Direct One-Pot Synthesis of 2,3-Diarylbuta-1,3-diene via Self-Coupling of Acetophenones

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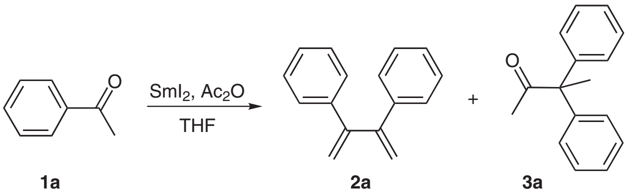
Abstract: A mild and straightforward route to 2,3-diarylbuta-1,3-diene is described here. By treatment with SmI_2–Ac_2O, acetophenone and its analogues underwent self-coupling reactions and subsequent elimination to give a series of 2,3-diarylbuta-1,3-dienes in moderate to good yields.

Key words: 2,3-diarylbuta-1,3-diene, self-coupling, acetophenone

As an important synthetic intermediate, 2,3-diarylbuta-1,3-dienes play an important role in organic chemistry.[1] Therefore, the efficient synthesis of these compounds continues to attract the interest of organic chemists. They can be prepared by palladium-catalyzed intermolecular coupling reactions of vinyl halides mediated by indium,[2] palladium-catalyzed reactions of propargyl carbonates with organoboron or organotin(IV) reagents,[3] dehydration of 2,3-diarylbutane-2,3-diol,[4] and copper(I)-catalyzed reactions of 1,4-disubstituted but-2-yne with Grignard reagents.[5] However, the use of expensive or toxic reagents, high reaction temperature (180 °C), and time-consuming multiple steps have limited the utility of these reactions in some cases.[2–4]

It has been well established that ketones and other carbonyl compounds could act as good starting materials for the preparation of olefins via McMurry coupling reactions.[6] On the other hand, the direct conversion into buta-1,3-dienes from ketones is rare and still remains a challenging subject. More recently, Taylor et al. have disclosed an interesting route to buta-1,3-dienes from ketones.[7] However, this method was not atom-economical as the ketones must be converted into their corresponding sulfonylhydrazones, which were then isolated and used for the next step. In addition, aromatic ketones only gave 2,3-diarylbuta-1,3-dienes in poor yields. As a result, the direct synthesis of 2,3-diarylbuta-1,3-diene from acetophenones is highly desirable. As a continuation of our interest in the synthesis of substituted alkenes,[8] herein we wish to report a mild and efficient approach to 2,3-diarylbuta-1,3-diene from acetophenones (Scheme 1).



Scheme 1

In an effort to develop a better reaction system, a variety of reaction parameters were screened for self-coupling of acetophenone (**1a**) to yield 2,3-diphenylbuta-1,3-diene (**2a**) and the results are presented in Table 1. The readily prepared SmI_2 solution in THF was added dropwise to a suspension of acetophenone under a nitrogen atmosphere. After the **1a** was consumed completely (as detected by TLC), acetic anhydride was added to the mixture until the reaction was complete. As showed in Table 1, SmI_2 (1 mmol) combined with acetic anhydride (1.2 mmol) in THF under reflux showed the highest catalytic activity, giving **2a** together with the rearranged ketone **3a** (Table 1, entry 3). When the reaction was conducted in the presence of 0.05 equivalent or 0.5 equivalent of acetic anhydride, buta-1,3-diene **2a** was isolated in low yield (Table 1, entries 4 and 5). In the absence of acetic anhydride, no coupling product was observed and the pinacol was obtained exclusively (Table 1, entry 6). Furthermore, the reaction time was dependent on the reaction temperature (Table 1, entries 1–3). Accordingly, the process was accelerated significantly at higher reaction temperatures.

We chose a variety of structurally diverse acetophenones to understand the scope and the generality of the SmI_2–Ac_2O-promoted coupling reaction to yield 2,3-diarylbuta-

Table 1 Screening Reaction Parameters for the Synthesis of 2,3-Diphenylbuta-1,3-diene[a]

Entry	Ac_2O (equiv)	Temp	Time (h)	Yield (%)[b]	
				2a	**3a**
1	1.2	r.t.	20	12	60
2	1.2	50 °C	8	43	50
3	1.2	reflux	3	78	18
4	0.5	reflux	10	42	25
5	0.05	reflux	48	5	15
6	none	reflux	72	0	0

[a] Unless otherwise noted, all reactions were carried out with **1a** (1 mmol) in the presence of SmI_2 (1 equiv).
[b] Isolated yields.

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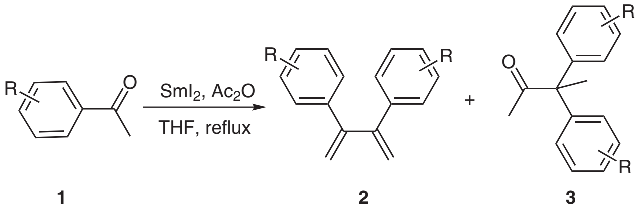


Scheme 2

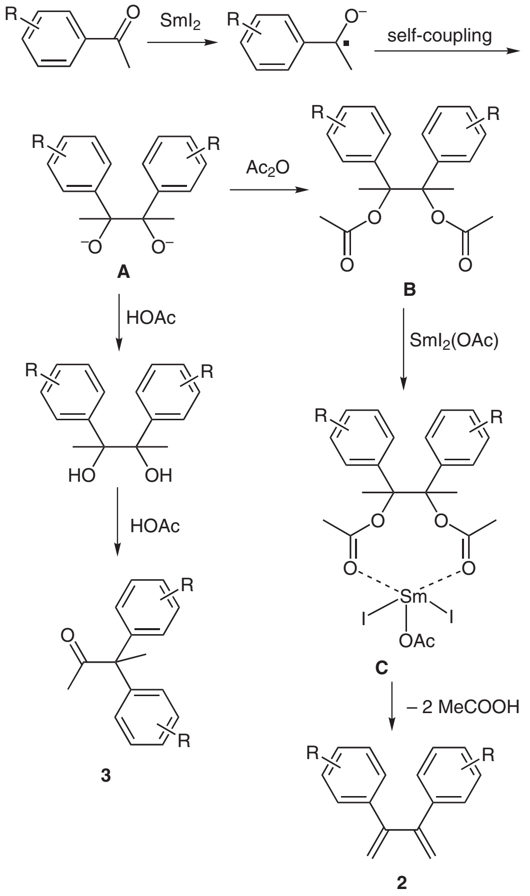
1,3-diene under the optimal reaction conditions (Scheme 2) and the results are summarized in Table 2. We were pleased to find that the reactions proceeded smoothly to produce the desired buta-1,3-dienes **2** in good yields (method A). As can be seen, the present conversion was susceptible to electronic factors. In the presence of an electron-donating group, the desired products **2** were obtained in higher yields within short time (Table 2, entries 2–4). In contrast, when electron-deficient substrates were utilized, the reaction became sluggish and resulted in lower product yield (Table 2, entry 6). In particular, when the 4-bromo-substituted substrate was used, the corresponding diene could not be isolated and only a complex mixture was obtained even with prolonged reaction time (Table 2, entry 7). However, this problem could be resolved by using method B (Table 2, entries 8 and 9). Hence, after the reaction of 4-chloro- or 4-bromo-substituted acetophenone with SmI$_2$ in THF was complete under the optimized reaction conditions, THF was removed under reduced pressure, then MeCN and Ac$_2$O were added successively, and the resulting mixture was stirred under reflux to afford the corresponding diene (method B). Moreover, it should be noted that the electron-donating group 2-methyl gave rise to a low yield of the corresponding buta-1,3-diene (47%), which may be attributed to steric hindrance. According to the above reaction results, the current optimal conditions were superior for the following reasons: (1) In all cases, only 1 mmol of samarium diiodide was needed. (2) The reaction time was significantly shortened especially when electron-rich substrates were used. (3) No formation of McMurry coupling product was observed and the desired 2,3-diarylbuta-1,3-dienes were obtained as the major products.

It has been well known that samarium diiodide can promote the coupling reaction of carbonyl compounds efficiently,[9] and the formation of pinacol-type coupling species was also detected during our investigations. Accordingly, we suggest that the formation of the corresponding buta-1,3-dienes proceeded via the pinacol-type dianion intermediate **A**. The reactive dianion is rapidly captured by acetic anhydride to form a diacetate **B**, which undergoes double elimination to give product **2**. Although we are not clear about the exact nature, we believe that the presence of Sm(III) species play a significant role in this process. The chelation of the trivalent samarium with oxygen (intermediate **C**) facilitates the cleavage of the C–O bond to give the final product. Also, rearrangement of **A** gives product **3** in the presence of acetic acid (Scheme 3).

Table 2 SmI$_2$–Ac$_2$O-Mediated Syntheses of 2,3-Diarylbuta-1,3-dienes from Acetophenones

Entry	R	Time (h)	Yield (%)[c]	
			2	**3**
1[a]	H	3	78	18
2[a]	4-MeO	2	88	10
3[a]	3-MeO	1	69	16
4[a]	4-Me	2	77	20
5[a]	2-Me	5	47	33
6[a]	4-Cl	18	37	10
7[a]	4-Br	24	–[d]	–[d]
8[b]	4-Cl	20	62	14
9[b]	4-Br	24	43	10

[a] Method A.
[b] Method B.
[c] Isolated yields.
[d] In this case, a very complex mixture was produced.



Scheme 3

To verify our proposition, further investigations on the reaction mechanism are underway in our laboratory.

In conclusion, we have developed a mild and efficient method for the construction of 2,3-diarylbuta-1,3-dienes in moderate to good yields, using SmI_2–Ac_2O system.[10] A variety of acetophenones were converted directly into the corresponding 2,3-diarylbuta-1,3-dienes, which makes this method superior to most existing reports. The simple operation and mild conditions also add to its attractiveness. In this regard, we believe that our method will find use in organic synthesis.

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References and Notes

(1) (a) Boehrner, J.; Grigg, R. *Tetrahedron* **1999**, *55*, 13463. (b) Shimizu, H.; Hatano, T.; Matsuda, T.; Iwamura, T. *Tetrahedron Lett.* **1999**, *40*, 1505. (c) Ikeda, Z.; Oshima, K.; Matsubara, S. *Org. Lett.* **2005**, *7*, 4859. (d) Abu-Yousef, I. A.; Harpp, D. N. *J. Org. Chem.* **1997**, *62*, 8366. (e) Paik, I. H.; Xie, S.; Shapiro, T. O.; Labonte, T.; Sarjeant, A. A. N.; Baege, A. C.; Posner, G. H. *J. Med. Chem.* **2006**, *49*, 2731. (f) Takahashi, T.; Xi, Z.; Fischer, R.; Huo, S.; Xi, C.; Nakajima, K. *J. Am. Chem. Soc.* **1997**, *119*, 4561. (g) Dell, C. P. *J. Chem. Soc., Perkin Trans. 1* **1998**, 3867.

(2) Lee, P. H.; Seomoon, D.; Lee, K. *Org. Lett.* **2005**, *7*, 343.

(3) Bohmer, J.; Grigg, R. *Tetrahedron* **1999**, *55*, 13463.

(4) (a) Dodson, R. M.; Srinivasan, V.; Sharma, K. S.; Sauers, R. F. *J. Org. Chem.* **1972**, *37*, 2367. (b) Baldwin, J. E.; Lusch, M. J. *J. Org. Chem.* **1979**, *44*, 1923. (c) Johlin, J. M. *J. Am. Chem. Soc.* **1917**, *39*, 292. (d) Iwai, I.; Ide, J. *Org. Synth., Coll. Vol. VI*; Wiley: New York, **1988**, 531. (e) Alder, K.; Haydn, J. *Justus Liebigs Ann. Chem.* **1950**, *570*, 201. (f) Wagner, R. A.; Brinker, U. H. *Synthesis* **2001**, 376.

(5) Ishino, Y.; Nishiguchi, I.; Takihira, F.; Hirashima, T. *Tetrahedron Lett.* **1980**, *21*, 1527.

(6) (a) McMurry, J. E.; Felming, M. P. *J. Am. Chem. Soc.* **1974**, *96*, 4708. (b) Mukaiyama, T.; Sato, T.; Hanna, J. *Chem. Lett.* **1973**, *2*, 1041. (c) Fürstner, A.; Bogdanovic, B. *Angew. Chem. Int. Ed.* **1996**, *35*, 2442. (d) McMurry, J. E. *Chem. Rev.* **1989**, *89*, 1513. (e) Lenoir, D. *Synthesis* **1989**, 883. (f) Duan, X. F.; Zeng, J.; Lu, J. W.; Zhang, Z. B. *J. Org. Chem.* **2006**, *71*, 9873.

(7) Addie, M. S.; Taylor, R. J. K. *ARKIVOC* **2000**, *(v)*, 660.

(8) (a) Li, J.; Xu, X. X.; Zhang, Y. M. *Tetrahedron Lett.* **2003**, *44*, 9349. (b) Li, J.; Wang, X. X.; Zhang, Y. M. *Tetrahedron* **2004**, *60*, 5793.

(9) (a) Namy, J. L.; Kagan, H. B. *Tetrahedron Lett.* **1983**, *24*, 765. (b) Molander, G. A.; Etter, J. B.; Harring, L. S.; Thorel, P. J. *J. Am. Chem. Soc.* **1991**, *113*, 8036. (c) Fuchs, J. R.; Mitchell, M. L.; Shabangi, M.; Flowers, R. A. *Tetrahedron Lett.* **1997**, *38*, 8157. (d) Chiara, J. L.; Cabri, W.; Hanessian, S. *Tetrahedron Lett.* **1991**, *32*, 1125. (e) Uenishi, J.; Masuda, S.; Wakabayashi, S. *Tetrahedron Lett.* **1991**, *32*, 5097.

(10) **General Procedure for the Synthesis of 2,3-Diarylbuta-1,3-dienes (Method A)**: To the stirred acetophenone or its analogues **1** (1 mmol) in an oven-dried glassware under a nitrogen atmosphere, samarium diiodide (1 mmol) in THF (15 mL) was added dropwise. Generally the reaction finished within 15 min. After the deep blue color faded, Ac_2O (1.2 mmol) was added to the yellow mixture rapidly. The reaction mixture was stirred under reflux until reaction completion. After the usual workup, the crude product was purified by silica gel column chromatography using EtOAc–PE (1:20) as eluent to afford the corresponding pure buta-1,3-diene **2**.

General Procedure for the Synthesis of 2,3-Bis(4-bromophenyl)buta-1,3-diene and 2,3-Bis(4-chlorophenyl)buta-1,3-diene (Method B): To the stirred 4-chloro- or 4-bromo-substituted acetophenone (1 mmol) in an oven-dried glassware under a nitrogen atmosphere, samarium diiodide (1 mmol) in THF (15 mL) was added dropwise. Generally the reaction finished within 15 min. After the deep blue color faded, THF was removed under reduced pressure, then MeCN (3 mL) and Ac_2O (3.0 mmol) were added to the yellow mixture successively, and the resulting mixture was stirred under reflux until reaction completion. After the usual workup, the crude product was purified by silica gel column chromatography using EtOAc–PE (1:20) as eluent to afford the corresponding diene.