Journal of Organometallic Chemistry, 152 (1978) 359—365

REACTION OF LITHIUM DIMETHYLCUPRATE WITH α-ALLENIC CARBONYL COMPOUNDS: A 1,2-ADDITION TO THE ACTIVATED CARBON—CARBON DOUBLE BOND. DIRECT EVIDENCE FOR AN α-CUPRIO KETONE/COPPER ENOLATE EQUILIBRIUM

JACQUES BERLAN *, JEAN-PAUL BATTIONI and KARIM KOOSHA
E.R.A. du C.N.R.S., No. 490, Laboratoire de Chimie Organique de l'Ecole Nationale Supérieure de Chimie de Paris, 11 rue P. et M. Curie, 75005 Paris (France)

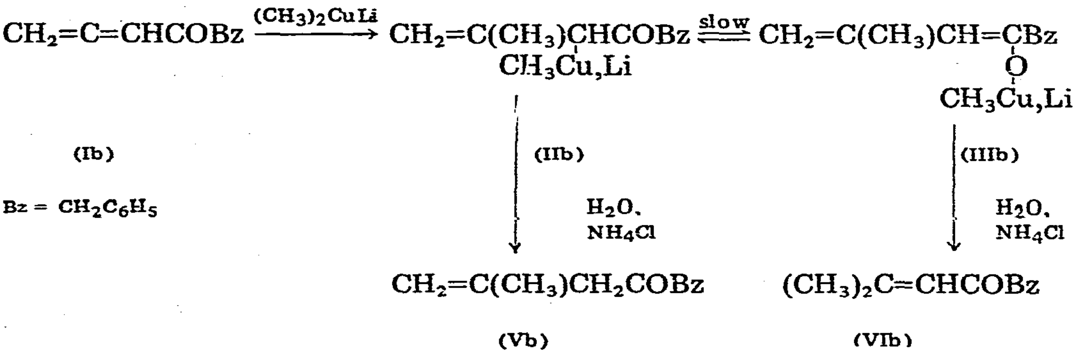
(Received December 20th, 1977)

Summary

The intermediates resulting from the addition of lithium dimethylcuprate to the 1-phenyl-3,4-pentadien-2-one have been identified by NMR and IR spectroscopy. These intermediates are α-cuprio ketone and copper enolate species. The reported results are consistent with a 1,2 addition of the cuprate to the activated carbon—carbon double bond. This mechanism seems to be general for α-allenic carbonyl compounds.

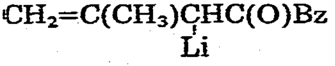
Recently we reported [1] that the reaction of lithium dimethylcuprate with the allenic ketone Ib proceeds by 1,2-addition to the activated carbon—carbon double bond to give a cuprate-type intermediate IIb. This species is slowly established in equilibrium with the isomer copper enolate IIIb. Upon hydrolysis IIb leads to the β,γ-ethylenic ketone Vb and IIIb to the α,β-unsaturated ketone VIb as illustrated in Scheme 1.

SCHEME 1



$$\begin{array}{ccccc} CH_2{=}C{=}CHCOBz & \xrightarrow{(CH_3)_2CuLi} & CH_2{=}C(CH_3)\underset{CH_3Cu,Li}{\underset{|}{C}}HCOBz & \overset{slow}{\rightleftharpoons} & CH_2{=}C(CH_3)CH{=}\underset{\underset{CH_3Cu,Li}{|}}{\underset{O}{\underset{|}{C}}}Bz \\ (Ib) & & \Big\downarrow {\scriptstyle (IIb)}\ H_2O,\ NH_4Cl & & \Big\downarrow {\scriptstyle (IIIb)}\ H_2O,\ NH_4Cl \\ Bz = CH_2C_6H_5 & & CH_2{=}C(CH_3)CH_2COBz & & (CH_3)_2C{=}CHCOBz \\ & & (Vb) & & (VIb) \end{array}$$

This mechanism was based on the analysis of the influence of time, temperature, and ligands on the ratio Vb/VIb and on a study of deuteriation of the intermediates. The absence of the lithium enolate IVb in the system was established.

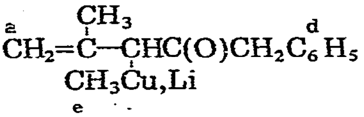


$$\mathrm{CH_2{=}C(CH_3)\underset{Li}{C}HC(O)Bz}$$

(IVb)

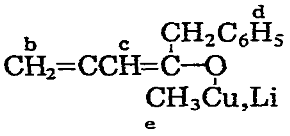
We have investigated this problem further by spectrometric techniques (IR; NMR) and by an asymmetric induction study. We compared the IR spectra of the reaction medium resulting from the addition of lithium dimethylcuprate to Ib to those of the anionic species obtained by metallation of VIb and of a Vb + VIb mixture. The results are reported in Table 1.

From the results it can be concluded that the two bands observed in run 1 must be assigned to at least one copper species, but more detailed analysis is difficult *. The same reactions have been examined by NMR spectroscopy, the results are reported in Table 2. In run 1 the integration curves lead us to the following assignments:



$$\overset{a}{\mathrm{CH_2}}{=}\overset{\mathrm{CH_3}}{\mathrm{C}}-\underset{\mathrm{\underset{e}{CH_3}Cu,Li}}{\mathrm{CH}}\mathrm{C(O)CH_2\overset{d}{C_6}H_5}$$

(IIb)



$$\overset{b}{\mathrm{CH_2}}{=}\mathrm{C}\overset{c}{\mathrm{CH}}{=}\underset{\mathrm{\underset{e}{CH_3}Cu,Li}}{\overset{\mathrm{\overset{d}{CH_2}C_6H_5}}{\mathrm{C}}}-\mathrm{O}$$

(IIIb)

As shown in Table 3 the Vb/VIb ratio observed after hydrolysis is in good agreement with the IIb/IIIb ratio calculated from this assignment. The results are consistent with the assumption that hydrolysis of IIb leads to Vb and of IIIb to VIb. We were able to induce some optical activity by the following sequence:

$$\mathrm{(CH_3)_2Cu,Li}\xrightarrow[0^\circ\mathrm{C};\ 30\ \mathrm{min}]{\mathrm{DIOP}}\xrightarrow[-78^\circ\mathrm{C};\ 3\ \mathrm{min}]{\mathrm{Ic}}\xrightarrow{\mathrm{H_2O;NH_4Cl}}$$

$$\mathrm{CH_2{=}C(CH_3)CH(CH_3)C(O)Bz} + \mathrm{(CH_3)_2C{=}C(CH_3)C(O)Bz}$$

(Vc) (VIc)

When (+)-DIOP is used the mixture Vc + VIc had $[\alpha]^{20}_{D}$ + 2° and when (—)-DIOP is used $[\alpha]^{20}_{D}$ —1.6°. The observed optical activity cannot arise from a chiral impurity because: (i) it slowly decreases, probably owing to the keto—enolic equilibrium and (ii) the same experiment performed with ketone Ib leads to an optically inactive product. The optical activity of Vc cannot be satisfactory explained if we assume that Vc arises from the hydrolysis of a copper or lithium enolate species **. Thus we assume that the β,γ-ethylenic ketones are derived from the hydrolysis of a cuprate-type species II. These results establish the formerly prop-

---

* Little is known about IR absorption spectra of cuprates or copper enolate species. However, by comparison with Klein's data [6] our assignments seem most likely.

** Metallation of the Vc + VIc mixture by NaH, followed by hydrolysis in the presence of DIOP gives an optically inactive product.

TABLE 1

IR SPECTRA (Solvent: 0.3 *M* diethyl ether)

Run		Characteristics (ν (cm^{-1}))
1	Ib + $(CH_3)_2Cu,Li; P(n\text{-}C_4H_9)_3$ [a]	1605s 1615s
2	Vb + VIb (80/20) + NaH [b]	1560w [c] 1585w [c]
3	VIb + NaH [b]	1560m 1585m

[a] Spectra were recorded after different reaction times (5, 30, 60 min) at various temperatures in the range −50— +20°C. Probably owing to the proximity of the two absorption bands no significant change in their relative intensities was observed. Under these conditions the addition was complete. [b] No displacement of the absorption bands was observed on addition of lithium iodide or on varying the temperature. [c] These two bands can be assigned to the anionic species resulting from the metallation of VIb as demonstrated in the appendix.

osed mechanism illustrated in Scheme 1. Such a mechanism appears to be general for α-allenic carbonyl compounds. The results reported in Table 4 show that the addition of lithium dimethylcuprate to the allenic ketone Ic or the allenic ester Id ($CH_2=C=CHC(O)OCH_3$) leads mainly to the corresponding β,γ-ethylenic compounds Vc/Vd for short time condensations. Then the ratio V/VI decreases with time to reach an equilibrium value.

These results are identical to those observed in the case of the ketone Ib [1] and can be rationalised by the mechanism shown in Scheme 1 for Ib. In conclusion it appears that the addition of lithium dimethylcuprate to α-allenic compounds proceeds by 1,2-addition to the activated carbon—carbon double bond. A similar conclusion was drawn for allenic phosphine oxides [2], sulfones and sulfoxides [3]. The formation of copper intermediates was also suggested by Rivière [4] and Posner [5] for α,β-ethylenic ketones, and established by Klein [6] and Normant [7] for acetylenic compounds.

This leads us to reconsider the concept of a 1,4 addition usually assumed for

TABLE 2

NMR SPECTRA (Solvent: 0.3 *M* diethyl ether)

Run [a]		Temp. (°C)	signals (δ (ppm))				
			(a)	(b)	(c)	(d)	(e)
1	Ib + $(CH_3)_2Cu,Li$-$P(n\text{-}C_4H_9)_3$ (b)	+30	4.4	5.18	4.94	7.1	−0.66
		−20	4.36	5.20	5.10	7.1	
		−80	4.36	5.20	5.20	7.1	
2	Vb + VIb (80%—20%) + NaH		only one signal within the range 10—4 ppm whatever the temperature be: δ = 7.1 ppm (aromatic protons)				
3	VIb + NaH						

[a] Owing to the use of ether as solvent and to the presence of tri-n-butylphosphine we could not investigate the 4—0 ppm region. Attempts in THF-d_8 failed: in pure THF the intermediate species in run 1 are unstable or different. [b] Reproducibility and reversibility (by alternately lowering or increasing the temperature) were demonstrated.

TABLE 3

RATIOS OBTAINED AT VARIOUS TEMPERATURES

Temperature (°C)	IIb/IIIb	Vb/VIb
+30	67—33	65—35
−20	75—25	74—26
−80	80—20	86—14

TABLE 4

$$CH_2{=}C{=}C(R)X \xrightarrow[H_2O;\ NH_4Cl]{(CH_3)_2CuLi} CH_2{=}C(CH_3)CH(R)X + (CH_3)_2{=}C(R)X$$

(I) (V) (VI)

(Ic, Vc, VIc: R = CH_3; X = $C(O)CH_2C_6H_5$; Id, Vd, VId: R = H; X = $C(O)OCH_3$)

	Reaction time (min) [a]	V (%)	VI (%)	Overall yield (%)
Ic	3	70	30	80
Ic	20	50	50	80
Ic	60	50	50	80
Id	5	90	10	76
Id	20	78	22	76
Id	60	78	22	76

[a] Temperature 80°C.

these reactions: the generality of a 1,2 addition to the activated carbon—carbon multiple bond, leading to a cuprate-type intermediate, can be suspected. As it has been demonstrated in the allenic series [1,2,3] the stability and the evolution of this first-formed intermediate depend on the nature of the substrate, the added cuprate, the solvent, and the presence of complexing agents..

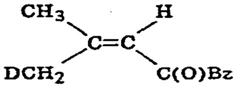
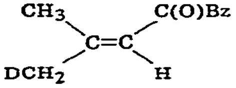
Appendix

The metallation of the ketones Vb and VIb can be studied by IR spectroscopy by following the disappearance of their absorption bands $\nu(C{=}O)$ (Vb, 1725 cm^{-1}; VIb, 1692 cm^{-1}) and $\nu(C{=}C)$ (Vb, 1658 cm^{-1}; VIb, 1628 cm^{-1}). When VIb is treated with NaH in refluxing ether the disappearance of the two bands takes 30 min. At the same time two new absorption bands appear at 1560 and 1585 cm^{-1}. Deuteration leads quantitatively to the compound $(CH_3)_2C{=}CHC(O)C(D)$-HC_6H_5 (IXb).

When a Vb/VIb (80/20) mixture is similarly treated, the disappearance of Vb within 5 min. can be assumed, but no new absorption band can be detected; then VIb slowly disappears and the two bands at 1560 and 1585 cm^{-1} can be seen; their intensities continue to increase after the metallation of Vb is complete. Deuteration gives the results shown in Table 5. From these results it can be assumed that: (i) the metallation of Vb is faster than that of VIb; (ii) the two

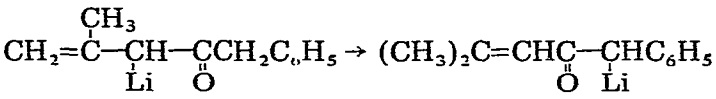
TABLE 5

DEUTERIATION OF Vb/VIb (80/20) in NaH/DIETHYL ETHER AT 36°C

Reaction time (min)	Products (%)[a]		
	 (VIIb)	 (VIIIb)	IXb
6	40	40	20
30	30	30	40

[a] Determined from NMR spectra; exp. error ±3%.

observed absorption bands at 1560 and 1585 cm^{-1} can be assigned to the enolate IVb'; (iii) the enolate IVb slowly isomerises to VI'b upon time.



$$CH_2{=}\underset{\substack{|\\ Li}}{\overset{\substack{CH_3\\|}}{C}}{-}\underset{}{CH}{-}\underset{\substack{\|\\ O}}{C}CH_2C_6H_5 \rightarrow (CH_3)_2C{=}CH\underset{\substack{\|\\ O}}{C}{-}\underset{\substack{|\\ Li}}{C}HC_6H_5$$

(IVb) (IVb')

Experimental

Diethyl ether was treated with stannous chloride and dried over sodium wire. Copper iodide was regenerated from the complex $[CuI, (n\text{-}C_4H_9)_3P]_4$ prepared according to ref. 10. Ethereal solutions of methyllithium (Alfa) were standardised against HCl and I_2 solutions. Compounds Ib, Id were prepared according to ref. 8.

The reactions were performed under dried argon. Reagents were added with a syringe via a side arm capped with a rubber septum. NMR and IR cells were cooled to the appropriate temperature, purged, and filled under argon. In a standard procedure, to a suspension or a solution of a copper(I) salt (CuI or CuI, $(n\text{-}C_4H_9)_3P$) 3×10^{-3} mol in 5 ml of ether two equivalents of CH_3Li were added at −23°C. After 10 min 3×10^{-3} mol of the allenic compound (in 5 ml of ether) were added at the relevant temperature. Part of the solution was transferred to the NMR or IR cell, and the residue quenched with a saturated NH_4Cl solution.

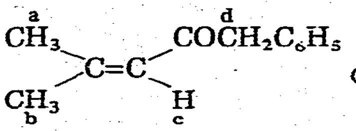
Asymmetric induction: 10^{-3} mol of solid DIOP were added to a solution of lithium dimethylcuprate (10^{-3} mol in 5 ml of ether). The mixture was stirred at 0°C for 30 min. A light green, almost homogeneous solution was obtained. After cooling at −78°C 10^{-3} mol of Ic (in 5 ml of ether) were added. After 3 min the solution was quenched with a saturated NH_4Cl solution and the product purified by preparative TLC (silica gel Merck 60 $PF_{254+366}$; hexane/ethyl acetate 80/20).

Metallation of Vb and VIb. Compounds Vb and VIb (3×10^{-3} mol in 5 ml of ether) were added to a suspension of sodium hydride (3×10^{-3} mol in 5 ml of ether) under argon. The mixture was refluxed and then transferred to the NMR or IR cell or hydrolysed with D_2O.

Compounds were identified from their IR and NMR spectra and by the observation of the molecular peak in mass spectrometry. The main features are indicated below. NMR: δ(ppm) (TMS internal standard); *J* (Hz); s, singlet; d, doublet; m, multiplet.

$\overset{a}{C}H_2{=}C(\overset{b}{C}H_3)\overset{c}{C}H_2CO\overset{d}{C}H_2C_6H_5$ (Vb)

IR: ν(C=C): 1650 cm^{-1}, ν(C=O): 1715 cm^{-1}. NMR: (a) 4.83; 5.0m; (b) 1.74m; (c) 3.17m; (d) 3.75s.

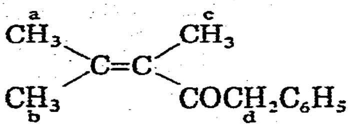


(VIb)

IR: ν(C=C): 1630 cm^{-1}, ν(C=O): 1690 cm^{-1}. NMR: (a) 2.16d, *J*(c) 1.25; (b) 1.86d, *J*(c) 1.25; (c) 6.14m; (d) 2.82s. The IR and NMR spectra of compounds VIIb; VIIIb and IXb are identical to those of VIb,

$\overset{a}{C}H_2{=}C(\overset{b}{C}H_3)\overset{c}{C}H(\overset{d}{C}H_3)CO\overset{e}{C}H_2C_6H_5$ (Vc)

IR: ν(C=C): 1650 cm^{-1}; ν(C=O): 1715 cm^{-1}. NMR: (a) 4.9m; (b) 1.66m; (c) 3.3q, *J*(d) 7; (d) 1.16d; (e) 3.86s.

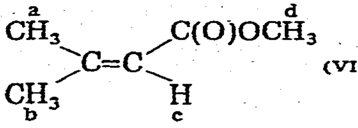


(VIc)

IR: ν(C=C): 1630 cm^{-1}; ν(C=O): 1695 cm^{-1}. NMR: (a) 2.0s; (b) 2.3s; (c) 1.76s; (d) 3.94s.

$\overset{a}{C}H_2{=}C(\overset{b}{C}H_3)\overset{c}{C}H_2C(O)O\overset{d}{C}H_3$ (Vd)

IR: ν(C=C): 1650 cm^{-1}; ν(C=O): 1735 cm^{-1}. NMR: (a) 4.86m; (b) 1.8m; (c) 3.03m; (d) 3.86s.



(VId)

IR: ν(C=C): 1636 cm^{-1}; ν(C=O): 1720 cm^{-1}. NMR: (a) 2.16d, *J*(c) 1; (b) 1.9d, *J*(c) 1; (c) 5.6m, (d) 3.66s.

Acknowledgements

We thank Dr. W. Chodkiewicz and Prof. G.H. Posner for stimulating discussions. We also thank Dr. P. Cresson for samples of compound Ic [9].

References

1 J. Berlan, J.P. Battioni, K. Koosha, Tetrahedron Lett., (1976) 3355.

2 J. Berlan, J.P. Battioni and K. Koosha, Tetrahedron Lett., (1976) 3351.

3 J. Berlan and K. Koosha, to be published.

4 H. Rivière and P.W. Tang, Bull. Soc. Chim. Fr., (1973) 2455; C.R. Acad. Sci. Paris Ser. C, 274 (1972) 1944; P. Four, H. Rivière and P.W. Tang, Tetrahedron Lett., (1977) 3879.

5 G.H. Psoner, C.M. Lentz, to be published.

6 J. Klein and R. Levene, J. Chem. Soc. Perkin II, (1973) 1971.

7 A. Alexakis, J. Normant and J. Villieras, Tetrahedron Lett., (1976) 3461.

8 R. Couffignal and M. Gaudemar, Bull. Soc. Chim. Fr., (1969) 898; M. Gaudemar, Ann. Chim., 13 (1956) 161.

9 P. Cresson, C.R. Acad. Sci. Paris Ser. C, 284 (1977) 247.

10 B. Kauffman and L.A. Teter, Inorg. Synth., 7 (1963) 9.