Organic LETTERS

Letter

pubs.acs.org/OrgLett

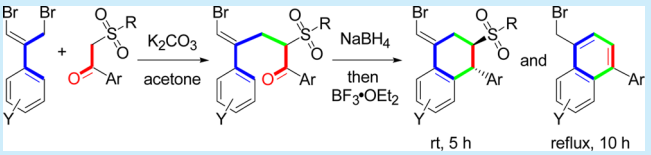
Synthesis of 1-Aryltetralins and 1-Arylnaphthalenes via (4 + 2) Annulation of β-Ketosulfones with Styryl Bromides

Meng-Yang Chang* and Yu-Chieh Cheng

Department of Medicinal and Applied Chemistry, Kaohsiung Medical University, Kaohsiung 807, Taiwan

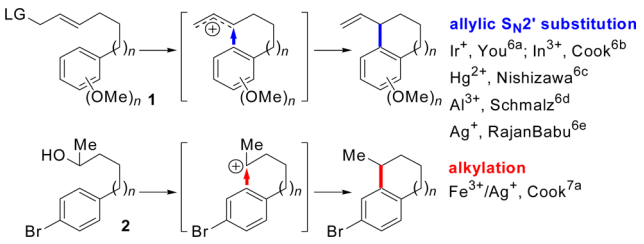
Supporting Information

ABSTRACT: A novel route has been developed for the synthesis of various substituted 1-aryltetralins **6** and 1-arylnaphthalenes **8** via (1) K_2CO_3-mediated α-styrylation of β-ketosulfones **3** with bromostyryl bromides **4** and (2) stereocontrolled $NaBH_4$-promoted reduction of the resulting γ-alkenones **5**, followed by $BF_3{\cdot}OEt_2$-catalyzed intramolecular annulation of the corresponding γ-alkenols **7** under rt/5 h and reflux/10 h conditions, respectively. The key structures of **6** and **8** were confirmed by X-ray crystallographic analysis. A plausible mechanism has been proposed.



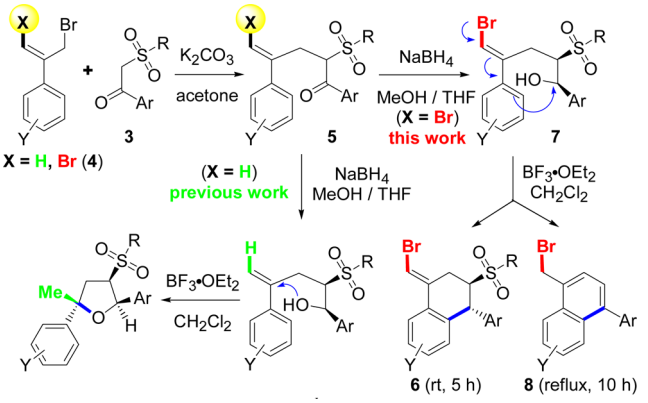
Tetralin is a highly privileged core structure found in many valuable biologically active molecules, pharmaceuticals, and natural products.[1−4] With regard to the construction of this key building block, the 90-year-old Darzens tetralin synthesis (H_2SO_4-mediated intramolecular ring-closure of a 1-phenyl-4-pentene)[5] still stands out as one of the most direct and convenient methods. It uses arenes with an allylic chain[6] **1** or an unactivated alcohol[7] **2** as the starting materials; it is especially effective when combined with the recent remarkable advances in metal-catalyzed annulation. Various catalysts have been employed to accelerate the formation of a carbon−carbon bond via a carbocation-like intermediate (Scheme 1).[8]

Scheme 1. Intramolecular Friedel−Crafts Substitution Reaction



As part of our recent studies of $BF_3{\cdot}OEt_2$-promoted tandem cyclization reactions,[9] we devised an efficient stereocontrolled synthesis of sulfonyl 2,5-diaryltetrahydrofurans in good yield via the Lewis acid promoted intramolecular hydroalkoxylation of sulfonyl γ-alkenols (X = H),[10] as shown in Scheme 2. In this paper, we report the $BF_3{\cdot}OEt_2$-mediated intramolecular Friedel−Crafts electrophilic substitution of sulfonyl γ-alkenols (X = Br) by tethering a β-bromovinyl group to the aryl rings. In contrast to a hydrogen atom, the weakly deactivating bromo group initiates the stereospecific progression of the delocalized electron pair (in an *exo* → *endo* → *exo* direction), leading to the formation of a six-membered ring under metal-free catalyzed conditions. This stereospecific annulation reaction provides facile access to

Scheme 2. Synthetic Route of 2,5-Diaryltetrahydrofurans, 1-Aryltetralins, and 1-Arylnaphthalenes



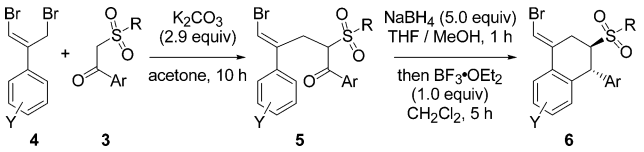
functionalized 1-aryltetralins. However, to the best of our knowledge, the bromo group-initiated intramolecular Friedel−Crafts alkylation procedure for the preparation of 1-aryltetralins has not been reported,[11] nor has the intramolecular annulation of bromostyryl β-ketosulfones been explored. Herein, we report our studies[12,13] on these two processes for aryltetralin synthesis.

K_2CO_3-mediated α-styrylation of β-ketosulfones **3a−r** with bromostyryl bromides **4a−d** (prepared by *p*-TsOH-catalyzed double bromination of styrene with 2.5 equiv of NBS in CH_2Cl_2 at reflux) in acetone at reflux provided **5a−x** in a yield range of 78−89%, as shown in Table 1. The yields of **5a−x** did not change much as a function of the structure of **3a−r** under these reaction conditions. The bromo group promoted intramolecular ring closure of **5** was examined via a two-step route: stereoselective $NaBH_4$-mediated reduction followed by $BF_3{\cdot}OEt_2$-promoted Friedel−Crafts annulation of the resulting sulfonyl 4-alkenols. For different R substituents on **5**, a diversity of electron-

Received: March 3, 2016

DOI: 10.1021/acs.orglett.6b00603
Org. Lett. XXXX, XXX, XXX−XXX

Table 1. Synthesis of 5 and 6[a,b]



4 3 5 6

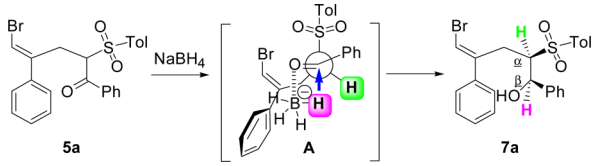
entry	3, Ar = , R =; 4, Y-Ar =	yield[c] (%) 5	6
1	**3a**, Ph, Me; **4a**, Ph	**5a**, 80	**6a**, 82
2	**3b**, Ph, Ph; **4a**, Ph	**5b**, 84	**6b**, 80
3	**3c**, Ph, Tol; **4a**, Ph	**5c**, 89	**6c**, 76
4	**3d**, 4-FC_6H_4, Tol; **4a**, Ph	**5d**, 83	**6d**, 78
5	**3e**, 4-$MeOC_6H_4$, Tol; **4a**, Ph	**5e**, 86	**6e**, 74
6	**3f**, 4-MeC_6H_4, Tol; **4a**, Ph	**5f**, 83	**6f**, 70
7	**3g**, 4-$CF_3C_6H_4$, Tol; **4a**, Ph	**5g**, 80	**6g**, –[d]
8	**3h**, 4-$NO_2C_6H_4$, Tol; **4a**, Ph	**5h**, 80	**6h**, –[d]
9	**3i**, 3-$NO_2C_6H_4$, Tol; **4a**, Ph	**5i**, 82	**6i**, –[d]
10	**3j**, 4-PhC_6H_4, Tol; **4a**, Ph	**5j**, 84	**6j**, 74
11	**3k**, 2-naphthalene, Tol; **4a**, Ph	**5k**, 88	**6k**, 70
12	**3l**, Ph, 4-FC_6H_4; **4a**, Ph	**5l**, 82	**6l**, 78
13	**3m**, Ph, 4-$MeOC_6H_4$; **4a**, Ph	**5m**, 80	**6m**, 81
14	**3n**, Ph, 3-MeC_6H_4; **4a**, Ph	**5n**, 84	**6n**, 82
15	**3o**, Ph, 4-EtC_6H_4; **4a**, Ph	**5o**, 82	**6o**, 78
16	**3p**, Ph, 4-*n*BuC_6H_4; **4a**, Ph	**5p**, 83	**6p**, 74
17	**3b**, Ph, Ph; **4b**, 4-FC_6H_4	**5q**, 84	**6q**, 80
18	**3c**, Ph, Tol; **4b**, 4-FC_6H_4	**5r**, 83	**6r**, 80
19	**3b**, Ph, Ph; **4c**, 4-PhC_6H_4	**5s**, 84	**6s**, 78
20	**3c**, Ph, Tol; **4c**, 4-PhC_6H_4	**5t**, 85	**6t**, 76
21	**3c**, Ph, Tol; **4d**, 2-naphthalene	**5u**, 82	**6u**, 80
22	**3k**, 2-naphthalene, Tol; **4d**, 2-naphthalene	**5v**, 79	**6v**, 80
23	**3q**, 3,4-$Cl_2C_6H_3$, Tol; **4a**, Ph	**5w**, 78	**6w**, 81
24	**3r**, 2-thiophene, Tol; **4a**, Ph	**5x**, 80	**6x**, 82

[a]Alkylation reaction: **3** (1.0 mmol), K_2CO_3 (2.9 mmol), **4** (1.05 mmol), acetone (15 mL), reflux, 10 h. [b]Annulation reaction: **5** (0.2 mmol), $NaBH_4$ (1.0 mmol), THF (5 mL)/MeOH (5 mL), 0 °C, 1 h, then $BF_3{\cdot}OEt_2$ (0.2 mmol), CH_2Cl_2 (5 mL), 25 °C, 5 h. [c]Isolated yields. [d]No reaction; **7g** (89%), **7h** (92%), and **7i** (90%) were recovered.

withdrawing and electron-donating groups was well-tolerated. However, when the Ar group was strongly electron-withdrawing, none of the desired products **6g–i** were formed, and only **7g–i** were observed. Thus, in the presence of 3- or 4-nitrophenyl and 4-(trifluoromethyl)phenyl groups, no intramolecular annulation was observed. Moreover, for entries 7–9, different substituents on **5** did not affect the annulation, and the isolated yield of **6** was maintained. The structures of **5e**, **6c**, **6f**, **6l**, and **6u** were all determined by single-crystal X-ray crystallography.[14]

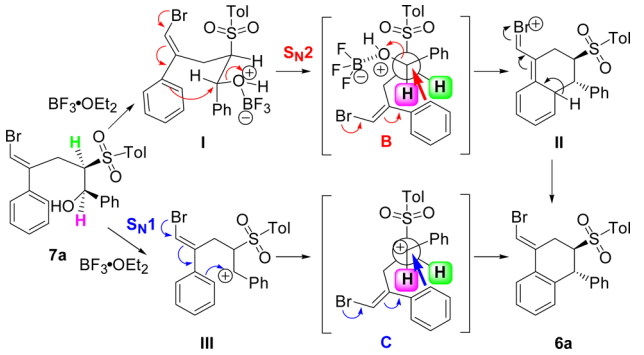
In accord with our previous experience, a single skeleton derived from the sulfonyl 4-alkenol was obtained. On the basis of the Felkin–Anh model **A**,[15] the stereochemical centers of two protons (green H–C_α and pink H–C_β in **7a**) are well established. As shown in Scheme 3, a plausible mechanism

Scheme 3. Proposed Reduction Mechanism



suggests that $NaBH_4$-mediated carbonyl reduction of **5a** is affected by the steric hindrance of the sulfonyl substituent such that the hydride can only attack the less hindered carbonyl face, yielding a single stereoisomer.[12b] Subsequently, complexation of the resulting hydroxyl group by $BF_3{\cdot}OEt_2$ gives **I** (Scheme 4).

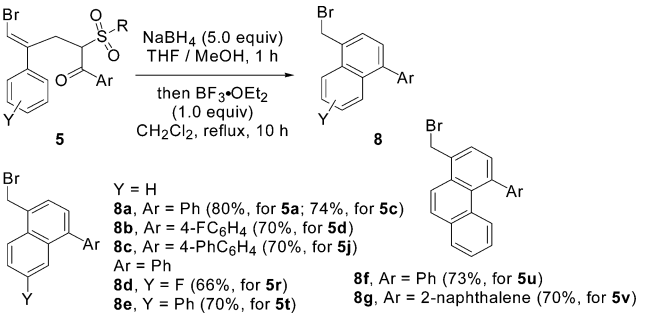
Scheme 4. Proposed Annulation Mechanism



Following model **B**, a stereocontrolled bromo group-initiated intramolecular S_N2 annulation leads to **II** via a six-membered chairlike conformation having two adjacent equatorial protons. An S_N1 process can also be envisioned with **III** (model **C**), deprotonation of **II** affording **6a** via a sequential aromatization process.

The $BF_3{\cdot}OEt_2$-mediated intramolecular annulation of **5** was investigated at elevated temperatures and longer reaction times, as shown in Scheme 5. Specifically, changing the reaction

Scheme 5. Synthesis of 8

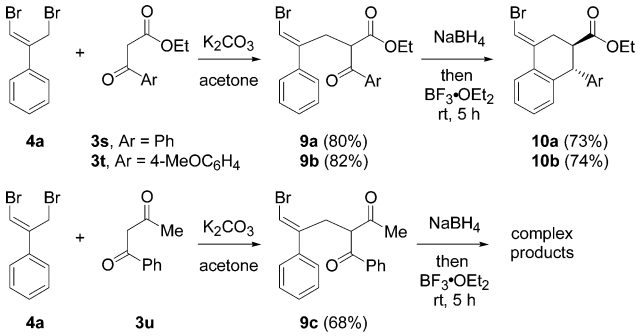


conditions from 25 °C and 5 h to CH_2Cl_2 at reflux for 10 h generated substituted 1-bromomethyl naphthalenes **8a–e** (66–80%) and 1-bromomethyl phenanthrenes **8f,g** (73% and 70%) via $BF_3{\cdot}OEt_2$-promoted cascade desulfonative aromatization of **5a,c,d,j,r,t–v**. 1-Arylnaphthalene has been shown to exhibit a wide range of potential biological activities.[16] The present protocol provides a novel synthetic route for the preparation of substituted naphthalenes.[17] The structure of **8d** was determined by single-crystal X-ray crystallography.[14]

By changing the α-substituent from a sulfonyl group to an ethyl ester group (**3s**, Ar = Ph; **3t**, Ar = 4-$MeOC_6H_4$), **9a** and **9b** were isolated in 80% and 82% yields, respectively, as shown in Scheme 6. Using the above synthetic protocol, **10a,b** were generated in 73% and 74% yields. Comparing the 1,3-dicarbonyl synthons, both β-ketosulfones and β-ketoesters provided similar yields of 1-aryltetralins. However, **9c** containing a β-diketone group (prepared by alkylation of **3u** with **4a**) failed to afford the tetralin skeleton under the standard reaction conditions.

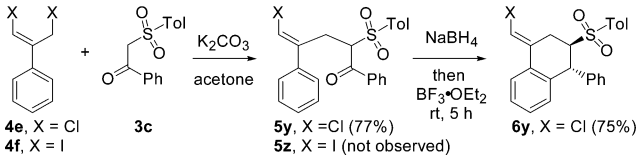
DOI: 10.1021/acs.orglett.6b00603
Org. Lett. XXXX, XXX, XXX–XXX

Scheme 6. Reaction of 4a with 3s−u



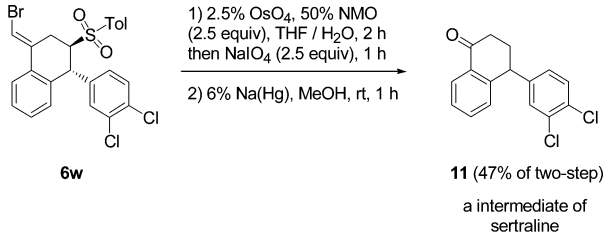
In further work, the bromo group was replaced with a chloro or iodo group, affording facile access to 1-aryltetralins. As shown in Scheme 7, α-styrylation of **3c** with chlorostyryl chloride **4e**

Scheme 7. Reaction of 3c with 4e,f



afforded **5y** in a 77% yield. The formation of **6y** (75%) was achieved via intramolecular annulation of **5y** using the above protocol. The structure of **5y** was determined by single-crystal X-ray crystallography.[14] However, when **3c** was allowed to react with **4f**, a complex mixture was formed and no **5z** was observed. To examine the applicability of this synthetic route, a formal synthesis of sertraline (Zoloft)[18] was developed (Scheme 8).

Scheme 8. Formal Synthesis of Sertraline



Sertraline is a potent selective serotonin reuptake inhibitor (SSRI), which has become a popular synthetic target. For the formal synthesis of sertraline, **6w** was chosen as the starting material. Oxidative cleavage of **6w**, which contains a bromovinyl group, provided the 1-tetralone skeleton via a one-pot reaction in the presence of OsO_4/NMO/$NaIO_4$.[19] Without further purification, removal of the β-sulfonyl group using freshly prepared 6% Na(Hg) (prepared from sodium and mercury in toluene at reflux) in MeOH at 25 °C[20] afforded the known intermediate **11**.[18a] The overall yield of the two-step process was 47%.

In summary, we have developed a novel synthesis of various substituted 1-aryltetralins **6** and 1-arylnaphthalenes **8** via (1) K_2CO_3-mediated α-styrylation of substituted β-ketosulfones **3** with bromostyryl bromides **4** and (2) stereocontrolled $NaBH_4$-promoted reduction of the resulting γ-alkenones **5**, followed by a BF_3·OEt_2-catalyzed intramolecular annulation of the corresponding γ-alkenols. A plausible mechanism has been proposed for these cyclization reactions. The structures of the key products **6** and **8** have been confirmed by X-ray crystallography. Further investigations regarding the asymmetric synthesis of chiral **6** will be studied via the desymmetrical annulation of **5**.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.orglett.6b00603.

X-ray analysis data of **5e** (CIF)
X-ray analysis data of **5y** (CIF)
X-ray analysis data of **6c** (CIF)
X-ray analysis data of **6f** (CIF)
X-ray analysis data of **6l** (CIF)
X-ray analysis data of **6u** (CIF)
X-ray analysis data of **8d** (CIF)
Detailed experimental procedures and spectroscopic data for all new compounds (PDF)

■ AUTHOR INFORMATION

Corresponding Author

*E-mail: mychang@kmu.edu.tw.

Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

We thank the Ministry of Science and Technology of the Republic of China for financial support (MOST 104-2113-M-037-012).

■ REFERENCES

(1) Tietze, L. F., Brasche, G., Gericke, K., Eds. *Domino Reactions in Organic Synthesis*; Wiley−VCH: Weinheim, 2006.

(2) For reviews, see: (a) Olah, G. A. In *Friedel−Crafts and Related Reactions*; Wiley: New York, 1963. (b) Olah, G. A. In *Friedel−Crafts Chemistry*; Wiley: New York, 1973. (c) Rueping, M.; Nachtsheim, B. J. *Beilstein J. Org. Chem.* **2010**, DOI: 10.3762/bjoc.6.6. (d) Bandini, M.; Melloni, A.; Umani-Ronchi, A. *Angew. Chem., Int. Ed.* **2004**, *43*, 550. (e) Bandini, M.; Melloni, A.; Tommasi, S.; Umani-Ronchi, A. *Synlett* **2005**, 1199. (f) Poulsen, T.; Jorgensen, K. A. *Chem. Rev.* **2008**, *108*, 2903.

(3) For biological activities, see: (a) Castro, M. A.; del Corral, J. M. M.; Gordaliza, M.; García, P. A.; Gómez-Zurita, M. A.; Garcia-Gravalos, M. D.; de la Iglesia-Vicente, J.; Gajate, C.; An, F.; Mollinedo, F.; Feliciano, A. S. *J. Med. Chem.* **2004**, *47*, 1214. (b) Perrone, R.; Berardi, F.; Colabufo, N. A.; Leopoldo, M.; Tortorella, V.; Fiorentini, F.; Olgiati, V.; Ghiglieri, A.; Govoni, S. *J. Med. Chem.* **1995**, *38*, 942. (c) Brewster, W. K.; Nichols, D. E.; Riggs, R. M.; Mottola, D. M.; Lovenberg, T. W.; Lewis, M. H.; Mailman, R. B. *J. Med. Chem.* **1990**, *33*, 1756. (d) Saladino, R.; Fiani, C.; Belfiore, M. C.; Gualandi, G.; Penna, S.; Mosesso, P. *Bioorg. Med. Chem.* **2005**, *13*, 5949. (e) Bernini, R.; Gualandi, G.; Crestini, C.; Barontini, M.; Belfiore, M. C.; Willfor, S.; Eklund, P.; Saladino, R. *Bioorg. Med. Chem.* **2009**, *17*, 5676. (f) Sun, Y.-J.; Li, Z.-L.; Chen, H.; Liu, X.-Q.; Zhou, W.; Hua, H.-M. *Bioorg. Med. Chem. Lett.* **2011**, *21*, 3794. (g) Wang, J.; Yu, X.; Zhi, X.; Xu, H. *Bioorg. Med. Chem. Lett.* **2014**, *24*, 4542.

(4) For podophyllotoxin, see: (a) Eyberger, A. L.; Dondapati, R.; Porter, J. R. *J. Nat. Prod.* **2006**, *69*, 1121. For isogalbulin, see: (b) Messiano, G. B.; Wijeratne, E. M. K.; Lopes, L. M. X.; Gunatilaka, A. A. L. *J. Nat. Prod.* **2010**, *73*, 1933. For aglacins A, see: (c) Wang, B.-G.; Ebel, R.; Nugroho, B. W.; Prijono, D.; Frank, W.; Steube, K. G.; Hao, X.-J.; Proksch, P. *J. Nat. Prod.* **2001**, *64*, 1521.

(5) Darzens, G. *Compt. Rend.* **1926**, *183*, 748.

DOI: 10.1021/acs.orglett.6b00603
Org. Lett. XXXX, XXX, XXX−XXX

(6) For Ir^{+}, see: (a) Xu, Q.-L.; Dai, L.-X.; You, S.-L. *Org. Lett.* **2012**, *14*, 2579. For In^{3+}, see: (b) Hayashi, R.; Cook, G. R. *Org. Lett.* **2007**, *9*, 1311. For Hg^{2+}, see: (c) Namba, K.; Yamamoto, H.; Sasaki, I.; Mori, K.; Imagawa, H.; Nishizawa, M. *Org. Lett.* **2008**, *10*, 1767. For Al^{3+}, see: (d) Werle, S.; Fey, T.; Neudorfl, J. M.; Schmalz, H.-G. *Org. Lett.* **2007**, *9*, 3555. For Ag^{+}, see: (e) Lim, H. J.; RajanBabu, T. V. *Org. Lett.* **2009**, *11*, 2924. For TFA, see: (f) Kraus, G. A.; Jeon, I. *Org. Lett.* **2006**, *8*, 5315.
(7) For Fe^{3+}/Ag^{+}, see: (a) Jefferies, L. R.; Cook, S. P. *Org. Lett.* **2014**, *16*, 2026. For Ca^{2+}, see: (b) Begouin, J.-M.; Capitta, F.; Niggemann, M. *Org. Lett.* **2013**, *15*, 1370.
(8) Naredla, R. R.; Klumpp, D. A. *Chem. Rev.* **2013**, *113*, 6905 and references cited therein.
(9) (a) Chang, M.-Y.; Lin, C.-H.; Chen, Y.-L.; Chang, C.-Y.; Hsu, R.-T. *Org. Lett.* **2010**, *12*, 1176. (b) Chang, M.-Y.; Lin, C.-H.; Chen, Y.-L.; Hsu, R.-T.; Chang, C.-Y. *Tetrahedron Lett.* **2010**, *51*, 3154.
(10) Chang, M.-Y.; Cheng, Y.-C. *Synlett* **2016**, *27*, 854.
(11) For selected examples on syntheses of 1-aryltetralins, see: (a) Hajra, S.; Maji, B.; Bar, S. *Org. Lett.* **2007**, *9*, 2783. (b) Tsoung, J.; Kramer, K.; Zajdlik, A.; Liebert, C.; Lautens, M. *J. Org. Chem.* **2011**, *76*, 9031. (c) Pelter, A.; Ward, R. S.; Li, Q.; Pis, J. *Tetrahedron: Asymmetry* **1994**, *5*, 909. (d) Maddaford, S.; Charlton, J. *J. Org. Chem.* **1993**, *58*, 4132. (e) Ting, C. P.; Maimone, T. J. *Angew. Chem., Int. Ed.* **2014**, *53*, 3115. (f) Vitale, M.; Prestat, G.; Lopes, D.; Madec, D.; Kammerer, C.; Poli, G.; Girnita, L. *J. Org. Chem.* **2008**, *73*, 5795. (g) Datta, P. K.; Yau, C.; Hooper, T. S.; Yvon, B. L.; Charlton, J. L. *J. Org. Chem.* **2001**, *66*, 8606. (h) Wu, Y.; Zhao, J.; Chen, J.; Pan, C.; Li, L.; Zhang, H. *Org. Lett.* **2009**, *11*, 597. (i) Tsoung, J.; Kramer, K.; Zajdlik, A.; Liebert, C.; Lautens, M. *J. Org. Chem.* **2011**, *76*, 9031. (j) Datta, P. K.; Yau, C.; Hooper, T. S.; Yvon, B. L.; Charlton, J. L. *J. Org. Chem.* **2001**, *66*, 8606. (k) Reddy, B. V. S.; Sundar, C. S.; Reddy, M. R.; Reddy, C. S.; Sridhar, B.; Reddy, B. V. S.; Sundar, C. S.; Reddy, M. R.; Reddy, C. S.; Sridhar, B. *Synthesis* **2015**, *47*, 1117.
(12) (a) Chang, M.-Y.; Lu, Y.-J.; Cheng, Y.-C. *Tetrahedron* **2015**, *71*, 6840. (b) Chang, M.-Y.; Lu, Y.-J.; Cheng, Y.-C. *Tetrahedron* **2015**, *71*, 1192. (c) Chang, M.-Y.; Cheng, Y.-J.; Lu, Y.-J. *Org. Lett.* **2014**, *16*, 6252. (d) Chang, M.-Y.; Cheng, Y.-J.; Lu, Y.-R. *Org. Lett.* **2015**, *17*, 1264. (e) Chang, M.-Y.; Cheng, Y.-C.; Lu, Y.-J. *Org. Lett.* **2015**, *17*, 3142. (f) Chang, M.-Y.; Cheng, Y.-J. *Org. Lett.* **2016**, *18*, 608.
(13) For recent syntheses of β-ketosulfones, see: (a) Zhou, G.; Ting, P. T.; Aslanian, R. G. *Tetrahedron Lett.* **2010**, *51*, 939. (b) Pospisil, J.; Sato, H. *J. Org. Chem.* **2011**, *76*, 2269. (c) Kumar, A.; Muthyala, M. K. *Tetrahedron Lett.* **2011**, *52*, 5368. (d) Tsui, G. C.; Glenadel, Q.; Lau, C.; Lautens, M. *Org. Lett.* **2011**, *13*, 208. (e) Kumar, R.; Namboothiri, I. N. N. *Org. Lett.* **2011**, *13*, 4016. (f) Sreedhar, B.; Rawat, V. S. *Synlett* **2012**, *23*, 413. (g) Bouhlel, A.; Curti, C.; Tabele, C.; Vanelle, P. *Molecules* **2013**, *18*, 4293. (h) Lu, Q.; Zhang, J.; Zhao, G.; Qi, Y.; Wang, H.; Lei, W. *J. Am. Chem. Soc.* **2013**, *135*, 11481. (i) Handa, S.; Fennewald, J. C.; Lipshutz, B. H. *Angew. Chem., Int. Ed.* **2014**, *53*, 3432. (j) Tang, X.; Huang, L.; Xu, Y.; Yang, J.; Wu, W.; Jiang, H. *Angew. Chem., Int. Ed.* **2014**, *53*, 4205. (k) Chawla, R.; Singh, A. K.; Yadav, L. D. S. *Eur. J. Org. Chem.* **2014**, *2014*, 2032. (l) Singh, A. K.; Chawla, R.; Yadav, L. D. S. *Tetrahedron Lett.* **2014**, *55*, 4742. (m) Shi, X.; Ren, X.; Ren, Z.; Li, J.; Wang, Y.; Yang, S.; Gu, J.; Gao, Q.; Huang, G. *Eur. J. Org. Chem.* **2014**, *2014*, 5083. (n) Xuan, J.; Feng, Z.-J.; Chen, J.-R.; Lu, L.-Q.; Xiao, W.-J. *Chem. - Eur. J.* **2014**, *20*, 3045. (o) Singh, A. K.; Chawla, A. K.; Chawla, R.; Keshari, T.; Yadav, V. K.; Yadav, L. D. S. *Org. Biomol. Chem.* **2014**, *12*, 8550. (p) Saraiva, M. T.; Costa, G. P.; Seus, N.; Schumacher, R. F.; Perin, G.; Paixao, M. W.; Luque, R.; Alves, D. *Org. Lett.* **2015**, *17*, 6206. (q) Yadav, V. K.; Srivastava, V. P.; Yadav, L. D. *Synlett* **2016**, *27*, 427.
(14) CCDC 1445559 (**5e**), 14455598 (**5y**), 1445564 (**6c**), 14455597 (**6f**), 1445560 (**6l**), 1445561 (**6u**) and 1446957 (**8d**) contain the supplementary crystallographic data for this paper. This data can be obtained free of charge via www.ccdc.cam.ac.uk/conts/retrieving.html (or from the CCDC, 12 Union Road, Cambridge CB2 1EZ, UK; fax: 44-1223-336033; e-mail: deposit@ccdc.cam.ac.uk).
(15) (a) Mengel, A.; Reiser, O. *Chem. Rev.* **1999**, *99*, 1191. (b) Gung, B. W. *Tetrahedron* **1996**, *52*, 5263. (c) Ager, D. J.; East, M. B. *Tetrahedron* **1992**, *48*, 2803.
(16) For reviews on the syntheses of naphthalenes, see: (a) de Koning, C. B.; Rousseau, A. L.; van Otterlo, W. A. L. *Tetrahedron* **2003**, *59*, 7. For reviews on the benzannulation of naphthalenes, see: (b) Kotha, S.; Halder, S. *Tetrahedron* **2008**, *64*, 10775.
(17) For $Pd_2(dba)_3/CsF$, see: (a) Patel, R. M.; Argade, N. P. *Org. Lett.* **2013**, *15*, 14. For $PtCl_4$, see: (b) Kang, D.; Kim, J.; Oh, S.; Lee, P. H. *Org. Lett.* **2012**, *14*, 5636. For microwave irradiation, see: (c) Kocsis, L.; Brummond, K. M. *Org. Lett.* **2014**, *16*, 4158. For $AgOAc/Na_2S_2O_8$, see: (d) Naresh, G.; Kant, R.; Narender, T. *Org. Lett.* **2015**, *17*, 3446. For $Pd(OAc)_2/Cu(OAc)_2$, see: (e) Peng, S.; Wang, L.; Wang, J. *Chem. - Eur. J.* **2013**, *19*, 13322. For $AuCl_3/AgSbF_6$, see: (f) Balamurugan, R.; Gudla, V. *Org. Lett.* **2009**, *11*, 3116. For $HNTf_2$, see: (g) Ponra, S.; Vitale, M. R.; Michelet, V.; Ratovelomanana-Vidal, V. *J. Org. Chem.* **2015**, *80*, 3250. For $AuCl_3/AgSbF_6$, see: (h) Gudla, V.; Balamurugan, R. *J. Org. Chem.* **2011**, *76*, 9919. For $Mn(OAc)_3$, see: (i) Kao, T.-T.; Lin, C.-C.; Shia, K.-S. *J. Org. Chem.* **2015**, *80*, 6708. For $(PhIO)_n/BF_3{\cdot}OEt_2$, see: (j) Gao, P.; Liu, J.; Wei, Y. *Org. Lett.* **2013**, *15*, 2872. For $AlCl_3$, see: (k) Kim, H. Y.; Oh, K. *Org. Lett.* **2014**, *16*, 5934. For $TiCl_4$, see: (l) Kabalka, G. W.; Ju, Y.; Wu, Z. J. *J. Org. Chem.* **2003**, *68*, 7915.
(18) For syntheses of sertraline, see: (a) Roesner, S.; Casatejada, J. M.; Elford, T. G.; Sonawane, R. P.; Aggarwal, V. K. *Org. Lett.* **2011**, *13*, 5740. (b) Han, Z.; Wang, Z.; Zhang, X.; Ding, K. *Angew. Chem., Int. Ed.* **2009**, *48*, 5345. (c) Ohmiya, H.; Makida, Y.; Li, D.; Tanabe, M.; Sawamura, M. *J. Am. Chem. Soc.* **2010**, *132*, 879. (d) Garcia, A. E.; Ouizem, S.; Cheng, X.; Romanens, P.; Kundig, E. P. *Adv. Synth. Catal.* **2010**, *352*, 2306. (e) Krumlinde, P.; Bogar, K.; Backvall, J. E. *Chem. - Eur. J.* **2010**, *16*, 4031. (f) Chen, F.; Wang, T.; He, Y.; Ding, Z.; Li, Z.; Xu, L.; Fan, Q. H. *Chem. - Eur. J.* **2011**, *17*, 1109. (g) Barluenga, J.; Florentino, L.; Aznar, F.; Valdes, C. *Org. Lett.* **2011**, *13*, 510. (h) Nair, V.; Rajan, R.; Rath, N. P. *Org. Lett.* **2002**, *4*, 1575. (i) Chen, C.-y.; Reamer, R. A. *Org. Lett.* **1999**, *1*, 293. (j) Lee, S. H.; Kim, I. S.; Li, Q. R.; Dong, G. R.; Jeong, L. S.; Jung, Y. H. *J. Org. Chem.* **2011**, *76*, 10011.
(19) (a) Yu, W.; Mei, Y.; Kang, Y.; Hua, Z.; Jin, Z. *Org. Lett.* **2004**, *6*, 3217. (b) Nielsen, T. E.; Meldal, M. *Org. Lett.* **2005**, *7*, 2695. (c) Nielsen, T. E.; Le Quement, S. T.; Meldal, M. *Org. Lett.* **2007**, *9*, 2469.
(20) For a review on desulfonylation reactions, see: Najera, C.; Yus, M. *Tetrahedron* **1999**, *55*, 10547.

DOI: 10.1021/acs.orglett.6b00603
Org. Lett. XXXX, XXX, XXX−XXX