CHEMISTRY LETTERS, pp. 937-940, 1993.

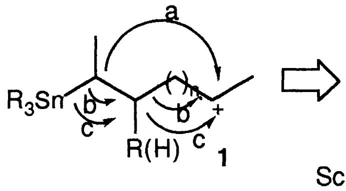
Lewis Acid-Induced Reactions of γ-Trialkylstannyl Ketones. Cyclization, Carbon-Carbon Bond Cleavage, and 1,5-Hydride Shift

Tadashi SATO,* Kazutaka TACHIBANA, Akira KAWASE, and Tomokazu HIROSE
Department of Applied Chemistry, Waseda University, Ookubo 3, Shinjuku-ku, Tokyo 169

γ-Trialkylstannyl ketones underwent cyclobutanation, C-C bond cleavage, or 1,5-hydride shift, depending upon the substitution pattern of the substrates.

Due to the latent carbanionic character of the carbon-tin bond, tin compounds containing cationic centers within the same molecule undergo various types of reactions.[1] Typical reaction types are cyclization (path a, Scheme 1), and 1,5-hydride shift through a cyclic transition state, or 1,2-alkyl shift through an antiperiplanar conformation of the tin atom and migrant (path c).[2] The reaction types are characteristically dependent upon (1) number and substitution patterns of the substituents, (2) distance between carbon-tin bond and cationic center (number of n in **1**), and (3) the nature of the Lewis acids. We have so far studied the chemistry of β-stannyl ketones,[3] and as an extension of the study, we now investigated the reaction of γ-stannyl ketones with various Lewis acids, and found that a carbon-carbon bond cleavage (path b) also competed under certain circumstances. The starting materials were conveniently prepared by the conjugate addition of the corresponding α-(trialkylstannyl)alkyl cuprates upon α,β-enones, which will be reported elsewhere.

Among several Lewis acids examined, trimethylsilyl phenyl sulfide (TMSSPh) in the presence of $TiCl_4$ induced a fairy clean reaction of the γ-stannyl ketones.[4] The reaction with six-membered substrates **2a** - **2c**



path a: cyclization
path b: bond cleavage
path c: alkyl or hydride shift

Scheme 1.

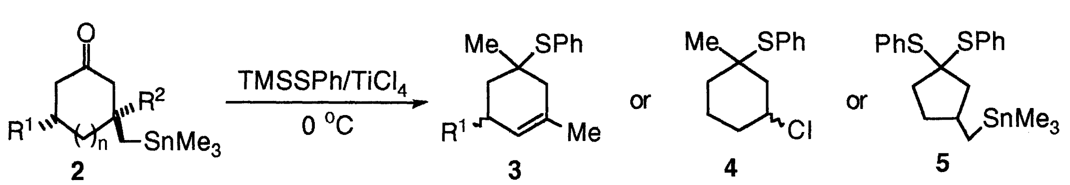
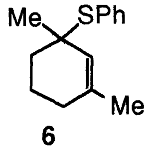


Table 1. TMSSPh-Induced Reaction of Cyclic γ-Stannyl Ketones **2**

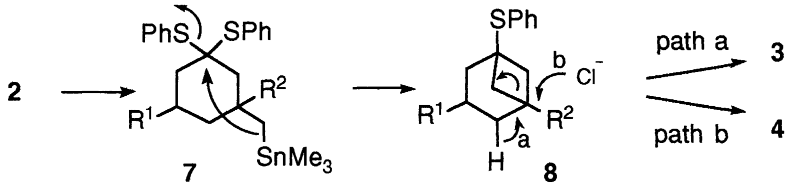
Run	Starting material					Product yield / %				
		d.r.[a]	R^1	R^2	n	**3**	(d.r.)[a]	**4**	(d.r.)[a]	**5**
1	**2a**	-	H	H	1	0		70	(10 : 1)	0
2	**2b**	-	H	Me	1	80	-	0		0
3	**2c**	1 : 0	Me	Me	1	50	(1.3 : 1)	0		0
4	**2d**	-	H	H	0	0		0		49

a) Diastereomer ratio.



6

was quite unique, resulting in the formation of methyl group at C-1 position to give **3** or **4**, as shown in runs 1 - 3 of Table 1. The structure **3b** was deduced in view of the spectroscopic data, particularly of NMR datum, which was quite similar to, but definitely different from that of **6**, obtained from 3-methyl-2-cyclohexen-1-one through reactions with methylmagnesium iodide followed by treatment with TMSSPh. Presumably the reaction might have been initiated by the thioketalization to **7**, followed by cyclization to **8**, and cyclobutane ring opening with either proton elimination from C-4 (path a, leading to **3b**/**3c**), or chloride attack at C-3 (path b, leading to **4**), depending upon whether R^2 = alkyl or H. Actually **7a** was isolated as an intermediate in the reaction of **2a** at −10 °C, which afforded **4** upon treatment with $TiCl_4$ at room temperature. It was found that the product **3c** was a 1 : 1.3 mixture of diastereomers, while the starting material **2c** was a single stereoisomer (*trans* with 5-methyl *vs.* 3-trimetylstannylmethyl group). The scrambling would be a support for the involvement of cyclobutane intermediate **8**, since the selectivity between the two possible pathways of the cyclobutane ring cleavage could hardly be expected. Another support for this reaction scheme is that the five-membered substrate **2d** did not undergo this type of reaction (run 4), affording only thioketal **5**. Understandably the cyclization to bicyclo[2.1.1] ring system should be an unfavorable path.



In contrast to the cyclobutanation observed with **2a** - **2c**, γ-stannyl ketones **9a** - **9d**, under the same conditions, underwent a bond cleavage to give **10**, sometimes accompanied by **11**, as shown in runs 5 - 8 of Table 2. However no bond cleavage occurred with **9e** (run 9), resulting in only thioketalization to **12**. Evidently the introduction of alkyl groups at α-position of the carbonyl group (**9a** - **9c**, $R^3 \neq$ H), or gem-dimethyl group in **9d** ($R^2 = R^4$ = Me) exerted a remarkable effect on the reaction pattern. Although the reactions under these

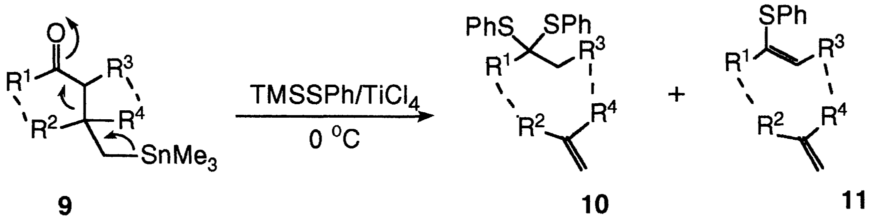


Table 2. TMSSPh-Induced Bond Cleavage of 9

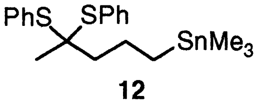
Run	Starting material						Product yield / %	
		d.r.[a]	R^1	R^2	R^3	R^4	10	11 (*trans/cis*)[b]
5	9a	1.4 : 1	-$(CH_2)_3$-		Me	H	15	23 (2.2 : 1)
6	9b	6 : 1	Me	H	-$(CH_2)_4$-		19	14 (1.6 : 1)
7	9c	1 : 1	Me	Me	-$(CH_2)_3$-		10	0
8	9d	-	Me	Me	H	Me	52[c]	0
9	9e	-	Me	H	H	H	0	0[d]

a) Diastereomer ratio.

b) *Trans/cis* ratio of the vinyl thioether moiety.

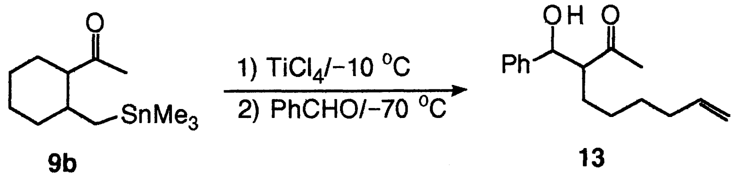
c) Acetone diphenylthioketal.

d)



12 59%

conditions are not clean, affording several byproducts, no products corresponding to **3** or **4** were identified. The bond cleavage of **9b** was induced by $TiCl_4$ alone, and when coupled with the reaction with benzaldehyde, it gave regiochemically defined aldol **13** in 40% yield from **9b** in one-pot.



The bond cleavage proceeded cleanly when ethylene ketals **14a** - **14c** were treated with $EtAlCl_2$,[5] as shown in Table 3, runs 10 - 12, while a 1,5-hydride shift also occurred with **14c** and **14d**. A datcaptive bond cleavage through electron pushing effect of the carbon-silicon bond and electron withdrawing effect of the carbonyl group was reported (Scheme 2).[6] However this reaction has been observed only with substrates of three or four-membered ring system, and probably the opening of the strained ring would be a driving force of this reaction. Notably the bond cleavage occurred with strain-free system with tin compounds. The bond fission seems to proceed stereospecifically, since the diastereomerically pure **17** (= **14a**) afforded *trans* olefin **18** (= **15a**) exclusively, while a 3 : 1 diastereomer mixture of **14b** afforded 3 : 1 mixture of *trans-cis* **15b**. The *trans* geometry of **18** was confirmed by referring to the large coupling constant (J = 18.3 Hz) of the olefinic protons (400 MHz ^1H NMR). The major isomer of **15b** was proved to have *trans* geometry by independent syntheses of the both isomers. In contrast to the smooth bond cleavage with **14**, their original ketones were recovered

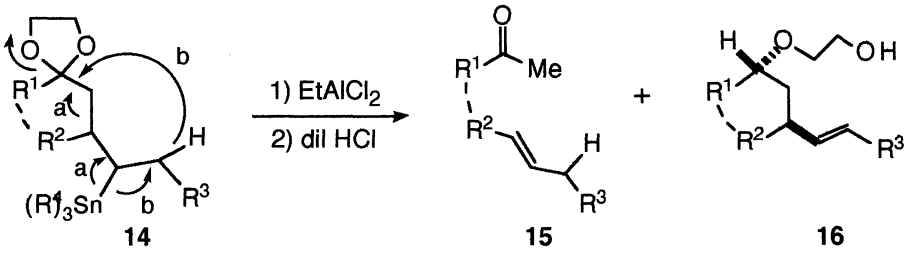
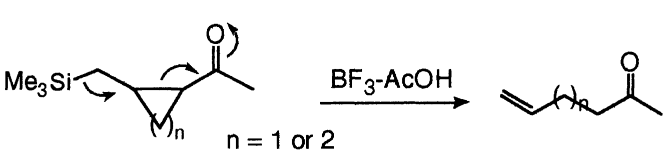


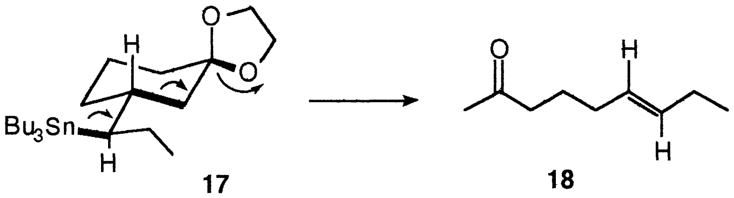
Table 3. $EtAlCl_2$-Induced Bond Cleavage *vs.* 1,5-Hydride Shift of **14**

Run	Starting material						Product yield / %	
		d.r.a)	R^1	R^2	R^3	R^4	15 (*trans/cis*)	16 (d.r.)a)
10	14a	1 : 0	-$(CH_2)_3$-		Me	Bu^n	54 (1 : 0)	0
11	14b	3 : 1	-$(CH_2)_3$-		H	Bu^n	70 (3 : 1)	0
12	14c	3 : 1	-$(CH_2)_2$-		Me	Bu^n	30 (1 : 0)b)	46 (1 : 0)
13	14d	-	Me	H	H	Me	0	67 -

a) Diastereomer ratio. b) Not determined.



Scheme 2.



Scheme 3.

unchanged under the same conditions, indicating that the antiperiplanar arrangement of the participating bonds (shown as bold) should facilitate the bond fission (Scheme 3). In view of the scheme, the stereochemistry of **17** was tentatively assigned as shown, assuming a concerted bond fission. The present reaction contrasts to the oxidative or radical Grob fragmentation of γ-stannyl alcohols,[7] which proceeds stereospecifically as shown in Scheme 4.

Scheme 4.

In our previous paper,[3] we reported that the 1,5-hydride shift proceeded with high stereoselectivity through a six-membered cyclic transition state, affording a single stereoisomer. In accord with the result, the product **16c** was also obtained as a single stereoisomer, to which we assigned *trans* structure concerning with two substituents at 1 and 3 positions.

This work was supported by The Grant-in-Aid for Scientific Research No. 03453033 from the Ministry of Education, Science and Culture.

References

1) T. Sato, *Synthesis*, **1990**, 259.
2) J. Fujiwara, M. Watanabe, and T. Sato, *Bull. Chem. Soc. Jpn.*, in press.
3) T. Sato, M. Hayashi, and T. Hayata, *Tetrahedron*, **48**, 4099 (1992).
4) Typical procedure: To a CH_2Cl_2 solution of **2** (0.568 mmol) was added TMSSPh (1.1 mmol) at 0 °C, and stirred for 40 min. $TiCl_4$ (0.570 mmol) was added slowly (10 min) at 0 °C, and stirred for another 30 min. The work-up afforded products.
5) Typical procedure: To a CH_2Cl_2 solution of **14** (0.467 mmol) was added a CH_2Cl_2 solution of $EtAlCl_2$ (1.868 mmol) at −78 °C. The solution was stirred for 1 h and quenched with brine. The CH_2Cl_2 extract was treated with 1 M HCl to hydrolyze the ketal.
6) M. Ochiai, K. Sumi, and E. Fujita, *Chem. Pharm. Bull.*, **31**, 3931 (1983); M. Ochiai, K. Sumi, and E. Fujita, *Chem. Lett.*, **1982**, 79.
7) M. Ochiai, T. Ukita, S. Iwaki, Y. Nagao, and E. Fujita, *J. Org. Chem.*, **54**, 4832 (1989); K. Nakatani and S. Isoe, *Tetrahedron Lett.*, **25**, 5335 (1984); J. E. Baldwin, R. M. Adlington, and R. Singh, *Tetrahedron*, **48**, 3385 (1992).

(Received February 24, 1993)