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A highly efficient Hg(OTf)₂-mediated Sakurai-Hosomi allylation of *N-tert*-butyloxycarbonylamino sulfones, aldehydes, fluoroalkyl ketones and α,β-unsaturated enones using allyltrimethylsilane

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General: Reactions were monitored by thin layer chromatography using UV light to visualize the course of reaction. Purification of reaction products was carried out by flash chromatography on silica gel. Chemical yields refer to pure isolated substances. Infrared (IR) spectra were obtained using a Bruker tensor 27 infrared spectrometer. ¹H, ¹³C, ¹⁹F NMR spectra were obtained using a Bruker DPX-300, DPX-400 or DPX-500spectrometer. Chemical shifts of ¹H NMR and ¹³C NMR spectra are reported in ppm from tetramethylsilane with the solvent resonance as the internal standard. The following abbreviations were used to designate chemical shift multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad.

All reactions were run in an atmosphere of N_2 except noted. Anhydrous Toluene and THF were prepared by distillation over sodium-benzophenone ketyl prior to use. Anhydrous EtOAc and acetone was prepared by first distillation over activated CaSO₄ and then stored in 5 Å molecular sieves. Anhydrous CH₂Cl₂, ClCH₂CH₂Cl and CH₃CN were prepared by first distillation over P₂O₅ and then from CaH₂. All the aldehydes, ketones and enones are commercially available and used as received. *N-tert*-Butyloxycarbonylamino sulfones were synthesized according to the reported method.¹

Cautions: During the reaction, bis(allyl)mercury complex might be generated in situ, although the toxicity of Hg(OTf)₂ and bis(allyl)mercury have not been reported,² special care should still be taken when using mercury salts and disposing the waste containing mercury compounds.

¹ Q.-G. Wang, M. Leutzsch, M. v. Gemmeren and B. List, J. Am. Chem. Soc., 2013, 135, 15334.

² M. Nishizawa, H. Imagawa and H. Yamamoto, Org. Biomol. Chem., 2010, 8, 511.

1. The allylation of *N-tert*-Butyloxycarbonylamino sulfones 2

R ¹ ↓ TMS ↓	NHBoc ↓	Hg(OTf) ₂ (1.0 mol%)	BocHN
	R´ `SO ₂ Tol	CH ₂ Cl ₂ , rt	R R ¹
1a: R ¹ = H; 1d: R ¹ = CH ₃	2	then H ⁺ , HCl/EtOAc	6

To a 10 mL vial was added *N-tert*-Butyloxycarbonylamino sulfones 2 (0.2 mmol), catalyst $Hg(OTf)_2$ (1.0 mg, 0.002 mmol), 1 mL of anhydrous CH_2Cl_2 and 1 (0.4 mmol). The resulting mixture was stirred at room temperature till almost full conversion of 2 by TLC analysis. The reaction mixture was diluted with 5.0 mL of EtOAc and ten drops of conc. HCl, then stirred for 10 minutes and washed successively with saturated aq. NaHCO₃ and brine. Then concentrated *in vacuo* and the residue was purified via flash chromatography to afford the title compounds, using PE/EtOAc (20:1 to 10:1, v/v) as eluent.

 NHBOC
 Product **6a**³ was obtained in 81% yield as white solid. ¹H NMR (300 MHz, CDCl₃): δ

 7.35-7.24 (m, 5H), 5.72-5.61 (m, 1H), 5.13-5.06 (m, 2H), 4.88 (s, br, 1H), 4.73 (s, br, 1H),

 6a

 2.51 (s, 2H), 1.40 (s, 9H); ¹³C NMR (75 MHz, CDCl₃): δ 155.18, 142.38, 133.97, 128.44,

 127.09, 126.19, 118.12, 79.45, 54.02, 41.20, 28.31.

 NHBoc
 Product 6b⁴ was obtained in 78% yield as white solid; ¹H NMR (300 MHz, CDCl₃): δ

 OMe
 7.26-7.14 (m, 2H), 6.93-6.86 (m, 2H), 5.72-5.63 (m, 1H), 5.35 (s, br, 1H), 5.07-4.99 (m, 2H), 4.94 (s, br, 1H), 3.86 (s, 3H), 2.54-2.50 (m, 2H), 1.42 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): 156.81, 155.19, 134.92, 129.90, 128.16, 120.47, 117.19, 110.75, 79.05, 55.24, 51.81, 39.88, 28.38.

51.81, 59.88, 28.58.

Product $6c^3$ was obtained in 90% yield as white solid; ¹H NMR (300 MHz, CDCl₃): δ 7.28-7.22 (m, 2H), 7.14-7.02 (m, 2H), 5.71-5.65 (m, 1H), 5.15-5.07 (m, 3H), 4.97 (s, br, 1H), 2.58-2.53 (m, 2H), 1.44 (s, 9H); ¹³C NMR (125 MHz, CDCl₃): 160.45 (d, J = 243.6Hz), 155.01, 133.78, 129.17 (d, J = 13 Hz), 128.68 (d, J = 8.4 Hz), 128.21, 124.02 (d, J = 3.4 Hz), 118.19, 115.67 (d, J = 21.8 Hz), 79.50, 50.08, 40.11, 28.30; ¹⁹F NMR (376 MHz, CDCl₃): -118.41.



Product **6d**³ was obtained in 63% yield as white solid; ¹H NMR (400 MHz, CDCl₃): δ 7.24-7.22 (m, 1H), 6.86-6.77 (m, 3H), 5.73-5.63 (m, 1H), 5.14-5.06 (m, 2H), 4.86 (s, br, 1H), 4.71 (s, br, 1H), 3.80 (s, 3H), 2.52-2.49 (m, 2H), 1.41 (s, 9H); ¹³C NMR (100 MHz,

³ D. Ghosh, S. Saravanan, N. Gupta, S. H. R. Abdi, N. H. Khan, R. I. Kureshy and H. C. Bajaj, Asian J. Org. Chem., 2014, 3, 1173.

⁴ T. Vilaivan, C. Winotapan, V. Banphavichit, T. Shinada and Y. Ohfune, J. Org. Chem., 2005, 70, 3464.

CDCl₃): 159.71, 155.16, 144.14, 133.94, 129.49, 118.50, 118.13, 112.32, 112.10, 79.47, 55.19, 54.03, 41.17, 28.33.

Product **6e** was obtained in 75% yield as white solid (m.p. 48.0-50.0 °C); ¹H NMR (400 MHz, CDCl₃): δ 7.41-7.35 (m, 2H), 7.19-7.16 (m, 2H), 5.69-5.60 (m, 1H), 5.14-5.09 (m, Br **6e** 2H), 4.88 (s, br, 1H), 4.69 (s, br, 1H), 2.53-2.41 (m, 2H), 1.41 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): 155.07, 133.37, 130.17, 130.02, 129.23, 124.89, 122.59, 118.66, 79.75, 55.54, 41.06, 28.29; IR (ATR): 3662, 3383, 1681, 1514, 1159, 1043, 954, 692 cm⁻¹; HRMS (ESI-TOF): Exact mass calcd for C₁₅H₂₀O₂NBr⁷⁹Na [M+Na]⁺: 348.0570, Found: 348.0565.

 NHBoc
 Product **6f**³ was obtained in 78% yield as white solid; ¹H NMR (400 MHz, CDCl₃): δ

 Me
 7.17-7.12 (m, 4H), 5.73-5.63 (m, 1H), 5.12-5.05 (m, 2H), 4.85 (s, br, 1H), 4.70 (s, br, 1H), 2.51-2.48 (m, 2H), 2.32 (s, 3H), 1.41 (s, 9H); ¹³C NMR (100 MHz, CDCl₃):

 155.16, 139.35, 136.66, 134.12, 129.13, 126.12, 117.96, 79.34, 53.78, 41.18, 28.33, 20.99.

NHBoc Product $6g^3$ was obtained in 80% yield as white solid; ¹H NMR (400 MHz, CDCl₃): δ MeO f_{6g} 7.18 (d, J = 8.4 Hz, 2H), 6.85 (d, J = 8.4 Hz, 2H), 5.71-5.64 (m, 1H), 5.11-5.04 (m, 2H), 4.84 (s, br, 1H), 4.67 (s, br, 1H), 3.78 (s, 3H), 2.51-2.48 (m, 2H), 1.40 (s, 9H); 1^{3}C NMR (100 MHz, CDCl₃): 158.58, 155.14, 134.47, 134.12, 127.31, 117.91, 113.79, 79.31, 55.19, 53.44, 41.12, 28.30.

Product **6h**³ was obtained in 86% yield as white solid; ¹H NMR (400 MHz, CDCl₃): δ 7.24-7.21 (m, 2H), 7.03-6.98 (m, 2H), 5.71-5.60 (m, 1H), 5.13-5.07 (m, 2H), 4.84 (s, br, **6h** 1H), 4.70 (s, br, 1H), 2.49-2.46 (m, 2H), 1.40 (s, 9H); ¹³C NMR (125 MHz, CDCl₃): 161.73 (d, J = 243.4 Hz), 155.07, 138.16, 133.64, 127.68 (d, J = 7.9 Hz), 118.29, 115.15 (d, J = 21.4 Hz), 79.45, 53.31, 41.10, 28.23; ¹⁹F NMR (376 MHz, CDCl₃): -115.84.

Product 6i³ was obtained in 82% yield as white solid; ¹H NMR (400 MHz, CDCl₃): δ
7.83-7.81 (m, 3H), 7.71 (s, 1H), 7.48-7.45(m, 2H), 7.42-7.39 (m, 1H), 5.76-5.66 (m, 1H), 5.16-5.08 (m, 2H), 5.00 (s, br, 1H), 4.92 (s, br, 1H), 2.61 (s, br, 2H), 1.43 (s, 9H);
¹³C NMR (100 MHz, CDCl₃): 155.23, 139.77, 133.90, 133.30, 132.67, 128.27, 127.85, 127.57, 126.06, 125.66, 124.81, 124.54, 118.25, 79.55, 54.17, 41.09, 28.33.

Product $6i^4$ was obtained in 77% yield as white solid; ¹H NMR (300 MHz, CDCl₃): δ NHBoc 7.34-7.33 (m, 1H), 6.30-6.28 (m, 1H), 6.15-6.14 (m, 1H), 5.74-5.65 (m, 1H), 5.14-5.05 (m, 6j 2H), 4.84 (s, br, 2H), 2.56 (s, 2H), 1.44 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): 155.05, 154.54, 141.68, 133.55, 118.22, 110.07, 105.90, 79.61, 48.20, 38.58, 28.33.



۰'n

Product 6k was obtained in 74% yield as white solid (m.p. 55.0-57.0 °C); ¹H NMR (400 MHz, CDCl₃): δ 7.19-7.18 (m, 1H), 6.95-6.93(m, 2H), 5.79-5.72 (m, 1H), 5.17-5.09 (m, 2H), 5.03 (s, br, 1H), 4.85 (s, br, 1H), 2.63-2.59 (m, 2H), 1.44 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): 154.97, 146.42, 133.54, 126.73, 123.96, 123.88, 118.50, 79.68, 49.94, 41.29, 28.33; IR (ATR): 3363, 2978, 1680, 1519, 1267, 1163, 918, 598 cm⁻¹; MS (EI): 253 (M⁺, 3), 212 (28), 156 (89), 137 (21), 112 (66), 57 (100); HRMS (EI): Exact mass calcd for C₁₃H₁₉NO₂S [M]⁺: 253.1137, Found: 253.1133.

Product $6l^5$ was obtained in 84% yield as white solid; ¹H NMR (400 MHz, CDCl₃): δ NHBoc 7.31-7.27 (m, 2H), 7.23-7.18 (m, 3H), 5.85-5.75 (m, 1H), 5.12-5.07 (m, 2H), 4.40 (s, br, 61 1H), 3.90 (s, br, 1H), 2.80-2.77 (m, 2H), 2.29-2.08 (m, 2H), 1.41 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): 155.33, 138.13, 134.42, 129.46, 128.34, 126.32, 117.94, 79.12, 51.03, 40.47, 38.09, 28.36.

Product $6m^4$ was obtained in 80% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ NHBoc 5.82-5.72 (m, 1H), 5.09-5.04 (m, 2H), 4.33 (s, br, 1H), 3.63 (s, br, 1H), 2.25-2.13 (m, 2H), 6m 1.43 (s, 9H), 1.42-1.28 (m, 4H), 0.92-0.88 (m, 3H); ¹³C NMR (100 MHz, CDCl₃):155.59, 134.59, 117.48, 78.90, 49.83, 39.56, 36.90, 28.41, 19.13, 13.95.

Product $6n^4$ was obtained in 74% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ NHBoc 5.82-5.71 (m, 1H), 5.08-5.02 (m, 2H), 4.33 (s, br, 1H), 3.49 (s, br, 1H), 2.27-2.05 (m, 2H), 6n 1.73-1.42 (m, 1H), 1.42 (s, 9H), 0.92-0.86 (m, 6H); ¹³C NMR (100 MHz, CDCl₃):155.86, 135.06, 117.06, 78.83, 55.06, 36.95, 31.42, 28.38, 19.23, 17.70.

Product **60**³ was obtained in 74% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ NHBoc 5.81-5.70 (m, 1H), 5.07-5.02 (m, 2H), 4.34 (s, br, 1H), 3.48 (s, br, 1H), 2.29-2.06 (m, 2H), 60 1.76-1.61 (m, 5H), 1.42 (s, 9H), 1.14-0.93 (m, 6H); ¹³C NMR (100 MHz, CDCl₃):155.82, 135.05, 117.09, 78.79, 54.50, 41.46, 36.78, 29.72, 28.39, 26.38, 26.21.

⁵ S. B. Lang, K. M. O'Nele, J. T. Douglas and J. A. Tunge., *Chem. Eur. J.*, 2015, **21**, 18589.

 NHBoc
 Product 6p⁴ was obtained in 71% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ

 5.79-5.75 (m, 1H), 5.05-4.99 (m, 2H), 4.26-4.23 (m, 1H), 3.46-3.41 (m, 1H), 2.42-2.37 (m, 1H), 1.88-1.82 (m, 1H), 1.41 (s, 9H), 0.89 (s, 9H); ¹³C NMR (100 MHz, CDCl₃):156.12, 136.12, 116.41, 78.69, 58.37, 35.22, 34.65, 28.38, 26.37.

 NHBoc
 Product 6q⁶ was obtained in 75% yield as white solid. ¹H NMR (400 MHz, CDCl₃): δ

 6q
 7.32-7.24 (m, 5H), 4.82-4.81 (m, 3H), 4.73 (s, 1H), 2.46-2.38 (m, 2H), 1.73 (s, 3H), 1.40 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ 155.24, 143.16, 141.88, 128.45, 127.05, 126.08, 113.76, 79.42, 52.80, 45.80, 28.30, 21.96.

The allylation of enones 5 using allyltrimethylsilane 1.



To a 10 mL vial was added quinoline (65 mg, 0.5 mmol), ClCO₂Me (0.75 mmol, 1.5 equivs) and anhydrous CH₂Cl₂ (1 mL). The resulting mixture was stirred at room temperature for 2 hours, then the Hg(OTf)₂ (12.5mg, 5.0 mol%) and **1a** (1.0 mmol, 2.0 equivs) were added, the mixture was stirred at room temperature for 10 hours. The reaction was quenched with water and extracted with CH₂Cl₂ and the combined extracts were washed with 15% solution of sodium thiosulfate, dried over anhydrous Na₂SO₄, and concentrated *in vacuo*. The residue was purified via flash chromatography using PE/EtOAc (20:1, v/v) as eluent to afford the desired product **10** in 44% yield as colorless oil.⁷ ¹H NMR (400 MHz, CDCl₃): δ 7.54 (s, br, 1H), 7.23-7.20 (m, 1H), 7.08-7.06 (m, 2H), 6.48 (d, *J* = 9.6 Hz, 1H), 6.06-6.02 (m, 1H), 5.81-5.71 (m, 2H), 5.09-4.93 (m, 3H), 3.79 (s, 3H), 2.25-2.10 (m, 2H); ¹³C NMR (100 MHz, CDCl₃): δ 154.85, 134.27, 133.52, 129.25, 127.39, 127.21, 126.10, 124.95, 124.69, 124.18, 117.61, 52.88, 52.16, 37.51.

⁶ R. C. D. Brown, M. L. Fisher and L. J. Brown, Org. Biomol. Chem., 2003, 1, 2699.

⁷ M. Moriyasu, M. Yoshioka, M. Kawanisi and R. Yamaguchi, J. Org. Chem., 1988, 53, 3507.

2. The allylation of aldehydes 3 using allyltrimethylsilane 1



To a 15 mL vial was added catalyst $Hg(OTf)_2$ (5.0 mg, 0.01 mmol), aldehyde **3** (2.0 mmol), 5 mL of anhydrous CH₂Cl₂ and **1** (4.0 mmol). The resulting mixture was stirred at room temperature till almost full conversion of **3** by TLC analysis. The reaction mixture was diluted with 5.0 mL of EtOAc and ten drops of conc. HCl, then stirred for 10 minutes and washed successively with saturated aq. NaHCO₃ and brine. The organic layer was concentrated *in vacuo* and the residue was purified via flash chromatography to afford the title compounds, using PE/EtOAc (30:1 to 15:1, v/v) as eluent.

OH Product 7a⁸ was obtained in 86% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ
 7.34-7.24 (m, 5H), 5.84-5.73 (m, 1H), 5.17-5.10 (m, 2H), 4.72-4.69 (m, 1H), 2.51-2.48(m, 2H), 2.20 (s, br, 1H); ¹³C NMR (100 MHz, CDCl₃): 143.83, 134.41, 128.35, 127.47, 125.77, 118.29, 73.26, 43.74.

OH Product $7b^8$ was obtained in 78% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ 7.50-7.48 (d, J = 8.0 Hz, 1H), 7.24-7.13 (m, 3H), 5.92-5.82 (m, 1H), 5.22-5.15 (m, 2H), 4.99-4.96 (m, 1H), 2.55-2.40 (m, 2H), 2.35 (s, 3H), 2.04 (s, 1H); ¹³C NMR (100 MHz, CDCl₃): 141.90, 134.70, 134.31, 130.31, 127.20, 126.22, 125.14, 118.24, 69.63, 42.58, 19.03.

 OH
 Product 7c⁹ was obtained in 91% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ

 7.34-7.32 (m, 1H), 7.25-7.22 (m, 1H), 6.98-6.94 (m, 1H), 6.88-6.86 (m, 1H), 5.90-5.80 (m, 1H), 5.15-5.09 (m, 2H), 4.96-4.95 (m, 1H), 3.84 (s, 3H), 2.59-2.46 (m, 3H); ¹³C

 NMR (100 MHz, CDCl₃): 156.34, 135.18, 131.70, 128.26, 126.77, 120.64, 117.54, 110.39, 55.24, 41.81.

Product $7d^9$ was obtained in 93% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ 7.58-7.56 (d, J = 8.0 Hz, 1H), 7.34-7.28 (m, 2H), 7.23-7.18 (m, 1H), 5.92-5.82 (m, 1H), 5.21-5.14 (m, 3H), 2.67-2.61 (m, 1H), 2.42-2.34 (m, 1H), 2.19 (s, br, 1H); ¹³C NMR (100 MHz, CDCl₃): 141.12, 134.20, 131.63, 129.32, 128.39, 127.02, 126.97, 118.64, 69.55, 41.96.

⁸ M. C. Warner, G. A. Shevchenko, S. Jouda, K. Bogr and J.-E. Bckvall, Chem. Eur. J., 2013, 19, 13859.

⁹ M. Vasylyev and H. Alper, J. Org. Chem., 2010, 75, 2710.

Product $7e^{10}$ was obtained in 71% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ 7.24-7.07 (m, 4H), 5.85-5.75 (m, 1H), 5.18-5.10 (m, 2H), 4.69-4.66 (m, 1H), 2.51-2.47 (m, 2H), 2.35 (s, 3H), 2.14 (s, 1H); ¹³C NMR (100 MHz, CDCl₃): 143.81, 138.00, 134.56, 128.26, 128.23, 126.45, 122.84, 118.21, 73.29, 43.73, 21.40.

OH Product $7f^{11}$ was obtained in 84% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ 7.36 (m, 1H), 7.29-7.20 (m, 3H), 5.83-5.73 (m, 1H), 5.18-5.14 (m, 2H), 4.71-4.68 (m, 1H), 2.54-2.41 (m, 2H), 2.23 (s, br, 1H); ¹³C NMR (100 MHz, CDCl₃): 145.87, 134.26, 133.85, 129.64, 127.57, 125.97, 123.92, 118.90, 72.51, 43.75.

Product $7g^8$ was obtained in 85% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ 7.24-7.22 (m, 2H), 7.16-7.13 (m, 2H), 5.84-5.73 (m, 1H), 5.16-5.10 (m, 2H), 4.70-4.66 (m, 1H), 2.50-2.47 (m, 2H), 2.33 (s, 3H), 2.08 (s, br, 1H); ¹³C NMR (100 MHz, CDCl₃): 140.90, 137.13, 134.58, 129.04, 125.74, 118.15, 73.16, 43.70, 21.07.

OH Product 7h⁸ was obtained in 88% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ
 7.32-7.25 (m, 4H), 5.81-5.71 (m, 1H), 5.16-5.12 (m, 2H), 4.71-4.67 (m, 1H),
 2.52-2.40 (m, 2H), 2.20 (s, br, 1H); ¹³C NMR (100 MHz, CDCl₃): 142.26, 133.93,
 133.09, 128.47, 127.16, 118.76, 72.52, 43.78.

Product $7i^{12}$ was obtained in 86% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ 7.61 (d, J = 8.4 Hz, 2H), 7.47 (d, J = 8.0 Hz, 2H), 5.84-5.74 (m, 1H), 5.20-5.15 (m, 2H), 4.82-4.78 (m, 1H), 2.58-2.42 (m, 2H), 2.25-2.22 (m, 1H); ¹³C NMR (100 MHz, CDCl₃): 147.71, 133.66, 129.69 (q, J = 32.1 Hz), 126.05, 125.35 (q, J = 3.7 Hz), 124.17 (q, J = 270.3Hz), 119.15, 72.50, 43.85; ¹⁹F NMR (376 MHz, CDCl₃): -62.46.

Product $7j^{13}$ was obtained in 92% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ 7.58 (d, J = 8.4 Hz, 2H), 7.44 (d, J = 8.4 Hz, 2H), 5.77-5.71 (m, 1H), 5.14-5.10 (m, 2H), 4.78-4.75 (m, 1H), 2.65 (s, br, 1H), 2.49-2.40 (m, 2H); ¹³C NMR (100 MHz, CDCl₃): 149.24, 133.29, 132.03, 126.43, 119.01, 118.70, 110.86, 72.29, 43.58.

¹⁰ S. Ito, A. Hayashi, H. Komai, H. Yamaguchi, Y. Kubota and M. Asam, *Tetrahedron Lett.*, 2011, **67**, 2081.

¹¹ B. Kashyap and P. Phukan, *Tetrahedron Lett.*, 2013, **54**, 6324.

¹² A. Theodorou, I. Triandafillidi and C. G. Kokotos, Eur. J. Org. Chem., 2017, 1502.

Product $7k^{13}$ was obtained in 81% yield as colorless oil; ¹H NMR (400 MHz, $CDCl_3$): δ 7.98 (d, J = 8.4 Hz, 2H), 7.40 (d, J = 8.4 Hz, 2H), 5.82-5.71 (m, 1H), 5.16-5.11 (m, 2H), 4.79-4.75 (m, 1H), 3.88 (s, 3H), 2.55-2.41 (m, 3H); ¹³C NMR (100 MHz, CDCl_3): 168.94, 148.99, 133.80, 129.64, 129.13, 125.68, 118.80, 72.71, 52.02, 43.72.

Product $7l^{11}$ was obtained in 83% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): $\delta 8.17$ (d, J = 8.4 Hz, 2H), 7.51 (d, J = 8.4 Hz, 2H), 5.80-5.73 (m, 1H), 5.19-5.13 (m, 2H), 4.87-4.83 (m, 1H), 2.56-2.51 (m, 1H), 2.48-2.40 (m, 2H); ¹³C NMR (100 MHz, CDCl₃): 151.11, 147.14, 133.16, 126.51, 123.55, 119.51, 72.11, 43.80.

Product $7m^8$ was obtained in 87% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ 7.85-7.80 (m, 4H), 7.52-7.48 (m, 3H), 5.89-5.79 (m, 1H), 5.22-5.14 (m, 2H), 4.91-4.88 (m, 1H), 2.65-2.55 (m, 2H), 2.39 (s, 1H); ¹³C NMR (100 MHz, CDCl₃): 141.19, 134.31, 133.18, 132.88, 128.13, 127.89, 127.61, 126.05, 125.74, 124.45, 123.95, 118.40, 73.33, 43.62.

Ph Product $7n^{10}$ was obtained in 64% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ Ph 7, 30-7.17 (m, 5H), 5.87-5.76 (m, 1H), 5.16-5.12 (m, 2H), 3.70-3.67 (m, 1H), 2.85-2.77 (m, 1H), 2.70-2.65 (m, 1H), 2.34-2.30 (m, 1H), 2.20-2.16 (m, 1H), 1.81-1.76 (m, 2H), 1.67 (s, br, 1H); ¹³C NMR (100 MHz, CDCl₃): 142.02, 134.57, 128.41, 125.80, 118.32, 69.88, 42.03, 38.40, 32.01.

Product 70^{12} was obtained in 94% yield as colorless oil; ¹H NMR (400 MHz, CDCl₃): δ 7.38-7.32 (m, 4H), 7.29-7.24 (m, 1H), 4.92-4.85 (m, 2H), 4.81 (t, J = 6.4 Hz, 1H), 2.43-2.41 (m, 2H), 2.21 (s, br, 1H), 1.79 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): 144.04, 142.34, 128.35, 127.42, 125.72, 114.00, 71.40, 48.30, 22.30.

¹³ A. Gualandi, G. Rodeghiero, A. Faraone, F. Patuzzo, M. Marchini, F. Calogero, R. Perciaccante, T. P. Jansen, P. Ceroni and P. G. Cozz, *Chem. Commun.*, 2019, **55**, 6838.

3. The allylation of activated ketones 4 using allyltrimethylsilane 1a



To a 10 mL vial was added catalyst Hg(OTf)₂ (5.0 mg, 0.01 mmol), activated ketones **4** (0.2 mmol), TMSOTf (44.4mg, 0.2 mmol), 1 mL of anhydrous CH₃CN and **1a** (0.4 mmol). The resulting mixture was stirred at 25 °C or 50 °C till almost full conversion of **4** by TLC analysis. Then TBAF (62 mg, 0.24 mmol) was added and stirred for 10 minutes. The reaction mixture was concentrated *in vacuo* and the residue was purified via flash chromatography to afford the title compounds, using PE/EtOAc (20:1 to 10:1, v/v) as eluent. (Products **8b** and **8d** were run at 50 °C, others were run at 25 °C, and the reaction of **8f** with no TMSOTf as additive.)

Product $8a^{14}$ was obtained in 80% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ 7.61-7.58 (m, 2H), 7.44-7.37 (m, 3H), 5.61-5.54 (m, 1H), 5.29-5.22 (m, 2H), 3.03-2.98 (m, 1H), 2.89-2.84 (m, 1H), 2.65 (s, br, 1H); ¹³C NMR (100 MHz, CDCl₃): δ 136.84, 130.38, 129.56, 128.52, 128.32, 126.72, 125.34 (q, J = 283.7 Hz), 121.93, 75.82 (q, J = 28.1 Hz), 40.29; ¹⁹F NMR (376 MHz, CDCl₃): δ -79.19.

Product **8b**¹⁵ was obtained in 57% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ HO CF₃ 7.47-7.45 (d, J = 8.0 Hz, 2H), 7.23-7.21 (d, J = 8.0 Hz, 2H), 5.63-5.52 (m, 1H), 5.28-5.20 (m, 2H), 3.01-2.96 (m, 1H), 2.86-2.80 (m, 1H), 2.60 (s, 1H), 2.37 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 138.37, 133.86, 130.53, 129.05, 126.36, 125.17 (q, J = 309.9 Hz), 121.76, 75.77 (q, J = 27.8 Hz), 40.20, 21.03; ¹⁹F NMR (376 MHz, CDCl₃): δ -79.41.

Product $8c^{16}$ was obtained in 98% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ CF_3 7.52 (d, J = 8.8 Hz, 2H), 7.38 (d, J = 8.4 Hz, 2H), 5.60-5.50 (m, 1H), 5.28-5.23 (m, 2H), 2.97-2.91 (m, 1H), 2.87-2.81 (m, 1H), 2.68 (s, 1H); ¹³C NMR (100 MHz, CDCl₃): δ 135.38, 134.71, 129.94, 128.54, 128.00, 125.12 (q, J = 283.7 Hz), 122.28, 75.60 (q, J = 28.3 Hz), 40.25; ¹⁹F NMR (376 MHz, CDCl₃): δ -79.30.

¹⁴ C. Felix, A. Laurent and P. Mison, J. Fluorine Chem., 1995, 70, 71.

¹⁵ C. B. Kelly, M. A. Mercadante, E. R. Carnaghan, M. J. Doherty, D. C. Fager, J. J. Hauck, A. E. MacInnis, L. J. Tilley and N. E. Leadbeater, *Eur. J. Org. Chem.*, 2015, 4071.

¹⁶ Z.-F. Xie, G.-L. Li, G. Zhao, and J.-D. Wang, Chin. J. Chem., 2010, 28, 1212.

Product **8d**¹⁷ was obtained in 80% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ 7.54-7.51 (m, 2H), 7.43-7.39 (m, 2H), 7.39-7.32 (m, 1H), 5.75 (t, J = 56.4 Hz, 1H), 5.66-5.57 (m, 1H), 5.25-5.17 (m, 2H), 2.91-2.86 (m, 1H), 2.77-2.72 (m, 1H), 2.49 (s, 1H); 8d ¹³C NMR (100 MHz, CDCl₃): δ 138.66, 131.15, 128.37, 128.07, 126.20, 120.94, 116.78 (td, *J* = 2.8 Hz, J = 102.5 Hz), 75.41 (t, J = 21.2 Hz), 39.62; ¹⁹F NMR (376 MHz, CDCl₃): δ -129.07 (d, J = 277.5 Hz), -130.73 (d, J = 276.7 Hz).

Product 8e was obtained in 96% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ 7.85-7.79 (m, 2H), 7.72-7.71 (m, 1H), 7.60-7.56 (m, 1H), 5.74-5.64 (m, 1H), 5.19-5.10 (m, 2H), 3.05 (s, 1H), 2.80-2.75 (m, 1H), 2.67-2.61 (m, 1H); ¹³C NMR (100 MHz, CDCl₃): δ 8e 189.03 (dd, J = 25.4 Hz, J = 26.5 Hz), δ 152.11 (dd, J = 1.7 Hz, J = 6.9 Hz), 137.36, 131.81 (t, J = 3.6 Hz), 130.50, 130.16, 125.18, 124.45, 121.69, 115.90 (dd, J = 256.8 Hz, J = 267.8 Hz), 75.84 (dd, J = 20.3 Hz, J = 22.7 Hz) 41.30 (d, J = 4.1 Hz); ¹⁹F NMR (376 MHz, CDCl₃): δ -117.94 (d, J= 271.1 Hz), -127.58 (d, J = 271.1 Hz); IR (ATR): 2362, 1735, 1604, 1211, 1190, 1066, 997, 966, 912, 767, 590 cm⁻¹; MS (EI): 224 (M⁺, 3), 183 (100), 135 (37), 107 (22), 104 (7), 77 (10); HRMS (EI): Exact mass calcd for C₁₂H₁₀O₂F₂ [M]⁺: 224.0649, Found: 224.0651.

Product **8f**¹⁸ was obtained in 82% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ ΗΟ 7.44-7.41 (m, 2H), 7.37-7.29 (m, 3H), 6.87 (d, *J* = 16 Hz, 1H), 6.22 (d, *J* = 16 Hz, 1H), 5.84-5.74 (m, 1H), 5.28-5.24 (m, 2H), 2.70-2.59 (m, 2H), 2.39 (s, 1H); ¹³C NMR (100 8f MHz, CDCl³): δ 135.61, 133.23, 130.30, 128.68, 128.46, 126.82, 125.25 (q, J = 227.0 Hz), 124.67, 121.40, 75.21 (q, J = 22.4 Hz), 39.55. ¹⁹F NMR (376 MHz, CDCl3): δ -80.43.

¹⁷ K. Lee, D. L. Silverio, S. Torker, D. W. Robbins, F. Haeffner, F. W. van der Mei and A. H. Hoveyda, Nat. Chem., 2016, 8, 768. ¹⁸ S. K. Mandal, Sk. R. Amin and W. E. Crowe, J. Am. Chem. Soc., 2001, **123**, 457.

4. The allylation of enones 5 using allyltrimethylsilane 1



To a 10 mL vial was added catalyst Hg(OTf)₂ (1.0 mg, 0.01 mmol), enones **5** (0.2 mmol), 1 mL of anhydrous CH₃CN and **1** (0.4 mmol). The resulting mixture was stirred at room temperature till almost full conversion of **5** by TLC analysis. The reaction mixture was added with TBAF (62 mg, 0.24 mmol), stirred for 10 minutes and then concentrated *in vacuo*, the residue was purified via flash chromatography to afford the title compounds, using PE/EtOAc (40:1 to 20:1, v/v) as eluent. (The products **9d**, **9e** and **9f** are run with 15 mol% TMSOTf as additive)

Product 9a¹⁹ was obtained in 96% yield as white solid. ¹H NMR (400 MHz, CDCl₃): δ 7.90-7.88 (m, 2H), 7.54-7.51 (m, 1H), 7.44-7.40 (m, 2H), 7.30-7.23 (m, 4H), 7.19-7.16 (m, 1H), 5.74-5.64 (m, 1H), 5.02-4.94 (m, 2H), 3.51-3.44 (m, 1H), 3.30-3.28 (m, 2H), 2.48-2.44 (m, 2H); ¹³C NMR (100 MHz, CDCl₃): δ 198.90 144.30, 137.14, 136.24, 132.91, 128.49, 128.38, 127.98, 127.52, 126.33, 116.76, 44.49, 40.67.



9b

Product **9b** was obtained in 83% yield as white solid (m.p. 32.0-34.0 °C). ¹H NMR (400 MHz, CDCl₃): δ 7.36-7.29 (m, 2H), 7.28-7.24 (m, 2H), 7.22-7.13 (m, 5H), 5.71-5.62 (m, 1H), 5.02-4.95 (m, 2H), 3.41-3.33 (m, 1H), 3.31-3.21 (m, 2H), 2.43 (t, J = 7.2 Hz, 2H); ¹³C NMR (125 MHz, CDCl₃): δ 202.38, 143.66, 139.72, 136.01,

131.41, 130.53, 130.24, 128.71, 128.35, 127.56, 126.74, 126.42, 116.87, 48.87, 41.11, 40.75; IR (ATR): 2904, 1695, 1589, 1429, 1396, 1236, 995, 748 cm⁻¹; MS (EI): 284 (M⁺, 2), 139 (100), 131 (10), 130 (67), 111 (22), 77 (5); HRMS (EI): Exact mass calcd for C₁₈H₁₇OCl³⁵ [M]⁺: 284.0968, Found: 284.0972.



Product **9c** was obtained in 93% yield as white solid (m.p. 35.0-37.0 °C). ¹H NMR (400 MHz, CDCl₃): δ 7.49-7.47 (m, 1H), 7.33-7.24 (m, 3H), 7.21-7.17 (m, 5H), 5.74-5.64 (m, 1H), 5.02-4.94 (m, 2H), 3.44-3.37 (m, 1H), 3.27-3.13 (m, 2H), 2.43 (t, J = 7.2 Hz, 2H), 2.26 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 203.47, 143.99,

138.48, 137.68, 136.17, 131.71, 130.91, 128.35, 127.91, 127.54, 126.34, 125.45, 116.77, 47.58, 41.09, 40.88, 20.66; IR (ATR): 2908, 1678, 1452, 1238, 1107, 957, 854, 700 cm⁻¹; MS (EI): 264 (M⁺, 7), 131

¹⁹ P. H. Lee, K. Lee, S.-Y Sung, and S. Chang, J. Org. Chem., 2001, 66, 8646.

(11), 130 (63), 119 (100), 43 (43), 77 (3); HRMS (EI): Exact mass calcd for C₁₉H₂₀O [M]⁺: 264.1514, Found: 264.1516.



Product **9d** was obtained in 78% yield as white solid (m.p. 34.0-35.0 °C). ¹H NMR (400 MHz, CDCl₃): δ 7.81 (d, J = 8.4 Hz, 2H), 7.38 (d, J = 8.8 Hz, 2H), 7.29-7.15 (m, 5H), 5.73-5.63 (m, 1H), 5.03-4.94 (m, 2H), 3.47-3.41 (m, 1H), 3.26-3.24 (m, 2H), 2.45 (t, J = 6.8 Hz, 2H); ¹³C NMR (125 MHz, CDCl₃): δ 197.67, 144.08,

139.30, 136.10, 135.45, 129.39, 128.77, 128.42, 127.46, 126.42, 116.86, 44.42, 40.73, 40.63; IR (ATR): 3120, 2916, 1680, 1467, 1396, 912, 756, 698 cm⁻¹; MS (EI): 284 (M⁺, 5), 141 (33), 139 (100), 131 (11), 130 (78), 111 (26); HRMS (EI): Exact mass calcd for C₁₈H₁₇OCl³⁵ [M]⁺: 284.0968, Found: 284.0966.



Product $9e^{20}$ was obtained in 84% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ 7.73 (d, J = 8.4 Hz, 2H), 7.54 (d, J = 8.4 Hz, 2H), 7.29-7.15 (m, 5H), 5.72-5.63 (m, 1H), 5.02-4.94 (m, 2H), 3.48-3.41 (m, 1H), 3.25-3.23 (m, 2H), 2.45 (t, J = 6.8 Hz, 2H); ¹³C NMR (125 MHz, CDCl₃): δ 197.84, 144.05, 136.09, 135.83,

131.75, 129.49, 128.41, 128.02, 127.45, 126.41, 116.86, 44.39, 40.71, 40.62.



Product $9f^{21}$ was obtained in 64% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ 7.80 (d, J = 8.4 Hz, 2H), 7.29-7.14 (m, 7H), 5.73-5.63 (m, 1H), 5.01-4.93 (m, 2H), 3.50-3.43 (m, 1H), 3.26-3.24 (m, 2H), 2.47-2.43 (m, 2H), 2.37 (s, 3H); ¹³C NMR (125 MHz, CDCl₃): δ 198.48, 144.38, 143.63, 136.26, 134.70,

129.14, 128.34, 128.10, 127.51, 126.27, 116.66, 44.37, 40.75, 40.61, 21.54.

²⁰ J. A. Hilf, M. S. Holzwarth and S. D. Rychnovsky, J. Org. Chem., 2016, 81, 10376.

²¹ J. P. Reid, C. A. McAdam, A. J. S. Johnston, M. N. Grayson, J. M. Goodman and M. J. Cook, J. Org. Chem., 2015, 80, 1472.

Product $9h^{22}$ was obtained in 80% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ 7.55 (d, J = 4.8 Hz, 1H), 7.49 (d, J = 4.8 Hz, 1H), 7.21-7.16 (m, 4H), 7.11-7.07 (m, 1H), 7.00-6.98 (m, 1H), 5.65-5.55 (m, 1H), 4.94-4.86 (m, 2H), 3.41-3.34 (m, 1H), 9h 3.18-3.07 (m, 2H), 2.41-2.37 (m, 2H); ¹³C NMR (100 MHz, CDCl₃): δ 191.73, 144.57,

143.95, 136.08, 133.50, 131.71, 128.38, 127.96, 127.48, 126.40, 116.83, 116.80, 45.34, 41.08, 40.44.



Product 9i²³ was obtained in 61% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ 7.30-7.28 (m, 2H), 7.20-7.17 (m, 3H), 5.70-5.59 (m, 1H), 5.00-4.94 (m, 2H), 3.30-3.24 (m, 1H), 2.77-2.66 (m, 2H), 2.37-2.34 (m, 2H), 2.32-2.17 (m, 2H), 9i 1.48-1.40 (m, 2H), 1.24-1.15 (m, 2H) 0.85-0.81 (t, J = 7.2 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 210.05, 144.17, 136.24, 128.40, 127.46, 126.36, 116.65, 48.63, 43.31, 40.76, 40.64, 25.62, 22.18, 13.79.



Product 9j was obtained in 99% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ 7.29-7.25 (m, 2H), 7.18-7.15 (m, 3H), 5.69-5.58 (m, 1H), 4.99-4.93 (m, 2H), 3.33-3.26 (m, 1H), 2.75-2.73 (m, 2H), 2.39-2.33 (m, 2H), 2.21-2.16 (m, 1 H),

1.74-1.63 (m, 5H), 1.27-1.14 (m, 5H); ¹³C NMR (100 MHz, CDCl₃): δ 212.64, 144.39, 136.30, 128.30, 127.45, 126.22, 116.51, 51.21, 46.66, 40.58, 40.22, 28.15, 28.03, 25.75, 25.55, 25.53; IR (ATR): 2928, 1705, 1495, 1450, 1144, 997, 698 cm⁻¹; MS (EI): 256 (M⁺, 3), 173 (9), 145 (1), 131 (29), 130 (100), 111 (40), 83 (96); HRMS (EI): Exact mass calcd for C₁₈H₂₄O [M]⁺: 256.1827, Found: 256.1830.

Product $9k^{24}$ was obtained in 91% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ 7.29-7.25 (m, 2H), 7.19-7.17 (m, 3H), 5.68-5.61 (m, 1H), 5.00-4.92 (m, 2H) 3.37-3.30 (m, 1H), 2.84-2.72 (m, 2H), 2.38-2.34 (t, J = 7.2 Hz, 2H), 1.01 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ 214.17, 144.54, 136.44, 128.27, 127.58, 126.20, 116.47, 44.06, 42.83, 40.28, 40.11, 26.05.

Product $9l^{25}$ was obtained in 32% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ 7.30-7.20 (m, 2H), 7.19-7.17 (m, 3H), 5.68-5.59 (m, 1H), 5.01-4.94 (m, 2H), 3.29-3.22 (m, 1H), 2.80-2.68 (m, 2H), 2.37-2.34 (m, 2H), 2.02 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): 8 207.66, 143.99, 136.111, 128.42, 127.40, 126.39, 116.71, 49.43, 40.82, 40.64, 30.61.

²² P. Fries, M. K. Muller and J. Hartung, *Tetrahedron*, 2014, **70**, 1336.

²³ M. C. Whisler, E. D. Soli and P. Beak, Tetrahedron Lett., 2000, 41, 9527.

²⁴ M. Behnke and G. Majetich, J. Org. Chem., 1986, 51, 1745.

²⁵ I. Shibata, T. Kano, N. Kanazawa, S. Fukuoka and A. Baba, Angew. Chem. Int. Ed., 2002, 41, 1389.

Product $9m^{20}$ was obtained in 99% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ 7.90-7.88 (m, 2H), 7.54-7.49 (m, 1H), 7.43-7.39 (m, 2H), 7.30-7.24 (m, 4H), 7.19-7.15 (m, 1H), 4.72-4.66 (m, 2H), 3.66-3.59 (m, 1H), 3.29-3.27 (d, J = 6.8 Hz, 2H), 2.49-2.37 (m, 2H), 1.72 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 198.89, 144.64,

143.38, 137.24, 132.80, 128.42, 128.31, 128.91, 127.42, 126.24, 112.78, 44.94, 44.83, 38.93, 22.17.

Product $9n^{26}$ was obtained in 95% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ 7.81-7.79 (m, 2H), 7.47-7.43 (m, 1H), 7.36-7.32 (m, 2H), 7.17-7.15 (m, 2H), 7.09-7.07 (m, 2H), 5.63-5.53 (m, 1H), 4.94-4.88 (m, 2H), 3.42-3.34 (m, 1H), 3.24-3.13 (m, 2H), 2.41-2.28 (m, 2H); ¹³C NMR (100 MHz, CDCl₃): δ 198.48, 142.76, 136.98, 135.79, 133.03, 131.90, 128.90, 128.53, 128.48, 127.92, 117.10, 44.29, 40.60, 40.05.

Product **90** was obtained in 88% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ 7.96-7.93 (m, 2H), 7.54-7.52 (m, 1H), 7.47-7.43 (m, 2H), 5.81-5.71 (m, 1H), 5.02-4.96 (m, 2H), 2.97-2.81 (m, 2H), 2.23-2.14 (m, 2H), 2.05-1.99 (m, 1H), 1.75-1.63 (m, 5H), 1.44-1.36 (m, 1H), 1.26-1.02 (m, 5H); ¹³C NMR (100 MHz, CDCl₃): δ 200.56, 137.48, 137.43, 132.72, 128.46, 127.99, 116.27, 40.33, 39.79, 38.83, 35.85, 29.99, 29.63, 26.65; IR (ATR): 2922, 2851, 1684, 1597, 1447, 1362, 750, 689 cm⁻¹; MS (EI): 256 (M⁺, 2), 215 (8), 173 (56), 120 (100), 105 (98), 77 (52); HRMS (EI): Exact mass calcd for C₁₈H₂₄O [M]⁺: 256.1827, Found: 256.1829.

Product $9p^{25}$ was obtained in 32% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ 5.78-5.67 (m, 1H), 5.00-4.95 (m, 2H), 2.42-2.34 (m, 3H), 2.21-2.15 (m, 1H), 2.12-2.07 (m, 1H), 2.00-1.94 (m, 2H), 1.02 (t, J = 7.6 Hz, 3H), 0.88 (d, J = 6.8 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 211.36, 136.64, 116.31, 48.89, 41.12, 36.48, 28.90, 19.73, 7.71.

 9q
 Product 9q²⁵ was obtained in 39% yield as colorless oil. ¹H NMR (400 MHz, CDCl₃): δ

 9q
 5.79-5.69 (m, 1H), 5.04-5.00 (m, 2H), 2.43-2.33 (m, 2H), 2.27-2.20 (m, 1H), 2.11-1.99 (m, 4H), 1.92-1.80 (m, 2H), 1.67-1.61 (m, 1H), 1.41-1.32 (m, 1H); ¹³C NMR (100 MHz, CDCl₃): δ 211.68, 135.62, 116.73, 47.67, 41.33, 40.74, 38.70, 30.80, 25.07.

²⁶ J. S.Yadav, B.V. S.Reddy, K. Sadasiv and G. Satheesh, *Tetrahedron Lett.*, 2002, 43, 9695.

5. The NMR spectra of compound 6



































f1 (ppm)








































6. The NMR spectra of compound 7











5 80 75 f1 (ppm) 55 10 5 145 140 135 130 125 120 115 110 105 100 95 90 85 60 55 50 40 35 30 25 20 15 75 70 65 45










































































7. The NMR spectra of compound 8











































8. The NMR spectra of compound 9



101



















f1 (ppm)


























































110 100 f1 (ppm)

9. The NMR spectra of compound 10



