Supplementary Material (ESI) for Chemical Communications

An asymmetric organocatalytic approach towards allylic amines and β-keto amino compounds

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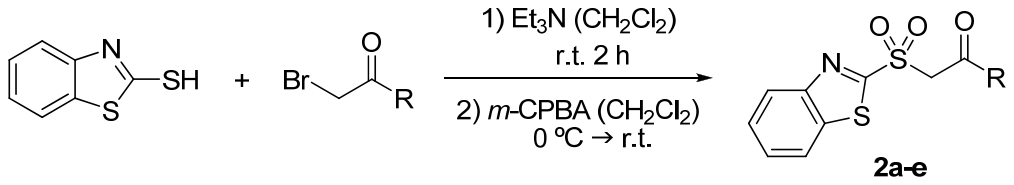
Contents

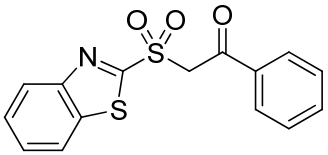
1. General Methods

NMR spectra were acquired on a Varian AS 400 spectrometer, running at 400 and 100 MHz for ^{1}H and ^{13}C acquisition, respectively. Chemical shifts (δ) are reported in ppm relative to residual solvent signals ($CDCl_3$, 7.26 ppm for ^{1}H NMR; $CDCl_3$, 77.0 ppm for ^{13}C NMR). The following abbreviations are used to indicate the multiplicity in ^{1}H NMR spectra: s, singlet; d, doublet; t, triplet; dd, double doublet; m, multiplet; bs, broad signal. ^{13}C NMR spectra were acquired on a broad band decoupled mode. Mass spectra were recorded on a micromass LCT spectrometer using electrospray (ES^{+}) ionization techniques. Analytical thin layer chromatography (TLC) was performed using pre-coated aluminium-backed plates (Merck Kieselgel 60 F254) and visualized by ultraviolet irradiation, $KMnO_4$ or vanillin dip. Optical rotations were measured on a Perkin-Elmer 241 polarimeter. The enantiomeric excess (ee) of the products was determined by chiral stationary-phase HPLC (Daicel Chiralpak AD and Daicel Chiralcel OD/OJ columns). Analytical grade solvents and commercially available reagents were used without further purification. Propionitrile was dried over activated molecular sieves (4Å) prior to use. Racemates were prepared using Et_3N as catalyst. For flash chromatography (FC) silica gel (Silica gel 60, 230-400 mesh, Fluka) or Iatrobeads (Iatrobeads 6RS-8060) were used. Imines **1a-c**[1] and sulfones **2a-e**[2] were prepared according to literature.

2. General procedure for the synthesis of nucleophiles 2a-e

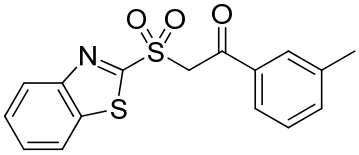


The nucleophiles **2a-e** was prepared according to literature procedure.[2] Hereafter the crude products was recrystallised in MeOH yielding the pure nucleophiles.



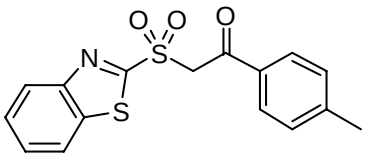
2-(Benzothiazole-2-sulfonyl)-1-phenyl-ethanone (2a)

Following the general procedure **2a** was obtained as a white solid. ^{1}H NMR ($CDCl_3$) δ ppm 8.19 (d, *J* = 8.0 Hz, 1H), 8.00 (d, *J* = 7.7 Hz, 1H), 7.93 (d, *J* = 7.3 Hz, 2H), 7.65-7.56 (m, 3H), 7.46 (t, *J* = 7.9 Hz, 2H), 5.21 (s, 2H). ^{13}C NMR ($CDCl_3$) δ ppm 187.1, 165.2, 152.3, 137.0, 135.3, 134.6, 129.0 (2 C), 128.9 (2 C), 128.1, 127.6, 125.4, 122.3, 61.1. HRMS calc. for $C_{15}H_{11}NNaO_3S_2$: 340.0078; found: 340.0079.



2-(Benzothiazole-2-sulfonyl)-1-*m*-tolyl-ethanone (2b)

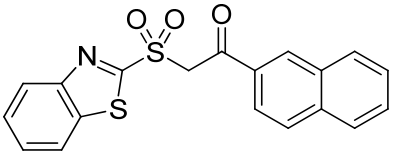
Following the general procedure **2b** was obtained as a white solid. ^{1}H NMR ($CDCl_3$) δ ppm 8.19 (d, *J* = 7.4 Hz, 1H), 7.99 (d, *J* = 7.5 Hz, 1H), 7.74-7.69 (m, 2H), 7.65-7.56 (m, 2H), 7.40 (d, *J* = 7.6 Hz, 1H), 7.34 (t, *J* = 7.6 Hz, 1H), 5.19 (s, 2H), 2.35 (s, 3H). ^{13}C NMR ($CDCl_3$) δ ppm 187.2, 165.3, 152.4, 138.9, 137.0, 135.4, 135.4, 129.3, 128.8, 128.1, 127.6, 126.2, 125.5, 122.3, 61.2, 21.2. HRMS calc. for $C_{16}H_{13}NNaO_3S_2$: 354.0235; found: 354.0234.



2-(Benzothiazol-2-ylsulfonyl)-1-*p*-tolylethanone (2c)

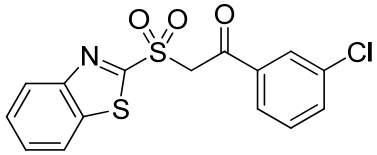
Following the general procedure **2c** was obtained as a white solid. ^{1}H NMR ($CDCl_3$) δ ppm 8.19 (d, *J* = 7.9 Hz, 1H), 8.00 (d, *J* = 7.9 Hz, 1H), 7.82 (d, *J* = 8.3 Hz, 2H), 7.65-7.56 (m, 2H), 7.25 (d, *J* = 8.3 Hz, 2H), 5.17 (s, 2H), 2.40 (s,

3H). ^{13}C NMR ($CDCl_3$) δ ppm 186.6, 165.3, 152.4, 145.9, 137.0, 132.9, 129.6 (2 C), 129.1 (2 C), 128.1, 127.6, 125.5, 122.3, 61.1, 21.8. HRMS calc. for $C_{16}H_{13}NNaO_3S_2$: 354.0235; found: 354.0238.



2-(Benzothiazol-2-ylsulfonyl)-1-(naphthalen-2-yl)ethanone (2d)

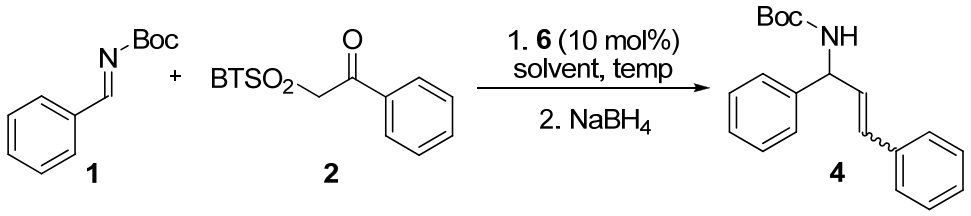
Following the general procedure **2d** was obtained as a white solid. ^{1}H NMR ($CDCl_3$) δ ppm 8.44 (s, 1H), 8.20 (d, *J* = 8.0 Hz, 1H), 8.03-7.82 (m, 5H), 7.69-7.52 (m, 4H), 5.33 (s, 2H). ^{13}C NMR ($CDCl_3$) δ ppm 187.2, 165.5, 152.7, 137.3, 136.3, 133.0, 132.4, 132.0, 130.1, 129.7, 129.2, 128.4, 128.0, 127.9, 127.5, 125.7, 123.8, 122.6, 61.6. HRMS calc. for $C_{19}H_{13}NNaO_3S_2$: 390.0235; found: 390.0238.

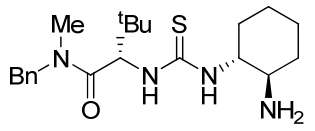


2-(Benzothiazol-2-ylsulfonyl)-1-(3-chlorophenyl)ethanone (2e)

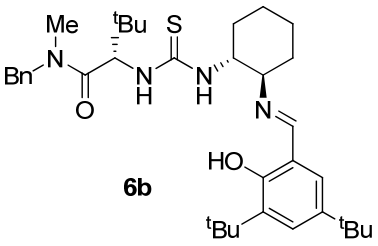
Following the general procedure **2e** was obtained as a white solid. ^{1}H NMR ($CDCl_3$) δ ppm 8.21-8.16 (m, 1H), 8.02-7.97 (m, 1H), 7.88 (t, *J* = 1.6 Hz, 1H), 7.85-7.79 (m, 1H), 7.67-7.52 (m, 3H), 7.41 (t, *J* = 8.0 Hz, 1 H), 5.18 (s, 2 H). ^{13}C NMR ($CDCl_3$) δ ppm 186.0, 164.9, 152.3, 137.0, 136.8, 135.3, 134.5, 130.2, 128.9, 128.3, 127.7, 127.2, 125.5 122.3, 61.2. HRMS calc. for $C_{15}H_{10}ClNNaO_3S_2$: 373.9688; found: 373.9694.

3. Initial screening results[a]

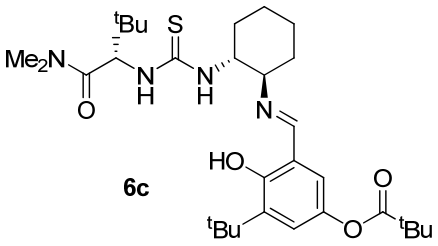




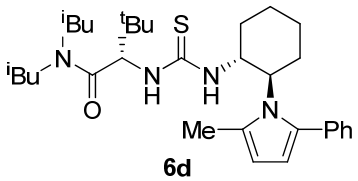
6a



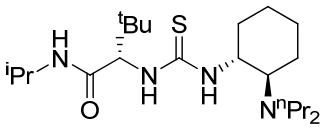
6b



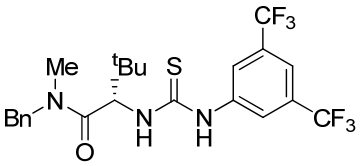
6c



6d



6e



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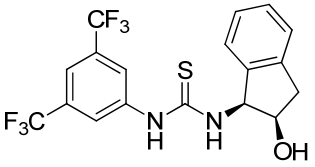
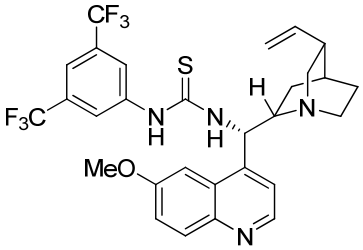
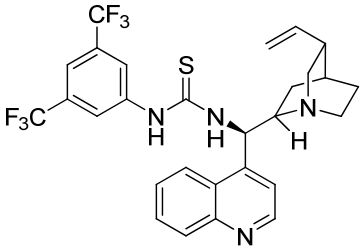


6g



6h



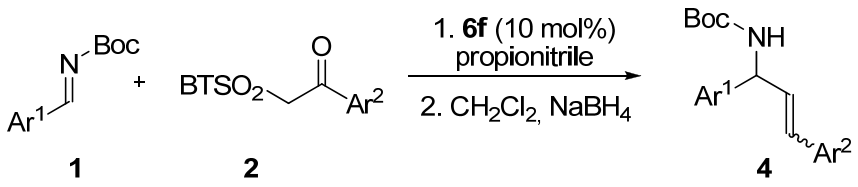
6i

Entry	Solvent	Catalyst (10 mol%)	Time (h)	Temp (°C)	Conv. (1st step) [b] (%)	Ee[c] (%)
1	Toluene	**6a**	48	rt	90	Rac
2	Toluene	**6b**	48	rt	95	Rac
3	Toluene	**6c**	48	rt	90	Rac
4	Toluene	**6d**	48	rt	90	Rac
5	Toluene	**6e**	48	rt	90	25
6	Toluene	**6f**	48	rt	95	35
7	Toluene	$(DHQD)_2PYR$	20	0	95	Rac
8	CH_2Cl_2	**6g**	48	-30	n.d.	10
9	CH_2Cl_2	**6h**	48	-30	n.d.	6
10	CH_2Cl_2	**6i**	48	-30	n.d.	Rac
11	CH_2Cl_2	**6e**	48	-30	n.d.	8
12	CH_2Cl_2	**6f**	18	-30	n.d.	70
13	Toluene	**6f**	24	-30	0	n.d.
14	$CHCl_3$	**6f**	24	-30	Full	37
15	Et_2O	**6f**	24	-30	Full	30
16	THF	**6f**	24	-30	Full	57
17	Acetone	**6f**	48	-30	Full	76

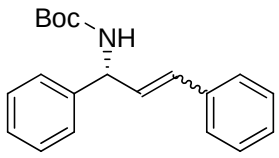
18	MeCN	**6f**	42	-30	Full	67
19	Propionitrile	**6f**	48	-30	Full	84
20[d]	Propionitrile	**6f**	72	-40	Full	89
21[e]	Propionitrile	**6f**	72	-40	Full	n.d.
22[f]	Propionitrile	**6f**	72	-40	Full	n.d.

[a] All reactions performed on a 0.10 mmol scale (0.20 M) using **1a** (0.25 mmol), **2a** (0.10 mmol) and **6** (0.01 mmol). [b] Determined by ^{1}H NMR. [c] Determined by chiral stationary-phase HPLC after reduction with $NaBH_4$. [d] Reduction performed in CH_2Cl_2 giving an *E*:*Z* ratio of 9:1 (determined by ^{1}H-NMR). [e] Reduction performed in propionitrile giving an *E*:*Z* ratio of 3:1 (determined by ^{1}H-NMR). [f] Reduction performed in CH_2Cl_2 with $LiBH_4$ giving an *E*:*Z* ratio of 2:1 (determined by ^{1}H-NMR).

4. General procedure for the formation of allylic amines 4a-h

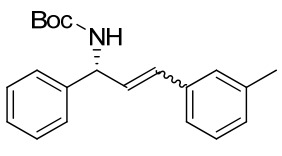


An ordinary vial equipped with a magnetic stirring bar was charged with β-keto benzothiazole (BT) sulfone nucleophile **2** (0.10 mmol, 1.0 equiv.) and catalyst **6f** (0.01 mmol, 0.1 equiv.), which were dissolved in 0.5 mL propionitrile and cooled to the desired temperature (see below). Upon cooling the imine **1** (0.25 mmol, 2.5 equiv.) was added. The reaction was run until judged complete by ^{1}H NMR spectroscopy. The solvent was evaporated (0.5 mL of toluene was added to ensure complete evaporation of propionitrile) and 1.0 mL of CH_2Cl_2 and 0.1 mL of MeOH was added. The reaction mixture was cooled to -30 ºC and treated with $NaBH_4$ (0.50 mmol, 5.0 equiv.). After 1 h the reaction was allowed to warm up to room temperature and was left until judged complete by TLC (aprox. 30 min – 1 h). The reaction was then quenched with NH_4Cl, extracted with CH_2Cl_2 and purified by FC.



(*R*)-*tert*-Butyl 1,3-diphenylallylcarbamate (4a)

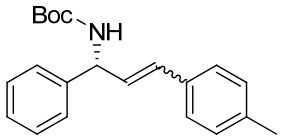
Following the general procedure (-40 ºC) **4a** was isolated by FC (CH_2Cl_2/pentane) in 63% yield (*E*:*Z* 9:1) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.42-7.20 (m, 10H), 6.55 (d, *J* = 16.0 Hz, 1H), 6.32 (dd, *J* = 6.0, 15.6 Hz, 1H), 5.47 (bs, 1H), 4.98 (bs, 1H), 1.46 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 154.9, 139.2, 136.6, 130.8, 129.4, 128.5 (2C), 127.6 (2C), 127.5 (2C), 126.5 (2C), 126.3, 126.2, 79.7, 52.8, 28.4 (3C). HRMS: Calculated for [$C_{20}H_{23}NNaO_2$]: 332.1626; found: 332.1631. The enantiomeric excess was determined by HPLC using a Chiralcel OD column [hexane/*i*-PrOH (95:5)]; flow rate 1.0 mL/min; τ_{minor} = 10.11 min, τ_{major} = 8.96 min (89% ee); $[\alpha]_D^{20}$ -4.4 (c = 0.73, CH_2Cl_2).



(*R*)-*tert*-Butyl 1-phenyl-3-*m*-tolylallylcarbamate (4b)

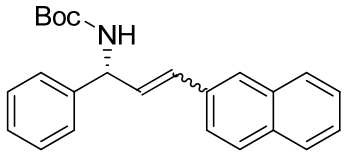
Following the general procedure (-40 ºC) **4b** was isolated by FC (CH_2Cl_2) in 65% yield (*E*:*Z* 12:1) as a clear oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm

7.27-6.97 (m, 9H), 6.43 (d, *J* = 16.0 Hz, 1H), 6.23 (dd, *J* = 4.0, 15.9 Hz, 1H), 5.39 (bs, 1H), 4.90 (bs, 1H), 2.26 (s, 3H), 1.38 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 155.1, 141.5, 138.2, 136.6, 131.1, 129.5, 128.8, 128.6 (2C), 127.7, 127.4, 127.1, 123.8, 79.9, 56.4, 28.5 (3C), 21.5. HRMS: Calculated for [$C_{21}H_{25}NO_2Na$]: 346.1783; found: 343.1779. The enantiomeric excess was determined by HPLC using two Chiralcel OD column [hexane/*i*-PrOH (97:3)]; flow rate 0.5 mL/min; τ_{minor} = 33.80 min, τ_{major} = 31.24 min (90% ee); $[\alpha]_D^{20}$ –10.5 (c = 0.47, CH_2Cl_2).



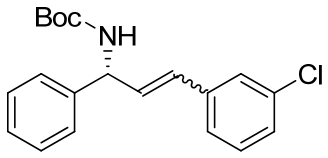
(*R*)-*tert*-Butyl 1-phenyl-3-*p*-tolylallylcarbamate (4c)

Following the general procedure (-30 ºC) **4c** was isolated by FC (CH_2Cl_2/pentane) in 61% yield (*E*:*Z* 13:1) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.40-7.08 (m, 9H), 6.51 (dd, *J* = 1.6, 15.6 Hz, 1H), 6.27 (dd, *J* = 6.0, 16.0 Hz, 1H), 5.45 (bs, 1H), 4.97 (bs, 1H), 2.33 (s, 3H), 1.46 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 155.0, 141.5, 137.5, 133.7, 130.8, 129.2 (2C), 128.7 (2C), 128.5, 127.5, 127.0 (2C), 126.4 (2C), 79.8, 56.3, 28.4 (3C), 21.2. HRMS: Calculated for [$C_{21}H_2NNaO_2$]: 346.1783; found: 346.1782. The enantiomeric excess was determined by HPLC using a Chiralpak AD column [hexane/*i*-PrOH (95:5)]; flow rate 1.0 mL/min; τ_{minor} = 13.01 min, τ_{major} = 15.29 min (84% ee); $[\alpha]_D^{20}$ –6.4 (c = 0.53, CH_2Cl_2).



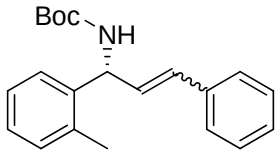
(*R*)-*tert*-Butyl 3-(naphthalen-2-yl)-1-phenylallylcarbamate (4d)

Following the general procedure (-30 ºC) **4d** was isolated by FC (CH_2Cl_2/pentane) in 65% yield (*E*:*Z* 9:1) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.84-7.74 (m, 3H), 7.73 (s, 1H), 7.58 (d, *J* = 8.8 Hz, 1H), 7.49-7.29 (m, 7H), 6.70 (d, *J* = 16.0 Hz, 1H), 6.46 (dd, *J* = 6.0, 16.0 Hz, 1H), 5.53 (bs, 1H), 5.01 (bs, 1H), 1.47 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 155.0, 141.3, 134.0, 133.5, 133.0, 131.0, 130.0, 128.8 (2C), 128.2, 128.0, 127.6 (2C), 127.0 (2C), 126.6, 126.3, 125.9, 123.4, 79.8, 56.4, 28.4 (3C). HRMS: Calculated for [$C_{24}H_{25}NNaO_2$]: 382.1783; found: 382.1776. The enantiomeric excess was determined by HPLC using a Chiralcel OD column [hexane/*i*-PrOH (85:15)]; flow rate 1.0 mL/min; τ_{minor} = 11.04 min, τ_{major} = 8.32 min (85% ee); $[\alpha]_D^{20}$ –14.3 (c = 0.39, CH_2Cl_2).



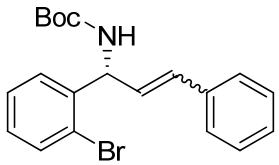
(*R*)-*tert*-Butyl 3-(3-chlorophenyl)-1-phenylallylcarbamate (4e)

Following the general procedure (-40 °C) **4e** was isolated by FC (CH_2Cl_2/pentane) in 54% yield (*E*:*Z* 10:1) as a clear oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.41-7.18 (m, 9H), 6.48 (dd, *J* = 1.2, 15.6 Hz, 1H), 6.34 (dd, *J* = 6.0, 16.0 Hz, 1H), 5.45 (bs, 1H), 4.95 (bs, 1H), 1.46 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 154.9, 140.9, 138.4, 134.5, 131.2, 129.7, 129.5, 128.8 (2C), 127.7, 127.6, 127.0 (2C), 126.4, 124.8, 79.9, 56.2, 28.4 (3C). HRMS: Calculated for [$C_{20}H_{22}ClNNaO_2$]: 366.1237; found: 366.1237. The enantiomeric excess was determined by HPLC using a Chiralcel OJ column [hexane/*i*-PrOH (98:2)]; flow rate 1.0 mL/min; τ_{minor} = 14.44 min, τ_{major} = 10.77 min (82% ee); $[\alpha]_D^{20}$ –3.4 (c = 0.50, CH_2Cl_2).



(*R*)-*tert*-Butyl 3-phenyl-1-*o*-tolylallylcarbamate (4f)

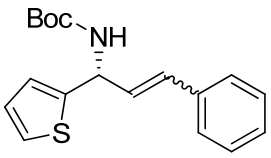
Following the general procedure (-40 ºC) **4f** was isolated by FC (CH_2Cl_2/pentane) in 61% yield (*E*:*Z* 10:1) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.40-7.16 (m, 9H), 6.46 (d, *J* = 16.4 Hz, 1H), 6.35 (dd, *J* = 5.2, 16.0 Hz, 1H), 5.66 (bs, 1H), 4.93 (bs, 1H), 2.42 (s, 3H), 1.46 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 154.9, 139.3, 136.6, 130.8, 130.6, 129.4, 128.6, 128.5 (2C), 127.6, 127.5, 126.5 (2C), 126.3, 126.2, 79.7, 52.8, 28.4 (3C), 19.3. HRMS: Calculated for [$C_{21}H_{25}NNaO_2$]: 346.1783; found: 346.1772. The enantiomeric excess was determined by HPLC using a Chiralcel OD column [hexane/*i*-PrOH (95:5)]; flow rate 1.0 mL/min; τ_{minor} = 25.20 min, τ_{major} = 18.61 min (96% ee); $[\alpha]_D^{20}$ +27.5 (c = 0.80, CH_2Cl_2).



(*R*)-*tert*-Butyl 1-(2-bromophenyl)-3-phenylallylcarbamate (4g)

Following the general procedure (0 ºC) **4g** was isolated by FC (CH_2Cl_2/pentane) in 42% yield (*E*:*Z* >20:1) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.59 (dd, *J* = 0.8, 8.0 Hz, 1H), 7.43-7.11 (m, 8H), 6.48 (d, *J* = 16.0 Hz, 1H), 6.31 (bs, 1H), 5.79 (bs, 1H), 5.11 (bs, 1H), 1.44 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 154.7, 140.4, 136.4, 133.4, 131.5, 129.0, 128.5 (2C), 127.8, 127.7, 126.5 (2C), 123.5, 79.9, 55.9, 28.3 (3C). HRMS: Calculated for [$C_{20}H_{22}BrNNaO_2$]: 410.0732; found: 410.0728. The enantiomeric

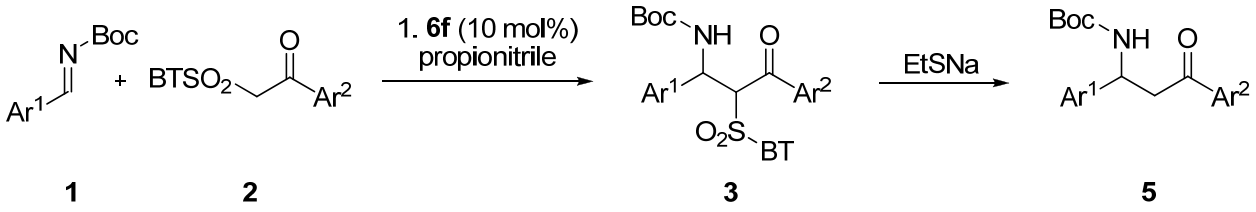
excess was determined by HPLC using a Chiralpak AD column [hexane/*i*-PrOH (95:5)]; flow rate 1.0 mL/min; τ_{minor} = 10.52 min, τ_{major} = 11.40 min (87% ee); $[\alpha]_D^{20}$ +2.2 (c = 0.50, CH_2Cl_2).



(*R*)-*tert*-Butyl 3-phenyl-1-(thiophen-2-yl)allylcarbamate (4h)

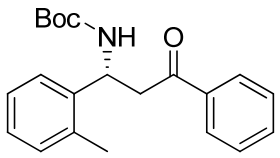
Following the general procedure (-30 ºC) **4h** was isolated by FC (CH_2Cl_2) in 83% yield as a white solid. The *E*:*Z* ratio could not be determined accurately by neither NMR or GC. ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.32 (d, *J* = 6.0 Hz, 1H), 7.28-7.25 (m, 4H), 7.00-6.98 (m, 2H), 6.65 (d, *J* = 12.0 Hz, 1H), 6.37 (dd, *J* = 4.0, 16.0 Hz, 1H), 5.71 (bs, 1H), 5.03 (bs, 1H), 1.48 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 154.9, 145.6, 136.5, 131.4, 128.8, 128.7, 128.0, 127.1, 126.8, 124.9, 124.7, 80.2, 52.3, 28.5 (3C). HRMS: Calculated for [$C_{18}H_{21}NO_2SNa$]: 338.1191; found: 338.1190. The enantiomeric excess was determined by HPLC using a Chiralcel OD column [hexane/*i*-PrOH (95:5)]; flow rate 1.0 mL/min; τ_{minor} = 10.33 min, τ_{major} = 8.24 min (58% ee); $[\alpha]_D^{20}$ –8.8 (c = 0.84, CH_2Cl_2).

5. General procedure for the formation of β-keto amino compounds 5a-c



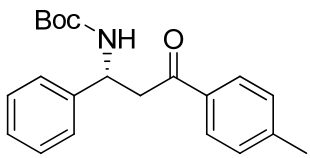
1 **2** **3** **5**

An ordinary vial equipped with a magnetic stirring bar was charged with β-keto benzothiazole (BT) sulfone nucleophile **2** (0.10 mmol, 1.0 equiv.) and catalyst **6f** (0.01 mmol, 0.1 equiv.), which were dissolved in 0.5 mL propionitrile and cooled to the desired temperature (see below). Upon cooling the imine **1** (0.25 mmol, 2.5 equiv.) was added. The reaction was run until judged complete by ^{1}H NMR spectroscopy. The adduct was plugged through a pad of silica (1% Et_2O in CH_2Cl_2), and dissolved in 1 mL CH_2Cl_2. EtSNa (0.30 mmol, 3.0 equiv.) was added and the reaction was allowed to stir at ambient temperature until judged complete by TLC (approx. 2–4 h). The reaction was washed with water and purified by FC on silica.



(*R*)-*tert*-Butyl 3-oxo-3-phenyl-1-*o*-tolylpropylcarbamate (5a)

Following the general procedure (-40 ºC) **5a** was isolated by FC (CH_2Cl_2) in 80% yield as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.93-7.87 (m, 2H), 7.59-7.51 (m, 1H), 7.48-7.40 (m, 2H), 7.34-7.28 (m, 1H), 7.19-7.13 (m, 3H), 5.46 (dd, *J* = 6.0, 13.2 Hz, 1H), 5.29 (bs, 1H), 3.65-3.37 (m, 2H), 2.44 (s, 3H), 1.40 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 197.9, 154.9, 139.7, 136.8, 135.5, 133.2, 130.7, 128.6 (2C), 128.1 (2C), 127.3, 126.6, 125.3, 79.5, 48.0, 43.7, 28.3, 19.3. HRMS: Calculated for [$C_{21}H_{25}NNaO_3$]: 362.1732; found: 362.1733. The enantiomeric excess was determined by HPLC using a Chiralpak AD column [hexane/*i*-PrOH (85:15)]; flow rate 0.5 mL/min; τ_{minor} = 12.79 min, τ_{major} = 11.43 min (86% ee); $[\alpha]_D^{20}$ +24.0 (c = 0.73, CH_2Cl_2, measured on sample with 82% ee).

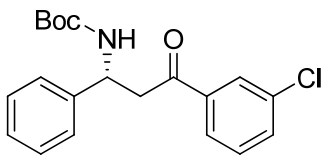


(*R*)-*tert*-Butyl 3-oxo-1-phenyl-3-*p*-tolylpropylcarbamate (5b)

Following the general procedure (-24 ºC) **5b** was isolated by FC (CH_2Cl_2) in 85% yield as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ

ppm 7.79 (d, *J* = 8.0 Hz, 2H), 7.39-7.14 (m, 7H), 5.62 (bs, 1H), 5.24 (bs, 1H), 3.61 (bs, 1H), 3.41 (dd, *J* = 6.0, 16.4 Hz, 1H), 2.39 (s, 3H), 1.41 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 197.7, 155.2, 144.2, 141.8, 134.3, 129.3 (2C), 128.5 (2C), 128.2 (2C), 127.2, 126.3 (2C), 79.6, 51.4, 44.2, 28.3 (3C), 21.6. HRMS: Calculated for $[C_{21}H_{25}NNaO_3]$: 362.1732; found: 362.1737. The enantiomeric excess was determined by HPLC using a Chiralcel AD column [hexane/*i*-PrOH (85:15)]; flow rate 1.0 mL/min; τ_{minor} = 25.10 min, τ_{major} = 26.60 min (76% ee); $[\alpha]_D^{20}$ -5.4 (c = 0.70, $CHCl_3$).

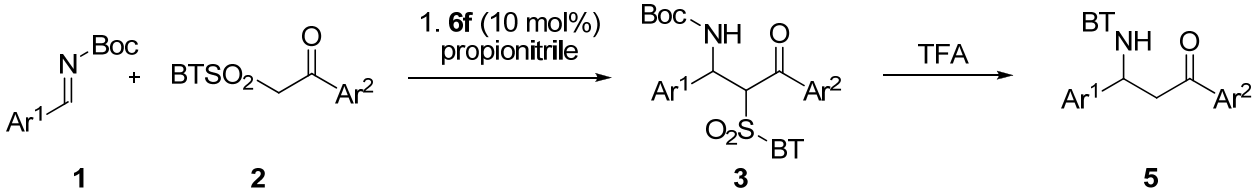
The absolute configurations of the products **4** and **5** were correlated to the absolute configuration of **5b**, which was determined to be *R* by comparison of the specific rotation to the literature.[3]



(*R*)-*tert*-Butyl 3-(3-chlorophenyl)-3-oxo-1-phenylpropylcarbamate (5c)

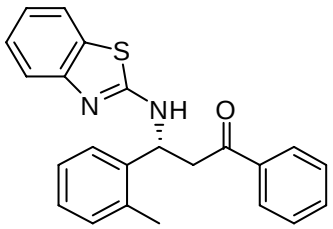
Following the general procedure (-40 ºC) **5c** was isolated by FC (CH_2Cl_2) in 88% yield as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.78 (t, *J* = 1.6 Hz, 1H), 7.73-7.68 (m, 1H), 7.49-7.42 (m, 1H), 7.31 (t, *J* = 7.6 Hz, 1H), 7.30-7.13 (m, 5H), 5.40 (bs, 1H), 5.18 (m, 1H), 3.57 (bs, 1H), 3.35 (dd, *J* = 6.4, 16.4 Hz, 1H), 1.35 (9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 196.7, 155.1, 141.4, 138.2, 135.0, 133.2, 130.0, 128.6 (2C), 128.2, 127.5, 126.3 (2C), 126.2, 79.7, 51.3, 44.6, 28.3 (3C). HRMS: Calculated for $[C_{20}H_{22}ClNNaO_3]$: 382.1186; found: 382.1183. The enantiomeric excess was determined by HPLC using a Chiralcel OD column [hexane/*i*-PrOH (70:30)]; flow rate 0.5 mL/min; τ_{minor} = 11.24 min, τ_{major} = 14.73 min (73% ee); $[\alpha]_D^{20}$ -0.8 (c = 0.50, CH_2Cl_2).

6. General procedure for the formation of β-keto amino compounds 5d-f



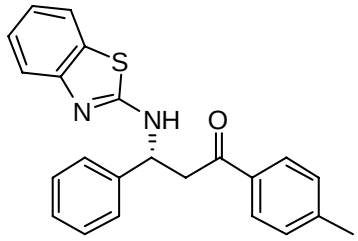
1 **2** **3** **5**

An ordinary vial equipped with a magnetic stirring bar was charged with β-keto benzothiazole (BT) sulfone nucleophile **2** (0.10 mmol, 1.0 equiv.) and catalyst **6f** (0.01 mmol, 0.1 equiv.), which were dissolved in 0.5 mL propionitrile and cooled to the desired temperature (see below). Upon cooling the imine **1** (0.25 mmol, 2.5 equiv.) was added. The reaction was run until judged complete by ^{1}H NMR spectroscopy. The adduct was plugged through a pad of silica (1% Et_2O in CH_2Cl_2), and dissolved in 3 mL CH_2Cl_2/TFA (5:1). The reaction was allowed to stir at ambient temperature until judged complete by ^{1}H NMR (approx. 1–2 h), after which the solvent was evaporated. 1 mL of toluene was added and evaporated to remove TFA as an azeotrope, after which the product was purified by FC on silica.



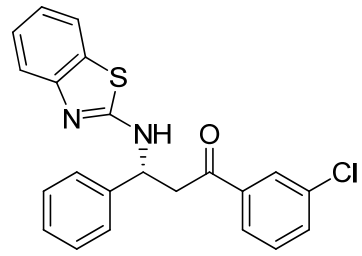
(*R*)-3-(Benzothiazol-2-ylamino)-1-phenyl-3-*o*-tolylpropan-1-one (5d)

Following the general procedure (-40 ºC) **5d** was isolated by FC (Et_2O/CH_2Cl_2) in 87% yield as a white foam. ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.82 (d, *J* = 7.6 Hz, 2H), 7.56-7.44 (m, 4H), 7.38 (t, *J* = 8.0 Hz, 2H), 7.25-7.14 (m, 4H), 7.08 (bs, 1H), 7.05 (t, J = 7.2 Hz, 1H), 5.57 (bs, 1H), 3.70 (dd, *J* = 6.8, 16.8 Hz, 1H), 3.43 (dd, *J* = 5.6, 16.8 Hz, 1H), 2.53 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 197.3, 167.0, 152.0, 138.9, 136.4, 135.8, 133.3, 130.9, 130.7, 128.6 (2C), 128.0 (2C), 127.8, 126.6, 125.8, 125.6, 121.4, 120.8, 118.9, 52.8, 43.9, 19.4. HRMS: Calculated for [$C_{23}H_{20}N_2NaOS$]: 395.1194; found: 395.1200. The enantiomeric excess was determined by HPLC using a Chiralcel OD column [hexane/*i*-PrOH (70:30)]; flow rate 0.5 mL/min; τ_{minor} = 14.73 min, τ_{major} = 18.88 min (92% ee); $[\alpha]_D^{20}$ +29.4 (c = 0.50, CH_2Cl_2).



(*R*)-3-(Benzothiazol-2-ylamino)-3-phenyl-1-*p*-tolylpropan-1-one (5e)

Following the general procedure (-24 ºC) **5e** was isolated by FC (Et_2O/CH_2Cl_2) in 92% yield as a white foam. ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.81-7.74 (m, 2H), 7.57-7.46 (m, 4H), 7.40-7.25 (m, 4H), 7.24-7.18 (m, 2H), 7.15-7.08 (m, 1H), 5.36-5.31 (m, 1H), 3.80 (dd, *J* = 6.8, 17.2 Hz, 1H), 3.47 (dd, *J* = 5.2, 17.2 Hz, 1H), 2.39 (3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 196.6, 167.8, 148.0, 144.5, 140.3, 133.9, 129.3 (2C), 128.9 (2C), 128.3, 128.2 (2C), 128.0, 126.7 (2C), 126.4, 122.3, 121.3, 117.6, 56.7, 44.8, 21.6. HRMS: Calculated for [$C_{23}H_{20}N_2NaOS$]: 395.1194; found: 395.1195. The enantiomeric excess was determined by HPLC using a Chiralpak AD column [hexane/*i*-PrOH (80:20)]; flow rate 1.0 mL/min; τ_{minor} = 23.50 min, τ_{major} = 19.70 min (74% ee); $[\alpha]_D^{20}$ -16.2 (c = 1.30, CH_2Cl_2).



(*R*)-3-(Benzothiazol-2-ylamino)-1-(3-chlorophenyl)-3-phenylpropan-1-one (5f)

Following the general procedure (-40 ºC) **5f** was isolated by FC (Et_2O/CH_2Cl_2) in 90% yield as a white foam. ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.83 (t, *J* = 1.6 hz, 1H), 7.72-7.66 (m, 1H), 7.56-7.42 (m, 5H), 7.41-7.23 (m, 5H), 7.12-7.03 (m, 1H), 5.41 (t, *J* = 6.0 Hz, 1H), 3.79 (dd, *J* = 6.4, 17.2 Hz, 1H), 3.46 (dd, *J* = 6.0, 17.2 Hz, 1H), 1.71 (bs, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 196.0, 167.1, 151.8, 140.6, 137.9, 134.9, 133.3, 130.6, 129.9, 128.9 (2C), 128.2, 128.0, 126.6 (2C), 126.1, 125.9, 121.7, 120.9, 118.8, 55.8, 45.0. HRMS: Calculated for [$C_{22}H_{18}ClN_2OS$]: 393.0828; found: 393.0829. The enantiomeric excess was determined by HPLC using a Chiralpak AD column [hexane/*i*-PrOH (85:15)]; flow rate 1.0 mL/min; τ_{minor} = 19.70 min, τ_{major} = 27.50 min (70% ee); $[\alpha]_D^{20}$ +14.0 (c = 0.89, CH_2Cl_2).

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[1] See *e.g.*: A. G. Wenzel, E. N. Jacobsen, *J. Am. Chem. Soc.*, 2002, **124**, 12964.

[2] M. Nielsen, C. B. Jacobsen, M. W. Paixão, N. Holub, K. A. Jørgensen, *J. Am Chem. Soc.*, 2009, DOI: 10.1021/ja903920j.

[3] A. L. Tillman, D. J. Dixon, *Org. Biomol. Chem.*, 2007, **5**, 606.