Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Supporting Information

Formamidation of a Wide Range of Substituted and Functionalized Amines with CO and a Base

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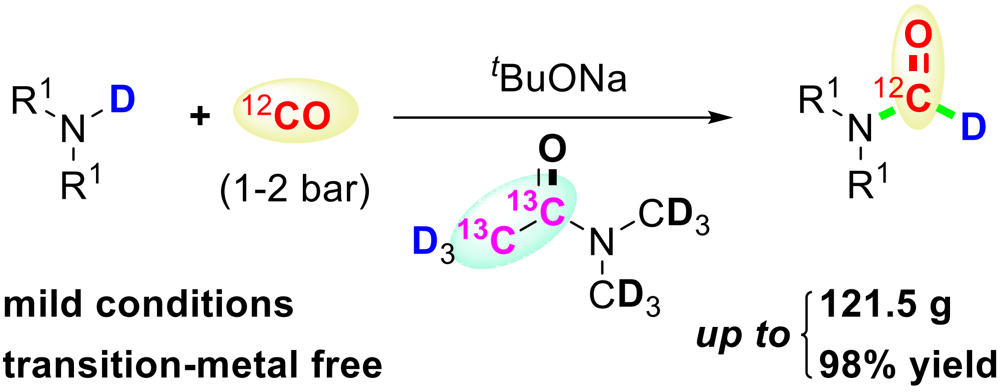

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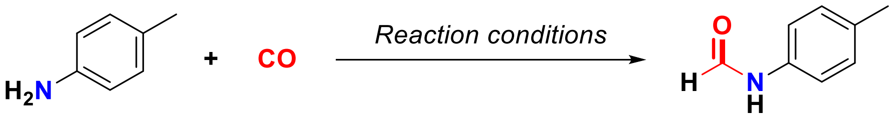
1. General

Experimental: All reactions and manipulations with air sensitive compounds being present were performed under dry argon (Ar 5.0) or nitrogen (N_2 5.0), using Schlenk and glove box techniques. Deuterated solvents were bought from Cambridge Isotope Laboratories, distilled accordingly, and stored over molecular sieves (3 Å). Other chemicals were purchased from commercial vendors and used without further purification. NMR spectra were collected on a Varian INOVA 300 and 400 MHz spectrometer. Chemical shifts (δ) are reported in ppm relative to residual solvent signal. Coupling constants (J) are given in Hz (coupling patterns: s: singlet, s_br: broad singlet, d: doublet, t: triplet, q: quartet, m: multiplet). GC analyses were carried out using an Agilent Technologies 6890N system equipped with a Machinery-Nagel (MN) Optima 5 HT column (30 m, 320 µm, 0.25 µm) or an Agilent Technologies 6850 system equipped with a MN Optima 17 column (30 m, 320 µm, 0.25 µm). GC/MS analyses were carried out on an Agilent 7890A/MSD 5975C system equipped with a HP-5MS column (30 m, 320 µm, 0.25 µm). High resolution mass spectra (HRMS) were recorded on Bruker MicroTOF-QII mass (ESI). MN silica gel 60 (0.040 – 0.063 mm particle size) was used for flash column chromatography.

2. Screening of reaction parameters

Closed system:

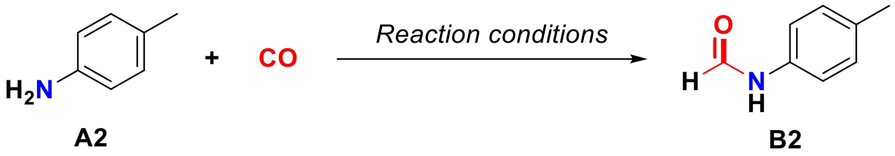


A2 **B2**

Using a nitrogen-filled glove box, an oven-dried pressure tube was charged with a magnetic stirring bar, base, amines (**A2**), additive and solvent. Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO and immersed into a pre-heated metal bath (design temperature) for design time. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released under well ventilated fume hood. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with ethyl acetate or DCM (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1) on silica gel to give the product **B2**.

Entry	Parameter
Table S1	The difference of base screening
Table S2	The loading of base screening
Table S3	The difference of solvent screening
Table S4	The loading of solvent screening
Table S5	The pressure screening
Table S6	Reaction temperature screening
Table S7	Reaction time screening

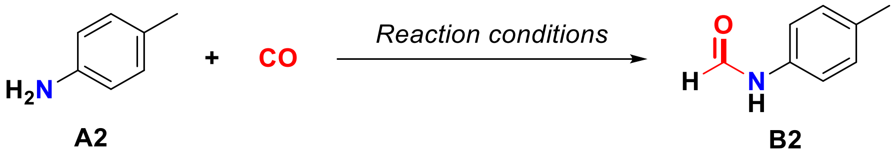
Table S1: The difference of base screening [a]



Entry	Base (1.0 equiv)	**B2** (%)
1	LiOH	0
2	NaOH	0
3	KOH	0
4	CsOH	0
5	Li_2CO_3	0
6	Na_2CO_3	0
7	K_2CO_3	0
8	Cs_2CO_3	0
9	^{t}BuOLi	<5
10	**^{t}BuONa**	**68**
11	^{t}BuOK	67
12	^{t}BuOCs	<5
13	pyridine	<5
14	TEA	0
15	TBD	0
16	DBU	0
17	^{t}BuLi	0
18	NaH	<5
19	$NaNH_2$	<5
20	KH	<5

[a] Reaction conditions: base (1.0 mmol), **A2** (1.0 mmol, 110 µL), DMAc (2.0 mL), CO (1 bar), 60 °C, 6 h. Yield of **B2** determined by GC-analysis using *n*-dodecane (100 µL) as internal standard.

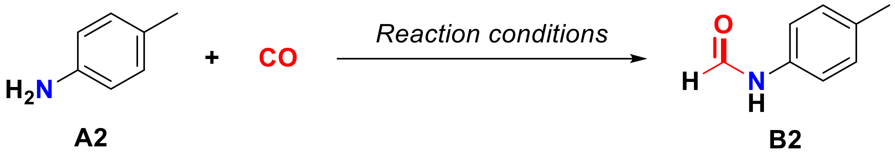
Table S2: The loading of base screening [a]



Entry	^{t}BuONa (mmol)	**B2** (%)
1	0	0
2	0.1	6
3	0.2	13
4	0.3	20
5	0.4	26
6	0.5	29
7	0.6	35
8	0.7	48
9	0.8	56
10	0.9	63
11	**1.0**	**69**
12	1.1	69
13	1.2	68
14	1.3	68
15	1.4	67
16	1.5	68
17	2.0	65
18	2.5	60
19	3.0	53

[a] Reaction conditions: ^{t}BuONa (x mmol), **A2** (1.0 mmol, 110 μL), DMAc (2.0 mL), CO (1 bar), 60 °C, 6 h. Yield of **B2** determined by GC-analysis using *n*-dodecane (100 μL) as internal standard.

Table S3: The difference of solvent screening [a]



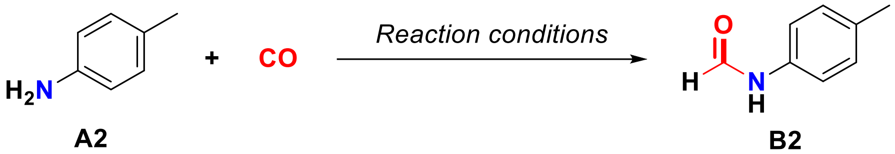
A2

B2

Entry	Solvent (2 mL)	**B2** (%)
1	nitrobenzene	0
2	chlorobenzene	0
3	toluene	0
4	mesitylene	0
5	benzotrifluoride	0
6	THF	<5
7	1,4-dioxane	<5
8	DME	<5
9	anisole	<5
10	pyridine	0
11	Et_3N	0
12	methanol	0
13	ethanol	0
14	^{i}PrOH	0
15	^{t}BuOH	0
16	^{t}AmOH	0
17	DCM	0
18	DMSO	21
19	DMF	68
20	**DMAc**	**69**
21	NMP	50
22	HMPA	<5

[a] Reaction conditions: ^{t}BuONa (1.0 mmol), **A2** (1.0 mmol, 110 μL), solvent (2.0 mL), CO (1 bar), 60 °C, 6 h. Yield of **B2** determined by GC-analysis using *n*-dodecane (100 μL) as internal standard.

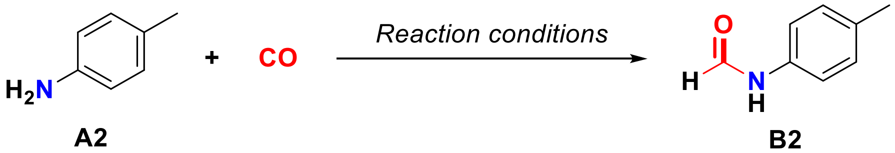
Table S4: The loading of solvent screening [a]



Entry	DMAc (ml)	**B2** (%)
1	-	67
2	0.5	72
3	**1.0**	**73**
4	1.5	72
5	2.0	73
6	2.5	73
7	3.0	74

[a] Reaction conditions: ^{t}BuONa (1.0 mmol), **A2** (1.0 mmol, 110 μL), DMAc (x mL), CO (1 bar), 60 °C, 6 h. Yield of **B2** determined by GC-analysis using *n*-dodecane (100 μL) as internal standard.

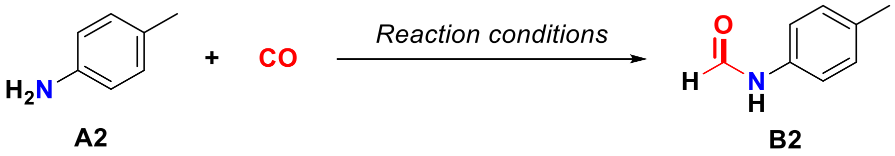
Table S5: The pressure screening [a]



Entry	P [bar]	**B2** (%)
1	1	53
2	**2**	**76**
3	3	76
4	4	75
5	6	76
6	8	75
7	10	76
8	20	75

[a] Reaction conditions: ^{t}BuONa (1.0 mmol), **A2** (1.0 mmol, 110 μL), DMAc (1.0 mL), CO (x bar), 60 °C, 6 h. Yield of **B2** determined by GC-analysis using *n*-dodecane (100 μL) as internal standard.

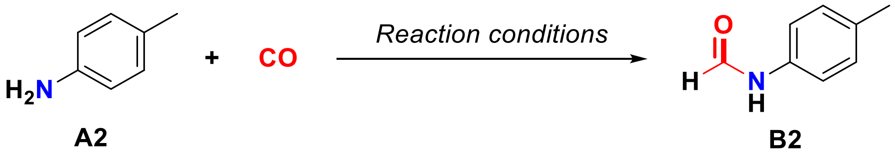
Table S6: Reaction temperature screening [a]



Entry	T [° C]	**B2** (%)
1	RT	0
2	40	36
3	60	76
4	80	81
5	**100**	**89**
6	120	81
7	140	80

[a] Reaction conditions: ^{t}BuONa (1.0 mmol), **A2** (1.0 mmol, 110 µL), DMAc (1.0 mL), CO (2 bar), T, 6 h. Yield of **B2** determined by GC-analysis using *n*-dodecane (100 µL) as internal standard.

Table S7: Reaction time screening [a]

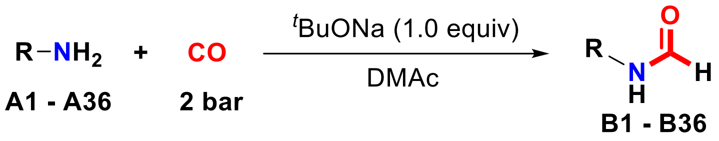


Entry	t [h]	**B2** (%)
1	3	31
2	6	89
3	9	95
4	**12**	**99 (92)[b]**
5	15	98

[a] Reaction conditions: ^{t}BuONa (1.0 mmol), **A2** (1.0 mmol, 110 µL), DMAc (1.0 mL), CO (2 bar), 60 °C, x h. Yield of **B2** determined by GC-analysis using *n*-dodecane (100 µL) as internal standard. [b] Isolated yield.

3. Experimental characterization data for products

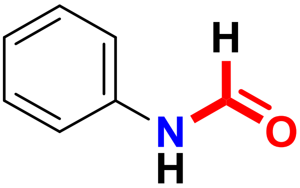
Closed system:



Using a nitrogen-filled glove box, an oven-dried pressure tube (50 mL) was charged with a magnetic stirring bar, ^{t}BuONa (961 mg, 10.0 mmol), amines **A** (10.0 mmol), and DMAc (10.0 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released under well ventilated fume hood. Sat. aq. NH_4Cl (50 mL) was then added and the mixture was extracted with ethyl acetate or DCM (3 × 50 mL) and the combined organics were washed with brine (50 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 2%, Et_3N 2%) on silica gel to give the corresponding products **B**.

4. Characterization data

***N*-phenylformamide**[1]



B1:

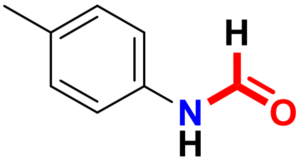
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.1379 gram, 94% yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.04 (br, 0.5H), 8.70 (d, J = 11.2 Hz, 0.5H), 8.33 (s, 0.5H), 8.22 (br, 0.5H), 7.56 (d, J = 7.6 Hz, 1H), 7.36 – 7.29 (m, 2H), 7.23 – 6.98 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.10, 158.60, 135.99, 135.79, 128.67, 128.00, 124.20, 123.71, 119.12, 119.10, 117.72.

HRMS (ESI) calcd. for C_7H_8NO [M+H]: 122.0606, found: 122.0607.

***N*-*p*-tolylformamide**[1]



B2:

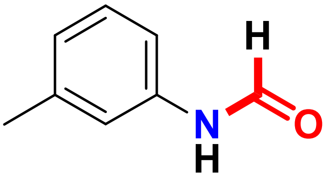
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.2967 gram, 96% yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.85 (d, *J* = 9.4 Hz, 1H), 8.62 (d, *J* = 11.4 Hz, 1H), 8.31 (d, *J* = 1.9 Hz, 1H), 7.92 (s, 1H), 7.50 – 7.35 (m, 1H), 7.13 (dd, *J* = 13.0, 8.2 Hz, 2H), 7.01 – 6.97 (m, 1H), 2.31 (d, *J* = 8.8 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 163.27, 159.39, 135.14, 134.45, 134.18, 130.23, 129.56, 120.15, 119.10, 20.90, 20.82.

HRMS (ESI) calcd. for $C_8H_{10}NO$ [M+H]: 136.0762, found: 136.0764.

N-*m*-tolylformamide[1]



B3:

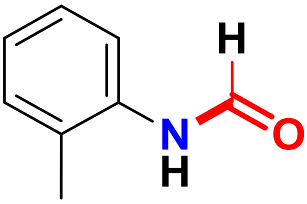
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.2156 gram, 93% yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.96 – 8.76 (m, 1H), 8.69 (d, *J* = 11.3 Hz, 1H), 8.33 (d, *J* = 2.0 Hz, 1H), 7.88 (s, 1H), 7.40 (t, *J* = 1.8 Hz, 1H), 7.36 – 7.28 (m, 1H), 7.29 – 7.14 (m, 2H), 6.99 – 6.89 (m, 4H), 2.33 (d, *J* = 9.8 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 163.09, 159.42, 139.84, 139.04, 136.93, 136.76, 129.53, 128.89, 126.04, 125.58, 120.72, 119.48, 117.16, 115.72, 21.46, 21.40.

HRMS (ESI) calcd. for $C_8H_{10}NO$ [M+H]: 136.0762, found: 136.07625.

N-*o*-tolylformamide[1]



B4:

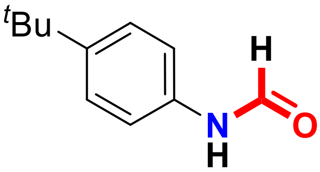
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.2156 gram, 90% yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.46 (d, *J* = 11.2 Hz, 1H), 8.36 (d, *J* = 1.8 Hz, 1H), 8.09 – 7.87 (m, 1H), 7.85 – 7.78 (m, 1H), 7.21 – 6.95 (m, 4H), 2.22 (d, *J* = 11.8 Hz, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.40, 158.15, 134.00, 133.59, 130.21, 129.54, 128.71, 127.57, 126.09, 125.81, 125.01, 124.49, 122.01, 119.65, 16.69.

HRMS (ESI) calcd. for $C_8H_{10}NO$ [M+H]: 136.0762, found: 136.0761.

N-(4-(tert-butyl)phenyl)formamide[2]



B5:

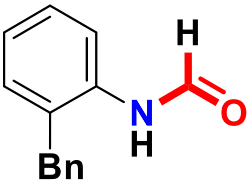
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.7358 gram, 98% yield.

^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 10.24 – 9.84 (m, 1H), 8.72 (d, J = 11.0 Hz, 1H), 8.24 (d, J = 1.9 Hz, 1H), 7.54 – 7.45 (m, 1H), 7.37 – 7.28 (m, 1H), 7.15 – 7.07 (m, 1H), 1.25 (s, 7H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 162.94, 159.80, 146.54, 146.37, 136.16, 136.13, 126.49, 125.90, 119.36, 117.91, 40.60, 40.39, 40.18, 34.48, 34.44, 31.63.

HRMS (ESI) calcd. for $C_{11}H_{16}NO$ [M+H]: 178.1232, found: 178.1231.

N-([1,1'-biphenyl]-2-yl)formamide[3]



B6:

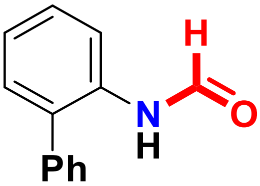
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.9210 gram, 91% yield.

^{1}H NMR (400 MHz, CDCl$_3$) δ 8.40 (d, *J* = 11.3 Hz, 1H), 8.22 (d, *J* = 1.7 Hz, 1H), 7.88 (d, *J* = 8.0 Hz, 1H), 7.71 (d, *J* = 10.6 Hz, 1H), 7.33 – 7.25 (m, 1H), 7.25 – 7.15 (m, 3H), 7.15 – 7.08 (m, 3H), 3.99 (d, *J* = 3.8 Hz, 2H).

^{13}C NMR (101 MHz, CDCl$_3$) δ 163.21, 159.31, 138.83, 138.61, 135.09, 134.68, 132.94, 131.44, 131.31, 131.00, 128.96, 128.52, 128.43, 127.90, 127.61, 126.77, 126.47, 125.81, 124.12, 122.00, 38.01, 37.82.

HRMS (ESI) calcd. for $C_{14}H_{14}NO$ [M+H]: 212.1075, found: 212.1078.

N-(2-benzylphenyl)formamide[4]



B7:

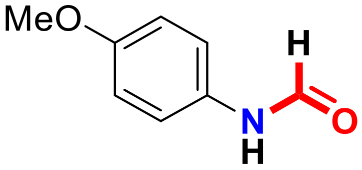
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.7540 gram, 89% yield.

^{1}H NMR (400 MHz, CDCl$_3$) δ 8.64 (d, *J* = 11.3 Hz, 1H), 8.36 (d, *J* = 8.2 Hz, 1H), 8.25 (d, *J* = 1.5 Hz, 1H), 7.71 – 6.93 (m, 8H).

^{13}C NMR (101 MHz, CDCl$_3$) δ 162.02, 158.99, 137.82, 137.36, 133.84, 133.78, 133.01, 132.01, 131.20, 130.18, 129.34, 129.20, 129.18, 128.75, 128.52, 128.16, 128.12, 125.37, 124.65, 121.57, 118.34.

HRMS (ESI) calcd. for $C_{13}H_{12}NO$ [M+H]: 198.0919, found: 198.0918.

N-(4-methoxyphenyl)formamide[1]



B8:

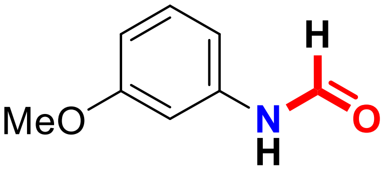
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.4804 gram, 98% yield.

^{1}H NMR (400 MHz, CDCl$_3$) δ 8.50 (d, *J* = 11.0 Hz, 1H), 8.28 (s, 1H), 7.84 (s, 1H), 7.45 (s, 1H), 7.03 (d, *J* = 8.6 Hz, 1H), 6.85 (dd, *J* = 14.0, 8.7 Hz, 2H), 3.78 (d, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, CDCl$_3$) δ 162.32, 158.19, 156.54, 155.64, 129.02, 128.63, 120.84, 120.49, 113.85, 113.16, 54.52, 54.45.

HRMS (ESI) calcd. for $C_8H_{10}NO_2$ [M+H]: 152.0712, found: 152.0715.

N-(3-methoxyphenyl)formamide[5]



B9:

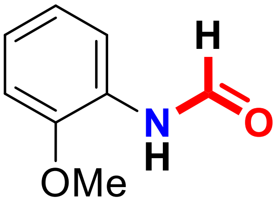
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.4502 gram, 96% yield.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.17 (s, 1H), 8.82 (d, J = 10.8 Hz, 1H), 8.28 (d, J = 1.7 Hz, 1H), 7.31 (t, J = 2.2 Hz, 1H), 7.26 – 7.17 (m, 1H), 7.14 – 7.12 (m, 1H), 6.81 – 6.75 (m, 1H), 6.66 – 6.64 (m, 1H), 3.73 (s, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 163.02, 160.57, 160.09, 160.01, 140.05, 139.82, 130.69, 130.12, 111.90, 110.10, 109.43, 105.55, 103.79, 55.51, 55.39.

HRMS (ESI) calcd. for $C_8H_{10}NO_2$ [M+H]: 152.0712, found: 152.0714.

N-(2-methoxyphenyl)formamide[1]



B10:

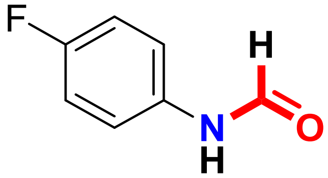
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.3746 gram, 91% yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.73 (d, *J* = 11.6 Hz, 1H), 8.45 (d, *J* = 1.9 Hz, 1H), 8.36 (dd, *J* = 8.0, 1.7 Hz, 1H), 8.03 – 7.53 (m, 1H), 7.19 (dd, *J* = 7.7, 1.6 Hz, 1H), 7.16 – 7.00 (m, 1H), 7.00 – 6.86 (m, 2H), 3.94 – 3.75 (m, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.24, 161.53, 158.85, 148.75, 147.82, 127.69, 126.75, 126.17, 125.25, 124.29, 123.62, 121.06, 120.45, 119.79, 116.69, 111.29, 110.07, 109.89, 55.72, 55.64.

HRMS (ESI) calcd. for $C_8H_{10}NO_2$ [M+H]: 152.0712, found: 152.0710.

N-(4-fluorophenyl)formamide[1]



B11:

The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.3487 gram, 97% yield.

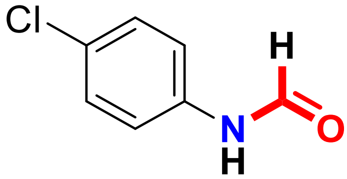
^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 10.42 – 10.20 (m, 1H), 10.15 (d, *J* = 10.8 Hz, 1H), 8.83 – 8.62 (m, 1H), 8.29 – 8.26 (m, 1H), 7.66 – 7.59 (m, 1H), 7.25 – 7.19 (m, 1H), 7.19 – 7.10 (m, 2H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 163.11, 160.42, 159.90, 159.78, 158.03, 157.40, 135.18, 135.15, 135.10, 135.08, 121.39, 121.31, 120.00, 119.92, 116.52, 116.29, 115.94, 115.72.

^{19}F NMR (376 MHz, DMSO) δ -118.84, -119.76.

HRMS (ESI) calcd. for C_7H_7FNO [M+H]: 140.0512, found: 140.0511.

N-(4-chlorophenyl)formamide[1]



B12:

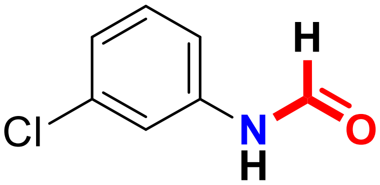
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.5346 gram, 99% yield.

^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 10.33 (s, 1H), 8.79 (d, *J* = 8.1 Hz, 1H), 8.29 (s, 1H), 7.66 – 7.59 (m, 1H), 7.41 – 7.33 (m, 2H), 7.26 – 7.19 (m, 1H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 162.99, 160.18, 137.86, 137.61, 129.69, 129.22, 127.93, 127.62, 121.17, 119.44.

HRMS (ESI) calcd. for C_7H_7ClNO [M+H]: 156.0216, found: 156.0217.

N-(3-chlorophenyl)formamide[1]



B13:

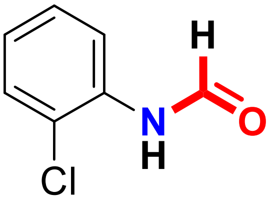
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.4571 gram 94% yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.71 (d, *J* = 11.1 Hz, 1H), 8.64 (s, 1H), 8.38 (d, *J* = 1.4 Hz, 1H), 7.66 (t, *J* = 1.9 Hz, 1H), 7.39 (dd, *J* = 8.1, 1.0 Hz, 1H), 7.30 – 7.22 (m, 1H), 7.20 – 7.14 (m, 1H), 7.14 – 7.08 (m, 1H), 7.00 (dd, *J* = 8.0, 1.3 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.54, 159.23, 138.00, 137.97, 135.46, 134.74, 130.85, 130.14, 125.35, 124.93, 120.14, 118.77, 117.96, 116.70.

HRMS (ESI) calcd. for C_7H_7ClNO [M+H]: 156.0216, found: 156.0212.

N-(2-chlorophenyl)formamide[7]



B14:

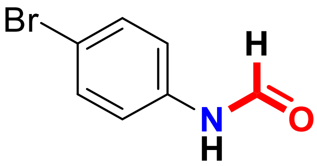
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.3951 gram, 90% yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.72 (d, *J* = 11.2 Hz, 1H), 8.51 (d, *J* = 1.0 Hz, 1H), 8.41 (dd, *J* = 8.3, 1.2 Hz, 1H), 7.76 (s, 1H), 7.44 (d, *J* = 8.0 Hz, 1H), 7.39 (dd, *J* = 8.0, 1.3 Hz, 1H), 7.33 – 7.22 (m, 1H), 7.16 – 7.12 (m, 1H), 7.10 – 7.06 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.55, 159.01, 158.93, 133.70, 130.32, 129.21, 129.13, 128.03, 127.89, 127.81, 125.96, 125.23, 125.15, 122.58, 122.09, 122.01, 118.78, 118.70.

HRMS (ESI) calcd. for C_7H_7ClNO [M+H]: 156.0216, found: 156.0218.

N-(4-bromophenyl)formamide[1]



B15:

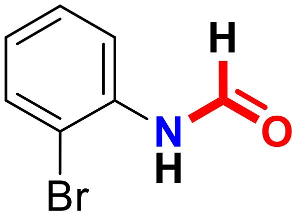
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.9100 gram, 96% yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.66 (d, *J* = 11.3 Hz, 1H), 8.39 (d, *J* = 1.4 Hz, 1H), 7.99 (s, 1H), 7.54 – 7.39 (m, 2H), 7.29 (s, 1H), 6.98 (d, *J* = 8.7 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.07, 158.79, 135.83, 135.69, 132.81, 132.10, 121.44, 120.36, 118.29, 117.48.

HRMS (ESI) calcd. for C_7H_7BrNO [M+H]: 199.9711, found: 199.9715.

N-(2-bromophenyl)formamide[1]



B16:

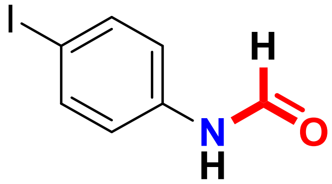
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.7707 gram, 89% yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.71 (d, *J* = 11.1 Hz, 1H), 8.50 (d, *J* = 1.8 Hz, 1H), 8.39 (dd, *J* = 8.3, 1.6 Hz, 1H), 7.87 – 7.50 (m, 1H), 7.36 – 7.24 (m, 1H), 7.12 – 6.96 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.54, 158.85, 135.03, 134.79, 133.52, 132.37, 128.72, 128.49, 126.39, 125.67, 122.24, 118.93, 114.45, 113.00.

HRMS (ESI) calcd. for C_7H_7BrNO [M+H]: 199.9711, found: 199.9714.

N-(4-iodophenyl)formamide[6]



B17:

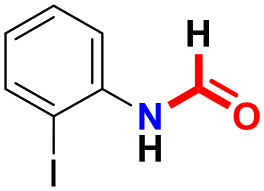
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 2.2966 gram, 93% yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.67 (d, *J* = 11.3 Hz, 1H), 8.39 (d, *J* = 1.7 Hz, 1H), 8.19 (d, *J* = 11.2 Hz, 1H), 7.70 – 7.55 (m, 1H), 7.43 – 7.29 (m, 1H), 6.92 – 6.70 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.13, 158.90, 138.74, 138.07, 136.56, 136.46, 121.75, 120.51, 88.71, 88.16.

HRMS (ESI) calcd. for C_7H_7INO [M+H]: 247.9572, found: 247.9574.

N-(2-iodophenyl)formamide[5]



B18:

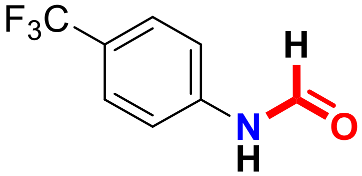
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 2.0991 gram, 85% yield.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.57 (s, 1H), 8.35 (s, 1H), 7.88 (dd, *J* = 7.9, 1.1 Hz, 1H), 7.79 (dd, *J* = 8.1, 1.2 Hz, 1H), 7.45 – 7.31 (m, 1H), 7.16 – 6.80 (m, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 164.16, 160.78, 139.96, 139.62, 138.94, 129.86, 129.16, 128.27, 127.41, 125.08, 95.54, 93.16.

HRMS (ESI) calcd. for C_7H_7INO [M+H]: 247.9572, found: 247.9575.

N-(4-(trifluoromethyl)phenyl)formamide[4]



B19:

The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.8148 gram, 96% yield.

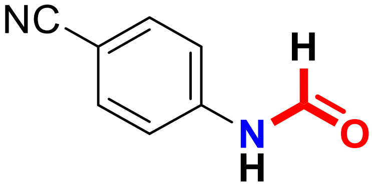
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.49 – 10.06 (m, 1H), 8.81 (s, 1H), 8.31 (s, 1H), 7.74 – 7.67 (m, 2H), 7.31 (t, J = 4.2 Hz, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 168.96, 163.10, 160.21, 144.64, 144.22, 144.20, 138.95, 138.16, 137.85, 124.37, 122.73, 122.14, 121.92, 121.83, 120.96, 120.67, 119.29, 119.19, 116.75.

^{19}F NMR (376 MHz, DMSO) δ -57.29, -57.37.

HRMS (ESI) calcd. for $C_8H_7F_3NO$ [M+H]: 190.0480, found: 190.0478.

N-(4-cyanophenyl)formamide[5]



B20:

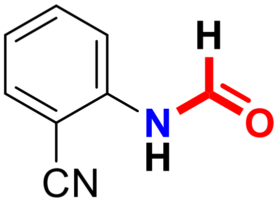
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.3729 gram, 94% yield.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.64 (s, 1H), 8.99 (s, 1H), 8.37 (s, 1H), 7.84 – 7.70 (m, 2H), 7.38 (d, J = 8.4 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 163.14, 160.88, 143.36, 142.75, 134.25, 133.88, 119.76, 119.40, 117.52, 105.90, 105.68.

HRMS (ESI) calcd. for $C_8H_7N_2O$ [M+H]: 147.0558, found: 147.0556.

N-(2-cyanophenyl)formamide[5]



B21:

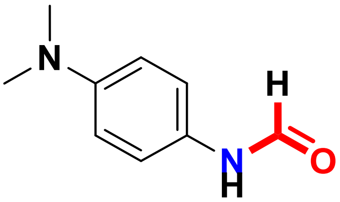
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.2560 gram, 86% yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ 10.40 (s, 1H), 8.49 (d, *J* = 90.8 Hz, 1H), 7.94 (d, *J* = 8.4 Hz, 1H), 7.83 (dd, *J* = 7.9, 1.5 Hz, 1H), 7.72 – 7.68 (m, 1H), 7.44 (d, *J* = 15.8 Hz, 1H), 7.34 (t, *J* = 7.7 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.56, 158.87, 135.05, 134.80, 133.54, 132.39, 128.73, 128.51, 126.40, 125.68, 122.25, 118.94, 114.46, 113.01.

HRMS (ESI) calcd. for $C_8H_7N_2O$ [M+H]: 147.0558, found: 147.0559.

N-(4-(dimethylamino)phenyl)formamide[6]



B22:

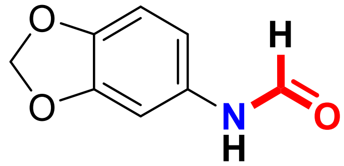
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.2301 gram, 75% yield.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.04 – 9.58 (m, 1H), 8.50 (d, *J* = 11.3 Hz, 1H), 8.15 (d, *J* = 2.0 Hz, 1H), 7.53 – 7.30 (m, 2H), 7.11 – 6.91 (m, 1H), 6.83 – 6.57 (m, 2H), 2.84 (s, 6H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 162.96, 159.16, 148.31, 147.70, 128.55, 128.06, 120.92, 120.48, 113.80, 113.13, 40.95, 40.90.

HRMS (ESI) calcd. for $C_9H_{13}N_2O$ [M+H]: 165.1028, found: 165.1026.

N-(benzo[d][1,3]dioxol-5-yl)formamide[8]



B23:

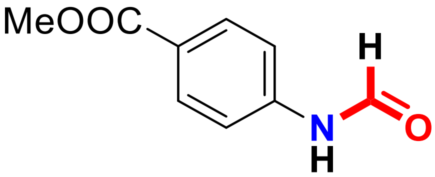
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.5514 gram, 94% yield.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.16 – 9.93 (m, 1H), 8.61 (d, *J* = 10.9 Hz, 1H), 8.20 (d, *J* = 1.8 Hz, 1H), 7.30 (d, *J* = 2.1 Hz, 1H), 6.97 (dd, *J* = 8.4, 2.1 Hz, 1H), 6.87 (dd, *J* = 9.9, 5.3 Hz, 1H), 6.61 (dd, *J* = 8.3, 2.2 Hz, 1H), 5.99 (d, *J* = 2.1 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 163.08, 159.64, 148.31, 147.54, 144.16, 143.57, 133.11, 133.08, 112.36, 111.34, 108.97, 108.58, 101.73, 101.62, 101.47, 100.60.

HRMS (ESI) calcd. for $C_8H_8NO_3$ [M+H]: 166.0505, found: 166.0509.

methyl 4-formamidobenzoate[5]



B24:

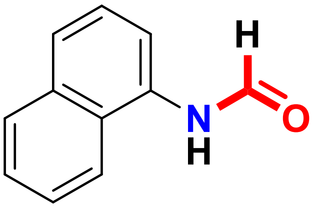
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.7190 gram, 96% yield.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.71 – 10.42 (m, 1H), 8.97 (d, *J* = 10.5 Hz, 1H), 8.35 (s, 1H), 8.06 – 7.86 (m, 2H), 7.72 (d, *J* = 8.7 Hz, 2H), 7.32 (d, *J* = 8.6 Hz, 1H), 3.82 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 166.20, 163.04, 160.63, 143.44, 142.95, 131.26, 130.87, 124.81, 119.11, 116.90, 52.38.

HRMS (ESI) calcd. for $C_9H_{10}NO_3$ [M+H]: 180.0661, found: 180.0663.

N-(naphthalen-1-yl)formamide[1]



B25:

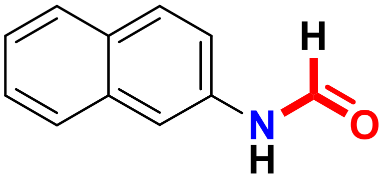
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.5567 gram, 91% yield.

^{1}H NMR (400 MHz, DMSO-d_6) δ 8.67 (d, *J* = 10.9 Hz, 1H), 8.37 (d, *J* = 1.1 Hz, 1H), 7.90 (s, 1H), 7.52 – 7.38 (m, 5H), 7.00 (t, *J* = 5.7 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 162.83, 160.56, 144.22, 142.52, 125.43, 125.10, 119.02, 116.58.

HRMS (ESI) calcd. for $C_{11}H_{10}NO$ [M+H]: 172.0762, found: 172.0765.

N-(naphthalen-2-yl)formamide[1]



B26:

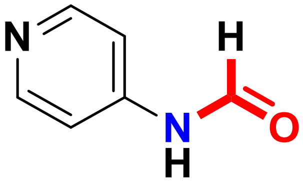
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.6594 gram, 97% yield.

^{1}H NMR (400 MHz, CDCl$_3$) δ 8.77 (d, *J* = 11.3 Hz, 1H), 8.46 (s, 1H), 8.38 (d, *J* = 1.8 Hz, 1H), 8.15 (d, *J* = 2.0 Hz, 1H), 7.80 – 7.66 (m, 3H), 7.52 (s, 1H), 7.47 – 7.30 (m, 3H), 7.18 (d, *J* = 1.5 Hz, 1H).

^{13}C NMR (101 MHz, CDCl$_3$) δ 161.80, 158.18, 133.23, 133.16, 132.74, 132.68, 130.06, 129.79, 128.92, 127.90, 126.77, 126.65, 126.55, 126.20, 126.10, 125.64, 124.48, 124.26, 118.57, 117.72, 116.06, 114.15.

HRMS (ESI) calcd. for $C_{11}H_{10}NO$ [M+H]: 172.0762, found: 172.0766.

N-(pyridin-4-yl)formamide[5]



B27:

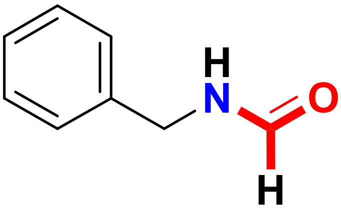
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.0862 gram, 89% yield.

^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 10.59 (s, 1H), 10.46 (d, *J* = 9.5 Hz, 1H), 9.06 (d, *J* = 10.5 Hz, 1H), 8.50 – 8.32 (m, 3H), 7.54 (d, *J* = 6.2 Hz, 2H), 7.20 (d, *J* = 5.8 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 163.00, 161.33, 151.05, 151.00, 146.03, 145.07, 113.82, 111.62.

HRMS (ESI) calcd. for $C_6H_7N_2O$ [M+H]: 123.0558, found: 123.0555.

N-benzylformamide[1]



B28:

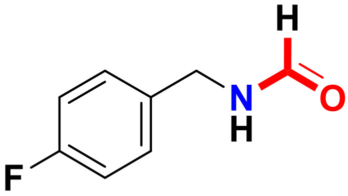
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.1076 gram, 82% yield.

^{1}H NMR (400 MHz, CDCl$_3$) δ 8.33 – 8.02 (m, 1H), 7.45 – 7.13 (m, 4H), 6.22 (s, 1H), 4.41 (dd, *J* = 28.1, 6.2 Hz, 2H).

^{13}C NMR (101 MHz, CDCl$_3$) δ 164.82, 161.26, 137.67, 128.74, 127.74, 126.99, 45.67, 42.10.

HRMS (ESI) calcd. for $C_8H_{10}NO$ [M+H]: 136.0762, found: 136.0760.

N-(4-fluorobenzyl)formamide[9]



B29:

The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.2398 gram, 82% yield.

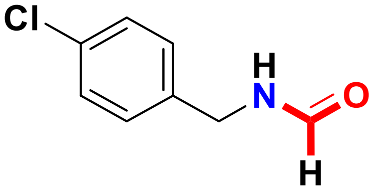
^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 8.54 (s, 1H), 8.14 (d, *J* = 1.8 Hz, 1H), 7.31 (dd, *J* = 8.6, 5.6 Hz, 1H), 7.23 – 7.04 (m, 2H), 4.29 (d, *J* = 6.1 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 169.62, 165.34, 162.86, 161.52, 160.45, 136.29, 135.70, 135.67, 129.78, 129.70, 115.73, 115.60, 115.52, 115.39, 44.29, 41.84.

^{19}F NMR (376 MHz, DMSO-*d*$_6$) δ -115.83, -116.06.

HRMS (ESI) calcd. for C_8H_9FNO [M+H]: 154.0668, found: 154.0664.

N-(4-chlorobenzyl)formamide[9]



B30:

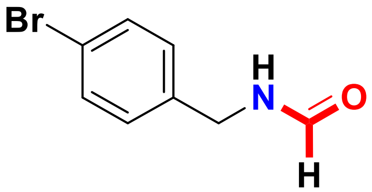
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.4537 gram, 86% yield.

^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 8.56 (s, 1H), 8.15 (d, *J* = 1.7 Hz, 1H), 7.45 – 7.35 (m, 1H), 7.29 (dd, *J* = 11.3, 5.2 Hz, 2H), 4.30 (d, *J* = 6.2 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 169.71, 165.40, 161.61, 139.16, 138.54, 131.90, 129.60, 128.72, 44.32, 41.90.

HRMS (ESI) calcd. for C_8H_9ClNO [M+H]: 170.0373, found: 170.0370.

N-(4-bromobenzyl)formamide[10]



B31:

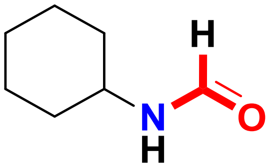
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.7038 gram, 80% yield.

^{1}H NMR (400 MHz, DMSO-d_6) δ 8.50 (t, J = 33.1 Hz, 1H), 8.26 – 8.07 (m, 1H), 7.57 – 7.48 (m, 1H), 7.22 (t, J = 8.2 Hz, 2H), 4.28 (d, J = 6.2 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 169.71, 165.41, 161.62, 139.58, 138.97, 131.64, 129.97, 120.36, 44.38, 41.96.

HRMS (ESI) calcd. for C_8H_9BrNO [M+H]: 213.9868, found: 213.9864.

N-cyclohexylformamide[11]



B32:

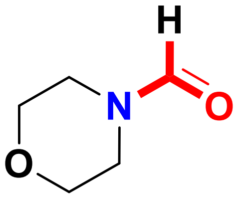
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.0295 gram, 82% yield.

^{1}H NMR (400 MHz, CDCl$_3$) δ 8.11 (t, J = 7.4 Hz, 1H), 6.06 (d, J = 78.7 Hz, 1H), 4.01 – 3.75 (m, 1H), 3.42 – 3.18 (m, 1H), 2.08 – 1.83 (m, 2H), 1.75 – 1.69 (m, 1H), 1.67 – 1.56 (m, 1H), 1.39 – 1.31 (m, 2H), 1.22 – 1.16 (m, 2H).

^{13}C NMR (101 MHz, CDCl$_3$) δ 163.68, 160.42, 77.42, 77.10, 76.78, 51.04, 47.06, 34.64, 32.98, 25.40, 25.00, 24.74, 24.71.

HRMS (ESI) calcd. for $C_7H_{14}NO$ [M+H]: 128.1075, found: 128.1077.

Morpholine-4-carbaldehyde[11]



B33:

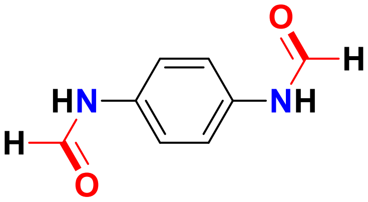
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.0125 gram, 82% yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07 (s, 1H), 3.81 – 3.63 (m, 4H), 3.63 – 3.51 (m, 2H), 3.47 – 3.33 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 160.84, 67.23, 66.43, 45.79, 40.59.

HRMS (ESI) calcd. for $C_5H_{10}NO_2$ [M+H]: 116.0712, found: 116.0717.

N,*N'*-(1,4-phenylene)diformamide[6]



B34:

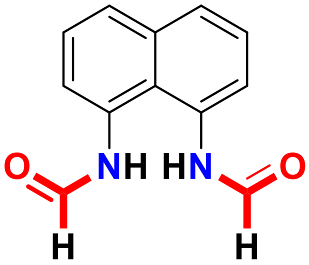
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.3461 gram, 82% yield.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.14 (s, 1H), 10.08 (d, *J* = 11.3 Hz, 1H), 8.69 (dd, *J* = 11.1, 2.0 Hz, 1H), 8.23 (d, *J* = 2.0 Hz, 1H), 7.59 – 7.46 (m, 2H), 7.15 (t, *J* = 4.4 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 162.90, 159.74, 134.82, 134.45, 120.64, 120.06, 119.32, 118.72, 40.60, 40.40, 40.19, 39.98, 39.77, 39.56, 39.35.

HRMS (ESI) calcd. for $C_8H_9N_2O_2$ [M+H]: 165.0664, found: 165.0666.

N,*N'*-(naphthalene-1,8-diyl)diformamide



B35:

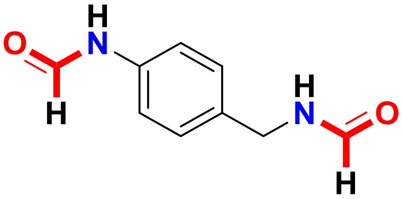
The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.5627 gram, 73% yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.73 – 8.53 (m, 2H), 8.02 (d, *J* = 7.8 Hz, 1H), 7.91 – 7.85 (m, 1H), 7.79 (d, *J* = 8.3 Hz, 1H), 7.72 (d, *J* = 8.2 Hz, 1H), 7.62 – 7.44 (m, 3H), 7.32 (d, *J* = 7.3 Hz, 1H), 7.26 (s, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 164.11, 159.65, 134.29, 134.08, 132.13, 131.00, 128.85, 128.55, 127.77, 127.04, 126.81, 126.52, 126.23, 126.14, 125.71, 125.52, 121.32, 120.90, 120.38, 119.07.

HRMS (ESI) calcd. for $C_{12}H_{11}N_2O_2$ [M+H]: 215.0821, found: 215.0823.

N-(4-formamidobenzyl)formamide[6]



B36:

The title compound was prepared according to the general procedure and purified by column chromatography to give a white solid, 1.3533 gram, 76% yield.

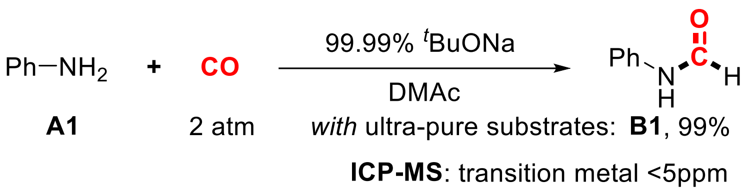
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.30 – 10.01 (m, 1H), 8.75 (d, *J* = 11.0 Hz, 1H), 8.47 (s, 1H), 8.26 (t, *J* = 2.0 Hz, 1H), 8.11 (t, *J* = 7.5 Hz, 1H), 7.62 – 7.48 (m, 2H), 7.26 – 7.10 (m, 3H), 4.22 (dd, *J* = 23.0, 6.0 Hz, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 165.30, 162.97, 161.44, 159.96, 137.49, 134.62, 128.90, 128.33, 119.55, 117.99, 40.78, 40.69.

HRMS (ESI) calcd. for $C_9H_{11}N_2O_2$ [M+H]: 179.0821, found: 179.0824.

5. Control experiments.

5.1 Ultra-pure substrates experiment:



Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, 99.99% ^{t}BuONa (96.1 mg, 1.0 mmol), amines **A1** (91 μL, 1.0 mmol), and DMAc (1.0 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with DCM (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC, GC-MS and ICP-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 2%, Et_3N 2%) on silica gel to give the corresponding products **B1**.

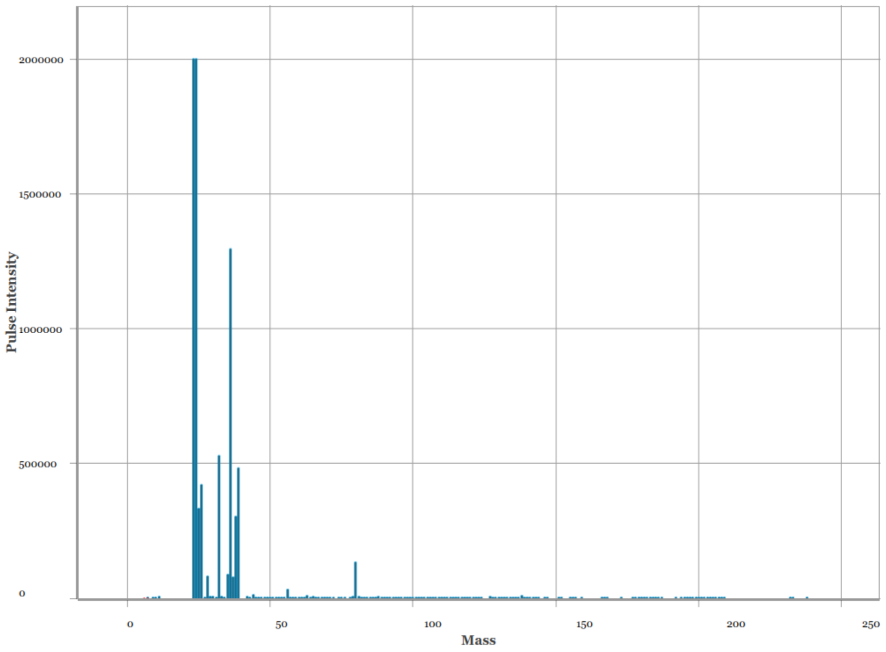
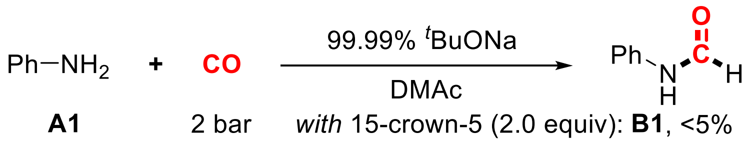


Figure R3. The spectrum of ICP-MS

Na (ppm)	Ca (ppm)	Fe (ppm)	K (ppm)	Mg (ppm)	Al 27/27 (ppb)
10.39	0.26	0	0.56	4.47	0
Pd 106/106 (ppb)	Rh 103/103 (ppb)	Cr 52/52 (ppb)	Pb 208/208 (ppb)	V 51/51 (ppb)	Zn 66/66 (ppb)
0.06	0.00	0.00	0.00	0.03	4.04
Cu 63/63 (ppb)	Mn 55/55 (ppb)	Ti 48/48 (ppb)	Ba 138/138 (ppb)	Cd 111/111 (ppb)	Co 59/59 (ppb)
1.69	0.09	0.21	0.32	0.01	0.01
Ni 60/60 (ppb)					
0.26					

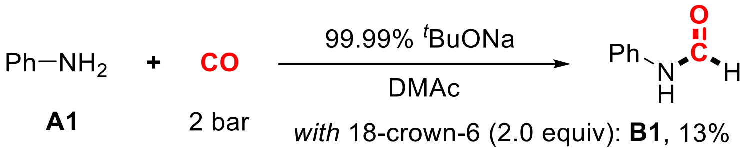
Table R1 The data of ICP-MS

5.2 Control experiment with 15-crown-5:



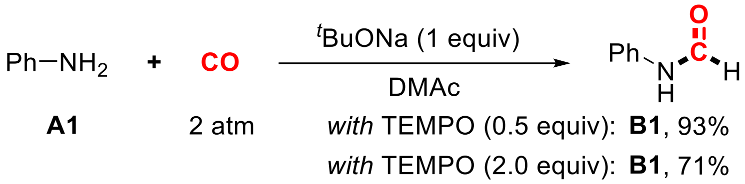
Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, ^{t}BuONa (96.1 mg, 1.0 mmol), amines **A1** (91 μL, 1.0 mmol), 15-crown-5 (2 mmol), and DMAc (1.0 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with DCM (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 2%, Et_3N 2%) on silica gel to give the corresponding products **B1**.

5.3 Control experiment with 18-crown-6:



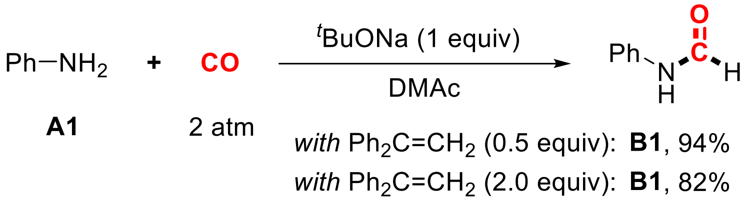
Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, ^{t}BuONa (96.1 mg, 1.0 mmol), amines **A1** (91 μL, 1.0 mmol), 18-crown-6 (2 mmol), and DMAc (1.0 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with DCM (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 2%, Et_3N 2%) on silica gel to give the corresponding products **B1**.

5.4 Radical capture experiment with TMEPO:



Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, ^{t}BuONa (96.1 mg, 1.0 mmol), amines **A1** (91 μL, 1.0 mmol), TMEPO (0.5 mmol or 2 mmol), and DMAc (1.0 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with DCM (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 2%, Et_3N 2%) on silica gel to give the corresponding products **B1**.

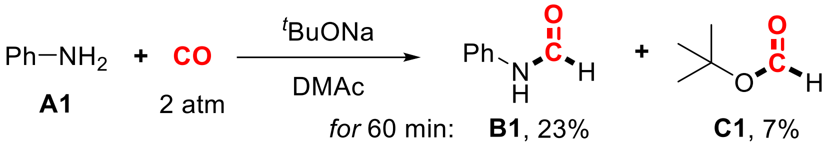
5.5 Radical capture experiment with $Ph_2C=CH_2$:



Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, ^{t}BuONa (96.1 mg, 1.0 mmol), amines **A1** (91 μL, 1.0 mmol), $Ph_2C=CH_2$ (0.5 mmol or 2 mmol), and DMAc (1.0 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with DCM (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 2%, Et_3N 2%) on silica gel to give the corresponding products **B1**.

6 Mechanism investigations

6.1 Mechanism investigations for 60 minutes:



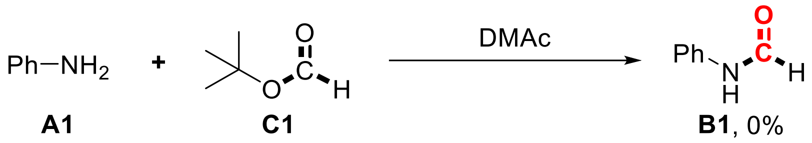
Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, ^{t}BuONa (96.1 mg, 1.0 mmol), amines **A1** (91 μL, 1.0 mmol), and DMAc (1.0 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 30 minutes. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with ethyl acetate (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor products formation.

6.2 Synthesis of C1:

Using a nitrogen-filled glove box, an oven-dried pressure tube (50 mL) was charged with a magnetic stirring bar, ^{t}BuONa (96.1 mg, 10 mmol), and DMAc (10 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with Et_2O (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product **C1** formation. The solvent was evaporated under reduced pressure for giving the **C1** (163 mg, 16% yield) as colorless oil.

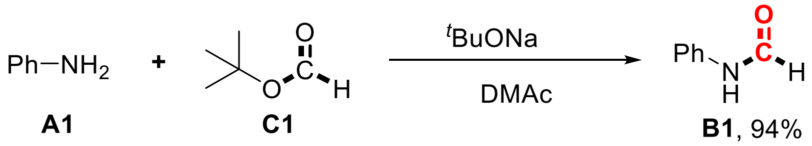
^{1}H NMR (400 MHz, $CDCl_3$): 7.99 (s, 1H), 1.48 (s, 9H). **^{13}C NMR** (100 MHz, $CDCl_3$): 160.7, 81.4, 28.3. **HRMS** (ESI) calcd. for $C_5H_{11}O_2$ [M+H]: 103.0759, found: 103.0758.

6.3 Mechanism investigations with C1 in absence of base:



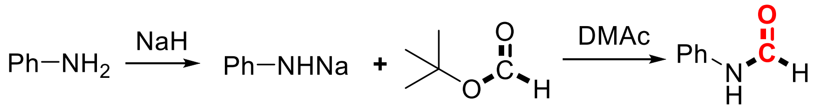
Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, **C1** (2.0 mmol), amines **A1** (91 μL, 1.0 mmol), and DMAc (1.0 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the tube immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the mixture was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with ethyl acetate (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product **B1** formation.

6.4 Mechanism investigations with C1 in presence of base:



Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, ^{t}BuONa (96.1 mg, 1.0 mmol), **C1** (2.0 mmol), amines **A1** (91 μL, 1.0 mmol), and DMAc (1.0 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the tube immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the mixture was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with ethyl acetate (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product **B1** formation.

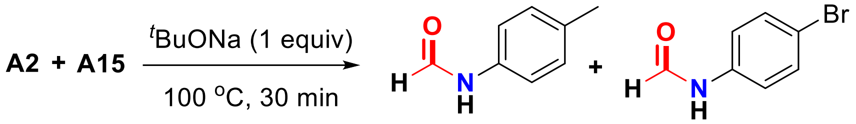
6.5 Mechanism investigations with A1-Na and C1



A1 **A1-Na** **C1** **B1**, 68%

Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, NaH (26.4 mg, 1.1 mmol), amines **A1** (91 µL, 1.0 mmol). Then the glass tube was closed tightly and removed from the glove box. Then the mixture immersed into a pre-heated metal bath (100 °C) for an hour. After the reaction was finished, the tube was cooled to room temperature and put into the glove box again. The **C1** (2.0 mmol) and DMAc (1.0 mL) were added. Then the tube closed tightly and removed from the glove box. The mixture was immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the mixture was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with ethyl acetate (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product **B1** formation.

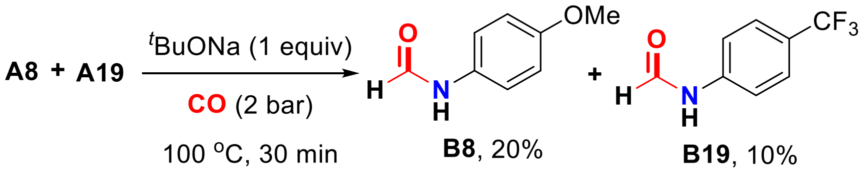
6.6 Mechanism investigations for the competition experiment:



B2, 19% **B15**, 11%

Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, ^{t}BuONa (0.96 g, 10.0 mmol), amines **A2** (5.0 mmol) and **A15** (5.0 mmol), and DMAc (10.0 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 30 minutes. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with ethyl acetate (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC or GC-MS to monitor products formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 2%, Et_3N 2%) on silica gel to give the corresponding products **B2**, 128.0 mg, 19% yield. **B15**, 110.1 mg, 11% yield.

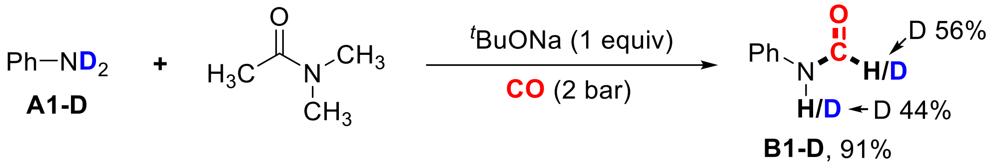
6.7 Mechanism investigations for the competition experiment:



Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, ^{t}BuONa (0.96 g, 10.0 mmol), amines **A8** (5.0 mmol) and **A19** (5.0 mmol), and DMAc (10.0 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 30 minutes. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with ethyl acetate (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC or GC-MS to monitor products formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 2%, Et_3N 2%) on silica gel to give the corresponding products **B8**, 151.1 mg, 20% yield. **B19**, 94.6 mg, 10% yield.

7 Deuterium-labeled investigations

7.1 Deuterium-labeled investigations with A1-D:



Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, 99.99% ^{t}BuONa (96.1 mg, 1.0 mmol), amines **A1-D** (93 μL, 1.0 mmol), and DMAc (1.0 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with DCM (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC, GC-MS and ICP-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 2%, Et_3N 2%) on silica gel to give the corresponding products **B1-D**. **HRMS** (ESI) calcd. for $C_7H_6D_2NO$ [M+H]: 124.0731, found: 124.0733.

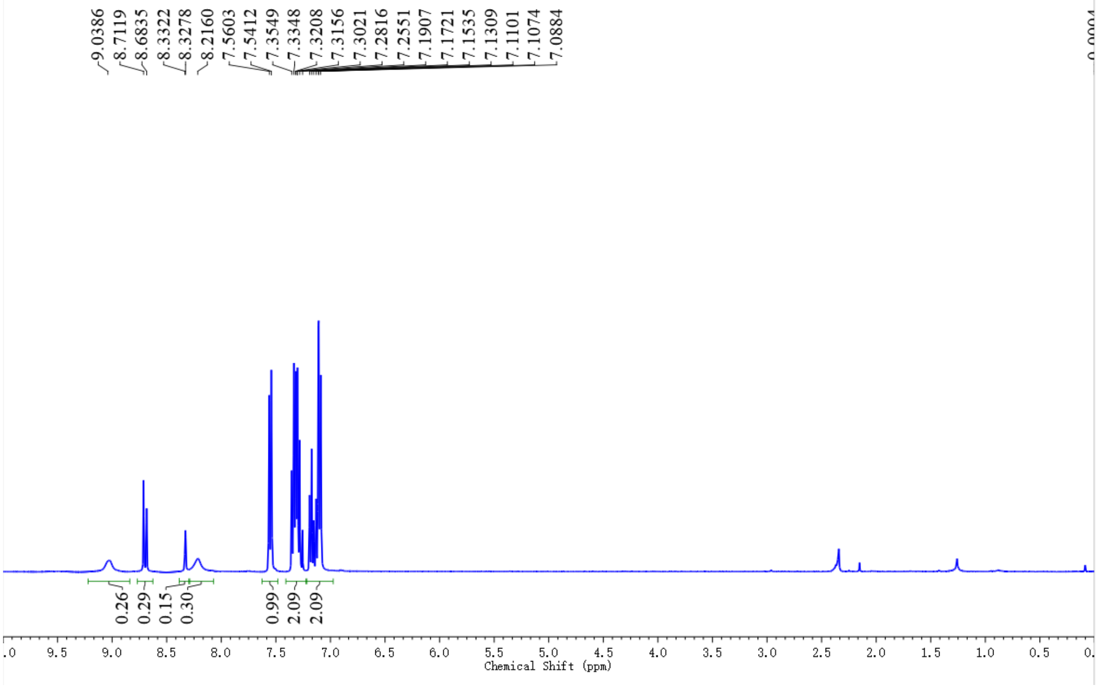
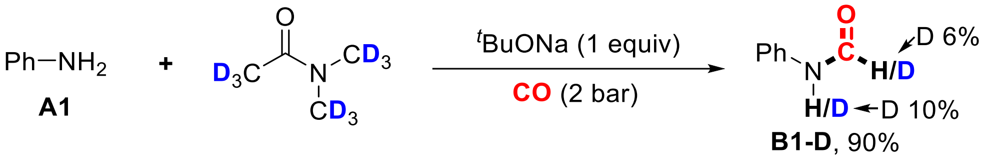


Figure S1

7.2 Deuterium-labeled investigations with DMAc-d_9:



Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, 99.99% ^{t}BuONa (96.1 mg, 1.0 mmol), amines **A1** (91 µL, 1.0 mmol), and DMAc-d_9 (1.0 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with DCM (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC, GC-MS and ICP-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 2%, Et_3N 2%) on silica gel to give the corresponding products **B1-D**. **HRMS** (ESI) calcd. for C_7H_8NO [M+H]: 122.0606, found: 122.0604.

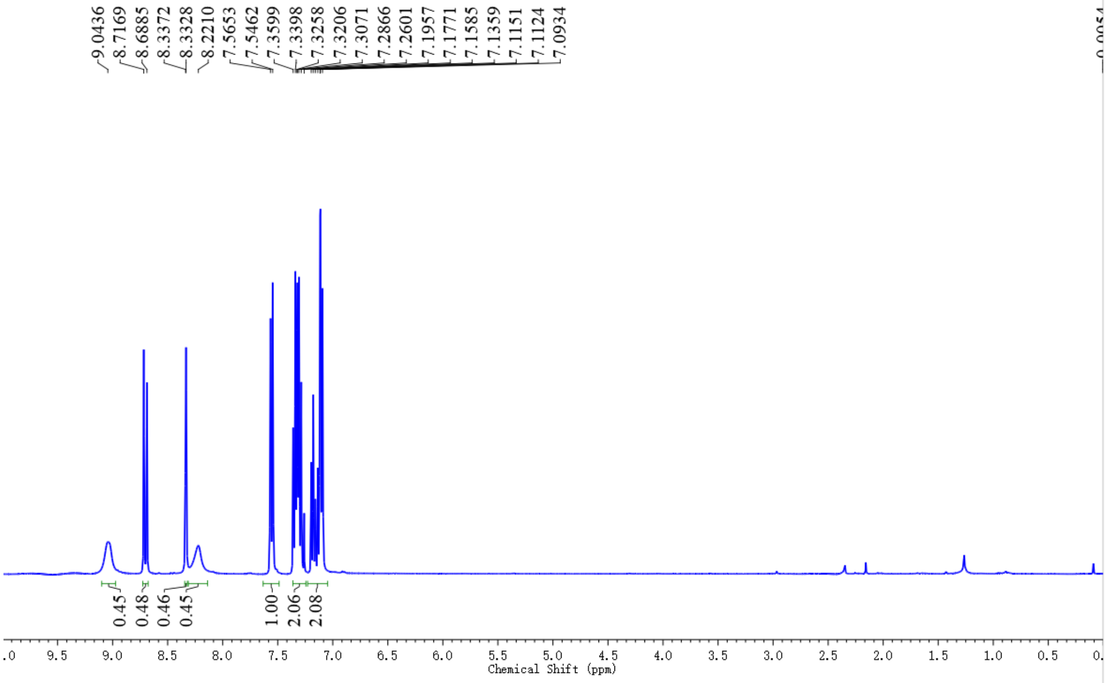
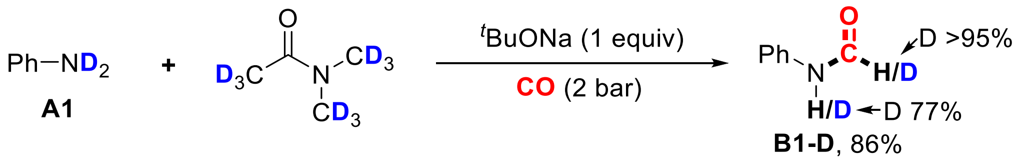


Figure S2

7.3 Deuterium-labeled investigations with A1-D and DMAc-*d*$_9$:



Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, 99.99% ^{t}BuONa (96.1 mg, 1.0 mmol), amines **A1-D** (93 µL, 1.0 mmol), and DMAc-*d*$_9$ (1.0 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with DCM (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC, GC-MS and ICP-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 2%, Et_3N 2%) on silica gel to give the corresponding products **B1-D**. **HRMS** (ESI) calcd. for $C_7H_6D_2NO$ [M+H]: 124.0731, found: 124.0733.

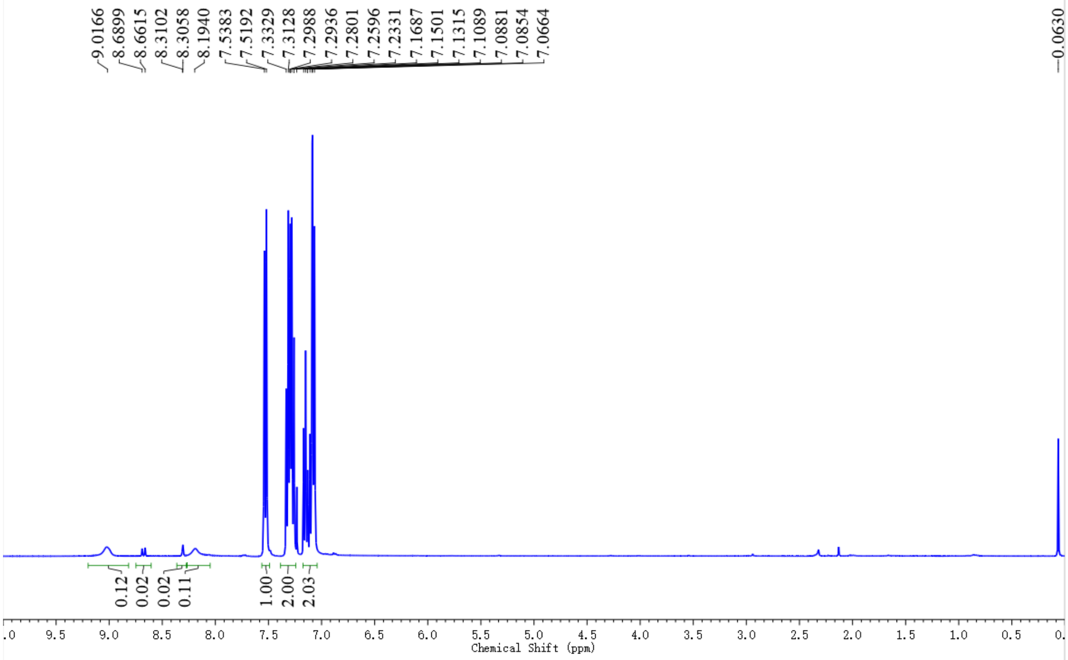
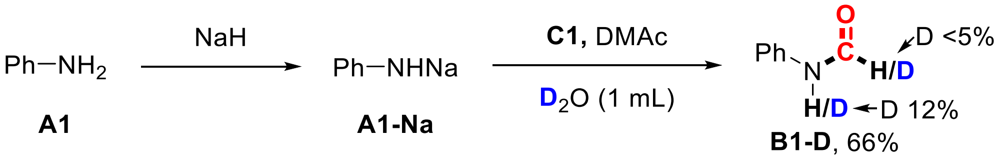


Figure S3

7.4 Deuterium-labeled investigations with D_2O:



Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, NaH (26.4 mg, 1.1 mmol), amines **A1** (91 µL, 1.0 mmol). Then the glass tube was closed tightly and removed from the glove box. Then the mixture immersed into a pre-heated metal bath (100 °C) for an hour. After the reaction was finished, the tube was cooled to room temperature and put into the glove box again. The **C1** (2.0 mmol) and DMAc (1.0 mL) were added. Then the tube closed tightly and removed from the glove box. The mixture was immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the mixture was cooled to room temperature and D_2O (1.0 mL) was then added. Then mixture was extracted with ethyl acetate (3 × 5 mL) and the combined organics were washed with brine (5 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product **B1-D** formation. **HRMS** (ESI) calcd. for C_7H_7DNO [M+H]: 123.0669, found: 123.0668.

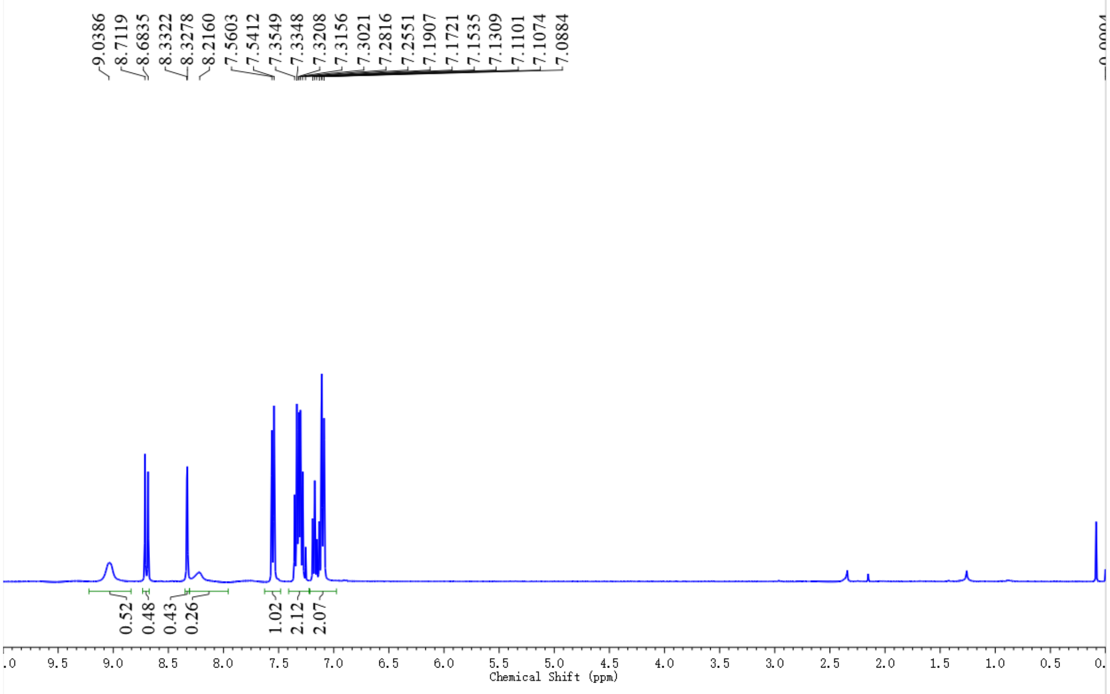
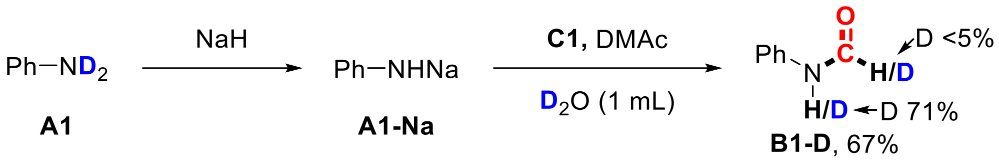


Figure S4

7.5 Deuterium-labeled investigations with D_2O:



Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, NaH (26.4 mg, 1.1 mmol), amines **A1-D** (93 µL, 1.0 mmol). Then the glass tube was closed tightly and removed from the glove box. Then the mixture immersed into a pre-heated metal bath (100 °C) for an hour. After the reaction was finished, the tube was cooled to room temperature and put into the glove box again. The **C1** (2.0 mmol) and DMAc (1.0 mL) were added. Then the tube closed tightly and removed from the glove box. The mixture was immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the mixture was cooled to room temperature and D_2O (1.0 mL) was then added. Then mixture was extracted with ethyl acetate (3 × 5 mL) and the combined organics were washed with brine (5 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product **B1-D** formation. **HRMS** (ESI) calcd. for C_7H_7DNO [M+H]: 123.0669, found: 123.0670.

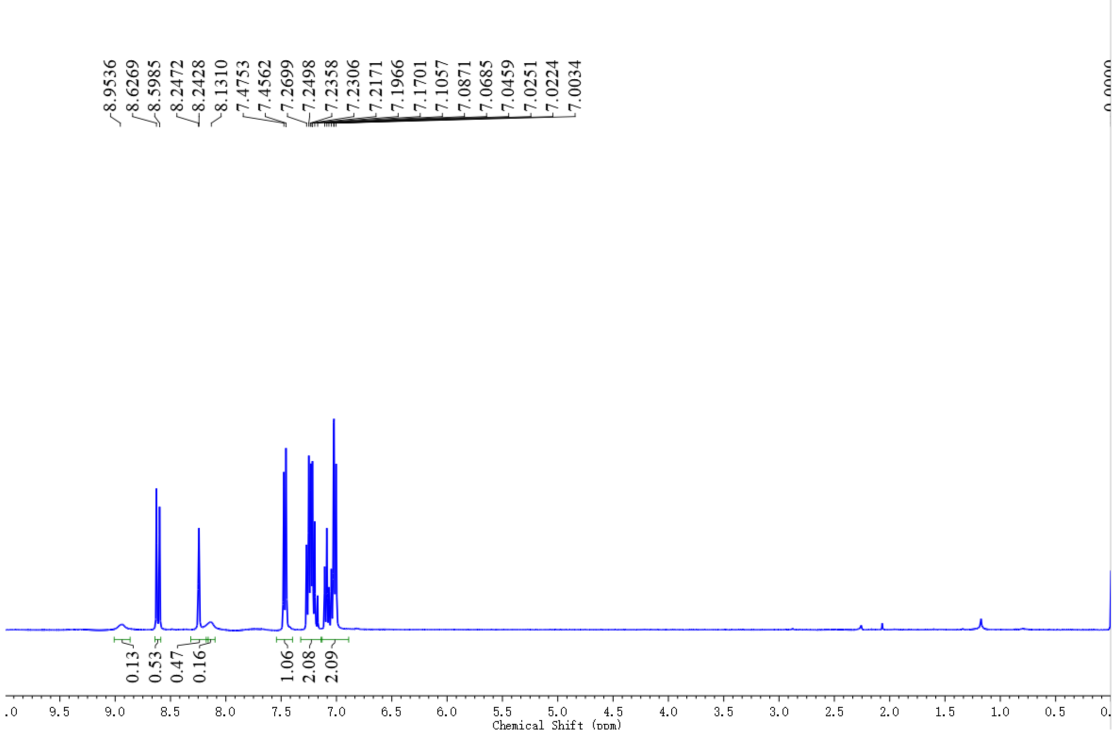
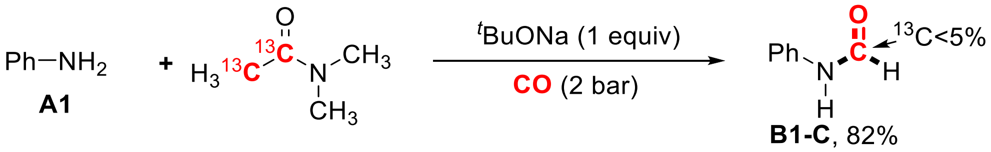


Figure S5

7.6 Labeled investigations with $CH_3{}^{13}C(O)N(CH_3)_2$:

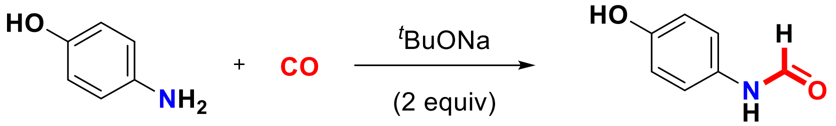


Using a nitrogen-filled glove box, an oven-dried pressure tube (10 mL) was charged with a magnetic stirring bar, 99.99% ^{t}BuONa (96.1 mg, 1.0 mmol), amines **A1** (91 µL, 1.0 mmol), and $CH_3{}^{13}C(O)N(CH_3)_2$ (0.5 mL). Then the glass tube was placed in an autoclave which was closed tightly and removed from the glove box. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 12 hours. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released. Sat. aq. NH_4Cl (10 mL) was then added and the mixture was extracted with DCM (3 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC, GC-MS and ICP-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 2%, Et_3N 2%) on silica gel to give the corresponding products **B1-C**.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.04 (br, 0.5H), 8.70 (d, J = 11.2 Hz, 0.5H), 8.33 (s, 0.5H), 8.22 (br, 0.5H), 7.56 (d, J = 7.6 Hz, 1H), 7.36 – 7.29 (m, 2H), 7.23 – 6.98 (m, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 162.10, 158.60, 135.99, 135.79, 128.67, 128.00, 124.20, 123.71, 119.12, 119.10, 117.72. **HRMS** (ESI) calcd. for C_7H_8NO [M+H]: 122.0606, found: 122.0604.

8. Application and further transformation

8.1 Gram experiment for Paracetamol



A37 (100 mmol) (2 bar) **Paracetamol**, 75% (10.27 g)

Using a nitrogen, an oven-dried tube (1.0 L) was charged with a mechanical agitator bar, ^{t}BuONa (19.2 g, 200 mmol), amine **A37** (10.9 g, 100 mmol), and DMAc (200 mL). Then the tube was placed in an autoclave which was closed tightly. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 48 hours. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released under well ventilated fume hood. Sat. aq. NH_4Cl (200 mL) was then added and the mixture was extracted with DCM (3 × 200 mL) and the combined organics were washed with brine (200 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by recrystallization (DCM) to give the corresponding product **Paracetamol**.

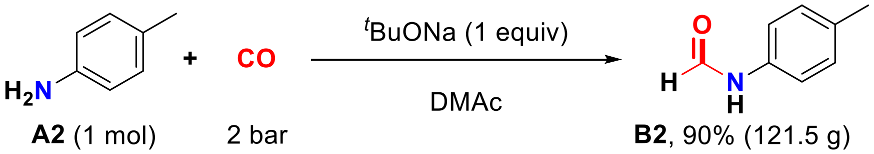
Paracetamol:[6]

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.99 – 9.84 (m, 1H), 9.30 (s, 1H), 8.56 (d, J = 11.2 Hz, 1H), 8.21 (t, J = 3.0 Hz, 1H), 7.52 – 7.31 (m, 1H), 7.13 – 6.91 (m, 1H), 6.84 – 6.66 (m, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 163.01, 159.27, 154.64, 153.97, 130.43, 130.10, 121.23, 120.63, 116.24, 115.62.

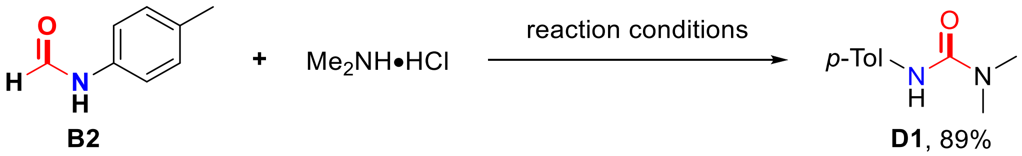
HRMS (ESI) calcd. for $C_7H_8NO_2$ [M+H]: 138.0555, found: 138.0558.

8.2 Gram experiment for B2



Using a nitrogen, an oven-dried tube (2.5 L) was charged with a mechanical agitator bar, ^{t}BuONa (96.1 g, 1.0 mol), amine **A2** (107.1g, 1.0 mol), and DMAc (1.0 L). Then the tube was placed in an autoclave which was closed tightly. Then the autoclave was purged and charged with CO (2 bar) and immersed into a pre-heated metal bath (100 °C) for 48 hours. After the reaction was finished, the autoclave was cooled to room temperature and the pressure was carefully released under well ventilated fume hood. Sat. aq. NH_4Cl (1 L) was then added and the mixture was extracted with DCM (3 × 1 L) and the combined organics were washed with brine (1 L), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by recrystallization (DCM) to give the corresponding product **B2**.

8.3 Synthesis of D1



To a stirring 0 °C mixture of $Me_2NH \cdot HCl$ (3 mmol) and **B2** (1 mmol) in DCM (5 mL), as added Et_3N (3 mmol) dropwise under argon. After 5 min at 0°C and 12 hours at room temperature, 5 mL water was added and mixed vigorously until the organic layer became clear. The mixture was extracted with DCM (3 × 5 mL) and the combined organics were washed with brine (5 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 10%) on silica gel to give the corresponding products **D1**.

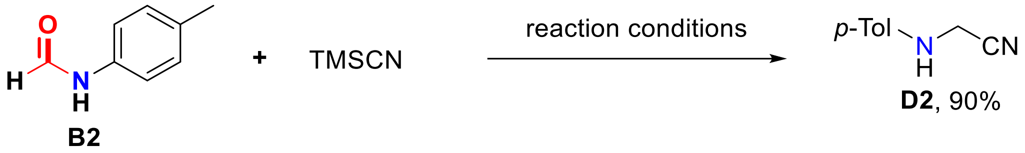
1,1-dimethyl-3-(p-tolyl)urea (D1): [12]

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22-7.25 (m, 2H), 7.04-7.07 (m, 2H), 6.30 (br, 1H), 2.99 (s, 6H), 2.27 (s, 3H);

^{13}C NMR (101 MHz, CDCl$_3$) δ 156.0, 136.6, 132.6, 129.4, 120.2, 36.5, 20.8;

HRMS (ESI) calcd. for $C_{10}H_{15}N_2O$ [M+H]: 179.1180, found: 179.1182

8.4 Synthesis of D2



Using a nitrogen-filled glove box, an oven-dried pressure tube (38 mL volume) was charged with a magnetic stirring bar, **B2** (1 mmol), FeI$_2$ (0.1 mmol), MeCN (3.0 mL), TMDS (2 mmol) and TMSCN (2 mmol). Then the seal tube was closed tightly with a rubber stopper, removed from the glove box and stirred at room temperature for 12 h. After the reaction was finished, sat. aq. NH$_4$Cl (5 mL) was then added. The mixture was extracted with DCM (3 × 5 mL) and the combined organics were washed with brine (5 mL), dried over Na$_2$SO$_4$. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 5:1, DCM 2%) on silica gel to give the corresponding products **D2**.

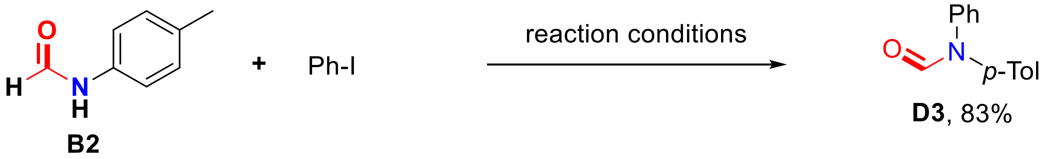
2-(*p*-tolylamino)acetonitrile (D2): [13]

^{1}H NMR (400 MHz, CDCl$_3$) δ 7.05 (d, J = 8.4 Hz, 2H), 6.64 – 6.58 (m, 2H), 4.01 (d, J = 7.1 Hz, 2H), 3.82 (s, 1H), 2.26 (s, 3H);

^{13}C NMR (101 MHz, CDCl$_3$) δ 142.6, 130.0, 129.3, 117.0, 113.7, 33.0, 20.4;

HRMS (ESI) calcd. for $C_9H_{11}N_2$ [M+H]: 147.0922, found: 147.0924.

8.4 Synthesis of D3



Using a nitrogen-filled glove box, an oven-dried pressure tube (38 mL volume) was charged with a magnetic stirring bar, **B2** (1.2 mmol), PhI (1 mmol), CuI (0.05 mmol), *N,N*-dimethylglycine (0.1 mmol), K$_2$CO$_3$ (2 mmol), and DMF (0.5 mL). Then the seal tube was closed tightly with a rubber stopper, removed from the glove box and immersed into a pre-heated metal bath (110 °C) for 48 hours. After the reaction was finished, the mixture was cooled to room temperature sat. aq. NH_4Cl (5 mL) was then added. The mixture was extracted with DCM (3 × 5 mL) and the combined organics were washed with brine (5 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 2:1, DCM 2%) on silica gel to give the corresponding products **D3**.

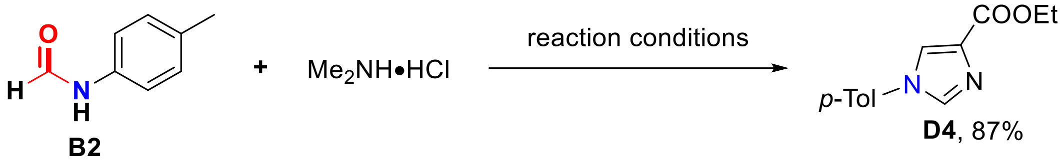
***N*-Phenyl-*N*-(*p*-tolyl)formamide (D3)**: [14]

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.68 (s, 1H), 8.63 (s, 1H), 7.46−7.35 (m, 5H), 7.35−7.27 (m, 5H), 7.23 (s, 2H), 7.20−7.13 (m, 4H), 7.13−7.06 (m, 2H), 2.38 (s, 3H), 2.36 (s, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.7, 141.8, 139.7, 139.1, 137.1, 136.9, 130.5, 129.7, 129.6, 129.0, 126.8, 126.5, 126.2, 125.7, 125.3, 124.6, 29.7, 21.1, 20.8;

HRMS (ESI) calcd. for $C_{14}H_{14}NO$ [M+H]: 212.1075, found: 212.1078

8.5 Synthesis of D4



Using a nitrogen-filled glove box, an oven-dried pressure tube (38 mL volume) was charged with a magnetic stirring bar, **B2** (1.0 mmol), pyridine (1.5 mL), DPPA (2.0 mmol). Then the seal tube was closed tightly with a rubber stopper, removed from the glove box and immersed into a pre-heated metal bath (90 °C) for 24 hours. After the reaction was finished, the mixture was cooled to room temperature sat. aq. NH_4Cl (5 mL) was then added. The mixture was extracted with DCM (3 × 5 mL) and the combined organics were washed with brine (5 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 2%) on silica gel to give the corresponding products **D4**.

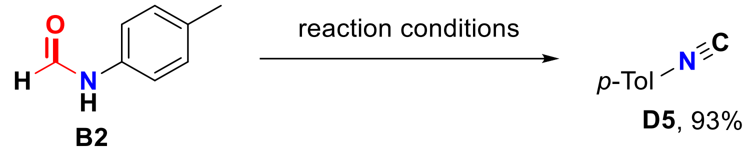
ethyl 1-(*p*-tolyl)-1H-imidazole-4-carboxylate (D4):[15]

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (d, *J* = 1.3 Hz, 1H), 7.78 (d, *J* = 1.2 Hz, 1H), 7.26 (s, 2H), 4.37 (q, 2H), 2.38 (s, 3H), 1.37 (t, *J* = 7.1 Hz, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.7, 138.5, 136.2, 134.9, 134.0, 130.6, 124.0, 121.6, 60.7, 21.0, 14.3;

HRMS (ESI) calcd. for $C_{13}H_{15}N_2O_2$ [M+H]: 231.1134, found: 231.1133.

8.6 Synthesis of D5



To a stirring 0 °C mixture of DIPA (2.7 equiv, 0.26 mL) and **B2** (1 mmol g) in DCM (0.9 M), as added $POCl_3$ (1.1 mmol) dropwise under argon. After 5 min at 0°C and 15 min at room temperature, 1 mL water was added and mixed vigorously until the organic layer became clear. The mixture was extracted with DCM (3 × 2 mL) and the combined organics were washed with brine (2 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 4:1) on silica gel to give the corresponding products **D5**.

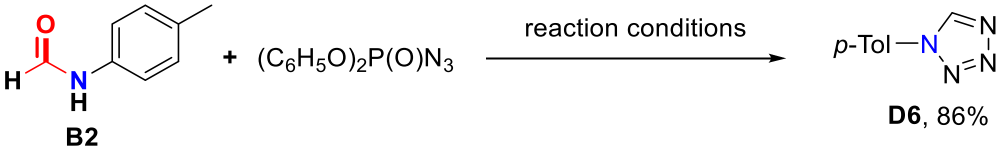
4-methylphenyl isocyanide (D5): [16]

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25 (d, *J* = 8.4 Hz, 2H), 7.22 (d, *J* = 8.4 Hz, 2H), 4.59 (s, 2H), 2.38 (s, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 157.2 (t, *J* = 5.2 Hz), 138.2, 129.5, 126.6, 45.3 (t, *J* = 7.1 Hz), 21.0;

HRMS (ESI) calcd. for C_8H_9N [M+H-HCN]: 105.0699, found: 105.0694.

8.7 Synthesis of D6



Using a nitrogen-filled glove box, an oven-dried pressure tube (38 mL volume) was charged with a magnetic stirring bar, **B2** (1.0 mmol), pyridine (1.5 mL), DPPA (2.0 mmol). Then the seal tube was closed tightly with a rubber stopper, removed from the glove box and immersed into a pre-heated metal bath (90 °C) for 24 hours. After the reaction was finished, the mixture was cooled to room temperature sat. aq. NH_4Cl (5 mL) was then added. The mixture was extracted with DCM (3 × 5 mL) and the combined organics were washed with brine (5 mL), dried over Na_2SO_4. A small aliquot of the organic phase was analyzed by GC and GC-MS to monitor product formation. Then the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 10:1 – 1:1, DCM 2%) on silica gel to give the corresponding products **D6**.

1-(*p*-Tolyl)-1H-tetrazole (D6):[15]

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.95 (s, 1H), 7.57 (d, *J* = 8.4 Hz, 2H), 7.36 (d, *J* = 8.5 Hz, 2H), 2.44 (s, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 140.4, 140.4, 130.7, 121.0, 21.2;

HRMS (ESI) calcd. for $C_8H_9N_4$ [M+H]: 161.0827, found: 161.0826.

9. References

(1) Jia, M.; Zhang, H.; Lin, Y.; Chen, D.; Chen, Y.; Xia, Y. *Org. Biomol. Chem.* **2018**, *16*, 3615 – 3624.

(2) Nguyen, T. V. Q.; Yoo, W.-J.; Kobayashi. *Angew. Chem., Int. Ed.* **2011**, *54*, 9209 – 9212.

(3) Wang, C.; Wu, L.; Xu, W.; He, F.; Qu, J.; Chen, Y. *Org. Lett.* **2020**, *22*, 6954 – 6959.

(4) Yu, Y.; Zhang, Y.; Sun, C.; Shi, L.; Wang, W.; Li, H. *J. Org. Chem.* **2020**, *85*, 2725 – 2732.

(5) Ghosh, T.; Jana, S.; Dash, J. *Org. Lett.* **2019**, *21*, 6690 – 6694.

(6) Yin, J.; Zhang, J.; Cai, C.; Deng, G-J.; Gong, H. *Org. Lett.* **2019**, *21*, 387 – 392.

(7) Tan, Z; Li, Z; Ma, Y; Qin, J; Yu, C. *Eur. J. Org. Chem.* **2019**, *28*, 4538 – 4545.

(8) Shen, N.; Zhai, S.-J.; Cheung, C.; Ma, J.-A. *Chem. Commun.* **2020**, *56*, 9620 – 9623.

(9) Ortega, N.; Richter, C.; Glorius, F. *Org. Lett.* **2013**, *15*, 1776 – 1779.

(10) Kang, B.; Hong, S. H. *Adv. Synth. Catal.* **2015**, *357*, 834 – 840.

(11) Pathare, S. P.; Jain, A. K. H.; Akamanchi, K. G. *RSC Adv.* **2013**, *3*, 7697 – 7703.

(12) Houlden, C. E.; Bailey, C. D.; Ford, J. G.; Gagne, M. R.; Lloyd-Jones, G. C.; Booker-Milburn, K. I. *J. Am. Chem. Soc.* **2008**, *130*, 10066 – 10067.

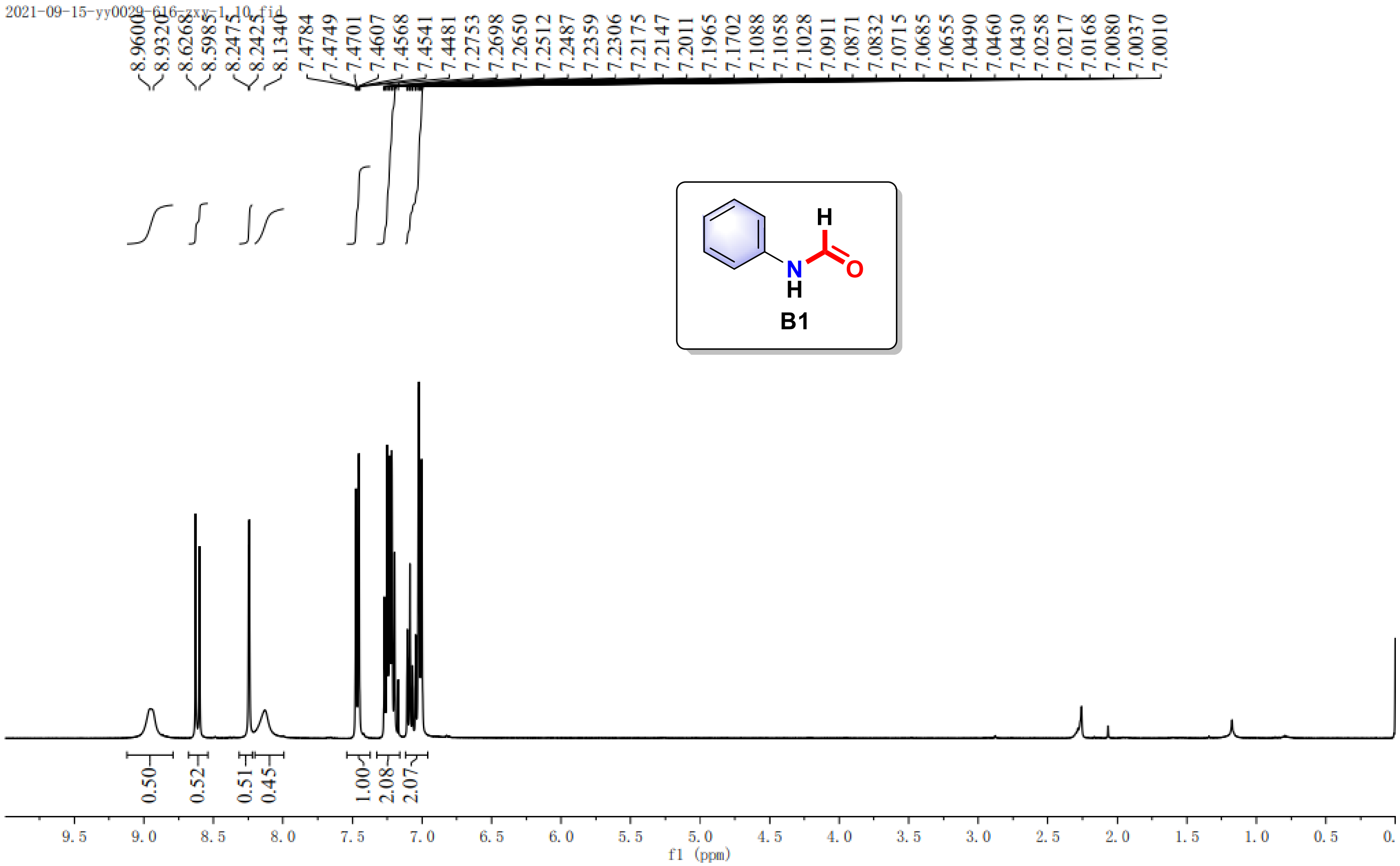
(13) Wang, H.; Shao, Y.; Zheng, H.; Wang, H.; Cheng, J.; Wan, X. *Chem.–Eur. J.* **2013**, *21*. 18333-18337.

(14) Natalia, L.; Patricia, G.; Alejandro, B. *J. Org. Chem.* **2020**, *85*, 11072-11079.

(15) Song, Q.; Wang, Y.; Zhou, Y. *Chem. Commun.* **2020**, *56*, 6106 – 6109.

(16) Polisar, J.G.; Li, L.; Norton, J. R. *Tetrahedron Lett.* **2011**, *52*, 2933 – 2934.

10. NMR Spectra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7.0037
7.0010
H
N
H
O
B1
0.50
0.52
0.51
0.45
1.00
2.08
2.07
9.5
9.0
8.5
8.0
7.5
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6.0
5.5
5.0
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3.5
3.0
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2.0
1.5
1.0
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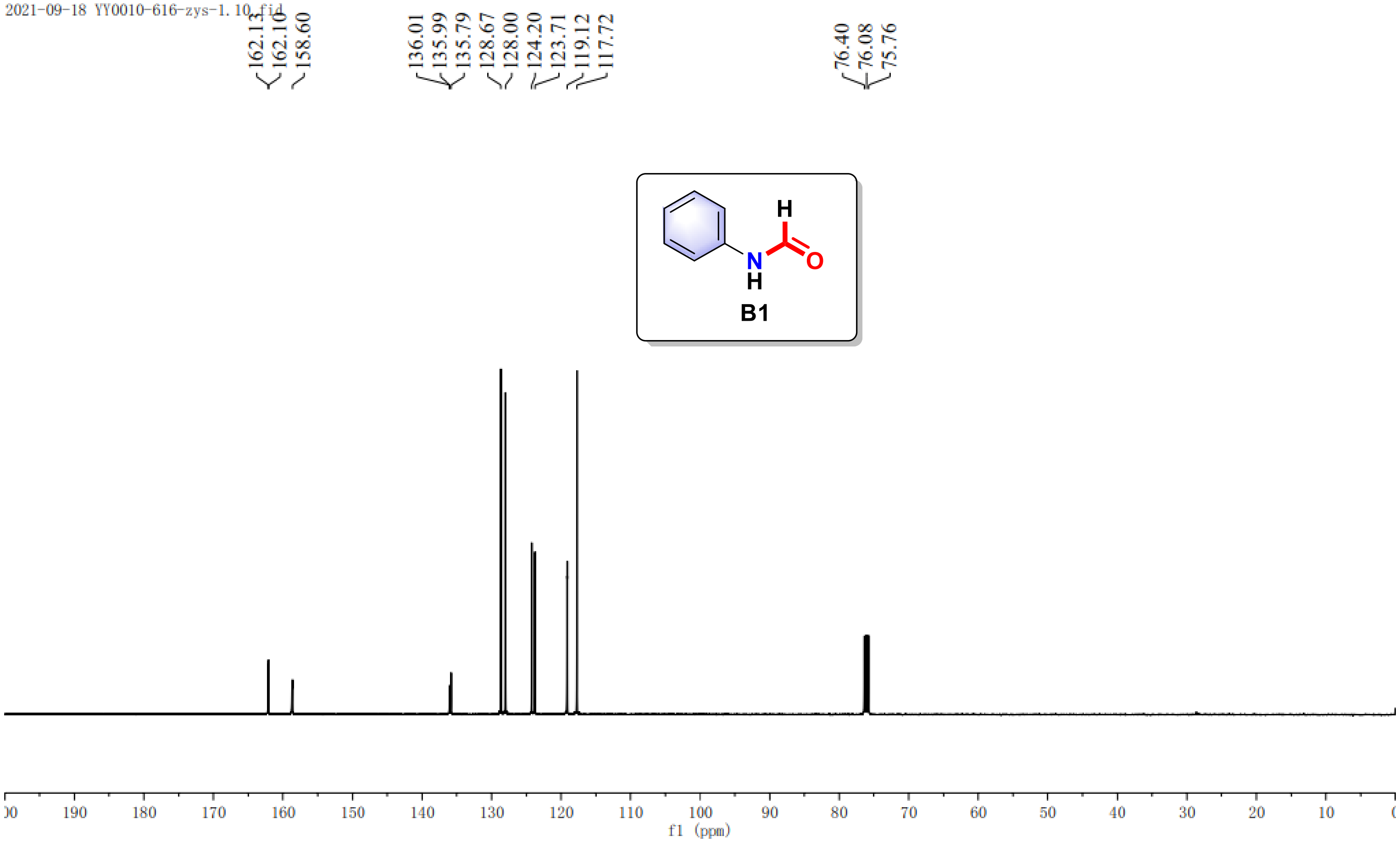
f1 (ppm)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76.08
75.76
H
N
H
O
B1
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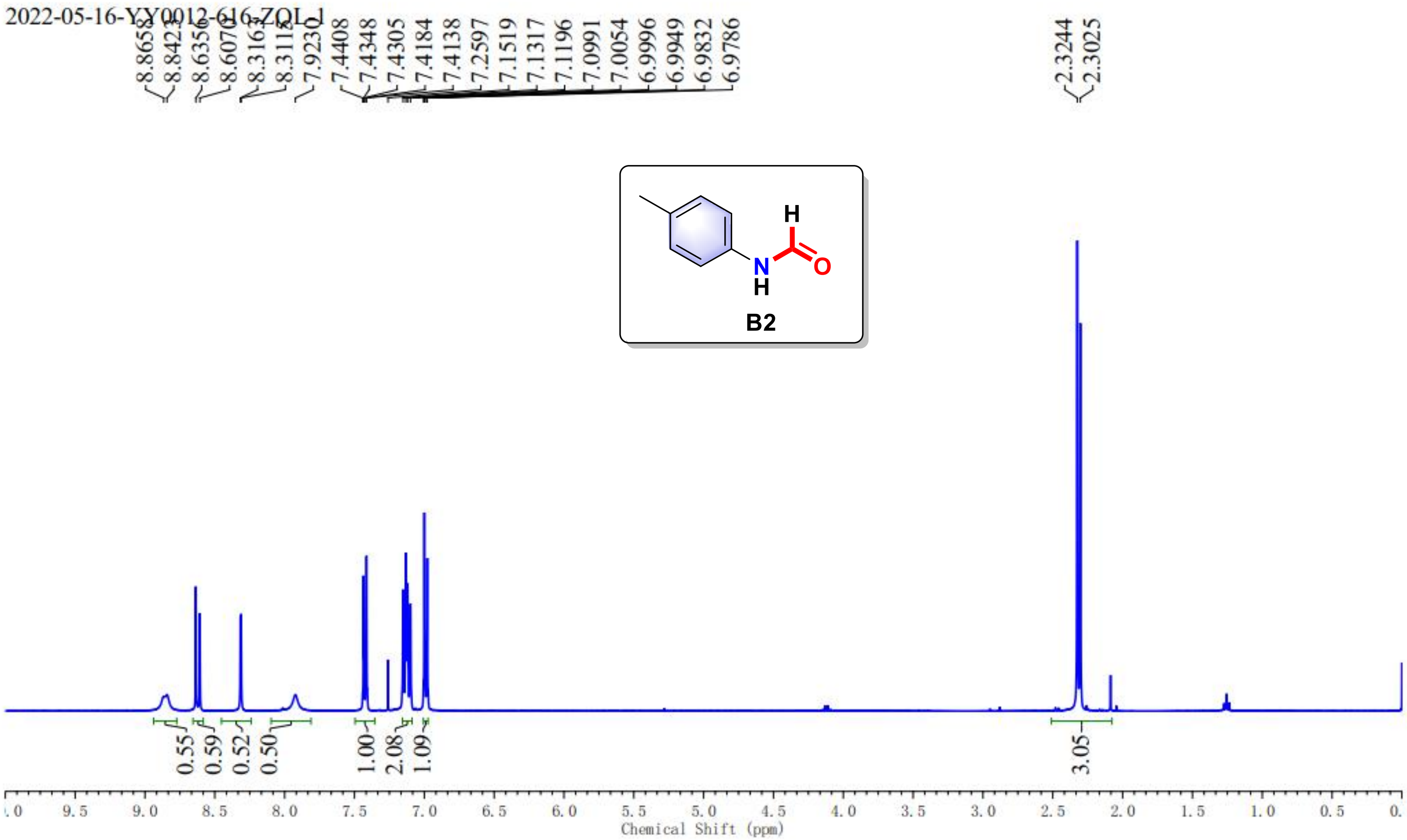
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


2022-05-16-YY0012-616-ZQL-1
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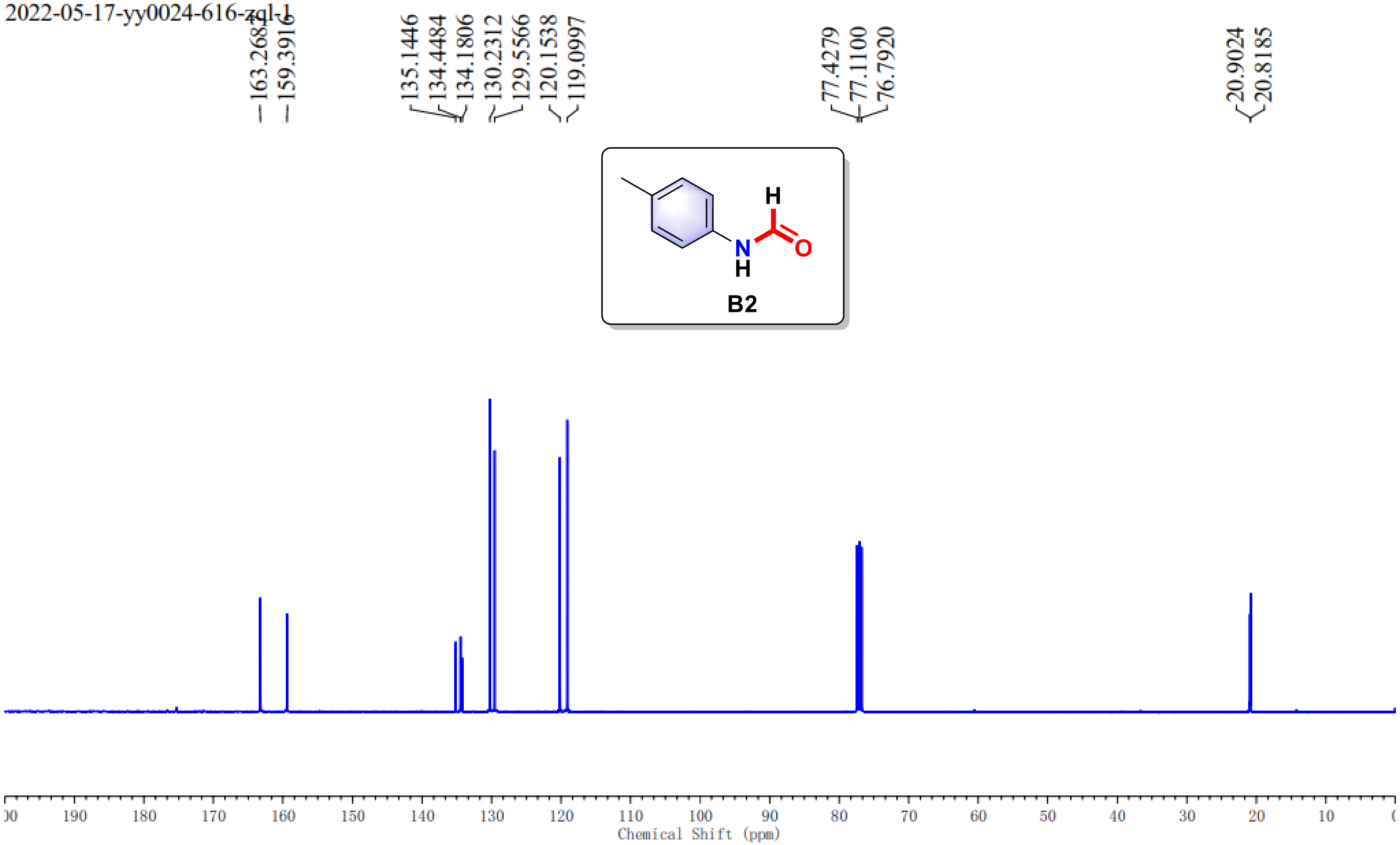
8.8423
8.6356
8.6070
8.3163
8.3118
7.9230
7.4408
7.4348
7.4305
7.4184
7.4138
7.2597
7.1519
7.1317
7.1196
7.0991
7.0054
6.9996
6.9949
6.9832
6.9786
2.3244
2.3025
H
N
H
O
B2
0.55
0.59
0.52
0.50
1.00
2.08
1.09
3.05
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
Chemical Shift (ppm)


2022-05-17-yy0024-616-zql-1
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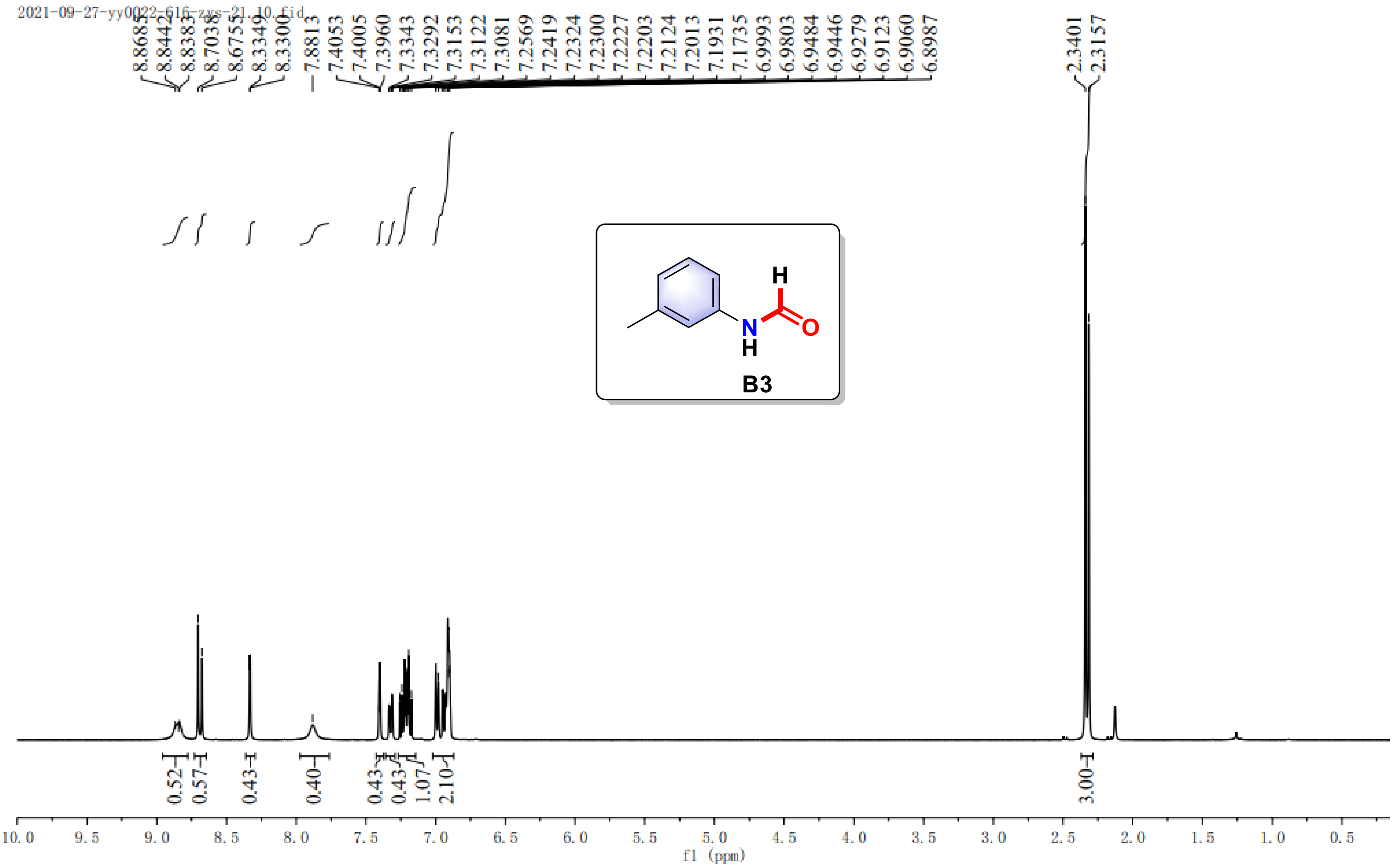
159.3916
135.1446
134.4484
134.1806
130.2312
129.5566
120.1538
119.0997
77.4279
77.1100
76.7920
20.9024
20.8185
H
N
H
O
B2
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Chemical Shift (ppm)


2021-09-27-yy0022-616-zys-21.10.fid
8.8685
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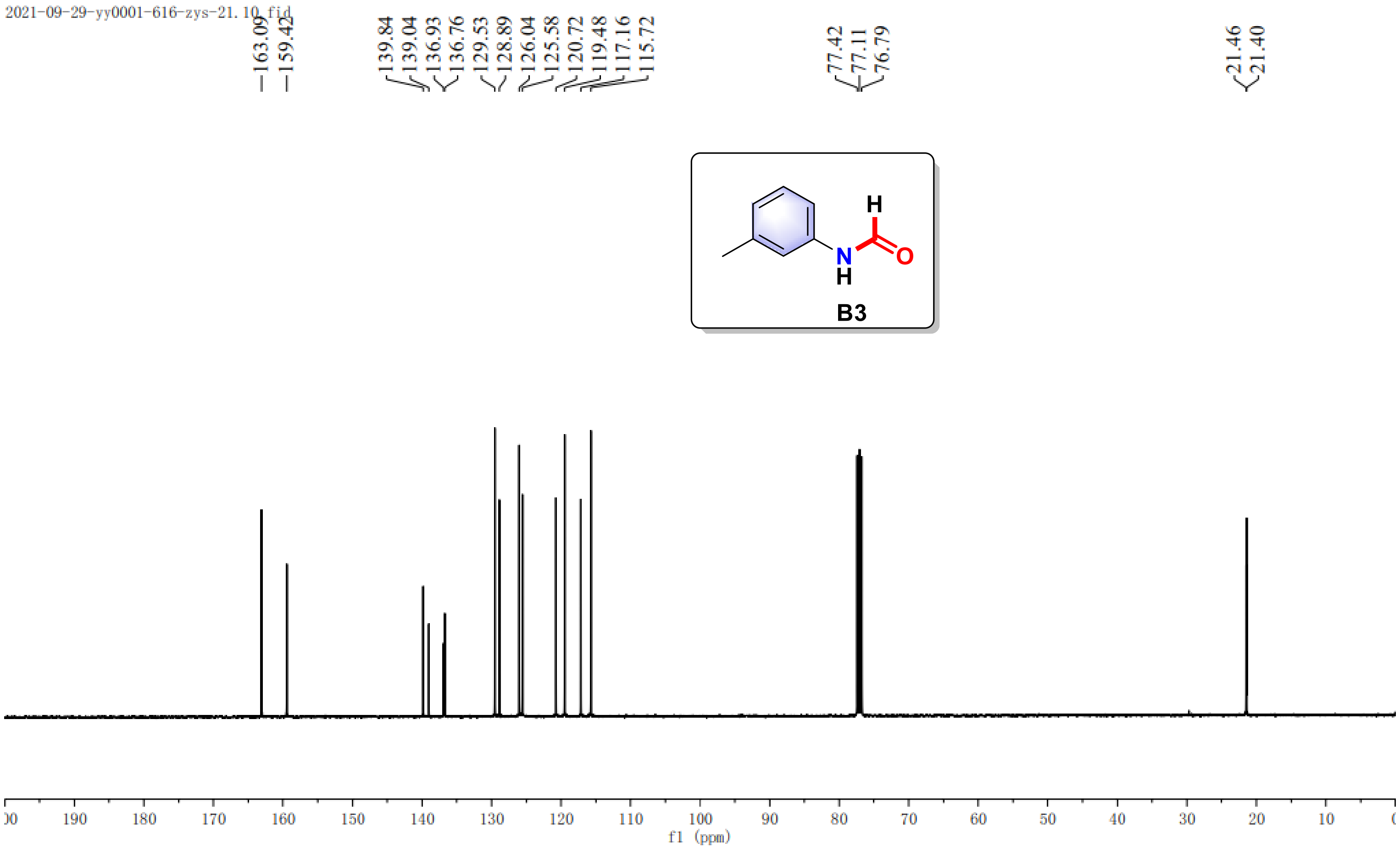
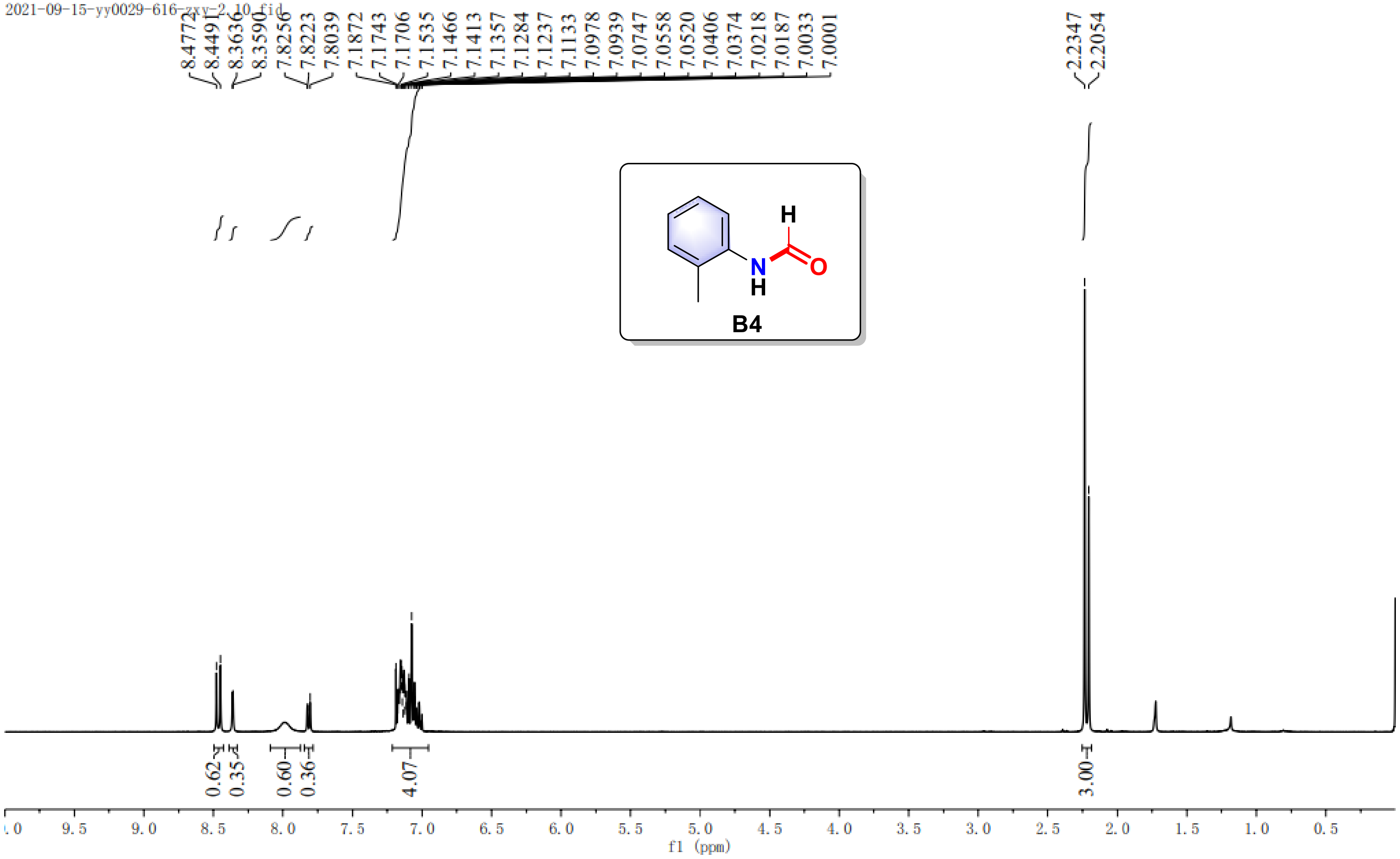
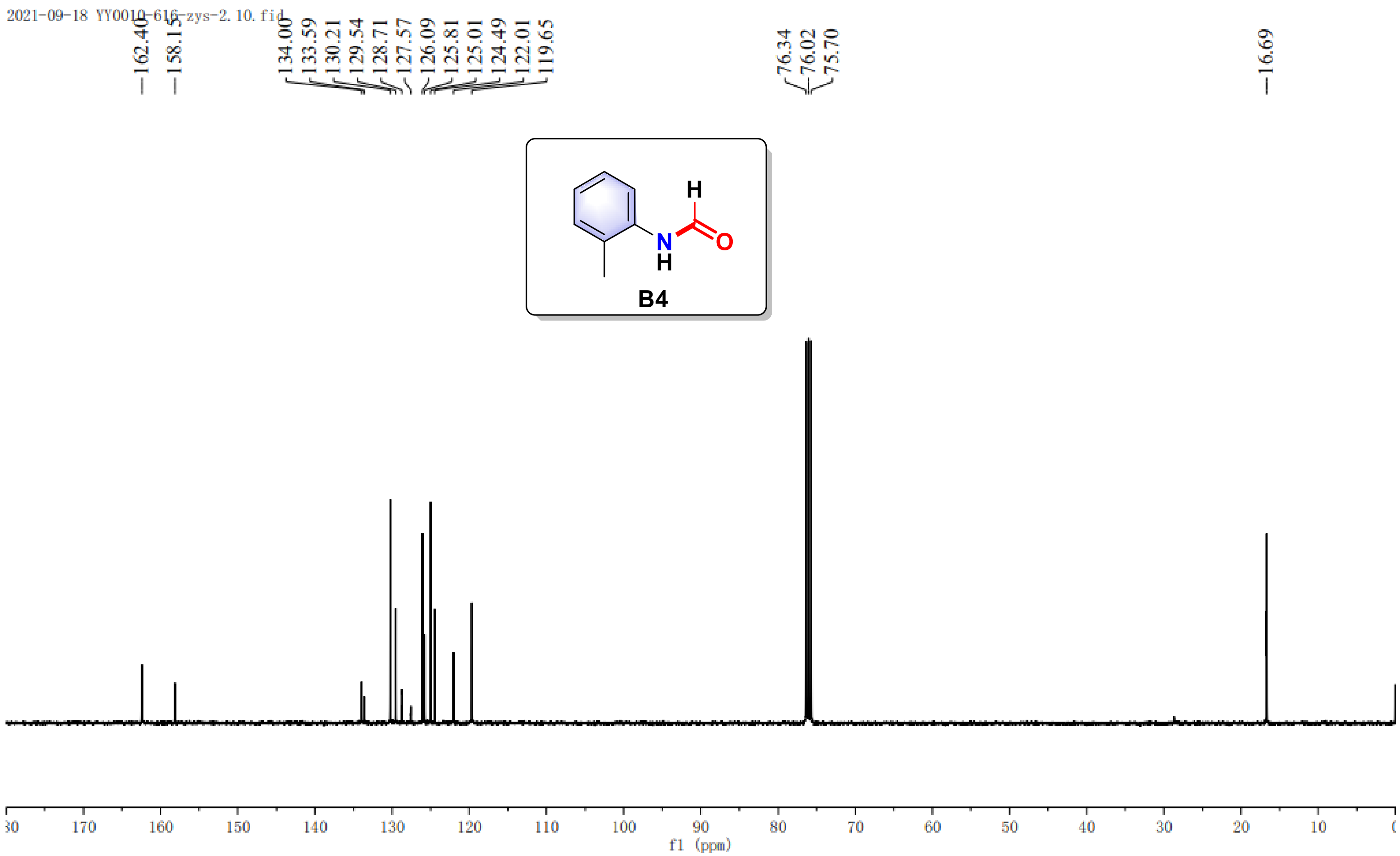
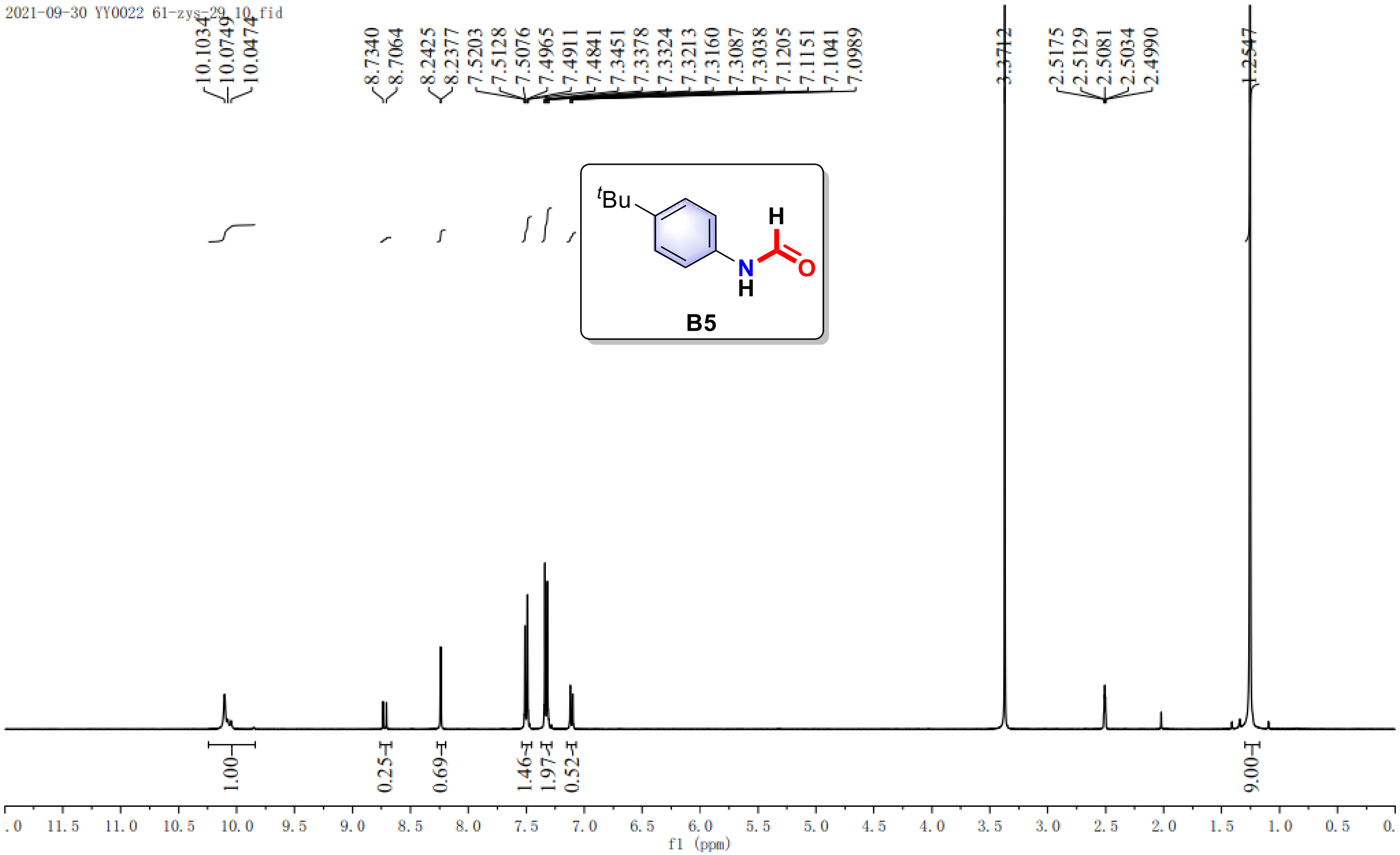
8.8383
8.7038
8.6755
8.3349
8.3300
7.8813
7.4053
7.4005
7.3960
7.3343
7.3292
7.3153
7.3122
7.3081
7.2569
7.2419
7.2324
7.2300
7.2227
7.2203
7.2124
7.2013
7.1931
7.1735
6.9993
6.9803
6.9484
6.9446
6.9279
6.9123
6.9060
6.8987
2.3401
2.3157
H
N
H
O
B3
0.52
0.57
0.43
0.40
0.43
0.43
1.07
2.10
3.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


2021-09-29-yy0001-616-zys-21.10.fid
163.09
159.42
139.84
139.04
136.93
136.76
129.53
128.89
126.04
125.58
120.72
119.48
117.16
115.72
77.42
77.11
76.79
21.46
21.40
H
N
H
O
B3
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


2021-09-15-yy0029-616-zxy-2.10.fid
8.4772
8.4491
8.3636
8.3590
7.8256
7.8223
7.8039
7.1872
7.1743
7.1706
7.1535
7.1466
7.1413
7.1357
7.1284
7.1237
7.1133
7.0978
7.0939
7.0747
7.0558
7.0520
7.0406
7.0374
7.0218
7.0187
7.0033
7.0001
2.2347
2.2054
H
N
H
O
B4
0.62
0.35
0.60
0.36
4.07
3.00
. 0
9. 5
9. 0
8. 5
8. 0
7. 5
7. 0
6. 5
6. 0
5. 5
5. 0
4. 5
4. 0
3. 5
3. 0
2. 5
2. 0
1. 5
1. 0
0. 5
f1 (ppm)


2021-09-18 YY0010-616-zys-2.10.fid
162.40
158.15
134.00
133.59
130.21
129.54
128.71
127.57
126.09
125.81
125.01
124.49
122.01
119.65
76.34
76.02
75.70
16.69
H
N
H
O
B4
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


2021-09-30 YY0022 61-zys-29 10 fid
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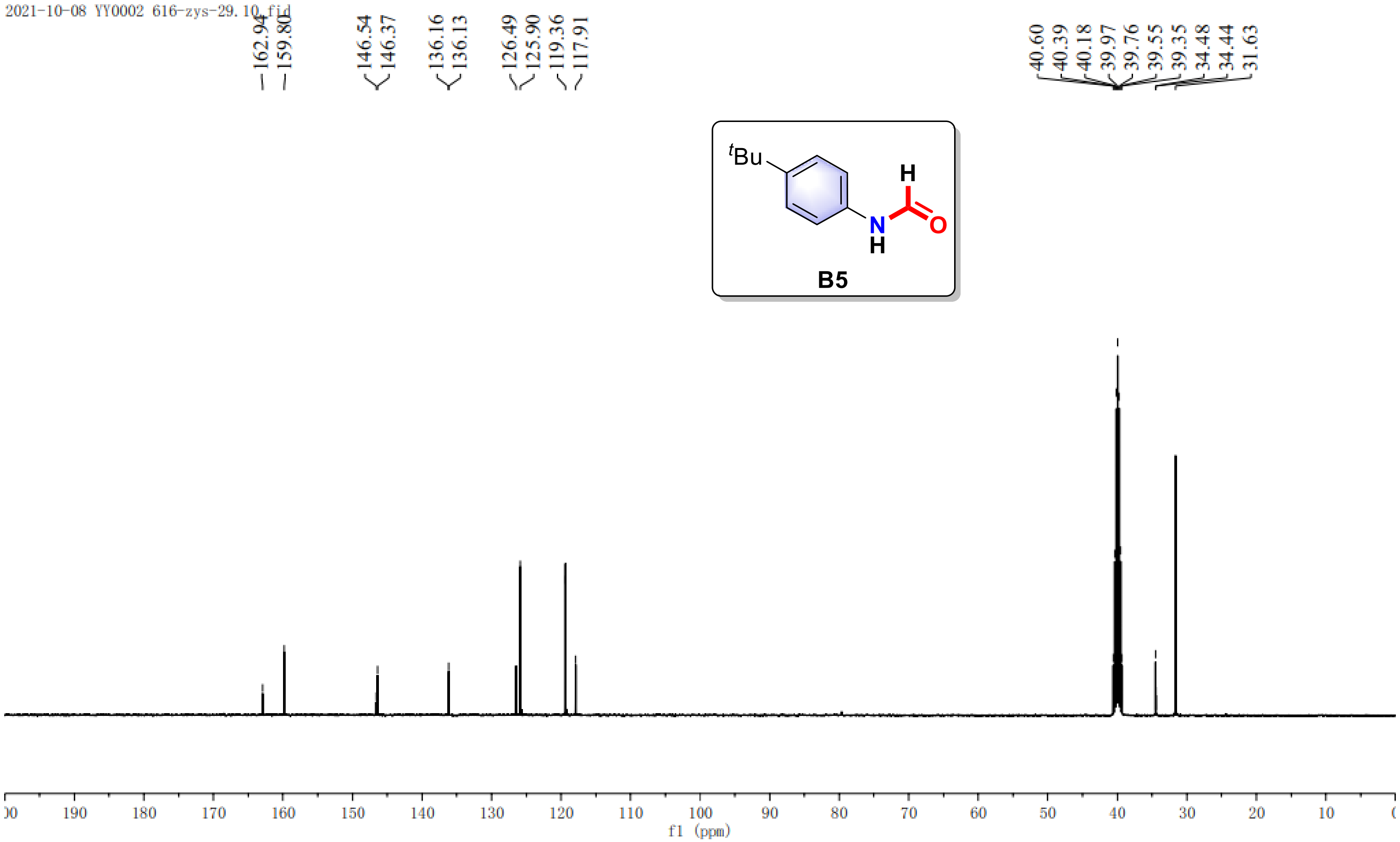
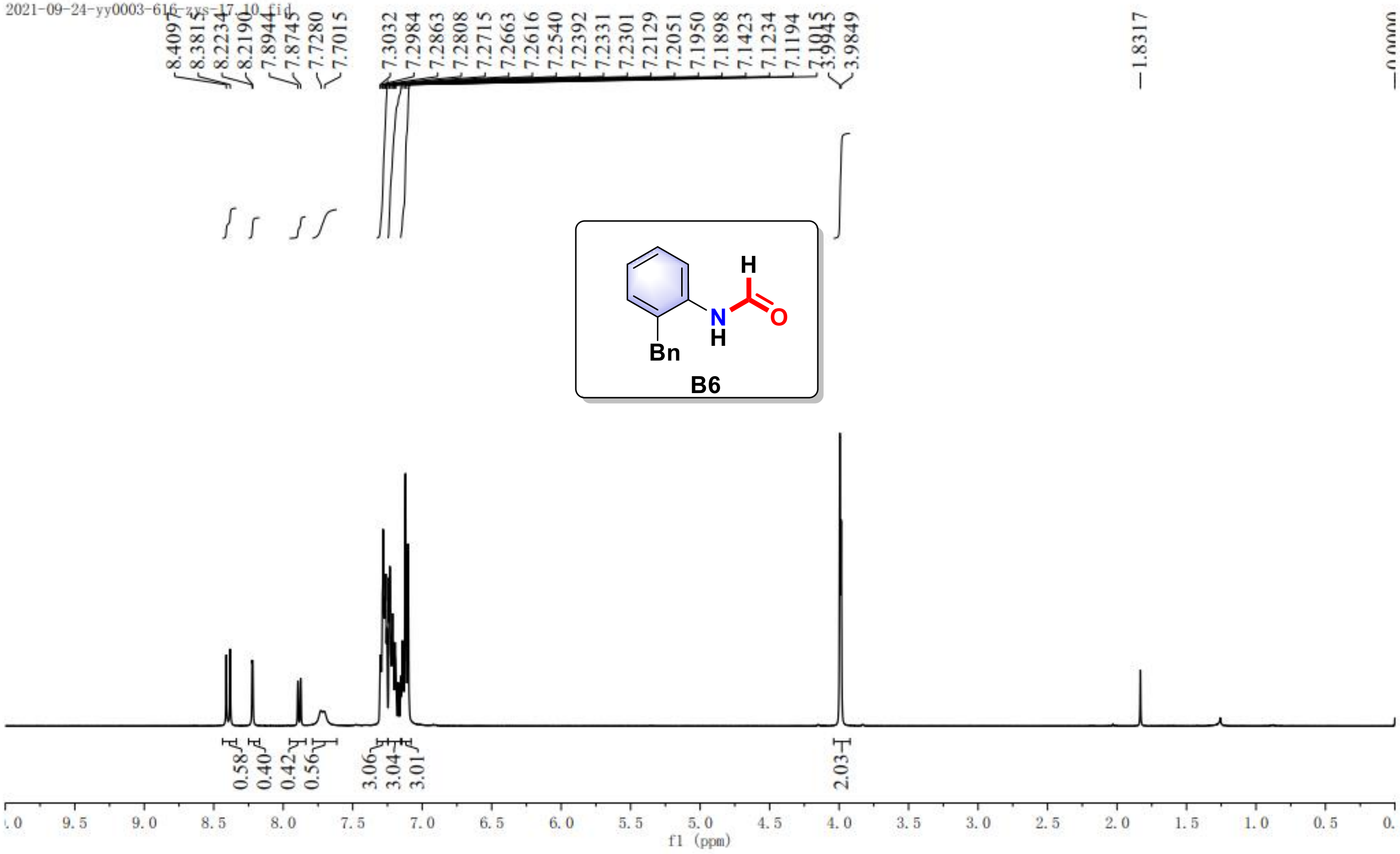
10.0749
10.0474
8.7340
8.7064
8.2425
8.2377
7.5203
7.5128
7.5076
7.4965
7.4911
7.4841
7.3451
7.3378
7.3324
7.3213
7.3160
7.3087
7.3038
7.1205
7.1151
7.1041
7.0989
3.3712
2.5175
2.5129
2.5081
2.5034
2.4990
1.2547
tBu
N
H
H
O
B5
1.00
0.25
0.69
1.46
1.97
0.52
9.00
.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)


2021-10-08 YY0002 616-zys-29.10.fid
162.94
159.80
146.54
146.37
136.16
136.13
126.49
125.90
119.36
117.91
40.60
40.39
40.18
39.97
39.76
39.55
39.35
34.48
34.44
31.63
tBu
H
N
H
O
B5
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


2021-09-24-yy0003-616-zys-17.10.fid
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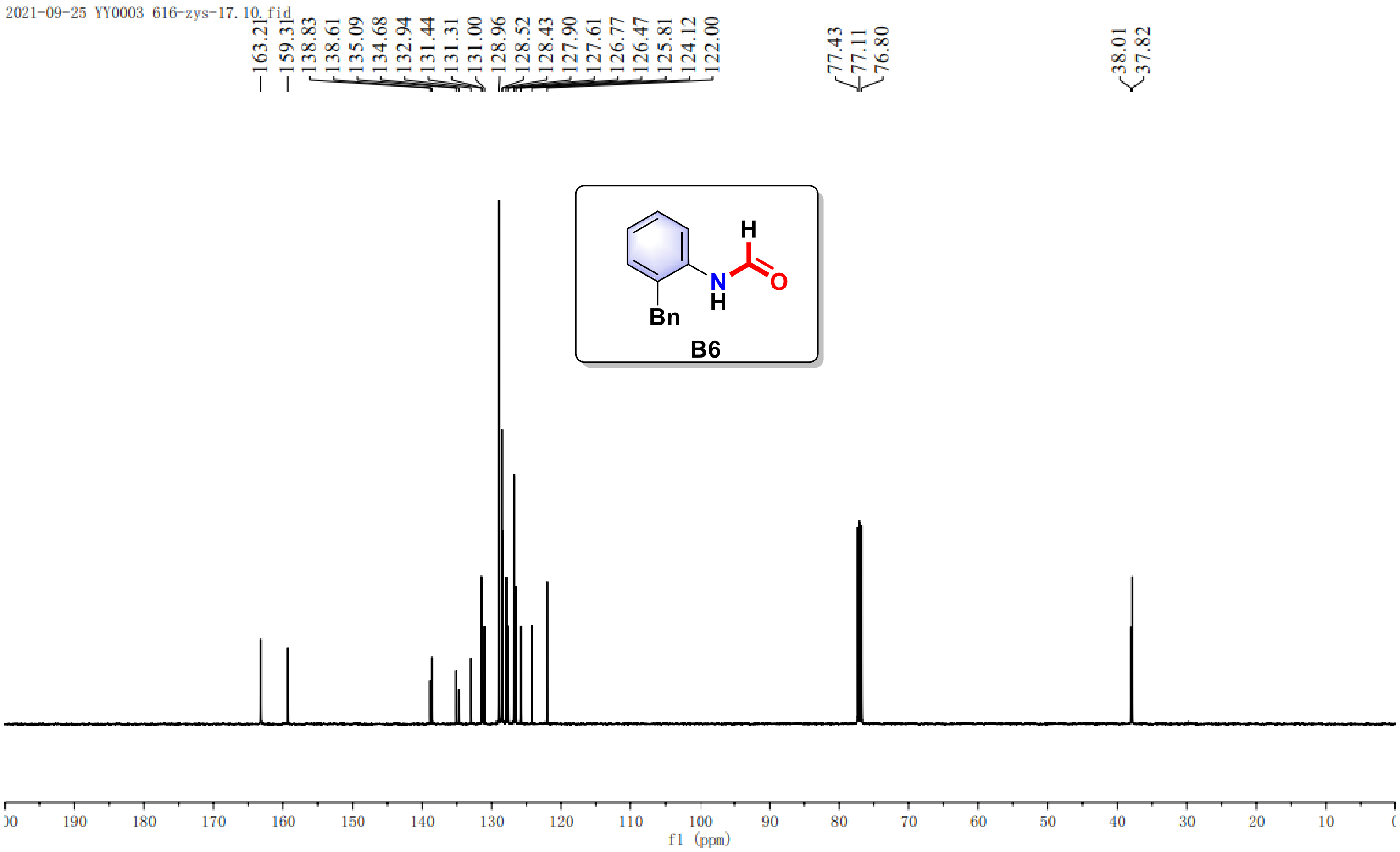
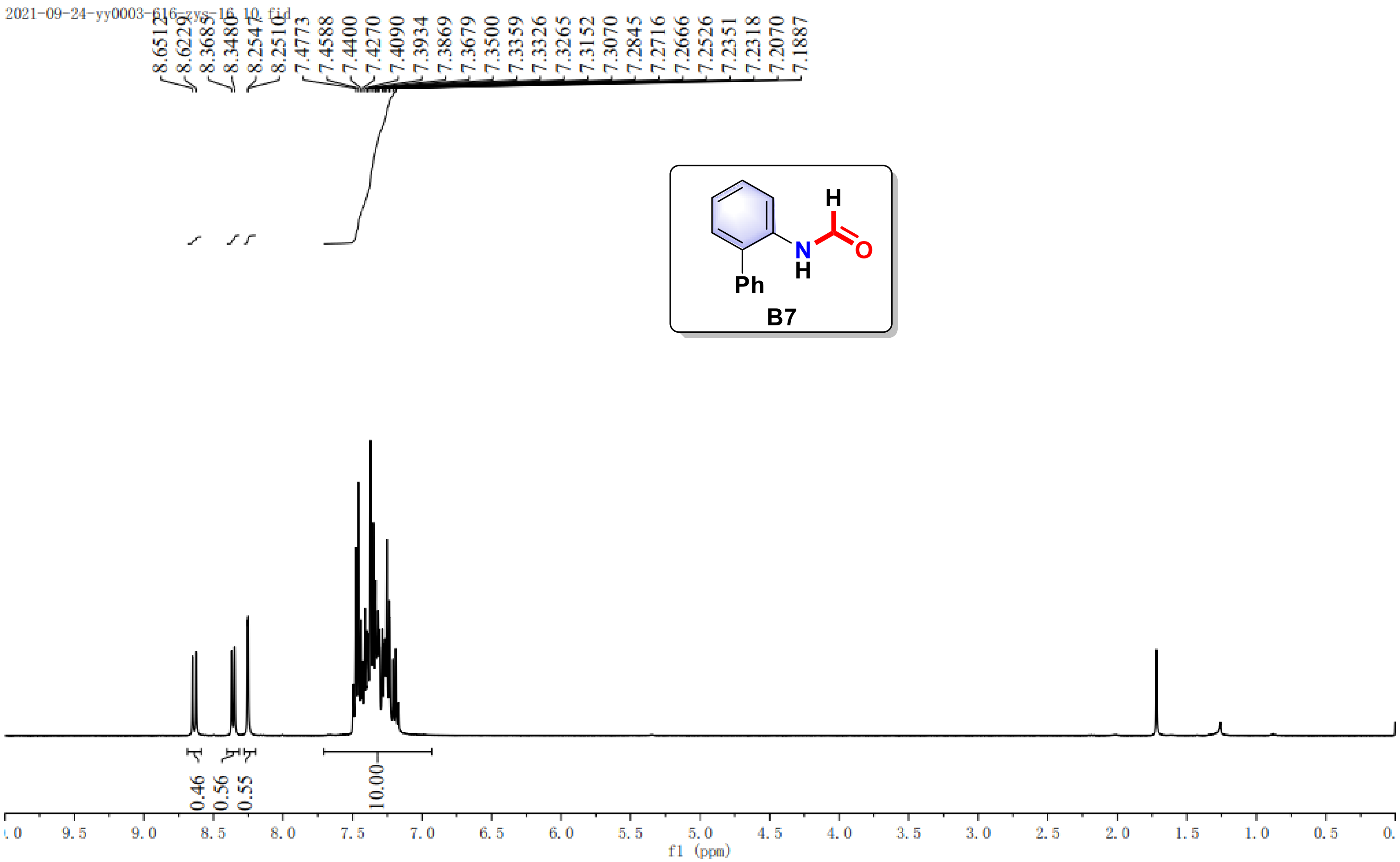
8.3815
8.2234
8.2190
7.8944
7.8745
7.7280
7.7015
7.3032
7.2984
7.2863
7.2808
7.2715
7.2663
7.2616
7.2540
7.2392
7.2331
7.2301
7.2129
7.2051
7.1950
7.1898
7.1423
7.1234
7.1194
7.1015
3.9945
3.9849
1.8317
0.0000
H
N
H
O
Bn
B6
0.58
0.40
0.42
0.56
3.06
3.04
3.01
2.03
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


2021-09-25 YY0003 616-zys-17.10.fid
163.21
159.31
138.83
138.61
135.09
134.68
132.94
131.44
131.31
131.00
128.96
128.52
128.43
127.90
127.61
126.77
126.47
125.81
124.12
122.00
77.43
77.11
76.80
38.01
37.82
H
N
H
O
Bn
B6
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


2021-09-24-yy0003-616-zys-16.10.fid
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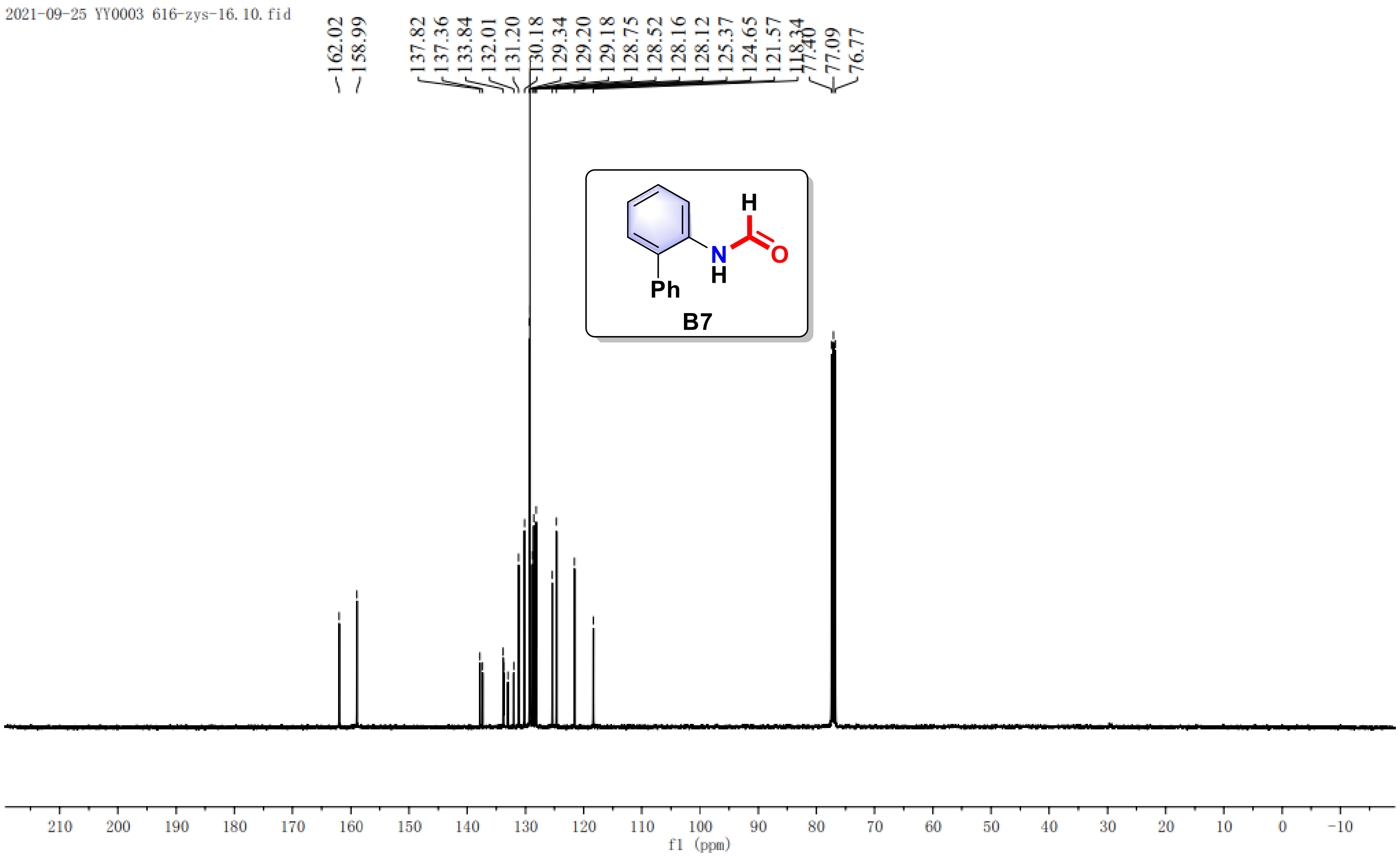
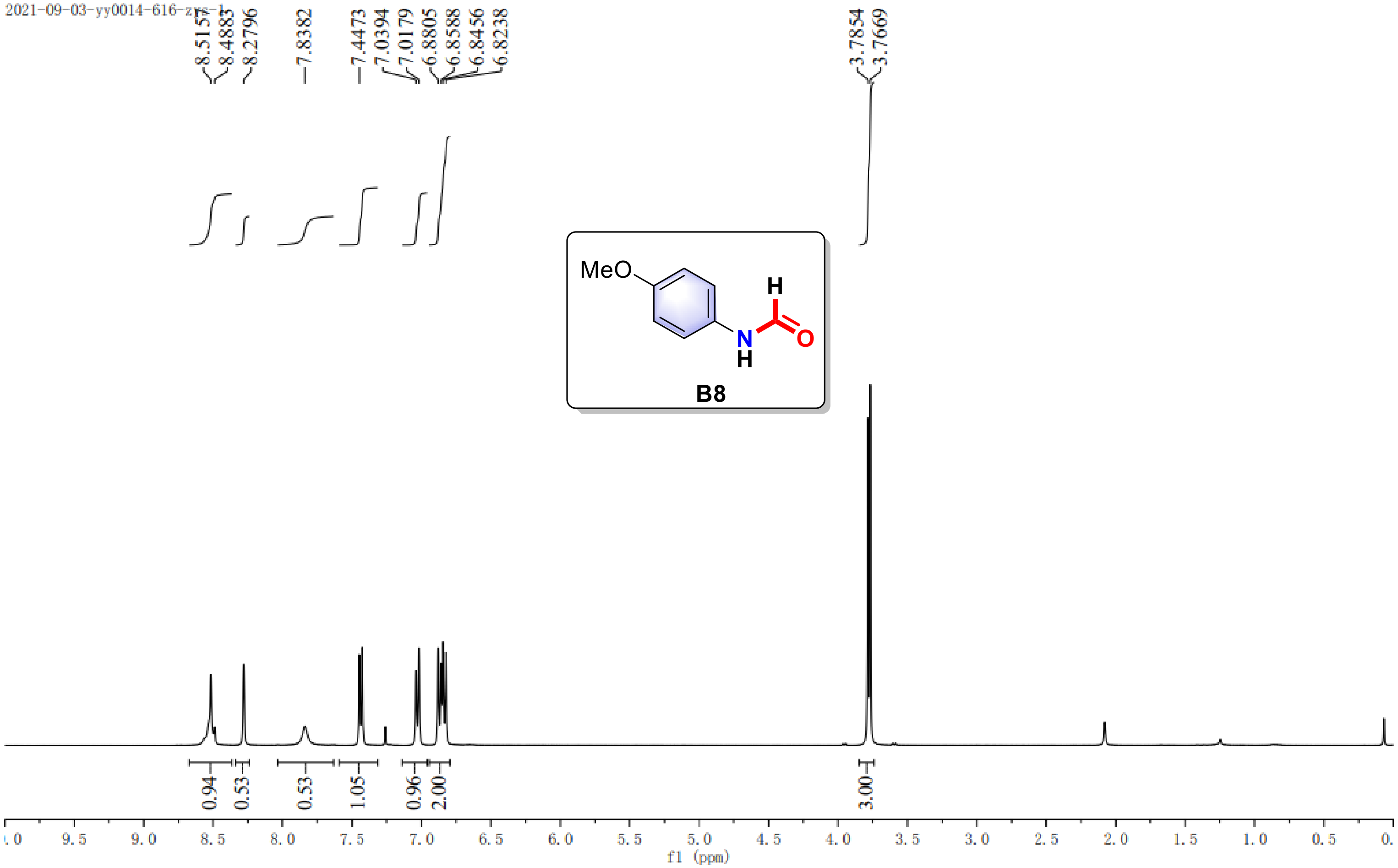
8.6229
8.3685
8.3480
8.2547
8.2510
7.4773
7.4588
7.4400
7.4270
7.4090
7.3934
7.3869
7.3679
7.3500
7.3359
7.3326
7.3265
7.3152
7.3070
7.2845
7.2716
7.2666
7.2526
7.2351
7.2318
7.2070
7.1887
H
N
H
O
Ph
0.46
0.56
0.55
10.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

B7


2021-09-25 YY0003 616-zys-16.10.fid
162.02
158.99
137.82
137.36
133.84
132.01
131.20
130.18
129.34
129.20
129.18
128.75
128.52
128.16
128.12
125.37
124.65
121.57
118.34
77.40
77.09
76.77
H
N
H
O
Ph
B7
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

2021-09-03-yy0014-616-zys-1
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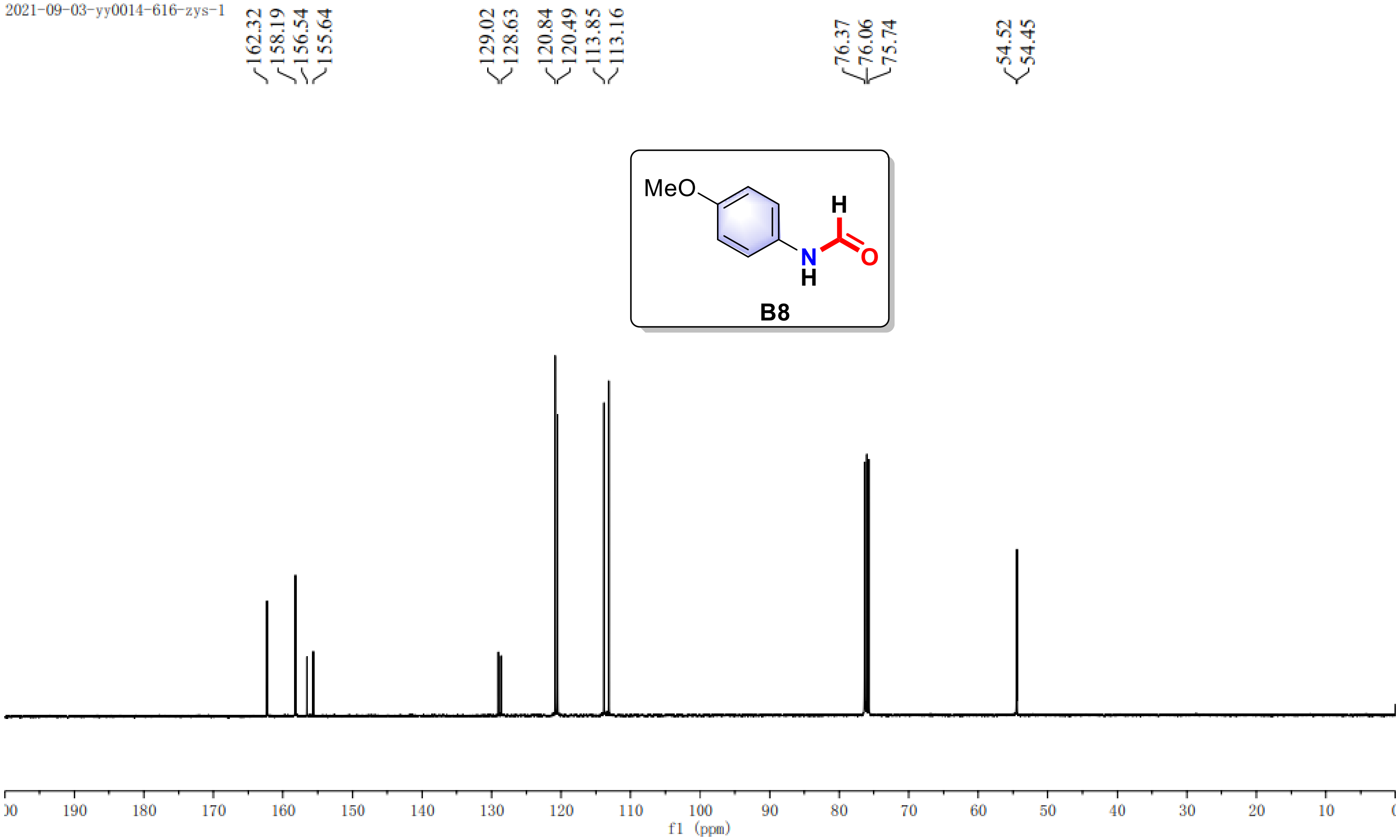
7.4473
7.0394
7.0179
6.8805
6.8588
6.8456
6.8238
3.7854
3.7669
MeO
H
N
H
O
B8
0.94
0.53
0.53
1.05
0.96
2.00
3.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


2021-09-03-yy0014-616-zys-1
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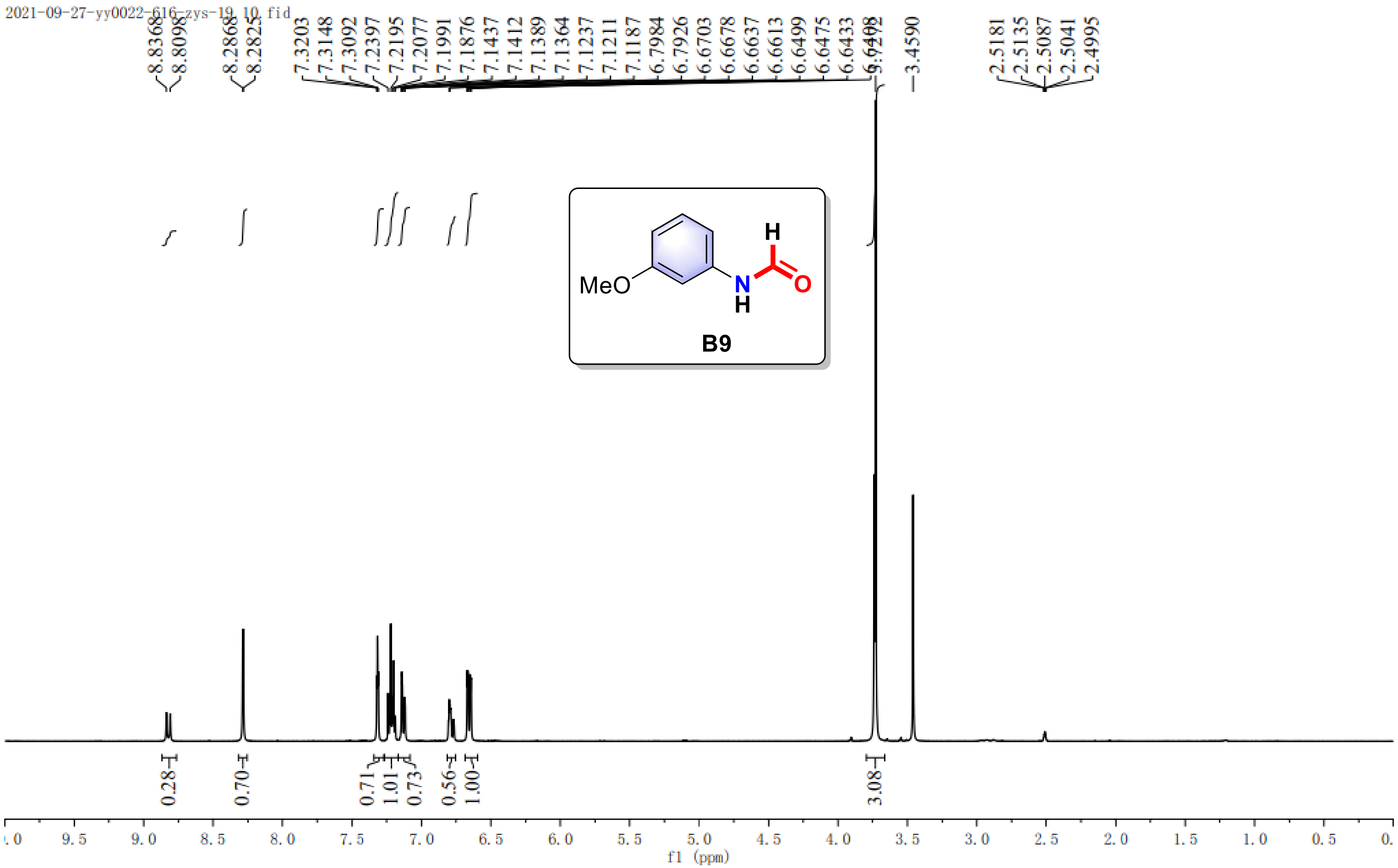
158.19
156.54
155.64
129.02
128.63
120.84
120.49
113.85
113.16
76.37
76.06
75.74
54.52
54.45
MeO
H
N
H
O
B8
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


2021-09-27-yy0022-616-zys-19.10.fid
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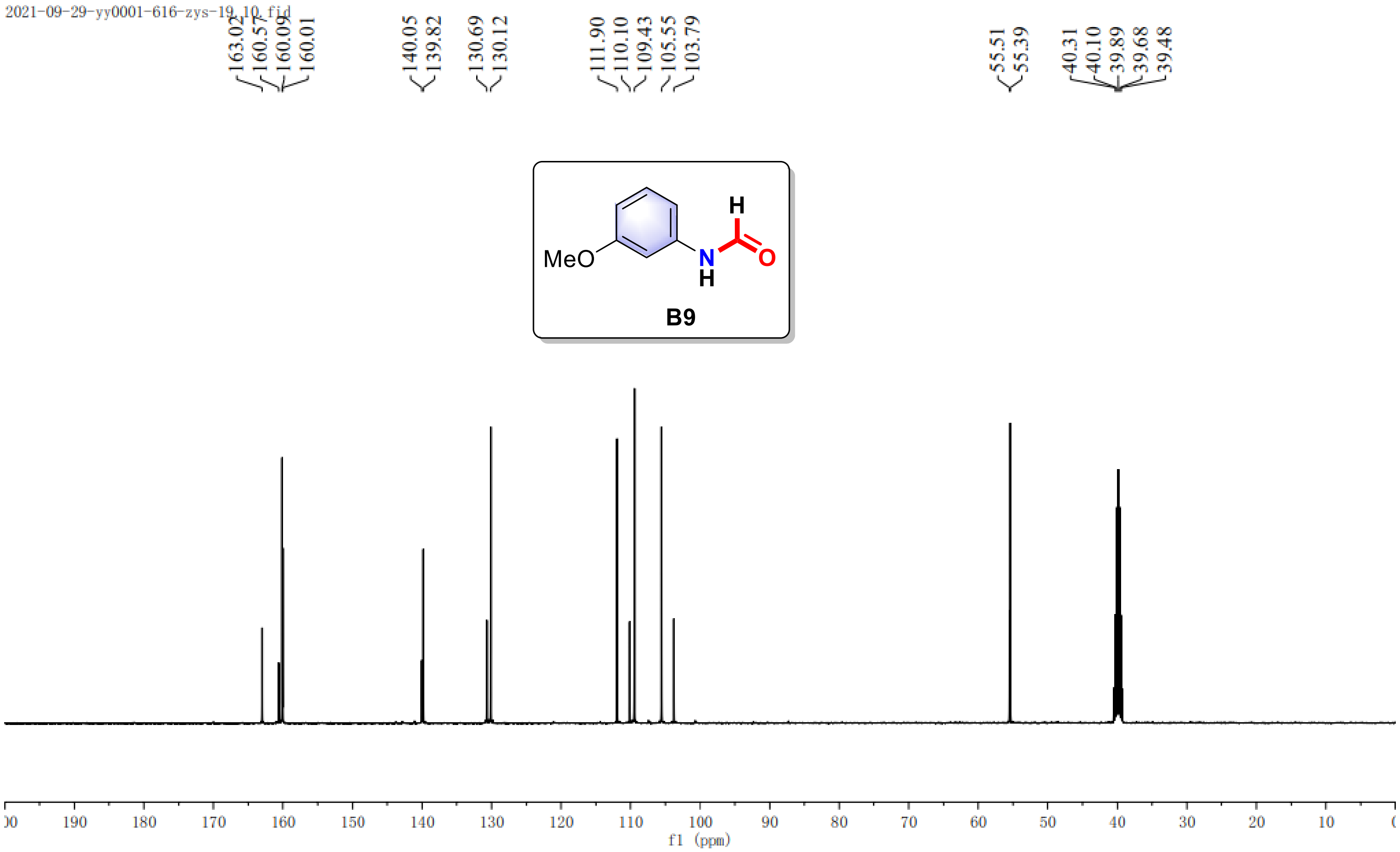
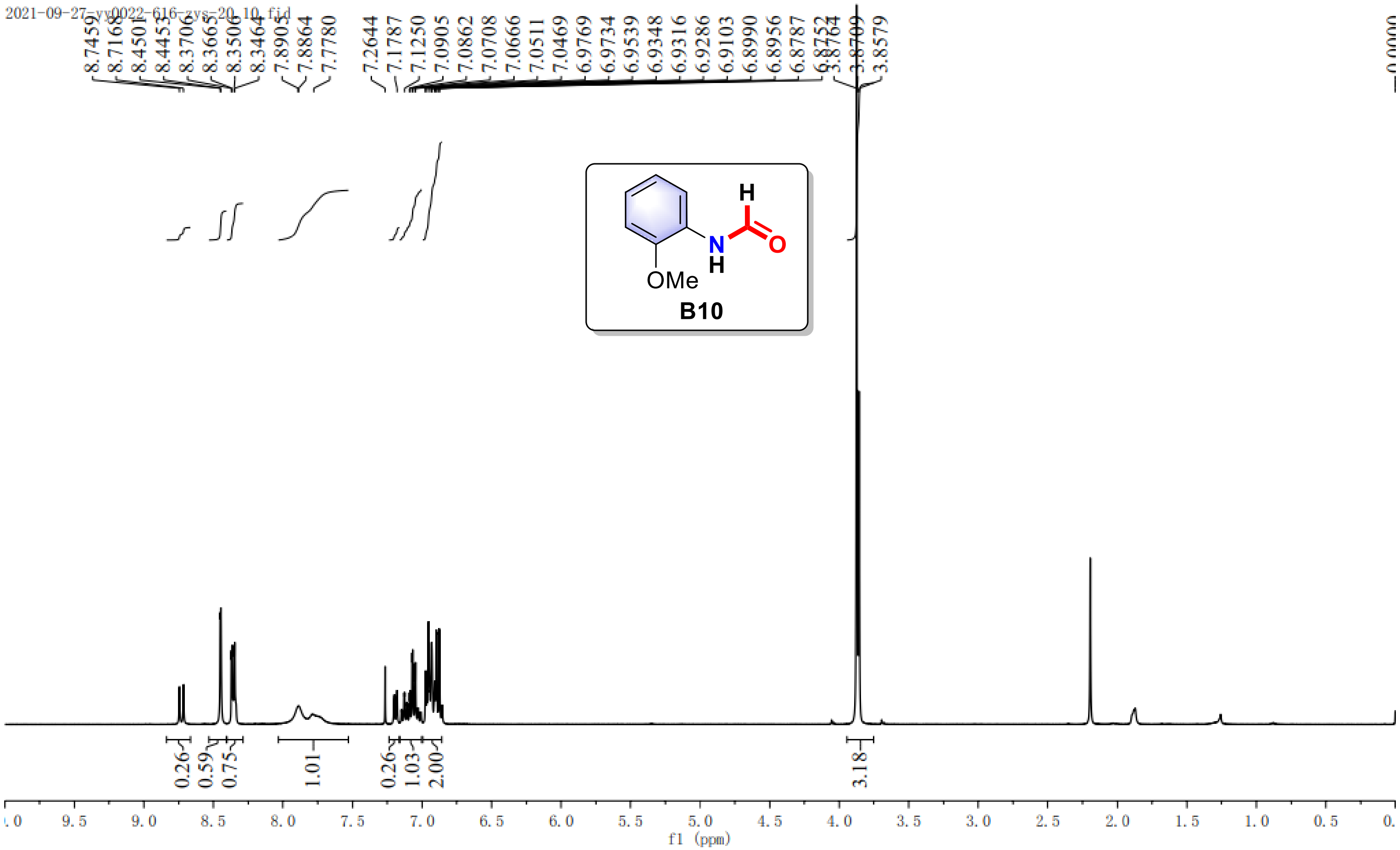
8.8098
8.2868
8.2825
7.3203
7.3148
7.3092
7.2397
7.2195
7.2077
7.1991
7.1876
7.1437
7.1412
7.1389
7.1364
7.1237
7.1211
7.1187
6.7984
6.7926
6.6703
6.6678
6.6637
6.6613
6.6499
6.6475
6.6433
6.6408
3.7272
3.4590
2.5181
2.5135
2.5087
2.5041
2.4995
MeO
H
N
H
O
B9
0.28
0.70
0.71
1.01
0.73
0.56
1.00
3.08
.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)


2021-09-29-yy0001-616-zys-19.10.fid
163.02
160.57
160.09
160.01
140.05
139.82
130.69
130.12
111.90
110.10
109.43
105.55
103.79
55.51
55.39
40.31
40.10
39.89
39.68
39.48
MeO
N
H
H
O
B9
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


2021-09-27-yy0022-616-zys-20_10.fid
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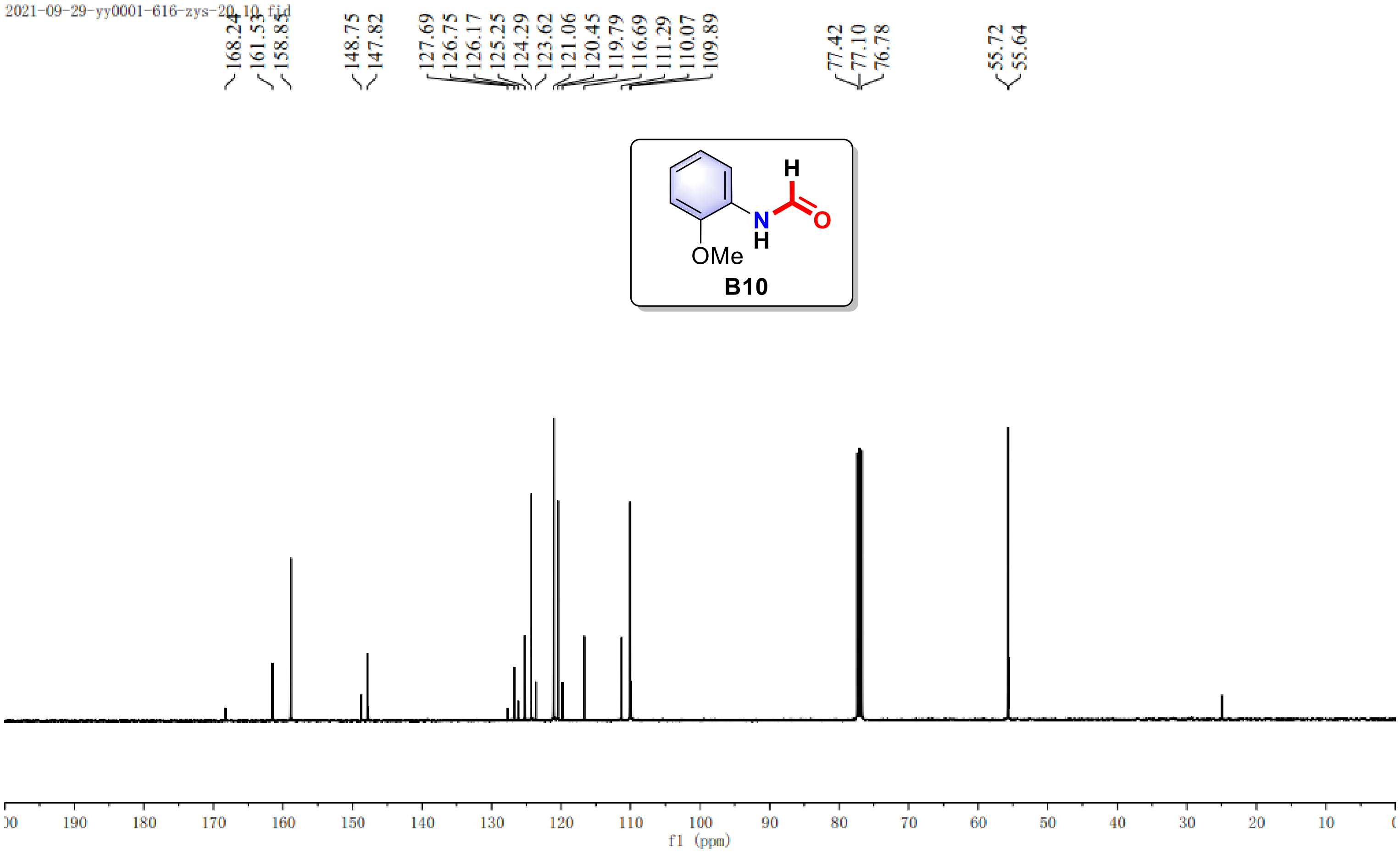
8.4501
8.4453
8.3706
8.3665
8.3506
8.3464
7.8905
7.8864
7.7780
7.2644
7.1787
7.1250
7.0905
7.0862
7.0708
7.0666
7.0511
7.0469
6.9769
6.9734
6.9539
6.9348
6.9316
6.9286
6.9103
6.8990
6.8956
6.8787
6.8752
3.8764
3.8709
3.8579
0.0000
H
N
H
O
OMe
B10
0.26
0.59
0.75
1.01
0.26
1.03
2.00
3.18
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)


2021-09-29-yy0001-616-zys-20.10.fid
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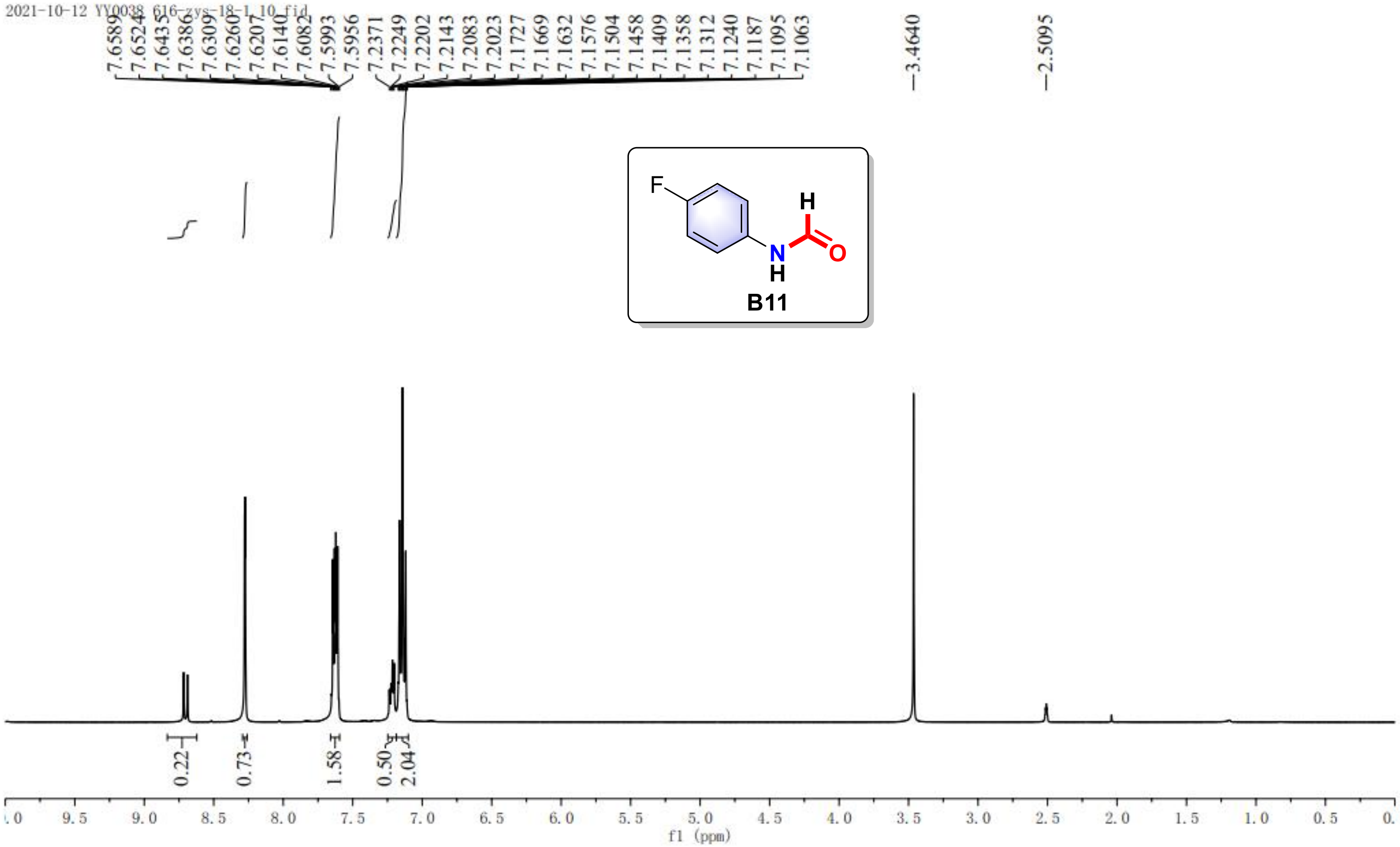
161.53
158.85
148.75
147.82
127.69
126.75
126.17
125.25
124.29
123.62
121.06
120.45
119.79
116.69
111.29
110.07
109.89
77.42
77.10
76.78
55.72
55.64
H
N
H
O
OMe
B10
00
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


2021-10-12 YY0038 616-zys-18-1.10.fid
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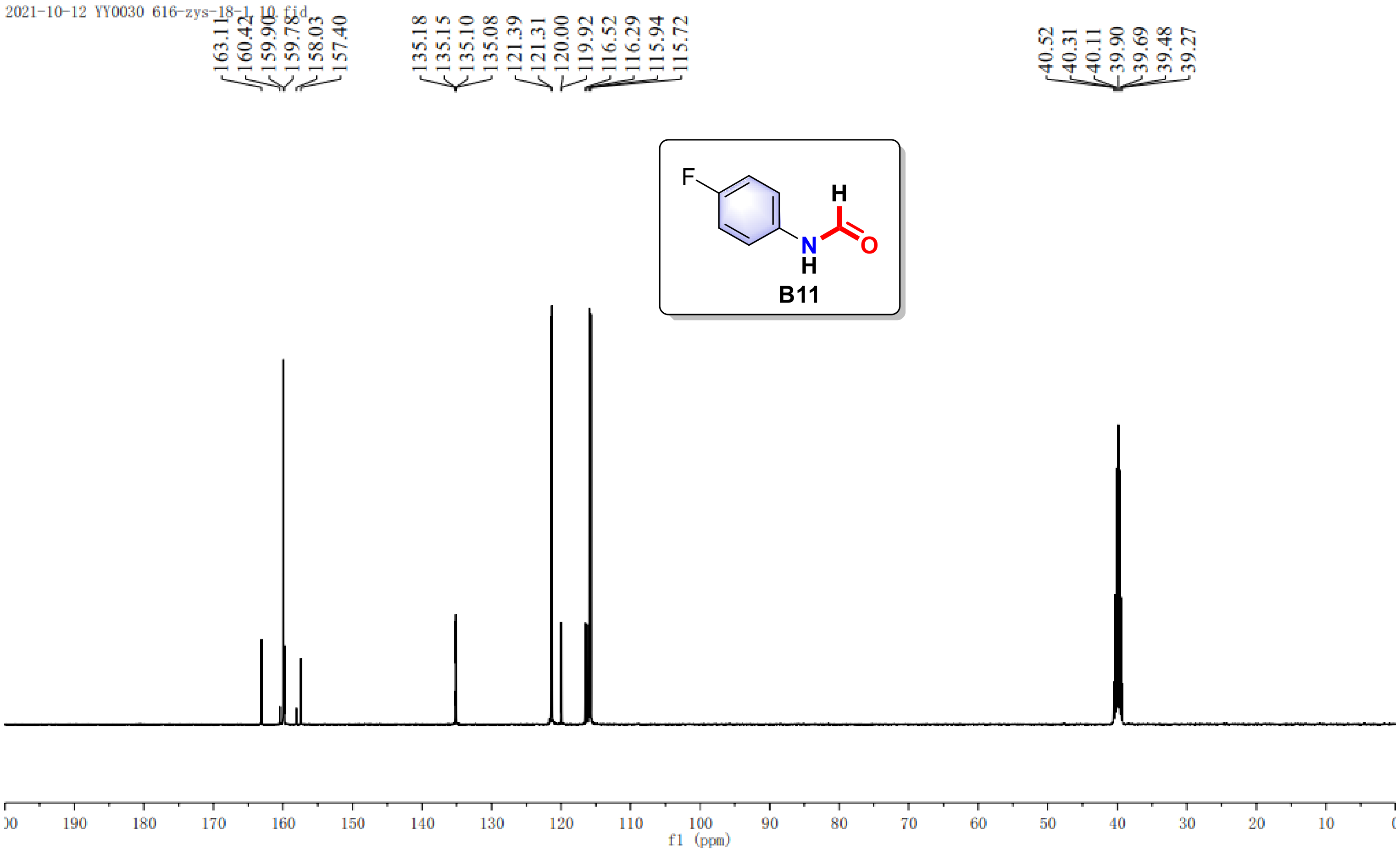
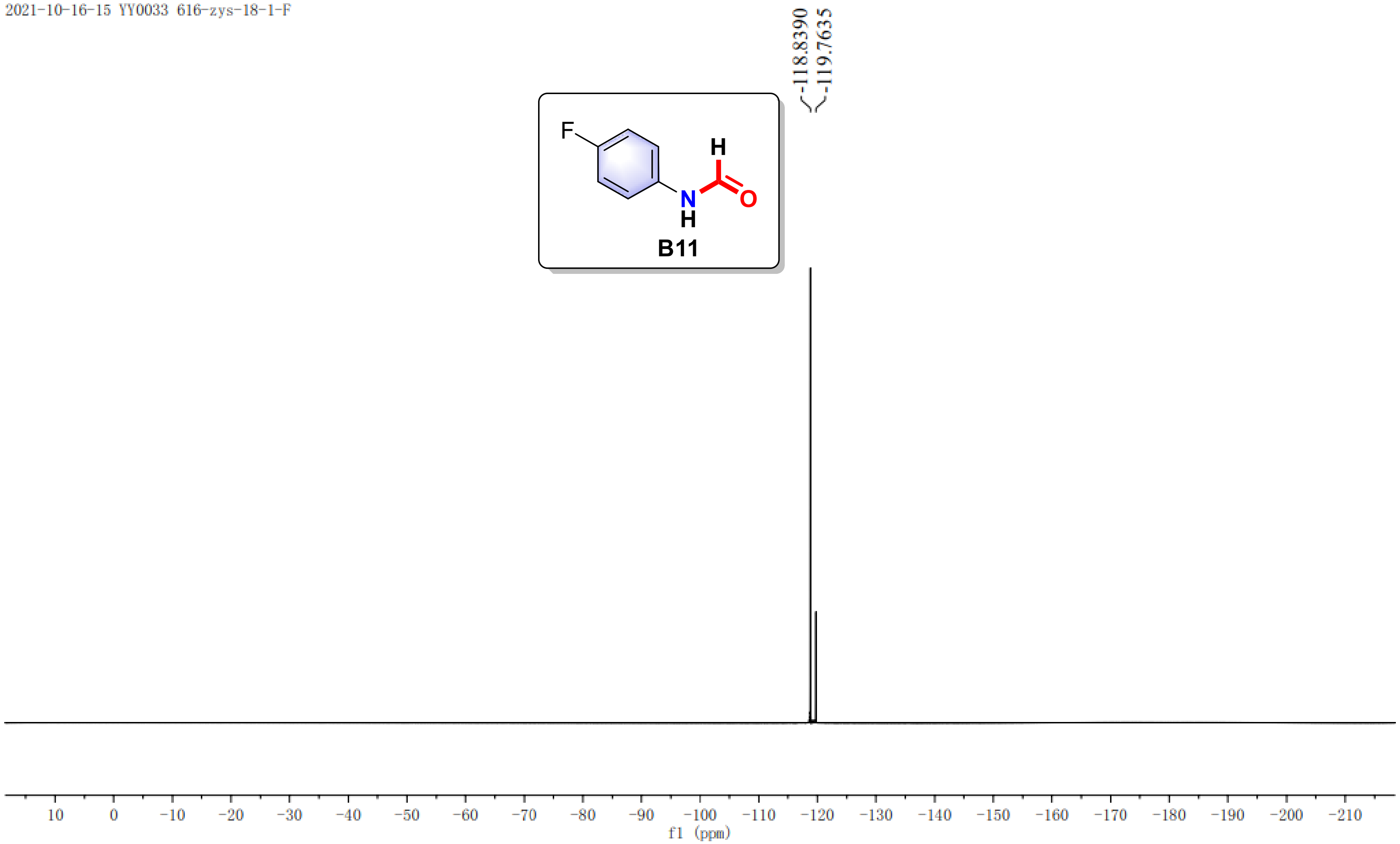
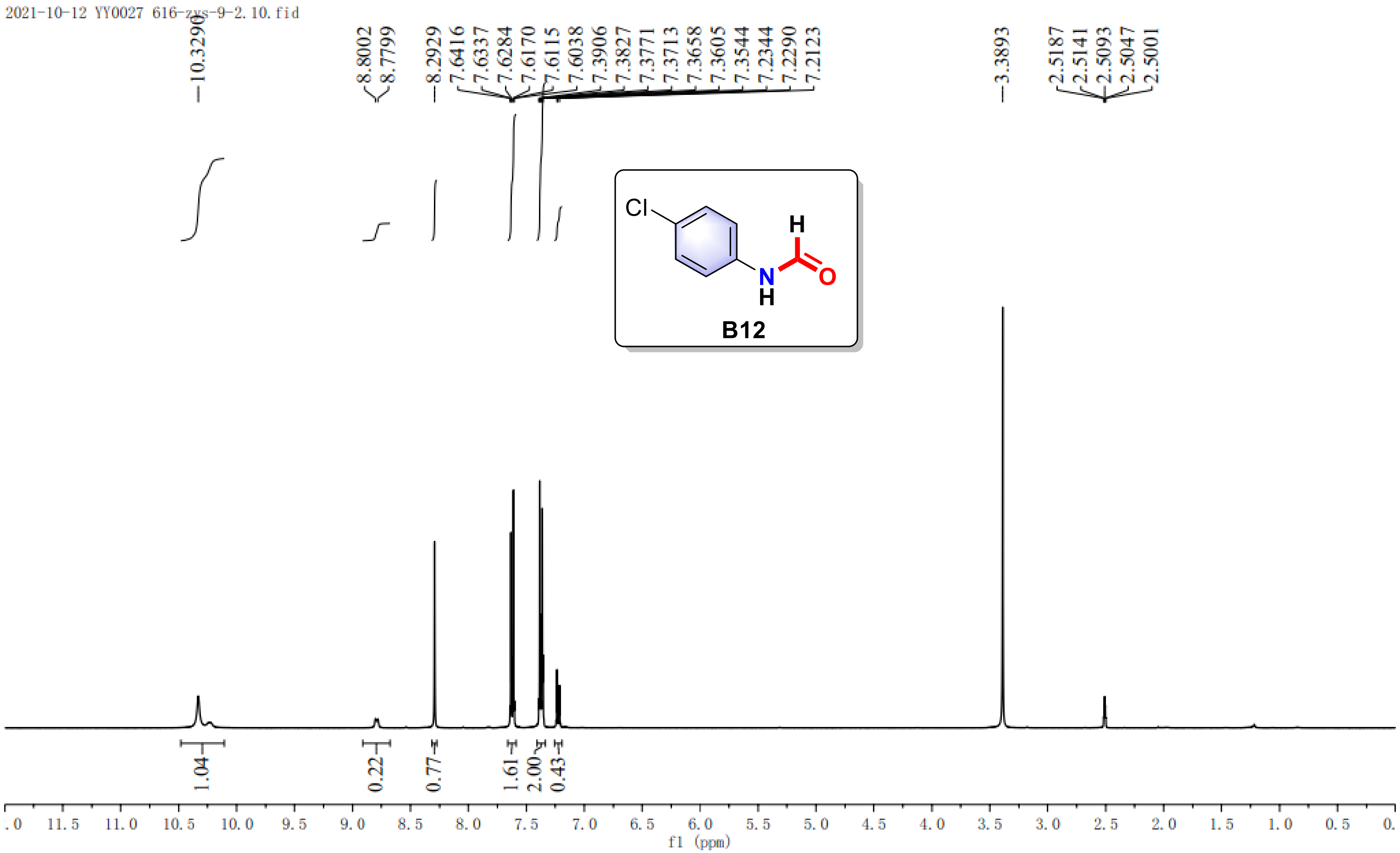
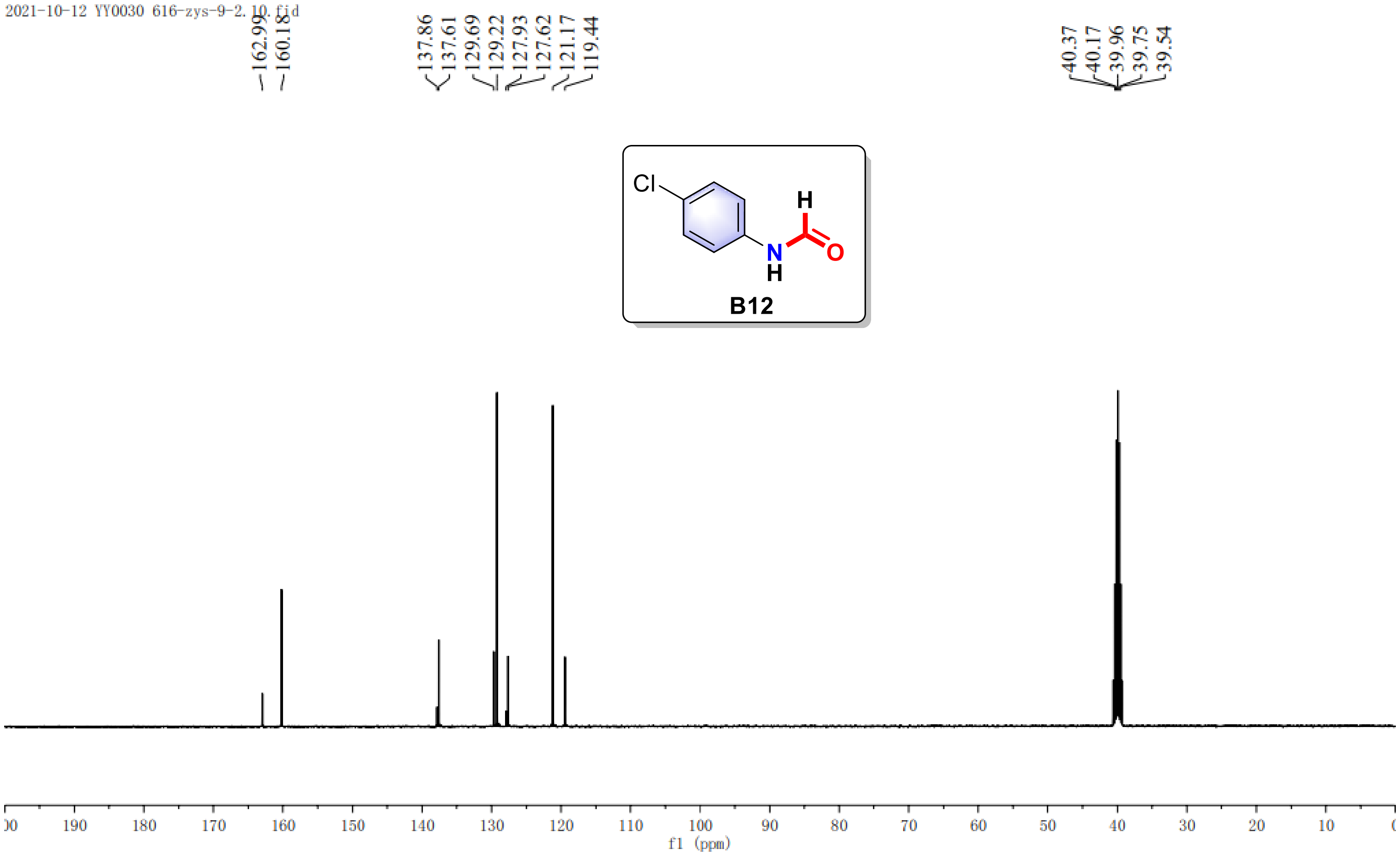
7.6524
7.6435
7.6386
7.6309
7.6260
7.6207
7.6140
7.6082
7.5993
7.5956
7.2371
7.2249
7.2202
7.2143
7.2083
7.2023
7.1727
7.1669
7.1632
7.1576
7.1504
7.1458
7.1409
7.1358
7.1312
7.1240
7.1187
7.1095
7.1063
3.4640
2.5095
F
H
N
H
O
B11
0.22
0.73
1.58
0.50
2.04
.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)

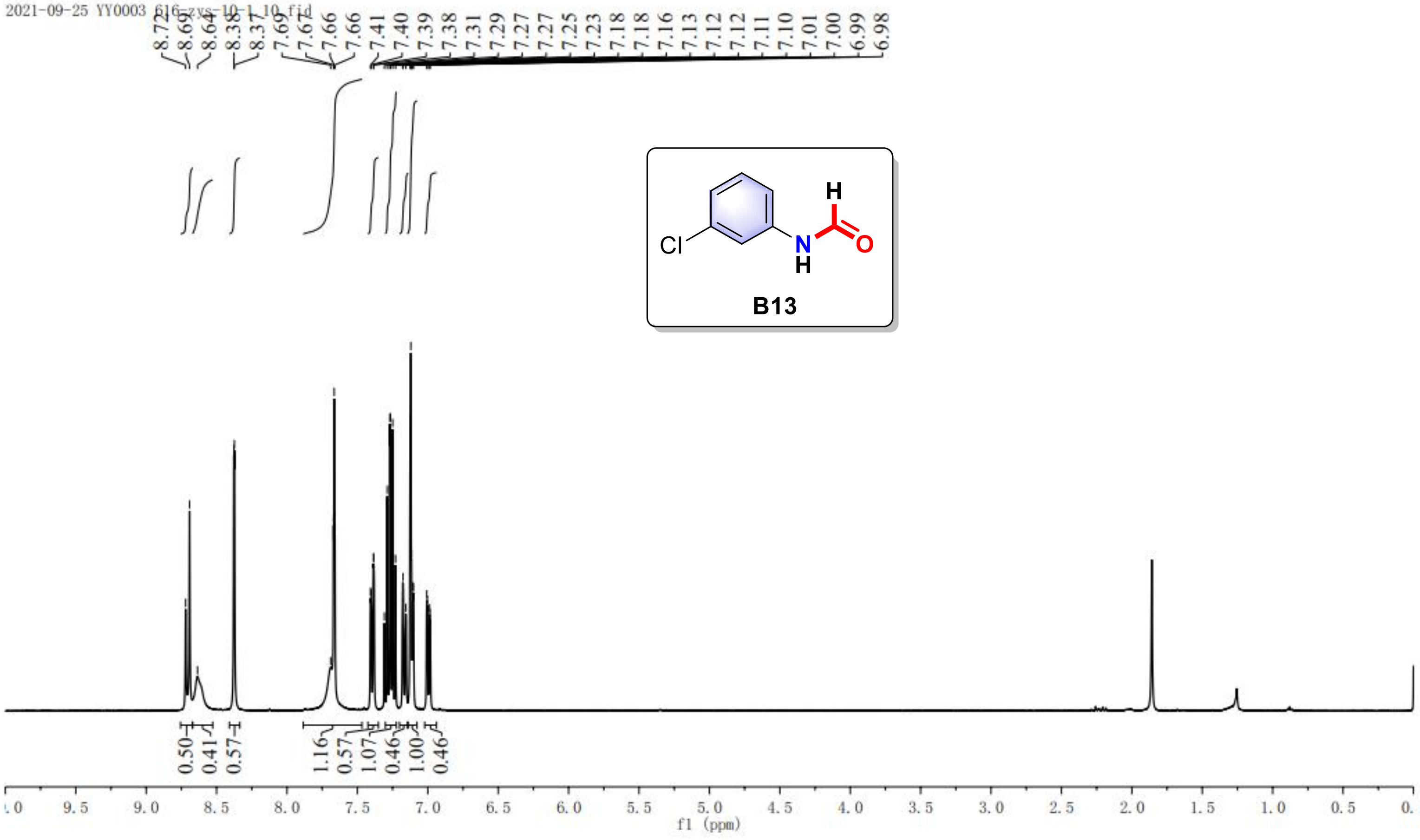

2021-10-12 YY0030 616-zys-18-1.10.fid
163.11
160.42
159.90
159.78
158.03
157.40
135.18
135.15
135.10
135.08
121.39
121.31
120.00
119.92
116.52
116.29
115.94
115.72
40.52
40.31
40.11
39.90
39.69
39.48
39.27
F
H
N
H
O
B11
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

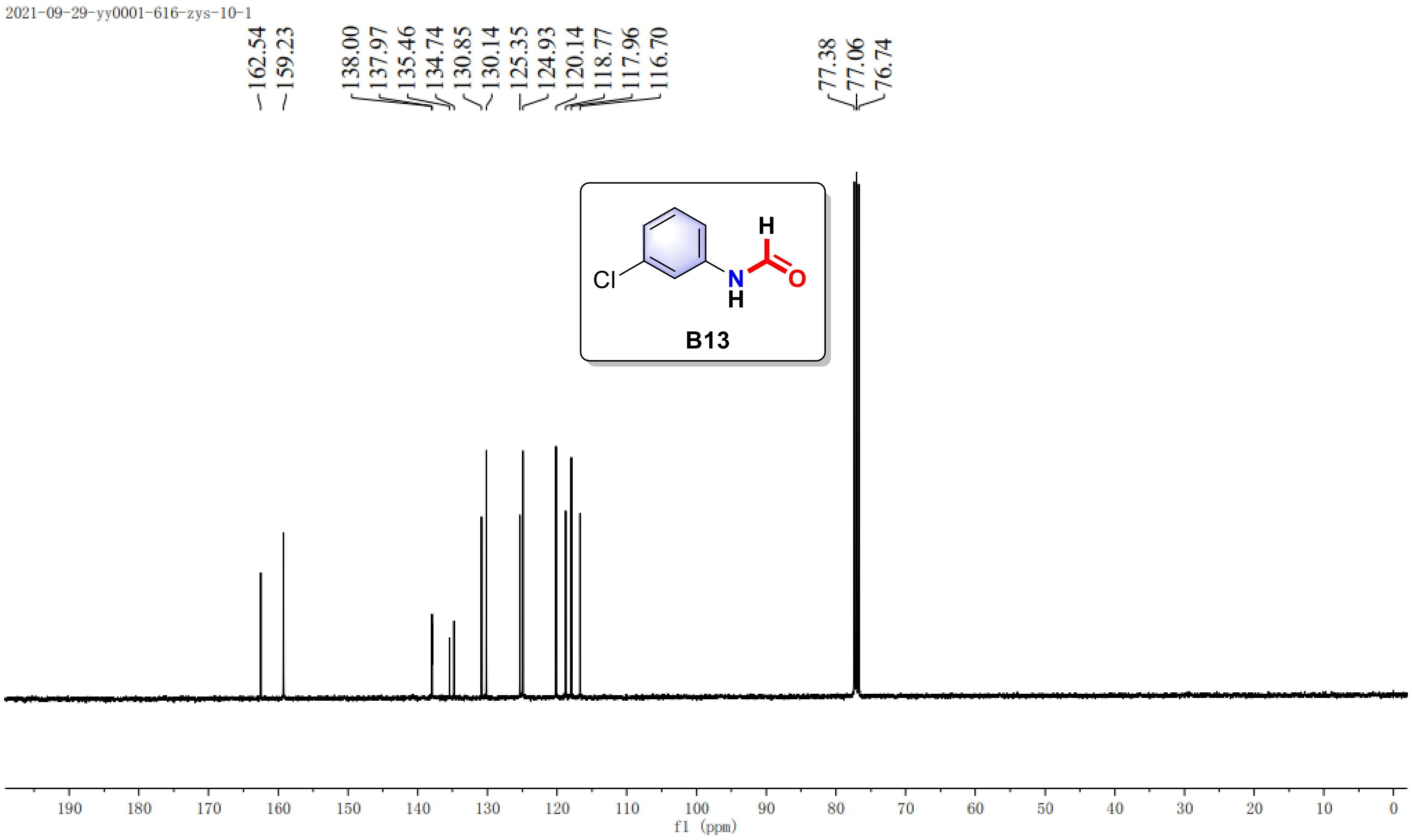

2021-10-16-15 YY0033 616-zys-18-1-F
-118.8390
-119.7635
F
N
H
H
O
B11
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)

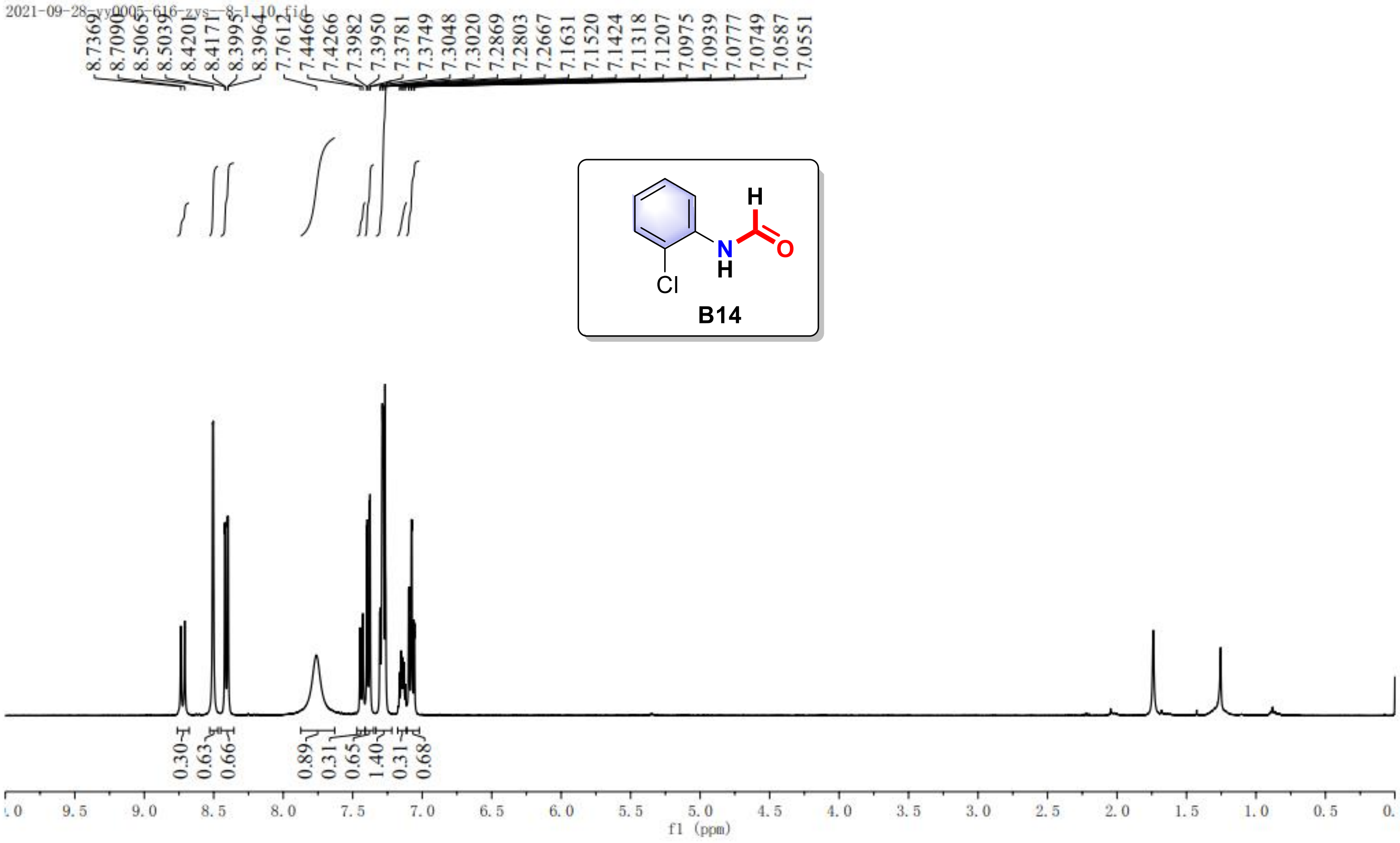

2021-10-12 YY0027 616-zys-9-2.10.fid
10.3290
8.8002
8.7799
8.2929
7.6416
7.6337
7.6284
7.6170
7.6115
7.6038
7.3906
7.3827
7.3771
7.3713
7.3658
7.3605
7.3544
7.2344
7.2290
7.2123
3.3893
2.5187
2.5141
2.5093
2.5047
2.5001
Cl
N
H
H
O
1.04
0.22
0.77
1.61
2.00
0.43
.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)

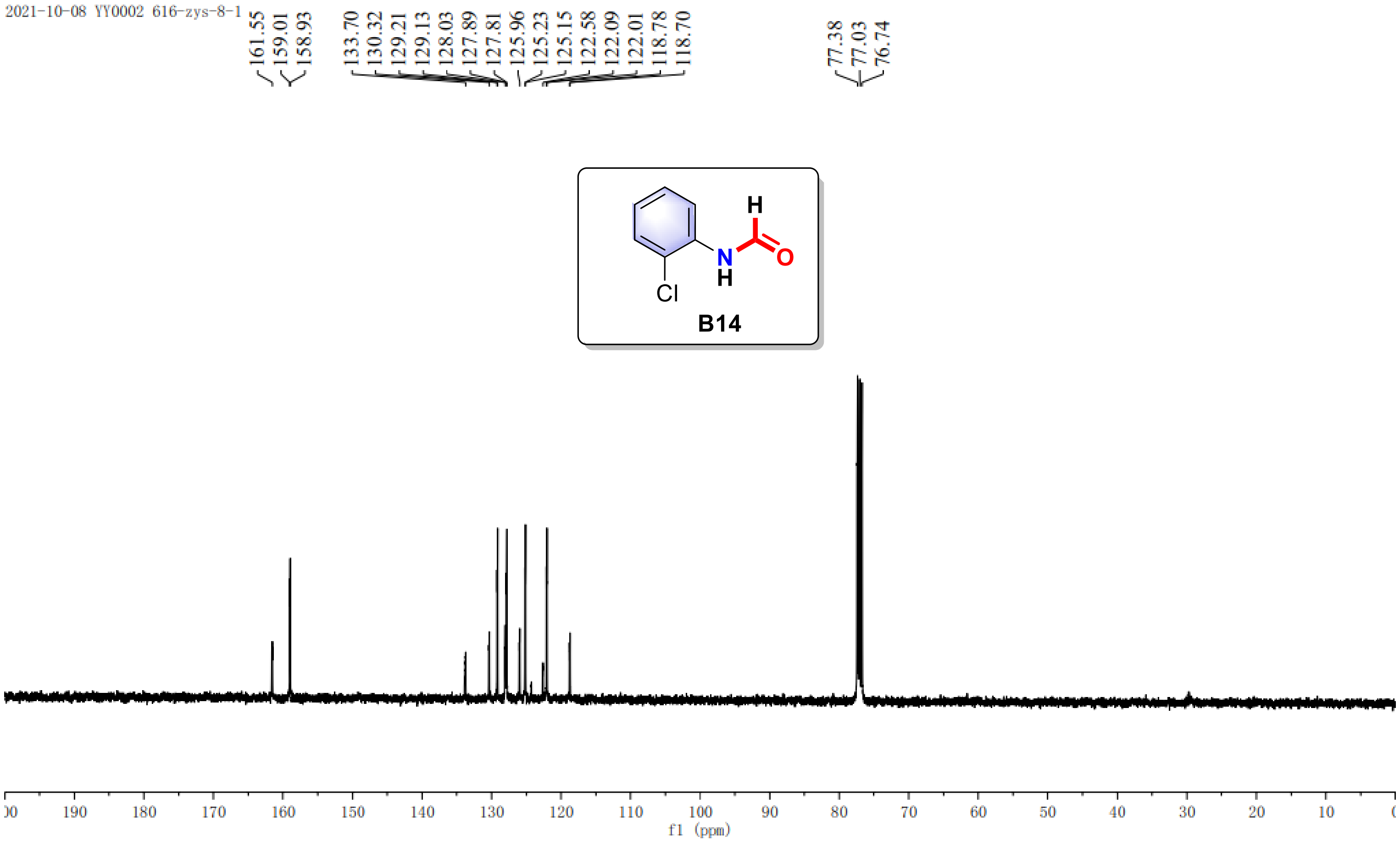
B12

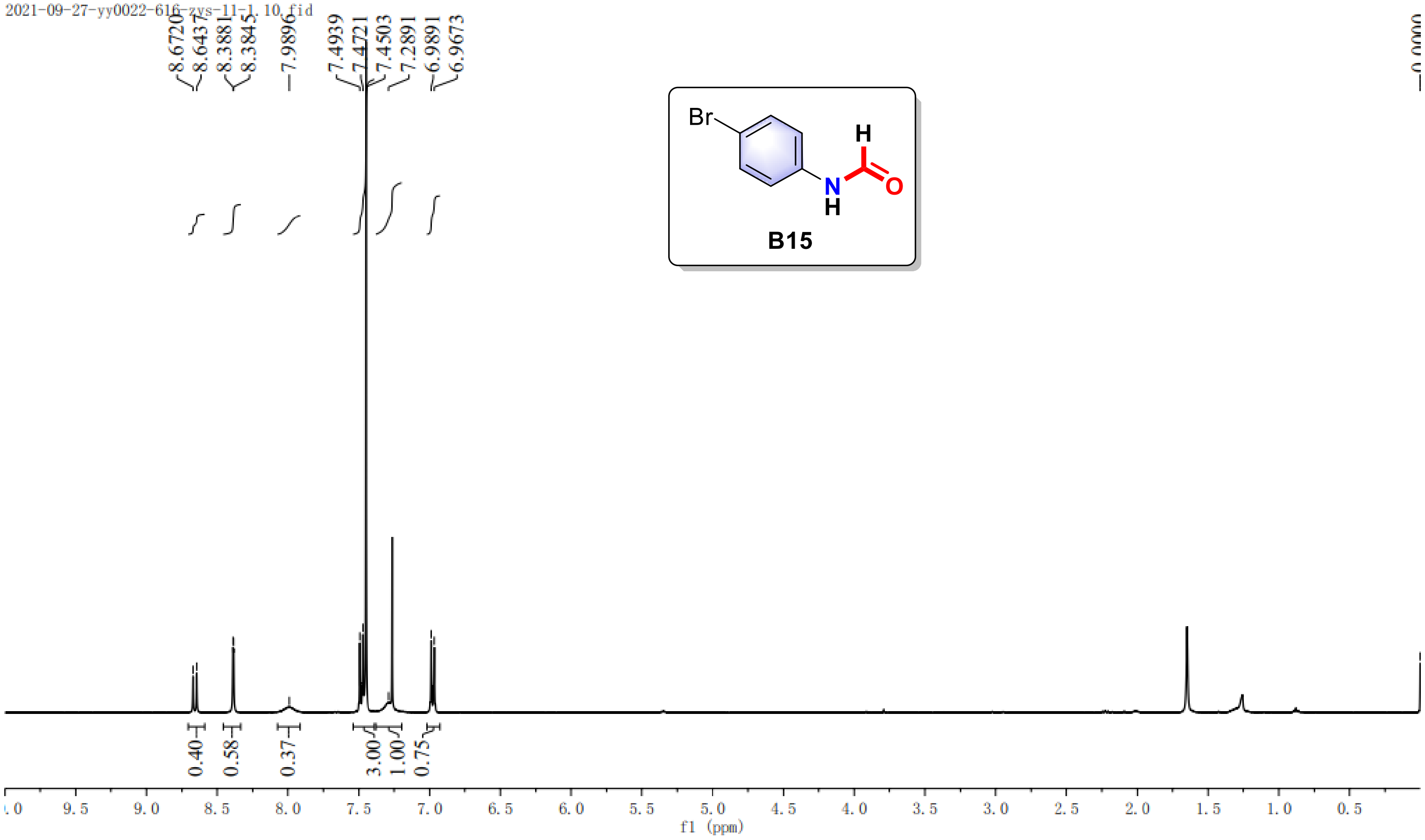

2021-10-12 YY0030 616-zys-9-2.10.fid
162.99
160.18
137.86
137.61
129.69
129.22
127.93
127.62
121.17
119.44
40.37
40.17
39.96
39.75
39.54
Cl
N
H
H
O
B12
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


2021-09-25 YY0003 616-zys-10-1.10.fid
8.72
8.69
8.64
8.38
8.37
7.69
7.67
7.66
7.66
7.41
7.40
7.39
7.38
7.31
7.29
7.27
7.27
7.25
7.23
7.18
7.18
7.16
7.13
7.12
7.12
7.11
7.10
7.01
7.00
6.99
6.98
Cl
N
H
H
O
B13
0.50
0.41
0.57
1.16
0.57
1.07
0.46
1.00
0.46
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)

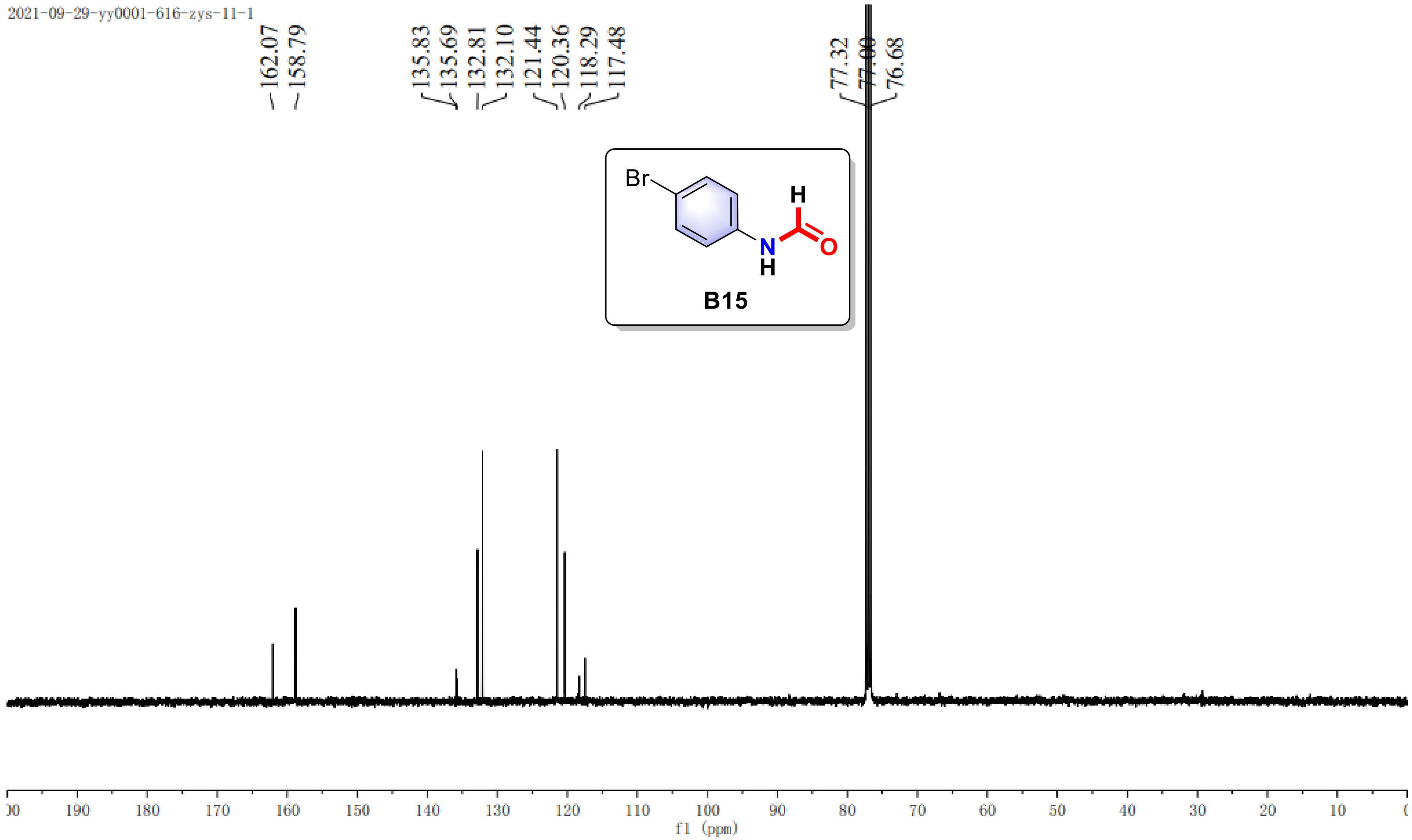

2021-09-29-yy0001-616-zys-10-1
162.54
159.23
138.00
137.97
135.46
134.74
130.85
130.14
125.35
124.93
120.14
118.77
117.96
116.70
77.38
77.06
76.74
Cl
N
H
H
O
B13
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

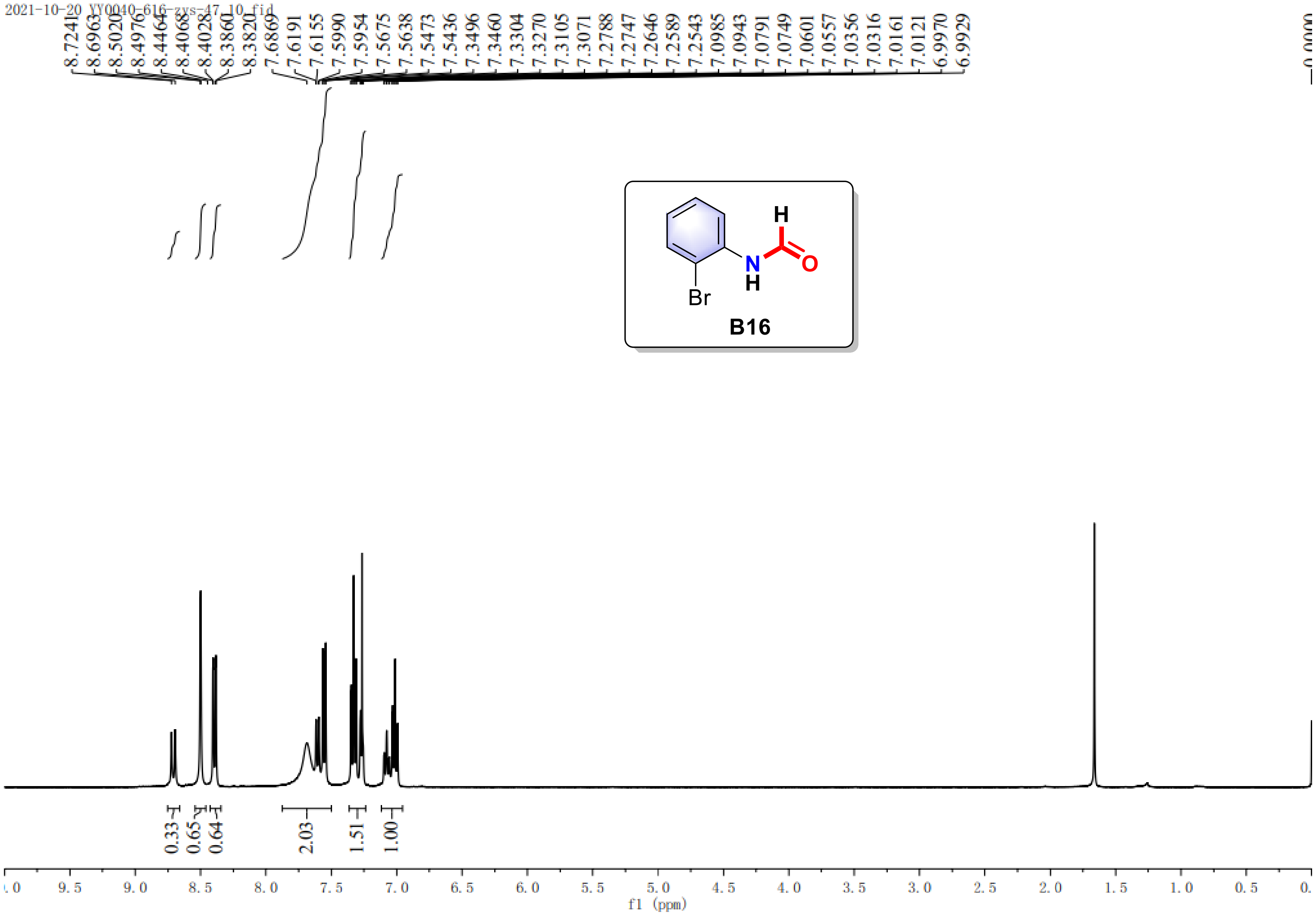

2021-09-28-yy0005-616-zys--8-1-10.fid
8.7369
8.7090
8.5065
8.5039
8.4201
8.4171
8.3995
8.3964
7.7612
7.4466
7.4266
7.3982
7.3950
7.3781
7.3749
7.3048
7.3020
7.2869
7.2803
7.2667
7.1631
7.1520
7.1424
7.1318
7.1207
7.0975
7.0939
7.0777
7.0749
7.0587
7.0551
H
N
H
O
Cl
B14
0.30
0.63
0.66
0.89
0.31
0.65
1.40
0.31
0.68
.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)

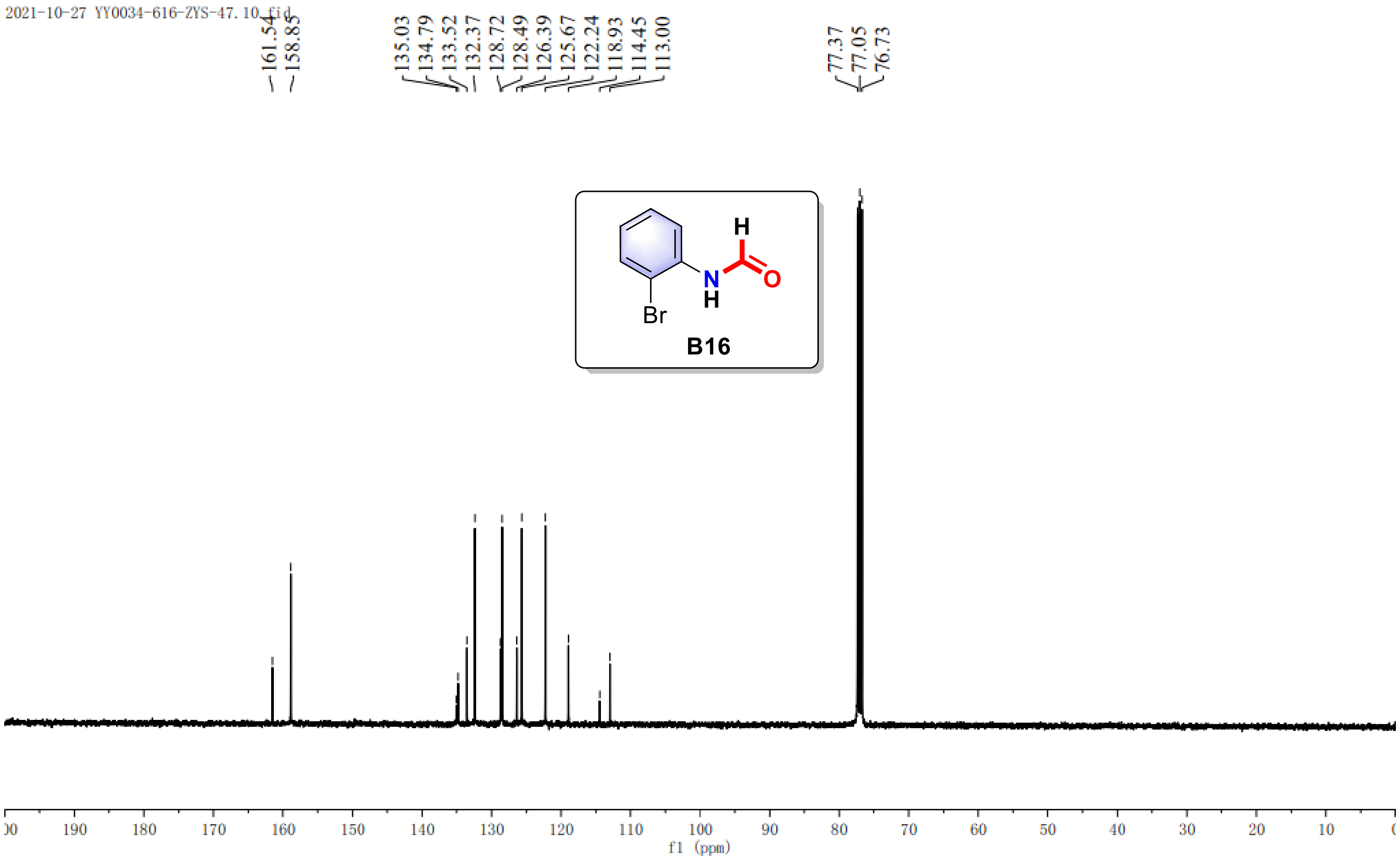

2021-10-08 YY0002 616-zys-8-1
161.55
159.01
158.93
133.70
130.32
129.21
129.13
128.03
127.89
127.81
125.96
125.23
125.15
122.58
122.09
122.01
118.78
118.70
77.38
77.03
76.74
H
N
H
O
Cl
B14
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

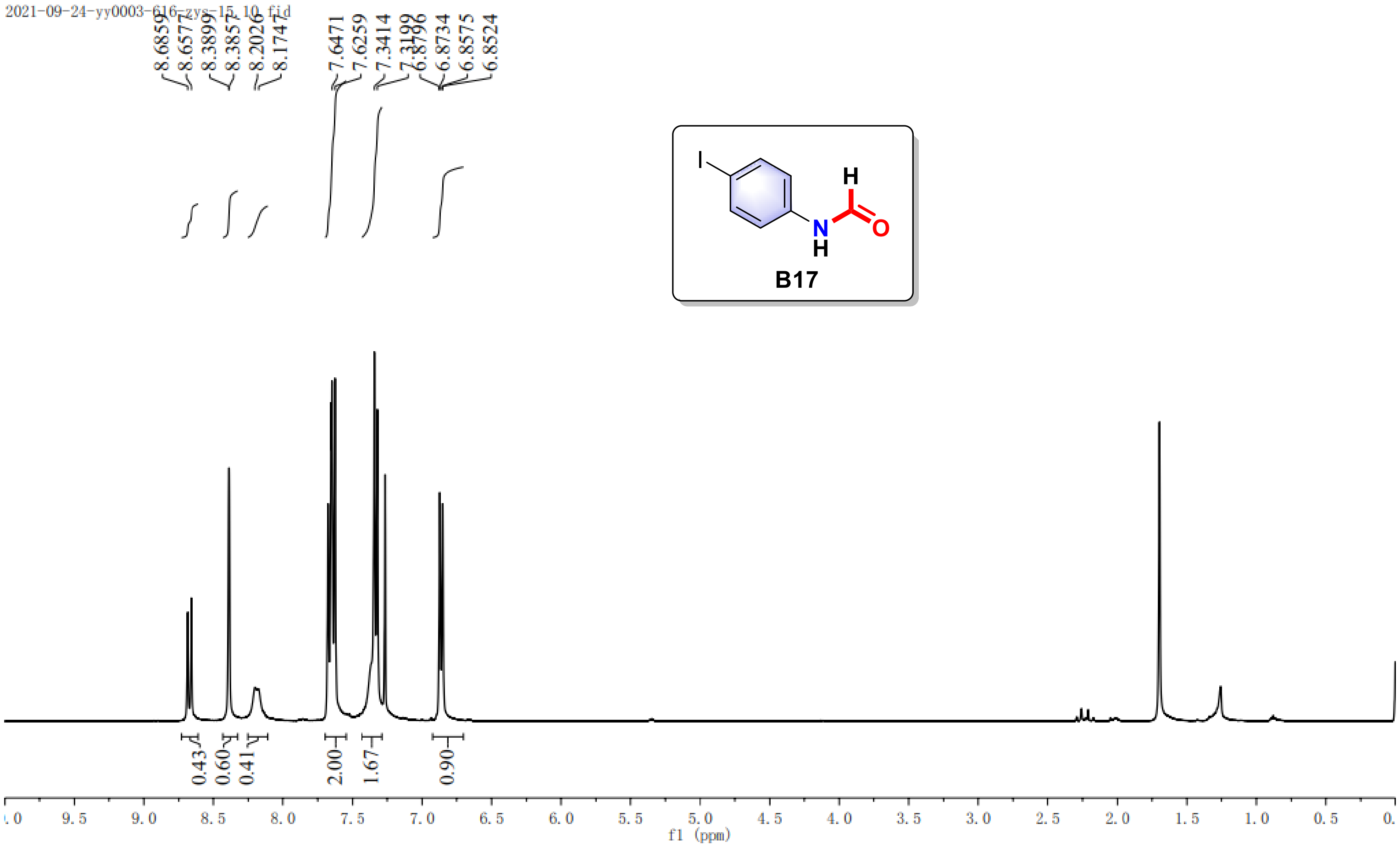

2021-09-27-yy0022-616-zys-11-1.10.fid
8.6720
8.6437
8.3881
8.3845
7.9896
7.4939
7.4721
7.4503
7.2891
6.9891
6.9673
0.0000
Br
H
N
H
O
0.40
0.58
0.37
3.00
1.00
0.75
.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

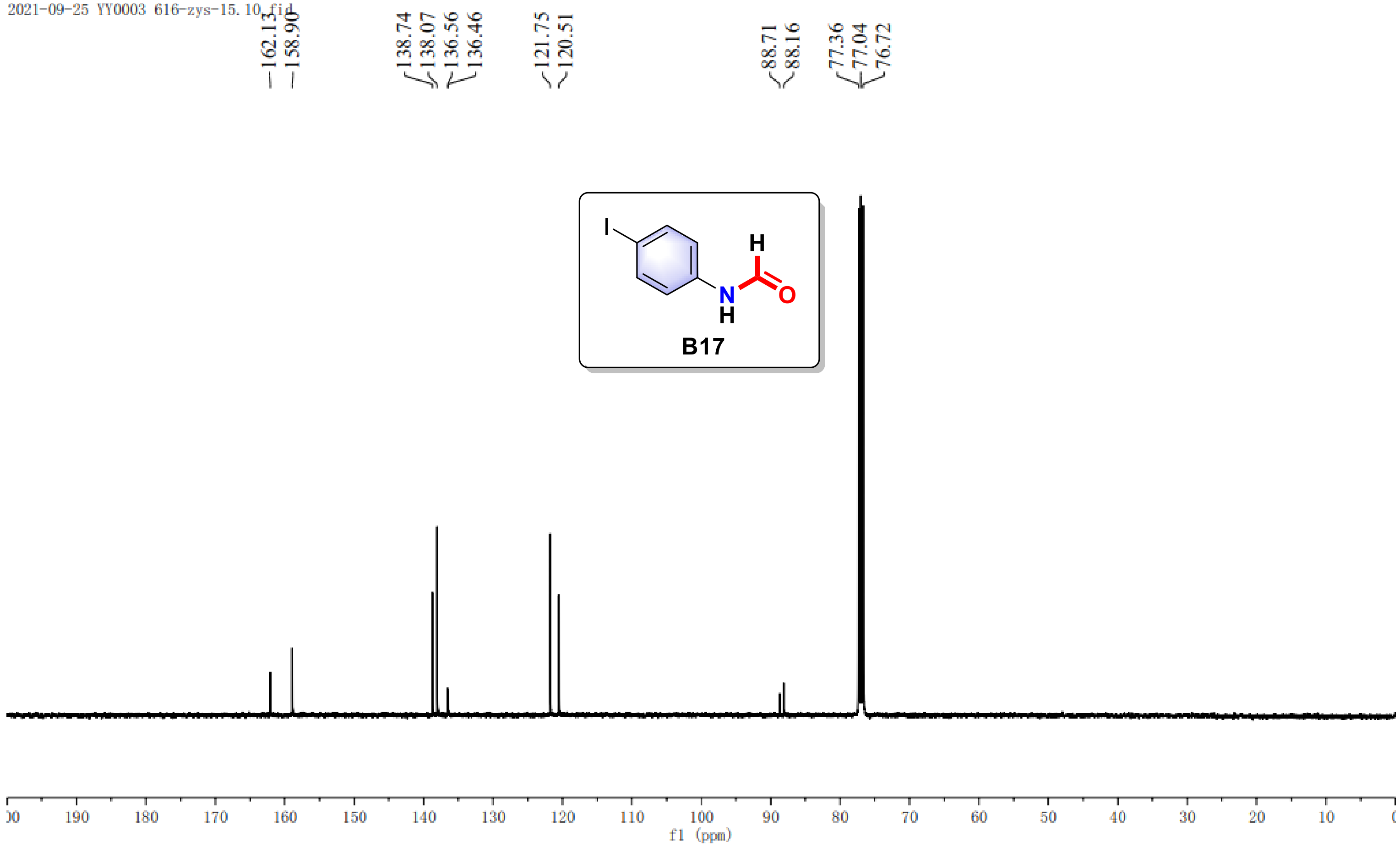
B15

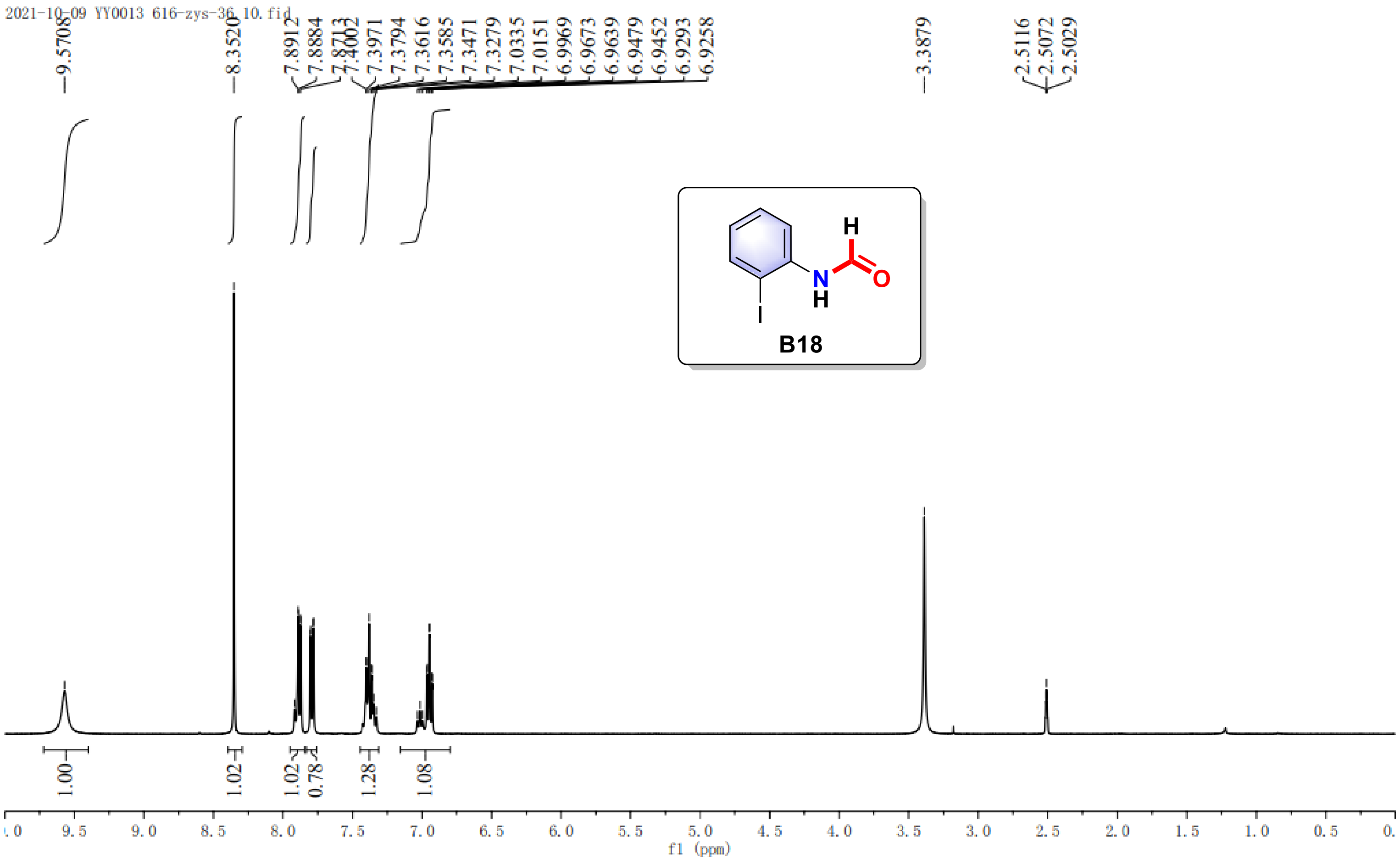

2021-09-29-yy0001-616-zys-11-1
162.07
158.79
135.83
135.69
132.81
132.10
121.44
120.36
118.29
117.48
77.32
77.00
76.68
Br
H
N
H
O
B15
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

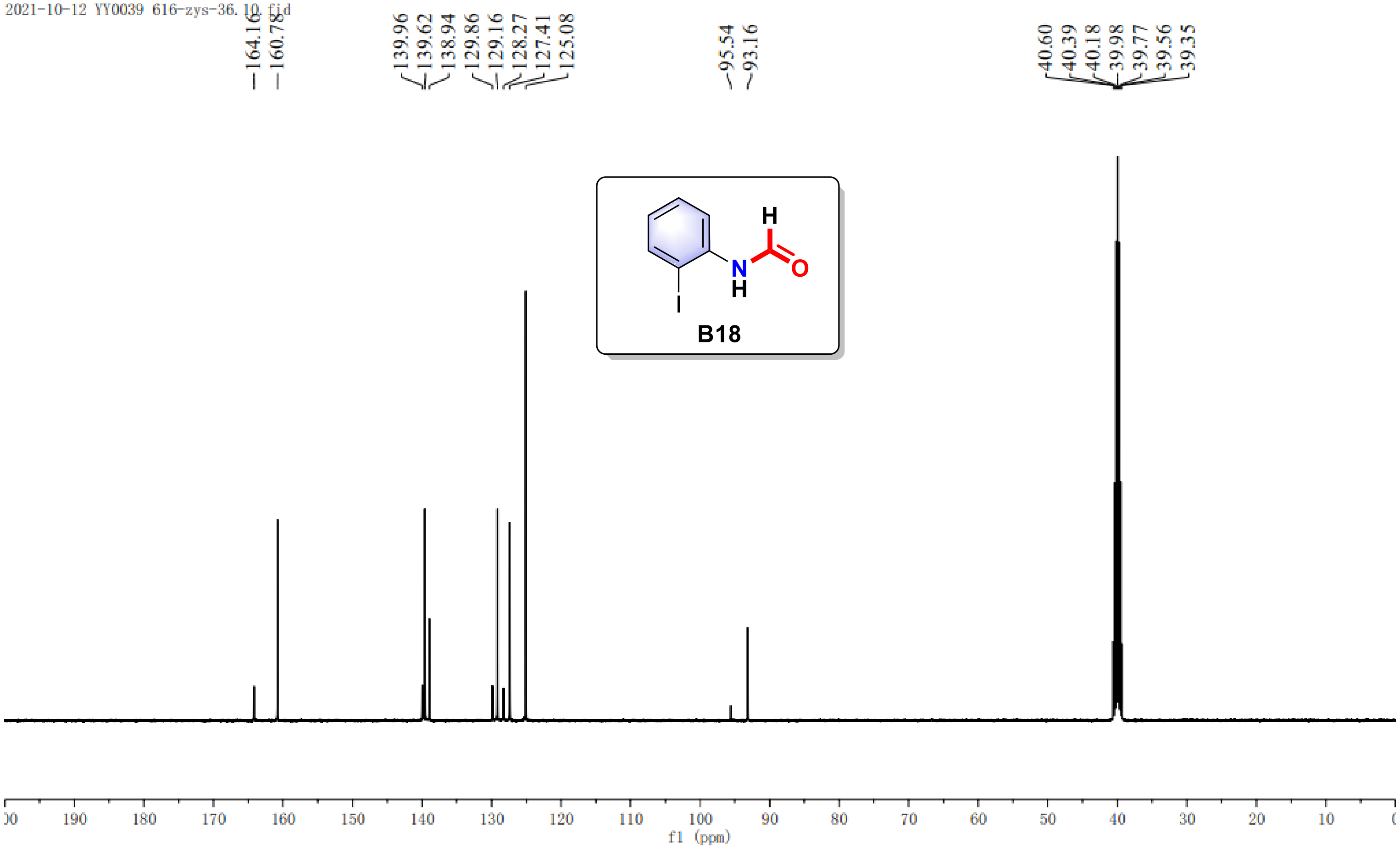

2021-10-20 YY0040-616-zys-47_10_fid
8.7241
8.6963
8.5020
8.4976
8.4464
8.4068
8.4028
8.3860
8.3820
7.6869
7.6191
7.6155
7.5990
7.5954
7.5675
7.5638
7.5473
7.5436
7.3496
7.3460
7.3304
7.3270
7.3105
7.3071
7.2788
7.2747
7.2646
7.2589
7.2543
7.0985
7.0943
7.0791
7.0749
7.0601
7.0557
7.0356
7.0316
7.0161
7.0121
6.9970
6.9929
0.0000
H
N
H
O
Br
B16
0.33
0.65
0.64
2.03
1.51
1.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)

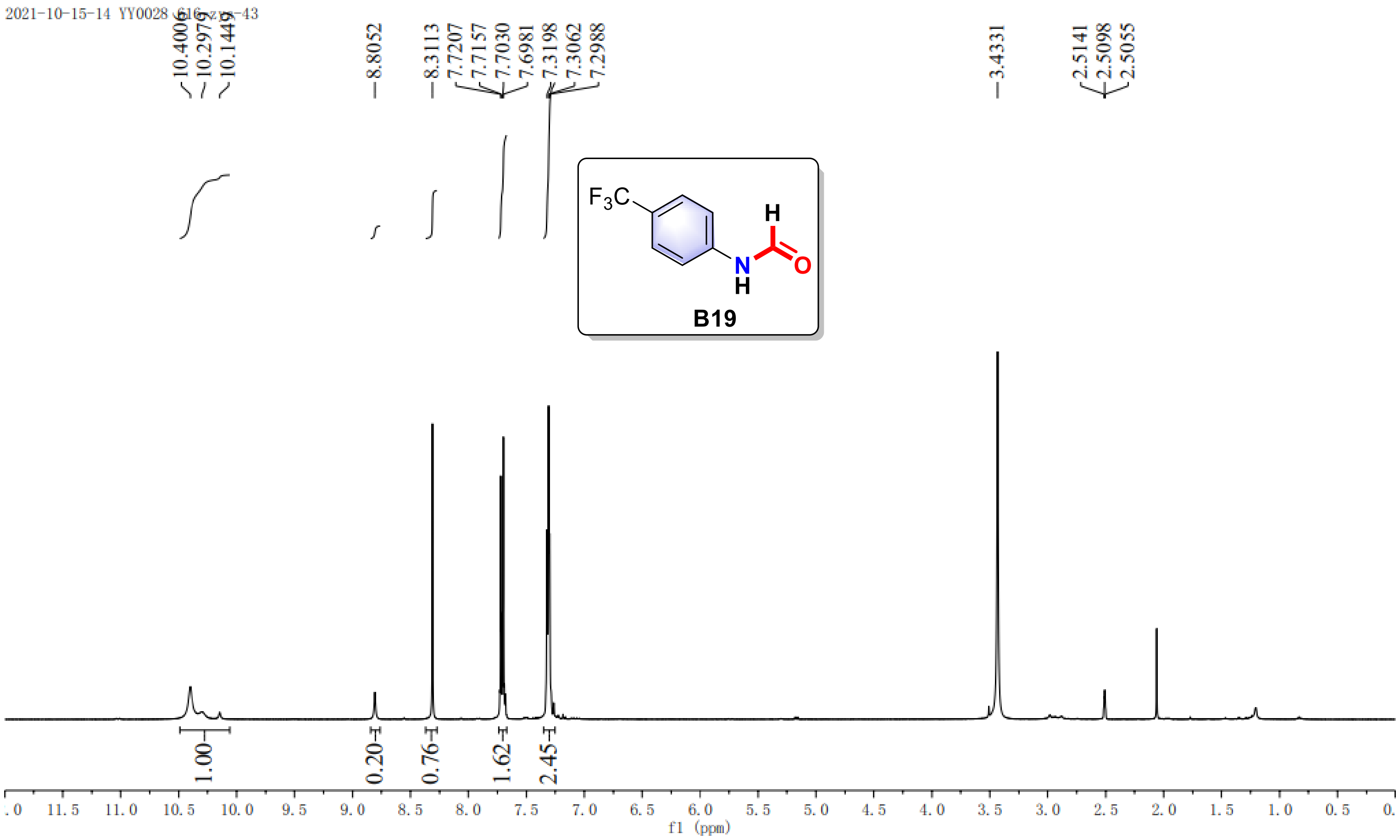

2021-10-27 YY0034-616-ZYS-47.10.fid
161.54
158.85
135.03
134.79
133.52
132.37
128.72
128.49
126.39
125.67
122.24
118.93
114.45
113.00
77.37
77.05
76.73
H
N
H
O
Br
B16
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

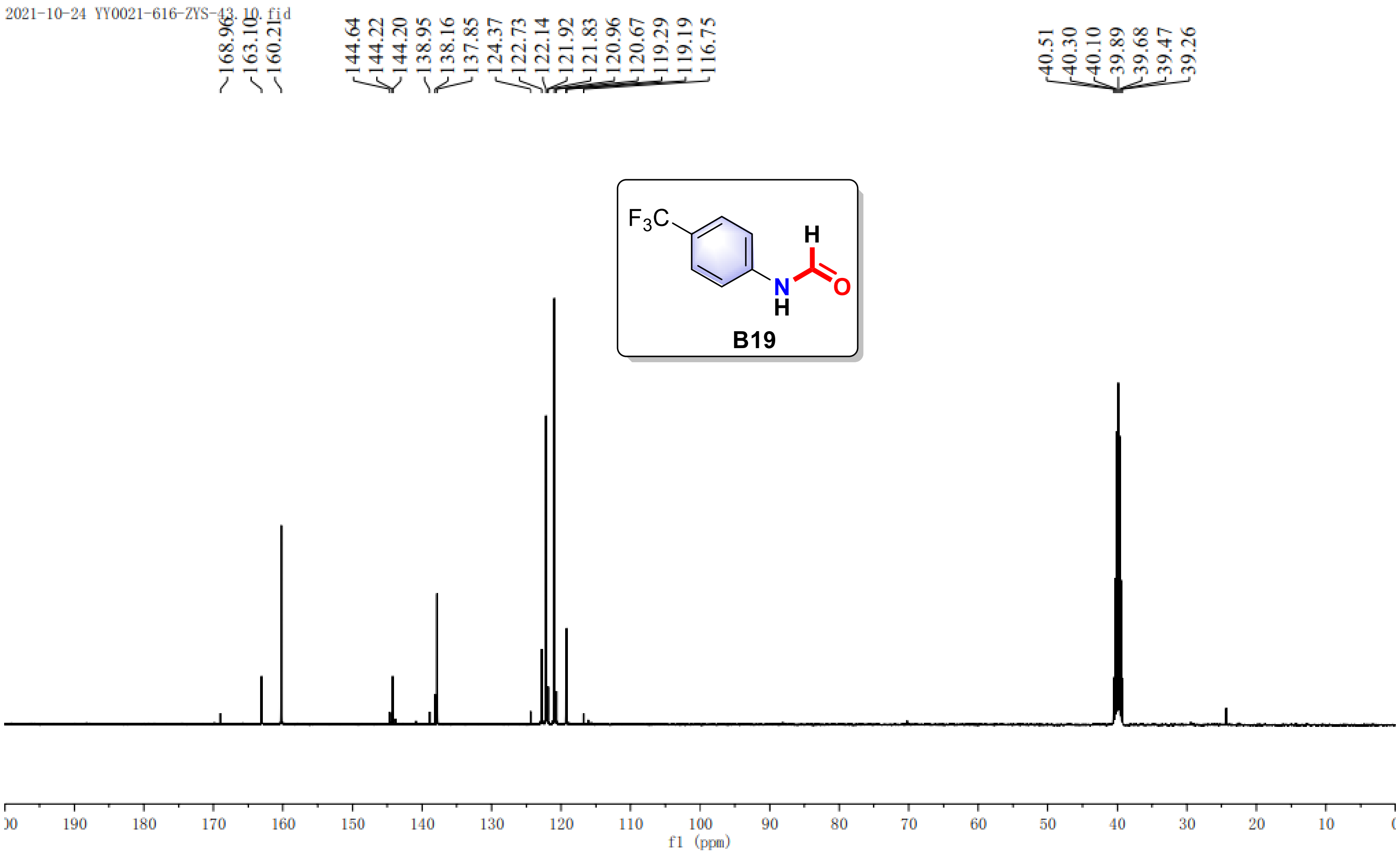

2021-09-24-yy0003-616-zys-15.10.fid
8.6859
8.6577
8.3899
8.3857
8.2026
8.1747
7.6471
7.6259
7.3414
7.3199
6.8796
6.8734
6.8575
6.8524
I
H
N
H
O
B17
0.43
0.60
0.41
2.00
1.67
0.90
.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)

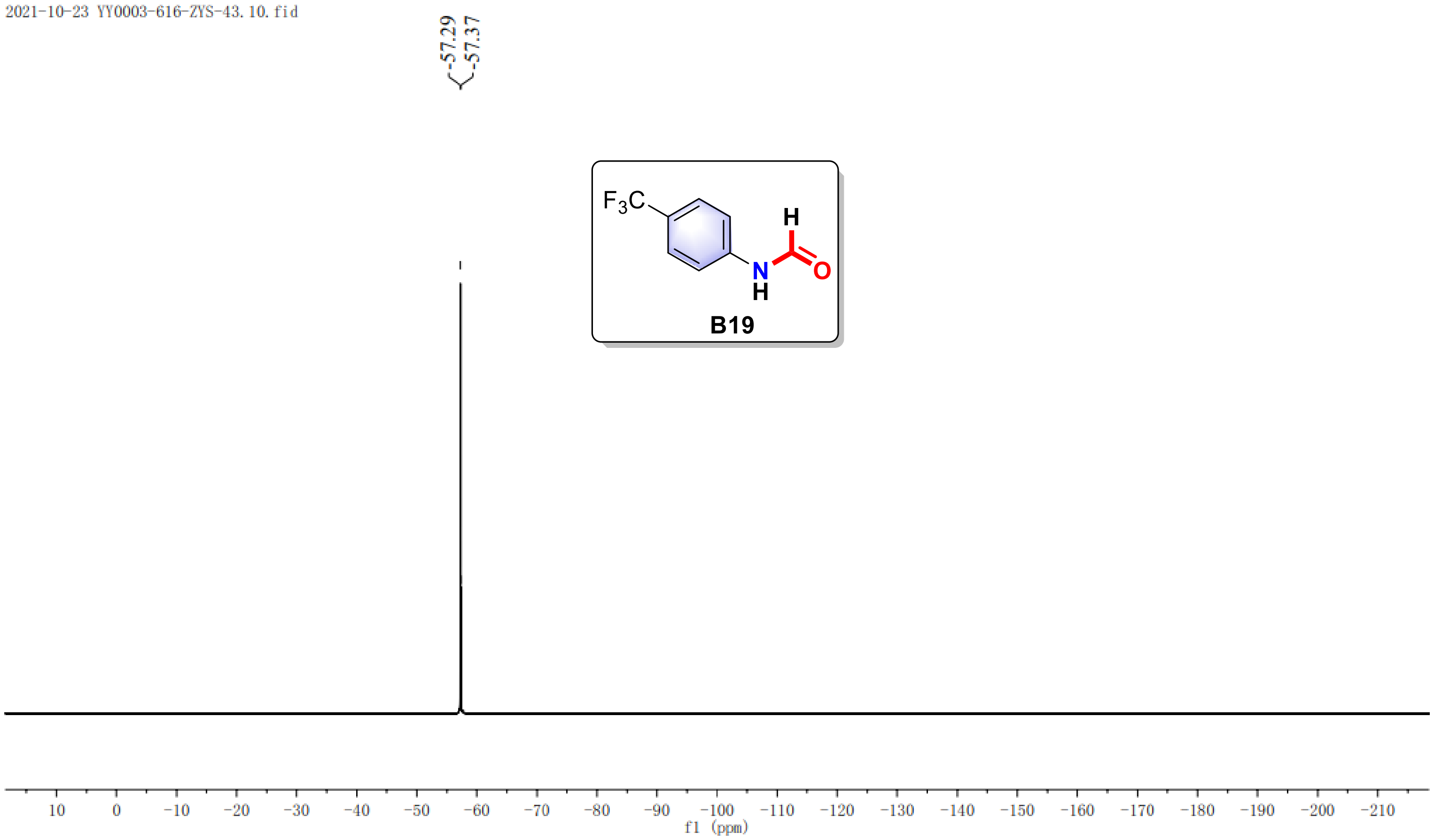

2021-09-25 YY0003 616-zys-15.10.fid
162.13
158.90
138.74
138.07
136.56
136.46
121.75
120.51
88.71
88.16
77.36
77.04
76.72
I
N
H
H
O
B17
)0
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
(
f1 (ppm)

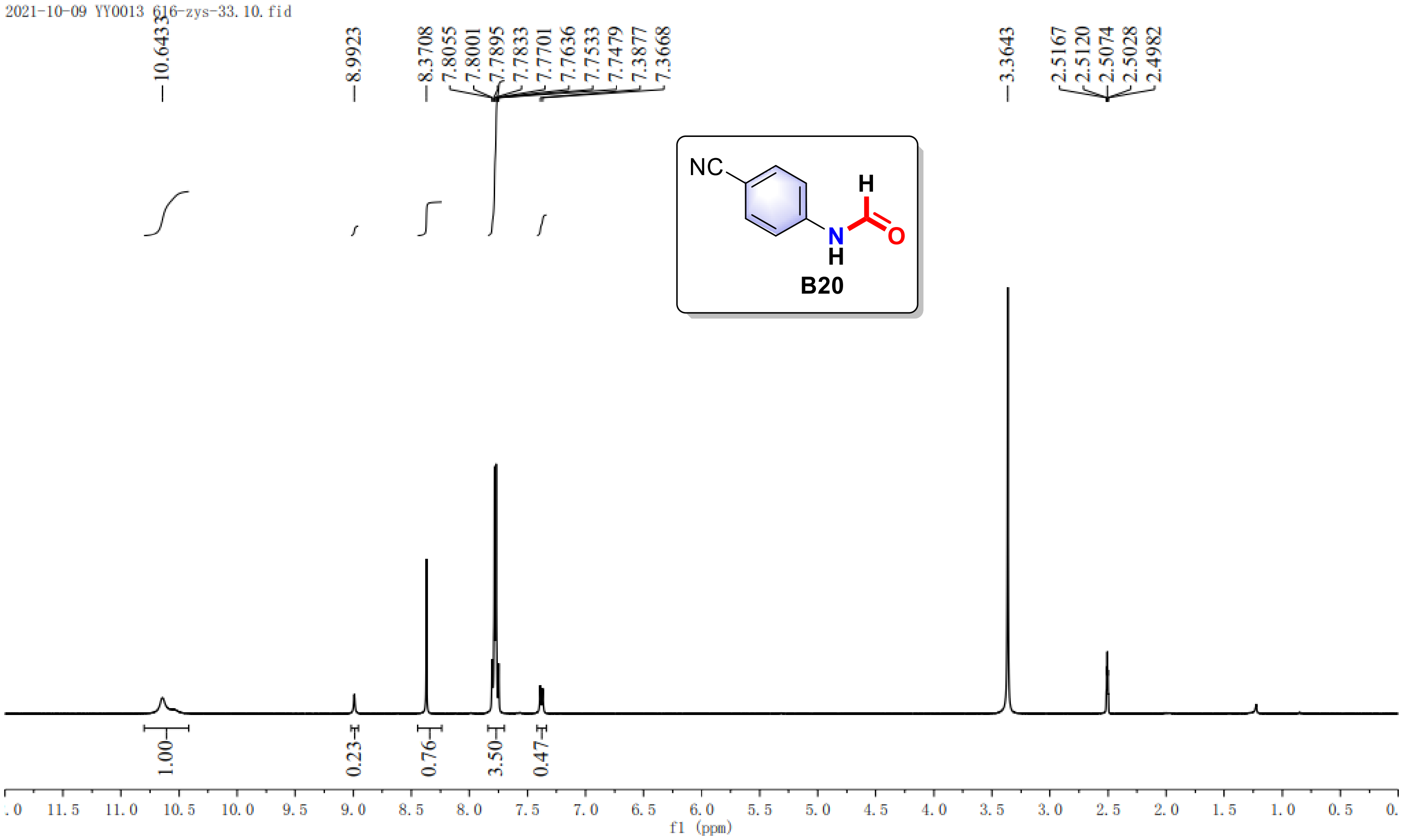

B18
2021-10-09 YY0013 616-zys-36 10.fid
9.5708
8.3520
7.8912
7.8884
7.8713
7.4002
7.3971
7.3794
7.3616
7.3585
7.3471
7.3279
7.0335
7.0151
6.9969
6.9673
6.9639
6.9479
6.9452
6.9293
6.9258
3.3879
2.5116
2.5072
2.5029
1.00
1.02
1.02
0.78
1.28
1.08
H
N
H
O
I
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)


2021-10-12 YY0039 616-zys-36.10.fid
164.16
160.78
139.96
139.62
138.94
129.86
129.16
128.27
127.41
125.08
95.54
93.16
40.60
40.39
40.18
39.98
39.77
39.56
39.35
H
N
H
O
I
B18
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

2021-10-15-14 YY0028 616-zyx-43
10.4006
10.2979
10.1449
8.8052
8.3113
7.7207
7.7157
7.7030
7.6981
7.3198
7.3062
7.2988
3.4331
2.5141
2.5098
2.5055
F3C
H
N
H
O
B19
1.00
0.20
0.76
1.62
2.45
.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)


2021-10-24 YY0021-616-ZYS-43.10.fid
168.96
163.10
160.21
144.64
144.22
144.20
138.95
138.16
137.85
124.37
122.73
122.14
121.92
121.83
120.96
120.67
119.29
119.19
116.75
40.51
40.30
40.10
39.89
39.68
39.47
39.26
F3C
H
N
H
O
B19
00
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


2021-10-23 YY0003-616-ZYS-43.10.fid
-57.29
-57.37
F3C
H
N
H
O
B19
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)


2021-10-09 YY0013 616-zys-33.10.fid
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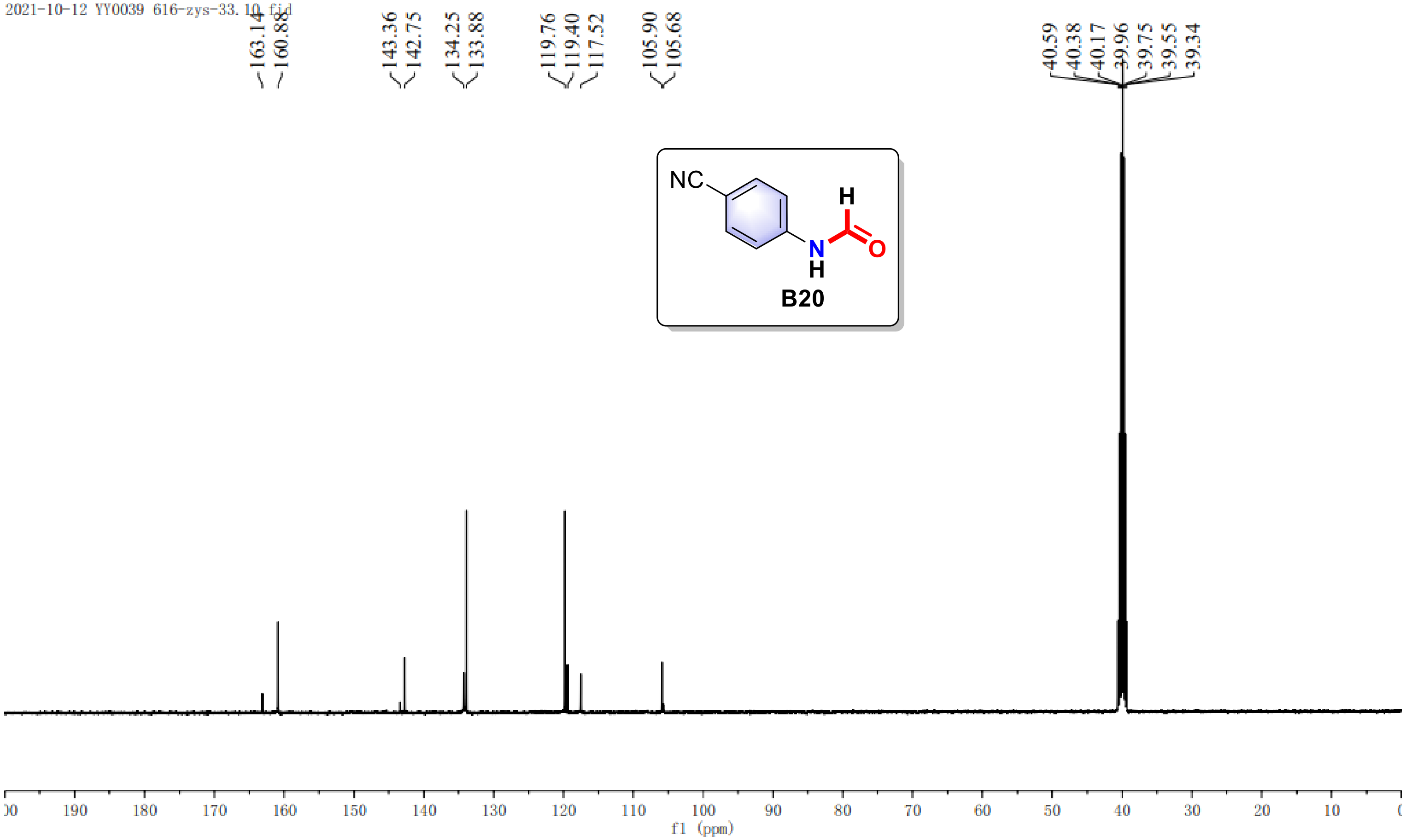
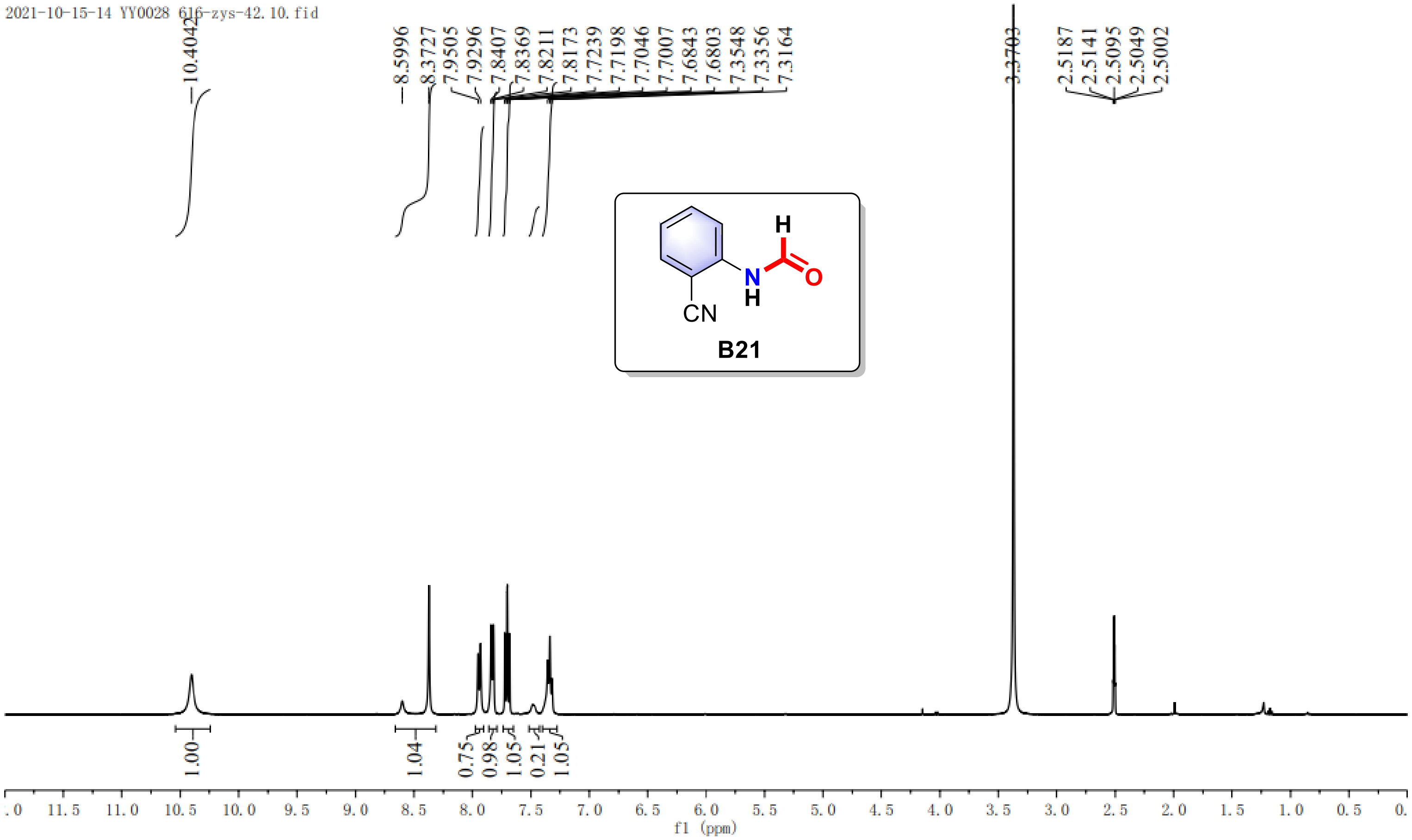
8.3708
7.8055
7.8001
7.7895
7.7833
7.7701
7.7636
7.7533
7.7479
7.3877
7.3668
3.3643
2.5167
2.5120
2.5074
2.5028
2.4982
NC
H
N
H
O
B20
1.00
0.23
0.76
3.50
0.47
.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)


2021-10-12 YY0039 616-zys-33.10.fid
163.14
160.88
143.36
142.75
134.25
133.88
119.76
119.40
117.52
105.90
105.68
40.59
40.38
40.17
39.96
39.75
39.55
39.34
NC
H
N
H
O
B20
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


2021-10-15-14 YY0028 616-zys-42.10.fid
10.4042
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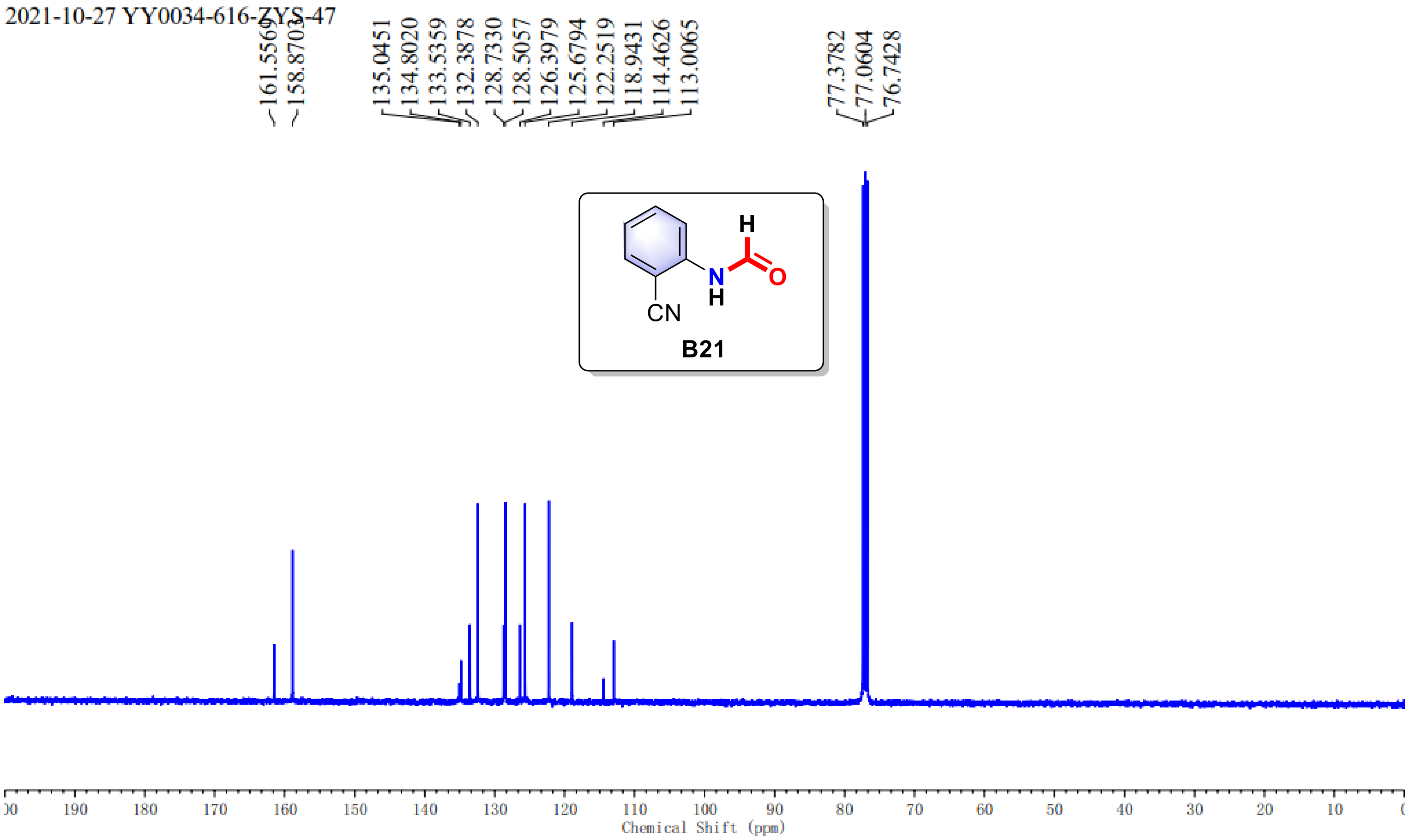
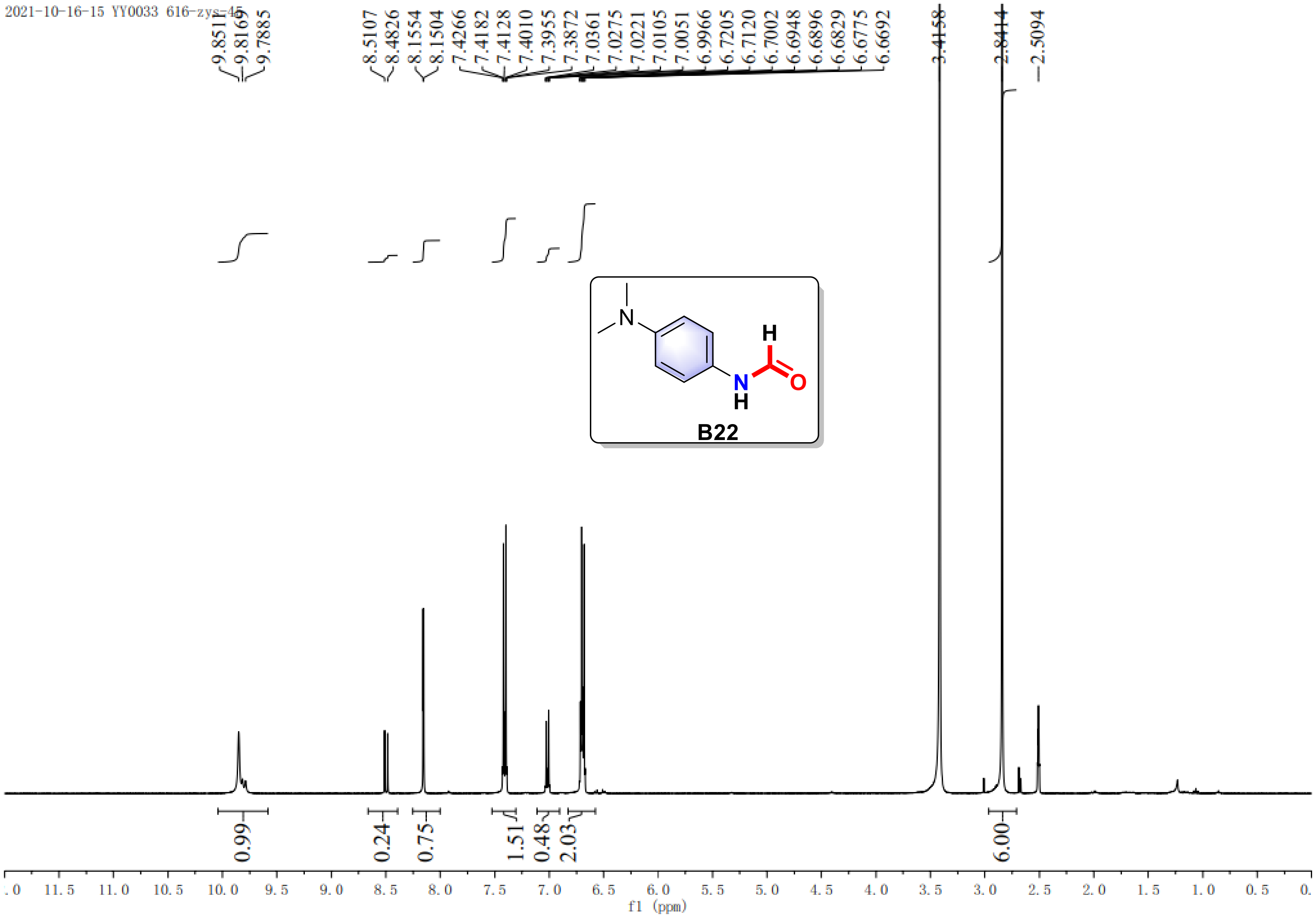
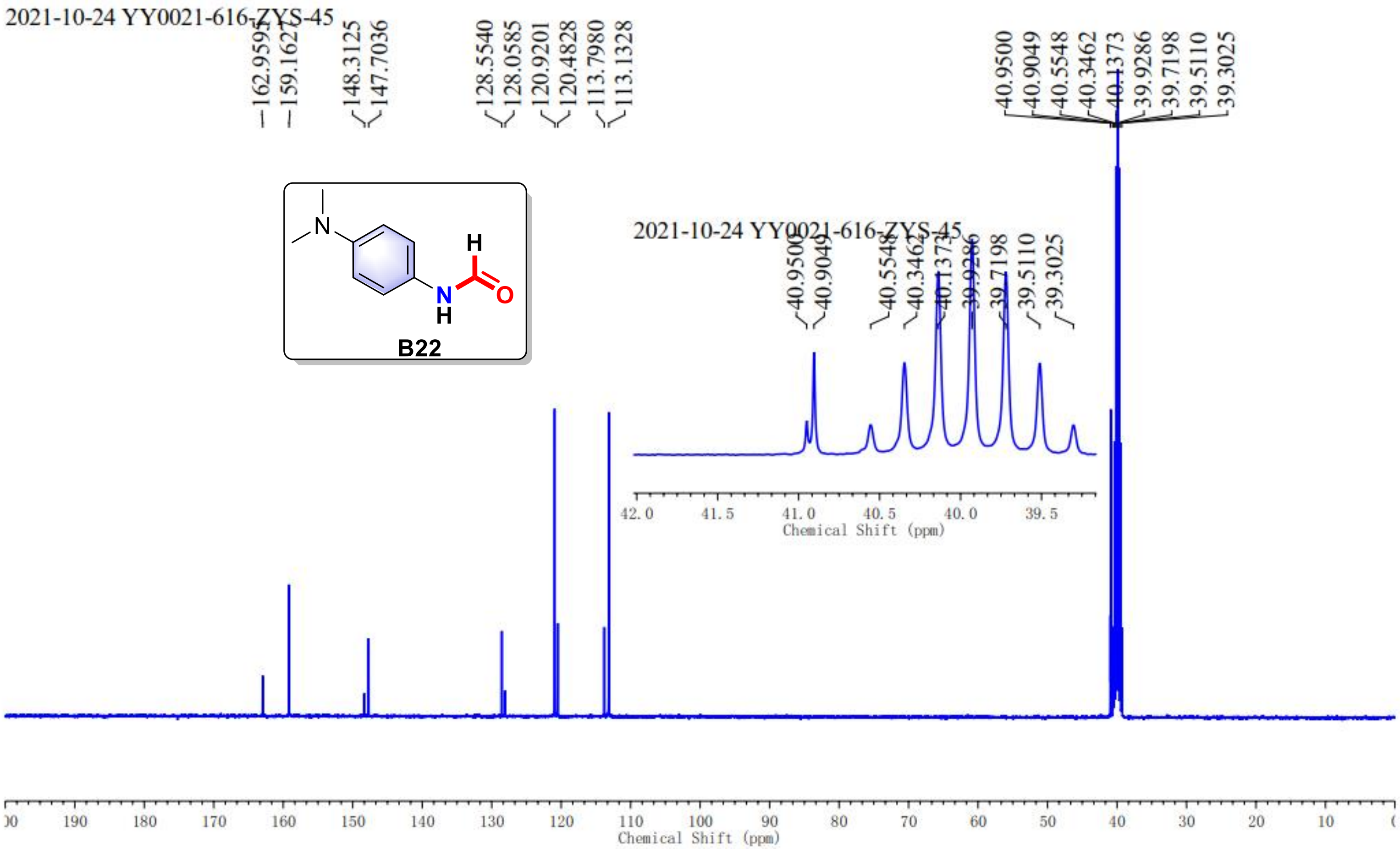
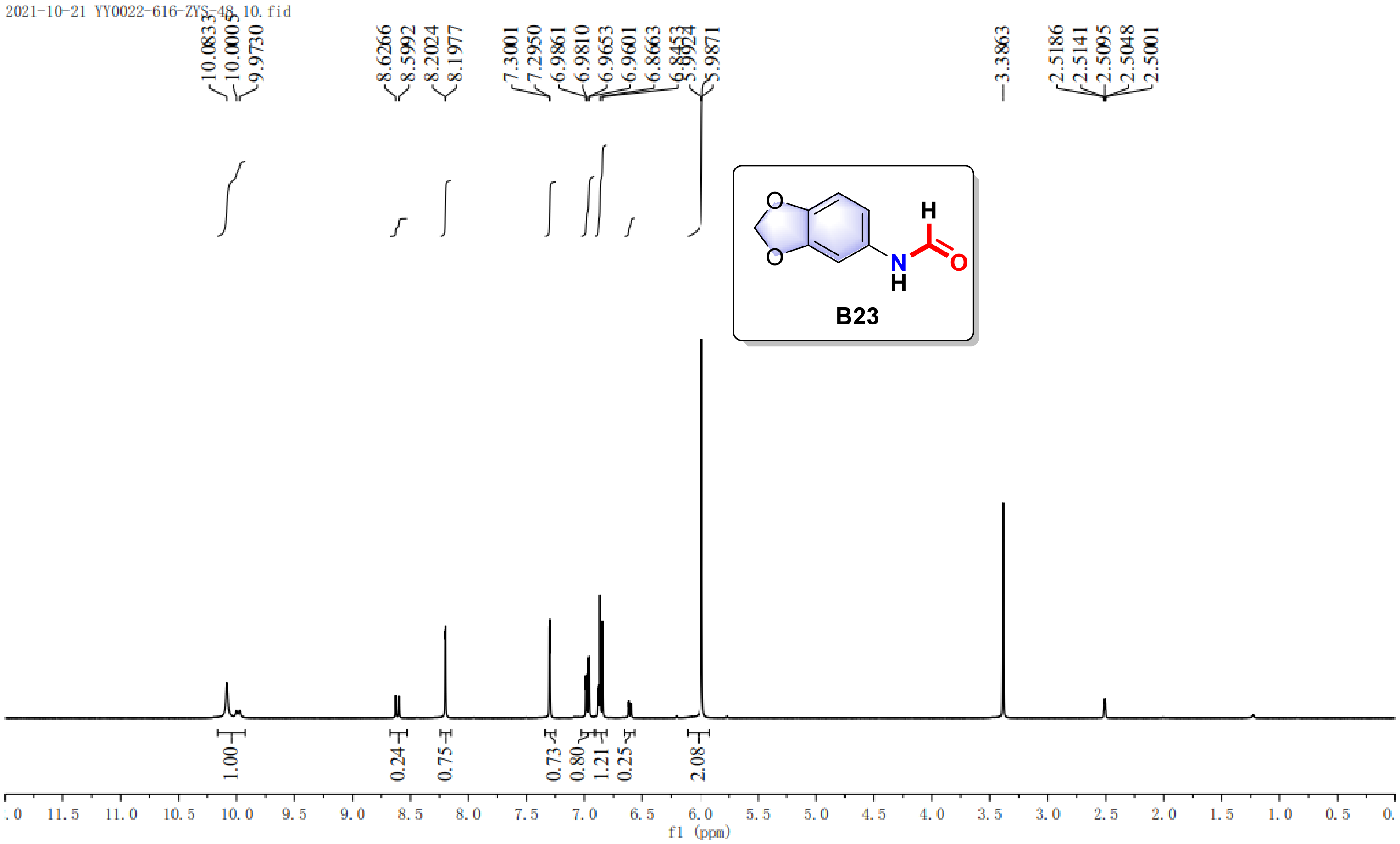
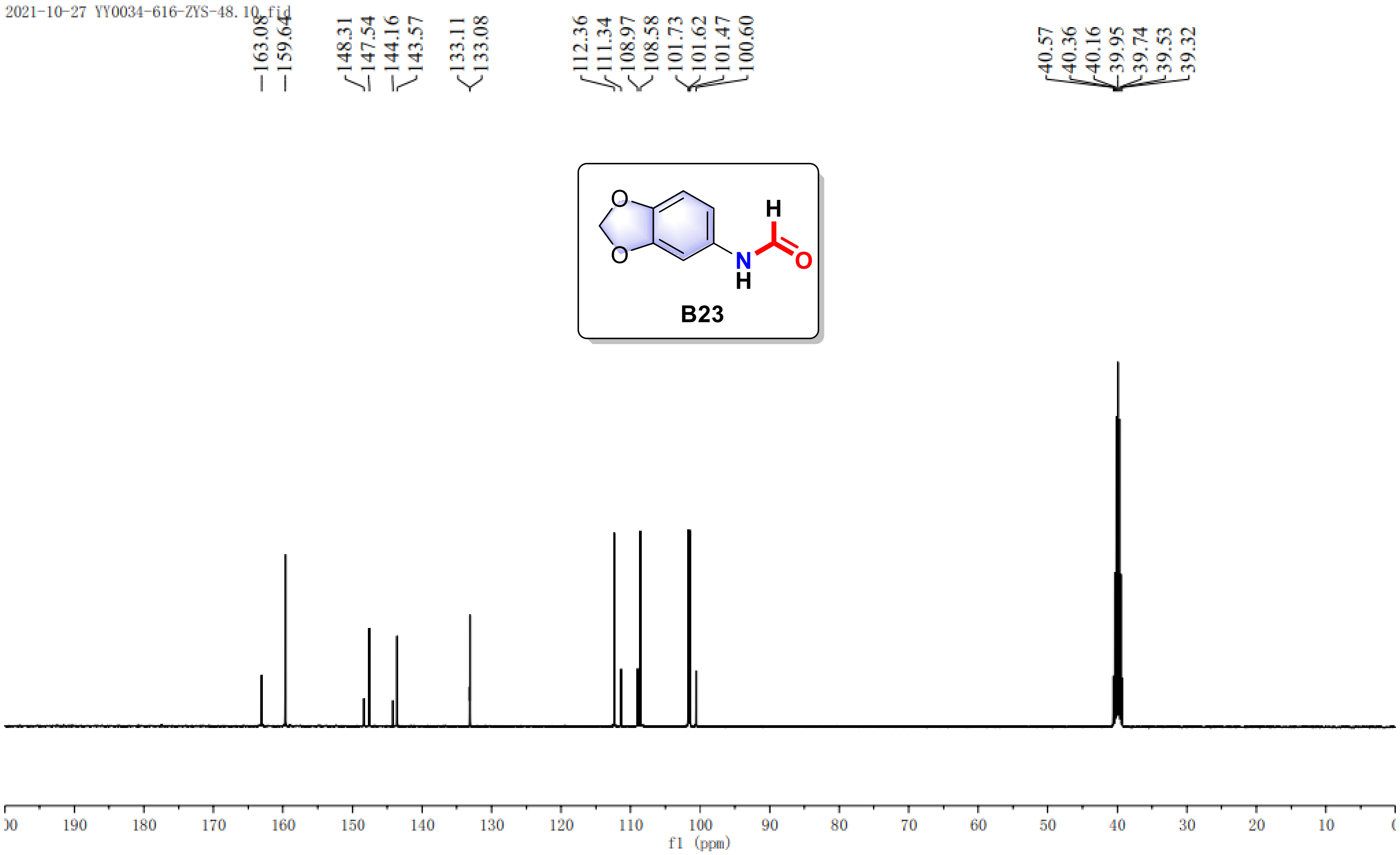
8.3727
7.9505
7.9296
7.8407
7.8369
7.8211
7.8173
7.7239
7.7198
7.7046
7.7007
7.6843
7.6803
7.3548
7.3356
7.3164
3.3703
2.5187
2.5141
2.5095
2.5049
2.5002
H
N
H
O
CN
B21
1.00
1.04
0.75
0.98
1.05
0.21
1.05
.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)

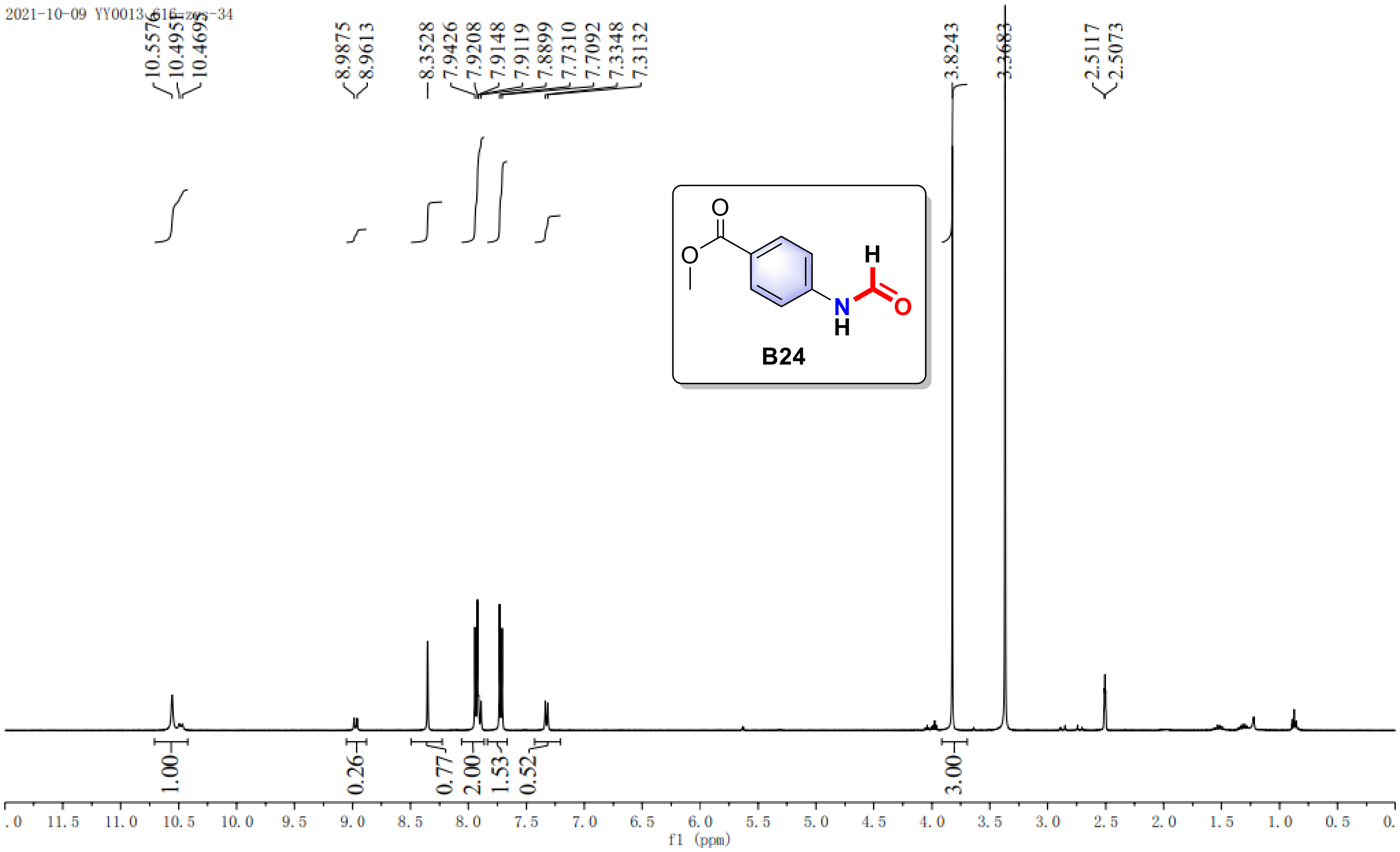

2021-10-27 YY0034-616-ZYS-47
161.5569
158.8703
135.0451
134.8020
133.5359
132.3878
128.7330
128.5057
126.3979
125.6794
122.2519
118.9431
114.4626
113.0065
77.3782
77.0604
76.7428
H
N
H
O
CN
B21
00
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Chemical Shift (ppm)


2021-10-16-15 YY0033 616-zys-45
9.8511
9.8169
9.7885
8.5107
8.4826
8.1554
8.1504
7.4266
7.4182
7.4128
7.4010
7.3955
7.3872
7.0361
7.0275
7.0221
7.0105
7.0051
6.9966
6.7205
6.7120
6.7002
6.6948
6.6896
6.6829
6.6775
6.6692
3.4158
2.8414
2.5094
N
H
N
H
O
B22
0.99
0.24
0.75
1.51
0.48
2.03
6.00
.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)

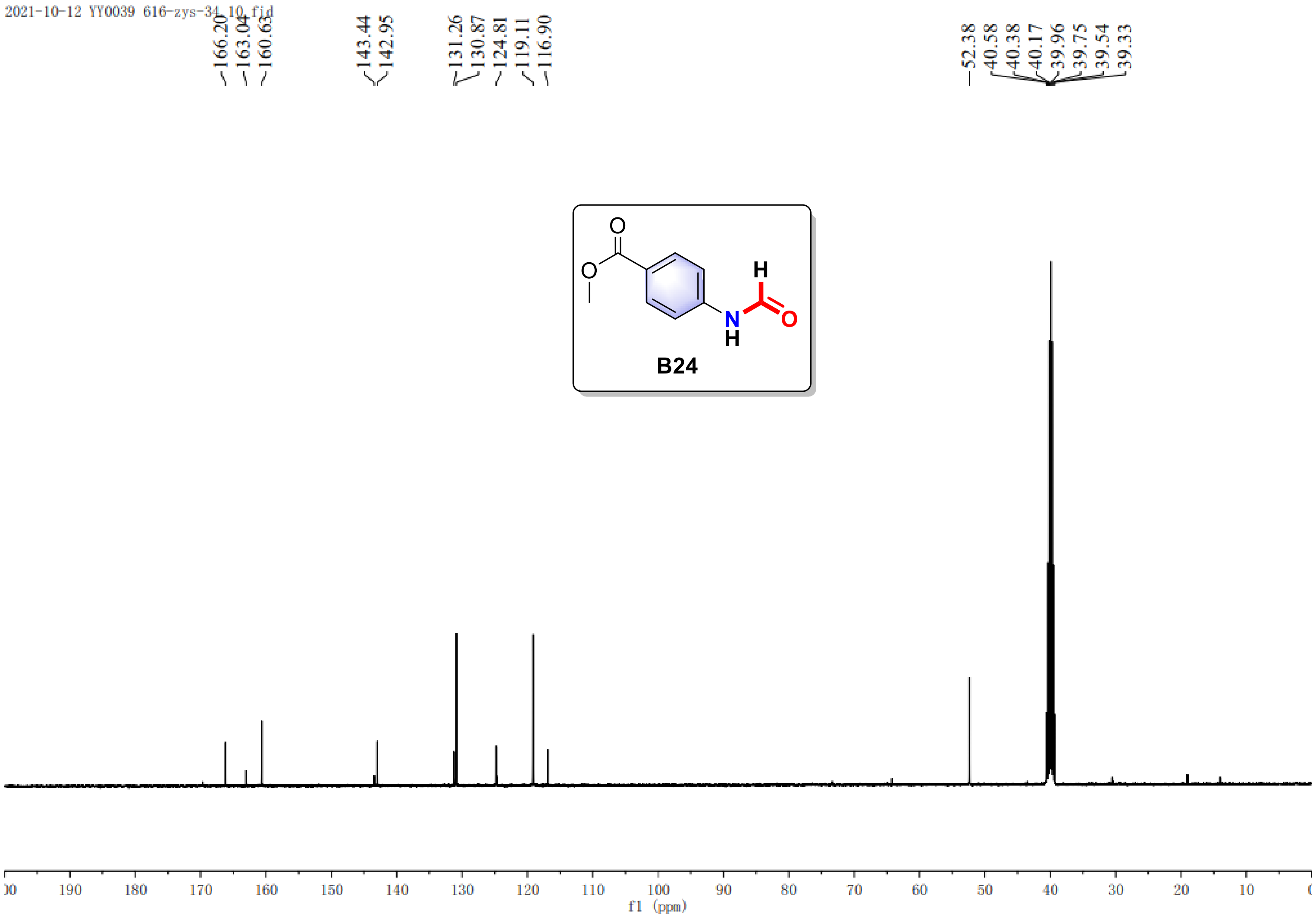

2021-10-24 YY0021-616-ZYS-45
162.9595
159.1627
148.3125
147.7036
128.5540
128.0585
120.9201
120.4828
113.7980
113.1328
40.9500
40.9049
40.5548
40.3462
40.1373
39.9286
39.7198
39.5110
39.3025
N
N
H
H
O
B22
2021-10-24 YY0021-616-ZYS-45
40.9500
40.9049
40.5548
40.3462
40.1373
39.9286
39.7198
39.5110
39.3025
42.0
41.5
41.0
40.5
40.0
39.5
Chemical Shift (ppm)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Chemical Shift (ppm)

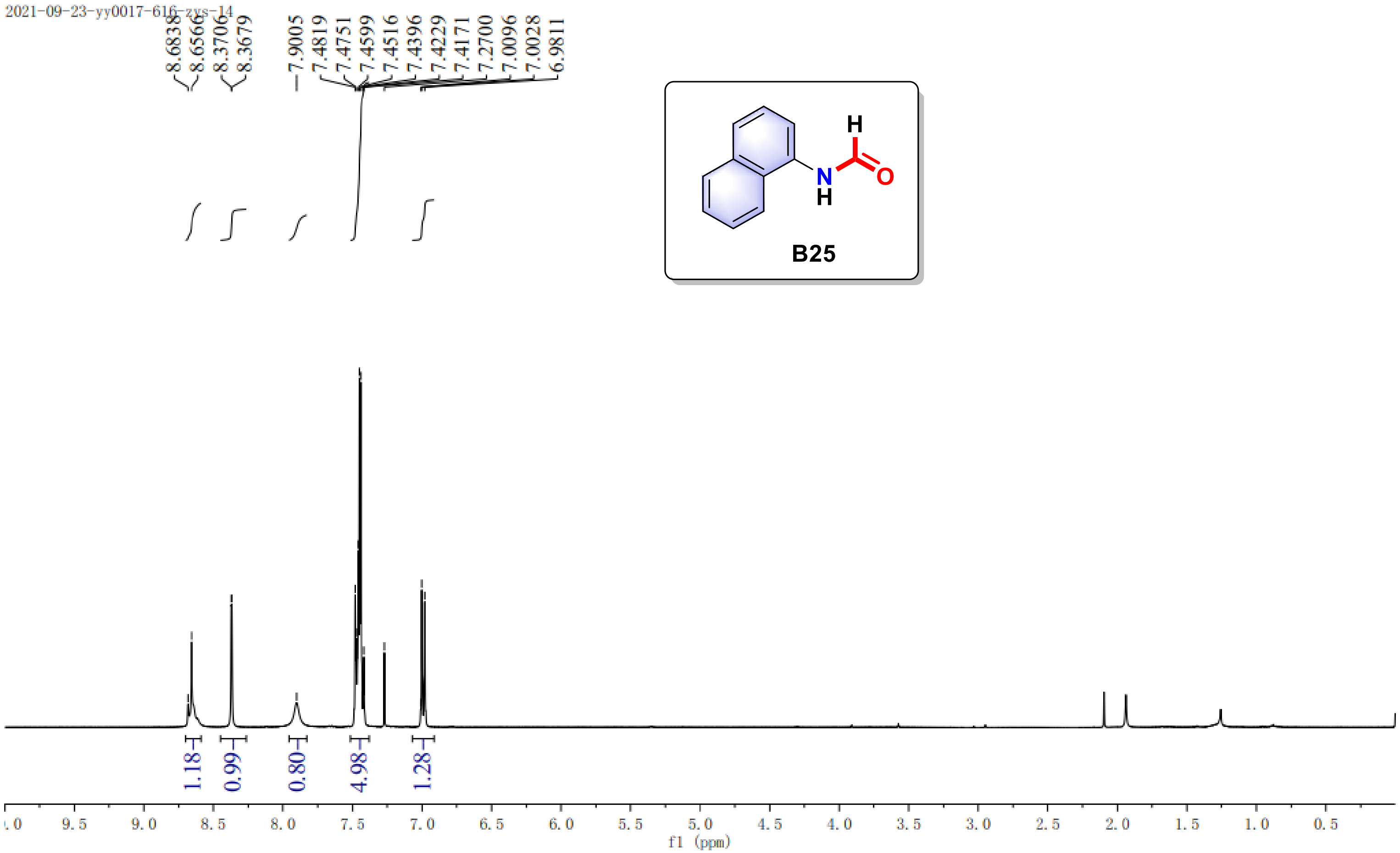

2021-10-21 YY0022-616-ZYS-48.10.fid
10.0833
10.0005
9.9730
8.6266
8.5992
8.2024
8.1977
7.3001
7.2950
6.9861
6.9810
6.9653
6.9601
6.8663
6.8453
5.9924
5.9871
3.3863
2.5186
2.5141
2.5095
2.5048
2.5001
O
O
H
N
H
O
B23
1.00
0.24
0.75
0.73
0.80
1.21
0.25
2.08
.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)


2021-10-27 YY0034-616-ZYS-48.10.fid
163.08
159.64
148.31
147.54
144.16
143.57
133.11
133.08
112.36
111.34
108.97
108.58
101.73
101.62
101.47
100.60
40.57
40.36
40.16
39.95
39.74
39.53
39.32
O
O
N
H
H
O
B23
00
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



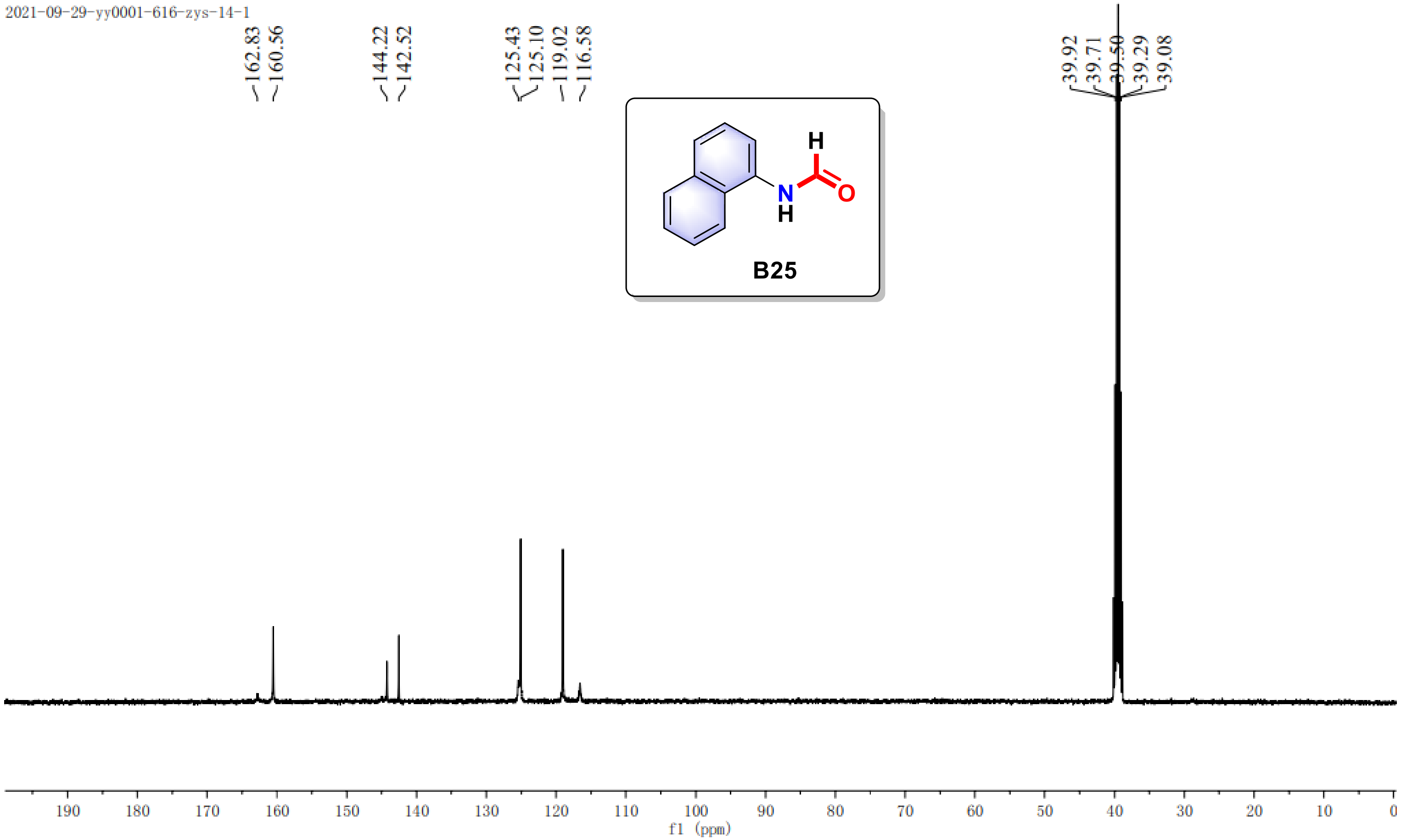
2021-10-09 YY0013-616-zys-34
10.5576
10.4951
10.4692
8.9875
8.9613
8.3528
7.9426
7.9208
7.9148
7.9119
7.8899
7.7310
7.7092
7.3348
7.3132
3.8243
3.3683
2.5117
2.5073
1.00
0.26
0.77
2.00
1.53
0.52
3.00
O
O
H
N
H
O
B24
.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)

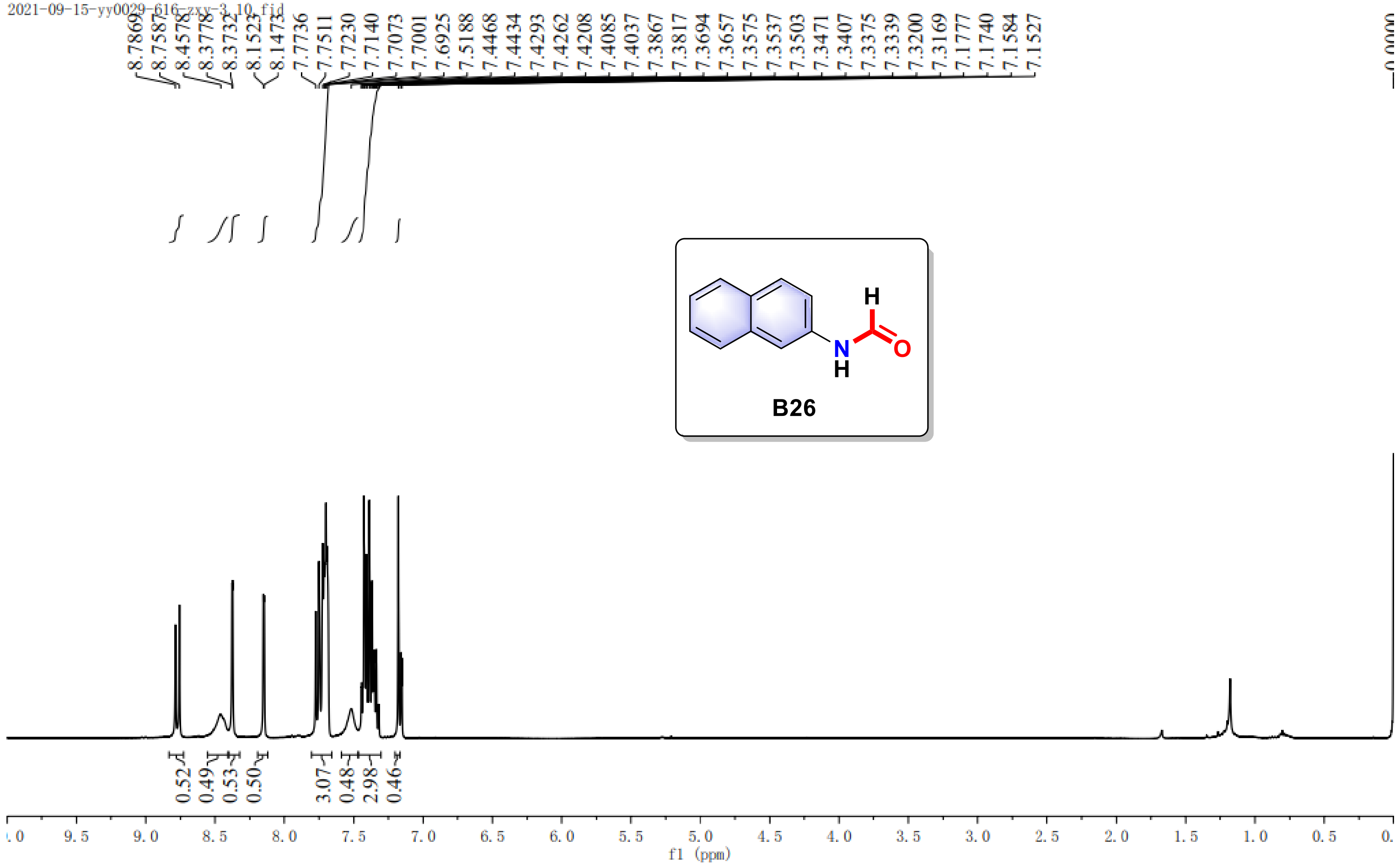

2021-10-12 YY0039 616-zys-34_10_fid
166.20
163.04
160.63
143.44
142.95
131.26
130.87
124.81
119.11
116.90
52.38
40.58
40.38
40.17
39.96
39.75
39.54
39.33
O
O
H
N
H
O
B24
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

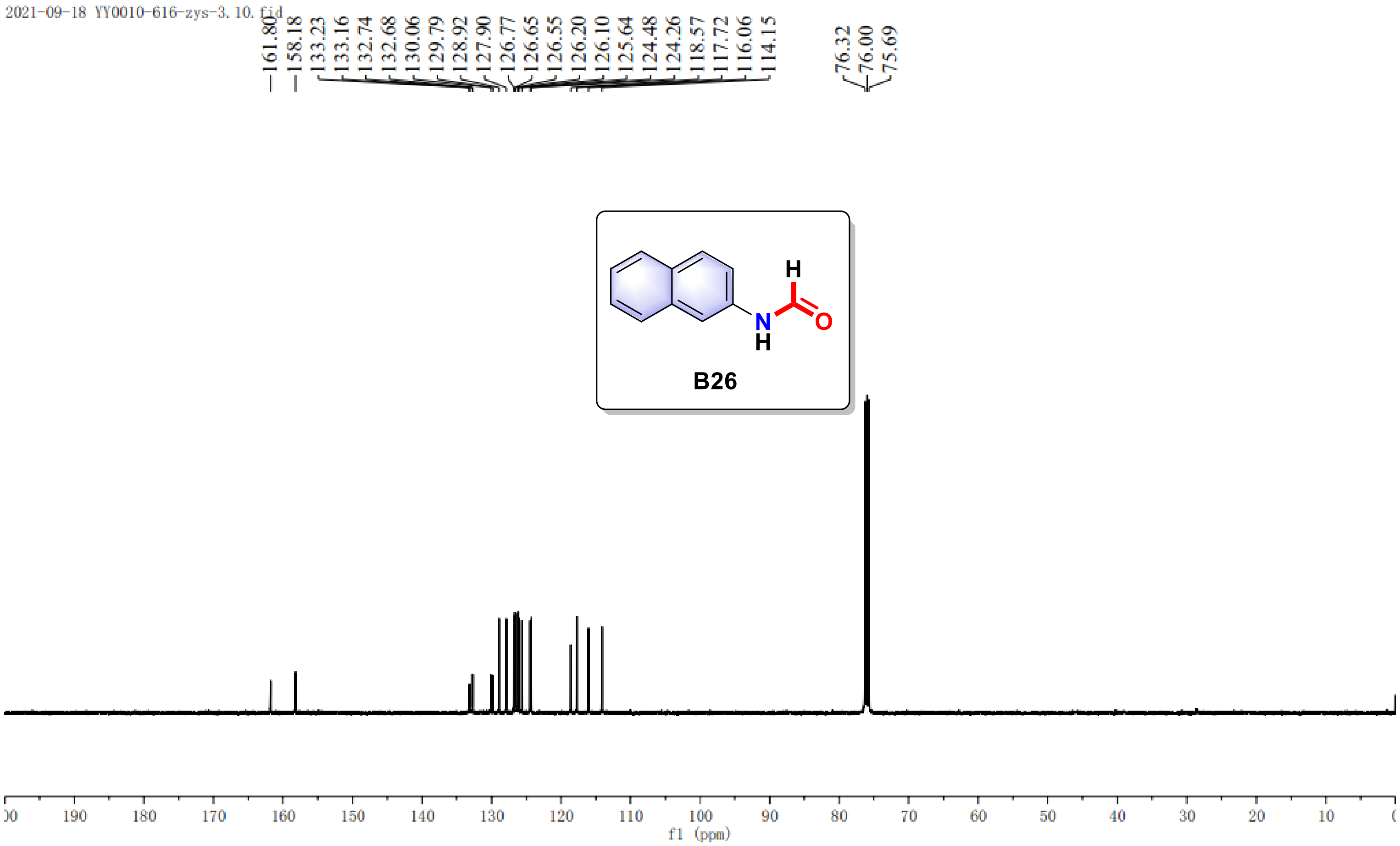

2021-09-23-yy0017-616-zys-14
8.6838
8.6560
8.3706
8.3679
7.9005
7.4819
7.4751
7.4599
7.4516
7.4396
7.4229
7.4171
7.2700
7.0096
7.0028
6.9811
1.18
0.99
0.80
4.98
1.28
. 0
9. 5
9. 0
8. 5
8. 0
7. 5
7. 0
6. 5
6. 0
5. 5
5. 0
4. 5
4. 0
3. 5
3. 0
2. 5
2. 0
1. 5
1. 0
0. 5
f1 (ppm)

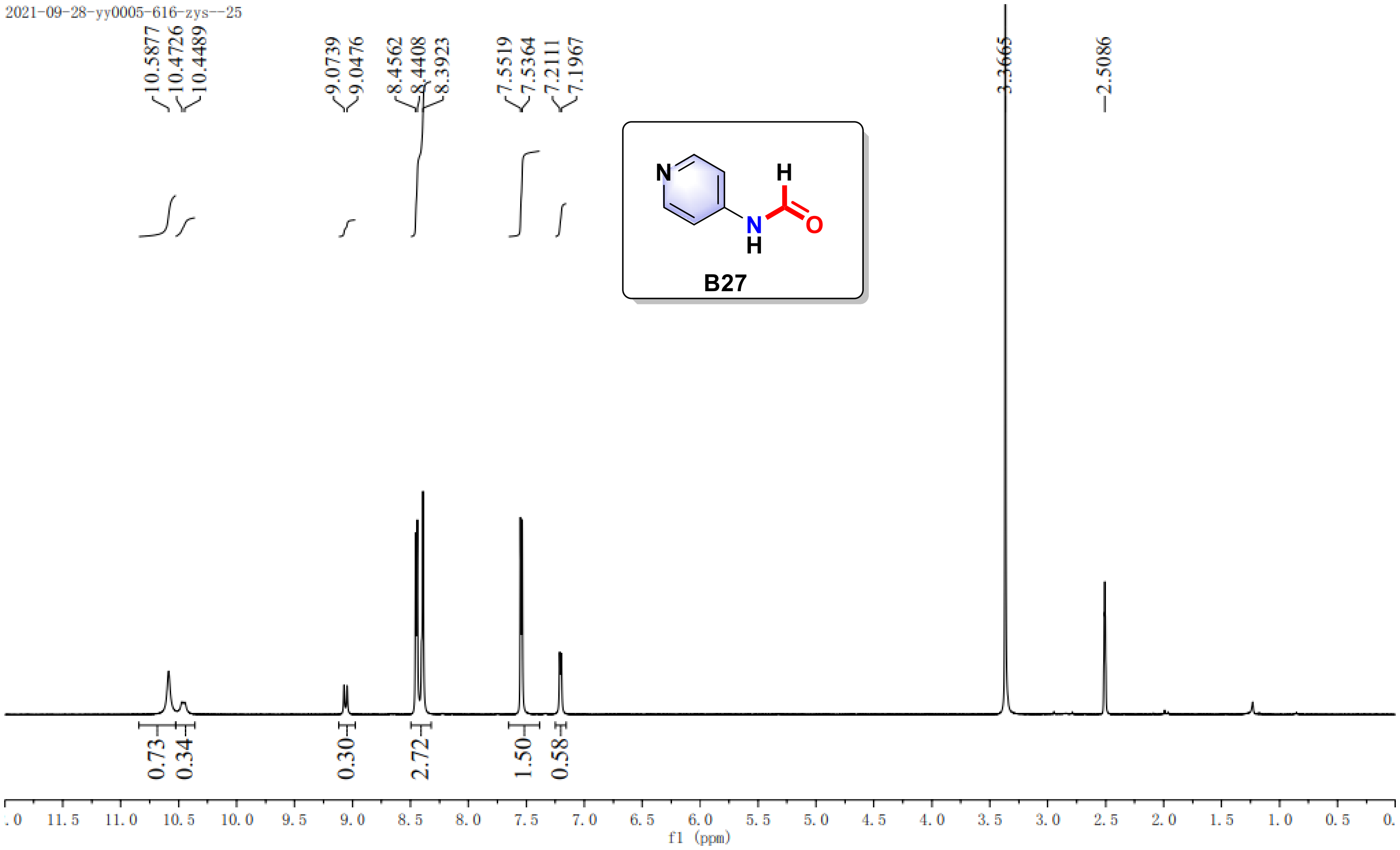
H
N
H
O

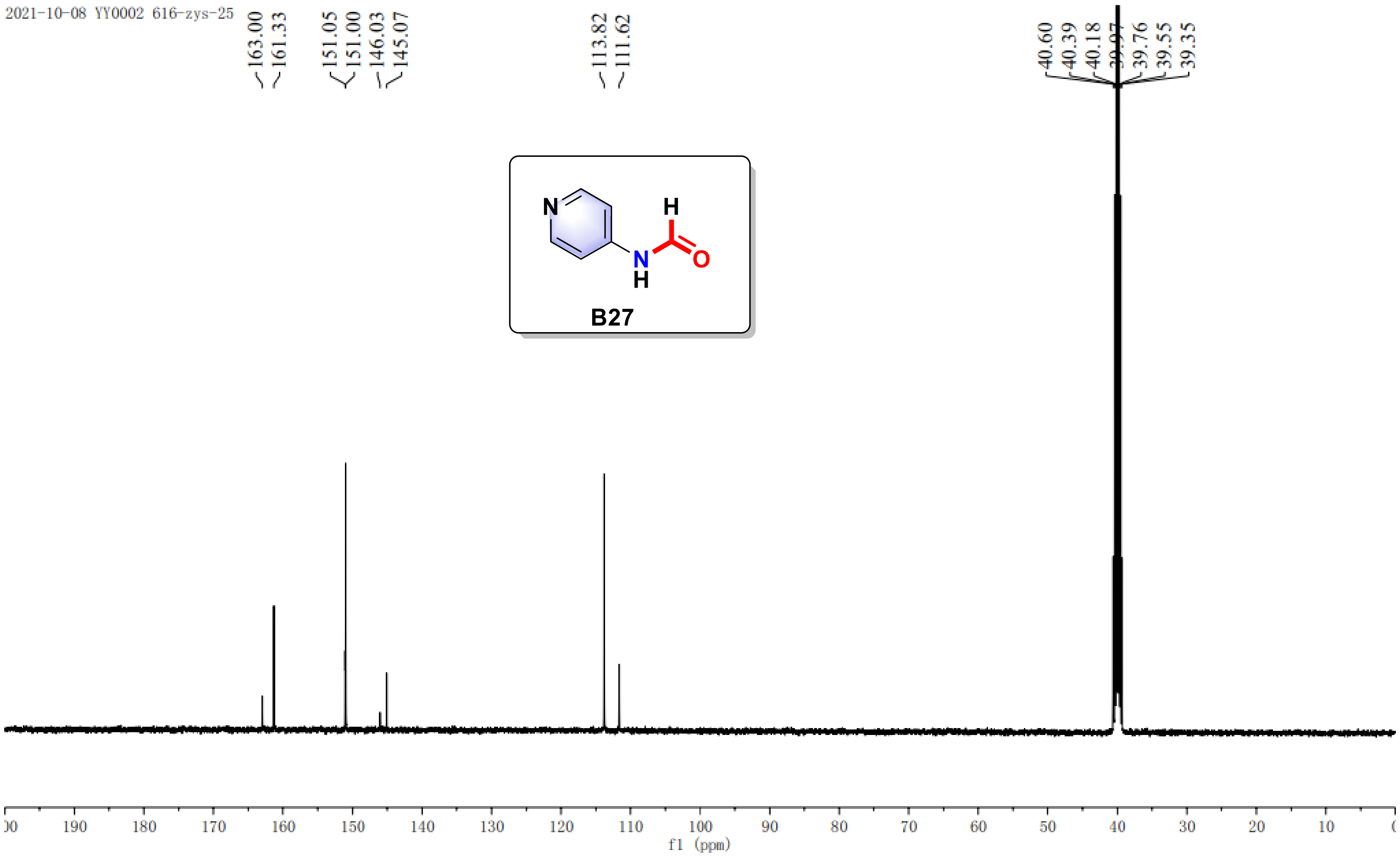
B25

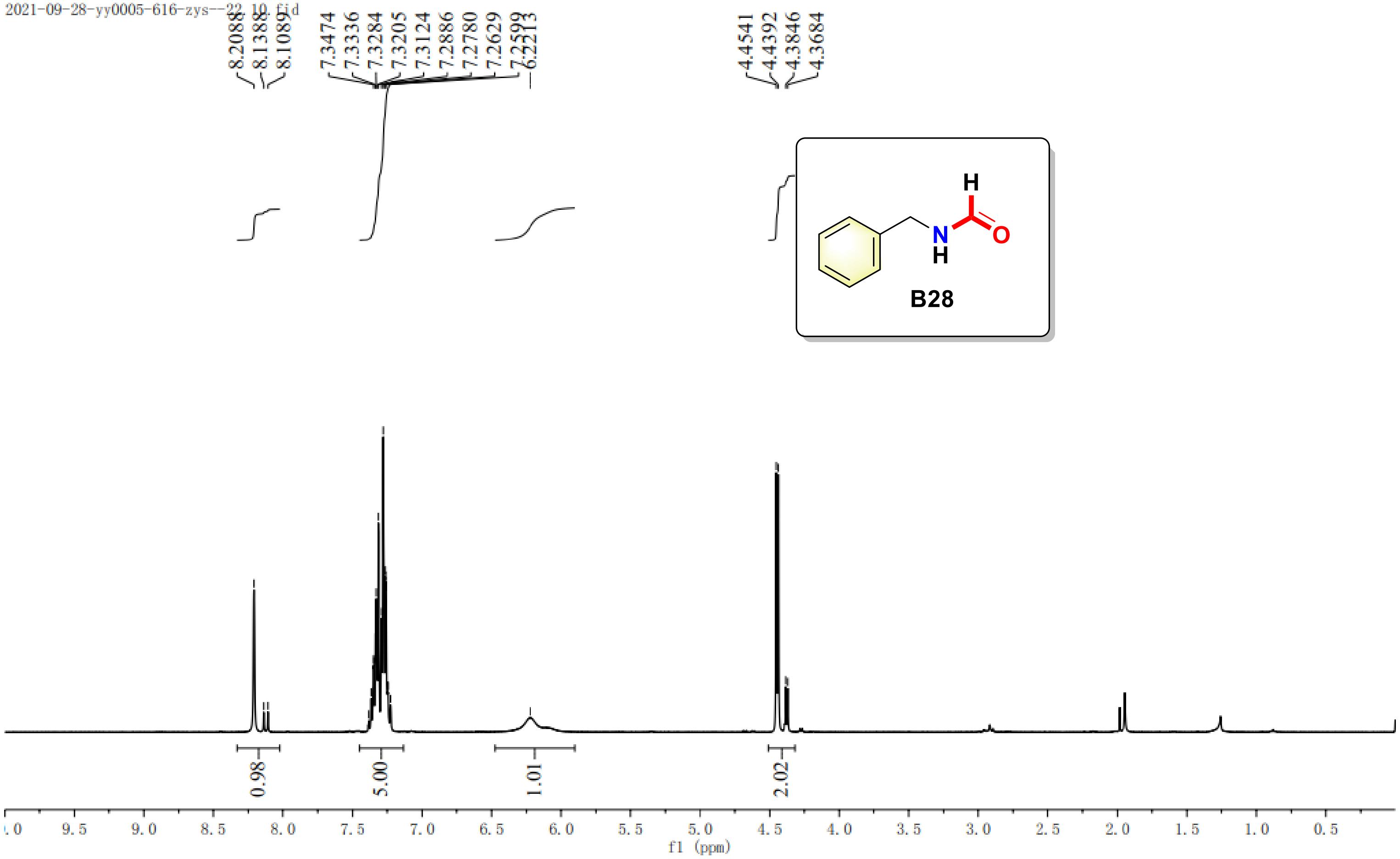

2021-09-29-yy0001-616-zys-14-1
162.83
160.56
144.22
142.52
125.43
125.10
119.02
116.58
39.92
39.71
39.50
39.29
39.08
H
N
H
O
B25
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

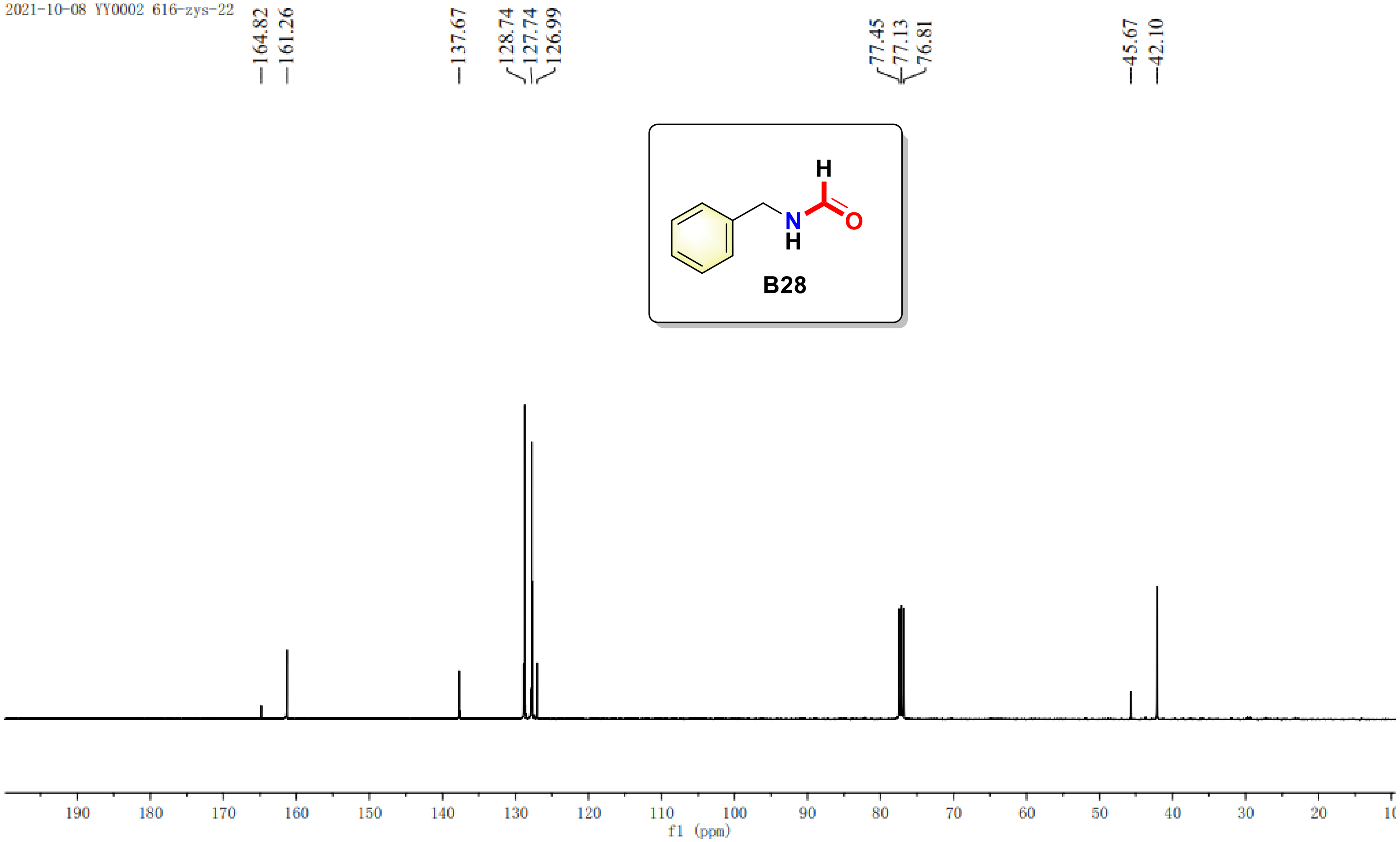

2021-09-15-yy0029-616-zxy-3.10.fid
8.7869
8.7587
8.4578
8.3778
8.3732
8.1523
8.1473
7.7736
7.7511
7.7230
7.7140
7.7073
7.7001
7.6925
7.5188
7.4468
7.4434
7.4293
7.4262
7.4208
7.4085
7.4037
7.3867
7.3817
7.3694
7.3657
7.3575
7.3537
7.3503
7.3471
7.3407
7.3375
7.3339
7.3200
7.3169
7.1777
7.1740
7.1584
7.1527
0.0000
H
N
H
O
B26
0.52
0.49
0.53
0.50
3.07
0.48
2.98
0.46
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)

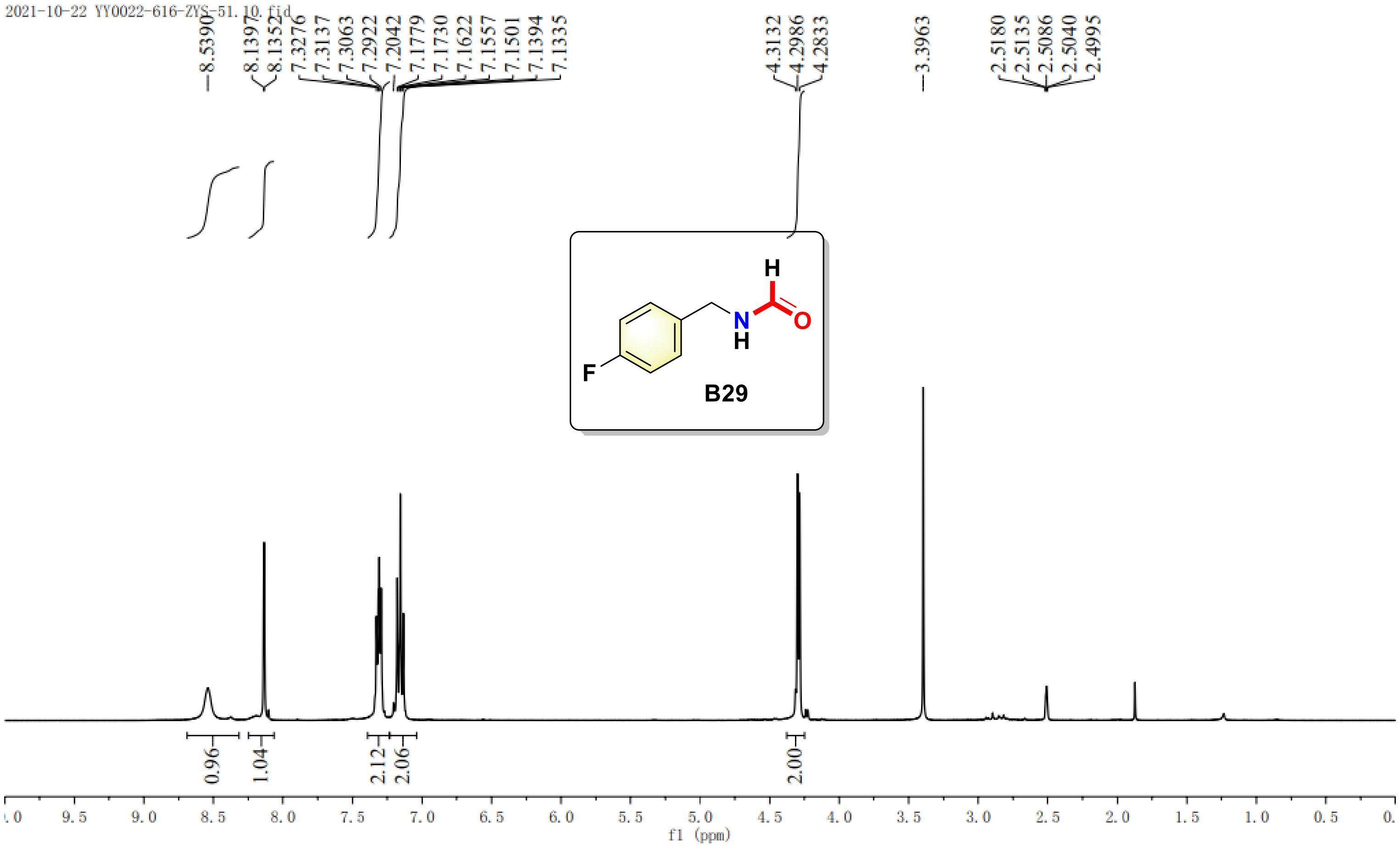

2021-09-18 YY0010-616-zys-3.10.fid
161.80
158.18
133.23
133.16
132.74
132.68
130.06
129.79
128.92
127.90
126.77
126.65
126.55
126.20
126.10
125.64
124.48
124.26
118.57
117.72
116.06
114.15
76.32
76.00
75.69
H
N
H
O
B26
00
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

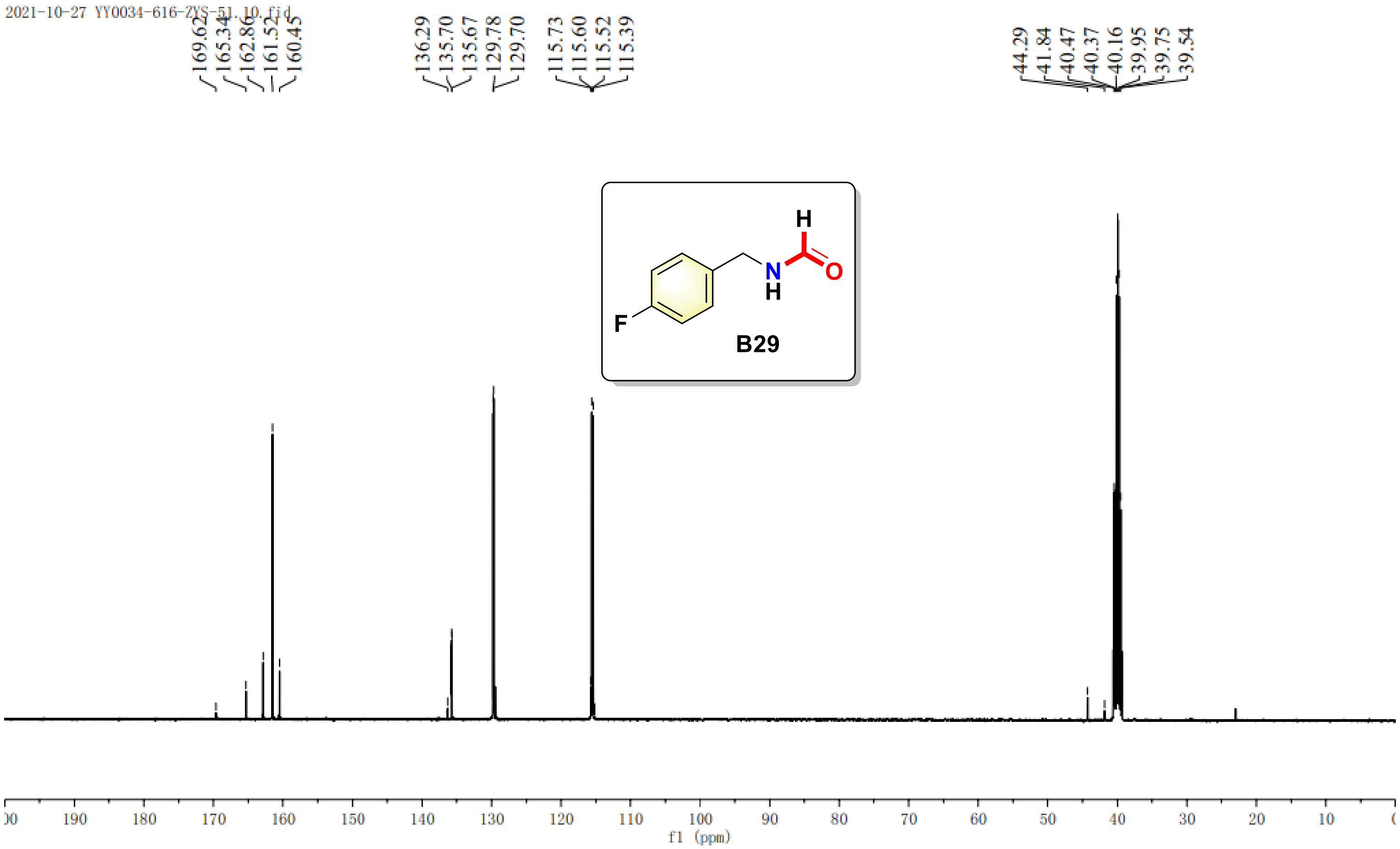

2021-09-28-yy0005-616-zys--25
10.5877
10.4726
10.4489
9.0739
9.0476
8.4562
8.4408
8.3923
7.5519
7.5364
7.2111
7.1967
3.3665
2.5086
N
H
N
H
O
B27
0.73
0.34
0.30
2.72
1.50
0.58
.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)

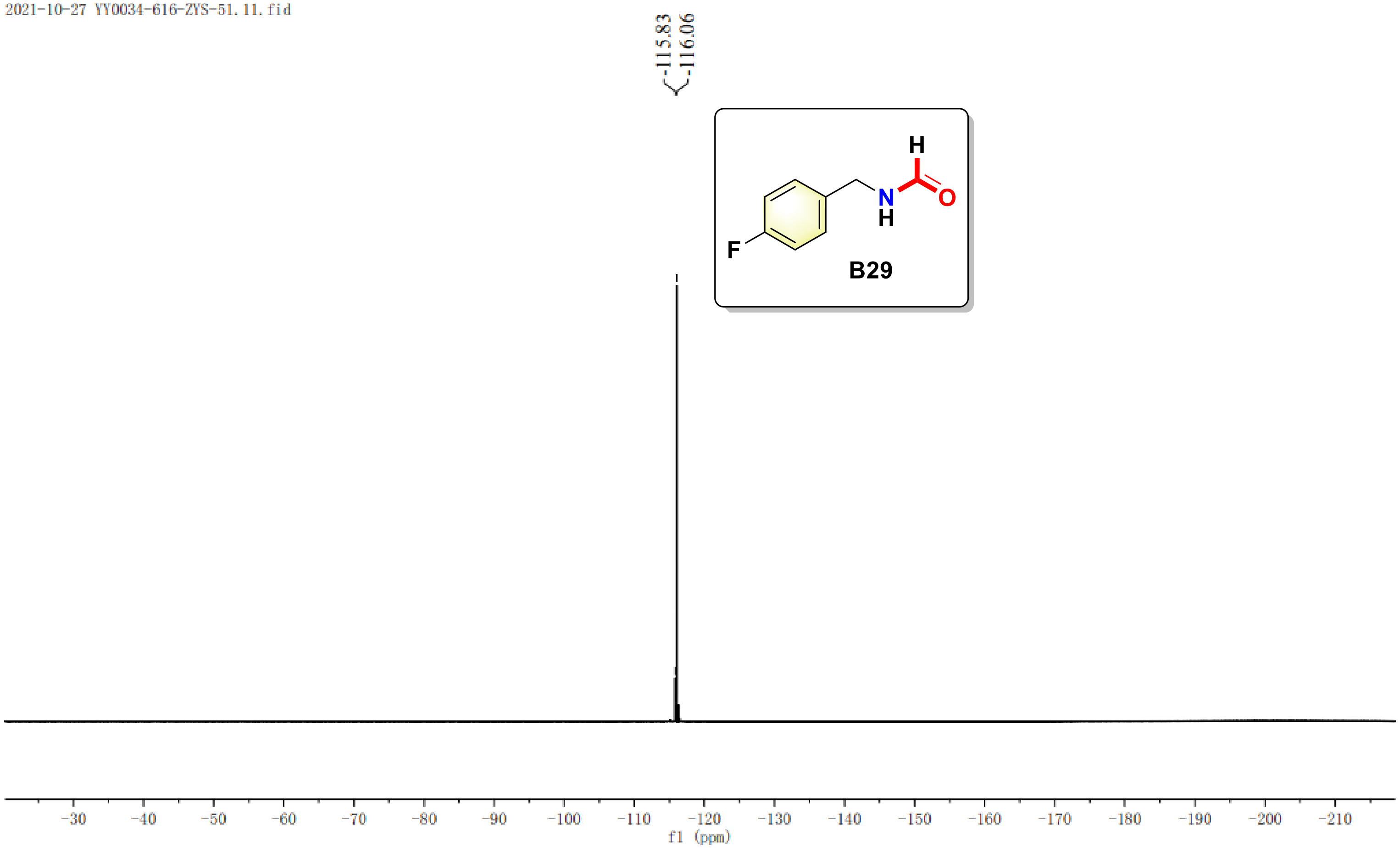

2021-10-08 YY0002 616-zys-25
163.00
161.33
151.05
151.00
146.03
145.07
113.82
111.62
40.60
40.39
40.18
39.97
39.76
39.55
39.35
N
H
N
H
O
B27
00
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

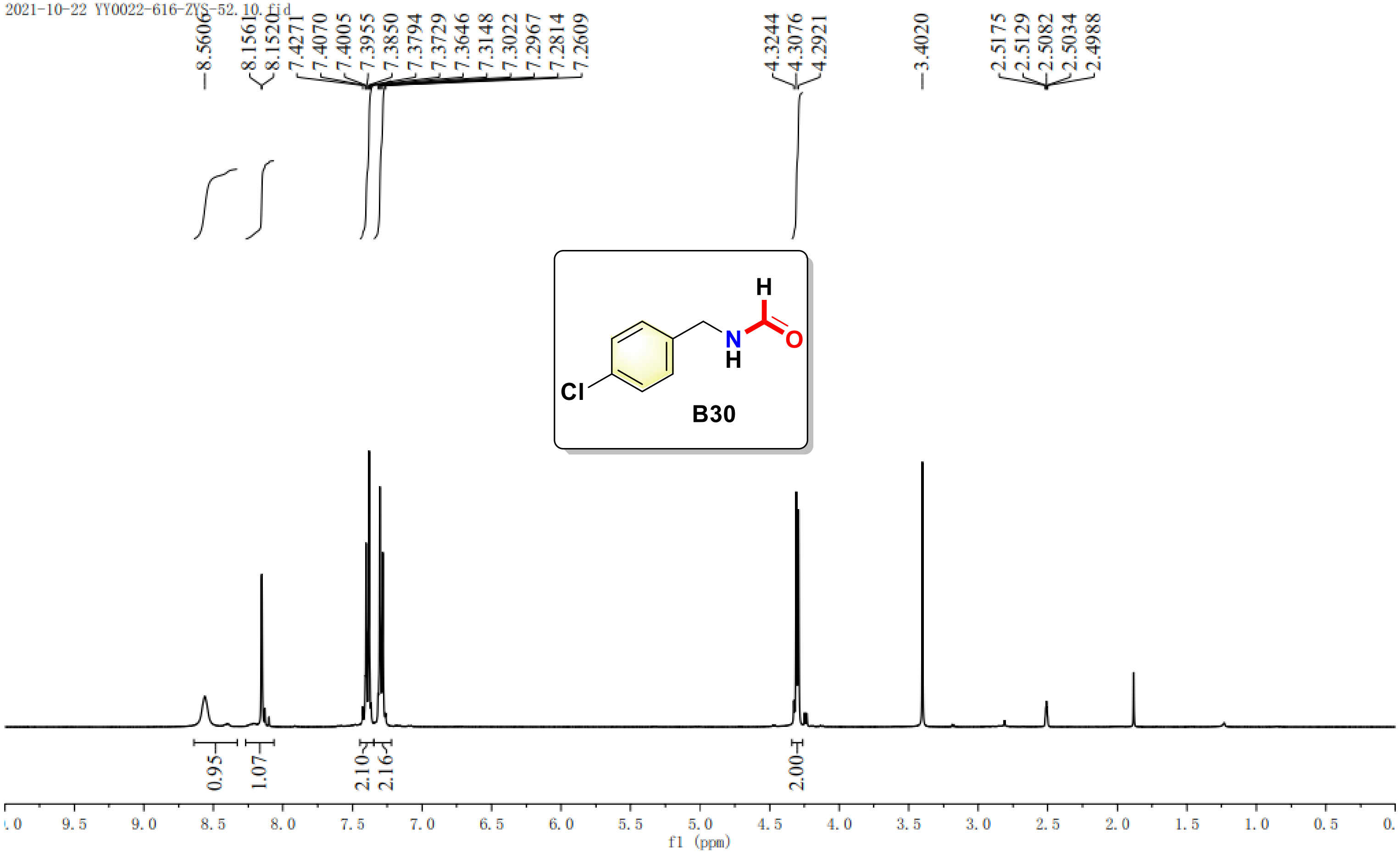

2021-09-28-yy0005-616-zys--22.10.fid
8.2088
8.1388
8.1089
7.3474
7.3336
7.3284
7.3205
7.3124
7.2886
7.2780
7.2629
7.2599
6.2213
4.4541
4.4392
4.3846
4.3684
H
N
H
O
B28
0.98
5.00
1.01
2.02
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


2021-10-08 YY0002 616-zys-22
164.82
161.26
137.67
128.74
127.74
126.99
77.45
77.13
76.81
45.67
42.10
H
N
H
O
B28
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
f1 (ppm)


2021-10-22 YY0022-616-ZYS-51.10.fid
8.5390
8.1397
8.1352
7.3276
7.3137
7.3063
7.2922
7.2042
7.1779
7.1730
7.1622
7.1557
7.1501
7.1394
7.1335
4.3132
4.2986
4.2833
3.3963
2.5180
2.5135
2.5086
2.5040
2.4995
H
N
H
O
F
B29
0.96
1.04
2.12
2.06
2.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)


2021-10-27 YY0034-616-ZYS-51.10.fid
169.62
165.34
162.86
161.52
160.45
136.29
135.70
135.67
129.78
129.70
115.73
115.60
115.52
115.39
44.29
41.84
40.47
40.37
40.16
39.95
39.75
39.54
H
N
H
O
F
B29
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


2021-10-27 YY0034-616-ZYS-51.11.fid
-115.83
-116.06
H
N
H
O
F
B29
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)


2021-10-22 YY0022-616-ZYS-52.10.fid
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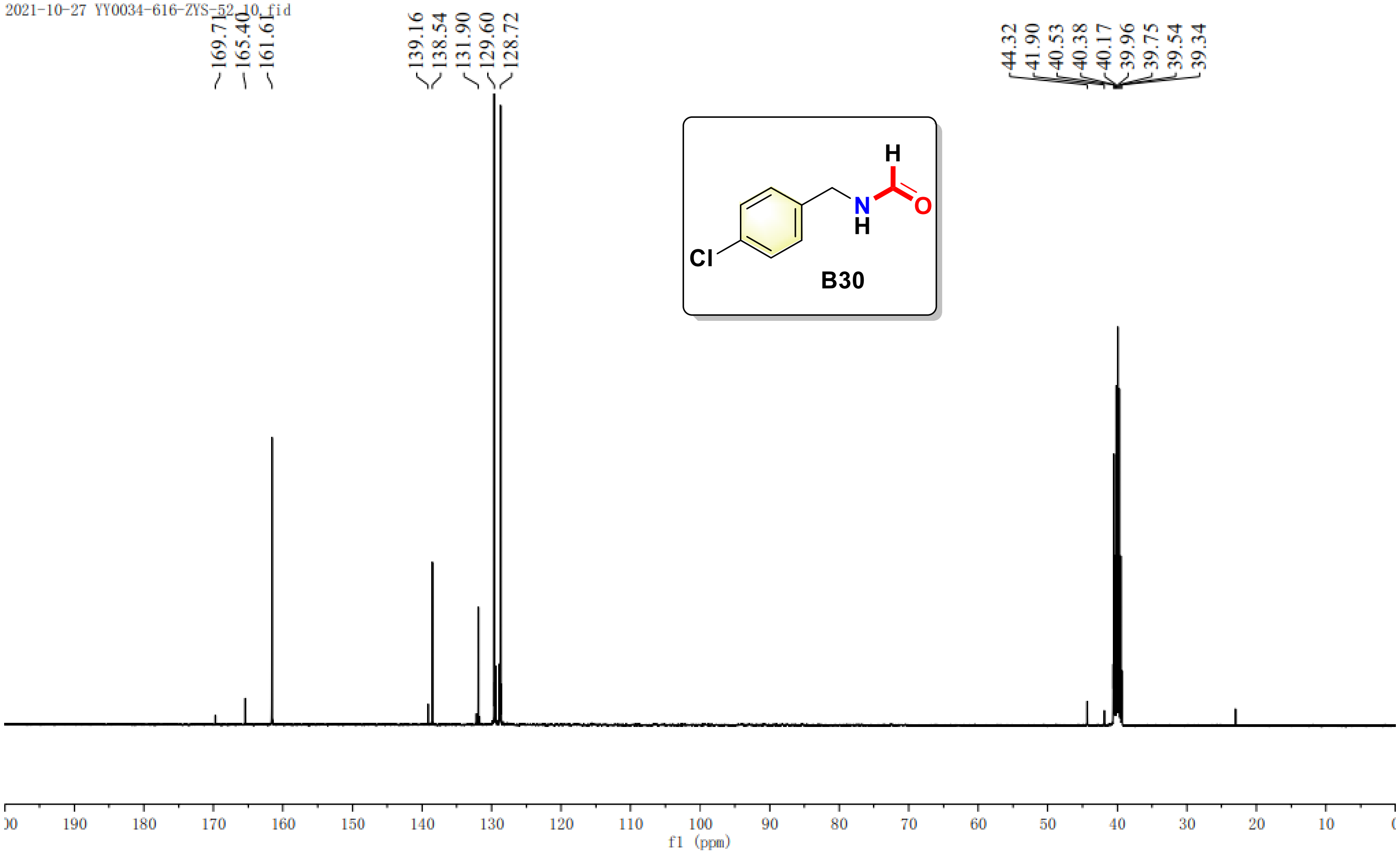
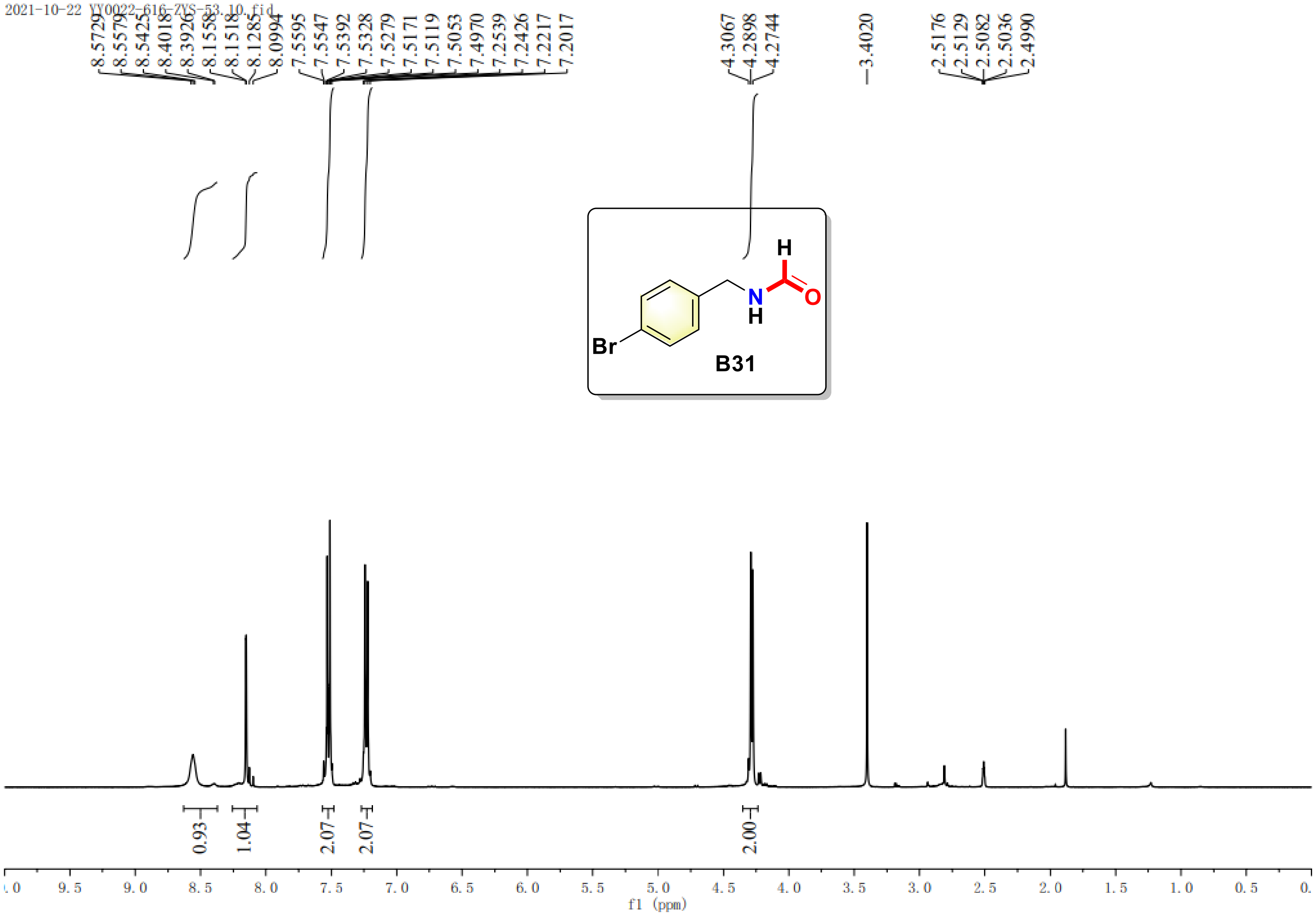
8.1520
7.4271
7.4070
7.4005
7.3955
7.3850
7.3794
7.3729
7.3646
7.3148
7.3022
7.2967
7.2814
7.2609
4.3244
4.3076
4.2921
3.4020
2.5175
2.5129
2.5082
2.5034
2.4988
H
N
H
O
Cl
B30
0.95
1.07
2.10
2.16
2.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)


2021-10-27 YY0034-616-ZYS-52.10.fid
169.71
165.40
161.61
139.16
138.54
131.90
129.60
128.72
44.32
41.90
40.53
40.38
40.17
39.96
39.75
39.54
39.34
Cl
H
N
H
O
B30
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


2021-10-22 YY0022-616-ZYS-53.10.fid
8.5729
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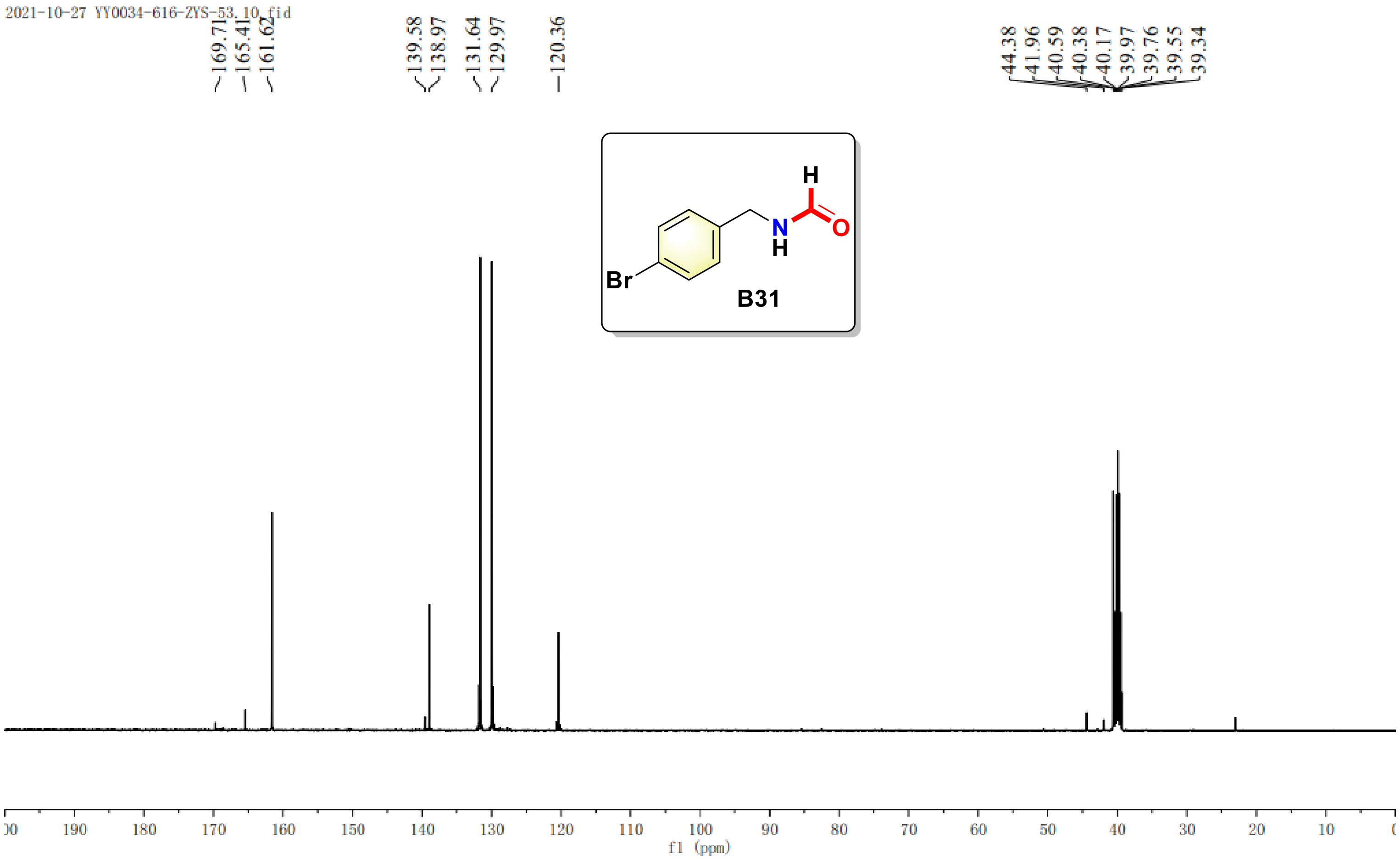
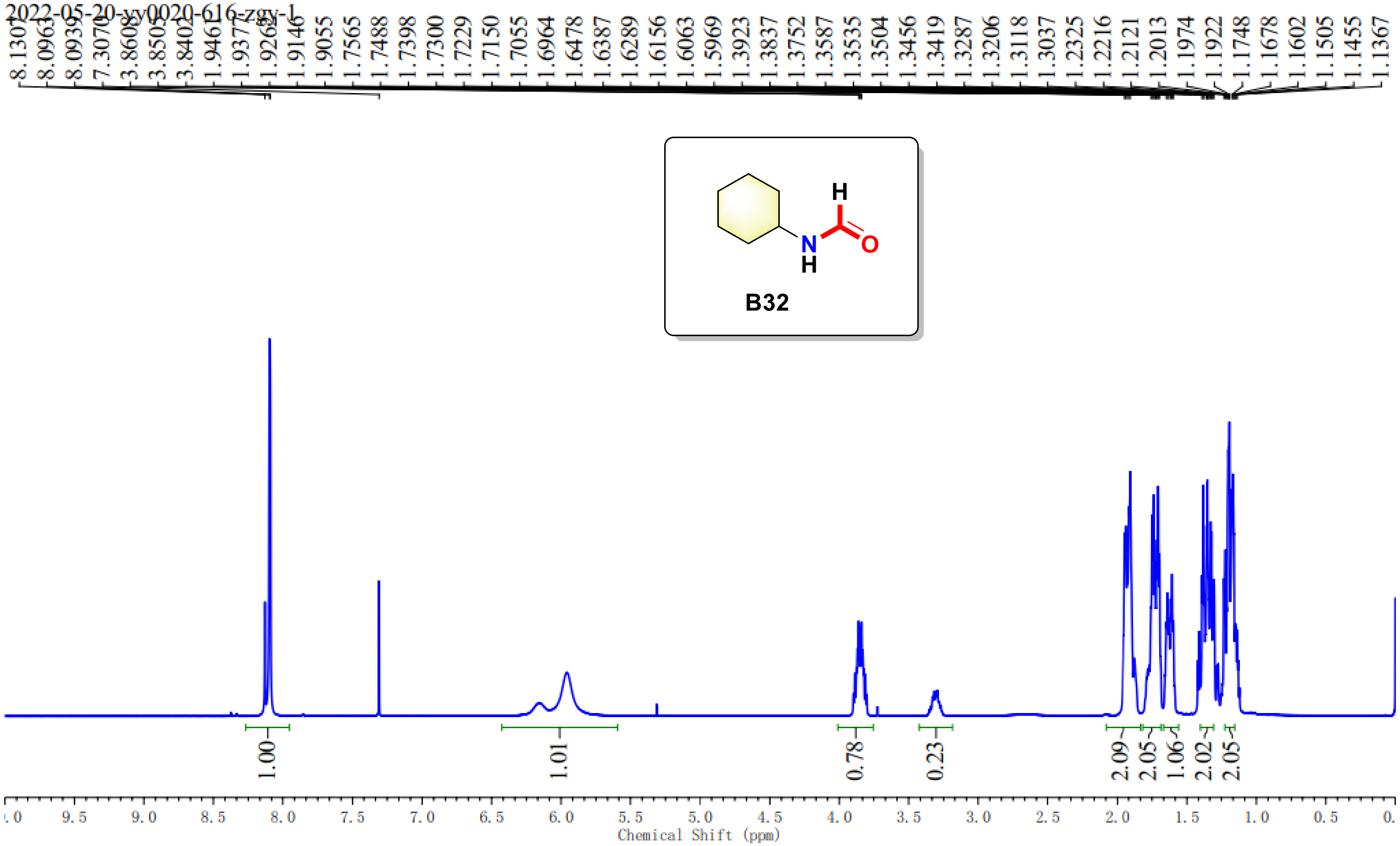
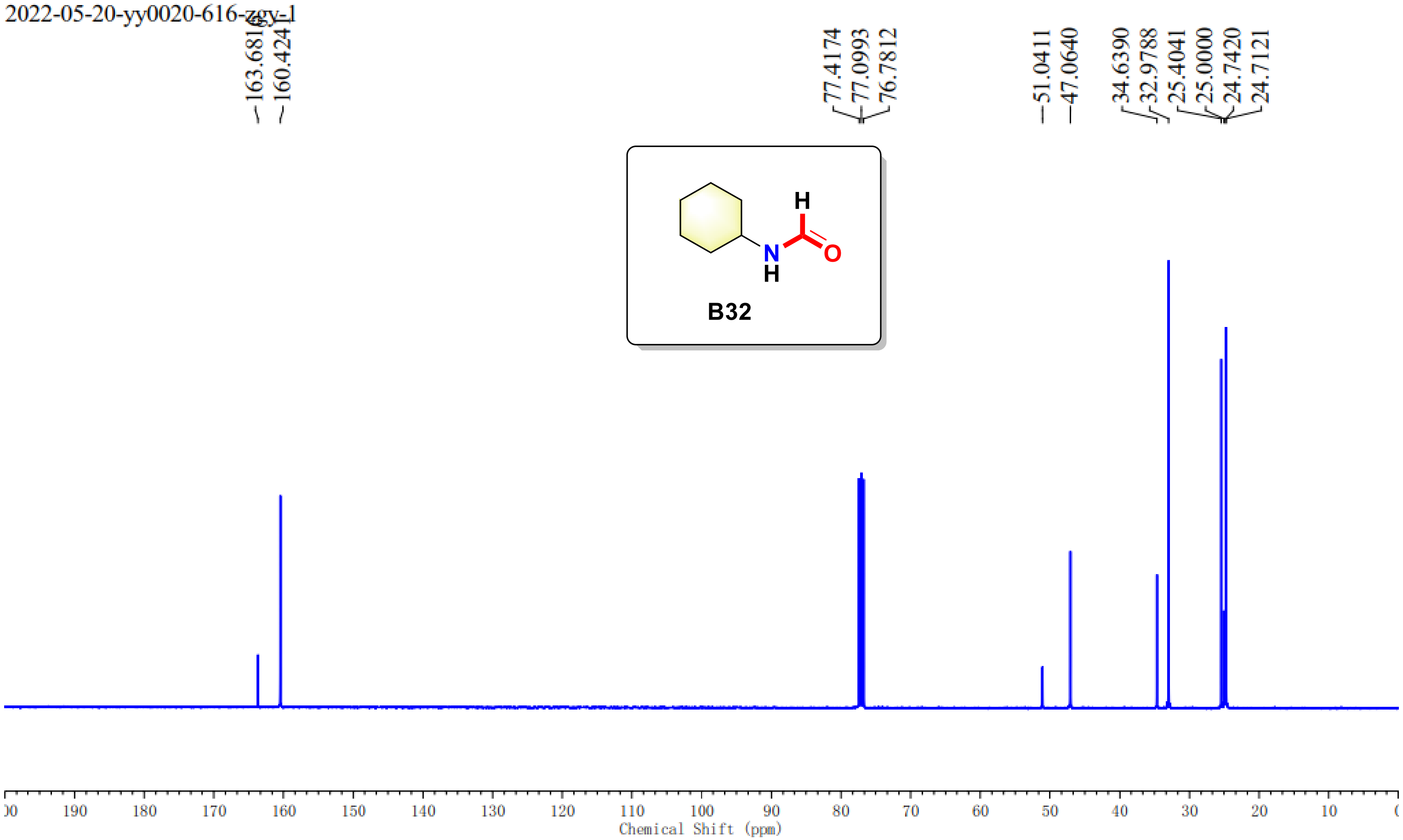
8.5425
8.4018
8.3926
8.1558
8.1518
8.1285
8.0994
7.5595
7.5547
7.5392
7.5328
7.5279
7.5171
7.5119
7.5053
7.4970
7.2539
7.2426
7.2217
7.2017
4.3067
4.2898
4.2744
3.4020
2.5176
2.5129
2.5082
2.5036
2.4990
Br
N
H
H
O
B31
0.93
1.04
2.07
2.07
2.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)


2021-10-27 YY0034-616-ZYS-53.10.fid
169.71
165.41
161.62
139.58
138.97
131.64
129.97
120.36
44.38
41.96
40.59
40.38
40.17
39.97
39.76
39.55
39.34
Br
N
H
H
O
B31
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


2022-05-20-yy0020-616-zgy-1
8.1307
8.0963
8.0939
7.3070
3.8608
3.8505
3.8402
1.9461
1.9377
1.9268
1.9146
1.9055
1.7565
1.7488
1.7398
1.7300
1.7229
1.7150
1.7055
1.6964
1.6478
1.6387
1.6289
1.6156
1.6063
1.5969
1.3923
1.3837
1.3752
1.3587
1.3535
1.3504
1.3456
1.3419
1.3287
1.3206
1.3118
1.3037
1.2325
1.2216
1.2121
1.2013
1.1974
1.1922
1.1748
1.1678
1.1602
1.1505
1.1455
1.1367
H
N
H
O
B32
1.00
1.01
0.78
0.23
2.09
2.05
1.06
2.02
2.05
.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
Chemical Shift (ppm)


2022-05-20-yy0020-616-zgy-1
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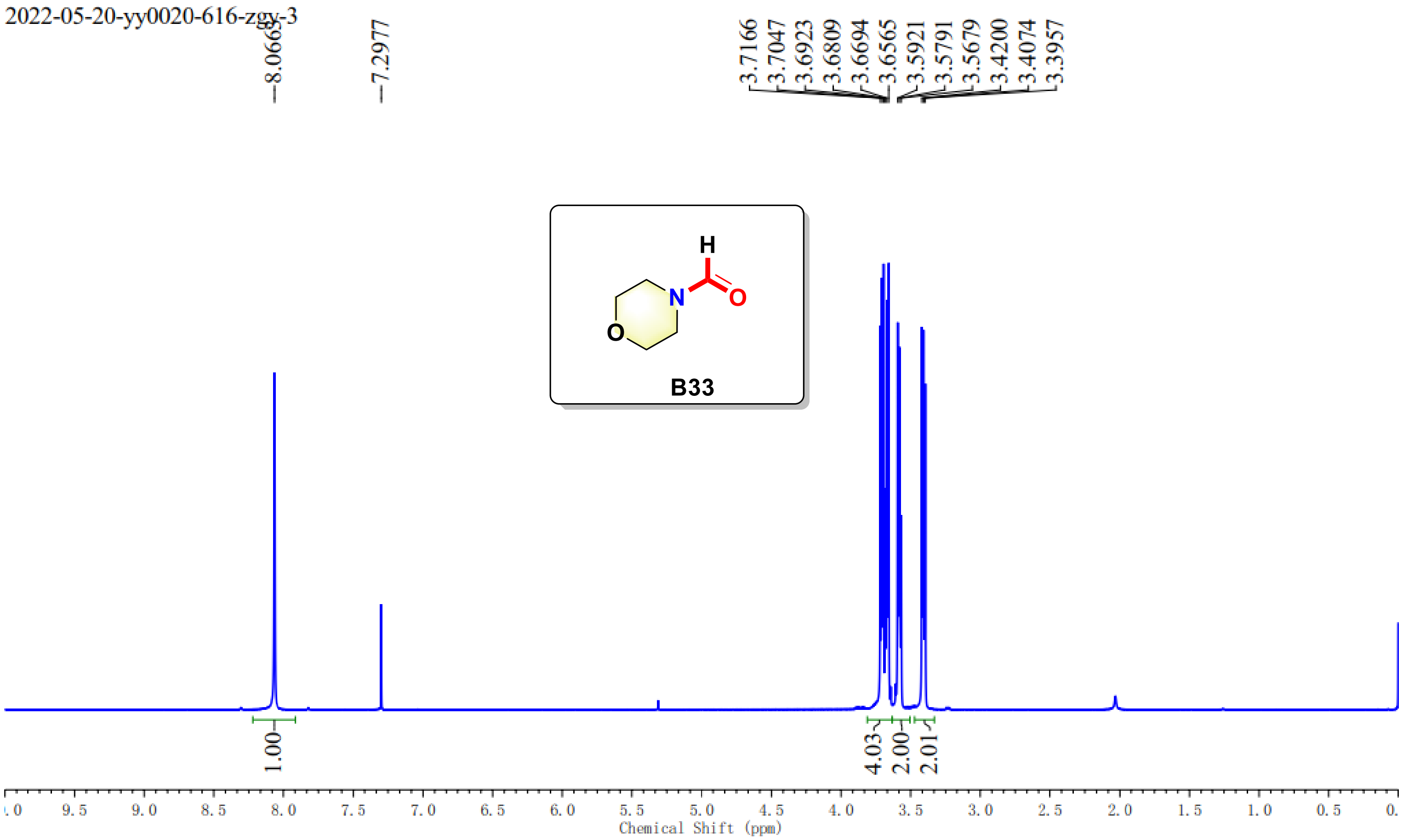
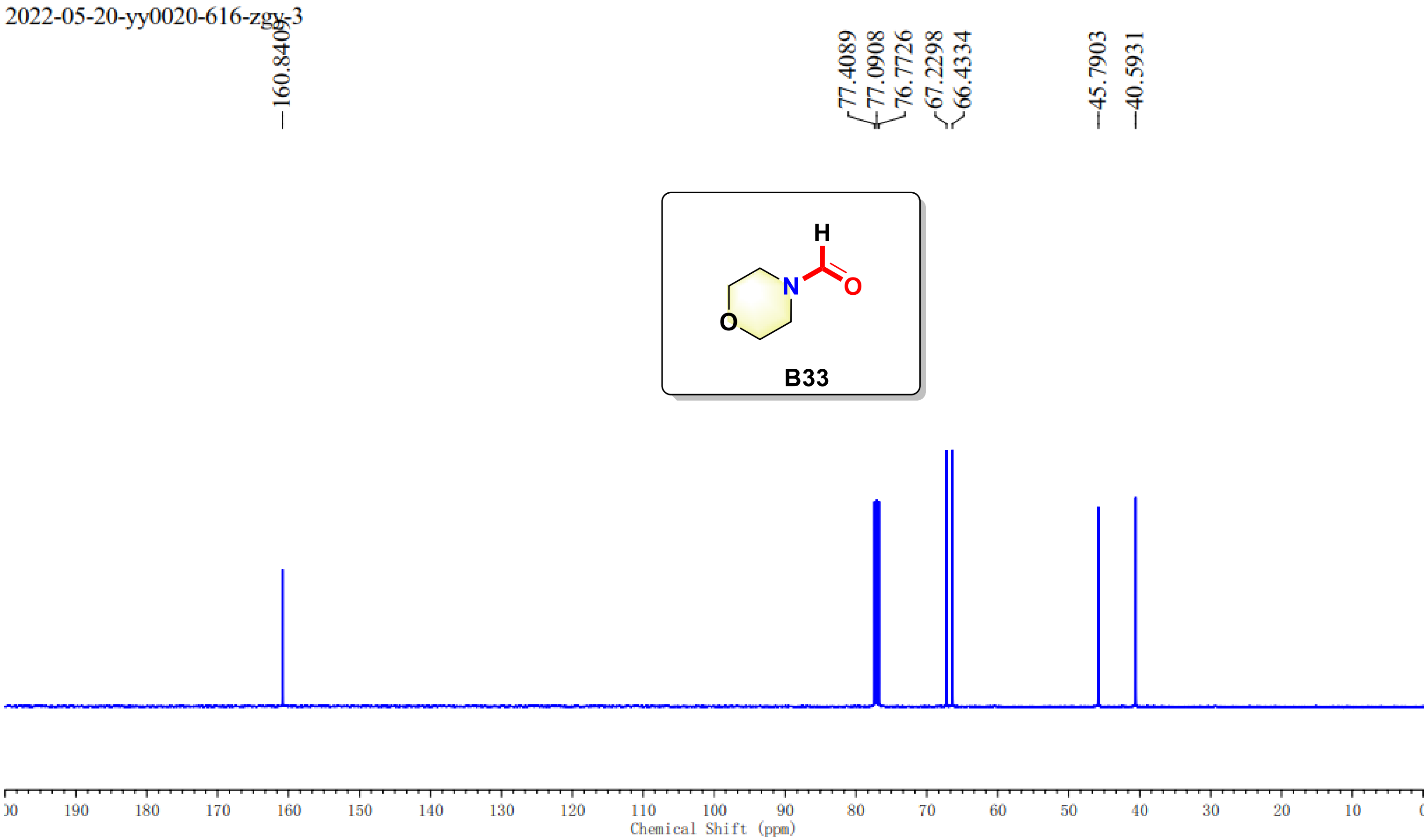
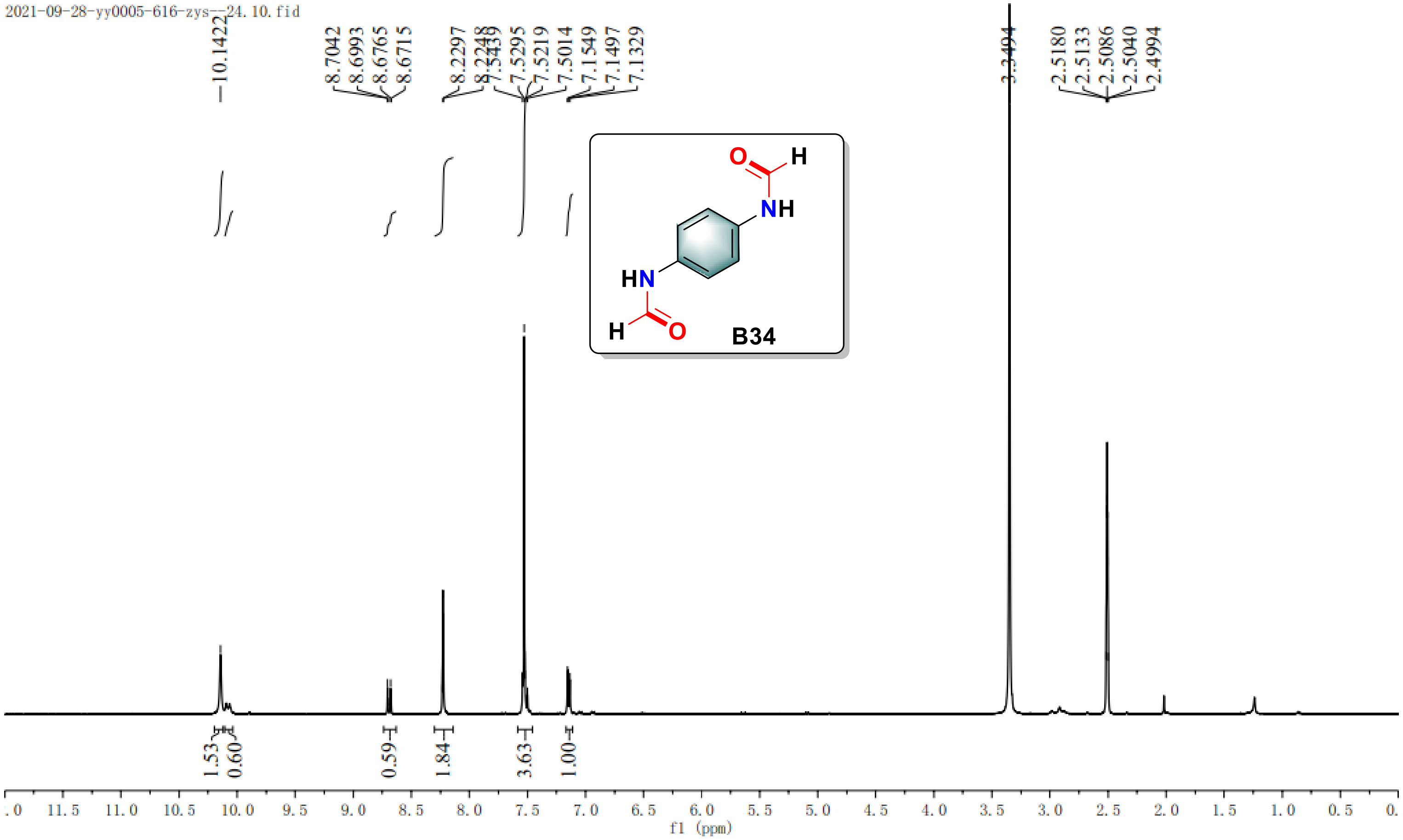
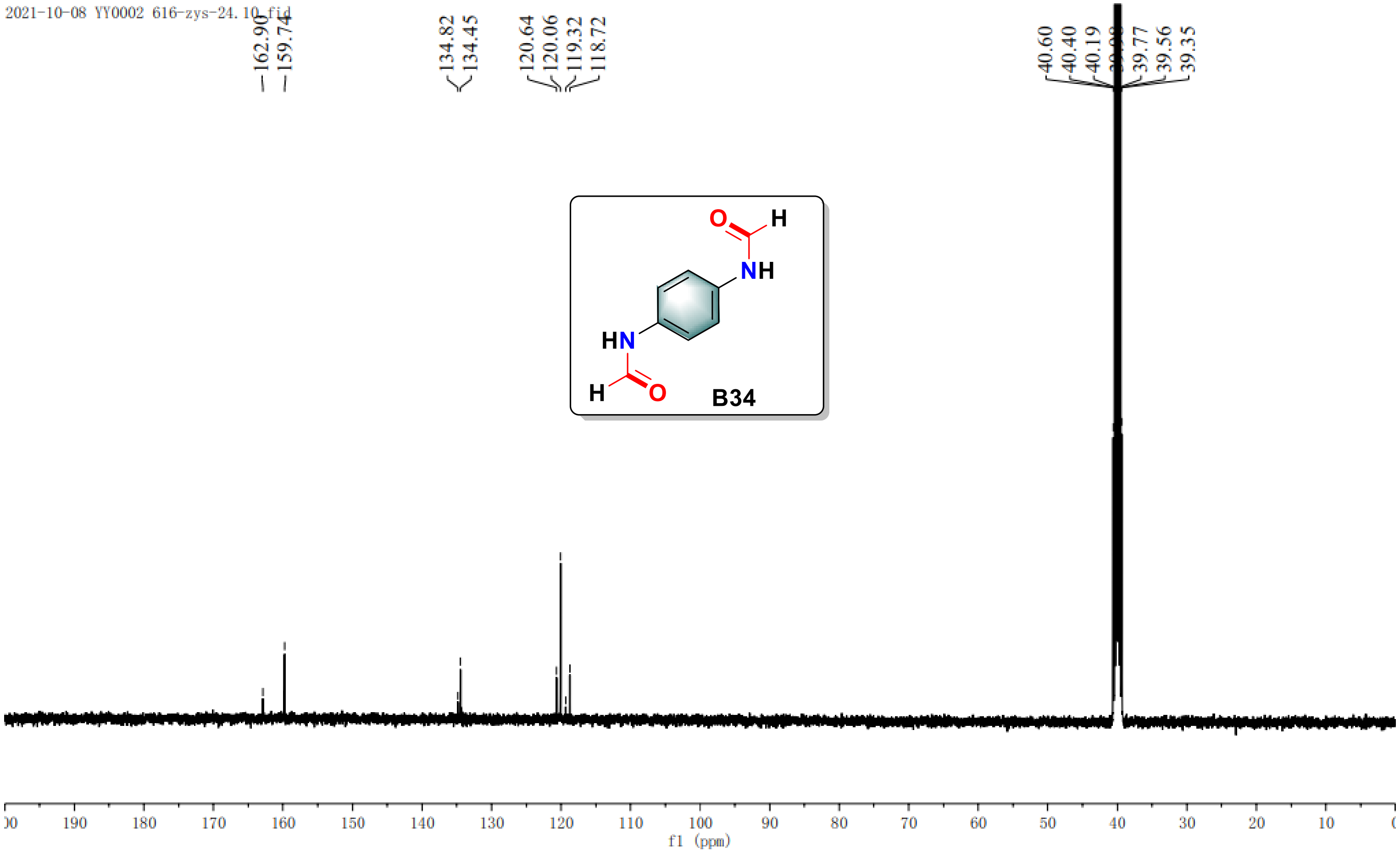
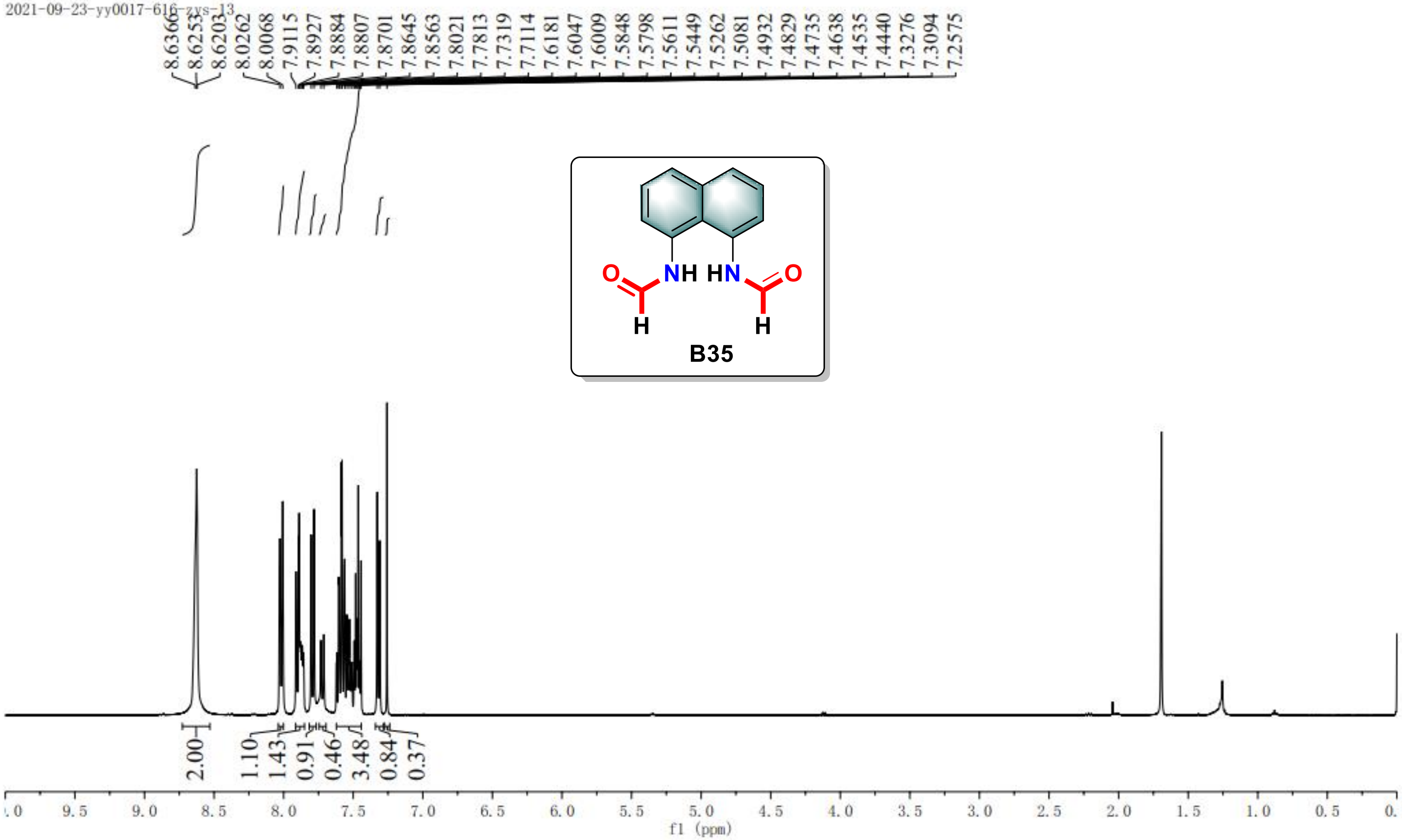
160.4241
77.4174
77.0993
76.7812
51.0411
47.0640
34.6390
32.9788
25.4041
25.0000
24.7420
24.7121
H
N
H
O
B32
00
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Chemical Shift (ppm)

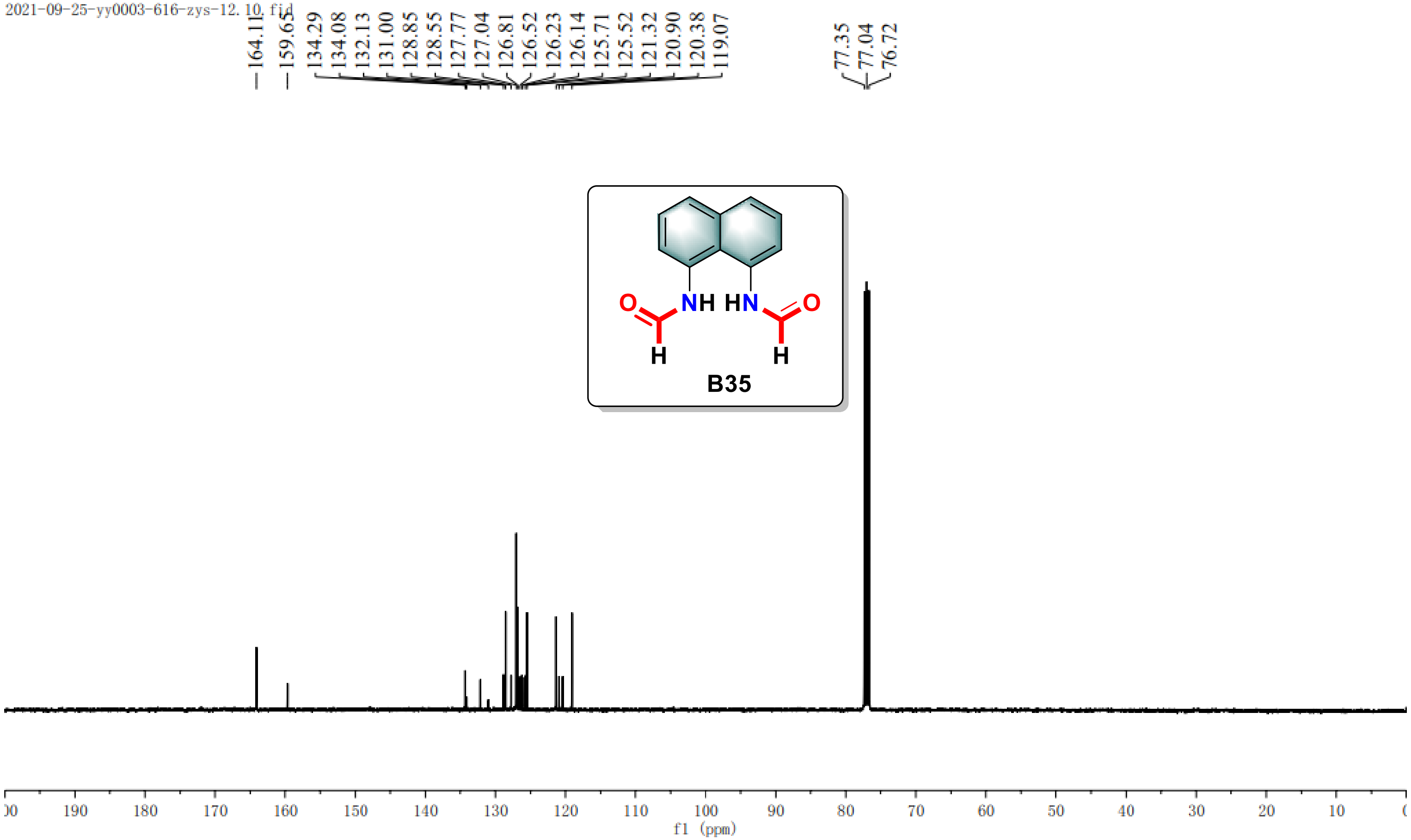

2022-05-20-yy0020-616-zgy-3
8.0665
7.2977
3.7166
3.7047
3.6923
3.6809
3.6694
3.6565
3.5921
3.5791
3.5679
3.4200
3.4074
3.3957
H
N
O
O
B33
1.00
4.03
2.00
2.01
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
Chemical Shift (ppm)

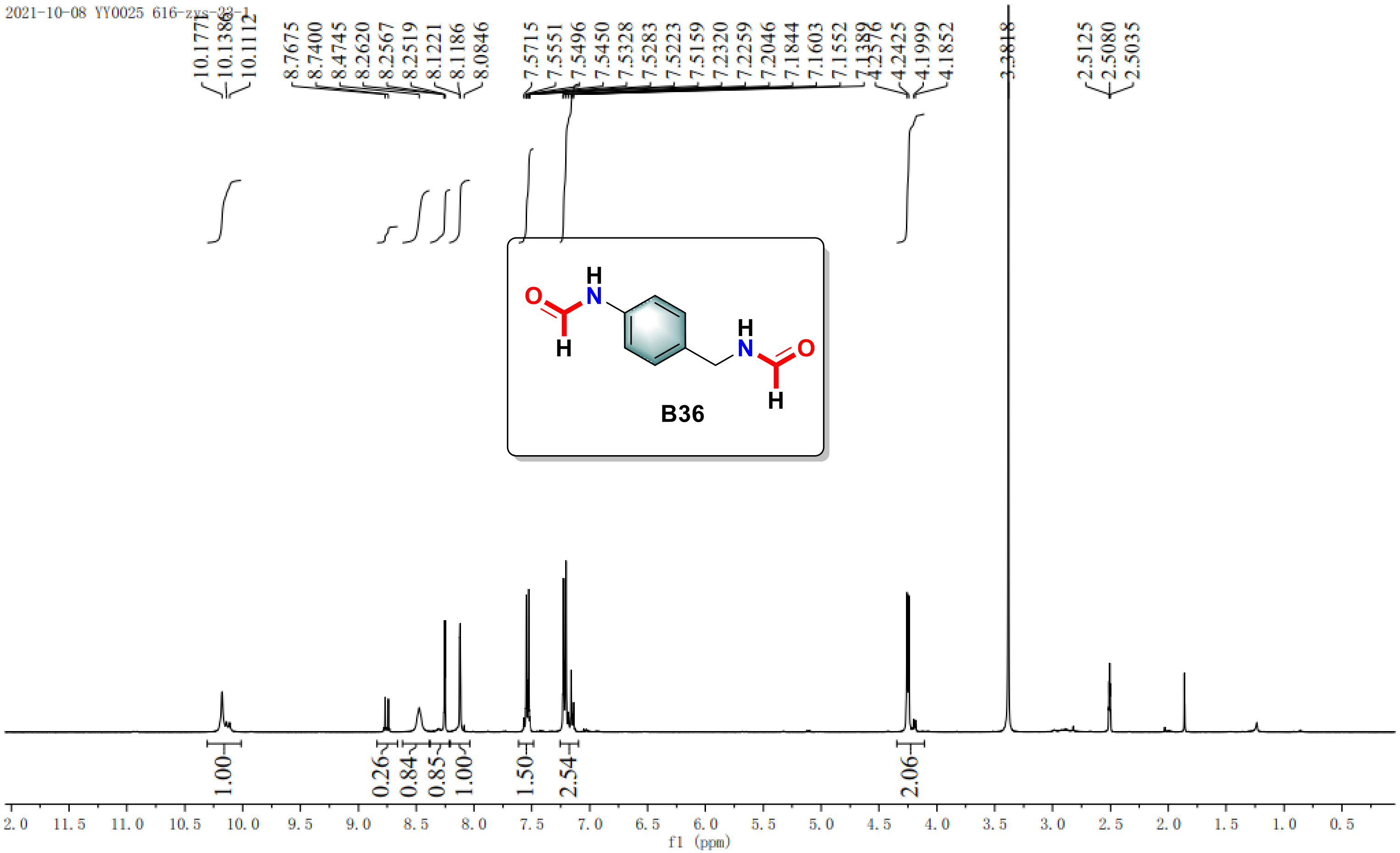

2022-05-20-yy0020-616-zgy-3
160.8409
77.4089
77.0908
76.7726
67.2298
66.4334
45.7903
40.5931
H
N
O
O
B33
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Chemical Shift (ppm)

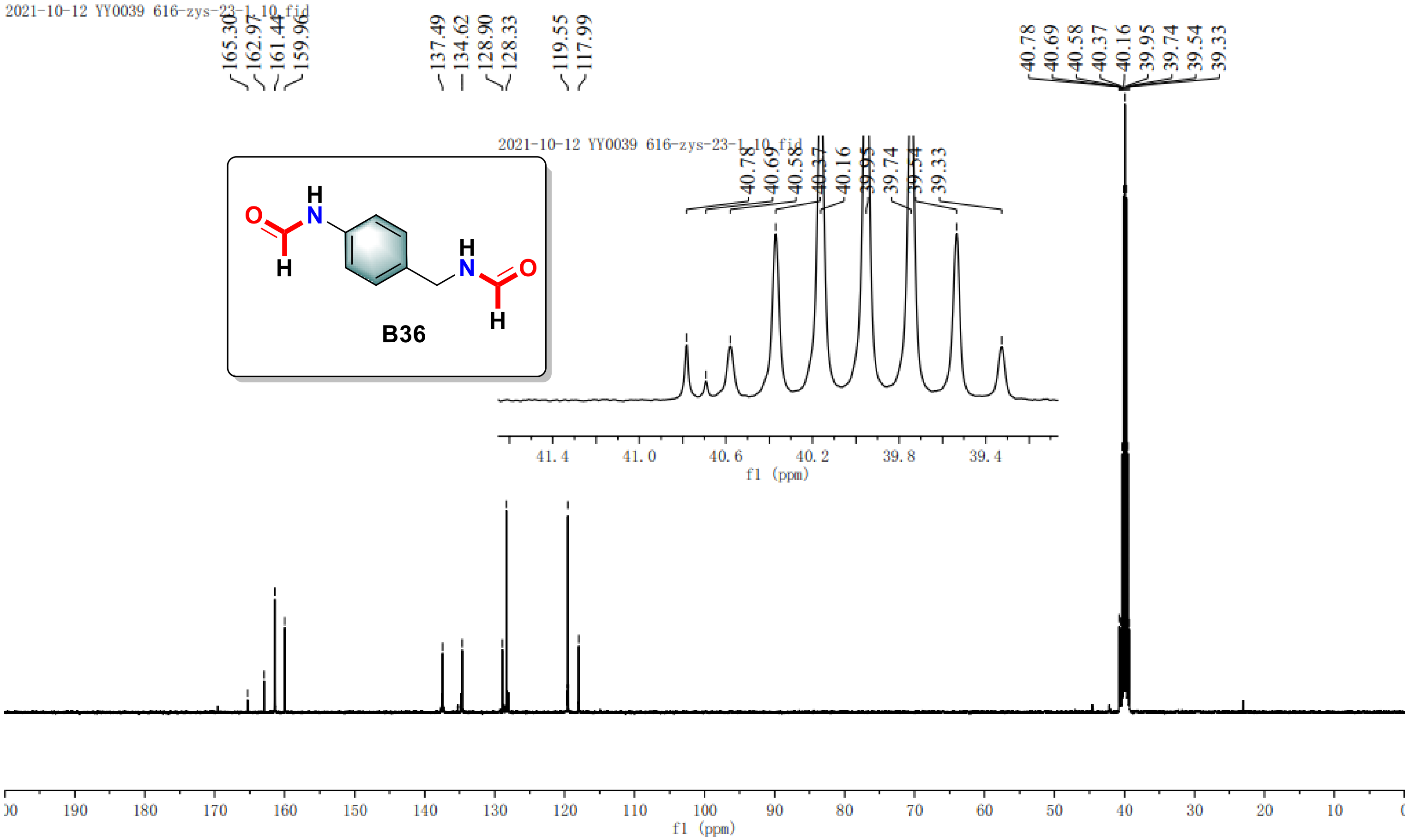

2021-09-28-yy0005-616-zys--24.10.fid
10.1422
8.7042
8.6993
8.6765
8.6715
8.2297
8.2248
7.5439
7.5295
7.5219
7.5014
7.1549
7.1497
7.1329
3.3494
2.5180
2.5133
2.5086
2.5040
2.4994
O
H
NH
HN
H
O
B34
1.53
0.60
0.59
1.84
3.63
1.00
.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)

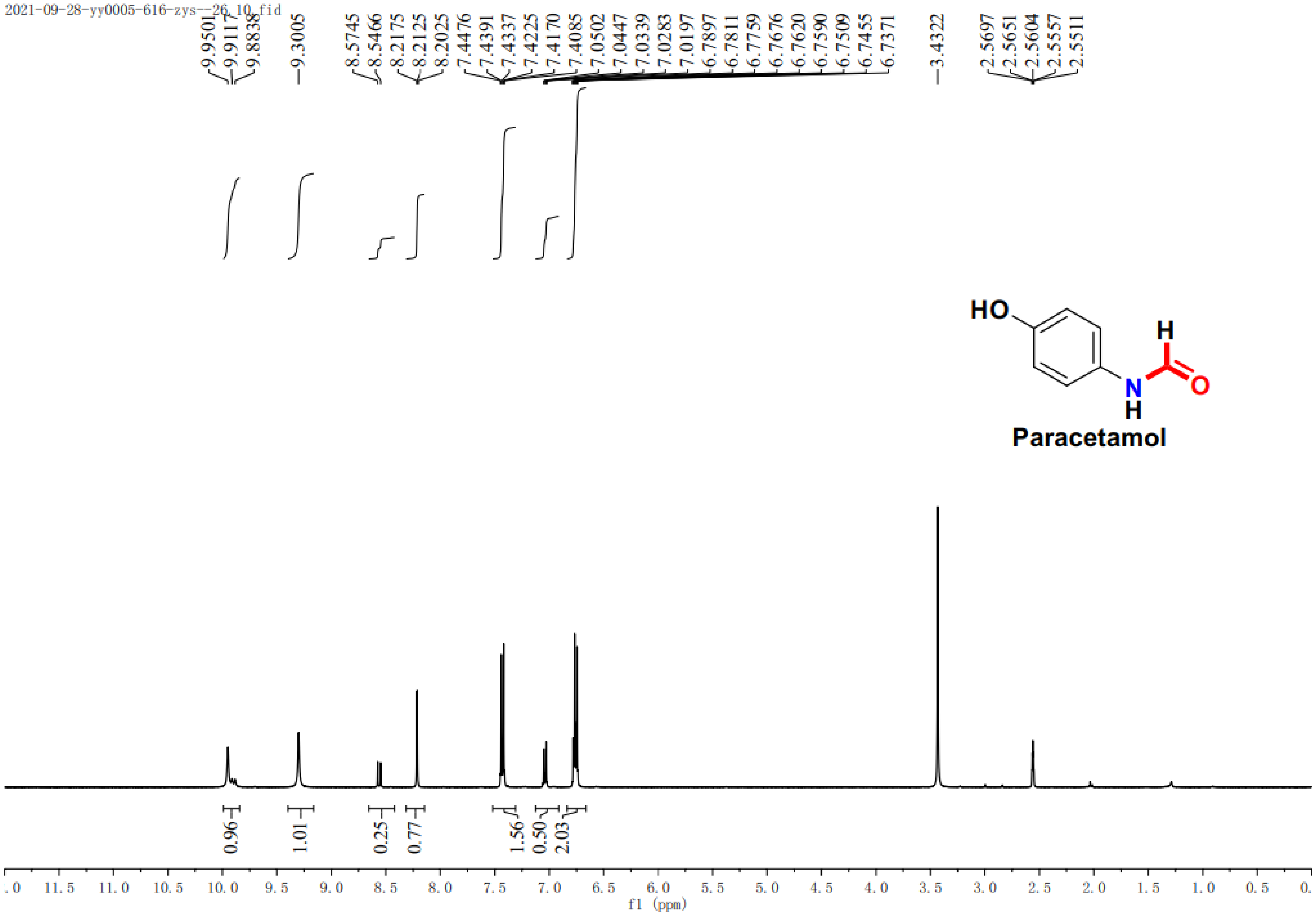

2021-10-08 YY0002 616-zys-24.10.fid
162.90
159.74
134.82
134.45
120.64
120.06
119.32
118.72
40.60
40.40
40.19
39.77
39.56
39.35
B34
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

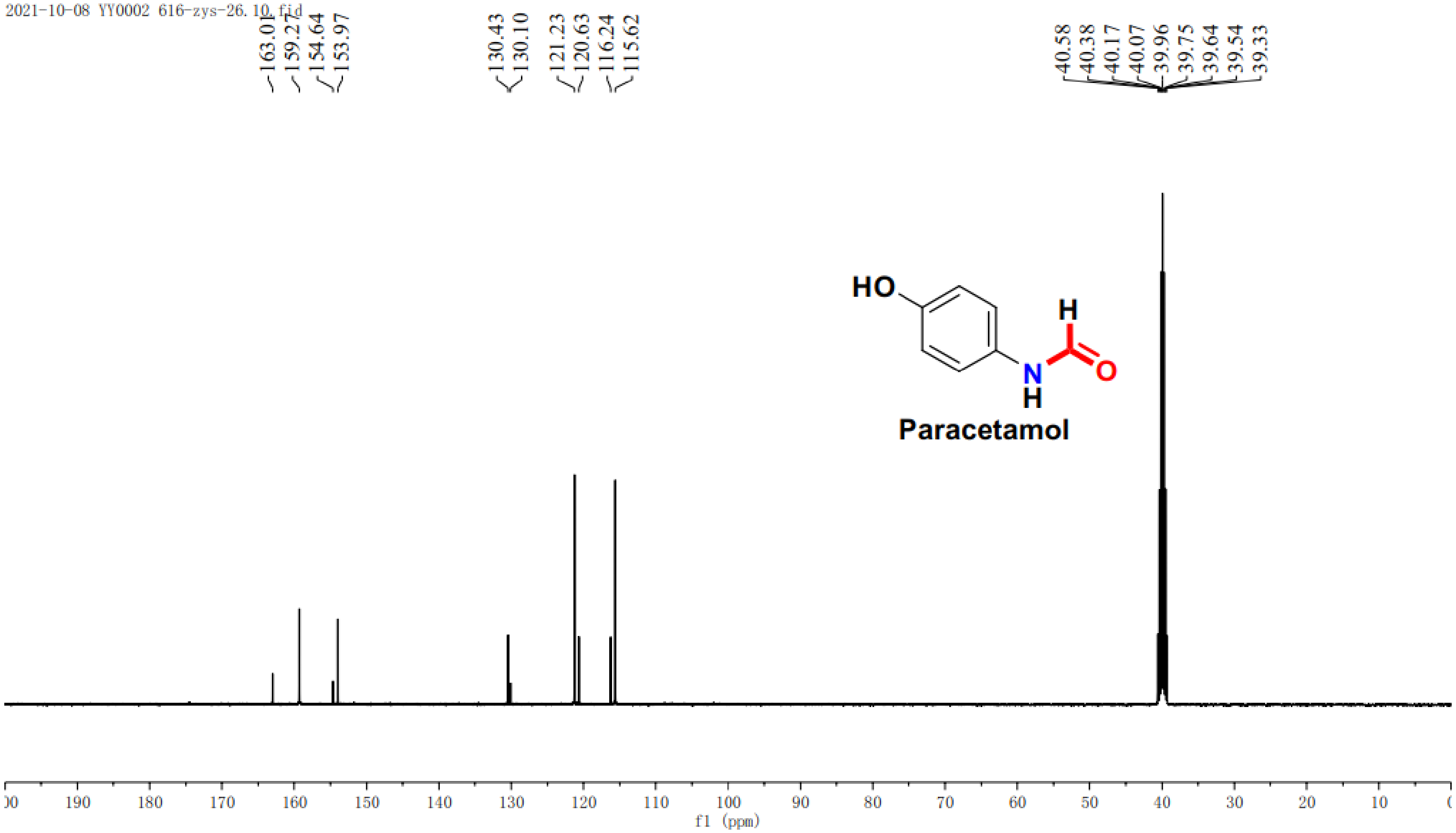

2021-09-23-yy0017-616-zys-13
8.6366
8.6253
8.6203
8.0262
8.0068
7.9115
7.8927
7.8884
7.8807
7.8701
7.8645
7.8563
7.8021
7.7813
7.7319
7.7114
7.6181
7.6047
7.6009
7.5848
7.5798
7.5611
7.5449
7.5262
7.5081
7.4932
7.4829
7.4735
7.4638
7.4535
7.4440
7.3276
7.3094
7.2575
O
NH
HN
O
H
H
B35
2.00
1.10
1.43
0.91
0.46
3.48
0.84
0.37
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)


2021-09-25-yy0003-616-zys-12.10.fid
164.11
159.65
134.29
134.08
132.13
131.00
128.85
128.55
127.77
127.04
126.81
126.52
126.23
126.14
125.71
125.52
121.32
120.90
120.38
119.07
77.35
77.04
76.72
O
NH
HN
O
H
H
B35
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


2021-10-08 YY0025 616-zys-33-1
10.1771
10.1386
10.1112
8.7675
8.7400
8.4745
8.2620
8.2567
8.2519
8.1221
8.1186
8.0846
7.5715
7.5551
7.5496
7.5450
7.5328
7.5283
7.5223
7.5159
7.2320
7.2259
7.2046
7.1844
7.1603
7.1552
7.1389
4.2576
4.2425
4.1999
4.1852
3.3818
2.5125
2.5080
2.5035
H
N
O
H
H
N
O
H
B36
1.00
0.26
0.84
0.85
1.00
1.50
2.54
2.06
2.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


2021-10-12 YY0039 616-zys-23-1 10 fid
165.30
162.97
161.44
159.96
137.49
134.62
128.90
128.33
119.55
117.99
40.78
40.69
40.58
40.37
40.16
39.95
39.74
39.54
39.33
B36
2021-10-12 YY0039 616-zys-23-1 10 fid
40.78
40.69
40.58
40.37
40.16
39.95
39.74
39.54
39.33
41.4
41.0
40.6
40.2
39.8
39.4
f1 (ppm)
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


2021-09-28-yy0005-616-zys--26.10.fid
9.9501
9.9117
9.8838
9.3005
8.5745
8.5466
8.2175
8.2125
8.2025
7.4476
7.4391
7.4337
7.4225
7.4170
7.4085
7.0502
7.0447
7.0339
7.0283
7.0197
6.7897
6.7811
6.7759
6.7676
6.7620
6.7590
6.7509
6.7455
6.7371
3.4322
2.5697
2.5651
2.5604
2.5557
2.5511
HO
H
N
H
O
Paracetamol
0.96
1.01
0.25
0.77
1.56
0.50
2.03
.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)


2021-10-08 YY0002 616-zys-26.10.fid
163.01
159.27
154.64
153.97
130.43
130.10
121.23
120.63
116.24
115.62
40.58
40.38
40.17
40.07
39.96
39.75
39.64
39.54
39.33
HO
H
N
H
O
Paracetamol
00
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)