Supplementary Material

Synthesis of acylnaphthylamines and their applications in the formation of benzoquinazolines

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1. General information

Biology

Cells cultures. The experiments were performed with the use of HCT116 (colorectal carcinoma) and HT29 (colorectal adenocarcinoma) cancer cell lines (human colon cancer cells) derived from the American Type Culture Collection (ATCC; CCL-247, HTB-38) and human lymphocytes obtained from the Blood Donation Centre (Lodz, Poland). HCT116 cells were cultured in RPMI 1640 medium (CytoGen) supplemented with 10% FBS (Foetal Bovine Serum, CytoGen) and penicillin/streptomycin solution (1%). RPMI 1640 medium (CytoGen) was used for HT29 cells contained FBS (10%), penicillin/streptomycin solution (1%) and MEM non-essential amino acids solution (1%). Human lymphocytes were cultured in RPMI 1640 medium complemented with inactivated FBS (15%), penicillin/streptomycin (1%) and mitogen PHA (1%, phytohemagglutinin; CytoGen). Cells were cultured at 37 °C in a 5% CO_2 humidified atmosphere.

Inhibition growth assay. Cancer cells and human lymphocytes were grown for 24 hours on 96-well plates at a density of 6-8×10^3 cells/well and 8×10^5 cells/well, respectively. Then the cells were treated with the tested compounds for 72 h. After the treatment MTT dye dissolved in PBS was added to each plate well (20 µL, 5 mg/mL) for 4 hours. Purple crystals formed in cancer cells after reduction of MTT were dissolved by DMSO (100 µL/well) after removing of the medium. In the case of lymphocytes it was done by adding 100 µL of 20% DMF and 50% SDS mixture to each well for 24h. Absorbance at 595 nm was measured with a spectrophotometer PowerWave XS (BioTek Instruments, Inc.). The cell survival effect was expressed as the IC_{50}value which is the concentration of the compound required to reduce cell survival to 50% as compared to the negative control. The experiments were done in triplicate. All the results were presented as the means ± SD.

MTT assay. MTT assay is a quantitative colorimetric method to determine cell proliferation after treatment with the tested compounds. It is widely used to estimate the cytotoxic effect of chemicals on different types of cells. The assay is based on the reduction of the yellow water soluble tetrazolium MTT (3-(4,5-dimethylthiazolyl-2)-2,5-diphenyltetrazolium bromide) by mitochondrial enzymes of living (not dead) cells which results in formation of an insoluble purple formazan product. Formazan crystals are solubilized with organic solvent. The amount of formazan is measured spectrophotometrically and it is directly proportional to the number of living cells.

Computational details

All of the potential tautomers of compounds **22a** and **22b** were taken into account and their starting geometries were created from a scratch with the ChemSketch v.12 software. The initial geometries of tautomers were fully optimized in vacuum using the density functional method (DFT) with the B3LYP hybrid functional[1] and the 6-311++(d,p) basis set. Afterwards, the preoptimized tautomers were reoptimized in dimethyl sulphoxide at the same level of theory. The geometry optimizations were performed without constraints and the default methods and convergence criteria of the SCF procedure were applied. The ^{1}H and ^{13}C NMR isotropic chemical shifts were calculated using the Gauge-Independent Atomic Orbital (GIAO) method[2] with dimethyl sulphoxide as solvent. The ^{1}H and ^{13}C NMR chemical shifts of TMS in dimethyl sulphoxide were also calculated at the B3LYP/6-311++g(d,p) level of theory and they equal to 31.9516 and 184.6255 ppm, respectively. The implicit dimethyl sulphoxide environment (ε = 46.826) in geometry optimization and GIAO calculations was simulated by the Integral Equation Formalism of the Polarizable Continuum Model (IEF-PCM).[3] All calculations were performed using Gaussian 09 (Rev. B.01) package.[4]

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2. Compounds characterization data

tert-Butyl [2-(2,2-dimethylpropanoyl)naphthalen-1-yl]carbamate (2b). Beige solid, yield 60%, 413 mg, mp 144−146 °C; R_f (DCM/Hex 1:1) = 0.28. FTIR (KBr, ν_{max}, cm^{-1}) = 3259, 3007, 2995, 2980, 2970, 2930, 2875, 1709, 1670. ^{1}H NMR ($CDCl_3$): δ = 7.97 (1H, d, *J* 8.4 Hz, Ar–H), 7.84 (1H, d, *J* 7.8 Hz, Ar–H), 7.75 (1H, d, *J* 8.5 Hz, Ar–H), 7.58–7.50 (2H, m, Ar–H), 7.36 (1H, d, *J* 8.4 Hz, Ar–H), 6.70 (1H, s, NH), 1.47 (9H, s, ^{t}Bu–Me), 1.32 (9H, s, Boc–Me); ^{13}C NMR ($CDCl_3$): δ=213.5, 154.1, 135.6, 134.3, 130.8, 129.8, 128.2, 127.1, 127.1, 126.6, 124.5, 122.2, 80.7, 45.4, 28.4, 27.6. HRMS (ESI) *m/z* calcd for $C_{20}H_{26}NO_3$: 328.1907; found $[M+H]^+$: 328.1910.

tert-Butyl acetyl(naphthalen-1-yl)carbamate (3). Light orange solid, yield 20%, 120 mg, mp 82−84 °C; R_f (Hex/AcOEt 5:1) = 0.40. FTIR (KBr, ν_{max}, cm^{-1}) = 3065, 2976, 2935, 2862, 1746, 1700. ^{1}H NMR ($CDCl_3$): δ = 7.89–7.84 (2H, m, Ar–H), 7.69–7.66 (1H, m, Ar–H), 7.53–7.46 (3H, m, Ar–H), 7.29–7.27 (1H, m, Ar–H), 2.64 (3H, s, Me), 1.25 (9H, s, Boc–Me). ^{13}C NMR ($CDCl_3$): δ = 173.0, 153.0, 135.7, 134.4, 130.6, 128.7, 128.6, 127.0, 126.2, 126.1, 125.5, 121.9, 83.2, 27.8, 26.4. HRMS (ESI) *m/*z calcd for $C_{17}H_{20}NO_3$: 286.1438; found $[M+H]^+$: 286.1439.

tert-Butyl [1-(2-methylpropanoyl)naphthalen-2-yl]carbamate (5b). Light orange solid, yield 40%, 194 mg, mp 60−62 °C; R_f (Hex/AcOEt 10:1) = 0.38. FTIR (KBr, ν_{max}, cm^{-1}) = 3315, 3058, 2976, 2930, 2872, 1728, 1691. ^{1}H NMR ($CDCl_3$): δ = 8.09 (1H, d, *J* 8.9 Hz, Ar–H), 7.85 (1H, d, *J* 9.0 Hz, Ar–H), 7.82 (1H, d, *J* 8.1 Hz, Ar–H), 7.56 (1H, d, *J* 8.4 Hz, Ar–H), 7.50–7.46 (1H, m, Ar–H), 7.45–7.37 (2H, m, NH, Ar–H), 3.37 (1H, m, C–H), 1.51 (9H, s, Boc–Me), 1.21 (6H, d, *J* 6.8 Hz, C–Me). ^{13}C NMR ($CDCl_3$): δ = 213.4, 153.3, 133.4, 130.9, 130.5, 130.3, 128.6, 127.2, 127.1, 125.2, 124.5, 121.6, 81.0, 42.6, 28.4, 18.5. HRMS (ESI) *m/z* calcd for $C_{19}H_{23}NO_3$: 314.1751; found $[M+H]^+$: 314.1753; m/z calcd for $C_{19}H_{23}NO_3Na$: 336.1570; found $[M+Na]^+$: 336.1568.

N-(Naphthalen-2-yl)-3-oxobutanamide (6). Beige solid, yield 8%, 28 mg, mp 86−88 °C; R_f (DCM/AcOEt 5:3) = 0.54. FTIR (KBr, ν_{max}, cm^{-1}) = 3254, 3093, 3058, 1719, 1672; ^{1}H NMR ($CDCl_3$): δ = 9.27 (1H, br s, NH), 8.24–8.19 (3H, m, Ar-H), 7.81–7.76 (1H, m, Ar-H), 7.53–7.49 (1H, m, Ar-H), 7.47–7.44 (1H, m, Ar-H), 7.42–7.38 (1H, m, Ar-H), 3.64 (2H, s, CH_2), 2.35 (3H, s, Me). ^{13}C NMR ($CDCl_3$): δ = 205.4, 163.7, 135.1, 134.0, 131.0, 128.9, 127.8, 127.7, 126.6, 125.2, 120.2, 117.2, 49.9, 31.4. HRMS (ESI) *m/z* calcd for $C_{14}H_{14}NO_2$: 228.1019; found $[M+H]^+$: 228.1015.

1-Butyl-1-(propan-2-yl)-1,4-dihydro-3H-naphtho[2,1-d][1,3]oxazin-3-one (8). Beige solid, yield 10%, 46 mg, mp 200−203 °C; R_f (Hex/AcOEt 3:1) = 0.24. FTIR (KBr, ν_{max}, cm^{-1}) = 3223, 3110, 2962, 2928, 2862, 1699; ^{1}H NMR ($CDCl_3$): δ = 9.23 (1H, s, NH), 7.98 (1H, d, *J* 8.7 Hz,Ar–H), 7.78 (1H, d, *J* 7.4 Hz, Ar–H), 7.72 (1H, d, *J* 8.6 Hz, Ar–H), 7.50–7.41 (1H, m, Ar–H), 7.40–7.32 (1H, m, Ar–H), 7.03 (1H, d, *J* 8.6 Hz, Ar–H), 2.85–2.72 (1H, m, C–CH), 2.55 (1H, m, CH_2), 2.26 (1H, m, CH_2), 1.42–1.34 (1H, m, CH_2), 1.28–1.15 (5H, m, CH–Me, CH_2), 0.89–0.81 (4H, m, CH–Me, CH_2), 0.74 (3H, t, *J* 7.3 Hz, Me). ^{13}C NMR ($CDCl_3$): δ=152.4, 133.5, 131.5, 130.5, 129.9, 129.3, 127.1, 124.0, 123.5, 116.0, 114.1, 95.3, 39.1, 37.9, 26.7, 22.9, 17.7, 15.8, 13.9. HRMS (ESI) *m/z* calcd for $C_{19}H_{24}NO_2$: 298.1802; found $[M+H]^+$: 298.1805.

1-(1-Aminonaphthalen-2-yl)ethan-1-one (15a).[5,6] Yellow solid, yield 66%, 59 mg, mp 124-126 °C, (lit. 122-124 °C),[5] R_f (Hex/AcOEt 1:1) = 0.83. ^{1}H NMR ($CDCl_3$): δ = 7.92 (1H, d, *J* 8.4 Hz, Ar–H), 7.76–7.72 (1H, m, Ar–H), 7.70 (1H, d, *J* 8.9 Hz, Ar–H), 7.68–7.50 (3H, m, Ar–H, NH_2), 7.49–7.44 (1H, m, Ar–H), 7.05 (1H, d, *J* 8.9 Hz, Ar–H), 2.66 (3H, s, Me). ^{13}C NMR ($CDCl_3$): δ = 200.5, 149.1, 136.5, 129.0, 128.6, 127.6, 125.5, 123.5, 121.9, 115.5, 111.7, 28.6.

4-tert-Butylbenzo[h]quinazoline (16b). Yellow solid, yield 60% (*Method B*), 44 mg, mp 68−70 °C; R_f (Hex/AcOEt 5:1) = 0.62. FTIR (KBr, ν_{max}, cm^{-1}) = 3052, 3029, 2992, 2978, 2952, 2927, 2871, 1621. ^{1}H NMR ($CDCl_3$): δ = 9.37 (1H, s, Ar–H), 9.35–9.29 (1H, m, Ar–H), 8.32 (1H, d, *J* 9.3 Hz, Ar–H), 7.93–7.90 (1H, m, Ar–H), 7.84 (1H, d, *J* 9.3 Hz, Ar–H), 7.80–7.73 (2H, m, Ar–H), 1.70 (9H, s, ^{t}Bu–Me). ^{13}C NMR ($CDCl_3$): δ = 175.4, 153.8, 151.3, 134.3,

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131.3, 130.0, 127.7, 127.5, 127.1, 125.4, 122.9, 121.3, 40.0, 30.9. HRMS (ESI) *m/z* calcd for $C_{16}H_{17}N_2$: 237.1386; found $[M+H]^+$: 237.1383.

6-Bromo-4-methylbenzo[h]quinazoline (20). Orange solid, yield 30% (*Method A*), 18 mg, 50% (*Method B*), 30 mg, mp 111−113 °C; R_f (Hex/AcOEt 1:1) = 0.62. FTIR (KBr, ν_{max}, cm^{-1}) = 3038, 2962, 2924, 1611. ^1H NMR ($CDCl_3$): δ = 9.34–9.29 (2H, m, Ar–H), 8.34 (1H, d, *J* 8.2 Hz, Ar–H), 8.24 (1H, s, Ar–H), 7.90–7.85 (1H, m, Ar–H), 7.85–7.79 (1H, m, Ar–H), 2.96 (3H, s, Me). ^{13}C NMR ($CDCl_3$): δ = 165.7, 155.0, 149.3, 133.6, 131.6, 131.1, 128.6, 127.8, 125.5, 124.8, 123.6, 122.7, 22.0. HRMS (ESI) *m/z* calcd for $C_{13}H_{10}BrN_2$: 273.0022; found $[M+H]^+$: 273.0018.

1-(Propan-2-yl)benzo[f]quinazolin-3(4H)-one (22b). White solid, yield 40%, 51 mg, mp 260−262 °C; R_f (Acetone/DCM 5:1) = 0.5; FTIR (KBr, ν_{max}, cm^{-1}) = 3439, 2963, 2924, 2812, 1660. ^1H NMR (DMSO-d_6): δ = 12.06 (1H, s, NH), 8.39 (1H, d, *J* 8.6 Hz, Ar-H), 8.20 (1H, d, *J* 8.9 Hz, Ar-H), 8.02 (1H, d, *J* 7.7 Hz, Ar-H), 7.78–7.73 (1H, m, Ar-H), 7.61–7.55 (1H, m, *J* 7.4 Hz, Ar-H), 7.43 (1H, d, *J* 8.9 Hz, Ar-H), 4.07–3.95 (1H, m, *i*Pr-CH), 1.41–1.33 (6H, m, *i*Pr- Me). ^{13}C NMR (DMSO-d_6): δ = 181.7, 154.4, 144.8, 136.8, 129.9, 129.8, 128.8, 128.4, 125.1, 124.8, 116.3, 109.4, 34.5, 21.8. HRMS (ESI) *m/z* calcd for $C_{15}H_{15}N_2O$: 239.1179; found $[M+H]^+$: 239.1182.

N-(3-Benzyl-4-oxo-3,4-dihydrobenzo[h]quinazolin-6-yl)formamide (27a). Mixture of rotamers 3:1*, white solid, yield 60%, 53 mg, mp 227−230 °C; R_f (AcOE/Hex 3:1) = 0.4. FTIR (KBr, ν_{max}, cm^{-1}) = 3230, 3068, 3034, 2935, 1688. ^1H NMR (DMSO-d_6): δ = 10.62 (1H, d, *J* 10.2 Hz, NH*), 10.49 (1H, br s, NH), 9.03–8.96 (2H, m, Ar-H, Ar-H*), 8.81 (1H, s, Ar-H*), 8.78 (1H, s, Ar-H), 8.68 (2H, s, CHO*, ArH), 8.55 (1H, s, ACHO), 8.31 (1H, d, *J* 8.4 Hz, Ar-H), 8.28–8.23 (1H, m, Ar-H*), 7.90–7.78 (5H, m, 2Ar-H, 3Ar-H*), 7.42–7.28 (10H, m, 5Ar-H, 5Ar-H*), 5.30 (4H, s, CH_2, CH_2*). ^{13}C NMR (DMSO-d_6): δ = 160.4, 159.7, 159.3, 147.7, 143.3, 136.7, 131.7, 129.9, 129.4, 128.8, 128.6, 127.6, 127.3, 125.0, 121.9, 117.9, 112.9, 49.1. HRMS (ESI) *m/z* calcd for $C_{20}H_{16}N_3O_2$: 330.1237; found $[M+H]^+$: 330.1234.

N-{3-[(3,4-Dimethoxyphenyl)methyl]-4-oxo-3,4-dihydrobenzo[h]quinazolin-6-yl}formamide (27b). Mixture of rotamers 3:1*, beige solid, yield 40%, 42 mg, mp 247−249 °C; R_f (AcOE/Hex 3:1) = 0.27. FTIR (KBr, ν_{max}, cm^{-1}) = 3244, 3075, 3007, 2945, 2842, 1677. ^1H NMR (DMSO-d_6): δ = 10.62 (1H, br s, NH*), 10.49 (1H, br s, NH), 8.99 (2H, d, *J* 8.1 Hz, Ar-H, Ar-H*), 8.77 (2H, br s, Ar-H, Ar-H*), 8.68 (2H, br s, CHO*, Ar−H), 8.55 (1H, br s, CHO), 8.33–8.22 (2H, m, Ar-H, Ar-H*), 7.91–7.75 (5H, m, 2Ar-H, 3Ar-H*), 7.12 (2H, d, *J* 1.8 Hz, DMB, DMB*), 6.97–6.89 (4H, m, 2DMB, 2DMB*), 6.97–6.89 (4H, m, CH_2, CH_2*), 3.75 (6H, s, OMe, OMe*), 3.71 (6H, s, OMe, OMe*). ^{13}C NMR (DMSO-d_6): δ = 160.4, 159.7, 148.8, 148.5, 147.6, 143.2, 131.6, 129.9, 129.4, 129.0, 128.8, 127.3, 124.9, 121.9, 120.4, 117.9, 113.0, 112.2, 111.9, 55.5, 55.5, 48.8. HRMS (ESI) *m/z* calcd for $C_{22}H_{20}N_3O_4$: 390.1448; found $[M+H]^+$: 390.1445.

3-(3,4-Dimethoxybenzyl)-6-(morpholin-4-yl)benzo[h]quinazolin-4(3H)-one (28b). White solid, yield 68%, 123 mg, mp 209−211 °C; R_f (DCM/AcOEt 1:1) = 0.54. FTIR (KBr, ν_{max}, cm^{-1}) = 3082, 3053, 3012, 2953, 2945, 2923, 2891, 2866, 2843, 2831, 1683. ^1H NMR ($CDCl_3$): δ = 8.98 (1H, d, *J* 8.0 Hz, Ar–H), 8.28 (1H, d, *J* 8.2 Hz, Ar-H), 8.25 (1H, s, Ar–H), 7.80 (1H, s, Ar–H), 7.75–7.66 (2H, m, Ar–H), 6.98–6.93 (2H, m, DMB), 6.84 (1H, d, *J* 8.0 Hz, DMB), 5.21 (2H, s, CH_2), 4.03–3.98 (4H, m, Morf), 3.87 (3H, s, OMe), 3.86 (3H, s, OMe), 3.24–3.15 (4H, m, Morf). ^{13}C NMR ($CDCl_3$): δ = 161.2, 149.7, 149.4, 149.2, 145.1, 143.7, 132.1, 131.5, 129.0, 128.5, 127.3, 125.7, 123.8, 121.0, 119.2, 111.8, 111.6, 109.5, 67.5, 56.2, 56.1, 53.6, 49.9. HRMS (ESI) *m/z* calcd for $C_{25}H_{26}N_3O_4$: 432.1918; found $[M+H]^+$: 432.1919.

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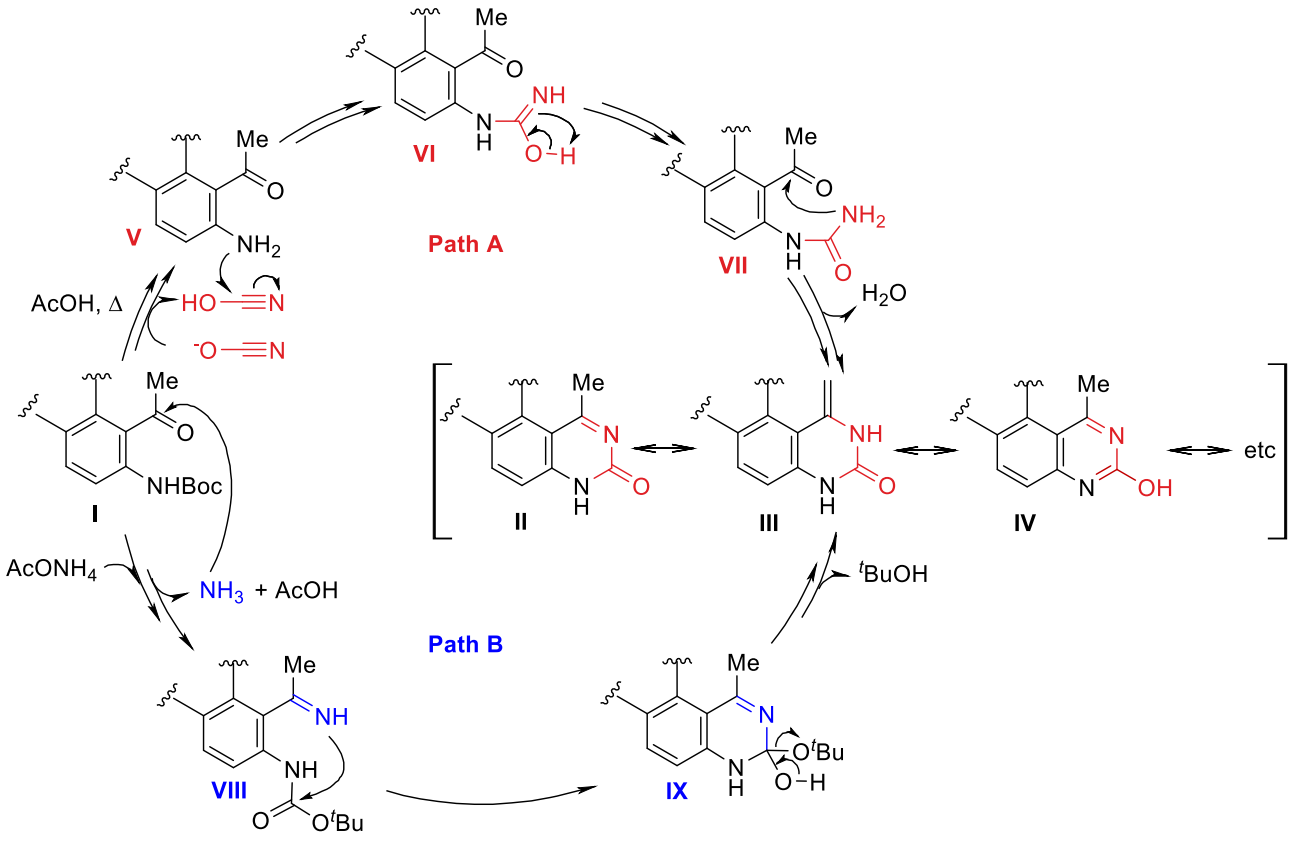
3. Tabeles and Schemes



Scheme S1. Possible mechanism for synthesis of quinazolinones from *orto*-acyl carbamates.

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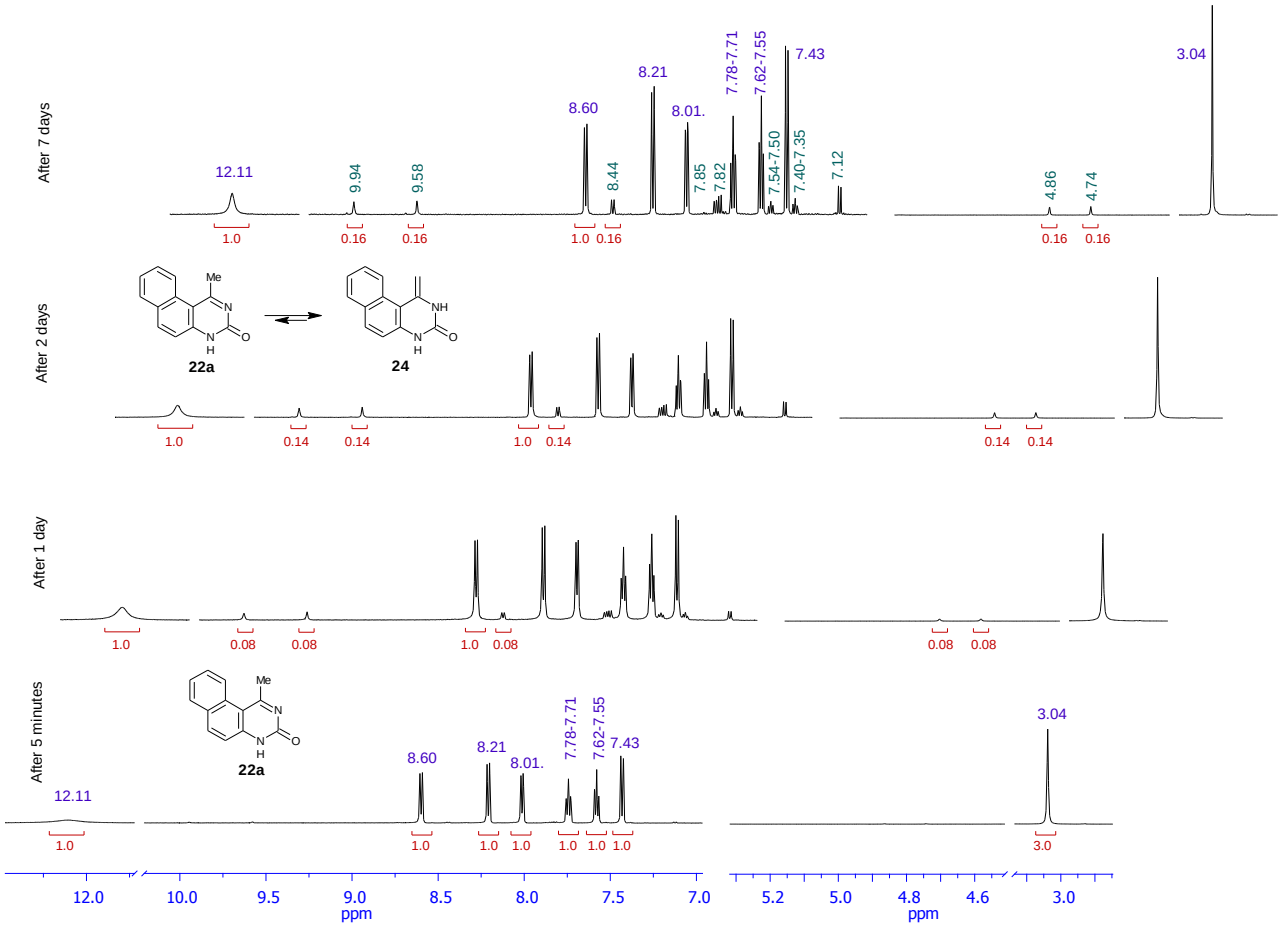

Fig. S1 Tautomerism process of compound **22a** in DMSO-d_6 solution within 7 days of experiment.

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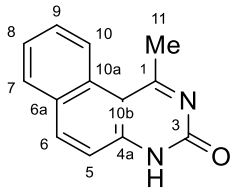
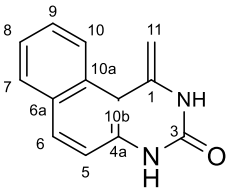
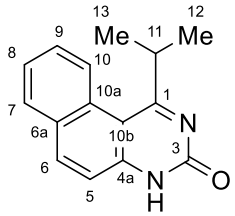
Table S1. ^{13}C NMR data of **22a**,**b**, **24**.

Entry	^{13}C NMR (DMSO-d_6) **22a** ⇆ **24** (r^2=0.9992 for **22a**; r^2=0.9913 for **24**; r^2=0.9977 for **22a** ⇆ **24**)					^{13}C NMR (DMSO-d_6) **22b** (r^2=0.9996)		
					δ^{exp} (ppm)			δ^{exp} (ppm)
	22a		**24**			**22b**		
	Carbon atom **22a**	δ^{calc} (ppm)	Carbon atom **24**	δ^{calc} (ppm)		Carbon atom **22b**	δ^{calc} (ppm)	
1	C*1*	185.8			174.0	C*1*	193.5	181.7
2	C*3*	160.4			154.1	C*3*	161.1	154.4
3			***C3***	**157.3**	**151.1**			
4	C*4a*	152.3			144.8	C*4a*	151.6	144.8
5			***C1***	**149.3**	**138.5**			
6			***C4a***	**143.5**	**138.4**			
7	C*6*	146.6			136.9	C*6*	145.7	136.8
8			***C6***	**138.7**	**136.7**			
9			***C6a***	**137.9**	**130.8**			
10	C*6a*	138.1			129.8	C*6a*	137.9	129.9
11	C*10a*	137.9			129.7	C*7*	137.1	129.8
12	C*7*	137.8			129.2	C*10a*	136.8	128.8
13			***C10a***	**137.0**	**128.9**			
14	C*9*	137.0			128.9	C*9*	135.7	128.4
15			***C7***	**136.1**	**128.7**			
16			***C9***	**134.3**	**127.5**			
17	C*8*	131.9			125.0	C*10*	132.2	125.1
18	C*10*	131.0			124.9	C*8*	132.1	124.8
19			***C8***	**130.6**	**123.8**			
20			***C10***	**130.2**	**123.1**			
21	C*5*	121.8			116.3	C*5*	120.8	116.3
22			***C5***	**121.3**	**115.8**			
23	C*10b*	117.4			110.2	C*10b*	117.7	109.4
24			***C10b***	**117.2**	**110.2**			
25			***C11***	**96.8**	**91.7**			
26	C*11*	34.5			30.0	C*11*	41.0	34.5
27						C*12*	24.1	21.8
28						C*13*	23.7	21.8

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4. References cited for experimental section

1. Stephens, P. J.; Devlin, F. J.; Chabalowski, C. F.; Frisch, M. J. *J. Phys. Chem.* **1994**, *98*, 11623–11627. http://dx.doi.org/10.1021/j100096a001
2. Wolinski, K.; Hilton, J. F.; Pulay, P. *J. Am. Chem. Soc.* **1990**, *112*, 8251–8260. http://dx.doi.org/10.1021/ja00179a005
3. Cancès, M. T.; Mennucci, B.; Tomasi, J. *J. Chem. Phys*. **1997**, *107*, 3032–3041. http://dx.doi.org/10.1063/1.474659
4. Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G.E.; Robb, M. A.; Cheeseman, J. R.; Scalmani, G.; Barone, V.; Mennucci, B.; Petersson, G. A.; Nakatsuji, H.; Caricato, M.; Li, X.; Hratchian, H.P.; Izmaylov, A. F.; Bloino, J.; Zheng, G.; Sonnenberg, J. L.; Hada, M.; Ehara, M.; Toyota, K.; Fukuda, R.; Hasegawa, J.; Ishida, M.; Nakajima, T.; Honda, Y.; Kitao, O.; Nakai, H.; Vreven, T.; Montgomery, Jr., J.A.; Peralta, J.E.; Ogliaro, F.; Bearpark, M.; Heyd, J. J.; Brothers, E.; Kudin, K. N.; Staroverov, V. N.; Keith, T.; Kobayashi, R.; Normand, J.; Raghavachari, K.; Rendell, A.; Burant, J. C.; Iyengar, S.S.; Tomasi, J.; Cossi, M.; Rega, N.; Millam, J. M.; Klene, M.; Knox, J. E.; Cross, J. B.; Bakken, V.; Adamo, C.; Jaramillo, J.; Gomperts, R.; Stratmann, R. E.; Yazyev, O.; Austin, A. J.; Cammi, R.; Pomelli, C.; Ochterski, J. W.; Martin, R. L.; Morokuma, K.; Zakrzewski, V. G.; Voth, G. A.; Salvador, P.; Dannenberg, J. J.; Dapprich, S.; Daniels, A. D.; Farkas, O.; Foresman, J. B.; Ortiz, J. V.; Cioslowski, J.; Fox, D. J. Gaussian 09 (Revision B.01, Gaussian, Inc., Wallingford CT, **2010**).
5. Katsuhara, Y.; Maruyama, H.; Shigemitsu, Y.; Odaira, Y. *Tetrahedron Lett*. **1973**, *16*, 1323–1226. http://dx.doi.org/10.1016/S0040-4039(01)95930-1
6. Iguchi, D.; Erra-Balsells, R.; Bonesi, S. M. *Photochem. Photobiol. Sci*. **2016**, *15*, 105–116. http://dx.doi.org/10.1039/C5PP00349K

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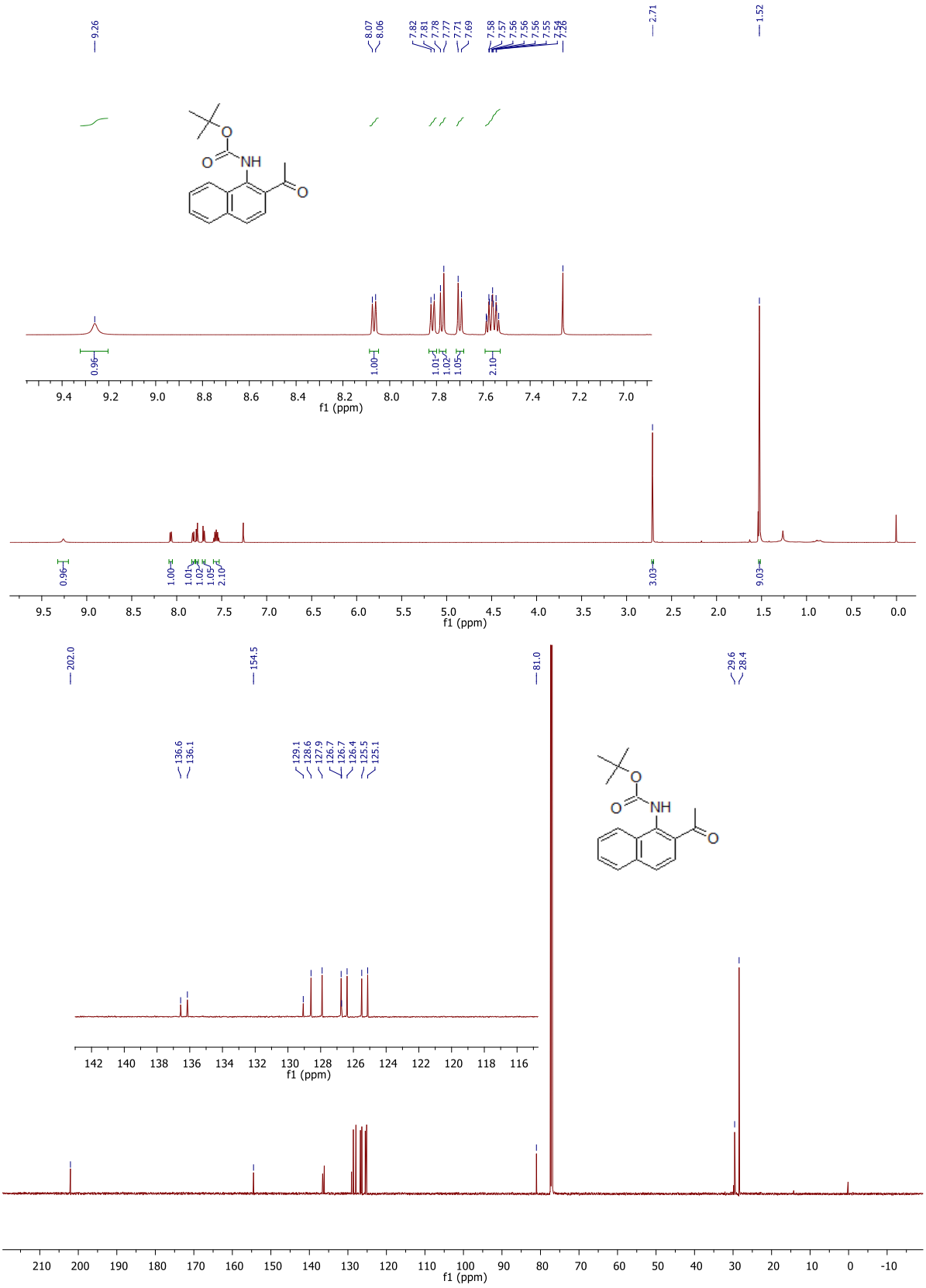
5. Selected spectra

Compound **2a**



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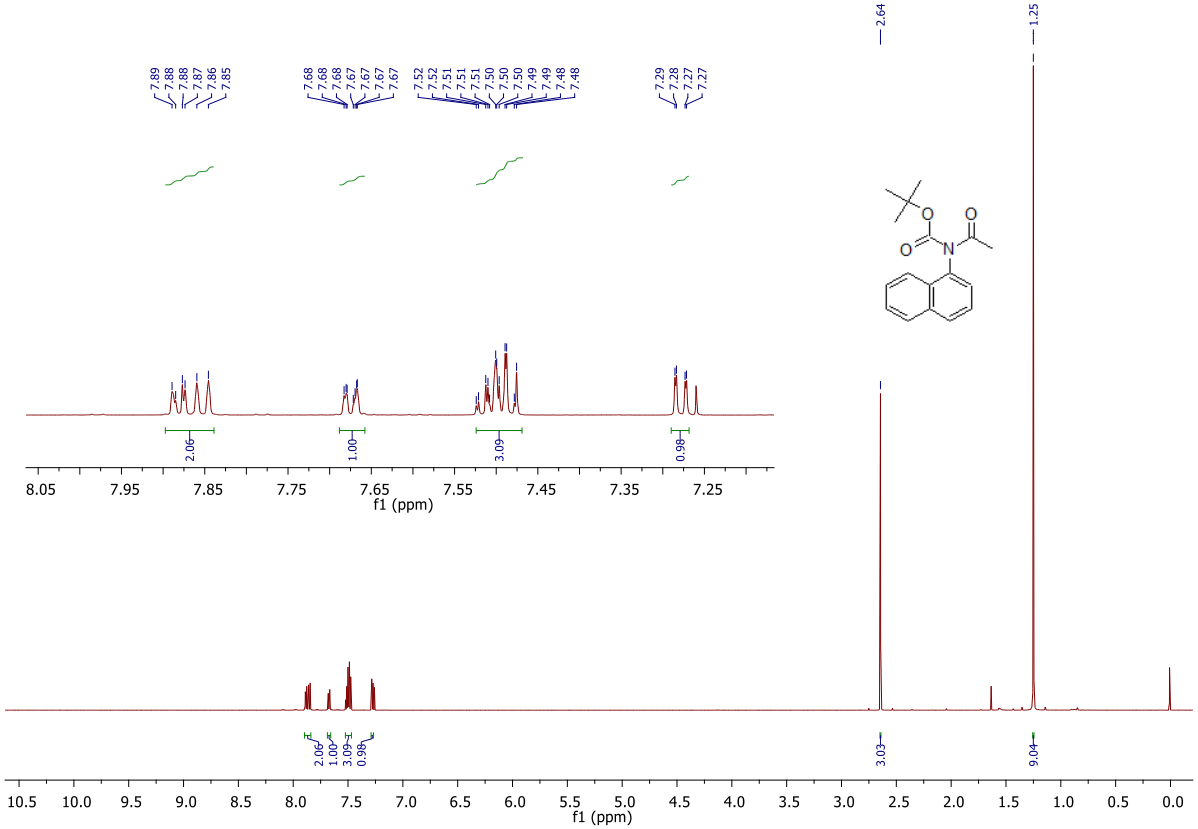
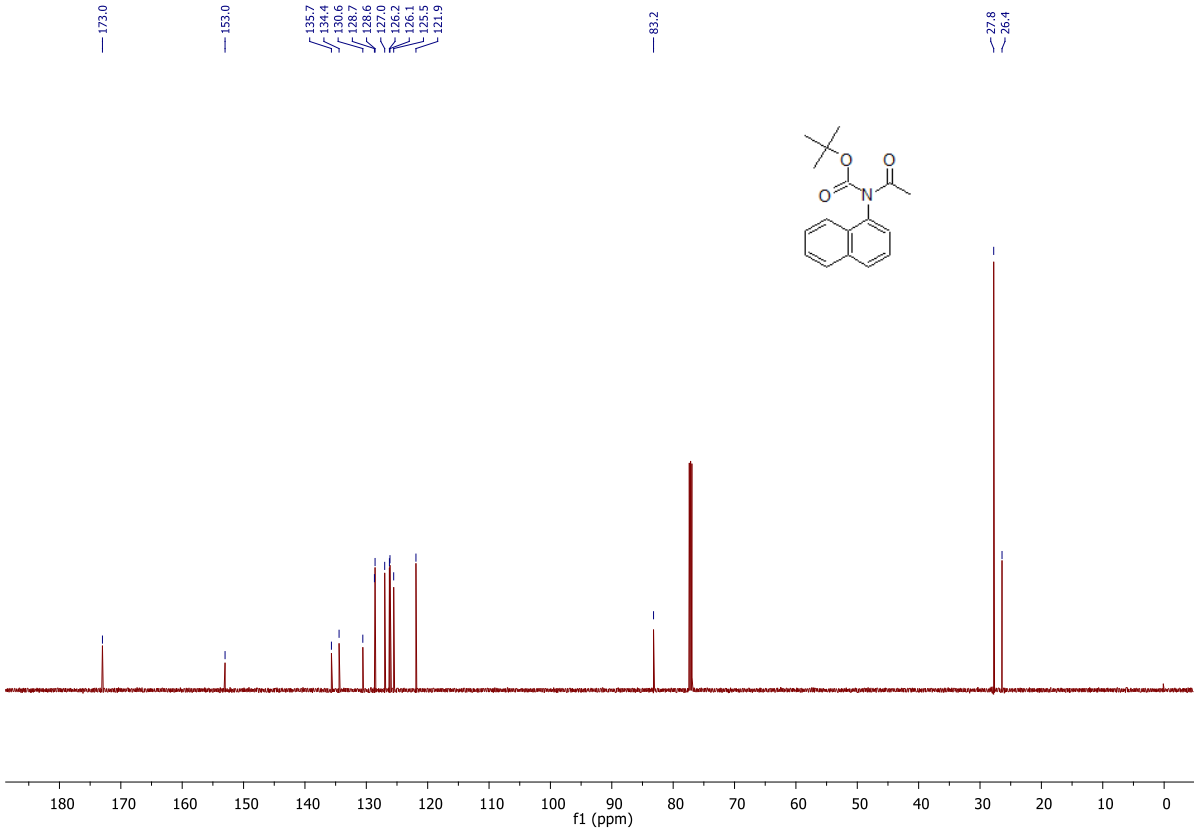
Compound **3**





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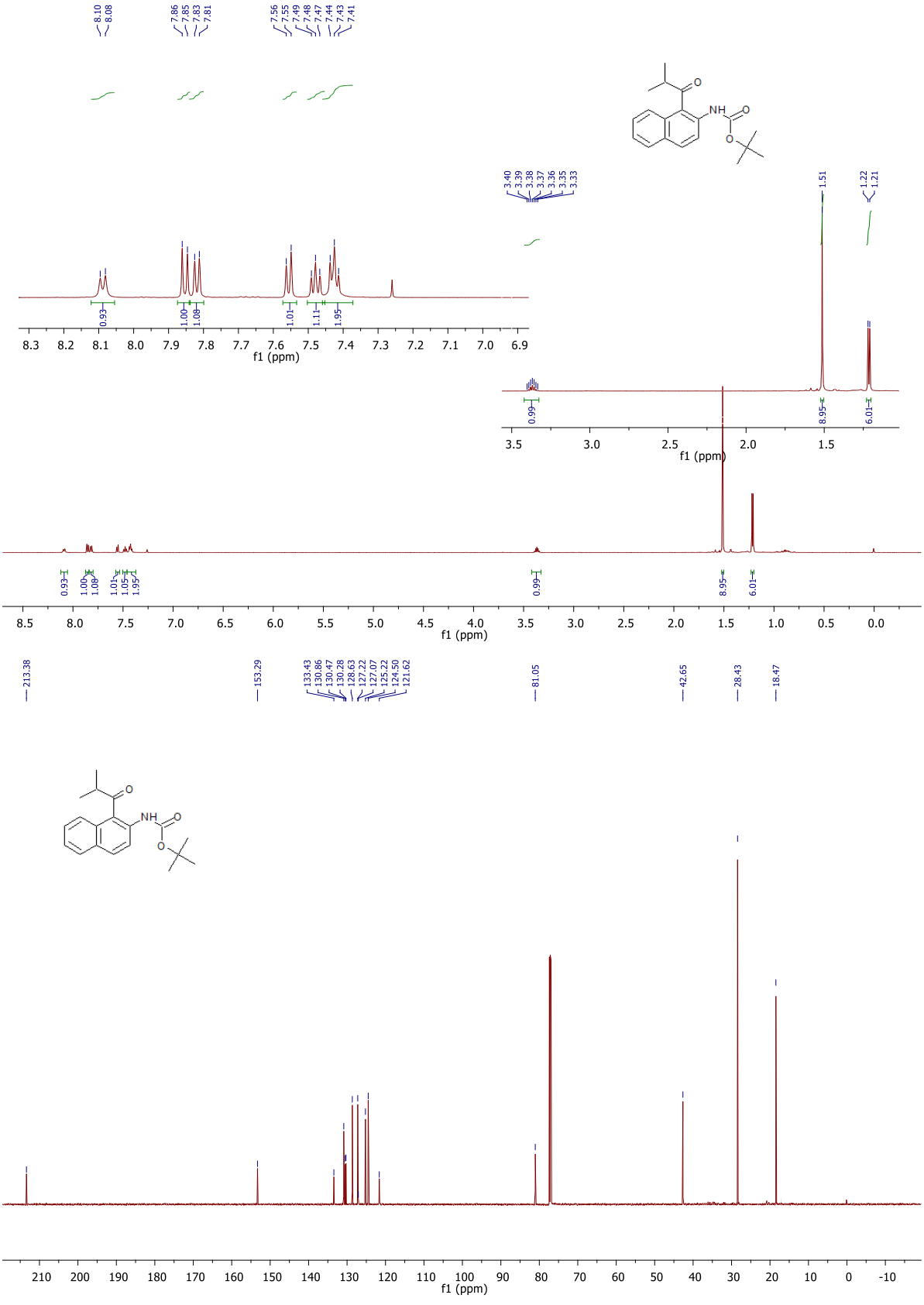
Compound **5b**



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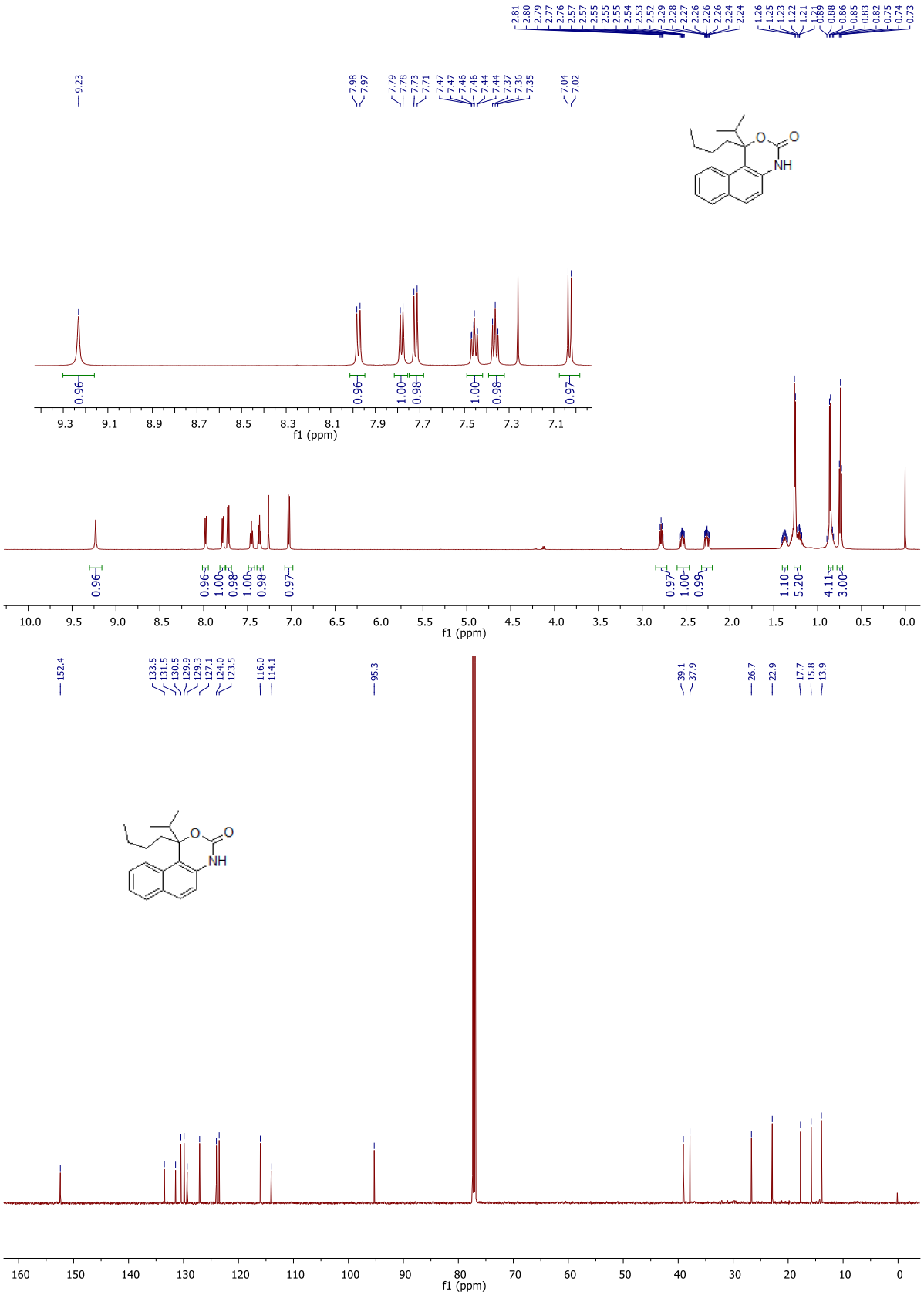
Compound **7**



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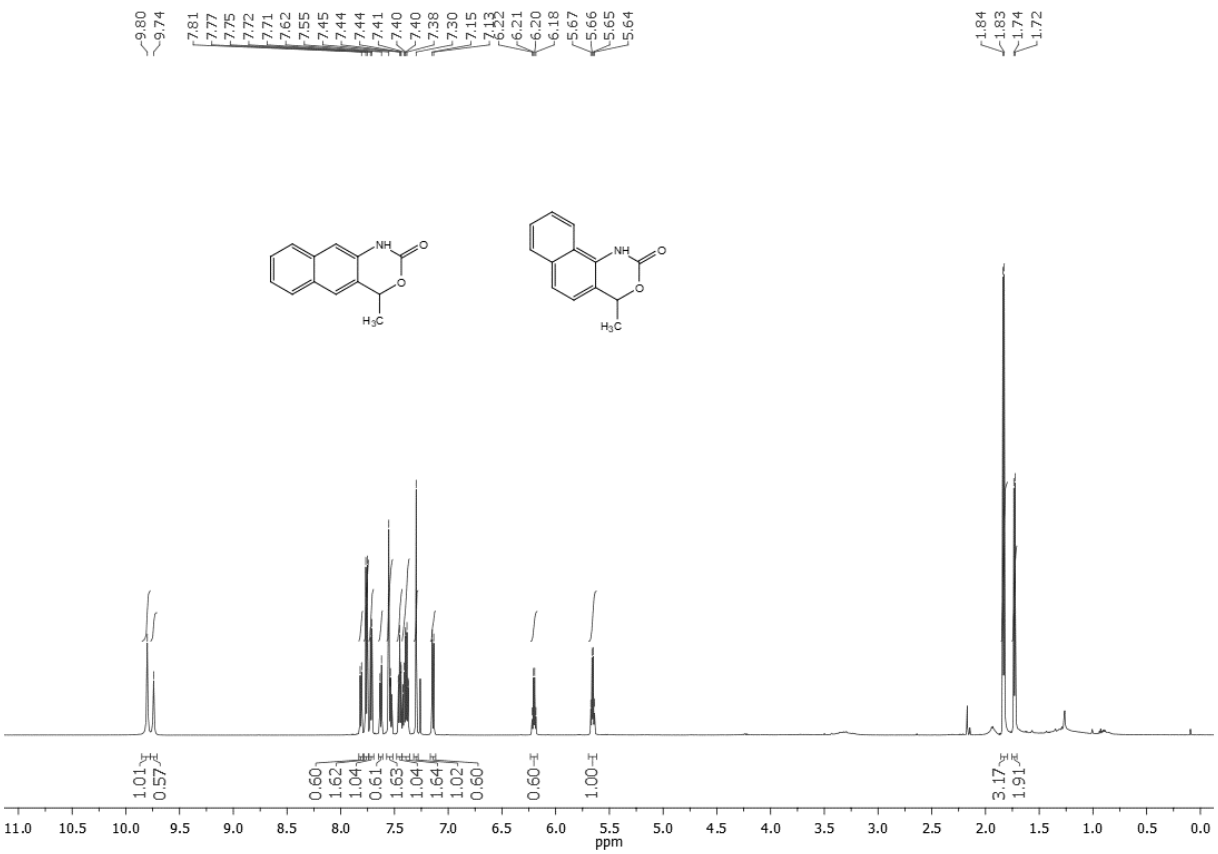
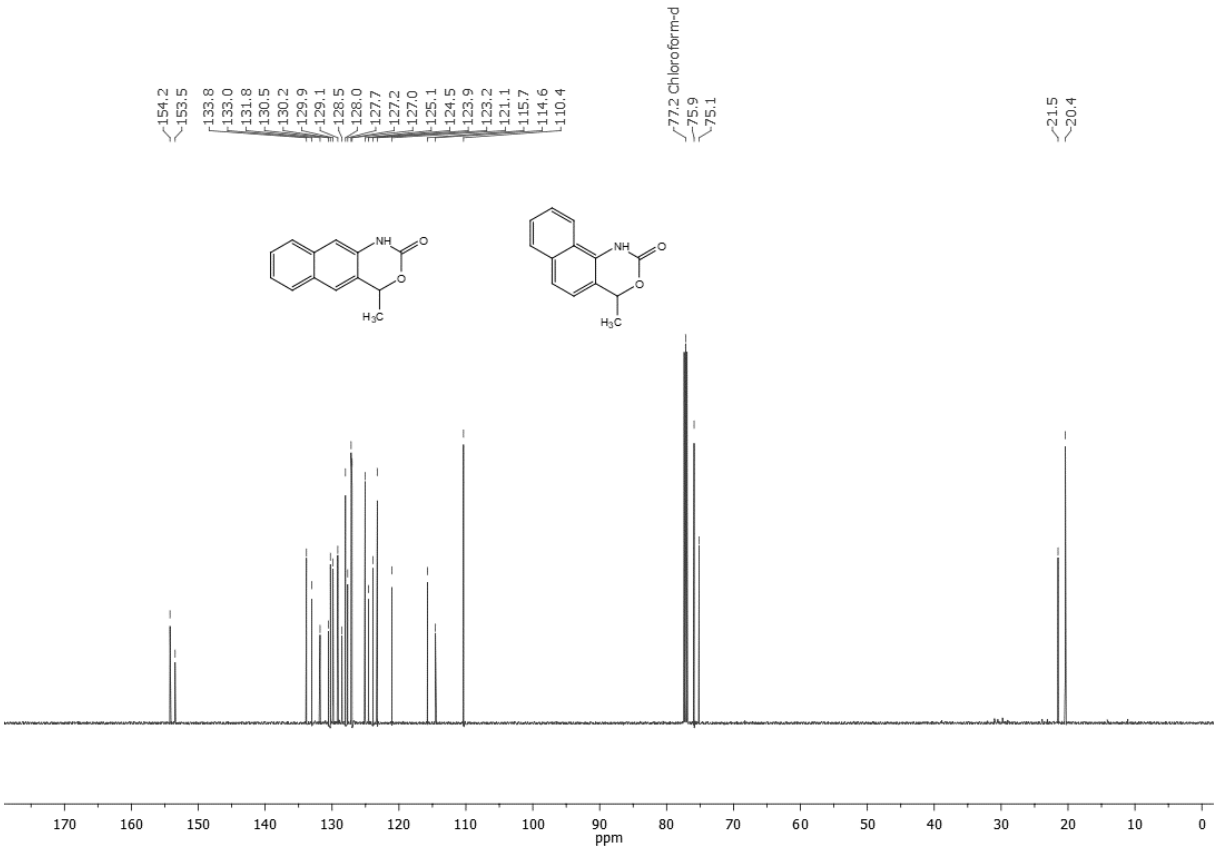
Mixture **13** and **14**





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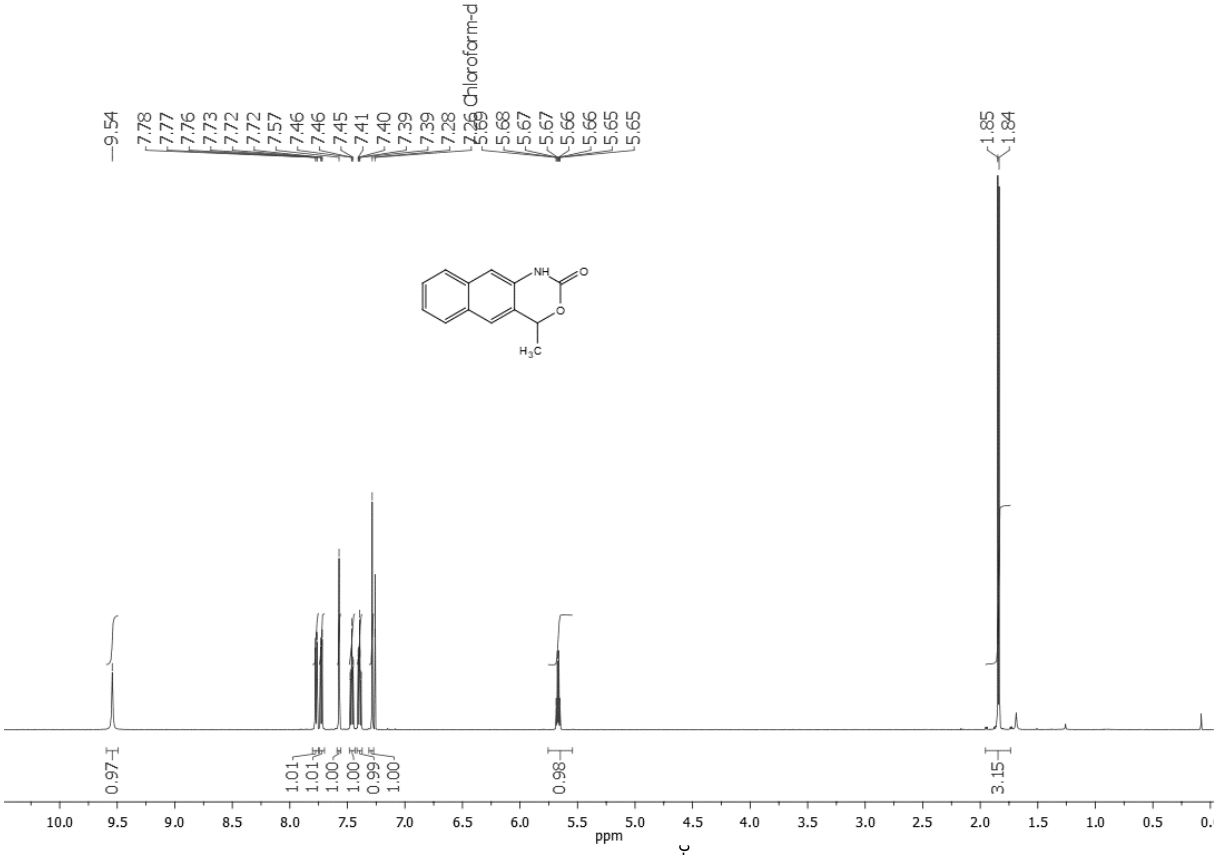
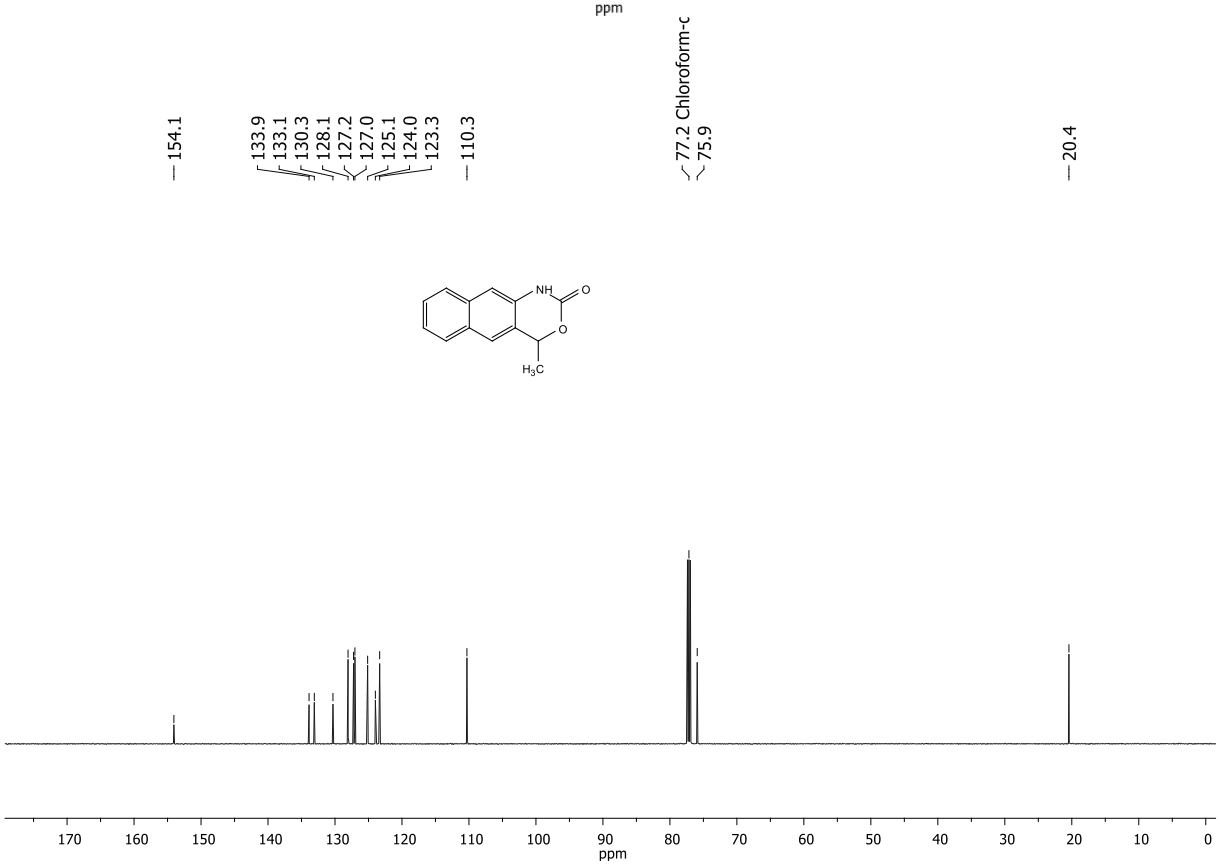
Compound **14**





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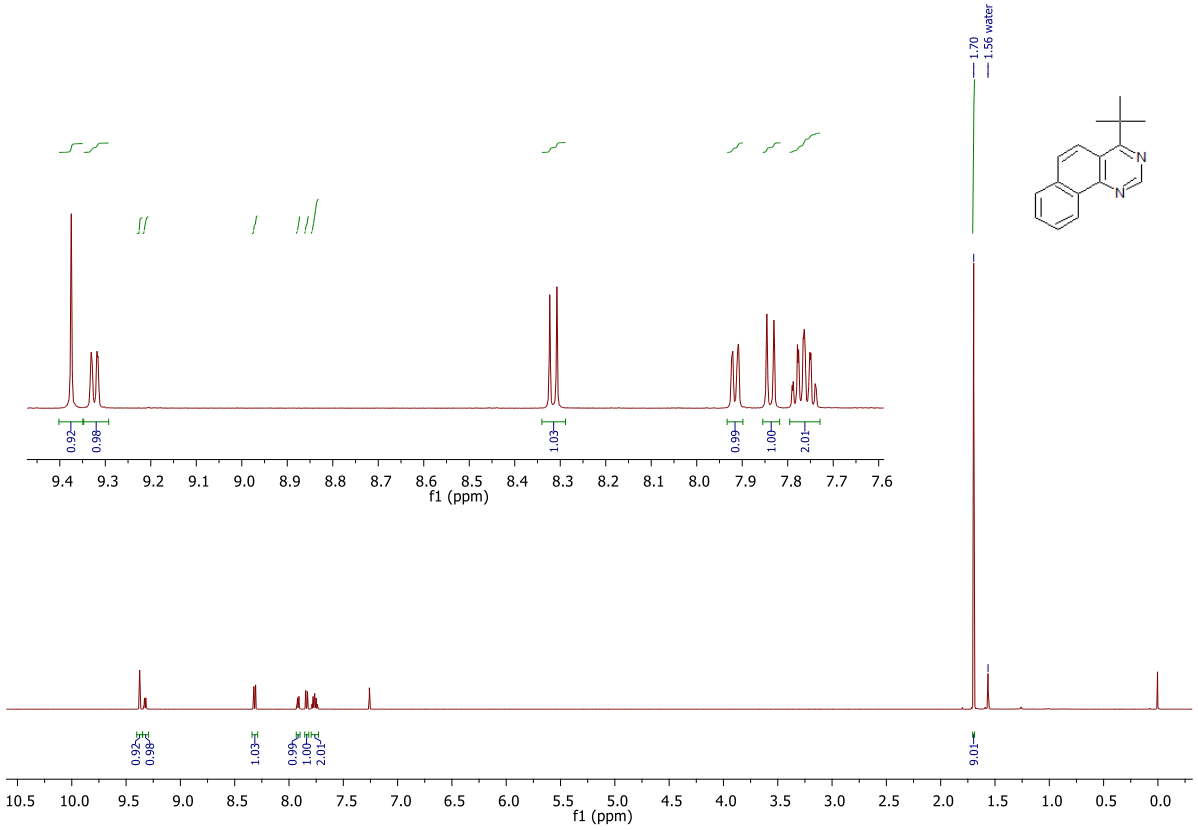
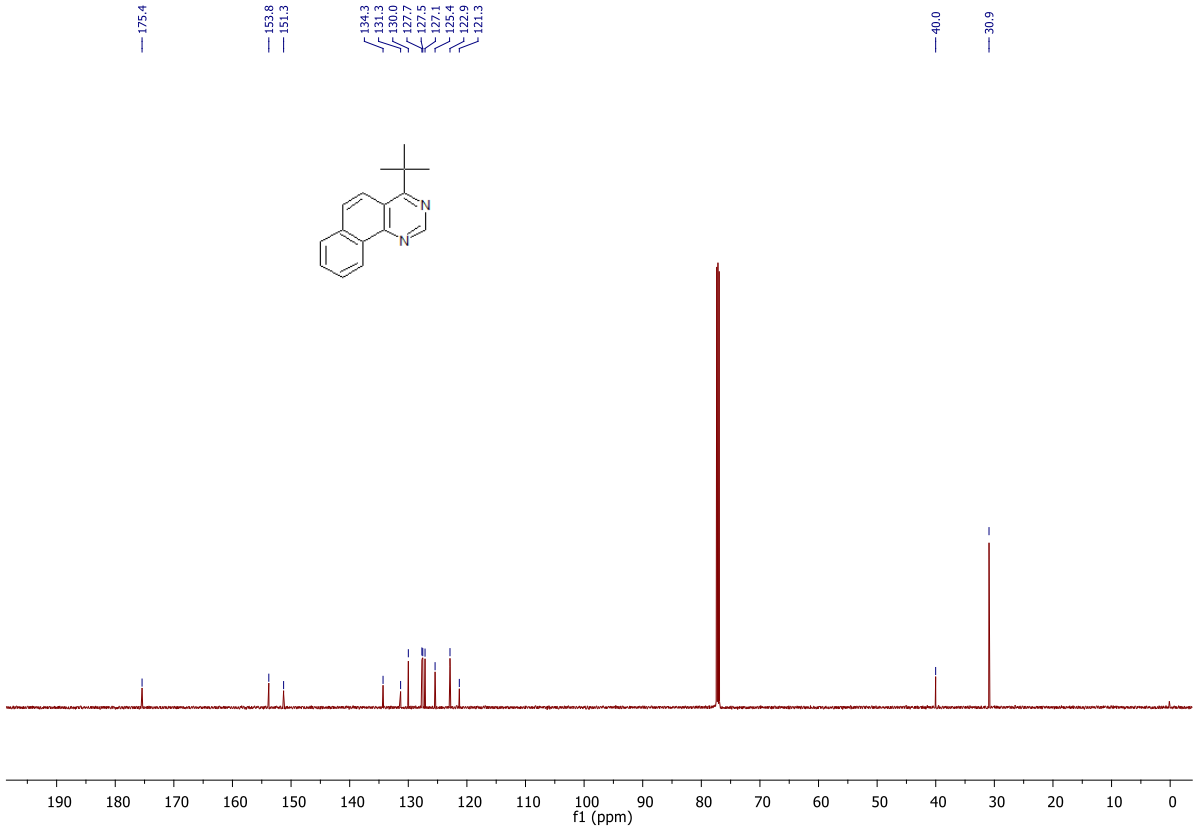
Compound **16b**





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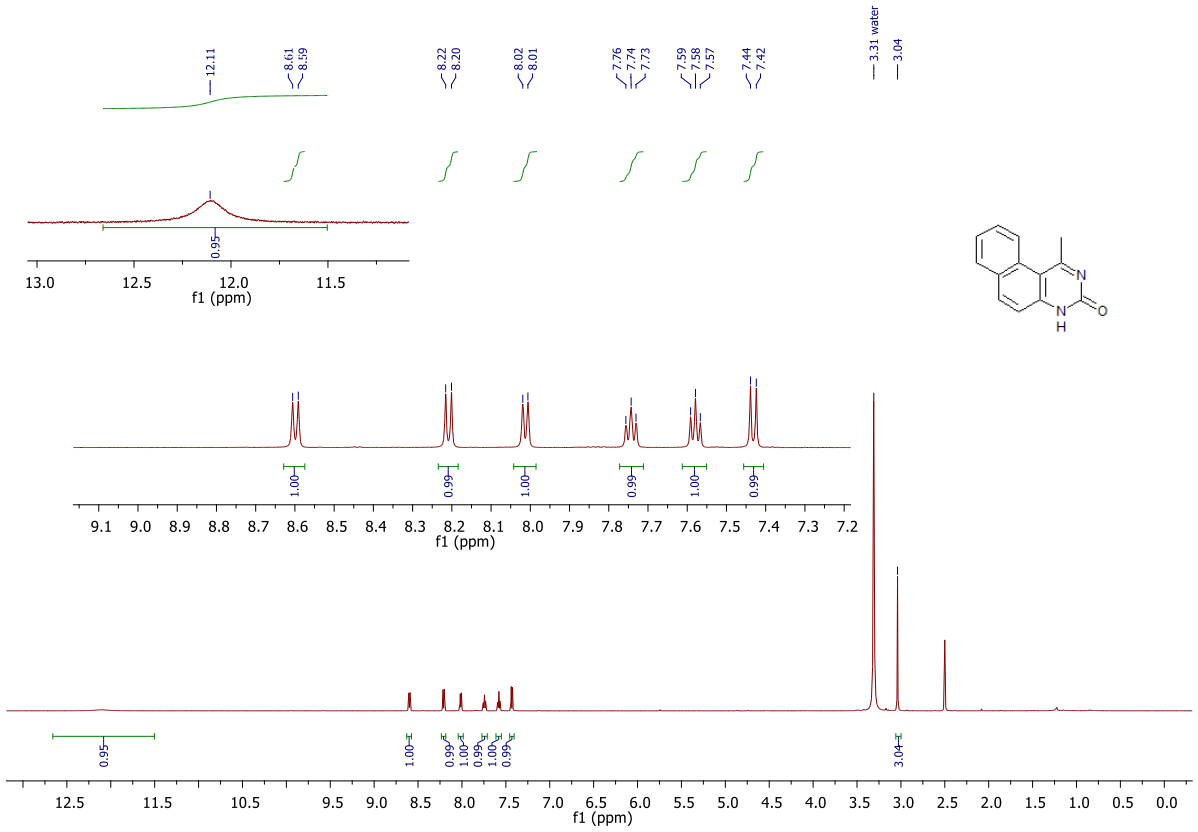
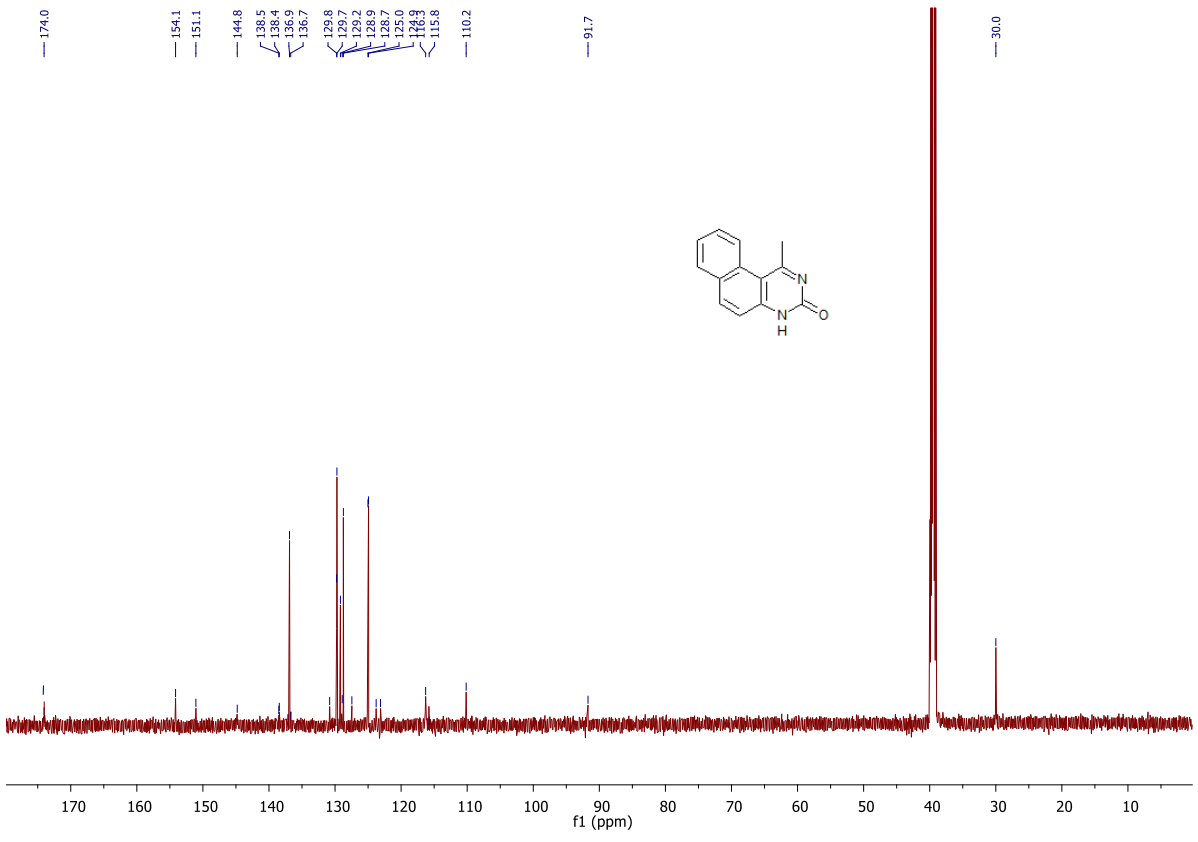
Compound **22a**





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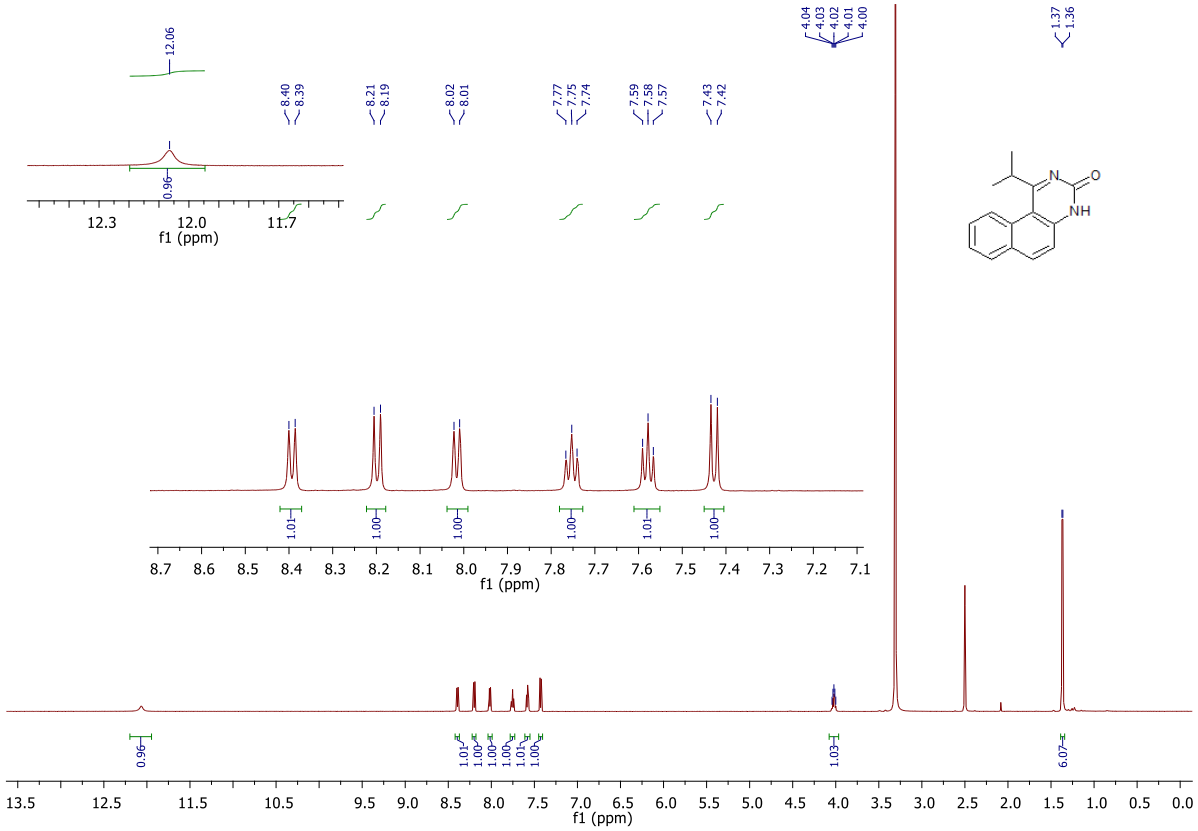
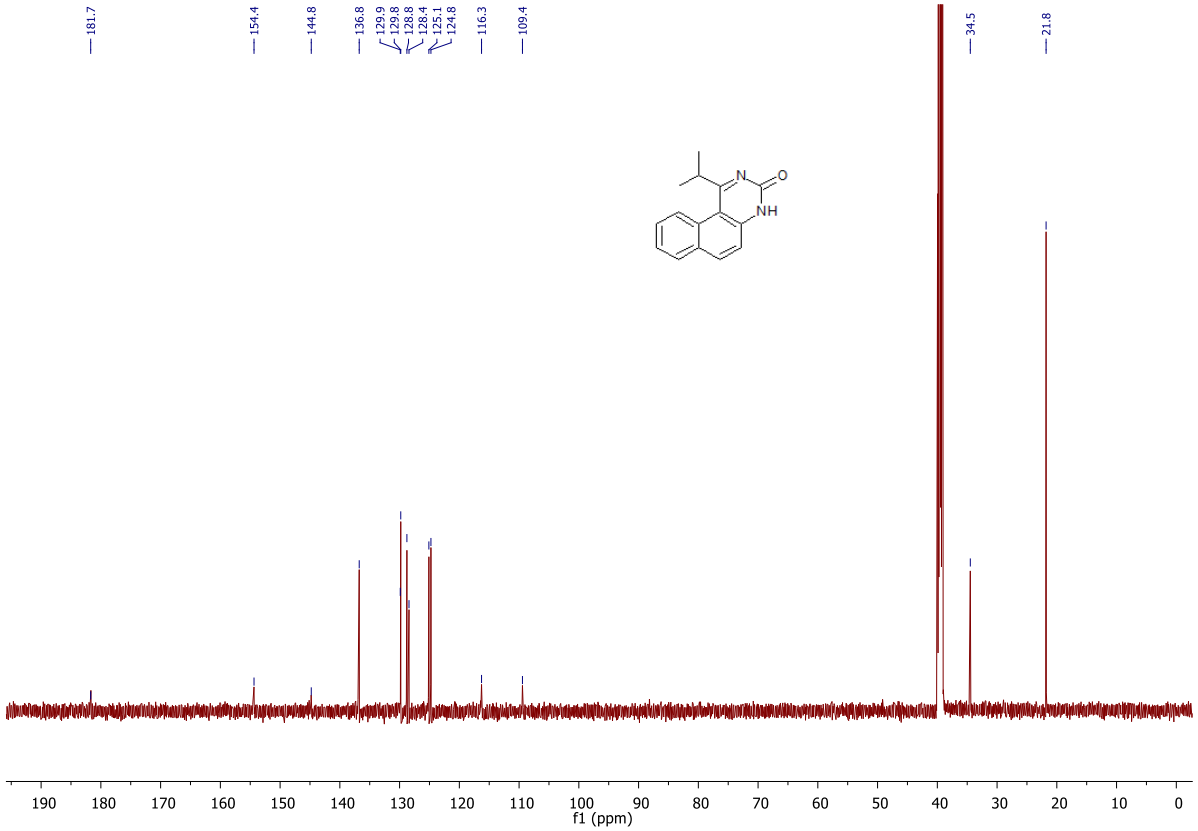
Compound **22b**





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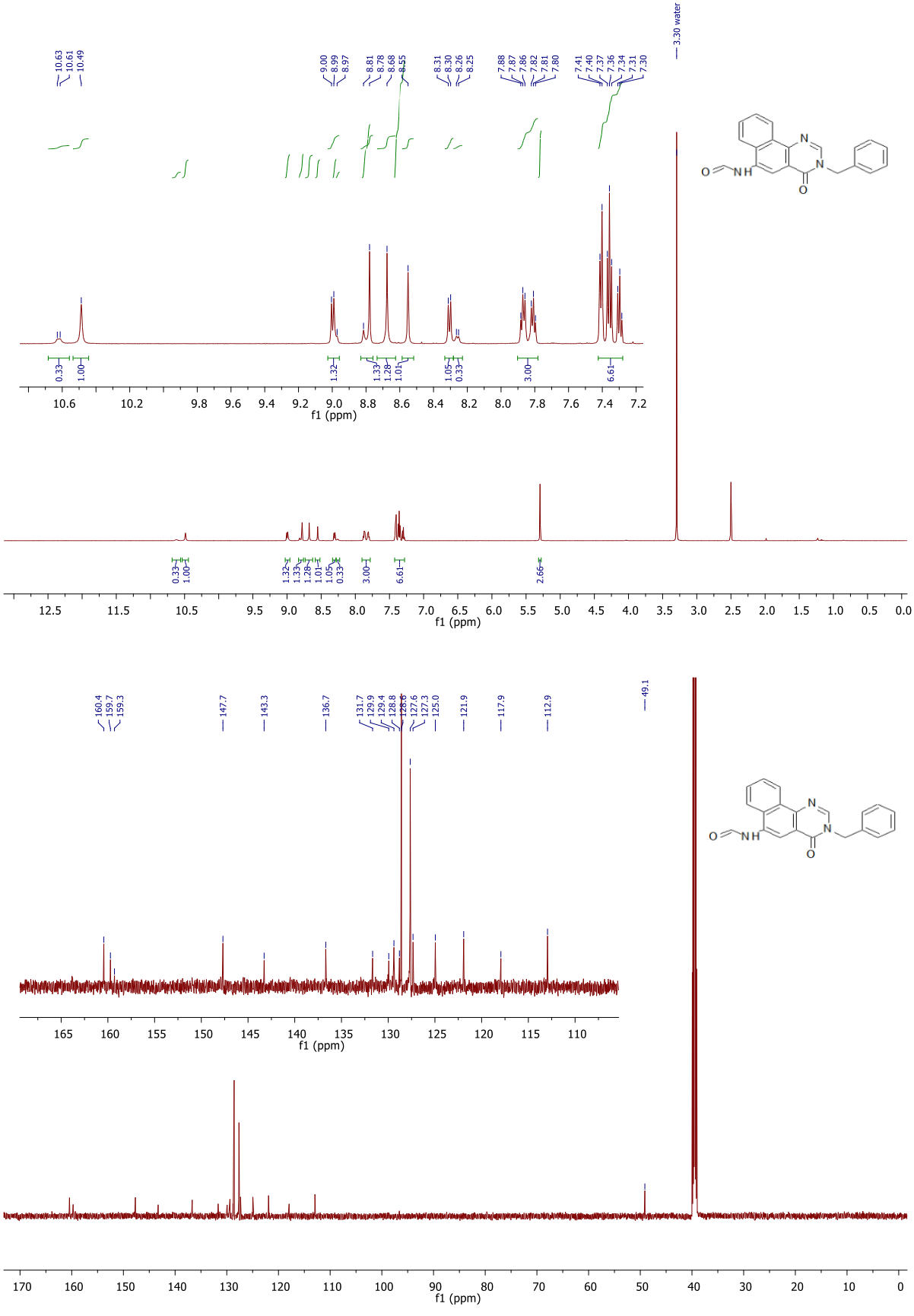
Compound **27a**



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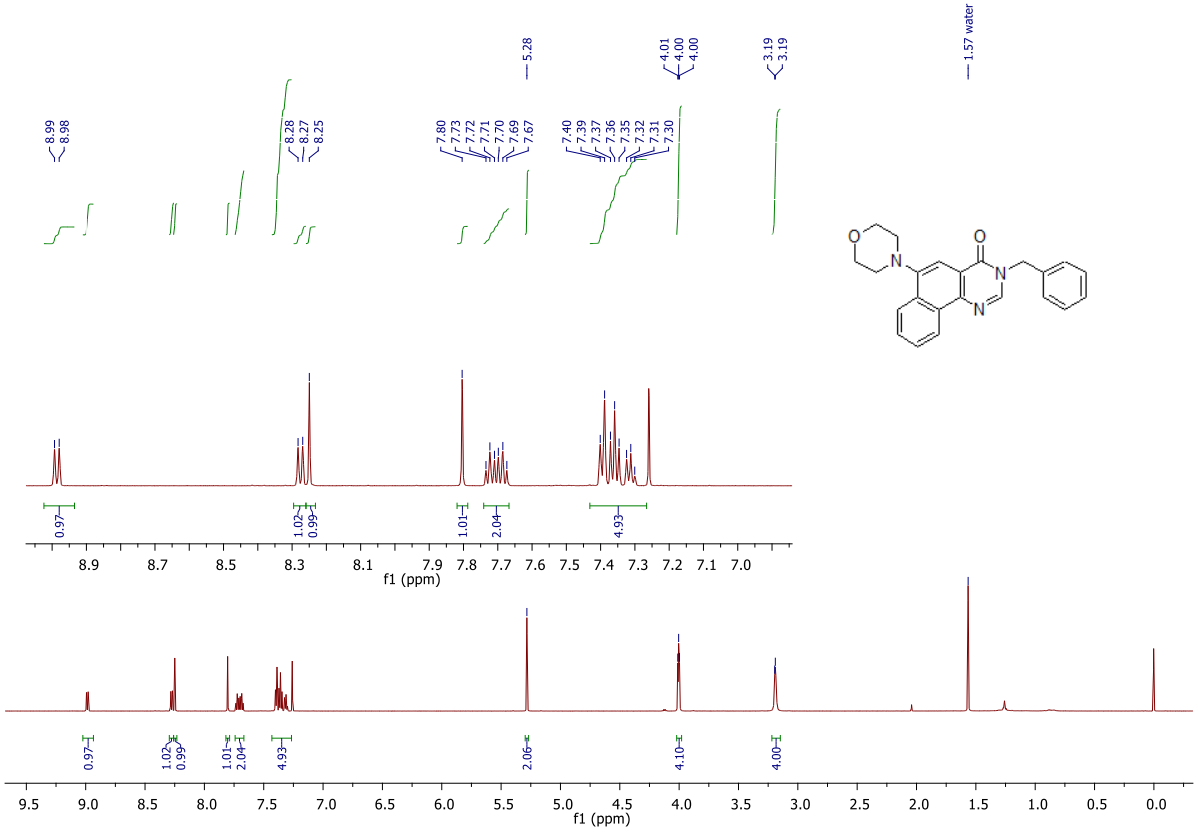
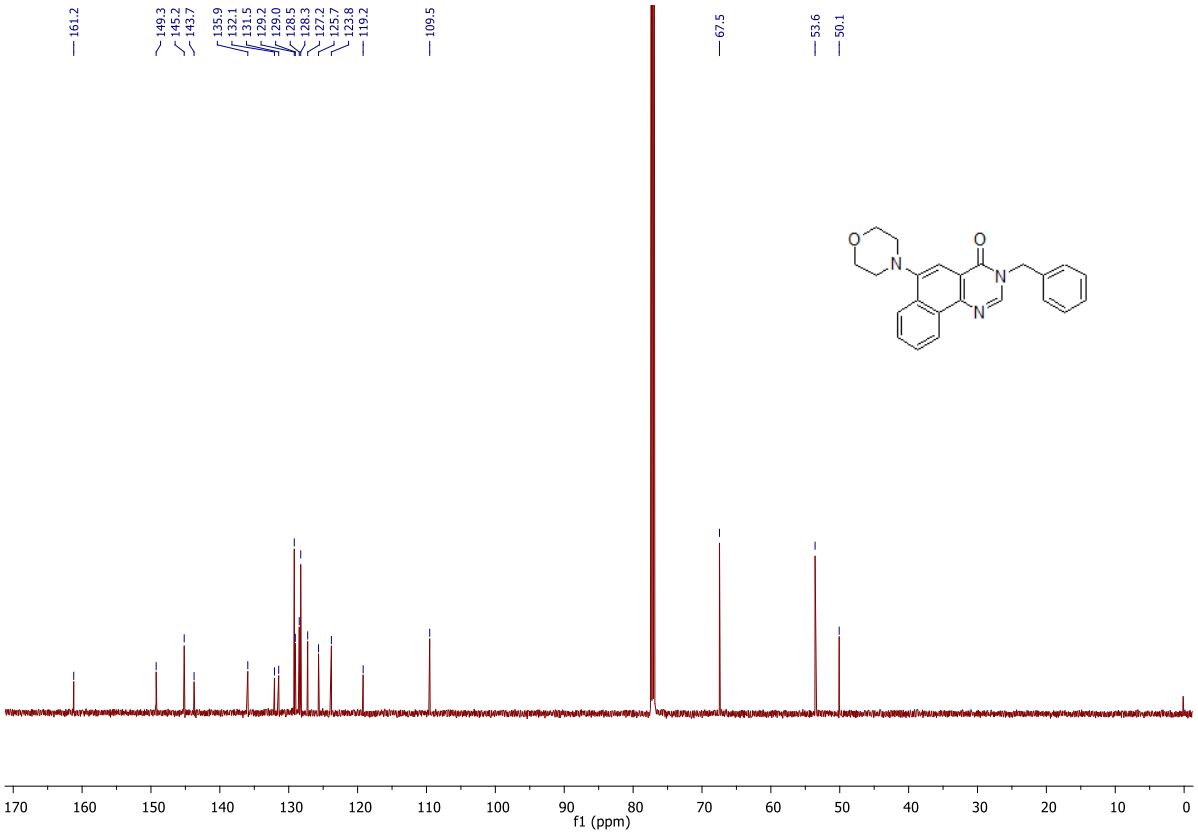
Compound **28a**





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