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NEW C-C BOND FORMATION WITH PYRIDINIUM METHYLIDE: HYDROMETHYLENATION OF OLEFIN

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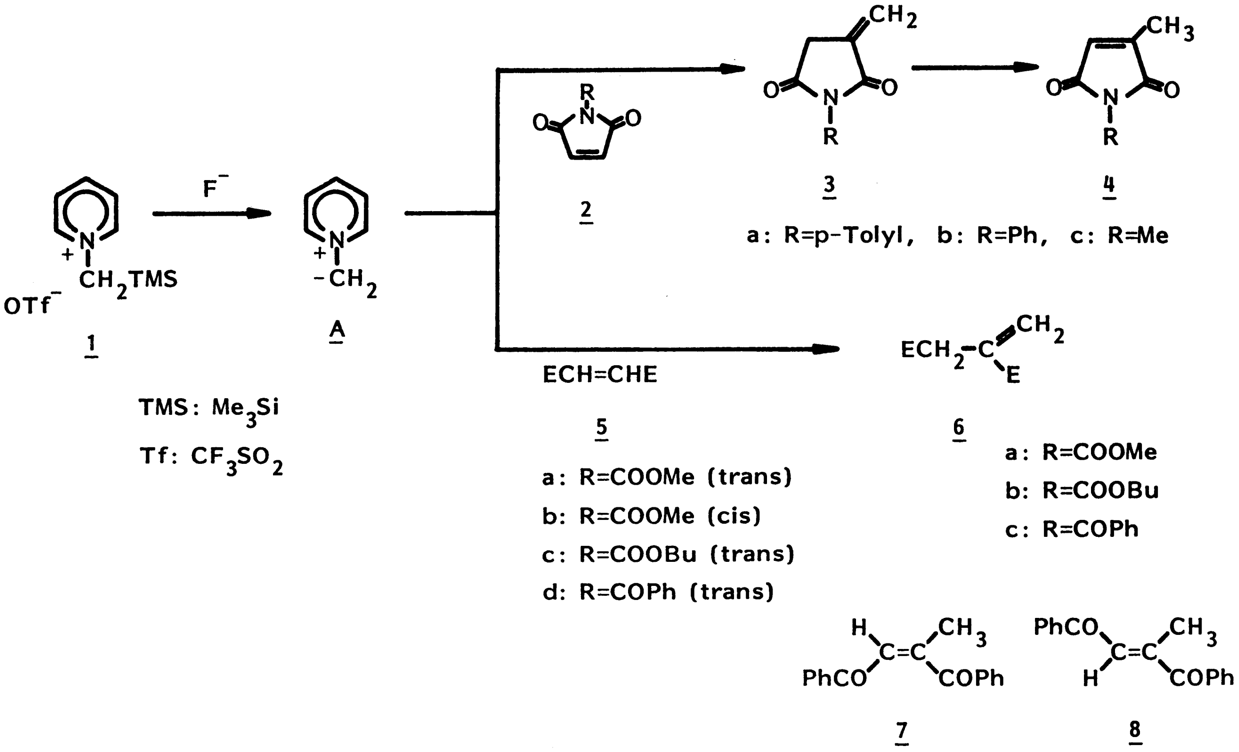
New C-C bond formation with pyridinium methylide is presented: Pyridinium methylide reacts with electron-deficient olefins providing the next higher homologs of olefins, in which the double bond of starting olefin is saturated and, instead, a C=C double bond is newly formed. This reaction mode has been never reported before in the study of nitrogen ylide and is to be referred to as hydromethylenation of olefin. In the presence of base, 1,2-double bond migration occurs leading to the methylated derivatives of starting olefins.

The preceding communication has presented the first synthesis of N-(trimethylsilylmethyl)pyridinium triflates as convenient precursors for nonstabilized pyridinium methylides.[1] The methylides generated by desilylation with fluoride ion underwent ready cycloaddition reactions to an acetylenic dipolarophile giving indolizine derivatives with no substituent at the 3-position. Although the generation of nonstabilized pyridinium methylide was suggested long ago in the reaction of N-methylpyridinium bromide with benzaldehyde in the presence of piperidine[2] and in the reaction among pyridine, bromoacetic acid, and benzaldehyde at elevated temperature,[3] its use in organic synthesis is hardly known.

The use of N-ylides of nitrogen aromatics was often limited to the cycloaddition reactions to acetylenic dipolarophiles. However, quite recently some examples of stereoselective cycloaddition reactions to olefinic dipolarophiles[4] as well as the first cyclopropanation[5] with N-ylides of nitrogen aromatics have been reported. Since these new findings, an interest in the chemistry of N-ylides of nitrogen aromatics is rapidly growing. It is attractive to exploit the utility of nonstabilized pyridinium methylides in organic synthesis.

The present communication presents a new mode of reaction for the N-ylides of nitrogen aromatics: Pyridinium methylide reacts with electron-deficient olefins giving the next higher homologs of olefins, in which the double bond of starting olefin is saturated and, instead, a C=C double bond is newly formed.

An equimolar mixture of N-(trimethylsilylmethyl)pyridinium triflate 1, N-(p-tolyl)maleimide 2a, and cesium fluoride in dry 1,2-dimethoxyethane (DME) was stirred under nitrogen at room temperature for 24 h. The reaction mixture was poured into water, extracted with chloroform, the chloroform was dried, and removed off under reduced pressure. The residue was separated and purified through a column chromatography on silica gel to afford two products 3a (mp 128-129 °C) and 4a (mp 116-117 °C) in 65 and 12% yields, respectively (Scheme 1 and Table 1). The major product 3a was identical with a known compound, N-(p-tolyl)itaconimide, on the basis of the spectral data as well as the elemental analysis.[6] The minor one 4a, an isomer of 3a, was assigned as N-(p-tolyl)citraconimide.[7] It was found that the minor product 4a was secondarily derived from the major one 3a since this conversion actually took place in a quantitative yield when 3a was treated with a catalytic amount of triethylamine in chloroform at room temperature.



Scheme 1.

To our surprise, this reaction is very sensitive to the reaction conditions, in particular to the solvents: Although the reaction in DME at room temperature provided the satisfactory result, the same reaction in dichloromethane quantitatively recovered the maleimide 2a. On the other hand, 2a mostly polymerized when the reaction was carried out in hexamethylphosphoric triamide (HMPA) or acetonitrile also at room temperature. Therefore, similar reactions of 1 with N-phenyl- 2b and N-methylmaleimides 2c were investigated in DME and the itaconimides 3b, 3c and citraconimide 4b were obtained in fair yields (Table 1).[8]

Symmetrically substituted acyclic olefins are much less reactive than the maleimides 2. The reactions of 1 with dimethyl fumarate 5a in the presence of cesium fluoride in such solvents as DME, HMPA, and acetonitrile at room temperature recovered the starting 5a in quantitative yields in all cases. But fortunately, 5a hardly polymerizes even under harder conditions so that this reaction was successfully carried out under reflux in DME to give a low melting product 6a (mp 35 °C, in 75% yield) which was assigned as dimethyl itaconate again by the comparison of the spectral data with those of an authentic sample. Dibutyl fumarate 5c and trans-dibenzoylethene 5d also reacted with 1 under reflux in DME to give the similar results.[9] In the latter case, the ready isomerization of the initial product 6c occurred leading to the cis- 7 and trans-propenes 8.[10]

Contrary to the smooth reaction of trans-olefin 5a, its cis-isomer 5b, dimethyl maleate, did not react with 1 under the same conditions. This dramatic difference of reactivity indicates that the reac-

Table 1. Hydromethylenation of Olefins with Pyridinium Methylide.

Entry	Olefins	Conditions[a)]	Products (yield)	Isomerization[b)] (yield)
1	2a	A[c)]	3a (65%), 4a (12%)	3a → 4a (100%)
2	2b	A	3b (50%), 4b (12%)	3b → 4b (100%)
3	2c	A	3c (30%)	
4	5a	B[d)]	6a (75%), recovered 5a (19%)	
5	5b	B	recovered 5b (100%)	
6	5c	B	6b (50%), recovered 5c (22%)	
7	5d	B	6c (18%), 7 (30%), 8 (28%)	6c → 7 + 8 (80%)

a) A: At room temperature for 24 h in DME in the presence of cesium fluoride (1 equiv.). B: Under reflux in DME for 24 h in the presence of cesium fluoride (1 equiv.).

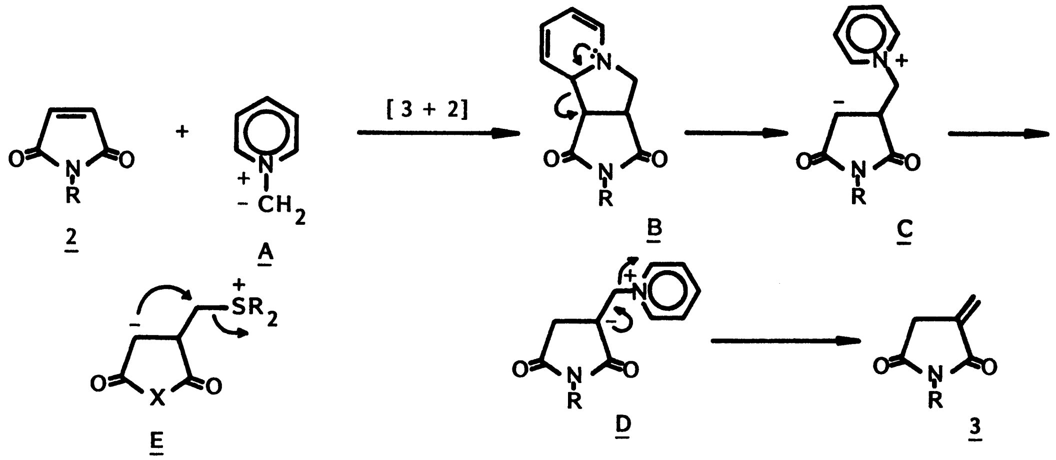
b) With a catalytic amount of triethylamine in chloroform at room temperature.

c) When the solvent was replaced with HMPA or MeCN, the only isolated product was polymer of 2a, and with CH_2Cl_2, the starting 2a was recovered (90%).

d) The reactions at room temperature in DME, HMPA, MeCN all recovered the starting 5a, but polymerization occurred at 100 °C in DMF.

tion of nonstabilized pyridinium methylide A with electron-deficient olefins 2 and 5 proceeds via the intermediary [3 + 2] cycloadducts. The alternative mechanism that involves the nucleophilic addition of the ylide carbon of A onto the electron-poor carbon of olefins would not have shown such a great difference.

In our reactions, as described above, the ylide carbon of pyridinium methylide A is transferred as a methylene unit onto the carbon of olefins which are converted into dihydro derivatives with methylene substituent. Accordingly, this conversion may be referred to as hydromethylenation of olefin. A possible mechanism is presented in Scheme 2 that takes a maleimide 2 as an example. The [3 + 2] cycloaddition reaction between the pyridinium methylide A and 2 is the initial reaction that forms the



Scheme 2.

cycloadduct B. Ring opening of B leads to the zwitterionic intermediate C. The 1,2-proton migration followed by the 1,2-elimination of pyridine yields the isolated product 3. A point to be emphasized in this reaction is the 1,2-proton migration of C. In the case of such similar zwitterion E as has been posturated in the cyclopropanation with sulfur ylides, the anion directly attacks the carbon attached with a sulfur moiety forming a three-membered ring. So far it is not obvious what such a contrast has come from.

References

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5) Y. Yamashita, Y. Miyauchi, and M. Masumura, Chem. Lett., 1983, 489.

6) The reported melting point of 3a is 59-60 °C (H. Akashi, Kogyo Kagaku Zasshi, 65, 148 (1962)) that is quite different from that of 3a we obtained.

3a: IR (KBr) 1695 and 1650 cm^{-1} (C=O); ^1H-NMR ($CDCl_3$) δ2.37 (3H, s, p-Me), 3.47 (2H, t, J=2.3 Hz, CH_2), 5.70, 6.43 (each 1H, t, J=2.3 Hz, =CH_2), and 7.07-7.30 ppm (4H, m, ArH); ^{13}C-NMR ($CDCl_3$) δ21.08 (q, Me), 33.76 (t, CH_2), 121.06 (t, =CH_2), 126.11 (d), 129.28 (s), 129.57 (d), 133.16 (s), 138.44 (s), 168.50 (s, CO), and 172.84 ppm (s, CO); Mass m/e 201 (M^+).

All the new compounds reported herein gave satisfactory elemental analyses.

7) 4a: IR (KBr) 1680 cm^{-1} (C=O); ^1H-NMR ($CDCl_3$) δ2.17 (3H, d, J=2.0 Hz, Me), 2.39 (3H, s, p-Me), 6.44 (1H, q, J=2.0 Hz, =CH), and 7.12-7.31 ppm (4H, m, ArH); ^{13}C-NMR ($CDCl_3$) δ10.98 (q, Me), 21.02 (q, p-Me), 125.76 (d), 127.34 (d, =CH), 128.98 (s), 129.57 (d), 137.50 (s), 145.54 (s), 169.56 (s, CO), and 170.61 ppm (s, CO); Mass m/e 201 (M^+).

8) 3b: Mp 116.5-117 °C (reported mp 96-97 °C (see the reference in Ref. 6)). ^1H-NMR ($CDCl_3$) δ 3.51 (2H, t, J=2.5 Hz, CH_2), 5.72, and 6.45 ppm (each 1H, t, J=2.5 Hz, =CH_2); ^{13}C-NMR ($CDCl_3$) δ 33.82 (t, CH_2), 121.39 (t, =CH_2), 168.36 (s, CO), and 172.70 ppm (s, CO); Mass m/e 187 (M^+).

4b: Mp 93-94 °C. ^1H-NMR ($CDCl_3$) δ2.18 (3H, d, J=2.0 Hz, Me) and 6.45 ppm (1H, q, J=2.0 Hz, =CH); ^{13}C-NMR ($CDCl_3$) δ 11.06 (q, Me), 127.58 (d, =CH), 169.43 (s, CO), and 170.50 ppm (s, CO); Mass m/e 187 (M^+).

3c: Colorless liquid. ^1H-NMR ($CDCl_3$) δ 3.04 (3H, s, Me), 3.29 (2H, t, CH_2), 5.58, and 6.31 ppm (each 1H, t, =CH).

9) 6b: Bp 89-93 °C/2 mmHg (reported bp 135-136 °C/10 mmHg (M. A. Askarov and L. N. Semenova, Uzb. Khim. Zh., 11, 42 (1967)). It gave satisfactory spectral data.

6c: Mp 57-58 °C. IR (KBr) 1645 (C=O) and 1585 cm^{-1} (C=C); ^1H-NMR ($CDCl_3$) δ4.24 (2H, s, CH_2), 5.80, 5.95 (each 1H, s, =CH_2), 7.38-7.56, and 7.80-8.00 ppm (10H, m, ArH); ^{13}C-NMR ($CDCl_3$) δ42.62 (t, CH_2), 128.16 (t, =CH_2), and 196.97 ppm (s, CO); Mass m/e 250 (M^+).

10) 7: Yellow viscous oil, bp 175-180 °C/0.5 mmHg (bulb-to-bulb). IR (neat) 1650 (C=O) and 1600 cm^{-1} (C=C); ^1H-NMR ($CDCl_3$) δ2.20 (3H, d, J=1.3 Hz, Me), 7.11 (1H, q, J=1.3 Hz, =CH), 7.20-7.50, and 7.80-7.95 ppm (10H, m, ArH); ^{13}C-NMR ($CDCl_3$) δ22.08 (q, Me), 122.88 (d, =CH), 187.93 (s, CO), and 199.20 ppm (s, CO); Mass m/e 250 (M^+).

8: Yellow viscous oil, bp 190-195 °C/0.3 mmHg (bulb-to-bulb). IR (neat) 1650 (C=O) and 1590 cm^{-1} (C=C); ^1H-NMR ($CDCl_3$) δ2.35 (3H, d, J=1.6 Hz, Me), 7.07 (1H, Q, J=1.6 Hz, =CH), 7.30-7.60, and 7.78-7.92 ppm (10H, m, ArH); ^{13}C-NMR ($CDCl_3$) δ15.84 (q, Me), 130.11 (d, =CH), and 191.41 ppm (s, CO); Mass m/e 250 (M^+).

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