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Comparison of Boron-Assisted Oxime and Hydrazone Formations Leads to the Discovery of a Fluorogenic Variant

Electronic Supplementary Information

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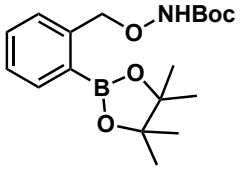
1. Synthesis

1.1 General Experimental Information

1,4-dioxane was freshly distilled from sodium benzophenone ketyl under dry nitrogen prior to use. Other reagents and solvents used were of analytical grade and purchased from Sigma-Aldrich, Alfa Aesar, Apollo Scientific Ltd., Fluka, Fluorochem or Acros and used as received. Buffers and HPLC eluents were prepared with nanopure water (resistivity 18.2 MΩ). Analytical TLC was performed on Silica gel 60 F254 pre-coated glass plates (Merck) and visualized by fluorescence quenching under UV light at 254 nm and subsequent $KMnO_4$ staining. Flash chromatography was performed on SilicaFlash® gel P60 40-63 µm (230-400 mesh) (SiliCycle, Quebec). Concentration under reduced pressure was performed by rotatory evaporation at 40°C. ^{1}H, ^{13}C and 2D-NMR spectra were acquired on a BrukerAvance (400, 500 or 600 MHz proton frequency) spectrometer at 298.15 K. Chemical shifts (δ values) are referenced to the solvent's residual peak and reported in ppm. Multiplicities are reported as follows: s = singlet, s_{br} = broad singlet, d = doublet, t = triplet, dd = doublet of doublets, td = triplet of doublets, m = multiplet or unresolved and coupling constant *J* in Hz. Due to the quadrupole effect carbon atoms attached to a boron atom are omitted in ^{13}C spectra. ESI-MS spectra were recorded on a Bruker Esquire3000+ spectrometer by direct injection in positive polarity of the ion trap detector. High resolution mass spectra (HRMS) were recorded by the mass spectrometric service of the University of Basel on a Bruker maXis 4G QTOF ESI mass spectrometer. Preparative RP-HPLC was carried out on a Shimadzu Prominence UFLC Preparative Liquid Chromatograph using a C18 column (Gemini NX 5 µm, 110Å, AXIA, 250 x 21.2 mm) from Phenomenex with a flow rate of 20 mL/min, gradient: 1% (3 min) - 99% (25 min) - 99% (3 min) (B), monitoring and collecting the products at 254 nm. A buffer (A): 0.1% TFA (v/v) in H_2O, B buffer (B): MeCN. The crude compound mixtures were injected as MeCN solutions. Aqueous product fractions were frozen in liquid N_2 and lyophilized on a Christ Alpha 2-4 LDplus flask lyophilizer at 0.3 mbar or below. UPLC-MS was carried out on an Agilent 1290 Infinity system equipped with an Agilent 6130 Quadrupole LC/MS using a C18 column (ZORBAX Eclipse Plus RRHD, 1.8 µm, 2.1 x 50 mm) from Agilent with a flow rate of 0.45 mL/min at 40°C. A buffer (A): 0.1% (v/v) formic acid in H_2O/1% MeCN (v/v), B buffer (B): 0.1% (v/v) formic acid in MeCN/1% H_2O (v/v) using the following gradient: 5-90% (3.5 min) - 90% (1 min) (B), detection at 254 nm, ESI-MS in positive ion mode of the ion trap.

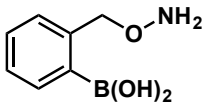
1.2 Experimental and Characterization Data

2-(*N*-Boc-aminooxymethyl)phenylboronic acid pinacol ester (29)



Under a N_2 atmosphere in a dry Schlenk tube, *N*-Boc-hydroxylamine (33.6 mg, 0.25 mmol, 1.5 eq.) and 2-bromomethylphenylboronic acid pinacol ester (50.0 mg, 0.17 mmol, 1.0 eq.) were dissolved in dry MeCN (0.5 mL) and cooled to 0°C. NaH (9.0 mg, 0.34 mmol, 2.0 eq.) was slowly added and the mixture was stirred for 30 min. The cooling bath was removed and the mixture was stirred for another 4 h whereupon UPLC-MS showed complete conversion. The mixture was diluted with H_2O (3 mL) and EtOAc (3 mL) and the layers were separated. The aqueous layer was extracted with EtOAc (2 x 5 mL) and the combined organic layers were washed with H_2O (5 mL), brine (5 mL), dried over Na_2SO_4 and the solvent removed *in vacuo*. The residue was purified by preparative HPLC (t_R = 24.5 min) and product containing fractions were lyophilized to yield the desired product as fluffy white solid (20.0 mg, 0.06 mmol, 34%). ^{1}H-NMR (400 MHz, $CDCl_3$) δ/ppm: 7.81 (dt, *J* = 7.33, 0.97 Hz, 1H), 7.45-7.42 (m, 2H), 7.35-7.30 (m, 1H), 7.18 (s, 1H), 5.14 (s, 2H), 1.46 (s, 9H), 1.35 (s, 12H). ^{13}C NMR (101 MHz, $CDCl_3$) δ/ppm: 156.71, 141.82, 135.98, 131.03, 129.63, 127.72, 83.97, 81.52, 77.87, 28.37, 25.02. HRMS (ESI): $C_{18}H_{29}BNO_5^+$ *calcd.*: 350.2133, *found:* 350.2137, $C_{18}H_{28}BNNaO_5^+$ *calcd.*: 372.1953, *found:* 372.1956.

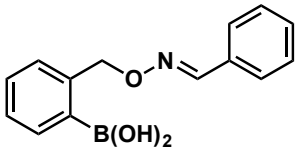
2-Aminooxymethylphenylboronic acid (10)



29 (35.0 mg, 0.10 mmol, 1.0 eq.) was dissolved in CH_2Cl_2 (0.5 mL) while cooling to 0°C. Trifluoroacetic acid (300 µL, 3.92 mmol, 39.1 eq.) was added drop wise over 2 min. After 10 min the cooling bath was removed and the mixture stirred at room temperature for 20 min. H_2O (0.25 mL) and CH_3CN (0.1 mL) were added and the biphasic mixture was stirred at room temperature for 3 h. The volatiles were removed *in vacuo* and the mixture was purified by preparative HPLC (H_2O/CH_3CN, t_R = 9.5 min). The fractions were lyophilized to yield the desired product as white fluffy solid (5.0 mg, 0.03 mmol, 30%). NMR showed a mixture of the free boronic acid and pinacol ester in a ratio of 3:2. ^{1}H NMR (400 MHz, DMSO-d_6) δ/ppm: 7.68-7.64 (m, 1H), 7.52-7.49 (m, 1H, pinacol ester), 7.22-7.18 (m, 2H), 7.17-7.13 (m, 2H, pinacol ester), 7.10-7.07 (m, 1H), 7.04-7.01 (m, 1H, pinacol ester), 5.04 (s, 2H), 4.78 (s, 2H, pinacol ester), 1.14 (s, 12H, pinacol ester). ^{13}C NMR (500 MHz, HMQC, HMBC,

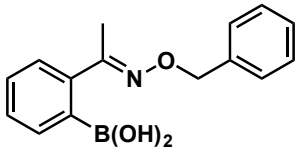
DMSO-d_6) δ/ppm: 142.64, 138.25, 132.12, 126.29, 126.14, 124.64, 72.83 (boronic aicd); 140.02, 131.5, 126.13, 126.00, 123.52, 79.22, 71.65, 25.88 (pinacol ester). HRMS (ESI): $C_{13}H_{21}BNO_3^+$ *calcd.*: 250.1609, *found:* 250.1611 (pinacol ester).

(*E*)-(2-(((Benzylideneamino)oxy)methyl)phenyl)boronic acid (12)



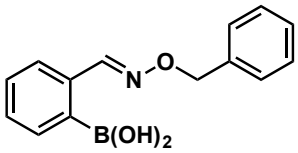
10 (3.0 mg, 0.02 mmol, 1.0 eq.) and benzaldehyde (2.8 μL, 0.03 mmol, 1.5 eq.) were dissolved in MeOH (0.2 mL) and the solution was stirred at room temperature overnight. The solution was directly purified by preparative HPLC (t_R = 20.1 min). Product containing fractions were lyophilized to yield the desired compound as white solid (1.0 mg, 3.9 μmol, 22%). ^{1}H NMR (500 MHz, CD_3CN) δ/ppm: 8.17 (s, 1H), 7.67-7.64 (m, 1H), 7.57-7.54 (m, 2H), 7.44-7.39 (m, 5H), 7.35-7.31 (m, 1H), 6.88 (s, 2H), 5.29 (s, 2H). ^{13}C NMR (500 MHz, HMQC, HMBC, DMSO-d_6) δ/ppm: 150.97, 142.00, 135.17, 132.66, 131.15, 130.80, 130.65, 129.72, 128.46, 127.92, 76.94. HRMS (ESI): $C_{14}H_{15}BNO_3^+$ *calcd.*: 256.1140, *found:* 256.1142, $C_{14}H_{14}BNNaO_3^+$ *calcd.*: 278.0959, *found:* 278.0961.

(*E*)-(2-(1-((Benzyloxy)imino)ethyl)phenyl)boronic acid (14)



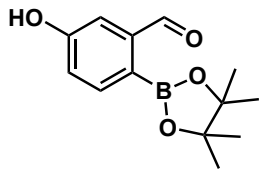
This compound was synthesized according to a published procedure.[1] White solid (56.0 mg, 0.20 mmol, 68%). Analytical data was in agreement with the reported data.

(*E*)-(2-(((Benzyloxy)imino)methyl)phenyl)boronic acid (7)



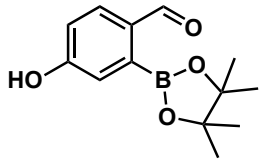
This compound was synthesized according to a published procedure.[1] Analytical data was in agreement with the reported data.

2-Formyl-4-hydroxyphenylboronic acid pinacol ester (15)



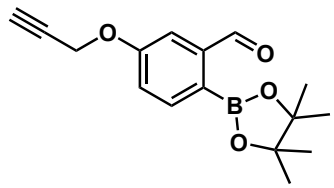
This compound was synthesized according to a published procedure.[2] White solid (151.0 mg, 0.61 mmol, 49%). Analytical data was in agreement with the reported data.

2-Formyl-5-hydroxyphenylboronic acid pinacol ester (30)



Under an Ar atmosphere, 2-bromo-4-hydroxybenzaldehyde (250.0 mg, 1.24 mmol, 1.0 eq.), bis(pinacolato)diboron (410.6 mg, 1.62 mmol, 1.3 eq.), Pd(dppf)Cl_2 (91.0 mg, 0.12 mmol, 10 mol%) and KOAc (366.2 mg, 3.73 mmol, 3.0 eq.) were suspended in freshly distilled dioxane (5 mL). The mixture was heated to reflux (100°C) for 16 h. After cooling the solvent was removed. The residue was diluted with CH_2Cl_2 (20 mL) and washed with H_2O (3 x 20 mL), followed by brine (20 mL). The organic layer was dried over Na_2SO_4, concentrated *in vacuo* and purified by flash chromatography (10:1→ 5:1→ 3:1 cyclohexane/EtOAc) to yield the desired product as a slightly orange solid (141.0 mg, 0.57 mmol, 46%). TLC (3:1 cyclohexane/EtOAc, UV/$KMnO_4$) R_f = 0.33. ^{1}H NMR (400 MHz, $CDCl_3$) δ/ppm: 10.33 (s, 1H), 7.89 (d, J = 8.47 Hz, 1H), 7.23 (d, J = 2.64 Hz, 1H), 6.96 (dd, J = 8.48, 2.62 Hz, 1H), 1.39 (s, 12H). ^{13}C NMR (101 MHz, $CDCl_3$) δ/ppm: 193.13, 160.16, 134.78, 132.52, 131.34, 121.89, 117.64, 84.71, 25.00. HRMS (ESI): $C_{13}H_{17}BNaO_4^+$ *calcd.*: 271.1112, *found:* 271.1114.

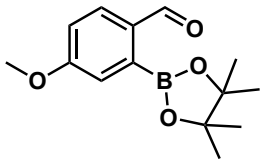
2-Formyl-4-(propargyloxy)phenylboronic acid pinacol ester (31)



Under a N_2 atmosphere **15** (50.0 mg, 0.20 mmol, 1.0 eq.) and propargyl bromide (26.9 µL, 0.24 mmol, 1.3 eq., 80% solution in toluene) were dissolved in DMF (0.5 mL) and K_2CO_3 (41.8 mg, 0.30 mmol, 1.5 eq.) was added. The mixture was stirred at room temperature for 21 h and then diluted with H_2O (15 mL) and EtOAc (15 mL). The layers were separated and the aqueous layer was washed

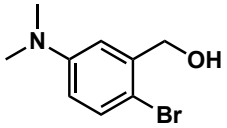
with EtOAc (2 x 15 mL). The combined organic layers were washed with brine (10 mL), dried over Na_2SO_4 and the solvent was removed *in vacuo*. The crude product was purified by flash chromatography (10:1 cyclohexane/EtOAc) to yield the desired product as white solid (37.0 mg, 0.13 mmol, 64%). TLC (10:1 cyclohexane/EtOAc, UV/$KMnO_4$) R_f = 0.24. ^{1}H NMR (400 MHz, $CDCl_3$) δ/ppm: 10.67 (s, 1H), 7.89 (d, *J* = 8.29 Hz, 1H), 7.57 (d, *J* = 2.65 Hz, 1H), 7.19 (dd, *J* = 8.29, 2.69 Hz, 1H), 4.77 (d, *J* = 2.40 Hz, 2H), 2.53 (t, *J* = 2.38 Hz, 1H), 1.37 (s, 12H). ^{13}C NMR (101 MHz, $CDCl_3$) δ/ppm: 194.72, 159.92, 143.64, 138.11, 120.66, 111.63, 84.38, 77.89, 76.23, 55.94, 25.02. LRMS (ESI): $C_{16}H_{19}BNaO_4^+$ *calcd.*: 309.13, *found:* 309.24.

2-Formyl-5-methoxyphenylboronic acid pinacol ester (32)



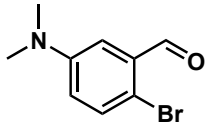
Under a N_2 atmosphere **30** (70.0 mg, 0.28 mmol, 1.0 eq.) was dissolved in DMF (1.0 mL) and K_2CO_3 (58.5 mg, 0.42 mmol, 1.5 eq.) was added. MeI (21.1 μL, 0.34 mmol, 1.2 eq.) was added drop wise and the mixture was stirred at room temperature overnight. The mixture was diluted with H_2O (15 mL) and extracted with EtOAc (3 x 15 mL). The combined organic layers were washed with H_2O (2 x 15 mL) and brine (15 mL). The organic layers were concentrated *in vacuo* and purified by flash chromatography (cyclohexane→ 20:1→ 10:1→ 5:1 cyclohexane:EtOAc) to yield the desired product as slightly yellow oil (18.0 mg, 0.07 mmol, 24%). TLC (5:1 cyclohexane/EtOAc, UV/$KMnO_4$) R_f= 0.26. Analytical data was in agreement with reported data.[3]

2-Bromo-5-(dimethylamino)phenylmethanol (33)



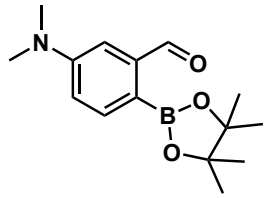
This compound was synthesized according to a published procedure.[4] White solid (162.0 mg, 0.70 mmol, 75%). Analytical data was in agreement with the reported data.

2-Bromo-5-dimethylaminobenzaldehyde (34)



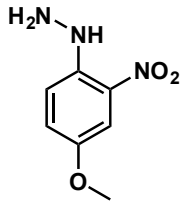
This compound was synthesized according to a published procedure.[4] Yellow solid (76.0 mg, 0.33 mmol, 77%). Analytical data was in agreement with the reported data.

2-Formyl-4-(dimethylamino)phenylboronic acid pinacol ester (28)



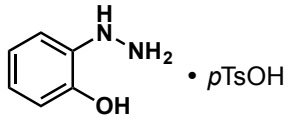
Under an Ar atmosphere, **34** (50.0 mg, 0.22 mmol, 1.0 eq.), bis(pinacolato)diboron (72.4 mg, 0.28 mmol, 1.3 eq.), Pd(dppf)Cl_2 (16.0 mg, 0.02 mmol, 10 mol%) and KOAc (64.5 mg, 0.66 mmol, 3.0 eq.) were suspended in freshly distilled dioxane (1.5 mL). The mixture was heated to reflux for 3 h. After cooling the solvent was removed, diluted with CH_2Cl_2 (20 mL) and washed with H_2O (3 x 20 mL) followed by brine (20 mL). The organic layer was dried over Na_2SO_4, concentrated *in vacuo* and purified by flash chromatography (cyclohexane→ 20:1→ 15:1→ 10:1 cyclohexane:EtOAc) to yield the desired product as yellow solid (43.0 mg, 0.16 mmol, 71%). TLC (10:1 cyclohexane/EtOAc, UV/$KMnO_4$) R_f = 0.27. Analytical data was in agreement with reported data.[5]

2-Nitro-4-methoxyphenyhydrazine (35)



This compound was synthesized according to a published procedure.[6] Dark red solid (853.0 mg, 4.66 mmol, 16%). Analytical data was in agreement with the reported data.

2-Hydroxyphenylhydrazine pTsOH salt (36)

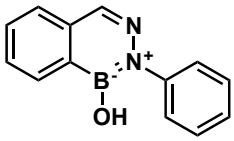


This compound was synthesized according to a published procedure.[7] Colorless plates (4.39 g, 14.8 mmol, 54%). Analytical data was in agreement with the reported data.

General Procedure for the Synthesis of 4,3-Borazaroisoquinolines (BIQ)

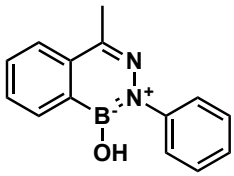
Boronic acid aldehyde (1.0 eq.) and phenylhydrazine (1.4 eq.) were suspended in DMSO/H_2O (1:4) and the suspension was stirred at room temperature for 2 h. The mixture was diluted with MeCN until a clear solution was obtained. The product was purified by preparative HPLC (0.1% TFA) and the fractions were lyophilized.

2-Phenylbenzo[*d*][1,2,3]diazaborinin-1(2*H*)-ol (4)



4 was synthesized according to the general procedure. 2-Formylphenylboronic acid (2-FPBA) (5.0 mg, 0.03 mmol, 1.0 eq.) and phenylhydrazine (4.6 μL, 0.05 mmol, 1.4 eq.) were mixed in the solvent (1 mL). The product was isolated as white solid (4.0 mg, 0.02 mmol, 54%). Preparative HPLC: t_R = 20.5 min. Analytical data was in agreement with reported data.[8]

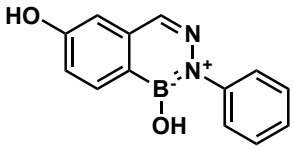
4-Methyl-2-phenylbenzo[*d*][1,2,3]diazaborinin-1(*2H*)-ol (18)



18 was synthesized according to the general procedure. 2-Acetylphenylboronic acid (5.0 mg, 0.03 mmol, 1.0 eq.) and phenylhydrazine (4.2 μL, 0.04 mmol, 1.4 eq.) were mixed in the solvent (1 mL). The product was isolated as yellow solid (6.0 mg, 0.03 mmol, 83%). Preparative HPLC: t_R = 21.8 min. ^{1}H NMR (400 MHz, CD_3CN) δ/ppm: 8.21-8.17 (m, 1H), 7.95-7.91 (m, 1H), 7.82-7.77 (m, 1H), 7.70-7.65 (m, 1H), 7.56-7.51 (m, 2H), 7.47-7.41 (m, 2H), 7.30-7.24 (m, 1H), 2.58 (s, 3H). ^{13}C NMR (500 MHz, HMQC, HMBC, CD_3CN) δ/ppm: 147.01, 144.40, 136.10, 132.29, 132.00,

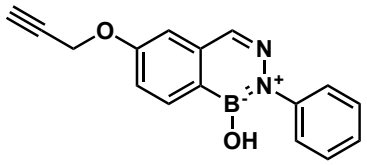
129.78, 129.38, 126.44, 126.33, 126.04, 20.27. HRMS (ESI): $C_{14}H_{14}BN_2O^+$ *calcd.*: 237.1194, *found:* 237.1198.

2-Phenylbenzo[*d*][1,2,3]diazaborinine-1,6(*2H*)-diol (17)



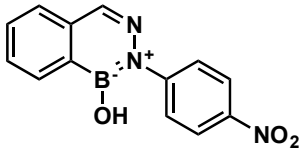
17 was synthesized according to the general procedure. **15** (5.0 mg, 0.02 mmol, 1.0 eq.) and phenylhydrazine (2.8 μL, 0.03 mmol, 1.4 eq.) were mixed in the solvent (0.25 mL). The product was isolated as white solid (4.0 mg, 0.02 mmol, 83%). Preparative HPLC: t_R = 18.2 min. ^{1}H NMR (400 MHz, CD_3CN) δ/ppm: 8.06-8.02 (m, 1H), 8.01 (s, 1H), 7.54-7.50 (m, 2H), 7.45-7.40 (m, 2H), 7.29-7.24 (m, 1H), 7.17-7.13 (m, 1H), 7.12-7.10 (m, 1H). ^{13}C NMR (500 MHz, HMQC, HMBC, CD_3CN) δ/ppm: 160.63, 147.20, 140.05, 138.50, 134.04, 129.37, 126.33, 125.90, 119.23, 112.15. HRMS (ESI): $C_{13}H_{12}BN_2O_2^+$ *calcd.*: 239.0986, *found:* 239.0989.

2-Phenyl-6-(propargyloxy)benzo[*d*][1,2,3]diazaborinin-1(*2H*)-ol (19)



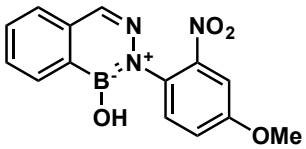
19 was synthesized according to the general procedure. **31** (5.0 mg, 0.02 mmol, 1.0 eq.) and phenylhydrazine (2.4 μL, 0.03 mmol, 1.4 eq.) were mixed in the solvent (0.25 mL). The product was isolated as white solid (4.0 mg, 0.01 mmol, 83%). Preparative HPLC: t_R = 21.2 min. ^{1}H NMR (400 MHz, CD_3CN) δ/ppm: 8.14-8.11 (m, 1H), 8.08 (s, 1H), 7.55-7.51 (m, 2H), 7.46-7.41 (m, 2H), 7.32-7.29 (m, 2H), 7.29-7.27 (m, 1H), 6.25 (s, 1H), 4.89 (d, *J* = 2.39 Hz, 2H), 2.86 (t, J = 2.34 Hz, 1H). ^{13}C NMR (500 MHz, HMQC, HMBC, CD_3CN) δ/ppm: 160.83, 147.03, 139.86, 138.27, 133.82, 129.29, 126.56, 125.91, 119.21, 110.93, 79.23, 77.11, 56.59. HRMS (ESI): $C_{16}H_{14}BN_2O_2^+$ *calcd.*: 277.1143, *found:* 277.1146.

2-(4-Nitrophenyl)benzo[*d*][1,2,3]diazaborinin-1(*2H*)-ol (20)



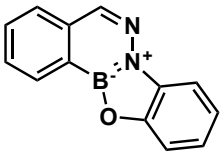
2-Formylphenylboronic acid (10.0 mg, 0.07 mmol, 1.0 eq.) and 4-nitrophenylhydrazine (22.0 mg, 0.09 mmol, 1.4 eq., 65% in H_2O) were dissolved in H_2O/DMSO (4:1, 1.0 mL). The suspension was acidified with HCl (0.1 mL, 1N) and stirred for 32 h at room temperature. The mixture was directly purified by preparative HPLC (0.1% TFA, t_R = 22.2 min) to yield the desired product as yellow solid (14.0 mg, 0.05 mmol, 79%). ^{1}H NMR (400 MHz, DMSO-d_6) δ/ppm: 9.64 (s, 1H), 8.44 (d, J = 7.44 Hz, 1H), 8.33-8.27 (m, 3H), 8.03-7.97 (m, 2H), 7.88-7.78 (m, 2H), 7.71 (td, J = 7.05, 1.49 Hz, 1H). ^{13}C NMR (101 MHz, DMSO-d_6) δ/ppm: 152.28, 143.52, 140.86, 134.70, 132.00, 131.97, 129.63, 127.40, 123.96, 123.81. HRMS (ESI): $C_{13}H_{11}BN_3O_3^+$ *calcd.*: 268.0888, *found:* 268.0893.

2-(4-Methoxy-2-nitrophenyl)benzo[*d*][1,2,3]diazaborinin-1(*2H*)-ol (21)



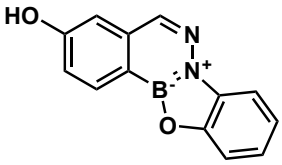
2-Formylphenylboronic acid (10.0 mg, 0.07 mmol, 1.0 eq.) and **35** (17.1 mg, 0.09 mmol, 1.4 eq.) were dissolved in H_2O/DMSO (4:1, 1.0 mL). The suspension was acidified with HCl (0.1 mL, 1N) and stirred for 67 h at 70°C. The mixture was directly purified by preparative HPLC (0.1% TFA, t_R = 19.9 min) to yield the desired product as brown solid (12.0 mg, 0.04 mmol, 61%). ^{1}H NMR (400 MHz, DMSO-d_6) δ/ppm: 9.12 (s_{br}, 1H), 8.36-8.31 (m, 1H), 8.15 (s, 1H), 7.84-7.76 (m, 2H), 7.70-7.65 (m, 1H), 7.57 (d, J = 8.95 Hz, 1H), 7.51 (d, J = 3.05 Hz, 1H), 7.35 (dd, J = 8.86, 2.97 Hz, 1H), 3.89 (s, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ/ppm: 157.19, 145.62, 139.74, 135.16, 132.07, 131.67, 131.65, 130.25, 129.28, 127.26, 119.17, 109.03, 56.12. HRMS (ESI): $C_{14}H_{13}BN_3O_4^+$ *calcd.*: 298.0994, *found:* 298.0996.

Benzo[*d*]benzo[4,5][1,3,2]oxazaborolo[3,2-*b*][1,2,3]diazaborinine (22)



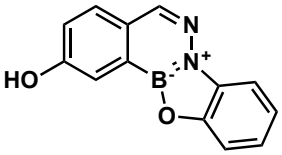
22 was synthesized according to the general procedure. 2-Formylphenylboronic acid (10.0 mg, 0.07 mmol, 1.0 eq.) and **36** (27.7 mg, 0.09 mmol, 1.4 eq.) were mixed in the solvent (1.0 mL). The product was isolated as white solid (14.0 mg, 0.06 mmol, 95%). Preparative HPLC: t_R = 23.8 min. ^{1}H NMR (400 MHz, DMSO-d_6) δ/ppm: 8.73 (s, 1H), 8.34 (d, *J* = 7.39 Hz, 1H), 8.18 (d, *J* = 7.91 Hz, 1H), 7.96 (td, *J* = 7.25, 1.37 Hz, 1H), 7.88 (td, *J* = 7.41, 1.06 Hz, 1H), 7.82 (dd, *J* = 7.51, 1.25 Hz, 1H), 7.62 (dd, *J* = 7.98, 0.92 Hz, 1H), 7.35 (td, *J* = 7.53, 1.27 Hz, 1H), 7.29 (td, *J* = 7.70, 1.54 Hz, 1H). ^{13}C NMR (101 MHz, DMSO-d_6) δ/ppm: 148.12, 144.64, 135.75, 134.35, 131.99, 130.62, 130.37, 129.49, 123.17, 122.89, 113.69, 110.35. HRMS (ESI): $C_{13}H_{10}BN_2O^+$ *calcd.*: 221.0881, *found:* 221.0883.

Benzo[*d*]benzo[4,5][1,3,2]oxazaborolo[3,2-*b*][1,2,3]diazaborinin-3-ol (23)



23 was synthesized according to the general procedure. **15** (15.0 mg, 0.06 mmol, 1.0 eq.) and **36** (25.1 mg, 0.08 mmol, 1.4 eq.) were mixed in the solvent (1.0 mL). The product was isolated as white solid (13.0 mg, 0.06 mmol, 91%). Preparative HPLC: t_R = 21.0 min. ^{1}H NMR (400 MHz, DMSO-d_6) δ/ppm: 10.56 (s_{br}, 1H), 8.55 (s, 1H), 8.16 (d, *J* = 8.30 Hz, 1H), 7.75 (dd, *J* = 7.52, 1.12 Hz, 1H), 7.55 (dd, *J* = 7.82, 1.12 Hz, 1H), 7.43 (d, *J* = 2.12, Hz, 1H), 7.35-7.27 (m, 2H), 7.24 (td, *J* = 7.72, 1.41 Hz, 1H). ^{13}C NMR (101 MHz, DMSO-d_6) δ/ppm: 160.75, 148.19, 144.37, 138.17, 134.51, 132.44, 122.92, 122.81, 120.36, 113.74, 113.59, 110.12. HRMS (ESI): $C_{13}H_{10}BN_2O_2^+$ *calcd.*: 237.0830, *found:* 237.0832.

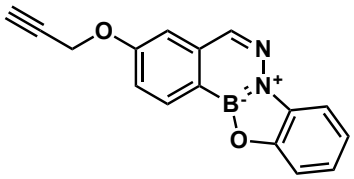
Benzo[*d*]benzo[4,5][1,3,2]oxazaborolo[3,2-*b*][1,2,3]diazaborinin-3-ol (24)



24 was synthesized according to the general procedure. **30** (15.0 mg, 0.06 mmol, 1.0 eq.) and **36** (25.1 mg, 0.08 mmol, 1.4 eq.) were mixed in the solvent (1.0 mL). The product was isolated as white solid (13.0 mg, 0.06 mmol, 91%). Preparative HPLC: t_R = 20.5 min. ^{1}H NMR (400 MHz, DMSO-d_6) δ/ppm:

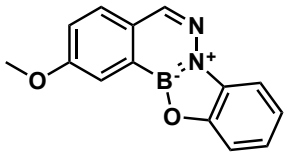
10.63 (s_{br}, 1H), 8.54 (s, 1H), 8.02 (d, J = 8.25 Hz, 1H), 7.77 (dd, J = 7.53, 1.23 Hz, 1H), 7.58 (dd, J = 7.80, 0.96 Hz, 1H), 7.55 (d, J = 2.56, Hz, 1H), 7.38-7.29 (m, 2H), 7.26 (td, J = 7.80, 1.51 Hz, 1H). ^{13}C NMR (101 MHz, DMSO-d_6) δ/ppm: 159.48, 148.06, 144.41, 134.58, 132.09, 128.91, 122.97, 122.90, 121.27, 114.07, 113.69, 110.35. HRMS (ESI): $C_{13}H_{10}BN_2O_2^+$ *calcd.*: 237.0830, *found:* 237.0832.

3-(Propargyloxy)benzo[*d*]benzo[4,5][1,3,2]oxazaborolo[3,2-*b*][1,2,3]diazaborinine (25)



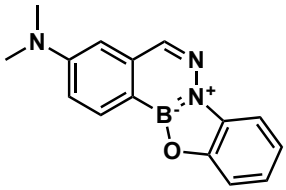
25 was synthesized according to the general procedure. **31** (15.0 mg, 0.05 mmol, 1.0 eq.) and **36** (21.8 mg, 0.07 mmol, 1.4 eq.) were mixed in the solvent (1.0 mL). The product was isolated as white solid (12.0 mg, 0.04 mmol, 84%). Preparative HPLC: t_R = 23.8 min. ^{1}H NMR (400 MHz, DMSO-d_6) δ/ppm: 8.65 (s, 1H), 8.28 (d, J = 8.47 Hz, 1H), 7.79 (dd, J = 7.54, 1.25 Hz, 1H), 7.75 (d, J = 2.38 Hz, 1H), 7.58 (d, J = 7.99 Hz, 1H), 7.51 (dd, J = 8.45, 2.47, 1H), 7.33 (td, J = 7.51, 1.23 Hz, 1H) 7.27 (td, J = 7.70, 1.44 Hz, 1H), 5.02 (d, J = 2.37 Hz, 2H), 3.66 (t, J = 2.37 Hz, 1H). ^{13}C NMR (101 MHz, DMSO-d_6) δ/ppm: 159.93, 148.20, 144.24, 137.78, 134.39, 132.33, 123.15, 122.90, 120.13, 113.69, 112.76, 110.28, 78.92, 78.77, 55.79. HRMS (ESI): $C_{16}H_{12}BN_2O_2^+$ *calcd.*: 275.0986, *found:* 275.0989.

2-Methoxybenzo[*d*]benzo[4,5][1,3,2]oxazaborolo[3,2-*b*][1,2,3]diazaborinine (26)



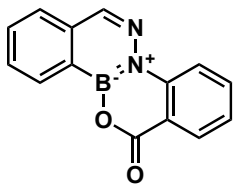
26 was synthesized according to the general procedure. **32** (16.0 mg, 0.06 mmol, 1.0 eq.) and **36** (25.3 mg, 0.09 mmol, 1.4 eq.) were mixed in the solvent (1.0 mL). The product was isolated as white solid (10.0 mg, 0.04 mmol, 66%). Preparative HPLC: t_R = 23.9 min. ^{1}H NMR (400 MHz, DMSO-d_6) δ/ppm: 8.62 (s, 1H), 8.11 (d, J = 8.81 Hz, 1H), 7.80 (dd, J = 7.67, 1.31 Hz, 1H), 7.74 (d, J = 2.67 Hz, 1H), 7.60 (dd, J = 7.77, 0.95 Hz, 1H), 7.52 (dd, J = 8.72, 2.67, 1H), 7.34 (td, J = 7.58, 1.20 Hz, 1H) 7.28 (td, J = 7.69, 1.64 Hz, 1H), 3.98 (s, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ/ppm: 160.57, 148.02, 144.12, 134.44, 131.65, 129.96, 123.03, 122.86, 120.96, 113.60, 111.48, 110.37, 55.68. HRMS (ESI): $C_{14}H_{12}BN_2O_2^+$ *calcd.*: 251.0986, *found:* 251.0989.

_N_,_N_-dimethylbenzo[_d_]benzo[4,5][1,3,2]oxazaborolo[3,2-_b_][1,2,3]diazaborinin-3-amine (27)



27 was synthesized according to the general procedure. **28** (15.0 mg, 0.05 mmol, 1.0 eq.) and **36** (22.6 mg, 0.08 mmol, 1.4 eq.) were mixed in the solvent (1.0 mL). The product was isolated as white solid (11.0 mg, 0.04 mmol, 77%). Preparative HPLC: t_R = 24.5 min. ^{1}H NMR (400 MHz, DMSO-d_6) δ/ppm: 8.52 (s, 1H), 8.11-8.06 (m, 1H), 7.72 (dd, J = 7.71, 1.19 Hz, 1H), 7.53 (dd, J = 7.97, 0.99 Hz, 1H), 7.31-7.25 (m, 3H), 7.21 (td, J = 7.62, 1.47, 1H), 3.09 (s, 6H). ^{13}C NMR (101 MHz, DMSO-d_6) δ/ppm: 152.54, 148.19, 145.00, 137.87, 134.57, 131.32, 122.57, 122.49, 116.18, 113.35, 109.77, 109.70, 39.50. HRMS (ESI): $C_{15}H_{15}BN_3O^+$ *calcd.*: 264.1303, *found:* 264.1305.

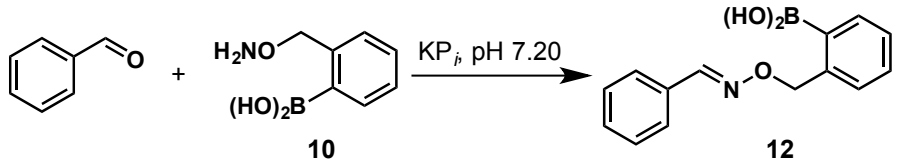
14_H_-benzo[_d_]benzo[4,5][1,2,3]diazaborinino[3,2-_b_][1,3,2]oxazaborinin-14-one (37)



37 was synthesized according to the general procedure. 2-FPBA (11.0 mg, 0.07 mmol, 1.0 eq.) and 2-hydrazinobenzoic acid (19.4 mg, 0.10 mmol, 1.4 eq.) were mixed in the solvent (1.0 mL). The product was isolated as white solid (18.0 mg, 0.07 mmol, 99%). Preparative HPLC: t_R = 22.5 min. ^{1}H NMR (400 MHz, DMSO-d_6) δ/ppm: 8.42 (s, 1H), 8.20-8.15 (m, 1H), 8.13-8.05 (m, 2H), 7.90-7.85 (m, 1H), 7.83-7.76 (m, 2H), 7.74 (td, J = 7.37, 1.12, 1H), 7.30-7.24 (m, 1H). ^{13}C NMR (101 MHz, DMSO-d_6) δ/ppm: 160.75, 145.82, 142.16, 135.38, 133.87, 131.50, 130.31, 130.25, 130.15, 127.62, 122.77, 115.14, 114.42. HRMS (ESI): $C_{14}H_{10}BN_2O_2^+$ *calcd.*: 249.0830, *found:* 249.0832, $C_{14}H_9BN_2NaO_2^+$ *calcd.*: 271.0652, *found:* 271.0652.

2. HPLC Studies on Oxime Formation

2.1 Oxime Formation of 12



Stock solutions:

Benzaldehyde: 50 mM in HPLC grade MeCN

10: 5 mM in HPLC grade MeCN

Phosphate buffer (KP*i*): 100 mM in *dd* H_2O, pH 7.2

Phosphate buffer (156 µL), benzaldehyde (4 µL) and **10** (40 µL) were mixed in a PP HPLC vial (BGB, Part Nr. PPSV0903K) to achieve a final concentration of 1 mM. Sample and references were analyzed by RP-HPLC on an Agilent 1100 LC system equipped with a YMC-Gel ODS-A 10 µm 4.6 x 150 mm column from Dr. Maisch GmbH at 25°C. Buffer A (A): 0.1% TFA (v/v) in H_2O/1% MeCN (v/v), Buffer B (B): 0.1% TFA (v/v) in MeCN/1% H_2O (v/v). Gradient: 1% (2 min) - 99% (24 min) - 99% (2 min) (B). Samples were measured after 1 min, 30 min, 60 min, 90 min and 15 h with injection volumes of 20 µL at 254 nm. Conversions were calculated according to the area change of the benzaldehyde signal. New peaks at 17.522 and 19.295 min of the 15 h run were collected and analyzed by UPLC-MS.

Calculated conversions after several time points:

1 min:	< 1%
30 min:	< 1%
60 min:	1%
90 min:	2%
15 h:	44%

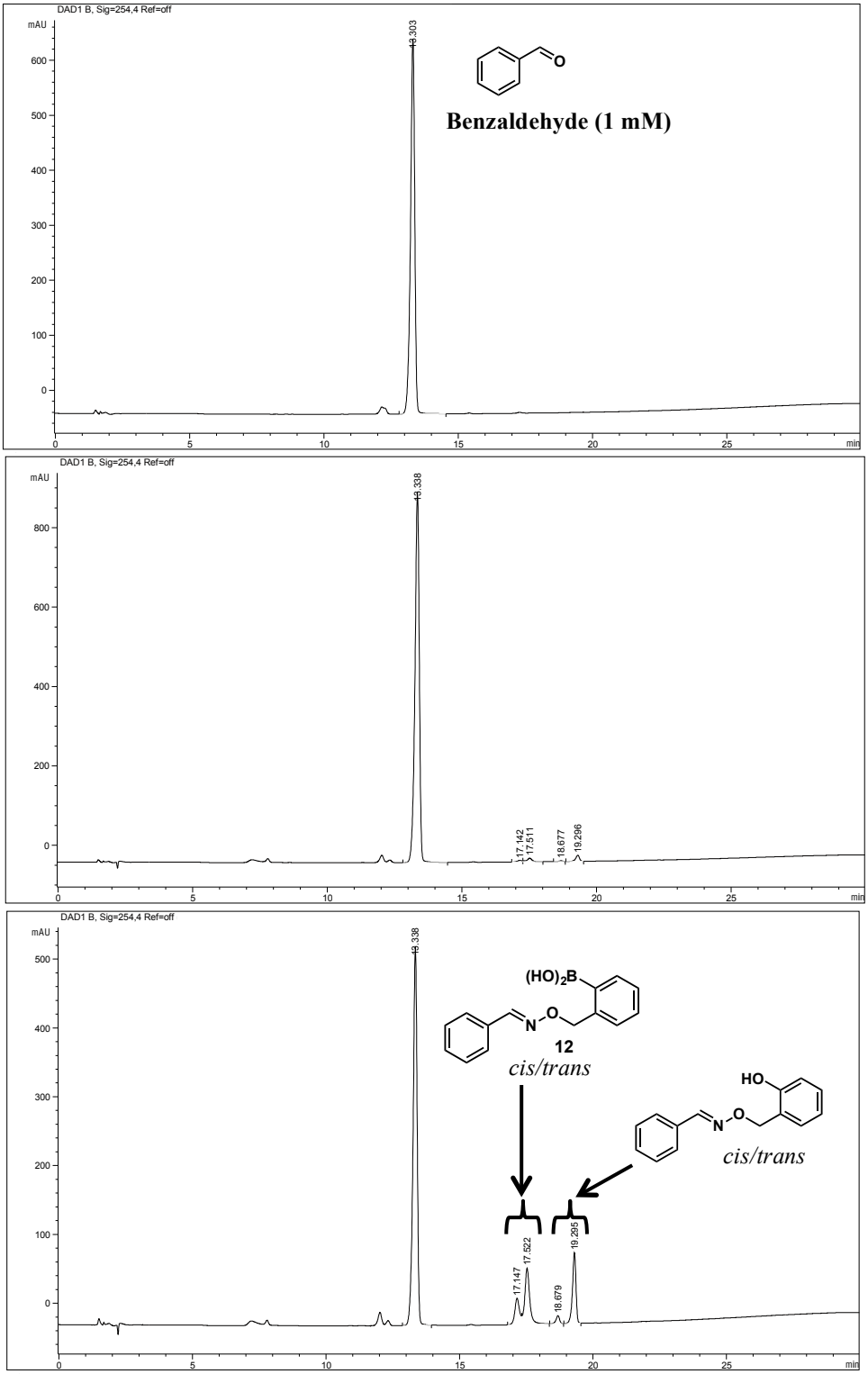


Figure S1: **Top:** HPLC trace of 1 mM benzaldehyde, **Middle**: HPLC trace after 60 min, **Bottom:** HPLC trace after 15 h.

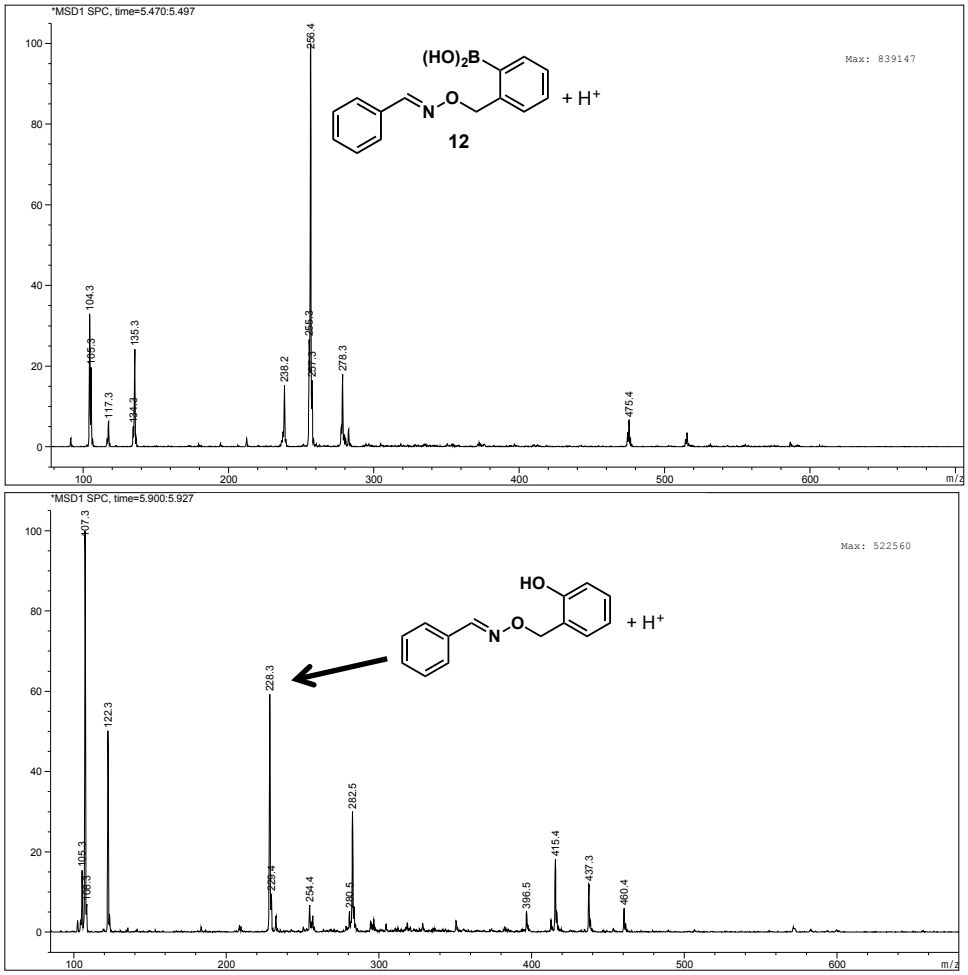
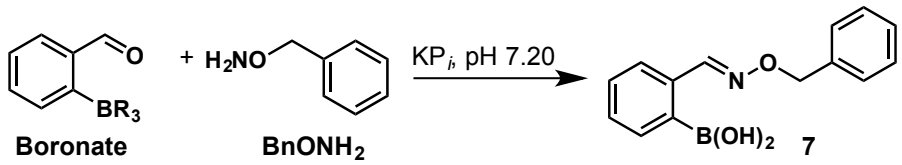


Figure S2: **Top**: ESI-MS spectrum (LC-MS) of peak 17.522 min, which shows the mass of **12**, **Bottom:** ESI-MS spectrum (LC-MS) of peak 19.295 min, which shows the mass of the oxidized compound.

2.2 Oxime Condensation with Triply Coordinated Boronates



Stock solutions:

Potassium 2-formylphenyltrifluoroborate (**13**, 2-FPTFB): 5 mM in HPLC grade MeCN

2-Formylphenylboronic acid MIDA ester: 5 mM in HPLC grade MeCN

Benzylhydroxylamine ($BnONH_2$): 5 mM in HPLC grade MeCN

Phosphate buffer: 100 mM in *dd* H_2O, pH 7.2

Phosphate buffer (192 µL), boronate (4 µL) and $BnONH_2$ (4 µL) were mixed in a PP HPLC vial (BGB, Part Nr. PPSV0903K) to achieve a final concentration of 100 µM. Samples and references were analyzed by RP-HPLC on an Agilent 1100 LC system equipped with a Zorbax Eclipse XDB-C8 5 µm 4.6 x 150 mm column from Agilent at 25°C. Buffer A (A): H_2O/1% MeCN (v/v), Buffer B (B): MeCN/1% H_2O (v/v). Gradient: 1% (2 min) - 99% (24 min) - 99% (2 min) (B). Samples were measured after 1 min, 30 min, 60 min and 90 min with injection volumes of 20 µL at 254 nm. Conversions were calculated according to the area increase of the oxime product signal compared to a 100 µM product reference sample (2-FPTFB) or the area decrease of the starting material (MIDA boronate).

Table S1: Calculated conversions after several time points:

Time	2-FPTFB	MIDA boronate
1 min	5%	12%
30 min	51%	26%
60 min	76%	46%
90 min	93%	60%

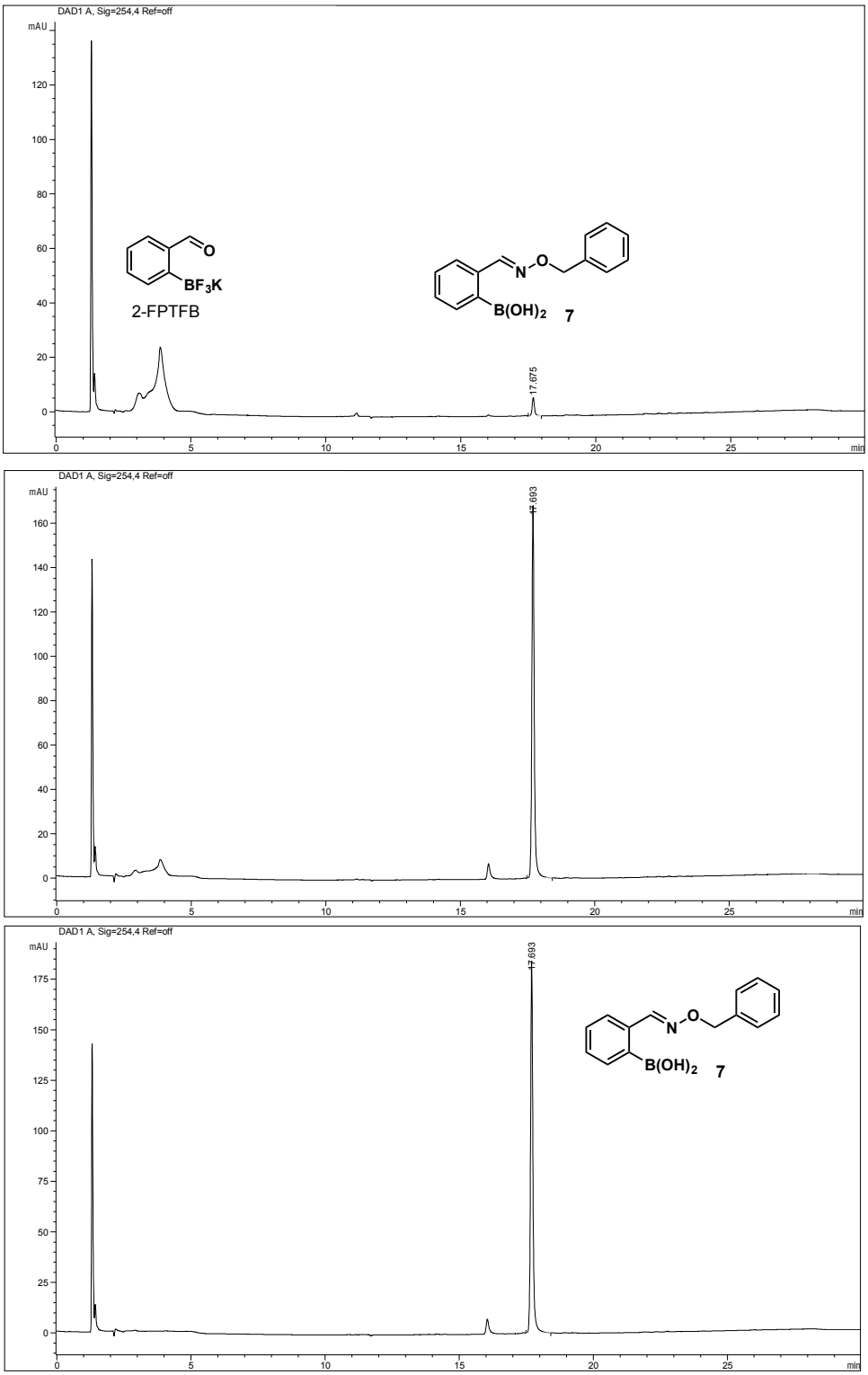


Figure S3: HPLC traces of oxime condensation with 2-FPTFB. **Top**: HPLC trace after 1 min. **Middle**: HPLC trace after 90 min. **Bottom:** HPLC trace of product **7**.

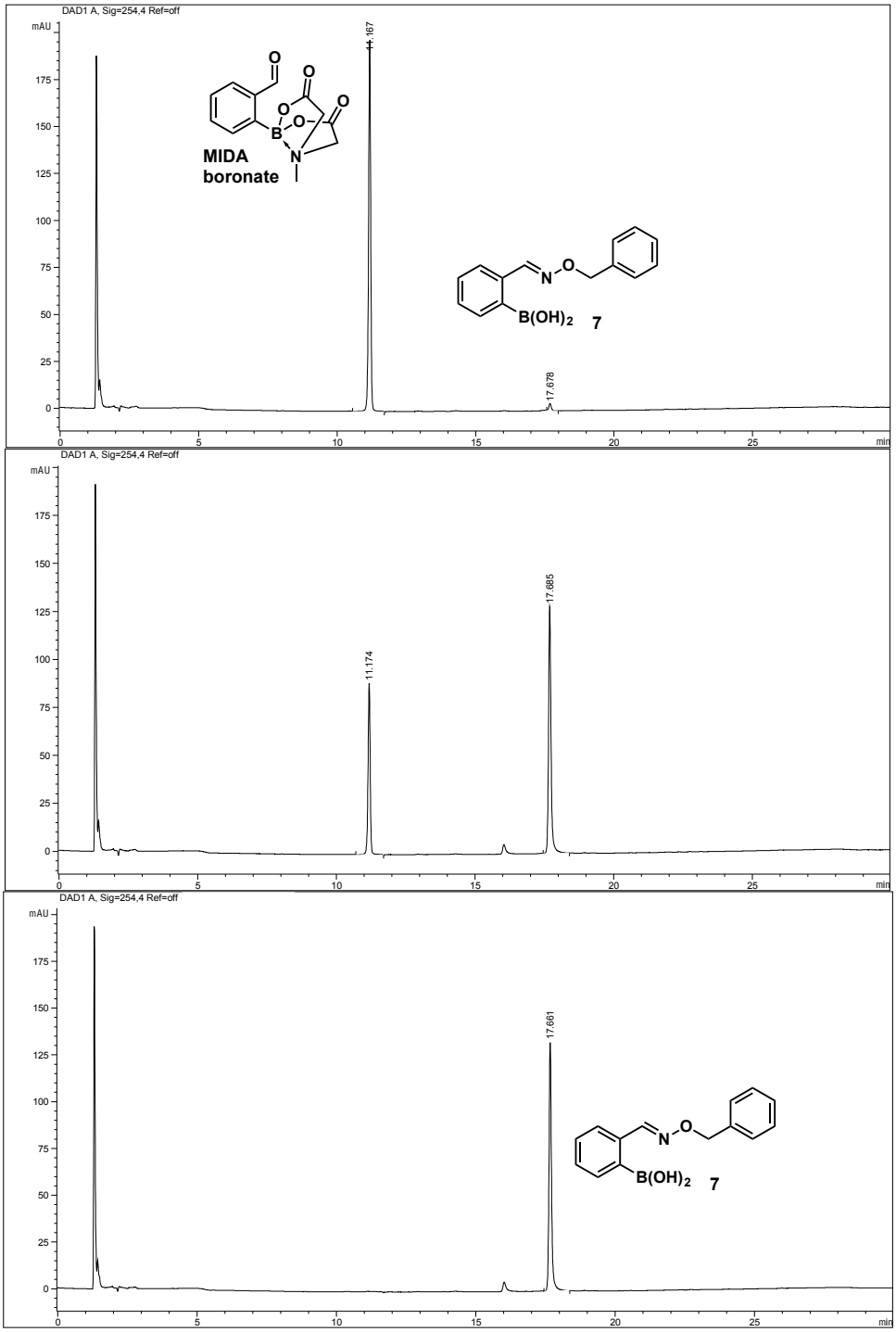


Figure S4: HPLC traces of oxime condensation with 2-formylphenylboronic acid MIDA ester. **Top**: HPLC trace after 1 min. **Middle**: HPLC trace after 90 min. **Bottom:** HPLC trace of product **7**.

3. NMR Studies

3.1 General Information

NMR experiments were performed at 298 K either on a Bruker Avance III NMR spectrometer operating at 600.13 MHz and equipped with a direct observe 5- mm BBFO smart probe or a Bruker Avance III HD NMR spectrometer operating at 600.13 MHz equipped with a cryogenic 5 mm four-channel QCI probe (H/C/N/F). All ^{1}H experiments were recorded using the same parameters (256 scans, relaxation delay of 4.0 s and an acquisition time of 2.00 s) and were processed using TopSpin software from Bruker using line broadening of 0.5 Hz and after manual phase correction automated baseline correction was applied. Chemical shifts were referenced to the residual solvent peak of acetonitrile (1.94 ppm) and TMSP-d_4 (3-(trimethylsilyl)-2,2',3,3'-tetradeuteropropionic acid) was used as an internal standard. The pH (no correction for deuterium) was adjusted by addition of concentrated DCl from ABCR (DCl, 38% wt% in D_2O, 99.5% atom%D) measured with a 827 pH Lab - Metrohm equipped with a glass minitrode which was pre-rinsed with D_2O. Standard NMR tubes (throw away quality) were rinsed with D_2O and dried in the oven prior to use. Stock solutions were mixed in the NMR tube, vortexed and sonicated before measurement.

3.2 Reversibility of Ketoximes

Stock solutions:

550 µM **14** in CD_3CN

27.5 mM 2-FPBA in CD_3CN

275 µM TMSP-d_4 in D_2O

13.1 mM potassium phosphate buffer in D_2O, pH 7.28

The stock solutions were mixed in the NMR tube to achieve the following final concentrations: 100 µM **14**, 500 µM 2-FPBA, 5 µM TMSP-d_4, 10 mM potassium phosphate buffer with a final volume of 550 µL and a ratio of 4:1 KP_i in D_2O/CD_3CN. The sample was locked to acetonitrile and shimmed prior to the first measurement. Reversibility measurements were conducted every 30 min over 26 h. The integrals were compared to the signal of TMSP-d_4. After 75 min the equilibrium was almost reached. Disappearance of the methyl signals was due to H-D exchange (Figure S5).

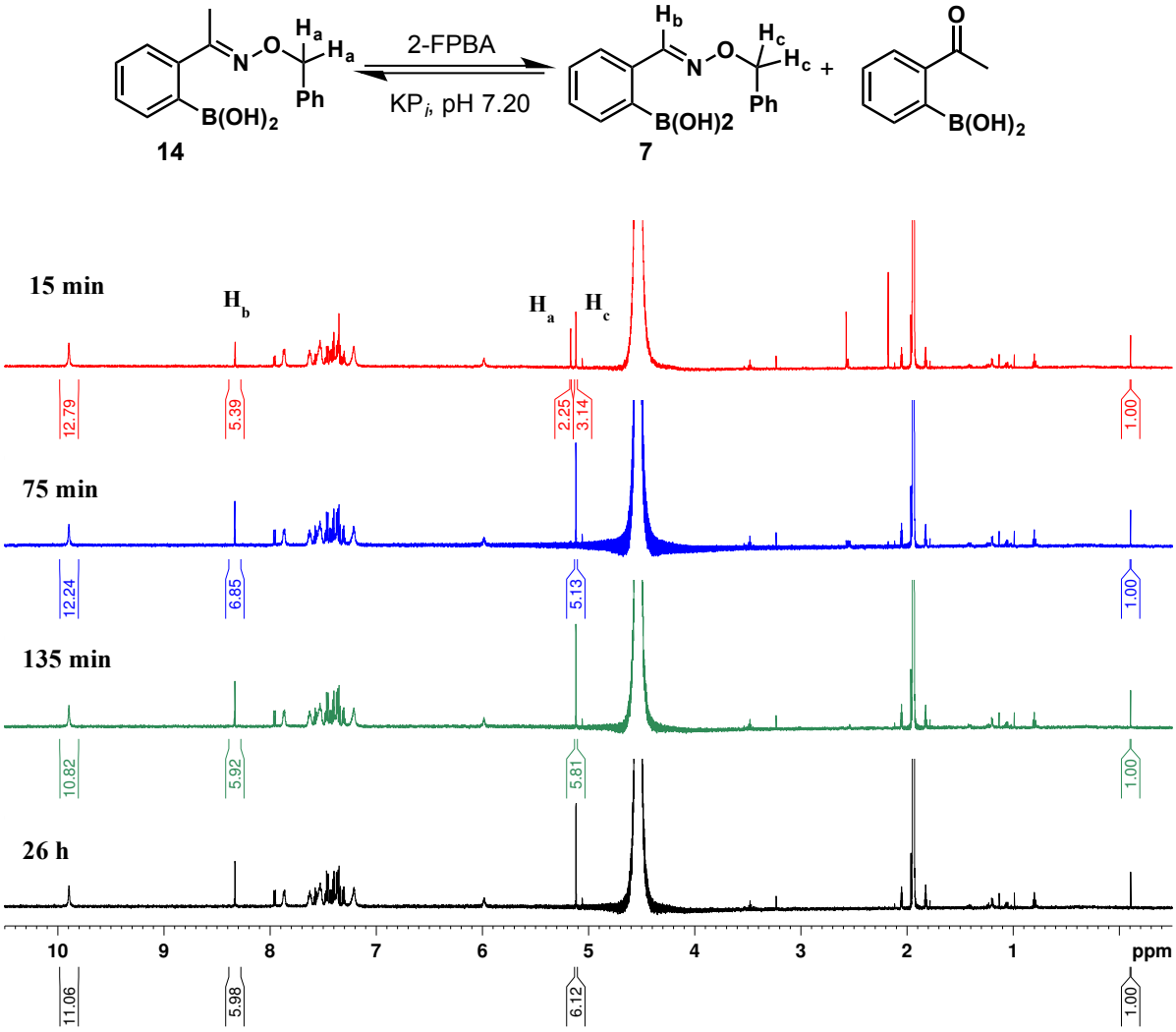


Figure S5: Stacked ^{1}H NMR spectra (4 out of 52 traces) of the ketoxime **14** reversibility assay. Benzylic protons H_a/H_c and oxime proton H_b are specified.

3.3 BIQ Formation

Stock solutions:

207.5 µM **15** in CD_3CN

5.5 mM phenylhydrazine in CD_3CN

275 µM TMSP-d_4 in D_2O

20.75 mM potassium phosphate buffer in D_2O, pH 7.25

The stock solutions were mixed in a NMR tube with the following final concentrations: 100 μM **15**, 100 μM phenylhydrazine, 5 μM TMSP-d_4, 10 mM potassium phosphate buffer with a final volume of 550 μL and a ratio of 1:1 KP_i in D_2O/CD_3CN. The sample was locked to acetonitrile and shimmed prior to the first measurement. BIQ formation measurements were conducted every 30 min over 23 h. The integrals were compared to the signal of TMSP-d_4. After 8.5 h the reaction was complete (Figure S6).

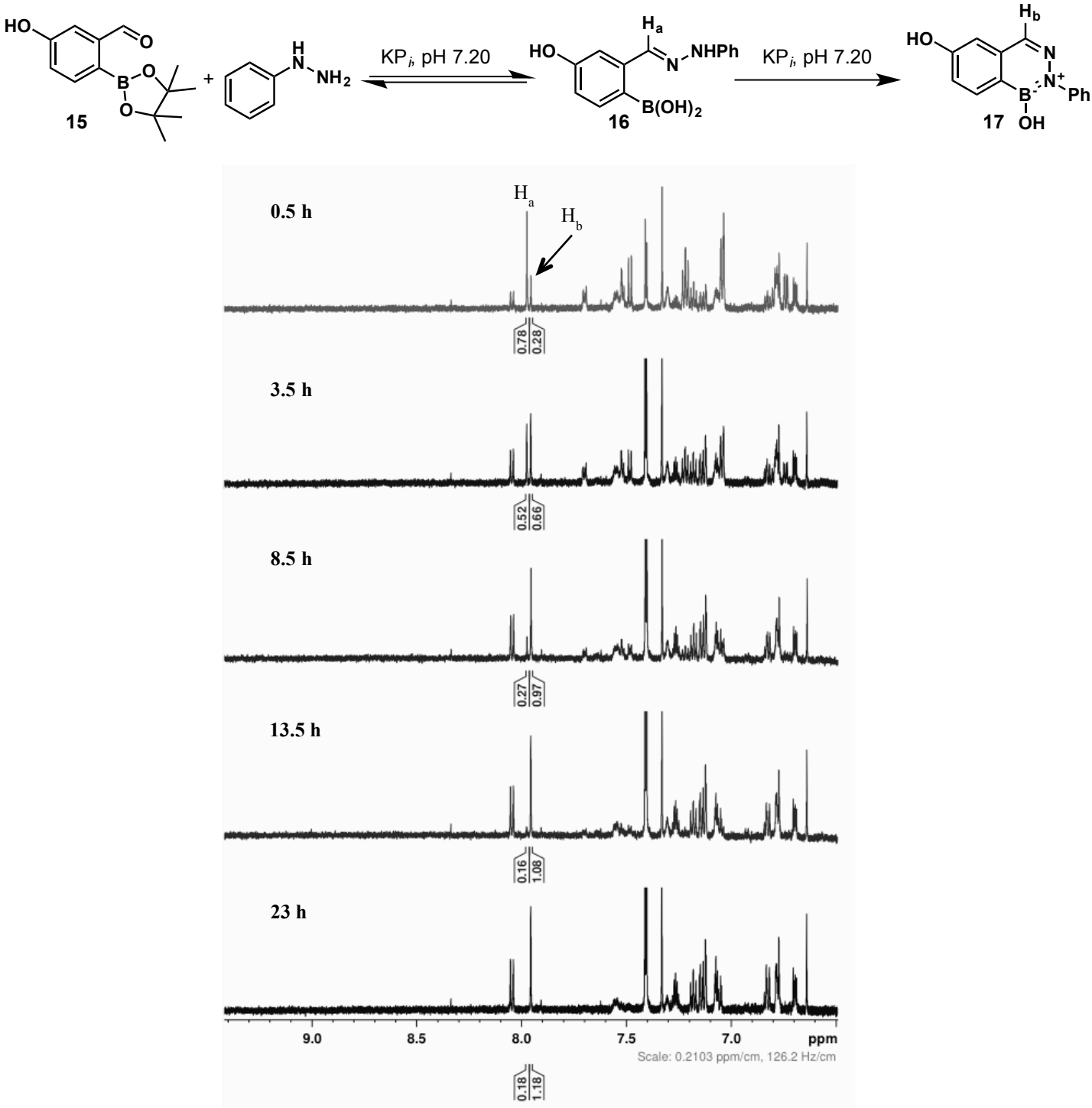


Figure S6: Stacked ^{1}H NMR spectra (5 out of 46 traces) of the BIQ formation between **15** and phenylhydrazine at 100 μM. The intermediate hydrazone proton H_a and the BIQ proton H_b are specified.

3.4 BIQ Reversibility

Stock solutions:

207.5 µM **17** in CD_3CN

27.5 mM 2-FPBA in CD_3CN

275 µM TMSP-d_4 in D_2O

20.75 mM potassium phosphate buffer in D_2O, pH 7.25

The stock solutions were mixed in a NMR tube with the following final concentrations: 100 µM **17**, 500 µM 2-FPBA, 5 µM TMSP-d_4, 10 mM potassium phosphate buffer with a final volume of 550 µL and a ratio of 1:1 KP_i in D_2O/CD_3CN. The sample was locked to acetonitrile and shimmed prior to the first measurement. BIQ reversibility measurements were conducted every 30 min over 24 h starting with the first measurement after 10 min. The integrals were compared to the signal of TMSP-d_4. After 24 h no changes have been observed (Figure S7).

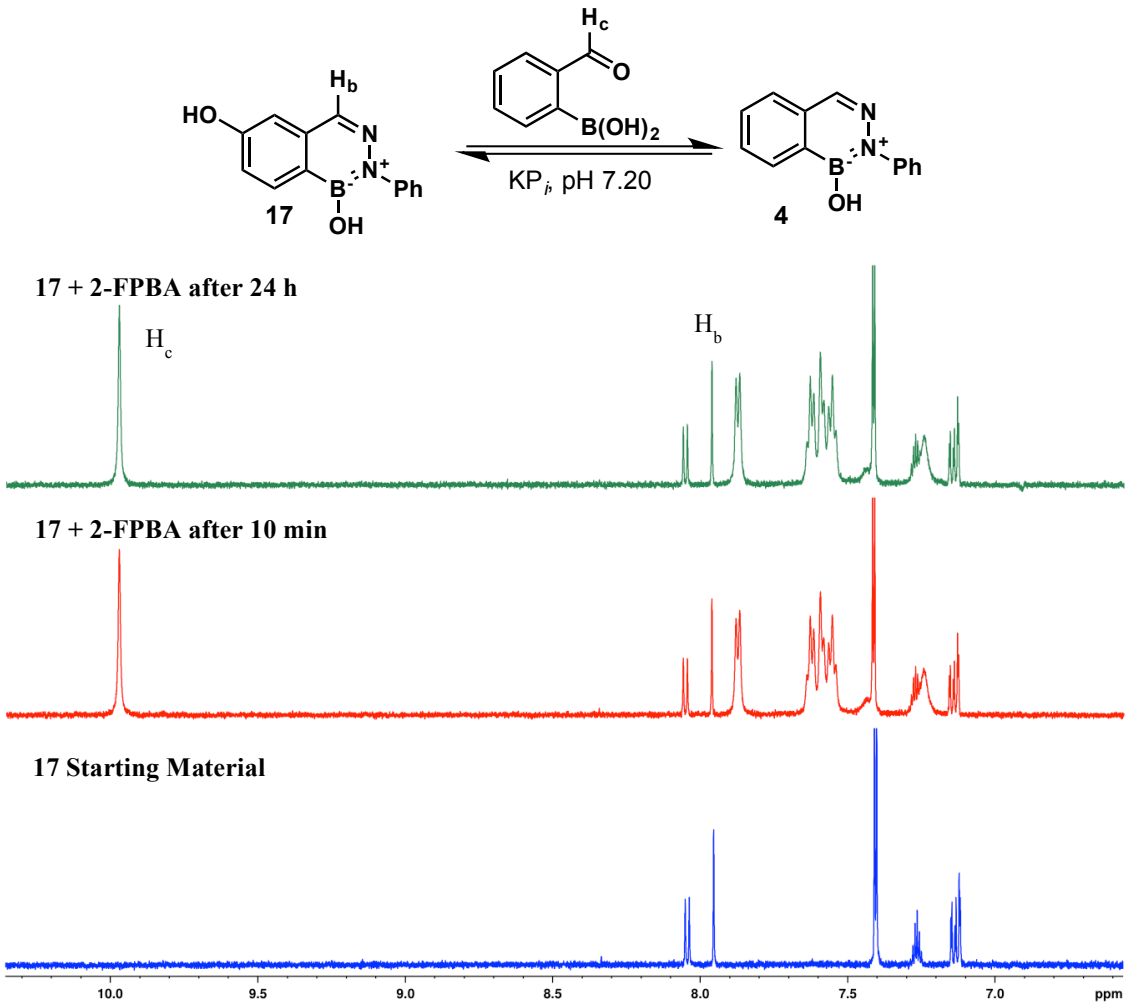


Figure S7: Stacked ^{1}H NMR spectra (2 out of 48 traces) of the BIQ reversibility assay between **17** and 2-FPBA (5 eq.).

4. UV Studies on BIQ formation

4.1 General Information

All measurements were conducted on a Shimadzu UV-1800 UV-Vis spectrophotometer (190-1100 nm, bandwidth 1 nm) using 10 x 10 mm quartz cuvettes from Hellma Analytics (3500 μL). Human Serum (HS) type AB (male) and reduced *L*-glutathione (GSH) were purchased from Sigma-Aldrich. Cuvettes were rinsed with deionized H_2O followed by technical EtOH and dried under a N_2 stream prior to use. For all UV measurements the boronic acid was dissolved in the solvent and measured for 10 s. The hydrazine stock solution (freshly prepared, could not be used for longer than 1 h) was directly added into the cuvette, gently shaken three times and the measurement was continued. Formation of the hydrazone and BIQ were recorded in triplicate at 340 nm. The absorbance was measured every 0.5 s over a period of about 1500 s. The recorded data was analyzed with MS Excel. Hydrazone formation was too fast to determine exact rate constants by the described method. The intramolecular BIQ formation showed first order behavior and was measured by the signal decrease at 340 nm (only hydrazone visible). Extinction coefficients for the hydrazone intermediate at 340 nm were determined by addition of 1.5 equivalents of the corresponding hydrazine to a known concentration of aldehyde (typically 10 μM), assuming that the highest absorbance is equal to complete conversion to the hydrazone (Lambert-Beer law).

4.2 pH Effects on BIQ formation

Stock solutions:

10.04 μM **15** in 100 mM potassium phosphate buffer pH 5.50/MeCN 9:1

10.04 μM **15** in 100 mM potassium phosphate buffer pH 7.20/MeCN 9:1

10.04 μM **15** in 100 mM potassium phosphate buffer pH 8.50/MeCN 9:1

2.5 mM phenylhydrazine in *dd* H_2O/MeCN 1:1

2490 μL of **15** stock solution was measured for 10 s, after which 10 μL of the phenylhydrazine stock solution was added and measured. The results were analyzed and calculated by MS Excel. Accuracy is given by the calculated standard deviation (SD).

Extinction coefficients:

$\varepsilon = 11390\ M^{-1}\ cm^{-1}$ (pH 5.50)

$\varepsilon = 10006\ M^{-1}\ cm^{-1}$ (pH 7.20)

$\varepsilon = 7810\ M^{-1}\ cm^{-1}$ (pH 8.50)

Calculated first order rate constants for BIQ formation dependent on pH:

$k = 3.95 \bullet 10^{-3}\ s^{-1}$ SD = $1.32 \bullet 10^{-4}\ s^{-1}$ (pH 5.50)

$k = 2.57 \bullet 10^{-3}\ s^{-1}$ SD = $1.19 \bullet 10^{-4}\ s^{-1}$ (pH 7.20)

$k = 1.32 \bullet 10^{-3}\ s^{-1}$ SD = $1.36 \bullet 10^{-4}\ s^{-1}$ (pH 8.50)

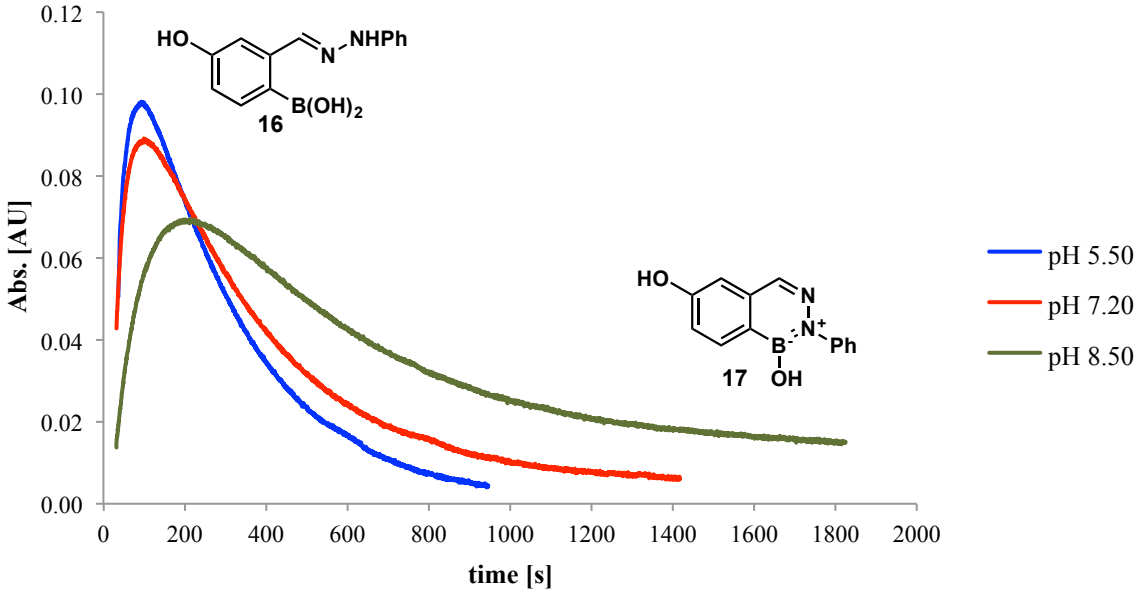


Figure S8: pH dependent UV measurement for determining kinetic parameters. All spectra were recorded at 340 nm and 10 µM of starting materials. The maxima represent the intermediate hydrazone whereas the product BIQ **17** showed no absorbance at 340 nm.

4.3 Effects of Glutathione and Human Serum on BIQ formation

Stock solutions:

10.04 µM **15** in 100 mM potassium phosphate buffer pH 7.20/MeCN/**HS** 8:1:1

10.04 µM **15** in 100 mM potassium phosphate buffer pH 7.20 with 5 mM **GSH**/MeCN 9:1

2.5 mM phenylhydrazine in MeCN

2490 µL of **15** stock solution was measured for 10 s, after which 10 µL of the phenylhydrazine stock solution was added and measured. The results were analyzed and calculated by MS Excel.

Calculated first order rate constants for BIQ formation dependent on pH:

$k = 1.68 \bullet 10^{-3}\ s^{-1}$ SD = $1.04 \bullet 10^{-4}\ s^{-1}$ (HS)

$k = 2.22 \bullet 10^{-3}\ s^{-1}$ SD = $8.64 \bullet 10^{-5}\ s^{-1}$ (GSH)

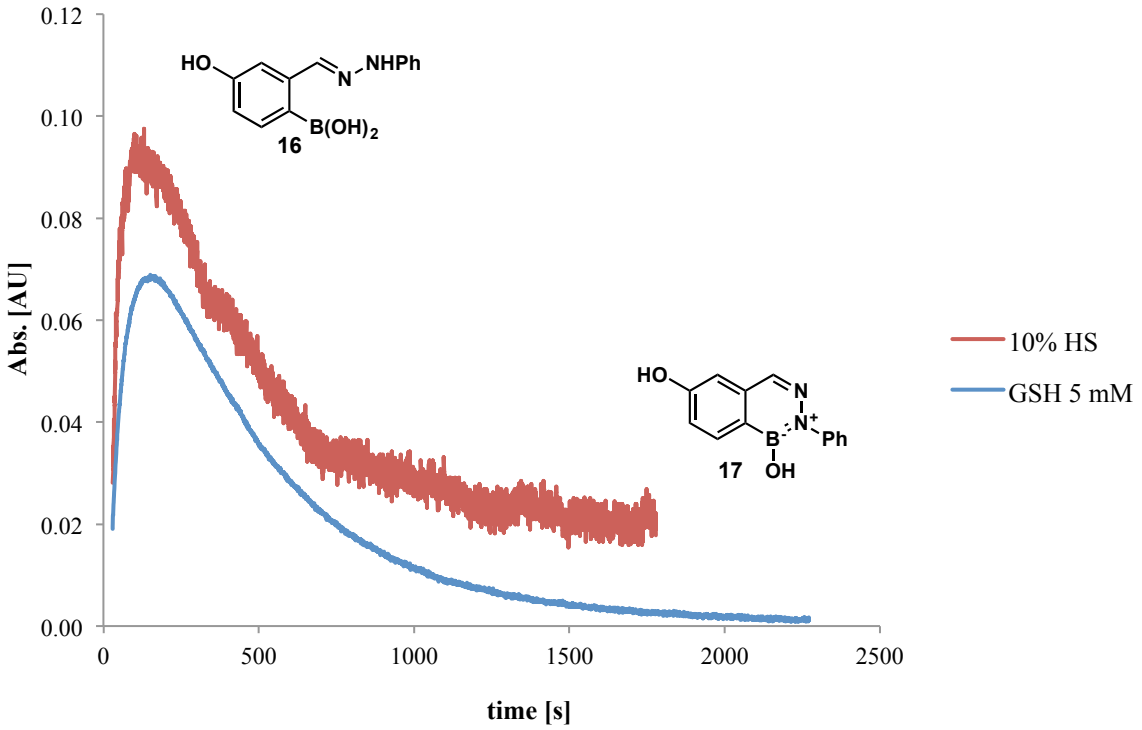


Figure S9: UV absorption intensity over time with HS or GSH as additives, pH 7.20. All spectra were recorded at 340 nm and 10 µM concentration of starting materials. The maxima represent the intermediate hydrazone whereas the product BIQ **17** showed no absorbance at 340 nm. Big noise in UV absorption was observed in the case of HS due to the turbidity of the resulting solution.

5. Hydrazone Reversibility (1:1 H_2O/MeCN)

Stock solutions:

100.4 µM **15** in 100 mM potassium phosphate buffer pH 7.20/MeCN 1:1

25 mM phenylhydrazine in MeCN

25 mM benzylhydroxylamine in MeCN

2490 µL of **15** stock solution was measured for 10 s, after which 15 µL (1.5 eq.) of the phenylhydrazine stock solution was added and measured. After 3.5 min 30 µL (3 eq.) of the hydroxylamine stock solution was added. BIQ formation showed to be much slower compared to previous results even though a ten times higher concentration was used (Figure S10). This showed the decelerating effect of higher organic solvent concentrations. The results were analyzed and processed by MS Excel. After 13 h the mixture was analyzed by UPLC-MS (3% - 25% (3 min) - 95% (3.5 min) - 95% (0.5 min) (B)). About 15% of the corresponding oxime product were observed, proving that the BIQ formation was faster than the hydrazone hydrolysis.

Calculated first order rate constant for BIQ formation during hydrzone reversibility assay:

$k_{BIQ} = 1.03 \bullet 10^{-4}\ s^{-1}$

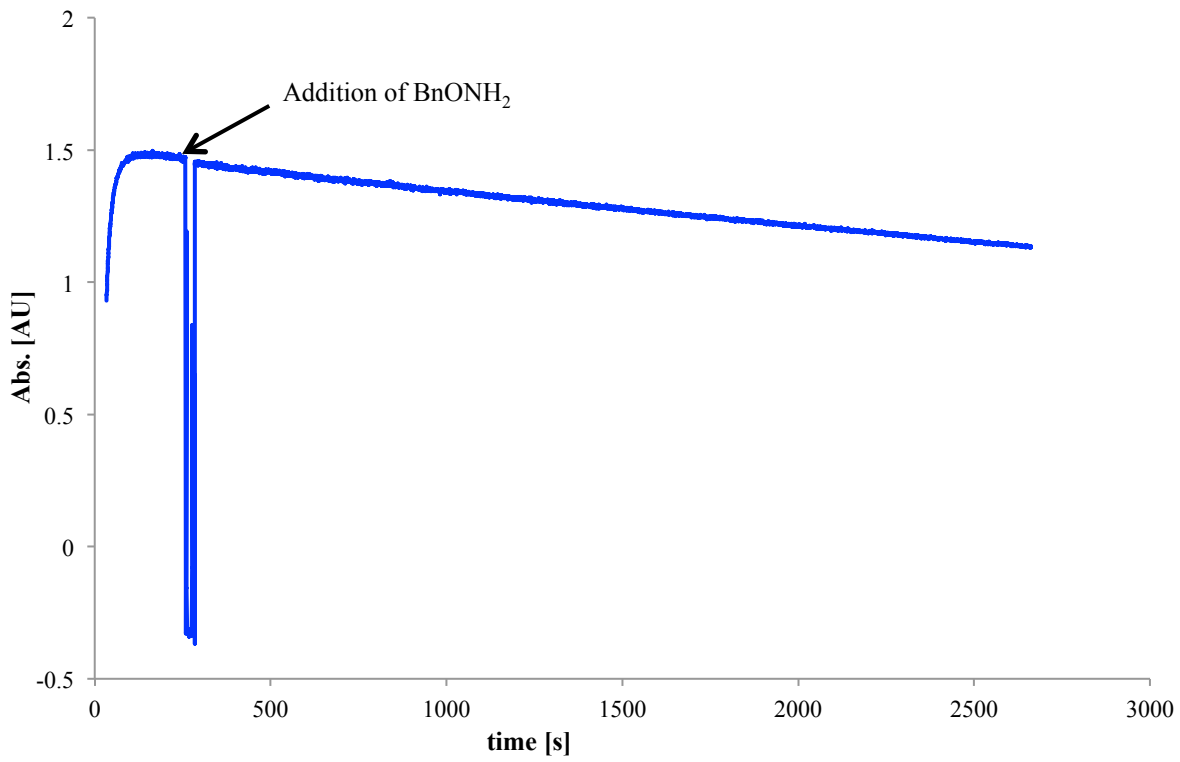


Figure S10: UV absorption intensity over time in KP_i/MeCN 1:1 pH 7.20. The spectrum was recorded at 340 nm with a 100 µM concentration of **15**. The drop in intensity is attributed to the addition of $BnONH_2$.

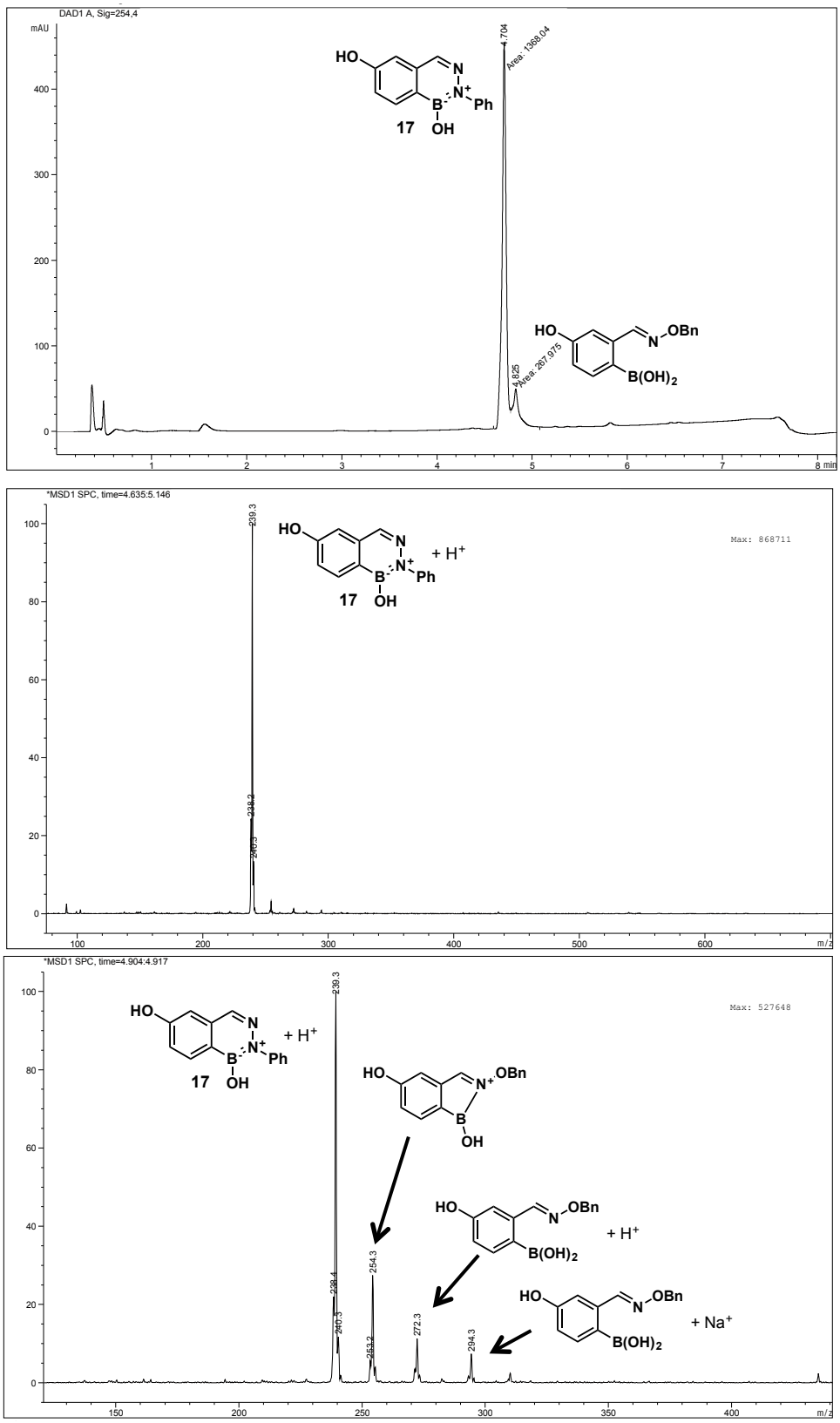


Figure S11: **Top**: UPLC-MS spectrum of the hydrazone reversibility assay mixture after 13 h. **Middle**: MS spectrum of the peak at t = 4.704 min, showing BIQ **17**. **Bottom**: MS spectrum of peak at t = 4.825 min, showing BIQ **17** and the corresponding oxime product.

6. Fluorescence Measurements

6.1 General Information

UV-Vis measurements were conducted on a Shimadzu UV-1800 UV-Vis spectrophotometer (190-1100 nm, bandwidth 1 nm) using 10 x 10 mm quartz cuvettes from Hellma Analytics (3500 µL). Fluorescence emission measurements were performed on a Shimaduzu RF-5301PC spectrofluorophotometer with 3 nm spectral bandwidth. Quantum yield measurements were done on a Hamamatsu Quantaurus-QY Absolute PL quantum yields measurement system C11347-11 with an integrating sphere. All samples were prepared as 10 µM samples in DMSO. UV and fluorescence files were processed by MS Excel.

6.2 UV-Vis/Fluorescence Spectra

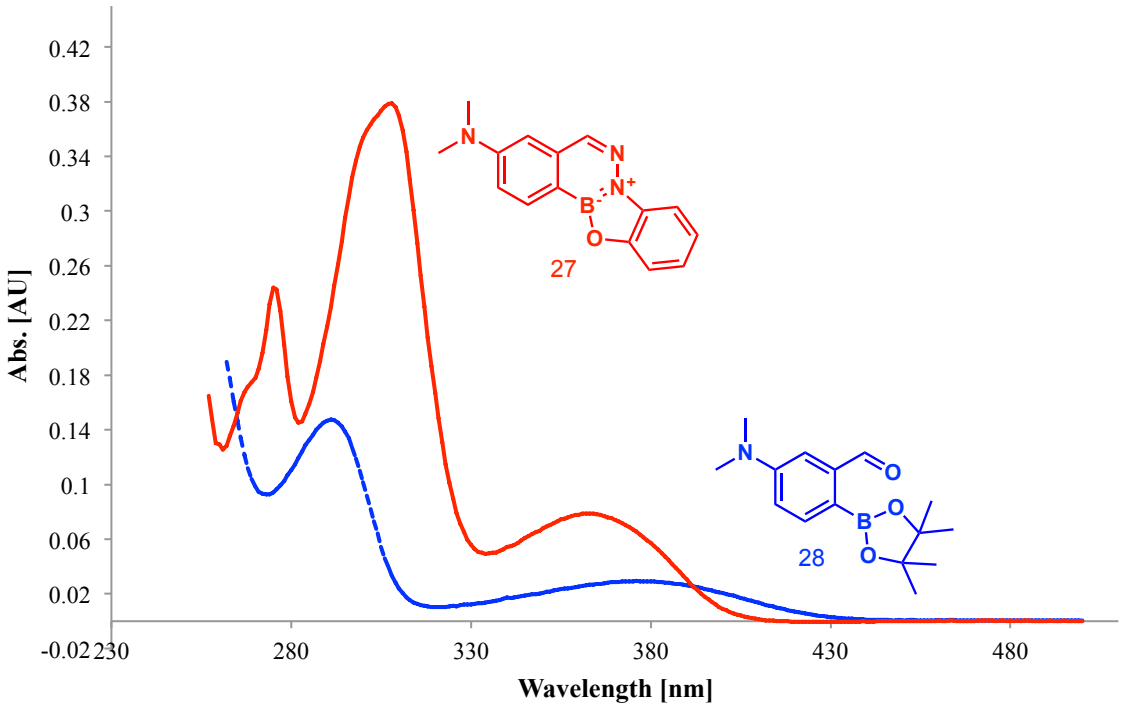


Figure S12: UV spectra of **28** and **27** at 10 µM in DMSO. Local maxima for **28**: 290 nm, 370 nm; local maxima for **27**: 275 nm, 310 nm and 365 nm.

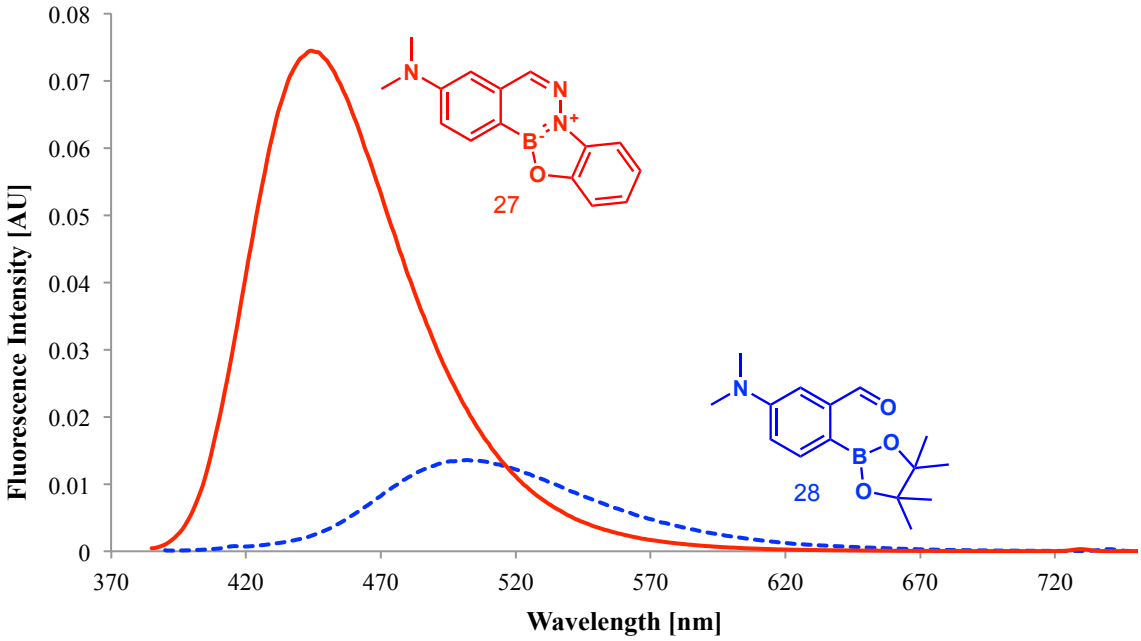


Figure S13: Fluorescence spectra of **28** and **27** 10 μM in DMSO. Excitation wavelengths: 370 nm for **28** and 365 nm for **27**.

6.3 Quantum Yield Determination

Quantum yields were determined at 10 μM concentration in DMSO with excitation wavelengths 370 nm and 365 nm for **28** and **27** respectively.

$\phi_{(370\ nm)} = 0.279$ (28)

$\phi_{(365\ nm)} = 0.386$ (27)

7. X-Ray Structure of 7

Crystal data for **7**: Formula $C_{14}H_{14}B_1N_1O_3$, M = 255.08, F(000) = 2144, colourless block, size 0.100 · 0.120 · 0.140 mm^3, monoclinic, space group C 2/c , Z = 16, a = 18.5248(15) Å, b = 15.2275(12) Å, c = 18.9615(16) Å, α = 90°, β = 94.102(4)°, γ = 90°, V = 5335.1(5) $Å^3$, $D_{calc.}$ = 1.270 Mg · m^{-3}. The crystal was measured on a Bruker Kappa Apex2 diffractometer at 123K using graphite-monochromated Cu K_α-radiation with λ = 1.54178 Å, Θ_{max} = 68.196°. Minimal/maximal transmission 0.88/0.93, μ = 0.718 mm^{-1}. The Apex2 suite has been used for datacollection and integration. From a total of 17258 reflections, 4673 were independent (merging r = 0.020). From these, 4673 were considered as observed (I>2.0σ(I)) and were used to refine 427 parameters. The structure was solved by other methods using the program Superflip. Least-squares refinement against Fsqd was carried out on all non-hydrogen atoms using the program CRYSTALS. R = 0.0386 (observed data), wR = 0.0884 (all data), GOF = 0.8971. Minimal/maximal residual electron density = -0.20/1.03 e $Å^{-3}$. Chebychev polynomial weights were used to complete the refinement. Plots were produced using CAMERON.

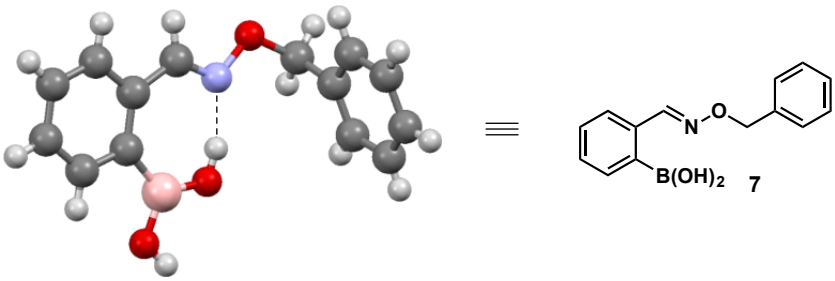
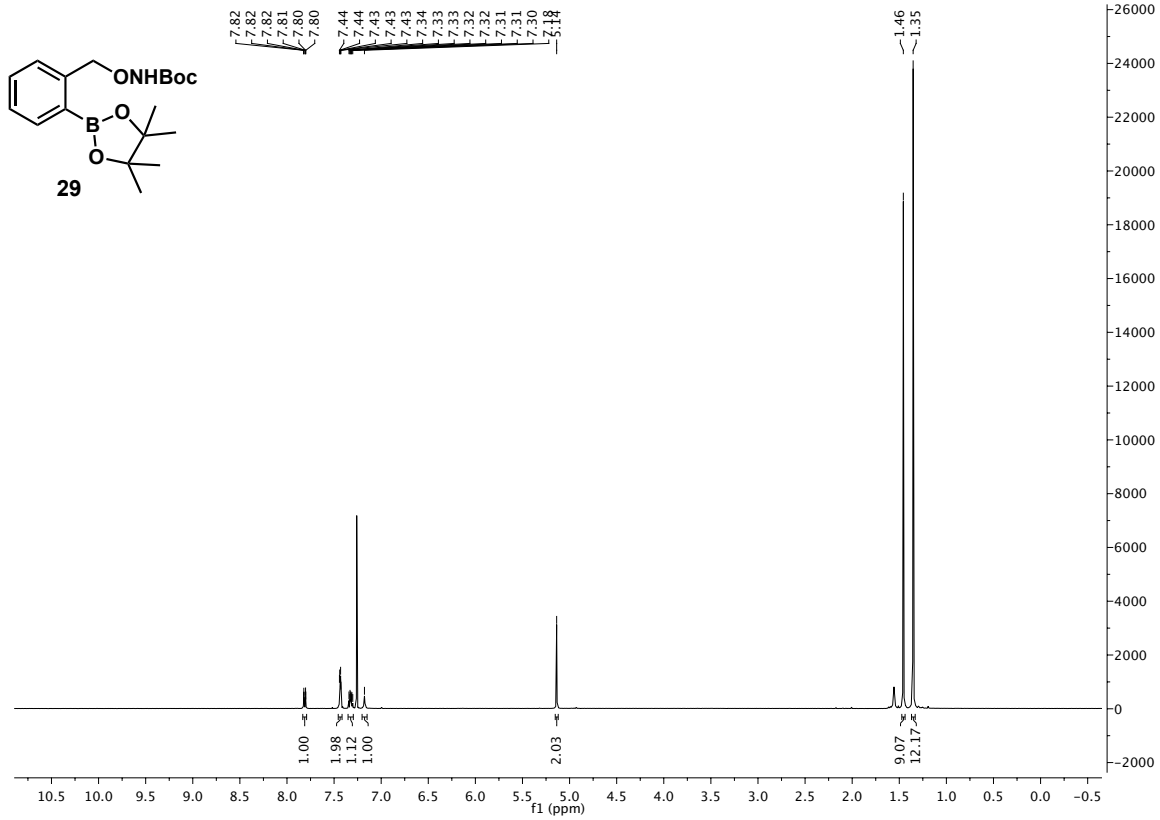
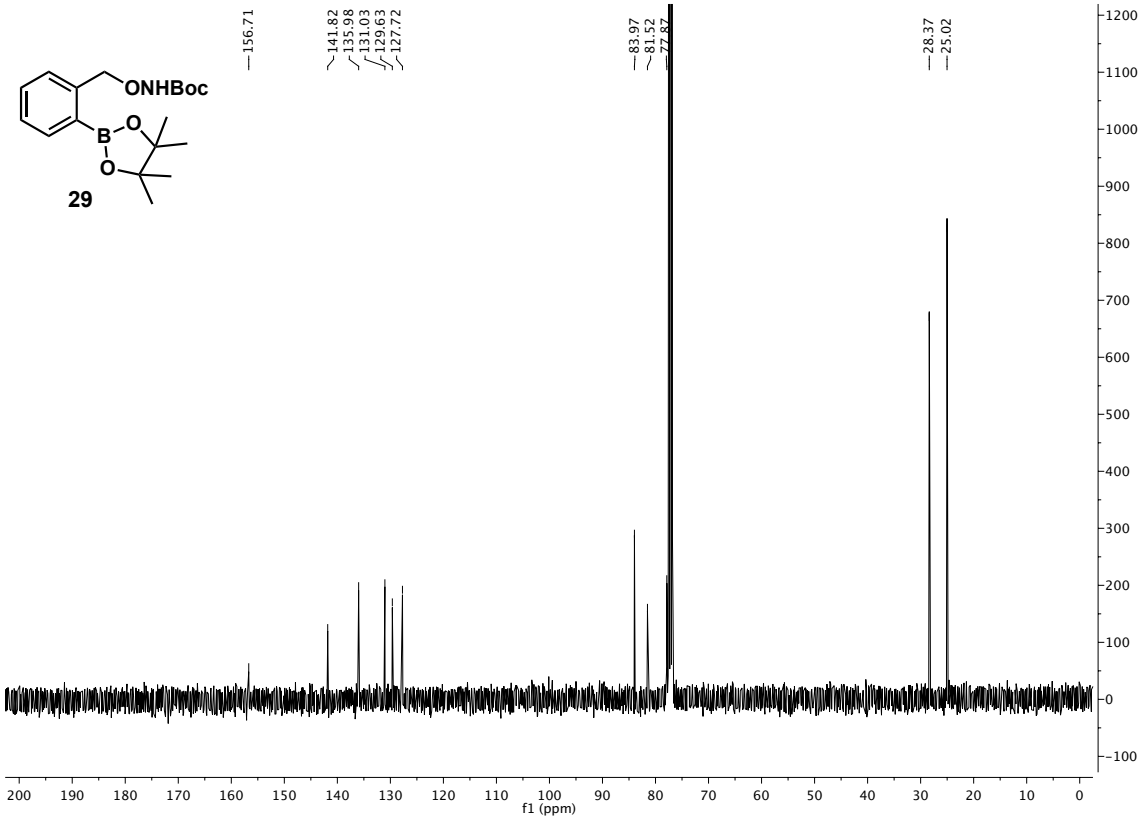
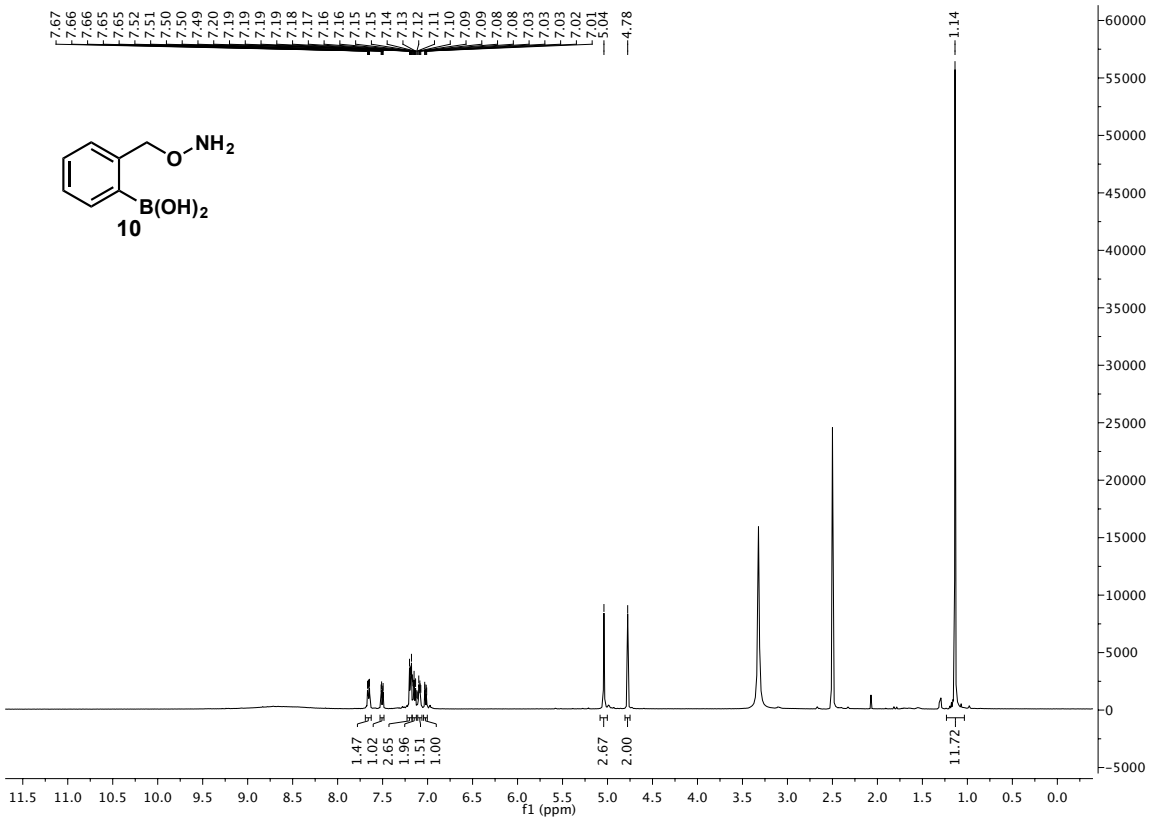


Figure S14: Crystal structure of oxime **7**.

8. NMR spectra



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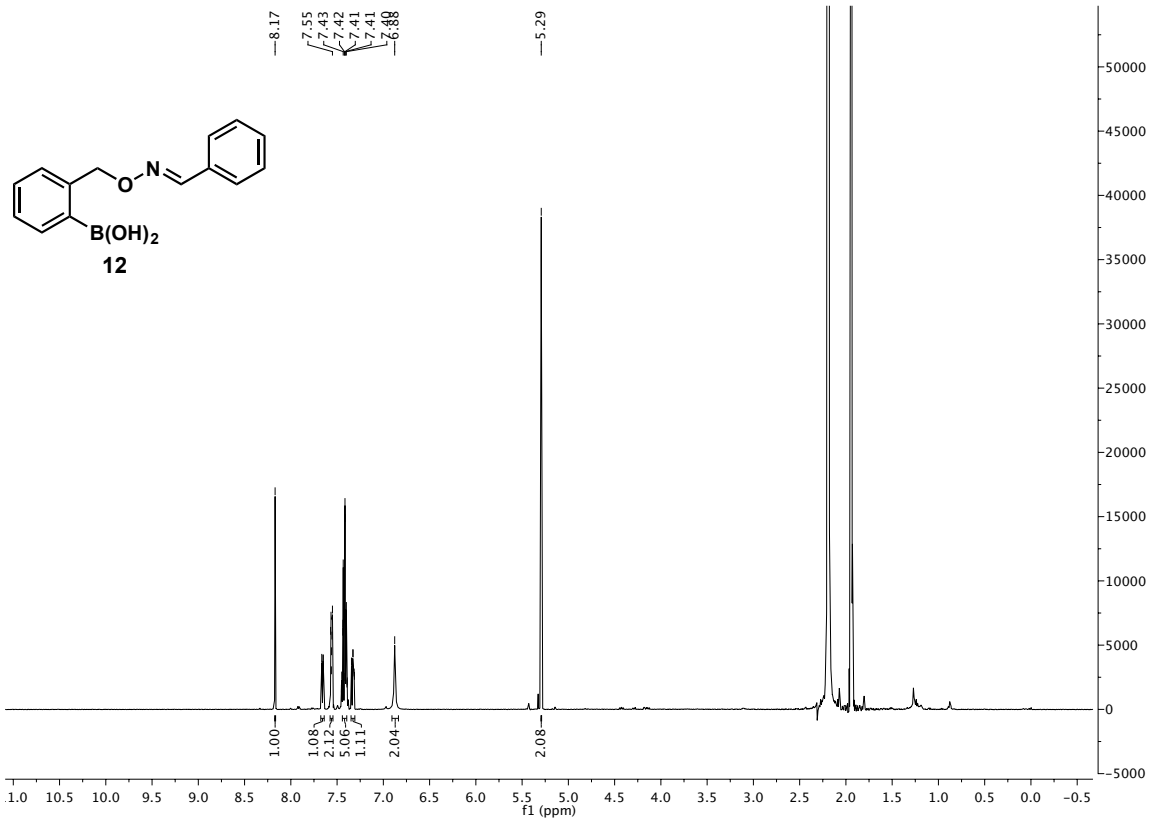
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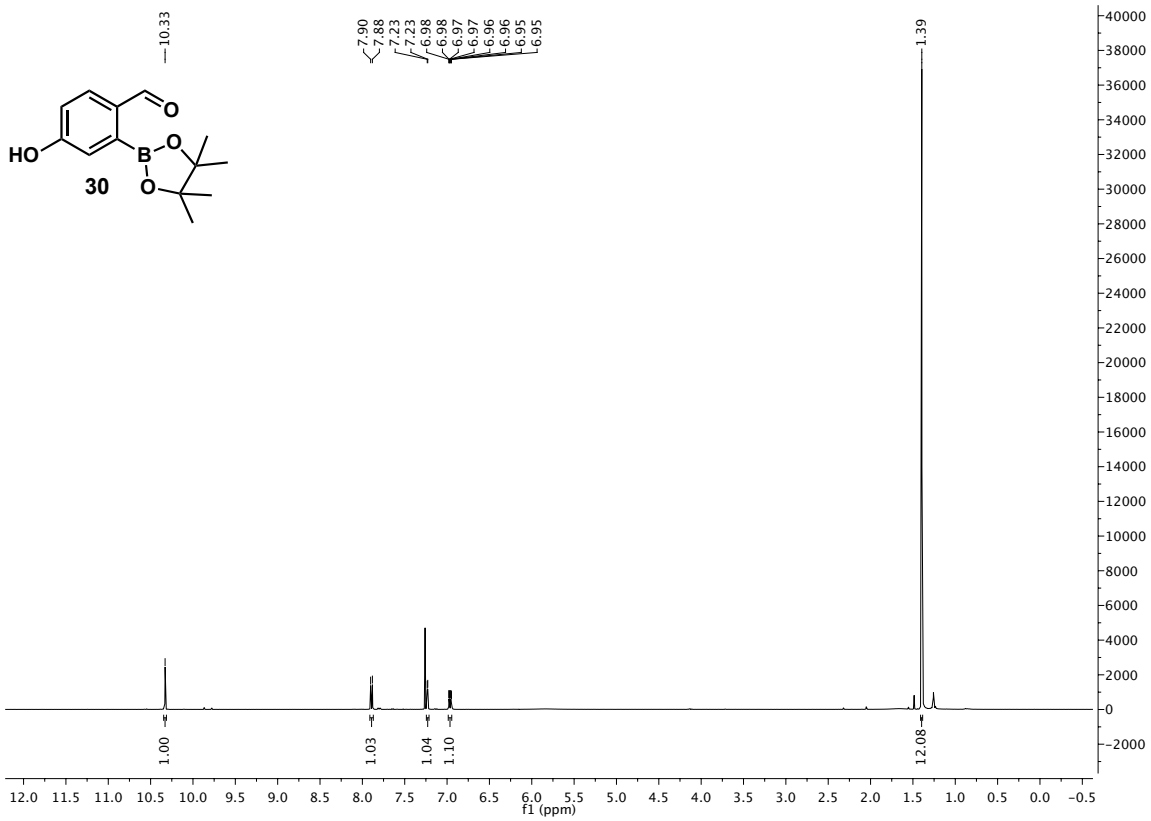
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B
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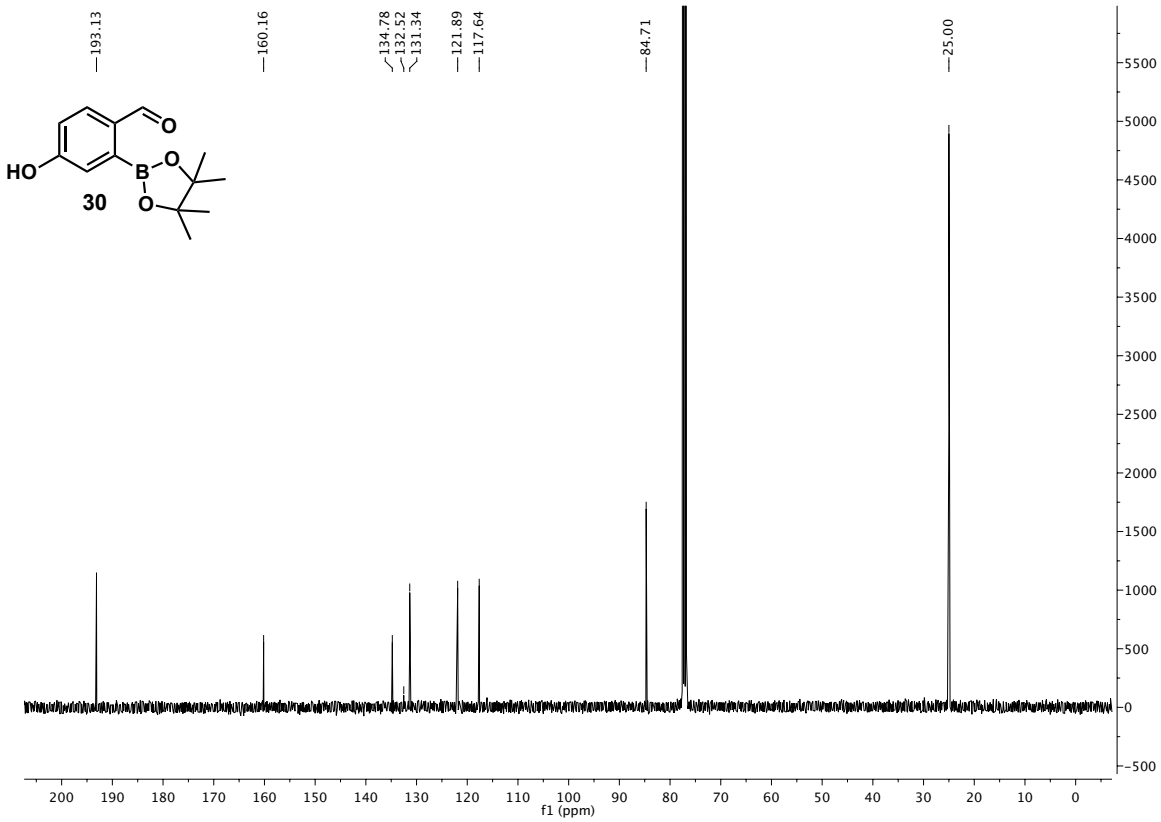
f1 (ppm)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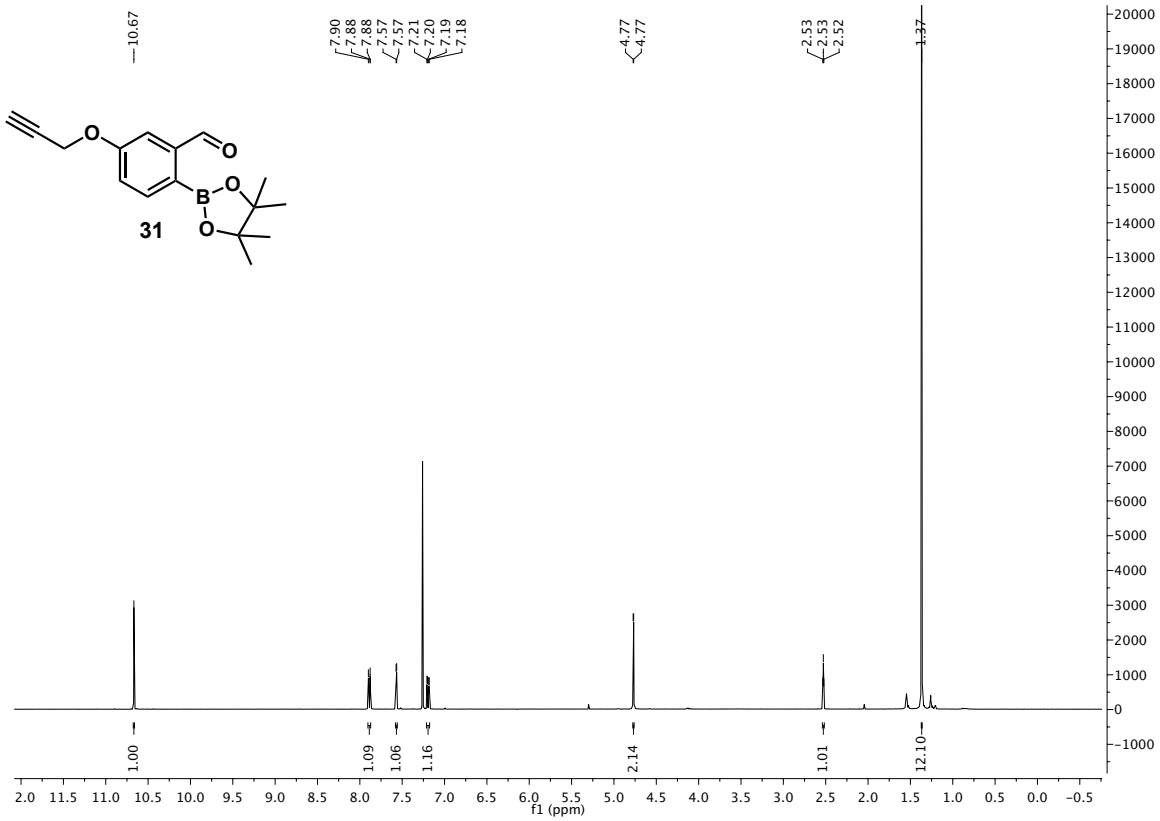
f1 (ppm)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1.16
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1.01
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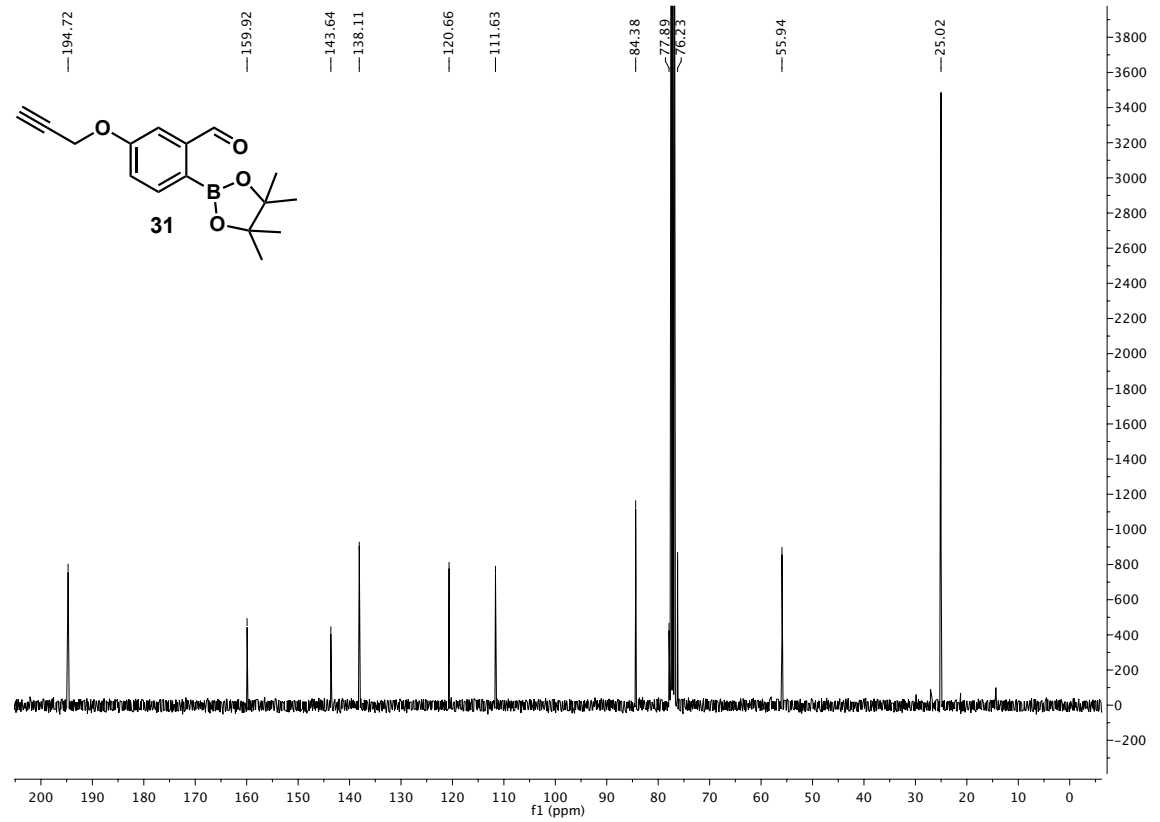
f1 (ppm)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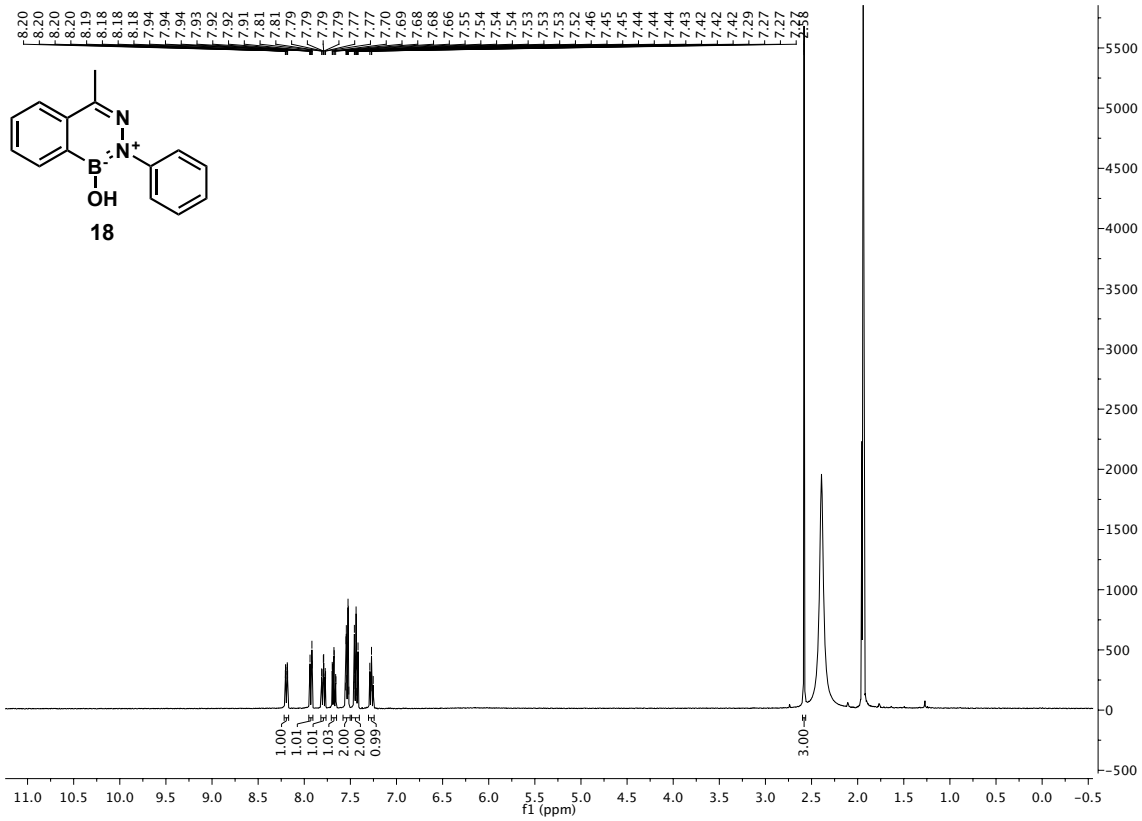
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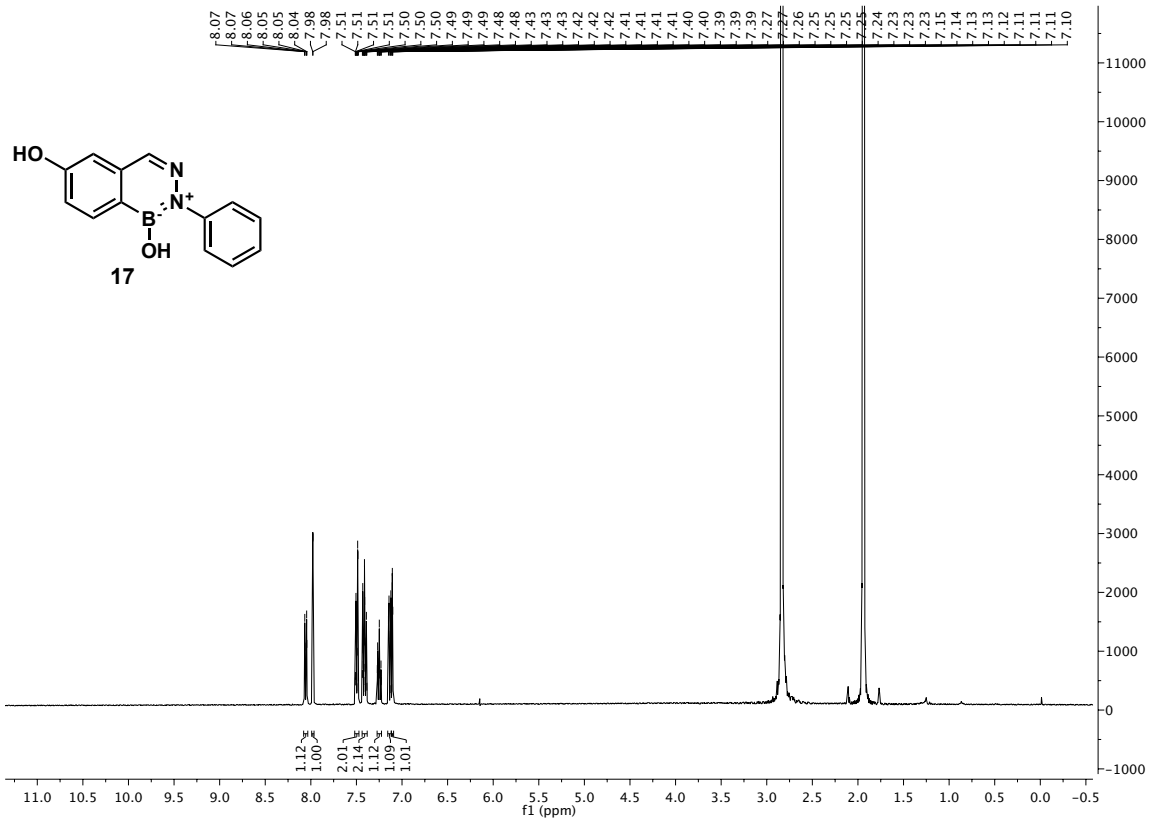
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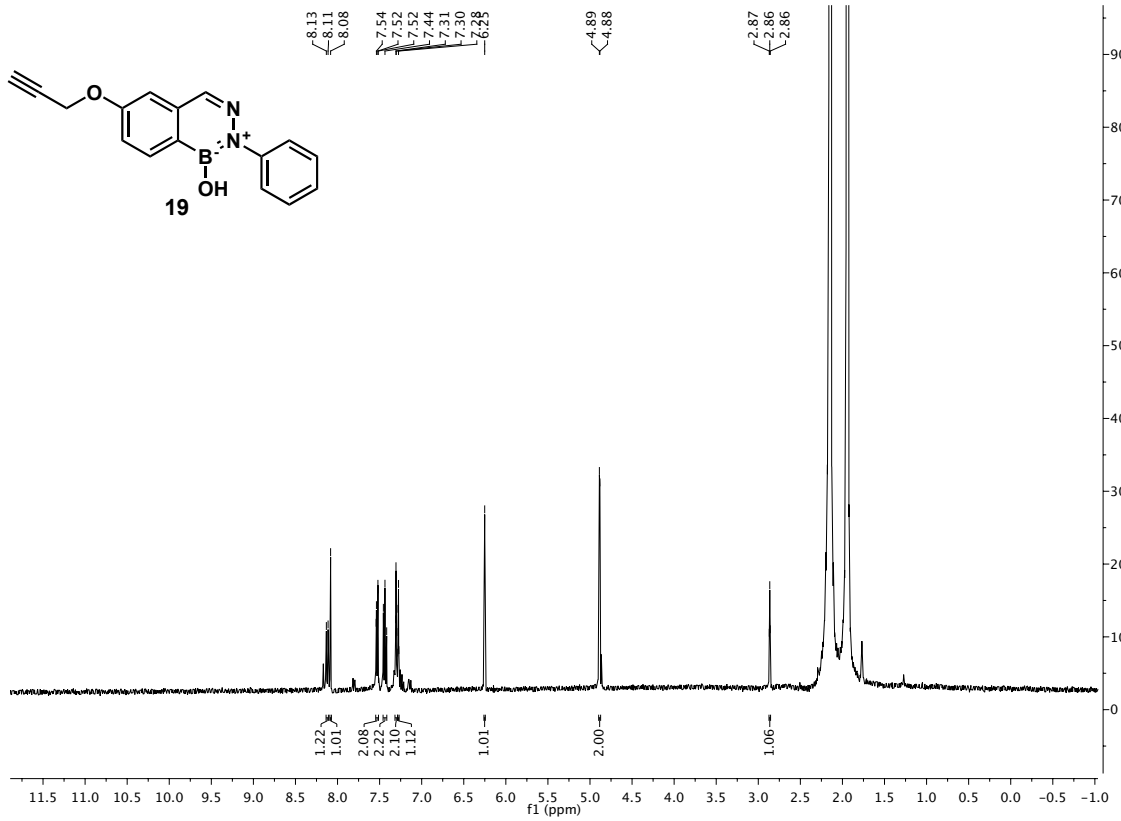
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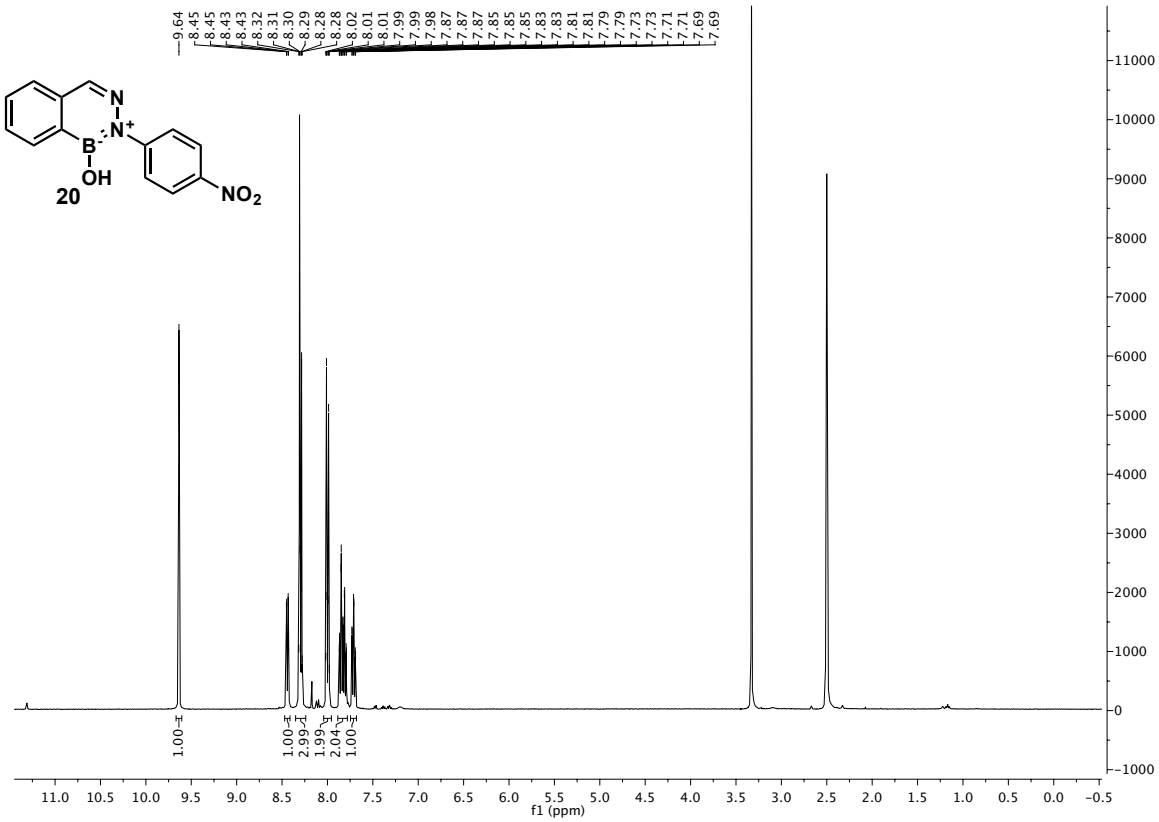
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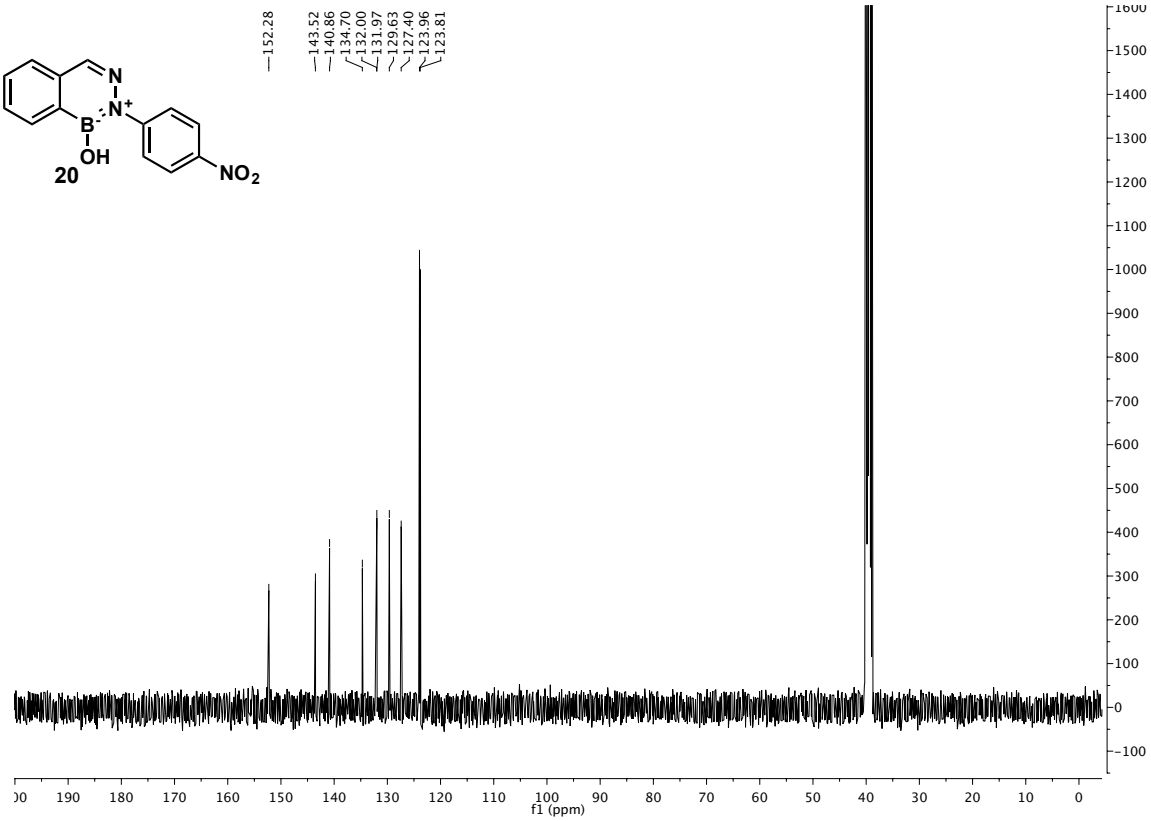
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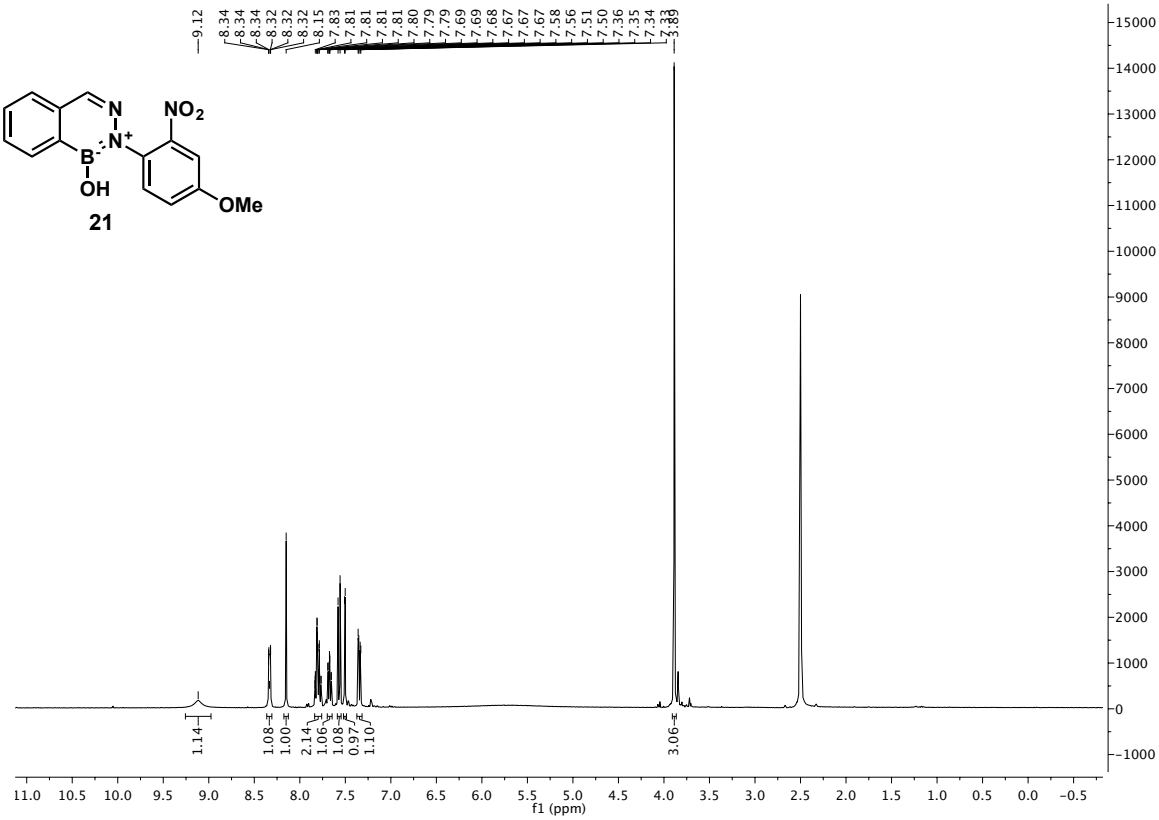
f1 (ppm)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N+
B-
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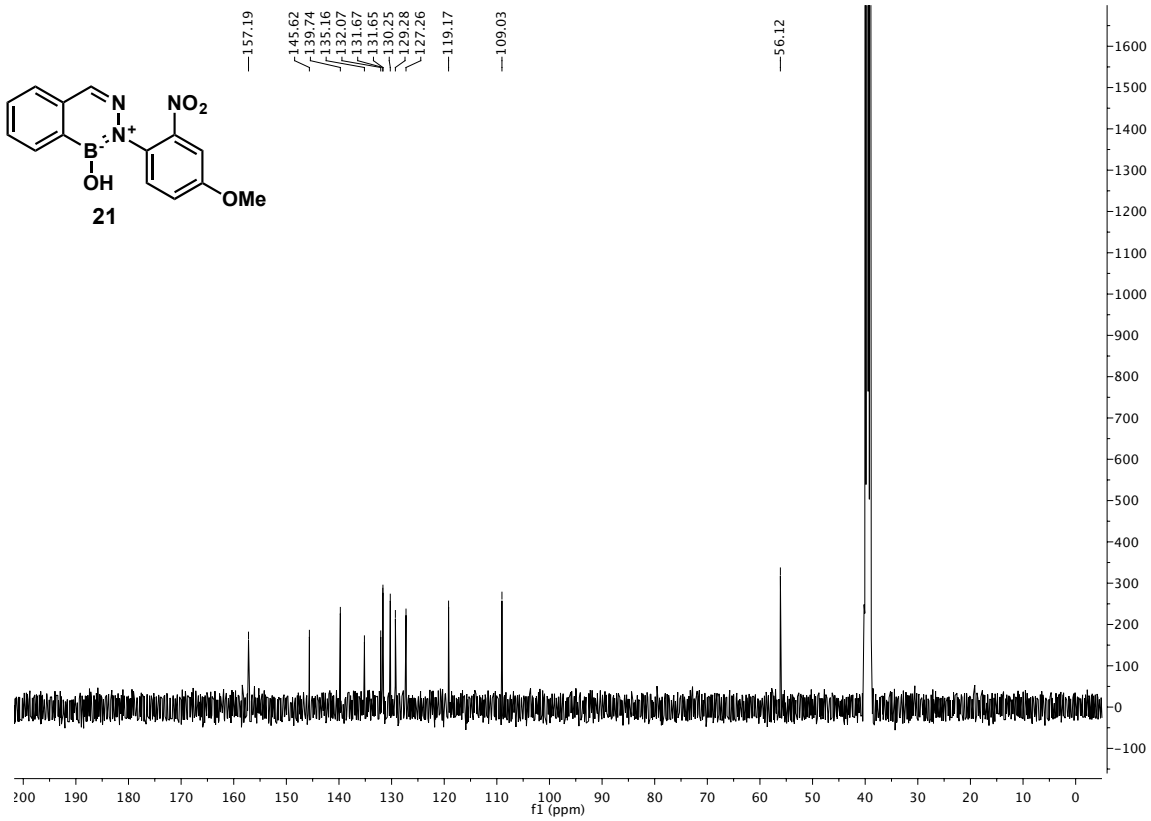
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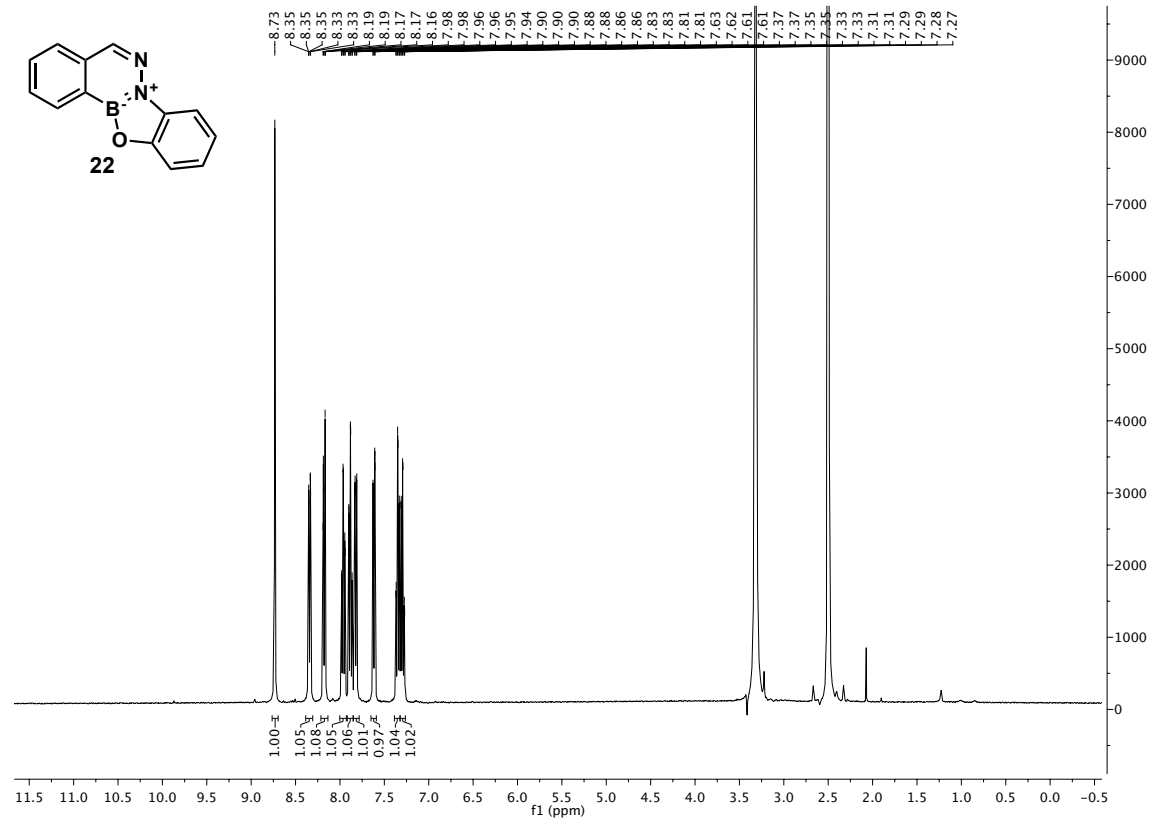
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7.31
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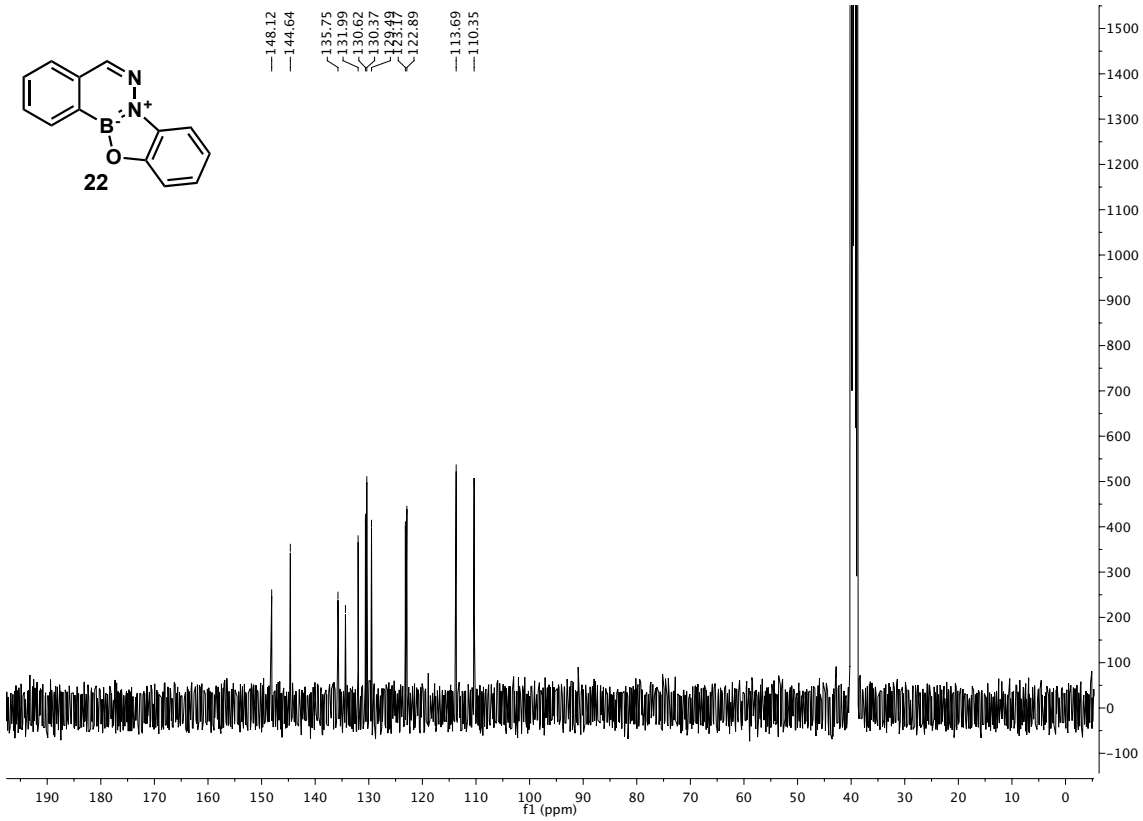
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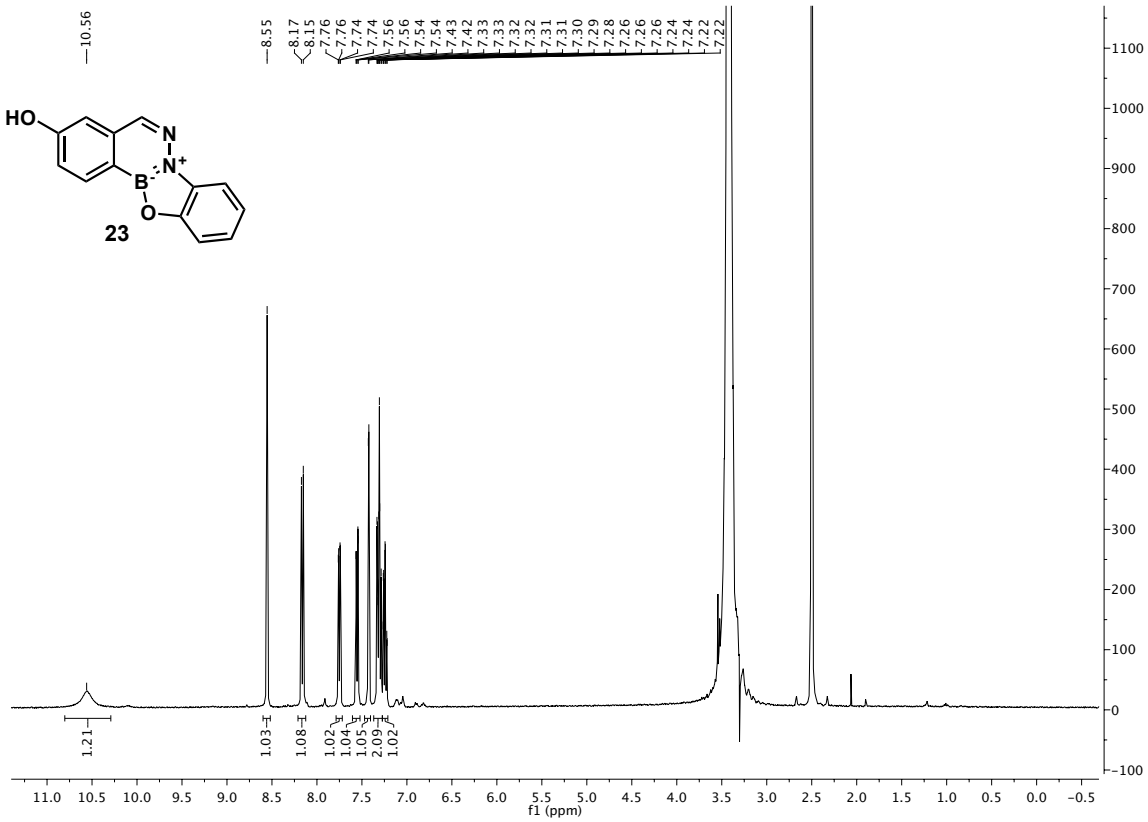
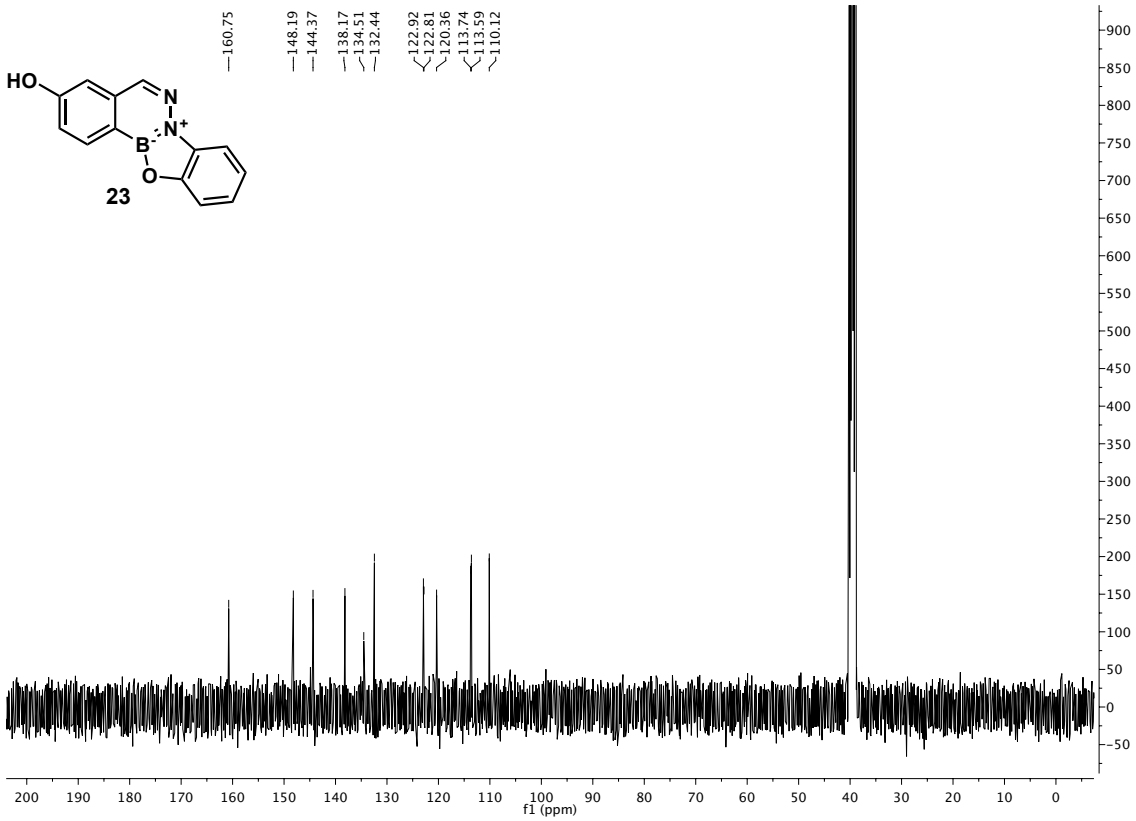
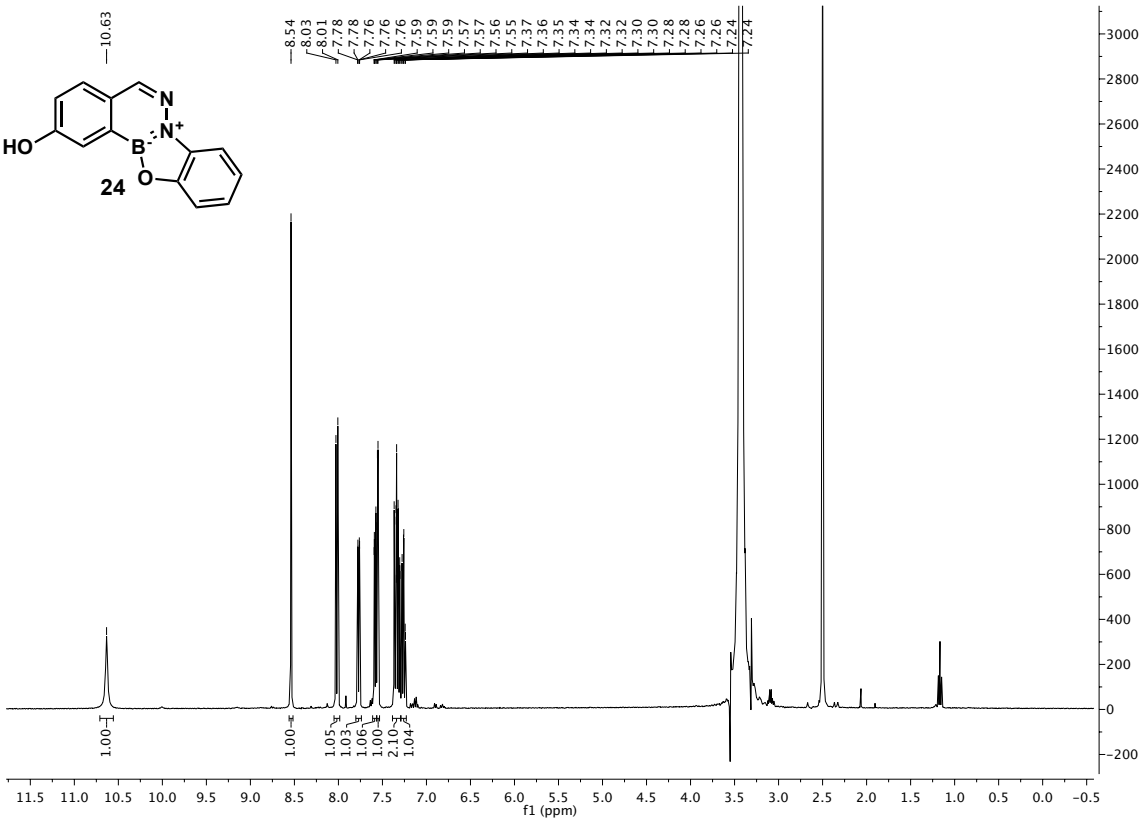
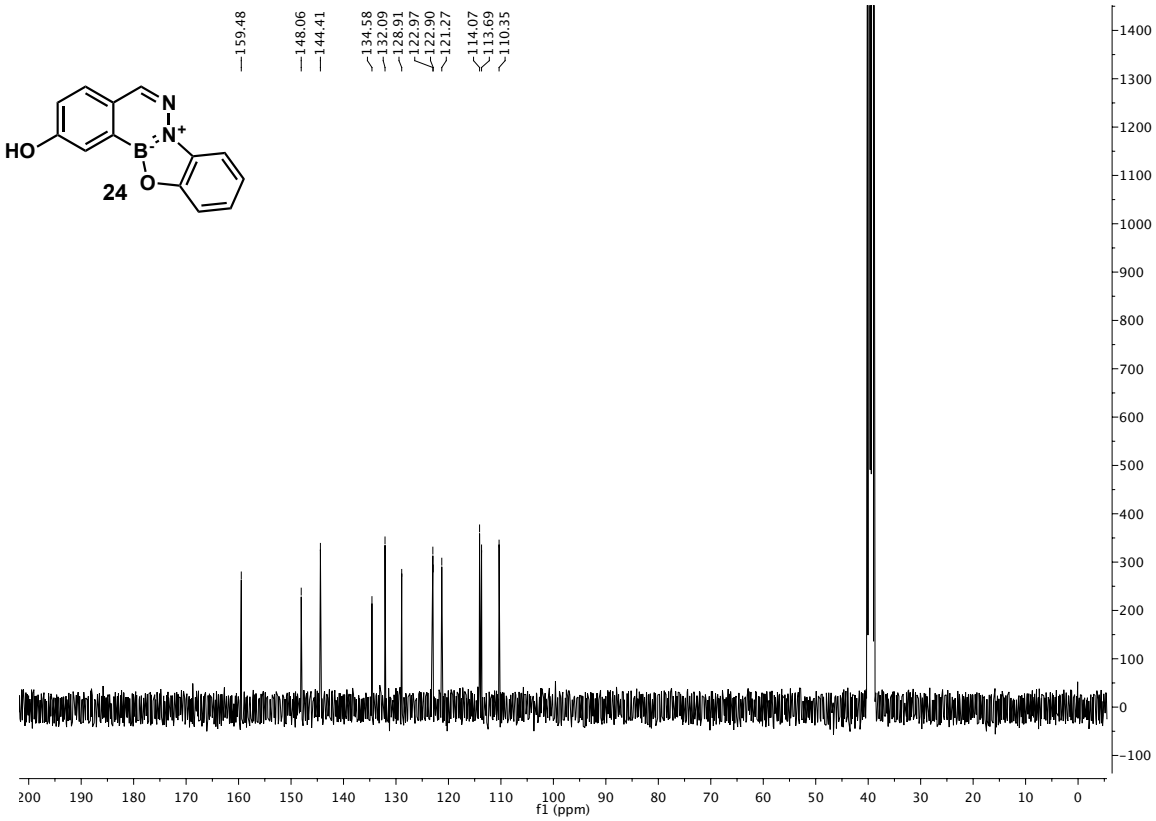
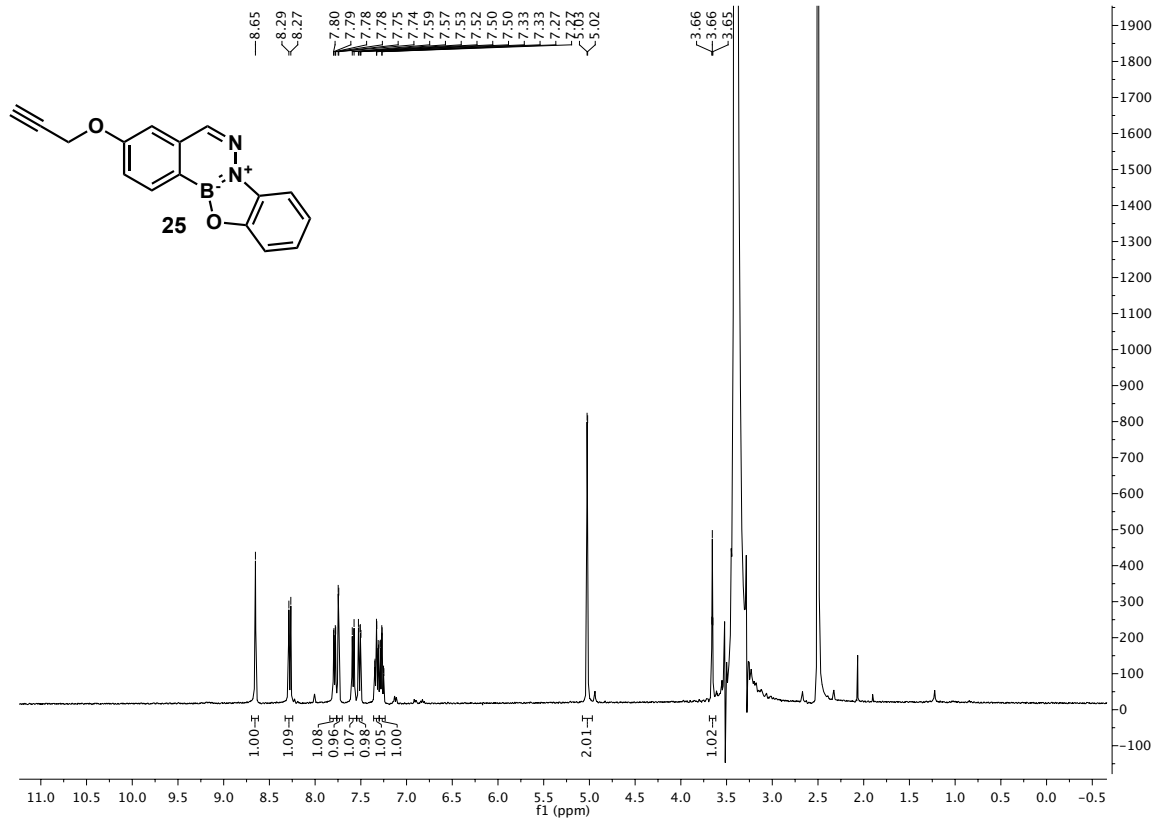
f1 (ppm)

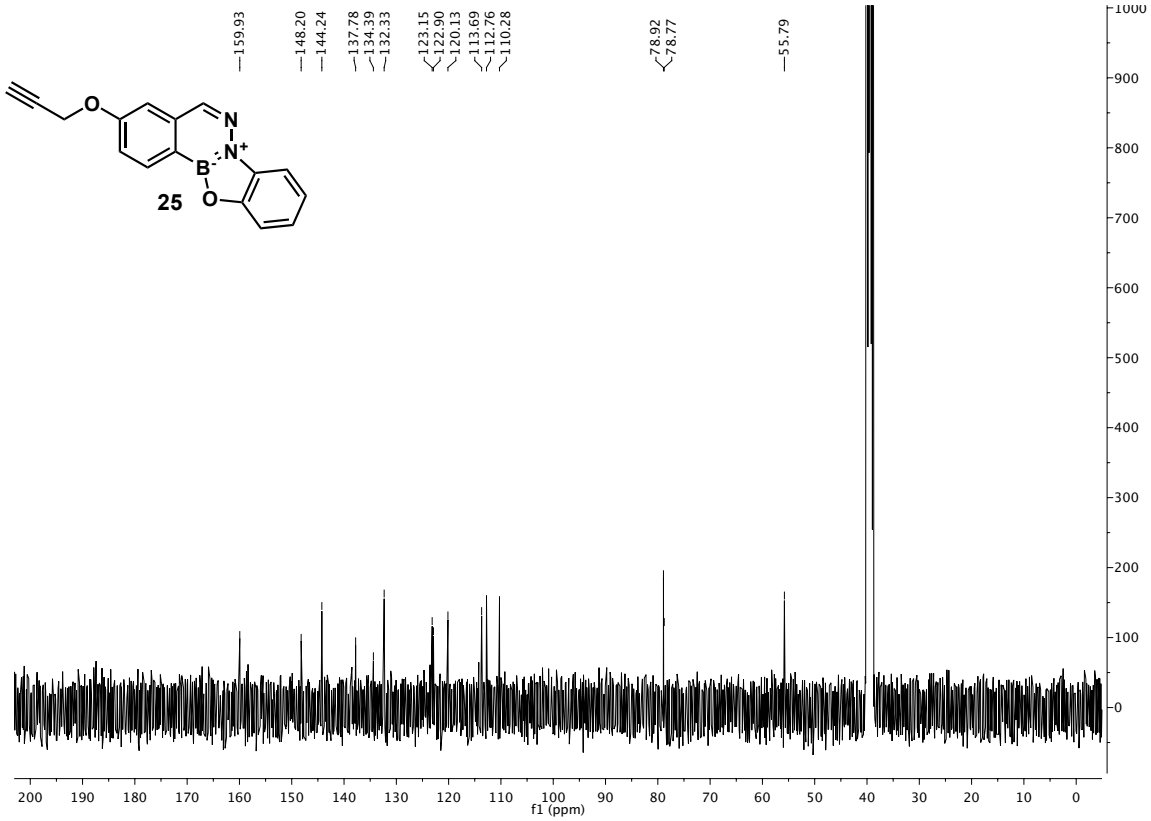

HO
23
10.56
8.55
8.17
8.15
1.21
1.03
1.08
1.02
1.04
1.05
2.09
1.02
f1 (ppm)

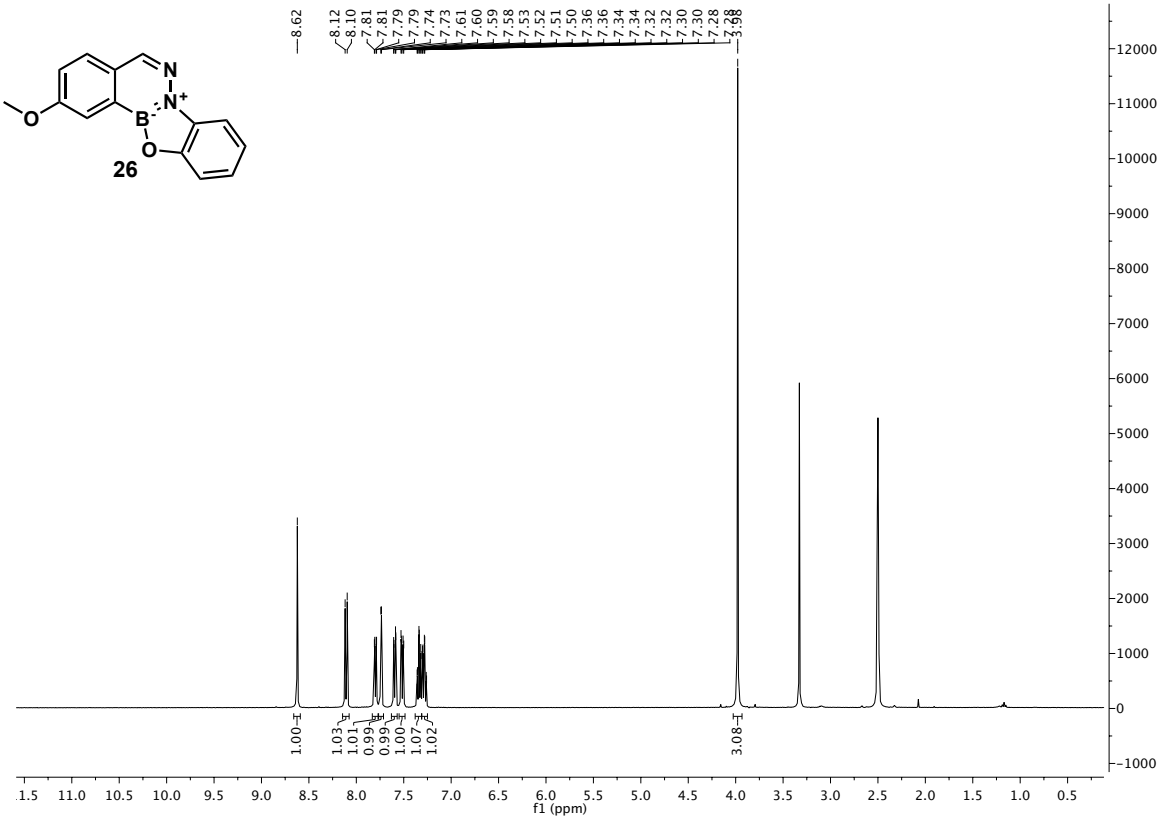

160.75
148.19
144.37
138.17
134.51
132.44
122.92
122.81
120.36
113.74
113.59
110.12
HO
N
N+
B
O
23
f1 (ppm)

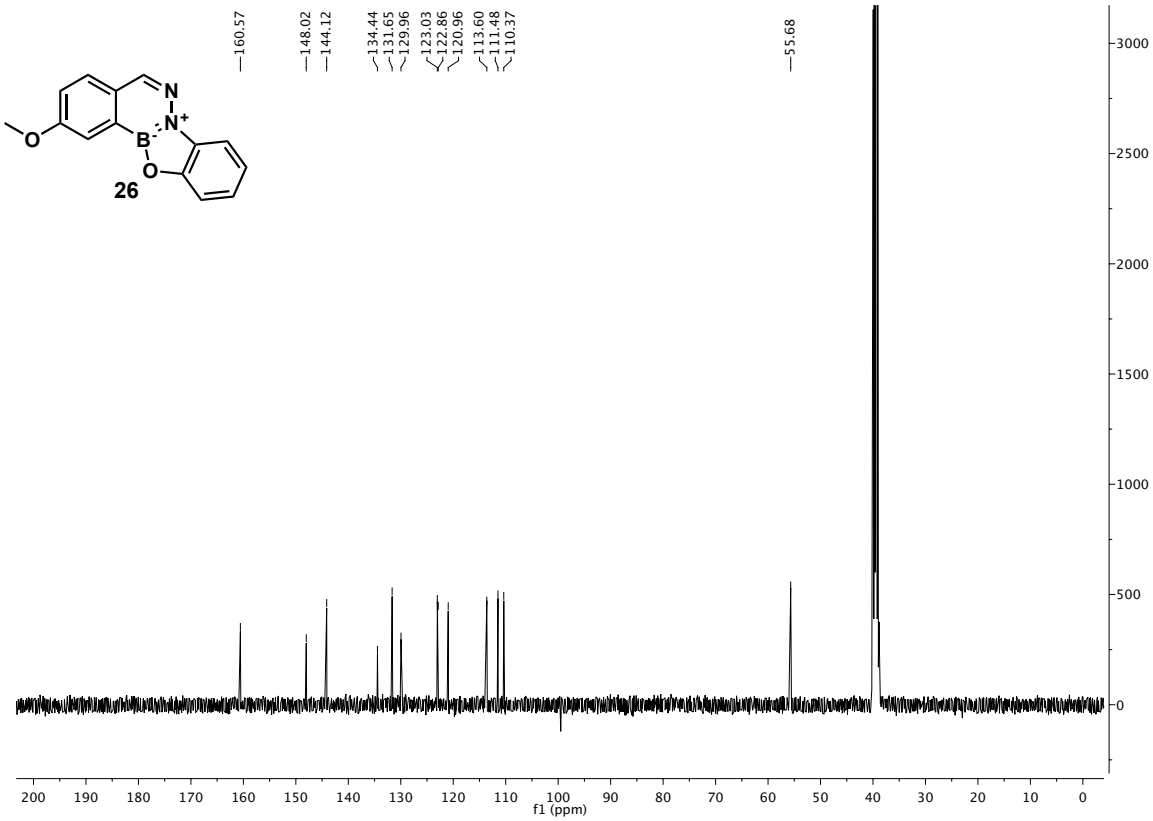

10.63
8.54
8.03
8.01
7.78
7.78
7.76
7.76
7.76
7.76
7.59
7.59
7.59
7.59
7.57
7.57
7.57
7.56
7.55
7.37
7.36
7.35
7.34
7.34
7.32
7.32
7.30
7.30
7.30
7.28
7.28
7.26
7.26
7.24
7.24
HO
N
N+
B
O
24
1.00
1.00
1.05
1.03
1.06
1.00
2.10
1.04
f1 (ppm)

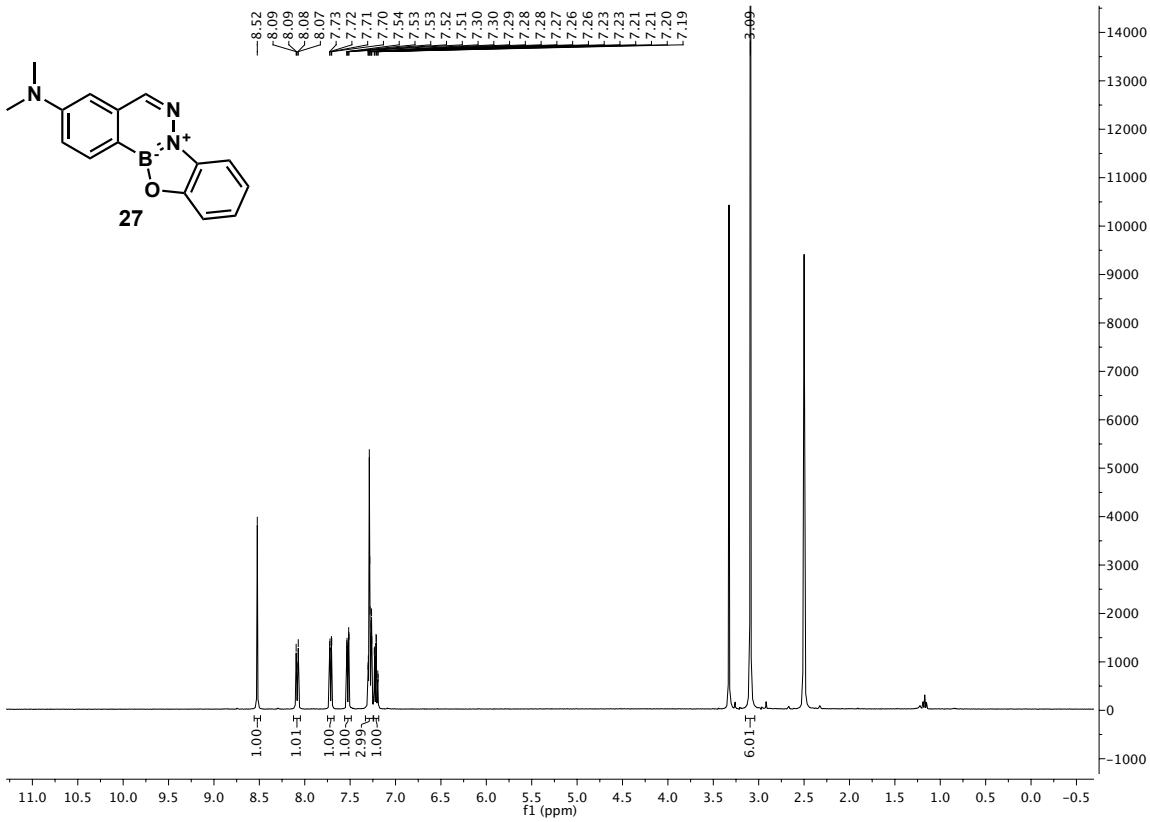

159.48
148.06
144.41
134.58
132.09
128.91
122.97
122.90
121.27
114.07
113.69
110.35
HO
N
N+
B
O
24
f1 (ppm)

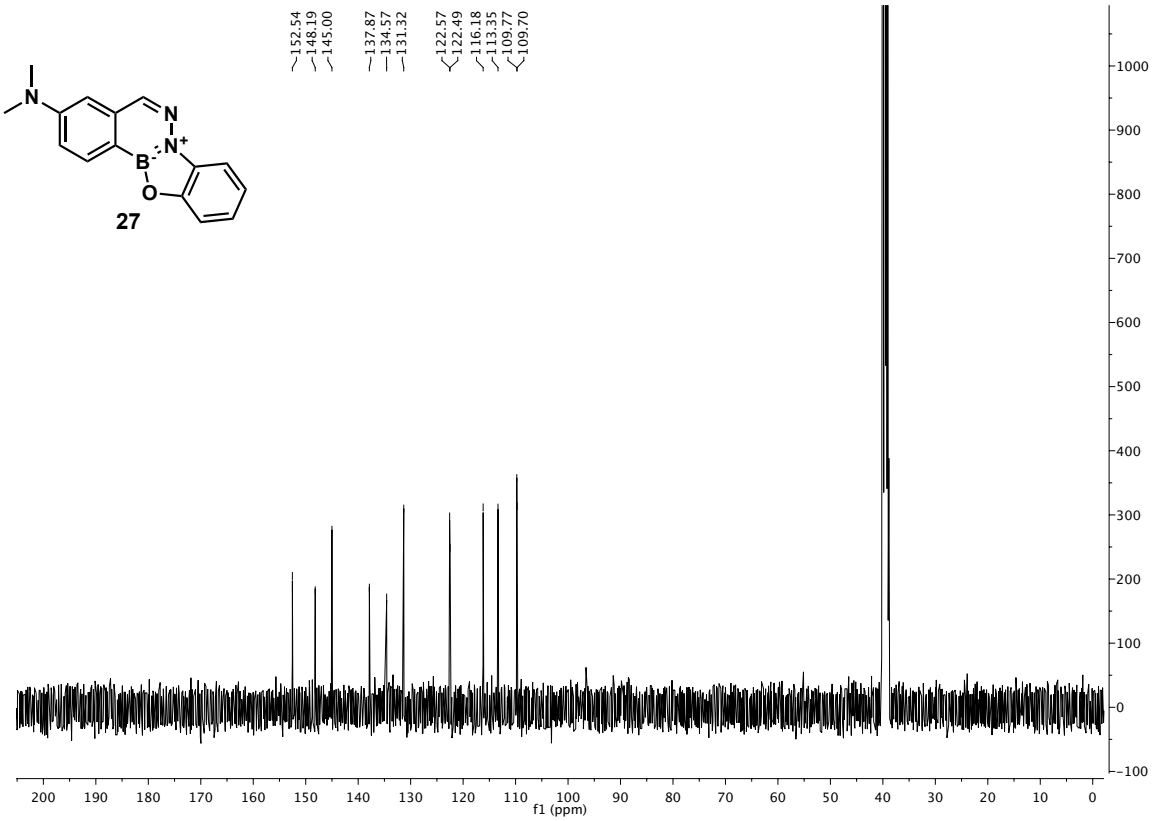

8.65
8.29
8.27
7.80
7.79
7.78
7.78
7.75
7.74
7.59
7.57
7.53
7.52
7.50
7.50
7.33
7.33
7.27
5.02
3.66
3.66
3.65
O
N
N+
B
O
25
1.00
1.09
1.08
0.96
1.07
0.98
1.05
1.00
2.01
1.02
f1 (ppm)

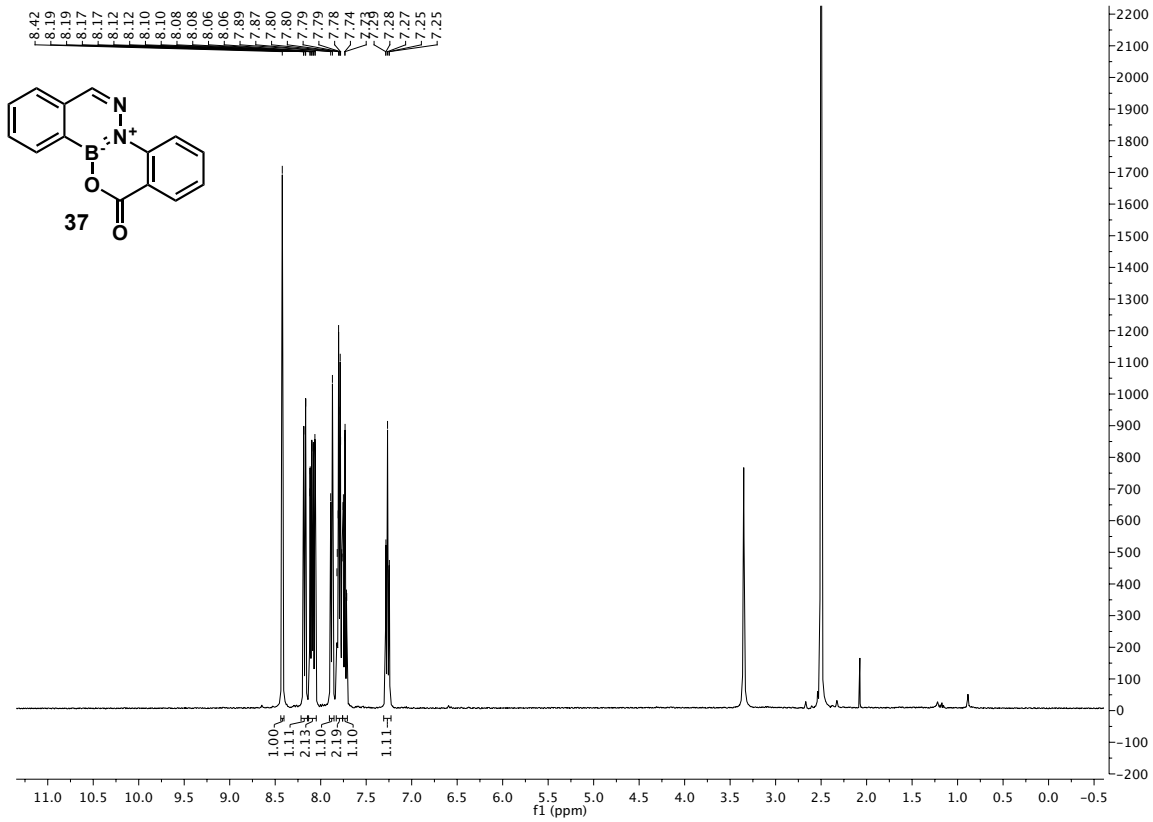

159.93
148.20
144.24
137.78
134.39
132.33
123.15
122.90
120.13
113.69
112.76
110.28
78.92
78.77
55.79
25
f1 (ppm)

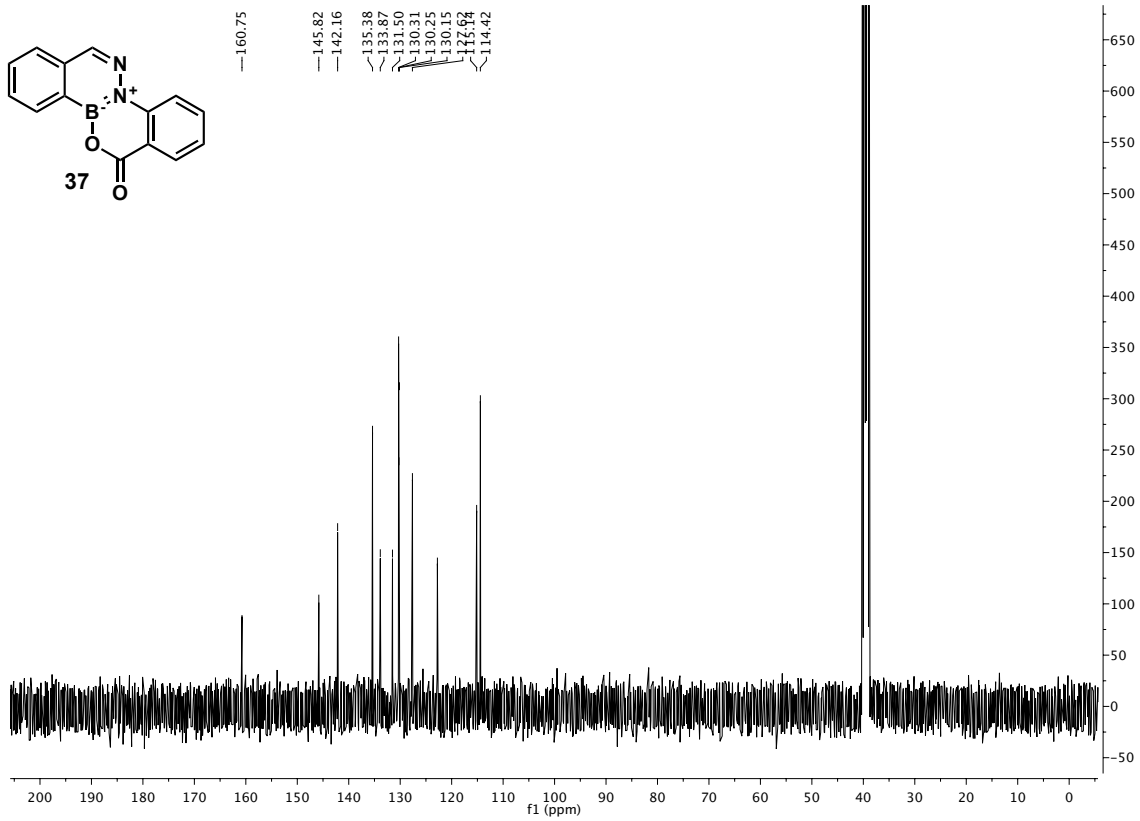

8.62
8.12
8.10
7.81
7.81
7.79
7.79
7.74
7.73
7.61
7.60
7.59
7.58
7.53
7.52
7.51
7.50
7.36
7.36
7.34
7.34
7.32
7.32
7.30
7.30
7.28
7.28
3.98
26
1.00
1.03
1.01
0.99
0.99
1.00
1.07
1.02
3.08
f1 (ppm)


160.57
148.02
144.12
134.44
131.65
129.96
123.03
122.86
120.96
113.60
111.48
110.37
55.68
26
f1 (ppm)


8.52
8.09
8.09
8.08
8.07
7.73
7.72
7.71
7.70
7.54
7.53
7.53
7.52
7.51
7.30
7.30
7.29
7.28
7.28
7.27
7.26
7.26
7.23
7.23
7.21
7.21
7.20
7.19
3.09
1.00
1.01
1.00
1.00
2.99
1.00
6.01
27
f1 (ppm)


152.54
148.19
145.00
137.87
134.57
131.32
122.57
122.49
116.18
113.35
109.77
109.70
27
f1 (ppm)


8.42
8.19
8.19
8.17
8.17
8.12
8.12
8.10
8.10
8.08
8.08
8.06
8.06
7.89
7.87
7.80
7.80
7.79
7.79
7.78
7.74
7.73
7.29
7.28
7.27
7.25
7.25
37
1.00
1.11
2.13
1.10
2.19
1.10
1.11
f1 (ppm)



9. References

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