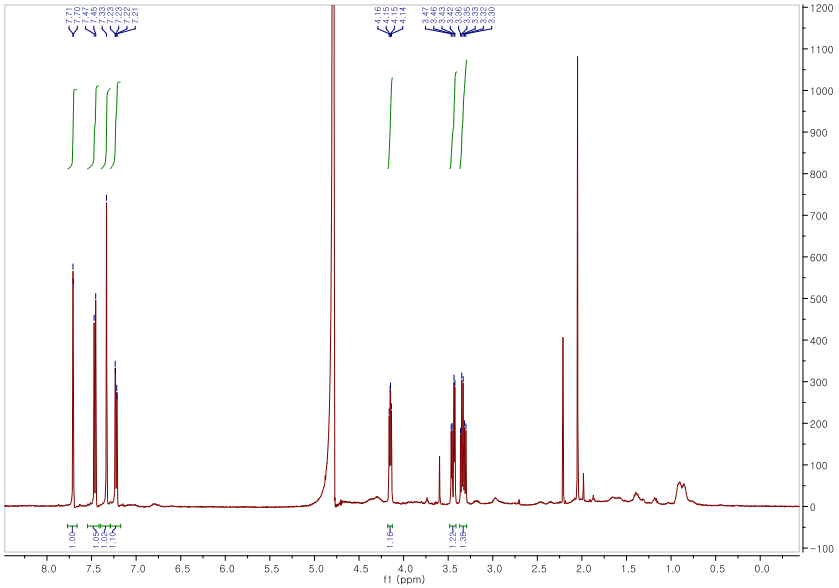
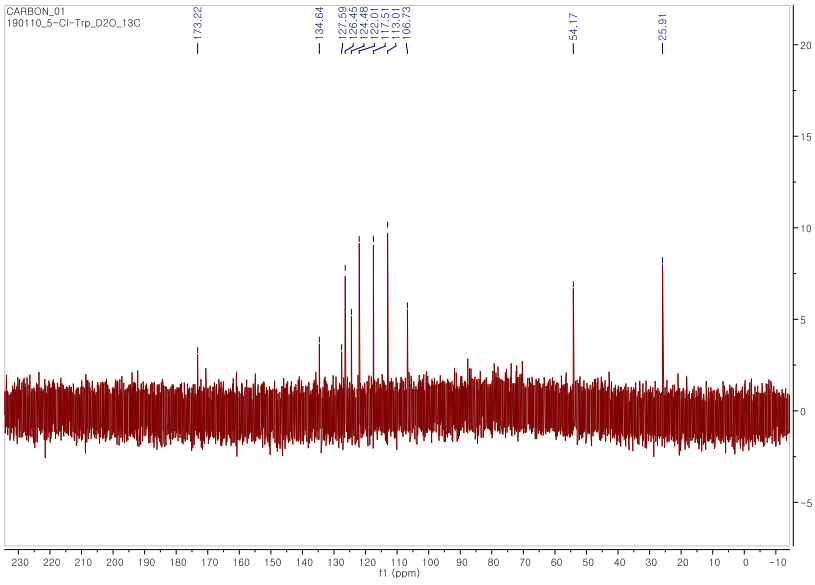
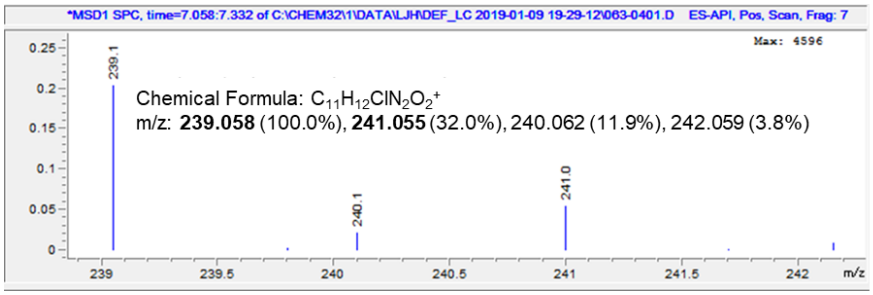
Characterization of halogenated product by ^{1}H and ^{13}C NMR spectroscopy and Mass spectroscopy

5-Chloro-L-tryptophan. The product was isolated from the reaction of Hal6, tryptophan, and NaCl. **^{1}H NMR** (500 MHz, D_2O) δ 7.71 (d, *J* = 1.6 Hz, 1H), 7.46 (d, *J* = 8.7 Hz, 1H), 7.33 (s, 1H), 7.22 (dd, *J* = 8.7, 1.8 Hz, 1H), 4.15 (dd, *J* = 7.5, 5.2 Hz, 1H), 3.45 (dd, *J* = 15.4, 5.0 Hz, 1H), 3.39 – 3.26 (m, 1H) **^{13}C NMR** (100.53 MHz, D_2O) δ 173.22, 134.64, 127.59, 126.45, 124.48, 122.01, 117.51, 113.01, 106.73, 54.17, 25.91 **Mass** (ES-API) (*m/z*) calculated for $C_{11}H_{12}ClN_2O_2^+$ $[M+H]^+$: 239.058, 241.055, observed: 239.1, 241.0

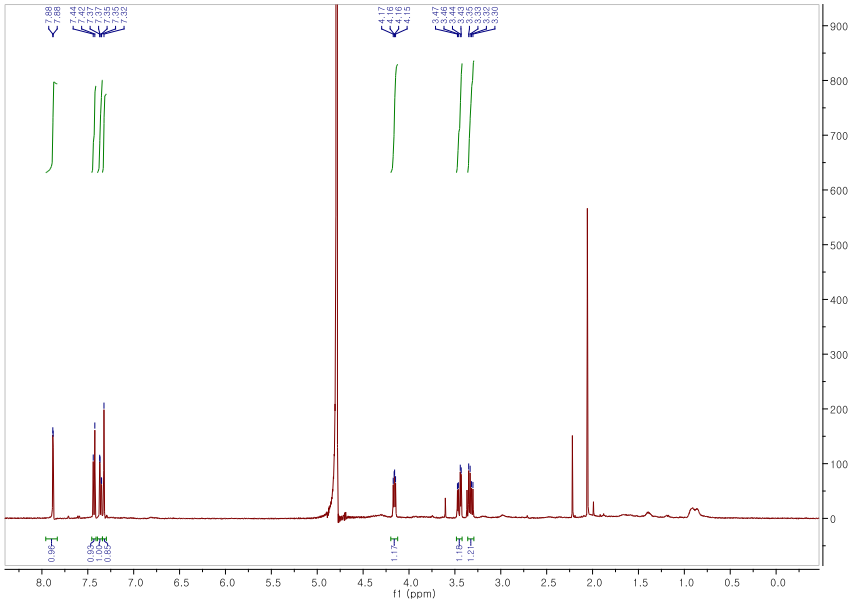


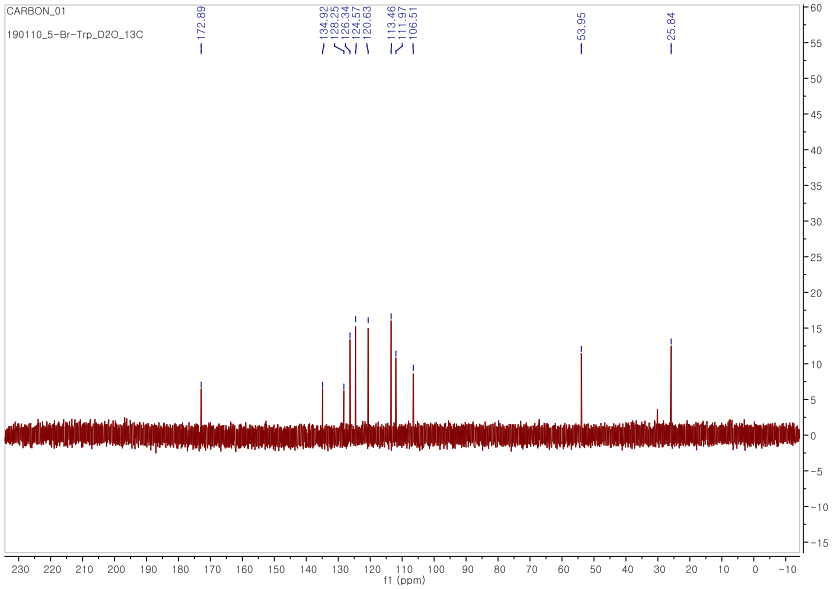


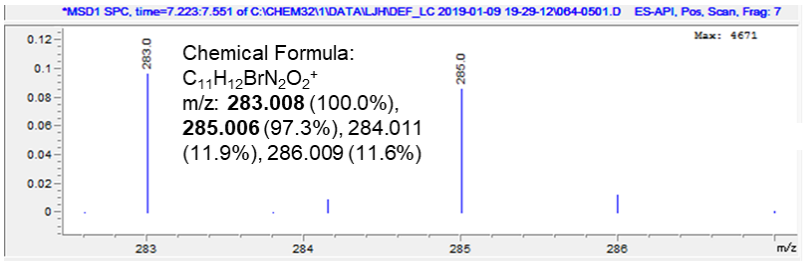


5-Bromo-L-tryptophan. The product was isolated from the reaction of Hal6, tryptophan, and NaBr.

^{1}H NMR (500 MHz, D_2O) δ 7.88 (d, *J* = 1.6 Hz, 1H), 7.43 (d, *J* = 8.7 Hz, 1H), 7.36 (dd, *J* = 8.7, 1.7 Hz, 1H), 7.32 (s, 1H), 4.16 (dd, *J* = 7.6, 5.1 Hz, 1H), δ 3.39 (m, 2H) **^{13}C NMR** (100.53 MHz, D_2O) δ 172.89, 134.92, 128.25, 126.34, 124.57, 120.63, 113.46, 111.97, 106.51, 53.95, 25.84 **Mass** (ES-API) (*m*/*z*) calculated for $C_{11}H_{12}BrN_2O_2^+$ **[**M+H]$^+$: 283.008, 285.006, observed: 283.0, 285.0

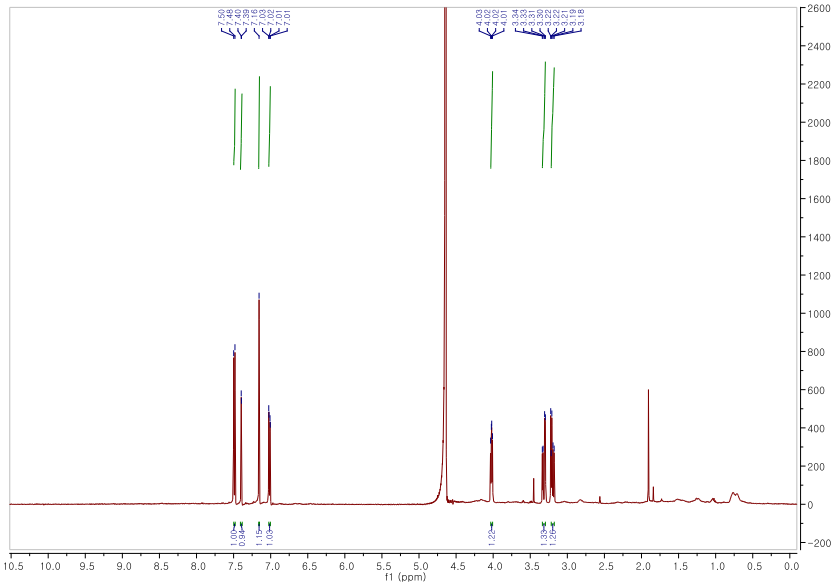


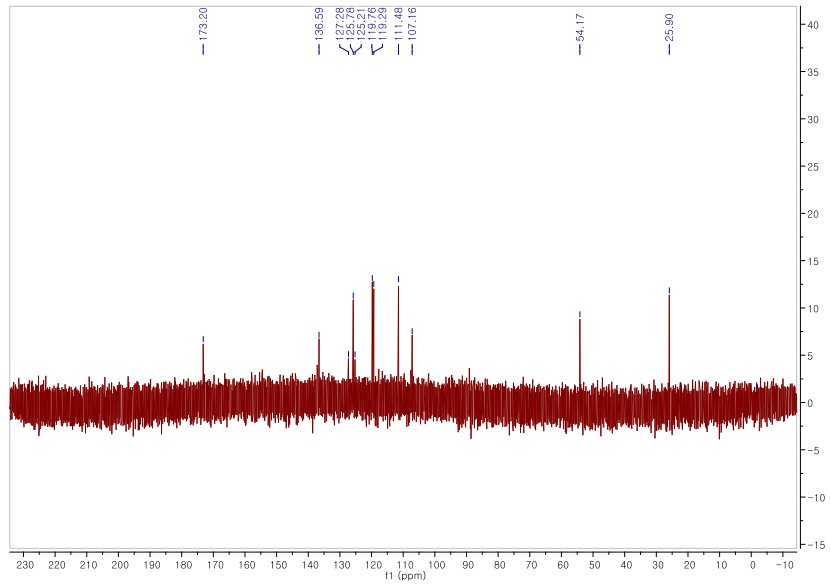


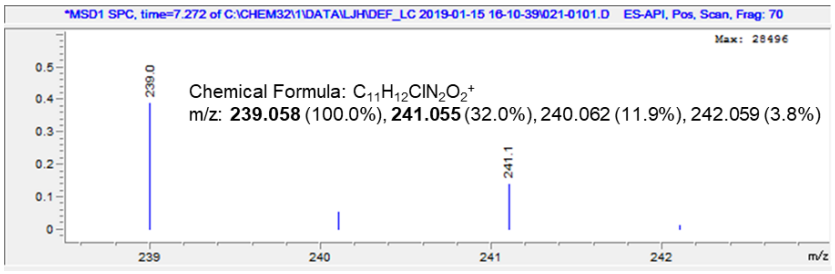


6-Chloro-L-tryptophan. The product was isolated from the reaction of Hal2 variant (P110L), trpytophan, and NaCl.

^{1}H NMR (500 MHz, D_2O) δ 7.49 (d, *J* = 8.5 Hz, 1H), δ 7.40 (d, *J* = 1.6 Hz, 1H), δ 7.16 (s, 1H), δ 7.02 (dd, *J* = 8.5, 1.7 Hz, 1H), δ 4.02 (dd, *J* = 7.5, 5.2 Hz, 1H), δ 3.35 – 3.15 (m, 2H) **^{13}C NMR** (100.53, D_2O) δ 173.20, 136.59, 127.28, 125.78, 125.21, 119.76, 119.29, 111.48, 107.16, 54.17, 25.90 **Mass** (ES-API) (*m*/*z*) calculated for $C_{11}H_{12}ClN_2O_2^+$ $[M+H]^+$: 239.058, 241.055, observed: 239.0, 241.1

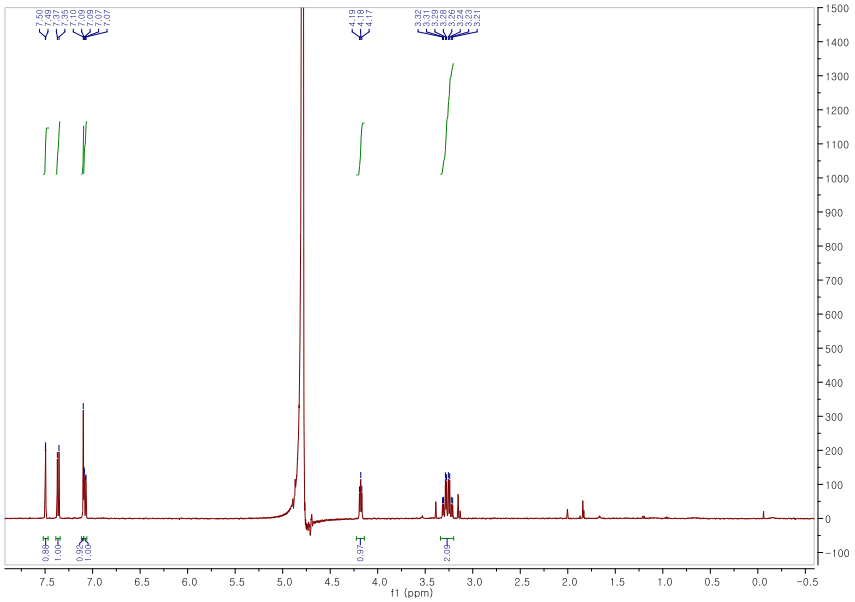


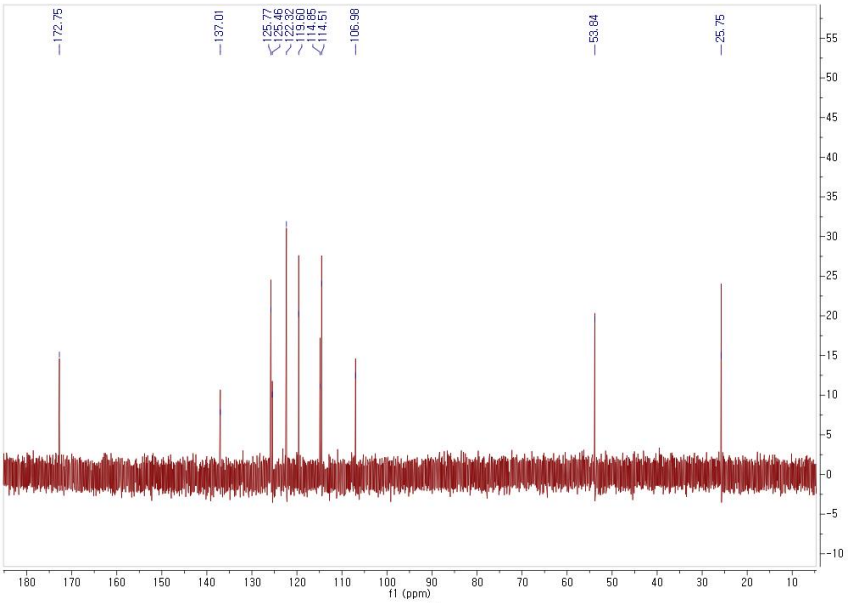


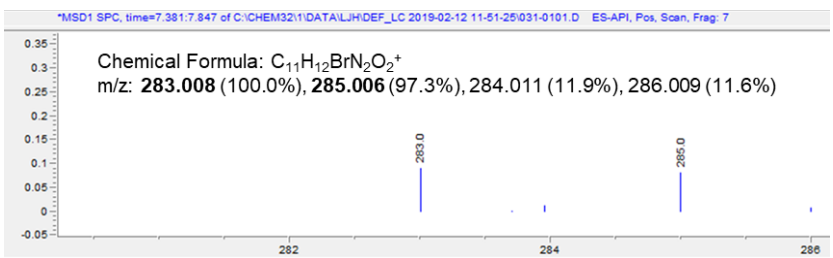


6-Bromo-L-tryptophan. The product was isolated from the bromination of tryptophan with Hal2 variant (P110L).

^{1}H NMR (500 MHz, D_2O) δ 7.50 (d, *J* = 1.2 Hz, 1H), 7.36 (d, *J* = 8.5 Hz, 1H), 7.10 (s, 1H), 7.08 (dd, *J* = 8.6, 1.5 Hz, 1H), 4.18 (t, *J* = 6.2 Hz, 1H), 3.27 (qd, *J* = 15.5, 6.3 Hz, 2H)**^{13}C NMR** (100.53 MHz, D_2O), δ 172.75, 137.01, 125.77, 125.46, 122.32, 119.60, 114.85, 114.51, 106.98, 53.84, 25.75 **Mass** (ES-API) (*m*/*z*) calculated for $C_{11}H_{12}BrN_2O_2^+$ $[M+H]^+$: 283.008, 285.006, observed: 283.0, 285.0

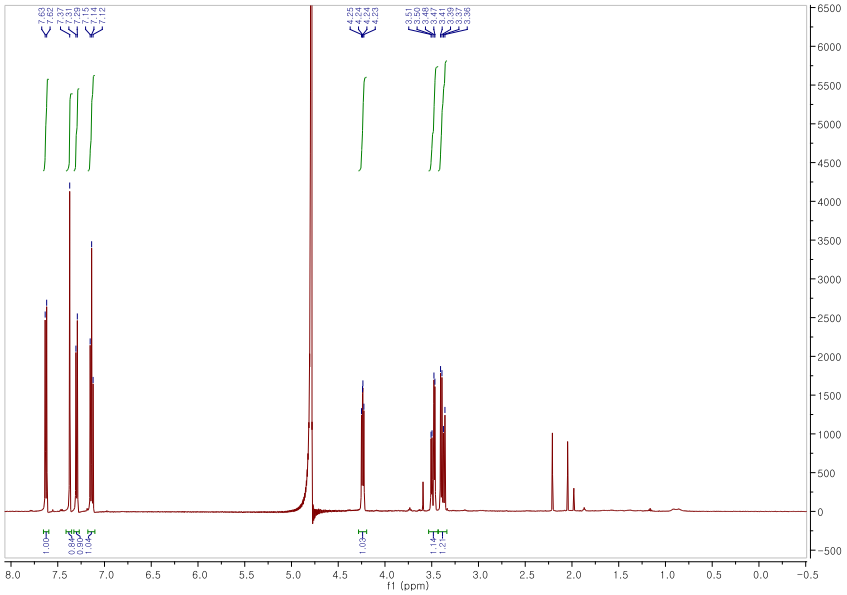


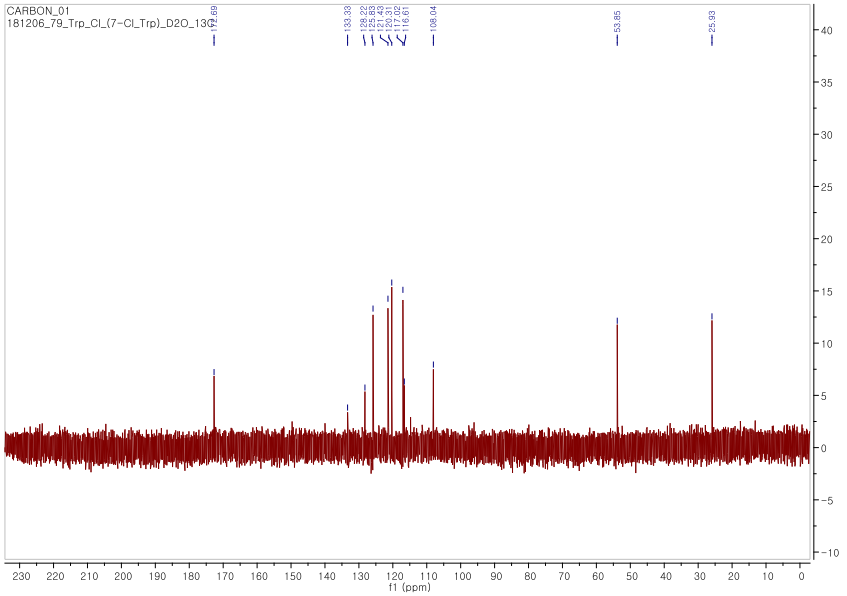


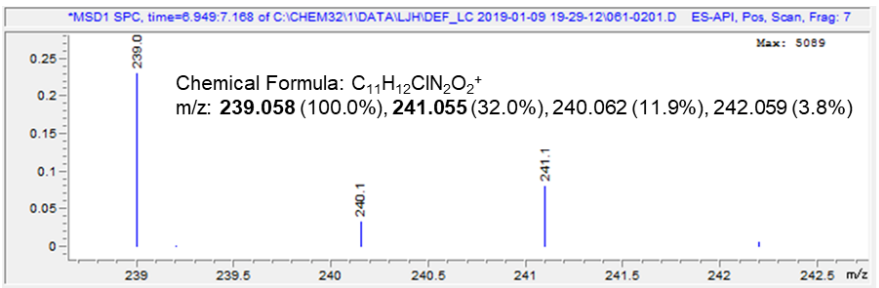


7-Chloro-L-tryptophan. The product was isolated from the chlorination of tryptophan with Hal1.

^{1}H NMR (500 MHz, D_2O) δ 7.63 (d, *J* = 8.0 Hz, 1H), 7.37 (s, 1H), 7.30 (d, *J* = 7.6 Hz, 1H), 7.14 (t, *J* = 7.8 Hz, 1H), 4.24 (dd, *J* = 7.4, 5.3 Hz, 1H), 3.43 (m, 2H) **^{13}C NMR** (100.53, D_2O) δ 172.69, 133.33, 128.22, 125.83, 121.43, 120.31, 117.02, 116.61, 108.04, 53.85, 25.93 **Mass** (ES-API) (*m*/*z*) calculated for $C_{11}H_{12}ClN_2O_2^+$ $[M+H]^+$: 239.058, 241.055, observed: 239.0, 241.1

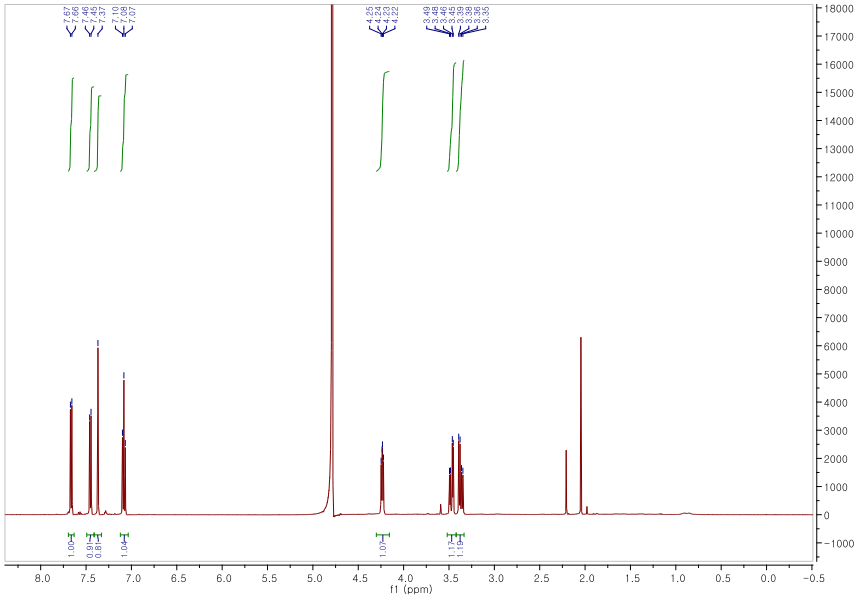


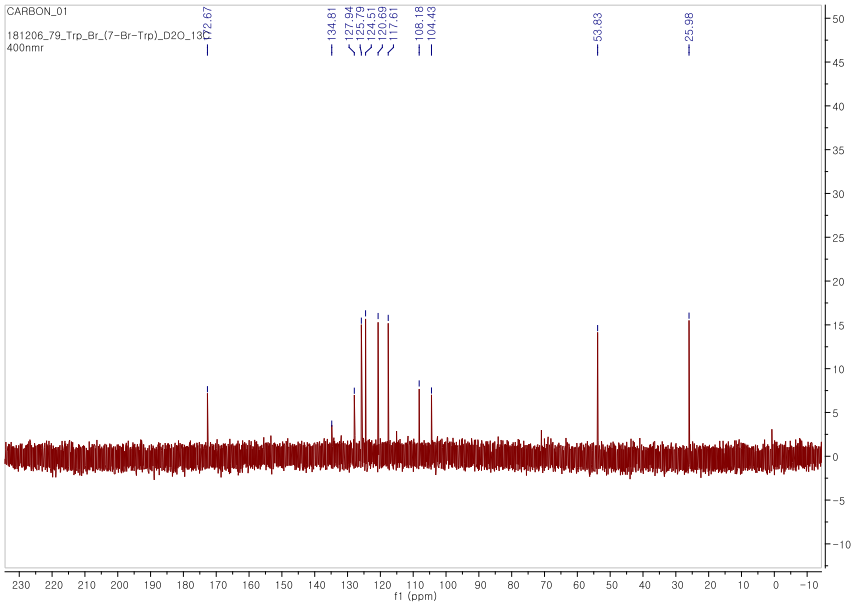


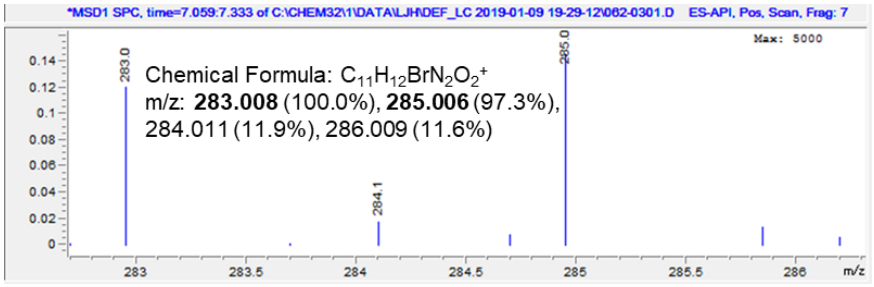


7-Bromo-L-tryptophan. The product was isolated from the reaction of Hal1, tryptophan, and NaBr.

^{1}H NMR (500 MHz, D_2O) δ 7.66 (d, *J* = 7.9 Hz, 1H), 7.45 (d, *J* = 7.6 Hz, 1H), 7.37 (s, 1H), 7.08 (t, *J* = 7.8 Hz, 1H), 4.24 (dd, *J* = 7.4, 5.3 Hz, 1H), 3.42 (m, 2H) **^{13}C NMR** (100.53 MHz, D_2O) δ 172.67, 134.81, 127.94, 125.79, 124.51, 120.61, 117.61, 108.18, 104.43, 53.83, 25.98 **Mass** (ES-API) (*m*/*z*) calculated for $C_{11}H_{12}BrN_2O_2^+$ **[**M+H]$^+$: 283.008, 285.006, observed: 283.0, 285.0

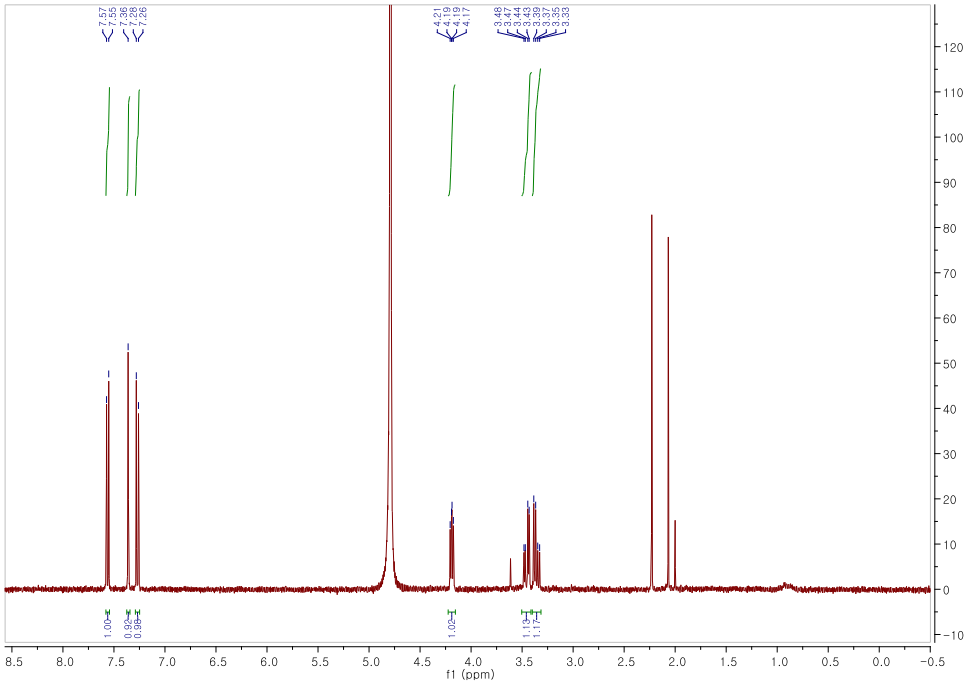


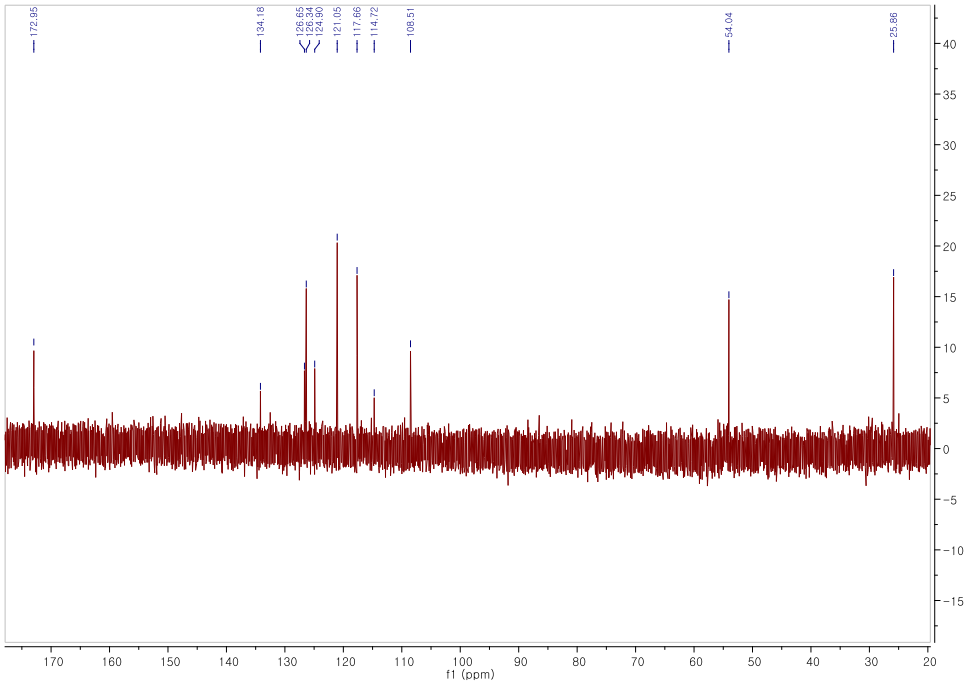


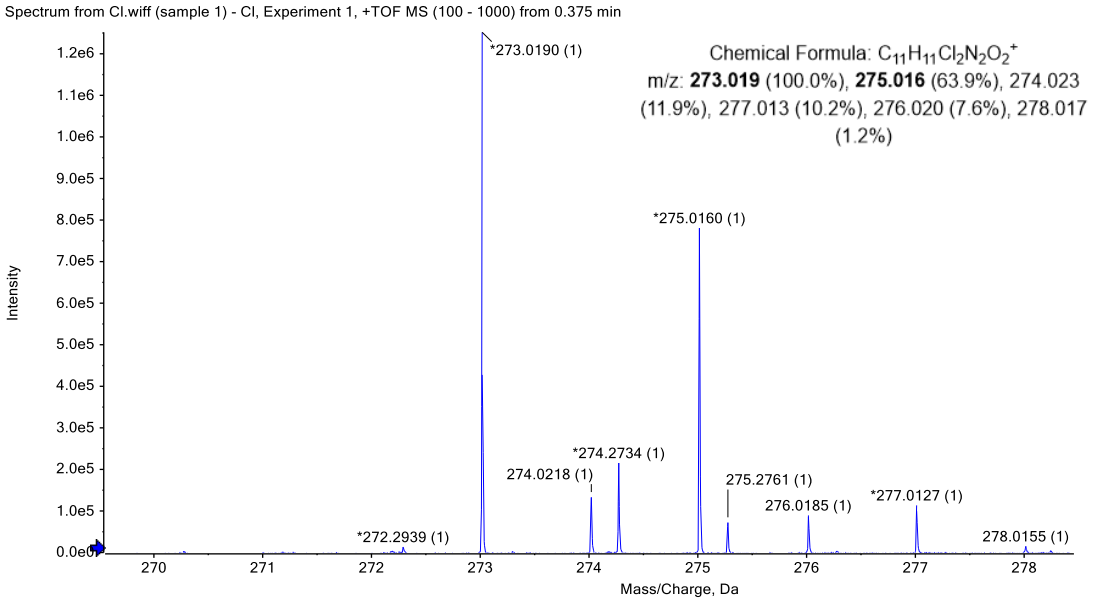


6,7-Dichloro-L-tryptophan. The product was isolated from the reaction of Hal7 N470S mutant, tryptophan, and NaCl.

^{1}H NMR (400 MHz, D_2O δ 7.56 (d, *J* = 8.5 Hz, 1H), 7.36 (s, 1H), 7.27 (d, *J* = 8.5 Hz, 1H), 4.19 (dd, *J* = 7.3, 5.3 Hz, 1H), 3.46 (dd, *J* = 15.1, 5.2 Hz, 1H), 3.36 (dd, *J* = 15.5, 7.4 Hz, 1H).**^{13}C NMR** (100.53 MHz, D_2O) δ172.95, 134.18, 126.65, 126.34, 124.90, 121.05, 117.66, 114.72, 108.51, 54.04, 25.86 **Mass** (ESI TOF-MS) (*m*/*z*) calculated for $C_{11}H_{11}Cl_2N_2O_2$ $[M+H]^+$: 273.019, 275.016, observed: 273.019, 275.016

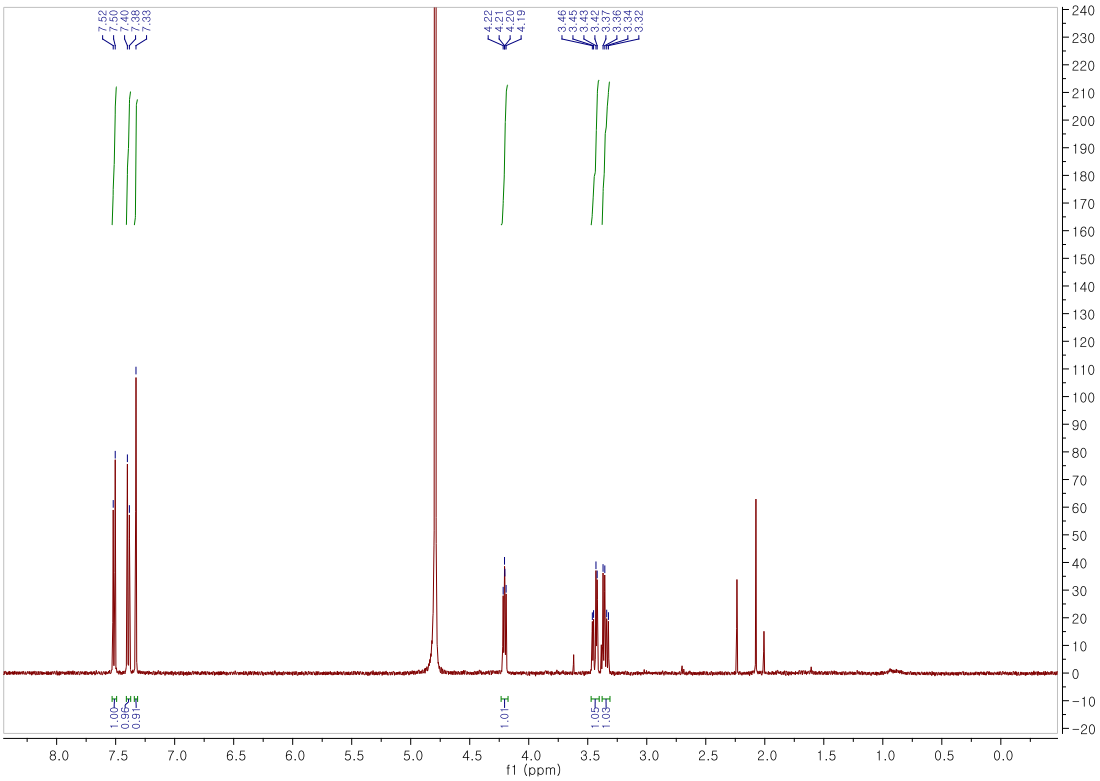


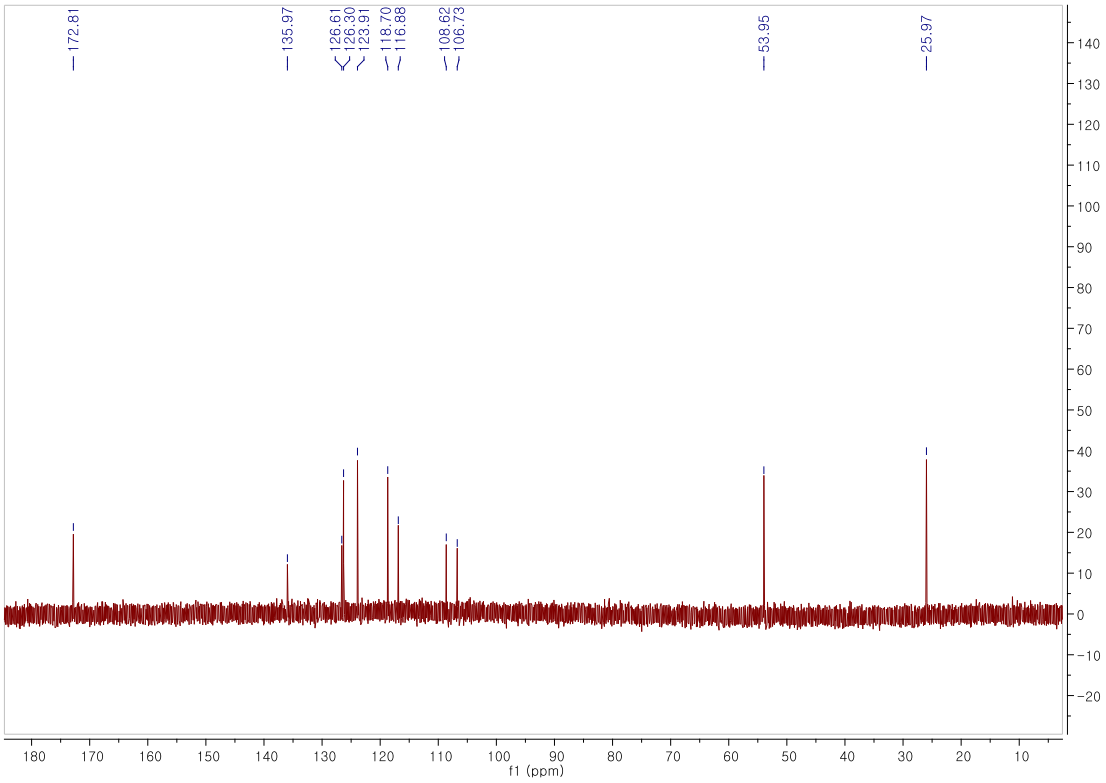


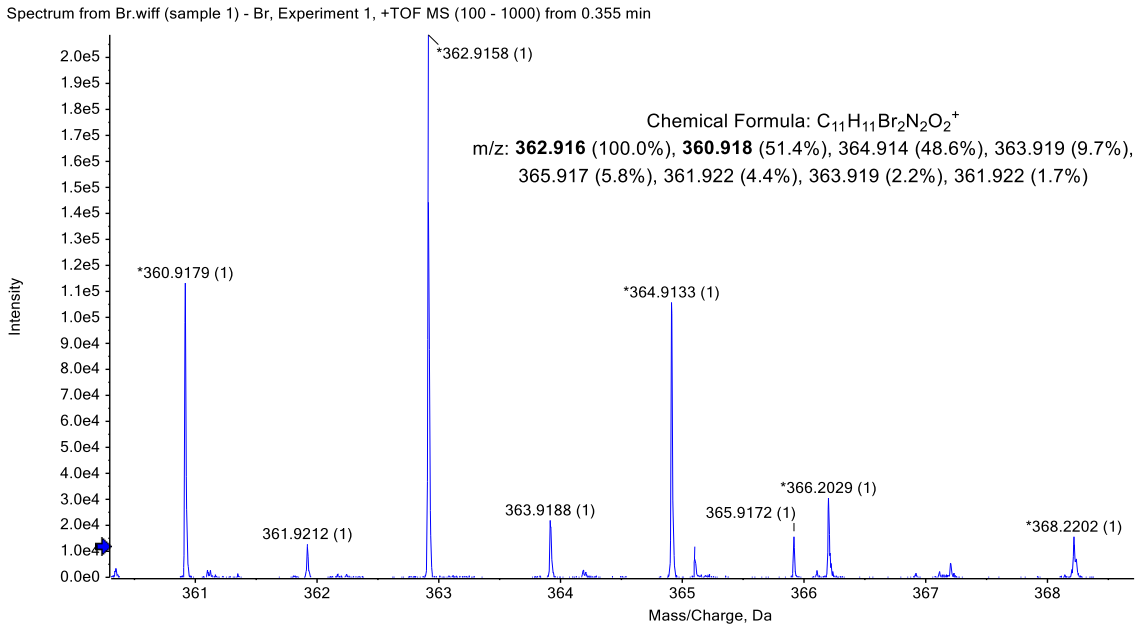


6,7-Dibromo-L-tryptophan. The product was isolated from the reaction of Hal7 L111P/ N470S mutant, tryptophan, and NaBr.

^{1}H NMR (500 MHz, D_2O) δ 7.51 (d, *J* = 8.5 Hz, 1H), 7.39 (d, *J* = 8.5 Hz, 1H), 7.33 (s, 1H), 4.20 (dd, *J* = 6.9, 5.6 Hz, 1H), 3.44 (dd, *J* = 15.3, 5.1 Hz, 1H), 3.35 (dd, *J* = 15.4, 7.4 Hz, 1H). **^{13}C NMR** (100.53 MHz, D_2O) δ 172.81, 135.97, 126.61, 126.30, 123.91, 118.70, 116.88, 108.62, 106.73, 53.95, 25.97 **Mass** (ESI TOF-MS) (*m*/*z*) calculated for $C_{11}H_{11}Br_2N_2O_2^+$ $[M+H]^+$: 362.916, 360.918, observed: 362.9158, 360.9179

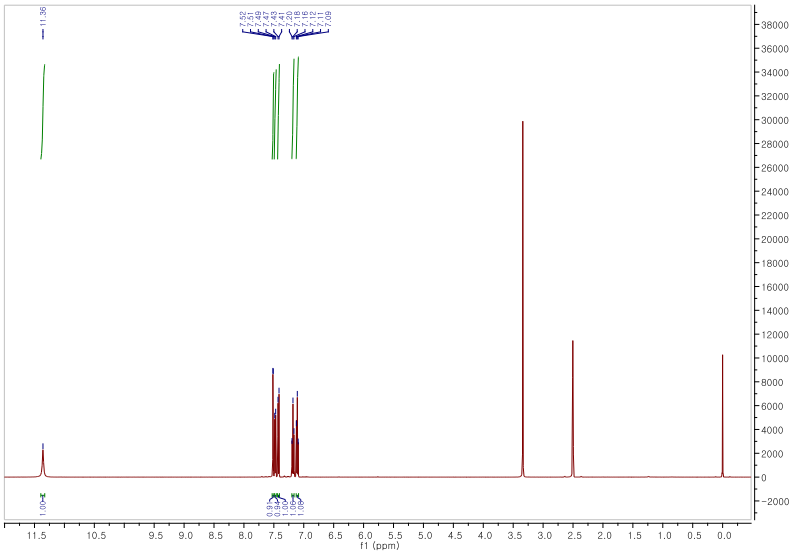


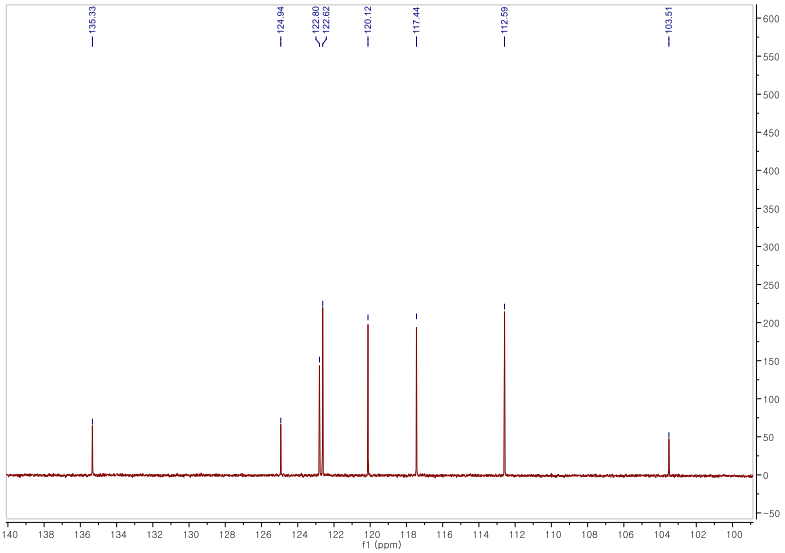


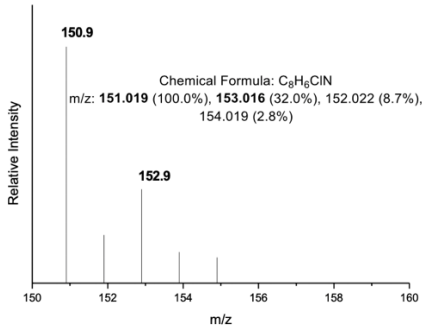


3-Chloroindole. The product was isolated from the chlorination of indole with Hal1.

^{1}H NMR (500 MHz, DMSO) δ 11.36 (s, 1H), δ 7.51 (d, *J* = 2.6 Hz, 1H), δ 7.48 (d, *J* = 7.9 Hz, 1H), δ 7.42 (d, *J* = 8.2 Hz, 1H), δ 7.18 (t, *J* = 8.1 Hz, 1H), δ 7.11 (t, *J* = 7.4 Hz, 1H) **^{13}C NMR** (100.53 MHz, DMSO) δ 135.33, 124.94, 122.80, 122.62, 120.12, 117.44, 112.59, 103.51 **Mass** (GC-MS) (*m*/*z*) calculated for C_8H_6ClN $[M]^+$: 151.02, 153.02, observed: 150.9, 152.9



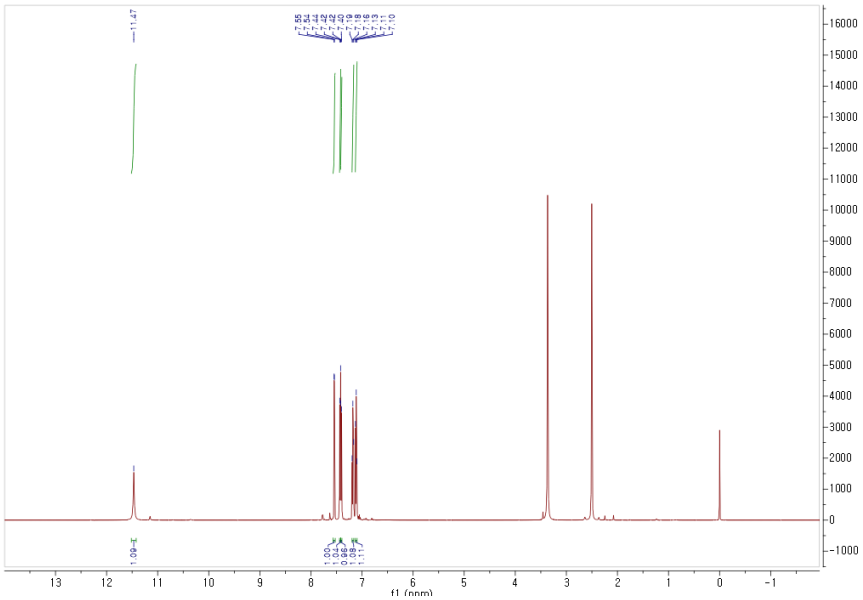


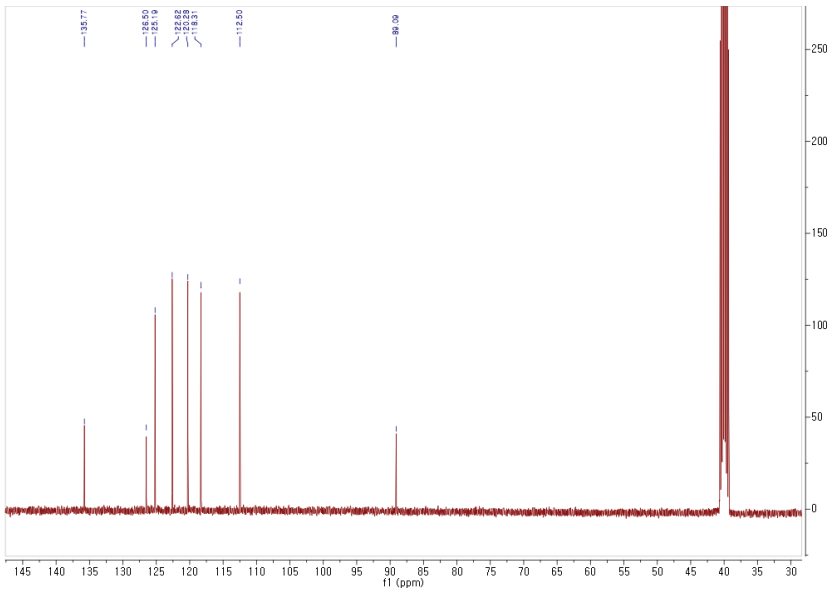


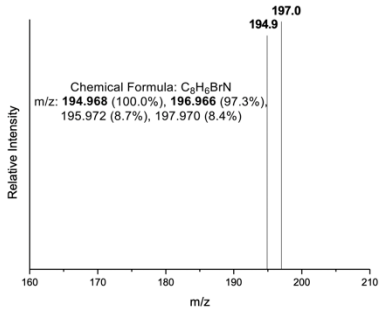
3-Bromoindole. The product was isolated from the reaction of Hal1, indole, and NaBr.

^{1}H NMR (500 MHz, DMSO) δ 11.47 (s, 1H), δ 7.54 (d, *J* = 2.5 Hz, 1H), δ 7.43 (d, *J* = 8.4 Hz, 1H), δ 7.41 (d, *J* = 8.2 Hz, 1H), δ 7.18 (t, *J* = 7.6 Hz, 1H), δ 7.11 (t, *J* = 7.5 Hz, 1H) **^{13}C NMR** (100.53 MHz, DMSO) δ 135.77, 126.50, 125.19, 122.62, 120.28, 118.31, 112.50, 89.09 **Mass** (GC-MS) (*m*/*z*) calculated for

C_8H_6BrN [M]$^+$: 194.97, 196.97, observed: 194.6, 197



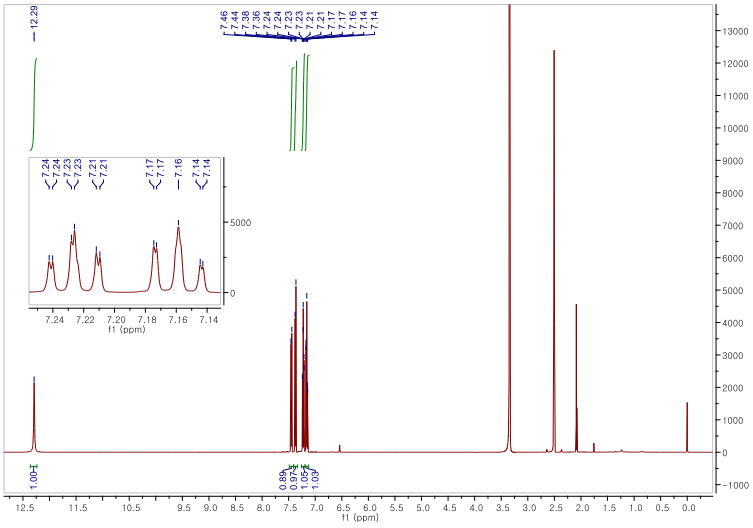


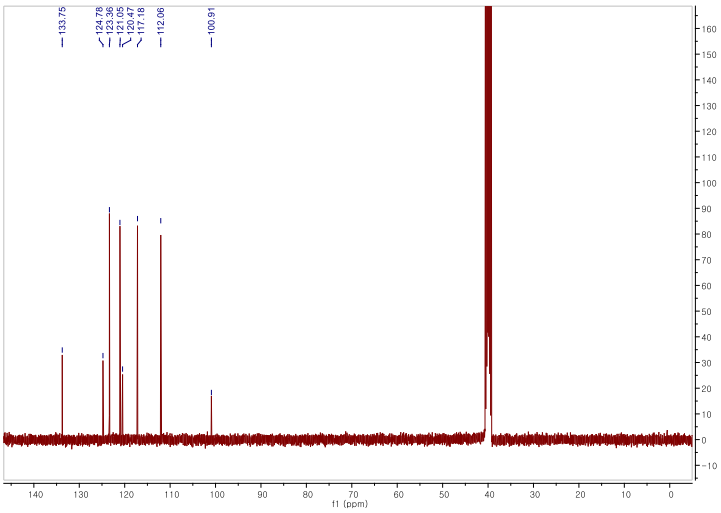


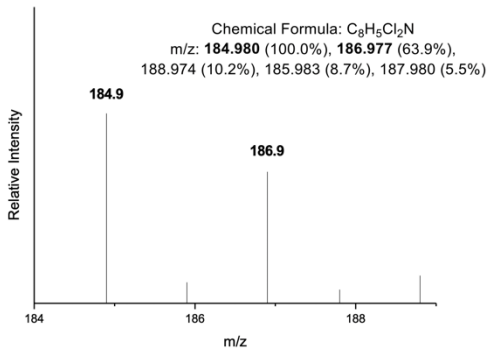
2,3-Dichloroindole. The product was isolated from the reaction of Hal1, 3-chloroindole, and NaCl.

^{1}H NMR (500 MHz, DMSO) δ 12.29 (s, 1H), δ 7.45 (d, *J* = 7.9 Hz, 1H), δ 7.37 (d, *J* = 8.1 Hz, 1H), δ 7.26

– 7.19 (m, 1H), δ 7.18 – 7.12 (m, 1H) **^{13}C NMR** (100.53 MHz, DMSO) δ 133.75, 124.78, 123.36, 121.05, 120.47, 117.18, 112.06, 100.91 **Mass** (GC-MS) (*m*/*z*) calculated for $C_8H_5Cl_2N$ $[M]^+$: 184.98, 186.98, observed: 184.9, 186.9

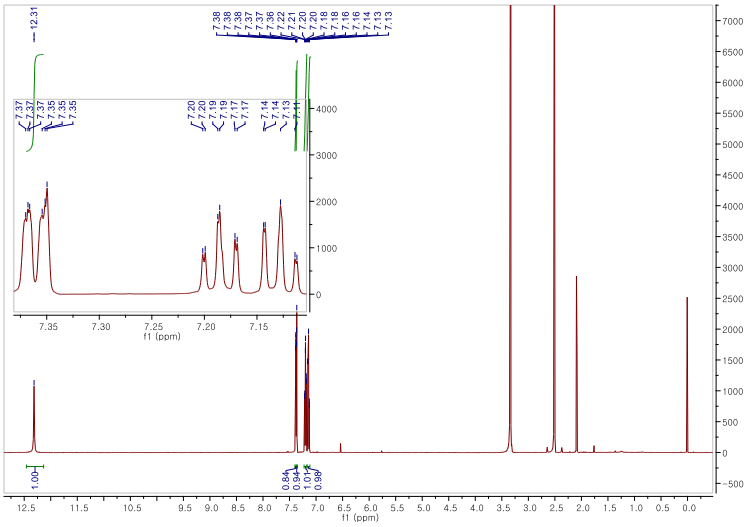


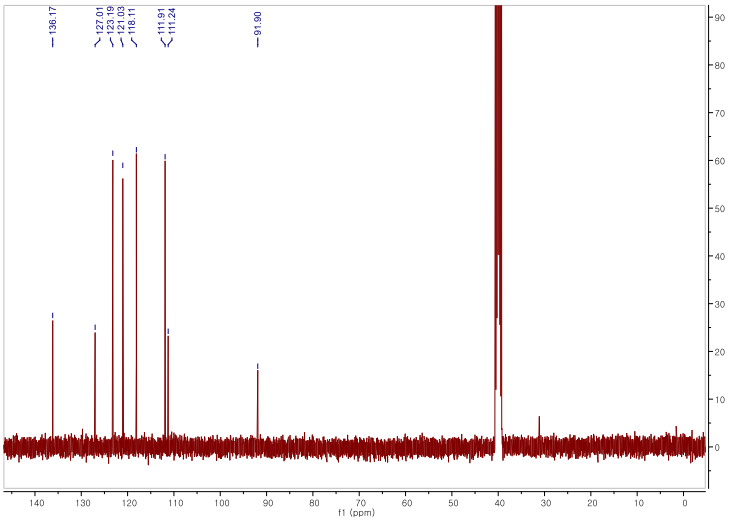


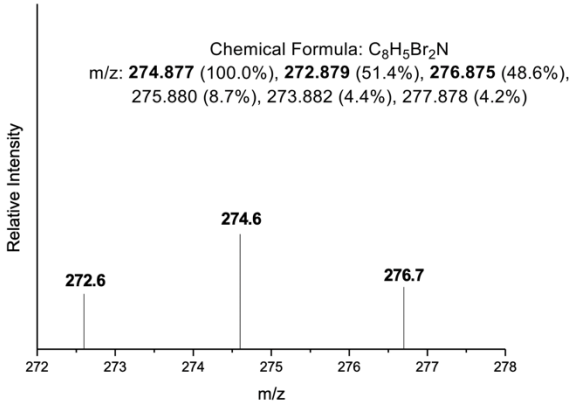


2,3-Dibromoindole. The product was isolated from the reaction of Hal1, 3-bromoindole, and NaBr.

^{1}H NMR (500 MHz, DMSO) δ 12.31 (s, 1H), δ 7.39 – 7.37 (m, 1H), δ 7.37 – 7.36 (m, 1H), δ 7.24 – 7.17 (m, 1H), δ 7.17 – 7.12 (m, 1H) **^{13}C NMR** (100.53 MHz, DMSO) δ 136.17, 127.01, 123.19, 121.03, 118.11, 111.91, 111.24, 91.90 **Mass** (GC-MS) (*m*/*z*) calculated for $C_8H_5Br_2N$ $[M]^+$: 274.88, 272.88, 276.88, observed: 274.8, 272.8, 276.8.

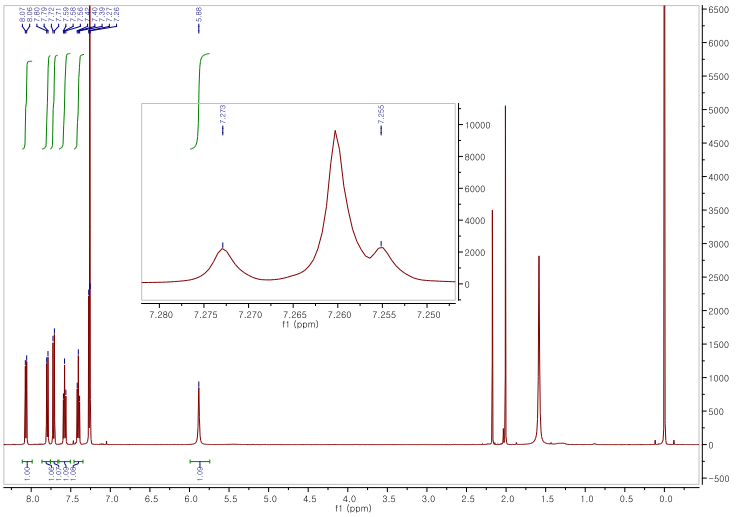


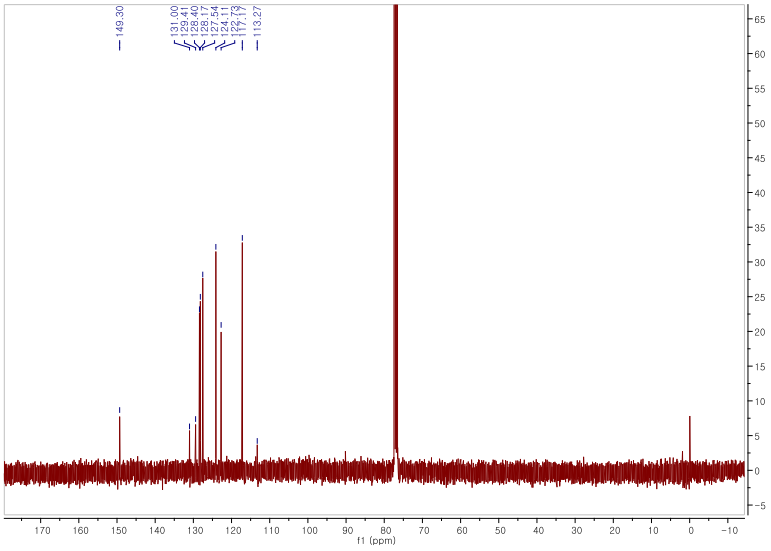


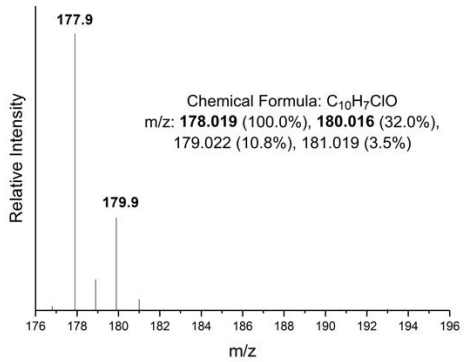


1-Chloro-2-naphthol. The product was isolated from the reaction of HaI1, 1-naphthol, and NaCl.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 (d, *J* = 8.5 Hz, 1H), δ 7.80 (d, *J* = 8.1 Hz, 1H), δ 7.72 (d, *J* = 8.9 Hz, 1H), δ 7.58 (t, *J* = 7.7 Hz, 1H), δ 7.40 (t, *J* = 7.5 Hz, 1H), δ 7.273 ~ 7.255 (d, *J* = 8.9 Hz, peak is merged with $CHCl_3$, 1H), δ 5.88 (s, 1H) **^{13}C NMR** (100.53 MHz, $CDCl_3$) δ 149.30, 131.00, 129.41, 128.40, 128.17, 127.54, 124.11, 122.73, 117.17, 113.27 **Mass** (GC-MS) (*m*/*z*) calculated for $C_{10}H_7ClO$ $[M]^+$: 178.02, 180.02 observed: 177.9, 179.9

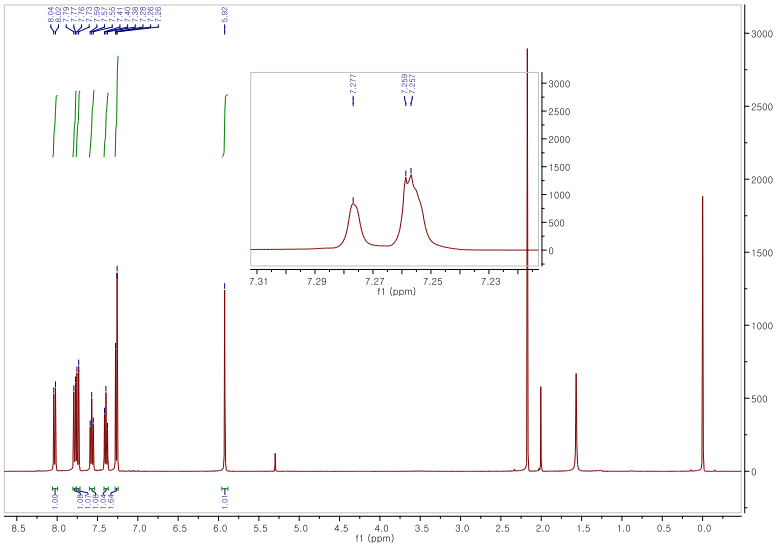


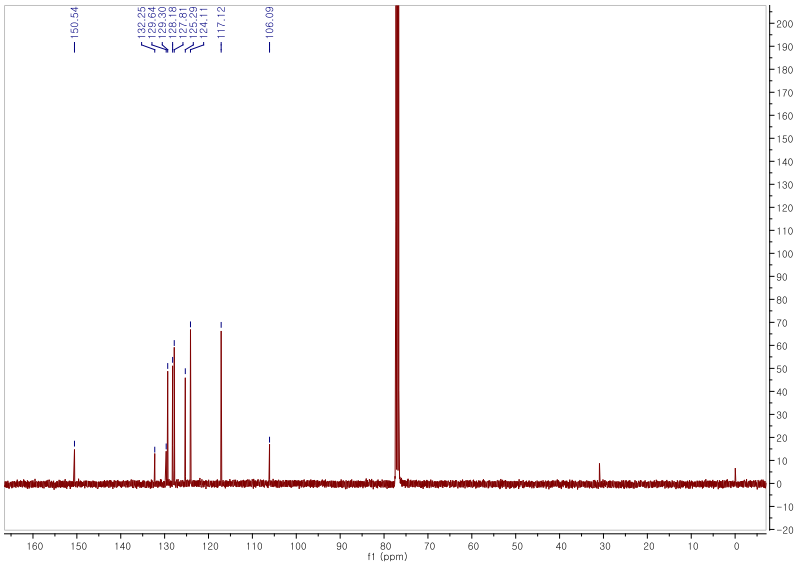


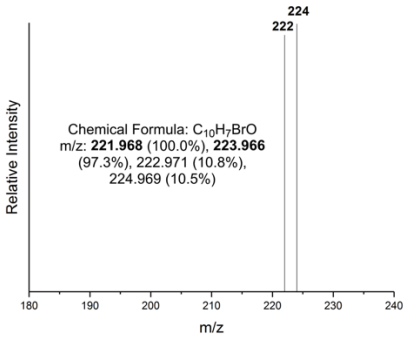


1-Bromo-2-naphthol. The product was isolated from the reaction of HaI1, 1-naphthol, and NaBr.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 (d, *J* = 8.5 Hz, 1H), δ 7.78 (d, *J* = 8.2 Hz, 1H), δ 7.74 (d, *J* = 8.9 Hz, 1H), δ 7.57 (t, *J* = 7.7 Hz, 1H), δ 7.39 (t, *J* = 7.5 Hz, 1H), δ 7.27 (d, *J* = 8.0 Hz, 1H, peak is merged with $CHCl_3$), δ 5.92 (s, 1H) **^{13}C NMR** (100.53 MHz, $CDCl_3$) δ 150.54, 132.25, 129.64, 129.30, 128.18, 127.81, 125.29, 124.11, 117.12, 106.09 **Mass** (GC-MS) (*m*/*z*) calculated for $C_{10}H_7BrO$ $[M]^+$: 221.97, 223.97, observed: 222, 224

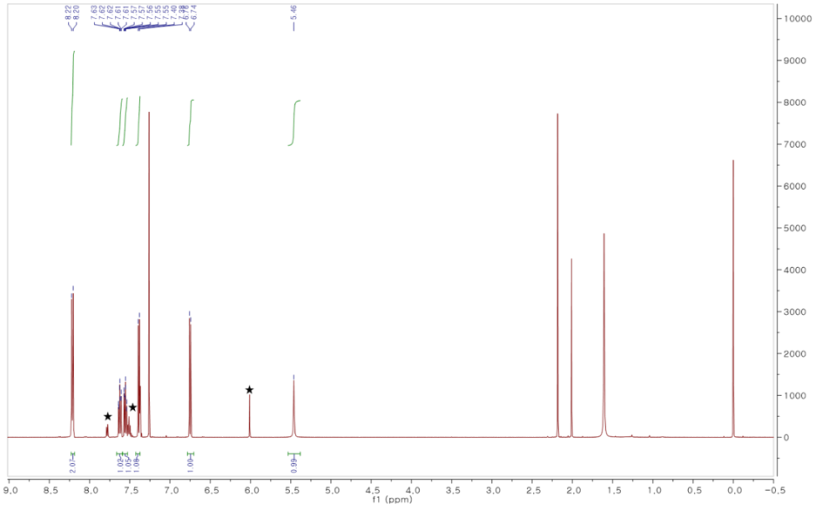


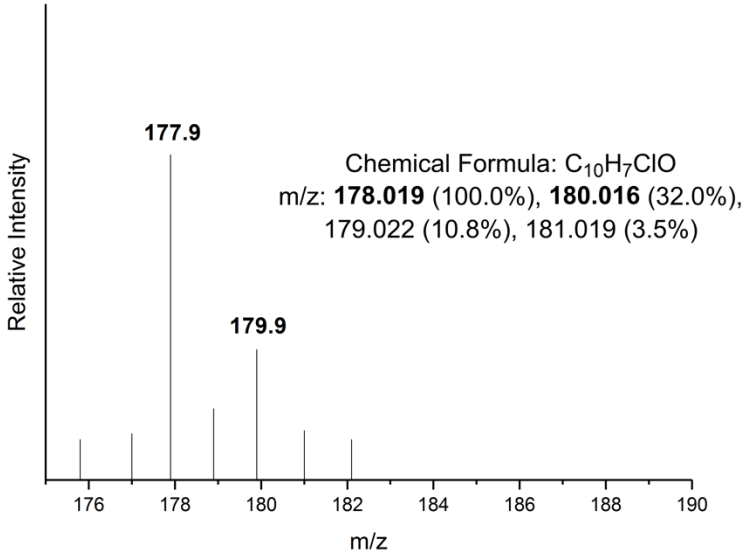




4-Chloro-1-naphthol (a). The product was purified from the reaction of Hal1, 1-naphtol, and NaCl. As a minor product, 2-chloro-1-naphthol was co-eluted as marked with asterisks.

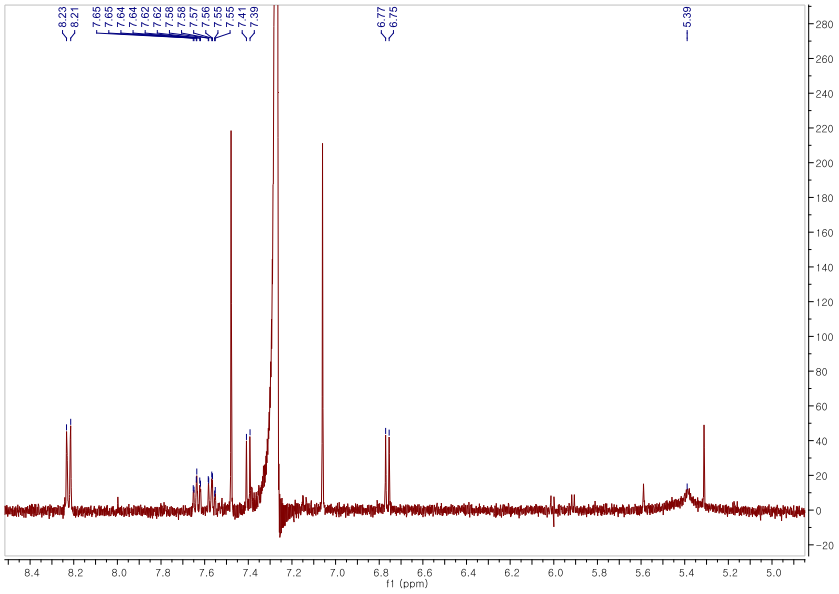
^{1}H NMR (500 MHz, $CDCl_3$) δ 8.21 (d, *J* = 9.6 Hz, 2H), δ 7.66 – 7.58 (m, 1H), δ 7.57 – 7.53 (m, 1H), δ 7.39 (d, *J* = 8.0 Hz, 1H), δ 6.75 (d, *J* = 8.0 Hz, 1H), δ 5.46 (s, 1H) 27 **Mass** (GC-MS) (*m*/*z*) calculated for $C_{10}H_7ClO$ $[M]^+$: 178.02, 180.02 observed: 177.9, 179.9





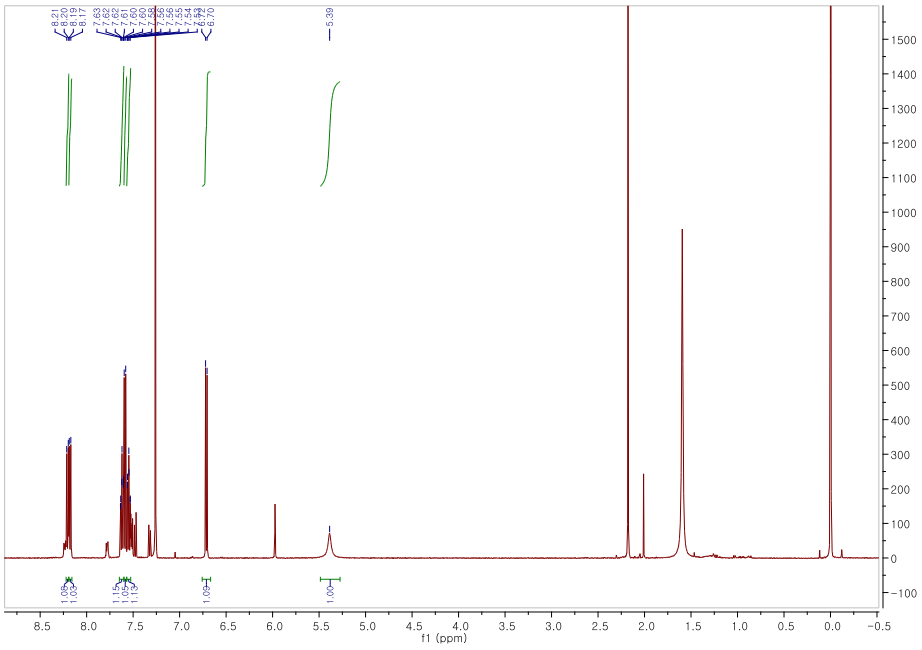
4-Chloro-1-naphthol (b). The product was isolated from the reaction of Hal3, 1-naphthol and NaCl. Although the sample concentration was too low to obtain accurate integration, 4-chloro-1-naphthol was purely isolated whereas in **4-Chloro-1-naphthol (a)**, the mixtures of 2-chloro-1-naphthol and 4-chloro-1-naphthol were monitored.

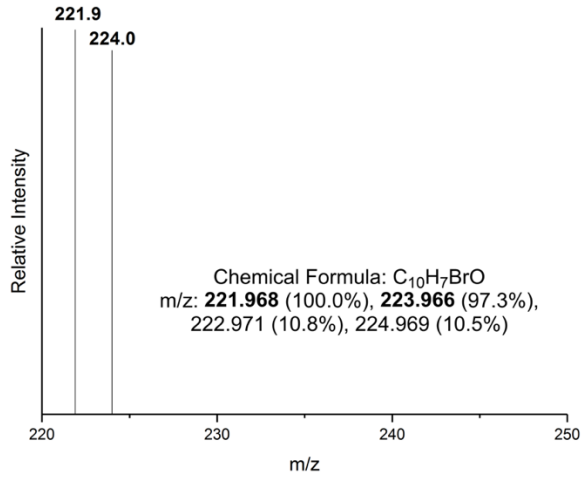
^{1}H NMR (500 MHz, $CDCl_3$) δ 8.22 (d, *J* = 9.6 Hz), δ 7.66 – 7.61 (m), δ 7.59 – 7.55 (m), δ 7.40 (d, *J* = 8.2 Hz), δ 6.76 (d, *J* = 8.0 Hz), δ 5.39 (s)



4-Bromo-1-naphthol. The product was purified from the reaction of Hal1, 1-naphtol, and NaBr. Due to the close retention time, 2-bromo-1-naphthol was co-eluted as a minor product and was observed in NMR spectrum.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.21 (d, *J* = 8.4 Hz, 1H), δ 8.18 (d, *J* = 8.4 Hz, 1H), δ 7.64 – 7.60 (m, 1H), δ 7.59 (d, *J* = 8.0 Hz, 1H), δ 7.57 – 7.53 (m, 1H), δ 6.71 (d, *J* = 8.0 Hz, 1H), δ 5.39 (s, 1H) **Mass** (GC-MS) (*m*/*z*) calculated for $C_{10}H_7BrO$ $[M]^+$: 221.97, 223.97, observed: 221.9, 224.





4-Bromophenol. The product was isolated from the reaction of Hal1, phenol, and NaBr.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35 – 7.31 (m, 2H), δ 6.74 – 6.70 (m, 2H), δ 4.84 (s, 1H) **^{13}C NMR** (100.53 MHz, $CDCl_3$) δ 154.63, 132.42, 117.14, 112.80. **Mass** (GC-MS) (*m*/*z*) calculated for C_6H_5BrO $[M]^+$: 171.952, 173.950, observed: 171.9, 173.9