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α,β-Unsaturated Orthoesters as Michael Acceptors. The Trityl Salt-Catalyzed Michael Reaction of α,β-Unsaturated Orthoesters with Silyl Enol Ethers

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In the presence of a catalytic amount of trityl salts, α,β-unsaturated orthoesters react with various silyl enol ethers to afford the corresponding Michael adducts in good yields.

α,β-Unsaturated esters are useful Michael acceptors though their reactivities are generally rather low. Recently it was reported that Li enolates of esters or amides stereoselectively react with α,β-unsaturated esters to produce the corresponding Michael adducts in good yields.1) However, this reaction has several synthetical limitations, that is, i) the reaction proceeds under strongly basic conditions, ii) the competitive polymerization sometimes occurs by the use of acrylic acid ester derivatives, and iii) no desired adducts can be obtained when β-disubstituted α,β-unsaturated esters are employed as Michael acceptors. Further, iv) there has never been reported on the reaction of Li enolates (or any other metal enolates) derived from ketones with α,β-unsaturated esters.2) Thus, it is strongly desired to develop a widely applicable method which is carried out under mild reaction conditions.

In the previous papers,3) we have demonstrated that, in the presence of a catalytic amount of trityl salts, silyl enol ethers derived from ketones or thioesters stereoselectively react with α,β-unsaturated ketones to afford the corresponding Michael adducts in high yields. This reaction has advantages over the conventional acid promoted reactions such as $TiCl_4$-mediated one4) because of the achievement of high regio- and stereoselectivities by the catalytic use of the promoter and the possible isolation of the products as synthetically valuable silyl enol ethers. In this communication, we wish to report the trityl salt-catalyzed Michael reaction of α,β-unsaturated orthoesters, α,β-unsaturated ester equivalents, with silyl enol ethers.

In the first place, the reaction of methyl acrylate with silyl enol ether of acetophenone was tried in the presence of a catalytic amount of trityl perchlorate. And the corresponding Michael adduct was obtained in rather low yield (30%). Next, in order to improve the yield, several α,β-unsaturated ester equivalents were examined, and it was found that α,β-unsaturated orthoesters5) are suited for the Michael acceptors. The reaction of triethyl orthoacrylate with silyl enol ether of acetophenone was smoothly carried out in the presence of a

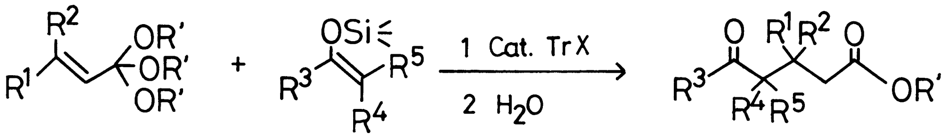
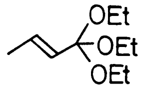
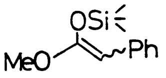
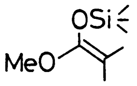
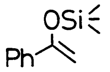
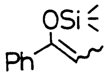
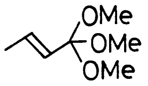
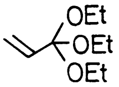
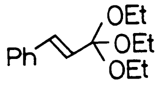
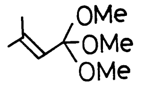


Table 1. The reaction of α,β-unsaturated orthoesters with silyl enol ethers[a)]

Entry	α,β-Unsaturated orthoester	Silyl enol ether	Yield/%
1	 1	 4[c)]	73 (77:23)[b)]
2	1	 5	75
3	1	 6	67
4	1	 d)	58 (78:22)[b)]
5	 2	4	84 (82:18)[b)]
6	2	5	87
7	2	6	65
8	 3	4	61
9	3	5	86
10	3	6	70
11		5	92
12		5	90

a) All the products gave satisfactory spectral data.

b) Determined by ^{1}H NMR and/or HPLC. Relative configuration assignment was not made.

c) Z/E = 95/5.

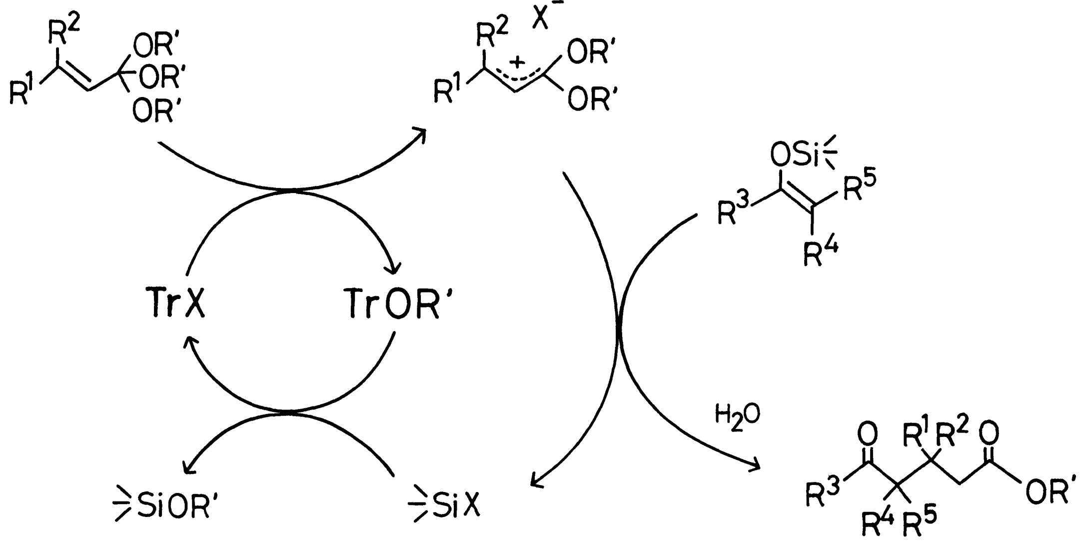
d) Z/E = >95/5.

catalytic amount of trityl perchlorate to afford the corresponding Michael adduct (after hydrolysis) in 70% yield.

Several examples of the reaction of α,β-unsaturated orthoesters with silyl enol ethers are demonstrated in Table 1.[6)] In this reaction, nucleophilic attack of silyl enol ethers to α,β-unsaturated orthoesters regioselectively took place and no 1,2-addition product was obtained. Silyl enol ethers derived from ketones as well as esters, smoothly react with α,β-unsaturated orthoesters to produce the corresponding Michael adducts in good yields. α,β-Unsaturated orthoesters of acrylic acid ester derivatives also react with silyl enol ethers and no polymeric adduct was detected. Furthermore, trimethyl ortho-3-methyl-2-butenoate, a β-disubstituted α,β-unsaturated orthoester, can be successfully employed in this reaction and the corresponding adducts is obtained in high yield.

A typical procedure is described for the reaction of trimethyl orthocrotonate (2) with silyl enol ether of methyl phenylacetate (4); the mixture of 2 (0.4 mmol), 4 (0.44 mmol), and trityl perchlorate (5 mol%) in dichloromethane (3 ml) was stirred at -78 °C overnight. Aqueous sodium hydrogencarbonate was added at -78 °C and aqueous layer was extracted with dichloromethane. After the organic layer was dried, the solvent was removed under reduced pressure and the residue was separated by silica gel column chromatography to afford dimethyl 3-methyl-2-phenylpentanedioate (84%).

It is postulated that effective activations of α,β-unsaturated orthoesters by the use of a catalytic amount of trityl salts under especially mild conditions are realized by the catalytic cycle as shown below.



To our knowledge, this is the first example of using α,β-unsaturated orthoesters successfully as Michael acceptors. It is noted that, by treating α,β-unsaturated orthoesters with silyl enol ethers in the presence of a catalytic amount of trityl salts, i) the reaction of enolates derived from ketones with α,β-unsaturated ester derivatives and ii) the reaction of enolates with β-disubstituted α,β-unsaturated ester derivatives, both of which can not be carried out according to any other conventional methods, are performed.

References

1) M. Yamaguchi, M. Tsukamoto, S. Tanaka, and I. Hirao, Tetrahedron Lett., 25, 5661 (1984); E. J. Corey and R. T. Peterson, ibid., 26, 5025 (1985).

2) Recently, the Michael reaction of 2-alkenyl-1,3-dithiolan or dithian-2-ylium cations with silyl enol ethers of ketones was reported from our laboratory; Y. Hashimoto and T. Mukaiyama, Chem. Lett., 1986, 755, 1623. Enders also reported the stereoselective Michael reaction of Li enolates of chiral hydrazones, ketone enolate equivalents, with α,β-unsaturated esters; D. Enders, K. Papadopoulos, and B. E. M. Rendenbach, Tetrahedron Lett., 27, 3491 (1986).

3) T. Mukaiyama, M. Tamura, and S. Kobayashi, Chem. Lett., 1986, 1817, and references cited therein.

4) K. Narasaka, K. Soai, Y. Aikawa, and T. Mukaiyama, Bull. Chem. Soc. Jpn., 49, 779 (1976); K. Saigo, M. Osaki, and T. Mukaiyama, Chem. Lett., 1976, 163.

5) α,β-Unsaturated orthoesters are easily prepared from the corresponding orthoesters; H. Stetter and W. Uerdingen, Synthesis, 1973, 207.

6) As kinds of trityl salts and those of substituents on silicon of silyl enol ethers were little effects on yields and diastereoselectivities, trityl perchlorate and trimethylsilyl enol ethers were employed as representatives.

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