

Ethynylation of Ketones Using Dilithium Acetylide^{1a}K. R. MARTIN,^{1b} C. W. KAMIENSKI, M. H. DELLINGER, AND R. O. BACH

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Dilithium acetylide, Li_2C_2 , reacts rapidly with acetylene in liquid ammonia to give lithium acetylide, $\text{LiC}\equiv\text{CH}$. The rate of the reaction has been studied conductometrically and has been shown to be essentially dependent on the rate of acetylene addition. A heterogeneous ethynylation, or "crowding" technique using excess dilithium acetylide over the solubility limit of $\text{LiC}\equiv\text{CH}$, is described. An investigation into the nature of the side reactions is discussed.

The synthesis of tertiary alkynols from the reaction of metal acetylides with ketones is a well-known procedure. In general, lithium acetylide² is superior to the other alkali metal acetylides, especially in ethynylations of α,β -unsaturated ketones.³ It is, however, unstable in the absence of a complexing agent,⁴ disproportionating rapidly and almost completely to dilithium acetylide and acetylene.

Lithium acetylide is usually prepared by the direct reaction of acetylene with lithium metal dissolved in liquid ammonia.^{2,3} The ketone or other compound to be ethynylated is then added to the solution. This method has the disadvantage that acetylene is partially reduced to ethylene according to eq 1.⁵ Reduc-



tion can be minimized by first converting the metal into its amide,^{6,7} or by adding the metal to acetylene-saturated liquid ammonia in small increments.² This latter method has the disadvantage that it greatly lengthens the time of the ethynylation reaction. The reaction time can be decreased by using the lithium acetylide-ethylenediamine complex reported by Beumel and Harris.⁸ We have observed that the ethylenediamine released as the ethynylation reaction proceeds causes self-condensation and polymerization of α,β -unsaturated ketones to the extent of 20–25%, even when the procedure of Beumel and Harris^{8b} is followed rigorously, which is in contrast to their published results.

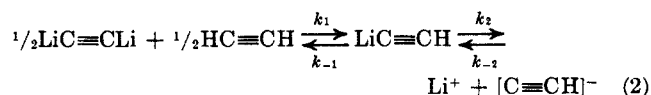
Results and Discussion

We have recently found that dilithium acetylide suspended in liquid ammonia reacts almost instantaneously with acetylene to produce a clear solution of lithium acetylide which reacts with carbonyl compounds in the same manner as does lithium acetylide prepared from lithium metal or amide. Dilithium acetylide may be prepared by heating lithium with graphite in a bomb or tube above 850°, according to

the method of Herold, *et al.*⁹ It is a yellow to light gray refractory material which may be ground to a fine powder. Analysis by reaction of the released acetylene with alcoholic silver nitrate showed the composition to be 99.7% dilithium acetylide. The powder may be handled in air for a short time if adequate ventilation is provided to prevent inhalation of the powder.

Rate of Reaction.—The rate of reaction of dilithium acetylide with acetylene was studied conductometrically. A conductivity curve for solutions of lithium acetylide in liquid ammonia at -33° was determined for concentrations of from 0.033 *M* to the saturation point at 1.04 *M* (Figure 1). Both lithium metal and dilithium acetylide were used as sources of lithium; the conductivity plots were identical. For all but very dilute solutions, the conductance increases linearly with concentration, indicating that lithium acetylide is only slightly ionized in liquid ammonia.

The conductometrically measured rate of formation of lithium acetylide from dilithium acetylide, $d[\text{LiC}\equiv\text{CH}]/dt$, is the slope of the plot in Figure 2. The rate-determining step is assumed to be the reaction of acetylene with dilithium acetylide (eq 2); k_1



is actually measured only indirectly as $[\text{Li}^+]$, requiring the additional assumption that ionic equilibrium is attained rapidly. It is not known whether that is the case, but the assumption appears to be reasonable. The alternative rate-determining step is the solution of acetylene in ammonia. In view of the high solubility of acetylene in this system (10.6 moles/l. at -42°),¹⁰ it does not appear likely that this process would be rate-determining. A third assumption is made that the reaction takes place at the surface of the dilithium acetylide, since the reaction rate is markedly decreased when larger pieces (*i.e.*, smaller total surface area) are used in place of the 100- μ material for which these data are reported.

Based on the foregoing assumptions and since the conductance measures

$$\frac{d[\text{Li}^+]}{dt} = k_2[\text{LiC}\equiv\text{CH}] - k_{-2}[\text{Li}^+]^2$$

the falling-off of the rate of reaction as the equivalence point is approached can be explained by the increased ionic concentration. As $[\text{Li}^+]$ increases, the second

(1) (a) Presented at the Southeast Regional Meeting of the American Chemical Society, Louisville, Ky., Oct 29, 1966. (b) Author to whom all correspondence should be addressed.

(2) K. N. Campbell and B. K. Campbell, *Proc. Indiana Acad. Sci.*, **50**, 123 (1940); *Chem. Abstr.*, **35**, 5457 (1941).

(3) W. Oroshnik and A. D. Mebane, *J. Am. Chem. Soc.*, **71**, 2062 (1949).

(4) M. Corbellini and L. Turner, *Chim. Ind. (Milan)*, **42**, 251 (1960); *Chem. Abstr.*, **54**, 19250f (1960).

(5) G. W. Watt, *Chem. Rev.*, **46**, 326 (1950).

(6) M. Picon, *Compt. Rend.*, **173**, 155 (1921).

(7) A. L. Henne and K. W. Greenlee, *J. Am. Chem. Soc.*, **65**, 2020 (1943); **67**, 484 (1945).

(8) (a) O. F. Beumel and R. F. Harris, *J. Org. Chem.*, **28**, 2775 (1963); (b) *ibid.*, **29**, 1872 (1964).

(9) A. Herold, *Bull. Soc. Chim. France*, 999 (1955).

(10) S. A. Miller, "Acetylene," Ernest Benn Ltd., London, 1965, p 99.

TABLE I
COMPARATIVE ETHYNYLATIONS WITH Li_2C_2 AND LI METAL^a

Parent ketone	Source of $\text{LiC}\equiv\text{CH}$	Moles of Li source	Moles of ketone	Volume of NH_3 , ml	Reacn time, hr	Yield of alkynol, %	Bp, °C (mm)	Lit. bp, °C (mm)
Benzalacetone	Li_2C_2	0.25	0.50	500	3	74	51 (mp)	50.5 (mp) ^b
	Li metal	0.49	0.49	500	5	73		
β -Ionone	Li_2C_2	0.06	0.12	125	3	69	98 (1.0)	84 (0.5) ^b
	Li metal	0.12	0.12	125	3	74		
Diisopropyl	Li_2C_2	0.25	0.50	500	3	91	43 (60)	163-165 (760) ^b
	Li metal	0.51	0.50	500	4	83		
Ethyl β -chlorovinyl	Li_2C_2	0.20	0.36	400	2	96	60-61 (1.0)	29-30 (0.1) ^c
	Li metal	0.50	0.45	500	2	83		
Methyl vinyl	Li_2C_2	0.25	0.45	500	3 ^d	77.5	58 (60)	58-59 (60) ^b
	Li metal	0.50	0.45	500	3 ^d	68		
Mesityl oxide	Li_2C_2	0.20	0.42	400	3	72	72 (25)	73-74 (26) ^b
	Li metal	<i>f</i>			3 ^{b,e}	26 ^b		
Cyclopentanone	Li_2C_2	0.25	0.50	500	3	92	69-70 (26)	

^a All reactions were run at -33° except where otherwise noted. ^b Reference 3. ^c W. M. McLamore, S. Y. P'an, and A. Bavelly, *J. Org. Chem.*, 20, 109 (1955). ^d Reaction temperature -55° . ^e Reaction temperature -60° . ^f 1.0 M solution used, reaction size not specified.

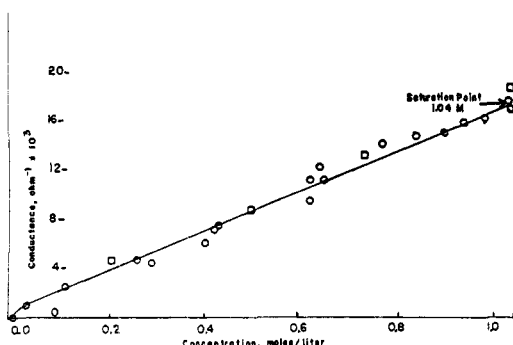


Figure 1.—Conductance of $\text{LiC}\equiv\text{CH}$ solutions in liquid ammonia: \circ , $\text{Li}_2\text{C}_2 + \text{HC}\equiv\text{CH}$; \square , Li Metal + $\text{HC}\equiv\text{CH}$.

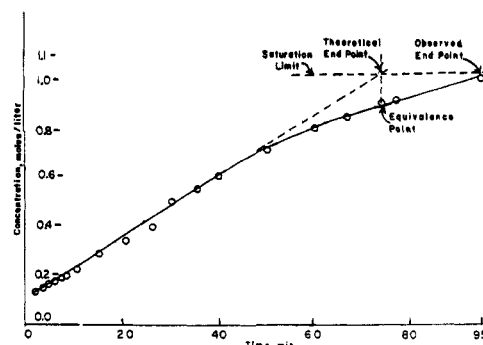


Figure 2.—Rate of formation of $\text{LiC}\equiv\text{CH}$ from Li_2C_2 and $\text{HC}\equiv\text{CH}$, determined by conductivity.

term in the rate equation begins to contribute significantly and the rate decreases.

Ethynylation Reactions.—Table I shows a comparison of the yields of alkynol using lithium metal and dilithium acetylide as sources of lithium acetylide. The yields are increased in most cases when Li_2C_2 is used. A partial explanation for this may be that more concentrated solutions (1.0 M) were used in this experiment; Orshnik and Mebane³ generally used 0.67 M solutions. In both cases, a 10% excess of acetylide was used.

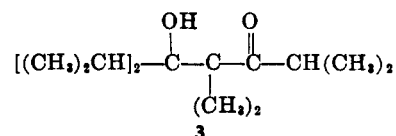
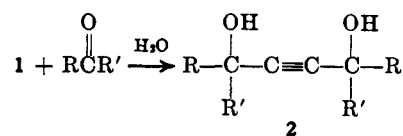
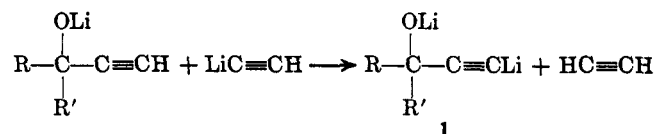
“Crowding” Reaction.—High yields of several alkynols were obtained when as much as 100% of dilithium acetylide was used over the solubility limit of monolithium acetylide. Table II shows the results of this series

TABLE II
RESULTS OF “CROWDING” REACTIONS

Ketone	Excess of Li_2C_2 over	
	1.04 M solubility limit, %	Yield of alkynol, %
Ethyl β -chlorovinyl	0 (1.04 M solution)	96
	100	100
	150	87
	200	63
Methyl vinyl	0 (1.04 M solution)	78
	100	72

of reactions. The decreased yields obtained with greater than a 100% excess of dilithium acetylide are probably due to the exceeding of the solubility limit of the lithium alkynolate formed in the reaction.

Side Reactions.—For diisopropyl ketone, the products other than the expected alkynol were examined. The residue remaining after removal of the alkynol (75% yield) and unreacted ketone (3-5%) by distillation showed strong infrared absorption at 1710 cm^{-1} (saturated ketone). Two possible sources of this band are **3**, obtained from self-condensation of diisopropyl ketone, and **2**, obtained from reaction of 2 equiv of ketone with 1 equiv of acetylenic compound.^{8b}



Experimental Section

Conductometric Studies.—A Leeds and Northrup platinumized platinum electrode (No. 4917) was connected to a General Radio No. 1650-A impedance bridge. The average cell con-

stant was determined as 0.978 ± 0.002 for 0.470 and 0.990 *M* lithium nitrate in liquid ammonia at -33° . The constant was calculated from the standard values given by Gmelin.¹¹

The cell was placed in 850 ml of a liquid ammonia suspension of dilithium acetylide¹² at -33° in a 1-l. flask. Acetylene was admitted to the suspension by means of a fritted-glass disperser at a rate of 146 ml/min. Aliquots of 5 ml each were withdrawn at 8.8-min intervals by means of a pipet whose only entrance was a medium-fritted-glass filter, so that only dissolved material was withdrawn. At the same time, the resistance of the solution was determined. Each aliquot was hydrolyzed at once in water and the pipet thoroughly washed with water. The solution was boiled until evolution of ammonia ceased, cooled, and titrated with 0.1071 *N* HCl to the phenolphthalein end point. The results are plotted in Figure 1. This is the standard curve used in the rate studies. The concentration of the saturated solution was determined as 1.04 *M*.

Rate of Solution of Dilithium Acetylide.—A slight excess of dilithium acetylide was suspended in 850 ml of liquid ammonia at -33° and acetylene was admitted at a rate of 146 ml/min. The resistance of the solution was determined at periods varying from 10 sec at the beginning to 120 sec at the end of the experiment. The concentration of the solution at each reading was determined from the standard curve (Figure 1) and the data were plotted as concentration vs. time (Figure 2).

Example of a Saturated Ethynylation Reaction (3-Methyl-1-penten-4-yn-3-ol).—To a 240-ml, nitrogen-swept flask, equipped with a magnetic stirrer, Dry Ice condenser, dropping funnel, and inlet tube, was added 3.8 g (0.10 mole) of dilithium acetylide, and 100 ml of ammonia was condensed over it. Acetylene was bubbled through the suspension at a rate of 146 ml/min until a nearly clear solution was obtained (12–15 min). The solution was then cooled to -55° by means of a Dry Ice-acetone bath, and neat methyl vinyl ketone (6.3 g, 0.90 mole) was added dropwise over a 10-min period. The reaction mixture was held at -55° with continuous acetylene passage for 2 hr and then gradually allowed to warm to -5° over a 1-hr period while 100 ml of ether was added dropwise. Then the reaction mixture was hydrolyzed over a mixture of ice and excess glacial acetic acid. Solid sodium chloride was added,

(11) Gmelins Handbuch der Anorganischen Chemie, System No. 20 (Lithium), p 105.

(12) Available from Lithium Corp. of America, Bessemer City N. C.

and the mixture was neutralized with a saturated sodium bicarbonate solution. The mixture was extracted twice with ether; the combined extracts were dried over anhydrous sodium sulfate and weighed. An aliquot (0.5–0.7 g) was taken and titrated with AgNO_3 . The yield was calculated by the method of Siggia.¹³ The average yield obtained (three runs) was 6.7 g (77.5%) of 3-methyl-1-penten-4-yn-3-ol.

Example of a "Crowding" Reaction (3-Methyl-1-penten-4-yn-3-ol).—To a 250-ml, nitrogen-swept flask, equipped with a magnetic stirrer, Dry Ice condenser, dropping funnel, and inlet tube, was added 7.9 g (0.208 mole) of dilithium acetylide, and 100 ml of ammonia was condensed over it. Acetylene was bubbled through the suspension at a rate of 146 ml/min until a 50% excess had been added (about 15 min). The reaction mixture still appeared to be a gray suspension. The reaction mixture was cooled to -55° and, with acetylene passage continuing, neat methyl vinyl ketone (12.8 g, 1.82 mole) was added dropwise over a 25-min period. At the end of this period a slightly hazy yellow solution formed, indicating that all of the dilithium acetylide had been consumed. The reaction mixture was held at -55° for 2 hr with continuous acetylene passage, then gradually allowed to warm to -5° over a 1-hr period while 100 ml of ether was added dropwise. The mixture was then hydrolyzed, extracted, and analyzed as in the previous example. The yield of alkynol was 72%.

Registry No.—Delithium acetylide, 1070-75-3; benzalacetone, 122-57-6; β -ionone, 79-77-6; diisopropyl ketone, 123-19-3; ethyl β -chlorovinyl ketone, 105-32-8; methyl vinyl ketone, 78-94-4; mesityl oxide, 141-79-7; cyclopentanone, 120-92-3; 2 (R,R' = $-(\text{CH}_2)_4-$), 5325-62-2.

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(13) S. Siggia, "Quantitative Organic Analysis via Functional Groups," 3rd ed, John Wiley and Sons, Inc., New York, N. Y., 1963, p 381.

A Carbonyl Olefination Reaction Using Silyl-Substituted Organometallic Compounds

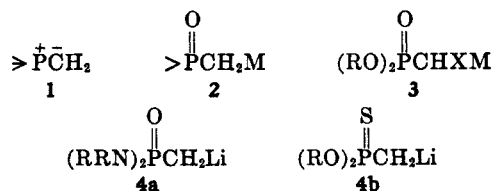
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Trimethylsilyl-substituted organometallic compounds, $(\text{CH}_3)_3\text{SiCHMR}$, have been demonstrated to be effective intermediates in the conversion of carbonyl compounds to the corresponding olefins, $>\text{C}=\text{CHR}$. These conversions, which involve the formation and decomposition of $>\text{SiCHRC}(\text{OM})<$ compounds, appear to be closely related to the classical methods of preparing olefins from reactions of phosphorus-substituted carbanions with aldehydes and ketones.

During the past few years, several methods have been developed for the conversion of carbonyl compounds to the corresponding methylene derivatives. The most frequently used methods for this conversion have the common feature of employing phosphorus-substituted carbanions, *i.e.*, the well-known "Wittig" reagents,¹ which are phosphorus ylides (1), as the reactive intermediates. The phosphinylalkyl metal compounds (2) resulting principally from the work of Horner and coworkers² and the phosphonate carbanions (3) of Wadsworth and Emmons³ have been



similarly employed. Corey and Kwiatkowski have extended this series of phosphorus-substituted carb-

(2) L. Horner, H. Hoffmann, H. G. Wippel, and G. Klahre, *Chem. Ber.*, **92**, 2499 (1959).

(3) W. S. Wadsworth, Jr., and W. D. Emmons, *J. Am. Chem. Soc.*, **83**, 1733 (1961).

(1) For a review of the Wittig reagent, see A. W. Johnson, "Ylid Chemistry," Academic Press Inc., New York, N. Y., 1966.