A Convenient Preparation of Aldehyde Enol Acetates and Aldehyde Enol Trimethylsilyl Ethers

D. Ladjama, J. J. Riehl*

Institut de Chimie, Université Louis Pasteur, B.P. 296/R8, F-67008 Strasbourg, France

The generation of ketone enolates has been extensively investigated in recent years in view of their applicability in organic synthesis, in particular, of their alkylation and acylation reactions. On the other hand, aldehyde enolates have found little application in synthesis due to their tendency to undergo aldol reactions[1]. Thus, indirect methods for the generation of aldehyde enolates or their equivalents have been developed; these methods use anions of imines[2], dimethylhydrazones[3], silyl enol ethers[4,5,6], or enol acetates[7]. Aldehydes from which tertiary carbanions can be formed have been alkylated under phase-transfer conditions[8].

We were interested in finding an efficient method for the preparation of aldehyde enol acetates, useful starting materials for the synthesis of 2-alkenals[9].

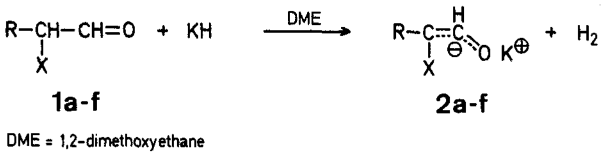
The classical preparations of ketone enol acetates such as the transacylation with isopropenyl acetate or the acid-catalyzed *O*-acylation with acetic anhydride give only poor yields when applied to aldehydes. Better yields are obtained under basic conditions (acetic anhydride/potassium acetate) but these yields (50–60%)[10] are still not satisfactory. The concomitant formation of *gem*-diacyloxy compounds in this latter reaction, probably by addition of acetic acid to part of

0039-7881/79/0732-0504 $ 03.00

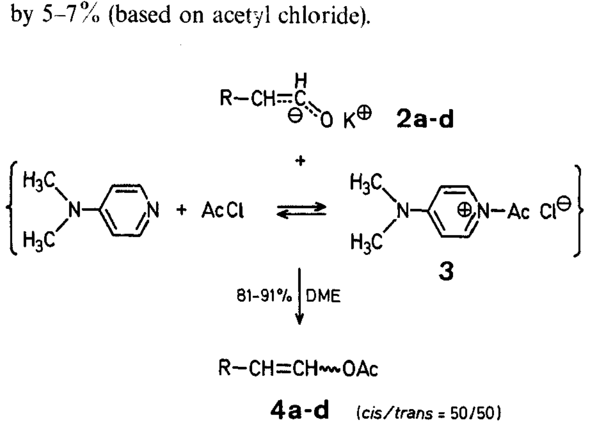
the enol acetate formed, suggested the use of potassium carbonate as acid scavenger[11]. In fact, the yields could thus be improved but performance of the reaction was tedious. A few years ago it was reported that the strong base potassium hydride can be used to advantage for the rapid and quantitative metallation of ketones[12] without competing aldol reactions or reductions. Also potassium enolates of aldehydes have recently been prepared in this manner and their *C*-alkylation has been studied[13].

We report here that the O-acylation of potassium enolates (**2**) generated by treatment of aldehydes (**1**) with potassium hydride[14] in 1,2-dimethoxyethane affords the corresponding enol acetates (**4**) in high yields (81–91% of distilled product).

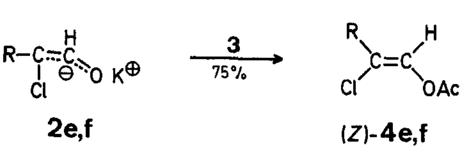
Formation of the enolates **2** generally is complete within 30 min at −30° and in less than 10 min at 0°.



The enolate **2** is then added to excess acetyl chloride in the same solvent or, better, to an acetyl chloride solution containing catalytic amounts of 4-dimethylaminopyridine[15]. This latter compound forms a highly reactive 1-acylpyridinium intermediate (**3**); the yield of **4** may thus be raised by 5–7% (based on acetyl chloride).

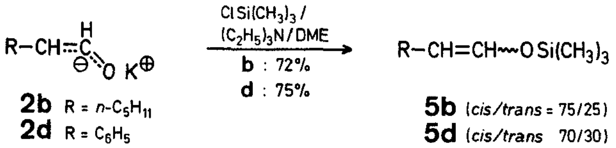


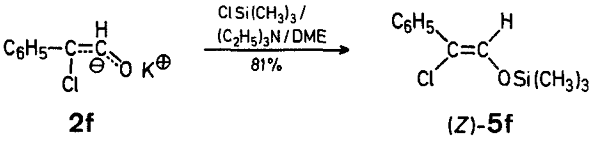
This method is also applicable to the synthesis of 2-chloroenol acetates (**4e, f**; 75% yield) starting from 2-chloroalkanals (**2e, f**).



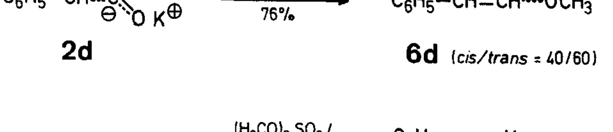
It has to be mentioned that substrates of the latter type (**2e, f**) having a sufficiently acidic α-H-atom may also be converted into the enolates, though less rapidly, by sodium hydride alone or sodium hydride activated by catalytic amounts of potassium hydride.

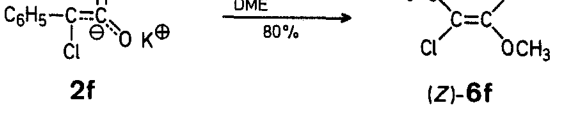
Apart from their conversion to enol acetates, the potassium enolates **2** are useful starting materials for the synthesis of aldehyde enol silyl ethers (**5**) which are important educts[16] of further syntheses such as that of 2-bromoalkanals (by bromination)[17,18] and of cyclopropanols (via Simmons-Smith reaction)[19,20]. Silyl enol ethers (**5**) are usually prepared by refluxing the carbonyl compound in a solution of chlorotrimethylsilane and triethylamine in dimethylformamide, the yields ranging from 55 to 66%[5]. We have now prepared aldehyde enol silyl ethers (**5**, 1-alkenyl trimethylsilyl ethers) from the potassium enolates **2** and chlorotrimethylsilane in 1,2-dimethoxyethane containing a catalytic amount of triethylamine at −30° to 0° (see Table 2).





The analogous reaction of **2** with hard alkylating agents such as dimethyl sulfate provides a convenient and high-yield synthesis of aldehyde enol ethers (e.g. **6d**) including their 2-chloro derivatives (**6f**; see Table 2).





It should be noted that ethers of the type **6d** may also be obtained by acid-catalyzed elimination of methanol from the corresponding acetals, i.e., by a two-step reaction starting from the aldehydes, whereas ethers of the type **6f** can only be obtained from the aldehydes by a multistep procedure[21].

The purity of all products was checked by G.L.C. (10% SE 30 on chromosorb W). The ^{1}H-N.M.R. spectra were recorded on a Perkin-Elmer R12B spectrometer at 60 MHz.

1-Acetoxy-1-heptene (4b, Heptanal Enol Acetate); Typical Procedure:

A solution of heptanal (11.4 g, 0.1 mol) in dry 1,2-dimethoxyethane (10 ml) is added to a stirred suspension of potassium hydride[14] (4.4 g, 0.11 mol) in dry 1,2-dimethoxyethane (50 ml) under nitrogen at −5°. Hydrogen evolution is quantitative within 10–12 min. The enolate solution thus obtained is added by syringe to a solution of excess acetyl chloride (15.7 g, 0.2 mol) in 1,2-dimethoxyethane (30 ml) containing 4-dimethylaminopyridine (0.6 g, 5 mmol). Stirring is continued for 15 min at room temperature. Then the reaction mixture is slurried into a two-phase ice-water/pentane system. After separation, the organic phase is washed twice with saturated aqueous sodium hydrogen carbonate, then with water, and dried with magnesium sulfate. The solvent is evaporated in vacuum, and the residual product distilled in vacuo to give a mixture of *cis*-**4b** and *trans*-**4b**; yield: 13.1 g (84%); b.p. 83–85°/15 torr (Ref.[10], b.p. 76–79°/10 torr).

Table 1. Aldehyde Enol Acetates (**4**) prepared

1			Yield of **4** [%]	b.p./torr		Molecular formula[a]	I.R. (CCl_4) [cm^{-1}]		^{1}H-N.M.R. (CCl_4, 60 MHz)			
	R	X		found	reported		$\nu_{C=O}$	$\nu_{C=C}$		δ_{H_1}	δ_{H_2} [ppm]	$J_{H_1H_2}$
a	*n*-C_4H_9	H	81	63–65°/15		$C_8H_{14}O_2$ (142.2)	1755	1680	*cis*	7.00	4.75	7 Hz
									trans	7.05	5.30	12.5 Hz
b	*n*-C_5H_{11}	H	84	83–85°/15	76–79°/10[10]							
c	*n*-C_6H_{13}	H	83	92–94°/14	90–94°/10[10]							
d	C_6H_5	H	91	90–92°/2	113–115°/10[22]		1755	1675	*cis*	7.25	5.55	8 Hz
									trans	7.80	6.25	13 Hz
e	*n*-C_5H_{11}	Cl	75	110–112°/16		$C_9H_{15}ClO_2$ (190.7)	1765	1680		7.30		
f	C_6H_5	Cl	75	99–100°/1		$C_{10}H_9ClO_2$ (196.6)	1765	1650		7.85		

[a] The microanalyses were in satisfactory agreement with the calculated values: C, ±0.88; H, ±0.31; Cl, ±0.12.

Table 2. Aldehyde Enol Silyl Ethers (**5**) and Enol Ethers (**6**) prepared

Product	Yield [%]	b.p./torr		Molecular formula[a]	I.R. (CCl_4) $\nu_{C=C}$ [cm^{-1}]	^{1}H-N.M.R. (CCl_4, 60 MHz)			
		found	reported				δ_{H_1}	δ_{H_2} [ppm]	$J_{H_1H_2}$
5b	72	81–83°/12	85°/15[18]		1655	*cis*	6.05 (d of t)	4.35 (d of t)	6.1 Hz
						trans	6.15 (d of t)	4.85 (d of t)	12.1 Hz
5d	75	60–63°/1		$C_{11}H_{16}OSi$ (192.3)	1640	*cis*	6.35 (d of t)	5.25 (d of t)	7.3 Hz
						trans	6.90 (d of t)	5.95 (d of t)	12 Hz
(*Z*)-**5f**	81[b]			$C_{11}H_{15}ClOSi$ (226.6)	1650		6.90	—	—
6d	76	46–48°/0.2	211–212°/760[23]		1640	*cis*	6.00	5.15	7 Hz
						trans	7.00	5.75	13.3 Hz
(*Z*)-**6f**	80	64–66°/0.2		C_9H_9ClO (168.6)	1645 *cis* 1655 *trans*		6.70		

[a] The microanalyses were in satisfactory agreement with the calculated values: C, ±0.15; H, ±0.07; Cl, ±0.08.

[b] Yield of crude product. The analytical data were obtained on samples isolated by G.L.C. (conditions: column packed with SE 30 (10%) on chromosorb W).

Styryl Trimethylsilyl Ether (5d, Phenylacetaldehyde Enol Trimethylsilyl Ether); Typical Procedure:

A solution of phenylacetaldehyde (6.01 g, 0.05 mol) in dry 1,2-dimethoxyethane (5 ml) is added to a stirred suspension of potassium hydride[14] (2.2 g, 0.055 mol) in dry 1,2-dimethoxyethane (25 ml) under nitrogen at −5°. Hydrogen evolution is quantitative within 10–12 min. To the enolate solution thus obtained is added, with stirring under nitrogen at 0°, a solution of chlorotrimethylsilane (10.87 g, 0.1 mol) and triethylamine (2.03 g, ~0.02 mol) in dry 1,2-dimethoxyethane (50 ml). After the addition is complete, stirring is continued for 15 min at room temperature. The mixture is then diluted with pentane (100 ml) and washed with cold aqueous sodium hydrogen carbonate. The organic layer is dried with magnesium sulfate, the solvent evaporated in vacuo, and the residual product distilled in vacuo to give a mixture of *cis*-**5d** and *trans*-**5d**; yield: 7.3 g (75%); b.p. 60–63°/1 torr.

$C_{11}H_{16}OSi$	calc.	C 68.69	H 8.37
(192.3)	found	68.83	8.41

(*Z*)-2-Chloro-1-methoxy-2-phenylethylene [(*Z*)-6f]:

To a solution of enolate, prepared as previously from α-chlorophenylacetaldehyde (7.73 g, 0.05 mol) and potassium hydride (2.2 g, 0.055 mol) in dry 1,2-dimethoxyethane, an excess of dimethyl sulfate (1.26 g, 0.1 mol) is added with stirring under nitrogen at 0°. After centrifugation, the liquid mixture is distilled under vacuum to give **6f**; yield: 6.7 g (80%); b.p. 64–66°/0.2 torr.

C_9H_9ClO	calc.	64.12	H 5.38	Cl 21.06
(168.6)	found	63.97	5.44	21.44

Received: November 29, 1978
(Revised form: January 25, 1979)

---

* Address for correspondence.

[1] H. O. House, *Modern Synthetic Reactions*, 2nd Ed., W. A. Benjamin Inc., New York, 1972, p. 492.

[2] G. Stork, S. R. Dowd, *J. Am. Chem. Soc.* **85**, 2178 (1963).

[3] E. J. Corey, D. Enders, *Tetrahedron Lett.* **1976**, 3.

[4] G. Stork, P. F. Hudrlik, *J. Am. Chem. Soc.* **90**, 4464 (1968).

[5] H. O. House, L. J. Czuba, M. Gall, H. D. Olmstead, *J. Org. Chem.* **34**, 2324 (1969).

[6] Lithium enolates of aldehydes and ketones generated from the enol silyl ethers have been used for the synthesis of α-mercaptoaldehydes and -ketones and their *S*-alkyl and *S*-aryl derivatives: D. Seebach, M. Teschner, *Chem. Ber.* **109**, 1601 (1976).

[7] H. O. House, B. M. Trost, *J. Org. Chem.* **30**, 1341, 2502 (1965).

[8] H. K. Dietl, K. C. Brannock, *Tetrahedron Lett.* **1973**, 1273.

[9] J. J. Riehl, F. Jung, *Tetrahedron Lett.* **1969**, 3139.
See also: F. Jung, D. Ladjama, J. J. Riehl, *Synthesis* **1979**, 507.

[10] F. W. Semmler, *Chem. Ber.* **42**, 1161, 2014 (1909).

[11] F. Jung, *Dissertation*, Université de Strasbourg, 1972.

[12] C. A. Brown, *J. Org. Chem.* **26**, 3913 (1974).

[13] P. Broenewegen, H. Kallenberg, A. Van Der Gen, *Tetrahedron Lett.* **1978**, 491.

[14] Potassium hydride was purchased as a suspension in mineral oil from Fluka AG, Buchs, Switzerland, and was separated from the mineral oil as described by C. A. Brown in Ref. 12.

[15] G. Höfle, W. Steglich, *Synthesis* **1972**, 619; and references cited therein.
[16] J. K. Rasmussen, *Synthesis* **1977**, 91.
[17] R. H. Reuss, A. Hassner, *J. Org. Chem.* **39**, 1785 (1974).
[18] L. Blanco, P. Amice, J. M. Conia, *Synthesis* **1976**, 194.
[19] J. M. Conia, C. Girard, *J. Chem. Research [S]* **1978**, 182.
[20] G. M. Rubottom, M. I. Lopez, *J. Org. Chem.* **38**, 2097 (1973).
[21] J. F. Arens, *Adv. Org. Chem.* **2**, 122 (1960).
[22] P. Z. Bedoukian, *J. Am. Chem. Soc.* **65**, 1325 (1944).
[23] F. Sigmund, R. Uchann, *Monatsh. Chem.* **51**, 234 (1929).

0039-7881/79/0732-0507 $ 03.00