SHORT PAPER

J. Chem. Research (S),
2000, 220–221

Cu (OTf)$_2$ catalysed reactions of furan and thiophene with α,β-unsaturated ketones[†]

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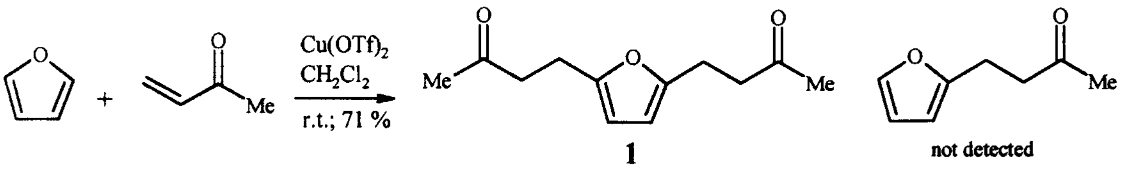
Lewis acid catalysed electrophilic substitution reaction of furan and thiophene with α,β-unsaturated ketones, at ambient temperature is described.

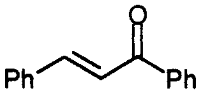
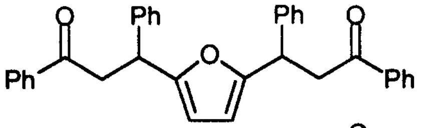
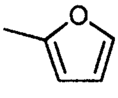
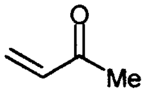
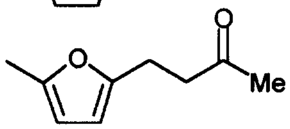
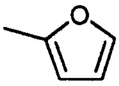
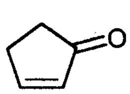
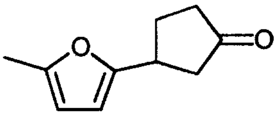
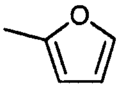
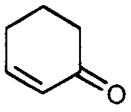
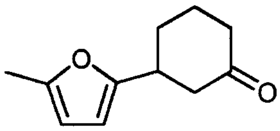
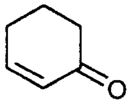
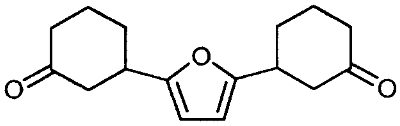
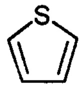
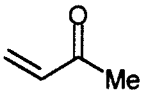
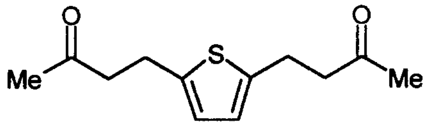
The reaction of furan with less reactive α,β-unsaturated carbonyl compounds often does not follow the expected Diels–Alder cycloaddition process due to the strong aromatic nature of the diene.[1] Several α,β-unsaturated carbonyl compounds fail to act as dienophiles in this reaction but give the Michael addition product in presence of acidic catalysts.[2] A recent report describes acidic clay catalysed similar electrophilic substitution reaction of furan.[3] In this report mixtures of both these possible reaction products were observed. We wish to present our results on the use of copper (II) trifluoromethanesulfonate [Cu (OTf)$_2$] as an efficient and selective catalyst for electrophilic substitution reaction.

Reaction of furan was carried out in dichloromethane at ambient temperature with excess of methyl vinyl ketone



Scheme 1

Table 1 Cu (OTf)$_2$ Catalyzed electrophilic substitution reaction of Furans and Thiophene with α,β-unsaturated ketones

Entry	Substrate	Ketone	Product	% yield[a,b]
1				**2** 60
2				**3** 77
3				**4** 53
4				**5** 55
5				**6** 63
6				**7** 54

[a]Isolated yield. All the reactions were performed with 5 mol % catalyst and the products were characterized by usual spectral and analytical methods. [b]For entries 1, 5 & 6 substrate to α,β-unsaturated ketone ratio was 1:4 while for 2, 3 and 4 it was 1:2.5.

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[†] This is a Short Paper, there is therefore no corresponding material in *J Chem. Research (M).*

Table 2 Spectroscopic data of products

No	Compound	ν_{max}/cm^{-1}	^{1}H NMR δ (200 MHz)	^{13}C NMR (50 MHz) δ	MS *m/z* (%)
1[a]	4-[5-(3-Oxabutyl-2-furyl]-2-butanone	2900, 1710, 1410, 1365, 1160, 780	2.15 (s, 6H), 2.70–2.90 (m, 8H) 5.85 (s, 2H)	22.12, 29.59, 41.58, 105.57, 152.88, 206.92	208 (M$^+$, 6), 165 (4), 150 (17), 135 (3), 107 (100), 81 (16)
2[b]	3-[5-(3-Oxo-1,3-diphenylpropyl)-2-furyl]-1,3-diphenyl-1-propanone	3016, 1680, 1589, 1489, 1444, 1258, 1210, 752	3.36–3.45 (m, 2H), 3.65–3.80 (m, 2H), 4.70–4.80 (m, 2H) 5.83 (m, 2H), 7.10–7.35 (m, 10H), 7.33–7.50 (m, 4H), 7.50–7.60 (m, 2H), 7.80–7.85 (m, 4H)	–	365 (M$^+$ – 119, 10), 364 (35), 273 (14), 260 (13), 259 (100), 246 (11), 105 (45), 77 (10)
3[c]	4-(5-Methyl-2-furyl)-2-butanone	2916, 1709, 1431, 1357, 1213, 1159, 751	2.15 (s, 3H), 2.20 (s, 3H), 2.71 (m, 2H), 2.85 (m, 2H), 5.80 (m, 2H)	13.76, 22.66, 30.13, 42.18, 106.15, 106.35 –	152 (M$^+$, 14), 135 (13), 123 (10), 10 (27), 99 (100), 81 (6), 77 (9), 71 (15), 55 (5)
4[a]	3-(5-Methyl-2-furyl)-1-cyclopentanone	2944, 2859, 1712, 1560, 1420, 1260, 788	2.00–2.65 (m with a singlet at 2.21, 9H), 3.30–3.50 (m, 1H) 5.80–5.90 (m, 2H)	12.8, 29.56, 36.26, 40.81, 45.33, 104.80, 105.52, 150.30, 156.05, 210.56	164 (M$^+$, 66), 147 (15), 140 (78), 12 (27) 119 (31), 108 (65), 100 (62), 9 (32) 85 (100), 71 (39), 67 (32), 55 (74)
5[a]	3-(5-Methyl-2-furyl)-1-cyclohexanone	2942, 2859, 1715, 1560, 1420, 1176, 788	1.70–2.80 (m with a singlet at 2.25, 11H), 3.05–3.24 (m, 1H) 5.85 (m, 2H)	12.9, 24.04, 29.59, 37.28, 40.84, 45.33, 104.80, 105.57, 150.34, 156.05, 210.59	178 (M$^+$, 13), 148 (43, 135 (14), 12 (47), 105 (33), 97 (91), 85 (20), 69 (86) 55 (100)
6[a]	3-[5-(3-Oxocyclohexyl)-2-furyl)]-1-cyclohexanone	2944, 2859, 1712, 1560, 1420, 1260, 748	1.60–2.75 (m, 16H), 3.05–3.30 (m, 2H), 5.85 (s, 2H)	24.02, 30.81, 38.56, 42.61, 46.87, 106.22, 156.92, 211.23	260 (M$^+$, 84), 217 (30) 203 (100), 190 (20), 177 (10), 163 (32), 147 (17), 133 (27), 105 (10, 55 (10)
7[a]	4-[5-(3-Oxobutyl)-2-thienyl]-2-butanone	2910, 1710, 1350, 780	2.20 (s, 6H), 2.70–2.90 (t, *J*=7.8 Hz, 4H), 2.95–3.15 (t, *J*=7.8 Hz, 2H), 8.60 (s, 2H)	24.02, 29.87, 44.97, 124.11, 141.61, 206.97	224 (M$^+$, 62), 166 (73), 123 (100), 9 (20) 77 (6), 55 (3)

[a]colourless oil; [b]pale yellow thick oil; [c]light yellow oil

(MVK) in the presence of catalytic amount of Cu (OTF)$_2$. Careful analysis of the reaction product indicated the formation of **1** (Scheme 1) arising due to double Michael type addition reaction. It was interesting to note the absence of mono Michael type product.

Other Lewis acids such as BF$_3$•Et$_2$O, FeCl$_3$, Mg (ClO$_4$)$_2$ and ZnCl$_{2-}$ failed to catalyse this reaction. However, AlCl$_3$ gave the bis product **1** in 17% yield under the identical conditions. For the generality a series of α,β-unsaturated ketones were subjected for this reaction with furan and 2-methylfuran and results are presented in Table 1. Reaction of furan with chalcone gave the product **2** due to a double Michael addition reaction (entry 1). Similarly, furan with cyclohexenone furnished a single product **6** (entry 5) of double addition. The sulfur analogue of furan, thiophene also gave double Michael type product **7** with MVK (entry 6).

Moor and Partain[4] in their work on the catalytic cycloaddition reaction of furan with acrylates, suggested the formation of Michael type product *via* the cleavage of initially formed Diels–Alder adduct at higher temperatures. The formation of the product in this case could be *via* Lewis acid catalysed electrophilic substitution reaction on the ring as suggested earlier.[2a, 2b]

Experimental

The NMR spectra were recorded in CDCl$_3$ with TMS as an internal standard on Bruker WM 200 NMR spectrometer (^{1}H NMR at 200 MHz and ^{13}C NMR at 50 MHz). Mass spectra were recorded on Finnigan MAT 1020B GC-MS (EI) instrument. Column chromatography was performed on silica gel as solid support and mixture of ethyl acetate (5–10%) in peterolium ether as fluent. Furan, 2-methylfuran, thiophene, methyl vinyl ketone, cyclohexenone, cyclopentenone and Cu(OTf)$_2$ were purchased from Aldrich Chemicals and chalcone was prepared by the literature procedure.[5]

4-[5-(3-Oxobutyl)-2-furyl]-2-butanone (**1**): In a typical experimental procedure, a mixture of furan (100 mg; 1.46 mmol), MVK (410 mg; 5.84 mmol) and Cu (OTf)$_2$ (25 mg; 0.07 mmol) was stirred in CH$_2$Cl$_2$ (5 ml) at room temperature for 6 h (TLC). After completion of the reaction (TLC), the reaction mixture was diluted with the same solvent (25 ml), washed with aqueous solution of ammonium chloride (10 %) and brine. The organic solution was then dried over MgSO$_4$ and concentrated in vacuum. The product was purified by column chromatography on silica gel to get **1** (389 mg; 71 %) as colourless oil.[2h]

We are grateful to CSIR, New Delhi for the award of a Pool Officership to AVB and to the trustees of Lady Tata Memorial Trust, Mumbai for a Senior Research Fellowship to VJB. We wish to dedicate this paper to Dr T. Ravindranathan on the occasion of his 60th birthday.

Received 23 November 1999; accepted 22 March 2000
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