Three-component coupling of benzyne: Domino intermolecular carbopalladation

Jaclyn L. Henderson, Andrew S. Edwards and Michael F. Greaney*

University of Edinburgh, School of Chemistry, Joseph Black Building, King's Buildings, West Mains Road, Edinburgh, EH9 3JJ, UK

Organon Laboratories Ltd., Newhouse, Lanarkshire, ML1 5SH, UK

Michael.Greaney@ed.ac.uk

Supporting Information

Part A: Experimental Procedures

General

NMR spectra were recorded on a Bruker dpx360 (360 MHz) instrument and calibrated to residual solvent peaks: proton (CDCl_3 7.26 ppm or DMSO 2.50 ppm) and carbon (CDCl_3 77.0 ppm or DMSO 39.4 ppm). The ^1H data is presented as follows: chemical shift (in ppm on the δ scale), multiplicity (s=singlet, d=doublet, t=triplet, q=quartet, m=multiplet), the coupling constant (J, in Hertz) and integration. The ^{13}C data is reported as the ppm on the δ scale followed by the interpretation. IR spectra were recorded on a JASCO FT/IR-460 plus instrument using 4 mm sodium chloride disks. The wavelengths of the maximum absorbance (ν_{max}) are quoted in cm^{-1} . Electrospray high resolution mass spectrometry was performed by the EPSRC National Mass Spectrometry Service Centre, Swansea, using a Finnigan MAT 900 XLT double focusing mass spectrometer and at Organon Laboratories using an Applied Biosystems Mariner time of flight mass spectrometer. The data is recorded as the ionisation method followed by the calculated and measured masses. TLC was performed on Merck 60F254 silica plates and visualised by UV light and/or anisaldehyde or potassium permanganate stains. The compounds were purified by wet flash chromatography using Merck Kieselgel 60 (particle size 35-70) silica under a positive pressure. The eluent is quoted as a percentage. All solvents were dried before use unless otherwise stated. DME was distilled over sodium with benzophenone as an indicator. DCM was distilled over calcium hydride. 4-methyl-2-(trimethylsilyl)phenyl trifluoromethanesulfonate was prepared according to published procedure.¹ All other chemicals were purchased from a chemical supplier and used as received.

¹ Peña, D.; Cobas, A.; Pérez, D.; Guitián, E. *Synthesis* **2002**, 1454-1458.

1. TCC of allyl chloride, benzyne and methyl acrylate

Catalyst Screen

Entry ^a	Pd source	Ligand	Yield of 7 or 8 (%)
1	Pd ₂ (dba) ₃	dppe	7 , 9
2	Pd(PPh ₃) ₄		7 , 18
3	Pd(OAc) ₂	PPh ₃	7 , 17
4	Pd(OAc) ₂	dppe	7 , 28 ; 8 , 58
5	Pd(OAc) ₂	P(Cy) ₃	0
6	Pd(OAc) ₂	dppp	Mainly phenanthrene
7	PdCl ₂ (CN) ₂		0
8	Pd(dppf)Cl ₂		0 (complex mixture)
9	Pd(PPh ₃) ₂ Cl ₂		Mainly phenanthrene

^a All reactions carried out in acetonitrile.

Solvent Screen

Entry ^a	Solvent	Ratio 7 : 8	Yield (%)
1	MeCN		28
2	MeCN/DCM	1:1	24
3	MeCN/Toluene	1:1	14
4	MeCN/1,4-dioxane ^b	1:2	34
5	DME		50
6	1,4-dioxane		Starting material
7	DME/1,4-dioxane	1:1	Starting material
8	THF		0 ^c
9	DMF		0 ^c

^a Catalyst system: Pd(OAc)₂/dppe 5 mol%. ^b MeCN added slowly over 6 hours. ^c Neither product or starting material evident in crude NMR

TCC of benzyne, allyl chloride and methyl acrylate

Methyl acrylate (0.49 mmol, 2.4 equiv) and allyl chloride (0.25 mmol, 1.2 equiv) were added to a stirred suspension of Pd(OAc)₂ (4 mg, 5 mol %), dppe (4 mg, 5 mol %) and CsF (4 equiv) in freshly distilled DME (1.5 mL) under N₂ in a 5 mL round bottomed flask. This was followed by the dropwise addition of 2-(trimethylsilyl)phenyl trifluoromethane sulfonate (**1**) (0.21 mmol, 1 equiv). The reaction was heated to 50 °C and stirred overnight. The reaction mixture was diluted with DCM and filtered through a short plug of silica then concentrated under reduced pressure. Purification by flash column chromatography on silica gel, eluting with 10% EtOAc/hexanes yielded the title compound.

(E)-methyl 3-(2-allylphenyl)acrylate (7): Isolated as a colourless oil in a yield of 50%. ¹H NMR (CDCl₃, 360 MHz) δ 8.06 (d, 1H, J = 15.8), 7.58 (dd, 1H, J = 7.5, 1.4), 7.33 (dd, 1H, J = 7.2, 1.4), 7.32 – 7.25 (m, 2H), 6.37 (d, 1H, J = 15.8), 5.96 (m, 1H), 5.08 (dd, 1H, J = 10.1, 1.6), 5.00 (dd, 1H, J = 15.3, 1.7), 3.83 (s, 3H), 3.58 (d,

2H, $J = 7.7$); ^{13}C NMR (CDCl_3 , 62.9 MHz) δ 167.4 (quat), 142.4 (CH), 139.2 (quat), 136.5 (CH), 133.3 (quat), 130.3 (CH), 130.2 (CH), 126.8 (CH), 126.6 (CH), 119.1 (CH), 116.4 (CH_2), 51.7 (CH_3), 37.4 (CH_2); IR (film/ cm^{-1}) 2949, 1717, 1634, 1434, 1318, 1272, 1194, 1171; HRMS (ES^+) calcd. for $\text{C}_{13}\text{H}_{15}\text{O}_2$: ($\text{M}+\text{H}$) $^+$ 203.1067; found 203.1067.

2. TCC of methyl bromoacetate, benzyne and acrylates

Catalyst Screen

Entry	Pd Source	Ligand	Yield of 12 (%)
1	$\text{Pd}(\text{OAc})_2$	dppe	30
2	$\text{Pd}(\text{PPh}_3)_4$		51
3	$\text{Pd}_2(\text{dba})_3$	dppent	60
4	$\text{Pd}_2(\text{dba})_3$	dppf	Complex mix
5	$\text{Pd}(\text{dppf})\text{Cl}_2$		75
6	$\text{Pd}(\text{dppf})\text{Cl}_2$	dppf	39
7	$\text{Pd}_2(\text{dba})_3$	dppp	65
8	$\text{Pd}_2(\text{dba})_3$	dppb	57
9	$\text{Pd}_2(\text{dba})_3$	dpphex	29
10	$\text{Pd}_2(\text{dba})_3$	dppm	Complex mix
11	$\text{Pd}(\text{OAc})_2$	dppb	42
12	$\text{Pd}_2(\text{dba})_3$	dppe	44
13	$\text{Pd}(\text{dppe})_2$		31

TCC of **1**, **10** and methyl acrylate was carried out in MeCN with $\text{Pd}(\text{dppf})\text{Cl}_2$ as catalyst. None of the desired product, **12a**, could be isolated.

General method for TCC of benzyne, bromoacetates and acrylates

Methyl acrylate (0.31 mmol, 1.5 equiv) and methyl bromoacetate, **10**, (0.21 mmol, 1 equiv) were added to a stirred suspension of $\text{Pd}(\text{dppf})\text{Cl}_2$ (8.4 mg, 5 mol%) and CsF (4.5 equiv) in freshly distilled DME (1 ml) under N_2 . This was followed by the dropwise addition of 2-(trimethylsilyl)phenyl trifluoromethane sulfonate (**1**) (0.31 mmol, 1.5 equiv). The reaction was stirred at 50 °C over two nights, after which time it was diluted with DCM and filtered through a short plug of silica then concentrated under reduced pressure. Flash chromatography on silica gel, eluting with 20% EtOAc/hexanes yielded the title compounds.

(E)-methyl 3-(2-((methoxycarbonyl)methyl)phenyl)acrylate (12a): Isolated as a colourless oil in a yield of 75%. ^1H NMR (CDCl_3 , 360 MHz) δ 7.96 (d, 1H, $J = 15.8$), 7.60 (dd, 1H, $J = 1.6, 7.3$), 7.38 - 7.27 (m, 3H), 6.38 (d, 1H, $J = 15.8$), 3.81 (s, 3H), 3.81 (s, 2H), 3.70 (s, 3H); ^{13}C NMR (CDCl_3 , 90.55 MHz) δ 171.3 (quat), 167.1 (quat), 141.8 (CH), 133.9 (quat), 133.5 (quat), 131.1 (CH), 130.1 (CH), 127.9 (CH), 126.9 (CH), 120.0 (CH), 52.2 (CH_3), 51.7 (CH_3), 38.6 (CH_2); IR (film/ cm^{-1}) 2952, 1716, 1634, 1434, 1319, 1170; HRMS (ES^+) calcd. for $\text{C}_{13}\text{H}_{15}\text{O}_4$: ($\text{M}+\text{H}$) $^+$ 235.0965. Found: 235.0967.

(E)-tert-butyl 3-(2-((methoxycarbonyl)methyl)phenyl)acrylate (12b): Isolated as a colourless oil in a yield of 80%. ^1H NMR (CDCl_3 , 360 MHz) δ 7.86 (d, 1H, $J = 15.7$), 7.59 (m, 1H), 7.37 - 7.25 (m, 3H), 6.31 (d, 2H, $J =$

15.7), 3.78 (s, 2H), 3.70 (s, 3H), 1.52 (s, 9H); ^{13}C NMR (CDCl_3 , 90.55 MHz) δ 171.3 (quat), 165.9 (quat), 140.3 (CH), 134.0 (quat), 133.2 (quat), 130.8 (CH), 129.7 (CH), 127.6 (CH), 126.7 (CH), 122.2 (CH), 80.4 (quat), 52.0 (CH₃), 38.4 (CH₂), 28.0 (CH₃); IR (film/ cm^{-1}) 2978, 1740, 1708, 1633, 1321, 1151; HRMS (ES^+) calcd. for $\text{C}_{16}\text{H}_{21}\text{O}_4$: ($\text{M}+\text{H}$) $^+$ 277.1434. Found: 277.1435.

(*E*)-*tert*-butyl 3-(2-((methoxycarbonyl)methyl)-4-methylphenyl)acrylate (12c) and (*E*)-*tert*-butyl 3-(2-((methoxycarbonyl)methyl)-5-methylphenyl)acrylate (12d): Isolated as a colourless oil in a yield of 70%. ^1H NMR (CDCl_3 , 360 MHz) δ 7.75 (d, 1H, J = 15.7), 7.42 (d, 0.5H, J = 7.9), 7.34 (s, 0.5H), 7.07 (m, 3H), 6.22 (d, 0.5H, J = 15.7), 6.20 (d, 0.5H, J = 15.7), 3.66 (s, 1H), 3.64 (s, 1H), 3.63 (s, 1.5H), 3.61 (s, 1.5H), 2.27 (s, 3H), 1.44 (s, 9H); ^{13}C NMR (CDCl_3 , 90.55 MHz) δ 171.6 (quat), 171.6 (quat), 166.2 (quat), 166.1 (quat), 140.6 (CH), 140.3 (CH), 140.2 (quat), 137.4 (quat), 133.8 (quat), 133.3 (quat), 131.7 (CH), 131.2 (quat), 130.9 (CH), 130.7 (CH), 130.5 (quat), 128.6 (CH), 127.4 (CH), 126.7 (CH), 122.0 (CH), 121.2 (CH), 80.5 (quat), 80.4 (quat), 52.2 (CH₃), 52.1 (CH₃), 38.5 (CH₂), 38.1 (CH₂), 28.1 (CH₃), 21.2 (CH₃), 21.0 (CH₃); IR (film/ cm^{-1}) 2978, 1741, 1707, 1633, 1321, 1251, 1151; HRMS (ES^+) calcd for $\text{C}_{13}\text{H}_{13}\text{O}_3$: ($\text{M}-\text{O}^t\text{Bu}$) $^+$ 217.0859. Found: 217.0852.

3. TCC of benzyl bromides, benzyne and *tert*-butyl acrylate

Catalyst Screen

Entry	Palladium Source	Ligand	Volume (mL)	Outcome
1	$\text{Pd}(\text{dppf})\text{Cl}_2$		1	1:1 15 with phenanthrene
2	$\text{Pd}(\text{OAc})_2$	dppe	1	64% yield of 15
3	$\text{Pd}_2(\text{dba})_3$	dppe	1	47% yield of 15
4	$\text{Pd}(\text{OAc})_2$	dppe	15	Complex mix
5	$\text{Pd}(\text{OAc})_2$	dppb	1	20% yield of 15
6	$\text{Pd}(\text{OAc})_2$	dppp	1	Complex mix
7	$\text{Pd}(\text{OAc})_2$	xantphos	1	0% yield of 15
8	$\text{Pd}(\text{PPh}_3)_4$		1	Complex mix

TCC of **13b**, **1** and **14** was also carried out in MeCN using the $\text{Pd}(\text{OAc})_2/\text{dppe}$ catalyst system. Product **15b** was isolated in a yield of 27%.

General method for TCC of benzyl bromides, benzyne and acrylates

Benzyl bromide (0.31 mmol, 1.5 equiv) and *tert*-butyl acrylate (0.21 mmol, 1 equiv) were added to a stirred suspension of $\text{Pd}(\text{OAc})_2$ (2.4 mg, 5 mol %), dppe (4.3 mg, 5 mol %) and CsF (3 equiv) in freshly distilled DME (1 ml) under N_2 . This was followed by the dropwise addition of 2-(trimethylsilyl)phenyl trifluoromethane sulfonate (**1**) (0.21 mmol, 1 equiv). The reaction was stirred at 50 °C over 2 nights. The reaction mixture was diluted with DCM and filtered through a pad of silica. Purification was achieved either by a) chromatography on silica gel eluting with EtOAc/hexanes to produce the ester, or b) treatment with TFA (0.3 mL) in DCM (1 mL) at room temperature followed by concentration under reduced pressure to afford a residue which could be triturated and / or recrystallised from hexane/EtOAc mixtures to afford the crystalline acids.

(*E*)-3-(2-benzylphenyl)acrylic acid (15a): Isolated in 65% yield as a colourless solid: m.p. (hexanes) 126 - 128 °C; ^1H NMR (DMSO, 360 MHz) δ 7.89 (d, 1H, J = 15.8), 7.77 (d, 1H, J = 7.6), 7.43 - 7.34 (m, 5H), 7.19 (m,

1H), 7.11 (d, 2H, J = 7.3) 6.41 (d, 1H, J = 15.8), 4.15 (s, 2H); ¹³C NMR (DMSO, 90.55 MHz) δ 166.9(quat), 140.7(quat), 139.9 (CH), 139.5 (CH), 132.4 (quat), 130.4 (CH), 129.7 (quat), 128.0 (CH), 127.8 (CH), 126.5 (CH), 126.3 (CH), 125.5 (CH), 119.8 (CH), 37.6 (CH₂); IR (film/cm⁻¹) 1684, 1624, 1418, 1283, 1220; HRMS (ES⁻) calcd for C₁₆H₁₃O₂: (M-H)⁻ 237.0910. Found: 237.0911.

(E)-tert-butyl 3-(2-(4-methoxybenzyl)phenyl)acrylate (15b): Isolated in a 76% yield as a colourless oil; ¹H NMR (CDCl₃, 360 MHz) δ 7.98 (d, 1H, J = 15.8), 7.62 (dd, 1H, J = 7.4, 1.1), 7.45 - 7.22 (m, 3H), 7.11 (d, 2H, J = 8.6), 6.87 (d, 2H, J = 8.6), 6.30 (d, 1H, J = 15.8), 4.12 (s, 2H), 3.82 (s, 3H), 1.58 (s, 9H); ¹³C NMR (CDCl₃, 90.55 MHz) δ 165.9 (quat), 157.7 (quat), 140.9 (quat), 140.2 (CH), 133.4 (quat), 132.0 (quat), 130.2 (CH), 129.6(CH), 129.4 (CH), 126.5 (CH), 126.4 (CH), 121.4 (CH), 113.6 (CH) 80.1 (quat), 54.9 (CH₃), 37.9 (CH₂), 27.9 (CH₃); IR (film/cm⁻¹) 2977, 1707, 1511, 1320, 1248, 1150; HRMS (ES⁺) calcd for C₂₁H₂₅O₃: (M+H)⁺ 325.1798. Found: 325.1802.

(E)-tert-butyl 3-(2-(4-nitrobenzyl)phenyl)acrylate (15c): Isolated in 69% yield as a colourless oil; ¹H NMR (CDCl₃, 360 MHz) δ 8.17 (d, 2H, J = 8.4), 7.82 (d, 1H, J = 15.8), 7.63 (dd, 1H, J = 7.4, 1.4), 7.42 - 7.34 (m, 2H), 7.32 (d, 2H, J = 8.4), 7.23 (dd, 1H, J = 7.4, 1.4), 6.29 (d, 1H, J = 15.8), 4.26 (s, 2H), 1.50 (s, 9H); ¹³C NMR (CDCl₃, 90.55 MHz) δ 165.7 (quat), 147.8 (quat), 146.2 (quat), 140.1 (CH), 137.8 (quat), 133.6 (quat), 130.6 (CH), 129.9 (CH), 129.2 (CH), 127.4 (CH), 126.8 (CH), 123.6 (CH), 122.1 (CH), 80.5 (quat), 38.7 (CH₂), 27.9 (CH₃); IR (film/cm⁻¹) 2977, 1707, 1519, 1346, 1151; HRMS (ES⁺) calcd for C₁₆H₁₂NO₃: (M-O^tBu)⁺ 266.0812. Found: 266.0815.

(E)-3-(2-(4-bromobenzyl)phenyl)acrylic acid (15d): Isolated in a yield of 80% as a light yellow solid; m.p. (hexanes) 174 °C; ¹H NMR (DMSO, 360 MHz) δ 7.99 (d, 1H, J = 15.8), 7.69 (d, 1H, J = 6.4, 1.4), 7.48 (d, 2H, J = 8.3), 7.43 - 7.31 (m, 3H), 7.08 (d, 2H, J = 8.3), 6.41 (d, 1H, J = 15.8), 4.14 (s, 2H); ¹³C NMR (DMSO, 90.55 MHz) δ 167.3 (quat), 141.0 (CH), 139.9 (quat), 139.4 (quat), 132.9 (quat), 131.3 (CH), 130.9 (CH), 130.6 (CH), 130.2 (CH), 127.2 (CH), 126.9 (CH), 120.6 (CH), 119.1 (CH), 37.4 (CH₂); IR (film/cm⁻¹) 1685, 1627, 1486, 1418, 1281, 1217; HRMS (ES⁻) calcd for C₁₆H₁₂O₂Br: (M-H)⁻ 315.0015. Found: 315.0022.

(E)-3-(2-(4-fluorobenzyl)phenyl)acrylic acid (15e): Isolated as a colourless solid in a 69% yield. m.p (hexanes) 147 °C; ¹H NMR (DMSO, 360 MHz) δ 7.86 (d, 1H, J = 15.8), 7.76 (d, 1H, J = 7.9), 7.41 (m, 1H), 7.33 (t, 2H, J = 7.3), 7.18 - 7.09 (m, 4H), 6.41 (d, 1H, J = 15.8), 4.16 (s, 2H); ¹³C NMR (DMSO, 90.55 MHz) δ 167.3 (quat), 161.9, 159.3 (CF), 141.0(CH), 139.8(quat), 136.6 (quat), 132.9 (quat), 130.8 (CH), 130.2 (CH), 130.1 (CH), 130.0 (CH), 127.1 (CH), 126.9 (CH), 120.5 (CH), 115.3 (CH), 115.1 (CH), 37.2 (CH₂); IR (film/cm⁻¹) 1680, 1621, 1509, 1224; HRMS (ES⁻) calcd for C₁₆H₁₂O₂F: (M-H)⁻ 255.0816. Found: 255.0809.

(E)-3-(2-(3-chlorobenzyl)phenyl)acrylic acid (15f): Isolated as a white powdery solid in a yield of 91%. m.p. (hexanes) 142 °C; ¹H NMR (DMSO, 360 MHz) δ 7.86 (d, 1H, J = 15.8), 7.77 (dd, 1H, J = 8.7, 1.7), 7.43 (m, 1H), 7.36 - 7.30 (m, 3H), 7.26 (m, 1H), 7.18 (t, 1H, J = 1.7), 7.09 (bd, 1H, J = 7.6), 6.41 (d, 1H, J = 15.8), 4.18 (s, 2H); ¹³C NMR (DMSO, 90.55 MHz) δ 167.2 (quat), 143.0 (quat), 140.9 (CH), 139.1 (quat), 133.0 (quat), 132.9 (quat), 130.8 (CH), 130.2 (CH), 128.1 (CH), 127.2 (CH), 127.0 (CH), 126.9 (CH), 126.0 (CH), 120.6 (CH), 37.5 (CH₂); IR (film/cm⁻¹) 1681, 1621, 1416, 1279, 1223; HRMS (ES⁻) calcd for C₁₆H₁₂O₂Cl: (M-H)⁻ 271.0520. Found: 271.0512.

(E)-3-(2-(4-cyanobenzyl)phenyl)acrylic acid (15g): Isolated as a colourless powdery solid in a yield of 89%. m.p. (hexanes) 175 °C; ¹H NMR (DMSO, 360 MHz) δ 7.95 - 7.76 (m, 4H), 7.44 - 7.30 (m, 5H), 6.41 (d, 1H, J = 15.8), 4.27 (s, 2H); ¹³C NMR (DMSO, 90.55 MHz) δ 168.7 (quat), 148.0 (quat), 142.3 (CH), 140.2 (quat), 134.5 (quat), 133.9 (CH), 132.5 (CH), 131.8 (CH), 128.9 (CH), 128.5 (CH), 122.2 (CH), 120.3 (quat), 110.4 (quat), 39.5 (CH₂); IR (film/cm⁻¹) 2360, 2341, 1677, 1623; HRMS (ES⁻) calcd for C₁₇H₁₂NO₂: (M-H)⁻ 262.0862. Found: 262.0867.

(E)-3-(2-(2-nitrobenzyl)phenyl)acrylic acid (15h): Isolated as a powdery yellow solid in a yield of 58%. m.p. (hexanes) 157 °C; ¹H NMR (DMSO, 360 MHz) δ 8.05 (d, 1H, J = 7.5), 7.82 - 7.78 (m, 2 H), 7.67 (t, 1H, J = 6.9),

7.55 (t, 1H, J = 7.5), 7.36 - 7.31 (m, 2H), 7.21 (d, 1H, J = 7.6), 7.00 (d, 1H, J = 8.6), 6.43 (d, 1H, J = 15.7), 4.46 (s, 2H); ^{13}C NMR (DMSO, 90.55 MHz) δ 167.2 (quat), 148.8 (quat), 140.6 (CH), 137.8 (quat), 134.3 (quat), 133.6 (CH), 133.2 (quat), 132.0 (CH), 130.2 (CH), 129.8 (CH), 128.0 (CH), 127.3 (CH), 127.0 (CH), 124.8 (CH), 121.0 (CH), 34.6 (CH₂); IR (film/cm⁻¹) 1699, 1634, 1523, 1348; HRMS (ES⁻) calcd for C₁₆H₁₂NO₄: (M-H)⁻ 282.0761. Found: 282.0763.

(E)-3-(2-(4-(trifluoromethyl)benzyl)phenyl)acrylic acid (15i): Isolated as a colourless crystalline solid in a yield of 67%; m.p (water) 122 – 123 °C; ^1H NMR (DMSO, 360 MHz) δ 7.85 (d, 1H, J = 15.8), 7.79 (d, 1H, J = 7.3), 7.67 (d, 2H, J = 8.1), 7.42 (q, 1H, J = 7.2), 7.36 - 7.33 (m, 4H), 6.42 (d, 1H, J = 15.8), 4.27 (s, 2H); ^{13}C NMR (DMSO, 90.55 MHz) δ 167.2 (quat), 145.4 (quat), 140.9 (CH), 139.0 (quat), 133.0 (quat), 131.0 (CH), 130.3 (CH), 129.1 (CH), 127.3 (CH), 127.0 (CH), 127.6 (CF₃) 125.3 (CH), 120.6 (CH), 37.8 (CH₂); ^{19}F NMR (DMSO, 235 MHz) δ -62.0; IR (film/cm⁻¹) 1699, 1633, 1325, 1164, 1122, 1066; HRMS (ES⁻) calcd for C₁₇H₁₂O₂F₃: (M-H)⁻ 305.0784. Found: 305.0798.

(E)-3-(2-(3-methoxybenzyl)phenyl)acrylic acid (15j): Isolated as a colourless crystalline solid in a yield of 62%. m.p (water) 134 – 135 °C; ^1H NMR (DMSO, 360 MHz) δ 7.91 (d, 1H, J = 15.8), 7.76 (d, 1H, J = 7.7), 7.40 (q, 1H, J = 8.3), 7.33 - 7.30 (m, 2H), 7.20 (t, 1H, J = 7.7), 7.78-6.67 (m, 3H), 6.41 (d, 1H, J = 15.8), 4.11 (s, 2H), 3.71 (s, 3H); ^{13}C NMR (DMSO, 90.55 MHz) δ 167.4 (quat), 159.3 (quat), 142.0 (quat), 141.2 (CH), 139.9 (quat), 132.9 (quat), 130.9 (CH), 130.2 (CH), 129.5 (CH), 127.1 (CH), 126.8 (CH), 120.6 (CH), 120.3 (CH), 114.2 (CH), 111.3 (CH), 54.8 (CH₃), 38.1 (CH₂); IR (film) 1681, 1620, 1279, 1222; HRMS (ES⁻) calcd for C₁₇H₁₅O₃: (M-H)⁻ 267.1016. Found: 267.1016.

(E)-3-(2-((naphthalen-3-yl)methyl)phenyl)acrylic acid (15k): Isolated as a colourless powdery solid in a yield of 92%; m.p. (hexane) 160-161 °C; ^1H NMR (DMSO, 360 MHz) δ 7.96 (d, 1H, J = 15.8), 7.88 - 7.78 (m, 4H), 7.50 (s, 1H), 7.48 - 7.32 (m, 6H), 6.41 (d, 1H, J = 15.8), 4.32 (s, 2H); ^{13}C NMR (DMSO, 90.55 MHz) δ 167.4 (quat), 141.3 (CH), 139.8 (quat), 138.2 (quat), 133.1 (quat), 133.0 (quat), 131.6 (quat), 131.0 (CH), 130.3 (CH), 128.0 (CH), 127.5 (CH), 127.4 (CH), 127.2 (CH), 126.9 (CH), 126.4 (CH), 126.2 (CH), 125.6 (CH), 120.4 (CH), 38.3 (CH₂); IR (film/cm⁻¹) 2977, 1740, 1707, 1321, 1150; HRMS (ES⁻) calcd for C₂₀H₁₅O₂: (M-H)⁻ 287.1077. Found: 287.1070.

(E)-tert-butyl 3-(2-(4-methoxybenzyl)-4-methylphenyl)acrylate and (E)-tert-butyl 3-(2-(4-methoxybenzyl)-5-methylphenyl)acrylate (15l): Isolated as a colourless oil in a yield of 70%. ^1H NMR (CDCl₃, 360 MHz) δ 7.92 (d, 1H, J = 15.8), 7.50 (d, 0.5 H, J = 7.9), 7.41 (bs, 0.5 H), 7.19 - 7.12 (m, 3.5H), 7.02 (bs, 0.5H), 6.85 - 6.80 (m, 2H), 6.26 (d, 0.5H, J = 15.8), 6.24 (d, 0.5H, J = 15.8), 4.05 (s, 2H), 3.77 (s, 3H), 1.53 (s, 9H); ^{13}C NMR (CDCl₃, 90.55 MHz) δ 166.3 (quat), 166.2 (quat), 157.8 (quat), 157.8 (quat), 141.2 (quat), 141.0 (quat), 140.3 (CH), 140.0 (CH), 137.5 (quat), 136.1 (quat), 133.3 (quat), 132.5 (quat), 132.4 (quat), 131.3 (CH), 130.7 (CH), 130.6 (CH), 130.5 (CH), 129.5 (CH), 127.6 (CH), 127.1 (CH), 126.5 (CH), 121.2 (CH), 120.4 (CH), 113.8 (CH), 80.2 (quat), 80.2 (quat), 55.1 (CH₃), 38.0 (CH₂), 37.7 (CH₂), 28.1 (CH₃), 21.3 (CH₃), 20.9 (CH₃); IR (film/cm⁻¹) 2977, 1707, 1511, 1248, 1150; HRMS (ES⁺) calcd for C₁₈H₁₇O₂: (M-O^tBu)⁺ 265.1223. Found: 265.1213.

Part B: Spectroscopic Data

15e

15f