeCN (120 mL) were added K_2CO_3 (54 mg, 0.39 mmol) and AuCl (44 mg, 0.19 mmol) [for **1f**,**g** $AuCl_3$ (5 mol%) was used]. The mixture was refluxed for 8 h. The solvent was then evaporated under reduced pressure. The crude residue was purified by flash chromatography (cyclohexane–cyclopentyl methyl ether, 7:3) (Table 2).

2-Methylidene-3,4-dihydro-2*H*-1,4-benzoxazine (2a)
Yield: 72%; red oil.

IR (Nujol): 3352 cm^{-1}.

^1H NMR (599 MHz, $CDCl_3$): δ = 3.68 (d, *J* = 1.9 Hz, 2 H), 4.25 (d, *J* = 0.6 Hz, 1 H), 4.48 (d, *J* = 0.6 Hz, 1 H), 5.91 (br s, 1 H, D_2O exch), 6.61 (td, *J* = 7.7, 1.6 Hz, 1 H), 6.69 (dd, *J* = 7.9, 1.6 Hz, 1 H), 6.76 (td, *J* = 7.9, 1.3 Hz, 1 H), 6.80 (d, *J* = 7.9 Hz, 1 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 41.9 (t), 88.3 (t), 115.1 (d), 115.2 (d), 118.1 (d), 121.8 (d), 135.2 (s), 142.0 (s), 152.5 (s).

HPLC-MS (ESI): *m*/*z* = 148.17 [MH^+].

Anal. Calcd for C_9H_9NO: C, 73.45; H, 6.16; N, 9.52. Found: C, 73.62; H, 6.02; N, 9.43

(2-Methylidene-2,3-dihydro-4*H*-1,4-benzoxazin-4-yl)(phenyl)methanone (2b)
Yield: 63%; light yellow solid; mp 115–116 °C (*i*-Pr_2O).

IR (Nujol): 1694 cm^{-1}.

^1H NMR (599 MHz, $CDCl_3$): δ = 4.33 (br s, 1 H), 4.46 (s, 2 H), 4.73 (d, *J* = 1.3 Hz, 1 H), 6.71 (br s, 2 H), 7.01–7.12 (m, 2 H), 7.35 (t, *J* = 6.9 Hz, 2 H), 7.44 (t, *J* = 6.9 Hz, 1 H), 7.48 (d, *J* = 7.9 Hz, 2 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 43.9 (t), 90.7 (t), 116.8 (d), 121.2 (d), 124.2 (d), 125.9 (d), 127.2 (s), 128.3 (d), 128.3 (d), 128.6 (d), 130.8 (d), 130.8 (d), 134.5 (s), 145.3 (s), 151.6 (s), 168.4 (s).

HPLC-MS (ESI): *m*/*z* = 252.27 [MH^+].

Anal Calcd for $C_{16}H_{13}NO_2$: C, 76.48; H, 5.21; N, 5.57. Found: C, 76.36; H, 5.32; N, 5.84.

These data are consistent with the partially reported literature values.[3a]

1-(2-Methylidene-2,3-dihydro-4*H*-1,4-benzoxazin-4-yl)ethanone (2c)
Yield: 61%; red oil.

IR (Nujol): 1680 cm^{-1}.

^1H NMR (599 MHz, $CDCl_3$): δ = 2.29 (s, 3 H), 4.33 (br s, 1 H,), 4.38 (br s, 1 H), 4.66 (d, *J* = 1.6 Hz, 2 H), 7.01 (dt, *J* = 7.6, 1.3 Hz, 1 H), 7.05 (d, *J* = 7.9 Hz, 1 H), 7.10–7.23 (m, 2 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 22.2 (q), 41.8 (t), 90.5 (t), 117.0 (d), 121.6 (d), 123.8 (d), 126.7 (d), 127.4 (s), 146.2 (s), 151.7 (s), 168.8 (s).

HPLC-MS (ESI): *m*/*z* = 190.21 [MH^+].

Anal. Calcd for $C_{11}H_{11}NO_2$: C, 69.83; H, 5.86; N, 7.40. Found: C, 69.67; H, 6.07; N, 7.26.

These data are consistent with the partially reported literature values.[3a]

2-Methylidene-4-[(4-methylphenyl)sulfonyl]-3,4-dihydro-2*H*-1,4-benzoxazine (2d)
Yield: 91%; white solid; mp 172–173 °C (EtOAc).

^1H NMR (599 MHz, $CDCl_3$): δ = 2.36 (s, 3 H), 4.06 (s, 1 H), 4.28 (s, 2 H), 4.32 (s, 1 H), 6.85 (d, *J* = 8.2 Hz, 1 H), 7.04 (t, *J* = 7.7 Hz, 1 H), 7.12 (d, *J* = 7.9 Hz, 2 H), 7.18 (t, *J* = 7.7 Hz, 1 H), 7.35 (d, *J* = 7.9 Hz, 2 H), 7.74 (d, *J* = 8.2 Hz, 1 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 21.5 (q), 46.0 (t), 91.3 (t), 116.6 (d), 122.0 (d), 124.2 (s), 126.8 (d), 127.6 (d), 127.6 (d), 127.6 (d), 129.2 (d), 129.2 (d), 134.4 (s), 144.1 (s), 147.1 (s), 148.5 (s).

HPLC-MS (ESI): *m*/*z* = 302.36 [MH^+].

Anal. Calcd for $C_{16}H_{15}NO_3S$: C, 63.77; H, 5.02; N, 4.65. Found: C, 63.85; H, 4.88; N, 4.46.

4-Benzyl-2-methylidene-3,4-dihydro-2*H*-1,4-benzoxazine (2e)
Yield: 65%; red oil.

^1H NMR (599 MHz, $CDCl_3$): δ = 3.60 (s, 2 H), 4.13 (d, *J* = 0.7 Hz, 1 H), 4.37 (s, 2 H), 4.62 (d, *J* = 0.7 Hz, 1 H), 6.74–6.92 (m, 3 H), 6.96 (dd, *J* = 7.7, 1.3 Hz, 1 H), 7.23–7.45 (m, 5 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 48.4 (t), 54.7 (t), 88.8 (t), 113.8 (d), 115.8 (d), 119.6 (d), 122.0 (d), 127.3 (d), 127.6 (d), 127.6 (d), 128.6 (d), 128.6 (d), 135.7 (s), 137.2 (s), 143.7 (s), 152.0 (s).

HPLC-MS (ESI): *m*/*z* = 238.29 [MH$^+$].

Anal. Calcd for $C_{16}H_{15}NO$: C, 80.98; H, 6.37; N, 5.90. Found: C, 81.15; H, 6.16; N, 5.73.

These data are consistent with the partially reported literature values.[3a]

[(2*Z*)-2-Ethylidene-2,3-dihydro-4*H*-1,4-benzoxazin-4-yl](phenyl)methanone [(*Z*)-2f]
Yield: 51%; white solid; mp 129–131 °C (*i*-Pr_2O).

IR (Nujol): 1705 cm^{-1}.

^{1}H NMR (599 MHz, $CDCl_3$): δ = 1.78 (d, *J* = 6.9 Hz, 3 H), 4.38 (br s, 2 H), 4.63–4.79 (m, 1 H), 6.70 (br s, 1 H), 6.70 (br s, 1 H), 7.01–7.14 (m, 1 H), 7.03–7.18 (m, 1 H), 7.29–7.40 (m, 2 H), 7.42–7.47 (m, 1 H), 7.48–7.55 (d, *J* = 6.9 Hz, 2 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 9.3 (q), 44.7 (t), 101.7 (d), 116.9 (d), 120.8 (d), 124.3 (d), 125.8 (d), 127.2 (s), 128.2 (d), 128.2 (d), 128.6 (d), 128.6 (d), 130.7 (d), 134.7 (s), 144.5 (s), 145.5 (s), 168.3 (s).

HPLC-MS (ESI): *m*/*z* = 266.30 [MH$^+$].

Anal. Calcd for $C_{17}H_{15}NO_2$: C, 76.96; H, 5.70; N, 5.28. Found: C, 76.91; H, 5.91; N, 5.05.

[(2*E*)-2-Ethylidene-2,3-dihydro-4*H*-1,4-benzoxazin-4-yl](phenyl)methanone [(*E*)-2f]
Yield: 32%; white solid; mp 116–117 °C (*i*-Pr_2O).

IR (Nujol): 1730 cm^{-1}.

^{1}H NMR (599 MHz, $CDCl_3$): δ = 2.02 (br s, 3 H), 4.44–4.56 (m, 2 H), 4.78 (br s, 1 H), 6.68 (br s, 1 H), 6.80 (br s, 1 H), 7.04–7.12 (m, 2 H), 7.16–7.22 (m, 2 H), 7.24–7.29 (m, 1 H), 7.33 (d, *J* = 7.2 Hz, 2 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 22.2 (q), 44.4 (t), 100.4 (d), 121.2 (d), 124.4 (d), 127.7 (d), 127.7 (d), 128.1 (d), 128.1 (d), 128.2 (d), 129.1 (d), 129.8 (d), 135.4 (s), 135.5 (s), 151.0 (s), 152.9 (s), 169.7 (s).

HPLC-MS (ESI): *m*/*z* = 266.30 [MH$^+$].

Anal. Calcd for $C_{17}H_{15}NO_2$: C, 76.96; H, 5.70; N, 5.28. Found: C, 77.14; H, 5.51; N, 5.39.

(2*Z*)-2-Benzylidene-4-[(4-methylphenyl)sulfonyl]-3,4-dihydro-2*H*-1,4-benzoxazine [(*Z*)-2g]
Yield: 36%; white solid; mp 144–145 °C (*i*-Pr_2O).

^{1}H NMR (599 MHz, $CDCl_3$): δ = 2.02 (s, 3 H), 4.33 (s, 2 H), 5.18 (s, 1 H), 6.89 (d, *J* = 7.9 Hz, 2 H), 7.02 (d, *J* = 7.9 Hz, 1 H), 7.11 (t, *J* = 7.7 Hz, 1 H), 7.12–7.21 (m, 1 H), 7.24–7.34 (s, 7 H), 7.76 (dd, *J* = 7.9, 0.9 Hz, 1 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 21.1 (q), 47.7 (t), 107.8 (d), 116.8 (d), 122.4 (d), 124.9 (s), 126.5 (d), 127.4 (d), 127.4 (d), 127.5 (d), 127.9 (d), 128.0 (d), 128.2 (d), 128.5 (d), 128.5 (d), 129.2 (d), 129.2 (d), 133.7 (s), 133.9 (s), 141.0 (s), 144.3 (s), 147.2 (s).

HPLC-MS (ESI): *m*/*z* = 378.45 [MH$^+$].

Anal. Calcd for $C_{22}H_{19}NO_3S$: C, 70.01; H, 5.07; N, 3.71. Found: C, 70.11; H, 5.11; N, 3.63.

(2*Z*)-2-Benzylidene-2*H*-1,4-benzoxazine [(*Z*)-4]
Yield: 7%; white solid; mp 112–113 °C (*i*-Pr_2O).

^{1}H NMR (599 MHz, $CDCl_3$): δ = 5.79 (s, 1 H), 7.05 (dd, *J* = 8.0, 1.1 Hz, 1 H), 7.03–7.15 (m, 1 H), 7.22 (td, *J* = 7.7, 1.3 Hz, 1 H), 7.26–7.33 (m, 1 H), 7.38 (dd, *J* = 7.6, 1.3 Hz, 1 H), 7.41 (t, *J* = 7.7 Hz, 2 H), 7.77 (d, *J* = 7.6 Hz, 2 H), 7.81 (s, 1 H).

^{13}C NMR (150.81 MHz, $CDCl_3$): δ = 112.5 (d), 115.3 (d), 123.9 (d), 127.8 (d), 128.1 (d), 128.5 (d), 128.5 (d), 129.0 (d), 129.0 (d), 129.5 (d), 132.5 (s), 134.0 (s), 143.4 (s), 145.5 (s), 154.5 (s).

HPLC-MS (ESI): *m*/*z* = 222.25 [MH$^+$].

HRMS (EI): *m*/*z* calcd for $C_{15}H_{11}NO$: C, 81.43; H, 5.01; N, 6.33. Found: C, 81.67; H, 4.84; N, 6.27.

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