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Article

Iodine(III)-Mediated Ring Contraction Reactions: Synthesis of Oxygen- and Nitrogen-Substituted Indanes

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The synthesis of oxygen- and nitrogen-substituted indanes was successfully performed by iodine(III)-mediated ring contraction of 1,2-dihydronaphthalenes. Acetoxy and benzoyloxy alkenes afforded indanes in 60-71% yield, irrespective of their position on aromatic ring. Similarly, the nitrogen containing substrates protected with 9-fluorenylmethyloxycarbonyl (Fmoc) and benzoyl (Bz) groups smoothly undergoes ring contraction giving indanes in 64-77% yield. The tosyl-protected substrate resulted only in addition products.

Keywords: indane, hypervalent iodine, ring contraction, 1,2-dihydronaphthalenes

Introduction

Indane skeleton occurs in many biologically active natural products[1,2] and pharmaceuticals, constituting an important target in organic synthesis and in drug discovery.[3] Numerous synthetic methodologies have been developed to construct indane core including cyclization,[4-6] cycloaddition,[7-9] and rearrangements.[10-13] Indanes substituted in the aromatic ring by nitrogen[14-18] or by oxygen[2,19-22] are present in compounds with promising biological activities. Hypervalent iodine reagents play a substantial role in chemical synthesis, promoting efficiently carbon-carbon bond formations, rearrangements and functional group interconversions, including asymmetric versions for many reactions.[23-28] The iodine(III)-mediated ring contraction of 1,2-dihydronaphthalenes gives functionalized indanes (Scheme 1, **1a**).[13,29] This transformation was successfully employed in total syntheses, such as (+)-mutisianthol,[30] (±)-indatraline,[29] and (+)-*trans*-trikentrin A.[31] Although the reactivity of several substrates was investigated under many conditions, the tolerance for substitution at aromatic ring was not high. For example, methoxy-substituted substrates furnished the desired indanes in low yield and additionally the main product were those related to the addition of solvent, as exemplified by the behavior of compound **1b**. Motivated by the importance of oxygen- and nitrogen-substituted indanes, we herein show the ring contraction of additional 1,2-dihydronaphthalenes with iodine(III).

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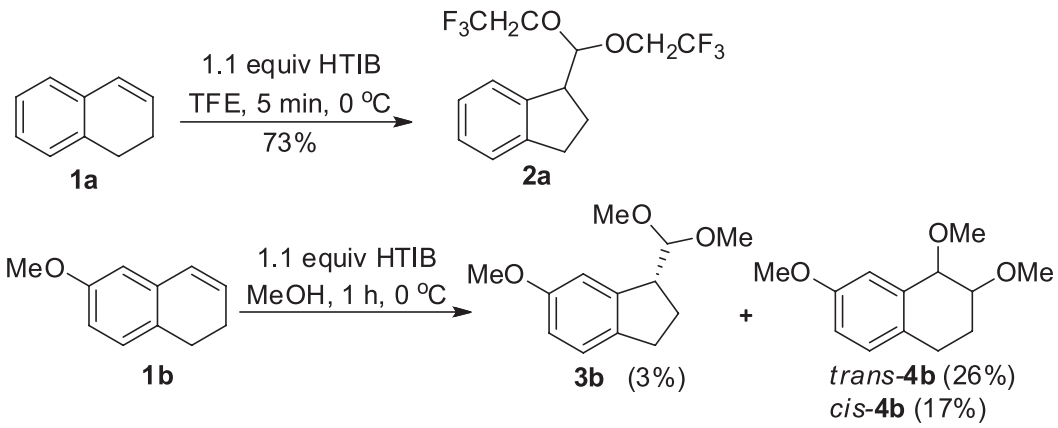
Results and Discussion

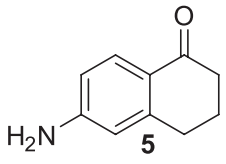
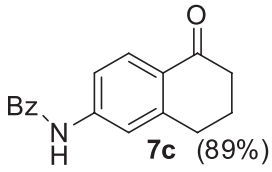
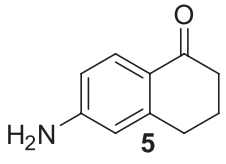
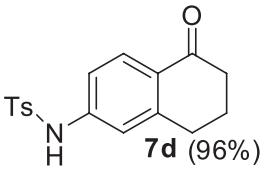
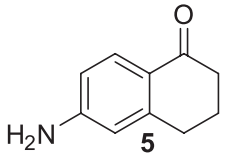
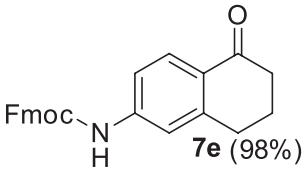
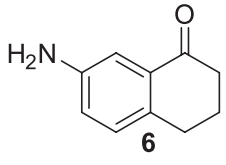
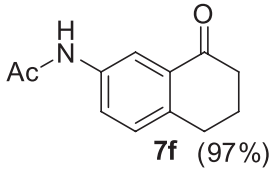
The preparation of the required substrates was performed as described in the following paragraphs. The protected amine tetralones (**7c**-**f**) were prepared by classical transformations (Table 1). Amine tetralone **5** in the presence of benzoyl chloride (BzCl), triethylamine (Et_3N) and dichloromethane (DCM) as solvent gave benzoyl protected amine **7c** in 89% yield (entry 1).[32] The tosyl protected amine tetralone **7d** was obtained in 96% yield in pyridine with tosyl chloride (p-TsCl) (entry 2).[33] In a similar manner, base labile Fmoc protected amine **7e** was formed in 98% yield with 9-fluorenylmethyloxycarbonyl chloride (Fmoc-Cl) and pyridine in DCM (entry 3).[34] The acetylation of tetralone **6** was achieved using 4-dimethylaminopyridine (DMAP), acetic anhydride (Ac_2O) in Et_3N giving acetyl protected ketone **7f** in 97% yield (entry 4).[13,35]

Several cyclic olefinic substrates were synthesized via reduction/dehydration protocol. The commercially available hydroxy ketone **8g** was reduced with $NaBH_4$ in MeOH to the corresponding alcohol as a white solid. Dehydration of alcohol at 130 °C in the presence of phosphoric acid (H_3PO_4) gave alkene product **1g** in 76% yield (Table 2, entry 1).[35] The methoxy functionalized ketones **8h** and **8b** were also transformed into cyclic alkenes **1h** and **1b** in 93 and 76% yields, respectively (entries 2 and 3).[13,36,37] The benzoyl, tosyl, Fmoc and acetyl protected amino ketones (**7c**-**f**) were smoothly converted into desired olefinic substrates (**1c**-**f**) in good yields (entries 4-7).[13,38]



Scheme 1. Oxidation of 1,2-dihydronaphthalenes **1a-b** with iodine(III).

Table 1. Synthesis of protected amines tetralones **7c-f**

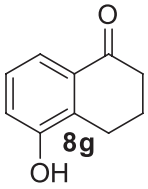
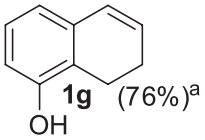
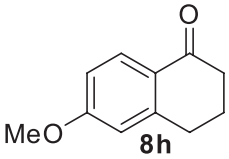
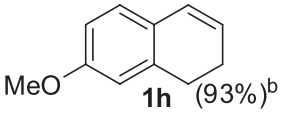
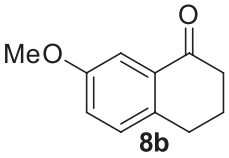
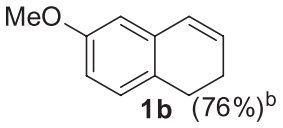
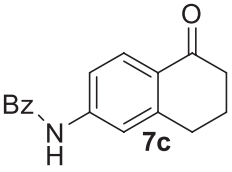
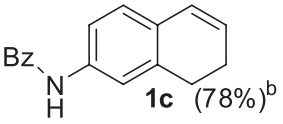
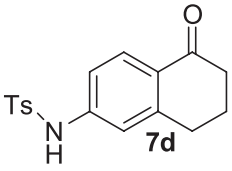
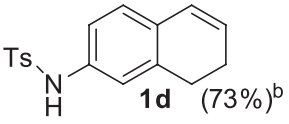
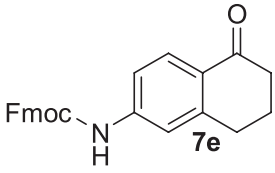
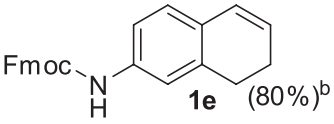
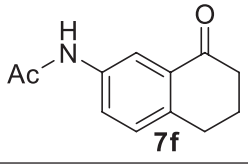
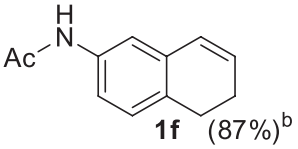
entry	Substrate	Condition	Product (Yield)
1		BzCl, Et_3N DCM, rt, 3 h	
2		*p*TsCl pyridine reflux, 16 h, rt	
3		Fmoc-Cl pyridine DCM, 0 °C to rt, 1 h	
4		Ac_2O DMAP Et_3N, rt, 1 h	

DCM: dichloromethane; rt: room temperature; DMAP: 4-dimethylaminopyridine.

The acetylation of phenol **1g** was accomplished with DMAP, Ac_2O in Et_3N as solvent,[13] leading to protected alkene **9g** in 96% yields (Table 3, entry 1). Similarly, phenol **1g** was also protected with benzoyl group in 94% yield using BzCl and Et_3N as a base (entry 2).[32] Methyl ethers (**1h** and **1b**) were first demethylated using sodium ethanethiolate (generated *in situ*) in dimethylformamide (DMF) at 140 °C giving the corresponding phenol,[39,40] which were acetylated under standard conditions (entries 3 and 4).

Iodine(III) is known to act as single-electron-transfer (SET) for methoxy-substituted aromatic compounds forming reactive cation radical intermediates.[41,42] The generation of these cation radicals could be a possible reason of rearrangement failure in substrates like **1b**, due to their susceptibility towards nucleophilic attack and other side reactions. Thus, we consider that the ring contraction could take place with an acetyl group instead of a methoxy making it useful in the synthesis of oxygen-substituted indanes. Several reaction conditions were tested for the

Table 2. Preparation of dihydronaphthalenes **1b-h** via reduction/dehydration

entry	Substrate	Product (Yield)
1	 **8g**	 **1g** (76%)[a]
2	 **8h**	 **1h** (93%)[b]
3	 **8b**	 **1b** (76%)[b]
4	 **7c**	 **1c** (78%)[b]
5	 **7d**	 **1d** (73%)[b]
6	 **7e**	 **1e** (80%)[b]
7	 **7f**	 **1f** (87%)[b]

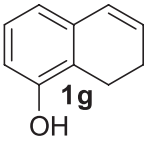
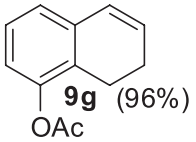
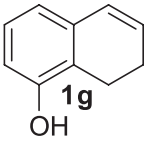
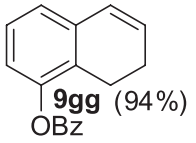
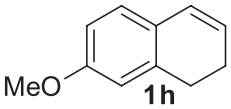
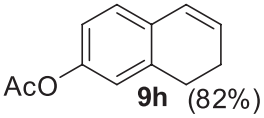
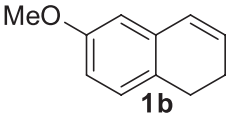
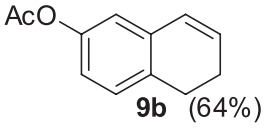
[a](*i*) $NaBH_4$, MeOH, 0 °C to rt, 1 h; (*ii*) H_3PO_4, THF, 80 °C, 2 h; [b](*i*) $NaBH_4$, MeOH, 0 °C to rt, 1 h; (*ii*) cat. $TsOH.H_2O$, toluene, 130 °C, 2 h.

oxidation of alkene **9g** with PhI(OH)OTs (HTIB) (Table 4). The desired ring contraction product **2g** was successfully obtained in 47% yield using trifluoroethanol (TFE)/DCM (1:4) as solvent (entry 1). Using pure TFE, the yield of acetal **2g** increased to 66% (entry 2). The deprotection of substrate **9g** into phenol **1g** was observed when MeOH was used as solvent (entry 3).

With the optimized conditions, ring contraction was successfully carried out in other oxygenated substrates (Table 5). Benzoyl protected alkene **9gg** gave acetal **2gg** in 71% yield (entry 1). Acetyl protected alkene **9h** smoothly afforded product **2h** in 60% yield (entry 2). Acetyl alkene **9b** gave acetal **2b** in 65% yield (entry 3).

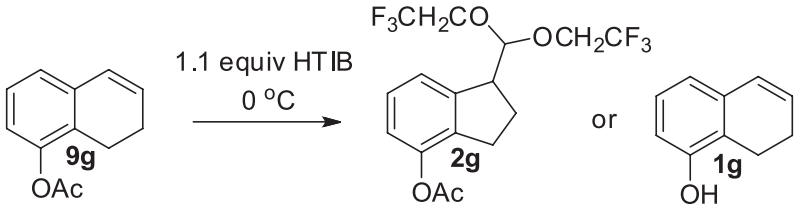
Oxidation with HTIB was also studied in amine protected alkenes (Table 6). Benzoyl protected alkene **1c** experienced ring contraction giving acetal product **3c** in 77% yield in MeOH/DCM (8:1) as solvent (entry 1). DCM was added to solubilize substrate **1c** and to increase

Table 3. Preparation of O-substituted dihydronaphthalenes

entry	Substrate	Condition	Product (Yield)
1		Ac_2O, DMAP, Et_3N	
2		BzCl, Et_3N, DCM	
3		(*i*) NaH, EtSH, DMF (*ii*) Ac_2O, DMAP, Et_3N	
4		(*i*) NaH, EtSH, DMF (*ii*) Ac_2O, DMAP, Et_3N	

DMAP: 4-dimethylaminopyridine; DCM: dichloromethane; DMF: dimethylformamide.

Table 4. Reactions of acetyl protected alkene **9g** with HTIB



entry	Solvent	time	Product	Yield / %
1	TFE/DCM (1:4)	5 min	**2g**	47
2	TFE	5 min	**2g**	66
3	MeOH	5 h	**1g**	55

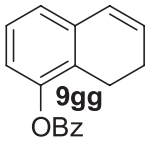
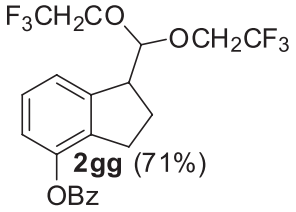
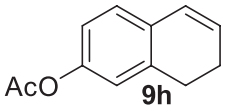
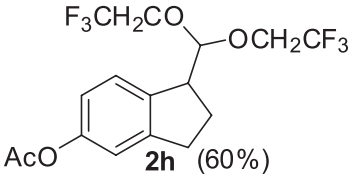
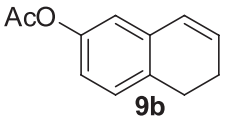
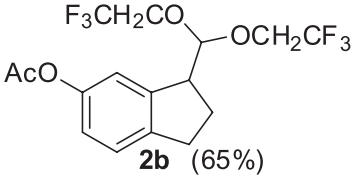
TFE: trifluoroethanol; DCM: dichloromethane.

the rate of reaction. When the reaction was tried in pure MeOH, indane **3c** was obtained in 51% yield and took 1 h to consume all starting material (entry 2). The protecting group tolerance was further investigated with Fmoc protected alkene **1e** and the anticipated ring contraction product **3e** was isolated in 64% yield (entry 3).

The reaction of tosyl protected 7-amine alkene **1d** with HTIB was also investigated under different reaction conditions (Table 7). Tosyl amide could have a facilitating effect on ring contraction by increasing electronic density on migrating carbon **4a**.[13] However, only the formation of addition products *trans*-**4d** and *cis*-**4d** were observed in MeOH and in DCM/MeOH as solvents (entries 1 and 2). Fluorinated solvents like TFE and hexafluoroisopropanol (HFIP) proved to be ineffective under the conditions tested (entries 3 and 4).

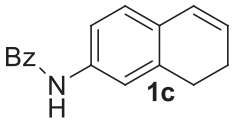
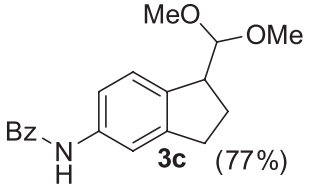
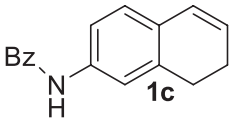
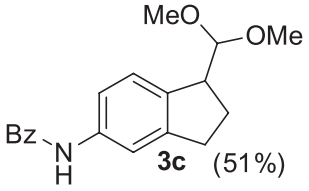
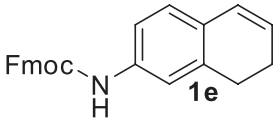
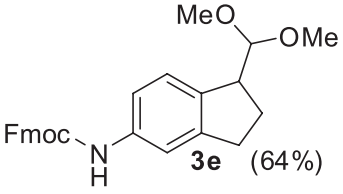
Oxidation in acetyl protected 6-amine alkene **1f** was explored. In this case, amide substituent *meta* to migrating carbon would decrease the electronic density by inductive effect of nitrogen atom and does not increase directly the electronic density at migrating carbon by mesomeric effect.[13] Several conditions were tested for ring contraction of alkene **1f** (Table 8). Slow reaction and complex mixtures were observed for substrate **1f** using HTIB either in MeOH or in DCM/MeOH at different temperatures (entries 1-3). Fluorinated solvents, such as TFE and HFIP/DCM, also did not provide ring contraction product (entries 4 and 5).

Table 5. Reactions of oxygenated alkenes **9b**, **9gg** and **9h** with 1.2 equiv of HTIB

entry	Substrate	Product (Yield)[a]
1		
2		
3		

[a]Trifluoroethanol, 0 °C, 5 min.

Table 6. Reaction of 7-amine alkenes with 1.2 equiv HTIB at 0 °C

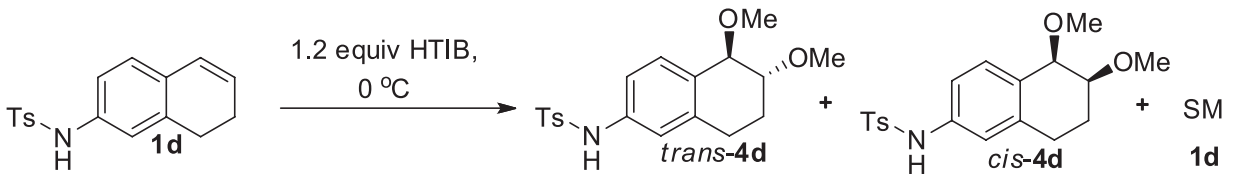
entry	Substrate	Condition	Product (Yield)
1		MeOH/DCM (8:1), 10 min	
2		MeOH, 1 h	
3		MeOH/DCM (4:1), 10 min	

DCM: dichloromethane.

Conclusions

In conclusion, the ring contraction of 1,2-dihydronaphthalenes using HTIB was expanded to substrates bearing oxygen and nitrogen substituents in the aromatic ring. Oxidative rearrangement was successfully carried out in oxygenated substrates independent on their position on aromatic ring. Acetoxy and benzoyloxy alkenes afforded indanes in 60-71% yield. The *N*-protecting groups Fmoc and Bz are stable under the reaction conditions giving indanes in 64-77% yield. The Ts-protected substrate gave only addition products. The results showed the tolerance

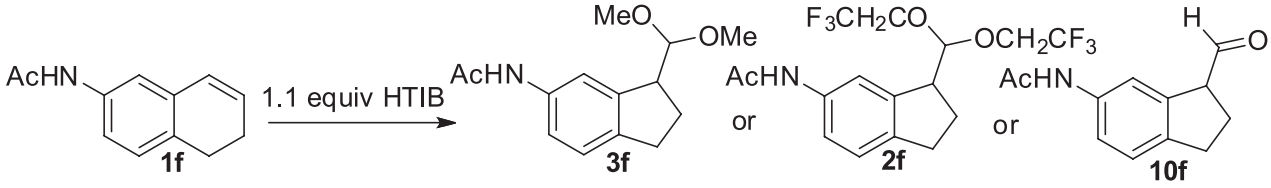
Table 7. Reaction of tosylamide **1d** with HTIB



entry	Condition	Result
1	MeOH, 30 min	*trans*-**4d** (10%), *cis*-**4d** (37%), **1d** (14%)[a]
2	DCM/50 equiv MeOH, 30 min	mixture of *cis*, *trans* addition products[b]
3	TFE, 10 min	complex mixture
4	H_2O, HFIP/DCM (1:4), 10 min	complex mixture

[a]Isolated yield; [b]GC monitored; DCM: dichloromethane; HFIP: hexafluoroisopropanol.

Table 8. Reaction of 6-acetamide **1f** with HTIB



entry	Solvent	Temperature / °C	Result[a]
1	MeOH	0 to rt[b]	complex mixture
2	DCM[c]/50 equiv MeOH	0 to rt[b]	complex mixture
3	MeOH	40	complex mixture
4	TFE[d]	0	complex mixture
5	H_2O, HFIP[e]/DCM (1:4)	0	complex mixture

[a]By TLC and GC; [b]rt: room temperature; [c]DCM: dichloromethane; [d]TFE: trifluoroethanol; [e]HFIP: hexafluoroisopropanol.

of protecting groups in ring contraction reaction mediated by HTIB.

Experimental

All commercially available reagents were used without further purification unless otherwise noted. All solvents used for reactions and chromatography were dried and purified by standard methods.[43] Thin-layer chromatography (TLC) analyses were performed using silica gel 60F 254 precoated plates, with detection by UV-absorption (254 nm) and by spraying with *p*-anisaldehyde and phosphomolybdic acid solutions followed by charring at ca. 150 °C for visualization. Flash column chromatography was performed using silica gel 200-400 Mesh. All nuclear magnetic resonance (NMR) analyses were recorded using $CDCl_3$ as solvent and tetramethylsilane (TMS) as internal standard. Chemical shifts are reported in ppm downfield from TMS with reference to internal solvent.

Preparation of substrates

N-(7,8-Dihydronaphthalen-2-yl)benzamide (**1c**)

To a stirred solution of ketone **5** (0.677 g, 4.20 mmol) and Et_3N (0.65 mL, 0.467 g, 4.62 mmol) in DCM (35 mL) was added BzCl (0.683 mL, 0.826 g, 5.88 mmol). After 3 h, the reaction mixture was washed with 10% HCl, saturated solution of $NaHCO_3$ and dried over anhydrous $MgSO_4$. Purification by flash column chromatography (40-60% EtOAc in hexane) gave benzoyl protected ketone **7c**.[44] Yield: 0.995 g (89%); light yellow solid; mp: 193.5-195.2 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.13 (quin, 2H, *J* 6.3 Hz), 2.64 (t, 2H, *J* 6.3 Hz), 2.97 (t, 2H, *J* 6 Hz), 7.37 (dd, 1H, *J* 8.4, 1.8 Hz), 7.45-7.52 (m, 2H), 7.55-7.61 (m, 1H), 7.86-7.89 (m, 3H), 8.04 (d, 1H, *J* 8.7 Hz), 8.11 (d, 1H, *J* 6.9 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 23.2, 30.0, 117.8, 118.8, 127.1, 128.6, 128.8, 130.1, 132.2, 134.4, 142.3, 146.3, 165.8, 197.4. To a two neck round bottom flask with magnetic stirrer under nitrogen atmosphere was added $NaBH_4$ (0.170 g, 4.50 mmol) to the solution of

ketone **7c** (0.995 g, 3.75 mmol) in MeOH (40 mL). The mixture was stirred for 30 minutes at 0 °C. The temperature was raised to room temperature (rt) for another 1 h. The reaction was quenched by addition of distilled H_2O (10 mL) and the mixture was extracted with EtOAc (3 × 30 mL). The combined organic extracts were washed with brine (2 × 10 mL) and dried over anhydrous $MgSO_4$. The solvent was removed under reduced pressure and *N*-(5-hydroxy-5,6,7,8-tetrahydronaphthalen-2-yl)benzamide was obtained as white solid (0.980 g, 3.67 mmol, 98.0%) and used in the next step without purification. The *N*-(5-hydroxy-5,6,7,8-tetrahydronaphthalen-2-yl)benzamide (0.980 g, 3.67 mmol) was dissolved in toluene (30 mL) with the addition of few crystals of $TsOH.H_2O$ in round bottom flask, fitted with Dean-Stark apparatus. The system was maintained at 130 °C and the reaction was monitored by TLC. The reaction was quenched by addition of saturated solution of $NaHCO_3$ and extracted with hexane (3 × 30 mL). The combined organic extracts were washed with brine (2 × 10 mL) and dried over anhydrous $MgSO_4$. The solvent was removed at reduced pressure and the residue was purified by flash chromatography (15-20% EtOAc in hexane) giving compound **1c**.[38] Yield: 0.735 g (80%); white solid; mp: 170.2-172 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.30-2.36 (m, 2H), 2.83 (t, 2H, *J* 8.2 Hz), 5.99 (dt, 1H, *J* 9.2, 4.5 Hz), 6.45 (dt, 1H, *J* 9.6, 1.8 Hz), 7.02 (d, 1H, *J* 8.1 Hz), 7.35 (dd, 1H, *J* 8.1, 2.4 Hz), 7.46-7.58 (m, 4H), 7.75 (bs, 1H), 7.84-7.88 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 23.0, 27.7, 117.8, 119.4, 126.3, 126.9, 127.1, 127.9, 128.8, 130.8, 131.8, 135.1, 136.4, 136.6, 165.4.

N-(7,8-Dihydronaphthalen-2-yl)-4-methylbenzenesulfonamide (**1d**)

To a stirred solution of ketone **5** (0.161 g, 1.00 mmol) in pyridine (5 mL) was added TsCl (0.191 g, 1.35 mmol). The reaction mixture was heated at reflux for 16 h. The solvent was removed under reduced pressure and the crude residue was extracted with EtOAc (3 × 10 mL) and washed with 1 mol L^{-1} HCl (10 mL), water (10 mL) and brine (10 mL) and dried over anhydrous $MgSO_4$. Purification by flash column chromatography (40-50% EtOAc in hexane) gave tosyl protected ketone **7d**.[45] Yield: 0.304 g (96%); white solid; mp: 214.2-215.6 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.03 (m, 2H), 2.39 (s, 3H), 2.59 (t, 2H, *J* 6.4 Hz), 2.87 (t, 2H, *J* 6 Hz), 6.94 (dd, 1H, *J* 8.7, 2.4 Hz), 6.98-6.99 (m, 1H), 7.15 (bs, 1H), 7.25-7.33 (m, 2H), 7.74 (d, 1H, *J* 8.1 Hz), 7.90 (d, 1H, *J* 8.4 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.6, 23.1, 29.8, 38.8, 117.2, 118.1, 124.8, 127.2, 129.1, 129.9, 135.9, 141.1, 144.4, 146.3, 197.1. The reaction was performed using ketone **7d** (0.788 g, 2.50 mmol), MeOH (30 mL) and $NaBH_4$ (0.283 g, 7.50 mmol). After workup, solvent was removed under reduced pressure and *N*-(5-hydroxy-5,6,7,8-tetrahydronaphthalen-2-yl)-4-methylbenzenesulfonamide (0.761 g, 2.39 mmol, 96.0%) was obtained as yellowish white solid and used in the next step without purification. The reaction was performed using *N*-(5-hydroxy-5,6,7,8-tetrahydronaphthalen-2-yl)-4-methylbenzenesulfonamide (0.761 g, 2.39 mmol), toluene (30 mL) and $TsOH.H_2O$ (cat. few crystals) at 130 °C. The crude product was purified by flash column chromatography (15-20% EtOAc in hexane) giving alkene **1d**. Yield: 0.542 g (76%); white solid; mp: 126.7-127.8 °C; IR (film) ν_{max} / cm^{-1} 3524, 3257, 3033, 2930, 2883, 2830, 1916, 1735, 1609, 1599, 1575, 1497, 1465, 1397, 1341, 1329, 1314, 1291, 1241, 1209, 1185, 1163, 1124; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.21-2.29 (m, 2H), 2.37 (s, 3H), 2.69 (t, 2H, *J* 8.4 Hz), 5.96 (dt, 1H, *J* 9.6, 4.4 Hz), 6.36 (dt, 1H, *J* 9.6 Hz), 6.78-6.86 (m, 4H), 7.22 (d, 2H, *J* 8.1 Hz), 7.67 (d, 2H, *J* 8.4 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5 (CH_3), 22.8 (CH_2), 27.4 (CH_2), 119.3 (CH), 121.0 (CH), 126.4 (CH), 126.8 (CH), 127.2 (CH), 128.3 (CH), 129.6 (CH), 131.5 (C), 134.7 (C), 136.1 (C), 136.7 (C), 143.7 (C); HRMS [ESI(+)-TOF] calcd. for $[C_{17}H_{17}NO_2S + H]^+$: 300.1053; found: 300.1060.

(9*H*-Fluoren-9-yl)methyl (7,8-dihydronaphthalen-2-yl) carbamate (**1e**)

To a stirred solution of amino ketone **5** (0.484 g, 3.00 mmol) and pyridine (0.29 mL, 3.60 mmol) in anhydrous DCM (25 mL) at 0 °C was added solution of Fmoc-Cl (0.854 g, 3.30 mmol) in anhydrous DCM and the resulting reaction mixture was allowed to stir at rt. After 1 h the solution was acidified with 1 mol L^{-1} HCl. The product was extracted with DCM (3 × 10 mL) and dried over anhydrous Mg_2SO_4. After workup solvent was removed under reduced pressure. The crude product was purified by flash column chromatography (15-25% EtOAc in hexane) giving Fmoc protected amino ketone **7e**. Yield: 1.13 g (98%); white solid; mp: 160.6-161.5 ºC; IR (film) ν_{max} / cm^{-1} 3305, 3065, 2946, 2890, 1737, 1665, 1602, 1585, 1537, 1495, 1478, 1450, 1427, 1412, 1350, 1336, 1323, 1287, 1219, 1185, 1164, 1129, 1105; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.06-2.15 (m, 2H), 2.62 (t, 2H, *J* 6.3 Hz), 2.91 (t, 2H, *J* 6.0 Hz), 4.27 (t, 1H, *J* 6.4 Hz, 1H), 4.57 (d, 2H, *J* 6.6 Hz), 6.95 (bs, 1H), 7.14 (dd, 1H, *J* 8.4, 1.5 Hz), 7.32 (td, 1H, *J* 7.6, 1.2 Hz, 1H), 7.37-7.44 (m, 3H), 7.56-7.62 (m, 2H), 7.78 (dt, 2H, *J* 7.5, 0.9 Hz), 7.98 (d, 1H, *J* 8.7 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 23.2 (CH_2), 30.0 (CH_2), 38.9 (CH_2), 47.0 (CH), 67.0 (CH_2), 116.4 (CH), 117.0 (CH), 120.1 (CH), 124.8 (CH), 127.1 (CH), 127.8 (CH), 128.1 (C), 128.7 (CH), 141.3 (C), 142.2 (C), 143.5 (C), 146.3 (C), 152.9 (C), 197.3 (C); HRMS [ESI(+)-TOF] calcd. for $[C_{25}H_{21}NO_3 + H]^+$: 384.1600; found: 384.1600. The reaction

was performed using ketone **7e** (1.15 g, 3.00 mmol), MeOH (50 mL) and $NaBH_4$ (0.227 g, 6.00 mmol). After workup, solvent was removed under reduced pressure and crude alcohol (1.12 g, 2.91 mmol, 97.0%) was obtained as white solid and used in the next step without purification. The reaction was performed using (9*H*-fluoren-9-yl)methyl (5-hydroxy-5,6,7,8-tetrahydronaphthalen-2-yl)carbamate (1.12 g, 2.91 mmol), toluene (50 mL) and $TsOH.H_2O$ (cat. few crystals) at 130 °C. The crude product was purified by flash column chromatography (10-30% EtOAc in hexane) giving alkene **1e**. Yield: 0.890 g (83%); white solid; mp: 141-142 °C; IR (film) ν_{max} / cm^{-1} 3307, 3030, 2931, 2882, 2826, 1703, 1612, 1585, 1527, 1478, 1465, 1450, 1425, 1326, 1308, 1278, 1219, 1170, 1104; ^1H NMR (300 MHz, $CDCl_3$) δ 2.25-2.33 (m 2H), 2.77 (t, 2H, *J* 8.2 Hz), 4.27 (t, 2H, *J* 6.6 Hz), 4.53 (d, 2H, *J* 6.9 Hz), 5.95 (dt, 1H, *J* 9.6, 4.4 Hz), 6.41 (dt, 1H, *J* 9.6, 1.6 Hz), 6.57 (bs, 1H), 6.94 (d, 1H, *J* 8.1 Hz), 7.08-7.18 (m, 2H), 7.32 (td, 2H, *J* 7.4, 1.2 Hz), 7.38-7.44 (m, 2H), 7.61 (d, 2H, *J* 7.2 Hz), 7.61 (d, 2H, *J* 7.2 Hz), 7.78 (d, 2H, *J* 7.5 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 23.0 (CH_2), 27.7 (CH_2), 47.1 (CH), 66.8 (CH_2), 116.5 (CH), 118.2 (CH), 120.0 (CH), 124.9 (CH), 126.4 (CH), 127.0 (CH), 127.1 (CH), 127.5 (CH), 127.7 (CH), 130.0 (C), 136.1 (C), 136.6 (C), 141.3 (C), 143.7 (C), 153.3 (C); HRMS [ESI(+)] calcd. for $[C_{25}H_{21}NO_2 + H]^+$: 368.1651; found: 368.1648.

N-(5,6-Dihydronaphthalen-2-yl)acetamide (**1f**)

Compound **1f** was prepared according to reported protocol in literature.[35] Yield: 0.184 g (98%); white solid; mp: 52.1-53.9 °C (lit. 51.2-54.6 °C).

7,8-Dihydronaphthalen-1-yl acetate (**9g**)

The reaction was performed using ketone **8g** (0.892 g, 5.50 mmol), MeOH (40 mL) and $NaBH_4$ (0.208 g, 5.50 mmol). After workup, solvent was removed under reduced pressure and 1,2,3,4-tetrahydronaphthalene-1,5-diol (0.885 g, 5.39 mmol, 98.0%) was obtained as white solid and used in the next step without purification. The crude 1,2,3,4-tetrahydronaphthalene-1,5-diol (0.885 g, 5.39 mmol), dissolved in anhydrous tetrahydrofuran (THF) (10 mL) was added with H_3PO_4 (6 mL). The system was maintained at 80 °C and the reaction was monitored by TLC. The reaction was quenched by addition of saturated solution of $NaHCO_3$ and the mixture was extracted with EtOAc (3 × 10 mL). The combined organic extracts were washed with brine and dried over anhydrous $MgSO_4$. The solvent was removed at reduced pressure and the residue was purified by flash chromatography (10-15% ethyl acetate in hexane) giving alkene **1g**.[35] Yield: 0.614 g (78%); white solid; mp: 66-67 °C (lit. 53.3-54.6 °C[46] and 73.5-74.5 °C).[35] To a stirred solution of alkene **1g** (0.614 g, 4.20 mmol) and DMAP (0.015 g, 0.12 mmol) in Et_3N (16 mL) was added Ac_2O (1.50 mL, 15.90 mmol) at rt. After 1 h, the reaction was quenched with MeOH (5 mL) and H_2O (8 mL). The reaction was extracted with EtOAc (3 × 10 mL), washed with brine (2 × 10 mL) and dried over anhydrous $MgSO_4$. Purification by flash column chromatography (3-5% EtOAc in hexane) gave acetyl protected alkene **9g**.[47] Yield: 0.760 g (96%); colorless liquid.

7,8-Dihydronaphthalen-1-yl benzoate (**9gg**)

The reaction was performed using phenol **1g** (0.248 g, 1.70 mmol), BzCl (0.22 mL, 0.267 g, 1.90 mmol) and Et_3N (0.51 mL, 0.374 g, 3.70 mmol) in DCM (10 mL). Purification by flash column chromatography (3-4% EtOAc in hexane) gave benzoyl protected alkene **9gg**. Yield: 0.398 g (94%); white solid; mp: 58.1-58.7 °C; IR (film) ν_{max} / cm^{-1} 3035, 2935, 2887, 2834, 2127, 1735, 1651, 1601, 1583, 1569, 1491, 1451, 1395, 1342, 1314, 1296, 1266, 1247, 1229, 1212; ^1H NMR (300 MHz, $CDCl_3$) δ 2.24-2.32 (m, 2H), 2.71 (t, 2H, *J* 8.4 Hz), 6.04 (dt, 1H, *J* 9.6, 4.5 Hz), 6.49 (dt, 1H, *J* 9.6, 1.8 Hz), 6.96 (d, 1H, *J* 7.5 Hz), 7.00 (dd, 1H, *J* 8.1, 1.2 Hz), 7.17-7.22 (m, 1H), 7.48-7.54 (m, 2H), 7.61-7.66 (m, 1H), 8.21-8.25 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 20.6 (CH_2), 22.3 (CH_2), 120.8 (CH), 123.8 (CH), 126.8 (CH), 127.2 (C), 127.3 (CH), 128.6 (CH), 129.0 (CH), 129.4 (C), 130.1 (CH), 133.5 (CH), 135.7 (C), 148.0 (C), 164.8 (C); LRMS *m/z* (rel. int.): 250 ($M^{+\bullet}$, 9), 144 (3), 128(11), 115 (10), 105 (100), 91 (2), 77 (36), 63 (3), 51 (10), 39 (2); HRMS [ESI(+)-TOF] calcd. for $[C_{17}H_{14}O_2 + Na]^+$: 273.0891; found: 273.0890.

7,8-Dihydronaphthalen-2-yl acetate (**9h**)

The reaction was performed using ketone **8h** (2.000 g, 11.35 mmol), MeOH (80 mL) and $NaBH_4$ (0.4290 g, 11.35 mmol). After workup, solvent was removed under reduced pressure and crude alcohol (1.986 g, 11.14 mmol, 98.0%) was obtained as white solid and used in the next step without purification. The reaction was performed following using 6-methoxy-1,2,3,4-tetrahydronaphthalen-1-ol (1.986 g, 11.14 mmol), toluene (60 mL) and $TsOH.H_2O$ (cat. few crystals) at 130 °C. The crude product was purified by flash column chromatography (20-40% EtOAc in hexane) giving alkene **1h**.[36] Yield: 1.702 g (95%); colorless oil. Under inert atmosphere N_2, NaH (6.24 g, 260 mmol, 60% in mineral oil) was washed with anhydrous hexanes (3 × 20 mL). After a few minutes, anhydrous DMF (75 mL) was added. To this mixture was slowly added a solution of EtSH (13.0 mL, 180 mmol, 30 equiv based on olefin **1h**) in anhydrous DMF (14 mL) at 0 °C and the resulting yellow solution was stirred for 20 min at rt. A solution of alkene **1h** (0.961 g, 6.0 mmol)

in DMF (15 mL) was then added dropwise and the resulting mixture was stirred for 5 h at 140 °C. When the reaction was becoming slightly brown, the mixture was cooled to the rt and a saturated solution of NH_4Cl was added. The mixture was extracted with Et_2O. The organic phase was washed with water, brine and dried over anhydrous $MgSO_4$. The solvent was removed under reduced pressure. The crude product was purified by flash column chromatography (20-40% EtOAc in hexane) giving 7,8-dihydronaphthalen-2-ol.[39] Yield: 0.851 g (97%); viscous colorless liquid. The reaction was performed using 7,8-dihydronaphthalen-2-ol (0.365 g, 2.50 mmol), DMAP (0.09 g, 0.07 mmol) and Ac_2O (0.9 mL, 9.5 mmol) in Et_3N (10 mL). Purification by flash column chromatography (3-5% EtOAc in hexane) gave acetyl protected alkene **9h**.[48] Yield: 0.398 g (85%); colorless liquid.

5,6-Dihydronaphthalen-2-yl acetate (**9b**)

The reaction was performed using ketone **8b** (0.705 g, 4.00 mmol), MeOH (40 mL) and $NaBH_4$ (0.152 g, 4.00 mmol). After workup, solvent was removed under reduced pressure and crude alcohol (0.691 g, 3.88 mmol, 97%) was obtained as white solid and used in the next step without purification. The reaction was performed using 7-methoxy-1,2,3,4-tetrahydronaphthalen-1-ol (0.691 g, 3.88 mmol), toluene (40 mL) and $TsOH.H_2O$ (cat. few crystals) at 130 °C. After workup solvent was removed under reduced pressure. The crude product was purified by flash column chromatography (1-2% EtOAc in hexane) giving alkene **1b**.[13,37] Yield: 0.488 g (78%); colorless liquid. The reaction was performed using alkene **1b** (0.481 g, 3.00 mmol), NaH (3.12 g, 130 mmol, 60% in mineral oil), EtSH (6.5 mL, 90 mmol, 30 equiv. based on olefin **1b**) in DMF (35 mL) at 140 °C. The crude product was purified by flash column chromatography (10-15% ethyl acetate in hexane) giving 5,6-dihydronaphthalen-2-ol. Yield: 0.351 g (80%); white solid; mp: 98-99 °C; IR (film) ν_{max} / cm^{-1} 3247, 3027, 2936, 2880, 2851, 2818, 1629, 1614, 1574, 1492, 1477, 1465, 1435, 1426, 1395, 1349, 1327, 1282, 1265, 1215; ^1H NMR (300 MHz, $CDCl_3$) δ 2.25-2.32 (m, 2H), 2.71 (t, 2H, *J* 8.1 Hz), 4.59 (s, 1H), 6.04 (dt, 1H, *J* 9.6, 4.4 Hz), 6.38 (dt, 1H, *J* 9.6, 1.8 Hz), 6.52 (d, 1H, *J* 2.7 Hz), 6.59 (dd, 1H, *J* 7.8, 2.7 Hz), 6.96 (d, 1H, *J* 8.1, Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 23.5 (CH_2), 26.6 (CH_2), 112.9 (CH), 113.1 (CH), 127.5 (CH), 127.7 (C), 128.3 (CH), 129.5 (CH), 135.3 (C), 154.0 (C); LRMS *m/z* (rel. int.): 146 ($M^{+\bullet}$, 100), 145 (71), 131 (45), 127 (43), 117 (36), 115 (55), 103 (5), 91 (12), 77 (7), 63 (14), 51 (13), 39 (10); HRMS [ESI(+)-TOF] calcd. for $[C_{10}H_{10}O + K]^+$: 185.0369; found: 185.0361. The reaction was performed using 5,6-dihydronaphthalen-2-ol (0.351 g, 2.40 mmol), DMAP (0.08 g, 0.065 mmol) and Ac_2O (0.9 mL, 9.0 mmol) in Et_3N (10 mL). Purification by flash column chromatography (3-5% EtOAc in hexane) gave acetyl protected alkene **9b**. Yield: 0.359 g (85%); colorless liquid; IR (film) ν_{max} / cm^{-1} 3034, 2935, 2885, 2831, 1761, 1609, 1575, 1491, 1432, 1369, 1328, 1271, 1210; ^1H NMR (300 MHz, $CDCl_3$) δ 2.27-2.36 (m, 2H), 2.28 (s, 3H), 2.77 (t, 2H, *J* 8.0 Hz), 6.06 (m, 1H), 6.41 (dt, 1H, *J* 9.6, 1.8 Hz), 6.74 (d, 1H, *J* 2.4 Hz), 6.81 (dd, 1H, *J* 8.1, 2.4 Hz), 7.08 (d, 1H, *J* 8.1 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.1 (CH_3), 23.2 (CH_2), 26.8 (CH_2), 118.8 (CH), 119.4 (CH), 127.3 (CH), 128.2 (CH), 129.6 (CH), 132.9 (C), 135.3 (C), 149.2 (C), 169.7 (C); LRMS *m/z* (rel. int.): 188 ($M^{+\bullet}$, 20), 146 (100), 145 (52), 131 (30), 127 (19), 117 (24), 115 (42), 91 (15), 77 (5), 63 (9), 43 (30), 39 (10); HRMS [ESI(+)] calcd. for $[C_{12}H_{12}O_2 + Na]^+$: 211.0735; found: 211.0724.

Ring contraction reactions mediated by HTIB: general procedure for **2b**, **2g**, **2gg** and **2h**

1-(Bis(2,2,2-trifluoroethoxy)methyl)-2,3-dihydro-1*H*-inden-4-yl acetate (**2g**)

To a solution of alkene **9g** (0.094 g, 0.50 mmol) in TFE (10 mL) was added HTIB (0.235 g, 0.60 mmol) at 0 °C. The reaction mixture was stirred at 0 °C for 5 min. The reaction was quenched with a saturated solution of $NaHCO_3$. The reaction mixture was extracted with EtOAc (3 × 15 mL), washed with brine (2 × 10 mL) and dried over anhydrous $MgSO_4$. The solvent was evaporated under reduced pressure. The crude product was purified by flash column chromatography (4-5% EtOAc in hexanes) giving acetal **2g**. Yield: 0.128 g (66%); white solid; mp: 61.6-63.4 °C; IR (film) ν_{max} / cm^{-1} 2947, 1764, 1615, 1587, 1468, 1433, 1372, 1281, 1213; ^1H NMR (300 MHz, $CDCl_3$) δ 1.98-2.10 (m, 1H), 2.22-2.32 (m, 1H), 2.30 (s, 3H), 2.70-2.91 (m, 2H), 3.47-3.55 (m, 1H), 3.84-4.07 (m, 4H), 4.71 (d, 1H, *J* 8.1 Hz), 6.94 (dt, 1H, *J* 7.8 Hz), 7.21 (t, 1H, *J* 7.8 Hz), 7.28 (d, 1H, *J* 7.5 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 20.8 (CH_3), 26.8 (CH_2), 28.1 (CH_2), 47.5 (CH), 61.8 (q, *J* 34.8 Hz) (CH_2), 63.3 (q, *J* 34.8 Hz) (CH_2), 105.0 (CH), 120.6 (CH), 123.2 (CH), 123.6 (q, *J* 276 Hz) (CF_3), 123.7 (q, *J* 276 Hz) (CF_3), 128.0 (CH), 136.6 (C), 143.3 (C), 147.1 (C), 168.9 (C); HRMS [ESI(+)-TOF] calcd. for $[C_{16}H_{16}F_6O_4 + Na]^+$: 409.0850; found: 409.0851.

1-(Bis(2,2,2-trifluoroethoxy)methyl)-2,3-dihydro-1*H*-inden-4-yl benzoate (**2gg**)

Yield: 0.159 g (71%); white solid; mp: 79-79.8 °C; IR (film) ν_{max} / cm^{-1} 3067, 2948, 1738, 1602, 1585, 1469, 1453, 1423, 1383, 1279, 1230, 1168, 1134; ^1H NMR (300 MHz, $CDCl_3$) δ 1.99-2.11 (m, 1H), 2.20-2.32 (m, 1H), 2.76-2.97 (m, 2H), 3.54 (q, 1H, *J* 8.1 Hz), 3.85-4.09 (m, 4H), 4.74

(d, 1H, *J* 8.1 Hz), 7.10 (dt, 1H, *J* 7.8, 1.2 Hz), 7.26 (t, 1H, *J* 7.8 Hz), 7.33 (d, 1H, *J* 7.8 Hz), 7.48-7.54 (m, 2H), 7.64 (tt, 1H, *J* 7.5, 1.5 Hz), 8.18-8.22 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 26.8 (CH_2), 28.2 (CH_2), 47.6 (CH), 61.9 (q, *J* 34.8 Hz) (CH_2), 63.4 (q, *J* 34.8 Hz) (CH_2), 105.1 (CH), 120.7 (CH), 123.2 (CH), 123.69 (q, *J* 276 Hz) (CF_3), 123.74 (q, *J* 276 Hz) (CF_3), 128.1 (CH), 128.6 (CH), 129.4 (C), 130.2 (CH), 133.6 (CH), 136.8 (C), 143.4 (C), 147.4 (C), 164.5 (C); HRMS [ESI(+)-TOF]: calcd. for $[C_{21}H_{18}F_6O_4 + Na]^+$: 471.1007; found: 471.1010.

1-(Bis(2,2,2-trifluoroethoxy)methyl)-2,3-dihydro-1*H*-inden-5-yl acetate (**2h**)

Yield: 0.117 g (60%); viscous colorless liquid; IR (film) ν_{max} / cm^{-1} 2953, 1761, 1610, 1592, 1485, 1460, 1431, 1372, 1282, 1216, 1163, 1134, 1103; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.97-2.09 (m, 1H), 2.21-2.33 (m, 1H), 2.28 (s, 3H), 2.82-3.01 (m, 2H), 3.43 (q, 1H, *J* 7.8 Hz), 3.86-4.08 (m, 4H), 4.68 (d, 1H, *J* 8.4 Hz), 6.87 (dd, 1H, *J* 8.4, 2.2 Hz), 6.94 (s, 1H), 7.38 (d, 1H, *J* 8.1 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.0 (CH_3), 27.4 (CH_2), 31.1 (CH_2), 46.4 (CH), 61.6 (q, *J* 34.8 Hz) (CH_2), 63.3 (q, *J* 34.8 Hz) (CH_2), 105.1 (CH), 117.8 (CH), 119.7 (CH), 123.6 (q, *J* 276 Hz) (CF_3), 123.7 (q, *J* 276 Hz) (CF_3), 126.1 (CH), 138.3 (C), 146.1 (C), 150.3 (C), 169.7 (C); LRMS *m/z* (rel. int.): 386 ($M^{+\bullet}$, 4), 344 (7), 245 (7), 211 (14), 175 (8), 145 (6), 133 (100), 115 (7), 105 (11), 83 (11), 77 (6), 43 (19); HRMS [ESI(+)-TOF]: calcd. for $[C_{16}H_{16}F_6O_4 + Na]^+$: 409.0850; found: 409.0851.

3-(Bis(2,2,2-trifluoroethoxy)methyl)-2,3-dihydro-1*H*-inden-5-yl acetate (**2b**)

Yield: 0.126 g (65%); white solid; mp: 63.6-65.2 °C; IR (film) ν_{max} / cm^{-1} 2919, 2850, 1760, 1610, 1591, 1540, 1484, 1459, 1429, 1372, 1281, 1214; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.98-2.09 (m, 1H), 2.21-2.33 (m, 1H), 2.28 (s, 3H), 2.79-2.99 (m, 2H), 3.46 (q, 1H, *J* 7.8 Hz), 3.85-4.06 (m, 2H), 4.69 (d, 1H, *J* 8.4 Hz), 6.91 (ddd, 1H, *J* 8.1, 2.1, 0.3 Hz), 7.10 (d, 1H, *J* 1.8 Hz), 7.20 (d, 1H, *J* 8.1 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.1 (CH_3), 27.5 (CH_2), 30.6 (CH_2), 61.7 (q, *J* 34.8 Hz) (CH_2), 63.5 (q, *J* 34.8 Hz) (CH_2), 105.1 (CH), 118.9 (CH), 120.9 (CH), 123.6 (q, *J* 276 Hz) (CF_3), 123.7 (q, *J* 276 Hz) (CF_3), 125.1 (CH), 142.0 (C), 142.2 (C), 149.5 (C), 169.8 (C); LRMS *m/z* (rel. int.): 386 ($M^{+\bullet}$, 2), 344 (25), 287 (7), 244 (8), 211 (100), 145 (17), 133 (92), 115 (15), 105 (17), 83 (29), 77 (12), 43 (43); HRMS [ESI(+)-TOF] calcd. for $[C_{16}H_{16}F_6O_4 + Na]^+$: 409.0850; found: 409.0851.

N-(1-(Dimethoxymethyl)-2,3-dihydro-1*H*-inden-5-yl) benzamide (**3c**)

To a solution of alkene **1l** (0.125 g, 0.500 mmol) in MeOH/DCM (8:1) (10 mL) was added HTIB (0.235 g, 0.60 mmol) at 0 °C for 10 min. The reaction was quenched with a saturated solution of $NaHCO_3$. The reaction mixture was extracted with EtOAc (3 × 15 mL), washed with brine (2 × 10 mL) and dried over anhydrous $MgSO_4$. The solvent was evaporated under reduced pressure. The crude product was purified by flash column chromatography (40-50% EtOAc in hexane), giving acetal **3c**. Yield: 0.12 g (77%); yellowish white solid; mp: 96-97.5 °C; IR (film) ν_{max} / cm^{-1} 3307, 3060, 2937, 2830, 1737, 1650, 1601, 1580, 1532, 1493, 1447, 1424, 1374, 1328, 1283, 1248, 1210, 1187, 1154, 1116; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.92-2.04 (m, 1H), 2.15-2.27 (m, 1H), 2.78-2.99 (m, 2H), 3.37-3.47 (m, 1H), 3.38 (s, 3H), 3.42 (s, 3H), 4.29 (d, 1H, *J* 7.5 Hz), 7.29 (dd, 1H, *J* 8.1, 2.1 Hz), 7.38 (d, 1H, *J* 8.4 Hz), 7.42-7.55 (m, 3H), 7.61 (s, 1H), 7.83-7.86 (m, 2H), 7.93 (bs, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 27.5 (CH_2), 31.4 (CH_2), 46.9 (CH), 52.8 (CH_3), 54.2 (CH_3), 107.1 (CH), 116.6 (CH), 118.5 (CH), 125.6 (CH), 126.9 (CH), 128.5 (CH), 131.5 (CH), 134.9 (C), 136.8 (C), 139.1 (C), 145.7 (C), 165.8 (C); HRMS [ESI(+)]: calcd. for $[C_{19}H_{21}NO_3 + H]^+$: 312.1600; found: 312.1600.

(9*H*-Fluoren-9-yl)methyl (1-(dimethoxymethyl)-2,3-dihydro-1*H*-inden-5-yl)carbamate (**3e**)

The reaction was performed using alkene **1e** (0.183 g, 0.50 mmol), HTIB (0.235 g, 0.60 mmol) and MeOH/DCM (4:1) (10 mL) at 0 °C for 10 min.[13] The crude product was purified by flash column chromatography (15-25% EtOAc in hexane) giving acetal **3e**. Yield: 0.138 g (64%); white solid; mp: 115-117 °C; IR (film) ν_{max} / cm^{-1} 3307, 3066, 2942, 2849, 2830, 1730, 1708, 1598, 1538, 1493, 1478, 1450, 1431, 1375, 1326, 1297, 1220; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.89-2.01 (m, 1H), 2.12-2.24 (m, 1H), 2.73-2.94 (m, 2H), 3.34-3.43 (m, 1H), 3.35 (s, 3H), 3.40 (s, 3H), 4.22-4.26 (m, 1H), 4.26 (d, 1H, *J* 7.5 Hz), 4.51 (d, 2H, *J* 6.6 Hz), 6.71 (bs, 1H), 7.04 (d, 1H, *J* 7.2 Hz), 7.27-7.32 (m, 4H), 7.36-7.41 (m, 2H), 7.59 (d, 2H, *J* 7.5 Hz), 7.76 (d, 2H, *J* 7.5 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 27.5 (CH_2), 31.4 (CH_2), 46.8 (CH), 47.0 (CH), 52.8 (CH_3), 54.1 (CH_3), 66.6 (CH_2), 107.1 (CH), 115.0 (CH), 117.0 (CH), 119.9 (CH), 124.8 (CH), 125.6 (CH), 127.0 (CH), 127.6 (CH), 136.6 (C), 138.0 (C), 141.2 (C), 143.7 (C), 145.7 (C), 153.5 (C); HRMS [ESI(+)-TOF]: calcd. for $[C_{27}H_{27}NO_4 + Na]^+$: 452.1832; found: 452.1836.

N-((5*R*,6*R*)-5,6-Dimethoxy-5,6,7,8-tetrahydronaphthalen-2-yl)-4-methylbenzenesulfonamide (*trans*-**4d**) and *N*-((5*R*,6*S*)-5,6-dimethoxy-5,6,7,8-tetrahydronaphthalen-2-yl)-4-methylbenzenesulfonamide (*cis*-**4d**)

The reaction was performed using alkene **1d** (0.150 g, 0.50 mmol), HTIB (0.235 g, 0.60 mmol) and MeOH (10 mL) at 0 °C.[13] The crude product was purified by flash column chromatography (20-50% EtOAc in hexane) giving

trans-**4d**, *cis*-**4d** and starting material **1d** (0.021 g, 0.070 mmol, 14%) was recovered.

N-((5*R*,6*R*)-5,6-Dimethoxy-5,6,7,8-tetrahydronaphthalen-2-yl)-4-methylbenzenesulfonamide (*trans*-**4d**)

Yield: 0.019 g (10%); viscous colorless oil; IR (film) ν_{max} / cm^{-1} 3257, 2932, 2825, 1919, 1614, 1599, 1502, 1463, 1399, 1341, 1320, 1292, 1270, 1185, 1162; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.82-1.92 (m, 1H), 1.99-2.09 (m, 1H), 2.37 (s, 3H), 2.57-2.80 (m, 2H), 3.42 (s, 3H), 3.48 (s, 3H), 3.65-3.70 (m, 1H), 4.14 (d, 1H, *J* 4.8 Hz), 6.82-6.88 (m, 3H), 7.17-7.23 (m, 3H), 7.67 (d, 2H, *J* 8.7 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.5 (CH_3), 22.9 (CH_2), 25.1 (CH_2), 56.5 (CH_3), 57.6 (CH_3), 77.5 (CH), 79.1 (CH), 118.5 (CH), 120.5 (CH), 127.2 (CH), 129.6 (CH), 130.9 (CH), 131.4 (C), 135.9 (C), 136.2 (C), 138.2 (C), 143.7 (C); HRMS [ESI(+)-TOF]: calcd. for $[C_{19}H_{23}NO_4S + K]^+$: 400.0985; found: 400.0988.

N-((5*R*,6*S*)-5,6-Dimethoxy-5,6,7,8-tetrahydronaphthalen-2-yl)-4-methylbenzenesulfonamide (*cis*-**4d**)

Yield: 0.068 g (37%); viscous colorless oil; IR (film) ν_{max} / cm^{-1} 3249, 3065, 2932, 2827, 1919, 1674, 1647, 1612, 1500, 1463, 1399, 1340, 1320, 1292, 1230; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.82-1.90 (m, 1H), 2.08-2.18 (m, 1H), 2.36 (s, 1H), 2.60-2.71 (m, 1H), 2.84-2.91 (m, 1H), 3.42 (s, 3H), 3.44 (s, 3H), 3.59 (dt, 1H, *J* 9.9, 3.0 Hz), 4.26 (d, 1H, *J* 2.7 Hz), 6.86 (d, 1H, *J* 2.1 Hz), 6.90 (dd, 1H, *J* 8.1, 2.4 Hz), 7.15 (d, 1H, *J* 8.4 Hz), 7.21 (dd, 2H, *J* 8.7, 0.6 Hz), 7.50 (bs, 1H), 7.69 (dt, 2H, *J* 8.4, 1.8 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.4 (CH_3), 22.1 (CH_2), 26.8 (CH_2), 56.3 (CH_3), 57.0 (CH_3), 77.3 (CH), 77.5 (CH), 117.9 (CH), 120.6 (CH), 127.1 (CH), 129.5 (CH), 130.5 (CH), 131.1 (C), 136.1 (C), 136.4 (C), 137.7 (C), 143.7 (C); HRMS [ESI(+)-TOF]: calcd. for $[C_{19}H_{23}NO_4S + Na]^+$: 384.1245; found: 384.1248.

Supplementary Information

Supplementary Information (^{1}H NMR and ^{13}C NMR spectra) is available free of charge at http://jbcs.sbq.org.br as PDF file.

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