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Reaction of the Conjugate Base of Propenylpyrrolidinocarbene Chromium Pentacarbonyl Complex with Electrophiles

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Abstract: *The conjugate base of pentacarbonyl(propenylpyrrolidinocarbene)chromium(0) is easily generated at -78 °C with LDA and reacts with electrophilic reagents to provide the corresponding addition products in satisfactory to good yields. The α/γ regioselectivity depends on the nature of the electrophile and is also discussed in comparison with the behavior of the anions of crotonamides*

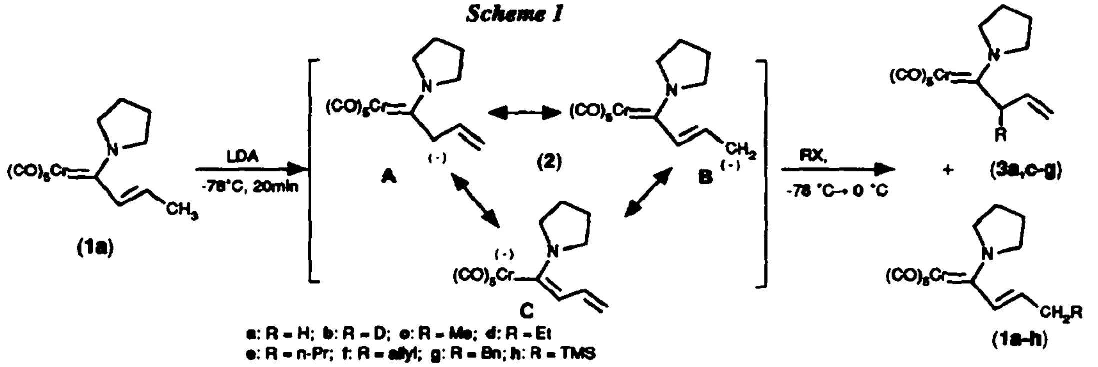
The broad, interesting and sometimes unpredictable reactivity shown by transition metal carbene complexes justifies the enormous amount of work which has done since their discovery by E. O. Fischer in 1964.[1] Among the systems under investigation, the α,β-unsaturated amino carbene complexes have recently received particular attention.[2] Aminolysis with primary amines of pentacarbonyl(alkenylalkoxycarbene)chromium(0) complexes represents the most useful method of synthesising the corresponding aminocarbene complexes. However, it gives poor results with secondary amines whose corresponding amino carbene complexes are satisfactorly obtained: *i*) by *N*-alkylation of the corresponding complexes coming from aminolysis with primary amines[3a], *ii*) by Peterson olefination using the conjugate base of α-silylamino carbene complexes[4] *iii*) by dehydration of the corresponding aldol addition products .[5]

The reactivity of α,β-unsaturated amino carbene complexes has been analyzed in cycloaddition reactions,[3a,b] in reactions with alkynes[2] and in photochemically stimulated reactions.[6] Since the $Cr(CO)_5$ group in carbene complexes is isolobal with an oxygen atom, their chemical behavior is often compared to that of the corresponding carbonyl derivatives. From this point of view, α,β-unsaturated amino carbene complexes can be considered as the synthetic equivalent of the corresponding α,β-unsaturated amides. It is known that tertiary crotonamides can be metallated by LDA only in the presence of HMPA (to prevent the formation of 1,4 Michael addition adducts[7]) and that, in most cases, the corresponding dienolates react regiospecifically with electrophiles, yielding α-substitution. [8,9a] The presence of copper salts (CuI), in some special cases, and with particular electrophiles, can shift regioselectivity in favor of γ-substituted products.

Since it has been reported that, owing to the unfavorable steric effects exerted by the $Cr(CO)_5$ moiety, the conjugate bases of α-substituted aminocarbene complexes are slightly reactive towards electrophiles[4,10], we expected that the "dienolate"[11] of alkenylaminocarbene complexes would react with electrophiles to give better γ-selectivity than that shown by crotonamides in the same reaction. So far, there are no published reports concerning the formation and reactivity of the vinylogous anions of aminocarbene complexes; in this paper, we report the preliminary results of our first study in this area.

We have found that, unlike tertiary crotonamides,the pentacarbonyl(propenylpyrrolidino)chromium carbene complex (**1a**) is easily metallated in the absence of HMPA by using LDA or *t*-BuLi in THF solution at -78°C, to give the corresponding "dienolate" (**2**) described by the resonance structures A, B, C shown in Scheme 1.

Scheme 1



When the proton was used as electrophile, the starting carbene complex (**1a**) was recovered as well as 20% of the corresponding isomeric allyl carbene complex (**3a**) (Table 1, Entry 1) and this ratio does not show any appreciable modification between -78°C and 0°C. As expected, the anion (**2**) also reacts with a variety of other electrophilic reagents (Entries 3-8), producing the corresponding products (**3c-g**) and (**1c-h**) in comparable and sometimes better overall yields than those obtained with tertiary crotonamides (Scheme 1).[9a] Chemical yields and the α/γ ratio are reported in Table 1.

Table 1 Reaction of propenylpyrrolidino carbene complex (**1a**) with RX

Entry	RX	Products (1:3 ratio)[a]	% yield[b]
1	AcOH[c]	**1a** + **3a** (80:20)	90
2	MeOD[d]	**1b**	80
3	MeI	**1c** + **3c** (16:84)	74
4	EtI	**1d** + **3d** (37:63)	60
5	PrI	**1e** + **3e** (38:62)	70
6	AllylI	**1f** + **3f** (41:59)	48
7	BnBr	**1g** + **3g** (25:75)	80
8	TMSCl	**1h**	30

[a] Ratio evaluated by ^{1}H NMR on the crude reaction mixture. [b] Yields based on recovered alkylated products. No starting material was detectable in the crude reaction mixture. [c] The anion (2) was quenched with 10% acetic acid solution in THF. [d] The anion (2) was generated by t-BuLi at -78°C in THF.

As shown in Table 1, regioselectivity is in favor of the α-position in almost all cases. We would like to emphasize that γ-substitution products also obtained even with MeI[9b] and BnBr (Entries 3 and 7) which are known to give regiospecifically α-substituted derivatives in reaction with the dienolate of crotonamides.[9a] In addition, with EtI, PrI and allylI, γ-selectivity becomes significatly higher (Entries 4-6). Complete γ-subtitution is obtained with the bulky and less reactive trimethylsilylchloride (Entry 8).

As previously mentioned, α-alkylation is quite unusual in the case of α-substituted aminocarbene complexes. Reduced hindrance of the planar vinyl substituent with respect to alkyl substituents, and the release of strain due to the deconjugation of the double bond in α-localized anions (Structure A, Scheme 1) as well as differences in the type and size of the possible aggregates in solution for (**2**) can be taken as a possible explanation for the rather unexpected α-reactivity observed in our case. The formation of complexes between (**2**) and diisopropylamine cannot also be excluded. We have observed that, when the dienolate (**2**) generated by LDA, was quenched with MeOD, the non-deuterated starting complex (**1a**) was recovered, whereas the γ-monodeuterated (**1b**) was obtained using *t*-BuLi as the base (Entry 2) . This behavior is very similar to that reported for enolates generated by LDA, where the complexed diisopropylamine compete with D^+ in quenching the enolate (the effect of hidden proton).[12]

Finally, to our knowledge, the β,γ unsaturated derivatives (**3**) represent a new class of aminocarbene complexes.[13] We have evidence that the double bond can be coordinated by the metal[14] and this should further increase their interest as potential starting materials in thermal reactions with alkynes.

From these preliminary results it is clear that, in comparison with crotonamides, the alkenylaminocarbene complexes, offer advantages both in the generation of the corresponding dienolate and (thanks to the $Cr(CO)_5$ group) in controlling the regioselectivity of its reaction with electrophiles. We wish to exploit the reactivity of "dienolate" (**2**) towards some other electrophilic reagents, as well as to study the reactivity of the newly generated classes of carbene complexes.

Typical procedure: To a tetrahydrofuran solution of dienolate (**2**) [generated by adding 1.3 mmol of LDA (from 1.3 mmol of diisopropylamine and 1.3 mmol of a 1.6M *n*-BuLi solution in hexane in 5ml of THF at 0°C) to 1mmol of (**1a**) at -78°C and keeping the mixture at the same temperature for 20 min] 3 eq. of alkylating reagent was added by means of a syringe at -78°C under inert atmosphere. The cooling bath was substituted with a ice bath and the mixture was allowed to react at 0°C for 1h. The reaction was quenched by adding 10 ml of saturated ammonium chloride solution, extracted with CH_2Cl_2 (2 x 50 ml), and the organic layer was dried over Na_2SO_4. The solvent was evaporated under reduced pressure and the crude reaction mixture was purified by means of filtering-column chromatography (eluent light petroluem/CH_2Cl_2, 8:2).[15] The first eluted product was always the γ-adduct. All of the new alkenylpyrrolidinocarbene complexes were fully characterized by means of spectroscopic techniques (^1H, ^{13}C NMR, I.R., M.S.) and gave satisfactorly elemental analysis. Data for:

3c: m.p. 45°C (Heptane, -78°C); IR(nujol): 2046 (ν CO *trans*),1977-1797 (broad, ν CO *cis*), 1640 (ν C=C) cm^{-1}; ^1H NMR (80 MHz, $CDCl_3$) δ ppm: 1.26 (d, 3H, J_{vic}= 7.0Hz, Cr=C-CH-CH_3), 2.10 (m, 4H, CH_2CH$_2$-$_Z$N$_E$-CH$_2$CH_2), 3.65 (m, 2H, N$_E$-CH_2CH$_2$), 4.20 (m, 3H, CH$_2$CH_2-$_Z$N + Cr=C-C*H*-CH$_3$), 5.04 [dt, 1H, J_{trans}= 17.1Hz, J_{gem}= $J_{allilic}$= 1.8Hz, -CH=C*H*(H)], 5.20 (dt, 1H, J_{cis}= 10.5Hz, J_{gem}= $J_{allilic}$= 1.8Hz, -CH=C(H)*H*], 6.00 (ddd, 1H, J_{trans}= 17.1Hz, J_{cis}= 10.5Hz, J_{vic}= 4.9Hz,-C*H*=CH$_2$); ^{13}C NMR (200MHz, $CDCl_3$) δ ppm: 15.91 (-CH-CH_3), 24.92 (N$_E$-C-*C*), 26.21 (*C*-C-$_Z$N), 55.05 (N$_E$-*C*-C), 58.54 (-*C*H-CH$_3$), 62.89 (C-*C*-$_Z$N), 116.05 (-CH=*C*H$_2$), 138.61 (-*C*H=CH$_2$), 219.02 (CO_{cis}), 223.72 (CO_{trans}), 276.92 (Cr=*C*-C); MS, m/z= 329 (M^+, very low intensity), 301 (M^+-CO), 273 (M^+-2CO), 245 (M^+-3CO), 217 (M^+-4CO), 189 (M^+-5CO, 100%)

1h: m.p. 71°C (pentane, -78°C); IR(nujol): 2055 (ν CO *trans*),1963-1880 (broad, ν CO *cis*), 1631 (ν

C=C), 866 (ν Si-C) cm^{-1}; ^{1}H NMR (80 MHz, $CDCl_3$) δ ppm: 0 .06 [s, 9H, $Si(CH_3)_3$], 1.67 (d, 2H, J_{vic}= 8.4Hz, Cr=C-CH=CH-CH_2-Si), 2.07 (m, 4H, CH_2CH_2-$_Z$N$_E$-CH_2CH_2), 3.63 (m, 2H, N$_E$-CH_2CH_2), 4.14 (m, 2H, CH_2CH_2-$_Z$N), 5.83 (dt, 1H, J_{trans}= 15.6Hz, J_{vic}= 8.4Hz, Cr=C-CH=CH-CH_2-Si), 6.36 (broad d, 1H, J_{trans}= 15.6Hz, Cr=C-CH=CH-CH_2-Si); ^{13}C NMR (300MHz, $CDCl_3$) δ ppm: -1.04 [-$Si(CH_3)_3$], 25.45 (Cr=C-C=C-*C*-Si), 25.71 (N$_E$-C-*C*), 26.12 (*C*-C-$_Z$N), 55.33 (N$_E$-*C*-C), 60.28 (C-*C*-$_Z$N), 131.12 (Cr=C-C=*C*-C), 140.68 (Cr=C-*C*=C-C), 219.22 (CO_{cis}), 224.32 (CO_{trans}), 264.40 (Cr=*C*-C); MS, m/z= 387 (M$^+$, very low intensity), 359 (M$^+$-CO), 331 (M$^+$-2CO), 303 (M$^+$-3CO), 275 (M$^+$-4CO), 247 (M$^+$-5CO, 100%)

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