Supplementary Material (ESI) for Chemical Communications

Copper-Catalyzed α-Amination of Aliphatic Aldehydes

Jie-Sheng Tian and Teck-Peng Loh*

Division of Chemistry and Biological Chemistry, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore 637371

teckpeng@ntu.edu.sg.

Supporting Information

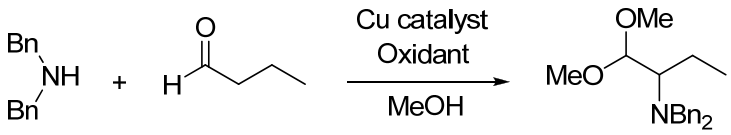
I. General Procedures

All reactions were carried out without exclusion of air or moisture unless otherwise stated. Copper salts, and peroxides such as *tert*-butyl hydroperoxide (~5.5 M in decane) (TBHP), di-*tert*-butyl peroxide, and *tert*-butyl benzoylperoxide were purchased from commercial suppliers, and used directly as received. Commercial solvents and reagents were used without further purification. Secondary amines **1 b**[1-2], enamine **1 c**[3], and aliphatic aldehydes **2 (f**, **h)**[4-5] were synthesized according to literatures.[1-5] Reactions were monitored through thin layer chromatography [Merck 60 F254 precoated silica gel plate (0.2 mm thickness)]. Subsequent to elution, spots were visualized using UV radiation (254 nm) on Spectroline Model ENF-24061/F 254 nm. Further visualization was possible using basic solution of potassium permanganate or acidic solution of ceric molybdate as stain, followed by heating on a hot plate. Flash chromatography was performed using Merck silica gel 60 with distilled solvents. Infrared spectra were recorded on a Shimadzu IR Prestige-21 FT-IR. Liquid samples were examined as film between NaCl salt plates. HRMS spectra were recorded on a Waters Q-Tof Permier Spectrometer. ^{1}H NMR and ^{13}C NMR spectra were recorded using Bruker Avance 300, 400 and 500 MHz spectrometers. Chemical shifts for ^{1}H NMR spectra are reported as δ in units of parts per million (ppm) downfield from $SiMe_4$ (δ 0.0) and relative to the signal of chloroform-*d* (δ 7.260, singlet). Multiplicities were given as: s (singlet); brs (broad singlet); d (doublet); t (triplet); q (quartet); dd (doublets of doublet); ddd (doublets of doublets of doublet); td (triplet of doublet); m (multiplets); ddt (doublet of doublet of triplet) and etc. Coupling constants are reported as a *J* value in Hz. Carbon nuclear magnetic resonance spectra (^{13}C NMR) are reported as δ in units of parts per million (ppm) downfield from $SiMe_4$ (δ 0.0) and relative to the signal of chloroform-*d* (δ 77.00, triplet).

II. Optimization of the reaction conditions [a]

Among the various solvents screened (Table 1, entries 2 and 11-14), acetonitrile emerged as the best medium for this reaction, rendering the desired product in 80% isolated yield (Table 1, entry 2). Other copper catalysts were also examined (Table 1, entries 15-20). CuBr and $CuBr_2$ also catalyzed the reaction to afford the desired product **3a** in moderate yield under the same conditions (Table 1, entries 15, 17). Other copper salts such as CuCl, $CuCl_2$, $Cu(OAc)_2$ and $Cu(OTf)_2$ showed low or even no catalytic activities for this reaction (Table 1, entries 16, 18-20).

Table 1: Optimization of the reaction conditions [a]



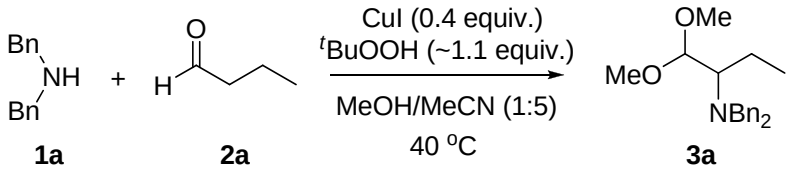
1a **2a** **3a**

Entry	Catalyst	Oxidant	Solvent	*T* (°C)	*t* (h)	Yield (%) [b]
1	CuI	O_2 or air (1 atm)	MeCN	40	24	0
2	CuI	^{t}BuOOH	MeCN	40	24	80
3	—	^{t}BuOOH	MeCN	40	24	0
4	CuI	^{t}BuO^{t}Bu	MeCN	40	24	trace
5	CuI	^{t}BuOOBz	MeCN	40	24	50
6	CuI	^{t}BuOOH	MeCN	20	96	75
7[c]	CuI	^{t}BuOOH	MeCN	40	72	57
8[d]	CuI	^{t}BuOOH	MeCN	40	24	50
9[e]	CuI	^{t}BuOOH	MeCN	40	24	70
10[f]	CuI	^{t}BuOOH	MeCN	40	24	62
11	CuI	^{t}BuOOH	MeOH	40	24	50
12	CuI	^{t}BuOOH	DCE	40	24	48
13	CuI	^{t}BuOOH	THF	40	24	53
14	CuI	^{t}BuOOH	DMSO	40	24	51
15	CuBr	^{t}BuOOH	MeCN	40	24	55
16	CuCl	^{t}BuOOH	MeCN	40	24	14
17	$CuBr_2$	^{t}BuOOH	MeCN	40	24	67
18	$CuCl_2$	^{t}BuOOH	MeCN	40	24	9
19	$Cu(OAc)_2$	^{t}BuOOH	MeCN	40	24	0
20	$Cu(OTf)_2$	^{t}BuOOH	MeCN	40	24	trace

[a] Reaction conditions: Dibenzylamine (0.5 mmol, 1 equiv.), butyraldehyde (0.75 mmol), copper catalyst (0.4 equiv.), oxidant (1.1 equiv.), methanol (0.4 mL), solvent (2 mL). [b] Isolated yields based on dibenzylamine. [c] The reaction was performed using 0.2 equiv. CuI. [d] The reaction was performed using 0.2 mL MeOH. [e] Dibenzylamine (0.5 mmol), butyraldehyde (0.5 mmol). [f] Dibenzylamine (0.75 mmol), butyraldehyde (0.5 mmol).

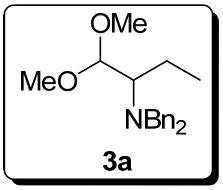
III

General Experimental Procedure for Copper-Catalyzed α-Amination of Aliphatic Aldehydes



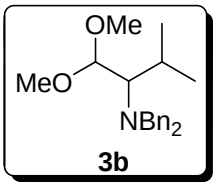
1a **2a** **3a**

Typical procedure for copper-catalyzed α-amination of aliphatic aldehydes for the synthesis of α-amino acetals using secondary amines with readily removable protecting groups as a nitrogen source (dibenzylamine **1a** and butyraldehyde **2a** as a model system): *tert*-butyl hydroperoxide (~5.5 M in decane) (0.1 mL, ~0.55 mmol) was added to a mixture of CuI (38 mg, 0.2 mmol), dibenzylamine **1a** (98 mg, 0.5 mmol), and butyraldehyde **2a** (54 mg, 0.75 mmol) in methanol (0.4 mL)/acetonitrile (2.0 mL) at room temperature. The mixture was stirred at 40 °C until dibenzylamine **1a** was completely converted by TLC detection. The resulting reaction mixture was mixed with a small amount of silica gel and concentrated. The crude product was purified by flash column chromatography (silica gel; ethyl acetate or diethyl ether/hexane = 1:100) to afford the desired product **3a** as a light yellowish oil (0.125 g, 80% yield).



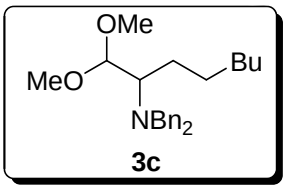
3a

***N,N*-dibenzyl-1,1-dimethoxybutan-2-amine (3a)**: R_f = 0.70 (hexane: ethyl acetate = 3:1); **^{1}H NMR ($CDCl_3$, 400 MHz)** δ 7.38-7.36 (m, 4H), 7.30-7.26 (m, 4H), 7.22-7.18 (m, 2H), 4.37 (d, *J* = 5.16 Hz, 1H), 3.74 (dd, *J* = 50.34, 13.61 Hz, 4H), 3.35 (s, 3H), 3.32 (s, 3H), 2.65-2.60 (m, 1H), 1.61-1.44 (m, 2H), 0.93 (t, *J* = 7.43 Hz, 3H) ppm; **^{13}C NMR ($CDCl_3$, 100 MHz)** δ 140.7 (C x 2), 129.0 (CH x 4), 128.0 (CH x 4), 126.6 (CH x 2), 107.4, 59.4, 54.8, 54.44 (CH_2 x 2), 54.38, 19.5, 12.0 ppm; **FTIR (neat): ν** = 3015, 1452, 1215, 754, 700, 494 cm^{-1}; **HRMS (ESI, m/z):** calcd for $C_{20}H_{28}NO_2^+$ $[M+H]^+$ 314.2120, found: 314.2119.



3b

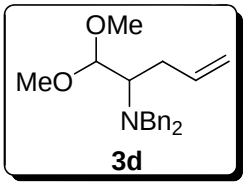
***N,N*-dibenzyl-1,1-dimethoxy-3-methylbutan-2-amine (3b)**: The product was prepared by above general procedure and the same chemicals except employing dibenzylamine (**1a**) (98 mg, 0.5 mmol), and 3-methylbutanal (**2b**) (64 mg, 0.75 mmol). After 24 h, The crude product was purified by flash column chromatography (silica gel; ethyl acetate or diethyl ether/hexane = 1:100) to afford the desired product **3b** as a light yellowish oil (0.108 g, 66% yield); R_f = 0.76 (hexane: ethyl acetate = 3:1); **^{1}H NMR ($CDCl_3$, 400 MHz)** δ 7.38-7.36 (m, 4H), 7.30-7.26 (m, 4H), 7.22-7.18 (m, 2H), 4.51 (d, *J* = 4.28 Hz, 1H), 3.77 (dd, *J* = 102.13, 13.70 Hz, 4H), 3.40 (s, 3H), 3.37 (s, 3H), 2.46-2.43 (m, 1H), 2.05-1.97 (m, 1H), 0.98 (t, *J* = 6.82 Hz, 3H), 0.83 (t, *J* = 6.68 Hz, 3H) ppm; **^{13}C NMR ($CDCl_3$, 100 MHz)** δ 140.7 (C x 2), 129.2 (CH x 4), 128.0 (CH x 4), 126.6 (CH x 2), 107.1, 62.5, 55.5 (CH_2 x 2), 55.2, 54.8, 27.2, 20.9, 20.7 ppm; **FTIR (neat): ν** = 3015, 1215, 754, 700, 494 cm^{-1}; **HRMS (ESI, m/z):** calcd for $C_{21}H_{30}NO_2^+$ $[M+H]^+$ 328.2277, found: 328.2273.



3c

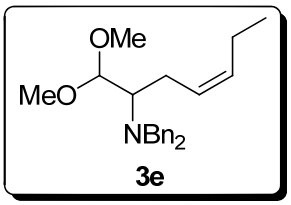
***N,N*-dibenzyl-1,1-dimethoxyoctan-2-amine (3c)**: The product was prepared by above general procedure and the same chemicals except employing dibenzylamine (**1a**) (98 mg, 0.5 mmol), and octanal (**2c**) (96 mg, 0.75 mmol). After 24 h, The crude product was purified by flash column chromatography (silica gel; ethyl acetate or diethyl ether/hexane = 1:100) to afford the desired product **3c** as a light yellowish oil (0.129 g, 70% yield); R_f = 0.77 (hexane: ethyl acetate = 3:1); **^{1}H NMR ($CDCl_3$, 400 MHz)** δ 7.37-7.35 (m, 4H), 7.30-7.26 (m, 4H), 7.23-7.18 (m, 2H), 4.37 (d, *J* = 5.03 Hz, 1H), 3.73 (dd, *J* = 50.95, 13.56 Hz, 4H), 3.35 (s, 3H), 3.32 (s, 3H), 2.73-2.68 (m, 1H), 1.59-1.36 (m, 3H), 1.25-1.17 (m, 5H), 1.15-1.08 (m, 2H), 0.87 (t, *J* = 7.07 Hz, 3H) ppm; **^{13}C NMR ($CDCl_3$, 100 MHz)** δ 140.8 (C x 2), 129.0 (CH x 4), 128.0 (CH x 4), 126.6 (CH x 2), 107.5, 57.4, 54.8, 54.5 (CH_2 x 2), 54.3, 31.9, 29.4, 26.9, 26.5, 22.7, 14.1

ppm; **FTIR (neat):** ν = 3015, 1215, 754, 700, 494 cm^{-1}; **HRMS (ESI, m/z):** calcd for $C_{24}H_{36}NO_2^+$ $[M+H]^+$ 370.2746, found: 370.2743.



3d

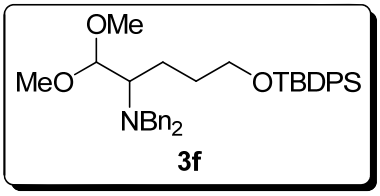
***N,N*-dibenzyl-1,1-dimethoxypent-4-en-2-amine (3d)**: The product was prepared by above general procedure and the same chemicals except employing dibenzylamine (**1a**) (98 mg, 0.5 mmol), and pent-4-enal (**2d**) (63 mg, 0.75 mmol). After 24 h, The crude product was purified by flash column chromatography (silica gel; ethyl acetate or diethyl ether/hexane = 1:100) to afford the desired product **3d** as a light yellowish oil (0.102 g, 63% yield); R_f = 0.70 (hexane: ethyl acetate = 3:1); **^{1}H NMR ($CDCl_3$, 400 MHz)** δ 7.38-7.37 (m, 4H), 7.30-7.26 (m, 4H), 7.21-7.18 (m, 2H), 5.89-5.79 (m, 1H), 5.06 (d, *J* = 17.14 Hz, 1H), 5.01 (d, *J* = 10.10 Hz, 1H), 4.38 (d, *J* = 4.93 Hz, 1H), 3.75 (dd, *J* = 25.44, 13.56 Hz, 4H), 3.35 (s, 3H), 3.28 (s, 3H), 2.89-2.84 (m, 1H), 2.44-2.26 (m, 2H) ppm; **^{13}C NMR ($CDCl_3$, 100 MHz)** δ 140.5 (C x 2), 137.8, 129.0 (CH x 4), 128.0 (CH x 4), 126.7 (CH x 2), 115.5, 107.0, 57.8, 54.7, 54.5, 54.4 (CH_2 x 2), 31.2 ppm; **FTIR (neat):** ν = 3015, 1454, 1215, 754, 700, 494 cm^{-1}; **HRMS (ESI, m/z):** calcd for $C_{21}H_{28}NO_2^+$ $[M+H]^+$ 326.2120, found: 326.2114.



3e

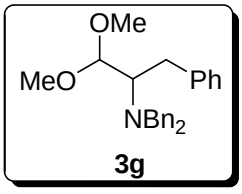
(Z)-*N,N*-dibenzyl-1,1-dimethoxyhept-4-en-2-amine (3e): The product was prepared by above general procedure and the same chemicals except employing dibenzylamine (**1a**) (98 mg, 0.5 mmol), and (Z)-hept-4-enal (**2e**) (84 mg, 0.75 mmol). After 48 h, The crude product was purified by flash column chromatography (silica gel; ethyl acetate or diethyl ether/hexane = 1:100) to afford the desired product **3e** as a light yellowish oil (0.115 g, 65% yield); R_f = 0.72 (hexane: ethyl acetate = 3:1); **^{1}H NMR ($CDCl_3$, 400 MHz)** δ 7.38-7.36 (m, 4H), 7.30-7.26 (m, 4H), 7.24-7.18 (m, 2H), 5.44-5.36 (m, 2H), 4.38 (d, *J* = 4.73

Hz, 1H), 3.79-3.71 (m, 4H), 3.36 (s, 3H), 3.28 (s, 3H), 2.86-2.81 (m, 1H), 2.44-2.37 (m, 1H), 2.28-2.20 (m, 1H), 2.08-2.01 (m, 2H), 0.93 (t, *J* = 7.53 Hz, 3H) ppm; **^{13}C NMR ($CDCl_3$, 100 MHz)** δ 140.6 (C x 2), 131.9, 129.0 (CH x 4), 128.0 (CH x 4), 127.6, 126.7 (CH x 2), 107.3, 58.0, 54.8, 54.6, 54.5 (CH_2 x 2), 24.2, 20.7, 14.2 ppm; **FTIR (neat):** ν = 3017, 1454, 1215, 1072, 756, 699, 498 cm^{-1}; **HRMS (ESI, m/z):** calcd for $C_{23}H_{32}NO_2^+$ $[M+H]^+$ 354.2433, found: 354.2443.



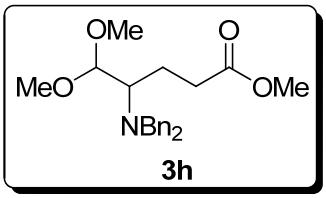
3f

***N,N*-dibenzyl-5-(tert-butyldiphenylsilyloxy)-1,1-dimethoxypentan-2-amine (3f)**: The product was prepared by above general procedure and the same chemicals except employing dibenzylamine (**1a**) (98 mg, 0.5 mmol), and 5-(*tert*-butyldiphenylsilyloxy)pentanal (**2f**) (0.255 g, 0.75 mmol). After 48 h, The crude product was purified by flash column chromatography (silica gel; ethyl acetate or diethyl ether/hexane = 1:100) to afford the desired product **3f** as a light yellowish oil (0.230 g, 79% yield); R_f = 0.72 (hexane: ethyl acetate = 3:1); **^{1}H NMR ($CDCl_3$, 400 MHz)** δ 7.66-7.64 (m, 4H), 7.43-7.33 (m, 10H), 7.28-7.17 (m, 6H), 4.38 (d, *J* = 5.42 Hz, 1H), 3.72 (dd, *J* = 40.61, 13.45 Hz, 4H), 3.61-3.45 (m, 2H), 3.33 (s, 3H), 3.32 (s, 3H), 2.73-2.68 (m, 1H), 1.86-1.76 (m, 1H), 1.68-1.40 (m, 3H), 1.04 (s, 9H) ppm; **^{13}C NMR ($CDCl_3$, 100 MHz)** δ 140.6 (C x 2), 135.6 (CH x 4), 134.2 (C x 2), 129.4 (CH x 2), 129.1 (CH x 4), 128.0 (CH x 4), 127.5 (CH x 4), 126.7 (CH x 2), 107.4, 63.9, 57.4, 54.7, 54.5 (CH_2 x 2), 54.2, 30.3, 26.9 (CH_3 x 3), 22.8, 19.2 ppm; **FTIR (neat):** ν = 3017, 1215, 1111, 758, 494 cm^{-1}; **HRMS (ESI, m/z):** calcd for $C_{37}H_{48}NO_3Si^+$ $[M+H]^+$ 582.3403, found: 582.3401.



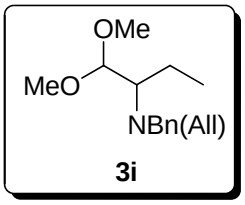
3g

***N,N*-dibenzyl-1,1-dimethoxy-3-phenylpropan-2-amine (3g):** The product was prepared by above general procedure and the same chemicals except employing dibenzylamine (**1a**) (98 mg, 0.5 mmol), and 3-phenylpropanal (**2g**) (0.100 g, 0.75 mmol). After 48 h, The crude product was purified by flash column chromatography (silica gel; ethyl acetate or diethyl ether/hexane = 1:100) to afford the desired product **3g** as a light yellowish oil (0.129 mg, 69% yield); R_f = 0.72 (hexane: ethyl acetate = 3:1); **^{1}H NMR ($CDCl_3$, 400 MHz)** δ 7.27-7.01 (m, 15H), 4.42 (d, *J* = 4.38 Hz, 1H), 3.74 (s, 4H), 3.37 (s, 3H), 3.30 (s, 3H), 3.13-3.08 (m, 1H), 2.88-2.86 (m, 2H) ppm; **^{13}C NMR ($CDCl_3$, 100 MHz)** δ 140.8, 140.3 (C x 2), 129.6 (CH x 2), 128.7 (CH x 4), 128.0 (CH x 6), 126.5 (CH x 2), 125.3, 107.2, 59.6, 54.9, 54.8, 54.4 (CH_2 x 2), 32.6 ppm; **FTIR (neat):** ν = 3019, 1495, 1454, 1215, 1072, 756, 698, 496 cm^{-1}; **HRMS (ESI, m/z):** calcd for $C_{25}H_{30}NO_2^+$ $[M+H]^+$ 376.2277, found: 376.2278.



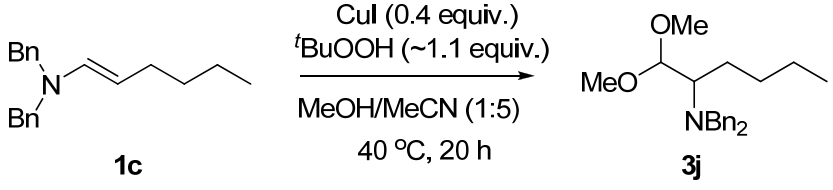
3h

Methyl 4-(dibenzylamino)-5,5-dimethoxypentanoate (3h): The product was prepared by above general procedure and the same chemicals except employing dibenzylamine (**1a**) (98 mg, 0.5 mmol), and methyl 5-oxopentanoate (**2h**) (97 mg, 0.75 mmol). After 48 h, The crude product was purified by flash column chromatography (silica gel; ethyl acetate or diethyl ether/hexane = 1:100) to afford the desired product **3h** as a light yellowish oil (0.124 g, 67% yield); R_f = 0.54 (hexane: ethyl acetate = 3:1); **^{1}H NMR ($CDCl_3$, 400 MHz)** δ 7.33-7.27 (m, 8H), 7.25-7.19 (m, 2H), 4.43 (d, *J* = 5.53 Hz, 1H), 3.72 (dd, *J* = 63.86, 13.41 Hz, 4H), 3.55 (s, 3H), 3.363-3.359 (m, 6H), 2.78-2.73 (m, 1H), 2.53-2.26 (m, 2H), 1.86-1.70 (m, 2H) ppm; **^{13}C NMR ($CDCl_3$, 100 MHz)** δ 174.2, 140.2 (C x 2), 129.1 (CH x 4), 128.1 (CH x 4), 126.8 (CH x 2), 106.7, 56.6, 54.8, 54.2 (CH_2 x 2), 53.6, 51.3, 31.1, 21.9 ppm; **FTIR (neat): ν** = 3017, 1454, 1215, 758, 494 cm^{-1}; **HRMS (ESI, m/z):** calcd for $C_{22}H_{30}NO_4^+$ $[M+H]^+$ 372.2175, found: 372.2178.



3i

***N*-allyl-*N*-benzyl-1,1-dimethoxybutan-2-amine (3i)**: The product was prepared by above general procedure and the same chemicals except employing *N*-benzylprop-2-en-1-amine (**1b**) (74 mg, 0.5 mmol), and butyraldehyde (**2a**) (55 mg, 0.75 mmol). After 24 h, The crude product was purified by flash column chromatography (silica gel; ethyl acetate or diethyl ether/hexane = 1:100) to afford the desired product **3i** as a light yellowish oil (92 mg, 69% yield); R_f = 0.72 (hexane: ethyl acetate = 3:1); **^{1}H NMR ($CDCl_3$, 400 MHz)** δ 7.36-7.34 (m, 2H), 7.30-7.26 (m, 2H), 7.24-7.18 (m, 1H), 5.85-5.75 (m, 1H), 5.15 (d, *J* = 17.21 Hz, 1H), 5.05 (d, *J* = 10.10 Hz, 1H), 4.31 (d, *J* = 5.35 Hz, 1H), 3.75 (dd, *J* = 72.44, 14.03 Hz, 2H), 3.36 (s, 6H), 3.28-3.15 (m, 2H), 2.72-2.67 (m, 1H), 1.57-1.41 (m, 2H), 0.96 (t, *J* = 7.41 Hz, 3H) ppm; **^{13}C NMR ($CDCl_3$, 100 MHz)** δ 141.1, 138.1, 128.7 (CH x 2), 128.0 (CH x 2), 126.5, 116.1, 107.3, 60.4, 54.7, 54.5, 54.4, 53.5, 19.7, 12.0 ppm; **FTIR (neat):** ν = 3017, 1452, 1215, 1065, 756, 494 cm^{-1}; **HRMS (ESI, m/z):** calcd for $C_{16}H_{26}NO_2^+$ $[M+H]^+$ 264.1964, found: 264.1965.



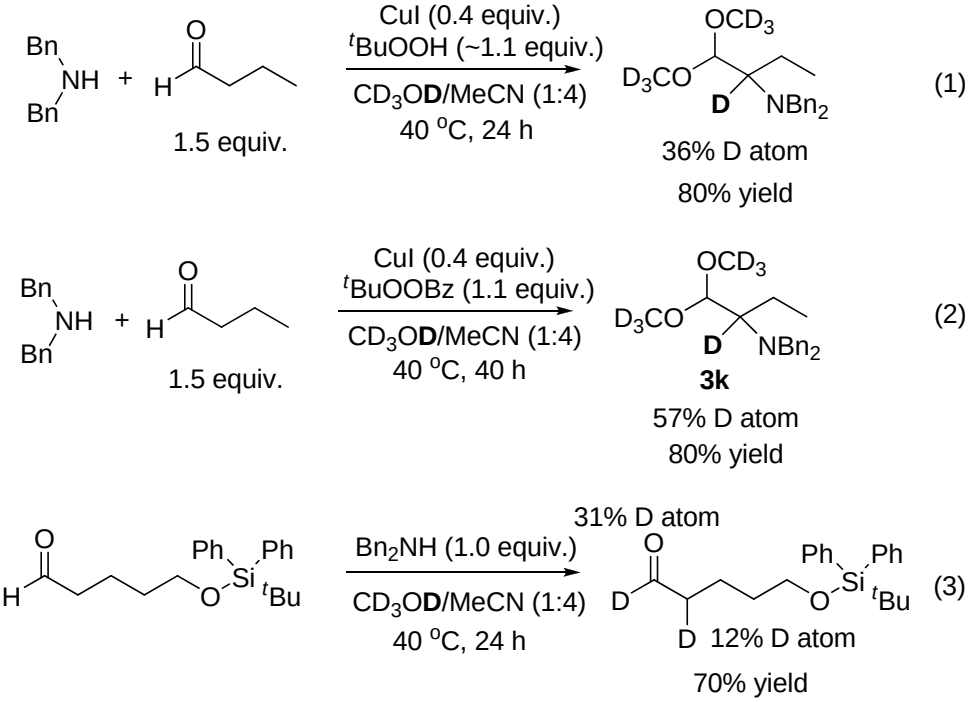
1c **3j**

76% yield

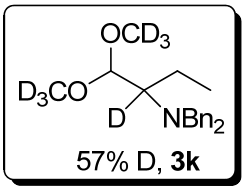
***N*,*N*-dibenzyl-1,1-dimethoxyhexan-2-amine (3j)**: The product was prepared by above general procedure and the same chemicals except employing *N*,*N*-dibenzylhex-1-en-1-amine (**1c**) (0.139 g, 0.5 mmol). After 20 h, the crude product was purified by flash column chromatography (silica gel; ethyl acetate or diethyl ether/hexane = 1:100) to afford the desired product **3l** as a light yellowish oil (0.129 g, 76% yield); R_f = 0.70 (hexane: ethyl acetate = 3:1); **^{1}H NMR ($CDCl_3$, 400 MHz)** δ 7.37-7.35 (m, 4H), 7.30-7.27 (m, 4H), 7.23-7.18 (m, 2H), 4.37 (d, *J* = 5.01 Hz, 1H), 3.74 (dd, *J* = 50.64, 13.59 Hz, 4H), 3.35 (s, 3H), 3.31 (s, 3H), 2.73-2.69 (m, 1H), 1.59-1.39 (m, 3H), 1.26-1.10 (m, 3H), 0.85 (t, *J* = 7.31 Hz, 3H) ppm; **^{13}C NMR ($CDCl_3$, 100 MHz)** δ 140.8 (C x 2), 129.0 (CH

x 4), 128.0 (CH x 4), 126.6 (CH x 2), 107.5, 57.4, 54.8, 54.5 (CH_2 x 2), 54.3, 29.2, 26.2, 22.7, 14.1 ppm; **FTIR (neat):** ν = 3015, 1452, 1215, 758, 494 cm^{-1}; **HRMS (ESI, m/z):** calcd for $C_{22}H_{32}NO_2^+$ $[M+H]^+$ 342.2433, found: 342.2436.

IV. Deuterium Labeling Exiperiment



Typical procedure for deuterium labeling experiment (eq. 2): *tert*-butyl benzoylperoxide (0.107 g, 0.55 mmol) was added to a mixture of CuI (38 mg, 0.2 mmol), dibenzylamine **1a** (98 mg, 0.5 mmol), and butyraldehyde **2a** (54 mg, 0.75 mmol) in CD_3OD (0.5 mL)/acetonitrile (2.0 mL) at room temperature. The mixture was stirred at 40 °C for 40 h. The resulting reaction mixture was mixed with a small amount of silica gel and concentrated. The crude product was purified by flash column chromatography (silica gel; ethyl acetate or diethyl ether/hexane = 1:100) to afford the desired product **3k** as a light yellowish oil (0.144 g, 80% yield).



57% D, **3k**

***N,N*-dibenzyl-1,1-dimethoxy-D6-butan-D1-2-amine (3k)**: R_f = 0.70 (hexane: ethyl acetate = 3:1); **^{1}H NMR ($CDCl_3$, 400 MHz)** δ 7.38-7.36 (m, 4H), 7.30-7.26 (m, 4H), 7.23-7.18 (m, 2H), 4.38-4.37 (m, 1H), 3.74 (dd, *J* = 49.61, 13.60 Hz, 4H), 2.64-2.60 (m, 0.43H), 1.59-1.44 (m, 2H), 0.92 (t, *J* = 7.43 Hz, 3H) ppm; **^{13}C NMR ($CDCl_3$, 100 MHz)** δ 140.7 (C x 2), 129.0 (CH x 4), 128.0 (CH x 4), 126.6 (CH x 2), 107.2, 59.4, 54.5 (CH_2 x 2), 19.54, 19.43, 12.03, 11.99 ppm; **FTIR (neat):** ν = 3015, 1215, 754, 700, 494 cm^{-1}; **HRMS (ESI, m/z):** calcd for $C_{20}H_{33}D_5NO_4^+$ $[M+H]^+$ 361.3115, found: 361.3109.

Reference:

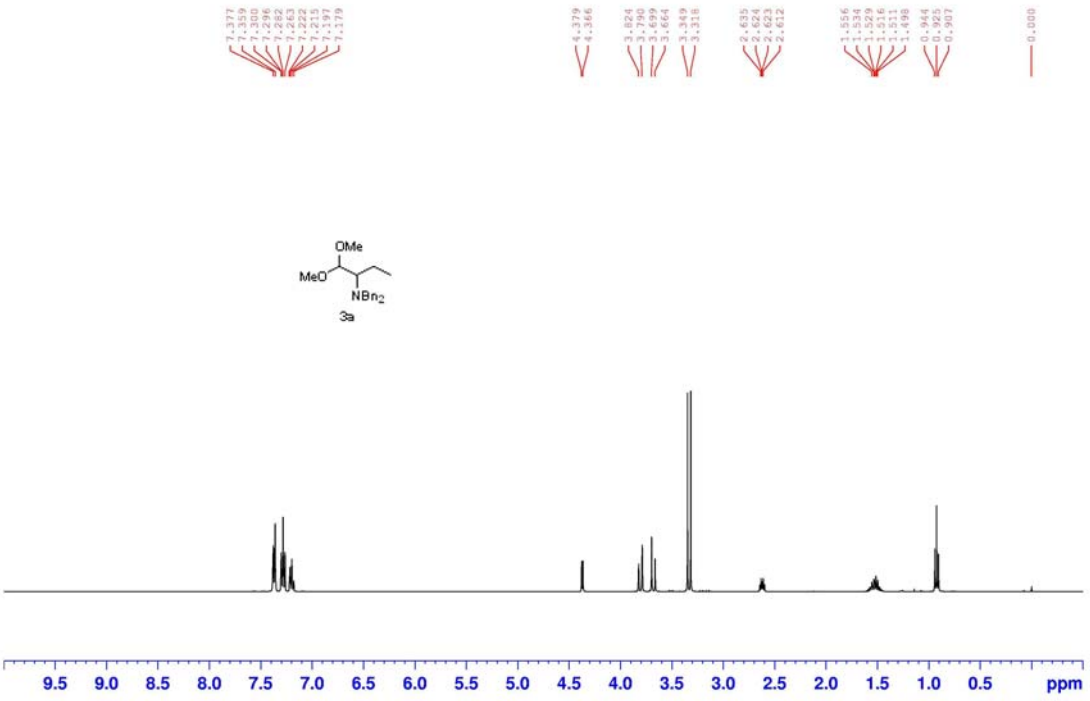
1 C. R. Smith, T. V. RajanBabu, *Org. Lett.,* 2008, **10**, 1657.

2 S. Mukherjee, B. List, *J. Am. Soc. Chem.,* 2007, **129**, 11336.

3 D. M. Hodgson, C. D. Bray, N. D. Kindon, N. J. Reynolds, S. J. Coote, J. M. Um, K. N. Houk, *J. Org. Chem.,* 2009, **74**, 1019.

4 M. Huckstep, R. J. K. Taylop, *Synthesis* 1982, 881.

5 S. Ciblat, J. Kim, C. A. Stewart, J. Z. Wang, P. Forgione, D. Clyne, L. A. Paquette, *Org. Lett.*, 2007, 719.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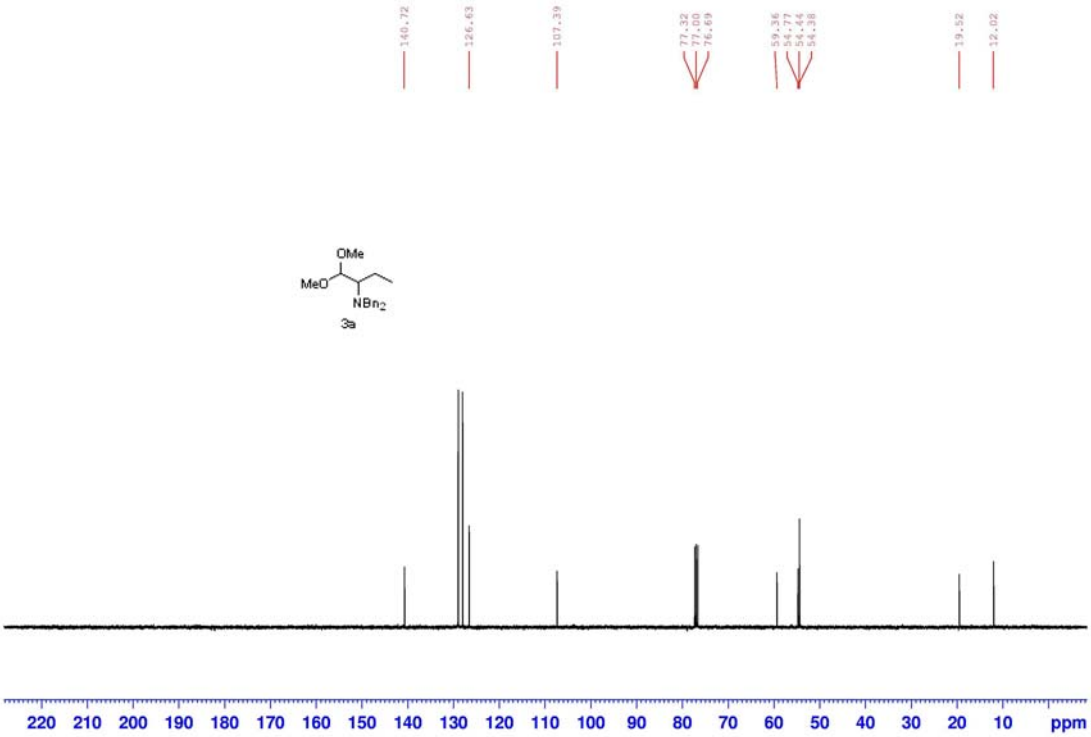
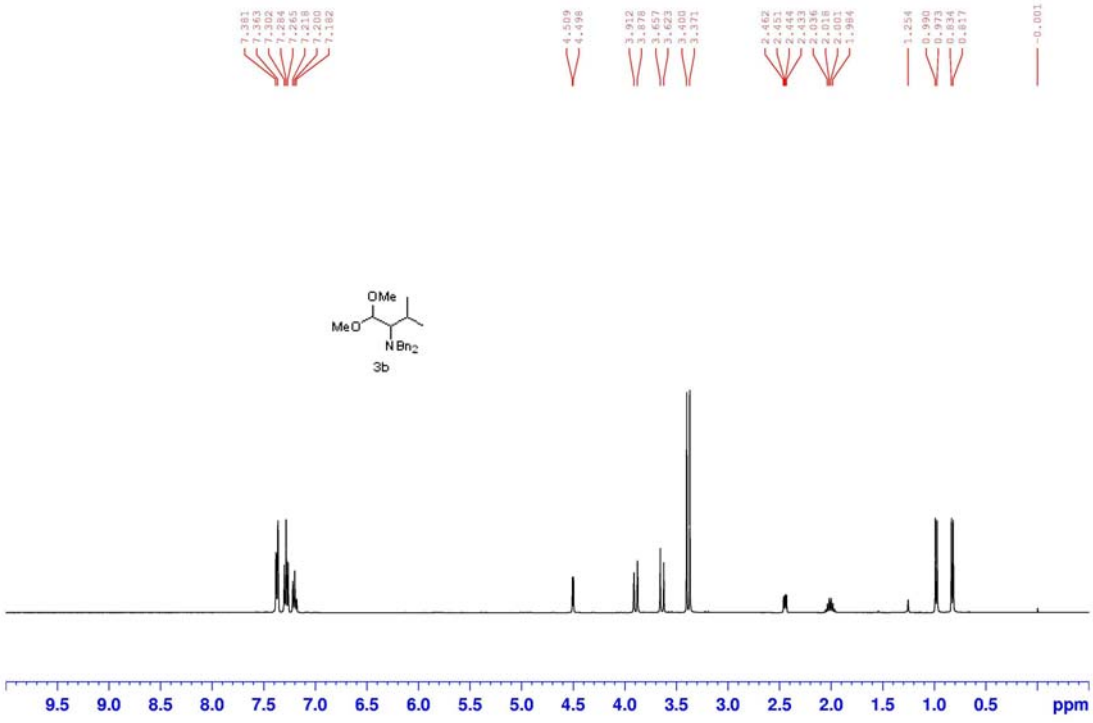
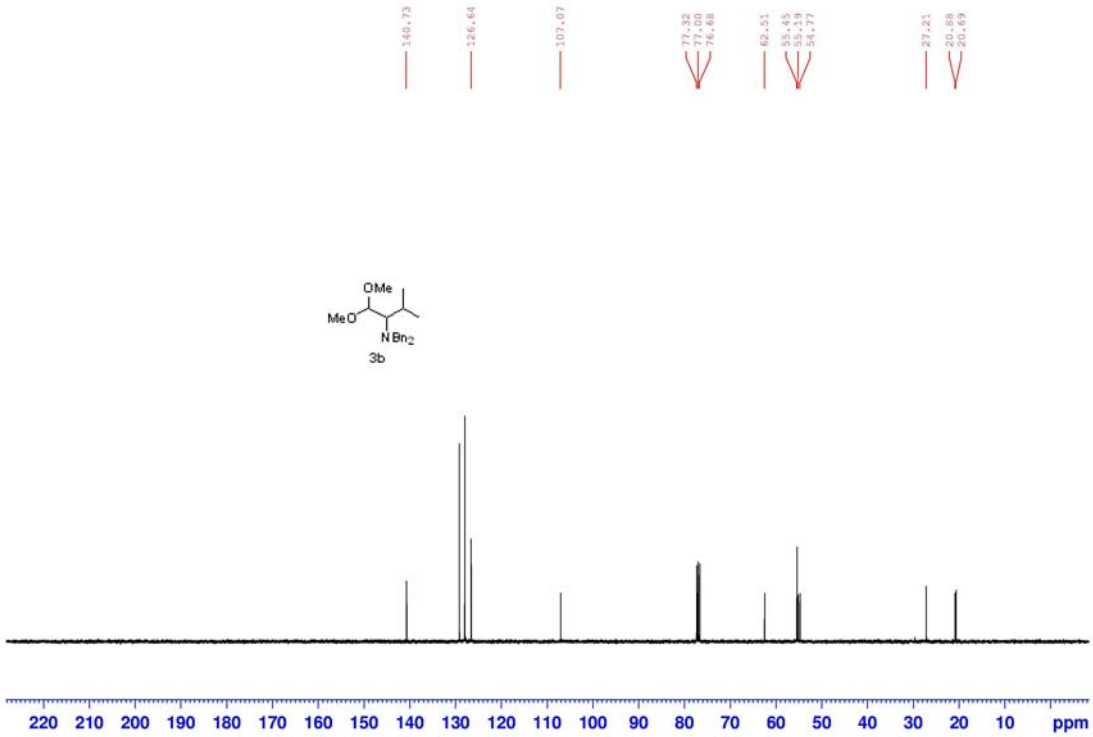
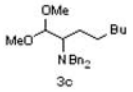
7.359
7.300
7.296
7.282
7.263
7.222
7.215
7.191
7.179
4.379
4.366
3.824
3.790
3.699
3.664
3.349
3.318
2.635
2.624
2.623
2.612
1.556
1.534
1.529
1.516
1.511
1.498
0.944
0.925
0.907
0.000
OMe
MeO
NBn2
3a
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm


140.72
126.63
107.39
77.32
77.00
76.69
59.36
54.77
54.46
54.38
19.52
12.02
OMe
MeO
NBn2
3a
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


7.381
7.363
7.302
7.284
7.265
7.218
7.200
7.182
4.509
4.498
3.912
3.878
3.657
3.623
3.400
3.371
2.462
2.451
2.434
2.418
2.036
2.018
2.001
1.984
1.254
0.990
0.973
0.834
0.817
-0.001
OMe
MeO
NBn2
3b
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm


140.73
126.64
107.07
77.32
77.00
76.68
62.51
55.45
55.19
54.77
27.21
20.88
20.69
OMe
MeO
NBn2
3b
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm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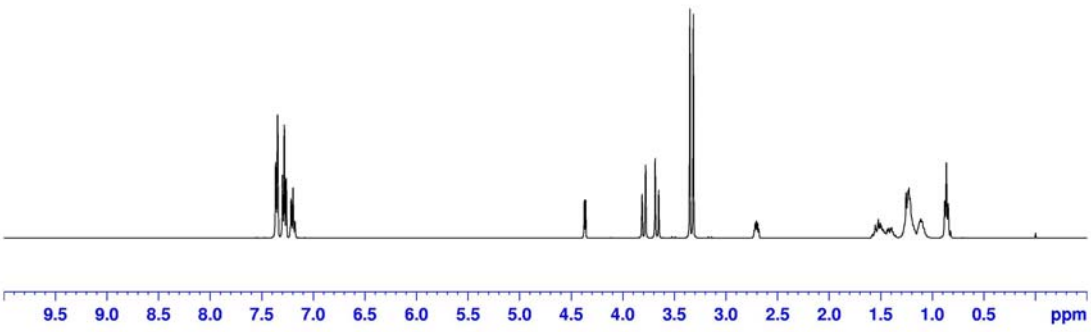
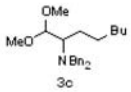
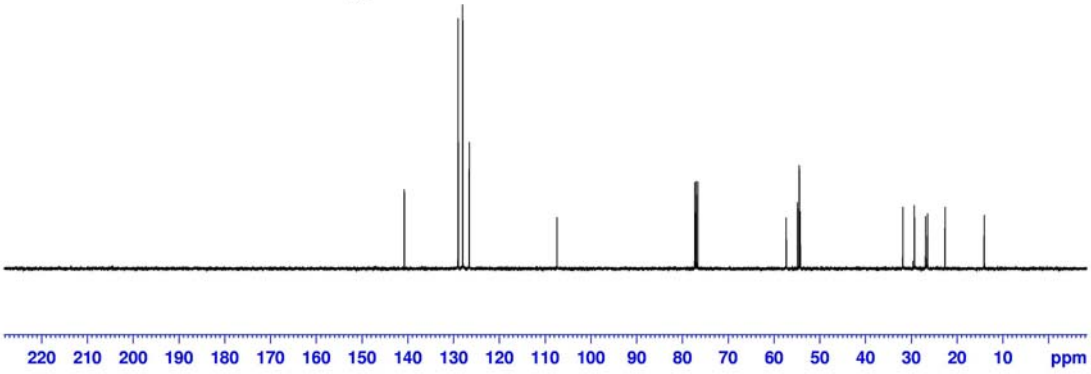
MeO
Bu
N Bn2

3c


9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm


OMe
MeO
Bu
N Bn2

3c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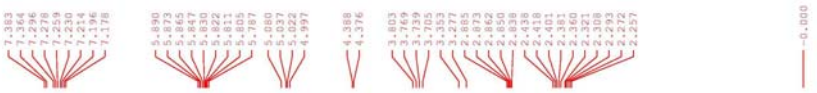
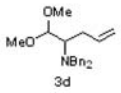
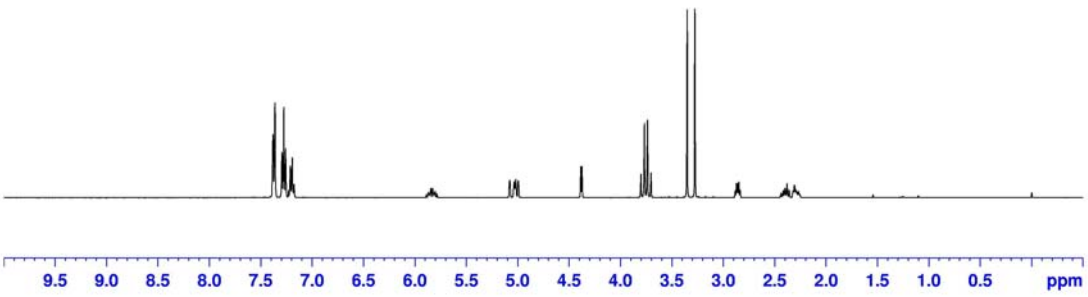
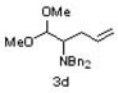


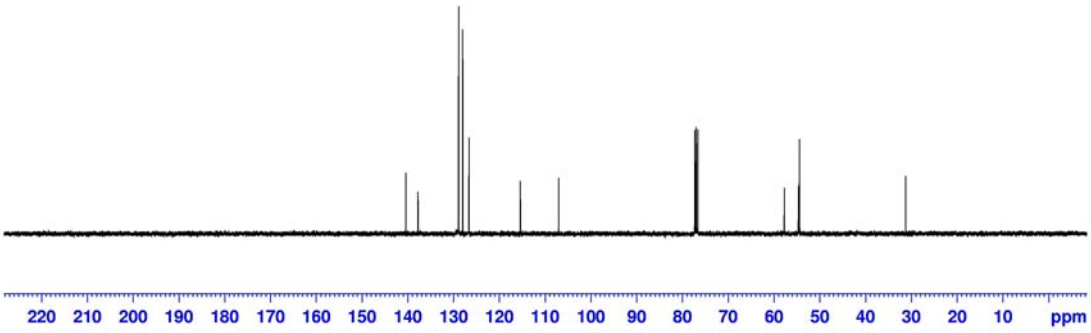

OMe
MeO
NBn2

3d


9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm


OMe
MeO
NBn2

3d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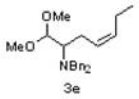
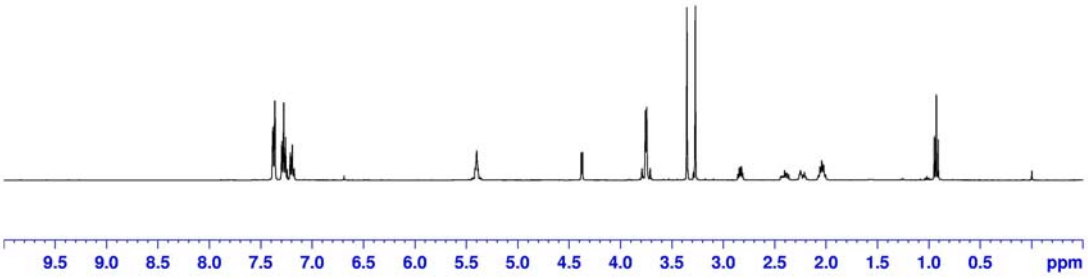
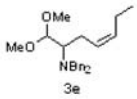
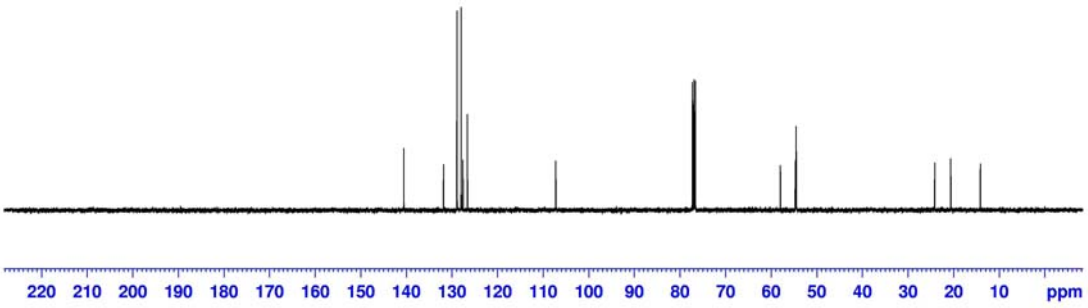

OMe
MeO
NBn2

3e


9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm


OMe
MeO
NBn2

3e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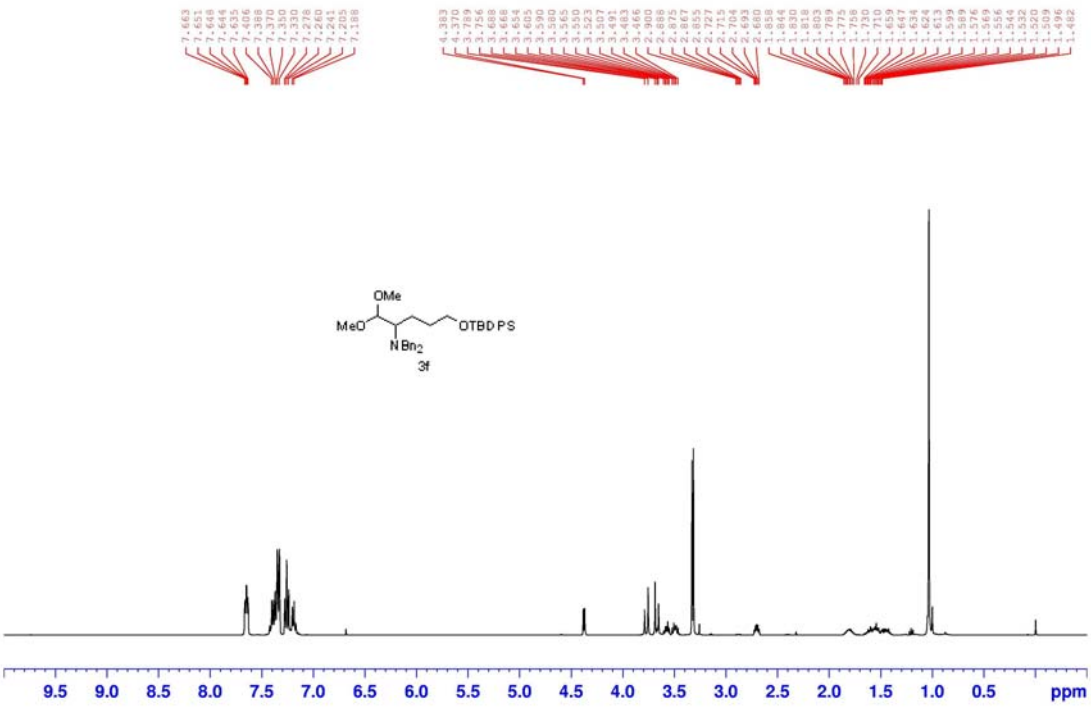
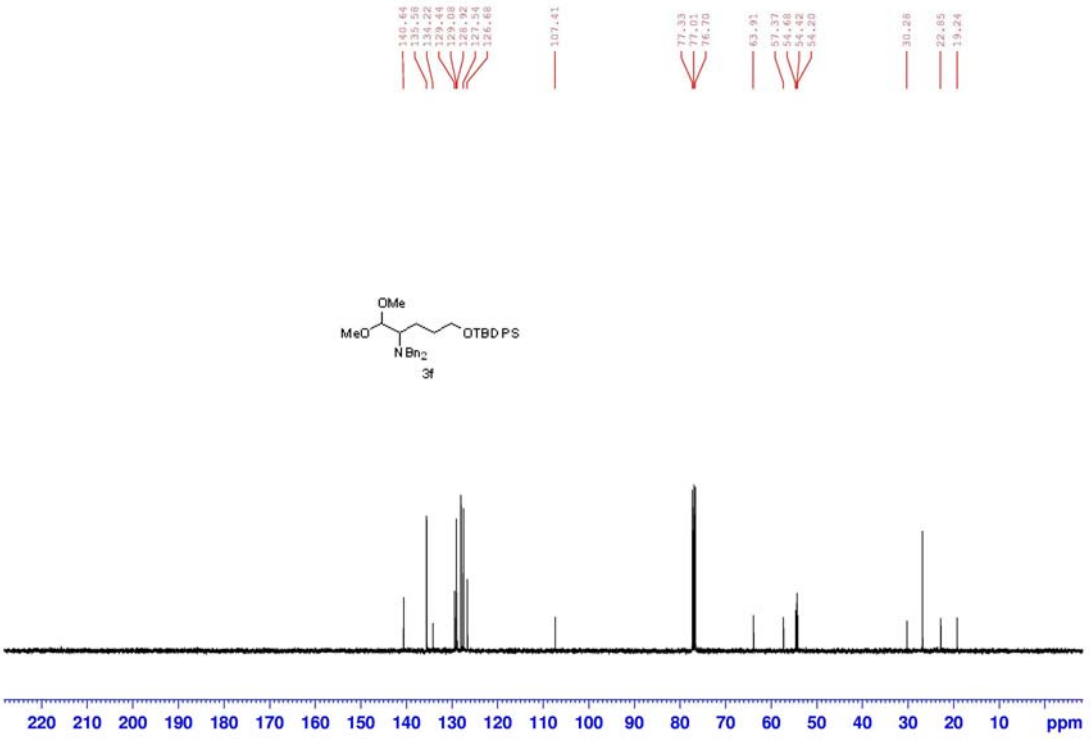
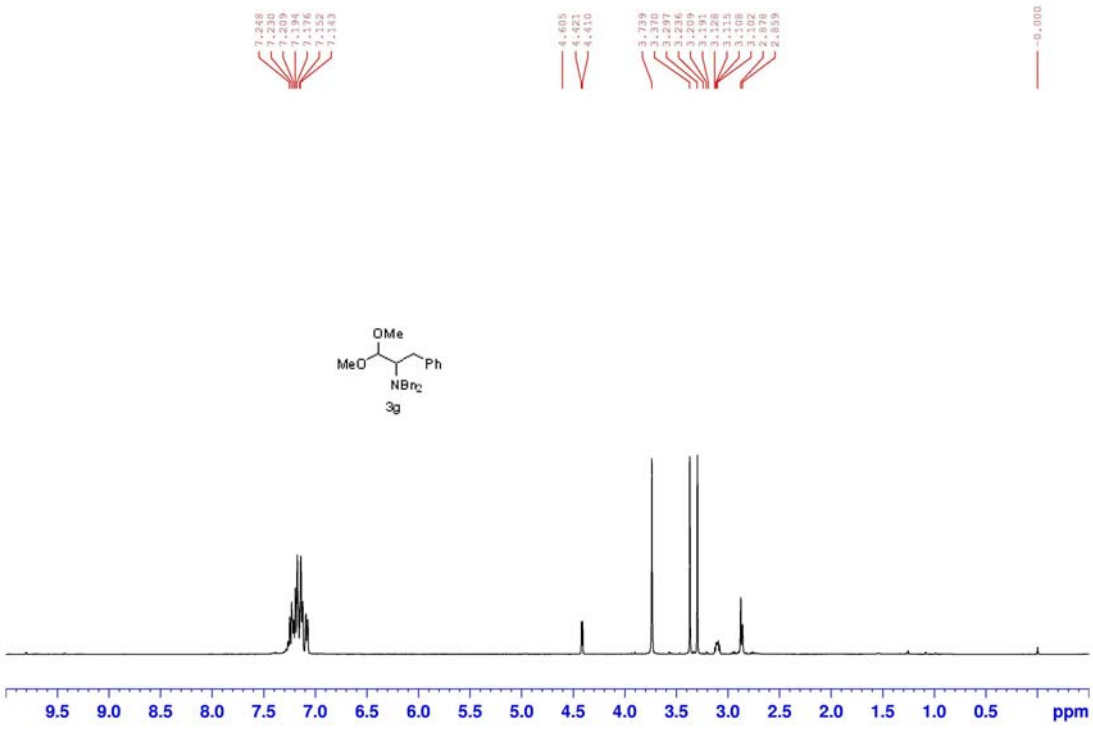

OMe
MeO
OTBDPS
NBn2
3f
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm


OMe
MeO
OTBDPS
NBn2
3f
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm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MeO
Ph
NBn2
3g
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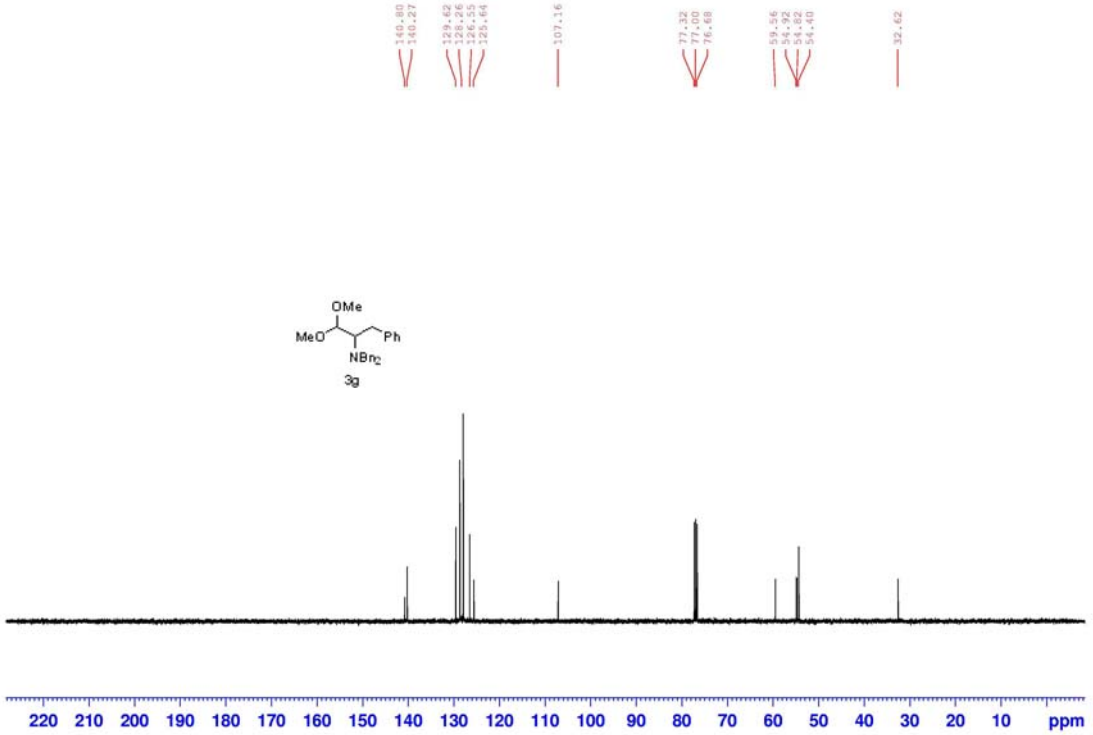
OMe
MeO
Ph
NBn2
3g
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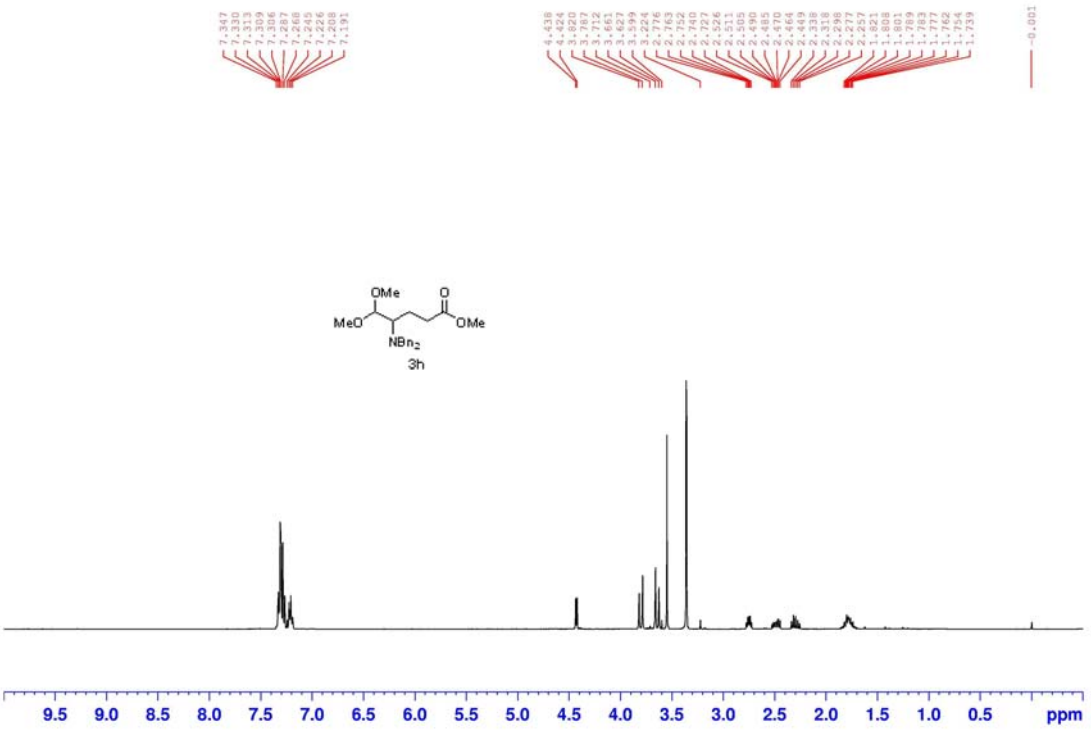
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O
MeO
OMe
NBn2
3h
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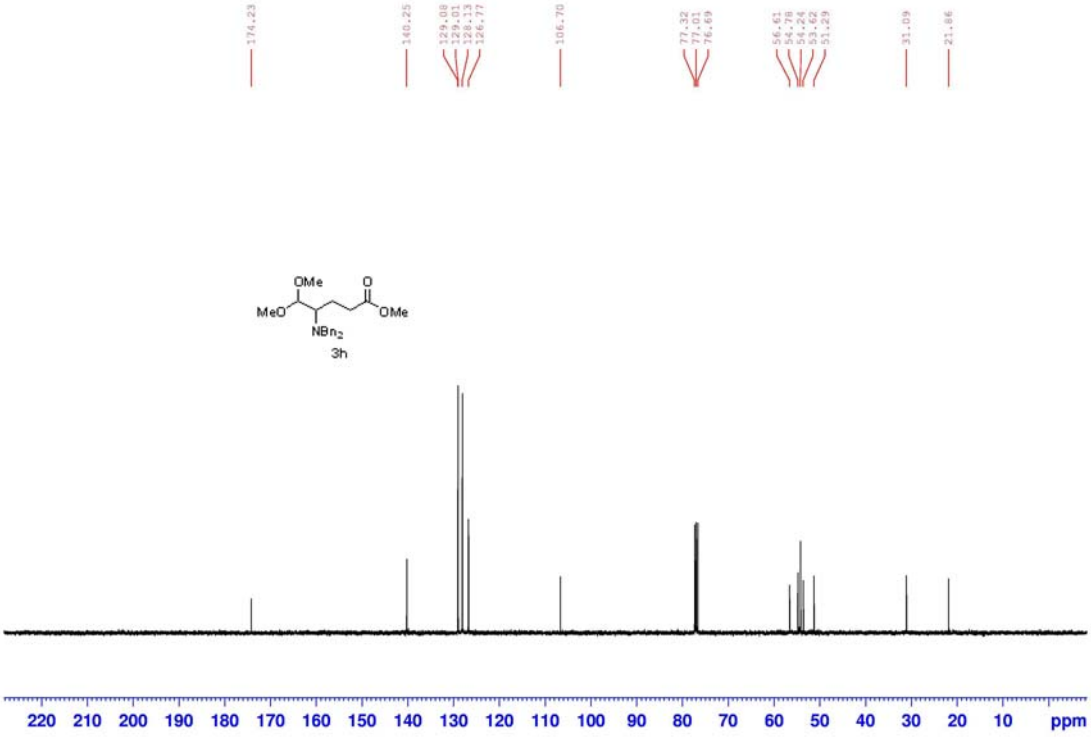
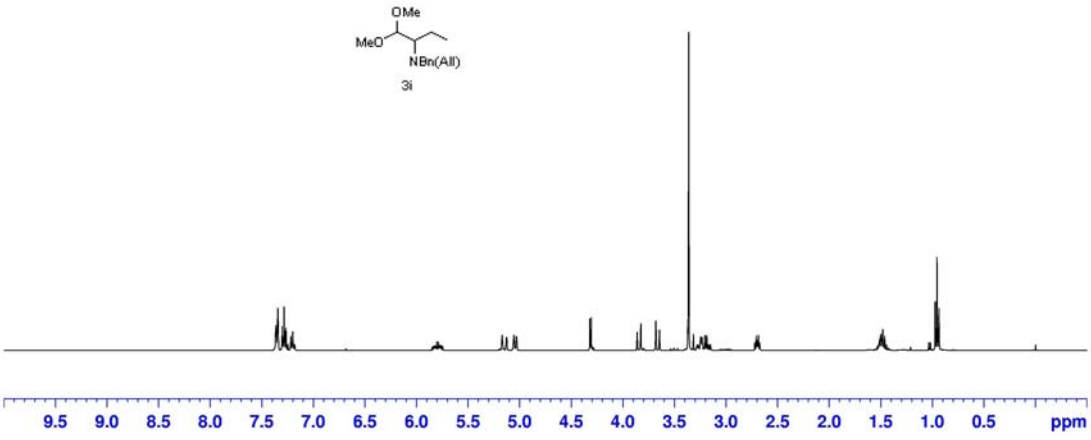

OMe
O
MeO
OMe
NBn2
3h
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


OMe
MeO
NBn(All)
3i
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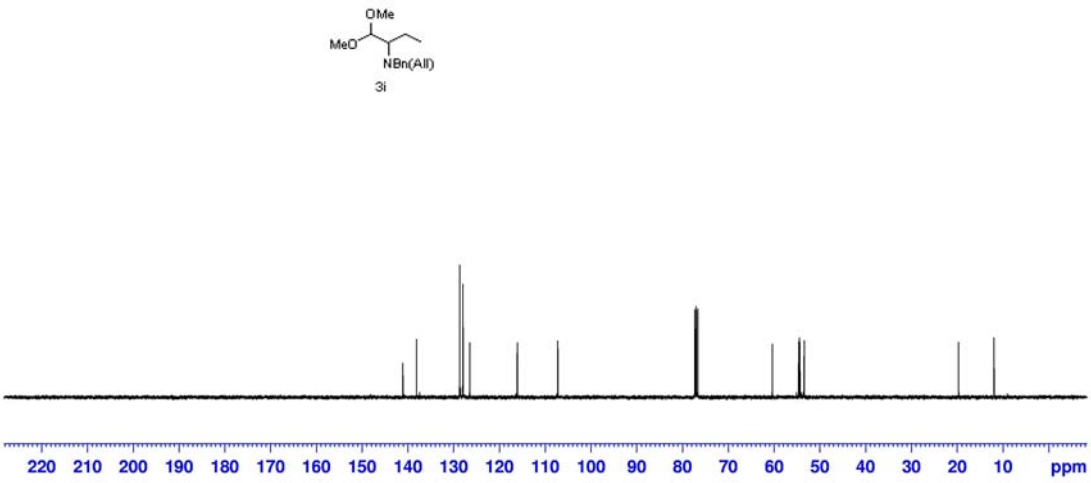
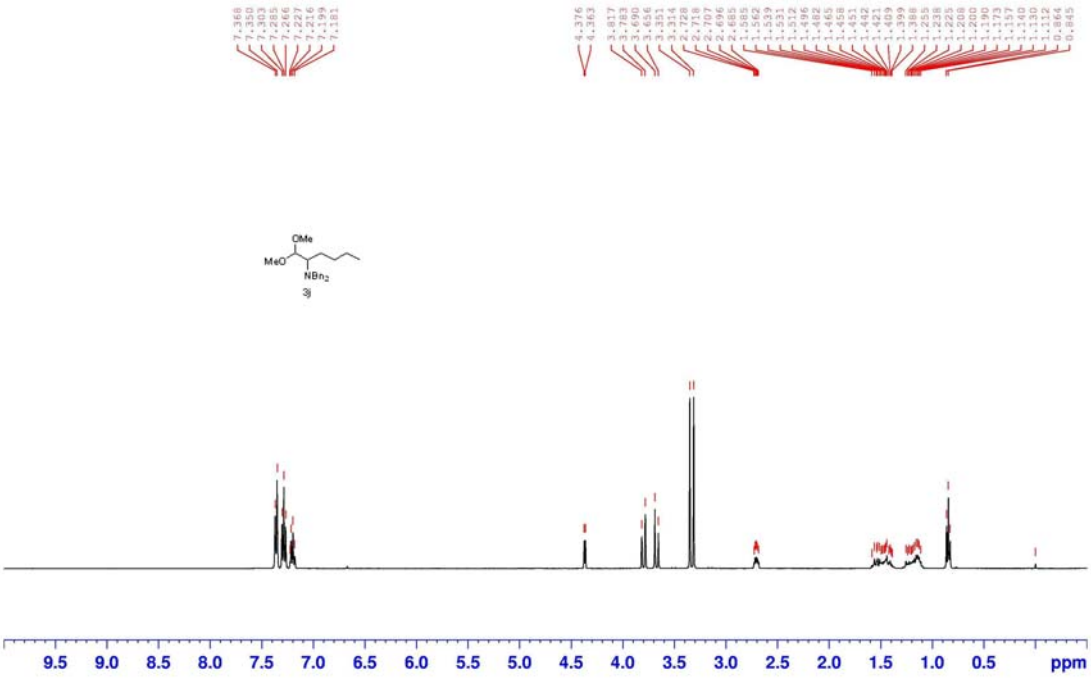

OMe
MeO
NBn(All)
3i
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm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4.363
3.817
3.783
3.690
3.656
3.631
3.314
2.728
2.718
2.707
2.696
2.685
2.675
1.562
1.539
1.531
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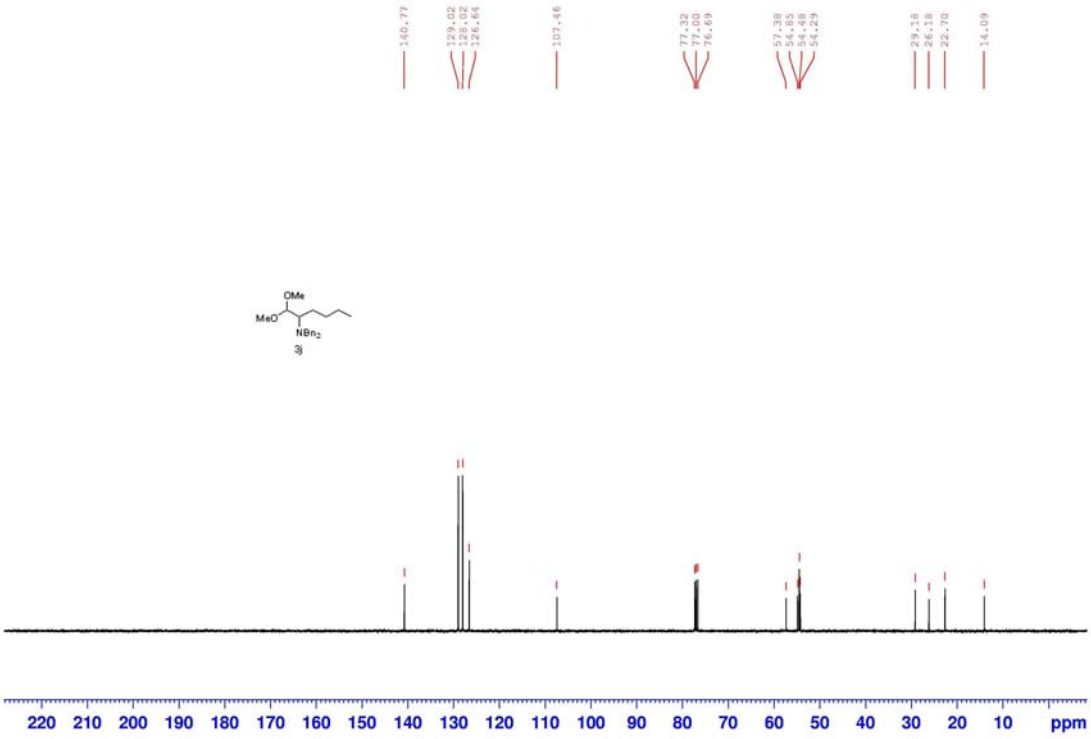
1.288
1.238
1.225
1.208
1.200
1.190
1.173
1.157
1.140
1.130
1.112
0.864
0.845
OMe
MeO
NBn2
3j
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm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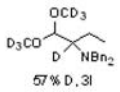
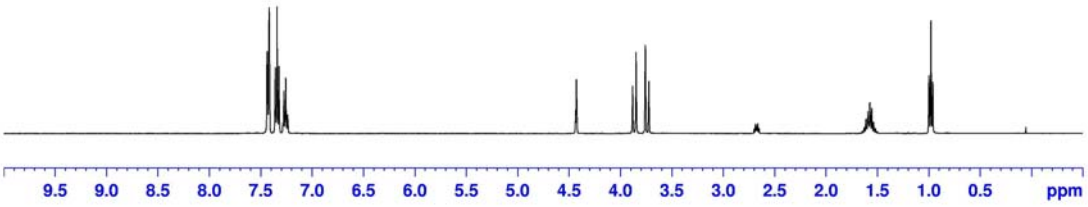
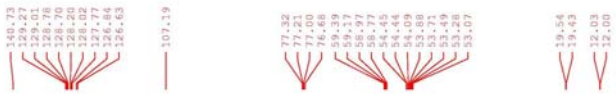
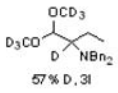
128.02
126.64
107.46
77.32
77.00
76.69
57.38
54.85
54.48
54.29
29.18
26.18
22.70
14.09
OMe
MeO
NBn2
3j
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


OCD3
D3CO
D
NBn2

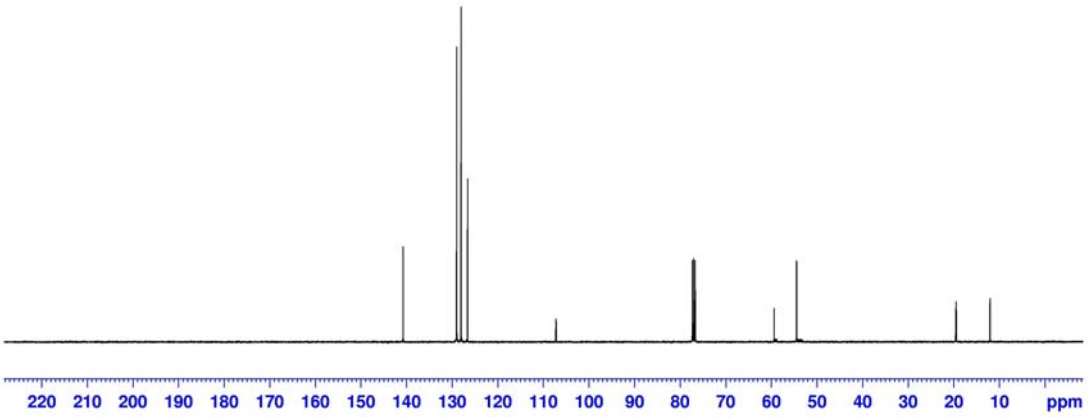
57 % D, 3I


9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm




OCD3
D3CO
D
NBn2

57 % D, 3I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