Supporting Information

A General Strategy for Aliphatic C–H Functionalization Enabled by Organic Photoredox Catalysis

Kaila A. Margrey,[†] William L. Czaplyski,[†] David A. Nicewicz,* and Erik J. Alexanian*

Department of Chemistry, The University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, United States

*eja@email.unc.edu
*nicewicz@email.unc.edu

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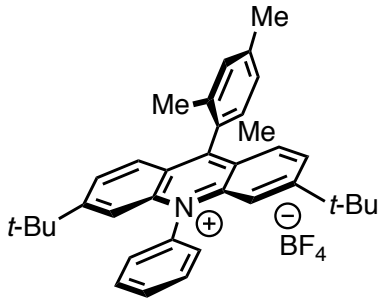
General Methods and Materials

Proton and carbon magnetic resonance spectra (^{1}H NMR and ^{13}C NMR) were recorded on a Bruker model DRX 400 or a Bruker Avance III 600 CryoProbe(^{1}H NMR at 400 MHz and 600 MHz and ^{13}C NMR at 100 and 151 MHz) spectrometer. Chemical shifts for protons are reported in parts per million downfield from tetramethylsilane and are referenced to residual protium in the solvent (^{1}H NMR: $CHCl_3$ at 7.26 ppm). Chemical shifts for carbons are reported in parts per million downfield from tetramethylsilane and are referenced to the carbon resonances of the solvent peak (^{13}C NMR: $CDCl_3$ at 77.16 ppm). Chemical shifts for fluorines are referenced to fluorobenzene as an internal standard (^{19}F NMR: C_6H_5F at –113.15 ppm). ^{1}H NMR data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, sept = septet, oct = octet, dd = doublet of doublets, ddt = doublet of doublet of triplets, ddd = doublet of doublet of doublets, dddd = doublet of doublet of doublet of doublets, m = multiplet, and prefixed br = broad), coupling constants (Hz), and integration.

High resolution mass spectra (HRMS) were obtained using a Thermo LTqFT mass spectrometer with electrospray ionization or atmospheric pressure chemical ionization in positive mode. Infrared (IR) spectra were obtained using a Jasco 260 Plus Fourier transform infrared spectrometer. Gas chromatography (GC) was performed on an Agilent 6850 series instrument equipped with a split-mode capillary injection system and Agilent 5973 network mass spec detector (MSD). Thin layer chromatography (TLC) was performed on SiliaPlate 250 µm thick silica gel plates provided by Silicycle. Visualization was accomplished with short wave UV light (254 nm), cerium ammonium molybdate, *p*-anisaldehyde, or potassium permanganate solution followed by heating. Flash chromatography was performed using SiliaFlash P60 silica gel (40-63 µm) purchased from Silicycle. Irradiation of photochemical reactions was carried out using a PAR38 blue aquarium LED lamp (Model #6851) fabricated with high-power Cree LEDs as purchased from Ecoxotic (www.ecoxotic.com) or Kessil KSH150B Blue 36W LED Grow Lights with standard borosilicate glass vials purchased from Fischer Scientific. For all photolyses, reactions were stirred using a PTFE coated magnetic stir bar on a magnetic stir plate. Yield refers to isolated yield of analytically pure material unless otherwise noted. NMR yields were determined using hexamethyldisiloxane as an internal standard. Tetrahydrofuran, diethyl ether, and dichloromethane were dried by passage through a column of neutral alumina under nitrogen prior to use. All other reagents were obtained from commercial sources and used without further purification unless otherwise noted.

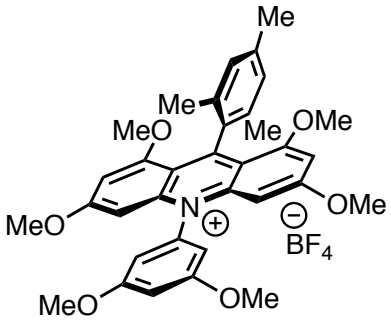
Preparation of Photocatalysts and Reagents

4-Acetamidobenzenesulfonyl azide, *N*-fluorobenzenesulfonimide, diethyl bromomalonate, and *N*-Chlorosuccinimide were used as purchased. Methyl acrylate and methyl vinyl ketone were purchased from commercial sources, deoxygenated via multiple freeze-pump-thaw cycles, purified by vacuum transfer, and stored at –35 ºC under in an argon-filled glovebox prior to use.



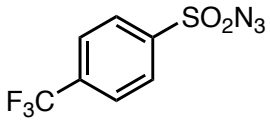
1

9-Mesityl-3,6-di-*tert*-butyl-10-phenylacridinium tetrafluoroborate (*t*-Bu$_2$-Mes-Acr+) (1) was prepared as previously reported by our lab. The spectral data matched the values reported in the literature.[1]



2

10-(3,5-Dimethoxyphenyl)-9-mesityl-1,3,6,8-tetramethoxyacridin-10-ium tetrafluoroborate (OMe$_6$-Mes-Acr+) (2) was prepared as previously reported by our lab. The spectral data matched the values reported in the literature.[2]

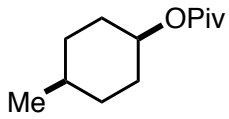


3

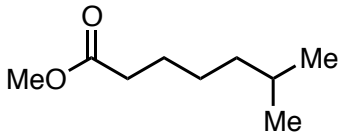
4-(Trifluoromethyl)benzenesulfonyl azide (3) was prepared as previously reported. The spectral data matched the values reported in the literature.[3]

Preparation of Substrates

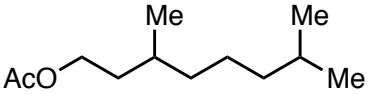
Cyclohexane, cycloheptane, cyclooctane, *trans*-decalin, adamantane, *n*-propylbenzene, *t*-butyl cyclohexane, isopropylbenzene, 3,7-dimethyl-1-octanol, 2-(1-adamantyl)-4-bromoanisole, and 5-α-cholestan-3-one were used as purchased.



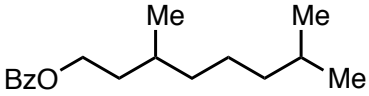
***Cis*-4-methylcyclohexyl pivalate** was prepared according to a published procedure; spectral data were in agreement with literature values.[4]



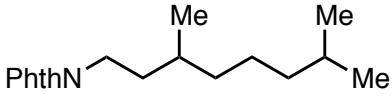
Methyl 6-methylheptanoate was prepared according to a published procedure; spectral data were in agreement with literature values.[5]



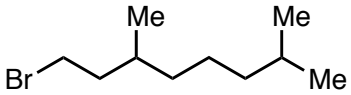
3,7-Dimethyloctyl acetate was prepared according to a published procedure; spectral data were in agreement with literature values.[6]



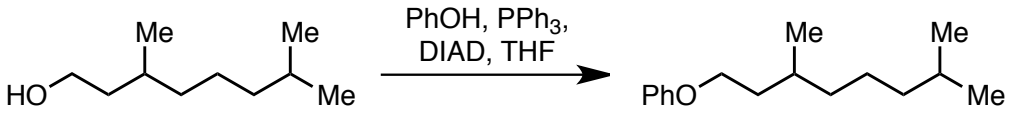
3,7-Dimethyloctyl benzoate was prepared according to a published procedure; spectral data were in agreement with literature values.[7]



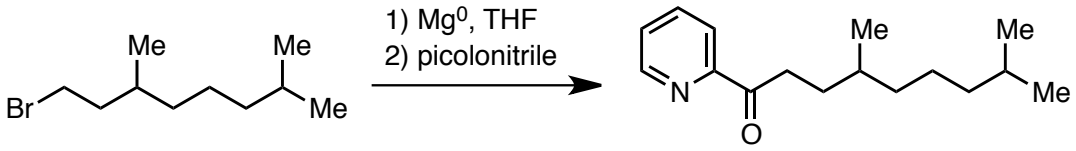
2-(3,7-Dimethyloctyl)isoindoline-1,3-dione was prepared according to a published procedure; spectral data were in agreement with literature values.[8]



1-Bromo-3,7-dimethyloctane was prepared according to a published procedure; spectral data were in agreement with literature values.[6]

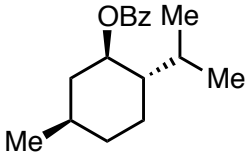


((3,7-Dimethyloctyl)oxy)benzene: To a solution of phenol (1 g, 10.6 mmol) and triphenylphosphine (6.1 g, 23.4 mmol) in THF (100 mL) at 0 ºC was added 3,7-dimethyloctanol (4.47 mL, 23.4 mmol) followed by DIAD (4.6 mL, 23.4 mmol). The solution was warmed to rt overnight, the concentrated *in vacuo*. The residue was triturated with hexanes, and the solution was concentrated *in vacuo* and purified by flash column chromatography (0 – 5% EtOAc in hexanes) affording the product as a colorless liquid (990 mg, 40% yield). Spectral data were in agreement with literature values.[9]

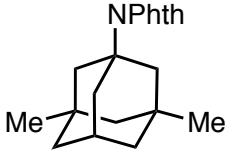


4,8-Dimethyl-1-(pyridin-2-yl)nonan-1-one: To a suspension of magnesium (100 mg, 4.1 mmol) and an iodine crystal in THF (2 mL) was added 1-bromo-3,7-dimethyloctane (995 mg, 4.5 mmol) in THF (7 mL) dropwise. Gentle heating to facilitate initiation was accomplished with a heat gun. Subsequently, picolonitrile (395 μL, 4.1 mmol) was added at room temperature and stirred overnight. The reaction was quenched with 1M HCl, stirred for 3 hours, and then quenched with aqueous $NaHCO_3$. The solution was extracted three times with EtOAc, and the combined organic layers were washed with brine, dried with $MgSO_4$, and concentrated *in vacuo*. The resultant oil was purified by flash column chromatography (10–20% EtOAc/Hex) affording the product in a 17% yield (170 mg):

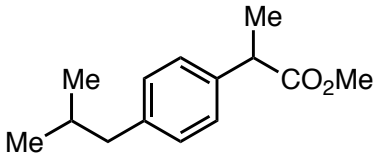
^{1}H NMR (600 MHz, $CDCl_3$) δ 8.63 (d, *J* = 5.0 Hz, 1H), 7.98 (d, *J* = 7.8 Hz, 1H), 7.83 – 7.66 (m, 1H), 7.40 (dd, *J* = 7.6, 4.8 Hz, 1H), 3.24 – 3.05 (m, 2H), 1.84 – 1.70 (m, 1H), 1.48 (ddt, *J* = 19.7, 13.4, 6.5 Hz, 3H), 1.33 – 1.16 (m, 2H), 1.10 (h, *J* = 6.7, 5.4 Hz, 4H), 0.88 (d, *J* = 6.3 Hz, 3H) 0.81 (d, *J* = 6.7 Hz, 6H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 202.45, 153.65, 148.94, 136.86, 126.97, 121.78, 39.36, 37.14, 35.48, 32.69, 31.03, 28.03, 24.81, 22.78, 22.68, 19.66.
HRMS (ESI): calculated for $C_{16}H_{26}NO$ $[M+H]^+$= 248.2009; found 248.2010.



(1*R*,2*S*,5*R*)-2-Isopropyl-5-methylcyclohexyl benzoate was prepared according to a published procedure; spectral data were in agreement with literature values.[10]



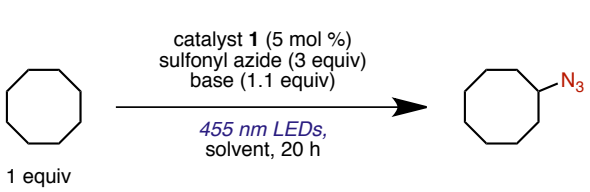
2-(3,5-Dimethyladamantan-1-yl)isoindoline-1,3-dione was prepared according to a published procedure; spectral data were in agreement with literature values.[11]

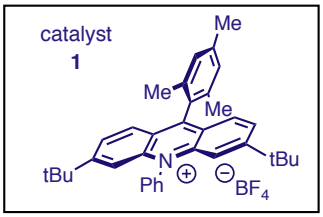


Methyl 2-(4-isobutylphenyl)propanoate was prepared according to a published procedure; spectral data were in agreement with literature values.[12]

Reaction Optimization

Table S1. Initial optimization of C–H azidation.

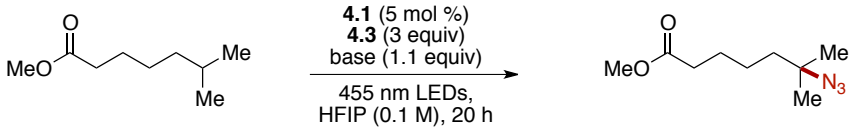




Entry	Sulfonyl Azide	Solvent (concentration)	Base	^{1}H NMR Yield
1	*p*-AcHN-$C_6H_4SO_2N_3$	DCE (0.1 M)	K_3PO_4	30%
2	*p*-AcHN-$C_6H_4SO_2N_3$	DCE (0.1 M)	K_3PO_4 (3 equiv)	23%
3	*p*-AcHN-$C_6H_4SO_2N_3$	DCE/TFE (1:1, 0.1 M)	K_3PO_4	40%
4	*p*-AcHN-$C_6H_4SO_2N_3$	TFE (0.1 M)	K_3PO_4	50%
5	*p*-AcHN-$C_6H_4SO_2N_3$	HFIP (0.1 M)	K_3PO_4	70%
6	*p*-AcHN-$C_6H_4SO_2N_3$	HFIP (0.05 M)	K_3PO_4	53%
7	*p*-AcHN-$C_6H_4SO_2N_3$	HFIP (0.2 M)	K_3PO_4	65%
8	*p*-AcHN-$C_6H_4SO_2N_3$	HFIP/pH 8 phosphate buffer (4:1, 0.1 M)	–	60%
9	*p*-F_3C-$C_6H_4SO_2N_3$	HFIP (0.1 M)	K_3PO_4	72%
10	*p*-F_3C-$C_6H_4SO_2N_3$	HFIP (0.1 M)	–	0%
11*	*p*-F_3C-$C_6H_4SO_2N_3$	HFIP (0.1 M)	K_3PO_4	0%

*no catalyst **1**

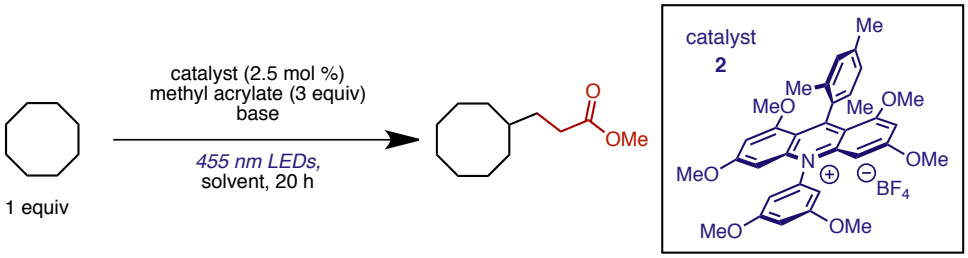
Table S2. Base screen for C–H azidation.



Entry	Base	^{1}H NMR Yield	Remaining Substrate
1	K_3PO_4	71%	28%
2	K_2HPO_4	52%	48%
3	KH_2PO_4	9%	71%
4	KOBz	39%	60%
5	$(NBu_4)OBz$	32%	68%
6	$NaHCO_3$	36%	56%
7	Na_2CO_3	61%	15%
8	Cs_2CO_3	33%	16%
9	iPr_2NEt	3%	95%
10	K_3PO_4 (3 equiv)	53%	44%
11	K_3PO_4 (10 mol %)	30%	68%

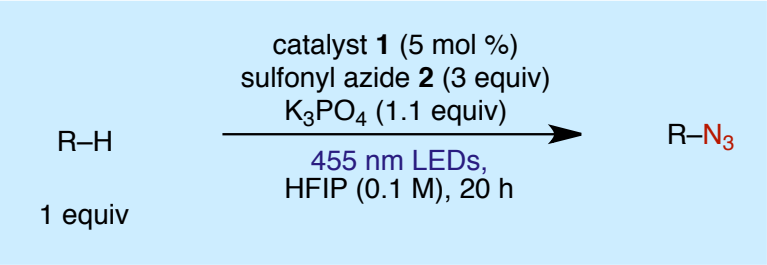
Several anionic inorganic bases provided the tertiary azide, and in no cases was secondary azidation observed, consistent with a common mechanistic role of the base.

Table S3. Optimization of C–H alkylation.

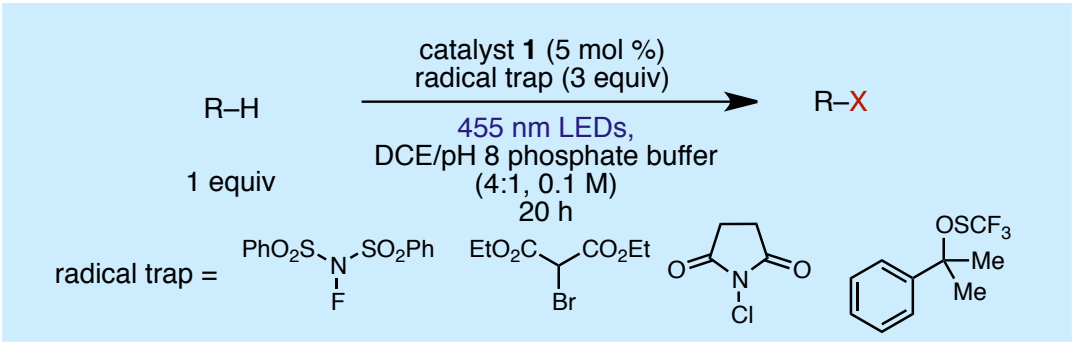


Entry	Catalyst	Solvent (concentration)	^{1}H NMR Yield
1	**1**	DCE/TFE/4M pH 8 phosphate buffer (7:1:2, 0.1 M)	10%
2	**2**	DCE/TFE/4M pH 8 phosphate buffer (7:1:2, 0.1 M)	23%
3	**2**	DCE/4M pH 8 phosphate buffer (4:1, 0.1 M)	0%
4	**2**	TFE/4M pH 8 phosphate buffer (4:1, 0.1 M)	5%
5	**2**	DCE/TFE/4M pH 9 phosphate buffer (7:1:2, 0.1 M)	12%
6	**2**	DCE/TFE/4M pH 10 phosphate buffer (7:1:2, 0.1 M)	2%
7	**2**	DCE/TFE/2M pH 8 phosphate buffer (7:1:2, 0.1 M)	23%
8	**2**	DCE/TFE/4M pH 8 phosphate buffer (7:1:4, 0.08 M)	**43%**
9	**2**	DCE/TFE/4M pH 8 phosphate buffer (7:1:8, 0.06 M)	23%

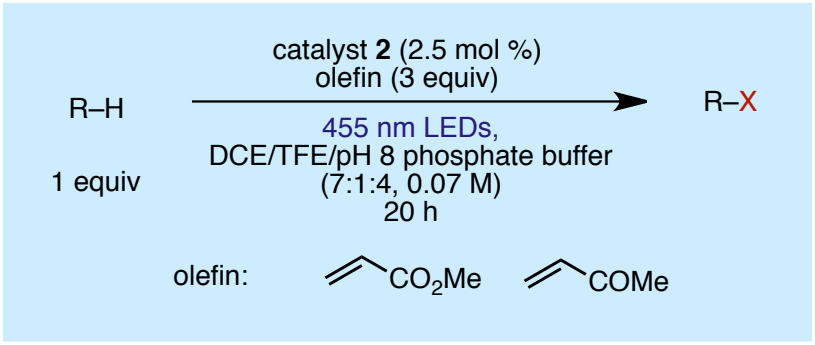
Products of Aliphatic C–H Functionalization



General Procedure A (Azidation): In an argon-filled glovebox, a 1 dram vial with a Teflon-coated magnetic stir bar was charged with ***t*Bu$_2$-Mes-Acr$^+$ 1** (0.05 equiv), 4-(trifluoromethyl)benzenesulfonyl azide (3 equiv), K_3PO_4 (1.1 equiv), and the alkane substrate (1 equiv). Hexafluoroisopropanol (HFIP) was added (0.1 M wrt alkane), and the vial was sealed with a Teflon-lined septum screw cap. The vial was positioned on a stir plate approximately 2 – 3 cm from a Par38 LED lamp supplying blue light (λ = 440-460 nm). After irradiation for 20 hours, the reaction mixture was passed over a short plug of silica and concentrated *in vacuo*. The residue was analyzed by ^{1}H NMR or purified by column chromatography on silica gel with the eluent noted for each substrate. Analysis of crude reaction mixtures by GC-MS indicated the formation of 1,1,1,3,3,3-hexafluoropropan-2-yl 4-(trifluoromethyl)benzenesulfonate as the main reaction byproduct, presumably formed via nucleophilic displacement of the corresponding alkoxide with 4-(trifluoromethyl)benzenesulfonyl azide.



General Procedure B (Halogenation and Trifluoromethylthiolation): In an argon-filled glovebox, a 1 dram vial with a Teflon-coated magnetic stir bar was charged with *t*Bu$_2$-Mes-Acr$^+$ 1 (0.05 equiv), radical trap (3 equiv), and the alkane substrate (1 equiv). 1,2-Dichloroethane (DCE) was added (0.125 M wrt alkane), and the vial was sealed with a Teflon-lined septum screw cap. Upon removal from the glovebox, 4 M pH 8 phosphate buffer was added (0.25 * amount of DCE added such that total solvent amount is 0.1 M wrt alkane). The vial was positioned on a stir plate approximately 2 – 3 cm from a Par38 LED lamp supplying blue light (λ = 440-460 nm). After irradiation for 4 – 20 hours, the reaction mixture was passed over a short plug of silica and concentrated *in vacuo*. The residue was analyzed by ^{1}H NMR or purified by column chromatography on silica gel with the eluent noted for each substrate.



General Procedure C (Alkylation): In an argon-filled glovebox, a 1 dram vial with a Teflon-coated magnetic stir bar was charged with OMe_6-Mes-Acr^+ **2** (0.0025 equiv), olefin (3 equiv), and the alkane substrate (1 equiv). A mixture of DCE and 2,2,2-trifluoroethanol (TFE) was added (7:1, 0.125 M wrt alkane), and the vial was sealed with a Teflon-lined septum screw cap. Upon removal from the glovebox, 4 M pH 8 phosphate buffer was added (0.5 * amount of organic solvent mixture added such that total solvent amount is 0.07 M wrt alkane). For methyl acrylate as the olefin, the vial was positioned on a stir plate approximately 2 – 3 cm from a Par38 LED lamp supplying blue light (λ = 440-460 nm). For methyl vinyl ketone as the olefin, the vial was positioned on a stir plate approximately 2 cm from two Kessil KSH150B Blue 36W LED Grow Lights supplying blue light. After irradiation for 20 hours, the reaction mixture was passed over a short plug of silica and concentrated *in vacuo*. The residue was analyzed by ^{1}H NMR or purified by column chromatography on silica gel with the eluent noted for each substrate. Analysis of crude reaction mixtures by GC-MS indicated the formation of methyl 3-(2,2,2-trifluoroethoxy)propanoate or 4-(2,2,2-trifluoroethoxy)butan-2-one as the main reaction byproducts (depending on olefin used), presumably formed via nucleophilic addition of the corresponding alkoxide to the olefin trap.

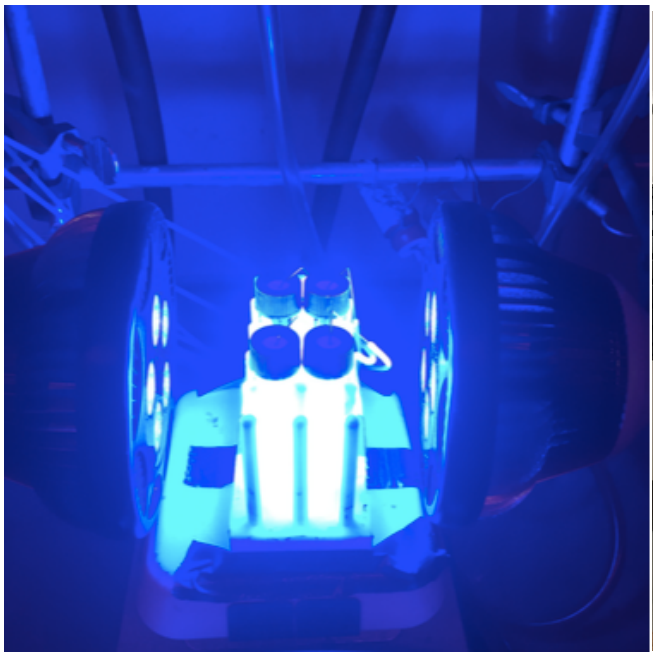
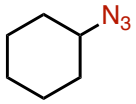
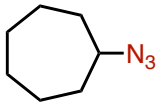


Figure S1. Photoreactor set up. Left: Ecoxotic Par38 LED lamp setup (General Procedures A, B, C for methyl acrylate). Right: Kessil Blue LED light setup (General Procedure C for methyl vinyl ketone).



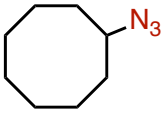
4

Azidocyclohexane (4): Prepared according to General Procedure A (0.1 mmol scale) using cyclohexane, giving 58% yield by ^{1}H NMR. The spectra matched literature values.[13]



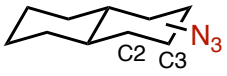
5

Azidocycloheptane (5): Prepared according to General Procedure A (0.1 mmol scale) using cycloheptane, giving 57% yield by ^{1}H NMR. The spectra matched literature values.[14]



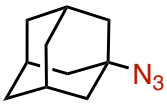
6

Azidocyclooctane (6): Prepared according to General Procedure A (0.1 mmol scale) using cyclooctane, giving 70% yield by ^{1}H NMR. The spectra matched literature values.[6]



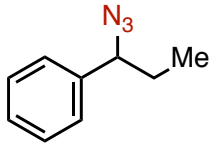
7

(2*R*,4a*R*,8a*R*)-2-Azidodecahydronaphthalene (7): Prepared according to General Procedure A (0.1 mmol scale) using *trans*-decalin, giving 57% yield by ^{1}H NMR and a 1.4:1 ratio of C3:C2. The spectra matched literature values.[13]



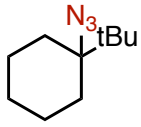
8

1-Azidoadamantane (8): Prepared according to General Procedure A (0.1 mmol scale) using adamantane, giving 75% yield by ^{1}H NMR. The spectra matched literature values.[13]



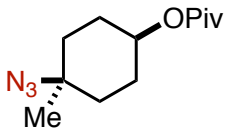
9

(1-Azidopropyl)benzene (9): Prepared according to General Procedure A (0.1 mmol scale) using *n*-propylbenzene, giving 46% yield by ^{1}H NMR. The spectra matched literature values.[13]



10

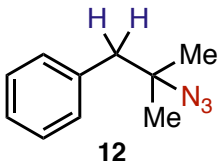
1-Azido-1-(*tert*-butyl)cyclohexane (10): Prepared according to General Procedure A (0.1 mmol scale) using *tert*-butylcyclohexane, giving 51% yield by ^{1}H NMR. The spectra matched literature values.[6]



11

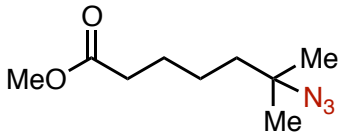
(1*s*,4*s*)-4-Azido-4-methylcyclohexyl pivalate (11): Prepared according to General Procedure A (0.1 mmol scale) using *cis*-4-methylcyclohexyl pivalate. ^{1}H NMR analysis of the crude reaction indicated a dr of 1.4:1 with a total NMR yield of 45%. The residue was purified by column chromatography on silica gel (0 to 10% Et_2O/Hexanes) to afford **12** (6.3 mg, 24% yield). Characterization data reported for a single isolated diastereomer:

^{1}H NMR (600 MHz, $CDCl_3$) δ 4.68 (tt, *J* = 9.8, 4.2 Hz, 1H), 1.85 – 1.71 (m, 4H), 1.68 (m, 2H), 1.52 – 1.43 (m, 2H), 1.32 (s, 3H), 1.19 (s, 9H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 178.21, 71.02, 60.54, 38.86, 34.28, 27.35, 27.29, 27.23.
HRMS (APCI): calculated for $C_{12}H_{21}N_3O_2Na$ $[M+Na]^+$= 262.1526; found 262.1436.
IR (film) cm^{-1} 2921.63, 2850.27, 2100.10, 1716.34, 1698.02, 1507.10, 1296.92.



12

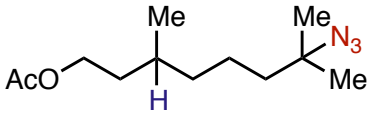
(2-Azido-2-methylpropyl)benzene (12). Prepared according to General Procedure A (0.1 mmol scale) using isopropylbenzene, giving 46% combined yield by ^{1}H NMR (1.3:1 site selectivity favoring the tertiary product). The spectra matched literature values.[15]



13

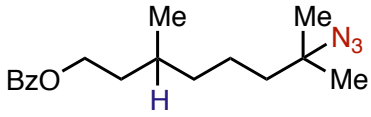
Methyl 6-azido-6-methylheptanoate (13): Prepared according to General Procedure A (0.1 mmol scale) using methyl 6-methylheptanoate. The crude residue was purified by column chromatography on silica gel (0 to 10% Et_2O/Hexanes) to afford **13** (14.2 mg, 71% yield):

^{1}H NMR (600 MHz, $CDCl_3$) δ 3.74 – 3.63 (m, 3H), 2.36 – 2.28 (m, 2H), 1.66 – 1.59 (m, 2H), 1.52 – 1.44 (m, 2H), 1.38 (dd, *J* = 7.4, 4.1 Hz, 2H), 1.24 (dd, *J* = 4.2, 2.4 Hz, 6H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 174.07, 61.59, 51.64, 41.21, 34.04, 26.09, 25.26, 23.94.
HRMS (ESI): calculated for $C_9H_{17}N_3O_2Na$ $[M+Na]^+$= 222.1213; found 222.1218.
IR (film) cm^{-1} 2949.59, 2869.56, 2096.24, 1740.44, 1463.71, 1370.18, 1252.54.



14

7-Azido-3,7-dimethyloctyl acetate (14): Prepared according to General Procedure A (0.1 mmol scale) using 3,7-dimethyloctyl acetate. The crude residue was purified by column chromatography on silica gel (0 to 10% Et_2O/Hexanes) to give **14** in 73% yield and a 4:1 ratio of inseparable 3° isomers. The spectra matched literature values.[6]



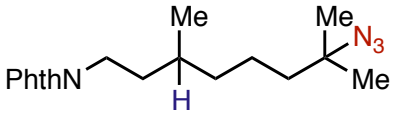
15

7-Azido-3,7-dimethyloctyl benzoate (15): Prepared according to General Procedure A (0.1 mmol scale) using 3,7-dimethyloctyl benzoate. The crude residue was purified by column chromatography on silica gel (0 to 10% Et_2O/Hexanes) to afford **15** (27.7 mg, 91% yield, 3:1 ratio of inseparable 3° isomers). Characterization data reported for major isomer:

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.06 – 8.02 (m, 2H), 7.60 – 7.53 (m, 1H), 7.45 (d, *J* = 7.8 Hz, 2H), 4.40 – 4.32 (m, 2H), 1.85 – 1.78 (m, 1H) 1.70 – 1.63 (m, 1H), 1.62 – 1.57 (m, 1H), 1.49 – 1.30 (m, 5H), 1.25 (s, 6H), 1.23 – 1.15 (m, 1H), 1.00 – 0.97 (m, 3H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 166.81, 132.97, 130.63, 129.67, 128.48, 63.57, 61.79, 41.81, 37.27, 35.69, 30.08, 26.17, 26.14, 21.73, 19.66.

HRMS (ESI): calculated for $C_{17}H_{25}N_3O_2Na$ $[M+H]^+$= 326.1839; found 326.1840.
IR (film) cm^{-1} 2959.23, 2131.92, 2098.17, 1719.23, 1406.82, 1275.68, 1176.36.

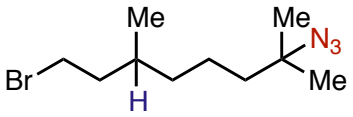
The reaction was also performed on 1 mmol scale in a scintillation vial with irradiation from 1 Ecoxotic lamp for 2 days and purified to afford **15** (182 mg, 60% yield). The decrease in yield is likely due to reduced light penetration through the thicker-walled scintillation vial.



16

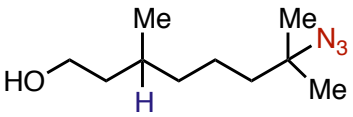
2-(7-Azido-3,7-dimethyloctyl)isoindoline-1,3-dione (16): Prepared according to General Procedure A (0.1 mmol scale) using 2-(3,7-dimethyloctyl)isoindoline-1,3-dione. The crude residue was purified by column chromatography on silica gel (0 to 10% Et_2O/Hexanes) to afford **16** (24.7 mg, 72% yield, 3:1 ratio of inseparable 3° isomers). Characterization data reported for major isomer:

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.83 (dd, *J* = 5.4, 3.0 Hz, 2H), 7.70 (dd, *J* = 5.4, 3.1 Hz, 2H), 3.70 (dq, *J* = 7.5, 2.9 Hz, 2H), 1.73 – 1.67 (m, 1H), 1.58 – 1.42 (m, 4H), 1.41 – 1.28 (m, 3H), 1.24 (s, 6H), 1.21 – 1.13 (m, 1H), 0.98 (d, *J* = 5.9 Hz, 3H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 168.53, 133.97, 132.35, 123.28, 61.80, 41.67, 37.07, 36.38, 35.61, 30.73, 26.13, 26.10, 21.63, 19.43.
HRMS (ESI): calculated for $C_{18}H_{24}N_4O_2Na$ $[M+Na]^+$= 351.1792; found 351.1797.
IR (film) cm^{-1} 2955.38, 2870.52, 2098.17, 1772.26, 1715.37, 1321.14, 1266.04.



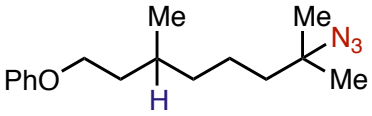
17

7-Azido-1-bromo-3,7-dimethyloctane (17): Prepared according to General Procedure A (0.1 mmol scale) using 1-bromo-3,7-dimethyloctane. The crude residue was purified by column chromatography on silica gel (0 to 10% Et_2O/Hexanes) to afford **17** in 67% yield and a 3:1 ratio of inseparable 3° isomers. The spectra matched literature values.[6]



18

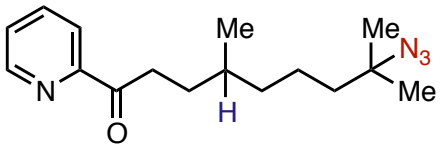
7-Azido-3,7-dimethyloctan-1-ol (18): Prepared according to General Procedure A (0.1 mmol scale) using 3,7-dimethyl-1-octanol to afford **18** in 63% yield and a 2.7:1 ratio of inseparable 3° isomers. The spectra matched literature values.[6]



19

((7-Azido-3,7-dimethyloctyl)oxy)benzene (19): Prepared according to General Procedure A (0.1 mmol scale) using ((3,7-dimethyloctyl)oxy)benzene. The crude residue was purified by column chromatography on silica gel (0 to 10% Et_2O/Hexanes) to afford **19** (8.6 mg, 31% yield by ^1H NMR, 2.1:1 ratio of inseparable 3˚ isomers). The product was characterized as an inseparable mixture from an impurity:

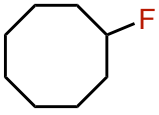
^1H NMR (600 MHz, $CDCl_3$) δ 7.30 – 7.26 (m, 2H), 6.95 – 6.91 (m, 1H), 6.91 – 6.87 (m, 2H), 4.04 – 3.95 (m, 2H), 2.05 – 1.94 (m, 1H), 1.83 (dtd, *J* = 13.8, 7.0, 5.3 Hz, 1H), 1.74 – 1.65 (m, 1H), 1.64 – 1.55 (m, 2H), 1.50 – 1.43 (m, 2H), 1.39 – 1.32 (m, 3H), 1.29 – 1.23 (m, 6H), 1.00 – 0.94 (m, 3H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 129.56, 128.86, 120.64, 114.64, 66.17, 61.84, 41.82, 37.38, 36.33, 29.92, 26.19, 22.72, 21.75, 19.71.
HRMS (ESI): calculated for $C_{16}H_{25}N_3ONa$ $[M+Na]^+$= 298.1890; found 298.1896.
IR (film) cm^{-1} 2929.34, 2870.52, 2098.17, 1558.20, 1540.85, 1520.60, 1244.83.



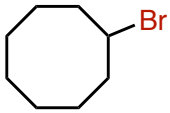
20

8-Azido-4,8-dimethyl-1-(pyridin-2-yl)nonan-1-one (20): Prepared according to General Procedure A (0.1 mmol scale) using 4,8-dimethyl-1-(pyridin-2-yl)nonan-1-one. The crude residue was purified by column chromatography on silica gel (0 to 10% Et_2O/Hexanes) to afford **20** (11.2 mg, 39% yield, 3:1 ratio of inseparable 3˚ isomers):

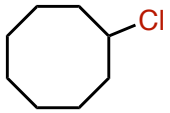
^1H NMR (600 MHz, $CDCl_3$) δ 8.68 (ddd, *J* = 4.8, 1.7, 0.9 Hz, 1H), 8.04 (dt, *J* = 7.9, 1.1 Hz, 1H), 7.83 (td, *J* = 7.7, 1.7 Hz, 1H), 7.50 – 7.43 (m, 1H), 3.25 – 3.18 (m, 2H), 1.83 – 1.75 (m, 1H), 1.58 – 1.51 (m, 3H), 1.50 – 1.43 (m, 2H), 1.43 – 1.31 (m, 2H), 1.25 (s, 6H), 1.21 – 1.17 (m, 1H), 0.95 (d, *J* = 6.4 Hz, 3H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 202.52, 153.69, 149.06, 137.01, 127.14, 121.93, 61.87, 41.86, 37.18, 35.53, 32.67, 31.03, 26.17, 26.14, 21.84, 19.66.
HRMS (ESI): calculated for $C_{16}H_{24}N_4ONa$ $[M+Na]^+$ = 311.1843; found 311.1852.
IR (film) cm^{-1} 2933.20, 2869.56, 2097.21, 1698.02, 1540.85, 1520.60,1321.00, 1267.69.



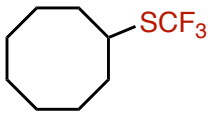
Fluorocyclooctane. Prepared according to General Procedure B (0.1 mmol scale) using cyclooctane as the substrate and NFSI as the radical trap with 4 hours of irradiation, affording 64% yield by ^{19}F NMR. The spectra matched literature values.[16]



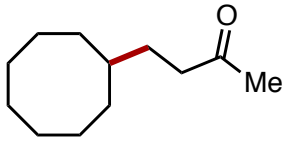
Bromocyclooctane. Prepared according to General Procedure B (0.1 mmol scale) using cyclooctane as the substrate and diethyl bromomalonate as the radical trap with 20 hours of irradiation, affording 60% yield by ^{1}H NMR. The spectra matched literature values.[17]



Chlorocyclooctane. Prepared according to General Procedure B (0.1 mmol scale) using cyclooctane as the substrate and NCS as the radical trap with 20 hours of irradiation, affording 32% yield by ^{1}H NMR. The spectra matched literature values.[18]

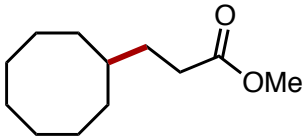


Cyclooctyl(trifluoromethyl)sulfane. Prepared according to General Procedure B (0.1 mmol scale) using cyclooctane as the substrate and ((2-phenylpropan-2-yl)oxy)(trifluoromethyl)sulfane[19] as the radical trap with 4 hours of irradiation. The title compound cyclooctyl(trifluoromethyl)sulfane was afforded in 30% yield by ^{1}H NMR. The spectra matched literature values.[20]

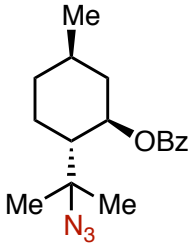


4-Cyclooctylbutan-2-one. Prepared according to General Procedure C using cyclooctane as the substrate and methyl vinyl ketone as the alkene. The title compound was afforded in 76% yield by ^{1}H NMR. The title compound was purified by column chromatography on silica gel to afford 4-cyclooctylbutan-2-one (13.8 mg, 74% yield):

^{1}H NMR (600 MHz, $CDCl_3$) δ 2.45 – 2.38 (m, 2H), 2.14 (s, 3H), 1.69 – 1.61 (m, 2H), 1.60 – 1.54 (m, 5H), 1.52 – 1.38 (m, 8H), 1.26 (dtd, *J* = 14.0, 8.6, 2.8 Hz, 2H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 209.79, 42.17, 37.06, 32.31, 32.08, 30.02, 27.38, 26.42, 25.57.
HRMS (ESI): calculated for $C_{12}H_{22}ONa$ $[M+Na]^+$= 205.1563; found 205.1563.
IR (film) cm^{-1} 2923.56, 2854.13, 1717.30, 1455.99, 1361.50.



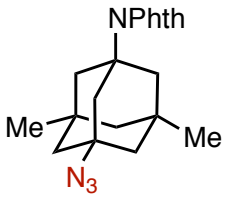
Methyl 3-cyclooctylpropanoate: Prepared according to General Procedure C using cyclooctane as the substrate and methyl acrylate as the alkene. The residue was purified by column chromatography on silica gel to give methyl 3-cyclooctylpropanoate in 43% yield. The spectra matched literature values:[21]



21

(1*R*,2*S*,5*R*)-2-(2-Azidopropan-2-yl)-5-methylcyclohexyl benzoate (21): Prepared according to General Procedure A (0.1 mmol scale) using (1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl benzoate. The crude residue was purified by column chromatography on silica gel (0 to 10% Et_2O/Hexanes) to afford **21** (16.3 mg, 54% yield, containing minor amounts of an inseparable regioisomer from functionalization on the tertiary position on the ring):

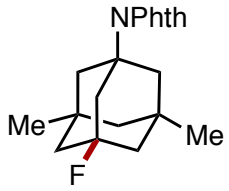
^{1}H NMR (600 MHz, $CDCl_3$) δ 8.07 (d, *J* = 7.8 Hz, 2H), 7.61 – 7.51 (m, 1H), 7.50 – 7.39 (m, 2H), 5.10 (td, *J* = 11.5, 10.9, 4.4 Hz, 1H), 2.10 (d, *J* = 12.3 Hz, 1H), 2.07 – 1.99 (m, 1H), 1.85 (td, *J* = 11.6, 10.9, 3.6 Hz, 1H), 1.78 – 1.70 (m, 1H), 1.66 – 1.52 (m, 1H), 1.29 (d, *J* = 4.9 Hz, 6H), 1.24 – 1.10 (m, 2H), 1.02 – 0.95 (m, 1H), 0.93 (dd, *J* = 6.6, 2.0 Hz, 3H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 165.84, 133.05, 130.77, 129.77, 128.53, 74.01, 63.74, 49.31, 41.48, 34.24, 31.38, 26.70, 25.32, 24.64, 21.86.
HRMS (ESI): calculated for $C_{17}H_{23}N_3O_2Na$ $[M+Na]^+$= 324.1683; found 324.1678.
IR (film) cm^{-1} 2958.27, 2872.45, 2131.92, 2102.03, 1715.37, 1322.93, 1276.65.



22

2-(3-Azido-5,7-dimethyladamantan-1-yl)isoindoline-1,3-dione (22): Prepared according to General Procedure A (0.1 mmol scale) using 2-(3,5-dimethyladamantan-1-yl)isoindoline-1,3-dione. The crude residue was purified by column chromatography on silica gel (0 to 10% Et_2O/Hexanes) to afford **22** (19.3 mg, 55% yield):

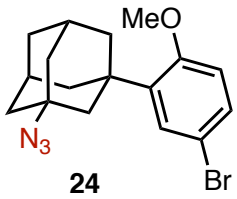
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.76 (dd, *J* = 5.4, 3.0 Hz, 2H), 7.68 (dd, *J* = 5.5, 3.0 Hz, 2H), 2.45 (s, 2H), 2.14 (s, 4H), 1.61 – 1.54 (m, 2H), 1.44 (d, *J* = 11.9 Hz, 2H), 1.26 (dt, *J* = 12.7, 2.3 Hz, 1H), 1.20 – 1.10 (m, 1H), 0.99 (s, 6H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 169.60, 134.04, 131.87, 122.86, 61.90, 60.79, 49.20, 46.57, 44.99, 42.78, 34.02, 29.55.
HRMS (ESI): calculated for $C_{20}H_{23}N_4O_2$ $[M+H]^+$= 351.1833; found 351.1816.
IR (film) cm^{-1} 2900.55, 2862.81, 2090.46, 1706.69, 1540.85, 1316.18, 1247.72.



23

2-(3-Fluoro-5,7-dimethyladamantan-1-yl)isoindoline-1,3-dione (23). Prepared according to General Procedure B (0.1 mmol scale) using 2-(3,5-dimethyladamantan-1-yl)isoindoline-1,3-dione as the substrate and NFSI as the radical trap with 4 hours of irradiation. The residue was purified by column chromatography on silica gel to afford **23** (28.2 mg, 86% yield). Minor amounts of secondary fluorination product are also present:

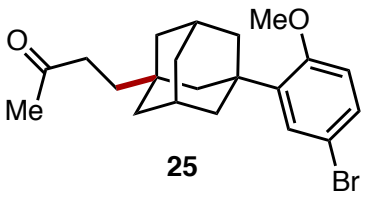
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.76 (dd, *J* = 5.4, 3.1 Hz, 2H), 7.68 (dd, *J* = 5.5, 3.0 Hz, 2H), 2.60 – 2.57 (m, 2H), 2.18 – 2.13 (m, 2H), 2.08 (ddd, *J* = 12.4, 2.4, 1.2 Hz, 2H), 1.70 – 1.64 (m, 2H), 1.58 – 1.53 (m, 2H), 1.23 (ddt, *J* = 12.8, 4.1, 2.2 Hz, 1H), 1.16 (dt, *J* = 12.7, 2.3 Hz, 1H), 1.01 (s, 6H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 169.57, 134.03, 131.84, 122.86, 93.50 (d, *J* = 183.7 Hz), 62.51 (d, *J* = 12.1 Hz), 49.18 (d, *J* = 1.5 Hz), 47.73 (d, *J* = 16.6 Hz), 45.01 (d, *J* = 1.5 Hz), 43.95 (d, *J* = 21.1 Hz), 34.91 (d, *J* = 10.6 Hz), 29.34.
^{19}F NMR (400 MHz, $CDCl_3$) δ –135.68.
HRMS (ESI): calculated for $C_{20}H_{22}FNO_2$ $[M+H]^+$= 328.1707; found 328.1720.
IR (film) cm^{-1} 2925.48, 2906.20, 1771.30, 1707.66, 1456.96, 1316.18, 717.39.



24

1-Azido-3-(5-bromo-2-methoxyphenyl)adamantane (24): Prepared according to General Procedure A (0.1 mmol scale) using 2-(1-adamantyl)-4-bromoanisole. The crude residue was purified by column chromatography on silica gel (0 to 10% Et_2O/Hexanes) to give **24** in 40% yield by ^{1}H NMR due to the product being inseparable from an impurity:

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.34 – 7.31 (m, 1H), 7.28 (s, 1H), 6.77 (d, *J* = 8.7 Hz, 1H), 3.84 (d, *J* = 3.8 Hz, 3H), 2.34 (dq, *J* = 6.5, 3.2 Hz, 2H), 2.14 (d, *J* = 5.9 Hz, 2H), 2.07 (dt, *J* = 12.9, 2.8 Hz, 2H), 1.97 (q, *J* = 14.5, 12.6 Hz, 2H), 1.86 (d, *J* = 3.3 Hz, 3H), 1.76 – 1.65 (m, 2H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 157.75, 138.48, 130.07, 129.73, 113.49, 112.42, 59.92, 55.61, 55.40, 44.02, 43.89, 41.00, 39.72, 39.69, 39.11, 35.48, 30.31.
HRMS (APCI): calculated for $C_{17}H_{20}N_3OBrNa$ $[M+Na]^+$= 384.0682; found 384.0738.
IR (film) cm^{-1} 2912.95, 2865.06, 2089.49, 1558.20, 1496.49, 1234.22.

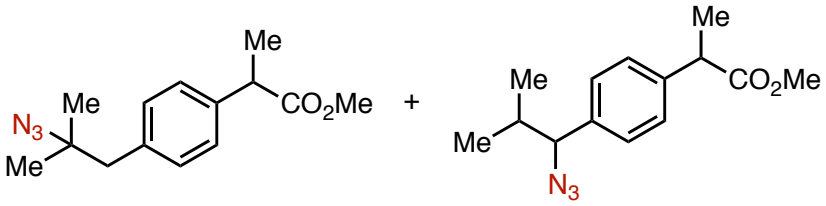


25

4-((1*r*,3*s*,5*R*,7*S*)-3-(5-bromo-2-methoxyphenyl)adamantan-1-yl)butan-2-one (25). Prepared according to General Procedure C using 2-(1-adamantyl)-4-bromoanisole as the substrate and methyl vinyl ketone as the alkene. The residue was purified by column chromatography on silica gel to afford **25** (17.6 mg, 45% yield):

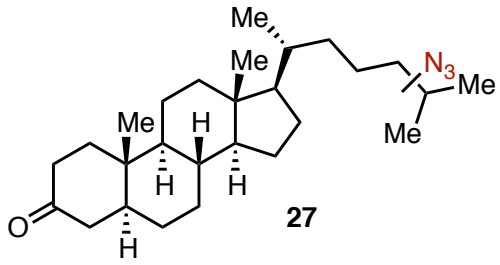
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.27 – 7.24 (m, 2H), 6.73 (d, *J* = 9.3 Hz, 1H), 3.80 (s, 3H), 2.44 – 2.37 (m, 2H), 2.15 (s, 3H), 2.14 – 2.11 (m, 2H), 1.98 – 1.94 (m, 3H), 1.85 – 1.68 (m, 4H), 1.65 – 1.57 (m, 2H), 1.47 (d, *J* = 2.7 Hz, 3H), 1.46 – 1.41 (m, 2H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 209.98, 157.96, 140.29, 129.81, 129.58, 113.49, 113.39, 55.36, 44.98, 41.59, 39.97, 38.02, 37.81, 37.66, 36.51, 32.84, 30.08, 29.38.
HRMS (ESI): calculated for $C_{21}H_{27}BrO_2Na$ $[M+Na]^+$ = 413.1087; found 413.1082.
IR (film) cm^{-1} 2904.27, 2848.35, 1716.34, 1520.61, 1473.35, 1234.22, 1027.87.

The reaction was also performed on 1 mmol scale in a scintillation vial with irradiation from 2 Kessil lamps for 2 days and purified to afford **25** (152 mg, 39% yield).



Methyl 2-(4-(2-azido-2-methylpropyl)phenyl)propanoate (26): Prepared according to General Procedure A (0.1 mmol scale) using methyl 2-(4-isobutylphenyl)propanoate. ^{1}H NMR analysis of the crude reaction mixture revealed a 1.1:1 ratio of benzylic to tertiary azide isomers. The residue was purified by column chromatography on silica gel (0 to 10% Et_2O/Hexanes) to afford **26** (14.8 mg, 57% yield). Characterization data are reported for the previously unreported tertiary isomer; both benzylic azide diastereomers are also present as inseparable impurities in the product:[13]

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.30 (d, *J* = 8.1 Hz, 1H), 7.25 – 7.20 (m, 2H), 7.16 (d, *J* = 8.1 Hz, 1H), 3.72 (m, 1H), 3.66 (s, 3H), 2.74 (s, 2H), 1.50 (dd, *J* = 7.2, 5.5 Hz, 3H), 1.26 (s, 6H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 175.17, 139.10, 135.81, 130.87, 127.34, 61.96, 52.17, 47.22, 45.19, 26.06, 18.73.
IR (film) cm^{-1} 2958.27, 2936.09, 2099.14, 1739.48, 1456.96, 1210.11.



27

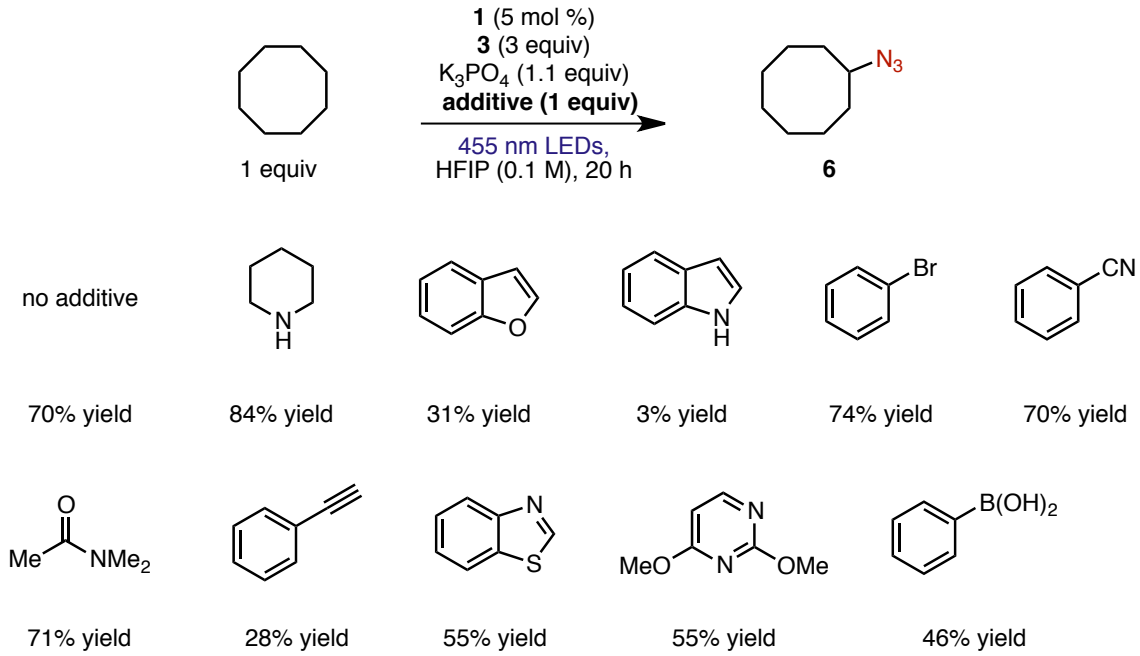
(5*S*,8*R*,9*S*,10*S*,13*R*,14*S*,17*R*)-17-((*R*)-6-Azido-6-methylheptan-2-yl)-10,13-dimethyltetradecahydro-1*H*-cyclopenta[*a*]phenanthren-3(2*H*)-one (27):
Prepared according to General Procedure A (0.1 mmol scale) using 5-α-cholestan-3-one. The crude residue was purified by column chromatography on silica gel (0 to 10% Et_2O/Hexanes) to afford **27** (13.8 mg, 37% yield), favoring functionalization at the C25 and C17 tertiary positions (approximately 1:1). The ^{13}C spectrum is complicated due to the presence of minor secondary azidation products:

^{1}H NMR (600 MHz, $CDCl_3$) δ 2.41 – 2.34 (m, 1H), 2.32 – 2.23 (m, 2H), 2.11 – 2.05 (m, 1H), 2.04 – 1.95 (m, 2H), 1.86 – 1.60 (m, 3H), 1.60 – 1.46 (m, 5H), 1.46 – 1.29 (m, 8H), 1.28 – 1.19 (m, 1H), 1.25 (s, 3H), 1.19 – 1.04 (m, 4H), 1.04 – 0.98 (m, 1H), 1.01 (d, *J* = 1.4 Hz, 3H), 0.97 – 0.85 (m, 7.5H), 0.85 – 0.77 (m, 1H), 0.77 – 0.71 (m, 1H), 0.68 (s, 1.5H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 212.34, 212.31, 80.95, 61.93, 56.44, 56.42, 56.33, 53.97, 53.95, 46.86, 44.89, 44.86, 44.80, 42.78, 42.75, 42.07, 42.02, 40.07, 40.05, 39.66, 38.72, 38.36, 38.33, 38.28, 36.30, 35.94, 35.85, 35.80, 35.74, 35.56, 31.89, 31.87, 31.82, 29.14, 29.13, 29.01, 28.39, 28.17, 28.13, 26.23, 26.16, 25.75, 24.39, 24.37, 23.99, 22.97, 22.92, 22.71, 22.65, 21.60, 21.36, 20.91, 18.82, 18.75, 14.80, 14.75, 12.23, 11.63, 11.59.
HRMS (ESI): calculated for $C_{27}H_{45}N_3ONa$ $[M+Na]^+$= 450.3455; found 450.3469.
IR (film) cm^{-1} 2932.23, 2866.62, 2098.17, 1715.37, 1455.99, 1267.97.

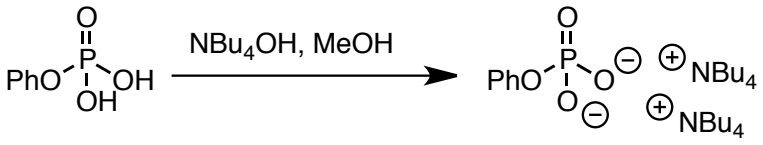
The singlet at δ 0.68 ppm corresponds to the methyl at C13, and this signal is underintegrated (1.5H instead of 3H), indicating that the methyl has been shifted for one of the azidation products. Since there is only trace secondary azidation, the methyl at C13 cannot be shifted from azidation at C12 and instead arises from tertiary azidation at C17. Additionally, the isopropyl methyl signals that lie between 0.85 and 0.90 ppm are underintegrated and there is a new signal at 1.25 ppm corresponding to azidation of the isopropyl group at C25. This signal integrates to 3H instead of 6H, however, indicating that it is only from one of the two products.

Robustness Screen

Below are the results from a robustness screen surveying several different additives containing useful functionality or pharmaceutically relevant heterocycles. Yields of the cyclooctane azidation product **6** are given below each additive.



Mechanistic Studies



28

Di(tetrabutylammonium) phenyl phosphate (28): To a solution of phenyl dihydrogen phosphate[22] (1.22 g, 7 mmol) in methanol (7 mL) was added tetrabutylammonium hydroxide in methanol (1M, 14 mL, 14 mmol). The solution was stirred overnight and then concentrated *in vacuo*. The resultant oil was dried via high vacuum for one week to afford **28** as an amorphous solid. The compound is extremely hygroscopic and unstable outside of an inert atmosphere:[23]

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.19 – 7.10 (m, 2H), 7.06 (t, J = 7.8 Hz, 1H), 6.97 (d, J = 8.0 Hz, 1H), 3.31 – 3.25 (m, 16H), 1.63 – 1.55 (m, 16H), 1.39 (q, J = 7.4 Hz, 16H), 0.94 (t, J = 7.3 Hz, 24H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 129.12, 128.85, 118.14, 116.11, 58.96, 24.20, 19.82, 13.79.

As determined by cyclic voltammetry, the oxidation potential of **28** was $E_{p/2}$ = + 0.87 V vs SCE in MeCN. Phosphate esters including **28** are known to be unstable for prolonged periods in MeCN.[23]

Stern-Volmer Quenching:

Emission lifetime measurements were taken at ambient temperature using a Edinburgh FLS920 spectrometer and fit to single exponential decay according to a modification of the method previously described by our laboratory.[24] Measurements were made by the time-correlated single photon counting (TCSPC) capability of the instrument with pulsed excitation light (444.2 nm, typical pulse width = 95 ps) generated by a Edinburgh EPL-445 ps pulsed laser diode operating at a repetition rate of 5 MHz. The maximum emission channel count rate was less than 5% of the laser channel count rate, and each data set collected greater than 10000 counts on the maximum channel. The lifetime of fluorescence was determined by reconvolution fit with the instrument response function using the Edinburgh FS900 software. In all cases, after reconvolution, fluorescence decay was satisfactorily fit with a monoexponential function of the form:

$$I_t = I_0 e^{-t/\tau}$$

where *I* is the intensity (counts), and *t* is the mean lifetime of fluorescence.

Stern-Volmer analysis on the quenching of fluorescence lifetime was carried out in DCE or HFIP with detection at 500 nm (15 nm bandwidth), where the concentration of acridinium was 1.6×10^{-5} M. The quenching constant was determined with quencher concentrations in the range of 0 M to 2.0×10^{-2} M. Bimolecular quenching constants, k_q, were determined from the corresponding Stern-Volmer constant.[25] Quenching constants were determined for ***t*-Bu$_2$-Mes-Acr+** with sulfonyl azide **3,** sodium 1,1,1,3,3,3-hexafluoroisopropoxide, and dibasic phosphate **28**. Comparison of UV-Vis absorption spectra taken before and after lifetime quenching studies verified that the acridinium was unchanged. UV-Vis spectra were taken on a Hewlett-Packard 8453 Chemstation spectrophotometer.

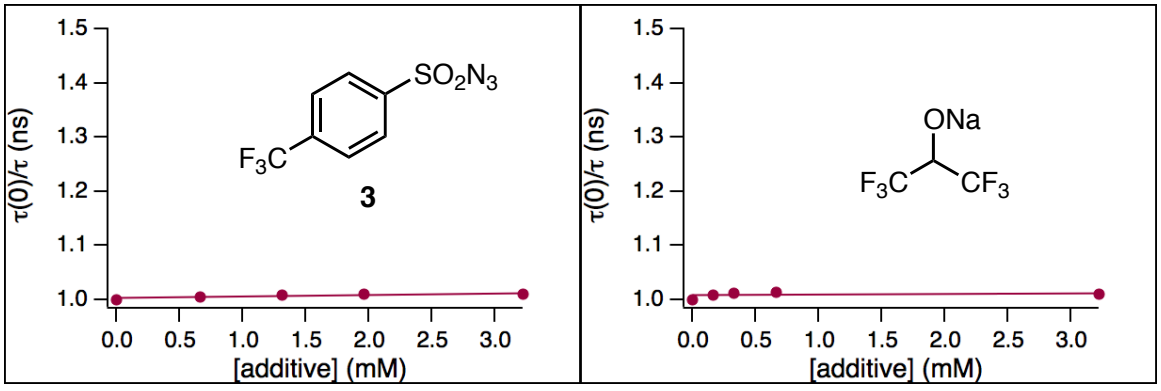


Figure S2. Stern-Volmer quenching of catalyst **1**. Left: Azide **3** as the additive in DCE solvent. Right: Sodium 1,1,1,3,3,3-hexafluoroisopropoxide (prepared via the reaction of sodium with HFIP) as the additive in HFIP as solvent.

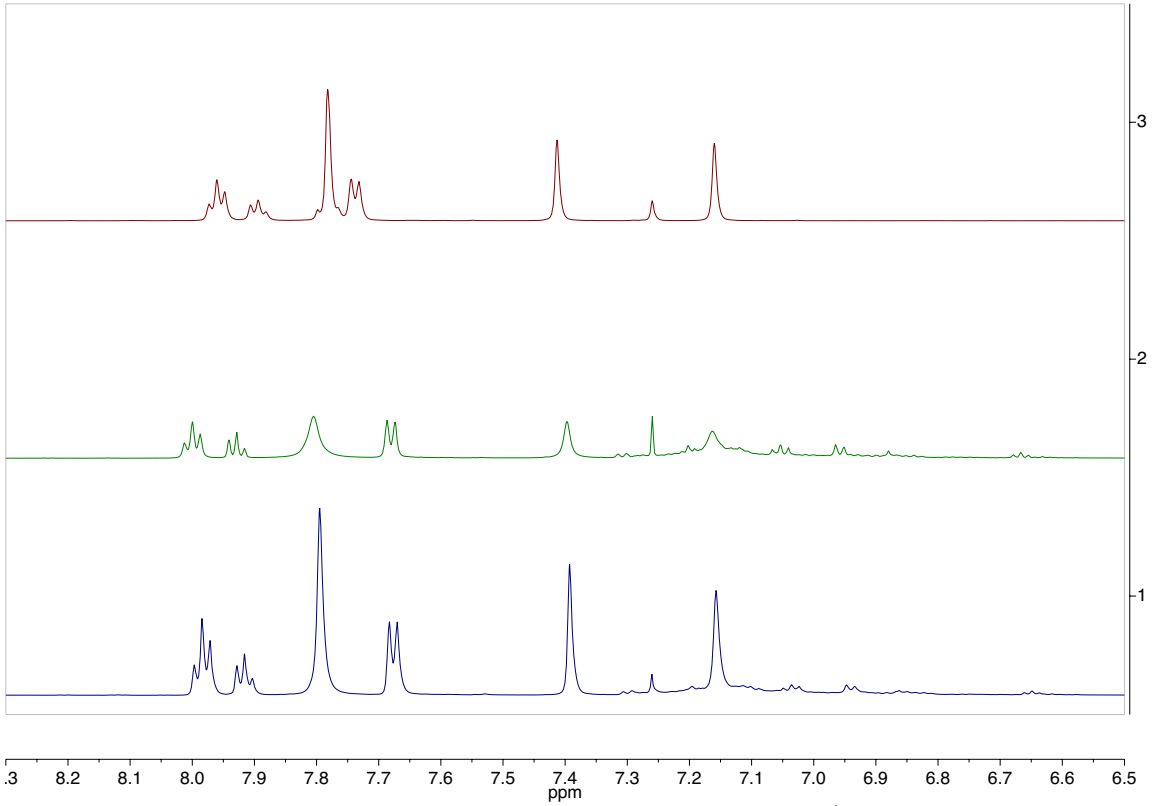


Figure S3. Addition of dibasic phosphate **28** to catalyst **1** ^{1}H NMR. Top: Catalyst **1**. Middle: 1 equiv of **1** and 1 equiv of **28**. Bottom: 2 equiv of **1** and 1 equiv of **28**.

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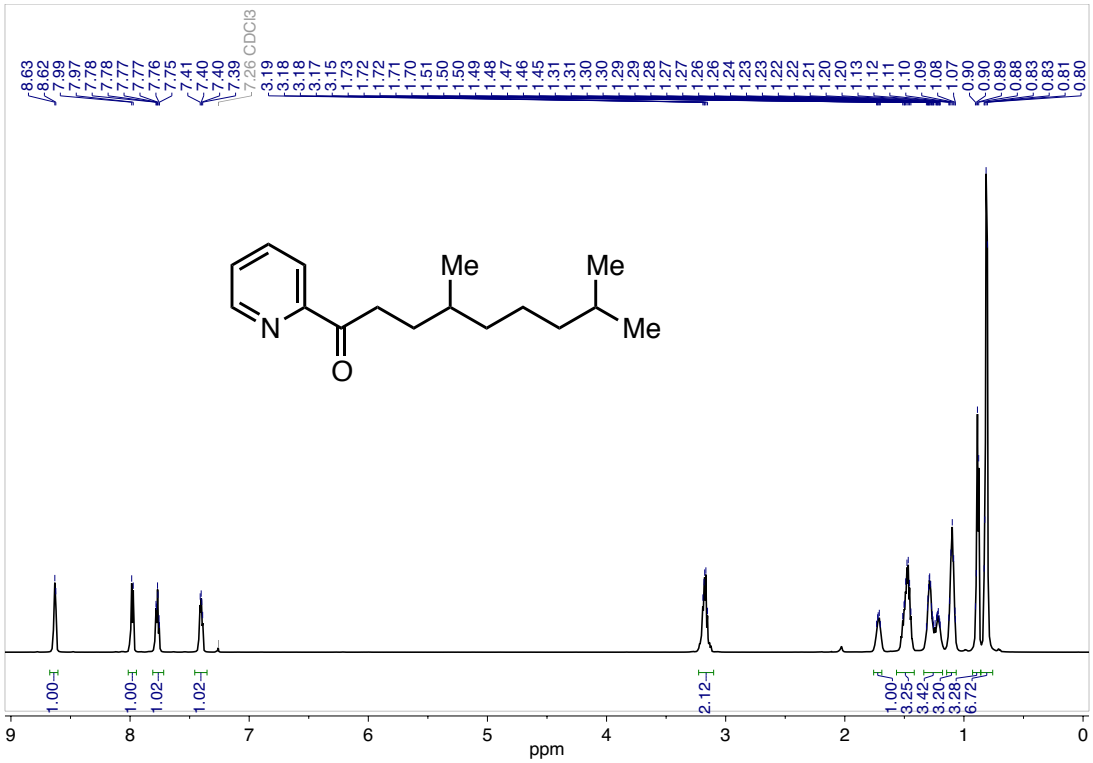
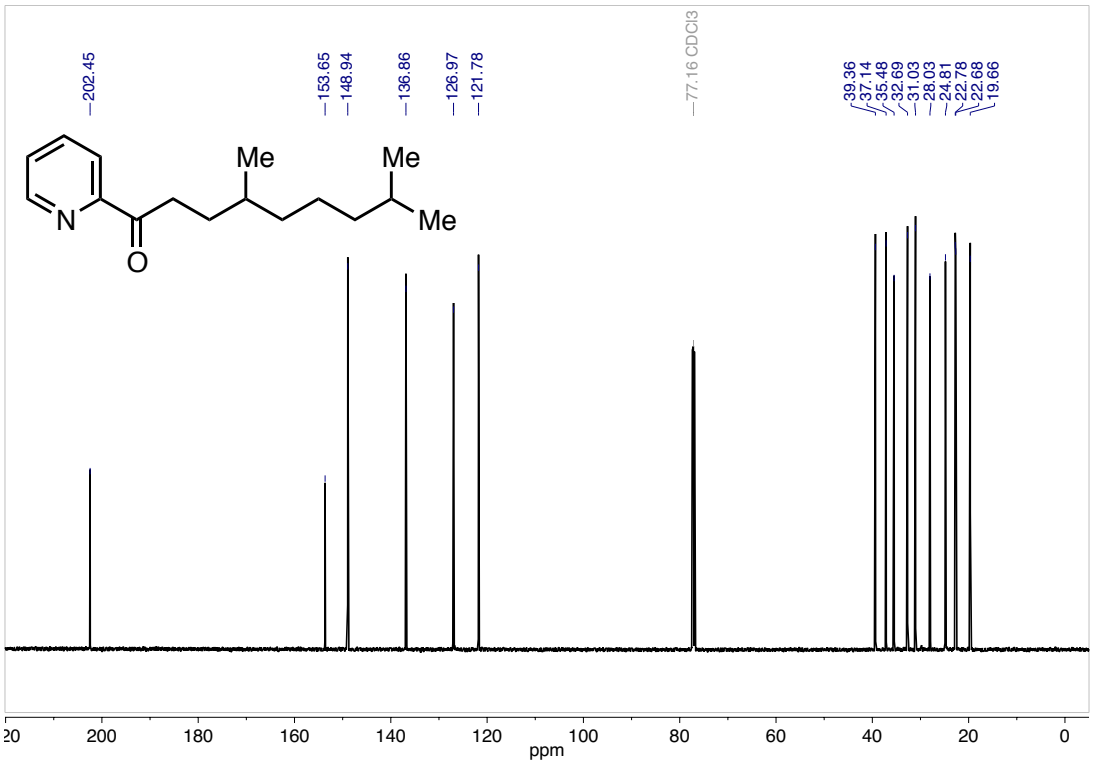
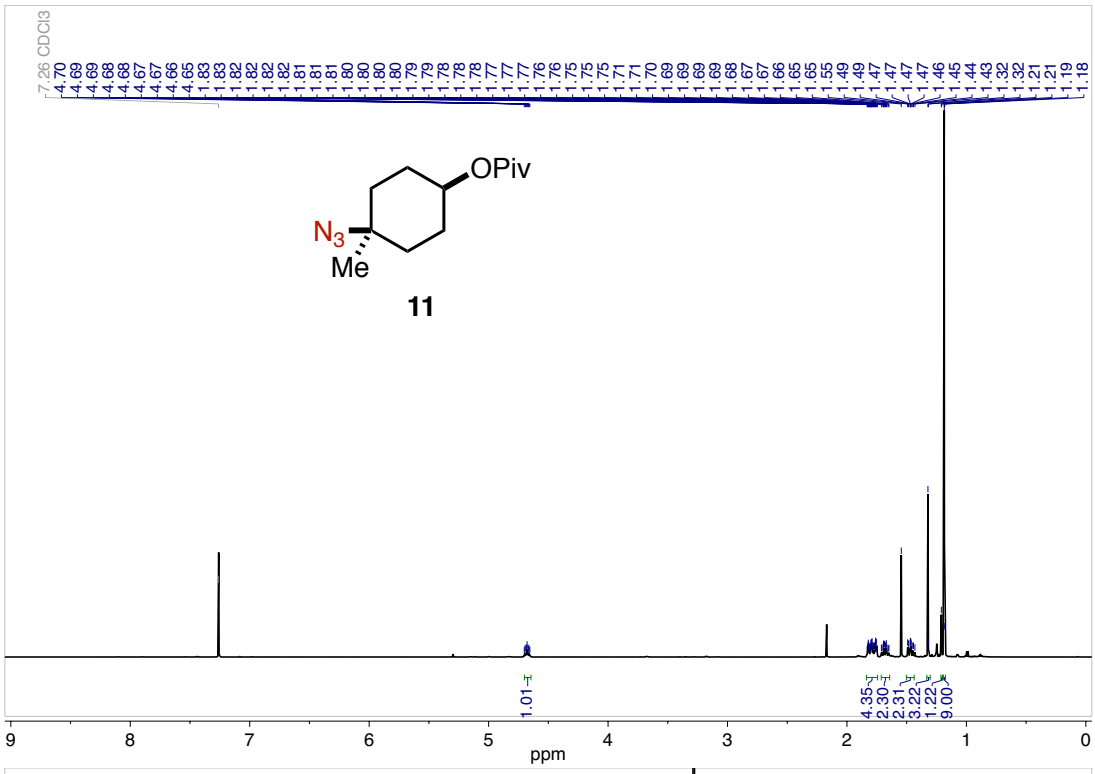
NMR Spectra for New Compounds






7.26 CDCl3
4.70 4.69 4.69 4.68 4.68 4.67 4.67 4.66 4.65 1.83 1.83 1.82 1.82 1.82 1.82 1.81 1.81 1.81 1.80 1.80 1.80 1.80 1.79 1.79 1.78 1.78 1.78 1.77 1.77 1.77 1.76 1.76 1.75 1.75 1.75 1.71 1.71 1.70 1.69 1.69 1.69 1.69 1.68 1.67 1.67 1.66 1.65 1.55 1.49 1.49 1.47 1.47 1.47 1.46 1.45 1.44 1.43 1.32 1.21 1.21 1.19 1.18
OPiv
N3
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4.35
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2.31
3.22
1.22
9.00
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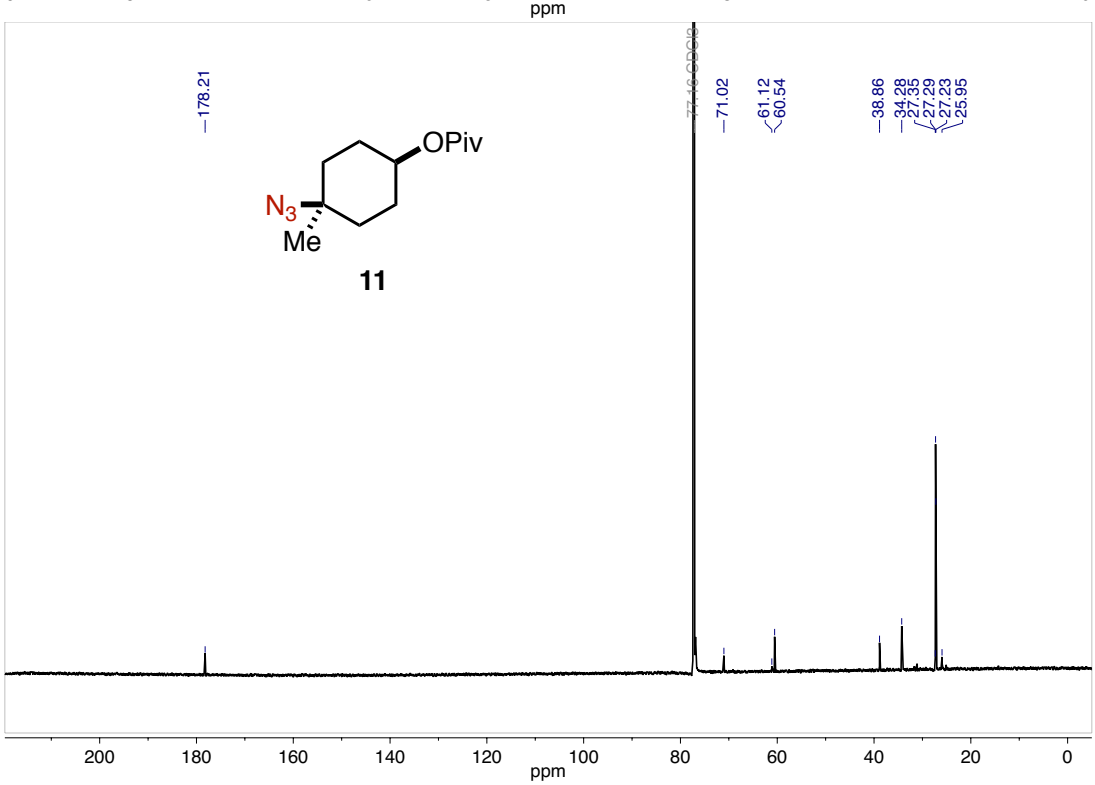
ppm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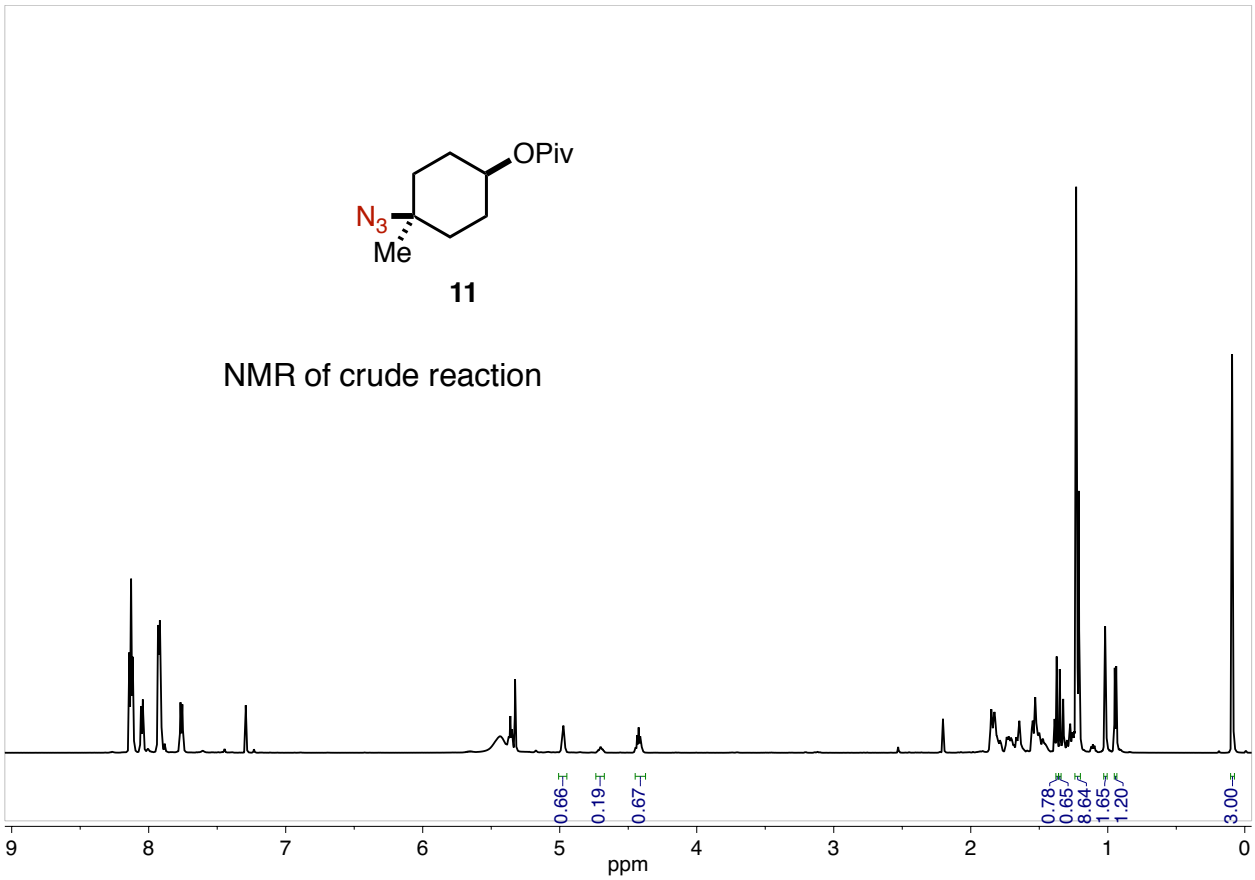
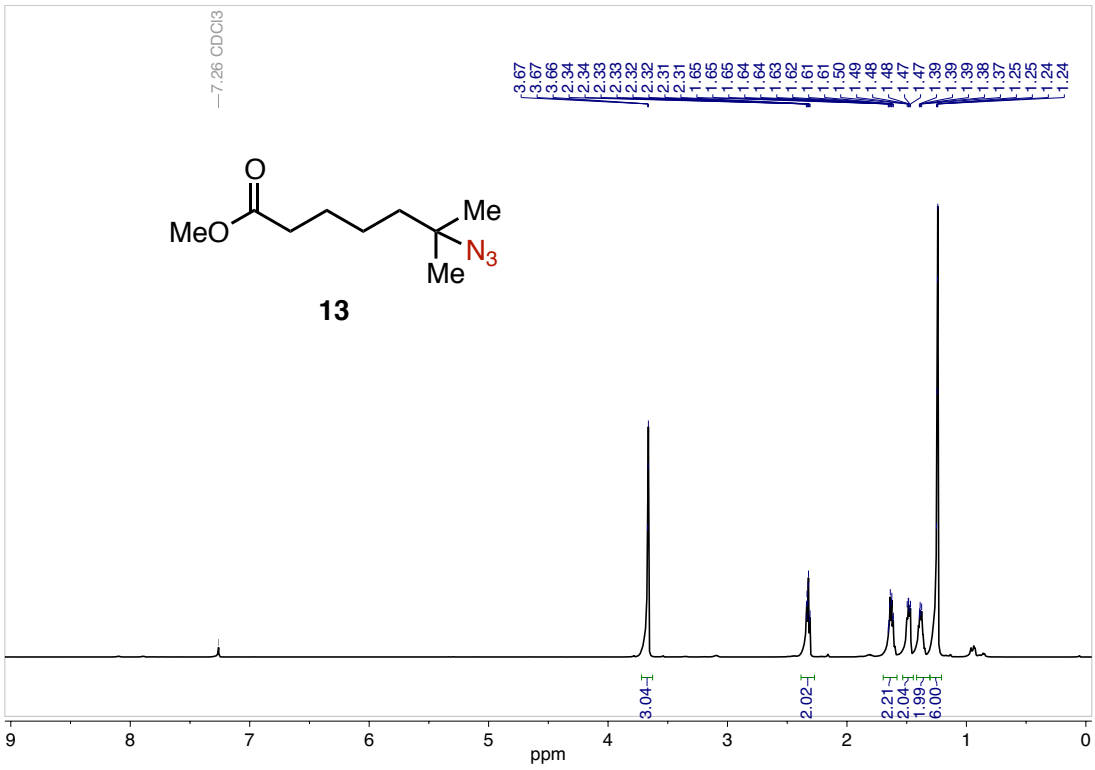
ppm



The methyl doublet below 1.0 ppm indicates 40% remaining starting material. The peaks at 5.0 ppm and 4.7 ppm correspond to both diastereomers of product, but the starting material also has a peak at 5.0 ppm. Subtraction of 40% from the peak at 5.0 ppm gives 26% yield of one diastereomer and 19% yield of the other, for a combined NMR yield of 45% and a dr 1.4:1.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1.65
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1.39
1.39
1.38
1.37
1.25
1.25
1.24
1.24
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N3
Me
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6.00
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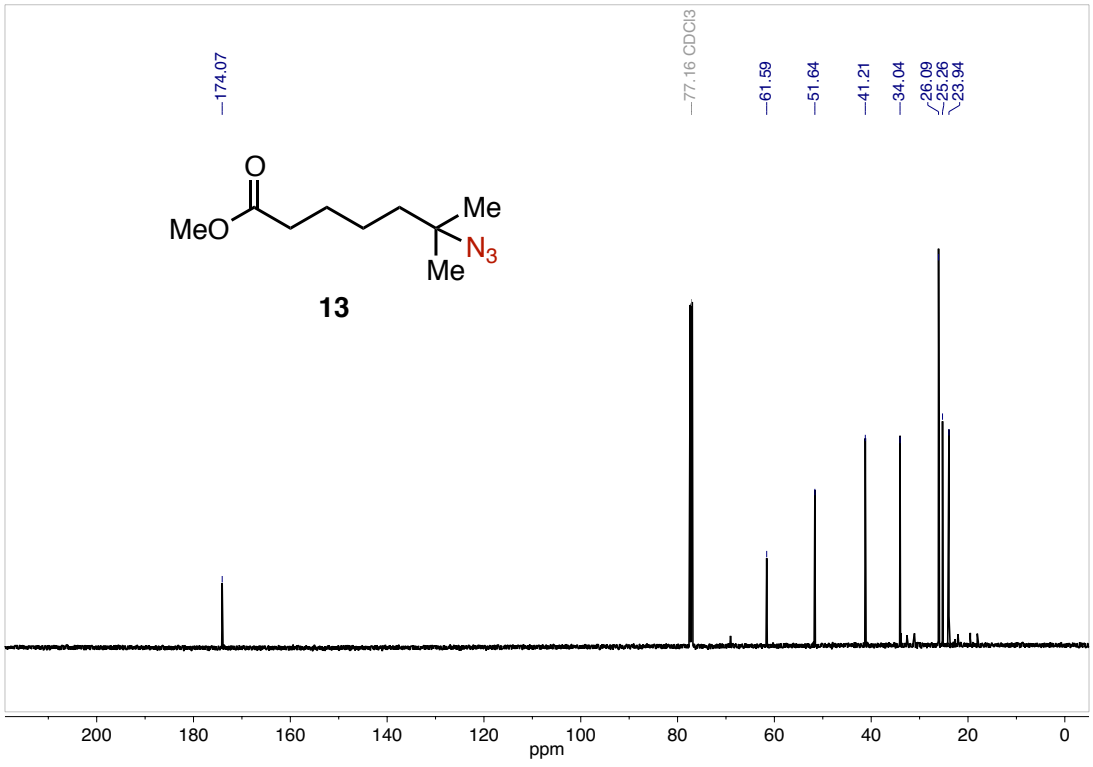
ppm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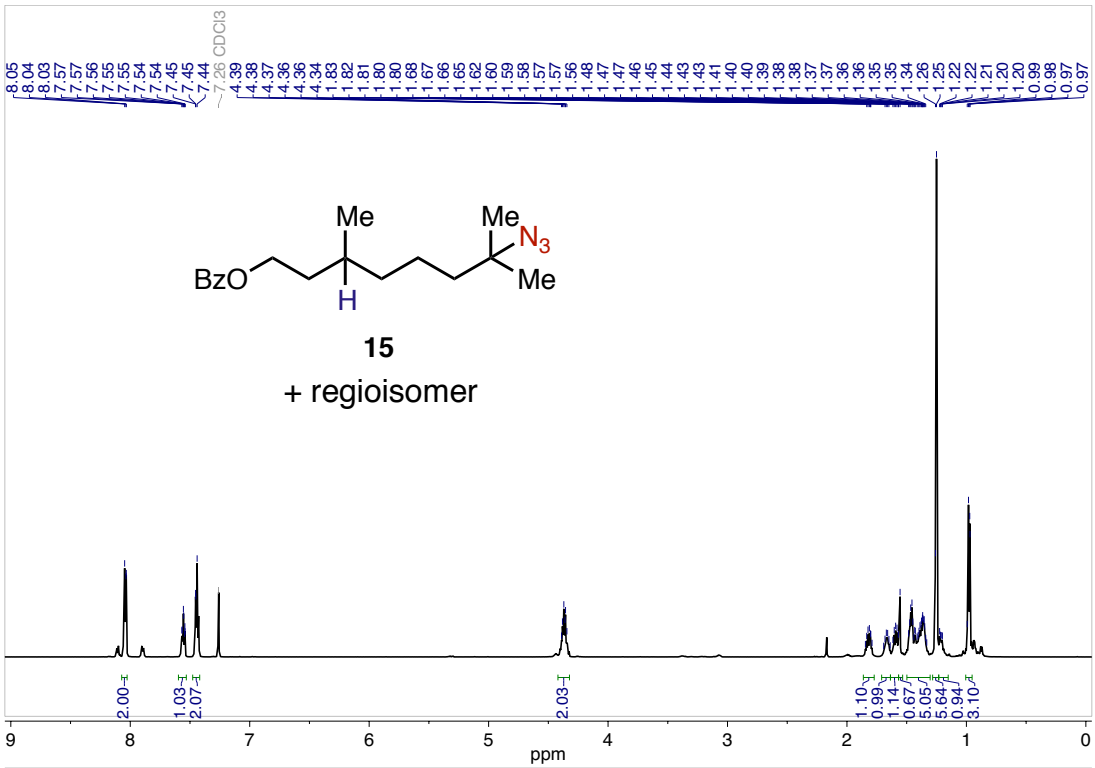
ppm


Me
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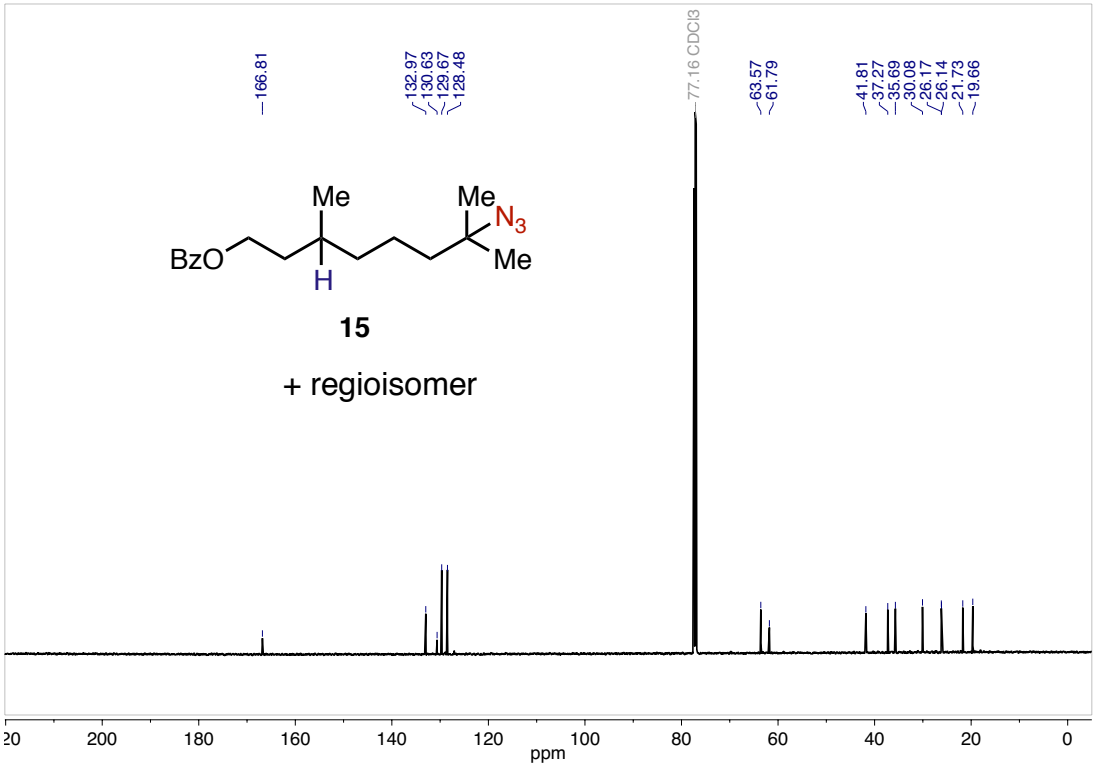
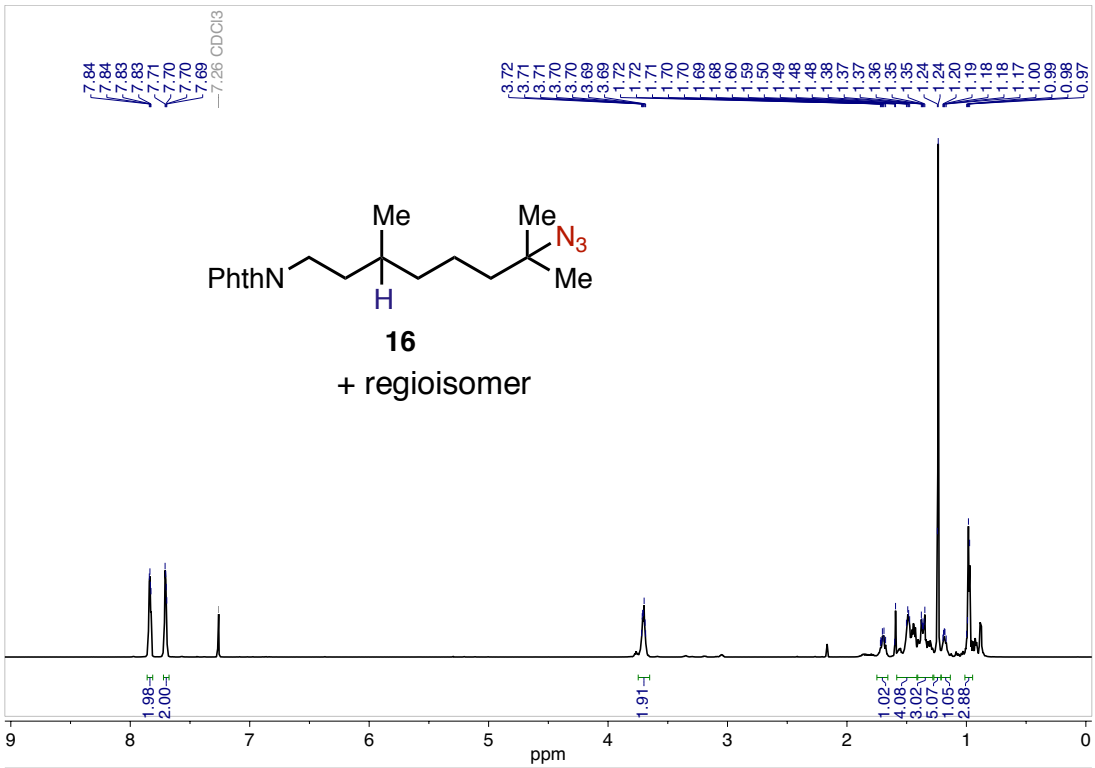
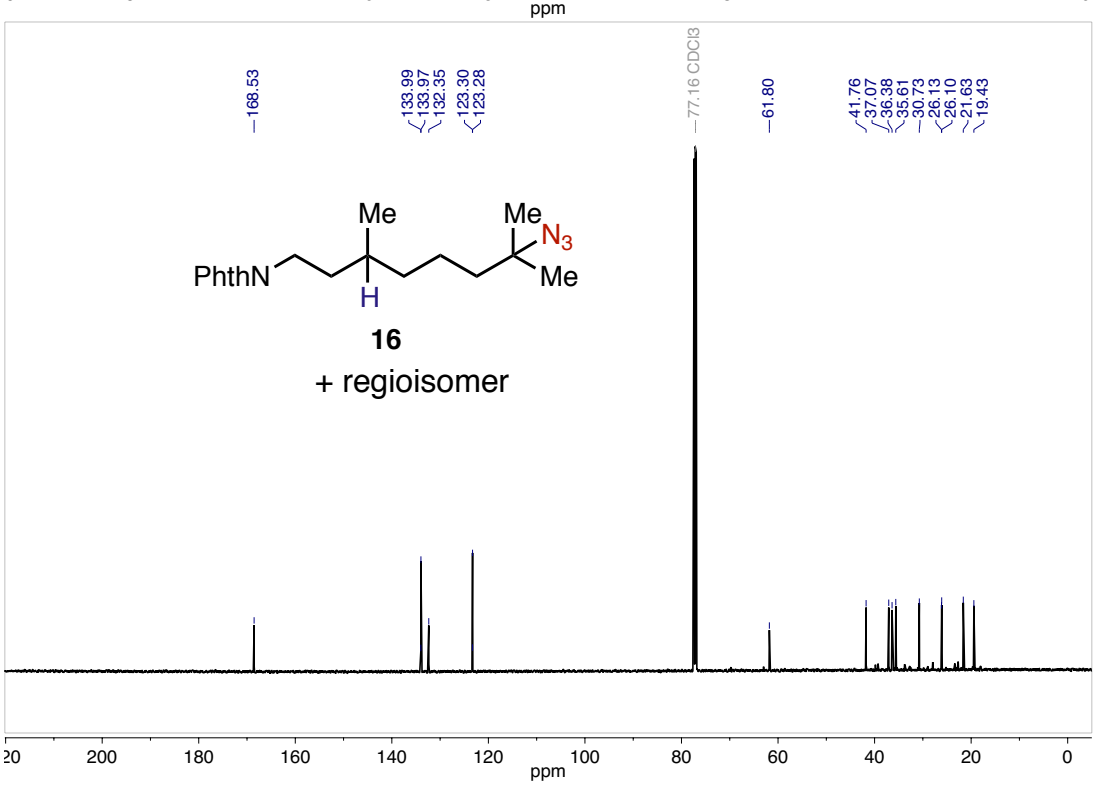
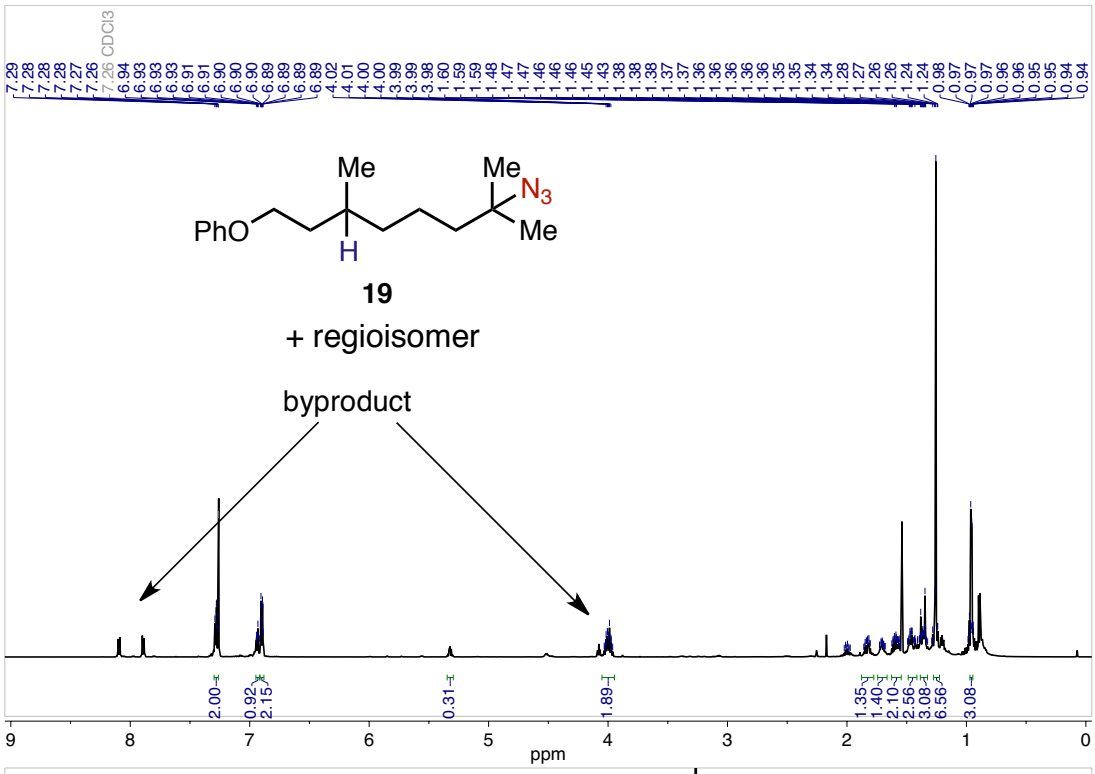
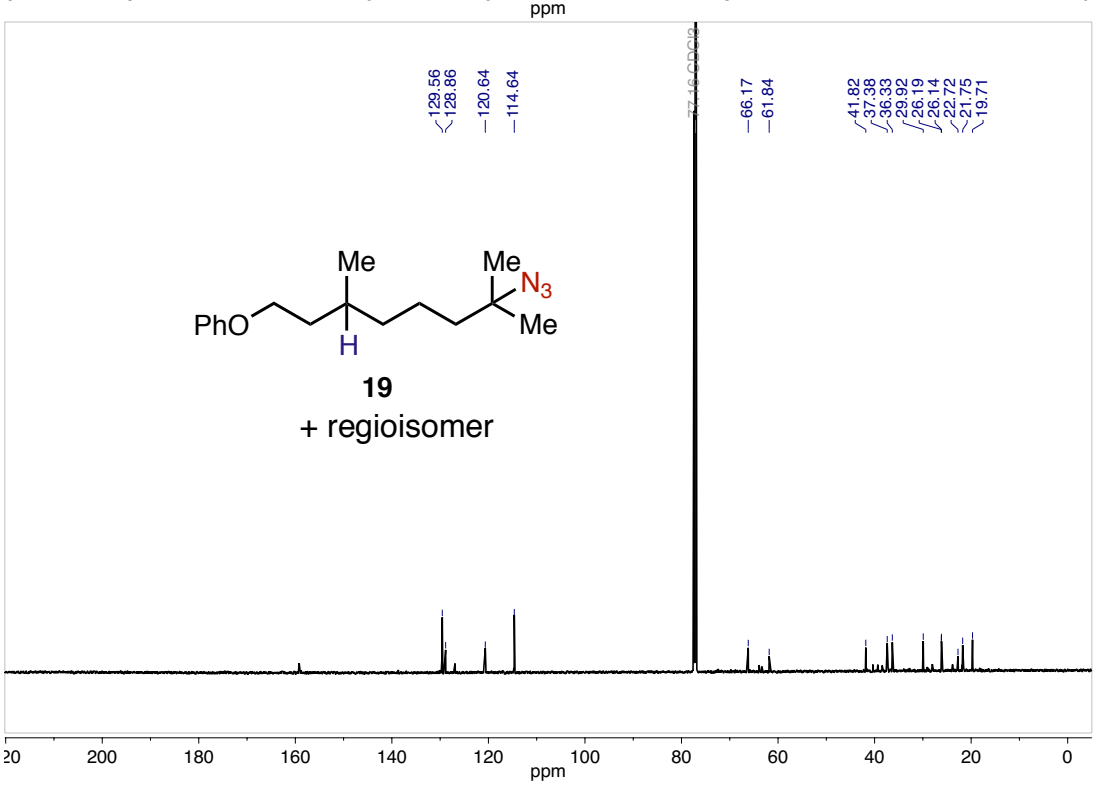
+ regioisomer
ppm

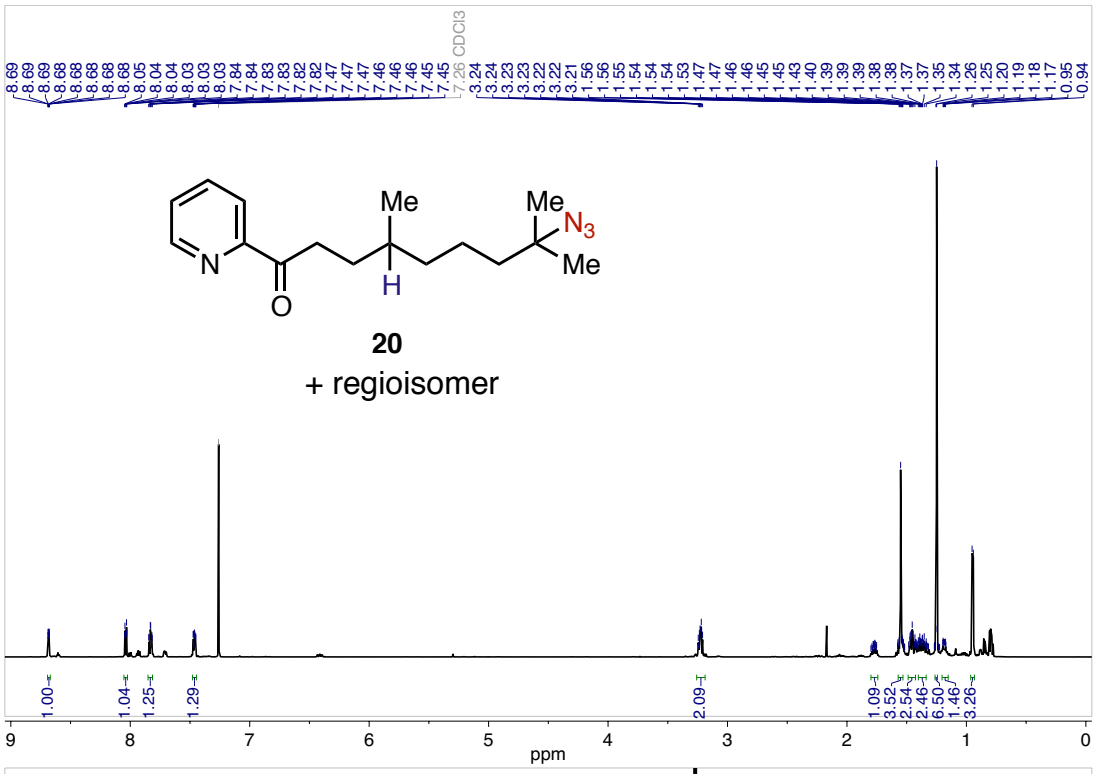

Me
Me
N3
BzO
H
Me
15
+ regioisomer
ppm

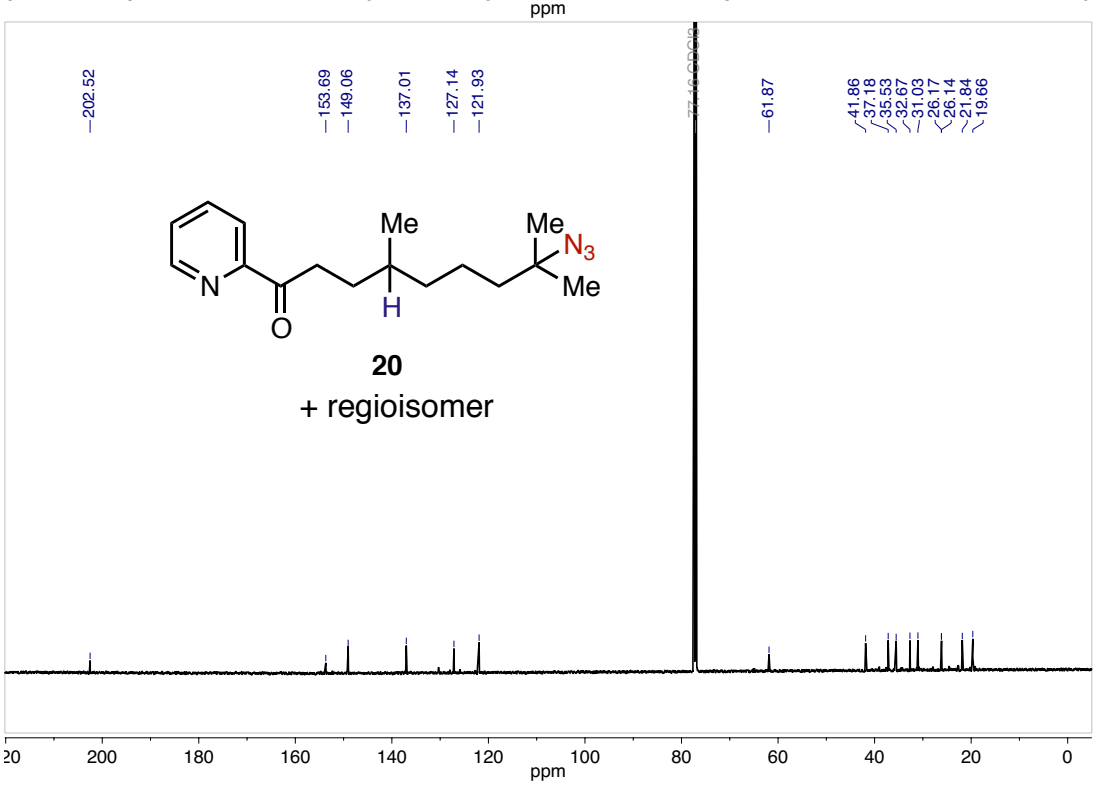

7.84
7.84
7.83
7.83
7.71
7.70
7.70
7.69
7.26 CDCl3
3.72
3.71
3.71
3.70
3.70
3.69
3.69
3.72
1.71
1.70
1.70
1.69
1.68
1.60
1.59
1.50
1.49
1.48
1.48
1.38
1.37
1.37
1.36
1.35
1.24
1.24
1.20
1.19
1.18
1.18
1.17
1.00
0.99
0.98
0.97
Me
Me
N3
PhthN
H
Me
16
+ regioisomer
1.98
2.00
1.91
1.02
4.08
3.02
5.07
1.05
2.88
9
8
7
6
5
4
3
2
1
0
ppm

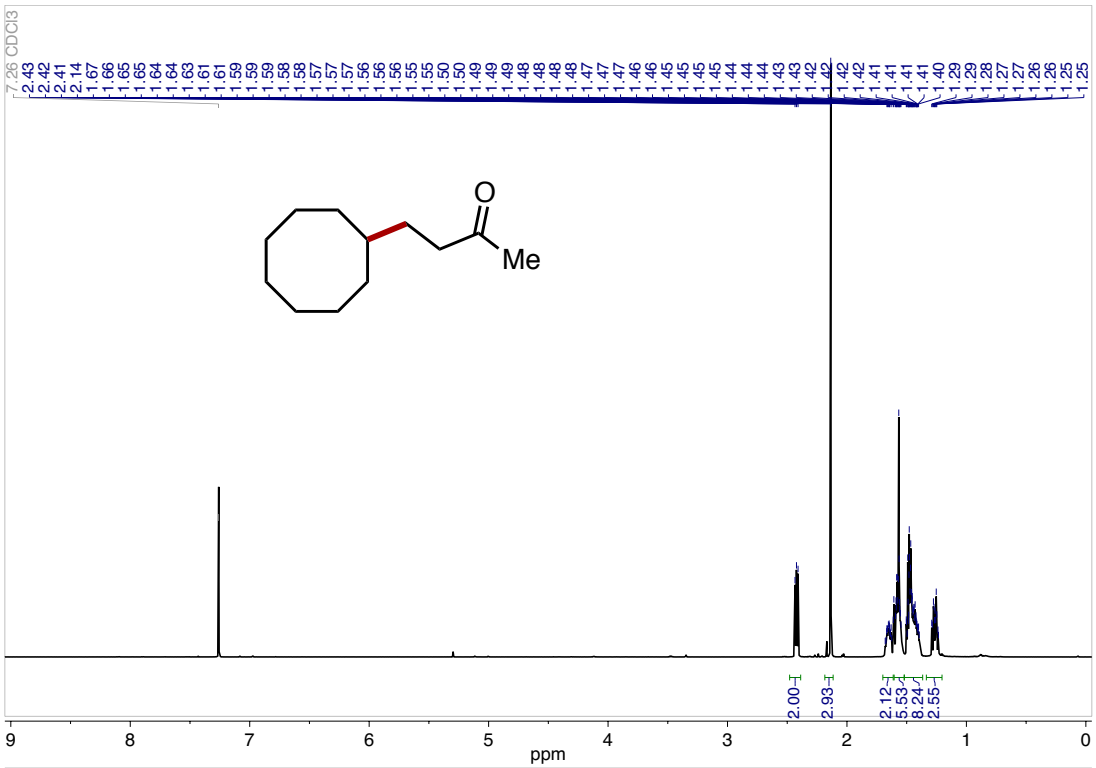

168.53
133.99
133.97
132.35
123.30
123.28
77.16 CDCl3
61.80
41.76
37.07
36.38
35.61
30.73
26.13
26.10
21.63
19.43
Me
Me
N3
PhthN
H
Me
16
+ regioisomer
200
180
160
140
120
100
80
60
40
20
0
ppm

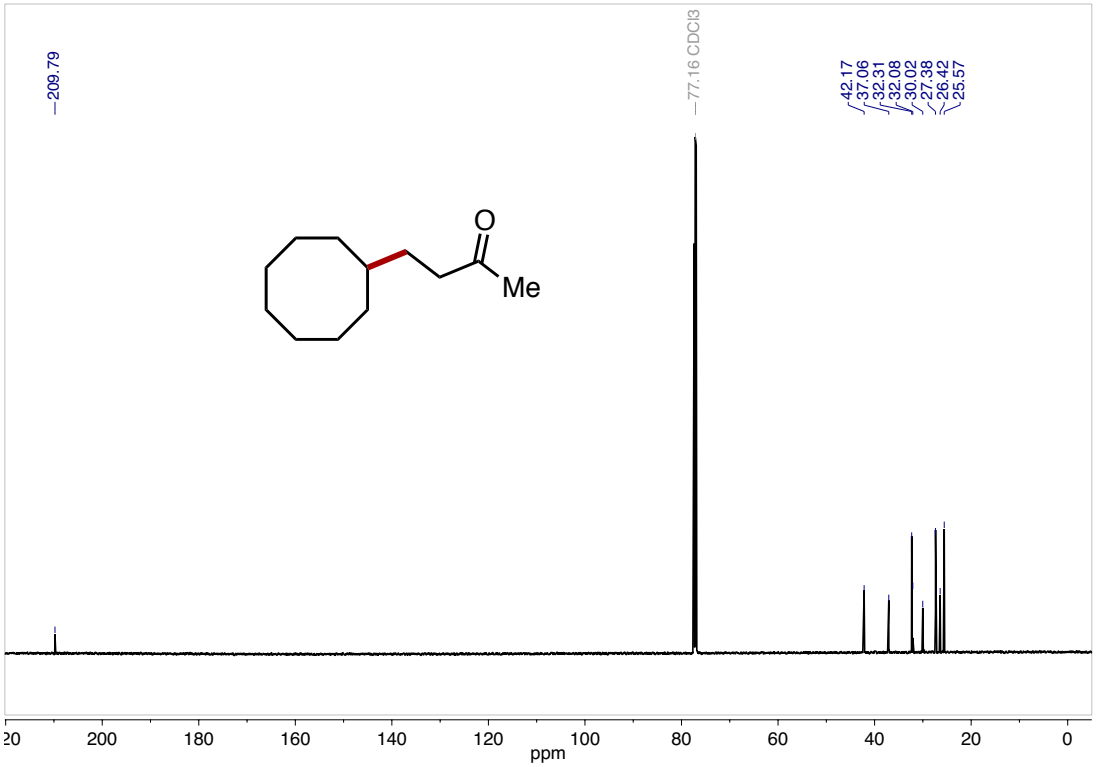

Me
Me
N3
PhO
H
Me
19
+ regioisomer
byproduct
ppm

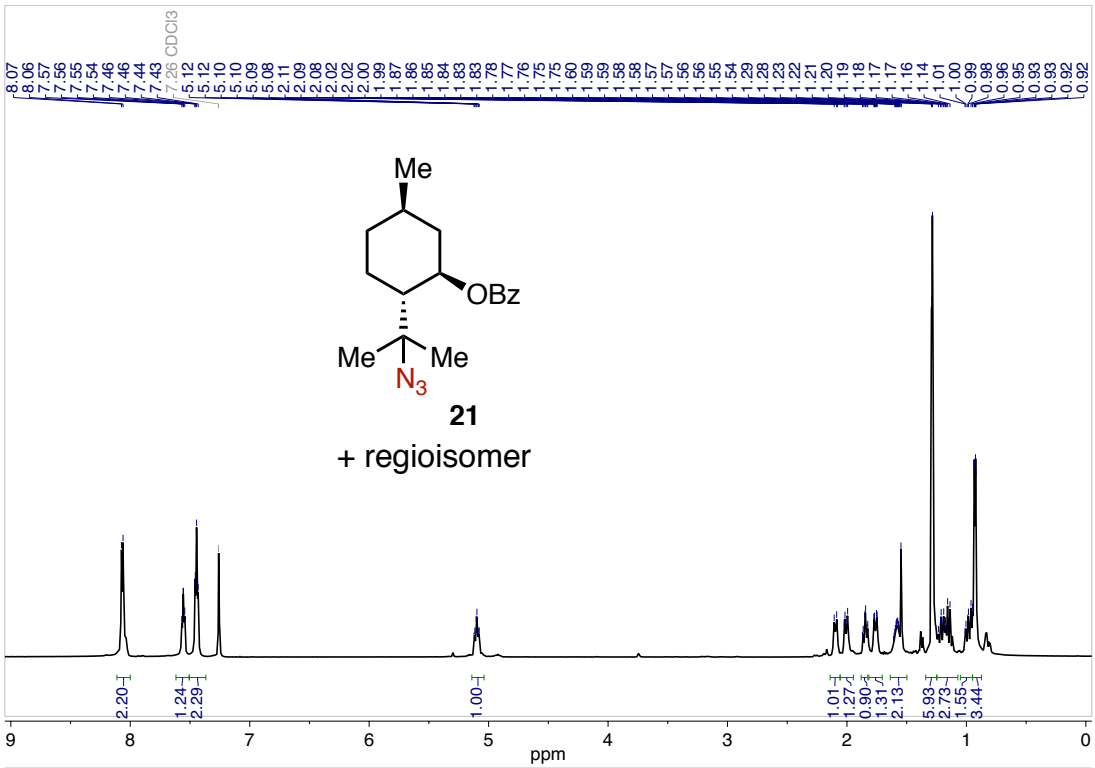

Me
Me
N3
PhO
H
Me
19
+ regioisomer
ppm

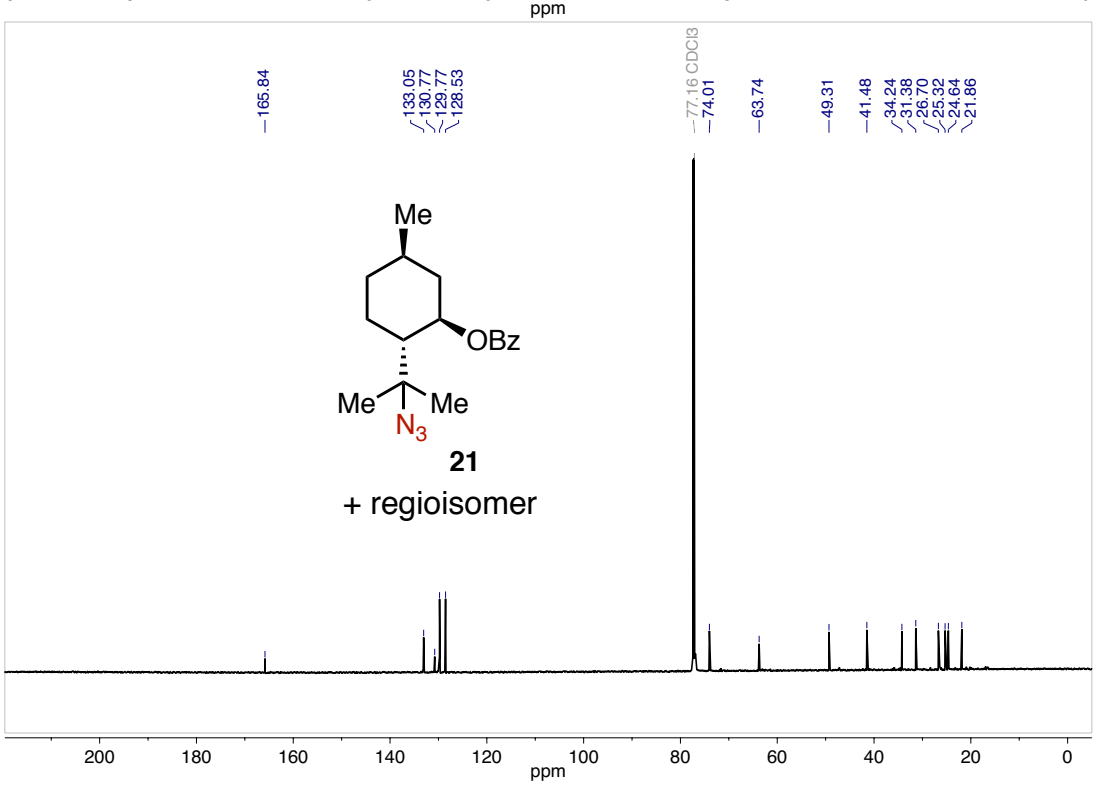

Me
Me
N_3
Me
H
N
O
20
+ regioisomer
ppm

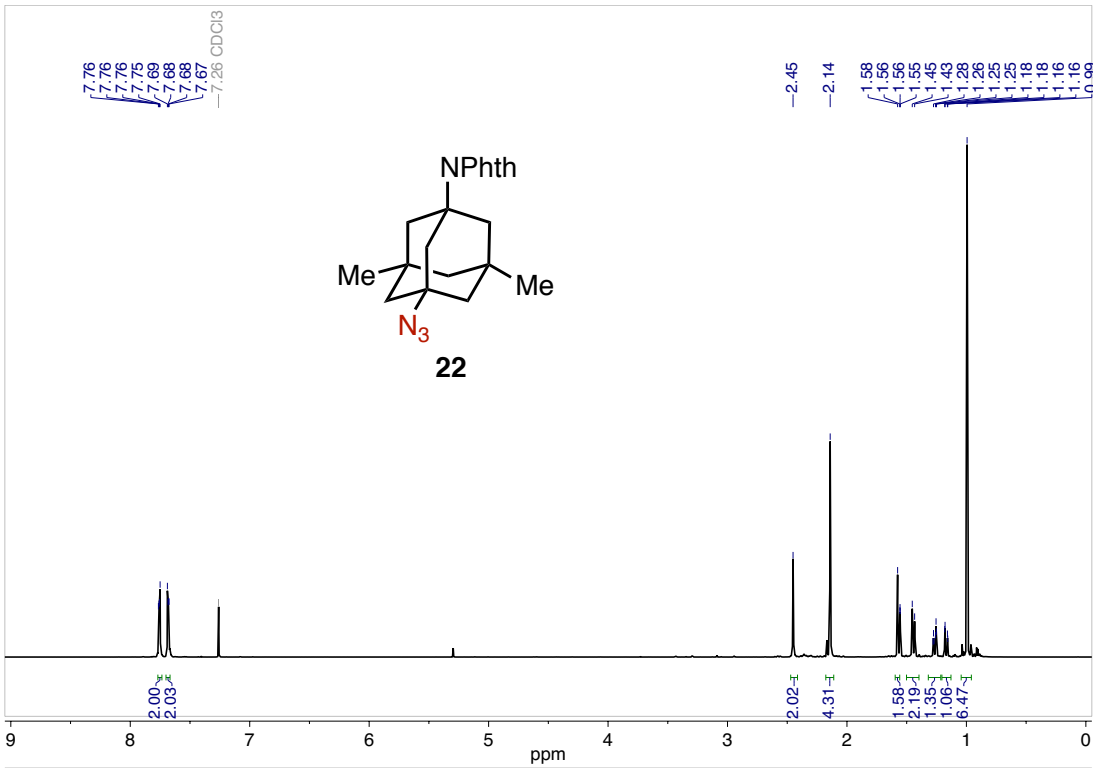

Me
Me
N_3
Me
H
N
O
20
+ regioisomer
ppm

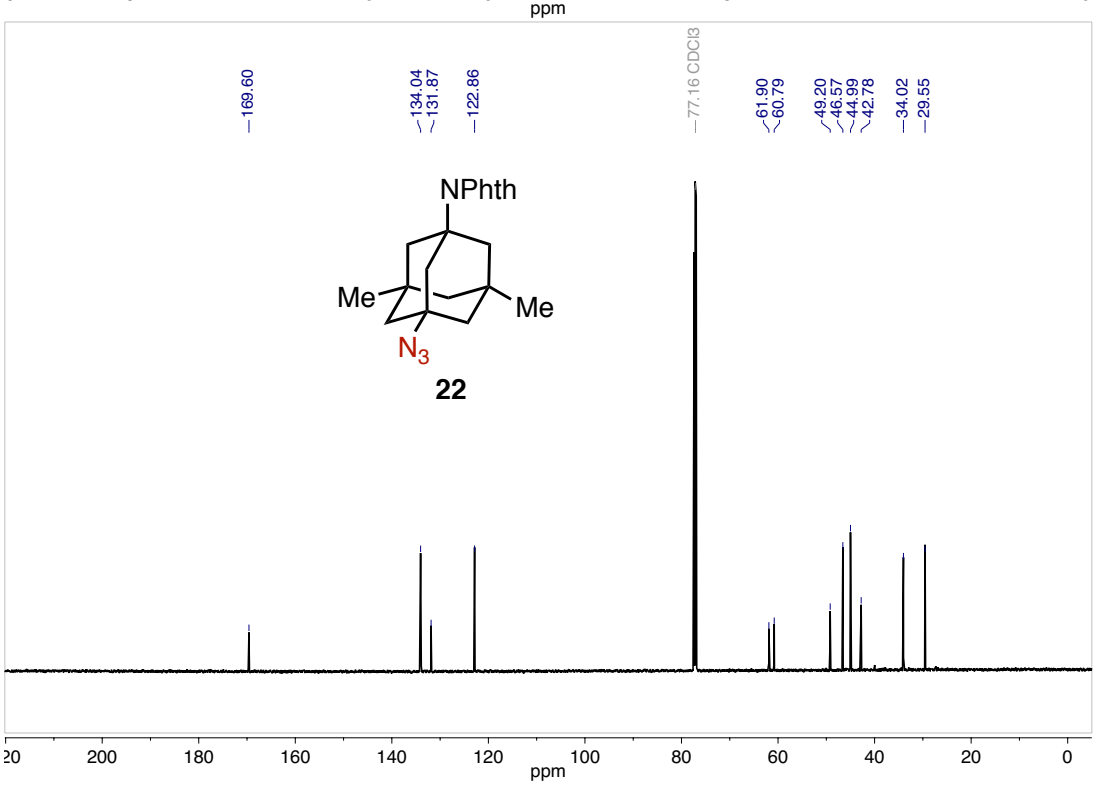

7.26 CDCl3
2.43
2.42
2.41
2.14
1.67
1.66
1.65
1.65
1.64
1.64
1.63
1.61
1.61
1.59
1.59
1.59
1.58
1.58
1.57
1.57
1.57
1.56
1.56
1.56
1.55
1.55
1.50
1.50
1.49
1.49
1.49
1.48
1.48
1.48
1.48
1.47
1.47
1.47
1.46
1.46
1.45
1.45
1.45
1.44
1.44
1.44
1.43
1.42
1.42
1.42
1.41
1.41
1.41
1.40
1.29
1.29
1.28
1.27
1.27
1.26
1.26
1.25
1.25
O
Me
2.00
2.93
2.12
5.53
8.24
2.55
9
8
7
6
5
4
3
2
1
0
ppm

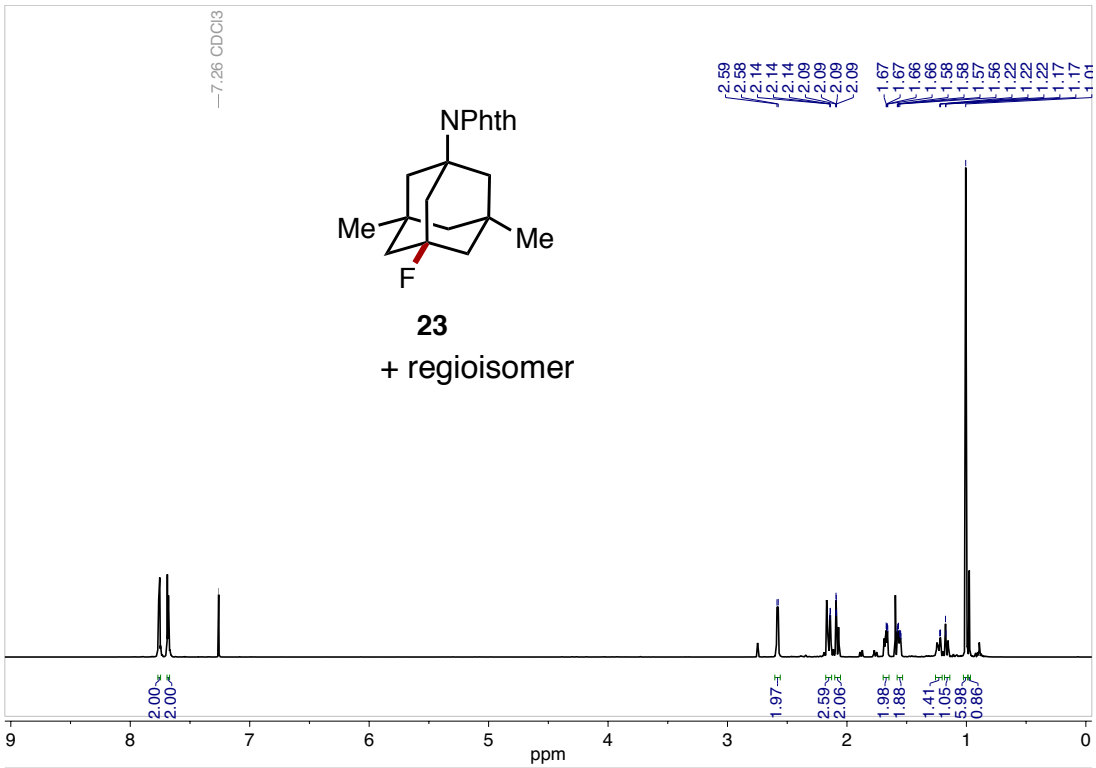

209.79
77.16 CDCl3
42.17
37.06
32.31
32.08
30.02
27.38
26.42
25.57
O
Me
220
200
180
160
140
120
100
80
60
40
20
0
ppm

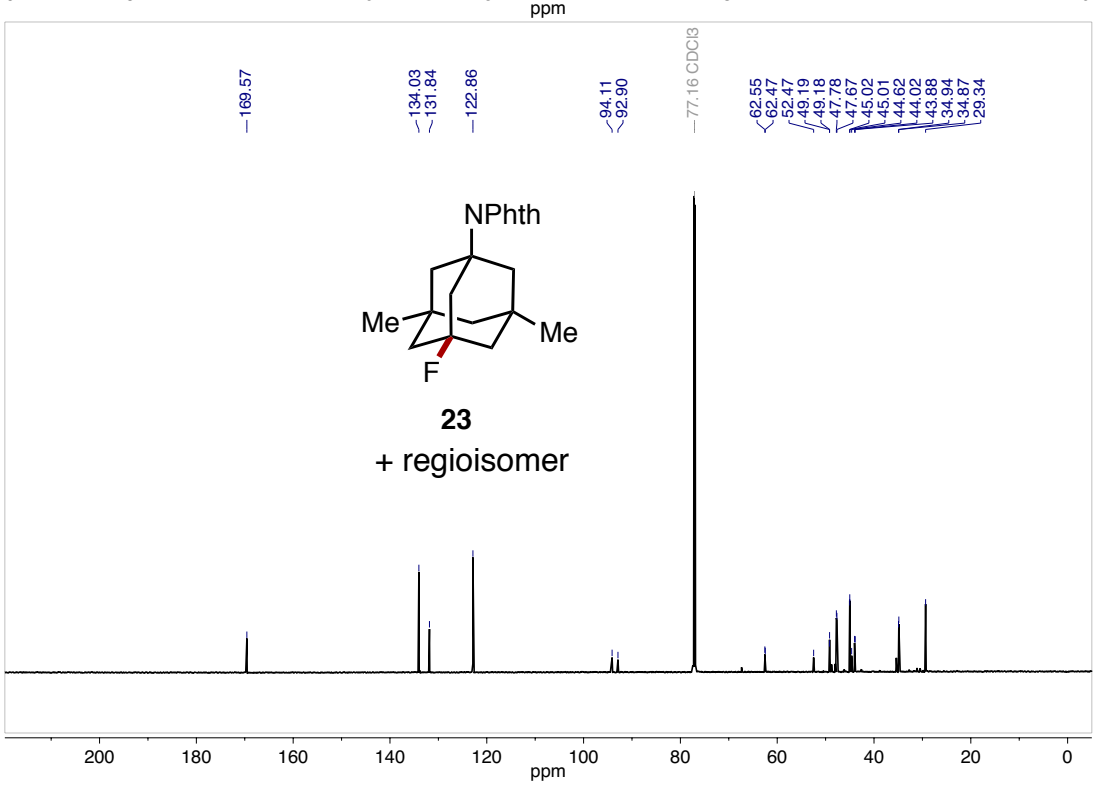

Me
OBz
Me
Me
N3
21
+ regioisomer
ppm

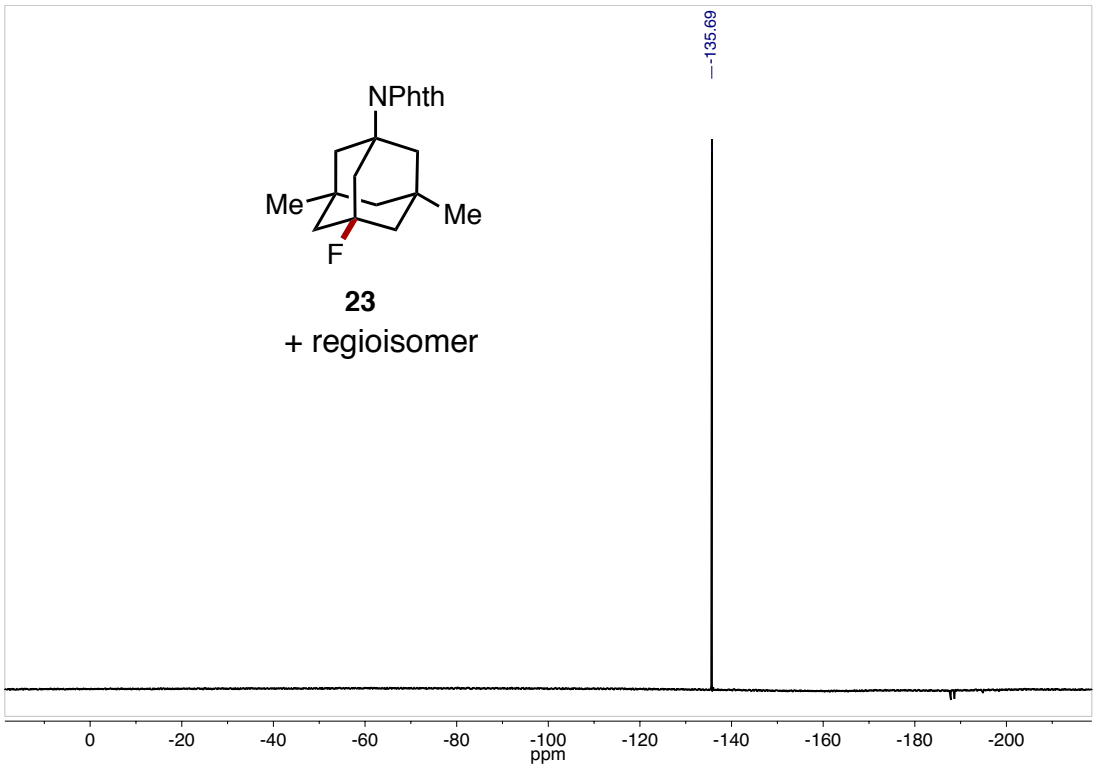

Me
OBz
Me
Me
N3
21
+ regioisomer
ppm

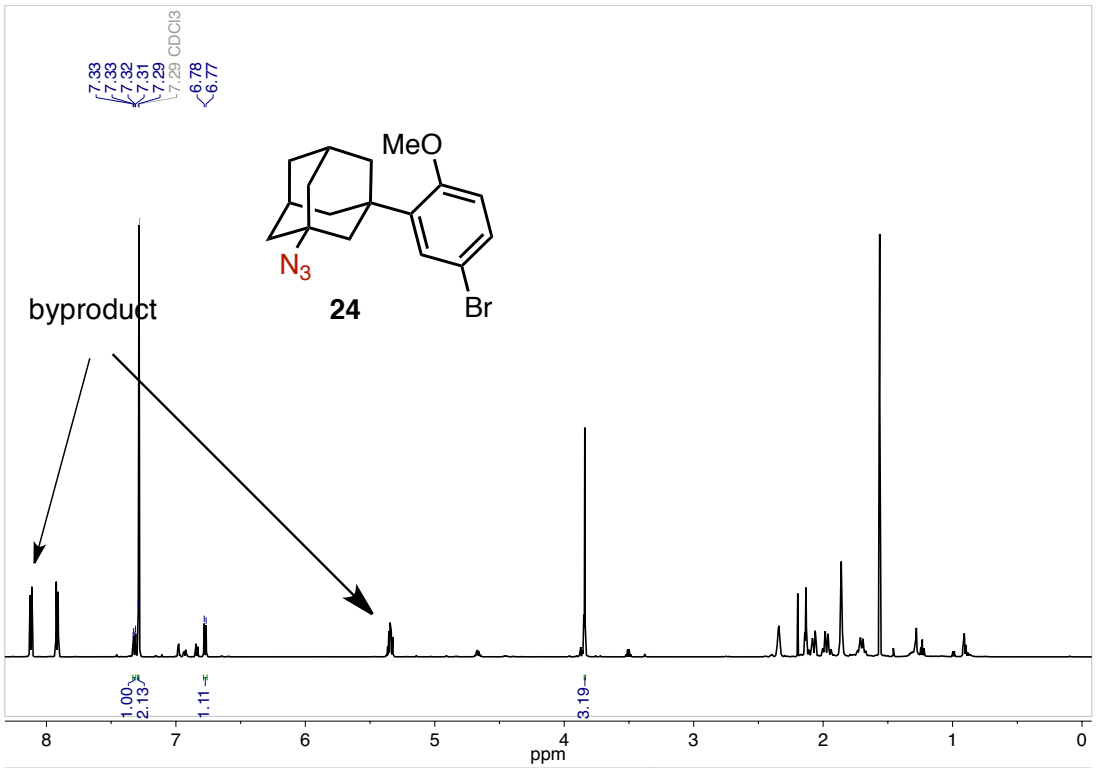

7.76
7.76
7.76
7.75
7.69
7.68
7.68
7.67
7.26 CDCl3
2.45
2.14
1.58
1.56
1.56
1.55
1.45
1.43
1.28
1.26
1.25
1.25
1.18
1.18
1.16
1.16
NPhth
Me
Me
N3
22
2.00
2.03
2.02
4.31
1.58
2.19
1.35
1.06
6.47
9
8
7
6
5
4
3
2
1
0
ppm

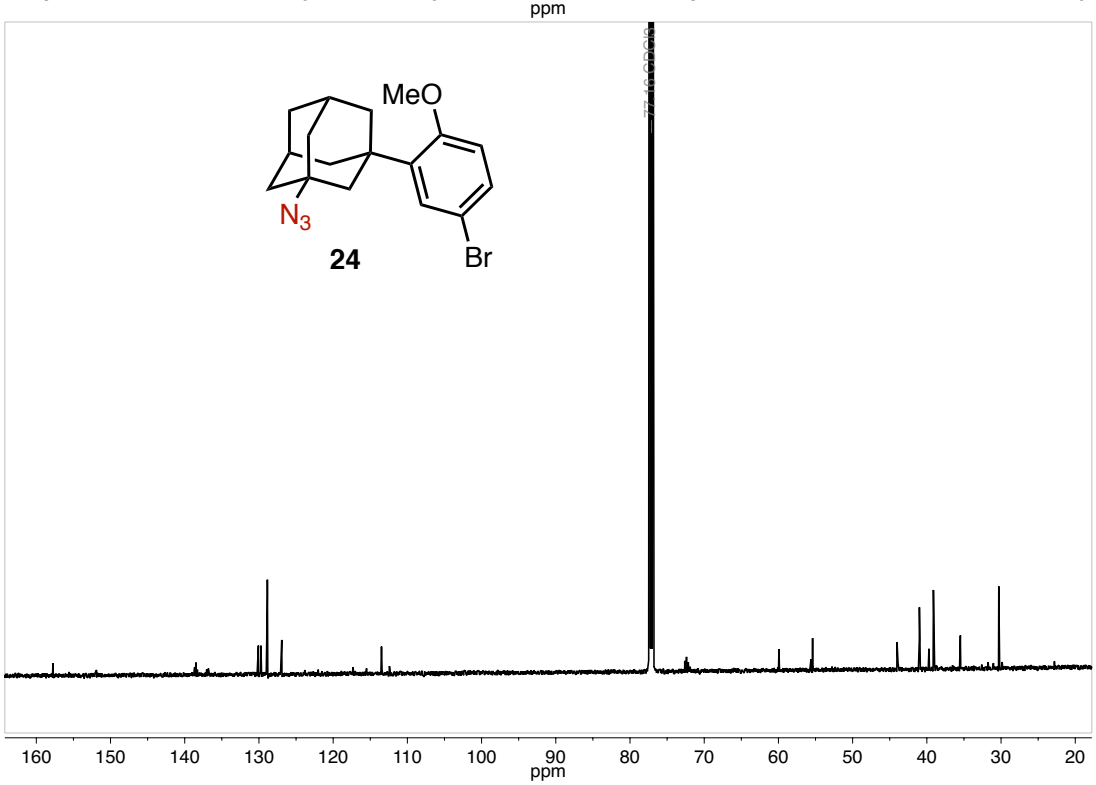

169.60
134.04
131.87
122.86
77.16 CDCl3
61.90
60.79
49.20
46.57
44.99
42.78
34.02
29.55
NPhth
Me
Me
N3
22
220
200
180
160
140
120
100
80
60
40
20
0
ppm

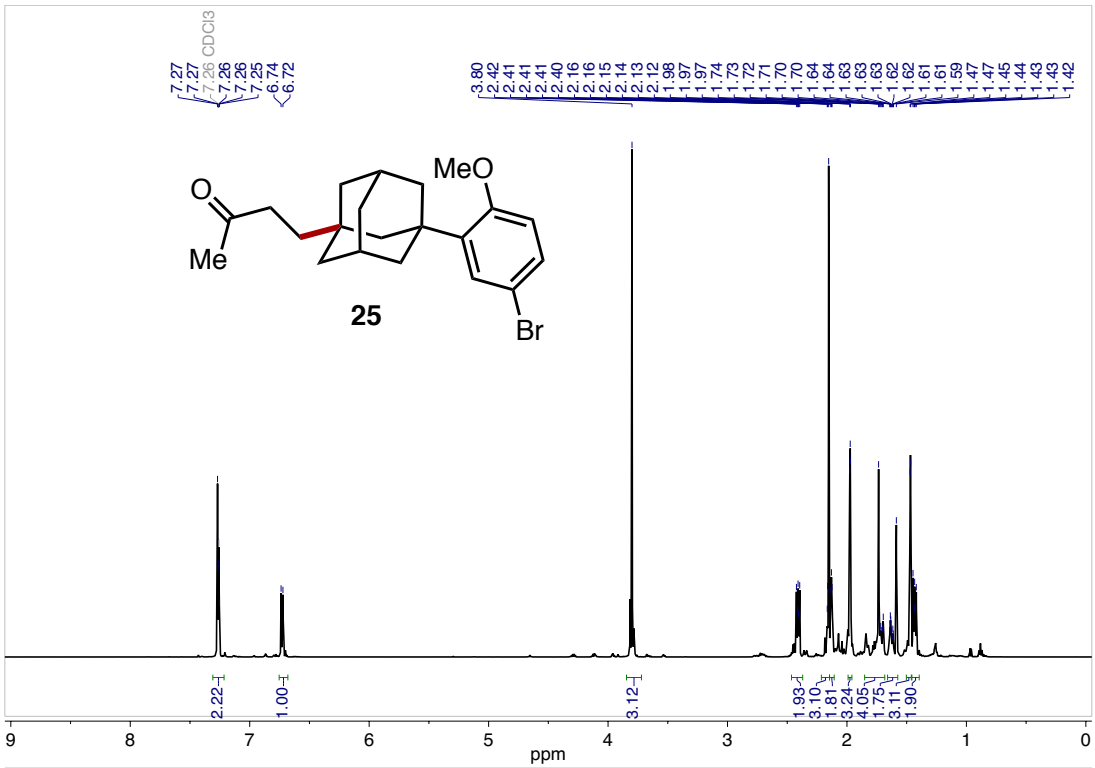

7.26 CDCl3
NPhth
Me
Me
F
23
+ regioisomer
2.59
2.58
2.14
2.14
2.14
2.09
2.09
2.09
2.09
1.67
1.67
1.66
1.66
1.58
1.58
1.57
1.56
1.22
1.22
1.22
1.17
1.17
2.00
2.00
1.97
2.59
2.06
1.98
1.88
1.41
1.05
5.98
0.86
9
8
7
6
5
4
3
2
1
0
ppm

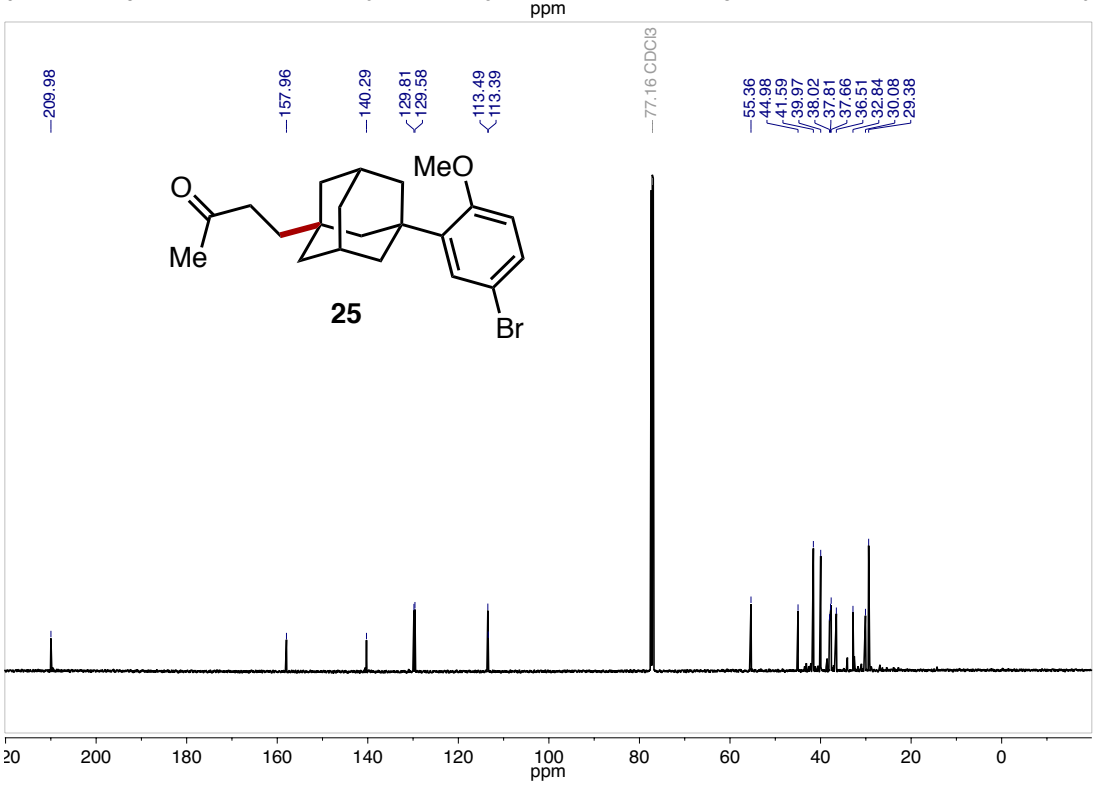

169.57
134.03
131.84
122.86
94.11
92.90
77.16 CDCl3
62.55
62.47
52.47
49.19
49.18
47.78
47.67
45.02
45.01
44.62
44.02
43.88
34.94
34.87
29.34
NPhth
Me
Me
F
23
+ regioisomer
200
180
160
140
120
100
80
60
40
20
0
ppm

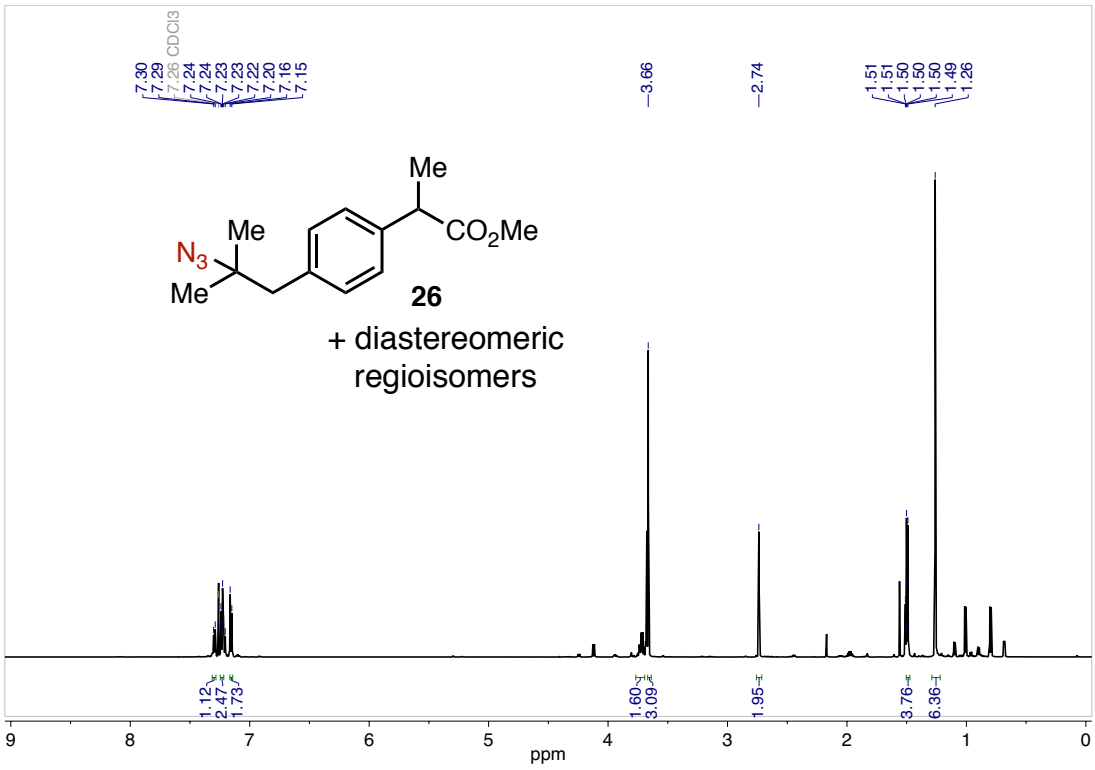

-135.69
NPhth
Me
Me
F
23
+ regioisomer
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
ppm

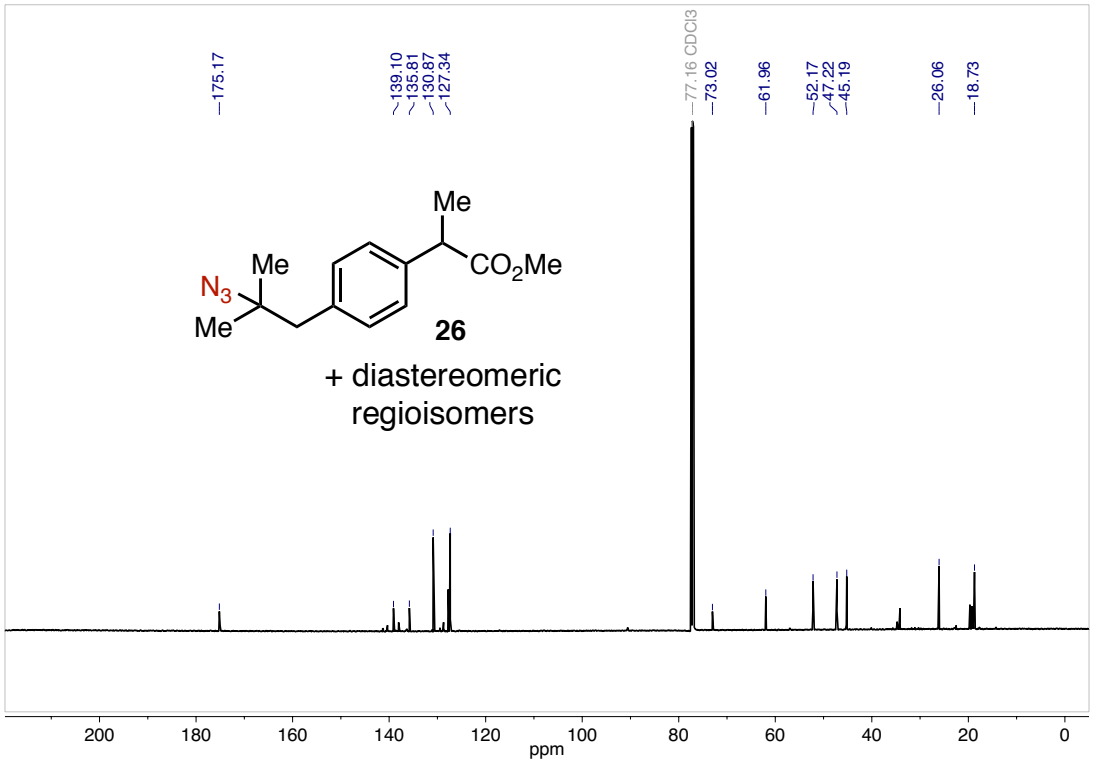

7.33
7.33
7.32
7.31
7.29
7.29 CDCl3
6.78
6.77
MeO
N3
24
Br
byproduct
1.00
2.13
1.11
3.19
8
7
6
5
4
3
2
1
0
ppm

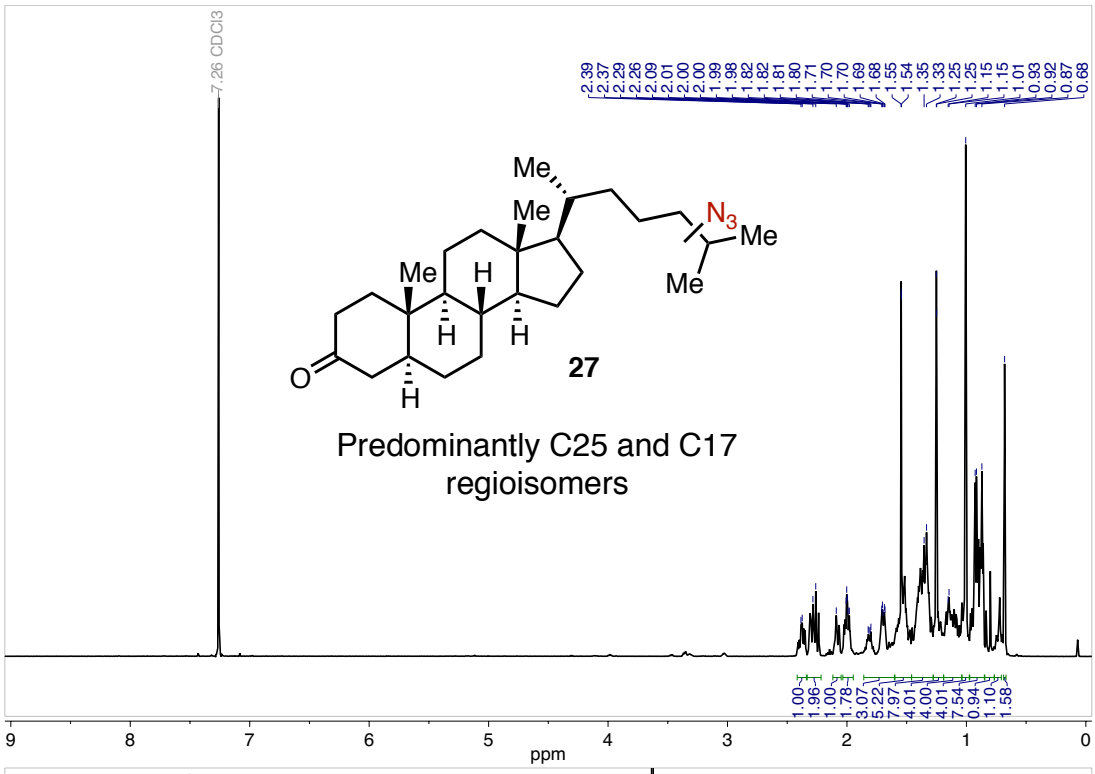

MeO
N3
24
Br
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm

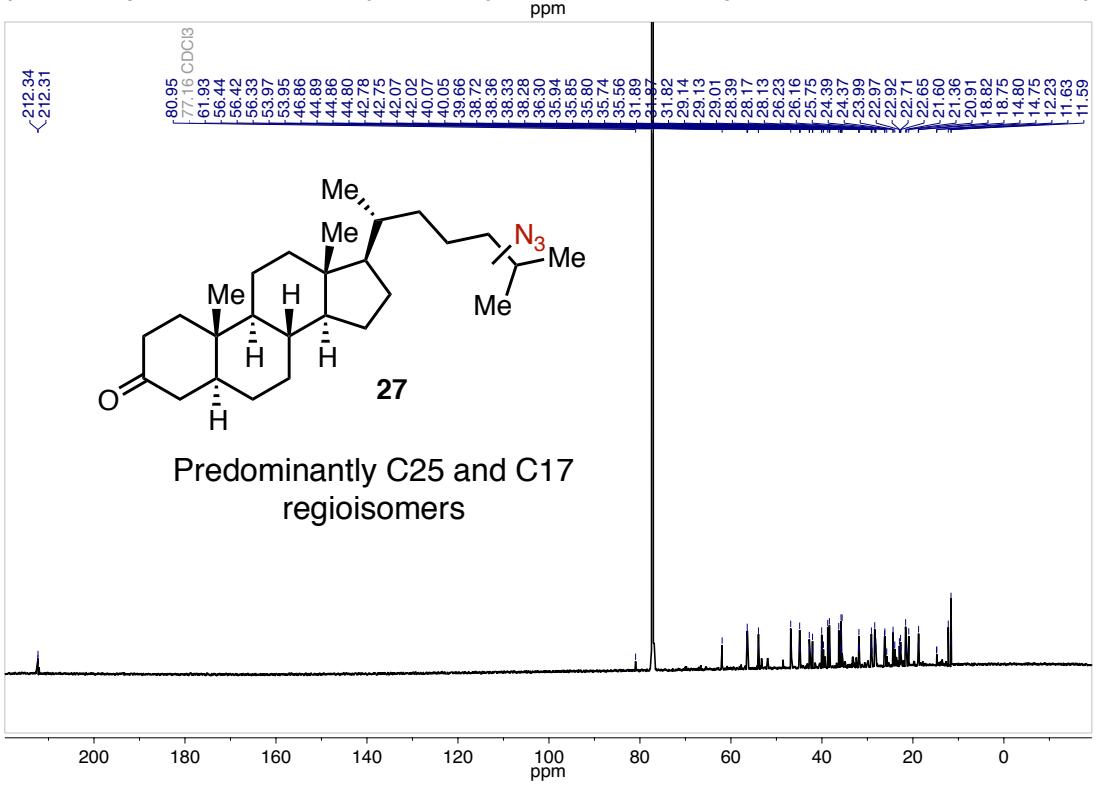

7.27
7.27
7.26 CDCl3
7.26
7.26
7.25
6.74
6.72
3.80
2.42
2.41
2.41
2.41
2.40
2.16
2.16
2.15
2.14
2.13
2.12
1.98
1.97
1.97
1.74
1.73
1.72
1.71
1.70
1.70
1.64
1.64
1.63
1.63
1.63
1.62
1.62
1.61
1.61
1.59
1.47
1.47
1.45
1.44
1.43
1.43
1.42
MeO
O
Me
25
Br
2.22
1.00
3.12
1.93
3.10
1.81
3.24
4.05
1.75
3.11
1.90
9
8
7
6
5
4
3
2
1
0
ppm

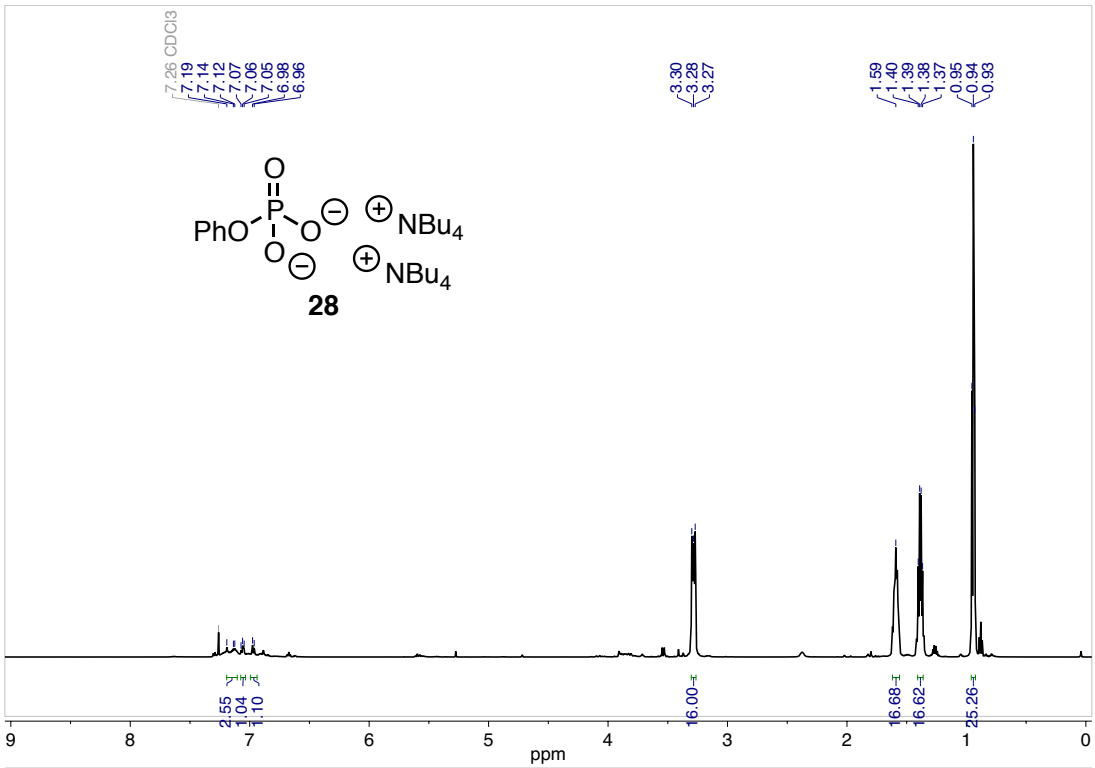

209.98
157.96
140.29
129.81
129.58
113.49
113.39
77.16 CDCl3
55.36
44.98
41.59
39.97
38.02
37.81
37.66
36.51
32.84
30.08
29.38
MeO
O
Me
25
Br
200
180
160
140
120
100
80
60
40
20
0
ppm

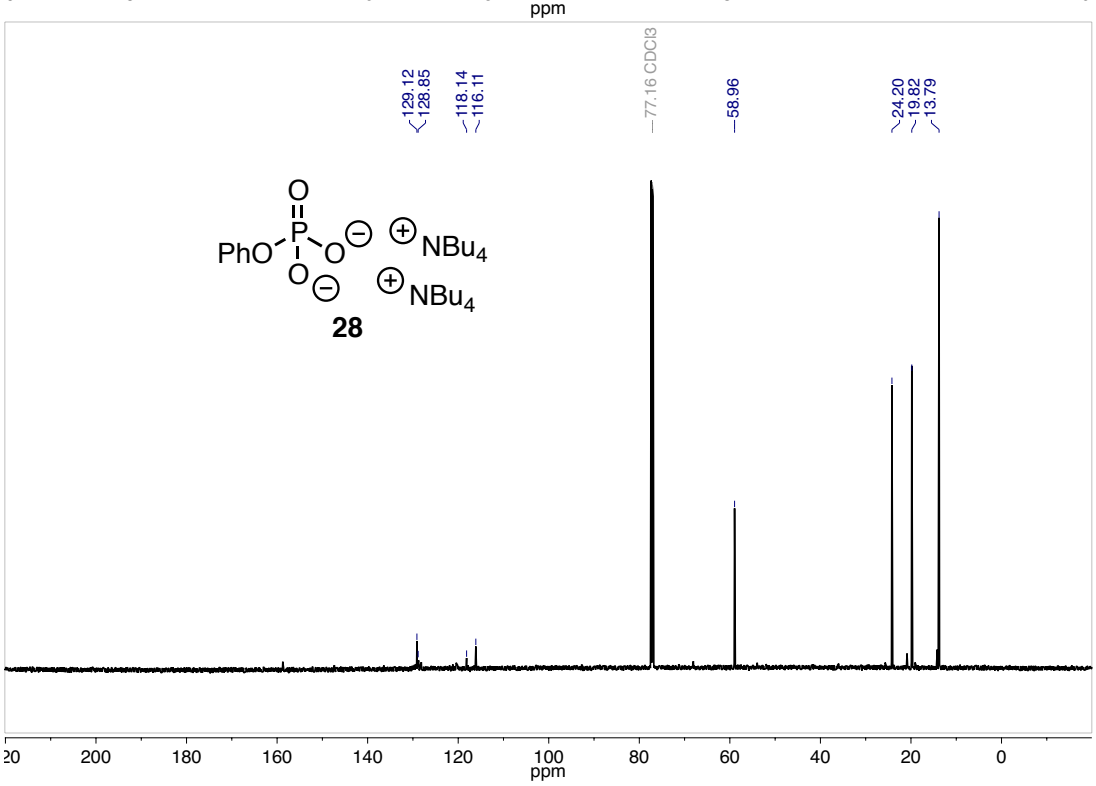

7.30
7.29
7.26 CDCl3
7.24
7.24
7.23
7.23
7.22
7.20
7.16
7.15
3.66
2.74
1.51
1.51
1.50
1.50
1.50
1.49
1.26
Me
CO2Me
N3
Me
Me
26
+ diastereomeric
regioisomers
1.12
2.47
1.73
1.60
3.09
1.95
3.76
6.36
9
8
7
6
5
4
3
2
1
0
ppm


175.17
139.10
135.81
130.87
127.34
77.16 CDCl3
73.02
61.96
52.17
47.22
45.19
26.06
18.73
Me
CO2Me
N3
Me
Me
26
+ diastereomeric
regioisomers
200
180
160
140
120
100
80
60
40
20
0
ppm


7.26 CDCl3
Me
Me
N3
Me
Me
Me
H
H
H
H
O
27
Predominantly C25 and C17
regioisomers
ppm


77.16 CDCl3
Me
Me
N3
Me
Me
Me
H
H
H
H
O
27
Predominantly C25 and C17
regioisomers
ppm


7.26 CDCl3
7.19
7.14
7.12
7.07
7.06
7.05
6.98
6.96
3.30
3.28
3.27
1.59
1.40
1.39
1.38
1.37
0.95
0.94
0.93
PhO
O
P
O
O
NBu4
NBu4
28
2.55
1.04
1.10
16.00
16.68
16.62
25.26
9
8
7
6
5
4
3
2
1
0
ppm


129.12
128.85
118.14
116.11
77.16 CDCl3
58.96
24.20
19.82
13.79
PhO
O
P
O
O
NBu4
NBu4
28
200
180
160
140
120
100
80
60
40
20
0
ppm