# Acid-promoted $C_1$-$C_2$ Bond Fission and Subsequent 1,5-Sulfenyl Shift of 1-Acceptor-1-sulfenyl-substituted 2-Vinylcyclopropanes. Formation of 6-Sulfenyl-α,β-γ,δ-unsaturated Carboxylic Esters and Nitriles

Tadashi Kataoka,* Harutoshi Matsumoto, Tetsuo Iwama, and Hiroshi Shimizu
*Gifu Pharmaceutical University, 6-1, Mitahora-higashi 5-chome, Gifu 502*

(Received March 23, 1995)

1-Acceptor-1-sulfenyl-substituted 2-vinylcyclopropanes were isomerized to 6-sulfenyl-α,β-γ,δ-unsaturated carboxylic esters and nitriles *via* a $C_1$-$C_2$ bond fission and *via* a 1,5-sulfenyl shift using an acid catalyst.

The cyclopropane ring is subject to a number of chemical transformations because of its unique bonding and high energy content.[1] Vinylcyclopropanes are the most important compounds among cyclopropane derivatives for the synthesis of complex molecules.[2] Although various types of vinylcyclopropanes have been utilized as versatile intermediates in synthetic transformations, 1-acceptor-1-sulfenyl-substituted vinylcyclopropanes have received considerably less attention.[3] Therefore, we intended to explore the novel transformation of 1-acceptor-1-sulfenyl-substituted 2-vinylcyclopropanes ( **I** ). There are

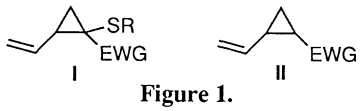
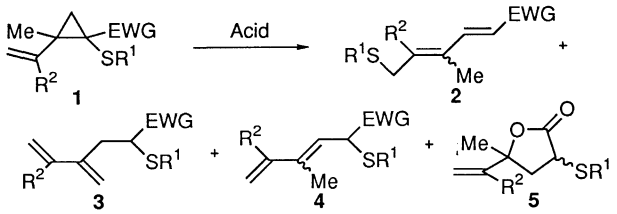



**Figure 1.**

several reports on the transformations of 1-acceptor-substituted 2-vinylcyclopropanes ( **II** ), mainly chrysanthemic acid derivatives, under acidic conditions.[4] We recently discovered the $C_1$-$C_2$ bond fission and 1,5-sulfenyl rearrangement of vinylcyclopropyl sulfides ( **I** ) by treatment with acids (Scheme 1). There has been reported only one example of the 1,5-alkylthio shift catalyzed by a base;[5] our finding, however, is the first example of the acid promoted 1,5-sulfenyl shift. We now report the $C_1$-$C_2$ bond cleavage followed by a 1,5-sulfenyl shift and formation of conjugated dienes.

Vinylcyclopropyl sulfides **1** were prepared according to the literature.[3] First, we examined an acid catalyst and solvent effects on the reaction of vinylcyclopropyl sulfide **1a**[6] (Table 1). The use of 42 % $HBF_4$, $CF_3CO_2H$ and $BF_3$•$Et_2O$ as an acid gave γ-lactone **5a** as the major product (entries 1, 2 and 5). The $C_1$-$C_2$ bond fission and 1,5-sulfenyl shift efficiently took place using a sulfonic acid such as *p*-toluenesulfonic acid monohydrate (*p*-TsOH) and $CF_3SO_3H$ in benzene, a nonpolar solvent, under reflux (entries 3 and 4). In entry 3, the rearranged diene **2a** formed by the 1,5-phenylthio shift was provided in 49% yield as a mixture of geometrical isomers, whose structures were characterized by the NOE technique, accompanied by an inseparable mixture of the ring-opened dienes **3a** and **4a** (the yields were estimated from the intensities of the signals in the $^1H$ NMR spectrum). When the reaction was carried out in EtOH, a polar protic solvent, γ-lactone **5a** was provided in 60% yield and no ring-opened diene was obtained (entry 6). Polar aprotic solvents, especially DMF and 1,2-dichloroethane, were ineffective for the $C_1$-$C_2$ bond fission and/or the 1,5-sulfenyl shift (entries 7 and 9). A considerable amount of diphenyl disulfide was obtained (36-41%) when EtOH, DMF or 1,2-dichloroethane was used as the solvent.




**a**: EWG=$CO_2Me$, $R^1$=Ph, $R^2$=Me;
**b**: EWG=$CO_2Me$, $R^1$=*m*-$MeC_6H_4$, $R^2$=Me;
**c**: EWG=$CO_2Me$, $R^1$=*p*-$ClC_6H_4$, $R^2$=Me;
**d**: EWG=$CO_2Me$, $R^1$=Ph, $R^2$=H;
**e**: EWG=$CO_2Me$, $R^1$=$R^2$=Me;
**f**: EWG=CN, $R^1$=Ph, $R^2$=Me;
**g**: EWG=CN, $R^1$=*p*-$ClC_6H_4$, $R^2$=Me;
**h**: EWG=CN, $R^1$=Ph, $R^2$=H;

**Scheme 1.**

**Table 1.** Acid-promoted isomerization of vinylcyclopropyl sulfide **1a**

| Entry | Conditions | Products (%yield) **2a**(*Z*:*E*)[a] | **3a**[b] | **4a**(*E*)[b] | **5a**[c] |
|---|---|---|---|---|---|
| 1 | 42%$HBF_4$(1.0),THF,r.t.,24h | - | - | - | 50 |
| 2 | $CF_3CO_2H$(1.0),benzene, r.t.,24h | - | - | - | 31 |
| 3 | *p*-TsOH(0.1),benzene,reflux,18h | 49(1:3) | 24 | 10 | 8 |
| 4 | $CF_3SO_3H$(0.1),benzene,reflux,20h | 41(2:3) | t[d] | 11 | 14 |
| 5 | $BF_3$•$Et_2O$(1.0),benzene,reflux,14h | 4(2:3) | - | - | 31 |
| 6 | *p*-TsOH(0.1),EtOH,reflux,9h | - | - | - | 60[e] |
| 7 | *p*-TsOH(0.1),DMF,80°C,9h | - | - | - | 15[e] |
| 8 | *p*-TsOH(0.1),THF,reflux,9h | 25(1:1) | 25 | - | 43 |
| 9 | *p*-TsOH(0.1),$(ClCH_2)_2$,reflux,9h | - | - | - | 26[e] |

[a]*Z*:*E* ratio was determined by $^1H$ NMR. [b]**3** and **4** were isolated as an inseparable mixture. Yields were estimated by $^1H$ NMR. [c]Diastereomeric mixture (*ca.* 1:1, estimated by $^1H$ NMR). [d]t: trace. [e]A considerable amount of $(PhS)_2$ was obtained in 36-41% yield.

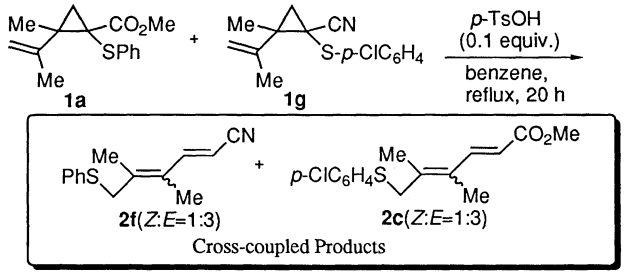
Next, several vinylcyclopropyl sulfides **1a-h** were treated with 0.1 or 1.0 equiv. of *p*-TsOH in toluene under reflux (Table 2). Vinylcyclopropyl sulfides, **1a-d, f-h**, carrying an arylthio group provided 6-sulfenyl-α,β-γ,δ-unsaturated carboxylic esters and nitriles **2a-d, f-h** in moderate to good yields, respectively. The rearranged dienes **2d** and **2h** were obtained as single isomers. The rearranged products **2f-h** having a cyano group were less stable than those bearing an ester group. The substituent effect of an arylthio group was slightly observed (entries 1-3). The yield of **2c** with an electron-withdrawing chloro substituent was lower than that of **2a**. In the reaction of **1b** bearing an electron-releasing methyl group, **4b** was not obtained because the rate of the arylthio shift of **4b** was faster than that of **4c**. The methylthio group was ineffective for the $C_1$-$C_2$ bond cleavage and for the 1,5-methylthio shift (entry 5), and no rearranged diene was isolated.

**Table 2.** Reactions of several vinylcyclopropyl sulfides **1** with *p*-toluenesulfonic acid•$H_2O$

| Entry | Compd No. | Equiv. of *p*-TsOH | Time(h) | Products (%yield) 2(*Z*:*E*)[a] | 3[b] | 4(*Z*:*E*)[b] | 5[c] |
|---|---|---|---|---|---|---|---|
| 1 | **1a** | 0.1 | 12 | 67(1:3) | 8 | t(*E*)[d] | 5 |
| 2 | **1b** | 0.1 | 12 | 68(1:3) | 6 | - | 4 |
| 3 | **1c** | 0.1 | 12 | 63(1:3) | 8 | 3(*E*) | 2 |
| 4 | **1d** | 0.1 | 10 | 60(*E*) | 7 | 3(1:2) | 6 |
| 5 | **1e** | 1.0 | 20 | complex mixture | | | |
| 6 | **1f** | 1.0 | 3 | 60(1:2) | 4 | - | - |
| 7 | **1g** | 1.0 | 3 | 55(1:3) | 3 | - | - |
| 8 | **1h** | 1.0 | 3 | 42(*E*) | - | - | - |

[a]*Z*:*E* ratio was determined by $^1$H NMR. [b]**3** and **4** were isolated as an inseparable mixture. Yields and *Z*:*E* ratios were estimated by $^1$H NMR. [c]Diastereomeric mixture (*ca.* 1:1, estimated by $^1$H NMR). [d]t: trace.

To determine whether the rearranged dienes **2** were formed by an intermolecular or intramolecular 1,5-sulfenyl shift, we carried out the cross-over reaction of vinylcyclopropanes **1a** (131 mg, 0.5 mmol) and **1g** (132 mg, 0.5 mmol) with a catalytic amount of *p*-TsOH (0.01 mmol) in 5 ml of benzene under reflux (Scheme 2). An inseparable mixture of cross-coupled product

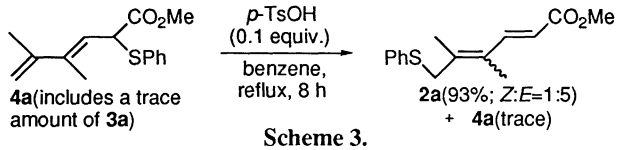



+ **2a**(*Z*:*E*=1:3) + **2g**(*Z*:*E*=1:4) + **3a** + **3g** + **4a** + **5a**

**2f**:**2c**:**2a**:**2g**:**3a**:**3g**:**4a**:**5a**=9:9:23:11:25:13:6:4, calculated by $^1$H NMR

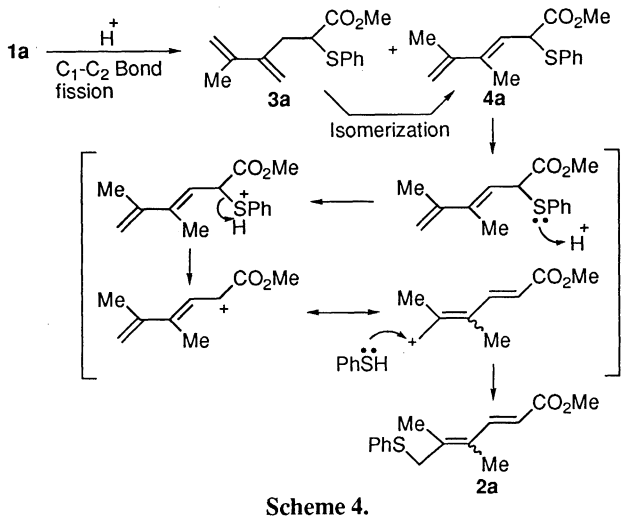
**Scheme 2.**

**2c** and normally rearranged diene **2a**, and that of another cross-coupled diene **2f** and noncross-coupled diene **2g** were isolated in 69 mg and 40 mg yields, respectively. Ring-opened dienes **3a**, **g** and **4a** were obtained as an inseparable mixture (92 mg) with a small amount of γ-lactone **5a**. This experiment revealed that the 1,5-sulfenyl shift proceeded intermolecularly. We also carried out the reaction of diene **4a** including a trace amount of **3a** (obtained from the reaction of **1a** with $CF_3SO_3H$, Table 1, entry 4) with 0.1 equiv. of *p*-TsOH (Scheme 3). The conjugated diene




**Scheme 3.**

**2a** was furnished in 93% yield. From these results, the plausible reaction mechanism for the 1,5-sulfenyl shift is assumed as shown in Scheme 4. The ring-opened dienes **3a** and **4a** are first formed by $C_1$-$C_2$ bond cleavage followed by deprotonation. The diene **3a** is isomerized to another diene **4a** under acidic conditions. Protonation on a sulfur atom of 2,4-pentadienyl sulfide **4a** followed by elimination of thiophenol gives cationic intermediates, which react with thiophenol at $C_6$ to provide **2a**.




**Scheme 4.**

In conclusion, the treatment of 1-acceptor-1-sulfenyl-substituted 2-vinylcyclopropanes with a sulfonic acid such as *p*-TsOH and $CF_3SO_3H$ in a nonpolar solvent efficiently caused the $C_1$-$C_2$ bond fission and the intramolecular 1,5-sulfenyl shift to give 6-sulfenyl-α,β-γ,δ-unsaturated carboxylic esters and nitriles.

## References and Note


1 J. R. Y. Salaün, *Top. Curr. Chem.*, **144**, 1 (1988); H.-U. Reißig, *Top. Curr. Chem.*, **144**, 73 (1988); I. Kuwajima and E. Nakamura, *Top. Curr. Chem.*, **155**, 1 (1990); R. R. Kostikov, A. P. Molchanov, and H. Hopf, *Top. Curr. Chem.* **155**, 41 (1990); H. N. C. Wong, M.-Y. Hou, C.-W. Tsu, Y.-C. Yip, J. Tanko, and T. Hudlicky, *Chem. Rev.*, **89**, 165 (1989); V. Nair, "Comprehensive Organic Synthesis," ed by B. M. Trost and I. Fleming, Pergamon Press, Oxford (1991), Vol. 4, p. 999.

2 T. Hudlicky, T. M. Kutchan, and S. M. Naqvi, *Org. React. (N. Y.)*, **33**, 247 (1985); Z. Goldschmidt and B. Crammer, *Chem. Soc. Rev.*, **17**, 229 (1988); T. Hudlicky and J. W. Reed, "Comprehensive Organic Synthesis," ed by B. M.Trost and I. Fleming, Pergamon Press, Oxford (1991), Vol. 5, p. 899.

3 H. Ishibashi, M. Okada, H. Nakatani, and M. Ikeda, *J. Chem. Soc., Perkin Trans. 1*, **1986**, 1763.

4 Y. Morizawa, T. Hiyama, K. Oshima, and H. Nozaki, *Bull. Chem. Soc. Jpn.*, **57**, 1123 (1984); D. A. Otieno, G. Pattenden, and C. R. Popplestone, *J. Chem. Soc., Perkin Trans 1*, **1977**, 196; L. Crombie, P. A. Firth, R. P. Houghton, D. A. Whiting, and D. K. Woods, *J. Chem. Soc., Perkin Trans 1*, **1972**, 642; G. Suzukamo, M. Fukao, and M. Tamura, *Tetrahedron Lett.*, **25**, 1595 (1984); Z. Goldshmidt and B. Crammer, *J. Chem. Soc., Perkin Trans. 1*, **1984**, 2697; N. F. Elmore, J. E. Roberts, and G. H. Whitham, *J. Chem. Res. (S)*, **1985**, 98.

5 S. Apparao, S. S. Bhattacharjee, H. Ila, and H. Junjappa, *J. Chem. Soc., Perkin Trans. 1*, **1985**, 641.

6 The relative configuration of **1a**, which agreed with the proposed structure from the mechanism for the vinylcyclopropanation,[3] was determined by the NOE technique.