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ARTICLE

Asymmetric Trifluoromethylthiolation of Azlactones under Chiral Phase Transfer Catalysis

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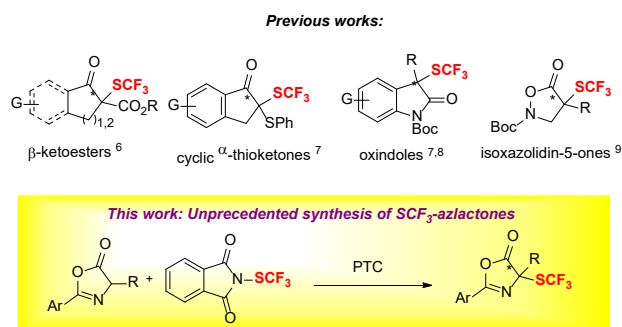
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The first enantioselective method for the installation of the SCF₃ group at the C-4 position of azlactones is described in the present communication under quinidinium phase transfer catalysis. The higher performance of substrates containing electron-rich 2-aryl groups at the azlactone was rationalized using DFT calculations.

Introduction

Over the last recent years, the design of new organofluorinated compounds has become one of the trending topics in the agrochemical and medicinal chemistry field, due to their peculiar physicochemical and biological features, leading to a plethora of reports on innovative fluorine-based drug candidates.¹ Worldwide research groups have thus focused their efforts in the development of diverse synthetic methodologies aimed to the asymmetric incorporation of fluorine atoms or fluoroalkyl groups into organic molecules.² In this regard, bioactive compounds bearing the trifluoromethylthio group (SCF₃) have shown a remarkably improved metabolic stability and transmembrane permeability, thanks to both its lipophilic and electron-withdrawing nature (Hansch parameter $\pi = 1,44$).³ Unsurprisingly, a powerful arsenal of strategies enabling the introduction of this group onto various scaffolds is now available at the synthetic chemist's tool box. Among them, the formation of C(sp²)- and C(sp)-SCF₃ bonds has been satisfactorily achieved through either transition-metal-promoted couplings, organocatalyzed reactions or radical processes.⁴ Nevertheless, the direct stereocontrolled nucleophilic or electrophilic installation of the SCF₃ group at C(sp³) centres remains as a challenging task.^{5,6} The most common approach to fulfil this challenge relies on the

direct asymmetric functionalization of reactive α -carbon in weakly acidic carbonyl compounds, with electrophilic SCF₃ sources. However, only a limited set of carbonyl substrates has been explored to date, being mainly comprised by β -keto esters,⁶ α -thioketones,⁷ and oxindoles,^{7,8} and isoxazolidin-5-ones.⁹ (Scheme 1).



Scheme 1. Carbonyl compounds used in the previous asymmetric α -trifluoromethylthiolation reactions and our working plan with azlactones

In this context, azlactones drew our interest because of their synthetic and biological significance, thanks to the wide range of attractive pharmacological activities displayed, as their high versatility as building blocks, arising from presence of both nucleophilic and electrophilic sites.¹⁰ In the light of this, we were intrigued by the possibility of incorporating the SCF₃ group into the azlactone core in an enantioselective fashion, through a phase transfer catalysed process (bottom, Scheme 1).

Initially, aiming to test the feasibility of our idea, azlactone **1a** was chosen as a model substrate, *N*-(trifluoromethylthio)phthalimide **2** as SCF₃ source,¹¹ in dichloromethane at $-20\text{ }^{\circ}\text{C}$ and in the presence of catalytic amount of K₃PO₄.¹² A wide family of different phase transfer catalysts (Table 1. Selected examples taken from ESI) was tested. Derived from this first screening, it was notorious that *O*-alkylated and *O*-acylated forms of the phase-transfer catalyst (**I-III**) were unsuitable for this transformation, leading to good yields but low stereocontrol (entries 1-3). A modest enantioselectivity was

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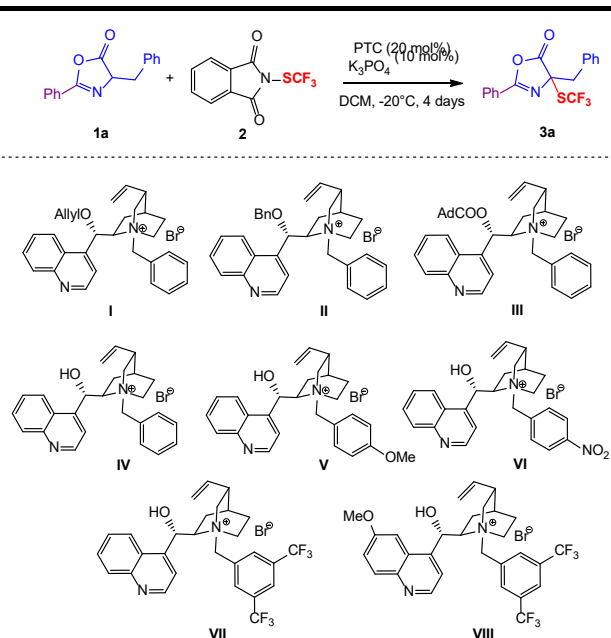
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achieved with cinchoninium bromide (**IV**) (entry 4). Additionally, although the presence of electron-rich aromatic rings at the *N*-benzyl moiety (catalyst **V**) provided a good yield of **3a**, it turned out to be detrimental for the stereocontrol (entry 5). Conversely, electron-poor *N*-benzyl groups (catalysts **VI–VII**) brought to a slight improvement of the e.r. (entries 6–7). It should be highlighted the importance of the free hydroxyl group by directing/assisting the electrophilic attack of **2** on one of the two enantiotopic faces of **1a** (compare entries 1–7).¹³ It is noteworthy that, upon switching from the cinchonine to a quinidine core, the enantiomeric ratio was further improved albeit with a decay of the yield (entry 8), leading to the identification of **VIII** as the most suitable phase-transfer catalyst. A wide array of parameters was further studied (temperature, solvent, base and catalyst loading) confirming as optimal the preliminarily chosen reaction conditions, as reported in Table 1, entry 8.¹⁴

Table 1. Screening of phase transfer catalysts



Entry	Catalyst	Yield (%) ^a	er ^b
1	I	80	51:49
2	II	86	52:48
3	III	72	51:49
4	IV	91	72:28
5	V	78	53:47
6	VI	57	77:23
7	VII	74	72:28
8	VIII	49	82:18

Reaction conditions: **1** (0.10 mmol), **2** (0.12 mmol), 0.1 M. ^aIsolated yield. ^bThe values of er were determined by HPLC.

Attempting to use different SCF₃-sources such as *N*-(trifluoromethylthio)saccharin and *N*-(trifluoromethylthio)succinimide under the best conditions (Table 1,

entry 8) affording complex mixtures and degradation of the starting materials. Aiming to increase both, yield and enantiomeric ratio of **3a**, we then decided to properly modify the substrate structure, surveying various substituent at its C-2 position, in the reaction catalysed by **VIII** (see Table 2). It was found that the electronic nature of the C-2 substituent was highly relevant, as the reaction did not take place when electron poor aromatic rings were used, even after extended reaction times, as complete degradation of the starting azlactones was only observed (Table 2, entries 1 and 2). Interestingly, when a chlorine atom was placed in the *para*-position of the aromatic ring, the reaction proceeded smoothly, with better yield and shorter time compared to the unsubstituted phenyl ring, but the enantioselectivity was lower (Table 2, entries 3 and 4). Finally, when an electron donating group was introduced at the *para*-position of the 2-aryl group (Table 2, entry 5), full conversion was accomplished in very short reaction time (1h), displaying excellent yield and high enantiomeric ratio (Table 2, entry 5).

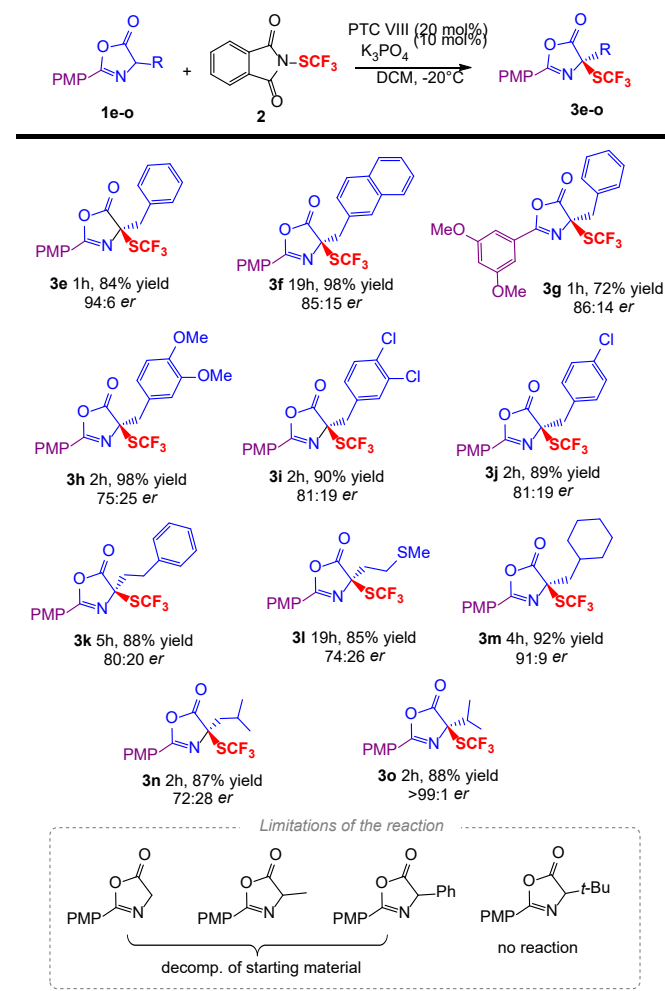
Table 2. Screening of C-2 substituent

Entry	R	Time	Conv./Yield (%) ^a	er ^b
1	4-CN(C ₆ H ₄) 1b	7 days	Degradation	-
2	4-CF ₃ (C ₆ H ₄) 1c	5 days	Degradation	-
3	4-Cl(C ₆ H ₄) 1d	19 h	100/83	70:30
4	C ₆ H ₅ 1a	4 days	50/49	82:18
5	4-OMe(C ₆ H ₄) 1e	1 h	100/84	94:6

Reaction conditions: **1** (0.10 mmol), **2** (0.12 mmol), 0.1 M. ^aIsolated yield. ^bThe values of er were determined by HPLC.

Subsequently, with the optimized reaction scenario, the reaction scope was carried out (Scheme 2), showing that both electron-donating and electron-withdrawing groups at the benzyl substituent of the azlactone core (**3h**, **3i** and **3j**) allowed the incorporation of the SCF₃ group without dramatically altering the good enantioselectivity and excellent yield. The substrate containing a β-naphthylmethyl side chain also reacted successfully under the standard conditions without losing quality in the results (**3f**). Good yield and enantioselectivity were also obtained upon replacing PMP with 3,5-(MeO)₂C₆H₃ at the C-2 position of the core (cf. **3e** and **3g**). Gratefully, the presence of an arylmethyl sidechain proved to be not mandatory to achieve good results. For instance, a homobenzyldisubstituted azlactone was smoothly transformed into the corresponding thiofluorinated compound **3k** in good yield and enantiomeric ratio. A similar result was obtained with a methionine derivative, affording **3l** albeit requiring a longer stirring time. Moreover, the reaction of substrates containing moderately sterically hindered cyclohexyl, *sec*-butyl and isopropyl chains, occurred smoothly, delivering the desired products **3m**, **3n** and **3o** respectively with e.r.'s from moderate to excellent. In particular, an outstanding result was achieved with the

valine-derived azlactone, that was transformed into the corresponding trifluoromethylthiolated product **3o** as a single enantiomer. During our investigation, we encountered some limitations in the scope of this methodology, as outlined in the bottom of Scheme 2. The configuration assignment of the resulting trifluoromethylthiolated azlactones was described as R by a comparison of simulated and experimental electronic circular dichroism spectra of compound **3k** (see ESI for details).



Experimental section

General procedure for the enantioselective trifluoromethylthiolation of azlactones

In a 4 ml vial, to a mixture of the selected azlactone (1.0 eq., 0.10 mmol), *N*-(trifluoromethylthio)phthalimide **2** (1.2 eq., 0.12 mmol, 29.7 mg), catalyst **VIII** (0.20 eq., 0.02 mmol, 12.6 mg), and K₃PO₄ (0.1 eq., 0.01 mmol, 2.1 mg) dichloromethane (1.0 mL) was added and the reaction mixture was stirred for the indicated time at -20 °C. Then, the mixture was filtered and concentrated in vacuo. The crude residue was purified by chromatography (10 g silica gel cyclohexane-ethyl acetate, 99/1 to 80/20) to afford the corresponding product.

4-benzyl-2-(4-methoxyphenyl)-4-(trifluoromethylthio)oxazol-5(4H)-one (3e)

5(4H)-one (3e): Obtained after 1 h as a yellow solid (32.0 mg, 84% yield), mp 115–116 °C. ¹H NMR (300 MHz, CDCl₃) δ 7.85 (d, *J* = 8.9 Hz, 2H), 7.21 (m, 5H), 6.94 (d, *J* = 8.9 Hz, 2H), 3.86 (s, 3H), 3.47 (d, *J* = 13.1 Hz, 1H), 3.32 (d, *J* = 13.1 Hz, 1H). ¹³C NMR (75 MHz, CDCl₃) δ 174.7, 164.0, 162.2, 131.4, 130.8, 130.4, 128.7 (q, *J* = 311.1 Hz), 128.5, 128.2, 116.8, 114.4, 76.8 (q, *J* = 1.1 Hz), 55.6, 42.5 (q, *J* = 1.1 Hz). ¹⁹F NMR (282 MHz, CDCl₃) δ -37.5. [α]_D²⁰ = -65.5° (c = 0.80, CHCl₃). Enantiomeric ratio 94:6 determined by SFC analysis (CHIRALPAK® AS-H column (φ 0.46 cm x 25 cm), *n*-hexane:*i*-PrOH = 95:5, 0.5 mL/min, *t*_{minor} = 7.2 min, *t*_{major} = 8.1 min). HRMS (ESI) [M + H⁺] calcd for C₁₈H₁₅F₃NO₃S⁺ 382.0719, found 382.0710.

2-(4-methoxyphenyl)-4-(naphthalen-2-ylmethyl)-4-((trifluoromethylthio)oxazol-5(4H)-one (3f)

((trifluoromethylthio)oxazol-5(4H)-one (3f): Obtained after 19 h as a yellow solid (42.3 mg, 98% yield), mp 119–120 °C. ¹H NMR (300 MHz, CDCl₃) δ 7.87–7.81 (m, 2H), 7.77–7.71 (m, 2H), 7.71–7.65 (m, 2H), 7.49–7.37 (m, 2H), 7.35 (dd, *J* = 8.6, 1.7 Hz, 1H), 6.94–6.87 (m, 2H), 3.83 (s, 3H), 3.65 (d, *J* = 13.1 Hz, 1H), 3.51 (d, *J* = 13.1 Hz, 1H). ¹³C NMR (75 MHz, CDCl₃) δ 174.7, 164.0, 162.4, 133.1, 132.8, 130.4, 129.9, 129.1, 128.8 (q, *J* = 309.8 Hz), 128.1, 128.0, 127.6, 126.3, 126.2, 116.8, 114.4, 76.9 (q, *J* = 1.1 Hz), 55.5, 42.7. ¹⁹F NMR (282 MHz, CDCl₃) δ -37.5. [α]_D²⁰ = -47.6° (c = 0.80, CHCl₃). Enantiomeric ratio 85:15 determined by HPLC analysis (CHIRALPAK® AS-H column (φ 0.46 cm x 25 cm), *n*-hexane:*i*-PrOH = 98:2, 0.5 mL/min, *t*_{minor} = 14.7 min, *t*_{major} = 17.3 min). HRMS (ESI) [M + H⁺] calcd for C₂₂H₁₇F₃NO₃S⁺ 432.0876, found 432.0873.

4-benzyl-2-(3,5-dimethoxyphenyl)-4-((trifluoromethylthio)oxazol-5(4H)-one (3g)

5(4H)-one (3g): Obtained after 1 h as a white solid (33.3 mg, 81% yield), mp 117–118 °C. ¹H NMR (300 MHz, CDCl₃) δ 7.22 (m, 5H), 7.02 (d, *J* = 2.3 Hz, 2H), 6.65 (t, *J* = 2.3 Hz, 1H), 3.81 (s, 6H), 3.48 (d, *J* = 13.2 Hz, 1H), 3.33 (d, *J* = 13.2 Hz, 1H). ¹³C NMR (75 MHz, CDCl₃) δ 174.4, 162.4, 161.0, 131.2, 130.5, 128.7 (q, 310.2 Hz), 128.6, 128.3, 126.2, 106.6, 105.9, 76.7 (q, *J* = 1.1 Hz), 55.7, 42.4 (q, *J* = 1.1 Hz). ¹⁹F NMR (282 MHz, CDCl₃) δ -37.5. [α]_D²⁰ = -51.0° (c = 0.80, CHCl₃). Enantiomeric ratio 86:14 determined by HPLC analysis (CHIRALPAK® AS-H column (φ 0.46 cm x 25 cm), *n*-hexane:*i*-PrOH = 99:1, 0.5 mL/min, *t*_{minor} = 21.4 min, *t*_{major} = 22.2 min). HRMS (ESI) [M + H⁺] calcd for C₁₉H₁₇F₃NO₄S⁺ 412.0825, found 412.0826.

4-(3,4-dimethoxybenzyl)-2-(4-methoxyphenyl)-4-((trifluoromethylthio)oxazol-5(4H)-one (3h)

((trifluoromethylthio)oxazol-5(4H)-one (3h): Obtained after 2 h as a yellow solid (43.2 mg, 98% yield), mp 107–108 °C. ¹H NMR (300 MHz, CDCl₃) δ 7.87 (d, *J* = 9.0 Hz, 2H), 6.94 (d, *J* = 9.0 Hz, 2H), 6.77–6.67 (m, 3H), 3.86 (m, 3H), 3.79 (s, 3H), 3.68 (s, 3H), 3.42 (d, *J* = 13.2 Hz, 1H), 3.26 (d, *J* = 13.2 Hz, 1H). ¹³C NMR (75 MHz, CDCl₃) δ 174.7, 164.1, 162.3, 148.9, 148.5, 130.3, 128.8 (q, *J* = 310.1 Hz), 123.7, 122.6, 116.8, 114.4, 113.5, 111.0, 76.8 (q, *J* = 1.1 Hz), 55.7, 55.7, 55.6, 42.1 (q, *J* = 1.1 Hz). ¹⁹F NMR (282 MHz, CDCl₃) δ -37.5. [α]_D²⁰ = -40.2° (c = 0.80, CHCl₃). Enantiomeric ratio 75:25 determined by HPLC analysis (CHIRALPAK® AS-H column (φ 0.46 cm x 25 cm), *n*-hexane:*i*-PrOH = 80:20, 0.5 mL/min, *t*_{minor} = 11.1 min, *t*_{major} = 12.1 min). HRMS (ESI) [M + H⁺] calcd for C₂₀H₁₉F₃NO₅S⁺ 442.0931, found 442.0930.

4-(3,4-dichlorobenzyl)-2-(4-methoxyphenyl)-4-((trifluoromethylthio)oxazol-5(4H)-one (3i)

thio)oxazol-5(4H)-one (3i): Obtained after 2 h as a yellow solid (40.5 mg, 90% yield), mp 109–110 °C. ¹H NMR (300 MHz, CDCl₃) δ 7.89 (d, *J* = 8.9 Hz, 1H), 7.33 (d, *J* = 2.0 Hz, 1H), 7.30 (d, *J* = 8.2 Hz, 1H), 7.06 (dd, *J* = 8.2, 2.0 Hz, 1H), 6.97 (d, *J* = 8.9 Hz, 1H), 3.88 (s, 3H), 3.43 (d, *J* = 13.4 Hz, 1H), 3.28 (d, *J* = 13.4 Hz, 1H). ¹³C NMR (75 MHz, CDCl₃) δ 174.3, 164.3, 162.7, 132.6, 132.6, 132.5, 131.8, 130.5, 130.4, 129.8, 128.6 (q, *J* = 310.0 Hz), 116.4, 114.5, 76.2 (q, *J* = 1.1 Hz), 55.6, 41.5 (q, *J* = 1.1 Hz). ¹⁹F NMR (282 MHz, CDCl₃) δ -37.3. [α]_D²⁰ = -53.8° (c = 0.80, CHCl₃). Enantiomeric ratio 81:19 determined by HPLC analysis (CHIRALPAK® IB column (φ 0.46 cm x 25 cm), *n*-hexane:*i*-PrOH = 99:1, 0.5 mL/min, *t*_{major} = 17.9 min, *t*_{minor} = 20.9 min). HRMS (ESI) [M + H⁺] calcd for C₁₈H₁₃Cl₂F₃NO₃S⁺ 449.9940, found 449.9942.

4-(4-chlorobenzyl)-2-(4-methoxyphenyl)-4-((trifluoromethylthio)oxazol-5(4H)-one (3j)

thio)oxazol-5(4H)-one (3j): Obtained after 2 h as a yellow solid (37.0 mg, 89% yield), mp 100–101 °C. ¹H NMR (300 MHz, CDCl₃) δ 7.87 (d, *J* = 8.9 Hz, 2H), 7.19 (d, *J* = 8.6 Hz, 2H), 7.14 (d, *J* = 8.6 Hz, 2H), 6.96 (d, *J* = 8.9 Hz, 2H), 3.87 (s, 3H), 3.44 (d, *J* = 13.3 Hz, 1H), 3.30 (d, *J* = 13.3 Hz, 1H). ¹³C NMR (75 MHz, CDCl₃) δ 174.6, 164.2, 162.4, 134.3, 131.9, 130.5, 130.0, 128.7, 128.7 (q, *J* = 310.0 Hz), 116.6, 114.5, 76.5 (q, *J* = 1.1 Hz), 55.6, 41.7 (q, *J* = 1.1 Hz). ¹⁹F NMR (282 MHz, CDCl₃) δ -37.4. [α]_D²⁰ = -52.0° (c = 0.80, CHCl₃). Enantiomeric ratio 81:19 determined by HPLC analysis (CHIRALPAK® IB column (φ 0.46 cm x 25 cm), *n*-hexane:*i*-PrOH = 99:1, 0.5 mL/min, *t*_{major} = 15.1 min, *t*_{minor} = 16.2 min). HRMS (ESI) [M + H⁺] calcd for C₁₈H₁₄ClF₃NO₃S⁺ 416.0330, found 416.0335.

2-(4-methoxyphenyl)-4-phenethyl-4-((trifluoromethylthio)oxazol-5(4H)-one (3k)

5(4H)-one (3k): Obtained after 5 h as a white solid (34.8 mg, 88% yield), mp 103–104 °C. ¹H NMR (300 MHz, CDCl₃) δ 8.05 (d, *J* = 8.8 Hz, 2H), 7.34–7.13 (m, 5H), 7.05 (d, *J* = 8.8 Hz, 2H), 3.93 (s, 3H), 2.78 (m, 1H), 2.65 (m, 1H), 2.56–2.33 (m, 2H). ¹³C NMR (75 MHz, CDCl₃) δ 175.2, 164.2, 162.7, 138.9, 130.6, 128.8 (q, *J* = 309.5 Hz), 128.7, 128.4, 126.7, 116.9, 114.5, 75.9 (q, *J* = 1.1 Hz), 55.6, 38.4 (q, *J* = 1.1 Hz), 30.1. ¹⁹F NMR (282 MHz, CDCl₃) δ -37.7. [α]_D²⁰ = -58.8° (c = 0.80, CHCl₃). Enantiomeric ratio 80:20 determined by HPLC analysis (CHIRALPAK® AS-H column (φ 0.46 cm x 25 cm), *n*-hexane:*i*-PrOH = 98:2, 0.5 mL/min, *t*_{minor} = 13.2 min, *t*_{major} = 16.2 min). HRMS (ESI) [M + H⁺] calcd for C₁₉H₁₇F₃NO₃S⁺ 396.0876, found 396.0870.

2-(4-methoxyphenyl)-4-(2-(methylthio)ethyl)-4-

((trifluoromethyl)thio)oxazol-5(4H)-one (3l): Obtained after 19 h as a pink solid (31.0 mg, 85% yield), mp 97–98 °C. ¹H NMR (300 MHz, CDCl₃) δ 8.02 (d, *J* = 9.0 Hz, 2H), 7.02 (d, *J* = 9.0 Hz, 2H), 3.92 (s, 3H), 2.67–2.41 (m, 4H), 2.09 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 175.2, 164.3, 159.7, 130.7, 116.9, 128.8 (q, *J* = 310.0 Hz), 114.5, 75.3 (q, *J* = 1.1 Hz), 55.6, 35.8, 28.4, 15.2. ¹⁹F NMR (282 MHz, CDCl₃) δ -37.5. [α]_D²⁰ = -29.4° (*c* = 0.50, CHCl₃). Enantiomeric ratio 74:26 determined by HPLC analysis (CHIRALPAK® AS-H column (ϕ 0.46 cm x 25 cm), *n*-hexane:*i*-PrOH = 98:2, 0.5 mL/min, *t*_{minor} = 15.5 min, *t*_{major} = 17.9 min). HRMS (ESI) [M + H⁺] calcd for C₁₄H₁₅F₃NO₃S₂⁺ 366.0440, found 366.0447.

4-(cyclohexylmethyl)-2-(4-methoxyphenyl)-4-

((trifluoromethyl)thio)oxazol-5(4H)-one (3m): Obtained after 4 h as a white solid (35.6 mg, 92% yield), mp 114–115 °C. ¹H NMR (300 MHz, CDCl₃) δ 8.00 (d, *J* = 8.9 Hz, 2H), 7.01 (d, *J* = 8.9 Hz, 2H), 3.90 (s, 3H), 2.10 (dd, *J* = 14.0, 5.3 Hz, 1H), 1.96 (dd, *J* = 14.0, 6.6 Hz, 1H), 1.78–1.52 (m, 5H), 1.50–1.38 (m, 1H), 1.29–1.08 (m, 3H), 1.08–0.87 (m, 2H). ¹³C NMR (75 MHz, CDCl₃) δ 176.0, 164.1, 162.1, 130.5, 128.8 (q, *J* = 310.1 Hz), 117.1, 114.5, 76.1 (q, *J* = 1.1 Hz), 55.6, 43.8, 34.4, 34.2, 33.6, 26.0, 25.9. ¹⁹F NMR (282 MHz, CDCl₃) δ -37.9. [α]_D²⁰ = -43.3° (*c* = 0.60, CHCl₃). Enantiomeric ratio 91:9 determined by HPLC analysis (CHIRALPAK® AS-H column (ϕ 0.46 cm x 25 cm), *n*-hexane:*i*-PrOH = 99.5:0.5, 0.3 mL/min, *t*_{minor} = 17.3 min, *t*_{major} = 18.8 min). HRMS (ESI) [M + H⁺] calcd for C₁₈H₂₁F₃NO₃S⁺ 388.1189, found 388.1193.

4-isobutyl-2-(4-methoxyphenyl)-4-((trifluoromethyl)thio)oxazol-

5(4H)-one (3n): Obtained after 2 h as a white solid (30.2 mg, 87% yield), mp 102–103 °C. ¹H NMR (300 MHz, CDCl₃) δ 8.07–7.93 (m, 2H), 7.07–6.95 (m, 2H), 3.90 (s, 3H), 2.14 (dd, *J* = 13.8, 5.6 Hz, 1H), 1.98 (dd, *J* = 13.8, 6.9 Hz, 1H), 1.88–1.68 (m, 1H), 1.00–0.86 (m, 6H). ¹³C NMR (75 MHz, CDCl₃) δ 175.9, 164.1, 162.1, 130.5, 128.8 (q, *J* = 309.7 Hz), 117.1, 114.5, 76.1 (q, *J* = 1.1 Hz), 55.6, 45.0, 25.4, 23.8, 23.0. ¹⁹F NMR (282 MHz, CDCl₃) δ -37.9. [α]_D²⁰ = -39.9° (*c* = 0.80, CHCl₃). Enantiomeric ratio 72:28 determined by HPLC analysis (CHIRALPAK® IB column (ϕ 0.46 cm x 25 cm), *n*-hexane:*i*-PrOH = 99.2:0.8, 0.35 mL/min, *t*_{major} = 17.8 min, *t*_{minor} = 19.1 min). HRMS (ESI) [M + H⁺] calcd for C₁₅H₁₇F₃NO₃S⁺ 347.0803, found 347.0800.

4-isopropyl-2-(4-methoxyphenyl)-4-((trifluoromethyl)thio)oxazol-

5(4H)-one (3o): Obtained after 19 h as a white solid (29.3 mg, 88% yield), mp 98–99 °C. ¹H NMR (300 MHz, CDCl₃) δ 8.06–7.96 (m, 2H), 7.04–6.96 (m, 2H), 3.89 (s, 3H), 2.39 (hept, *J* = 6.5 Hz, 1H), 1.20 (d, *J* = 6.8 Hz, 3H), 1.03 (d, *J* = 6.7 Hz, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 174.4, 163.0, 161.2, 129.5, 128.0 (q, 309.7 Hz), 116.0, 113.4, 79.1 (q, *J* = 1.1 Hz), 54.6, 34.8, 16.2, 15.8. ¹⁹F NMR (282 MHz, CDCl₃) δ -37.5. [α]_D²⁰ = -61.3° (*c* = 0.80, CHCl₃). Enantiomeric ratio >99:<1 determined by HPLC analysis (CHIRALPAK® AS-H column (ϕ 0.46 cm x 25 cm), *n*-hexane:*i*-PrOH = 99.5:0.5, 0.3 mL/min, *t*_{major} = 16.8 min. HRMS (ESI) [M + H⁺] calcd for C₁₄H₁₅F₃NO₃S⁺ 334.0719, found 334.0714.

4-benzyl-2-phenyl-4-((trifluoromethyl)thio)oxazol-5(4H)-one (3a):

Obtained after 19 h as a white solid (17.2 mg, 49% yield), mp 104–105 °C. ¹H NMR (300 MHz, CDCl₃) δ = 7.90 (dd, *J* = 8.4 Hz, 1.4 Hz, 2H), 7.59 (t, *J* = 7.4 Hz, 1.5 Hz, 1H), 7.46 (t, *J* = 7.7 Hz, 2H), 7.24–7.18 (m, 5H), 3.49 (d, *J* = 13.2 Hz, 1H), 3.35 (d, *J* = 13.2 Hz, 1H). ¹³C NMR (300 MHz, CDCl₃) δ = 174.5, 162.5, 133.7, 131.3, 130.6, 129.2 (q, *J* = 298 Hz), 128.9, 128.5, 128.34, 128.27, 124.7, 42.5. ¹⁹F NMR (300 MHz, CDCl₃): δ = -37.51 (s, 3 F). [α]_D²⁰ = -41.1° (*c* = 0.80, CHCl₃). Enantiomeric ratio 82:18 determined by HPLC analysis (CHIRALPAK® AS-H column (ϕ 0.46 cm x 25 cm), *n*-hexane:*i*-PrOH = 90:10, 0.5 mL/min, *t*_{minor} = 9.3 min, *t*_{major} = 11.1 min). HRMS (ESI) [M + H⁺] calcd for C₁₇H₁₃F₃NO₂S⁺ 352.3174, found 352.3170.

4-benzyl-2-(4-chlorophenyl)-4-((trifluoromethyl)thio)oxazol-5(4H)-

one (3d): Obtained after 19 h as a white solid (32.0 mg, 83% yield), mp 118–119 °C. ¹H NMR (300 MHz, CDCl₃) δ 7.83 (d, *J* = 6.9 Hz, 2H), 7.44 (d, *J* = 6.9 Hz, 2H), 7.21 (s, 5H), 3.48 (d, *J* = 13.2 Hz, 1H), 3.34 (d, *J* = 13.2 Hz, 1H). ¹³C NMR (75 MHz, CDCl₃) δ 174.2, 161.7, 140.3, 131.1, 130.5, 129.6, 129.4, 128.7 (q, *J* = 309.9 Hz), 128.5, 128.3, 123.0, 77.2, 42.4 (q, *J* = 1.1 Hz). ¹⁹F NMR (282 MHz, CDCl₃) δ -37.5. [α]_D²⁰ = -38.2° (*c* = 0.80, CHCl₃). Enantiomeric ratio 70:30 determined by HPLC analysis (CHIRALPAK® AS-H column (ϕ 0.46 cm x 25 cm), *n*-hexane:*i*-PrOH = 99:1, 0.5 mL/min, *t*_{minor} = 13.3 min, *t*_{major} = 17.5 min). HRMS (ESI) [M + H⁺] calcd for C₁₇H₁₂ClF₃NO₂S⁺ 386.0224, found 386.0228.

Conclusions

In conclusion, we have developed the first enantioselective direct installation of SCF₃ group at the C-4 position of azlactones by employing a phase transfer catalyzed methodology, affording a wide array of products with benzyl, homobenzyl and aliphatic α -side chains with high yields and good enantioselectivity. The most effective cinchona alkaloid derived catalyst is characterized by the electron poor nature of *N*-benzyl group and the presence of a free hydroxyl moiety. The absolute configuration of products has been determined by circular dichroism. In addition, DFT calculations gave interesting mechanistic insights and provided an explanation for the best performance achieved with substrates containing an electron-rich 2-aryl group. Further investigation aimed to expand the scope of enantioenriched trifluoromethylthiolated azacompounds are currently under way.

Conflicts of interest

The authors declare no conflict of interest.

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