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# Synthesis of polyfunctionalized vinyl cyclopropanes via the NaI-catalyzed ring-opening cyclization of doubly activated cyclopropenes with 1,1-bis(phenylsulfonyl)ethylene

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ABSTRACT

A NaI-catalyzed reaction of 3,3-bis(alkoxycarbonyl)cyclopropenes in the presence of 1,1-bis(phenylsulfonyl)ethylene providing an efficient route to a series of polyfunctionalized vinyl cyclopropanes is described. The reaction is general for a range of different 3,3-bis(alkoxycarbonyl)cyclopropenes affording the products in moderate to high yields. A plausible rationale for this transformation is discussed.



Cyclopropenes, which are highly strained but readily accessible carbocyclic molecules, have been shown to possess interesting reactivities in organic synthesis.[1–3] Functionalized cyclopropanes are important synthetic targets and common structural components in numerous biologically active natural products and pharmaceuticals.[4] Compounds containing cyclopropane fragments are valuable synthetic intermediates.[5,6] For example, functionalized vinyl cyclopropanes as a useful synthetic unit have been successfully used to prepare the core of yuremamine.[6] Some synthetic methods of functionalized cyclopropanes have been developed.[7,8] One of the most common methods is the transition metal-catalyzed cyclopropanation reaction of diazo compounds with olefins.[7]

In 2003, we described a regioselective cycloisomerization of cyclopropenyl ketones leading to 2,3,4-trisubstituted furans or 2,3,5-trisubstituted furans by using CuI or $PdCl_2(CH_3CN)_2$ as the catalysts, respectively.[9] In the same year, we noticed an $X^-$ (X = I, Br)-triggered ring-opening coupling reaction of cyclopropenyl carboxylates with organic halides providing an efficient and highly regio- and stereoselective route to a series of polyfunctionalized 1(*E*)-alkenyl halides.[10] However, in the presence of imines, the NaI-catalyzed reaction of cyclopropenyl carboxylates provided a highly regio- and stereoselective route to a series of polyfunctionalized vinyl aziridines.[11] Herein, we wish to further report a NaI-catalyzed reaction of cyclopropenyl carboxylates in the presence of 1,1-bis(phenylsulfonyl)ethylene providing a convenient route to a series of polysubstituted vinyl cyclopropanes.

As an initial trial, the reaction of dimethyl 2-butylcycloprop-2-ene-1,1-dicarboxylate **1a**, 1.0 equiv of 1,1-bis(phenylsulfonyl)ethylene **2**, and 1.0 equiv of NaI in the presence of 1.0 equiv of $Na_2CO_3$ in THF under reflux was studied. To our delight, the reaction took place smoothly to afford dimethyl 2-(1-(2,2-bis(phenylsulfonyl)cyclopropyl)pentylidene)malonate **3a** in 75% yield (Table 1, entry 1), the structure of which was established by its X-ray diffraction study (Fig. 1).[12] No reaction was observed in the absence of NaI (Table 1, entry 4). The reaction occurred smoothly with a catalytic amount of NaI (0.2 equiv). Control experiment indicated that the addition of $Na_2CO_3$ is not necessary in this case (Table 1, entry 6). Concerning the solvent, THF is the best for this transformation (Table 1, compare entries 7–15 with entry 6).

With the optimized reaction conditions in hand, the scope of the reaction was studied with some of the typical results being summarized in Table 2. With $R^1$ being alkyl, aryl, Bn, $PhCH_2CH_2$, protected alcohol, such as $TBSOCH_2CH_2CH_2$ or $THPOCH_2CH_2CH_2$ and $R^2$ being $CO_2Me$ or $CO_2Bn$, the reactions proceeded smoothly to afford the corresponding vinyl cyclopropanes in fairly good yields (Table 2, entries 1–9). However, for substrates with $R^1$ being *t*-Bu and $R^2$ being $CO_2Me$, no reaction occurred, and the starting material was recovered. Unfortunately, for substrates with $R^1$ being Ph or $n$-$C_4H_9$ and $R^2$ or $R^3$ being acyl, no expected product was formed. With $R^1$ being unprotected alcohol and $R^2$ being $CO_2Me$, the reactions were complicated.

A plausible mechanism for this transformation is depicted in Scheme 1. The regioselective nucleophilic attack of $I^-$ at the less substituted $sp^2$ carbon atom of cyclopropenes **1a** affords carbanion **4a,** which attacks the 1,1-bis(phenylsulfonyl)ethylene directly to afford **5a**. Subsequent intramolecular nucleophilic substitution leads to the formation of the three-membered compound **3a**.

In conclusion, we have developed a NaI-catalyzed ring-opening cyclization reaction of 3,3-bis(alkoxycarbonyl)cyclopropenes in the presence of 1,1-bis(phenylsulfonyl)ethylene providing a method for the synthesis of a series of polyfunctionalized vinyl

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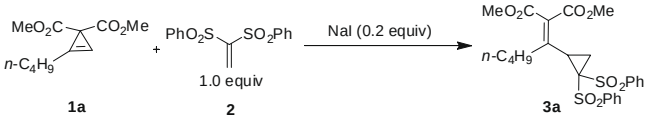
**Table 1**
Reaction of **1a** with **2** under different reaction conditions




1a 2 3a

| Entry | Solvent | Additive (X equiv $Na_2CO_3$) | Temp (°C) | Time (h) | Yield of **3a**[a] (%) |
|---|---|---|---|---|---|
| 1[b] | THF | 1.0 | Reflux | 1 | 75 |
| 2[b,c] | THF | 1.0 | Reflux | 1 | 81 |
| 3 | THF | 1.0 | Reflux | 1 | 77 |
| 4 | THF | 1.0 | Reflux | 17.6 | 0[d] |
| 5 | THF | 0.5 | Reflux | 1 | 78 |
| **6** | **THF** | **—** | **Reflux** | **1** | **81** |
| 7 | Acetone | — | Reflux | 11 | 70 |
| 8 | NMP | — | 60 | 10 | 67 |
| 9 | DCE | — | 60–80 | 24 | 52 |
| 10 | $CH_3CN$ | — | 60–80 | 24 | 46 |
| 11 | Toluene | — | 60-reflux | 24 | 45 |
| 12 | DMF | — | 60 | 24 | 32 |
| 13 | $CH_3NO_2$ | — | 60 | 11 | 0[e] |
| 14 | DME | — | 60 | 11 | 0[e] |
| 15 | Dioxane | — | 60-reflux | 26 | 0[f] |

[a] Isolated yield.
[b] 1.0 equiv of NaI was added.
[c] 1.2 equiv of **2** was added.
[d] The reaction was conducted in the absence of NaI, and 88% of **1a** was recovered after workup.
[e] The reaction was complicated.
[f] 69% of **1a** was recovered.

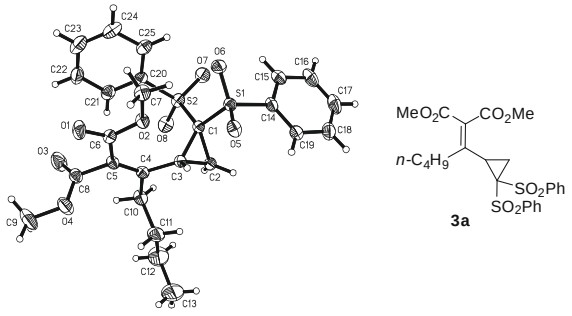
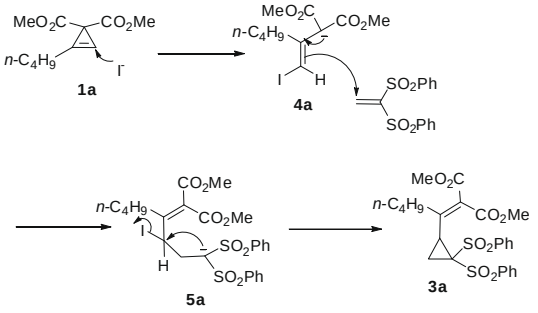


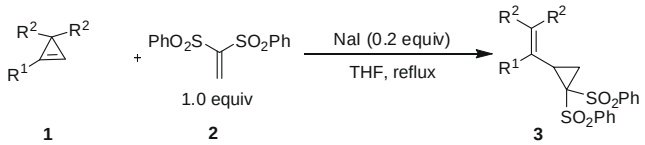

**Figure 1.** ORTEP representation of **3a**.




**Scheme 1.** Plausible mechanism of NaI-catalyzed ring-opening cyclization.

cyclopropanes. This reaction may be extended to other doubly activated or monoactivated alkenes, and further studies in this area are now being carried out in our laboratory.

**Table 2**
The reaction of cyclopropene **1** with **2**




1 2 3

| Entry | $R^1$ | $R^2$ | Time (h) | Yield of **3**[a] (%) |
|---|---|---|---|---|
| 1 | Ph | $CO_2Me$ (**1b**) | 2.7 | 76 (**3b**) |
| 2 | $TBSOCH_2CH_2CH_2$ | $CO_2Me$ (**1c**) | 1 | 75 (**3c**) |
| 3 | *p*-$MeC_6H_4$ | $CO_2Me$ (**1d**) | 2 | 81 (**3d**) |
| 4 | $THPOCH_2CH_2CH_2$ | $CO_2Me$ (**1e**) | 2.3 | 76 (**3e**) |
| 5 | *n*-$C_8H_{17}$ | $CO_2Me$ (**1f**) | 9 | 68 (**3f**) |
| 6 | Bn | $CO_2Me$ (**1g**) | 10 | 76 (**3g**) |
| 7 | $PhCH_2CH_2$ | $CO_2Me$ (**1h**) | 10 | 85 (**3h**) |
| 8 | *p*-$NO_2C_6H_4$ | $CO_2Me$ (**1i**) | 1 | 82 (**3i**) |
| 9 | *n*-$C_4H_9$ | $CO_2Bn$ (**1j**) | 9 | 68 (**3j**) |

[a] Isolated yield.

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## Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.tetlet.2009.01.097.

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12. *X-ray data for compound* **3a**: $C_{25}H_{28}O_8S_2$, $M_w$ = 520.59, monoclinic, space group *P*2(1)/*c*, Mo K$\alpha$, final *R* indices [$I > 2\sigma(I)$], $R_1$ = 0.0637, w$R_2$= 0.1548, *R* indices (all data), $R_1$ = 0.0842, w$R_2$ = 0.1662, $a$ = 22.0886 (19) Å, $b$ = 7.1012 (6) Å, $c$ = 16.2013 (14) Å, $\alpha$ = 90°, $\beta$ = 94.577 (2)°, $\gamma$ = 90°, $V$ = 2533.2(4) Å$^3$, $T$ = 293 (2) K, $Z$ = 4, reflections collected/unique: 14,261/5505 ($R_{int}$ = 0.0618), number of observation [>2$\sigma(I)$] 4193, parameters 319. Supplementary crystallographic data have been deposited at the Cambridge Crystallographic Data Center. CCDC: 712641.