SHORT PAPER

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A tandem Michael addition–rearrangement–carbonylation by (4-nitrophenylsulfonylmethyl) benzene and its derivatives with methacrylates under PTC[†]

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A novel tandem Michael addition–rearrangement–carbonylation was studied in the reaction of (4-nitrophenylsulfonylmethyl)benzene**(1)** and its derivatives with methacrylates **(2)** under solid–liquid PTC conditions and a probable mechanism is discussed.

Keywords: tandem Michael addition–rearrangement–carbonylation, (4-nitrophenylsulfonylmethyl)benzene, methacrylates

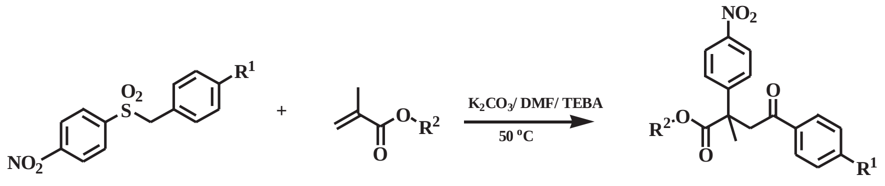
Many reports[1] have described using sulfur compounds for organic synthesis, since Seebach and Corey[2] reported the utilisation of 1,3-dithiane for the preparation of aldehydes and ketones. In general, an organic sulfur compound can be used as a synthetic agent according to two processes: (1) formation of a C–C bond between a sulfur agent and an organic compound to afford an intermediate and (2) its desulfurisation accompanied with the creation of a new functional group to produce a desired product. On the basis of our previous work,[3] we continued to search for mild methods of the formation of C–C bonds by sulfur-containing organic compounds. Herein, we report a novel tandem Michael addition–rearrangement–carbonylation by the reaction of (4-nitrophenylsulfonylmethyl)benzene and its derivatives **(1)** with methacrylates **(2),** where the formation of C–C bonds and the elimination of sulfur dioxide proceeded at the same time and the tandem Michael addition–rearrangement–carbonylation products, γ-keto esters, useful synthetic intermediates,[4] were easily obtained (Scheme 1). The structures of products **(3)** were characterised by mass spectroscopy (EI), IR spectroscopy, ^{1}H NMR, and elemental analysis.

To investigate the scope and limitation of this reaction, the effect of various substituent groups on the reaction was studied. When R^1 is an electron-withdrawing group such as cyano group or ester group, a higher yield and shorter time are found (Table 1). In contrast, the product was almost not obtained when R^1 is an electron-releasing group such as methyl or methoxy. We thought electron-withdrawing groups may favour the formation of carbanions to promote the Michael addition in this reaction. Based on our experimental results, the reaction mechanism via the Meisenheimer[3] complex and the oxygen-sulfur-ketone intermediates(4)[5] is put forward (Scheme 2).

In summary, under mild conditions of K_2CO_3/DMF/TEBA, γ-keto esters could be easily obtained via Michael addition-rearrangement-carbonylation, and the elimination of sulfur and formation of C–C bonds were accompanied by the production of a new carbonyl group. This method can provide a convenient pathway to synthesis of γ-keto esters or structurally similar products. The limitation and scope of this reaction will be studied.

Experimental

Unless noted materials were obtained from commercial suppliers and used without further purification. Melting points were determined with a Yancco MP-500 apparatus and were uncorrected. Microanalyses were performed with a Perkin-Elmer 240C instrument. IR spectra were recorded on a Nicolet 170SX FT-IR spectrometer (KBr pellet). ^{1}H NMR spectra were determined with a Bruker AM-400 spectrometer using TMS as an internal standard (chemical shifts in δ values). Mass spectra were obtained from a VG-ZAB-HS spectrometer at 70 eV (EI).



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1a, R^1 =H;
1b, R^1 =Cl;
1c, R^1 =CN;
1d, R^1 =$CO_2C_2H_5$

2a, R^2 =CH_3;
2b, R^2 =C_2H_5;

3aa, R^1 =H; R^2 =CH_3;
3ba, R^1 =Cl; R^2 =CH_3;
3bb, R^1 =Cl; R^2 =C_2H_5;
3ca, R^1 =CN; R^2 =CH_3;
3cb, R^1 =CN; R^2 =C_2H_5;
3da, R^1 =$CO_2C_2H_5$; R^2 =CH_3;
3db, R^1 =$CO_2C_2H_5$; R^2 =C_2H_5;

Scheme 1

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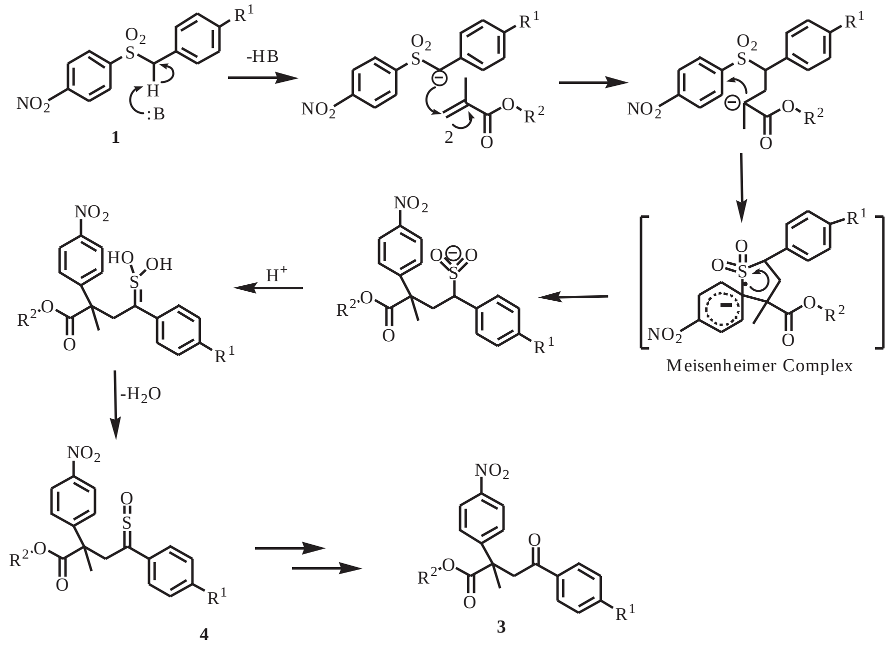
[†] This is a Short Paper, there is therefore no corresponding material in *J Chem. Research (M).*



Scheme 2

1.1: Ethyl 4-(4-nitrophenylsulfonylmethyl)benzoate **1d:**[6] Ethyl 4-(4-nitrophenylthio)benzoate 3.71g (10 mmol) was dissolved in glacial acetic acid (10 ml) at 60 ^{o}C. Sodium perborate tetrahydrate 4.62 g (30 mmol) was added. The mixture was continuously stirred for 2 hours at 50 ^{o}C. The solvent was removed under reduced pressure. Water was added to the residue. The precipitated product was collected, washed with water and recrystallised from ethanol (95 %) to give 2.86 g (82 %) of analytical sample of **1d**. M.P.169–170 ^{o}C. (Lit.[7], m.p. 167–168 ^{o}C). IR (KBr pellet): 1714 (CO), 1526, 1348 (NO_2), 1301, 1144 (SO_2) cm^{-1}, ^{1}H NMR ($CDCl_3$): 8.22 (2H, d, Ar–H, *J*=9.0 Hz), 7.94 (2H, d, Ar–H, *J*=9.2 Hz), 7.77 (2H, d, Ar–H, *J*=9.0 Hz), 7.16 (2H, d, Ar–H, *J*=9.2 Hz), 4.44 (2H, s, CH_2), 4.40 (2H, q, OCH_2, *J*=7.0 Hz), 1.44 (3H, t, O-C-CH_3, *J*=7.0 Hz)ppm.

1a, 1b and **1c** were synthesised by a method similar to **1d**.

The yield of **1a** was 90 %, m.p. 169–170 ^{o}C (from glacial acetic acid). (lit[7] m.p. 168–169 ^{o}C). IR: 1534, 1347 (NO_2), 1299, 1157 (SO_2) cm^{-1}, ^{1}H NMR ($CDCl_3$): 8.30 (2H, d, Ar–H, *J*=8.5 Hz), 7.77 (2H, d, Ar–H, *J*=8.5 Hz), 7.4–7.0 (5H, m, Ar–H), 4.31 (2H, s, CH_2)ppm. The yield of **1b** was 91%, m.p. 170–171 ^{o}C (from glacial acetic acid). Anal. Calcd. for $C_{13}H_{10}ClNO_4S$: C, 50.09; H, 3.23; N, 4.49; Found. C, 49.98; H, 3.10; N, 4.55. IR: 1539, 1348 (NO_2), 1302, 1150 (SO_2) cm^{-1}. ^{1}H NMR ($CDCl_3$): 8.36 (2H, d, Ar–H, *J*=8.5Hz), 7.85 (2H, d, Ar–H, *J*=8.5Hz), 7.32 (2H, d, Ar–H, *J*=8.6 Hz), 7.06(2H, d, Ar–H, *J*=8.6 Hz), 4.33 (2H,s,CH_2)ppm. The yield of **1c** was 82%, m.p. 209–210 ^{o}C (from glacial acetic acid) (lit[8] m.p. 207–209^{o}C). IR: 2228 (CN), 1531, 1355 (NO_2), 1311, 1152 (SO_2)cm^{-1}. ^{1}H NMR ($CDCl_3$): 8.37(2H, d, Ar–H, *J*=8.5 Hz), 7.92(2H, d, Ar–H, *J*=8.5 Hz), 7.67 (2H, d, Ar–H, *J*=8.0 Hz), 7.39 (2H, d, Ar–H, *J*=8.0 Hz), 4.75 (2H, s, CH_2)ppm.

1.2: Methyl 2-methyl-2-(4-nitrophenyl)- 3-benzoylpropanate **(3aa):** To a solution of **1a** (2 mmol, 0.54 g) in DMF (5 ml) was added anhydrous potassium carbonate 0.55 g (4 mmol) and TEBA (triethylbenzylammonium chloride) 0.1 g (0.44 mmol). The solution was stirred for 15 min at room temperature before methyl methacrylate 0.62 g (6 mmol) (**2a**) was added. The reaction progress was monitored by thin layer chromatography (TLC). After stirring for 60h at 75 ^{o}C, the reaction mixture was cooled and poured into cold water.

Table 1 Physical properties and data of elementary analysis and MS for products

Prod. no.	Formula (M.W)	React. time/h	Yield/%	M.p[a]/^{o}C	Elementary analysis found (cald./% C H N	MS/%
3aa	$C_{18}H_{17}NO_5$ (327.36)	60	60	138–139	66.32 5.34 4.05 (66.04) (5.24) (4.28)	327(M$^+$,1.4),295(1.6),268(1.5), 251(2.5),120(13.6),105(100), 77(26.9).
3ba	$C_{18}H_{16}ClNO_5$ (361.80)	25	65	174–175	59.72 4.40 3.81	363,361(1.0,3.5,M$^+$),331,329 (1.8,2.4),304,302(2.2,6.0),156, 154(10.0,30.9),141,139(52.2, 100),113,111(13.2,38.4),
3bb	$C_{19}H_{18}ClNO_5$ (375.83)	25	63	161–162	60.61 5.04 3.68 (60.72) (4.84) (3.73)	377,375(0.3,1.0,M$^+$),332,330 (0.4,1.7),304,302(0.7,1.9),156, 154(4.6,12.7),141,139(30.6, 100),113,111(5.1,14.9).
3ca	$C_{19}H_{16}N_2O_5$ (352.37)	15	74	180–181	64.64 4.54 7.80 (64.76) (4.59) (7.95)	352(1.6,M$^+$),320(3.4),293(4.7), 276(9.6),208(2.3),145(18.7), 130(100),102(30.4),
3cb	$C_{20}H_{18}N_2O_5$ (366.40)	15	75	149–150	65.64 4.98 7.42 (65.56) (4.96) (7.65)	366(1.4,M$^+$),321(3.4),296(9.4), 236(0.7),145(11.1),130(100), 102(69.0).
3da	$C_{21}H_{21}NO_7$ (399.43)	20	70	150–151	63.14 5.54 3.49 (63.14) (5.31) (3.51)	399(0.7,M$^+$),369(0.4),368(0.7), 354(4.5),340(3.9),192(17.0), 177(100),149(29.2).
3db	$C_{22}H_{23}NO_7$ (413.46)	20	72	82–83	63.91 5.83 3.37 (63.91) (5.62) (3.39)	413(1.8,M$^+$),368(15.9),340 (3.6),192(27.5),177(100), 149(37.2).

[a]Recrystallised from a mixed solvent of petroleum ether and ethyl acetate (6:1).

Table 2 Data of IR, ^{1}H NMR for products

Prod. no.	IR μ_{max}(cm^{-1}) C=O	 NO$_2$	^{1} H NMR δ(ppm) CDCl$_3$
3aa	1728 1685	1517 1346	8.10(2H,d,Ar-H,*J*=9.0Hz),7.50(2H,d,Ar-H,*J*=9.0Hz),7.9–7.3(5H,m,Ar-H), 3.85(1H,d,CH-H,*J*=18.0Hz),3.66(3H,s,OCH$_3$),3.45(1H,d,CH-H,*J*=18.0Hz), 1.80(3H,s,CH$_3$)
3ba	1728 1683	1516 1348	8.26(2H,d,Ar-H,*J*=9.0Hz),7.94(2H,d,Ar-H,*J*=8.5Hz),7.63(2H,d,Ar-H,*J*=9.0Hz), 7.47(2H,d,Ar-H,*J*=8.5Hz),3.88(1H,d,CH-H,*J*=18.0Hz),3.72(3H,s,OCH$_3$), 3.50(1H,d,CH-H,*J*=18.0Hz)1.80(3H,s,CH$_3$)
3bb	1723 1688	1514 1344	8.22(2H,d,Ar-H,*J*=9.0Hz),7.93(2H,d,Ar-H,*J*=8.5Hz),7.63(2H,d,Ar-H,*J*=9.0Hz), 7.46(2H,d,Ar-H,*J*=8.5Hz),4.26(2H,q,OCH$_2$,*J*=7.0Hz),3.94(1H,d,CH-H,*J*=18.0Hz), 3.55(1H,d,CH-H,*J*=18.0Hz),1.86(3H,s,C-CH$_3$),1.25(3H,t,O-C-CH$_3$,*J*=7.0Hz).
3ca	1729 1692 2226(CN)	1516 1353	8.16(2H,d,Ar-H,*J*=9.0Hz),8.00(2H,d,Ar-H,*J*=8.5Hz),7.70(2H,d,Ar-H,J=9.0Hz), 7.56(2H,d,Ar-H,*J*=8.5Hz),4.06(1H,d,CH-H,*J*=18.0Hz),3.86(3H,s,OCH$_3$), 3.62(1H,d,CH-H,*J*=18.0Hz),1.80(3H,s,CH$_3$)
3cb	1694 1737 2229(CN)	1346 1512	8.13(2H,d,Ar-H,*J*=9.0Hz),8.00(2H,d,Ar-H,*J*=8.5Hz),7.69(2H,d,Ar-H,*J*=9.0Hz), 7.56(2H,d,Ar-H,*J*=8.5Hz),4.16(2H,q,OCH$_2$,*J*=7.0Hz),3.88(1H,d,CH-H,*J*=18.0Hz), 3.47(1H,d,CH-H,*J*=18.0Hz),1.83(3H,s,C-CH$_3$),1.20(3H,t,O-C-CH$_3$,*J*=7.0Hz).
3da	1740 1720 1686	1520 1348	8.16(2H,d,Ar-H,*J*=9.0Hz),8.10(2H,d,Ar-H,*J*=8.5Hz),7.94(2H,d,Ar-H,*J*=9.0Hz), 7.66(2H,d,Ar-H,*J*=8.5Hz),4.47(2H,q,OCH$_2$,*J*=7.0Hz),3.85(1H,d,CH-H,*J*=18.0Hz), 3.66(3H,s,OCH$_3$),3.45(1H,d,CH-H,*J*=18.0Hz),1.66(3H,s,C-CH$_3$), 1.34(3H,t,O-C-CH$_3$,*J*=7.0Hz).
3db	1730 1720 1688	1517 1345	8.11(2H,d,Ar-H,*J*=9.0Hz),8.04(2H,d,Ar-H,*J*=8.5Hz),7.86(2H,d,Ar-H,*J*=9.0Hz), 7.54(2H,d,Ar-H,*J*=8.5Hz),4.26(2H,q,OCH$_2$,*J*=7.0Hz),4.07(2H,q,OCH$_2$,*J*=7.0Hz), 3.86(1H,d,CH-H,*J*=18.0Hz),3.46(1H,d,CH-H,*J*=18.0Hz),1.77(3H,s,C-CH$_3$),1.60-1.06(6H,m,2x-C-CH$_3$,*J*=7.0Hz).

The mixture was added with 2N HCl to adjust pH=6.5 and extracted with dichloromethane (3 x 15 ml). The combined organic phase was dried over anhydrous sodium sulfate and concentrated. The residue was chromatographied on silica. Elution with a mixed solvent of petroleum ether and ethyl acetate (6:1) afforded 0.40 g (60 %) of the product (**3aa**), which is methyl 2-methyl-2- (4-nitrophenyl)-3-benzoyl-propanate, as a white needles, m.p. 137–138 °C.

3ba–3db were synthesised by the method similar to **3aa** and the scale was the same. The principal reaction conditions and analytical data were listed in Tables 1 and 2.

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