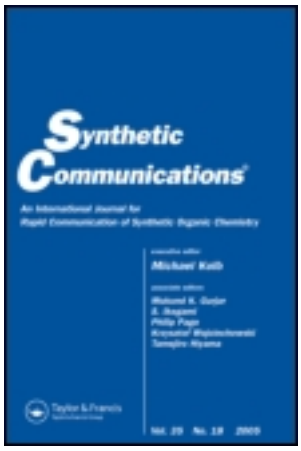


Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lsyc20

A HIGH YIELDING, REPRODUCIBLE SYNTHESIS OF TRIMETHYLSILYLKETENE

T. Howard Black [a] , John R. Farrell [a] , Donald A. Probst [a] & Michael C. Zotz [a]

[a] Department of Chemistry, Eastern Illinois University, Charleston, IL, 61920, U.S.A.

Published online: 16 Aug 2006.

To cite this article: T. Howard Black , John R. Farrell , Donald A. Probst & Michael C. Zotz (2002) A HIGH YIELDING, REPRODUCIBLE SYNTHESIS OF TRIMETHYLSILYLKETENE, Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry, 32:13, 2083-2088, DOI: 10.1081/SCC-120004861

To link to this article: http://dx.doi.org/10.1081/SCC-120004861

SYNTHETIC COMMUNICATIONS, 32(13), 2083–2088 (2002)

A HIGH YIELDING, REPRODUCIBLE SYNTHESIS OF TRIMETHYLSILYLKETENE

T. Howard Black,* John R. Farrell, Donald A. Probst, and Michael C. Zotz

Department of Chemistry, Eastern Illinois University, Charleston, IL 61920, USA

ABSTRACT

A two-step sequence for the preparation of trimethylsilylketene, from chloroacetaldehyde diethyl acetal via ethoxyacetylene, has been modified and optimized.

INTRODUCTION

Silyl ketenes are unique in their chemical behavior, when contrasted with their alkyl or aryl counterparts. One of their most valuable attributes is their extraordinary stability, such that they can be stored for extended periods in a refrigerator without the tendency to dimerize so prevalent with other types of ketenes. Trimethylsilylketene (TMSK), the prototypical member of this family, enjoys a wide diversity of implementations in synthetic chemistry, encompassing organic, organometallic, and inorganic applications.

*Corresponding author. E-mail: cthb@eiu.edu

The procedure reported herein is an adaptation of the method described by Ruden.[1] Although several other procedures for the synthesis of TMSK have been published[2] (and have been tested by this research group), we have found our modification of the Ruden method to be, by far, the most consistently high-yielding and reproducible. The formation of TMSK from ethoxyacetylene (which is the last step of the two-step Ruden protocol) has recently been subjected to a theoretical study.[3] Also, the ^{13}C, ^{17}O, and ^{29}Si NMR spectra and theoretical explanation for the stability of TMSK, in addition to other silylated ketenes, have been published.[4]

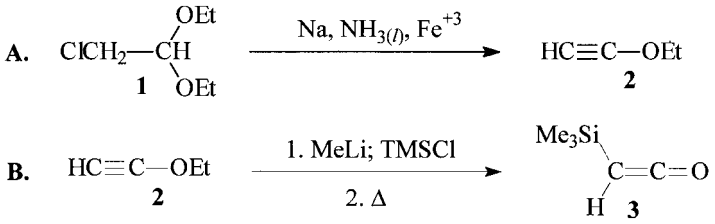
The utility of TMSK up to 1995 is well-documented in Danheiser's excellent, concise review.[4] Its utility has continued to expand in the intervening years. For instance, TMSK reacts with acyl isocyanates to yield 2-pyridones;[5] a theoretical study of this reaction has also been carried out.[6] It also forms ketenimines, via treatment with certain Wittig reagents,[7] which have then been exploited to form isoquinolines via electrocyclization.[8] α,*N*-Diarylnitrones react with TMSK to provide oxindoles in good yield.[9] In the organometallic area, TMSK was used quite recently in carbonyl coupling reactions to prepare functionalized iron ketene complexes.[10]

Silyl enol ethers are well known and commonly employed in organic synthesis; there is now a facile preparation of silyl ynol ethers via the reaction of ynolate anions derived from silylketenes with electrophiles.[11] α-Silyl ketones are easily synthesized from the reaction of silyl ketenes with carbanions, using organocerium reagents.[12]

Finally, TMSK undergoes facile [2 + 2] cycloaddition with aldehydes, with the ensuing trimethylsilyl β-lactones serving as versatile synthetic intermediates.[13] For instance, they have been converted into monoanomeric spiroketals,[14] the hypocholesterolemic agent 1233A,[15] and α,β-unsaturated carboxylic acids via a nonbasic alternative to the Wittig reaction.[16] The synthesis and chemistry of chiral silyl β-lactones are covered in Romo's excellent recent review.[17]

DISCUSSION

The two-step protocol is outlined in Scheme 1 below. Step A involves the double elimination of chloroacetaldehyde diethyl acetal (**1**) via treatment with sodium amide in liquid ammonia. Petroleum ether (b.p. 90–110°C) was added, and the liquid ammonia allowed to evaporate overnight, leaving the bright yellow sodium salt of ethoxyacetylene (**2**) adhering to the side of the flask. A large quantity of ice was added quickly, with vigorous stirring/swirling, to protonate the salt. This is a very exothermic reaction,



Scheme 1.

and the cooling is necessary to prevent loss of any product, which is quite volatile. The crude ethoxyacetylene **2** was then isolated through extraction. After being dried over magnesium sulfate, the solution was subjected to fractional distillation, affording pure product in 65% yield.

In step B, the ethoxyacetylene (**2**) was deprotonated via treatment with methyllithium at 0°C in ether solution, whereupon a very slight excess of chlorotrimethylsilane was slowly added. The mixture was stirred at room temperature for 12 h, acquiring a light yellow color, and was then filtered through a medium frit glass funnel. The resulting yellow filtrate was concentrated in vacuo to afford ethoxytrimethylsilylacetylene as a clear yellow oil, which was then distilled under reduced pressure (ca. 20 mm). The activation energy for the rearrangement leading to TMSK is quite high, in that the pot temperature must reach 125–135°C before distillation commences. The product distills at 75–82°C in yields from 50–70%.

EXPERIMENTAL SECTION

Ethoxyacetylene (2): To a 2 L 3-neck round bottom flask equipped with a condenser, gas inlet, and rubber septum was added 0.2 g $FeNO_3$ $9H_2O$. The flask was submerged in a methanol/liquid nitrogen bath, cooled to ca. −80°C, and filled with approximately 1 L of anhydrous liquid ammonia. Sodium (46 g, 2 mol) was then added in small portions over a two minute period. The solution was allowed to stir at −80°C for 90 min, at which point 0.2 g $FeNO_3$ $9H_2O$ was added and the solution stirred an additional 30 min. Next, 79.95 mL (81.4 g, 0.533 mol) of chloroacetaldehyde diethyl acetal (**1**) was added dropwise at a rate of ca. 1 mL/min. The solution was allowed to stir at −80°C for 30 min, then the bath was removed and 200 mL of petroleum ether (bp 90–110°C) was added. The solution was allowed to stir overnight to let the ammonia evaporate.

When the ammonia was gone, ca. 400 g of ice was added over 1 min, and the flask was swirled until all of the solid had been dissolved from the sides.

CAUTION: This is an exothermic reaction, and some product will be lost if the flask becomes too warm. Next, both phases were transferred to a separatory funnel and separated. The aqueous layer was extracted with four 50 mL portions of petroleum ether (bp 90–110°C). The combined organic layers were washed with ice cold water and dried over anhydrous magnesium sulfate. The drying agent was removed via gravity filtration, the filtrate was placed in a 1 L flask, and the ethoxyacetylene was distilled off at atmospheric pressure. Purification was achieved via fractional distillation through a 15 cm Vigreaux column to yield ethoxyacetylene in 65% yield (b.p. 50–51°C/760 mm Hg; lit.[18] 49–51°C/749 mm Hg). The following additional analytical data were collected: ^{1}H-NMR δ_{CDCl_3}: 1.348 (3H, t), 1.498 (1H, s), 4.09 (2H, q) ppm (Lit. 1.37 (3H, t), 1.53 (1H, s), 4.23 (2H, q) ppm). ^{13}C-NMR δ_{CDCl_3}: 14.08, 26.34, 74.49, 90.69 ppm. IR (neat) ν_{max}: 3320, 2960, 2140 cm^{-1} (Lit.[19] 3300, 2140 cm^{-1}).

Trimethylsilylketene (3): An oven dried 500 mL 2-necked round bottom flask equipped with a rubber septum, nitrogen inlet and magnetic stir bar was cooled under a continuous stream of nitrogen. The flask was cooled to 0°C, whereupon 250 mL of anhydrous ether and 8.3 g (118.4 mmol) of ethoxyacetylene were added to the reaction vessel. To the resulting mixture was added 88 mL of a 1.4 M solution (123 mmol) of methyllithium in ether, dropwise via syringe, over 30 min. After this period, 15.3 mL of freshly distilled (over CaH_2) chlorotrimethylsilane (13.1 g, 120 mmol) was added, dropwise via syringe, over 15 min. During this addition, a white precipitate was observed to form. After the addition was complete, the mixture was allowed to stir at ambient temperature overnight.

The following morning, the reaction mixture was carefully filtered through a (medium) sintered glass funnel and the filter cake washed with a small quantity of anhydrous ether. The reaction mixture was then transferred to a one neck 500 mL round bottom flask and the ether gradually removed via simple distillation at low heat.[20] Upon complete removal of the ether, the pot temperature was gradually increased to 120°C and the desired ketene was collected at 75–82°C/760 mm Hg (lit.[1] b.p. 81–82°C/760 mm Hg). Typical yields of pure trimethylsilylketene, using this procedure, range between 50 and 70%. The following additional analytical data were collected: ^{1}H-NMR δ_{CDCl_3}: 1.719 (1H, s), 0.122 (9H, s) ppm (Lit.[21] δ_{CCl_4}: 1.65 (s, 1H, *H*C=C=O), 0.12 (s, 9H, (C*H*$_3$)$_3$Si) ppm); ^{13}C-NMR δ_{CDCl_3} (300 MHz): 179.264, 0.373, −0.211 ppm (Lit.[21] δ_{CDCl_3} (50.3 MHz): 179.45 (C=*C*=O), 0.54 ((*C*H$_3$)$_3$Si), −0.25 (*C*=C=O) ppm; IR

(neat) ν_{max}: 3340, 3020, 2940, 2100, 1260, 1240, 1040, 840 cm^{-1} (Lit.[21] (CCl_4) 3050, 2980, 2130, 1280, 1260, 1060, 860, 630 cm^{-1}).

ACKNOWLEDGMENTS

We gratefully thank the National Institutes of Health (R15-GM52677-01), the Research Corporation, and the Council for Faculty Research of Eastern Illinois University, for their generous support of this work.

REFERENCES

1. Ruden, R.A. J. Org. Chem. **1974**, *39*, 3607.
2. Loebach, J.L.; Danheiser, R.L. *Trimethylsilylketene, in the Encyclopedia of Reagents for Organic Synthesis*, Paquette, L.A., Ed. - in-Chief; Wiley: W. Sussex, England (**1995**); pp. 5266-8 and Numerous References Cited Therein.
3. Oblin, M.; Rajzmann, M.; Pons, J.-M, Tetrahedron **1997**, *53*, 8165.
4. Allen, A.D.; Egle, I.; Janoschek, R.; Liu, H.W.; Ma, J.; Marra, R.; Tidwell, T.T. Chem. Lett. **1996**, 45.
5. Takaoka, K.; Aoyama, T.; Shiori, T. Tetrahedron Lett. **1996**, *37*, 4973, 4977.
6. Matsumoto, T.; Takaoka, K.; Aoyama, T.; Shiori, T. Tetrahedron **1997**, *53*, 225.
7. Barbaro, G.; Battaglia, A.; Giorgianni, P.; Guerrini, A.; Seconi, G. J. Org. Chem. **1995**, *60*, 6032.
8. Molina, P.; Vidal, A.; Tovar, F. Synthesis **1997**, 963.
9. Takaoka, K.; Aoyama, T.; Shioiri, T. Tetrahedron Lett. **1999**, *40*, 3017.
10. Kandler, H.; Bidell, W.; Janicke, M.; Knickmeier, M.; Veghini, D.; Berke, H. Organometallics **1998**, *17*, 960.
11. Akai, S.; Kitagaki, S.; Naka, T.; Yamamoto, K.; Tsuzuki, Y.; Matsumoto, K.; Kita, Y. J. Chem. Soc., Perkin Trans. 1 **1996**, 1705.
12. Akai, S.; Kitagaki, S.; Matsuda, S.; Tsuzuki, Y.; Naka, T.; Kita, Y. Chem. Pharm. Bull. **1997**, *45*, 1135.
13. Black, T.H. β-Lactones as Useful Synthetic Intermediates. In *Trends in Heterocyclic Chemistry*, Menon, J., Ed.; Research Trends: Trivandrum, 1993; Vol. *3*, 275, publ. 1995.
14. Zemribo, R.; Mead, K.T. Tetrahedron Lett. **1998**, *39*, 3891.
15. Dymock, B.W.; Kocienski, P.J.; Pons, J.-M. Synthesis **1998**, 1655.

16. Black, T.H.; Zhang, Y.; Huang.; J.; Smith, D.C.; Yates, B.E. Synth. Commun. **1995**, *21*, 15.
17. Yang, H.W.; Romo, D. Tetrahedron **1999**, *55*, 6403 and References cited therein.
18. Jones, E.R.H.; Eglinton, G.; Whiting, M.C.; Shaw, B.L. Org. Synth. **1963**, Coll. *Vol. IV*, 404.
19. McCarney, C.C.; Ward, R.S. Tetrahedron **1976**, *32*, 1189.
20. It is Best to Employ an Oil Bath for the Heating Element.
21. Valenti, E.; Pericas, M.A.; Serratosa, F. J. Org. Chem. **1990**, *55*, 395.

Received in the USA July 24, 2001