Synthesis of Allyl Aryl Sulfone Derivatives from *Baylis–Hillman* Acetates in Water

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Various phenyl and *p*-tolyl allyl sulfone derivatives were prepared stereoselectively by reacting *Baylis–Hillman* acetates with sodium 4-R-benzenesulfinate (R = H, Me) in H_2O. The reaction was very efficient in providing the corresponding sulfone derivatives in good to excellent yields (*Table*).

Introduction. – As a part of our ongoing programme initiated towards the development of ecological chemical methodologies [1], we became interested in *Baylis–Hillman* acetates as reactive intermediates. Herein, we report the synthesis of disubstituted phenyl or *p*-tolyl allyl sulfone derivatives in H_2O under catalyst-free conditions.

Results. – In the course of the present work, *Baylis–Hillman* acetates were treated with sodium benzenesulfinates in H_2O at room temperature. The reaction resulted in the corresponding allyl sulfone derivatives in 71% yield. However, the same reaction in H_2O under heating proceeded in a much better way. After having optimized the reaction conditions, *Baylis–Hillman* acetates and sodium 4-R-benzenesulfinates (R = H, Me) in H_2O were heated at 70–80° to give the products in excellent yields of up to 94% within 6 h (*Scheme*; *Table*, *Entry 1*). Encouraged by the result, we first prepared various *Baylis–Hillman* acetates by reported literature procedures from commercially available aldehydes R^1–CHO and *Michael* acceptors such as methyl or ethyl acrylate (CH_2=CHCOOR) or acrylonitrile (CH_2=CHCN) in the presence of DABCO (=1,4-

Scheme. *Synthesis of Allyl Aryl Sulfone Derivatives from* Baylis–Hillman *Acetates and Sodium Benzenesulfinates*

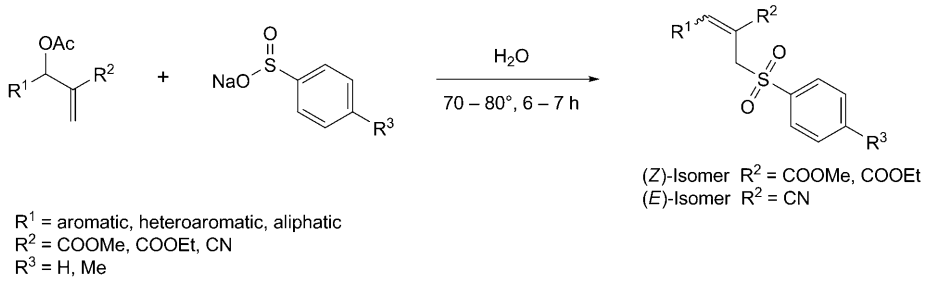


Table. *Synthesis of Allyl Phenyl or Allyl* p-*Tolyl Sulfone Derivatives from* Baylis–Hillman *Acetates and Sodium Benzenesulfinate or Sodium 4-Methylbenzenesulfinates*[a])

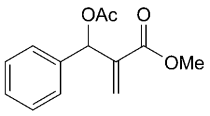
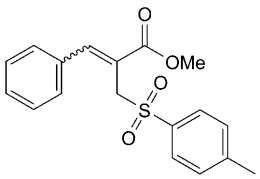
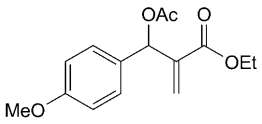
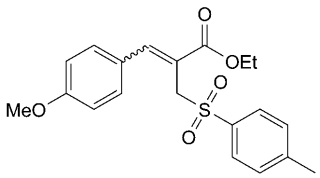
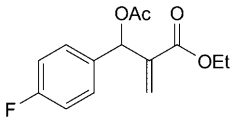
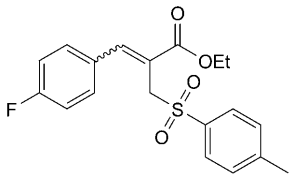
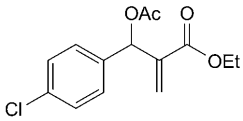
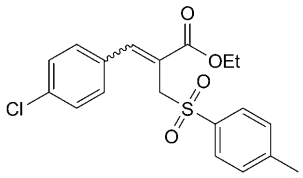
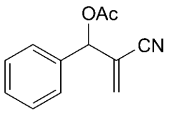
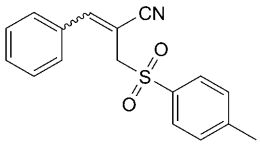
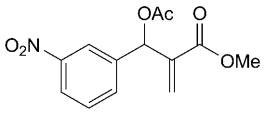
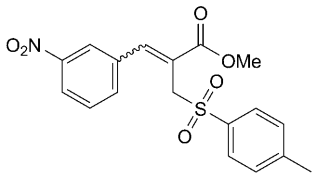
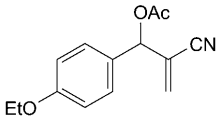
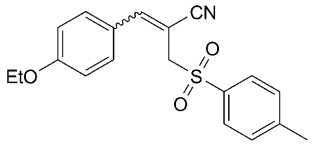
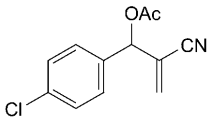
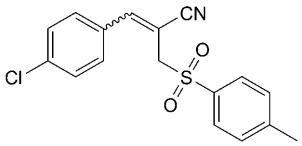
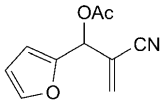
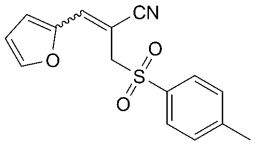
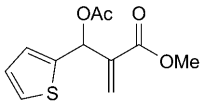
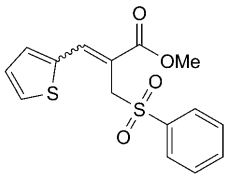
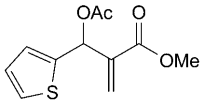
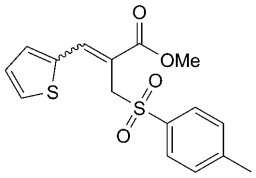
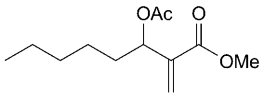
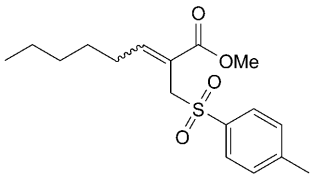
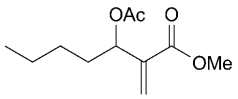
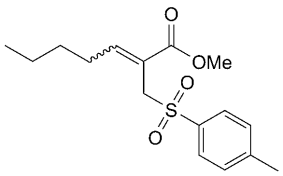
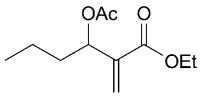
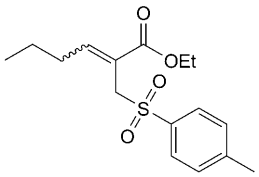
Entry	Substrate	Product	Time [h]	Yield [%][b])	(*E*)/(*Z*)[c])
1			6	94	2 : 98
2			7	92	3 : 97
3			6	91	3 : 97
4			6	91	3 : 97
5			6	87	95 : 5
6			6	95	4 : 96
7			6	91	95 : 5

Table (cont.)

Entry	Substrate	Product	Time [h]	Yield [%][b])	(*E*)/(*Z*)[c])
8			6	89	95 : 5
9			7	84	95 : 5
10			6	89	3 : 97
11			6	87	3 : 97
12			7	74	5 : 95
13			7	73	5 : 95
14			7	73	4 : 96

[a]) Reaction conditions: *Baylis–Hillman* acetate (1.0 mmol), sodium sulfinate (1.2 mmol), H_2O (15 ml), 70–80°, 6–7 h. [b]) Yield of isolated sulfone derivatives. [c]) Selectivity was determined by ^{1}H-NMR analysis.

diazabicyclo[2.2.2]octane) as catalyst and Ac_2O as acetylating agent. The resulting adducts were then treated with sodium benzenesulfinate or sodium 4-methylbenzenesulfinate (*Table*). In the present study, aldehydes R^1–CHO with electron-donating groups gave the corresponding allyl sulfone derivatives in lower yields in comparison to aldehydes with electron-withdrawing groups. In the case of acetates of aliphatic *Baylis–Hillman* adducts, the corresponding allyl sulfone derivatives were also obtained in lower yields (*Table*, *Entries 12–14*). The (2*Z*)-configuration of the 2-(sulfonylmethyl)acrylates were assigned on the basis of ^{1}H- and ^{13}C-NMR shifts in comparison with literature values [2]. In the case of *Baylis–Hillman* adducts prepared from acrylonitrile, the reaction with sodium 4-methylbenzenesulfinate gave the corresponding 2-(sulfonylmethyl)acrylonitriles with reversal of selectivity, *i.e.*, the (2*E*)-isomers were the major product. This fact was also confirmed by ^{1}H- and ^{13}C-NMR measurements and by comparison with reported values.

In conclusion, we developed an elegant protocol for the synthesis of allyl sulfone derivatives in high yields by reaction of *Baylis–Hillman* acetates with sodium 4-R-benzenesulfinates (R = H, Me) in H_2O. This practical method may have widespread applications in the context of ecologically oriented organic synthesis.

K. K., *J. S.*, and *S. N. M.* are grateful to the *Council of Scientific and Industrial Research (CSIR)*, New Delhi, India, for providing fellowships.

Experimental Part

General. TLC: Precoated silica-gel plates (*60 F_{254}*, 0.2-mm layer, *E. Merck*). Column chromatography (CC): Silica gel, 60–120 mesh. M.p.: *Fischer–Johns* apparatus; uncorrected. IR Spectra: *Thermo Nicolet Nexus 670* FT-IR spectrophotometer; in KBr; $\tilde{\nu}$ in cm^{-1}. ^{1}H- and ^{13}C-NMR Spectra: *Bruker Avance 300*, *Innova 400* MHz and *Bruker Gemini 200* MHz instrument; in $CDCl_3$; δ in ppm rel. to Me_4Si as internal standard, *J* in Hz. ESI-MS: *Finnigan MAT 1020* mass spectrometer; in *m/z*.

Allyl Aryl Sulfone Derivatives: General Procedure. To a flask containing the *Baylis–Hillman* acetate (1 mmol) in H_2O (15 ml), the sodium benzenesulfinate (1.2 mmol) was added. The suspension was magnetically stirred at 70–80° until the reaction was complete (TLC monitoring). The mixture was then extracted with AcOEt (4 × 10 ml), the extract washed with H_2O and brine dried (anh. Na_2SO_4), and concentrated, and the resulting crude product purified by CC (AcOEt/hexane 1:9): substituted allyl sulfone derivative in yields up to 94% (*Table*).

Methyl (2Z)-2-{[(4-Methylphenyl)sulfonyl]methyl}-3-phenylprop-2-enoate (*Table*, *Entry 1*): Light brown solid. M.p. 120°. IR: 2982, 1713, 1317, 1266, 1141. ^{1}H-NMR: 7.91 (*s*, 1 arom. H); 7.74 (*d*, *J* = 8.3, 2 arom. H); 7.52 (*d*, *J* = 7.5, 2 arom. H); 7.38 (*m*, 3 arom. H); 7.29 (*d*, *J* = 7.5, 2 arom. H); 4.41 (*s*, CH_2SO_2); 3.61 (*s*, MeO); 2.46 (*s*, Me). ^{13}C-NMR: 166.8; 146.0; 144.6; 136.1; 133.5; 129.5; 129.0; 128.6; 128.4; 120.9; 55.0; 52.2; 21.5. ESI-MS: 353 ($[M + Na]^+$).

Ethyl (2Z)-3-(4-Methoxyphenyl)-2-{[(4-methylphenyl)sulfonyl]methyl}prop-2-enoate (*Table*, *Entry 2*): Yellow oil. IR: 2987, 1713, 1610, 1510, 1319, 1144. ^{1}H-NMR: 7.89 (*s*, 1 H); 7.76 (*d*, *J* = 8.1, 2 arom. H); 7.58 (*d*, *J* = 8.6, 2 arom. H); 7.28 (*d*, *J* = 8.8, 2 arom. H); 6.92 (*d*, *J* = 8.8, 2 arom. H); 4.50 (*s*, CH_2SO_2); 4.00 (*q*, *J* = 7.1, MeCH_2O); 3.84 (*s*, MeO); 2.42 (*s*, Me); 1.20 (*t*, *J* = 7.1, *Me*CH_2O). ^{13}C-NMR: 166.7; 160.9; 145.2; 131.5; 129.5; 128.6; 126.2; 114.1; 61.3; 55.4; 55.3; 21.5; 14.0. ESI-MS: 397 ($[M + Na]^+$).

Ethyl (2Z)-3-(4-Fluorophenyl)-2-{[(4-methylphenyl)sulfonyl]methyl}prop-2-enoate (*Table*, *Entry 3*): White solid. M.p. 65°. IR: 2984, 1710, 1600, 1508, 1317, 1142. ^{1}H-NMR: 7.86 (*s*, 1 H); 7.71 (*d*, *J* = 7.1, 2 H); 7.54 (*t*, *J* = 6.7, 2 H); 7.27 (*d*, *J* = 7.7, 2 H); 7.05 (*t*, *J* = 8.4, 2 H); 4.41 (*s*, 2 H); 4.02 (*q*, *J* = 6.9, 2 H); 2.41 (*s*, 3 H); 1.22 (*t*, *J* = 6.9, 3 H). ^{13}C-NMR: 164.8; 161.5; 144.5; 132.5; 131.3; 131.2; 129.7; 129.4; 128.3; 121.0; 115.7; 115.4; 61.2; 54.8; 21.4; 14.0. ESI-MS: 385 ($[M + Na]^+$).

Ethyl (2Z)-3-(4-Chlorophenyl)-2-{[(4-methylphenyl)sulfonyl]methyl}prop-2-enoate (*Table*, *Entry 4*): Colorless oil. IR: 2985, 1715, 1315, 1268, 1131. ^{1}H-NMR: 7.85 (*s*, 1 H); 7.70 (*d*, *J* = 8.3, 2 H); 7.44 (*d*, *J* = 9.0, 2 H); 7.24–7.33 (*m*, 4 H); 4.44 (*s*, 2 H), 4.06 (*q*, *J* = 6.7, 2 H); 2.40 (*s*, 3 H); 1.22 (*t*, *J* = 6.7, 3 H). ^{13}C-NMR: 166.1; 144.9; 136.2; 132.1; 130.5; 129.6; 128.9; 128.4; 121.7; 61.6; 54.9; 21.5; 14.0. ESI-MS: 379 ($[M+H]^+$).

(2E)-2-{[(4-Methylphenyl)sulfonyl]methyl}-3-phenyl-prop-2-enenitrile (*Table*, *Entry 5*): Light brown solid. M.p. 90°. IR: 2212, 1623, 1311, 1146. ^{1}H-NMR: 7.81 (*d*, *J* = 8.3, 2 H); 7.55 (*s*, 1 H); 7.34–7.40 (*m*, 7 H); 4.17 (*s*, 2 H); 2.46 (*s*, 3 H). ^{13}C-NMR: 152.0; 132.2; 130.5; 130.1; 129.0; 128.9; 128.7; 118.1; 103.2; 56.4; 21.7. ESI-MS: 320 ($[M+Na]^+$).

Methyl (2Z)-2-{[(4-Methylphenyl)sulfonyl]methyl}-3-(3-nitrophenyl)prop-2-enoate (*Table*, *Entry 6*): Light yellow solid. M.p. 110°. IR: 2982, 1713, 1317, 1266, 1141. ^{1}H-NMR: 8.20 (*d*, *J* = 8.3, 2 H); 7.94 (*d*, *J* = 7.8, 1 H); 7.91 (*s*, 1 H); 7.71 (*d*, *J* = 7.8, 2 H); 7.60 (*t*, *J* = 7.8, 1 H); 7.28 (*d*, *J* = 7.8, 2 H); 4.33 (*s*, 2 H); 3.69 (*s*, 3 H); 2.43 (*s*, 3 H). ^{13}C-NMR: 166.5; 145.3; 140.3; 138.4; 135.6; 133.7; 129.5; 128.3; 127.4; 123.2; 56.5; 52.2; 21.2. ESI-MS: 376 ($[M+H]^+$).

(2E)-3-(4-Ethoxyphenyl)-2-{[(4-methylphenyl)sulfonyl]methyl}prop-2-enenitrile (*Table*, *Entry 7*): Yellow oil. IR: 2927, 2210, 1627, 1321, 1148. ^{1}H-NMR: 7.54 (*d*, *J* = 8.6, 2 H); 7.40 (*d*, *J* = 6.7, 2 H); 7.26 (*t*, *J* = 6.7, 2 H); 6.81 (*d*, *J* = 8.6, 2 H); 6.54 (*s*, 1 H), 4.01 (*q*, *J* = 6.7, 2 H); 3.69 (*s*, 2 H); 2.43 (*s*, 3 H); 1.41 (*t*, *J* = 6.7, 3 H). ^{13}C-NMR: 160.4; 144.0; 138.4; 133.2; 130.5; 129.3; 128.5; 127.4; 114.2; 104.2; 63.7; 57.2; 21.3; 14.6. ESI-MS: 364 ($[M+Na]^+$).

(2E)-3-(4-Chlorophenyl)-2-{[(4-methylphenyl)sulfonyl]methyl}prop-2-enenitrile (*Table*, *Entry 8*): White solid. M.p. 110°. IR: 2928, 2212, 1627, 1313, 1144. ^{1}H-NMR: 7.80 (*d*, *J* = 8.1, 1 H); 7.38 (*m*, 6 H); 7.30 (*d*, *J* = 8.3, 2 H); 4.42 (*s*, 2 H); 2.47 (*s*, 3 H). ^{13}C-NMR: 150.8; 145.2; 136.2; 134.9; 131.4; 130.7; 130.1; 129.3; 129.1; 128.6; 118.0; 103.4; 56.3; 21.7. ESI-MS: 354 ($[M+Na]^+$).

(2E)-3-(Furan-2-yl)-2-{[(4-methylphenyl)sulfonyl]methyl}prop-2-enenitrile (*Table*, *Entry 9*): Brown solid. M.p. 125°. IR: 2925, 2212, 1623, 1311, 1146. ^{1}H-NMR: 7.78 (*d*, *J* = 8.1, 2 H); 7.57 (*s*, 1 H); 7.38 (*d*, *J* = 8.1, 2 H); 7.04 (*d*, *J* = 3.5, 1 H); 6.96 (*s*, 1 H); 6.54 (*s*, 1 H); 3.98 (*s*, 2 H), 2.45 (*s*, 3 H). ^{13}C-NMR: 148.7; 145.8; 137.1; 134.5; 130.0; 128.5; 119.6; 117.1; 112.7; 112.2; 60.5; 21.6. ESI-MS: 305 ($[M+NH_4]^+$).

Methyl (2Z)-2-[(Phenylsulfonyl)methyl]-3-(thiophen-2-yl)prop-2-enoate (*Table*, *Entry 10*): Light brown oil. IR: 2984, 1710, 1600, 1508, 1317, 1142. ^{1}H-NMR: 8.00 (*s*, 1 H); 7.78 (*d*, *J* = 8.3, 2 H); 7.57 (*d*, *J* = 3.7, 1 H); 7.52 (*d*, *J* = 5.2, 1 H); 7.30 (*d*, *J* = 8.3, 3 H); 7.12 (*t*, *J* = 3.7, 1 H); 4.55 (*s*, 2 H); 3.54 (*s*, 3 H). ^{13}C-NMR: 166.4; 139.0; 137.5; 134.2; 133.5; 131.5; 129.3; 128.5; 128.2; 62.4; 52.7. ESI-MS: 345 ($[M+Na]^+$).

Methyl (2Z)-2-{[(4-Methylphenyl)sulfonyl]methyl}-3-(thiophen-2-yl)prop-2-enoate (*Table*, *Entry 11*): Light brown oil. IR: 2984, 1710, 1600, 1508, 1317, 1142. ^{1}H-NMR: 8.00 (*s*, 1 H); 7.78 (*d*, *J* = 8.3, 2 H); 7.57 (*d*, *J* = 3.7, 1 H); 7.52 (*d*, *J* = 5.2, 1 H); 7.30 (*d*, *J* = 8.3, 2 H); 7.12 (*t*, *J* = 3.7, 1 H); 4.55 (*s*, 2 H); 3.54 (*s*, 3 H); 2.45 (*s*, 3 H). ^{13}C-NMR: 166.4; 139.0; 137.5; 134.2; 133.5; 131.5; 129.3; 128.5; 128.2; 62.4; 52.7; 21.4. ESI-MS: 359 ($[M+Na]^+$).

Methyl (2Z)-2-{[(4-Methylphenyl)sulfonyl]methyl}oct-2-enoate (*Table*, *Entry 12*): Colorless oil. IR: 2953, 1720, 1321, 1143, 1085. ^{1}H-NMR: 7.72 (*d*, *J* = 8.3, 2 H); 7.32 (*d*, *J* = 8.3, 2 H); 7.09 (*t*, *J* = 7.5, 1 H); 4.22 (*s*, 2 H); 3.05 (*s*, 3 H); 2.42 (*s*, 3 H); 2.14 (*q*, *J* = 6.7, 2 H); 2.0 (*m*, 2 H); 1.32 (*m*, 4 H); 0.87 (*t*, *J* = 7.5, 3 H). ^{13}C-NMR: 165.7; 151.3; 144.3; 131.5; 129.2; 128.2; 120.2; 60.2; 53.6; 29.9; 28.7; 22.7; 21.9; 21.1; 13.7. ESI-MS: 347 ($[M+Na]^+$).

Methyl (2Z)-2-{[(4-Methylphenyl)sulfonyl]methyl}hept-2-enoate (*Table*, *Entry 13*): Colorless oil. IR: 2956, 1720, 1318, 1144, 1084. ^{1}H-NMR: 7.72 (*d*, *J* = 8.3, 2 H); 7.32 (*d*, *J* = 8.3, 2 H); 7.09 (*t*, *J* = 7.5, 1 H); 4.22 (*s*, 2 H); 3.05 (*s*, 3 H); 2.42 (*s*, 3 H); 2.14 (*q*, *J* = 6.7, 2 H); 1.32 (*m*, 4 H); 0.87 (*t*, *J* = 7.5, 3 H). ^{13}C-NMR: 165.7; 151.3; 144.5; 131.5; 129.2; 128.2; 120.2; 60.2; 53.6; 29.9; 28.7; 21.9; 21.1; 13.7. ESI-MS: 333 ($[M+Na]^+$).

Ethyl (2Z)-2-{[(4-Methylphenyl)sulfonyl]methyl}hex-2-enoate (*Table*, *Entry 14*): Colorless oil. IR: 2948, 1720, 1319, 1146, 1087. ^{1}H-NMR: 7.68 (*d*, *J* = 6.9, 2 H); 7.28 (*d*, *J* = 6.9, 2 H); 7.03 (*t*, *J* = 7.5, 1 H); 4.15 (*s*, 2 H); 3.91 (*q*, *J* = 7.1, 2 H); 2.42 (*s*, 3 H); 2.20 (*q*, *J* = 7.5, 2 H); 1.46 (*m*, 2 H); 1.13 (*t*, *J* = 7.1, 3 H); 0.94 (*t*, *J* = 7.1, 3 H). ^{13}C-NMR: 165.0; 150.4; 136.4; 129.3; 128.8; 128.7; 60.6; 53.9; 31.8; 31.3; 21.5; 14.0; 13.8. ESI-MS: 333 ($[M+Na]^+$).

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