Supporting Information for

Pd^0-Mediated Rapid Coupling of Methyl Iodide with Excess Amounts of Benzyl- and Cinnamylboronic Acid Esters: Efficient Method for Incorporation of Positron–Emitting ^{11}C Radionuclide into Organic Frameworks by Coupling between Two sp^3-Hybridized Carbons

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1. Synthesis of 4,4,5,5-tetramethyl-2-(3-phenylpropyl)-1,3,2-dioxaborolane (**9**) and the rapid *C*–methylation of **9**
2. The rapid *C*–methylation of *B*-benzyl-9-BBN (**12**) and *B*-(3-phenylpropyl)-9-BBN (**13**)
3. Synthesis of benzylboronic acid pinacol ester derivatives **7** and the corresponding ethylbenzenes **8**
4. a) HPLC (RI) chart after the rapid *C*–[^{11}C]methylation of [^{11}C]methyl iodide and **7c**, giving [^{11}C]**8c** (retention time; 7.8 min), b) HPLC (UV 254 nm) chart after the rapid

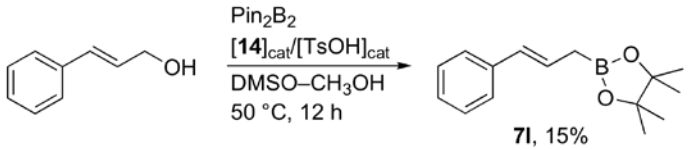
C–[^{11}C]methylation of [^{11}C]methyl iodide and **7c**, c) HPLC (RI) chart after purification of [^{11}C]**8c**, giving [^{11}C]**8c** (retention time; 3.8 min), and d) HPLC (UV 254 nm) chart after purification of [^{11}C]**8c**:

5. a) HPLC (RI) chart of [^{11}C]**8c**, b) HPLC (UV 254 nm) chart of [^{11}C]**8c**, c) HPLC (RI) chart for co-injection of [^{11}C]**8c** and **8c**, d) HPLC (UV 254 nm) chart for co-injection of [^{11}C]**8c** and **8c**

6. References

1. Synthesis of 4,4,5,5-tetramethyl-2-(3-phenylpropyl)-1,3,2-dioxaborolane (9) and the rapid *C*–methylation of 8l: (*E*)-2-(3-phenyl-2-propenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (7l):

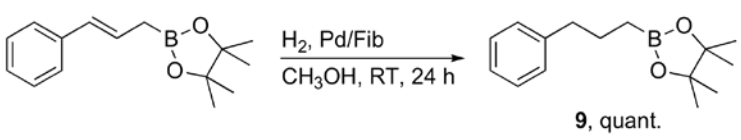
CAS Registry Number: 147609-46-9



14: di-μ-chlorobis{2-[(dimethylamino)methyl]phenyl-C,N}dipalladium (II)

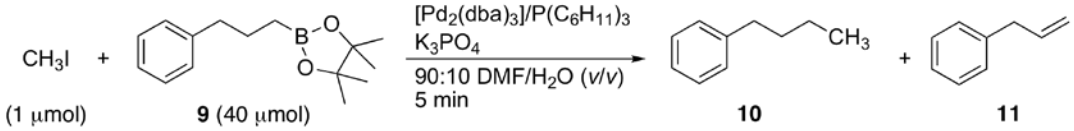
^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.13–7.33 (m, 5H), 6.23–6.38 (m, 2H), 1.86 (d, ^{3}J(H,H) = 6.8 Hz, 2H), 1.25 (s, 12H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 138.3, 130.3, 128.4 (2C), 126.5, 126.4, 125.9 (2C), 83.4 (2C), 26.2, 24.9 (4C) ppm.

4,4,5,5-tetramethyl-2-(3-phenylpropyl)-1,3,2-dioxaborolane (9): CAS Registry Number: 329685-40-7



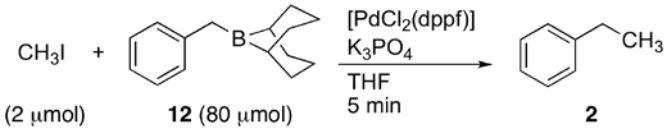
^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.13–7.27 (m, 5H), 2.60 (t, ^3J(H,H) = 8.0 Hz, 2H), 1.73 (qintet, ^3J(H,H) = 8.0 Hz, 2H), 0.81 (t, ^3J(H,H) = 8.0 Hz, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 142.8, 128.6, 128.2, 125.6, 83.0 (2C), 38.7, 26.2, 24.9 (4C) ppm.

Synthesis of butylbenzene (10) by rapid *C*-methylation using methyl iodide and an excess amount of 3-phenylpropylboronic acid pinacol ester (9)



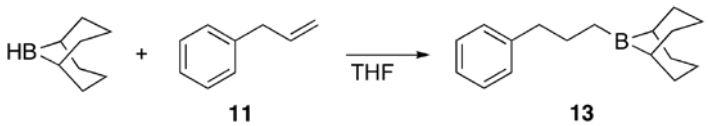
$[Pd_2(dba)_3]$ (0.5 mg, 0.5 μmol), $P(C_6H_{11})_3$ (0.6 mg, 2 μmol), and K_3PO_4 (2.1 mg, 10 μmol) were placed under Ar in a 2-mL Schlenk tube. Then, the solution of boronic acid ester **9** (9.8 mg, 40 μmol) in co–solvent 90:10 DMF/H_2O (*v*/*v*) (200 μL) was added, and then, a solution of CH_3I (0.2 M DMF solution, 5 μL, 1 μmol) was added. After stirring at 60 °C for 5 min, the resulting mixture was rapidly cooled in an ice bath, filtered through a short column of silica gel (0.5 g), and eluted with ethyl ether (ca. 2 mL), followed by the addition of *n*-nonane (0.1 M DMF solution, 10 μL, 1 μmol) as an internal standard. The resulting solution was analyzed by GLC under the conditions: Shimadzu GC-2010 instrument equipped with a flame ionization detector; capillary column: GL Science TC-1701 (60 m × 0.25 mm i.d.); carrier gas: He (flow rate: 0.57 mL min^{-1}); injector temperature: 280 °C; detector temperature: 280 °C; column temperature: initial 70 °C, final 230 °C; temperature gradient: +15 °C min^{-1}, from 5 to 9 min, and 20 °C min^{-1} from 15 to 20 min. The yield of **10** was 1% based on the starting CH_3I (retention time: 20.04 min). The yield of **11** was 3% based on the starting methyl iodide (retention time: 17.27 min), or 0.1% based on the boronic acid ester consumption. The product was identified by GC with an added authentic reference. The methylation reactions under other conditions shown in ref. 6 in the text were conducted by the same procedure.

2. The rapid *C*–methylation of *B*-benzyl-9-BBN (12) and *B*-(3-phenylpropyl)-9-BBN (13): Synthesis of ethylbenzene (2) by rapid *C*-methylation using methyl iodide and an excess amount of *B*-benzyl-9-BBN (12) using ferrocenyl complex



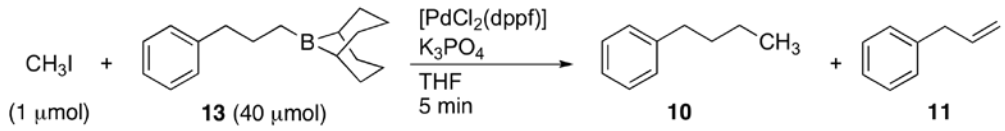
[1,1'-Bis(diphenylphosphino)ferrocene]dichloropalladium(II) ([$PdCl_2$(dppf)], 1.6 mg, 2 μmol) and K_3PO_4 (4.2 mg, 20 μmol) were placed under Ar in a 2-mL Schlenk tube. Then, the solution of *B*-benzyl-9-BBN (**12**) (0.5 M THF solution, 0.16 mL, 80 μmol) in THF was added, and then, a solution of CH_3I (0.1 M DMF solution, 20 μL, 2 μmol) was added. After stirring at 80 °C oil bath temperature for 5 min, the resulting mixture was rapidly cooled in an ice bath, filtered through a short column of silica gel (0.5 g), and eluted with ethyl ether (ca. 2 mL), followed by the addition of *n*-nonane (0.1 M DMF solution, 10 μL, 1 μmol) as an internal standard. The resulting solution was analyzed by GC. The yield of **2** was 30% based on the starting CH_3I.

Synthesis of butylbenzene (10) by rapid *C*-methylation using methyl iodide and an excess amount of *B*-(3-phenylpropyl)-9-BBN (13)[1] using ferrocenyl complex



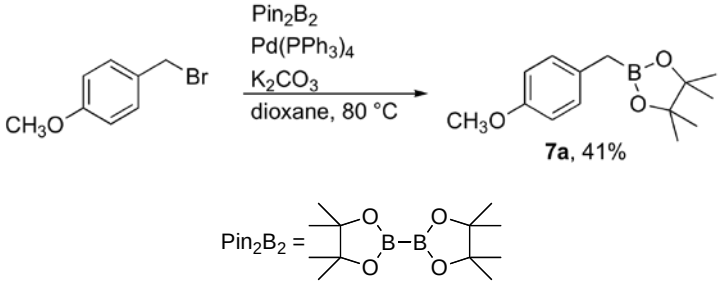
9-BBN (0.4 M in THF solution, 0.20 mL) was added to the solution of phenylpropene (**11**) (9.4 mg, 80 μmol) in THF (200 μL) at 0 °C in a 10-mL Schlenk tube. After addition, the mixture was stirred at RT for two hours.[2] The solvent was removed under reduced pressure. After the Schlenk

tube was filled with Ar, the residue was used as the substrate on the following reaction without further purification.



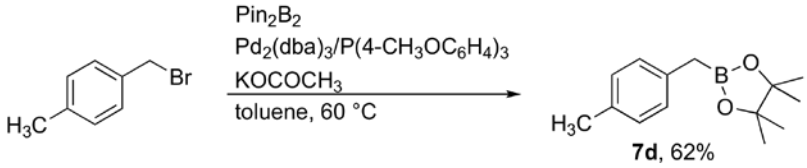
[$PdCl_2$(dppf)] (1.6 mg, 2 μmol) and K_3PO_4 (4.2 mg, 20 μmol) were placed under Ar in a 2-mL Schlenk tube. Then, the solution of *B*-(3-phenylpropyl)-9-borobicyclo[3.3.1]nonane (**13**) in THF (200 μL) was added, and then, a solution of CH_3I (0.1 M DMF solution, 20 μL, 2 μmol) was added. After stirring at 80 °C oil bath temperature for 5 min, the resulting mixture was rapidly cooled in an ice bath, filtered through a short column of silica gel (0.5 g), and eluted with ethyl ether (ca. 2 mL), followed by the addition of *n*-nonane (0.1 M DMF solution, 10 μL, 1 μmol) as an internal standard. The resulting solution was analyzed by GC. The yield of **10** was 2% based on the starting CH_3I. The yield of **11** was 235% based on the starting CH_3I, or 6% based on the alkyl 9-BBN substrate consumption.

3. Synthesis of benzylboronic acid pinacol ester derivatives 9 and the corresponding ethylbenzenes 10: 2-(4-methoxybenzyl)-4,4,5,5-tetramethyl-1,3,2-Dioxaborolane (7a): CAS Registry Number: 475250-52-3



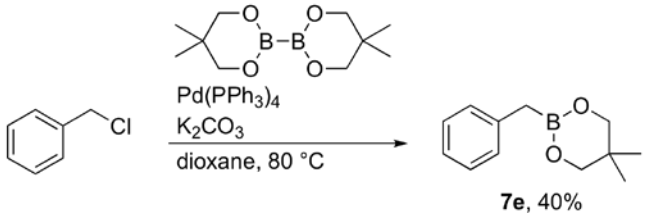
^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.09–7.06 (m, 2H), 6.79–6.76 (m, 2H), 3.75 (s, 3H), 2.21 (s, 2H), 1.24 (s, 12H) ppm; ^{13}C NMR (126 MHz, $CDCl_3$, 25 °C): δ = 154.6, 149.7, 130.2, 126.9, 110.5, 109.0, 83.5 (2C), 56.2, 56.1, 37.8, 24.8 (4C) ppm.

2-(4-Methylbenzyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (7d): CAS Registry Number: 356570-52-0



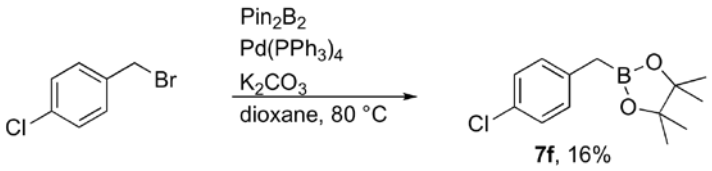
^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.03–7.08 (m, 4H), 2.29 (s, 3H), 2.25 (s, 2H), 1.23 (s, 12H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 135.5, 134.2, 129.1, 128.9, 83.4 (2C), 24.8 (4C), 21.0 ppm.

2-Benzyl-5,5-dimethyl-1,3,2-dioxaborinane (7e): CAS Registry Number: 162213-36-7



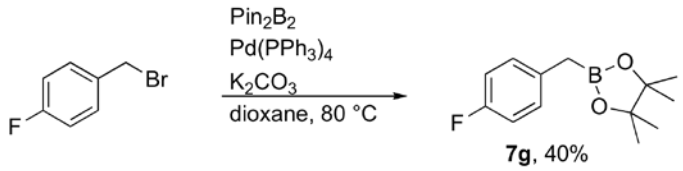
^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.08–7.25 (m, 5H), 3.58 (s, 4H), 0.92 ppm (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 140.0, 129.0 (2C), 128.2 (2C), 124.7, 72.3 (2C), 31.7, 24.0, 21.9 (2C) ppm.

2-(4-Chlorobenzyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (7f): CAS Registry Number: 475250-49-8



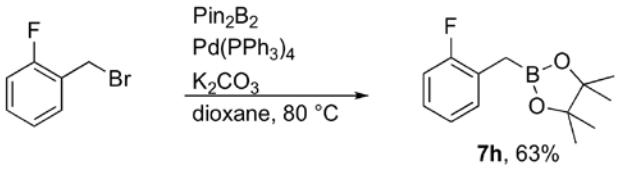
^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.09–7.20 (AA'BB', 4H), 2.25 (s, 2H), 1.23 (s, 12H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 137.2, 130.6, 130.4 (2C), 128.4 (2C), 83.6 (2C), 24.8 (4C), 19.2 ppm.

2-(4-Fluorobenzyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (7g): CAS Registry Number: 243145-83-7



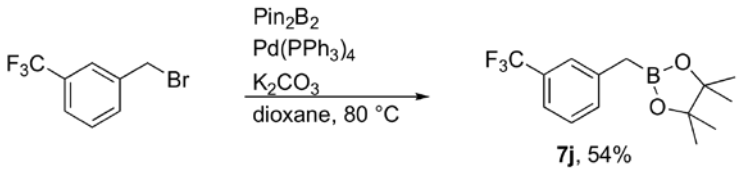
^{1}H NMR (400 MHz, $CDCl_3$): δ = 6.70–7.31 (m, 4H), 2.24 (s, 2H), 1.22 (s, 12H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 161.0 (d, ^{1}J(C,F) = 240 Hz), 134.2, 130.2 (d, J(C,F) = 6.7 Hz), 115.0 (d, J(C,F) = 20.9 Hz), 83.6 (2C), 24.8 (4C), 19.3 ppm.

2-(2-Fluorobenzyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (7h): CAS Registry Number: 517920-60-4



^{1}H NMR (400 MHz, $CDCl_3$): δ = 6.96–7.20 (m, 4H), 2.25 (s, 2H), 1.24 (s, 12H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 161.1 (d, ^{1}J(C,F) = 242 Hz), 131.4, 126.7 (d, J(C,F) = 7.6 Hz), 126.1 (d, J(C,F) = 16.2 Hz), 123.9, 115.0 (d, J(C,F) = 22 Hz), 83.6 (2C), 24.8 (4C), 13.2 ppm.

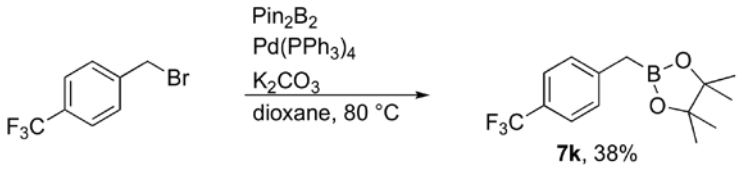
2-[3-(Trifluoromethyl)benzyl]-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (7j): CAS Registry Number: 1190235-39-2



7j, 54%

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.25–7.43 (m, 4H), 2.33 (s, 2H), 1.22 (s, 12H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 139.7, 132.5, 130.5 (q, ^{1}J(C,F) = 31.5 Hz), 128.6, 125.8, 123.1, 121.8, 83.8, (2C), 24.9 (4C), 20.3 ppm; HRMS (EI^+): *m*/*z*: calcd for $C_{14}H_{18}BF_3O_2$: 286.1352; found 286.1371.

2-[4-(Trifluoromethyl)benzyl]-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (7k): CAS Registry Number: 475250-46-5



7k, 38%

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.27–7.49 (AX, 4H), 2.35 (s, 2H), 1.23 (s, 12H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 143.2, 129.2 (2C), 127.3 (q, ^{1}J(C,F) = 32.5 Hz), 125.2, (2C), 123.3, 83.8, (2C), 24.8 (4C), 20.3 ppm.

1,2-Dimethoxy-4-ethylbenzene (8b): CAS Registry Number: 5888-51-7

^{1}H NMR (400 MHz, $CDCl_3$): δ = 6.71–6.81 (m, 3H), 3.88 (s, 3H), 3.86 (s, 3H), 2.62 (q, ^{3}J(H,H) = 7.7 Hz, 2H), 1.23 (t, ^{3}J(H,H) = 7.7 Hz, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 148.9, 147.1, 137.1, 119.5, 111.4, 111.3, 56.0, 55.9, 28.5, 15.9 ppm.

***N*-(4-Ethylphenyl)propionamide (8c):** CAS Registry Number: 20172-37-6

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.39 (d, ^{3}J(H,H) = 7.9 Hz, 2H), 7.11 (d, ^{3}J(H,H) = 7.6 Hz, 2H), 2.59 (q, ^{3}J(H,H) = 7.6 Hz, 2H), 2.36 (d, ^{3}J(H,H) = 7.6 Hz, 2H), 1.18–1.25 (m, 6H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 171.8, 140.3, 135.6, 128.4 (2C), 120.0 (2C), 30.8, 28.4, 15.7, 9.8 ppm; HRMS (EI^{+}): *m*/*z*: calcd for $C_{11}H_{15}NO$: 177.1154; found 177.1154.

1-Chloro-4-ethylbenzene (8f): CAS Registry Number: 622-98-0

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.11–7.26 (m, 4H), 2.61 (q, ^{3}J(H,H)=7.5 Hz, 2H), 1.22 (t, ^{3}J(H,H)=7.5 Hz, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 142.7, 131.3, 129.3 (2C), 128.4 (2C), 28.3, 15.6 ppm.

1-Ethyl-4-fluorobenzene (8g): CAS Registry Number: 459-47-2

^{1}H NMR (400 MHz, $CDCl_3$): δ = 6.92–7.15 (m, 4H), 2.61 (q, ^{3}J(H,H) = 7.6 Hz, 2H), 1.21 (t, ^{3}J(H,H) = 7.6 Hz, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 162.4, 139.9, 129.2 (d, ^{3}J(C,F) = 7.6 Hz, 2C), 115.0 (d, ^{3}J(C,F) = 21.0 Hz, 2C), 28.2, 15.8 ppm.

1-Ethyl-2-fluorobenzene (8h): CAS Registry Number: 446-49-1

^{1}H NMR (500 MHz, $CDCl_3$): δ = 6.98–7.21 (m, 4H), 2.68 (q, ^{3}J(H,H) = 7.5 Hz, 2H), 1.22 (t, ^{3}J(H,H)=7.5 Hz, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 161.2 (d, ^{1}J(C,F) = 244 Hz), 131.0 (d, ^{2}J(C,F) = 15.3 Hz), 129.9, 127.3, 124.0, 115.1 (d, ^{1}J(C,F) = 20.9 Hz), 22.5, 14.3 ppm.

4-Ethyl-benzoic acid ethyl ester (8i): CAS Registry Number: 136569-05-6

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.33–7.89 (m, 4H), 4.38 (q, ^{3}J(H,H) = 7.0 Hz, 2H), 2.70 (q, ^{3}J(H,H) = 7.5 Hz, 2H), 1.40 (t, ^{3}J(H,H)=7.0 Hz, 3H), 1.26 (t, ^{3}J(H,H)=7.5 Hz, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 166.8, 149.7, 129.7 (2C), 127.9 (2C), 60.8, 29.0, 15.3, 14.4 ppm.

1-Ethyl-4-(trifluoromethyl)benzene (8k): CAS Registry Number: 27190-69-8

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.29–7.54 (AA'BB', 4H), 2.71 (q, ^{3}J(H,H) = 7.5 Hz, 2H), 1.26 (t, ^{3}J(H,H)=7.5 Hz, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 148.4, 128.2, 125.3 (q, ^{1}J(C,F) = 3.8 Hz), 28.8, 15.4 ppm. Full signals for aromatic carbon were not observed.

(*E*)-But-1-enylbenzene (8l): CAS Registry Number: 1005-64-7

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.16–7.35 (m, 5H), 6.37 (d, ^{3}J(H,H) = 16.4 Hz, 1H), 6.26 (dt, ^{3}J(H,H) = 16.4 Hz, ^{3}J(H,H) = 6.4 Hz, 1H), 2.22 (dq, ^{3}J(H,H) = 6.4 Hz, ^{3}J(H,H) = 7.2 Hz, 2H), 1.08 (t, ^{3}J(H,H) = 7.2 Hz, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 137.9, 132.6, 128.8, 128.4 (2C), 126.7, 125.9 (2C), 26.1, 13.7 ppm.

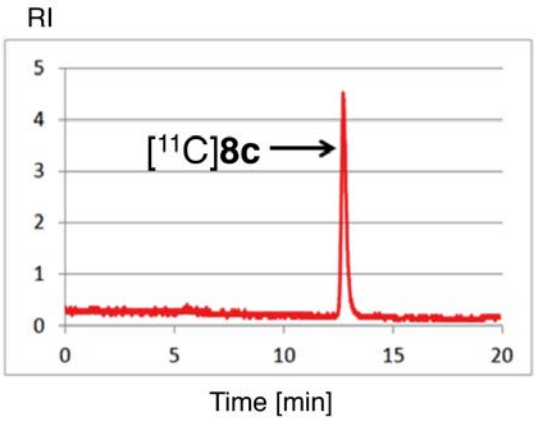
(*E*)-But-1-enyl-(4-methoxy)benzene (8m): CAS Registry Number: 18657-09-5

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.27 (d, ^{3}J(H,H) = 8.8 Hz, 2H), 6.83 (d, ^{3}J(H,H) = 8.8 Hz, 2H), 6.32 (d, ^{3}J(H,H) = 16.0 Hz, 1H), 6.12 (dt, ^{3}J(H,H) = 16.0 Hz, ^{3}J(H,H) = 6.4 Hz, 1H), 2.20 (dq,

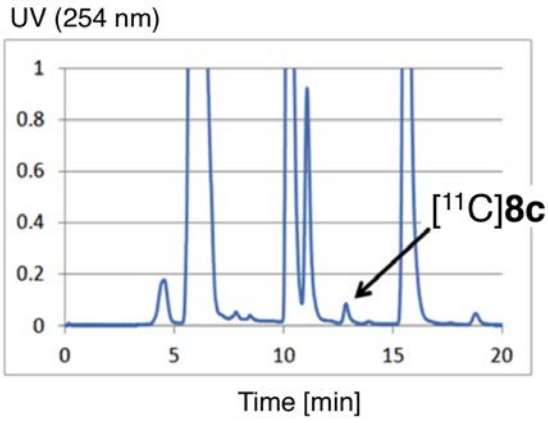
^{3}J(H,H) = 6.4 Hz, 7.2 Hz, 2H), 1.08 (t, ^{3}J(H,H) = 7.2 Hz, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ = 158.7, 130.9, 130.6, 128.2, 127.0 (2C), 114.0 (2C), 55.4, 26.1, 13.9 ppm.

4. a) HPLC (RI) chart after the rapid *C*–[^{11}C]methylation of [^{11}C]methyl iodide and 7c, giving [^{11}C]8c (retention time; 12.8 min), b) HPLC (UV 254 nm) chart after the rapid *C*–[^{11}C]methylation of [^{11}C]methyl iodide and 7c, c) HPLC (RI) chart after purification of [^{11}C]8c, giving [^{11}C]8c (retention time; 4.5 min), and d) HPLC (UV 254 nm) chart after purification of [^{11}C]8c:

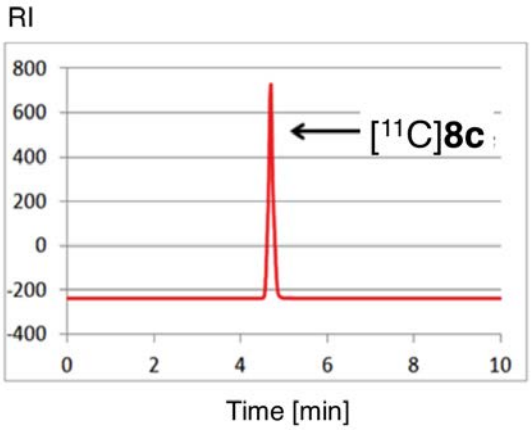
a)



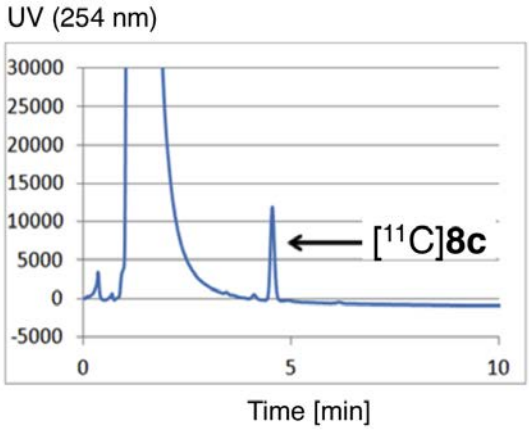
b)



c)

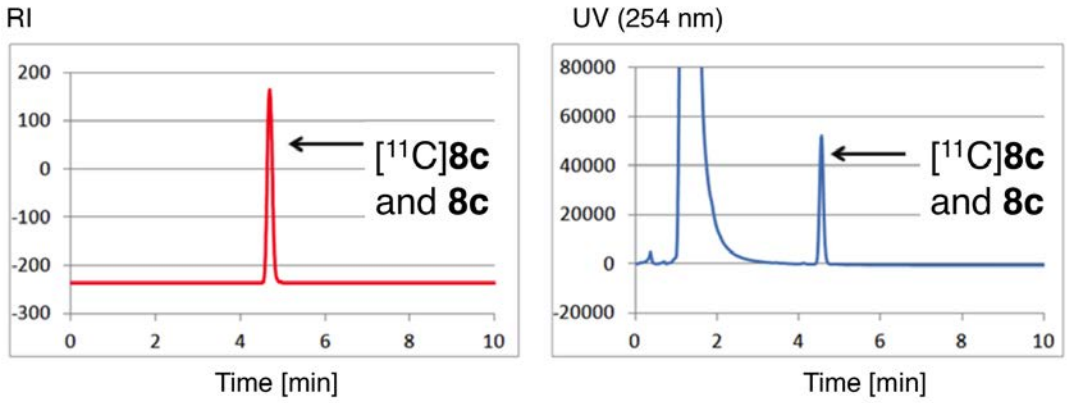


d)



5. a) HPLC (RI) chart for co-injection of [^{11}C]8c and 8c, b) HPLC (UV 254 nm) chart for co-injection of [^{11}C]8c and 8c:

a) b)



6. References

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