Lewis Acid-Promoted Reactions of 3-Methoxy-*N*-(benzenesulfonyl)-1,4-benzoquinone Monoimine with Propenylbenzenes

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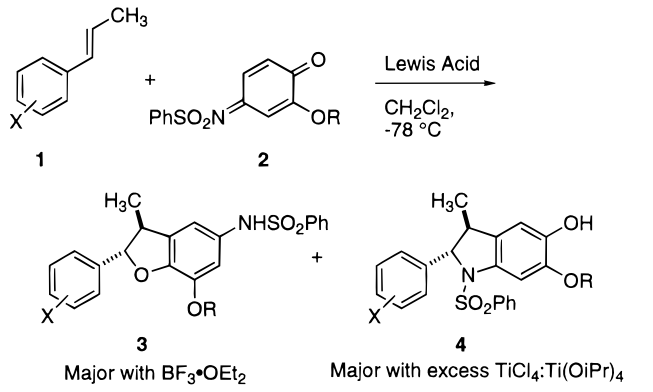
BF_3·OEt_2-promoted reactions of 4-*N*-(benzenesulfonyl)-3-methoxy-1,4-benzoquinone monoimine (**5**) with (*E*)-propenylbenzenes bearing strong electron-donating groups on their aromaric rings produce 2-aryl-6-methoxy-3-methyl-5-[*N*-(benzenesulfonyl)amino]-2,3-diydrobenzofurans (**6**). With neutral propenylbenzenes, either the dihydrobenzofurans, bicyclo[3.2.1]octenediones **17**, or products of tandem cycloaddition (**7**−**9**) are formed depending upon reaction conditions. In the latter, molecules with seven to eight asymmetric centers are formed in a single reaction from achiral starting materials. Thus, these seemingly simple reactions yield products of remarkable complexity, and with a high degree of stereoselectivity.

Lewis acid-promoted reactions of 2-alkoxy-1,4-benzoquinones,[1] and 1-*N*-(benzoyl)-4-*N*-(benzenesulfonyl) diimine[2] and 4-(*N*-benzenesulfonyl) monoimine[3] derivatives with styrenyl systems possessing electron-donating groups on the aromatic ring, yield primarily 2-aryl-2,3-dihydrobenzofuran or -dihydroindole products. Reactions with neutral styrenes are more complex, giving adducts of formal 2 + 2 and/or 5 + 2 cycloaddition in addition to the dihydrobenzofuran/-indole products. Of particular note is that many of these reactions can be directed by the nature of the Lewis acid promoter.[1b,3] For example, BF_3·OEt_2-promoted reactions of **1** with monoimine **2** give 7-alkoxy-2-aryl-5-[*N*-(benzenesulfonyl)amino]-2,3-dihydrobenzofurans **3** whereas reactions promoted by excess amounts Ti(IV) provide primarily *N*-(benzenesulfonyl)-6-alkoxy-2-aryl-2,3-dihydroindoles **4**.[3] In these reactions, and those of the quinones, the position of the alkoxy group on the quinonoid moiety presumably plays a key role in directing the regioselectivity.

To further explore the role of the alkoxy group in the regioselectivity of Lewis acid-promoted reactions of quinone monoimines,[4] reactions involving the isomeric 3-methoxy-4-*N*-(benzenesulfonyl)-1,4-benzoquinone monoimine **5**[4d] were studied. At the outset, the principal question was whether these reactions would give dihydrobenzofurans or indolines via Lewis acid activation of **5** either through binding to the imide moiety or the C-1 carbonyl group.[5]



Reactions of monoimine **5** with (*E*)-propenylbenzenes **1a**−**c** bearing strong electron-donating groups on the aromatic ring promoted by 1.5−2.0 equiv of BF_3·OEt_2 at −78 °C regio- and stereoselectively afforded 2-aryl-2,3-dihydrobenzofurans **1a**−**c** in moderate to good yields (Scheme 1, Table 1). The dihydrobenzofuran products were accompanied by variable quantities of *N*-(benzenesulfonyl)-4-hydroxy-2-methoxyaniline; the product of monoimine reduction.[4] The latter were not routinely isolated and probably resulted from single electron-transfer processes between the propenylbenzene and the Lewis acid-bound quinone; the fate of the propenylbenzene in these processes was not determined.

Similar reactions employing 1−1.3 equiv of the neutral propenylbenzenes **1d**−**g** were more complex. Initial studies with **1e** revealed that these reactions required higher temperatures and gave dihydrobenzofuran **6e** in 51% yield (Table 1, entry 6). More significantly, small amounts of a novel 2:1 quinone monoimine:propenylbenzene product **7e** were also found. In efforts to improve

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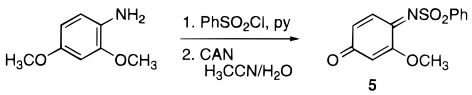
(1) (a) Engler, T. A.; Combrink, K. D.; Letavic, M. A.; Lynch, K. O., Jr.; Ray, J. E. *J. Org. Chem.* **1994**, *59*, 6567−6587. (b) Engler, T. A.; Wei, D.; Letavic, M. A.; Combrink, K. D.; Reddy, J. P. *J. Org. Chem.* **1994**, *59*, 6588−6599.

(2) Engler, T. A.; Meduna, S. P.; LaTessa, K. O.; Chai, W. *J. Org. Chem.* **1996**, *61*, 8598−8603.

(3) Engler, T. A.; Chai, W.; LaTessa, K. O. *J. Org. Chem.* **1996**, *61*, 9297−9308.

(4) (a) Boger, D. L.; Zarrinmayeh, H. *J. Org. Chem.* **1990**, *55*, 1379−1390. (b) Boger, D. L.; Coleman, R. S. *J. Am. Chem. Soc.* **1988**, *110*, 4796−4807. (c) Adams, R.; Reifschneider, W. *Bull. Chim. Soc. Fr.* **1958**, 23−65. (d) Monoimine **5** was prepared in two steps from 2,4-dimethoxyaniline.



(5) Swenton has demonstrated that *N*-acyl-1,4-benzoquinone imines play a role in acid-catalyzed reactions of *N*-acylquinone imine ketals with propenylbenzenes that give dihydrobenzofurans and dihydroindoles, Dalidowicz, P.; Swenton, J. S. *J. Org. Chem.* **1993**, *58*, 4802−4804.

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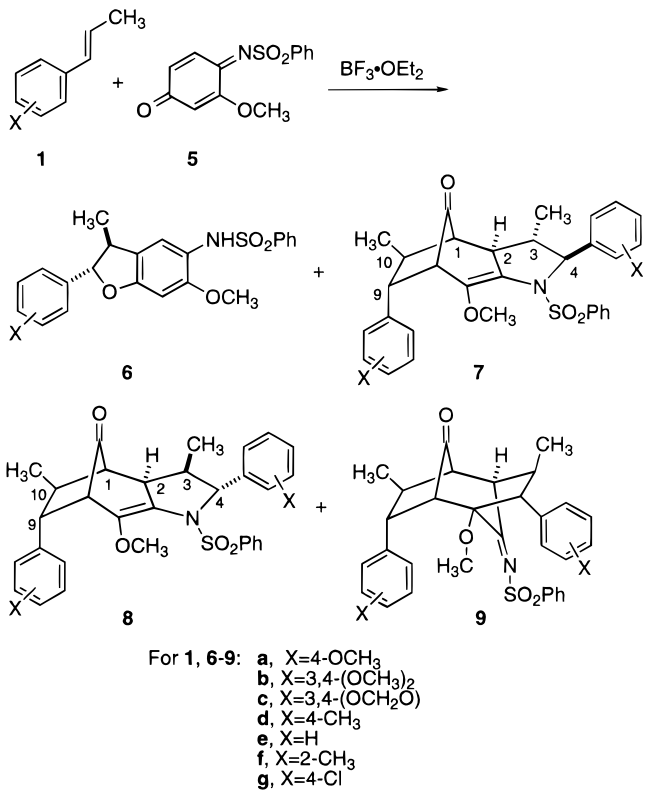
Scheme 1



the yield of **7e**, reactions using 2−2.5 equiv of the propenylbenzene **1e** were explored under various conditions; up to ∼50% yields of the tricyclic product were obtained, along with smaller amounts of an isomeric product **8e**. Similar products were then found in analogous reactions of **1d**,**f**,**g**. The yields of **7**/**8** varied somewhat with reaction time (Table 1, entries 7 and 8). In reactions of propenylbenzene **1g**, yet a third 2:1 adduct **9** was found in low yield, in addition to the dihydrobenzofuran and the tricyclic adducts (entry 11). In the latter reaction, a number of other unidentified products were evident by TLC, making isolation of the products difficult; in fact, benzofuran **6g** was detected only as the major part of an intractable mixture, and its identity was based on ^{1}H NMR.

In dihydrobenzofurans **6**, the trans stereochemistry and the assignments of the H-4 (∼7.3 ppm) and H-7 (∼6.25 ppm) signals, and thus the position of the C-6 methoxy group, are supported by ^{1}H−^{1}H NOE experiments on **6a**/**c** as representative examples (Figure 1). The structure of the tricyclic products **7e** and **9g** were assigned from spectral data and CHN analysis, and ultimately confirmed by X-ray crystallography;[6] analogous compounds **7f**,**g** were identified by spectral comparison. The structural similarity between tricyclic adducts **7** and **8** was evident from mass, IR, and ^{1}H and ^{13}C NMR spectra. Both exhibited proper molecular ions, carbonyl absorbances at ∼1748 cm^{-1}, the expected number of carbon signals in their ^{13}C spectra, and two CH_3 doublets, seven methine, and the appropriate number of aromatic resonances in their ^{1}H spectra. All of the methine signals were assigned through COSY, HMQC, and HMBC experiments. Similar coupling constants between H-8/H-9 (∼7 Hz), H-9/H-10 (5−6 Hz), and H-10/H-1 (0) in both **7** and **8** indicated the same relative configuration at C-1 and C-8 through C-10 and established the endo and exo orientations of the Ph group and the C-10 methyl groups, respectively. Furthermore, $J_{H-1/H-2}$ was 0 Hz in both, suggesting a similar configuration at C-2. However, significant differences in the chemical shifts of H-2 (2.6−2.8 in **7** vs 3.25−3.4 in **8**), H-3 (1.8−1.9 vs 2.3) and H-4 (4.6−5.1 vs 5.1−5.3), as well as $J_{H-2/H-3}$ (11 vs 5.5 Hz) and $J_{H-3/H-4}$ (9 vs 0) implied that the compounds differ in configuration at C-3 and C-4. A complete tabular listing of ^{1}H NMR spectral data is included in the Supporting Information. A comparison of ^{1}H−^{1}H NOE data from **7e**/**g** and **8g** was used to assign the stereochemistry at C-3/C-4 in **8**.[6]

A probable mechanism for the formation of all of the products is shown in Scheme 2 and is similar to reactions of propenylbenzenes with quinones and other imine derivatives.[1−3] Coordination of BF_3 to the benzenesulfonyl nitrogen initiates a cycloaddition between **5** and the (*E*)-propenylbenzene creating carbocation **11**. The stereochemistry of this cycloaddition results from a preference for the Ar group to occupy an endo orientation with respect to the pentadienyl carbocation moiety of the BF_3-activated imine **10**. The fate of carbocation **11** depends on the nature of the Ar substitutent and the reaction conditions. In adducts with electron rich Ar groups that can stabilize a positive charge, collapse to benzylic carbocation **12** is fast and is followed by C−O bond formation and loss of H^+ giving **6**.[5] In bicyclic carbocations **11** lacking electron-rich Ar groups, collapse to the benzylic carbocations is slower and requires higher temperatures (Table 1, entry 5). Alternatively, these allylic cations suffer attack of a second propenylbenzene from the more sterically accessible exo face giving benzylic cation **13**, and C−N bond formation produces **7**/**8**. The addition of the second propenylbenzene is likely a stepwise process that results in the two stereoisomers differing in configuration at C-3 and C-4. That they incorporate trans CH_3 and Ar groups is presumably due to steric effects. Adduct **9** is evidently formed from **13** through attack of the carbocation center on the carbon of the enamine moiety.

In reactions of **1e**, the ratio **7:8** varied with reaction times (Table 1, entries 7/8). In further studies, a number of parallel reactions were monitored in progress by HPLC and quenched at various times, and the products were isolated. Although there was some experimental error between the different reactions,[7] the results clearly indicated that mainly **7e** was present at short reaction times, but the amount of **8e** increased over time (Table 2). This suggested a possible conversion of **7e** to **8e** under the reaction conditions. However, attempts to form **8e** by resubjecting **7e** to the reaction conditions (temp, styrene, BF_3•OEt_2) failed. Similarly, treatment of pure **7e** with other acid catalysts (HCl, pTsOH, silica gel) also failed to give **8e**. Thus, the ratio of **7e:8e** formed in reactions of **1e** with **5** does change over time, but the process by which it does so is not apparent. Evidently an intermediate exists which collapses to **7e/8e** on workup, but is not accessed from the isolated product **7e**. Possibilities might include a structure like **14** in which

(6) X-ray data and summaries of NOE data can be found in the Supporting Information accompanying our preliminary report: Engler, T. A.; Scheibe, C. M.; Iyengar, R. *J. Org. Chem.* **1997**, *62*, 8274−8275.

(7) The presence of unidentified minor peaks in the HPLC traces complicated an accurate determination of product ratios; the ratios presented are approximate.

Table 1. BF_3-Promoted Reactions of Propenylbenzenes 1 with Monoimine 5[a]

entry	equiv[b] **1**	mmol **5**	equiv[b] BF_3·OEt_2	temp (°C)	time (h)	product(s) (% yields)[c]			
1	**1a**, 2.4	0.17	2.4	−78	0.08	**6a** (84)	—[d]	—	—
2	**1b**, 1.6	0.36	1.9	−78	0.08	**6b** (48)	—	—	—
3	**1c**, 2.4	0.21	2.4	−78	0.08	**6c** (76)	—	—	—
4	**1d**, 1.1	0.26	1.2	−78	5	**6d** (32)	**7d** (8)	**8d** (15)	—
5	**1d**, 2.3	0.20	2.0	−78 to −40	1	**6d** (10)	**7d** (19)	**8d** (15)	—
6	**1e**, 1.0	0.22	1.4	−78 to rt	10.5	**6e** (51)	**7e** (8)	—	—
7	**1e**, 2.4	0.34	1.5	−20	0.08	—	**7e** (56)	**8e** (9)	—
8	**1e**, 2.1	0.24	1.7	−20	22	—	**7e** (49)	**8e** (36)	—
9	**1f**, 2.4	0.19	1.1	−40	8.5	**6f** (17)	**7f** (50)	**8f** (6)	—
10	**1f**, 2.6	0.19	1.6	−20	0.3	**6f** (28)	**7f** (51)	**8f** (14)	—
11	**1g**, 2.6	0.23	1.7	−20	17	**6g** [e]	**7g** (24)	**8g** (20)	**9g** (13)

[a] All reactions were conducted in CH_2Cl_2. [b] With respect to monoimine **5**. [c] Isolated yields. [d] En dash signifies that none of this product was found. [e] Trace amounts, see text.

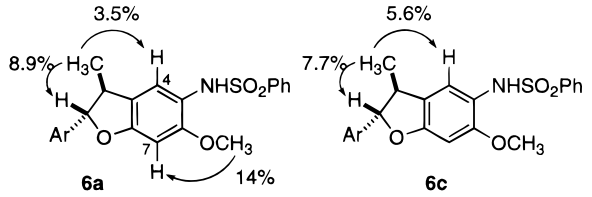
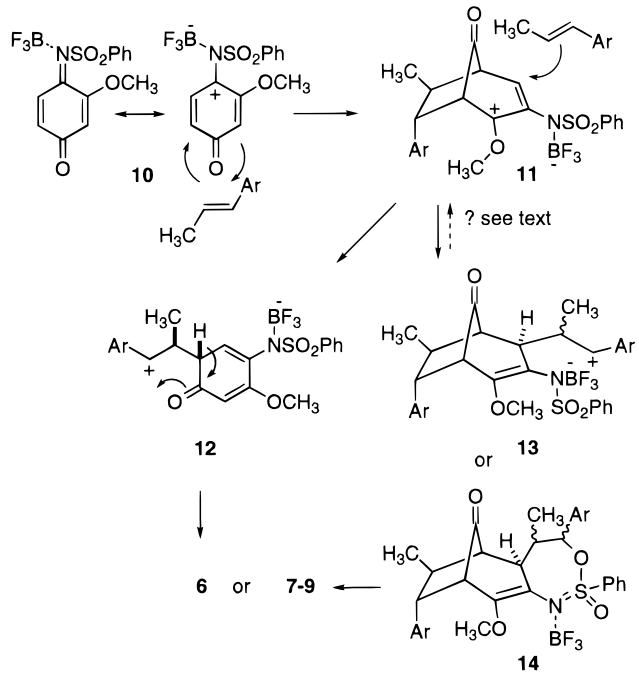


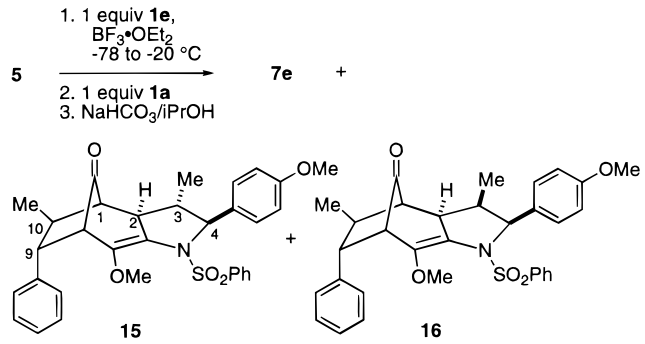
Figure 1. Selected $^1H-^1H$ NOE data from dihydrobenzofurans **6a** and **6c**.

Scheme 2



the positive ion center in **13** might be stabilized by active involvement with the *N*-benzenesulfonyl group.[8a,b]

Products **7**/**8** indicate that cation **11** reacts with a second equivalent of propenylbenzene. Experiments were then designed to attempt to trap **11** with a propenylbenzene different from which it was generated. The idea was that if this intermediate had sufficient lifetime, or if there was an equilibrium between **11** and **13** or **14**, which might also account for the varying ratios of **7**:**8** over time, then addition of a second *different* styrene at an appropriate time or temperature may produce unique hybrid tricyclic products similar to **7**/**8**, but with two different aryl groups. Remarkably, this hypothesis was reduced to practice in a reaction involving propenylbenzenes **1e** and **1a**. A mixture of **1e**, **5** (1 equiv of each), and BF_3·OEt_2 was warmed to −20 °C, and **1a** was then added; two new tricyclic products **15** and **16** were found in 15% and 22% yields, respectively, along with **7e** (10%).



The structure of **15** was determined by single-crystal X-ray analysis and comparison of its spectral data to that of **7e**. Indeed, the ^1H NMR spectra of the two are nearly identical with the differences expected for the different C-4 aryl groups. Adduct **16** also exhibited spectral characteristics consistent with the structure shown; however, an upfield methyl signal at 0.51 ppm in its ^1H NMR spectrum suggested that this methyl was cis to an aryl ring. The chemical shifts and coupling constants for H-1, H-2, and H-8 through H-10 were similar to the corresponding signals of **7e** and **15**, which suggested that in **16** the C-3 methyl and C-4 aryl groups were cis. The relative stereochemistry in **16** was determined by comparison of NOE data from it with corresponding data from **15**.[6] For the trans isomer **15**, irradiation of the C-3 methyl showed enhancement of H-4, H-2, and H-1. Furthermore, irradiation of H-2 provided evidence that it was on the same face of the molecule as H-4 and H-10. In the cis isomer **16**, irradiation of H-2 and H-3 showed that H-10, H-2, H-4, *and* H-3 were again all on the same side of the molecule, but irradiation of the C-3 methyl failed to result in enhancement of the H-2 or H-4 signals. That isomers **15**/**16**, both with the *p*-methoxyphenyl ring cis to the bridging carbonyl, are formed in contrast to isomers **7e**/**8e** is perhaps due to an attractive interaction

(8) (a) Neighboring group participation via nitrogen of a sulfonamido group has been observed in reactions of 2-β-iodo-1-α-sulfonamidohexoses, Griffith, D. A.; Danishefsky, S. J. *J. Am. Chem. Soc.* **1990**, *112*, 5811−5819. (b) Structures **11** and **13** might also be stabilized by an electrostatic interaction between the cationic center and the borate moiety (NBF_3^-) due to their proximity. Indeed, a fluoride bridge between the C^+ and the B^- is perhaps possible; such interactions are found in the solid state, Laube, T. In *Stable Carbocation Chemistry*; Prakash, G. K. S., Schleyer, P.v. R., Eds.; Wiley: New York, 1997; Chp. 14. (c) Participation via nitrogen is not geometrically feasible in **19**, but participation through the sulfonyl group is worthy of consideration.

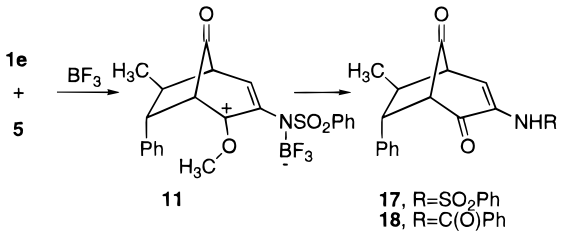
Table 2. Ratios of 7e:8e over Time from Reactions of 1e with 5

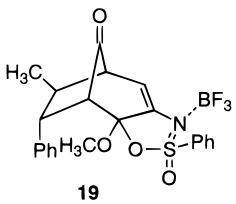
	ratio of **7e:8e**[a]					
time (h)	rxn 1	rxn 2	rxn 3	rxn 4	rxn 5	rxn 6
0.03	9.1:1					7.2:1
0.08	6.9:1 workup	6.2:1	7.2:1	7.0:1	7.5:1	6.2:1
1		5.7:1 workup		3.8:1	3.9:1	5.1:1
3						5.0:1
6						4.1:1
12			2.4:1 workup	1.7:1 workup		2.7:1
24					1.6:1 workup	2.7:1
48						1.8:1
60						1.6:1 workup
isolated ratio[b]	6.5:1	3.5:1	1.6:1	1.5:1	1.4:1	1.4:1
overall yield[b] (%)	68	74	79	68	74	62

[a] By HPLC. [b] Based on amounts of **7e**/**8e** obtained after workup and chromatography.

between the bridging carbonyl and the 4-methoxyphenyl group during ring closure.

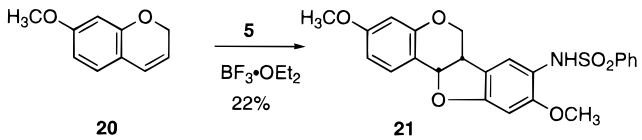
Thus, the initial cycloaddition intermediate **11** is apparently long-lived enough at −20 °C, or is present perhaps in equilibrium with **13** or **14**, to be trapped by a second propenylbenzene. Focus then shifted to other ways to intercept cation **11** and thus lend support to the proposed mechanism. As shown in Table 1, reactions of **5** with 1−1.3 equiv (*E*)-propenylbenzene (**1e**) at −78 °C followed by warming to room temperature gave dihydrobenzofuran **6e** (51%) and small amounts of **7e**. With excess propenylbenzene, **7e/8e** were found, along with small amounts of the dihydrobenzofuran. To trap **11**, the quantity of propenylbenzene was limited to 1.0 equiv, and the reaction was warmed from −78 to −20 °C over 2−2.5 h whereupon it was quenched with $NaHCO_3$/^{i}PrOH. Bicyclo[3.2.1]-adduct **17** was isolated in 50% yield. Identification of **17** was made by comparison to previously identified bicyclo[3.2.1]-system **18**[2] and detailed ^{1}H and 2D NMR experiments. The unexpected stability of **11** might again be attributable to a structure like **19** in which participation of the *N*-benzenesulfonyl group with the carbocation center serves to satisfy the electronic requirements of all atoms.[8b,c]





Reactions of **5** promoted by Ti(IV) were also studied briefly in attempts to reverse the regioselectivity and provide a complimentary route to indolines, a successful strategy employed in reactions of **2**. However, reactions of **5** promoted by excess quantities of a 1:1 mixture of $TiCl_4$:$Ti(OiPr)_4$ gave complex reaction mixtures, and only modest quantities of **6** (<30%) could be isolated. Apparently, reactions of **5** are governed by a preference for formation of the initial cycloadduct **11** in which the carbocation center is stabilized by the OCH_3 group.

In summary, Lewis acid-promoted reactions of **5** with propenylbenzenes **1d**−**g** can be manipulated to produce a variety of bi- and tricyclic systems including products of an orchestrated tandem reaction with two different propenylbenzenes. Reactions with electron rich propenylbenzenes **1a**−**c** afford alkoxy-substituted 2-aryl-2,3-dihydrobenzofurans, substructures found in a number of biologically active natural products.[1,9] The sulfonamido moiety in products **6** provides a means to access various derivatives via chemistry previously reported.[9] As a further example, reactions of **5** with 7-methoxy-2*H*-chromene, **20**, were studied as a route to nitrogen-substituted pterocarpans, analogues of compounds possessing interesting biological properties.[2,3,10] The target molecule **21** was found, although only in modest yield. In these reactions, reduction of the monoimine was a major process.



Experimental Section[11]

NMR spectra were recorded on samples dissolved in $CDCl_3$ at room temperature unless otherwise noted. Chemical shifts are reported in parts-per-million (δ) relative to residual chloroform or added tetramethylsilane (TMS) and coupling constants (J) are reported in hertz (Hz). Infrared spectra were recorded on samples as films or dissolved in the solvents indicated using sodium chloride plates or solution cells; absorbencies are reported in cm^{-1}.

***N*-(2-Methoxy-4-oxocyclohexa-2,5-dienylidene)benzenesulfonamide (5).** A solution of benzenesulfonyl chloride (5 mL, 40 mmol) and pyridine (5 mL, 60 mmol) in THF (5 mL) was added to 2,4-dimethoxyaniline (5.5 g, 36 mmol) in THF (150 mL) at room temperature. After 20 h, the reaction mixture was poured into H_2O (200 mL) and acidified with concd aqueous HCl to pH ∼1. The aqueous layer was separated and extracted with CH_2Cl_2 (2 × 150 mL), and the combined organic extracts were washed with brine (150 mL) and dried (Na_2SO_4). Upon concentration of the purple solution, white, shiny crystals formed which were collected by filtration,

(9) Engler, T. A.; Chai, W. *Tetrahedron Lett.* **1996**, *37*, 6969−6970.
(10) (a) Engler, T. A.; Lynch, K. O., Jr.; Reddy, J. P.; Gregory, G. S. *Bioorg. Med. Chem. Lett.* **1993**, *3*, 1229−1232. (b) Engler, T. A.; Lynch, K. O., Jr.; Iyengar, R.; Chai, W.; Agrios, K. *Bioorg. Med. Chem.* **1996**, 4, 1755−1769. (c) Engler, T. A.; Reddy, J. P.; Combrink, K. D.; Vander Velde, D. *J. Org. Chem.* **1990**, *55*, 1248−1254, and references therein.
(11) (a) For a description of general experimental details, see Engler, T. A.; Luterman, D. R. *J. Org. Chem.* **1998**, *63*, 314−318. (b) The propenylbenzenes employed were mixtures of (*E*):(*Z*) isomers (>5:1) as described in refs 1−3 and 8a.

washed with hexanes, and dried in vacuo to yield the corresponding sulfonamide (7.0 g, 66%) as a white crystalline solid, mp 108−110 °C (CH_2Cl_2/hexanes). ^{1}H NMR (400 MHz, $CDCl_3$) 7.66 (d, J = 7.5, 2H), 7.49 (t, J = 7.5, 1H), 7.44 (d, J = 8.5, 1H), 7.37 (t, J = 7.5, 2H), 6.65 (br s, 1H, NH), 6.4 (dd, J = 8.5, 2.5, 1H), 6.25 (d, J = 2.5, 1H), 3.75 (s, 3H), 3.43 (s, 3H). ^{1}H NMR (300 MHz, DMSO-d_6) 9.26 (s, 1H), 7.64−7.49 (m, 5H), 7.07 (d, J = 8.6, 1H), 6.45 (dd, J = 2.6, 8.6, 1H), 6.42 (d, J = 2.6, 1H), 3.70 (s, 3H), 3.34 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) 158.6, 152.0, 139.1, 132.6, 128.5, 127.3, 125.0, 118.5, 104.3, 98.7, 55.5, 55.4. IR ($CHCl_3$) 3343. HRMS m/z 293.0722 (Calcd for $C_{14}H_{15}NO_4S$, 293.0722).

A solution of $(NH_4)_2Ce(NO_3)_6$ (19 g, 35 mmol) in H_2O (60 mL) was added rapidly dropwise to a solution of the sulfonamide prepared as described above in CH_3CN (70 mL) at room temperature. After 2 min, a bright yellow-orange solid was isolated by filtration, washed with hexanes, and dried under reduced pressure to yield **5** (2.26 g, 77%) as a bright yellow powder, mp 132−142 °C (decomposition without melting). ^{1}H NMR (300 MHz) 8.11−8.01 (m, 3H), 7.70−7.55 (m, 3H), 6.59 (dd, J = 2.0, 10, 1H), 5.91 (d, J = 2.0, 1H), 3.78 (s, 3H). ^{13}C NMR (75 MHz) 186.3, 159.8, 140.0, 134.8, 133.7, 129.2, 128.8, 127.6, 116.9, 107.8, 56.5. IR ($CHCl_3$) 1650, 1630. HRMS m/z 278.0464 (Calcd for $C_{13}H_{12}NO_4S$, 278.0487).

General Procedure for BF_3·OEt_2-Promoted Reactions of Propenylbenzenes 1 with 1,4-Benzoquinone Monoimine 5. The propenylbenzene (0.22−0.56 mmol, Table 1),[11b] either neat or as a solution in CH_2Cl_2 (0−1 mL), was combined with the monoimine **5** (0.17−0.36 mmol) in CH_2Cl_2 (10 mL) and cooled to −78 °C, −40 °C, or −20 °C. After 10−15 min, BF_3·OEt_2 (0.2−0.7 mmol) was added neat via syringe. The reaction mixtures were stirred until starting monoimine was consumed (TLC) and/or for the times indicated in Tables 1 and 2 and then quenched by sequential addition of ^{i}PrOH (3 mL), saturated aqueous sodium bicarbonate (3 mL), and water (20 mL). The resultant mixture was extracted with CH_2Cl_2 (2 × 30 mL), and the extracts were washed with brine (30 mL), dried (Na_2SO_4 or $MgSO_4$), and concentrated. The residue was purified by flash column chromatography, preparative thin-layer chromatography, and/or recrystallization as indicated.

***rel*-*N*-[(2*R*,3*R*)-6-Methoxy-2-(4-methoxyphenyl)-3-methyl-2,3-dihydrobenzofuran-5-yl]benzenesulfonamide (6a).** Table 1, entry 1: flash chromatography with 2:3:5 CH_2Cl_2:Et_2O:hexanes as eluent gave **6a** (59 mg, 84%) as white crystals, mp 156−157.5 °C (Et_2O/hexanes). TLC R_f 0.33 (2:3:5 CH_2Cl_2:Et_2O:hexanes). ^{1}H NMR (500 MHz) 7.67 (d, 2H, J = 7.5), 7.50 (t, 1H, J = 7.5), 7.38 (t, 2H, J = 7.5), 7.31 (d, 2H, J = 8.8), 7.31 (s, 1H), 6.90 (d, 2H, J = 8.8), 6.58 (s, 1H), 6.23 (br s, N−H), 5.08 (d, 1H, J = 8.7), 3.81 (s, 3H), 3.40 (dq, 1H, J = 6.8, 8.7), 3.38 (s, 3H), 1.37 (d, 3H, J = 6.8). ^{13}C NMR (100 MHz) 160.2, 158.4, 152.3, 139.5, 133.0, 132.7, 128.9, 128.0, 127.7, 124.2, 120.8, 118.4, 114.5, 98.0, 93.8, 56.0, 55.8, 45.2, 18.6. IR (CH_2Cl_2) 3332. Anal. Calcd for $C_{23}H_{23}NO_5S$: C, 64.92; H, 5.45; N, 3.29. Found: C, 64.53; H, 5.28; N, 3.00.

***rel*-*N*-[(2*R*,3*R*)-2-(3,4-Dimethoxyphenyl)-6-methoxy-3-methyl-2,3-dihydrobenzofuran-5-yl]benzenesulfonamide (6b).** Table 1, entry 2: flash chromatography with 50% EtOAc/hexanes as eluent yielded **6b** (78 mg, 48%) as a white powder. Recrystallization from ∼1:5 CH_2Cl_2/hexanes gave a white powder, mp 176.5−177 °C. TLC R_f 0.23 (50% EtOAc/hexanes). ^{1}H NMR (400 MHz) 7.70 (d, 2H, J = 7.4), 7.53 (t, 1H, J = 7.4), 7.42 (t, 2H, J = 7.4), 7.33 (s, 1H), 6.95 (d, 1H, J = 8.0), 6.94 (s, 1H), 6.88 (d, 1H, J = 8.0), 6.61 (br s, N−H), 6.27 (s, 1H), 5.10 (d, 1H, J = 8.9), 3.91 (s, 3H), 3.90 (s, 3H), 3.44 (dq, 1H, J = 6.7, 8.9), 3.42 (s, 3H), 1.40 (d, 3H, J = 6.7). ^{13}C NMR (125 MHz) 157.8, 151.8, 149.2, 139.2, 132.6, 132.5, 128.4, 127.3, 126.0, 123.7, 120.2, 118.8, 118.0, 110.9, 109.2, 93.7, 93.6, 55.95, 55.92, 55.57, 44.6, 18.0. IR (CH_2Cl_2) 3331. HRMS m/z 455.1392 (M^+) (Calcd for $C_{24}H_{25}NO_6S$, 455.1403).

***rel*-*N*-[(2*R*,3*R*)-2-Benzo[1,3]dioxol-5-yl-6-methoxy-3-methyl-2,3-dihydrobenzofuran-5-yl]benzenesulfonamide (6c).** Table 1, entry 3: flash chromatography with 30% EtOAc/hexanes as eluent yielded **6c** (72 mg, 76%) as a white powder. Recrystallization from ∼1:5 CH_2Cl_2/hexanes gave white crystals, mp 188.8−189.2 °C. TLC R_f 0.20 (30% EtOAc/hexanes). ^{1}H NMR (400 MHz) 7.66 (d, 2H, J = 7.3), 7.5 (t, 1H, J = 7.3), 7.39 (t, 2H, J = 7.3), 7.30 (s, 1H), 6.86 (br s, 1H), 6.82 (br d, 1H, J = 8), 6.81 (d, 1H, J = 8), 6.62 (br s, N−H), 6.22 (s, 1H), 5.96 (s, 2H), 5.05 (d, 1H, J = 8.4), 3.38 (s, 3H), 3.35 (dq, 1H, J = 6.8, 8.4), 1.37 (d, 3H, J = 6.8). ^{1}H NMR (400 MHz, C_6D_6) 7.84 (dd, 2H, J = 1.7, 8.0), 7.40 (s, 1H), 6.94−6.89 (m, 3 aromatic CH + 1 NH), 6.72 (bs, 1H), 6.69 (d, 1H, J = 8.0), 6.66 (dd, 1H, J = 1.5, 8.0), 6.17 (s, 1H), 5.38 (dd, 2H, J = 1.3, 4.2), 4.95 (d, 1H, J = 8.6), 3.17 (dq, 1H, J = 6.8, 8.6), 2.77 (s, 3H), 1.12 (d, 3H, J = 6.8). ^{13}C NMR (100 MHz) 158.3, 152.3, 148.4, 148.1, 139.5, 134.7, 133.0, 128.9, 127.7, 124.0, 120.8, 120.3, 118.5, 108.6, 106.8, 101.6, 94.0, 93.8, 56.0, 45.4, 18.8. IR (CH_2Cl_2) 3331. Anal. Calcd for $C_{23}H_{21}NO_6S$: C, 62.86; H, 4.81; N, 3.19. Found: C, 62.68; H, 4.58; N, 2.90.

Reaction of (*E*)-1-Methyl-4-(1-propenyl)benzene (1d) with Monoimine 5. Table 1, entry 4: flash chromatography with 15% EtOAc/hexanes as eluent produced **6d** (34 mg, 32%), **7d** (11 mg, 8%) and **8d** (21 mg, 15%) as white solids. Compounds **6d** and **7d** were further recrystallized from ∼1:4 CH_2Cl_2/hexanes and ∼1:5 CH_2Cl_2/pentane, respectively; attempts to recrystallize **8d** were unsuccessful.

Table 1, entry 5: gave **6d** (8 mg, 10%), **7d** (21 mg, 19%), and **8d** (16 mg, 15%).

Physical and spectral data for *rel*-*N*-[(2*R*,3*R*)-6-methoxy-3-methyl-2-*p*-tolyl-2,3-dihydrobenzofuran-5-yl]benzenesulfonamide (**6d**): mp 163.5−164 °C, TLC R_f 0.17 (20% EtOAc/hexanes). ^{1}H NMR (400 MHz) 7.67 (d, 2H, J = 7.4), 7.50 (t, 1H, J = 7.4), 7.40 (t, 2H, J = 7.4), 7.31 (s, 1H), 7.27 (d, 2H, J = 7.9), 7.18 (d, 2H, J = 7.9), 6.57 (br s, N−H), 6.24 (s, 1H), 5.11 (d, 1H, J = 8.5), 3.40 (dq, 1H, J = 6.8, 8.5), 3.39 (s, 3H), 2.36 (s, 3H), 1.38 (d, 3H, J = 6.8). ^{13}C NMR (100 MHz) 158.4, 152.2, 139.5, 138.6, 137.8, 132.9, 129.7, 128.8, 127.7, 126.4, 124.1, 120.7, 118.4, 94.0, 93.8, 55.9, 45.3, 21.5, 18.7. IR (CH_2Cl_2) 3332. HRMS m/s 409.1341 (M^+) (Calcd for $C_{23}H_{23}NO_4S$, 409.1348).

Physical and spectral data for *rel*-(1*R*,2*R*,3*S*,4*S*,8*S*,9*R*,10*R*)-5-(benzenesulfonyl)-7-methoxy-3,10-dimethyl-4,9-di-*p*-tolyl-5-azatricyclo[6.2.1.0 2,6]undec-6-en-11-one (**7d**): mp 195−196 °C, TLC R_f 0.33 (20% EtOAc/hexanes).^{1}H NMR (400 MHz) 7.42 (d, 2H, J = 8.0), 7.39 (d, 2H, J = 7.9), 7.36 (t, 1H, J = 7.9), 7.25 (d, 2H, J = 8.0), 7.18 (t, 2H, J = 7.9), 7.04 (center of *AB* quartet, 4H, J = 8.3), 4.63 (d, 1H, J = 9.1), 3.12 (dd, 1H, J = 6.6, 6.7), 2.91 (dd, 1H, J = 1.5, 6.7), 2.59 (d, 1H, J = 11.4), 2.41 (dq, 1H, J = 6.6, 6.9), 2.37 (s, 3H), 2.30 (s, 3H), 2.06 (br s, 1H), 1.80 (ddq, 1H, J = 6.4, 9.1, 11.4), 1.13 (d, 3H, J = 6.9), 1.06 (d, 3H, J = 6.4). ^{13}C NMR (100 MHz) 209.9, 140.3, 139.7, 137.5, 137.2, 137.1, 137.0, 132.0, 129.3, 129.1, 129.0, 127.9, 127.7, 127.4, 121.8, 74.0, 56.9, 55.6, 54.5, 53.7, 51.7, 44.7, 43.4, 21.7, 21.12, 21.10, 14.6. IR (CH_2Cl_2) 1748, 1692. Anal. Calcd for $C_{33}H_{35}NO_4S$: C, 73.17; H, 6.51; N, 2.59. Found: C, 72.80; H, 6.80; N, 2.60.

Physical and spectral data for *rel*-(1*R*,2*R*,3*R*,4*R*,8*S*,9*R*,10*R*)-5-(benzenesulfonyl)-7-methoxy-3,10-dimethyl-4,9-di-*p*-tolyl-5-azatricyclo[6.2.1.0 2,6]undec-6-en-11-one (**8d**): mp 170−175 °C (decopmosition with melting), TLC R_f 0.23 (20% EtOAc/hexanes). ^{1}H NMR (400 MHz) 7.75 (d, 2H, J = 7.4), 7.47 (t, 1H, J = 7.4), 7.40 (d, 2H, J = 8.0), 7.38 (m, 2H), 7.28 (d, 2H, J = 8.0), 7.20 (center of *AB* quartet, 4H, J = 8.1), 5.13 (s, 1H), 3.35 (d, 1H, J = 5.4), 3.07 (dd, 1H, J = 5.0, 7.2), 2.74 (dd, 1H, J = 1.5, 7.2), 2.45 (s, 3H), 2.40 (s, 3H), 2.38 (s, 3H), 2.31 (dq, 1H, J = 5.4, 7.0), 2.18 (dq, 1H, J = 5.0, 7.0), 1.90 (d, 1H, J = 1.5), 1.07 (d, 3H, J = 7.0), 0.98 (d, 3H, J = 7.0). ^{13}C NMR (125 MHz) 209.4, 142.6, 140.0, 137.6, 137.0, 136.9, 132.0, 130.9, 129.2, 129.1, 128.4, 126.5, 125.2, 120.8, 75.0, 54.9, 54.2, 53.2, 50.8, 49.6, 44.7, 13.1, 22.0, 21.2, 21.0, 14.4. IR (CH_2Cl_2) 1747, 1711. HRMS m/z 542.2355 (M^+ + 1) (Calcd for $C_{33}H_{35}NO_4S$, 542.2365).

***rel*-*N*-[(2*R*,3*R*)-6-Methoxy-3-methyl-2-phenyl-2,3-dihydrobenzofuran-5-yl]benzenesulfonamide (6e).** Table 1, entry 6: after warming the reaction to 23 °C over 10.5 h, workup and flash chromatography with 20% EtOAc/hexanes as eluent gave **7e** (8 mg, 8%) and **6e** (44 mg, 51%), both as white powders. Recrystallization of **6e** from CH_2Cl_2/hexanes yielded white crystals, mp 164−165 °C. TLC R_f 0.25 (30% EtOAc/hexanes). ^{1}H NMR (400 MHz, $CDCl_3$) 7.67 (d, 2H, J =

7.4), 7.50 (t, 1H, $J = 7.4$), 7.48−7.33 (m, 7H), 7.31 (s, 1H), 6.59 (br s, N−H), 6.26 (s, 1H), 5.15 (d, 1H, $J = 8.4$), 3.41 (dq, 1H, $J = 6.8, 8.4$), 3.40 (s, 3H), 1.41 (d, 3H, $J = 6.8$). ^{1}H NMR (400 MHz, C_6D_6) 7.70 (d, 2H, $J = 6.8$), 7.59 (s, 1H), 7.19−7.07 (m, 5H), 6.84−6.78 (m, 3H), 6.56 (br s, N−H), 6.08 (s, 1H), 4.94 (d, 1H, $J = 8.5$), 3.10 (dq, 1H, $J = 6.8, 8.5$), 2.68 (s, 3H), 1.03 (d, 3H, $J = 6.8$). ^{13}C NMR (100 MHz) 158.4, 152.3, 140.8, 139.5, 133.0, 129.1, 128.8, 128.7, 127.7, 126.4, 124.0, 120.7, 118.5, 94.0, 93.7, 56.0, 45.5, 18.9. IR (CH_2Cl_2) 3332. HRMS *m*/*z* 395.1209 (M^+) (Calcd for $C_{22}H_{21}NO_4S$, 395.1191).

***rel*-(1*R*,2*R*,3*S*,4*S*,8*S*,9*R*,10*R*)-5-(Benzenesulfonyl)-7-methoxy-3,10-dimethyl-4,9-diphenyl-5-azatricyclo[6.2.1.0 2,6]undec-6-en-11-one (7e) and *rel*-(1*R*,2*R*,3*R*,4*R*,8*S*,9*R*,10*R*)-5-(benzenesulfonyl)-7-methoxy-3,10-dimethyl-4,9-diphenyl-5-azatricyclo[6.2.1.0 2,6]undec-6-en-11-one (8e).** A series of reactions were run according to the same procedure: Table 1, entries 7, 8, and Table 2. Thus, a solution of **1e** (0.52−1.05 mmol) and monoimine **5** (0.23−0.36 mmol) in CH_2Cl_2 (10−15 mL) at −20 °C was treated with $BF_3{\cdot}OEt_2$ (0.3−0.5 mmol, 1.3−1.7 equiv with respect to **5**), and the reactions were quenched after different times as indicated in the tables. Workup and flash chromatography with 15 or 20% EtOAc/hexanes as eluent gave **7e** and **8e** as white solids. Recrystallization of **7e** from ∼1:4 CH_2Cl_2/hexanes gave flat, narrow crystals, and recrystallization of **8e** from ∼1:5 Et_2O/hexanes afforded fine, small, white needles.

Physical and spectral data for **7e**: mp 174.5−175 °C, TLC R_f 0.38 (30% EtOAc/hexanes). ^{1}H NMR (400 MHz) 7.55 (d, 2H, $J = 7.4$), 7.47 (t, 2H, $J = 7.4$), 7.40−7.36 (m, 4H), 7.25−7.17 (m, 7H), 4.72 (d, 1H, $J = 9.1$), 3.19 (dd, 1H, $J = 6.6, 6.7$), 2.97 (dd, 1H, $J = 1.4, 6.6$), 2.68 (s, 3H), 2.66 (d, 1H, $J = 11.3$), 2.48 (dq, 1H, $J = 6.7, 6.9$), 2.11 (br s, 1H,), 1.86 (ddq, 1H, $J = 6.4, 9.1, 11.3$), 1.18 (d, 3H, $J = 6.9$), 1.13 (d, 3H, $J = 6.4$). ^{13}C NMR (100 MHz) 210.2, 143.8, 140.6, 140.4, 140.0, 132.5, 129.7, 129.0, 128.8, 128.3, 128.2, 128.1, 128.0, 127.9, 122.3, 73.5, 57.3, 56.4, 54.8, 54.0, 52.2, 45.3, 43.6, 22.2, 15.0. IR (CH_2Cl_2) 1750, 1693. Anal. Calcd for $C_{31}H_{31}NO_4S$: C, 72.49; H, 6.08; N, 2.73. Found: C, 72.15; H, 6.39; N, 2.48.

Physical and spectral data for **8e**: mp 177−184 °C (decomposition without melting), TLC R_f 0.28 (30% EtOAc/hexanes). ^{1}H NMR (400 MHz) 7.76 (d, 2H, $J = 7.3$), 7.5−7.3 (m, 13H), 5.16 (s, 1H), 3.35 (d, 1H, $J = 5.6$), 3.12 (dd, 1H, $J = 5.2, 7.2$), 2.76 (dd, 1H, $J = 1.5, 7.2$), 2.41 (s, 3H), 2.35 (dq, 1H, 5.6, 6.9), 2.22 (dq, 1H, $J = 5.2, 6.9$), 1.92 (d, 1H, $J = 1.5$), 1.10 (d, 3H, $J = 6.9$), 1.00 (d, 3H, $J = 6.9$). ^{13}C NMR (125 MHz) 209.2, 142.8, 142.6, 140.6, 132.1, 131.0, 129.3, 128.5, 128.47, 128.46, 127.4, 127.3, 126.5, 125.28, 120.9, 75.2, 55.3, 54.1, 53.2, 50.8, 49.5, 44.7, 42.8, 22.1, 14.4. IR (CH_2Cl_2) 1746, 1694. Anal. Calcd for $C_{31}H_{31}NO_4S$: C, 72.49; H, 6.08; N, 2.73. Found: C, 72.18; H, 6.10; N, 2.68.

HPLC analyses of reactions described in Table 2 utilized a μPorasil silica column (3.9 mm × 300 mm) with a UV detector set at 254 nm. The eluent was 98:2 hexanes:2-propanol with a flow rate of 1 mL/min; retention times of **7e** and **8e** were 4.1 and 5.7 min, respectively. Standard mixtures of authentic **7e** and **8e** examined by ^{1}H NMR and HPLC revealed a relative response factor **7e:8e** of 1.3:1.

Reaction of (*E*)-1-Methyl-2-(1-propenyl)benzene (1f) with Monoimine 5. Table 1, entry 9: flash chromatography with 15 or 20% EtOAc/hexanes as eluent gave **6f** (14 mg, 17%), **7f** (50 mg, 50%), and **8f** (7 mg, 6%) as white solids. Compound **6f** was recrystallized from ∼1:4 CH_2Cl_2/hexanes to small, white crystals. Compound **7f** was recrystallized from ∼1:4 CH_2Cl_2/hexanes to white, cube-shaped crystals. Attempts to recrystallize **8f** were unsuccessful.

Conditions described in Table 1, entry 10, gave **6f** (22 mg, 28%), **7f**, (54 mg, 51%) and **8f** (15 mg, 14%) as products.

Physical and spectral data for *rel*-*N*-[(2*R*,3*R*)-6-methoxy-3-methyl-2-*o*-tolyl-2,3-dihydrobenzofuran-5-yl]benzenesulfonamide (**6f**): mp 176−177 °C, TLC R_f 0.27 (30% EtOAc/hexanes). ^{1}H NMR (400 MHz) 7.67 (d, 2H, $J = 7.5$), 7.53 (t, 1H, $J = 7.5$), 7.40 (t, 2H, $J = 7.5$), 7.34 (s, 1H), 7.29 (d, 1H, $J = 7.0$), 7.26−7.20 (m, 3H), 6.62 (br s, NH), 6.28 (s, 1H), 5.46 (d, 1H, $J = 7.3$), 3.44 (dq, 1H, $J = 6.8, 7.3$), 3.43 (s, 3H), 2.41 (s, 3H), 1.44 (d, 3H, $J = 6.8$). ^{13}C NMR (100 MHz) 158.4, 152.4, 139.5, 138.8, 135.8, 132.9, 131.2, 128.8, 128.4, 127.7, 126.6, 126.4, 123.9, 120.9, 118.5, 93.9, 91.0, 55.9, 44.8, 19.9, 19.8. IR (CH_2Cl_2) 3332. HRMS *m*/*z* 409.1371 (M^+) (Calcd for $C_{23}H_{23}NO_4S$, 409.1348).

Physical and spectral data for *rel*-(1*R*,2*R*,3*S*,4*S*,8*S*,9*R*,10*R*)-5-(benzenesulfonyl)-7-methoxy-3,10-dimethyl-4,9-di-*o*-tolyl-5-azatricyclo[6.2.1.0 2,6]undec-6-en-11-one (**7f**): mp 198.5−200 °C, TLC R_f 0.53 (30% EtOAc/hexanes). ^{1}H NMR (400 MHz) 7.74 (d, 2H, $J = 7.7$), 7.44 (dt, 1H, $J = 1.0, 7.7$), 7.31−7.28 (m, 3H), 7.23 (dt, 1H, $J = 1.0, 7.5$), 7.17 (d, 1H, $J = 7.0$), 7.13−7.07 (m, 3H), 7.05 (d, 1H, $J = 7.0$), 6.99 (d, 2H, $J = 3.6$), 5.12 (d, 1H, $J = 9.1$), 3.47 (dd, 1H, $J = 6.3, 6.6$), 2.94 (dd, 1H, $J = 1.5, 6.6$), 2.84 (d, 1H, $J = 11.4$), 2.58 (dq, 1H, $J = 6.3, 6.8$), 2.42 (s, 3H), 2.38 (s, 3H), 2.34 (br s, 3H), 2.13 (br s, 1H), 1.94 (ddq, 1H, $J = 6.3, 9.1, 11.4$), 1.14 (d, 3H, $J = 6.8$), 1.13 (d, 3H, $J = 6.3$). ^{13}C NMR (125 MHz, 50 °C to equilibrate rotamers) 209.4, 140.6, 138.3, 137.9, 137.5, 135.9, 135.8, 131.5, 130.1, 129.6, 128.8, 128.0, 127.3, 127.2, 127.1, 126.8, 126.6, 125.8, 122.4, 69.4, 56.8, 53.1, 51.6, 51.5, 51.0, 44.4, 42.4, 21.5, 19.6, 18.8, 14.3. IR (CH_2Cl_2) 1746. Anal. Calcd for $C_{33}H_{35}NO_4S$: C, 73.17; H, 6.51; N, 2.59. Found: C, 73.34; H, 6.18; N, 2.36.

Physical and spectral data for *rel*-(1*R*,2*R*,3*R*,4*R*,8*S*,9*R*,10*R*)-5-(benzenesulfonyl)-7-methoxy-3,10-dimethyl-4,9-di-*o*-tolyl-5-azatricyclo[6.2.1.0 2,6]undec-6-en-11-one (**8f**): mp 187−192 °C (decomposition without melting), TLC R_f 0.40 (30% EtOAc/hexanes). ^{1}H NMR (400 MHz) 7.73 (d, 2H, $J = 7.3$), 7.67 (d, 1H, $J = 7.6$), 7.48−7.37 (m, 5H), 7.33 (d, 1H, $J = 7.6$), 7.28−7.20 (m, 2H), 7.22 (d, 1H, $J = 7.1$), 7.16 (d, 1H, $J = 7.1$), 5.25 (s, 1H), 3.43 (d, 1H, $J = 5.5$), 3.39 (dd, 1H, $J = 4.8, 7.1$), 2.82 (dd, 1H, $J = 1.4, 7.1$), 2.38 (s, 3H), 2.34 (s, 3H), 2.33 (s, 3H), 2.30 (dq, 1H, $J = 5.5, 7.0$), 2.23 (dq, 1H, $J = 4.8, 6.9$), 1.93 (d, 1H, $J = 1.4$), 1.12 (d, 3H, $J = 7.0$), 1.00 (d, 3H, $J = 6.9$). ^{13}C NMR (100 MHz) 209.8, 142.9, 141.1, 139.1, 137.0, 133.9, 132.5, 131.3, 131.2, 130.7, 128.9, 128.8, 127.7, 127.5, 126.9, 126.6, 126.4, 125.4, 121.9, 73.3, 54.3, 51.8, 51.3, 51.0, 49.9, 42.8, 42.6, 22.9, 20.5, 19.7, 14.6. IR (CH_2Cl_2) 1746. Anal. Calcd for $C_{33}H_{35}NO_4S$: C, 73.17; H, 6.51; N, 2.59. Found: C, 72.90; H, 6.70; N, 2.59.

Reaction of (*E*)-1-Chloro-4-(1-propenyl)benzene (1g) with Monoimine 5. Table 1, entry 11: multiple flash chromatography with 15% EtOAc/hexanes and 30% Et_2O/hexanes as eluents provided **7g** (33 mg, 24%), **8g** (27 mg, 20%), and **9g** (17 mg, 13%). Fractions (8 mg) containing **6g** contaminated with impurities were also collected. Compound **7g** was recrystallized from ∼1:4 CH_2Cl_2/hexanes to yield white crystals, **8g** was recrystallized from ∼1:1:4 CH_2Cl_2/Et_2O/hexanes to a threadlike powder, and **9g** was recrystallized from ∼1:1:4 CH_2Cl_2/Et_2O/hexanes to small, white crystals. Attempts to obtain **6g** free from impurities failed.

Selected physical and spectral data for *rel*-*N*-[(2*R*,3*R*)-2-(4-chlorophenyl)-6-methoxy-3-methyl-2,3-dihydrobenzofuran-5-yl]-benzenesulfonamide (**6g**): TLC R_f 0.07 (30% Et_2O/hexanes). ^{1}H NMR (400 MHz) 7.34 (s, 1H), 6.59 (br s, NH), 6.25 (s, 1H), 5.11 (d, 1H, $J = 8.4$), 3.41 (s, 3H), 3.21 (dq, 1H, $J = 6.8, 8.4$), 1.40 (d, 3H, $J = 6.8$). EIMS (relative intensity) *m*/*z* 429 [M^+ ($C_{22}H_{20}{}^{35}ClNO_4S$), 9] and 431 [$M^+$ ($C_{22}H_{20}{}^{37}ClNO_4S$), 3].

Physical and spectral data for *rel*-(1*R*,2*R*,3*S*,4*S*,8*S*,9*R*,10*R*)-5-(benzenesulfonyl)-4,9-bis(4-chlorophenyl)-7-methoxy-3,10-dimethyl-5-azatricyclo[6.2.1.0 2,6]undec-6-en-11-one (**7g**): mp 204−206 °C, TLC R_f 0.37 (30% EtOAc/hexanes). ^{1}H NMR (400 MHz) 7.50 (d, 2H, $J = 7.5$), 7.40−7.45 (m, 5H), 7.25 (t, 2H $J = 7.5$), 7.20 (d, 2H, $J = 8.4$), 7.10 (d, 2H, $J = 8.4$), 4.71 (d, 2H, $J = 9.2$), 3.15 (dd, 1H, $J = 6.6, 6.7$), 2.95 (dd, 1H, $J = 1.3, 6.6$), 2.70 (d, 1H, $J = 10.8$), 2.69 (s, 3H), 2.41 (dq, 1H, $J = 6.7, 6.9$), 2.12 (br s, 1H), 1.78 (ddq, 1H, $J = 6.4, 9.2, 10.8$), 1.16 (d, 3H, $J = 6.9$), 1.11 (d, 3H, $J = 6.4$). ^{13}C NMR (100 MHz) 209.6, 140.6, 139.9, 139.1, 138.8, 134.0, 133.9, 132.8, 131.0, 129.2, 129.1, 128.9, 128.5, 128.0, 122.2, 72.7, 57.3, 55.8, 54.8, 53.6, 52.0, 45.3, 43.9, 22.1, 14.9. IR (CH_2Cl_2) 1750. Anal. Calcd for $C_{31}H_{29}Cl_2NO_4S$: C, 63.92; H, 5.02; N, 2.40. Found: C, 63.80; H, 4.98; N, 2.01.

Physical and spectral data for *rel*-(1*R*,2*R*,3*R*,4*R*,8*S*,9*R*,10*R*)-5-(benzenesulfonyl)-4,9-bis(4-chlorophenyl)-7-methoxy-3,10-dimethyl-5-azatricyclo[6.2.1.0 2,6]undec-6-en-11-one (**8g**): mp 175−180 °C (decomposition with melting), TLC R_f 0.27 (30%

EtOAc/hexanes). ^{1}H NMR (400 MHz) 7.72 (d, 2H, J = 7.4), 7.51 (t, 1H, J = 7.4), 7.45−7.37 (m, 8H), 7.20 (d, 2H, J = 8.3), 5.12 (s, 1H), 3.25 (d, 1H, J = 5.4), 3.09 (dd, 1H, J = 5.0, 7.2), 2.78 (dd, 1H, J = 1.4, 7.2), 2.56 (s, 3H), 2.30 (dq, 1H, J = 5.4, 7.0), 2.15 (dq, 1H, J = 5.0, 7.0), 1.93 (br s, 1H), 1.10 (d, 3H, J = 7.0), 1.00 (d, 3H, J = 7.0). ^{13}C NMR (100 MHz) 208.5, 142.3, 141.3, 139.0, 133.3, 133.2, 132.3, 131.1, 130.3, 128.7, 128.6, 128.5, 126.6, 126.5, 120.6, 74.5, 54.6, 54.4, 52.6, 50.7, 49.6, 44.6, 43.2, 22.0, 14.4. IR ($CHCl_3$) 1743. IR (CH_2Cl_2) 1749. HRMS m/z 582.1293 (M^+ + 1) (Calcd for $C_{31}H_{30}{}^{35}Cl_2NO_4S$, 582.1273).

Physical and spectral data for *rel*-*N*-[(2*S*,3*R*,4*R*,5*R*,6*R*,7*S*,8*R*)-3,8-bis(4-chlorophenyl)-1-methoxy-4,7-dimethyl-10-oxotricyclo-[4.2.1.1 2,5]dec-9-ylidene]-benzenesulfonamide (**9g**): mp 265−270 °C (decomposition with melting), TLC R_f 0.23 (30% Et_2O/hexanes). ^{1}H NMR (400 MHz) 7.95 (d, 2H, J = 7.4), 7.66 (t, 1H, J = 7.4), 7.58 (t, 2H, J = 7.4), 7.22 (d, 2H, J = 8.4), 7.14 (d, 2H, J = 8.4), 7.13 (d, 2H, J = 8.5), 6.97 (d, 2H, J = 8.5), 4.25 (dd, 1H, J = 6.0, 6.3), 3.42 (dd 1H, J = 2.3, 5.6), 3.19 (dq, 1H, J = 6.2, 7.8), 3.06 (dd, 1H, J = 5.6, 6.2), 3.02 (d, 1H, J = 7.8), 2.63 (s, 3H), 2.53 (dd, 1H, J = 2.3, 6.3), 2.20 (ddq, 1H, J = 6.0, 7.4, 7.8), 1.90 (d, 3H, J = 7.4), 1.70 (d, 3H, J = 7.8). ^{13}C NMR (100 MHz) 208.5, 190.4, 139.9, 138.8, 134.7, 134.0, 133.4, 132.9, 130.2, 129.5, 129.4, 129.0, 128.5, 128.0, 86.9, 56.2, 54.3, 53.8, 51.7, 49.5, 48.9, 44.0, 33.3, 22.1, 12.7. IR (CH_2Cl_2) 1751, 1655. HRMS m/z 582.1292 (M^+ +1) (Calcd for $C_{31}H_{30}{}^{35}Cl_2NO_4S$, 582.1273).

Reaction of (*E*)-Propenylbenzene (1e), Monoimine 5, and (*E*)-4-Propenylanisole (1a). The general procedure for BF_3·OEt_2-promoted reactions was adapted slightly. A solution of (*E*)-propenylbenzene (**1e**, 21 mg, 0.18 mmol) and monoimine **5** (49 mg, 0.18 mmol) in CH_2Cl_2 (10 mL) at −78 °C was treated with BF_3·Et_2O (0.04 mL, 0.3 mmol) and the reaction warmed to −20 °C over 2 h. (*E*)-4-Propenylanisole (**1a**, 0.03 mL, 0.20 mmol) was then added. The reaction was warmed to −10 °C over 5 min and was quenched. Workup and flash chromatography with 20% EtOAc/hexanes as eluent yielded **7e** (9 mg, 10%) and a ∼2:3 mixture of **15** and **16** (36 mg, 37%), TLC R_f 0.30 (30% EtOAc/hexanes). Partial separation of **15**/**16** was achieved by preparative thin-layer chromatography, eluting twice with 2% EtOAc/benzene (**15** has the higher R_f). Recrystallization of a sample enriched in **15** from ∼1:5 CH_2Cl_2/hexanes produced white crystals, mp 166−167.5 °C, while **16** was isolated as a colorless oil, contaminated with small amounts of **15**.

Physical and spectral data for *rel*-(1*R*,2*R*,3*S*,4*S*,8*S*,9*R*,10*R*)-5-(benzenesulfonyl)-7-methoxy-4-(4-methoxyphenyl)-3,10-dimethyl-9-phenyl-5-azatricyclo[6.2.1.0 2,6]undec-6-en-11-one (**15**). ^{1}H NMR (400 MHz) 7.53 (d, 2H, J = 7.5), 7.44 (t, 2 H, J = 7.5), 7.37−7.31 (m, 4 H), 7.18 (t, 2H, J = 8.0), 7.09 (d, 2H, J = 8.6), 6.75 (d, 2H, J = 8.6), 4.65 (d, 1H, J = 9.2), 3.78 (s, 3H), 3.16 (dd, 1H, J = 6.6, 6.7), 2.93 (dd, 1H, J = 1.3, 6.6), 2.65 (s, 3H), 2.62 (d, 1H, J = 11.5), 2.45 (dq, 1H, J = 6.7, 6.9), 2.08 (br s, 1H), 1.81 (ddq, 1H, J = 6.4, 9.2, 11.5), 1.15 (d, 3H, J = 6.9), 1.07 (d, 3H, J = 6.4). ^{13}C NMR (125 MHz) 209.8, 159.3, 140.5, 140.0, 139.4, 132.2, 132.0, 129.3, 128.8, 128.6, 127.9, 127.6, 127.5, 121.9, 113.7, 72.7, 56.9, 56.0, 55.3, 54.3, 53.6, 51.8, 44.7, 41.2, 21.8, 14.5. IR ($CHCl_3$) 1744. HRMS m/z 544.2177 (M^+ +1) (Calcd for $C_{32}H_{34}NO_5S$, 544.2158).

Physical and spectral data for *rel*-(1*R*,2*R*,3*R*,4*S*,8*S*,9*R*,10*R*)-5-(benzenesulfonyl)-7-methoxy-4-(4-methoxyphenyl)-3,10-dimethyl-9-phenyl-5-azatricyclo[6.2.1.0 2,6]undec-6-en-11-one (**16**). ^{1}H NMR (400 MHz) 7.56 (d, 2H, J = 7.4), 7.49−7.39 (m, 5H), 7.37 (t, 1H, J = 7.4), 7.23 (d, 2H, J = 7.7), 6.97 (d, 2H, J = 8.2), 6.70 (d, 2H, J = 8.2), 5.26 (d, 1H, J = 6.4), 3.76 (s, 3H), 3.13 (dd, 1H, J = 6.5, 6.5), 3.05 (d, 1H, J = 6.2), 3.00 (dd, 1H, J = 1.2, 6.5), 2.98 (s, 3H), 2.63 (ddq, 1H, J = 6.2, 6.4, 7.3), 2.41 (dq, 1H, J = 6.5, 6.9), 2.17 (br s, 1H), 1.15 (d, 3H, J = 6.9), 0.51 (d, 3H, J = 7.3). ^{13}C NMR (125 MHz) 209.1, 158.7, 140.3, 140.2, 139.6, 132.3, 129.9, 129.1, 128.7, 128.5, 128.1 (2 C), 127.4, 120.1, 113.3, 69.2, 55.5, 55.2, 55.0, 54.5, 53.6, 51.9, 43.4, 41.3, 22.0, 11.1. IR (thin film on NaCl) 1747. HRMS m/z 544.2146 (M^+ +1) (Calcd for $C_{32}H_{34}NO_5S$, 544.2158).

***rel*-*N*-[(1*R*,5*R*,6*R*,7*R*)-7-Methyl-4,8-dioxo-6-phenylbicyclo[3.2.1]oct-2-en-3-yl]benzenesulfonamide (17).** According to the general procedure, (*E*)-propenylbenzene (**1e**, 34 mg, 0.29 mmol) was added to a solution of monoimine **5** (80 mg, 0.29 mmol) in CH_2Cl_2 (10 mL) at −78 °C followed by BF_3·OEt_2 (0.05 mL, 0.4 mmol). After warming to −20 °C over 2.5 h, workup and flash chromatography of the crude red oil with 15% EtOAc/hexanes as eluent gave **17** as a white solid (55 mg, 50%). Recrystallization from 2:2:6 CH_2Cl_2/Et_2O/hexanes gave colorless (white) crystals, mp 132−133 °C, TLC R_f 0.25 (30% EtOAc/hexanes). ^{1}H NMR (400 MHz) 7.88 (d, 2H, J = 7.4), 7.66 (t, 1H, J = 7.4), 7.56 (t, 2H, J = 7.4), 7.47 (d, 1H, J = 8.6), 7.21−7.12 (m, 3 H), 7.09 (br s, N−H), 6.73 (d, 2H, J = 7.1), 3.74 (dd, 1H, J = 1.9, 6.8), 3.15 (dd, 1H, J = 6.6, 6.8), 3.08 (dd, 1H, J = 1.9, 8.6), 2.39 (dq, 1H, J = 6.6, 6.9), 1.22 (d, 3H, J = 6.9). ^{13}C NMR (100 MHz) 198.5, 189.9, 138.5, 137.1, 133.9, 133.7, 129.4, 128.8, 128.04, 128.01, 127.7, 127.3, 70.1, 54.7, 49.2, 42.3, 21.3. IR (CH_2Cl_2) 3305, 1770, 1678. Anal. Calcd for $C_{21}H_{19}NO_4S$: C, 66.12; H, 5.02; N, 3.67. Found: C, 65.99; H, 4.98; N, 4.00.

***rel*-*N*-[(6a*S*,11a*S*)-6a,11a-Dihydro-3,9-dimethoxy-6*H*-benzofuro[3,2-*c*][1]benzopyran-8-yl]benzenesulfonamide (21).** According to the general procedure, BF_3·OEt_2 (40 μL, 0.32 mmol) was added to a solution of monoimine **5** (64 mg, 0.23 mmol) and 2*H*-chromene **20**[10] (98 mg, 0.60 mmol) in CH_2Cl_2 (10 mL) at −78 °C. After 30 min, workup and flash chromatography with 30, 40, and then 50% EtOAc/hexanes as eluent furnished **21** (22 mg, 22%) as a white solid, mp 186−187 °C; TLC R_f 0.29 (2:3:5 CH_2Cl_2/Et_2O/hexanes). ^{1}H NMR (500 MHz) 7.64 (d, J = 8.5, 2H), 7.49 (apparent t, J = 7.5, 1H), 7.44 (s, 1H), 7.38−7.35 (m, 3H), 6.63 (dd, J = 2.5, 8.5, 1H), 6.58 (br s, 1H), 6.48 (d, J = 2.5, 1H), 6.23 (s, 1H), 5.53 (d, J = 6.6, 1H), 4.30−4.25 (m, 1H), 3.79 (s, 3H), 3.65−3.59 (m, 2H), 3.38 (s, 3H). ^{13}C NMR (125 MHz) 161.1, 158.4, 156.7, 152.4, 139.0, 132.6, 131.6, 128.4, 127.2, 121.1, 118.6, 118.1, 112.0, 109.3, 101.6, 94.2, 78.8, 66.4, 55.6, 55.4, 39.8. IR (CH_2Cl_2) 3327. HRMS m/z 439.1070 (calcd for $C_{23}H_{21}NO_6S$, 439.1090).

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Supporting Information Available: Complete IR and mass spectral data for all new compounds, tabular summary of ^{1}H NMR data for **7** and **8**, and copies of NMR spectra of all compounds characterized by HRMS (32 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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