



Titanocene(II)-promoted reactions of thioacetals with ethylene: selective formation of terminal olefins with one- or two-carbon homologation

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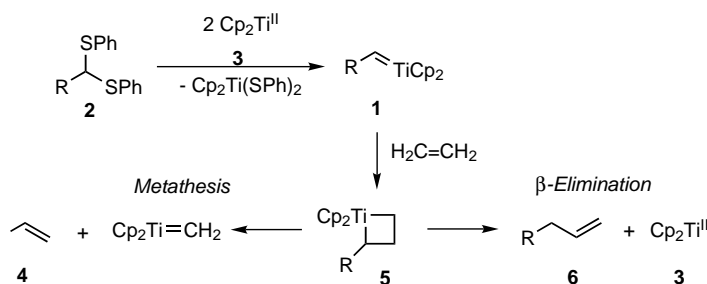
Abstract—Thioacetals are selectively transformed into two types of terminal olefins, one with one-carbon homologation and the other with two-carbon homologation, by treatment with a titanocene(II) species under ethylene. The mode of the reaction is controlled by changing the ligands coordinated to titanocene(II). © 2002 Elsevier Science Ltd. All rights reserved.

Methylenation of carbonyl compounds is a fundamental method for the preparation of terminal olefins; a number of procedures including the Wittig,¹ Horner–Wadsworth–Emmons,² and Peterson reactions,³ titanium-based methylenation,⁴ and the reaction of bis(iodozincio)methane⁵ have been developed for this transformation.

Recently, we reported the cross-metathesis between allylsilanes and titanium-alkylidene complexes **1** prepared by the desulfurization of thioacetals **2** with the titanocene(II) reagent $\text{Cp}_2\text{Ti}[\text{P}(\text{OEt})_3]_2$ **3a**.⁶ A similar metathesis between the carbene complexes **1** and ethylene giving terminal olefins **4** is of special interest because such a reaction is equivalent to the Wittig-type methylenation of ‘protected aldehydes.’ In this reaction, the methylene part of ethylene is introduced into the terminal olefin **4**

via the formation of titanacyclobutane intermediate **5** followed by the extrusion of methylidenetitanocene.⁷

Another conceivable mode of degradation of titanacyclobutanes **5** is the expulsion of a titanocene(II) species via β -elimination⁸ leading to the formation of terminal olefins **6** with two-carbon homologation. In the first report on the preparation and reactions of the Tebbe reagent, the formation of propene by the reaction of methylidenetitanocene with ethylene via a metalacycle intermediate was described.⁹ Despite the potential synthetic utility of this process, it has only been given scant attention until now. Here we describe selective transformation of thioacetals **2** to the two types of terminal olefins **4** and **6** by changing the titanocene(II) species **3** employed for generation of titanium-alkylidene complexes **1** (Scheme 1).



Scheme 1.

Keywords: β -elimination; carbene complexes; metathesis; terminal olefins; titanocene(II).

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When 3-benzyl-4-phenyl-1,1-bis(phenylthio)butane (**2a**) was treated with a triethyl phosphite complex of titanocene(II) **3a** (3 equiv.) under ethylene atmosphere at room temperature for 1.5 h, the terminal olefins, 4-benzyl-5-phenyl-1-pentene (**4a**) and 5-benzyl-6-phenyl-1-hexene (**6a**), were produced in 55 and 16% yields, respectively. The selective formation of **4a** was attained in an acceptable yield when the reaction was carried out at room temperature for 15 min and then at reflux in THF for 30 min (Table 1, entry 1). Under these conditions, desulfurization of several thioacetals with the titanocene(II) species **3a** was performed, and the olefins **4** were obtained as dominant products (Scheme 2). In the case of **2d**, the formation of the thermodynamically more stable internal olefin, 4-(dibenzylamino)-2-butene **7**, was observed. The formation of **7** might be attributable to the isomerization of **4d** by the action of titanocene(II).¹⁰ The present reaction showed tolerance to the γ -heteroatom functionalities such as *tert*-amines, ethers, and silyl ethers.

The following is a typical experimental procedure (Method A). Finely powdered molecular sieves 4 Å (90 mg), magnesium turnings (24 mg, 1 mmol; purchased from Nacalai Tesque Inc. Kyoto, Japan) and Cp_2TiCl_2 (224 mg, 0.9 mmol) were placed in a flask and dried by heating with a heat gun under reduced pressure (2–3 mmHg). After cooling, THF (1.5 ml) and $\text{P}(\text{OEt})_3$ (0.31 ml, 1.8 mmol) were added successively with stirring at room temperature under ethylene, and the reaction mixture was stirred for 3 h. A THF (0.9 ml) solution of **2a** (132 mg, 0.3 mmol) was added to the reaction mixture. After being stirred for 15 min at room temperature and then refluxed for 30 min, the reaction was quenched by addition of 1 M NaOH (30 ml). The insoluble materials were filtered off through celite and washed with ether (20 ml). The layers were separated, and the aqueous layer was extracted with ether (2×20 ml). The combined organic extracts were dried over Na_2SO_4 . The solvent was removed under atmospheric pressure, and the residue was purified by passing through a short silica gel column (hexane) and then PTLC [hexane and then hexane/ethyl acetate (98/2, v/v)] to yield 45 mg (65%) of **4a**.

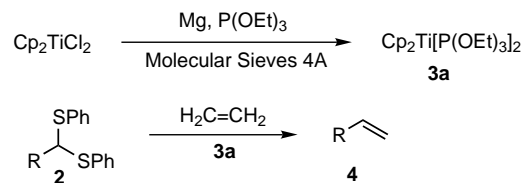
The β -elimination type degradation of titanacyclobutane **5** is extremely synthetically useful because it enables us to transform ‘protected aldehydes’ straightforward to the homologues of the Wittig-type methylenation products. To establish this process, we investigated the effect of the ligand coordinated to the titanium atom on the mode of degradation of titanacyclobutane intermediate **5**. The solution to this problem we found is the use of titanocene(II) species **3b** prepared by treatment of titanocene dichloride with 2 equiv. of *tert*-butyllithium.¹¹ As shown in Scheme 3, treatment of the thioacetal **2a** with **3b** under ethylene afforded the terminal olefin **6a** in 74% yield along with a small amount of the isomeric internal olefin **8a** (Table 2, entry 1). Similar reactions of various thioacetals **2** were performed and the terminal olefins **6** were obtained in good yields in all the cases examined. In certain cases, the use of hexamethylphosphoramide

Table 1. Transformation of thioacetals **2** into terminal olefins **4** with one-carbon homologation^a

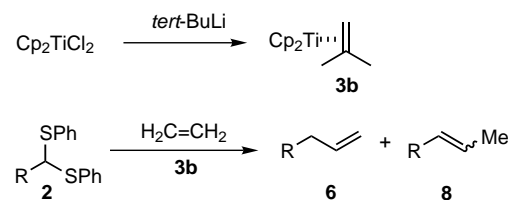
Entry	Thioacetal 2	Product (Yield / %)
1		 4a (65)
2		 4b (77)
3		 4c (65)
4 ^b		 4d (59) 7 (7)
5		 4e (54)
6		 4f (59)

^aAll reactions were carried out by method A.

^bThe product was obtained as a mixture of **4d**, **7**, and the homologous terminal olefin **6d** (2%). The yields of these compounds were determined by NMR analysis.

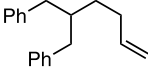
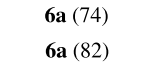
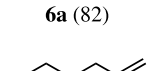
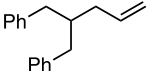
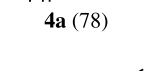
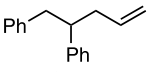
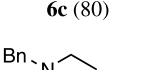
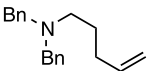
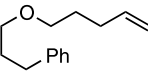
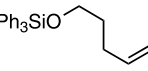


Scheme 2.



Scheme 3.

Table 2. Transformation of thioacetals **2** into terminal olefins **6** with two-carbon homologation^a

Entry	Thioacetal 2	Time / h ^b	Product (Yield / %) ^c
1	2a	2	 8a (5)  6a (74)
2 ^d	2a	0.5	 6a (82) 8a (5)
3	2b	1	 8b (4)  4a (78)
4	2c	1	 8c (7)  6c (80)
5	2d	2	 6d (73)
6 ^d	2e	2	 6e (84)
7	2f	2	 6f (60)

^aAll reactions were carried out by method B, unless otherwise noted.

^bThe reaction time after the reaction mixture was warmed up to 25°C.

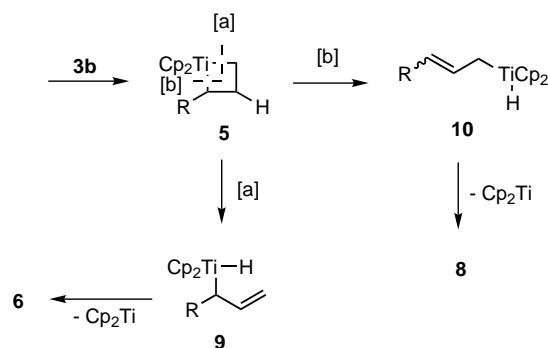
^cThe yields of the products obtained as a mixture of **6** and **8** were determined by NMR analysis.

^dHMPA (0.08 ml) was added at -50°C after addition of the thioacetals **2**.

(HMPA) as an additive improved the yield of **6** (see entry 2).

A typical experimental procedure (Method B) is as follows. To a THF (1.5 ml) suspension of Cp₂TiCl₂ (299 mg, 1.2 mmol) was added a pentane (2.0 ml) solution of *tert*-butyllithium (2.4 mmol) at -78°C. After 1 h, the reaction mixture was warmed up to -50°C. A THF (0.9 ml) solution of **2a** (132 mg, 0.3 mmol) was added at -50°C and then the reaction vessel was placed in a water bath (25°C). After being stirred for 30 min, the reaction was quenched by addition of 1 M NaOH (30 ml). The work-up described above gave a mixture of **6a** and its isomer, 5-benzyl-6-phenyl-2-hexene (**8a**) (65 mg). The yields of **6a** (74%) and **8a** (5%) were determined by NMR analysis.

Formation of the two types of olefins **6** and **8** might be explained by the following mechanism (Scheme 4). The β-elimination of the titanacyclobutane intermediate **5** through cleavage of the primary titanium–carbon bond in **5** (path [a]) affords a secondary allyltitanium species

**Scheme 4.**

9 which decomposes by reductive elimination to form the terminal olefin **6**. The minor isomer **8** would be produced via cleavage of the secondary titanium–carbon bond (path [b]).

In conclusion, we have found an interesting titanocene(II)-promoted olefination of thioacetals, by which two types of the terminal olefins with one- or two-carbon homologation were selectively produced using ethylene as a carbon source. The reaction mode (metathesis vs β-elimination) can be controlled by changing the ligand of the titanocene(II) species. Since thioacetals are readily prepared from various starting materials, this method provides a convenient way for the synthesis of terminal olefins. Further study on the reactions of thioacetals with a variety of olefins is currently under way.

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