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General Stereoselective Synthesis of (*E*)-*exo*-Alkylidene Tetrahydrofurans via Base-Mediated Cyclization of Hydroxyl Propargylic Sulfones†

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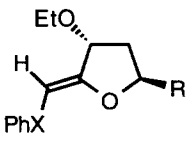
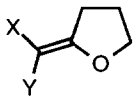
Abstract: The base-promoted cyclization of a number of phenyl propargylic sulfones possessing a β-hydroxyl group afforded 5-substituted (*E*)-2-[(benzenesulfonyl)methylene]tetrahydrofurans **3** in >80% yield. The phenyl allenic sulfone, formed by isomerization of the phenyl propargylic sulfone under the basic conditions, is attacked by the internal alkoxide to give an allylic anion which undergoes protonation to form the conjugated *exo* double bond. © 1998 Published by Elsevier Science Ltd. All rights reserved.

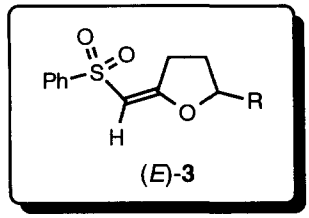
Tetrahydrofurans are important structural units found in bioactive natural products such as the polyether antibiotics[1] and annonaceous acetogenins.[2] Owing to their diverse bioactivities as immunosuppressive, antitumor, pesticidal, antiprotozoal, antifeedant, anthelmintic, and antimicrobial agents, syntheses of substituted tetrahydrofurans[3,4] and total syntheses of the natural products[5,6] have been the focus of many research efforts in recent years. (*Z*)-2-Alkylidenetetrahydrofurans have been obtained from mercury(II)- or palladium(II)-mediated cyclization of *cis*-2-prop-2-ynyl cyclopentanol[7] and used as the key intermediates in prostacyclin PGI_2 synthesis. In addition to mercury(II) and palladium(II) species, Ag(I) salt is also effective for intramolecular cyclization reactions of alkynyl alcohols.[8] Molybdenum pentacarbonyl, chromium pentacarbonyl, tungsten pentacarbonyl, and other middle and late transition metal complexes react with terminal alkynols to furnish cyclic oxacarbenes, from which endocyclic enol ethers such as dihydrofurans can be synthesized.[9] Very recently, several stereoselective syntheses of 5-membered exocyclic enol ethers have been reported. (*Z*)-2-[(phenylthio)methylene]- or (*Z*)-2-[(phenylseleno)methylene]tetrahydrofurans, (*Z*)-**1** (X = S or Se), were prepared via the base-induced cyclization of alkynols.[4h] (*E*)-2-[(benzenesulfonyl)methylene]tetrahydrofuran (*E*)-**2**[10a] and the *para*-toluenesulfonyl analog[10b] were obtained from the intramolecular addition-elimination reactions of hydroxyl (*E*)-β-iodo vinyl sulfones which were produced by addition of arenesulfonyl iodides to alkynols.[11] The isomer (*Z*)-**2** was generated via an intramolecular *O*-alkylation of enolate as an *ca.* 1:1 mixture with its *E*-isomer.[12] We report here the synthesis of (*E*)-2-[(benzenesulfonyl)methylene]tetrahydrofurans **3** by a



(*Z*)-**1**: X =S, Se



(*E*)-**2**: X = $PhSO_2$, Y = H
(*Z*)-**2**: X = H, Y = $PhSO_2$



(*E*)-**3**

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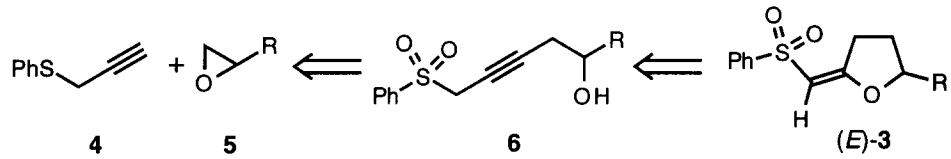
PII: S0040-4020(98)00730-3

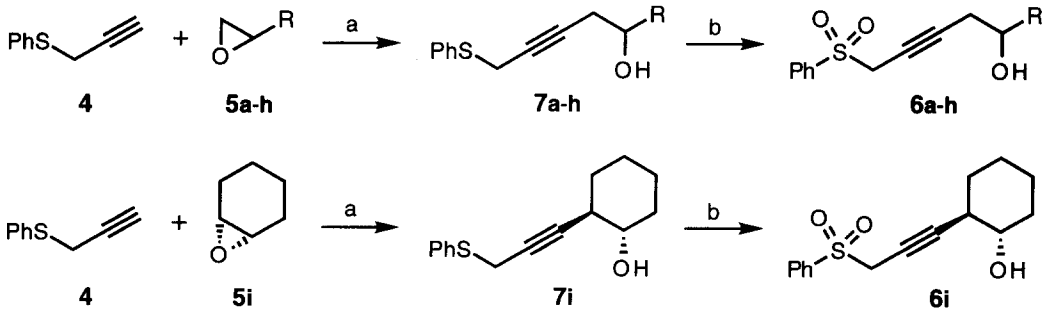
base-induced cyclization of hydroxyl propargylic sulfones **6** which can be readily obtained from phenyl propargylic sulfide **4**[13] and various epoxides **5** (Eq. 1). The stereoselective conversion of **6** into (*E*)-**3** is unique compared with the *Z* selectivity for the formation of (*Z*)-**1** via the base-mediated cyclization of (phenylthio)- or (phenylseleno)alkynyl alcohols.[4h] Moreover, our synthesis of (*E*)-**3** is superb in regioselectivity of the addition toward the acetylenic carbons compared to the previously reported cyclizations of alkynyl alcohols in the absence of metal catalysts, where mixtures of products were formed.[14]



4 **5** **6** (*E*)-**3**

Propargylic sulfones **6a-i** were readily synthesized from phenyl propargylic sulfide **4** and epoxides **5a-i** by the two-step sequence shown in Scheme 1. Deprotonation of **4** with *n*BuLi at -78 °C generated the lithium acetylide[13b] which reacted with the epoxides in the presence of BF_3•OEt_2 to give β-hydroxypropargylic sulfides **7a-i** in good to excellent yield (see Table 1).[15] Regioselectivity of the addition reactions with monoalkyl-substituted epoxides was generally very high as only one regioisomeric product was isolated (Entries 2-8, Table 1). In the case of styrene oxide (**5a**), an *ca.* 1:1 mixture of two regioisomers was formed in agreement with the early report[15] (Entry 1, Table 1). The product **7i** formed from cyclohexene oxide (**5i**) was confirmed to possess the *trans* stereochemistry based on the ^1H NMR data: the signal at 3.29 (td, J = 9.76, 3.90 Hz) ppm is assigned for the axial methine proton [-$CH_{ax}H_{eq}CH_{ax}(OH)_{eq}CH_{ax}(C{\equiv}CCH_2SPh)_{eq}$-] of the 2-substituted cyclohexanol having two axial and one equatorial vicinal protons. Conversion of sulfides **7a-i** into sulfones **6a-i** was achieved by oxidation with 2.0 equiv of *m*CPBA in CH_2Cl_2 at 0 °C in excellent yield (Scheme 1 and Table 1).

Scheme 1. Synthesis of compounds **6a-i** from phenyl propargylic sulfide **4** and epoxides **5a-i**.



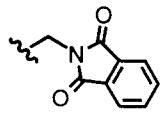
4 **5a-h** **7a-h** **6a-h**

4 **5i** **7i** **6i**

a) *n*BuLi, **4**, THF, -78 °C; **5**, BF_3•OEt_2, -78 °C, 30 min; b) *m*CPBA (2.0 equiv), CH_2Cl_2, 0 °C, 30 min.

Propargylic sulfones have been known to undergo nucleophilic addition reactions through their allenic isomers formed by a base-induced isomerization process.[16,17] Michael additions[17-19] of oxygen and sulfur nucleophiles toward allenic sulfones take place across the activated π-bond to afford 2-oxy- and 2-thioallylic sulfones, respectively. However, reactions of allenic sulfones with amines generally furnish *trans* β-sulfonyl enamines.[16c,d,18a,b,g,h] Bearing the precedent results in mind, we examined the intramolecular addition reaction

Table 1. Two-step synthesis of hydroxyl propargylic sulfones **6a-i**.

Entry	Epoxide **5**	Sulfide **7** (yield%)	Sulfone **6** (yield%)
1	**5a**: R = Ph	**7a** (36)[a]	**6a** (83)
2	**5b**: R = CH_2Ph	**7b** (72)	**6b** (95)
3	**5c**: R = CH_2OPh	**7c** (75)	**6c** (84)
4	**5d**: R = 	**7d** (68)	**6d** (82)
5	**5e**: R = $-CH_2CH_3$	**7e** (72)	**6e** (83)
6	**5f**: R = $-(CH_2)_3CH_3$	**7f** (83)	**6f** (81)
7	**5g**: R = $-(CH_2)_7CH_3$	**7g** (87)	**6g** (81)
8	**5h**: R = $-(CH_2)_2CH{=}CH_2$	**7h** (80)	**6h** (80)
9	**5i**	**7i** (89)	**6i** (87)

[a]The other regioisomer was isolated in 38% yield.

of β-hydroxypropargylic sulfone **6a** under the basic conditions (NaH, THF) used by us[17] in a related reaction (Scheme 2). Treatment of a THF solution of **6a** with 1.5 equiv of NaH at -40 °C for 1 h followed by addition of aqueous $NaHCO_3$ at the same temperature gave (*E*)-**3a** in 54% yield (Entry 1, Table 2). But, the expected 2,5-disubstituted 2,3-dihydrofuran **10a** was not detected. Examination on the quenching procedure revealed that the cyclization reaction is reversible and the isolated yield of (*E*)-**3a** is method-dependent. TLC analysis of the reaction mixture maintained at -40 °C on silica gel plate showed a new spot corresponding to the product (*E*)-**3a**, after quenching with MeOH or aqueous NH_4Cl, substantial amount of the starting materials were recovered (Entries 2 and 3, Table 2). When the cyclization was performed at higher temperatures (-10~0 °C), the product was either isolated in very low yield or not obtained at all (Entries 4-6). Finally, we found that the highest yield (81%) could be obtained by carrying out the reaction at -20 °C followed by quenching the reaction mixture with

Scheme 2. Base-induced cyclization of hydroxyl propargylic sulfone **6a**.

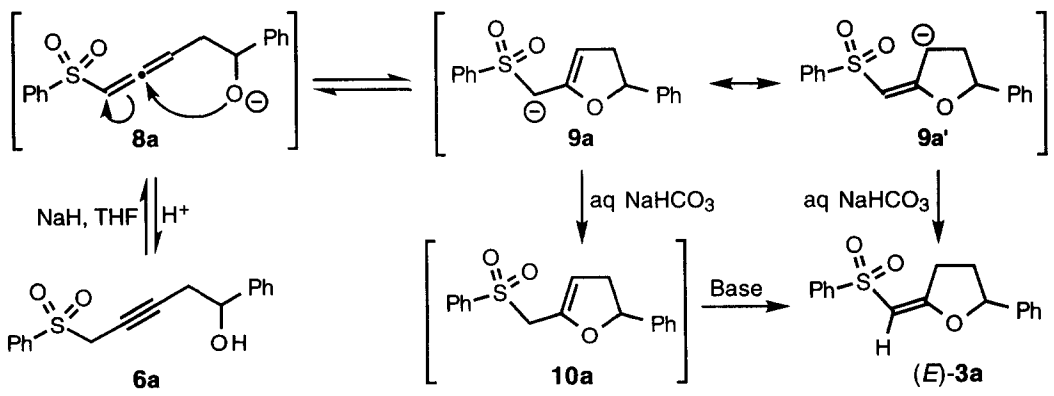


Table 2. Base-induced cyclization of hydroxyl propargylic sulfone **6a** under different conditions.[a]

Entry	Reaction Conditions	Quenching Method	(*E*)-**3a**, yield (%)[b]
1	-40 °C, 1 h	aq $NaHCO_3$, -40 → 20 °C	54
2	-40 °C, 1 h	MeOH, -40 → 20 °C	30-40[c]
3	-40 °C, 1 h	aq NH_4Cl, -40 → 20 °C	6[c]
4	-40 → -10 °C, 1 h	aq $NaHCO_3$, -10 → 20 °C	8.2[c]
5	-40 → 10 °C, 1 h	aq $NaHCO_3$, 10 → 20 °C	0[c]
6	0 °C, 1 h	aq $NaHCO_3$, 0 → 20 °C	17.5[c]
7	-20 °C, 1 h	aq $NaHCO_3$, -20 → 20 °C	81

[a]The reaction was performed in THF with 1.5 equiv of NaH. [b]Isolated yield. [c]Starting materials recovered.

aqueous $NaHCO_3$ (Entry 7, Table 2). We propose that in the presence of NaH, deprotonation of the hydroxyl group in **6a** gives the corresponding alkoxide which catalyzes the isomerization of the propargylic sulfone into allenic sulfone alkoxide **8a**. Intramolecular addition within **8a** should give allylic anion **9a** as the intermediate which exists with the other Lewis structure **9a'**. Interconversion between **8a** and **9a/9a'** is influenced by the reaction temperature and the pH of the solution. It is apparent that basic pH (quenching by aqueous $NaHCO_3$) favors the isolation of the cyclized product. Compound **10a** formed from protonation of **9a** may be not stable under the basic conditions and undergoes an isomerization into the conjugated (*E*)-**3a**, probably through the allylic anion pair **9a/9a'**.[20] We conducted the deuterium trapping experiment by quenching the reaction mixture of **6a** with CH_3OD (12.3 equiv) at -20 °C followed by warming up to room temperature within 10 min to give the deuterated product (*E*)-**3a**-d_3 in 40% yield. The ^1H NMR spectra of (*E*)-**3a** and (*E*)-**3a**-d_3 are illustrated in Figure 1. The vinyl proton [5.90 (s) ppm] and the allylic protons [3.55-3.46 (m) and 3.13 (dtd) ppm] observed in (*E*)-**3a** almost disappear in (*E*)-**3a**-d_3. This result supports the above argument for Scheme 2.

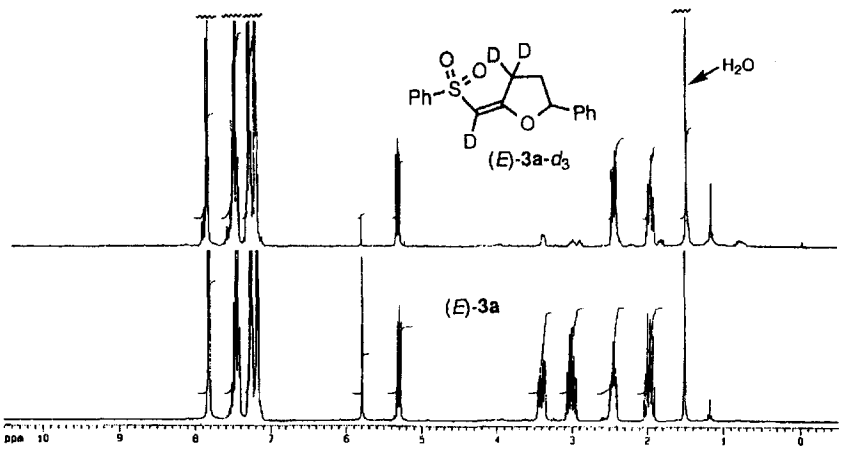
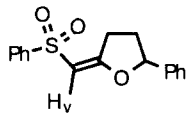
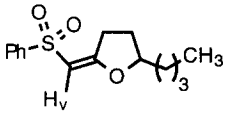
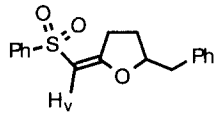
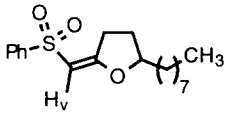
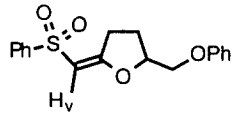
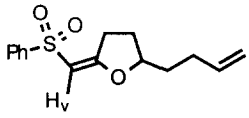
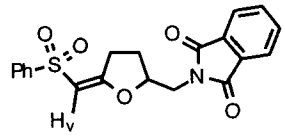
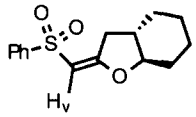
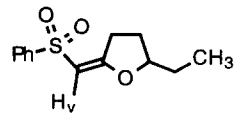


Figure 1. ^1H NMR spectra of (*E*)-**3a**-d_3 (top) and (*E*)-**3a** (bottom) recorded in $CDCl_3$.

Next, we carried out the cyclization of propargylic sulfones **6b-i** in THF at -20 °C using 1.5 equiv NaH. The reaction mixture was quenched by aqueous $NaHCO_3$ at -20 °C followed by warming up to room temperature. In all cases, (*E*)-*exo*-alkylidene tetrahydrofurans **3b-i** were isolated as the sole product in high yield. Table 3 summarizes the yield, mp, and selected chemical shift for the cyclization products (*E*)-**3a-i**. The structures of (*E*)-**3a-i** were determined by spectroscopic methods including ^1H and ^{13}C NMR, IR, and MS and satisfactory elemental analysis data have been obtained. It was reported that the chemical shift (δ) of the vinyl proton (H_v) of (*E*)-**2** appears at 5.8 ppm while that of (*Z*)-**2** at 5.5 ppm.[12] For *para*-toluenesulfonyl analog of (*E*)-**2**, the vinyl proton is recorded at 5.78 ppm.[10b] The observed chemical shift of H_v in compounds **3a-i** is in the range of 5.70-5.90 ppm, it suggests the *E* stereochemistry for the exocyclic double bond. The high-field shift of the H_v (5.70 ppm) in (*E*)-**3g** is attributed to the long-chain alkyl substituent at the C_5 position. Furthermore, we confirmed the assigned stereochemistry by difference nuclear Overhauser enhancement (NOE) experiments. Irradiation of H_v in (*E*)-**3a** at 5.90 ppm resulted in a 3.3% enhancement at the *ortho* proton of benzenesulfonyl group, NOE was not observed among the vinyl and the allylic protons. The same NOE was observed for (*E*)-**3f** (2.4%) or (*E*)-**3g** (2.5%).

Table 3. Chemical yield, mp, and selected chemical shift of tetrahydrofurans (*E*)-**3a-i**.[a]

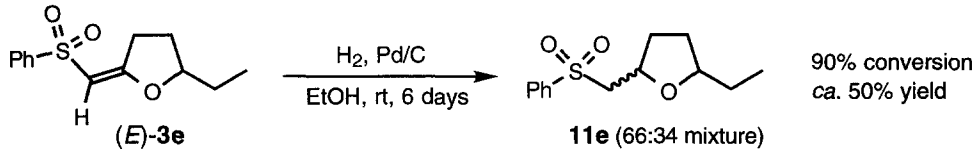
	(*E*)-**3a**: 81%[b] mp: 104-105 °C[c]† H_v: 5.90 ppm[d]		(*E*)-**3f**: 80% mp: 62-64 °C H_v: 5.76 ppm
	(*E*)-**3b**: 80% mp: 88-90 °C H_v: 5.83 ppm		(*E*)-**3g**: 80% mp: 44-47 °C H_v: 5.70 ppm
	(*E*)-**3c**: 82% mp: 114-115 °C H_v: 5.86 ppm		(*E*)-**3h**: 82% semi-solid H_v: 5.72 ppm
	(*E*)-**3d**: 85% mp: ~173 °C (dec) H_v: 5.81 ppm		(*E*)-**3i**: 80% mp: 133-136 °C H_v: 5.84 ppm
	(*E*)-**3e**: 84% mp: 55-57 °C H_v: 5.76 ppm	†Compounds (*E*)-**3a-c,e-g,i** are recrystallized from EtOAc-hexane and (*E*)-**3d** from THF-hexane.	

[a]The cyclization of **6a-i** was performed in THF at -20 °C for 1 h using 1.5 equiv of NaH and quenched by aqueous $NaHCO_3$ at -20 °C. [b]Isolated yield. [c]Not corrected. [d]Chemical shift of the vinyl proton recorded in $CDCl_3$.

Conversion of (*E*)-*exo*-alkylidene tetrahydrofurans **3** into 2,5-disubstituted tetrahydrofurans was examined by catalytic hydrogenation over Pd/C in EtOH at room temperature under 1 atm of hydrogen.[21] However, the reduction progressed very slowly, after 6 days, 90% of (*E*)-**3e** was consumed to produce a 66:34

mixture of two isomers of **11e** in *ca.* 50% isolated yield (Scheme 3). Similar hydrogenation of other substrates such as (*E*)-**3a** and (*E*)-**3i** gave unsuccessful results because the reaction was too slow to produce the products. Other catalysts such as Rh/Al_2O_3[21,22] and hydrogenation conditions should be tried in further experimentation. Replacement of the sulfonyl group in (*E*)-**3a-i** by alkyl groups is also possible via a Fe-mediated cross-coupling reaction of vinyl sulfones with Grignard reagents.[23] This will be examined in our future work.

Scheme 3. Catalytic hydrogenation of **3e**.



Finally, we examined the action of hydroxyl propargylic sulfones **6a-d** and **6f** on supercoiled ΦX174 Form I DNA. After the initial work by Nicolaou's group,[24] DNA cleavage by a number of propargylic sulfones has been reported.[13b,25] Nucleic base alkylation by the allenic sulfone generated from isomerization of the propargylic sulfone under basic conditions has been proposed.[24] After incubation of the DNA substrate with the sulfones **6a-d** and **6f** at 1.0 mM concentration under the conditions shown in Figure 2, the resultant DNA fragments were then separated by agarose gel electrophoresis and visualized by ethidium bromide stain. The Form II band in the gel picture represents the single strand cleavage products, the efficiency is quite lower for sulfones **6f** and **6a-d** (lanes 4-8) compared to the known compounds **12** and **13** (lanes 2 and 3) reported by us.[13b] The diminished potency is attributed to the self-reaction of these sulfones **6a-d** and **6f** to form the (*E*)-*exo*-alkylidene tetrahydrofurans (*E*)-**3a-d** and (*E*)-**3f** as discussed in Scheme 2. This explanation was confirmed to be correct by the enhanced DNA cleavage activity of the corresponding acetates (lanes 9-13) in which the hydroxyl group is masked.

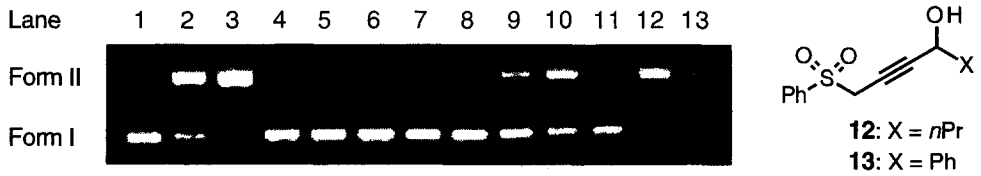


Figure 2. ΦX174 RFI DNA (54.3 μM/bp) was incubated with various propargylic sulfones at 1.0 mM concentration in TEA buffer solution (pH 8.5) containing 20% DMSO for 72 h at 37 °C and then analyzed using gel electrophoresis (1% agarose gel, ethidium bromide stain). Lane 1: DNA only; Lane 2: compound **12**; Lane 3: compound **13**; Lanes 4-8: compounds **6f** and **6a-d**, respectively; Lanes 9-13: the acetates of **6f** and **6a-d**, respectively.

In summary, we have developed a general and stereo-controlled synthesis of (*E*)-*exo*-alkylidene tetrahydrofurans (*E*)-**3a-i** by a base-mediated cyclization of hydroxyl propargylic sulfones **6a-i**. The deuterium quenching experiment demonstrated that the cyclization reaction takes place through the allenic species **8a**. DNA cleavage study on the hydroxyl propargylic sulfones and their acetates revealed that enhanced potency could be attained by protecting the hydroxyl group to prevent the self-cyclization. The observation is useful for molecular

design of highly efficient DNA cleaving agents.

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Experimental Section

General Techniques. ^1H and ^{13}C NMR spectra were recorded on a Bruker ARX 300 or JEOL EX-400 NMR instrument. IR spectra were taken on a Perkin-Elmer FT-IR spectrophotometer. Mass spectra (MS) were measured on a Finnigan TSQ 7000 mass spectrometer. High resolution mass spectra (HRMS) were measured by Kunming Institute of Botany, The Chinese Academy of Sciences. Elemental analysis was performed by Shanghai Institute of Organic Chemistry, The Chinese Academy of Sciences. All reactions were carried out under a nitrogen atmosphere and monitored by thin-layer chromatography on 0.25-mm E. Merck silica gel plates (60 F-254) using UV light, or 7% ethanolic phosphomolybdic acid and heating as the visualizing methods. E. Merck silica gel (60, particle size 0.040-0.063 mm) was used for flash column chromatography. Yields refer to chromatographically and spectroscopically (^1H NMR) homogeneous materials. Phenyl propargylic sulfide (**4**) was synthesized according to the literature procedure.[13] Epoxides **5a-i** were obtained commercially and used as received.

General Procedure for Addition of Lithium Acetylide of 4 with Various Epoxides 5a-i. 1-Phenyl-5-(phenylthio)pent-3-yn-1-ol (7a). To a solution of phenyl propargylic sulfide (**4**) (500 mg, 3.38 mmol) in dry THF (30 mL) cooled in a dry ice-acetone bath (-78 °C) was added *n*BuLi (2.35 mL, 1.44 M in hexane, 3.38 mmol) followed by stirring at the same temperature for 10 min. To the resultant yellowish solution was added BF_3•OEt_2 (0.62 mL, 5.07 mmol) at -78 °C, after stirring for another 10 min, a THF (3 mL) solution of epoxide **5a** (0.50 mL, 4.39 mmol) was added, and the mixture was stirred at -78 °C for 30 min. The reaction mixture was quenched with aqueous NH_4Cl and extracted with EtOAc (30 mL x 2). The combined organic layer was washed with brine, dried over anhydrous $MgSO_4$, and condensed under reduced pressure. The residue was purified by flash column chromatography (silica gel, 10% EtOAc in hexane) to give **7a** (325 mg, 36%) together with its regioisomer [2-phenyl-5-(phenylthio)pent-3-yn-1-ol] (348 mg, 38%). **7a**: pale-yellow oil; R_f = 0.27 (20% EtOAc in hexane); IR (film) 3426 (br), 2954, 2924, 2854, 1644, 1462, 1378 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.46–7.23 (m, 10 H), 4.74 (t, *J* = 6.11 Hz, 1 H), 3.61 (t, *J* = 2.44 Hz, 2 H), 2.60 (dt, *J* = 4.88, 2.44 Hz, 2 H), 2.50 (br s, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.5, 135.2, 129.8, 128.8, 128.2, 127.6, 126.6, 125.6, 79.9, 78.4, 72.2, 29.7, 22.8; MS (CI^+) *m/z* (relative intensity) 286 (M^++NH_4, 100), 268 (M^+, 13); HRMS (FAB^+) Calcd. for $C_{17}H_{16}OS$ (M^+): 268.0922. Found: 268.0977.

2-Phenyl-5-(phenylthio)pent-3-yn-1-ol. pale-yellow oil; R_f = 0.18 (20% EtOAc in hexane); IR (film) 3426 (br), 3060, 2928, 1584, 1480, 1434, 1236, 1052 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.51–7.27 (m, 10 H), 3.83 (t, *J* = 6.84 Hz, 1 H), 3.73 (d, *J* = 2.44 Hz, 2 H), 3.67-3.60 (m, 3 H); ^{13}C NMR (100 MHz,

$CDCl_3$) δ 137.7, 134.9, 130.5, 128.9, 128.5, 127.8, 127.2, 127.0, 82.5, 80.3, 67.5, 41.4, 23.1; MS (CI^+) *m/z* (relative intensity) 286 (M^++NH_4, 100).

1-Phenyl-6-(phenylthio)hex-4-yn-2-ol (7b). Prepared from **4** and **5b** in 72% yield after purification by flash column chromatography (silica gel, 20% EtOAc in hexane). **7b**: pale-yellow oil; R_f = 0.31 (20% EtOAc in hexane); IR (film) 3416 (br), 3060, 3020, 2912, 2232, 1584, 1496, 1480, 1454, 1438, 1236, 1070, 1044, 740, 702 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.49-7.17 (m, 10 H), 3.90 (br s, 1 H), 3.70 (t, *J* = 2.34 Hz, 2 H), 2.79 (ddd, *J* = 18.30, 13.53, 6.48 Hz, 1 H), 2.46-2.29 (m, 2 H), 1.83 (br s, 1 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 137.6, 135.1, 129.8, 129.3, 128.9, 128.4, 126.7, 126.4, 79.7, 78.6, 70.8, 42.3, 26.5, 22.8; MS (CI^+) *m/z* (relative intensity) 282 (M^+, 44), 265 (M^+-OH, 86), 155 (100); HRMS (FAB^+) Calcd. for $C_{18}H_{18}OS$ (M^+): 282.1078. Found: 282.1064.

1-Phenyloxy-6-(phenylthio)hex-4-yn-2-ol (7c). Prepared from **4** and **5c** in 75% yield after purification by flash column chromatography (silica gel, 20% EtOAc in hexane). **7c**: pale-yellow crystalline solid; mp 59-60 °C (recrystallized from EtOAc-hexane); R_f = 0.34 (20% EtOAc in hexane); IR (Nujol) 3452 (br), 2964, 1644, 1456, 1244, 1176, 1098 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.45 (d, *J* = 8.30 Hz, 2 H), 7.35-7.30 (m, 4 H), 7.24 (t, *J* = 6.84 Hz, 1 H), 7.02 (t, *J* = 7.32 Hz, 1 H), 6.91 (d, *J* = 8.79 Hz, 2 H), 4.10-4.00 (m, 1 H), 3.99-3.89 (m, 2 H), 3.67 (t, *J* = 2.44 Hz, 2 H), 2.59 (dt, *J* = 5.13, 2.4 Hz, 2 H), 2.35 (d, *J* = 4.88 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.4, 135.2, 130.0, 129.5, 129.0, 126.8, 121.2, 114.6, 79.1, 78.6, 70.3, 68.5, 24.0, 22.9; MS (CI^+) *m/z* (relative intensity) 299 (M^++1, 88), 281 (M^+-OH, 26), 189 (100); Anal. Calcd. for $C_{18}H_{18}O_2S$: C, 72.45; H, 6.08. Found: C, 72.73; H, 6.19.

1-Phthalimido-6-(phenylthio)hex-4-yn-2-ol (7d). Prepared from **4** and **5d** in 68% yield after purification by flash column chromatography (silica gel, 20% EtOAc in hexane). **7d**: pale-yellow oil; R_f = 0.36 (40% EtOAc in hexane); IR (film) 3446 (br), 3060, 2938, 1770, 1682, 1470, 1392, 1190, 1088 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.90-7.88 (m, 2 H), 7.78-7.75 (m, 2 H), 7.46 (d, *J* = 7.32 Hz, 2 H), 7.34 (t, *J* = 7.81 Hz, 2 H), 7.24 (t, *J* = 7.32 Hz, 1 H), 4.04 (m, 1 H), 3.87-3.78 (m, 2 H), 3.62 (t, *J* = 2.44 Hz, 2 H), 2.56-2.43 (m, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.7, 135.2, 134.1, 131.9, 130.1, 129.0, 126.8, 123.4, 79.1, 78.7, 68.4, 43.2, 25.7, 22.9; MS (CI^+) *m/z* (relative intensity) 352 (M^++1, 100); HRMS (FAB^+) Calcd. for $C_{20}H_{17}NO_3S$ (M^+): 351.0929. Found: 351.0934.

7-(Phenylthio)hept-5-yn-3-ol (7e). Prepared from **4** and **5e** in 72% yield after purification by flash column chromatography (silica gel, 20% EtOAc in hexane). **7e**: pale-yellow oil; R_f = 0.34 (20% EtOAc in hexane); IR (film) 3406 (br), 3058, 2964, 2932, 2876, 2230, 1584, 1480, 1438, 1236, 1100, 1026, 978, 740, 690 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.43 (d, *J* = 7.32 Hz, 2 H), 7.32 (t, *J* = 7.57 Hz, 2 H), 7.24 (t, *J* = 7.32 Hz, 1 H), 3.64 (t, *J* = 2.44 Hz, 2 H), 3.56 (tt, *J* = 6.35, 6.35 Hz, 1 H), 2.39 (ddt, *J* = 16.60, 4.40, 2.44 Hz, 1 H), 2.27 (ddt,, *J* = 16.60, 6.35, 2.44 Hz, 1 H), 1.72 (br s, 1 H), 1.50-1.41 (m, 2 H), 0.90 (t, *J* = 7.32 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 135.2, 130.1, 128.9, 126.8, 80.2, 78.2, 71.3, 29.0, 27.2, 23.0, 9.9; MS (CI^+) *m/z* (relative intensity) 220 (M^+, 80), 203 (M^+-OH, 100); HRMS (FAB^+) Calcd. for $C_{13}H_{16}OS$ (M^+): 220.0922. Found: 220.0930.

1-(Phenylthio)non-2-yn-5-ol (7f). Prepared from **4** and **5f** in 83% yield after purification by flash column chromatography (silica gel, 10% EtOAc in hexane). **7f**: pale-yellow oil; R_f = 0.42 (20% EtOAc in hexane); IR (film) 3396 (br), 3058, 2932, 2858, 1584, 1482, 1438, 1236, 1086, 1026, 738, 690 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.43 (d, J = 7.32 Hz, 2 H), 7.32 (t, J = 7.32 Hz, 2 H), 7.24 (t, J = 7.33 Hz, 1 H), 3.64 (t, J = 2.45 Hz, 2 H), 3.64-3.59 (m, 1 H), 2.40 (ddt, J = 16.60, 4.88, 2.44 Hz, 1 H), 2.26 (ddt, J = 16.60, 6.83, 2.44 Hz, 1 H), 1.64 (br s, 1 H), 1.46-1.21 (m, 6 H), 0.89 (t, J = 7.32 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 135.2, 130.1, 128.9, 126.8, 80.2, 78.3, 70.0, 35.9, 27.8, 23.0, 22.6, 14.0; MS (CI^+) *m/z* (relative intensity) 249 (M^++1, 93), 231 (M^+-OH, 90), 163 (100); HRMS (FAB^+) Calcd. for $C_{15}H_{20}OS$ (M^+): 248.1235. Found: 248.1202.

1-(Phenylthio)tridec-2-yn-5-ol (7g). Prepared from **4** and **5g** in 87% yield after purification by flash column chromatography (silica gel, 10% EtOAc in hexane). **7g**: pale-yellow oil; R_f = 0.45 (20% EtOAc in hexane); IR (film) 3406 (br), 3060, 2924, 2854, 1584, 1480, 1468, 1438, 1234, 1086, 1026, 738, 690 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.43 (d, J = 7.81 Hz, 2 H), 7.32 (t, J = 7.81 Hz, 2 H), 7.24 (t, J = 7.32 Hz, 1 H), 3.64 (t, J = 2.44 Hz, 2 H), 3.65-3.60 (br s, 1 H), 2.39 (ddt, J = 16.61, 4.40, 2.44 Hz, 1 H), 2.26 (ddt, J = 16.60, 6.35, 2.44 Hz, 1 H), 1.67 (br s, 1 H), 1.43-1.27 (m, 14 H), 0.89 (t, J = 7.32 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 135.2, 130.1, 128.9, 126.8, 80.2, 78.3, 70.0, 36.2, 31.8, 29.5, 29.2, 27.7, 25.6, 23.0, 22.6, 14.1; MS (CI^+) *m/z* (relative intensity) 305 (M^++1, 58), 287 (M^+-OH, 100); HRMS (FAB^+) Calcd. for $C_{19}H_{28}OS$ (M^+): 304.1861. Found: 304.1935.

1-(Phenylthio)non-8-en-2-yn-5-ol (7h). Prepared from **4** and **5h** in 80% yield after purification by flash column chromatography (silica gel, 10% EtOAc in hexane). **7h**: pale-yellow oil; R_f = 0.40 (20% EtOAc in hexane); IR (film) 3372 (br), 3076, 2936, 1640, 1584, 1482, 1440, 1236, 1086, 1026, 914, 740, 690 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.41 (d, J = 6.84 Hz, 2 H), 7.30 (t, J = 7.32 Hz, 2 H), 7.22 (t, J = 6.80 Hz, 1 H), 5.77 (ddt, J = 17.09, 10.25, 6.84 Hz, 1 H), 5.01 (dd, J = 17.09, 1.48 Hz, 1 H), 4.95 (dd, J = 10.26, 1.00 Hz, 1 H), 3.65-3.59 (m, 3 H), 2.37 (ddt, J = 16.60, 4.88, 2.44 Hz, 1 H), 2.26 (ddt, J = 16.60, 6.34, 2.44 Hz, 1 H), 2.16-2.03 (m, 2 H), 1.67-1.66 (m, 1 H), 1.51 (td, J = 7.36, 6.84 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.1, 135.1, 130.1, 128.9, 126.8, 114.9, 80.0, 78.4, 69.4, 35.1, 29.9, 27.7, 23.0; MS (CI^+) *m/z* (relative intensity) 247 (M^++1, 30), 229 (M^+-OH, 23), 85 (100); HRMS (FAB^+) Calcd. for $C_{15}H_{18}OS$ (M^+): 246.1078. Found: 246.1060.

***trans*-2-[(3-Phenylthio)prop-2-ynyl]cyclohexanol (7i)**. Prepared from **4** and **5i** in 89% yield after purification by flash column chromatography (silica gel, 20% EtOAc in hexane). **7i**: pale-yellow oil; R_f = 0.34 (20% EtOAc in hexane); IR (film) 3424 (br), 3058, 2934, 1664, 1584, 1438, 1236, 1066, 740, 690 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.43 (d, J = 7.32 Hz, 2 H), 7.35-7.22 (m, 3 H), 3.63 (d, J = 2.44 Hz, 2 H), 3.29 (td, J = 9.76, 3.90 Hz, 1 H), 2.17-2.10 (m, 1 H), 1.98-1.85 (m, 3 H), 1.73-1.68 (m, 1 H), 1.62-1.57 (m, 1 H), 1.33-1.06 (m, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 135.0, 130.5, 128.9, 127.0, 85.1, 77.9, 73.5, 39.0, 32.9, 30.9, 24.8, 24.1, 23.2; MS (CI^+) *m/z* (relative intensity) 247 (M^++1, 24), 246 (M^+, 28), 229 (M^+-OH, 100); HRMS (FAB^+) Calcd. for $C_{15}H_{18}OS$ (M^+): 246.1078. Found: 246.1027.

General Procedure for Oxidation of Sulfides 7a-i. 1-Phenyl-5-(benzenesulfonyl)pent-3-yn-1-ol (6a). To a solution of sulfide **7a** (260 mg, 0.97 mmol) in CH_2Cl_2 (10 mL) cooled in an ice-water bath (*ca.* 0 °C) was added *m*CPBA (50%, 670 mg, 1.94 mmol) followed by stirring at the same temperature for 30 min. The reaction mixture was quenched with aqueous $NaHCO_3$ and extracted with CH_2Cl_2 (10 mL x 2). The combined organic layer was washed with brine, dried over anhydrous $MgSO_4$, and condensed under reduced pressure. The residue was purified by flash column chromatography (silica gel, 20% EtOAc in hexane) to give **6a** (242 mg, 83%). **6a**: colorless oil; R_f = 0.42 (40% EtOAc in hexane); IR (film) 3506 (br), 2954, 2910, 2242, 1638 (br), 1448, 1310, 1136 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.89 (d, *J* = 7.32 Hz, 2 H), 7.67 (t, *J* = 7.32 Hz, 1 H), 7.54 (t, *J* = 7.57 Hz, 3 H), 7.42-7.30 (m, 4 H), 4.80 (t, *J* = 6.35 Hz, 1 H), 3.93 (s, 2 H), 2.62 (d, *J* = 5.86 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.3, 137.4, 134.0, 128.9, 128.4, 128.2, 127.7, 125.6, 85.1, 71.9, 69.9, 48.6, 29.4; MS (CI$^+$) *m/z* (relative intensity) 318 (M^++NH_4, 100); HRMS (FAB$^+$) Calcd. for $C_{17}H_{16}O_3S$ (M^+): 300.0820. Found: 300.0889.

1-Phenyl-6-(benzenesulfonyl)hex-4-yn-2-ol (6b). Prepared from **7b** in 95% yield after purification by flash column chromatography (silica gel, 40% EtOAc in hexane). **6b**: colorless oil; R_f = 0.32 (40% EtOAc in hexane); IR (film) 3448 (br), 3064, 3028, 2910, 2240, 1728, 1638 (br), 1448, 1322, 1254, 1136, 1084 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 8.04 (d, *J* = 7.33 Hz, 2 H), 7.72 (t, *J* = 7.57 Hz, 1 H), 7.61 (t, *J* = 7.32 Hz, 2 H), 7.37-7.22 (m, 5 H), 4.05 (t, *J* = 2.44 Hz, 2 H), 3.97 (tt, *J* = 5.86, 5.86 Hz, 1 H), 2.83 (m, 3 H), 2.40 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 137.6, 137.5, 134.1, 129.2, 129.0, 128.5, 128.4, 126.5, 85.2, 70.6, 70.1, 48.7, 42.3, 26.5; MS (CI$^+$) *m/z* (relative intensity) 315 (M^++1, 32), 297 (M^+-OH, 100); HRMS (FAB$^+$) Calcd. for $C_{18}H_{18}O_3S$ (M^+): 314.0977. Found: 314.0989.

1-Phenyloxy-6-(benzenesulfonyl)hex-4-yn-2-ol (6c). Prepared from **7c** in 84% yield after purification by flash column chromatography (silica gel, 40% EtOAc in hexane). **6c**: colorless oil; R_f = 0.35 (40% EtOAc in hexane); IR (film) 3452 (br), 2924, 2854, 1644 (br), 1460, 1378, 1308, 1132, 1084, 748, 692 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 7.81 Hz, 2 H), 7.67 (t, *J* = 7.82 Hz, 1 H), 7.56 (t, *J* = 7.81 Hz, 2 H), 7.36 (t, *J* = 7.81 Hz, 2 H), 7.04 (t, *J* = 7.32 Hz, 1 H), 6.95 (d, *J* = 8.31 Hz, 2 H), 4.15 (tt, *J* = 5.86, 5.86 Hz, 1 H), 4.02-3.95 (m, 4 H), 2.80-2.40 (m, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.3, 137.7, 134.2, 129.6, 129.1, 128.7, 121.4, 114.6, 84.3, 70.4, 70.1, 68.4, 48.9, 23.9; MS (CI$^+$) *m/z* (relative intensity) 331 (M^++1, 100); HRMS (FAB$^+$) Calcd. for $C_{18}H_{18}O_4S$ (M^+): 330.0926. Found: 330.0928.

1-Phthalimido-6-(benzenesulfonyl)hex-4-yn-2-ol (6d). Prepared from **7d** in 82% yield after purification by flash column chromatography (silica gel, 60% EtOAc in hexane). **6d**: pale-yellow crystalline solid; mp 151-154 °C (recrystallized from EtOAc-hexane); R_f = 0.36 (60% EtOAc in hexane); IR (Nujol) 3402 (br), 2924, 2854, 1694, 1464, 1378, 1152, 722 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 8.00 (d, *J* = 7.32 Hz, 2 H), 7.86 (dd, *J* = 5.62, 2.93 Hz, 2 H), 7.74 (dd, *J* = 5.37, 2.93 Hz, 2 H), 7.68 (t, *J* = 6.84 Hz, 1 H), 7.59 (t, *J* = 6.84 Hz, 2 H), 4.02 (tt, *J* = 5.85, 5.85 Hz, 1 H), 3.94 (t, *J* = 2.44 Hz, 2 H), 3.85-3.75 (m, 2 H), 2.53-2.40 (m, 2 H), 2.10-1.80 (br s, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.7, 137.8, 134.22, 134.19, 131.9, 129.2, 128.8, 123.5, 84.0, 70.9, 68.3, 48.8, 43.1, 25.6; MS (CI$^+$) *m/z* (relative intensity) 384 (M^++1, 100); Anal. Calcd. for $C_{20}H_{17}NO_5S$: C, 62.65; H, 4.47; N, 3.65. Found: C, 62.40; H, 4.54; N, 3.53.

7-(Benzenesulfonyl)hept-5-yn-3-ol (6e). Prepared from **7e** in 83% yield after purification by flash column chromatography (silica gel, 40% EtOAc in hexane). **6e**: colorless oil; R_f = 0.52 (40% EtOAc in hexane); IR (film) 3508 (br), 3066, 2964, 2240, 1586, 1448, 1310, 1256, 1136, 1086, 980, 876, 746, 688 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.97 (d, J = 7.82 Hz, 2 H), 7.69 (t, J = 7.81 Hz, 1 H), 7.59 (t, J = 7.81 Hz, 2 H), 3.97 (t, J = 2.44 Hz, 2 H), 3.61 (tt, J = 5.86, 5.86 Hz, 1 H), 2.40 (ddt, J = 16.61, 4.88, 2.44 Hz, 1 H), 2.29 (ddt, J = 16.60, 6.35, 2.44 Hz, 1 H), 2.25-1.70 (br s, 1 H), 1.48 (dq, J = 7.32, 7.32 Hz, 2 H), 0.92 (t, J = 7.32 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 137.8, 134.2, 129.1, 128.7, 85.5, 71.3, 70.0, 48.9, 29.0, 27.2, 9.8; MS (CI$^+$) m/z (relative intensity) 253 (M^++1, 56), 235 (M^+-OH, 52), 157 (100); HRMS (FAB$^+$) Calcd. for $C_{13}H_{16}O_3S$ (M^+): 252.0820. Found: 252.0835.

1-(Benzenesulfonyl)non-2-yn-5-ol (6f). Prepared from **7f** in 81% yield after purification by flash column chromatography (silica gel, 20% EtOAc in hexane). **6f**: colorless oil; R_f = 0.40 (40% EtOAc in hexane); IR (film) 3542 (br), 3066, 2932, 2240, 1732 (br), 1586, 1446, 1310, 1136, 1084, 744, 688 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.97 (d, J = 8.30 Hz, 2 H), 7.69 (t, J = 7.32 Hz, 1 H), 7.58 (t, J = 7.32 Hz, 2 H), 3.97 (t, J = 2.44 Hz, 2 H), 3.67 (tt, J = 5.86, 5.86 Hz, 1 H), 2.39 (ddt, J = 16.60, 4.89, 2.44 Hz, 1 H), 2.28 (ddt, J = 16.60, 6.84, 2.44 Hz, 1 H), 2.20-1.70 (br s, 1 H), 1.47-1.25 (m, 6 H), 0.90 (t, J = 6.84 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 137.8, 134.2, 129.1, 128.7, 85.5, 70.1, 69.8, 48.9, 35.9, 27.7, 22.5, 14.0; MS (CI$^+$) m/z (relative intensity) 281 (M^++1, 100); Anal. Calcd. for $C_{15}H_{20}O_3S$: C, 64.26; H, 7.19. Found: C, 64.17; H, 7.28.

1-(Benzenesulfonyl)tridec-2-yn-5-ol (6g). Prepared from **7g** in 81% yield after purification by flash column chromatography (silica gel, 20% EtOAc in hexane). **6g**: colorless oil; R_f = 0.68 (40% EtOAc in hexane); IR (film) 3514 (br), 3068, 2926, 2856, 2240, 1448, 1324, 1136, 1086, 744, 688 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.97 (d, J = 6.83 Hz, 2 H), 7.69 (t, J = 7.82 Hz, 1 H), 7.59 (t, J = 7.81 Hz, 2 H), 3.97 (t, J = 2.44 Hz, 2 H), 3.69-3.64 (m, 1 H), 2.40 (ddt, J = 16.60, 4.88, 2.44 Hz, 1 H), 2.28 (ddt, J = 16.60, 6.83, 2.44 Hz, 1 H), 2.40-1.80 (br s, 1 H), 1.43-1.27 (m, 14 H), 0.88 (t, J = 6.84 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 137.8, 134.2, 129.1, 128.7, 85.6, 70.1, 69.9, 48.9, 36.3, 31.8, 29.5, 29.2, 27.7, 25.6, 22.7, 14.1; MS (CI$^+$) m/z (relative intensity) 337 (M^++1, 100); Anal. Calcd. for $C_{19}H_{28}O_3S$: C, 67.82; H, 8.39. Found: C, 67.38; H, 8.61.

1-(Benzenesulfonyl)non-8-en-2-yn-5-ol (6h). Prepared from **7h** in 80% yield after purification by flash column chromatography (silica gel, 40% EtOAc in hexane). **6h**: colorless oil; R_f = 0.33 (40% EtOAc in hexane); IR (film) 3456 (br), 3076, 2942, 2240, 1640, 1448, 1310, 1136, 1084, 914, 876 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, J = 8.31 Hz, 2 H), 7.73 (t, J = 8.32 Hz, 1 H), 7.62 (t, J = 8.30 Hz, 2 H), 5.84 (ddt, J = 17.09, 10.26, 6.84 Hz, 1 H), 5.08 (dd, J = 17.09, 1.47 Hz, 1 H), 5.03 (d, J = 9.77 Hz, 1 H), 4.01 (t, J = 2.44 Hz, 2 H), 3.75 (tt, J = 5.86, 5.86 Hz, 1 H), 2.44 (ddt, J = 16.60, 4.88, 2.44 Hz, 1 H), 2.34 (ddt, J = 16.60, 6.83, 2.44 Hz, 1 H), 2.40-1.70 (br s, 1 H), 2.27-2.10 (m, 2 H), 1.58 (td, J = 7.32, 7.32 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 137.9, 137.7, 134.2, 129.1, 128.7, 115.1, 85.4, 70.1, 69.2, 48.9, 35.2, 29.8, 27.7; MS (CI$^+$) m/z (relative intensity) 279 (M^++1, 100), 261 (M^+-OH, 4); HRMS (FAB$^+$) Calcd. for $C_{15}H_{18}O_3S$ (M^+): 278.0977. Found: 278.0947.

***trans*-2-[(3-Benzenesulfonyl)prop-2-ynyl]cyclohexanol (6i).** Prepared from **7i** in 87% yield after purification by flash column chromatography (silica gel, 20% EtOAc in hexane). **6i**: colorless oil; R_f = 0.33 (20% EtOAc in hexane); IR (film) 3430 (br), 2924, 2854, 1652 (br), 1448, 1308, 1142, 1066, 748, 686 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.98 (d, J = 7.32 Hz, 2 H), 7.70 (t, J = 7.32 Hz, 1 H), 7.60 (t, J = 7.32 Hz, 2 H), 3.98 (d, J = 2.44 Hz, 2 H), 3.37 (dt, J = 9.76, 3.91 Hz, 1 H), 2.21-2.19 (m, 1 H), 2.20-1.95 (br s, 1 H), 1.99-1.95 (m, 1 H), 1.91-1.85 (m, 1 H), 1.77-1.63 (m, 1 H), 1.62-1.56 (m, 1 H), 1.34-1.11 (m, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 137.7, 134.2, 129.1, 128.8, 90.1, 73.3, 69.9, 48.9, 38.9, 33.1, 30.4, 24.6, 24.1; MS (CI^+) m/z (relative intensity) 279 (M^++1, 100); HRMS (FAB^+) Calcd. for $C_{15}H_{18}O_3S$ (M^+): 278.0977. Found: 278.0990. Anal. Calcd. for $C_{15}H_{18}O_3S$: C, 64.72; H, 6.52. Found: C, 64.48; H, 6.55.

General Procedure for Base-Mediated Cyclization of Hydroxyl Propargylic Sulfones 6a-i. (*E*)-Tetrahydro-2-[(benzenesulfonyl)methylene]-5-phenylfuran (3a). To a suspension of NaH (60%, 11 mg, 0.28 mmol) in dry THF (1 mL) cooled in a cooling bath maintained at -20 °C under nitrogen atmosphere was added a solution of sulfone **6a** (55 mg, 0.18 mmol) in THF (1 mL) followed by stirring at the same temperature for 1h. The reaction mixture was then quenched with aqueous $NaHCO_3$ and extracted with EtOAc (5 mL x 2). The combined organic layer was washed with brine, dried over anhydrous $MgSO_4$, and condensed under reduced pressure. The residue was purified by flash column chromatography (silica gel, 20% EtOAc in hexane) to give **3a** (45 mg, 81%). **3a**: colorless crystalline solid; mp 104-105 °C (recrystallized from EtOAc-hexane); R_f = 0.60 (40% EtOAc in hexane); IR (Nujol) 2924, 2854, 1460, 1376 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.93 (dd, J = 8.09, 1.37 Hz, 2 H), 7.59-7.54 (m, 3 H), 7.39-7.27 (m, 5 H), 5.90 (s, 1 H), 5.41 (dd, J = 8.42, 6.57 Hz, 1 H), 3.55-3.46 (m, 1 H), 3.13 (dtd, J = 18.03, 9.06, 1.70 Hz, 1 H), 2.58-2.54 (m, 1 H), 2.12-2.04 (m, 1 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.1, 143.8, 138.8, 132.5, 129.0, 128.7, 128.5, 126.4, 125.6, 100.2, 85.4, 32.1, 29.8; MS (CI^+) m/z (relative intensity) 301 (M^++1, 100); Anal. Calcd. for $C_{17}H_{16}O_3S$: C, 67.98; H, 5.37. Found: C, 68.06; H, 5.48.

(*E*)-Tetrahydro-2-[(benzenesulfonyl)methylene]-5-benzylfuran (3b). Prepared from **6b** in 80% yield after purification by flash column chromatography (silica gel, 10% EtOAc in hexane). **3b**: colorless crystalline solid; mp 88-90 °C (recrystallized from EtOAc-hexane); R_f = 0.59 (20% EtOAc in hexane); IR (Nujol) 3060, 2924, 2854, 1620, 1462, 1284, 1140, 1084 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, J = 7.32 Hz, 2 H), 7.65 (t, J = 7.32 Hz, 1 H), 7.58 (t, J = 6.84 Hz, 2 H), 7.38-7.24 (m, 5 H), 5.83 (s, 1 H), 4.72 (tt, J = 6.35, 6.35 Hz, 1 H), 3.29 (ddd, J = 18.06, 9.08, 4.40 Hz, 1 H), 3.10-2.93 (m, 3 H), 2.24 (m, 1 H), 1.90 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.3, 143.9, 136.3, 132.4, 129.2, 129.0, 128.6, 126.9, 126.4, 99.6, 85.1, 40.8, 29.5, 28.6; MS (CI^+) m/z (relative intensity) 315 (M^++1, 100); Anal. Calcd. for $C_{18}H_{18}O_3S$: C, 68.77; H, 5.77. Found: C, 68.82; H, 5.79.

(*E*)-Tetrahydro-2-[(benzenesulfonyl)methylene]-5-(phenyloxymethyl)furan (3c). Prepared from **6c** in 82% yield after purification by flash column chromatography (silica gel, 20% EtOAc in hexane). **3c**: colorless crystalline solid; mp 114-115 °C (recrystallized from EtOAc-hexane); R_f = 0.54 (40% EtOAc in hexane); IR (Nujol) 2924, 2854, 1712, 1464, 1378, 1140, 1082 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, J = 7.33 Hz, 2 H), 7.63 (t, J = 7.32 Hz, 1 H), 7.56 (t, J = 7.32 Hz, 2 H), 7.32 (t, J = 7.32 Hz, 1 H), 7.02 (t, J = 7.32 Hz, 1 H), 6.88 (d, J = 8.30 Hz, 2 H), 5.86 (s, 1 H), 4.88-4.82 (m, 1 H), 4.16 (dd, J =

10.25, 3.42 Hz, 1 H), 4.09 (dd, J = 10.25, 4.88 Hz, 1 H), 3.47-3.39 (m, 1 H), 3.21 (dt, J = 18.55, 9.28 Hz, 1 H), 2.40-2.31 (m, 1 H), 2.20-2.11 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.3, 158.1, 143.8, 132.5, 129.5, 129.0, 126.4, 121.5, 114.5, 100.2, 82.3, 68.9, 29.5, 25.7; MS (CI$^+$) *m/z* (relative intensity) 331 (M^++1, 100); Anal. Calcd. for $C_{18}H_{18}O_4S$: C, 65.44; H, 5.49. Found: C, 65.61; H, 5.61.

(*E*)-Tetrahydro-2-[(benzenesulfonyl)methylene]-5-(phthalimidomethyl)furan (3d). Prepared from **6d** in 85% yield after purification by flash column chromatography (silica gel, 30% EtOAc in hexane). **3d**: colorless crystalline solid; mp ~173 °C (dec., recrystallized from THF-hexane); R_f = 0.53 (60% EtOAc in hexane); IR (Nujol) 2924, 2854, 1464, 1378 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93-7.90 (m, 4 H), 7.80 (dd, J = 5.37, 2.93 Hz, 2 H), 7.63-7.49 (m, 3 H), 5.81 (s, 1 H), 4.83-4.76 (m, 1 H), 3.98 (dd, J = 14.16, 6.84 Hz, 1 H), 3.87 (dd, J = 14.16, 4.88 Hz, 1 H), 3.44-3.36 (m, 1 H), 3.13 (dtd, J = 18.56, 9.28, 1.44 Hz, 1 H), 2.37-2.23 (m, 1 H), 2.00-1.91 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.2, 167.9, 143.6, 134.3, 132.5, 131.8, 129.0, 126.5, 123.6, 100.8, 81.2, 40.8, 29.1, 27.1; MS (CI$^+$) *m/z* (relative intensity) 384 (M^++1, 100); Anal. Calcd. for $C_{20}H_{17}NO_5S$: C, 62.65; H, 4.47; N, 3.65. Found: C, 62.78; H, 4.80; N, 3.62.

(*E*)-Tetrahydro-2-[(benzenesulfonyl)methylene]-5-ethylfuran (3e). Prepared from **6e** in 84% yield after purification by flash column chromatography (silica gel, 20% EtOAc in hexane). **3e**: colorless crystalline solid; mp 55-57 °C (recrystallized from EtOAc-hexane); R_f = 0.60 (40% EtOAc in hexane); IR (Nujol) 2954, 2924, 2854, 1464, 1378 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (d, J = 8.30 Hz, 2 H), 7.68-7.53 (m, 3 H), 5.76 (s, 1 H), 4.37 (tt, J = 6.35, 6.35 Hz, 1 H), 3.39 (ddd, J = 18.56, 9.27, 3.90 Hz, 1 H), 3.01 (dtd, J = 18.56, 9.27, 1.95 Hz, 1 H), 2.29-2.09 (m, 1 H), 1.81-1.58 (m, 3 H), 1.00 (t, J = 7.32 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.6, 144.0, 132.3, 129.0, 126.3, 99.2, 86.4, 29.7, 28.7, 27.7, 9.7; MS (CI$^+$) *m/z* (relative intensity) 253 (M^++1, 100); Anal. Calcd. for $C_{13}H_{16}O_3S$: C, 61.88; H, 6.39. Found: C, 61.63; H, 6.48.

(*E*)-Tetrahydro-2-[(benzenesulfonyl)methylene]-5-butylfuran (3f). Prepared from **6f** in 80% yield after purification by flash column chromatography (silica gel, 20% EtOAc in hexane). **3f**: colorless crystalline solid; mp 62-64 °C (recrystallized from EtOAc-hexane); R_f = 0.64 (40% EtOAc in hexane); IR (Nujol) 2922, 2854, 1626, 1464, 1378, 1300, 1136, 1082 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (dd, J = 6.84, 1.47 Hz, 2 H), 7.62-7.53 (m, 3 H), 5.76 (s, 1 H), 4.42 (tt, J = 6.84, 6.84 Hz, 1 H), 3.40 (dddd, J = 18.55, 8.78, 3.91, 1.47 Hz, 1 H), 3.00 (dtd, J = 18.56, 9.28, 1.96 Hz, 1 H), 2.29-2.21 (m, 1 H), 1.78-1.55 (m, 3 H), 1.49-1.29 (m, 4 H), 0.95 (t, J = 7.32 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.6, 144.0, 132.3, 129.0, 126.3, 99.2, 85.3, 34.4, 29.8, 29.2, 27.7, 22.4, 13.9; MS (CI$^+$) *m/z* (relative intensity) 281 (M^++1, 100); Anal. Calcd. for $C_{15}H_{20}O_3S$: C, 64.26; H, 7.19. Found: C, 64.33; H, 7.18.

(*E*)-Tetrahydro-2-[(benzenesulfonyl)methylene]-5-octylfuran (3g). Prepared from **6g** in 80% yield after purification by flash column chromatography (silica gel, 10% EtOAc in hexane). **3g**: colorless crystalline solid; mp 44-47 °C (recrystallized from EtOAc-hexane); R_f = 0.63 (20% EtOAc in hexane); IR (Nujol) 2924, 1634, 1464, 1286, 1138, 1084 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.88-7.85 (m, 2 H), 7.58-7.46 (m, 3 H), 5.70 (s, 1 H), 4.36 (tt, J = 6.86, 6.86 Hz, 1 H), 3.24 (dddd, J = 18.21, 10.20, 3.72, 1.20 Hz,

1 H), 2.94 (dtd, J = 18.21, 9.15, 1.83 Hz, 1 H), 2.24-2.14 (m, 1 H), 1.74-1.20 (m, 15 H), 0.87 (t, J = 6.62 Hz, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.6, 144.1, 132.3, 129.0, 126.4, 99.2, 85.3, 34.7, 31.8, 29.8, 29.4, 29.3, 29.2, 29.1, 25.6, 22.6, 14.1; MS (CI$^+$) *m/z* (relative intensity) 337 (M^++1, 82), 199 (98), 157 (100); Anal. Calcd. for $C_{19}H_{28}O_3S$: C, 67.82; H, 8.39. Found: C, 67.86; H, 8.56.

(*E*)-Tetrahydro-2-[(benzenesulfonyl)methylene]-5-(3-butenyl)furan (3h). Prepared from **6h** in 82% yield after purification by flash column chromatography (silica gel, 20% EtOAc in hexane). **3h**: colorless semi-solid; R_f = 0.63 (40% EtOAc in hexane); IR (Nujol) 2954, 2924, 2854, 1462, 1376, 1302, 1138, 1084 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (d, J = 7.32 Hz, 2 H), 7.57-7.48 (m, 3 H), 5.78 (ddt, J = 16.85, 10.75, 6.84 Hz, 1 H), 5.72 (s, 1 H), 5.03 (dd, J = 15.62, 1.46 Hz, 1 H), 4.99 (dd, J = 12.21, 1.46 Hz, 1 H), 4.43 (m, 1 H), 3.36 (dddd, J = 18.06, 8.79, 3.90, 1.46 Hz, 1 H), 2.96 (dtd, J = 18.07, 9.28, 1.96 Hz, 1 H), 2.25-2.07 (m, 3 H), 1.82-1.61 (m, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.4, 143.9, 137.0, 132.3, 128.9, 126.3, 115.5, 99.4, 84.4, 33.8, 29.7, 29.1; MS (CI$^+$) *m/z* (relative intensity) 279 (M^++1, 100).

***trans*-(*E*)-Tetrahydro-2-[(benzenesulfonyl)methylene]-4,5-butylidenefuran (3i).** Prepared from **6i** in 72% yield after purification by flash column chromatography (silica gel, 20% EtOAc in hexane). **3i**: colorless crystalline solid; mp 133-136 °C (recrystallized from EtOAc-hexane); R_f = 0.75 (40% EtOAc in hexane); IR (Nujol) 2924, 2854, 1628, 1458, 1376, 1140, 1076, 1024 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (d, J = 7.32 Hz, 2 H), 7.63-7.54 (m, 3 H), 5.84 (s, 1 H), 3.62-3.55 (m, 2 H), 2.45 (ddd, J = 16.60, 12.69, 2.44 Hz, 1 H), 2.27-2.23 (m, 1 H), 2.12-2.06 (m, 1 H), 2.00-1.94 (m, 1 H), 1.90-1.75 (m, 1 H), 1.72-1.58 (m, 1 H), 1.54-1.23 (m, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.0, 143.9, 132.4, 129.0, 126.4, 101.3, 87.5, 44.3, 35.5, 30.2, 28.2, 25.2, 24.0; MS (CI$^+$) *m/z* (relative intensity) 279 (M^++1, 22), 278 (M^+, 42), 137 (100); Anal. Calcd. for $C_{15}H_{18}O_3S$: C, 64.72; H, 6.52. Found: C, 64.69; H, 6.58.

REFERENCES AND NOTES

†Dedicated to the memory of the late Professor Yu Wang.

1. (a) Dobler, M. *Ionophores and Their Structures*, John Wiley & Sons: New York, 1981. (b) Westley, J. W. *Polyether Antibitics: Naturally Occurring Acid Ionophores*; Marcel Dekker: New York, 1982; Vol. 1 and 2.
2. Zeng, L.; Ye, Q.; Oberlies, N. H.; Shi, G.; Gu, Z.-M.; He, K.; McLaughlin, J. L. *Nat. Prod. Rep.* **1996**, 275-306.
3. Reviews on synthesis of substituted tetrahydrofuranes, see: (a) Boivin, T. L. B. *Tetrahedron* **1987**, *43*, 3309-3362. (b) Harmange, J.-C.; Figadére, B. *Tetrahedron:Asymmetry* **1993**, *4*, 1711-1754.
4. Selected recent reports, see: (a) Engman, L.; Gupta, V. *J. Org. Chem.* **1997**, *62*, 157-173. (b) Calter, M. A.; Sugathapala, P. M.; Zhu, C. *Tetrahedron Lett.* **1997**, *38*, 3837-3840. (c) Hojo, M.; Aihara, H.; Hosomi, A. *J. Am. Chem. Soc.* **1996**, *118*, 3533-3534. (d) Bratt, K.; Garavelas, A.; Perlmutter, P.; Westman, G. *J. Org. Chem.* **1996**, *61*, 2109-2117. (e) Vaupel, A.; Knochel, P. *J. Org. Chem.* **1996**, *61*, 5743-5753. (f) Taber, D. F.; Song, Y. *J. Org. Chem.* **1996**, *61*, 6706-6712. (g) Paquette, L. A.; Stepanian, M.; Mallavadhani, U. V.; Cutarelli, T. D.; Lowinger, T. B.; Klemeyer, H. J. *J. Org. Chem.*

1996, *61*, 7492-7507. (h) Yoshimatsu, M.; Naito, M.; Shimizu, H.; Muraoka, O.; Tanabe, G.; Kataoka, T. *J. Org. Chem.* **1996**, *61*, 8200-8206.

5. Reviews, see: (a) Koert, U. *Synthesis* **1995**, 115-132. (b) Hoppe, R.; Scharf, H.-D. *Synthesis* **1995**, 1447-1464. (c) Figadére, B. *Acc. Chem. Res.* **1995**, *28*, 359-365.
6. Selected recent reports, see: (a) Martin, T.; Soler, M. A.; Betancort, J. M.; Martin, V. S. *J. Org. Chem.* **1997**, *62*, 1570-1571. (b) Figadére, B.; Peyrat, J.-F.; Cavé, A. *J. Org. Chem.* **1997**, *62*, 3428-3429. (c) Capon, R. J.; Barrow, R. A.; Skene, C.; Rochfort, S. *Tetrahedron Lett.* **1997**, *38*, 7609-7612. (d) Hoye, T. R.; Ye, Z. *J. Am. Chem. Soc.* **1996**, *118*, 1801-1802. (e) Metz, P.; Meiners, U.; Cramer, E.; Fröhlich, R.; Wibbeling, B. *Chem. Commun.* **1996**, 431-432. (f) Mavropoulos, I.; Perlmutter, P. *Tetrahedron Lett.* **1996**, *37*, 3751-3754. (g) Walkup, R. D.; Kim, S. W. *J. Org. Chem.* **1994**, *59*, 3433-3441.
7. (a) Riediker, M.; Schwartz, J. *J. Am. Chem. Soc.* **1982**, *104*, 5842-5844. (b) Suzuki, M.; Yanagisawa, A.; Noyori, R. *J. Am. Chem. Soc.* **1988**, *110*, 4718-4726.
8. Harding, K. E.; Tiner, T. H. In *Comprehensive Organic Synthesis*; Trost, B. M., Ed.; Pergamon Press: New York, 1991; Vol. 4, p 363.
9. (a) McDonald, F. E.; Connolly, C. B.; Gleason, M. M.; Towne, T. B.; Treiber, K. D. *J. Org. Chem.* **1993**, *58*, 6952-6953. (b) McDonald, F. E.; Schultz, C. C. *J. Am. Chem. Soc.* **1994**, *116*, 9363-9364 and references cited therein. (c) McDonald, F. E.; Bowman, J. L. *Tetrahedron Lett.* **1996**, *37*, 4675-4678. (d) Schmidt, B.; Kocienski, P.; Reid, G. *Tetrahedron* **1996**, *52*, 1617-1630.
10. (a) Short, K. M.; Ziegler, Jr. C. B. *Tetrahedron Lett.* **1995**, *36*, 355-356. (b) Edwards, G. L.; Muldoon, C. A.; Sinclair, D. J. *Tetrahedron* **1996**, *52*, 7779-7788.
11. Other related intramolecular reactions of (*E*)-β-iodo vinyl sulfones, see: (a) Padwa, A.; Austin, D. J.; Ishida, M.; Muller, C. L.; Murphree, S. S.; Yeske, P. E. *J. Org. Chem.* **1992**, *57*, 1161-1169. (b) Short, K. M.; Ziegler, Jr. C. B. *Tetrahedron Lett.* **1993**, *34*, 71-74. (c) Ziegler, Jr. C. B.; Curran, W. V.; Feigelson, G. B.; Bitha, P.; Fabio, P.; Strohmeyer, T.; Short, K.; Lin, Y.-i. *Tetrahedron* **1994**, *50*, 12085-12096.
12. Mussatto, M. C.; Savoia, D.; Trombini, C.; Umani-Ronchi, A. *J. Chem. Soc. Perkin Trans. 1* **1980**, 260-263.
13. (a) Denmark, S. E.; Harmata, M. A.; White, K. S. *J. Org. Chem.* **1987**, *52*, 4031-4042. (b) Dai, W.-M.; Fong, K. C.; Danjo, H.; Nishimoto, S.; Solow, M.; Mak, W. L.; Yeung, M. L. *BioMed. Chem. Lett.* **1996**, *6*, 1093-1098.
14. (a) Bottini, A. T.; Corson, F. P.; Böttner, E. F. *J. Org. Chem.* **1965**, *30*, 2988-2994. (a) Bottini, A. T.; Böttner, E. F. *J. Org. Chem.* **1966**, *31*, 389-391. (c) Bottini, A. T.; Maroski, J. G. *J. Org. Chem.* **1973**, *38*, 1455-1462. (d) Bohlmann, F.; Herbst, P.; Gleinig, H. *Chem. Ber.* **1961**, *94*, 948-957. The related reactions of alkynes with amide and thiol nucleophiles, see: (e) Migliorese, K. G.; Tanaka, Y.; Miller, S. I. *J. Org. Chem.* **1974**, *39*, 739-747. (f) Williams D. R.; Moore, L. J. *Tetrahedron Lett.* **1983**, *24*, 339-342.
15. Yamaguchi, M.; Hirao, I. *Tetrahedron Lett.* **1983**, *24*, 391-394. Also see: Chini, M.; Crotti, P.; Favero, L.; Macchia, F. *Tetrahedron Lett.* **1991**, *32*, 6617-6620.
16. (a) Stirling, C. J. M. *J. Chem. Soc.* **1964**, 5856-5862. (b) Stirling, C. J. M. *J. Chem. Soc.* **1964**, 5863-5868. (c) McMullen, H.; Stirling, C. J. M. *J. Chem. Soc. (B)* **1966**, 1217-1220. (d) McDowell,

S. T.; Stirling, C. J. M. *J. Chem. Soc. (B)* **1967**, 351-355. (e) Appleyard, G. D.; Stirling, C. J. M. *J. Chem. Soc. (C)* **1967**, 2686-2691.

17. Dai, W.-M.; Fong, K. C. *Tetrahedron Lett.* **1995**, *36*, 5613-5616.
18. (a) Cinquini, M.; Colonna, S.; Cozzi, F. *J. Chem. Soc., Perkin Trans. 1* **1978**, 247-249. (b) Cinquini, M.; Cozzi, F.; Polosi, M. *J. Chem. Soc., Perkin Trans. 1* **1979**, 1430-1432. (c) Denmark, S. E.; Harmata, M. A. *J. Am. Chem. Soc.* **1982**, *104*, 4972-4974. (d) Denmark, S. E.; Harmata, M. A. *J. Org. Chem.* **1983**, *48*, 3369-3370. (e) Denmark, S. E.; Harmata, M. A. *Tetrahedron Lett.* **1984**, *25*, 1543-1546 and ref. 13a. (f) Blechert, S. *Tetrahedron Lett.* **1984**, *25*, 1547-1550. (g) Fujii, I.; Ryu, K.; Hayakawa, K.; Kanematsu, K. *J. Chem. Soc., Chem. Commun.* **1984**, 844-845. (h) Mikhailova, V. N.; Yurevich, V. P.; Bulat, A. D. *J. Org. Chem. USSR (Engl. Transl.)* **1978**, *14*, 200-201. (i) Thyagarajan, B. S.; Wood, Jr., B. F.; Glowienka, J. A.; Delgado, P. *Phosphorus Sulfer* **1985**, *25*, 1-9. (j) Hayakawa, K.; Takewaki, M.; Fujimoto, I.; Kanematsu, K. *J. Org. Chem.* **1986**, *51*, 5100-5105. (k) Padwa, A.; Yeske, P. E. *J. Am. Chem. Soc.* **1988**, *110*, 1617-1618. (l) Padwa, A.; Bullock, W. H.; Kline, D. N.; Perumattam, J. *J. Org. Chem.* **1989**, *54*, 2862-2869.
19. (a) Landor, S. R. In *The Chemistry of the Allenes*, Landor, S. R., Ed.; Academic Press: London, 1982; Vol. 2, pp. 389-390. (b) Schuster, H. F.; Coppola, G. M. In *Allenes in Organic Synthesis*, Wiley: New York, 1984; pp. 235-239.
20. Isomerization in a similar cyclization of hydroxyl allenic phosphine oxides was proposed, see: Pravia, K.; White, R.; Fodda, R.; Maynard, D. F. *J. Org. Chem.* **1996**, *61*, 6031-6032.
21. Honda, T.; Ishige, H.; Araki, J.; Akimoto, S.; Hirayama, K.; Tsubuki, M. *Tetrahedron* **1992**, *48*, 79-88.
22. (a) Bartlett, P. A.; Meadows, J. D.; Ottow, E. *J. Am. Chem. Soc.* **1984**, *106*, 5304-5311. (b) Kim, B. H.; Lee, J. Y. *Tetrahedron Lett.* **1992**, *33*, 2557-2560.
23. Fabre, J.-L.; Julia, M.; Verpeaux, J.-N. *Tetrahedron Lett.* **1982**, *23*, 2469-2472.
24. (a) Nicolaou, K. C.; Skokotas, G.; Maligres, P.; Zuccarello, G.; Schweiger, E. J.; Toshima, K.; Wendeborn, S. *Angew. Chem. Int. Ed. Engl.* **1989**, *28*, 1272-1275. (b) Nicolaou, K. C.; Wendeborn, S.; Maligres, P.; Isshiki, K.; Zein, N.; Ellestad, G. *Angew. Chem. Int. Ed. Engl.* **1991**, *30*, 418-420.
25. (a) Sakai, Y.; Bando, Y.; Shishido, K.; Shibuya, M. *Tetrahedron Lett.* **1992**, *33*, 957-960. (b) Toshima, K.; Ohta, K.; Ohtsuka, A.; Matsumura, S.; Nakata, M. *J. Chem. Soc., Chem. Commun.* **1993**, 1406-1407. (c) Xie, G.; Morgan, A. R.; Lown, J. W. *BioMed. Chem. Lett.* **1993**, *3*, 1565-1570. (d) Gupta, R.; Xie, G.; Lown, J. W. *Gene* **1994**, *149*, 81-90. (e) Kerwin, S. M. *Tetrahedron Lett.* **1994**, *35*, 1023-1026. (f) Wu, M.-J.; Lin, C.-F.; Ong, C.-W. *BioMed. Chem. Lett.* **1996**, *6*, 675-678. (g) Dai, W.-M.; Fong, K. C.; Danjo, H.; Nishimoto, S. *Angew. Chem. Int. Ed. Engl.* **1996**, *35*, 779-781. (h) Dai, W.-M.; Li, Q.; Fong, K. C.; Chow, C. W.; Zhou, L.; Hamaguchi, W.; Nishimoto, S. *BioMed. Chem. Lett.* **1998**, *8*, 169-174.