CHEMISTRY LETTERS, pp. 2169-2172, 1987.

The Michael Reaction of Various Quinones with Silyl Enol Ethers.
A Facile Method for the Preparation of Benzofuran and Indole Derivatives

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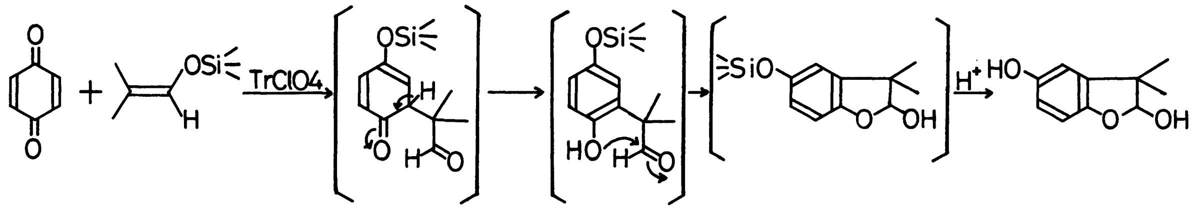
In the presence of a catalytic amount of trityl perchlorate, 1,4-benzoquinone, quinone monoimides, or imidoquinones react with silyl enol ethers to produce the corresponding benzofuran or indole derivatives in high yields via the corresponding Michael adducts.

The Michael-type addition to the α,β-unsaturated carbonyl system of quinones is generally complicated because of a lack of control of regiochemistry.[1)] In particular, there have been few reports on 1,4-addition (the Michael addition) of enolate derived from aldehydes or ketones in spite of its potential utilities.

Recently we have demonstrated that trityl salts are unique and excellent catalysts in the Michael reaction of α,β-unsaturated ketones[2)] or orthoesters[3)] with various silyl enol ethers. This reaction proceeds under extremely mild conditions to afford the corresponding Michael adducts stereoselectively in high yields. We have now investigated the Michael reactions of various quinones such as 1,4-benzoquinone, quinone monoimides, or imidoquinones with silyl enol ethers in the presence of a catalytic amount of trityl perchlorate, and found that the reactions proceed via 1,4-adducts to afford the corresponding benzofuran or indole derivatives after cyclization.

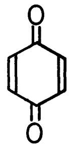
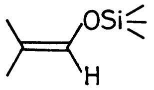
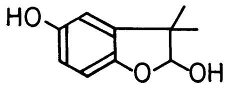
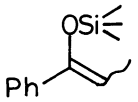
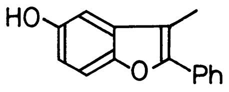
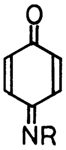
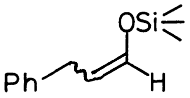
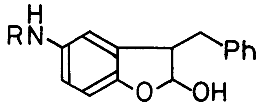
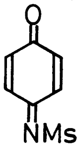
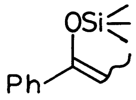
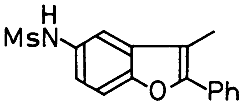
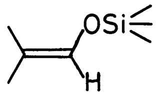
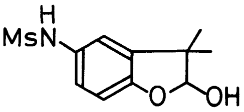
When the reaction of 1,4-benzoquinone with silyl enol ether derived from isobutylaldehyde was tried in the presence of a catalytic amount of trityl perchlorate, it was found that the benzofuran derivative was obtained in 71% yield. This product seemed to be produced by 1,4-addition of the silyl enol ether to benzoquinone, accompanied with aromatization followed by cyclization as shown in Scheme 1.[4)]



Scheme 1.

In order to confirm the generality and scope of this reaction, various quinones were examined in the similar reaction with silyl enol ethers. Quinone monoimides[5) smoothly reacted with silyl enol ethers to afford the corresponding 5-amino-substituted benzofuran derivatives in high yields and no other adducts were isolated[6) (Table 1). The reaction of imidoquinones[7) with silyl enol ethers is listed in Table 2. In this case, the aromatized 1,4-addition products and the indole derivatives formed by further cyclization are obtained in good yields. Further, it was made clear that the former products are easily converted to 5-amino-substituted indole derivatives (later products) on treatment with a catalytic amount of p-toluene sulfonic acid in refluxing benzene (80%-quant. yield). The isolation of the aromatized adducts may support our mechanistic consideration of this reaction.

Table 1. The Reaction of Quinone Monoimides with Silyl Enol Ethers. The Synthesis of Benzofuran Derivatives[a)

Entry	Quinone	Silyl enol ether	Product	Yield/%
1	 1			71
2	1			65
3	 R=Ts,Ms,Mbs[b)			quant.
4	 2			quant.
5	2			93

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a) All the products gave satisfactory NMR and IR spectral data.

b) Mbs- = p-methoxybenzenesulfonyl-

A typical procedure is described for the reaction of quinone monoimides with silyl enol ethers; the mixture of a quinone monoimide (0.4 mmol), a silyl enol ether (0.44 mmol), and trityl perchlorate (5-10 mol%) in dichloromethane (3 ml) was stirred at -45 °C for an appropriate time (1-2 h). Water was added and the aqueous layer was extracted with dichloromethane. Then the residue was treated with the solution of THF and 1 mol/dm^3 HCl (5:1) at room temperature. After usual work-up, the crude benzofuran derivative was purified by thin layer chromatography on silica gel.

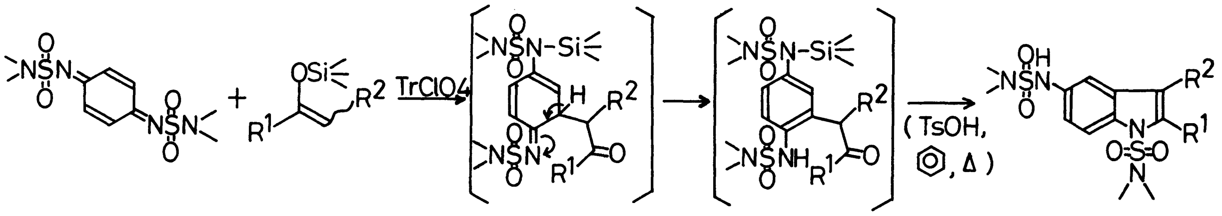
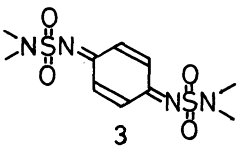
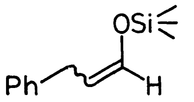
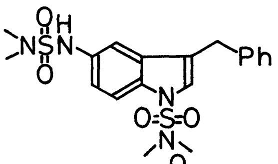
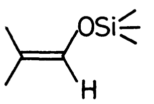
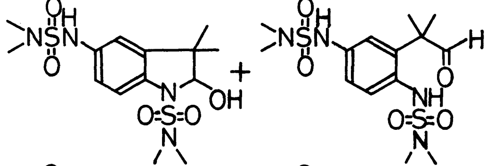
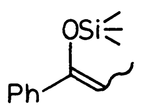
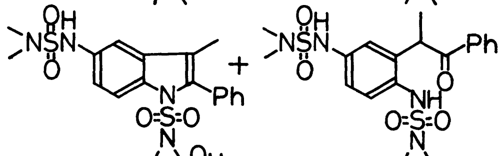
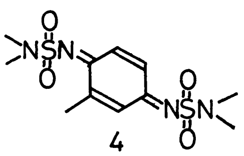
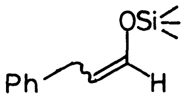
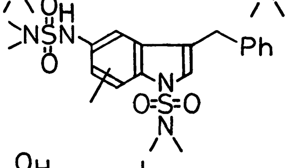
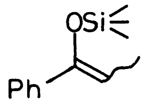
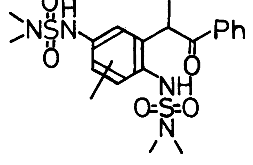


Table 2. The Reaction of Imidoquinones with Silyl Enol Ethers. The Synthesis of Indole Derivatives[a)]

Entry	Imidoquinone	Silyl enol ether	Product	Total yield/%
1	 3			56
2	3			62
3	3			quant.
4	 4			56
5	4		 8)	96

a) All the products gave satisfactory NMR and IR spectral date.

It is noted that, in the presence of a catalytic amount of trityl perchlorate, silyl enol ethers derived from ketones or aldehydes regioselectively react with various quinones to afford benzofuran and indole derivatives via initially formed 1,4- (Michael) adduct. Thus, the present reaction provides a facile synthetic method for the preparation of the above mentioned aromatic compounds. Further progress concerning the application of this reaction leading to biologically interesting compounds are now in progress.

References

1) "The Chemistry of the Quinonoid Compounds, Part I," ed by S. Patai, J. Wiley and Sons, London (1974); D. J. Crouse, M. M. Wheeler, M. Goemann, P. S. Tobin, S. K. Basu, and D. M. S. Wheeler, J. Org. Chem., 46, 1814 (1981) and references cited therein.
2) S. Kobayashi, M. Murakami, and T. Mukaiyama, Chem. Lett., 1985, 1535; T. Mukaiyama, M. Tamura, and S. Kobayashi, ibid., 1986, 1017; 1817; 1987, 743; T. Mukaiyama, Y. Sagawa, and S. Kobayashi, ibid., 1986, 1821; S. Kobayashi and T. Mukaiyama, ibid., 1986, 221; 1805; Heterocycles, 25, 205 (1987).
3) S. Kobayashi and T. Mukaiyama, Chem. Lett., 1987, 1183.
4) We consider that trityl perchlorate activates both 1,4-benzoquinone in the Michael addition and the aldehyde in the cyclization.
5) R. Adams and K. R. Eilar, J. Am. Chem. Soc., 73, 1149 (1951).
6) D. Rutolo, S. Lee, R. Sheldon, and H. W. Moore, J. Org. Chem., 43, 2304 (1978).
7) R. Adams and J. H. Looker, J. Am. Chem. Soc., 73, 1145 (1951).
8) A single isomer was obtained exclusively.

(Received August 10, 1987)