ORGANIC
LETTERS

2006
Vol. 8, No. 18
4085−4088

A Convenient Synthesis of Symmetric 1,2-Diarylethenes from Arylmethyl Phosphonium Salts

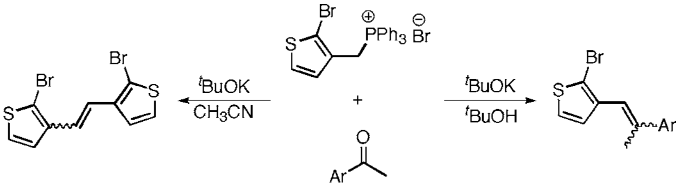
Julius N. Ngwendson, Walters N. Atemnkeng, Cassandra M. Schultze, and Anamitro Banerjee*

Department of Chemistry, University of North Dakota,
Grand Forks, North Dakota 58202-9024

abanerjee@chem.und.edu

Received June 28, 2006

ABSTRACT



Symmetric ethenyldithiophenes are important intermediates for synthesis of photochromic materials and organic conductors. When acetonitrile is used as a solvent, 3-methylthiophenylphosphonium salts form symmetric ethenyldithiophenes in the presence of a strong base (e.g., NaH, ^{t}BuOK) in moderate to high yields. This homocoupling reaction is faster than a Wittig reaction with aromatic ketones in acetonitrile. Our study shows that the presence of polar aprotic solvents promotes the homocoupling reaction.

Arylethenylthiophenes are important building blocks for photochromic compounds,[1] organic conductors,[2] and molecular switching devices.[3] While a variety of these compounds are commercially available, the importance and the potential applicability of these compounds are demonstrated by the fact that new compounds are still frequently reported in the literature.[4,5] Arylethenylthiophenes have been prepared by decarbonative Heck olefination,[6] Suzuki−Miyaura cross-coupling,[7] and Wittig reactions.[8] New and simple synthetic routes for these compounds will help researchers in synthesizing these compounds in efficient and cost-effective ways.

During our attempts to synthesize arylethenylthiophenes via a Wittig reaction, we discovered a solvent dependence of this reaction when 3-methylthiophenylphosphonium salts and its derivatives were used. We found that these phosphonium salts in the presence of a base in some solvents underwent a homocoupling reaction to form the symmetric ethenyldithiophenes in very high yields. When polar aprotic solvents were used in sufficient quantities along with multiple equivalents of base, other symmetric 1,2-diarylethenes could be synthesized via this homocoupling reaction.

When acetonitrile was used as a solvent, the phosphonium salt **1** reacted with benzaldehyde in the presence of a base

---

[1] (a) Irie, M.; Miyatake, O.; Uchida, K. *J. Am. Chem. Soc.* **1992**, *114*, 8715−8716. (b) Crano, J. C.; Guglielmetti, R. J. *Organic Photochromic and Thermochromic Compounds*; Vol. 1, Photochromic Families; Plenum Press: New York, 1999.

[2] (a) Martin, R. E.; Wytko, J. A.; Diederich, F.; Boudon, C.; Gisselbrecht, J. P.; Gross, P. *Helv. Chim. Acta* **1999**, *82*, 1470−1485. (b) Pearson, D. L.; Tour, J. M. *J. Org. Chem.*, **1997**, *62*, 1376−1387. (c) Jonas, F.; Schrader, L. *Synth. Met.* **1991**, *41*, 831−836.

[3] Guirado, G.; Coudret, C.; Hliwa, M.; Launay, J.-P. *J. Phys. Chem. B* **2005**, *109*, 17445−17459.

[4] (a) Li, X.; Tian, H. *Tetrahedron Lett.* **2005**, *46*, 5409−5412. (b) Li, X.; Tian, H. *Macromol. Chem. Phys.* **2005**, *206*, 1769−1777. (c) De Jong, J. J. D.; Tiemersma-Wegman, T. D.; Van Esch, J. H.; Feringa, B. L. *J. Am. Chem. Soc.* **2005**, *127*, 13804−13805. (d) Higashiguchi, K.; Matsuda, K.; Tanifuji, N.; Irie, M. *J. Am. Chem. Soc.* **2005**, *127*, 8922−8923 and references therein.

[5] (a) Choi, H.; Lee, H.; Kang, Y.; Kim, E.; Kang, S. O.; Ko, J. *J. Org. Chem.* **2005**, *70*, 8291−8297. (b) Lemieux, V.; Branda, N. R. *Org. Lett.* **2005**, *7*, 2969−2972. (c) Han, Y.; Zhang, Z. B.; Xiao, J. P.; Yan, W. P.; Fan, M. G. *Chin. Chem. Lett.* **2005**, *16*, 175−178.

[6] Goossen, L. J.; Paetzold, J. *Angew. Chem., Int. Ed.* **2004**, *43*, 1095−1098.

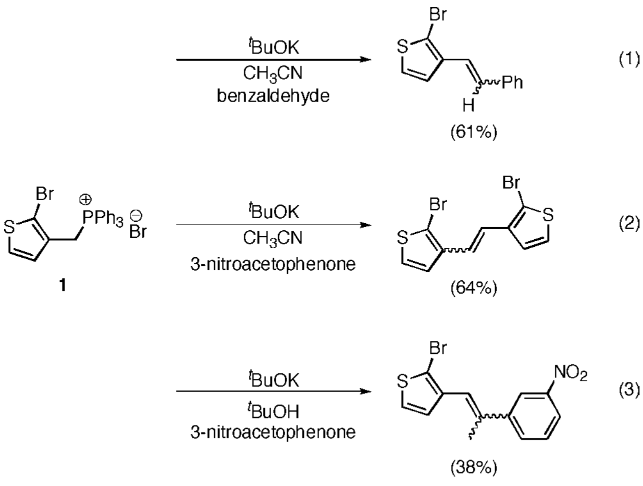
[7] Molander, G. A.; Bernardi, C. R. *J. Org. Chem.* **2002**, *67*, 8424−8429.

[8] (a) Cho, H.; Kim, E. *Macromolecules* **2002**, *35*, 8684−8687. (b) Kellog, R. M.; Groen, M. B.; Wynberg, H. *J. Org. Chem.* **1967**, *32*, 3093−3100.

10.1021/ol061594z CCC: $33.50

to produce the expected Wittig product, 2-bromo-3-styrylthiophene, in 61% yield as the major product (Scheme 1 eq 1). This is consistent with literature reports of the reaction of **1** with aldehydes in THF as solvent.[9] However, when **1** was treated with the base and reacted with acetophenone or 3-nitroacetophenone in acetonitrile, no products due to the Wittig reaction could be detected. Following analysis of the reaction mixture when 3-nitroacetophenone was used, only the homocoupling product and triphenylphosphine were detected (Scheme 1, eq 2). When the reaction was carried out in *tert*-butyl alcohol, the expected Wittig product was obtained (Scheme 1, eq 3). TLC analysis of the reaction mixture for eqs 1 and 3 indicated the presence of the homocoupling products in trace amounts. We wanted to exploit the results in eq 2 as a convenient way to synthesize symmetric ethenyldithiophenes.

Scheme 1. Homocoupling vs Wittig Reaction



The phosphonium salts (except **6**, which was obtained commercially) were synthesized from the corresponding methylthiophenes. The methylthiophenes were brominated with *N*-bromosuccinimide in the presence of benzoyl peroxide, and then treated with triphenylphosphine.[9,10] For the synthesis of compound **4**, 3-methylthiophene was first nitrated, using literature procedures,[11] followed by bromination and treatment with triphenylphosphine.

The phosphonium salt **1** was found to be stable in acetonitrile, which ruled out a direct interaction of **1** with solvent. However, in the presence of a base, we found that the starting material decomposed leading to the formation of the homocoupling product and triphenylphosphine. Typically, the phosphonium salt (50−70 mg) was dissolved in 10 mL of acetonitrile, and the solution was cooled to 0 °C. When larger amounts of the phosphonium salts were used, 200 mL of the solvent was used to dissolve the reagents. The base was then slowly added to solution. The reaction mixture was then stirred for 1 h (2 h when 200 mL of solvent was used) while allowing it to warm to room temperature. The solvent was then evaporated, and the products were separated from the triphenylphosphine byproduct and the unreacted starting material, using silica gel chromatography with hexanes as eluent, and characterized by NMR. The purity of the products was determined by GC-MS. The *E*:*Z* ratio was determined by integrating the alkenyl H peaks in the ^{1}H NMR spectrum (except in the case of the homocoupling reaction with **6** when the product distribution was assigned based on the peak integrations of GC). Table 1 lists the results of the reactions of various phosphonium salts with bases in acetonitrile. When **2** and its 2-bromo derivative **1** were treated with base in acetonitrile, 60−70% yields of the homocoupling products were obtained. Reaction of **2** with NaH in acetonitrile gave nearly quantitative yields of the product. Castle and co-workers synthesized 1,2-bis(3,3′-benzo[*b*]thienyl)ethane by the Wadsworth−Emmons reaction of diethyl 3-benzo[*b*]thienylphosphonate with benzo[*b*]-thiophene-3-carbaldehyde using NaH as a base in 83% yield.[12] However, using the homocoupling reaction of **3** with *t*-BuOK, we obtained the desired product in a comparable 78% yield. When **6** was stirred with *t*-BuOK in acetonitrile for 1 h, only 29% *E*-stilbene was obtained.[13] When **5** was subjected to similar conditions, only 21% yield of the homocoupling product was obtained. In both cases, large quantities of unreacted starting phosphonium salts were recovered. On the basis of these observations, it appears that the homocoupling reaction is specific to **2** and its derivatives. However, when a larger volume of the solvent was used, the homocoupling yields increased substantially. An additional equivalent of the base also helped improve the yields. For example, stilbene was obtained in 64% yield from **6** when 2 equiv of base and 200 mL of acetonitrile were used. Similarly 30−60% of homocoupling products were obtained from **7** and **8** when 200 mL of solvent was used. When 2 equiv of the NaH was used, quantitative yields of the homocoupling products were obtained from **7**. However, when an electron withdrawing group was present in the aromatic ring, e.g. **4**, no homocoupling product could be detected. This lack of reactivity could be attributed to the lower nucleophilicity of the resulting ylide.

Scheme 2 describes a possible mechanism for this reaction. The phosphonium salt reacts with the base to form the ylide **A**. The ylide then reacts with another equivalent of the phosphonium salt to form the intermediate **B**, which then

---

[9] Archer, W. J.; Cook, R.; Taylor, R. *J. Chem. Soc., Perkin Trans. 2* **1983**, 813−819.

[10] (a) Campaigne, E. E.; Tullar, B. F. *Org. Synth.* **1953**, *33*, 96−98. (b) Munro, D. P.; Sharp, J. T. *J. Chem. Soc., Perkin Trans. 1* **1980**, 1718−1723.

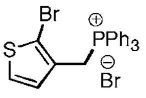
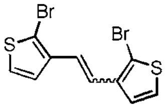
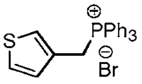
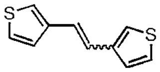
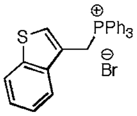
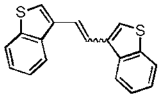
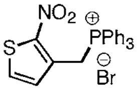
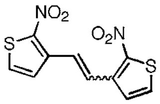
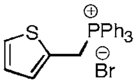
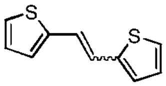
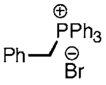
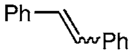
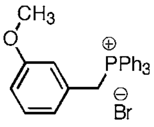
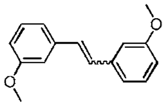
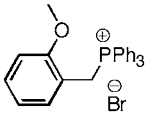
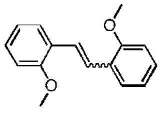
[11] (a) Threadgill, M. D.; Webb, P.; O'Neill, P.; Naylor, M. A.; Stephens, M. A.; Stratford, I. J.; Cole, S.; Adams, G. E.; Fielden, E. M. *J. Med. Chem.* **1991**, *34*, 2112−2120. (b) Snyder, H. R.; Carpino, L. A.; Zack, J. F.; Mills, J. F. *J. Am. Chem. Soc.* **1957**, *79*, 2556−2559.

[12] Kudo, H.; Tedjamulia, M. L.; Castle, R. N.; Lee, M. L. *J. Heterocycl. Chem.* **1984**, *21*, 185−192.

[13] GC-MS analysis of the isolated product showed one major peak. The EI-MS of this peak corresponds to the MS of authentic stilbene samples. ^{1}H NMR of the isolated product when compared to the spectra of authentic compounds (*The Aldrich Library of NMR Spectra*, 2nd ed.; Pouchert, C. J., Ed.; Aldrich Chemical Co., Inc.: Milwaukee, WI, 1983; Vol. 1, p 752 A−B) indicated it to be *trans*-stilbene while the *cis*-stilbene could not be detected in ^{1}H NMR.

[14] Vogel, A. I. *Textbook of Practical Organic Chemistry*, 4th ed.; Longman Group Limited: London, UK, 1978; p 1371.

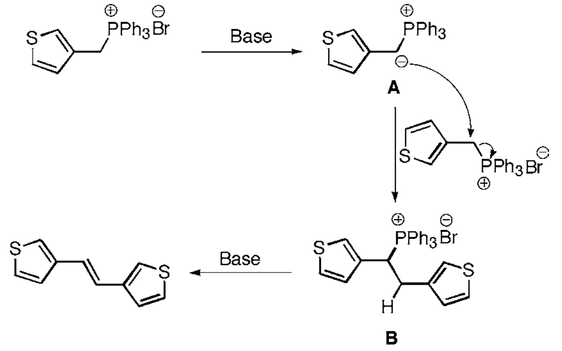
Table 1. Homocoupling of Phosphonium Salts in the Presence of a Base

salt	base	product	yield (%)	*E*:*Z*
 **1**	^{t}BuOK NaH		61 64	1:1.7 1:1.7
 **2**	^{t}BuOK NaH		68 91	1:0 1:0
 **3**	^{t}BuOK NaH		78 47	1:0 1:1
 **4**	^{t}BuOK		0	-
 **5**	^{t}BuOK		21	1:0
 **6**	^{t}BuOK		29 64^a	1:0.1 1:1.3
 **7**	^{t}BuOK NaH		59 48 100^a	1:1 1:1.2 1:1.1
 **8**	^{t}BuOK NaH		39 33	1:3.4 1:3.4

[a] 200 mL of CH_3CN and 2 equiv of the base were used.

undergoes an elimination reaction to form the product. The byproduct triphenylphosphine was isolated in about 20% yield. The presence of the ylide **A** can be confirmed by the fact that **1** undergoes a Wittig reaction with benzaldehyde in acetonitrile. All attempts to isolate the intermediate **B** have been futile so far since it is difficult to separate from the starting compounds.

Scheme 2. Proposed Mechanism of the Homocoupling Reaction



Scheme 1 indicated that the solvent could influence the course of the reaction when 3-methylthiophenylphosphonium salts and its derivatives were subjected to basic conditions. One important property of a solvent that can influence the solubility of the phosphonium salts or the efficiency of the substitution reaction (step 1 of the proposed mechanism) is its dielectric constant. We carried out the homocoupling reaction of **1** with *t*-BuOK in a variety of different solvents, the results of which are shown in Table 2. All the aprotic solvents led to the formation of the homocoupling product, whereas the use of methanol as a solvent resulted in the formation of trace amounts of the product after 48 h (detected by TLC). The *E*:*Z* ratio of the homocoupling products were not affected by the solvents. A plot of the homocoupling yield as a function of dielectric constant of the solvent (Figure 1) shows a roughly linear dependence. Only DMF, with a dielectric constant of 36.7, led to lower than expected yields of the homocoupling product. One possible explanation could be that the presence of water in the solvent may have quenched the ylide. While protic solvents resulted in Wittig reactions (Scheme 1), they did not support the homocoupling reaction even when they completely dissolved the phosphonium salt. These results led us to believe that the high dielectric constant of the solvent not only enhances the solubility of the starting compounds, but also influences the course of the reaction.

Table 2. Homocoupling Reaction of **1** with *t*-BuOK in Different Solvents

solvent	dielectric constant[14]	time (h)	yield (%)
DMSO	46.7	1	71
MeCN	37.5	1	61
DMF	36.7	1	34
MeOH	32.7	48	trace
THF	7.6	1	34
benzene	2.9	1	29

This homocoupling reaction is an efficient way to synthesize symmetric diarylalkenes, the simplicity of the reaction being a major advantage. While this reaction is very efficient for **2** and its derivatives, the conditions can be optimized to obtain high yields of homocoupling reaction for other phosphonim salts. In polar aprotic solvents, a moderate to

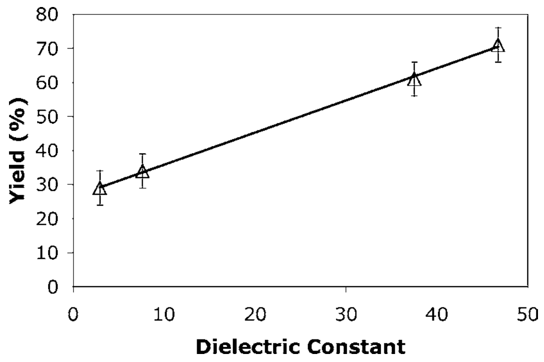


Figure 1. Yield of the homocoupling reaction of **1** with *t*-BuOK vs dielectric constant of the solvent. Yields from methanol and DMF as solvents are not included.

high yield of the product is obtained. We are currently optimizing the conditions (solvents, number of equivalents of base, temperature, etc.). While the polar aprotic solvents favor the homocoupling reaction over the Wittig reaction for **1**, we have no evidence of a similar behavior by the other salts studied so far. These results will be reported in the future.

Acknowledgment. The authors thank the Department of Chemistry, University of North Dakota for financial support. C.M.S. was also supported by the ND EPSCoR AURA program (NSF-EPS-0447679). Authors also thank Ms. Judy L. Miska, Shirin Naderipour, and the students of Chem 341L Summer 2006 DEDP for their help in the synthesis of some of the starting compounds.

Supporting Information Available: Experimental procedures and spectral data for all the materials and GC-MS of the isolated homocoupling products. This material is available free of charge via the Internet at http://pubs.acs.org.

OL061594Z