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Synthesis of fluorinated 2,3-dihydropyran-4-ones by cyclocondensation of 1,3-dicarbonyl dianions with aldehydes

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ABSTRACT

The reaction of the dianion of 1,1,1-trifluoro-pentane-2,4-dione with aldehydes and subsequent addition of hydrochloric acid afforded 2,3-dihydro-6-trifluoromethyl-pyran-4-ones. The reaction of the dianion of acetylacetone with fluorinated benzaldehydes gave the corresponding fluorinated 2-aryl-2,3-dihydro-6-methyl-pyran-4-ones. All reactions proceeded in very good yield and with very good regioselectivity.

1. Introduction

2,3-Dihydropyran-4-ones are of considerable pharmacological relevance and occur in a variety of natural products [1]. They have been prepared by hetero-Diels–Alder reaction of aldehydes with Danishefsky's diene or related dienes [2]. A catalytic approach to enantiomerically pure 2,3-dihydropyran-4-ones, based on the condensation of 1,3-bis(silyloxy)-1,3-butadienes with aldehydes using Lewis base-activated Lewis acids and subsequent TFA-catalyzed cyclization, has also been developed [3]. Other syntheses are based on the palladium(II)-catalyzed oxidative cyclization of β-hydroxyenones [4a], the reaction of β-ethoxy-α,β-unsaturated lactones [4b], the condensation of enol ethers derived from 1,3-dicarbonyl compounds with aldehydes [4c], and on the reaction of epoxides with lithiated dithianes and subsequent elaboration [4d]. An important method for synthesis of 2,3-dihydropyran-4-ones, which has been applied to the synthesis of the natural product stegobinone, relies on the reaction of 1,3-dicarbonyl dianions with aldehydes and subsequent acid-mediated cyclization [5,6]. We have recently reported a convenient variant of this transformation [5d]. Fluorinated heterocycles are of great importance in the field of medicinal and agricultural chemistry, due to their solubility, bioavailability and metabolic stability [7]. 5-Fluorouracil (anti-neoplastic activity) ciprofloxacin and flurithromycin (antimicrobial activity), fluoxetine (prozac, antidepressant activity), and faslodex (antitumor activity), efavirenz (antiviral activity), represent prominent fluorinated heterocycles which are used in the clinic [8]. Fluoroalkylated compounds are also used as ligands [9] in catalytic reactions and as organocatalysts [10]. Fluorinated 2,3-dihydropyran-4-ones have only scarcely been reported so far [11]. Herein, we report, based on our preliminary studies [5d], the synthesis of various fluorinated 2,3-dihydropyran-4-ones by reaction of the dianion of 1,1,1-trifluoro-pentane-2,4-dione with various aldehydes [11a]. In addition, we report the reaction of the dianion of acetylacetone with various fluorinated aromatic aldehydes.

2. Results and discussion

The reaction of the dianion of commercially available 1,1,1-trifluoro-pentane-2,4-dione (**1**), generated by means of 2 equiv. of LDA, with aldehydes **2a–l** and subsequent addition of hydrochloric acid (stirring for 15 min, then aqueous work-up) afforded the 2,3-dihydro-6-trifluoromethyl-pyran-4-ones **3a–l** (Scheme 1 and Table 1). The formation of the products can be explained by attack of the terminal carbon atom of the dianion to the aldehyde and subsequent acid-mediated cyclization upon addition of hydrochloric acid. Both aromatic, heterocyclic and aliphatic aldehydes

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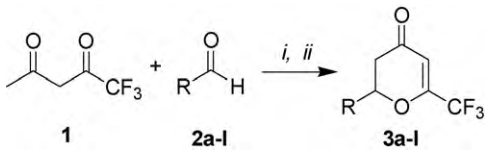
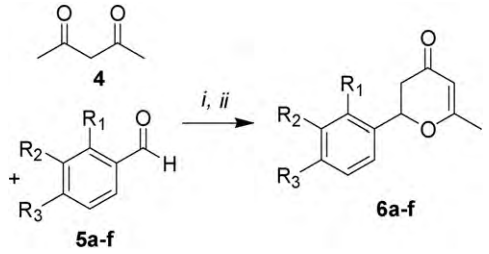


Scheme 1. Synthesis of **3a–l**: (i) (1) LDA (2.5 equiv.), THF, 0 °C, 1 h; (2) −78 °C, **1**, 1 h; (3) **2a–l**, −78 → 20 °C, 12 h; (ii) (1) HCl (10%), 15 min, 20 °C; (2) extraction (EtOAc).

Table 1
Synthesis of **3a–l**.

2,3	R	Yield (%)[a]
a	Ph	80
b	2-ClC_6H_4	62
c	4-ClC_6H_4	72
d	4-MeC_6H_4	83
e	4-EtC_6H_4	85
f	3-$(NO_2)C_6H_4$	63
g	4-$(NO_2)C_6H_4$	60
h	4-PhC_6H_4	81
i	2-Thienyl	71
j	*n*-Hept	78
k	*n*-Oct	79
l	*n*-Non	83

[a] Isolated yields.



Scheme 2. Synthesis of **6a–f**: (i) (1) LDA (2.5 equiv.), THF, 0 °C, 1 h; (2) −78 °C, **4**, 1 h; (3) **5a–f**, −78 → 20 °C, 12 h; (ii) (1) HCl (10%), 15 min, 20 °C, (2) extraction (EtOAc).

Table 2
Synthesis of **6a–f**.

5,6	R^1	R^2	R^3	Yield (%)[a]
a	CF_3	H	H	73
b	Cl	CF_3	H	71
c	Cl	H	CF_3	75
d	F	H	H	67
e	H	F	H	72
f	H	H	F	78

[a] Isolated yields.

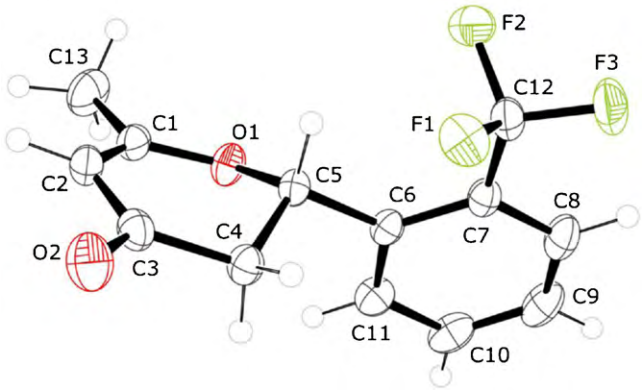


Fig. 1. Ortep plot of **6a** (50% probability level).

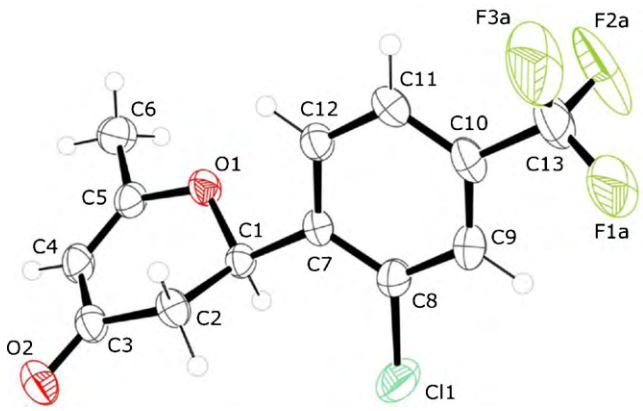


Fig. 2. Ortep plot of **6c** (50% probability level).

could be successfully employed. All products were isolated in good yields. The yields of products derived from electron-poor aromatic aldehydes are lower than the yields of products derived from electron-rich aromatic aldehydes and from aliphatic aldehydes.

The reaction of the dianion of acetylacetone (**4**) with the fluorinated benzaldehydes **5a–f** gave the 2-aryl-2,3-dihydro-6-methyl-pyran-4-ones **6a–f** (Scheme 2 and Table 2). Fluorine atoms and trifluoromethyl groups at all positions of the phenyl group are tolerated and the products are isolated in good yields.

The structures of **6a** and **6c** were independently confirmed by X-ray crystal structure analyses (Figs. 1 and 2) [12].

3. Conclusions

In conclusion, we have reported the synthesis of 2,3-dihydro-6-trifluoromethyl-pyran-4-ones by reaction of the dianion of 1,1,1-trifluoro-pentane-2,4-dione with aldehydes and subsequent addition of hydrochloric acid. The reaction of the dianion of acetylacetone with fluorinated benzaldehydes gave the corresponding fluorinated 2-aryl-2,3-dihydro-6-methyl-pyran-4-ones. All reactions proceeded in very good yield and with very good regioselectivity.

4. Experimental

General comments. All solvents were dried by standard methods and all reactions were carried out under an inert atmosphere. For ^1H and ^{13}C NMR spectra the deuterated solvents indicated and Bruker AVANCE 300 III and Bruker AVANCE 250 II machines were used. Mass spectrometric data (MS) were obtained by electron ionization (EI, 70 eV), chemical ionization (CI, H_2O) or electrospray ionization (ESI). The measurements were carried out using a Finnigan MAT 95-XP (Thermo Electron), GC 6890N/MSD 5973 (Agilent), and 6210 Time-of-Flight LC/MS (Agilent) machine. For preparative scale chromatography, silica gel (60–200 mesh) was used. Melting points are uncorrected.

4.1. General procedure for the synthesis of 2,3-dihydro-4H-pyran-4-ones 3a–l and 6a–f

A THF solution of LDA (12.5 mmol) was prepared by addition of *n*BuLi (5 mL, 12.5 mmol, 2.5 M solution in hexanes) to a THF solution (15 mL) of diisopropylamine (1.26 g, 12.5 mmol) at 0 °C. After stirring for 1 h, the solution was cooled to −78 °C and 2,4-pentanedione (0.50 g, 5.0 mmol) was added. After stirring for 1 h at −78 °C, aldehydes (5.0 mmol) were added and the solution was

allowed to warm to 20 °C within 24 h. Hydrochloric acid (10%, 15 mL) was added and the mixture was allowed to stand for 15 min. Ethyl acetate (25 mL) was added. The organic and aqueous layers were separated and the latter was extracted with ethyl acetate (3× 50 mL). The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in vacuo. The residue was purified by chromatography (silica gel, heptanes/ethyl acetate = 2:1) to give the product.

4.1.1. 2-Phenyl-6-(trifluoromethyl)-2H-pyran-4(3H)-one (3a)

Starting with a THF solution of LDA (12.5 mmol), **1** (0.77 g, 5.0 mmol) and **2a** (0.53 g, 5.0 mmol) in THF (15 mL), **3a** was isolated as a slightly yellow oil (0.97 g, 80%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.81 (ddd, J = 1.1, 3.6, 17.1 Hz, 1 H, H_A), 3.01 (dd, J = 13.6, 17.1 Hz, 1 H, H_B), 5.61 (dd, J = 3.6, 13.7 Hz, 1 H, CH), 5.98 (q, J = 1.0 Hz, 1 H, CH_{Olf}), 7.41–7.47 (m, 5 H, CH_{Ar}). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = −73.3. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 42.7 (CH_2), 82.6 (CH), 105.2 (q, $J_{C,F}$ = 2.8 Hz, CH_{Olf}), 118 (q, $J_{C,F}$ = 274.8 Hz, CF_3), 126.1, 129.0, 129.4 (CH_{Ar}), 136.3 (C_{Ar}), 159.4 (q, $J_{C,F}$ = 37.3 Hz, C_{Olf}), 191.2 (CO). IR (KBr): ν = 3368 (w), 3093 (w), 3067, 2976 (w), 2901 (w), 2707 (w), 1687 (s), 1638 (s), 1585 (m), 1498 (w), 1455 (w), 1413 (m), 1367 (w), 1270 (s), 1243 (m), 1194 (s), 1142 (s), 1067 (s), 986 (m), 941 (m), 877 (m), 828 (m), 756 (m), 695 (s), 620 (m) 593 (m), 533 (m) cm^{-1}. MS (EI, 70 eV): m/z (%) = 242 (M^+, 5), 173 (7), 145 (9), 117 (9), 105 (12), 104 (100), 103 (20), 78 (15), 77 (11), 69 (12), 51 (8). HRMS (ESI-TOF): calcd. for $C_{12}H_8O_2F_3$ [M−H]$^+$: 241.04819. Found: 241.04775. Anal. calcd. $C_{12}H_9O_2F_3$: C, 59.51; H, 3.75. Found: C, 59.75; H, 3.92.

4.1.2. 2-(2-Chlorophenyl)-6-(trifluoromethyl)-2H-pyran-4(3H)-one (3b)

Starting with a THF solution of LDA (12.5 mmol), **1** (0.77 g, 5.0 mmol) and **2b** (0.70 g, 5.0 mmol) in THF (15 mL), **3b** was isolated as a colourless oil (0.86 g, 62%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.81 (dd, J = 13.9, 17.1 Hz, 1 H, H_A), 2.95 (ddd, J = 1.2, 3.6, 17.1 Hz, 1 H, H_B), 5.97 (dd, J = 3.7, 14.0 Hz, 1 H, CH), 6.02 (q, J = 1.0 Hz, CH_{Olf}), 7.37–7.47 (m, 3 H, CH_{Ar}), 7.61–7.64 (m, 1 H, CH_{Ar}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −73.2. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 41.7 (CH_2), 79.7 (CH), 105.4 (q, $J_{C,F}$ = 3.0 Hz, CH_{Olf}), 115.1 (q, $J_{C,F}$ = 275.2 Hz, CF_3), 127.0, 127.6, 129.9, 130.3 (CH_{Ar}), 131.7, 134.5 (C_{Ar}), 159.3 (q, $J_{C,F}$ = 36.9 Hz, C_{Olf}), 190.7 (CO). IR (KBr): ν = 3034 (w), 2922 (w), 1678 (s), 1631 (s), 1410 (s), 1344 (m), 1261 (s), 1167 (s), 1152 (s), 1069 (s), 994 (m), 960 (m), 938 (m), 811 (s), 720 (m), 710 (m), 605 (m) cm^{-1}. MS (EI, 70 eV): m/z (%) = 276 (M^+, 8), 241 (13), 118 (100), 117 (51), 91 (15), 69 (12). HRMS (ESI-TOF): calcd. for $C_{12}H_9O_2ClF_3$ [M+H]$^+$: 277.02377; found: 277.02388.

4.1.3. 2-(4-Chlorophenyl)-6-(trifluoromethyl)-2H-pyran-4(3H)-one (3c)

Starting with a THF solution of LDA (12.5 mmol), **1** (0.77 g, 5.0 mmol) and **2c** (0.70 g, 5.0 mmol) in THF (15 mL), **3c** was isolated as a colourless crystalline solid (1.04 g, 72%), mp 76–77 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.69 (ddd, J = 0.9, 3.8, 17.0 Hz, 1 H, H_A), 2.87 (dd, J = 13.3, 17.0 Hz, 1 H, H_B), 5.48 (dd, J = 3.8, 13.6 Hz, 1 H, CH), 5.88 (brs, 1 H, CH_{Olf}), 7.25–7.36 (m, 4 H, CH_{Ar}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −73.3. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 42.6 (CH_2), 81.8 (CH), 105.3 (q, $J_{C,F}$ = 3.1 Hz, CH_{Olf}), 118.7 (q, $J_{C,F}$ = 275.0 Hz, CF_3), 127.5, 129.2 (CH_{Ar}), 135.4, 134.8 (C_{Ar}), 158.9 (q, $J_{C,F}$ = 37.0 Hz, C_{Olf}), 190.6 (CO). IR (KBr): ν = 3104 (w), 2884 (w), 1680 (s), 1634 (s), 1494 (s), 1410 (m), 1324 (m), 1274 (s), 1175 (s), 1141 (s), 1068 (s), 993 (m), 959 (m), 939 (m), 877 (m), 835 (s), 719 (m), 638 (m), 548 (m) cm^{-1}. MS (EI, 70 eV): m/z (%) = 276 (M^+, 6), 140 (33), 139 (12), 138 (100), 103 (23), 69 (13). HRMS (EI): calcd. for $C_{12}H_8O_2F_3Cl$ [M]$^+$: 276.01594; found: 276.015382.

4.1.4. 2-(p-Tolyl)-6-(trifluoromethyl)-2H-pyran-4(3H)-one (3d)

Starting with a THF solution of LDA (12.5 mmol), **1a** (0.77 g, 5.0 mmol) and **2d** (0.60 g, 5.0 mmol) in THF (15 mL), **3d** was isolated as a white solid (1.06 g, 83%), mp 81–82 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.31 (s, 3 H, CH_3), 2.66–2.97 (m, 2 H, $H_{A,B}$), 5.47 (dd, J = 3.5, 13.6 Hz, 1 H, CH), 5.87 (q, J = 1.0 Hz, 1 H, CH_{Olf}), 7.16–7.25 (m, 4 H, CH_{Ar}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −73.3. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 21.2 (CH_{3Ar}), 42.5 (CH_2), 82.6 (CH), 105.8 (q, $J_{C,F}$ = 3.0 Hz, CH_{Olf}), 118.3 (q, $J_{C,F}$ = 275.0 Hz, CF_3), 126.2, 129.6 (CH_{Ar}), 133.3, 139.5 (C_{Ar}), 159.5 (q, $J_{C,F}$ = 37.6 Hz, C_{Olf}), 191.4 (CO). IR (KBr): ν = 3039 (w), 2923 (w), 1679 (s), 1633 (s), 1411 (s), 1324 (m), 1271 (s), 1177 (s), 1142 (s), 1069 (s), 990 (m), 959 (m), 937 (m), 810 (s), 719 (m), 709 (m), 602 (m) cm^{-1}. MS (EI, 70 eV): m/z (%) = 256 (M^+, 7), 187 (8), 159 (8), 118 (100), 117 (51), 91 (15), 69 (12). HRMS (EI): calcd. for $C_{13}H_{11}O_2F_3$ [M]$^+$: 256.07057; found: 256.071111.

4.1.5. 2-(4-Ethylphenyl)-6-(trifluoromethyl)-2H-pyran-4(3H)-one (3e)

Starting with a THF solution of LDA (12.5 mmol), **1** (0.77 g, 5.0 mmol) and **2e** (0.67 g, 5.0 mmol) in THF (15 mL), **3e** was isolated as a colourless crystalline solid (1.15 g, 85%), mp 93–94 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.17 (t, J = 7.6 Hz, 3 H, CH_2CH_3), 2.56–2.99 (m, 4 H, CH_2CH_3, $H_{A,B}$), 5.46 (dd, J = 3.2, 13.6 Hz, 1 H, CH), 5.87 (q, 1.0 Hz, 1 H, CH_{Olf}), 7.17–7.27 (m, 4 H, 1 H, CH_{Ar}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −73.3. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 15.2 (CH_3), 28.6, 42.6 (CH_2), 82.7 (CH), 105.0 (q, $J_{C,F}$ = 3.0 Hz, CH_{Olf}), 117.9 (q, $J_{C,F}$ = 275.4 Hz, CF_3), 126.3, 128.4 (CH_{Ar}), 133.2, 139.3 (C_{Ar}), 159.3 (q, J = 37.1 Hz, C_{Olf}), 191.4 (CO). IR (KBr): ν = 3027 (m), 2967 (m), 2875 (m), 1688 (m), 1636 (m), 1600 (m), 1516 (m), 1410 (m), 1269 (s), 1194 (s), 1145 (s), 1067 (s), 984 (m), 940 (m), 827 (m), 793 (m), 710 (m), 636 (m), 544 (m) cm^{-1}. MS (EI, 70 eV): m/z (%) = 270 (8), 173 (10), 133 (13), 132 (100), 117 (95), 115 (18), 91 (14), 69 (17). HRMS: calcd. for $C_{14}H_{13}O_2F_3$ [M]$^+$: 270.08622; found: 270.085433.

4.1.6. 2-(3-Nitrophenyl)-6-(trifluoromethyl)-2H-pyran-4(3H)-one (3f)

Starting with a THF solution of LDA (12.5 mmol), **1** (0.77 g, 5.0 mmol) and **2f** (0.75 g, 5.0 mmol) in THF (15 mL), **3f** was isolated as a solid (0.90 g, 63%), mp 102–103 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.79 (ddd, J = 1.2, 3.9, 16.9 Hz, 1 H, H_A), 2.92 (dd, J = 13.4, 16.8 Hz, 1 H, H_B), 5.63 (dd, J = 4.4, 13.9 Hz, 1 H, CH), 5.95 (brs, 1 H, CH_{Olf}), 7.57–7.62 (m, 1 H, CH_{Ar}), 7.67–7.73 (m, 1 H, CH_{Ar}), 8.21–8.26 (m, 2 H, CH_{Ar}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −73.1. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 42.6 (CH_2), 81.2, 105.7 (q, $J_{C,F}$ = 3.0 Hz, 1 H, CH_{Olf}), 115 (q, $J_{C,F}$ = 275.2 Hz, CF_3), 121.2, 124.3, 130.3, 131.9 (CH_{Ar}), 138.4, 148.6 (C_{Ar}), 159.0 (q, $J_{C,F}$ = 37.7 Hz, C_{Olf}), 189.8 (CO). IR (KBr): ν = 3093 (w), 3067 (w), 2912 (w), 2878 (w), 1688 (s), 1640 (s), 1531 (s), 1417 (m), 1353 (m), 1271 (s), 1192 (s), 1143 (s), 1075 (s), 1005 (m), 943 (m), 912 (m), 868 (m), 808 (s), 736 (m), 683 (s), 626 (m), 538 (m) cm^{-1}. GC–MS (EI, 70 eV): m/z (%) = 287 (M^+, 43), 286 (6), 270 (8), 219 (13), 218 (100), 200 (14), 190 (12), 176 (84), 173 (28), 172 (13), 171 (12), 165 (17), 144 (25), 143 (20), 131 (12), 130 (10), 129 (17), 118 (11), 116 (19), 115 (64), 103 (17), 102 (33), 89 (12), 77 (13), 76 (14), 75 (11), 69 (49), 63 (12), 51 (12). HRMS (ESI-TOF): calcd. for $C_{12}H_7F_3NO_4$ [M−H]$^+$: 286.03327. Found: 286.03353. Anal. calcd. $C_{12}H_8F_3NO_4$: C, 50.19; H, 2.81; N, 4.88. Found: C, 50.18; H, 2.82; N, 4.87.

4.1.7. 2-(4-Nitrophenyl)-6-(trifluoromethyl)-2H-pyran-4(3H)-one (3g)

Starting with a THF solution of LDA (12.5 mmol), **1** (0.77 g, 5.0 mmol) and **2g** (0.75 g, 5.0 mmol) in THF (15 mL), **3g** was isolated as a colourless crystalline solid (0.86 g, 60%), mp 112 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.79 (ddd, J = 0.8, 4.5, 17.0 Hz, 1 H, H_A),

2.88 (dd, J = 12.7, 17.1 Hz, 1 H, H_B), 5.64 (dd, J = 4.6, 12.7 Hz, 1 H, CH), 5.95 (brs, 1 H, CH_{Olf}), 7.54–7.57 (m, 2 H, CH_{Ar}), 8.24–8.26 (m, 2 H, CH_{Ar}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −73.3. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 42.7 (CH_2), 81.1 (CH), 105.7 (q, $J_{C,F}$ = 3.0 Hz, 1 H, CH_{Olf}), 118.8 (q, $J_{C,F}$ = 274.4 Hz, CF_3), 124.1, 126.8 (CH_{Ar}), 143.8, 148.3 (C_{Ar}), 158.4 (q, $J_{C,F}$ = 37.6 Hz, C_{Olf}), 189.8 (CO). IR (KBr): ν = 3094 (w), 3068 (w), 2912 (w), 2879 (w), 1689 (s), 1640 (s), 1530 (s), 1418 (m), 1354 (m), 1270 (s), 1193 (s), 1144 (s), 1075 (s), 1005 (m), 944 (m), 912 (m), 868 (m), 807 (s), 737 (m), 684 (s), 626 (m), 539 (m) cm^{-1}. GC–MS (EI, 70 eV): m/z (%) = 287 (M^+, 4), 218 (9), 162 (11), 150 (10), 149 (100), 119 (31), 103 (31), 102 (11), 91 (24), 77 (38), 69 (19), 51 (10). HRMS (EI): calcd. for $C_{12}H_8O_2F_3$ $[M]^+$: 287.04054; found: 287.040243.

4.1.8. 2-(Biphenyl-4-yl)-6-(trifluoromethyl)-2H-pyran-4(3H)-one (**3h**)

Starting with a THF solution of LDA (12.5 mmol), **1** (0.77 g, 5.0 mmol) and **2h** (0.91 g, 5.0 mmol) in THF (15 mL), **3h** was isolated as a colourless crystalline solid (1.29 g, 81%), mp 124 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.75 (ddd, J = 1.0, 3.6, 17.1 Hz, 1 H, H_A), 2.96 (dd, J = 13.6, 17.1 Hz, 1 H, H_B), 5.56 (dd, J = 3.5, 13.6 Hz, 1 H, CH), 5.90 (q, J = 1.0 Hz, 1 H, CH_{Olf}), 7.36-7.43 (m, 4 H, CH_{Ar}), 7.51–7.61 (m, 5 H, CH_{Ar}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −73.2. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 42.6 (CH_2), 82.4 (CH), 105.2 (q, $J_{C,F}$ = 3.0 Hz, CH_{Olf}), 118.5 (q, $J_{C,F}$ = 275.0 Hz, CF_3), 126.6, 127.1, 127.71, 127.7, 128.8 (CH_{Ar}), 135.1, 140.1, 142.5 (C_{Ar}), 159.7 (q, $J_{C,F}$ = 37.2 Hz, C_{Olf}), 191.1 (CO). IR (KBr): ν = 3057 (m), 3028 (m), 2991 (m), 2837 (m), 1712 (w), 1660 (s), 1601 (s), 1485 (m), 1432 (m), 1394, 1332, 1235 (s), 1000 (s), 950 (m), 898 (m), 873 (m), 762 (s), 731 (s), 701 (s) 657 (m) cm^{-1}. MS (EI, 70 eV): m/z (%) = 318 (M^+, 32), 181 (16), 180 (100), 179 (13), 178 (18), 165 (10), 69 (10). HRMS (ESI-TOF): calcd. for $C_{18}H_{14}O_2F_3$ $[M+H]^+$: 319.09404; found: 319.09435.

4.1.9. 2-(Thien-2-yl)-6-(trifluoromethyl)-2H-pyran-4(3H)-one (**3i**)

Starting with a THF solution of LDA (12.5 mmol), **1** (0.77 g, 5.0 mmol) and **2i** (0.56 g, 5.0 mmol) in THF (15 mL), **3i** was isolated as a slight yellow oil (0.88 g, 71%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.88 (ddd, J = 0.9, 4.3, 17 Hz, 1 H, H_A), 3.03 (dd, J = 13.5, 17.0 Hz, 1 H, H_B), 5.46 (brs, 1 H, CH_{Olf}), 5.77 (dd, J = 4.2, 11.4 Hz, 1 H, CH), 7.04 (d, J = 3.3 Hz, 1 H, $CH_{thienyl}$), 7.12 (t, J = 3.5 Hz, 1 H, $CH_{thienyl}$), 7.39 (d, J = 5.0 Hz, 1 H, $CH_{thienyl}$). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −73.2. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 42.3 (CH_2), 76.2 (CH), 105.3 (q, $J_{C,F}$ = 3.0 Hz, CH_{Olf}), 118.3 (q, $J_{C,F}$ = 273.0 Hz, CF_3), 126.3, 126.6, 127.3 ($CH_{thienyl}$), 140.8 ($C_{thienyl}$), 159.3 (q, $J_{C,F}$ = 37.2 Hz, C_{Olf}), 191.6 (CO). IR (KBr): ν = 3086 (m), 3070 (m), 1686 (s), 1637 (m), 1410 (m), 1358 (m), 1317 (m), 1262 (s), 1193 (s), 1145 (s), 1065 (m), 965 (m), 823 (m), 701 (s) 640 (m) cm^{-1}. MS (EI, 70 eV): m/z (%) = 248 (M^+, 19), 111 (10), 110 (100), 109 (10), 69 (15). HRMS (ESI-TOF): calcd. for $C_{10}H_7O_2F_3S$ $[M]^+$: 248.01134; found: 248.010271.

4.1.10. 2-Heptyl-6-(trifluoromethyl)-2H-pyran-4(3H)-one (**3j**)

Starting with a THF solution of LDA (12.5 mmol), **1** (0.77 g, 5.0 mmol) and **2j** (0.64 g, 5.0 mmol) in THF (15 mL), **3j** was isolated as a slight yellow oil (1.02 g, 78%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.81 (t, J = 7.0 Hz, 3 H, $CH_3(CH_2)(CH2)_5$), 1.19–1.26 (m, 8 H, $CH_3(CH_2)_4(CH_2)_2$), 1.34–1.42 (m, 2 H, $CH_3(CH_2)_4(CH_2)(CH_2)$), 1.59–1.84 (m, 2 H), 2.50 (t, J = 7.1 Hz, 2 H, $CH_3(CH_2)_4(CH_2)(CH_2)$), 4.44–4.51 (m, 1 H, CH), 5.75 (brs, 1 H, CH_{Olf}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −73.6. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 13.0 (CH_3), 21.5, 23.6, 28.0, 28.1, 30.7, 32.9, 40.3 (CH_2), 80.7 (CH), 103.6 (q, J = 3 Hz, CH_{Olf}), 121.5 (q, $J_{C,F}$ = 276.5 Hz, CF_3), 158.3 (q, $J_{C,F}$ = 36.9 Hz, C), 190.8 (CO). IR (KBr): ν = 2921 (m), 2852 (m), 1688 (s), 1465 (m), 1417 (m), 1340 (w), 1270 (s), 1197 (s), 1156 (s), 1073 (m), 909 (m), 820 (m), 720 (w) cm^{-1}. MS (EI, 70 eV): m/z (%) = 264 (M^+, 16), 195 (29), 193 (10), 167 (16), 165 (100), 139 (68), 110 (17), 109 (10), 98 (11), 97 (23), 95 (10), 85 (12), 84 (22), 83 (18), 82 (12), 81 (14), 70 (22), 69 (86), 68 (13), 67 (16), 56 (30), 55 (41), 54 (15), 43 (30), 42 (13), 41 (48), 39 (17), 29 (17). HRMS: calcd. for $C_{13}H_{19}O_2F_3$ $[M]^+$: 264.3371; found: 264.33711.

4.1.11. 2-Octyl-6-(trifluoromethyl)-2H-pyran-4(3H)-one (**3k**)

Starting with a THF solution of LDA (12.5 mmol), **1** (0.77 g, 5.0 mmol) and **2k** (0.71 g, 5.0 mmol) in THF (15 mL), **3k** was isolated as a slight yellow oil (1.10 g, 79%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.81 (t, J = 7.0 Hz, 3 H, $CH_3(CH_2)(CH_2)_6$), 1.19–1.46 (m, 12 H, $CH_3(CH_2)_6(CH_2)$), 1.58–1.88 (m, 2 H), 2.47–2.51 (m, 2 H, CH_2), 4.43–4.52 (m, 1 H, CH), 5.74 (s, 1 H, CH_{Olf}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −73.6. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 13.0 (CH_3), 21.5, 23.6, 28.0, 28.1, 28.2, 30.7, 32.9, 40.2 (CH_2), 80.6 (CH), 103.4 (q, J = 3 Hz, CH_{Olf}), 121.9 (q, $J_{C,F}$ = 276.4 Hz, CF_3), 158.2 (q, $J_{C,F}$ = 36.7 Hz, C), 190.7 (CO). IR (KBr): ν = 2925 (m), 2855 (m), 1691 (s), 1466 (m), 1417 (m), 1339 (w), 1269 (s), 1194 (s), 1149 (s), 1073 (m), 909 (m), 819 (m), 720 (w) cm^{-1}. MS (EI, 70 eV): m/z (%) = 278 (M^+, 2), 209 (18), 167 (13), 165 (100), 139 (45), 97 (14), 83 (15), 82 (12), 81 (10), 70 (18), 69 (52), 67 (10), 57 (12), 56 (17), 55 (30), 54 (10), 43 (19), 41 (33), 39 (10), 29 (11). HRMS: calcd. for $C_{14}H_{21}F_3O_2$ $[M]^+$: 278.14882; found: 278.149378.

4.1.12. 2-Nonyl-6-(trifluoromethyl)-2H-pyran-4(3H)-one (**3l**)

Starting with a THF solution of LDA (12.5 mmol), **1** (0.77 g, 5.0 mmol) and **2l** (0.78 g, 5.0 mmol) in THF (15 mL), **3l** was isolated as a colourless crystalline solid (1.21 g, 83%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.80 (t, J = 7.0 Hz, 3 H, $CH_3(CH_2)_8$), 1.17–1.26 (m, 12 H, $CH_2(CH_2)_6(CH_2)_2$), 1.35–1.43 (m, 2 H, $CH_3(CH_2)_6(CH_2)(CH_2)$), 1.60–1.87 (m, 2 H, CH_2), 2.47–2.51 (m, 2 H, CH_2), 4.46–4.52 (m, 1 H, CH), 5.75 (brs, 1 H, CH_{Olf}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −73.6. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 14.0 (CH_3), 22.6, 24.5, 29.1, 29.3, 29.4, 31.8, 32.3, 33.8, 41.3 (CH_2), 81.6 (CH), 106.6 (q, J = 3 Hz, CH_{Olf}), 118.5 (q, $J_{C,F}$ = 277.9 Hz, CF_3), 159.2 (q, $J_{C,F}$ = 36.5 Hz, C_{Olf}), 191.8 (CO). IR (KBr): ν = 2924 (m), 2854 (m), 1691 (s), 1466 (m), 1418 (m), 1340 (w), 1269 (s), 1195 (s), 1150 (s), 1073 (m), 912 (m), 820 (m), 720 (w) cm^{-1}. MS (EI, 70 eV): m/z (%) = 292 (M^+, 1), 223 (14), 165 (100), 139 (30), 97 (11), 83 (12), 70 (12), 69 (35), 56 (10), 55 (22), 43 (15), 41 (25), 29 (10). HRMS: calcd. for $C_{15}H_{23}O_2F_3$ $[M]^+$: 319.09404; found: 319.09435.

4.1.13. 6-Methyl-2-(2-(trifluoromethyl)phenyl)-2H-pyran-4(3H)-one (**6a**)

Starting with a THF solution of LDA (12.5 mmol), **4** (0.50 g, 5.0 mmol) and **5a** (0.87 g, 5.0 mmol) in THF (15 mL), **6a** was isolated as a colourless crystalline solid (0.94 g, 73%), mp 127 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.00 (s, 3 H, CH_3), 2.2.49 (ddd, J = 0.7, 3.7, 16.8 Hz, 1 H, H_A), 2.64 (dd, J = 14.1, 16.9 Hz, 1 H, H_B), 5.38 (s, 1 H, CH_{Olf}), 5.69 (dd, J = 3.7, 14.0 Hz, 1 H, CH), 7.38-7.43 (m, 1 H, CH_{Ar}), 7.55–7.62 (m, 2 H, CH_{Ar}), 7.71–7.74 (m, 1 H, CH_{Ar}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −58.4. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 21.0 (CH_3), 43.1 (CH_2), 77.1 (q, $J_{C,F}$ = 2.3 Hz, CH), 105.3 (CH_{Olf}), 125.9 (q, J = 5.6 Hz, CH_{Ar}), 128.0, 128.7, 132.5 (CH_{Ar}), 123.9 (q, $J_{C,F}$ = 274.3 Hz, CF_3), 127.0 (q, $J_{C,F}$ = 32.1 Hz, C_{Ar}), 137.2 (q, $J_{C,F}$ = 1.0 Hz, CH_{Ar}), 174.2 (C_{Olf}), 191.3 (CO). IR (KBr): ν = 3078 (w), 3017 (w), 2970 (w), 1660 (s), 1613 (s), 1486 (m), 1396 (m), 1359 (m), 1310 (s), 1288 (m), 1240 (m), 1152 (s), 1100 (s), 1060 (m), 1035 (m), 1000 (m), 948 (m), 879 (m), 810 (m), 770 (s), 751 (m), 652 (m), 548 (m) cm^{-1}. MS (EI, 70 eV): m/z (%) = 256 (M^+, 5), 213 (23), 173 (11), 172 (100), 171 (40), 151 (24). HRMS (ESI-TOF): calcd. for $C_{13}H_{12}O_2F_3$ $[M+H]^+$: 257.0784; found: 257.0787.

4.1.14. 2-(2-Chloro-3-(trifluoromethyl)phenyl)-6-methyl-2H-pyran-4(3H)-one (**6b**)

Starting with a THF solution of LDA (12.5 mmol), **4** (0.50 g, 5.0 mmol) and **5b** (1.04 g, 5.0 mmol) in THF (15 mL), **6b** was

isolated as a colourless crystalline solid (1.03 g, 71%), mp 137 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.00 (s, 3H, CH_3), 2.45–2.64 (m, 2 H, $H_{A,B}$), 5.38 (s, 1 H, CH_{Olf}), 5.63 (dd, J = 4.2, 13.6 Hz, 1 H, CH), 7.35–7.39 (m, 1 H, CH_{Ar}), 7.54 (d, 1 H, J = 8.3 Hz, 1 H, CH_{Ar}), 7.71–7.73 (m, 1 H, CH_{Ar}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −58.4. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 20.9 (CH_3), 43.0 (CH_2), 76.6 (q, $J_{C,F}$ = 5.7 Hz, CH), 105.4 (CH_{Olf}), 121.7 (q, $J_{C,F}$ = 273 Hz, CF_3), 125.6 (q, $J_{C,F}$ = 31.3 Hz, CH_{Ar}), 127.4 (q, $J_{C,F}$ = 5.7 Hz, CH_{Ar}), 128.6 (q, $J_{C,F}$ = 42.0 Hz, CH_{Ar}), 139.1 (q, $J_{C,F}$ = 28.1 Hz, C_{Ar}), 173.8 (C_{Olf}), 190.6 (CO). IR (KBr): ν = 3117 (w), 2976 (w), 2926 (w), 1660 (w), 1601 (s), 1575 (m), 1440 (m), 1392 (m), 1330 (m), 1234 (m), 1557 (s), 1126 (m), 1105 (s), 1042 (m), 1000 (m), 958 (m), 880 (m), 848 (m), 770 (m), 706 (m), 596 (m) cm^{-1}. MS (EI, 70 eV): m/z (%) = 290 (M^+, 6), 255 (16), 247 (16), 208 (49), 207 (15), 206 (100), 171 (39), 151 (14), 43 (13). HRMS (ESI-TOF): calcd. for $C_{13}H_{11}ClO_2F_3$ $[M+H]^+$: 291.09305; found: 291.093056.

*4.1.15. 2-(2-Chloro-4-(trifluoromethyl)phenyl)-6-methyl-2H-pyran-4(3H)-one (**6c**)*

Starting with a THF solution of LDA (12.5 mmol), **4** (0.50 g, 5.0 mmol) and **5c** (1.04 g, 5.0 mmol) in THF (15 mL), **6c** was isolated as a colourless crystalline solid (1.09 g, 75%), mp 143 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.03 (s, 3 H, CH_3), 2.47 (dd, J = 14.1, 14.1 Hz, 1 H, H_A), 2.68 (ddd, J = 1.1, 3.5, 14.1 Hz, 1 H, H_B), 5.40 (s, 1 H, CH_{Olf}), 5.71 (dd, J = 3.5, 14.1 Hz, CH), 7.54 (d, J = 8.1 Hz, 1 H, CH_{Ar}), 7.58 (s, 1 H, CH_{Ar}), 7.69 (d, J = 8.3 Hz, 1 H, CH_{Ar}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −62.9. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 20.5 (CH_3), 40.8 (CH_2), 77.3 (CH), 105.6 (CH_{Olf}), 127.1 (q, $J_{C,F}$ = 272 Hz, CF_3), 131.8 (q, $J_{C,F}$ = 33.8 Hz, C_{Ar}), 124.2 (q, $J_{C,F}$ = 3.8 Hz, CH_{Ar}), 126.7 (q, $J_{C,F}$ = 3.8 Hz, CH_{Ar}), 127.7 (q, $J_{C,F}$ = 3.8 Hz, CH_{Ar}), 131.8 (q, $J_{C,F}$ = 33.8 Hz, C_{Ar}), 140.2 (C_{Ar}), 173.8 (C_{Olf}), 190.9 (CO). IR (KBr): ν = 3092 (w), 2966 (w), 2848 (w), 1666 (s), 1613 (s), 1388 (m), 1319 (s), 1240 (m), 1118 (s), 1064 (m), 1006 (m), 945 (m), 846 (m), 815 (m), 713 (m), 649 (m), 538 (m) cm^{-1}. MS (EI, 70 eV): m/z (%) = 290 (M^+, 4), 255 (13), 247 (15), 208 (32), 207 (11), 206 (100), 171 (27), 151 (17), 43 (10). HRMS: calcd. for $C_{13}H_{10}ClO_2F_3$ $[M]^+$: 319.09404; found: 319.09435.

*4.1.16. 2-(2-Fluorophenyl)-6-methyl-2H-pyran-4(3H)-one (**6d**)*

Starting with a THF solution of LDA (12.5 mmol), **4a** (0.50 g, 5.0 mmol) and **5d** (0.62 g, 5.0 mmol) in THF (15 mL), **6d** was isolated as a slight yellow oil (0.69 g, 67%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 1.98 (s, 3 H, CH_3), 2.51 (dd, J = 3.2, 16.8 Hz, 1 H, H_B), 2.69 (dd, J = 14.1, 16.8 Hz, 1 H, H_B), 5.35 (s, 1 H, CH_{Olf}), 5.58 (dd, J = 3.6, 14.1 Hz, 1 H, CH), 6.96-7.03 (m, 1 H, CH_{Ar}), 7.09–7.14 (m, 1 H, CH_{Ar}), 7.22–7.29 (m, 1 H, CH_{Ar}), 7.39–7.45 (m, 1 H, CH_{Ar}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −118.2. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 21.0 (CH_3), 41.3 (CH_2), 75.1 (d, $J_{F,C}$ = 3.1 Hz, CH), 105.2 (CH_{Olf}), 115.8 (d, $J_{F,C}$ = 21.7 Hz, CH_{Ar}), 124.5 (d, $J_{F,C}$ = 3.6 Hz, CH_{Ar}), 125.5 (d, $J_{F,C}$ = 12.7 Hz, CH_{Ar}), 127.5 (d, $J_{F,C}$ = 3.4 Hz, CH_{Ar}), 130.4 (d, $J_{F,C}$ = 8.3 Hz, C_{Ar}), 159.7 (d, $J_{F,C}$ = 247.8 Hz, C_{Ar}), 174.2 (C_{Olf}), 191.8 (CO). IR (KBr): ν = 3067 (w), 296 (w), 1722 (w), 1660 (m), 1605 (s), 1491 (m), 1436 (m), 1360 (m), 1330 (m), 1230 (m), 1151 (m), 1065 (m), 1001 (m), 950 (m), 871 (m), 810 (m), 755 (s), 657 (m), 553 (m) cm^{-1}. GC–MS (EI, 70 eV): m/z (%) = 206 (M^+, 2), 163 (20), 123 (10), 122 (100), 121 (14), 96 (11). HRMS: calcd. for $C_{12}H_{11}O_2F$ $[M]^+$: 206.07376; found: 206.07373. Anal. calcd. $C_{12}H_{11}O_2F$: C, 69.89; H, 5.38. Found: C, 69.86; H, 5.51.

*4.1.17. 2-(3-Fluorophenyl)-6-methyl-2H-pyran-4(3H)-one (**6e**)*

Starting with a THF solution of LDA (12.5 mmol), **4a** (0.50 g, 5.0 mmol) and **5e** (0.62 g, 5.0 mmol) in THF (15 mL), **6e** was isolated as a slight yellow oil (0.75 g, 72%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.02 (d, 3 H, CH_3), 2.53 (ddd, J = 1.0, 3.8, 16.7 Hz, 1 H, H_A), 2.68 (dd, J = 13.8, 16.8 Hz, 1 H, H_B), 5.31 (dd, J = 3.8, 13.8 Hz, 1 H, CH), 5.36 (s, 1 H, CH_{Olf}), 6.96–7.03 (m, 1 H, CH_{Ar}), 7.05–7.11 (m, 2 H, CH_{Ar}), 7.28–7.36 (m, 1 H, CH_{Ar}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −115.4. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 21.0 (CH_3), 42.3 (CH_2), 79.9 (CH), 105.3 (CH_{Olf}), 113.0 (d, $J_{F,C}$ = 23.0 Hz, CH_{Ar}), 115.6 (d, $J_{F,C}$ = 21 Hz, CH_{Ar}), 121.6 (d, $J_{F,C}$ = 3.7 Hz, CH_{Ar}), 130.8 (d, $J_{F,C}$ = 8.7 Hz, CH_{Ar}), 140.6 (d, $J_{F,C}$ = 7.5 Hz, C_{Ar}), 162.1 (d, $J_{F,C}$ = 246.5, C_{Ar}), 174.1 (C_{Olf}), 191.8 (CO). IR (KBr): ν = 3067 (w), 2921 (w), 1722 (w), 1666 (m), 1607 (s), 1590 (s), 1488 (m), 1448 (m), 1392 (s), 1392 (s), 1359 (m), 1326 (s), 1237 (s), 1041 (m), 1003 (s), 890 (m), 785 (s), 691 (s), 627 (w), 592 (w) cm^{-1}. GC–MS (EI, 70 eV): m/z (%) = 206 (M^+, 6), 188 (7), 173 (6), 163 (22), 122 (100), 121 (14), 96 (13). HRMS: calcd. for $C_{12}H_{11}O_2F$ $[M^+]$: 206.07376; found: 206.07469. Anal. calcd. $C_{12}H_{11}O_2F$: C, 69.89; H, 5.38. Found: C, 69.74; H, 5.66.

*4.1.18. 2-(4-Fluorophenyl)-6-methyl-2H-pyran-4(3H)-one (**6f**)*

Starting with a THF solution of LDA (12.5 mmol), **4a** (0.50 g, 5.0 mmol) and **5f** (0.62 g, 5.0 mmol) in THF (15 mL), **6f** was isolated as a colourless crystalline solid (0.81 g, 78%), mp 61–62 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.99 (s, 3 H, CH_3), 2.50 (dd, J = 3.4, 16.8 Hz 1 H, H_A), 2.70 (dd, J = 14.0, 16.6 Hz, 1 H, H_B), 5.29 (dd, J = 3.8, 13.9 Hz, 1 H, CH), 5.36 (s, 1 H, CH_{Olf}), 6.95–7.06 (m, 2 H, CH_{Ar}), 7.28–7.34 (m, 2 H, CH_{Ar}). ^{19}F NMR (282 MHz, $CDCl_3$): δ = −112.7. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 21.1 (CH_3), 42.3 (CH_2), 80.1 (CH), 105.3 (CH_{Olf}), 115.7 (d, $J_{F,C}$ = 21.8 Hz, CH_{Ar}), 128.1 (d, $J_{F,C}$ = 7.2 Hz, CH_{Ar}), 134.0 (d, $J_{F,C}$ = 3 Hz, C_{Ar}), 162.8 (d, $J_{F,C}$ = 247.0, C_{Ar}), 174.2 (C_{Olf}), 192.0 (CO). IR (KBr): ν = 3295 (w), 3119 (w), 2966 (w), 2849 (w), 1898 (w), 1651 (m), 1600 (s), 1511 (m), 1426 (m), 1396 (m), 1335 (m), 1248 (m), 1219 (s), 1159 (m), 1024 (m), 997 (m), 903 (m), 818 (s), 659 (m), 554 (m) cm^{-1}. GC–MS (EI, 70 eV): m/z (%) = 206 (M^+, 4), 188 (10), 163 (17), 122 (100), 121 (15), 96 (10), HRMS: calcd. for $C_{12}H_{11}O_2F$ $[M^+]$: 206.07376; found: 206.073710. Anal. calcd. $C_{12}H_{11}O_2F$: C, 69.89; H, 5.38. Found: C, 69.88; H, 5.56.

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