Accessing oxy-functionalized N-heterocycles through Rose-bengal and TBHP integrated photoredox C(sp^3)-O cross-coupling

Rahul Dev Mandal, Moumita Saha, Asish R. Das*

Department of Chemistry, University of Calcutta, Kolkata-700009, India

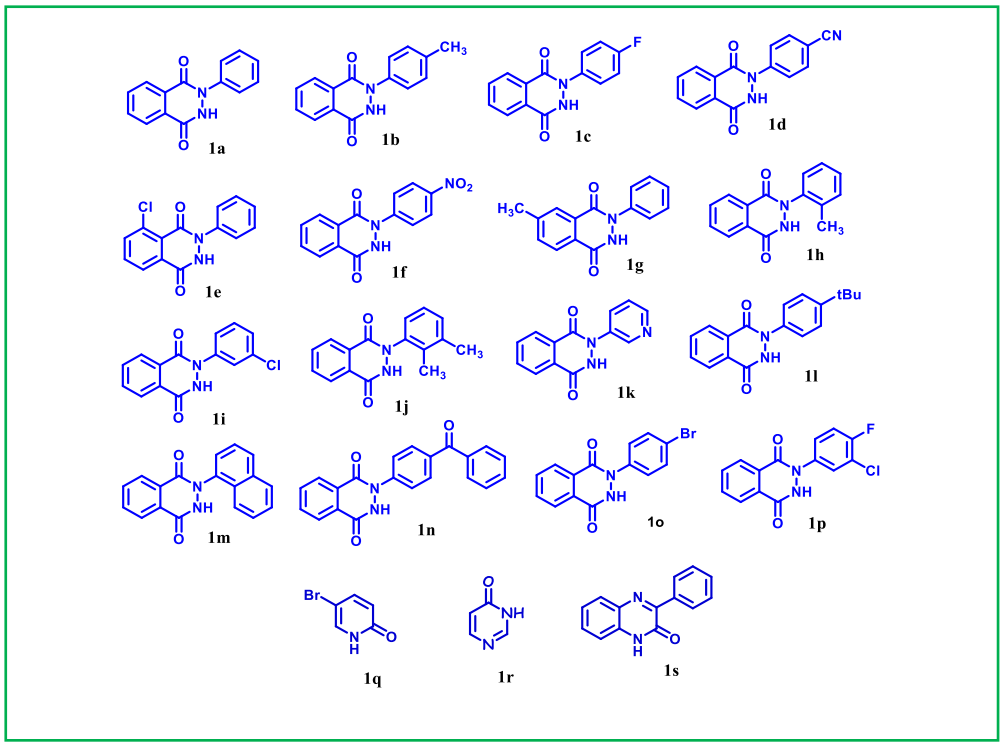
*Corresponding author: Tel.: +913323501014, +919433120265; fax: +913323519754;

E-mail address: ardchem@caluniv.ac.in, ardas66@rediffmail.com (A R Das)

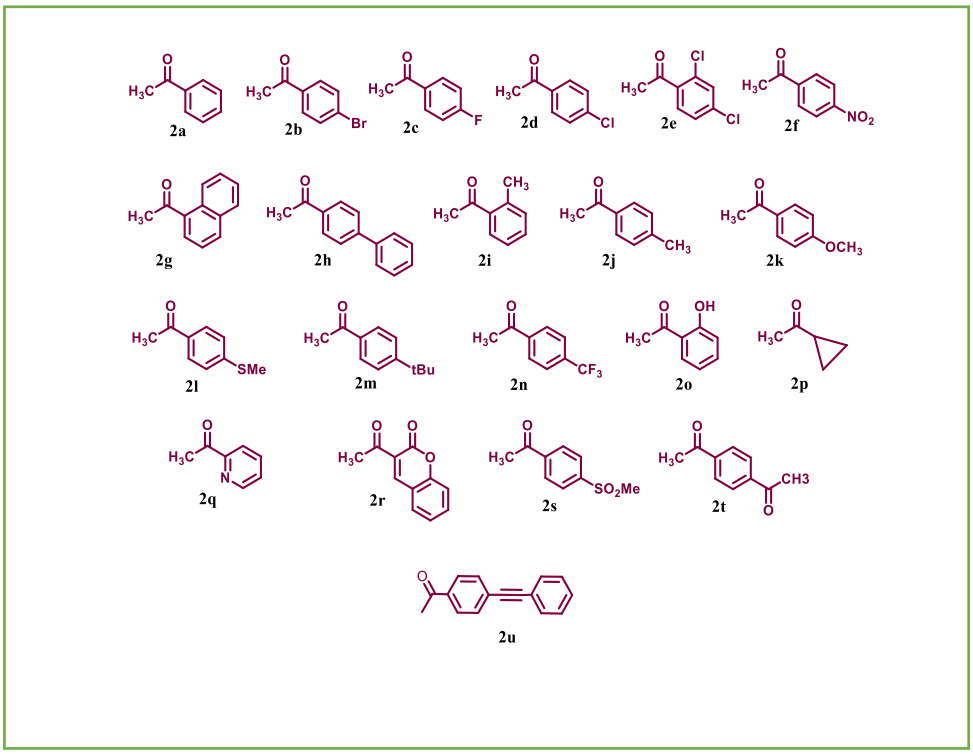
Supporting Information

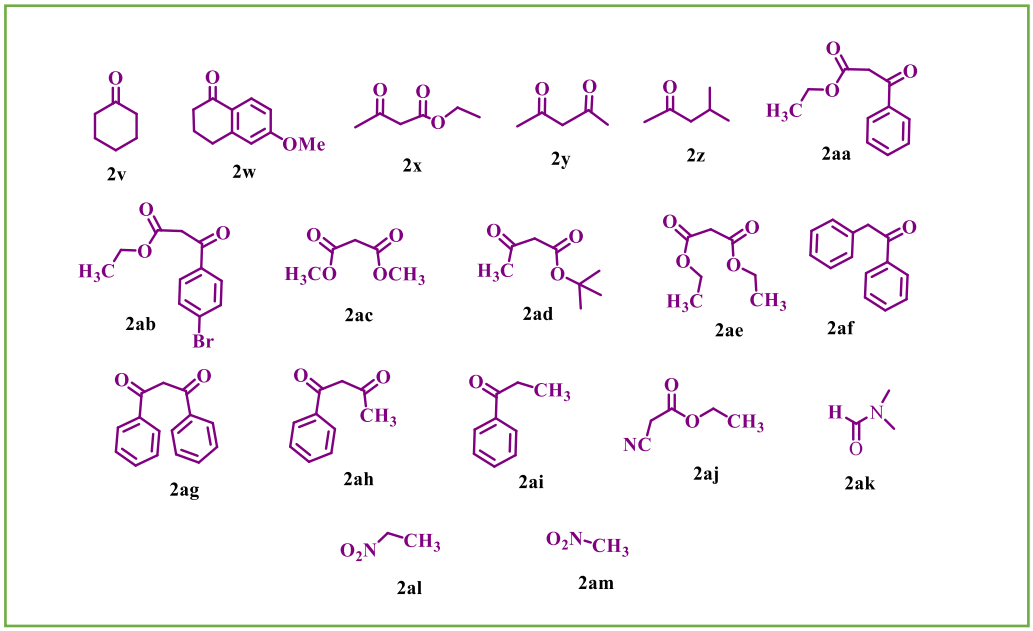
List of starting materials:

N-heterocycles: 2-phenyl-2,3-dihydrophthalazine-1,4-dione (1a-1p), 5-bromopyridin-2(1H)-one (1q), pyrimidin-4(3H)-one (1r), 3-phenylquinoxalin-2(1H)-one (1s):



Aryl alkyl aliphatic ketones (2v, 2w) ketone (2a,), di-alkyl ketones (2z, 2af, 2ai), *β*-ketoesters (2x, 22aa to 2ae, 2aj), *β*-diketones (2y, 2ag, 2ah), DMF (2ak) and nitroalkane (2al, 2am):





X-ray Crystallographic analysis of compound 3b (CCDC 2103982), 3e (CCDC 2103980) 4a (CCDC 2103983):

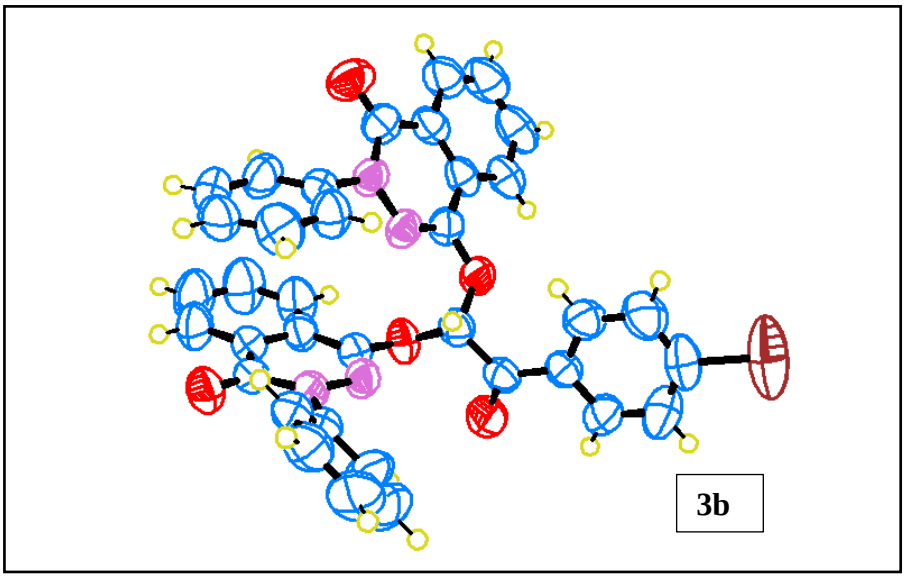


Figure S1. ORTEP diagram of X-ray crystal structure of compounds **3b** (CCDC No. **2103982**). The ellipsoid contour percent probability level is 60%. Color code: red, oxygen; pink, nitrogen; brown, bromine; blue, carbon; yellow, hydrogen. The crystal was grown from ethyl acetate. 30 mg of **3b** was dissolved in 0.5 mL of ethyl acetate under heating and the solvent was evaporated slowly in a cold atmosphere.

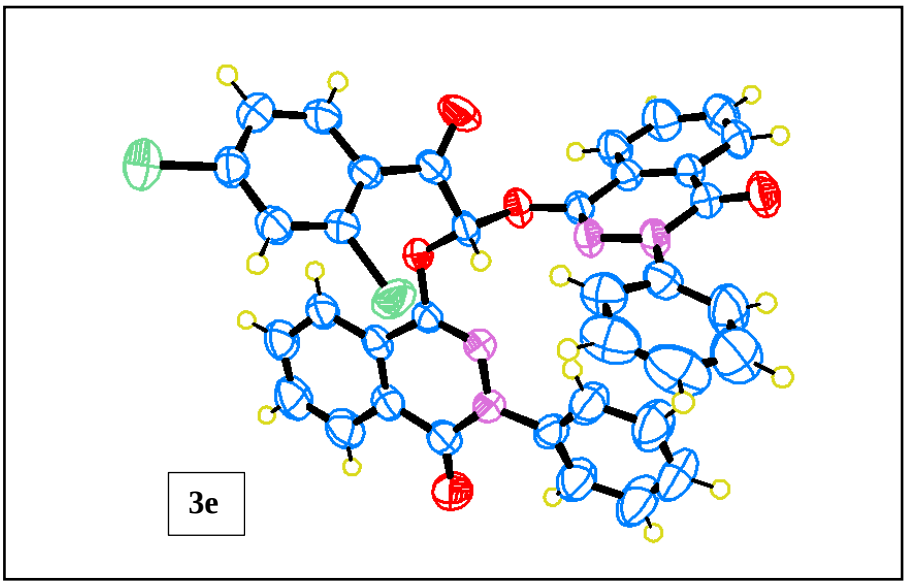


Figure S2. ORTEP diagram of X-ray crystal structure of compounds **3e** (CCDC No. **2103980**). The ellipsoid contour percent probability level is 60%. Color code: red, oxygen; pink, nitrogen; green, chlorine; blue, carbon; yellow, hydrogen. The crystal was grown from ethyl acetate. 33 mg of **3e** was dissolved in 0.5 mL of ethyl acetate under heating and the saturated solution was kept in open air for evaporated slowly to get crystal.

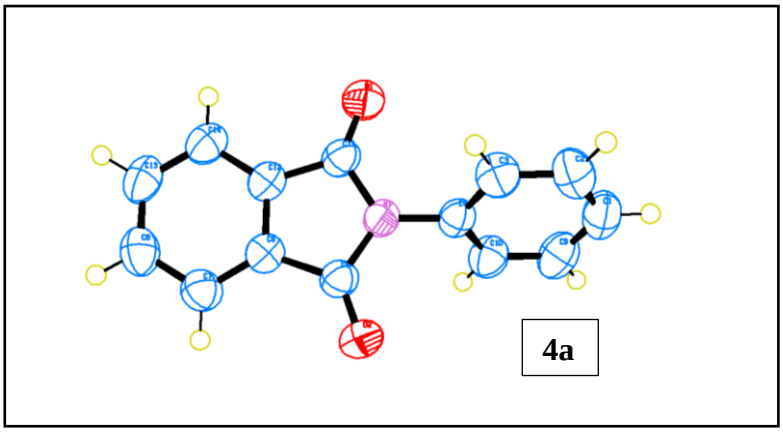


Figure S3. ORTEP diagram of X-ray crystal structure of compounds **4a** (CCDC No. **2103983**). The ellipsoid contour percent probability level is 60%. Color code: red, oxygen; pink, nitrogen; blue, carbon; yellow, hydrogen. The crystal was grown from ethyl acetate. 30 mg of **4a** was dissolved in 0.5 mL of ethyl acetate under heating and the solvent was evaporated slowly in a cold atmosphere.

Single crystal X-ray data of compound 3b (CCDC 2103982), 3e (CCDC 2103980) and 4a (CCDC 2103983):

Single crystals suitable for X-ray diffraction of **3b**, **3e** and **4a** were grown from ethyl acetate. The crystals were carefully chosen using a stereo zoom microscope supported by a rotatable polarizing stage. The data were collected at 273(2) K, 273(2) K and 296(2) K for **3b**, **3e** and **4a** on a Bruker-APEX III CCD diffractometer with graphite monochromated Mo-Kα radiation (0.71073Å). The data were processed using the package SAINT.[1] Structures were solved by direct and Fourier methods and refined by full-matrix least squares based on F2 using SHELXTL[2] and SHELXL-97[3] packages.

Table 1: Crystallographic data for the compound **3b**, **3e** and **4a.**

Compounds	**3b**	**3e**	**4a**
Empirical formula	C_{36} H_{23} Br N_4 O_5	C_{36} H_{22} Cl_2 N_4 O_5	C_{14} H_9 N O_2
FW	671.49	661.47	223.22
Crystal color	White	White	White
Crystal system	Monoclinic	Triclinic	Orthorhombic
Space group	P 21/n	P -1	P b c a
***a* (Å)**	13.543(3)	8.346(4)	11.6817(8)
***b*(Å)**	10.328(2)	12.269(6)	7.6497(6)
***c* (Å)**	22.564(5)	14.899(7)	23.7774(16)
α (°)	90	92.200(7)	90
β (°)	100.723(4)	101.408(7)	90
γ (°)	90	92.387(7)	90
***V* (Å^3)**	3101.0(12)	1492.5(13)	2124.8(3)
Z	4	2	8
***T*, K**	273(2)	273(2)	296(2)

Wavelength (Å)	0.71073	0.71073	0.71073
***2θ* (°)**	1.837-24.996	1.396-24.999	1.713-24.992
μ (mm^{-1})	1.376	0.271	0.095
ρ_{calcd} (g cm^{-3})	1.438	1.472	1.396
***F*(000)**	1368	680	928.0
absorption correction	multi-scan	multi-Scan	multi-Scan
index ranges	$-16\le h\le 16$	$-9\le h\le 9$	$-13\le h\le 13$
	$-12\le k\le 12$	$-14\le k\le 14$	$-8\le k\le 9$
	$-26\le l\le 26$	$-17\le l\le 17$	$-28\le l\le 28$
reflections collected	44463	30198	20151
independent reflections (R_{int})	889 (0.0785)	5760 (0.0359)	7530(0.0310)
Goodness-of-fit on F^2	1.143	1.011	0.936
$R_1{}^a$ /w$R_2{}^b$ ($I>2\sigma(I)$)	0.0509/0.1373	0.0431/0.1278	0.0310/0.1088
$R_1{}^a$/w$R_2{}^b$ (for all data)	0.0991/0.1749	0.0570/0.1600	0.0358/0.1199
Largest diff. peak/hole / e Å^{-3}	0.410/ -0.533	0.236/ -0.416	0.179/ -0.126

$^aR_1 = [\sum||F_o| - |F_c||/\sum|F_o|]$. $^bwR_2 = [\sum w(F_o^2 - F_c^2)^2/\sum wF_o^4]^{1/2}$

References:

1. *APEX-II*, *SAINT-Plus*, and *TWINABS;* Bruker-NoniusAXSInc.: Madison, WI,2004.

2. *SHELXTL*, version 6.10; Bruker AXS Inc.: Madison, WI, 2002.

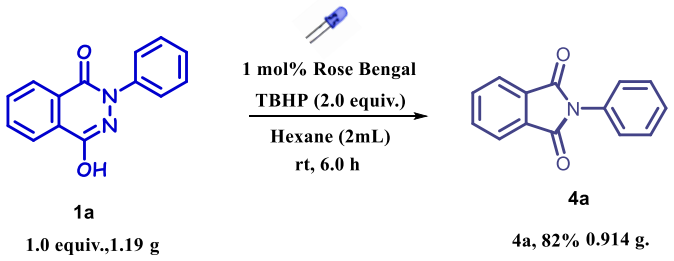
3. Sheldrick, G. M. *SHELXL-9, Crystal Structure Refinement Program;* University ofGöttingen: Göttingen, Germany, 1997.

4. Dolomanov, O.V., Bourhis, L.J., Gildea, R.J, Howard, J.A.K. &Puschmann, H. (2009), *J. Appl. Cryst*. 42, 339-341.

5. Sheldrick, G.M. (2015). *Acta Cryst*. A71, 3-8.

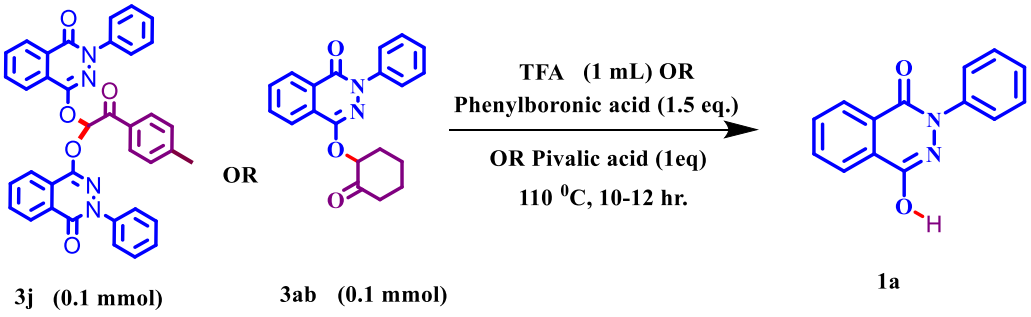
6. Sheldrick, G.M. (2015). *Acta Cryst*. C71, 3-8.

Gram scale experiment for compound 4a:



To a flame dried glass tube fitted with a screw-cap and a magnetic stir bar were added dihydrophthalazine-1,4-diones **1o** (1.19 g, 5 mmol; 1 equiv.) in 2 mL of hexane. Then TBHP in 70% in water (~1.8 mL; 10 mmol) was added dropwise to the above mixture. After the addition of TBHP, the reaction mixture was stirred at room temperature under the irradiation by 2*9 W blue LED for 6 h. The reaction was monitored by TLC. After the mentioned time interval, the mixture was extracted using ethyl acetate (5 × 10 mL) and brine solution (10 mL). The combined organic layer was then dried over anhydrous sodium sulphate, evaporated under reduced pressure and finally purified by silica gel column chromatography (100–200 mesh size) to obtain the pure products (**4a**) with 82% (0.914 g). The identity and purity of the product was confirmed by spectroscopic analysis.

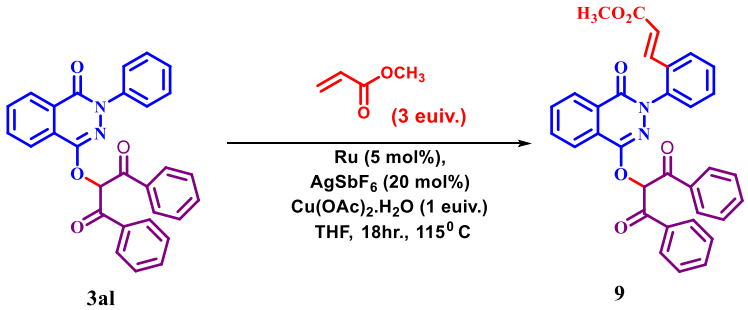
Deprotection study of ether linkage:



In an oven dried 15 mL pressure tube, to a solution of **3j/3ab**, TFA (Trifluoroacetic acid) (1mL) or phenylboronic acid (1.5 eq.) or pivalic acid (1 eq.) were added and the reaction mixture was stirred in a pressure tube sealed with a Teflon cap at 115 °C for 10-12 h. After completion of reaction, the solution was then extracted with ethyl acetate (2*15 mL) and saturated aqueous

solutions of NaCl (5 mL) and $NaHCO_3$ (5 mL). The combined organic layer was dried over anhydrous Na_2SO_4, filtered, and concentrated using rotary evaporator. The crude residue was finally subjected to silica gel column chromatography using EA/ petroleum ether as eluent to get the desired product **1a** with 72%.

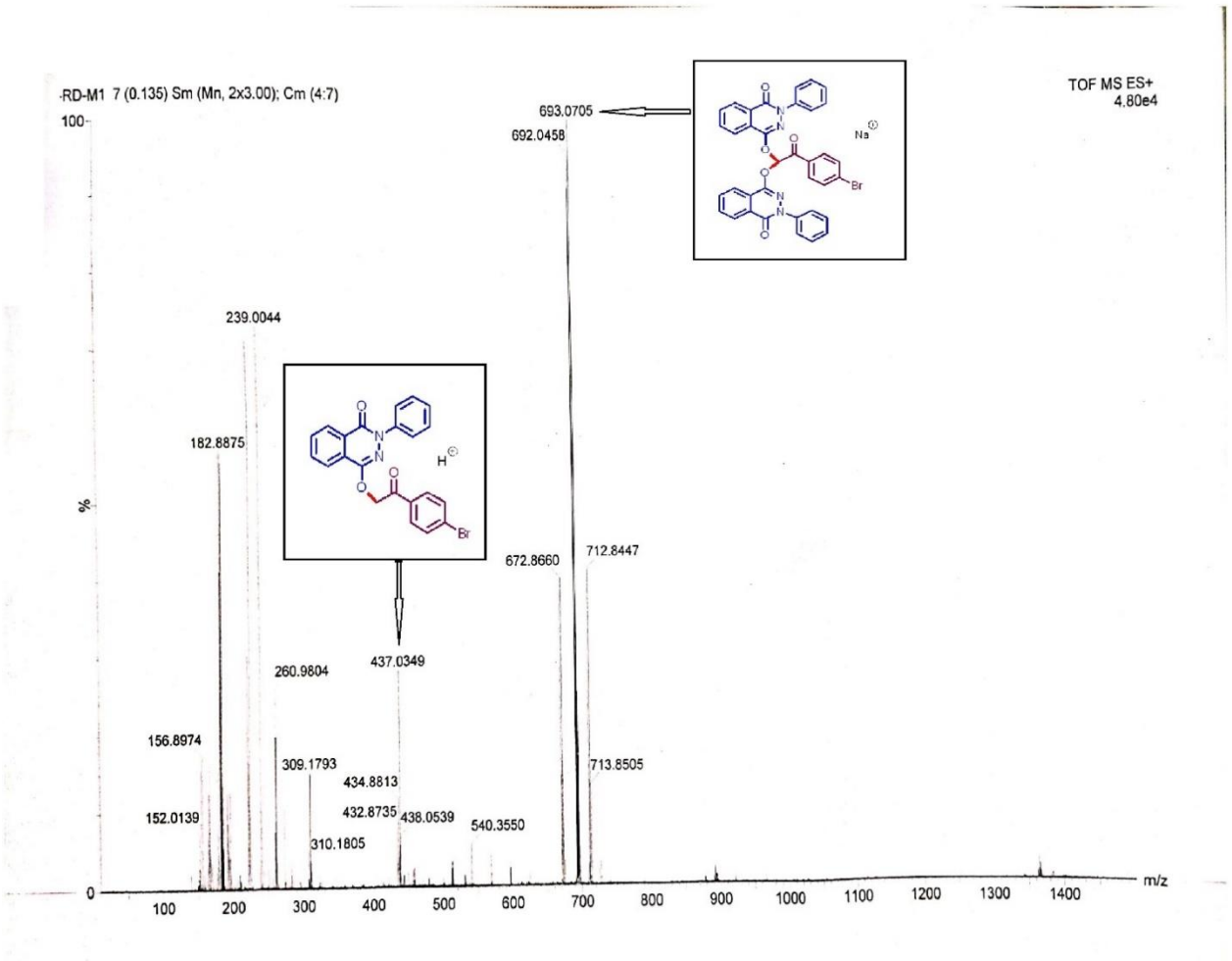
Alkenylation reaction:



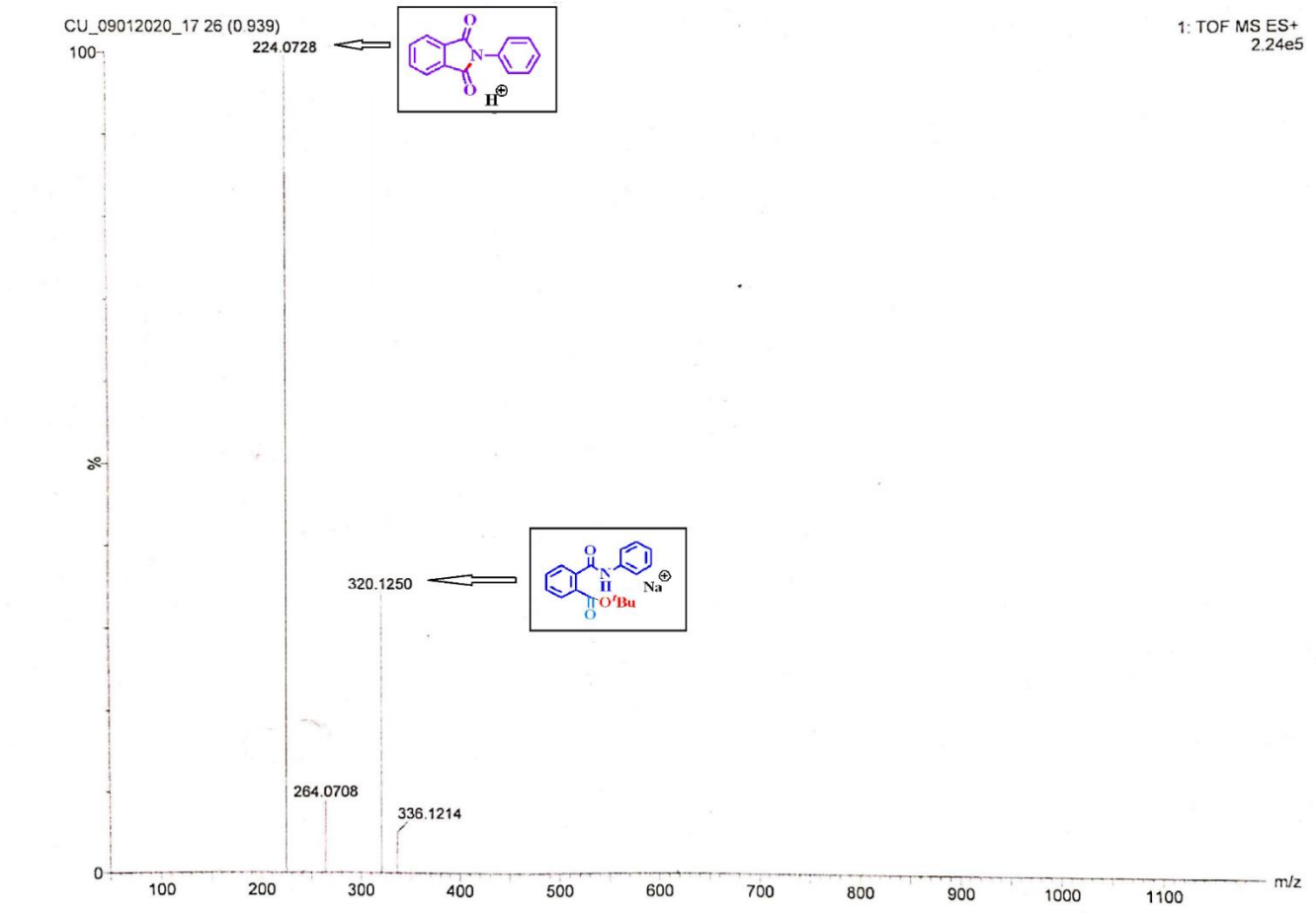
3al **9**

In an oven dried 15 mL pressure tube, to a solution of 2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)-1,3-diphenylpropane-1,3-dione **3al** (0.2 mmol, 1 eq.) and methyl acrylate (0.6 mmol, 3 eq.) in THF (1.5 mL) were added the combined solids: $[RuCl_2(p\text{-cymene})]_2$ (5 mol%), $AgSbF_6$ (20 mol%) and $Cu(OAc)_2.H_2O$ (0.1 mmol, 1 eq.). After that the pressure tube was sealed with a Teflon cap then it was heated to 115 °C for 18 h. After completion of reaction, the solution was then extracted with ethyl acetate (2*15 mL) and saturated aqueous solutions of NaCl (10 mL). The combined organic layer was dried over anhydrous Na_2SO_4, filtered, and concentrated using rotary evaporator. The crude residue was finally subjected to silica gel column chromatography using EA/ petroleum ether as eluent to get the desired product.

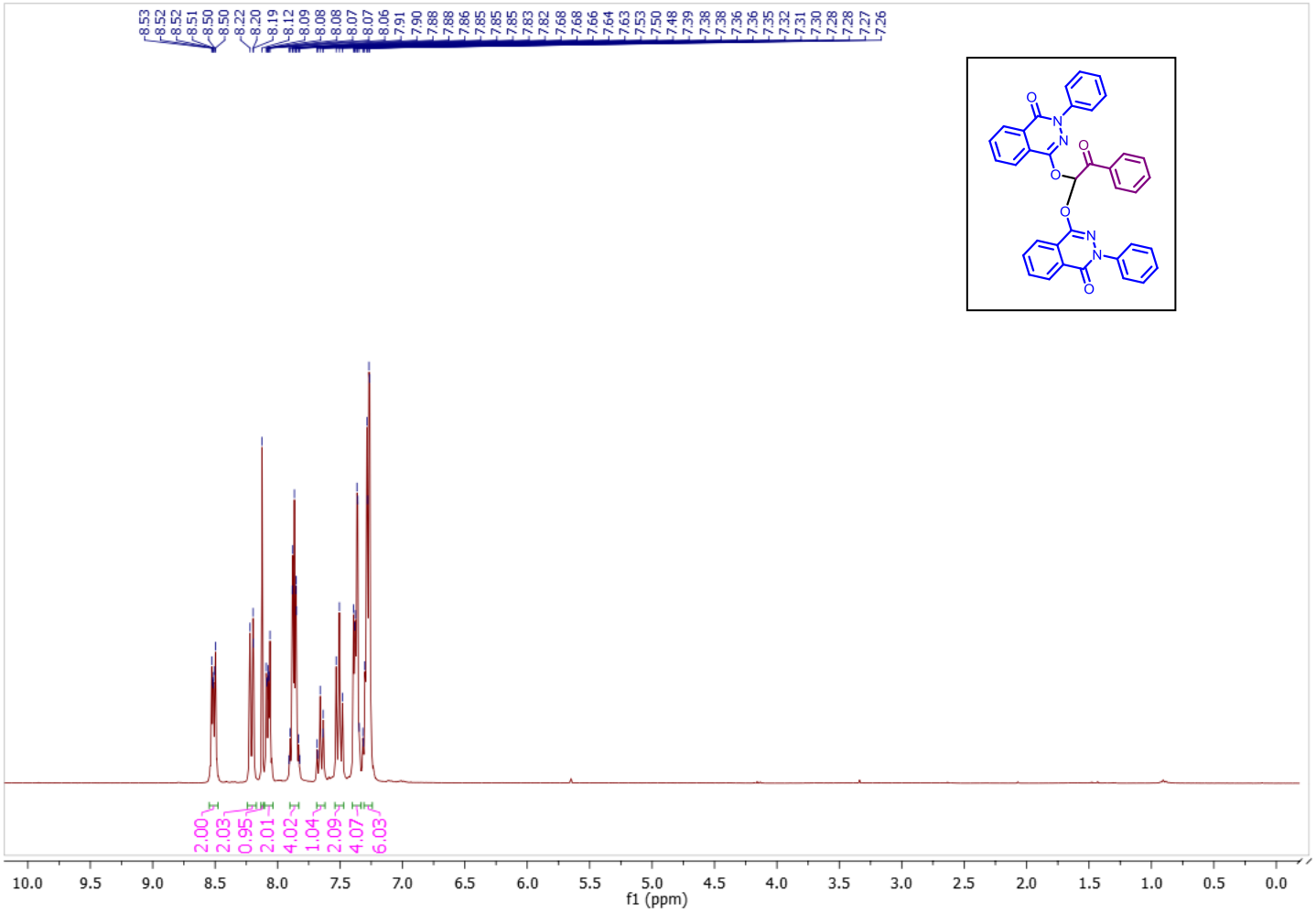
HRMS analysis of reaction mixture (RM-1) after 5hr. of oxidative C(sp^3)-O cross Coupling reaction of 2,3-dihydrophthalazine-1,4- diones (1a) with 4-bromo acetophenone (2b):



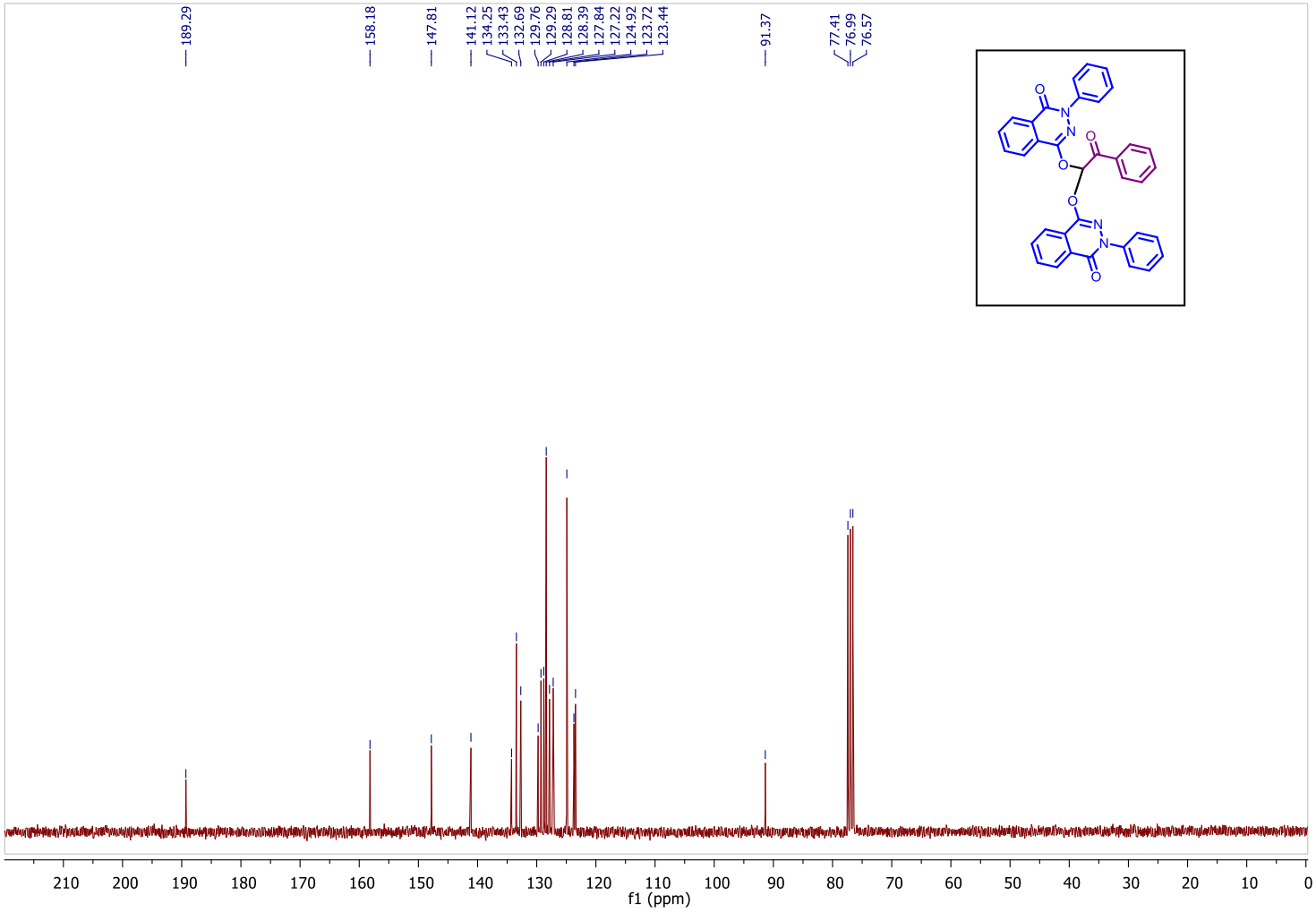
HRMS analysis of reaction mixture (RM-2) of TBHP-mediated ring contraction:



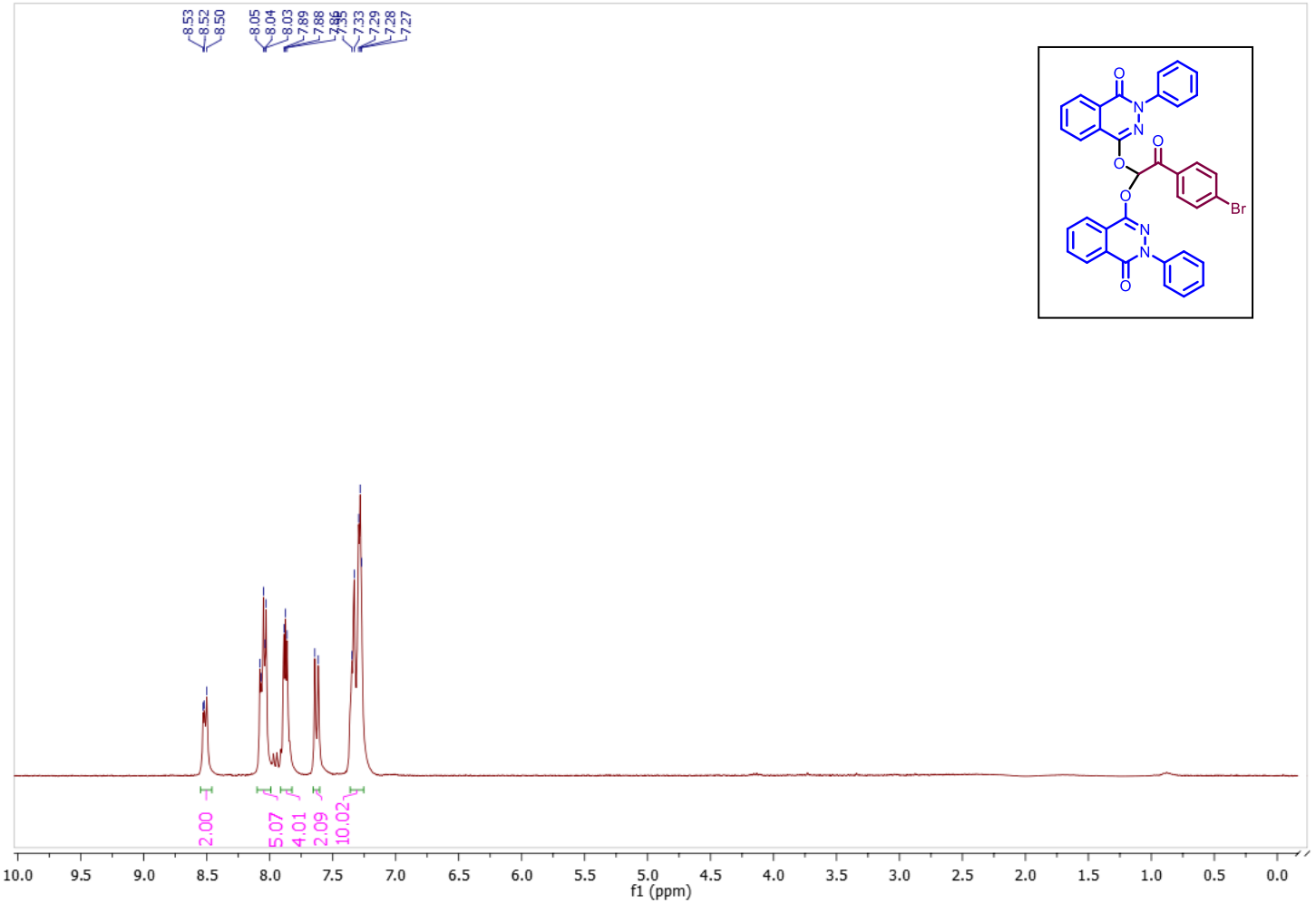
4,4'-((2-oxo-2-phenylethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3a): ^{1}H NMR (300 MHz, $CDCl_3$):



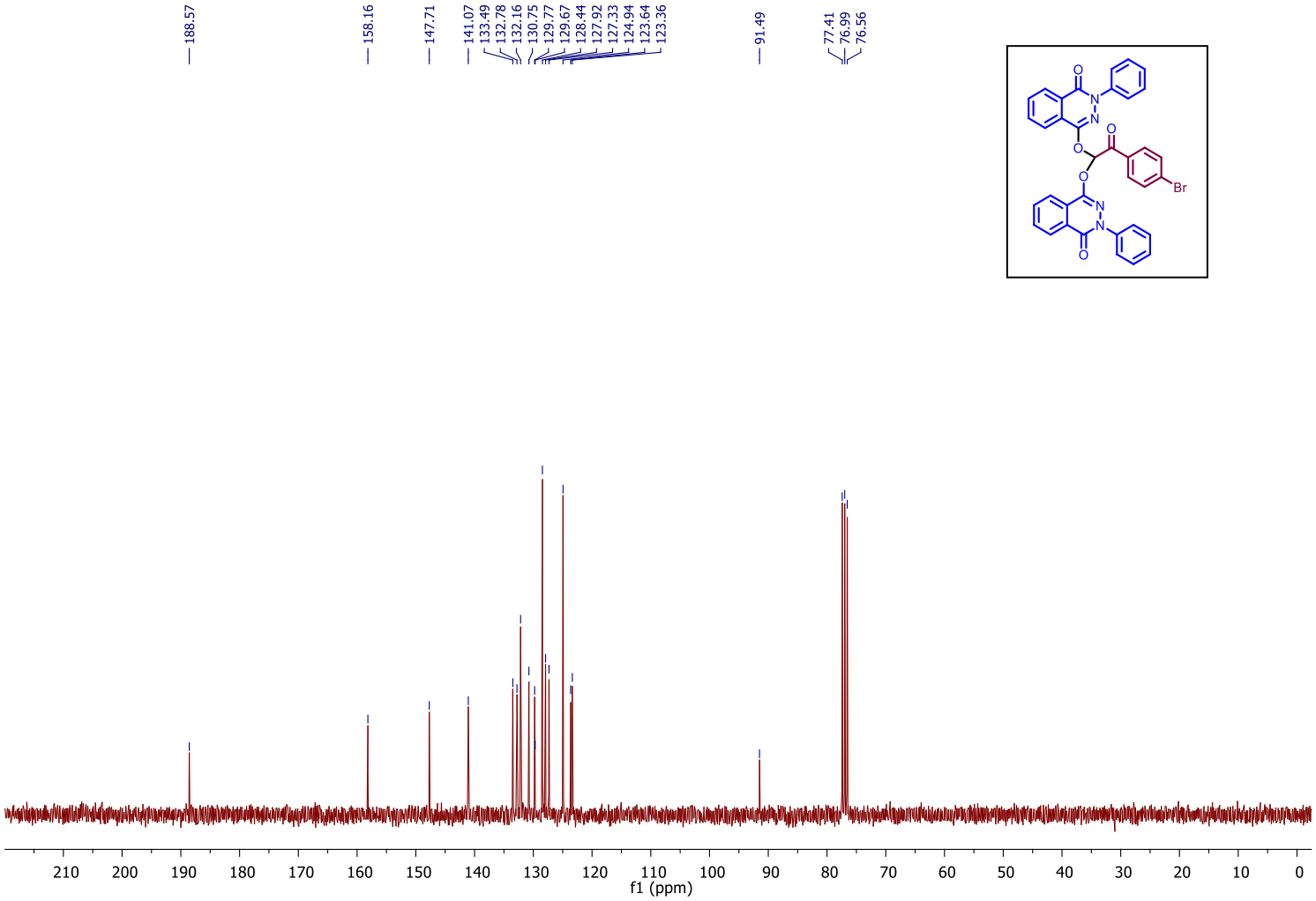
4,4'-((2-oxo-2-phenylethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3a): ^{13}C NMR (75 MHz, $CDCl_3$) :



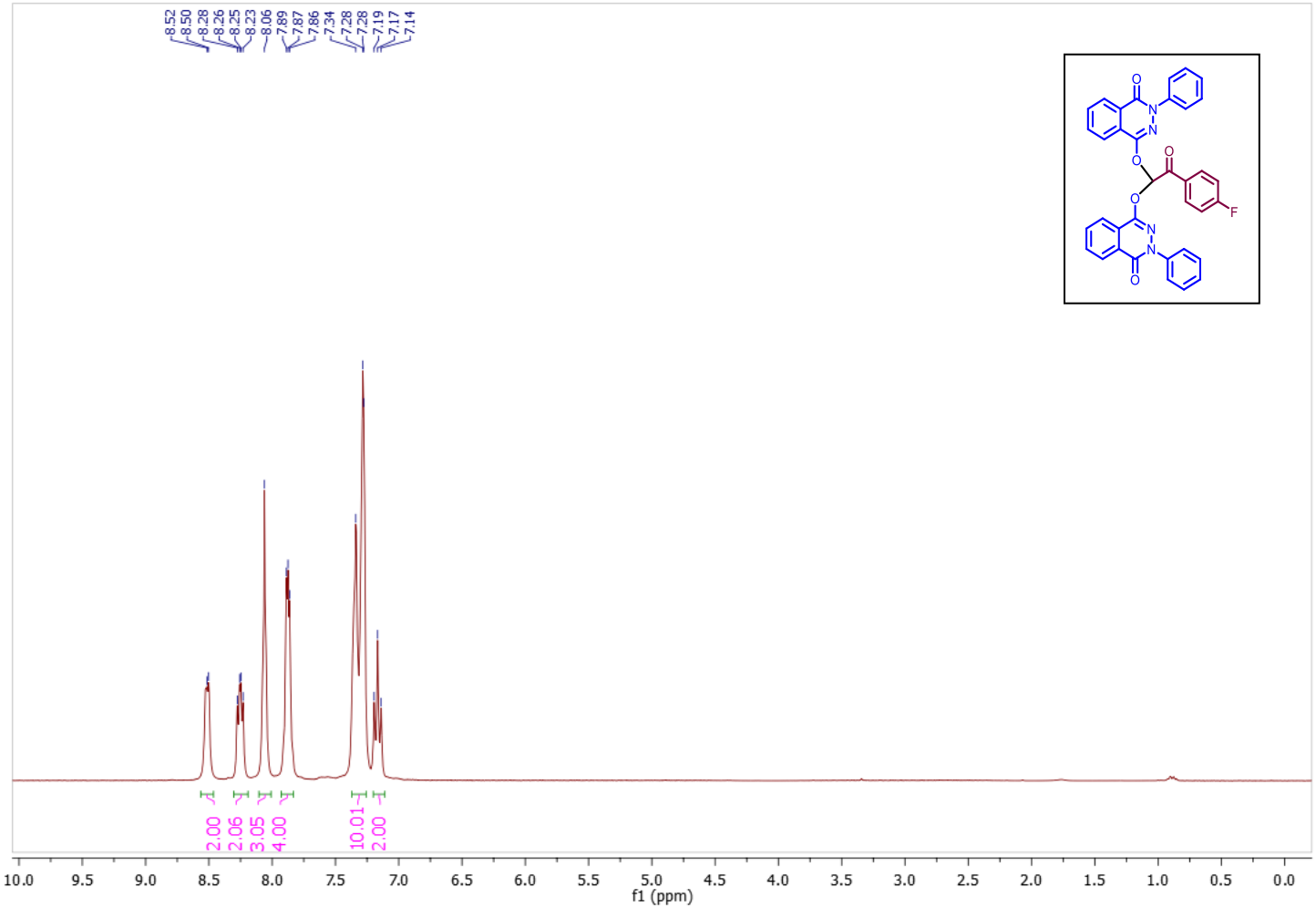
4,4'-((2-(4-bromophenyl)-2-oxoethane-1,1 diyl)bis(oxy))bis(2phenylphthalazin-1(2*H*) one) (3b): ^{1}H NMR (300 MHz, $CDCl_3$) :



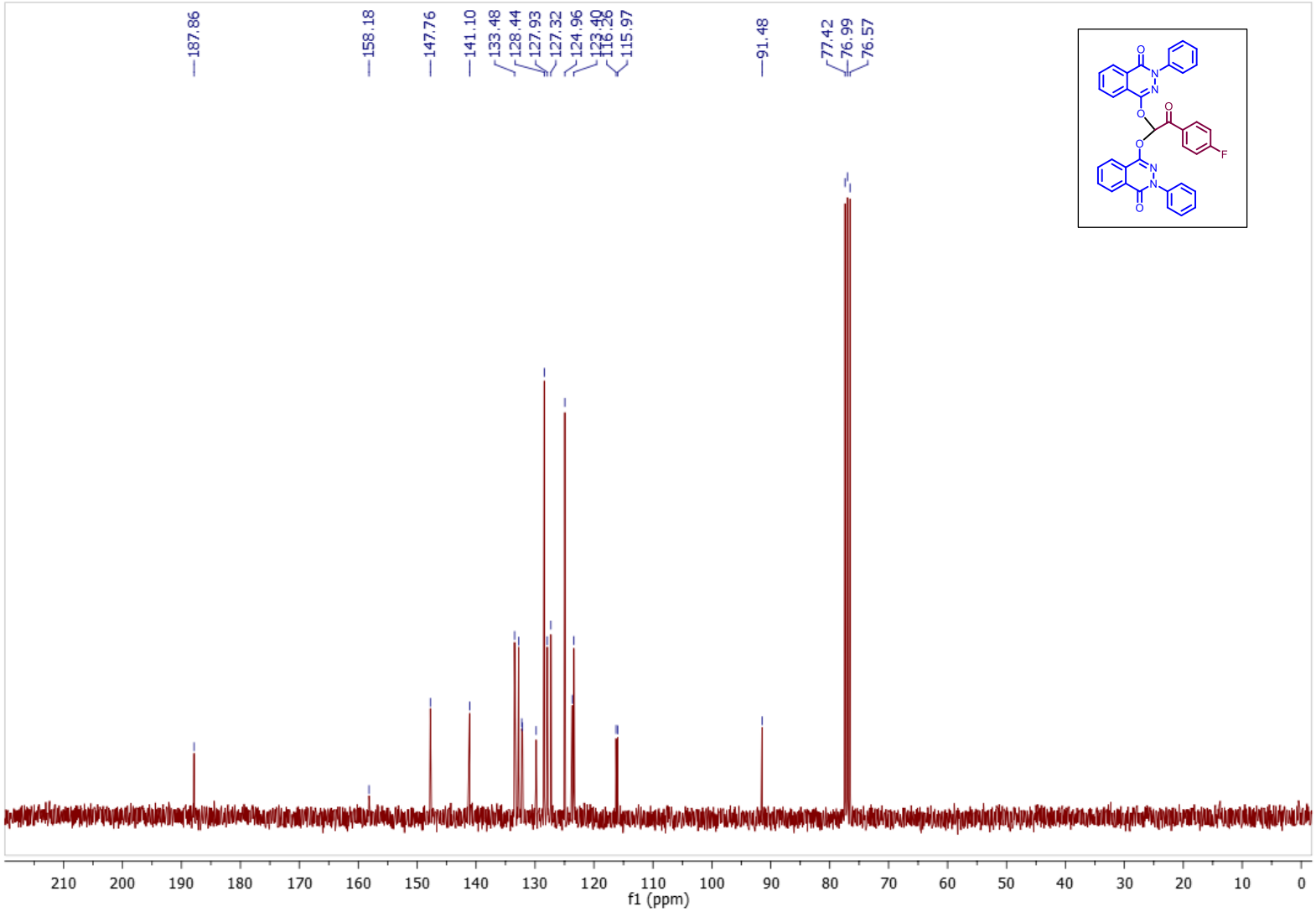
4,4'-((2-(4-bromophenyl)-2-oxoethane-1,1 diyl)bis(oxy))bis(2phenylphthalazin-1(2*H*) one) (3b): ^{13}C NMR (75 MHz, $CDCl_3$):



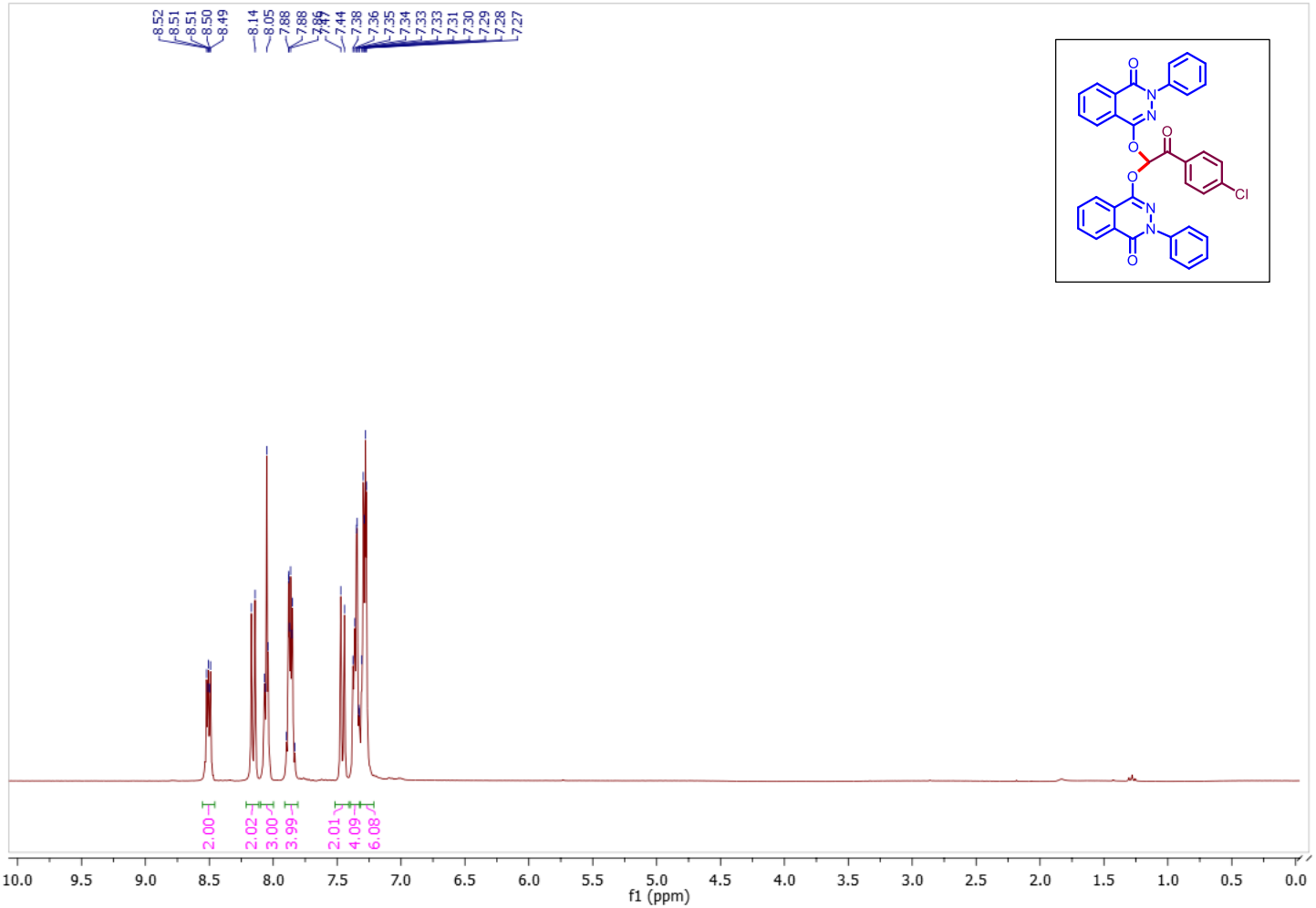
4,4'-((2-(4-fluorophenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3c): ^{1}H NMR (300 MHz, $CDCl_3$):



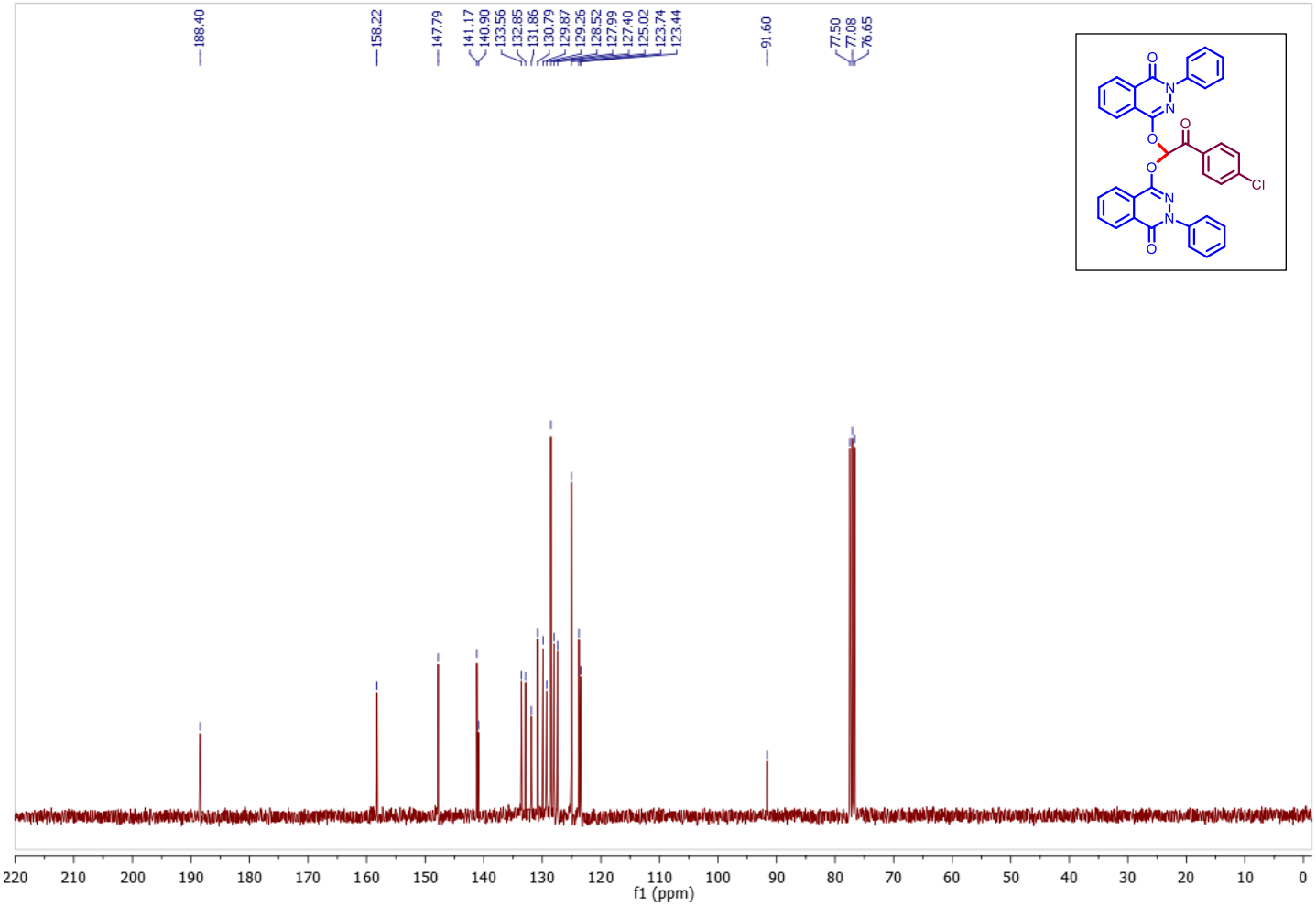
4,4'-((2-(4-fluorophenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(*2H*)-one) (3c): ^{13}C NMR (75 MHz, CDCl3):



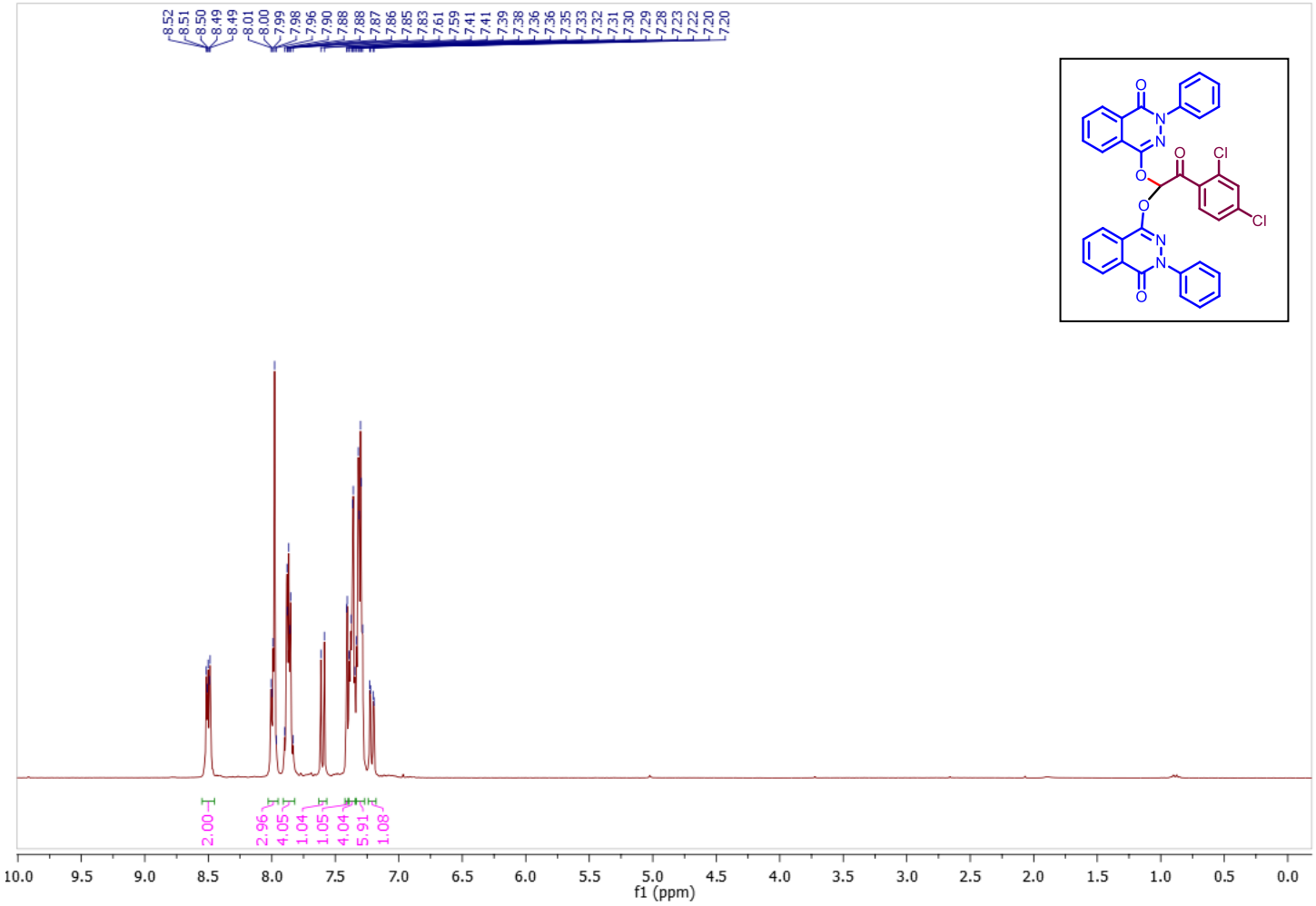
4,4'-((2-(4-chlorophenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3d): ^{1}H NMR (300 MHz, $CDCl_3$):



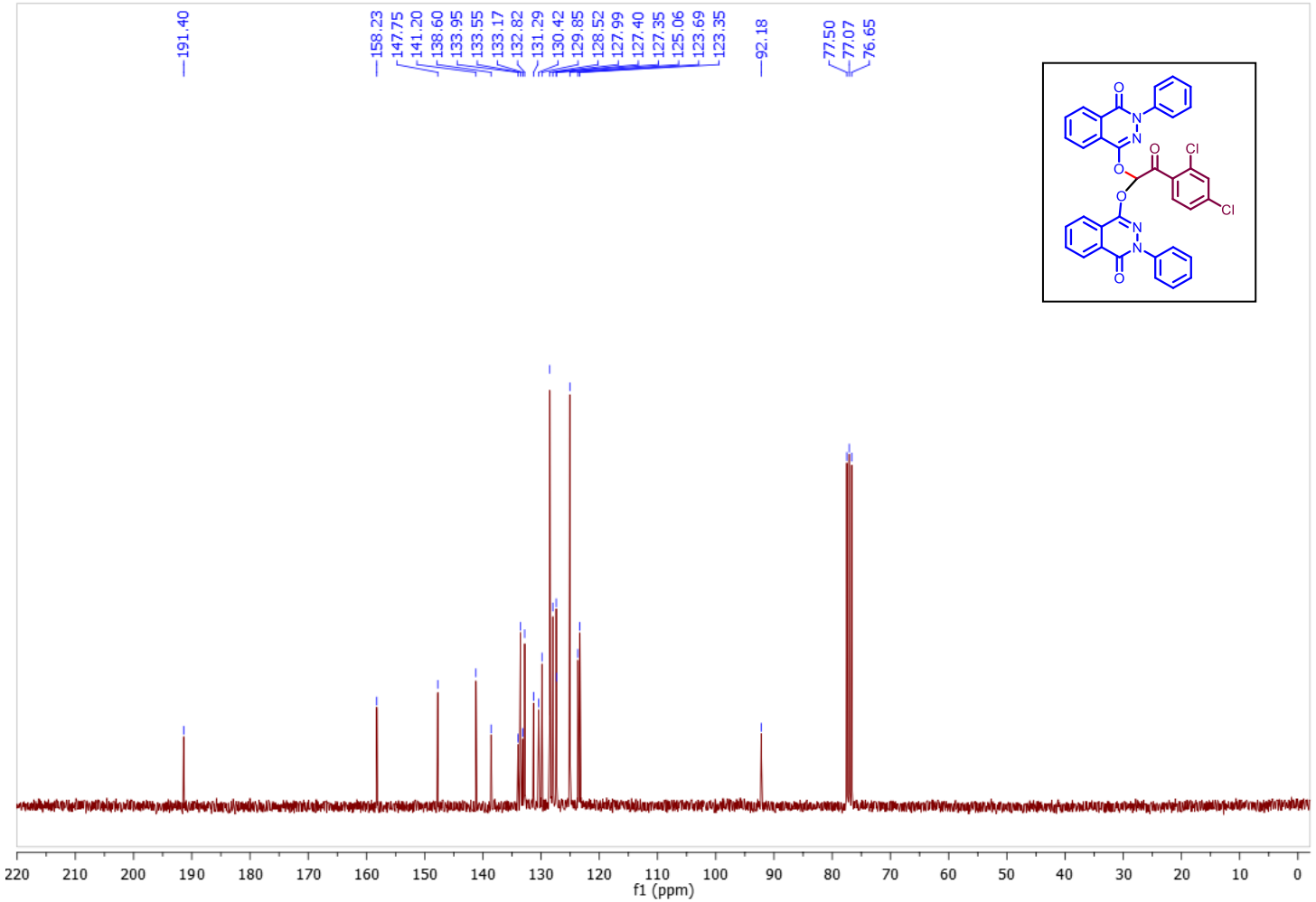
4,4'-((2-(4-chlorophenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3d): ^{13}C NMR (75 MHz, $CDCl_3$):



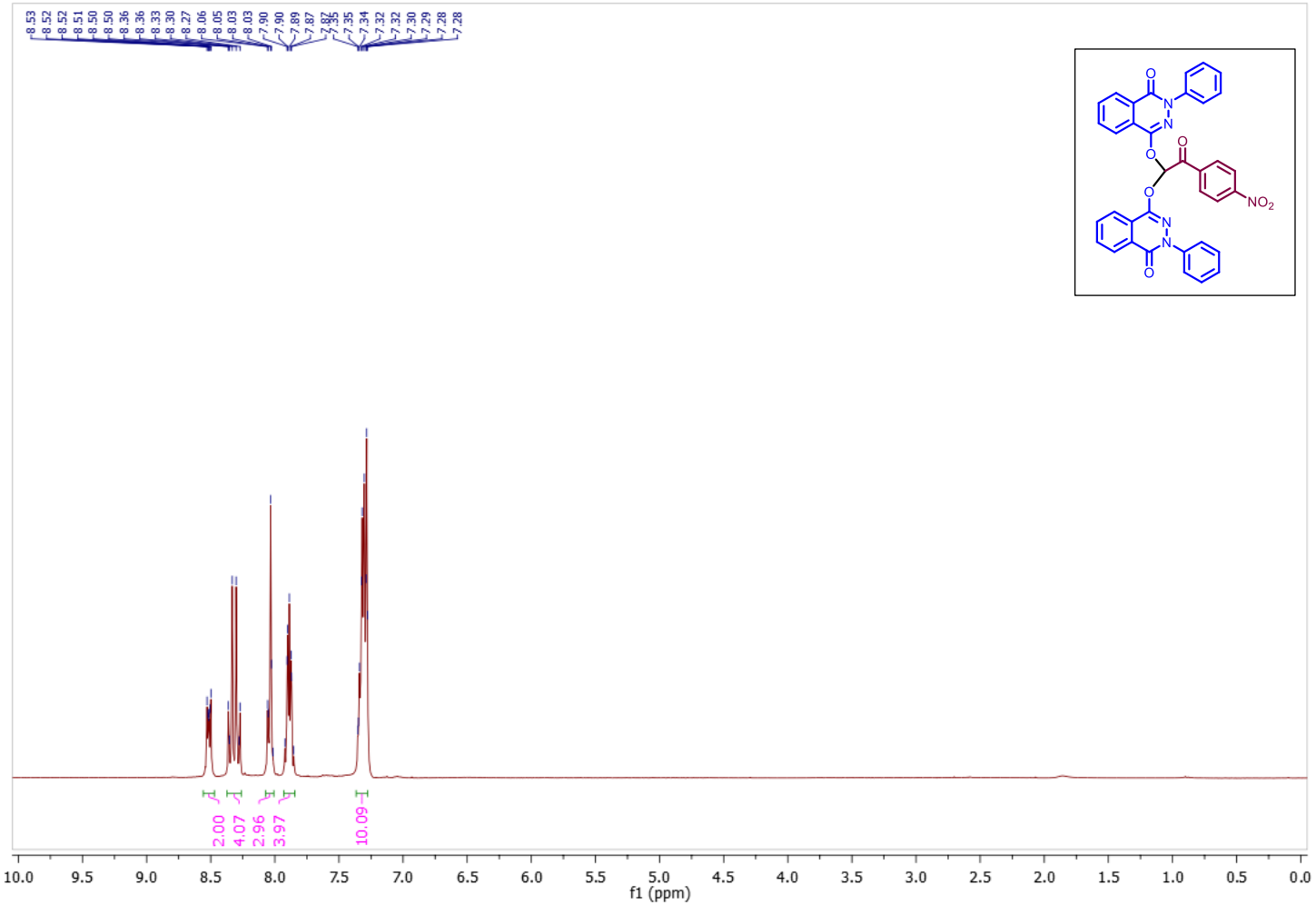
4,4'-((2-(2,4-dichlorophenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2 phenylphthalazin-1(2*H*)-one) (3e): ^{1}H NMR (300 MHz, $CDCl_3$):



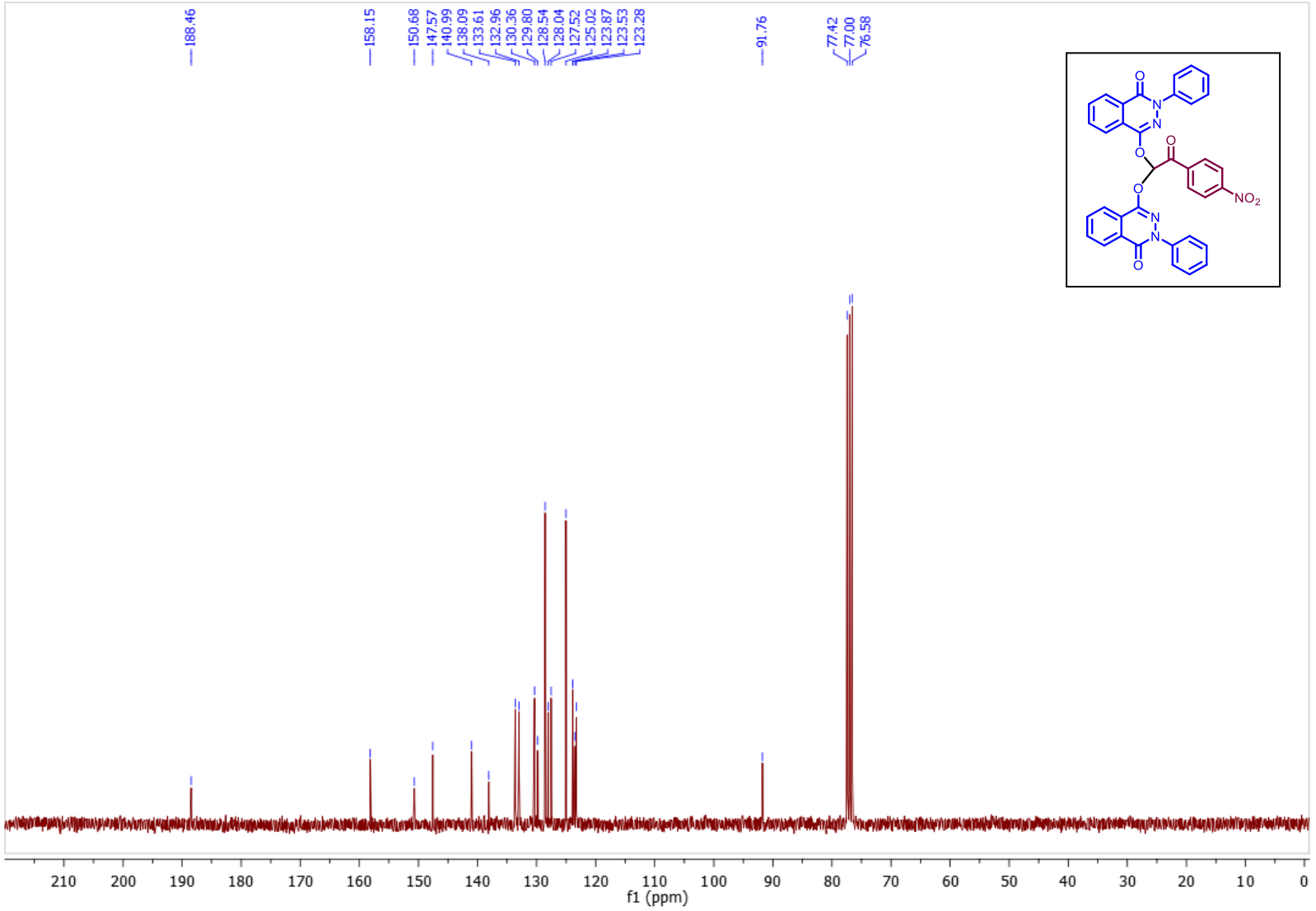
4,4'-((2-(2,4-dichlorophenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2 phenylphthalazin-1(2*H*)-one) (3e): ^{13}C NMR (75 MHz, $CDCl_3$):



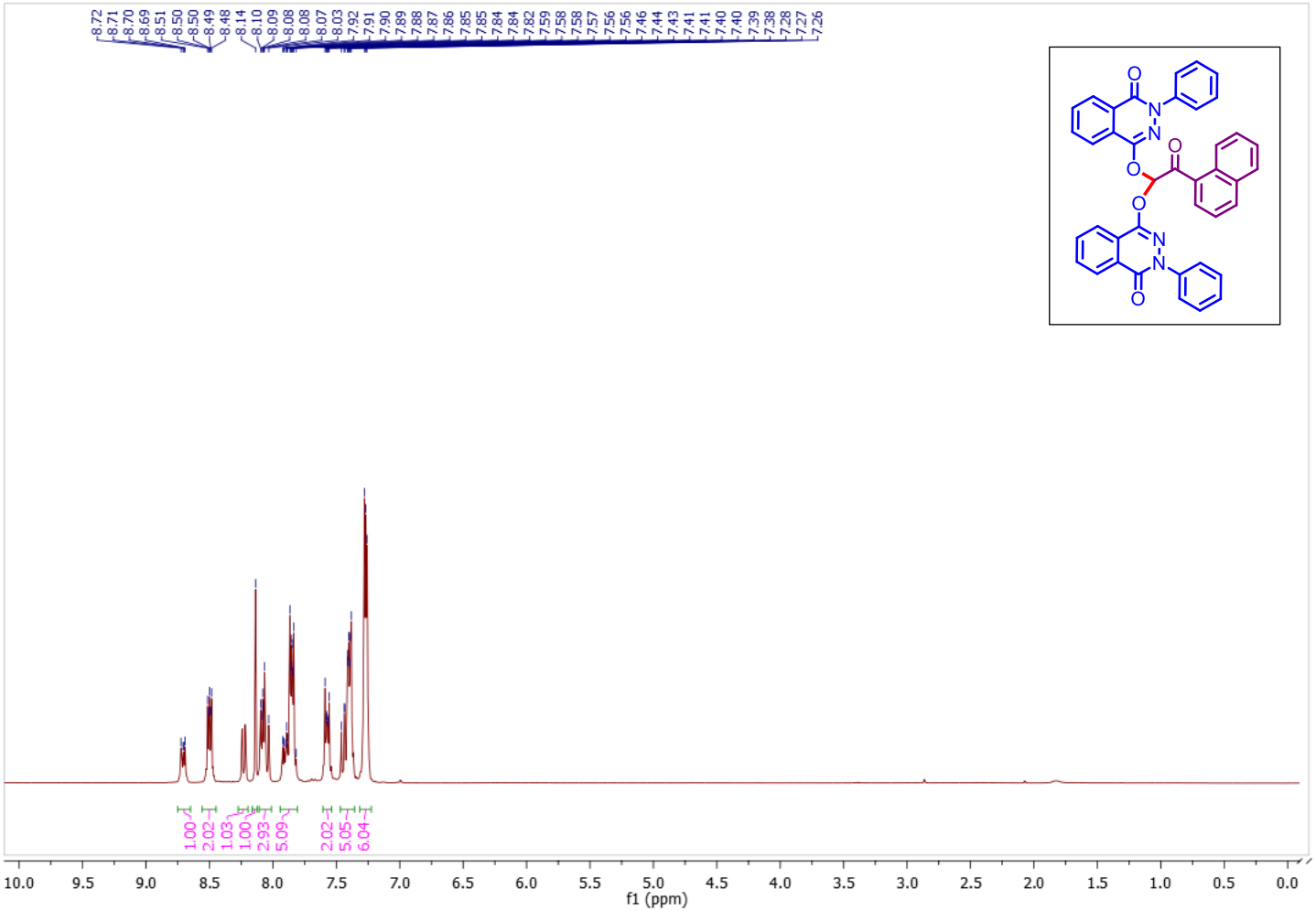
4,4'-((2-(4-nitrophenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3f): ^{1}H NMR (300 MHz, $CDCl_3$):



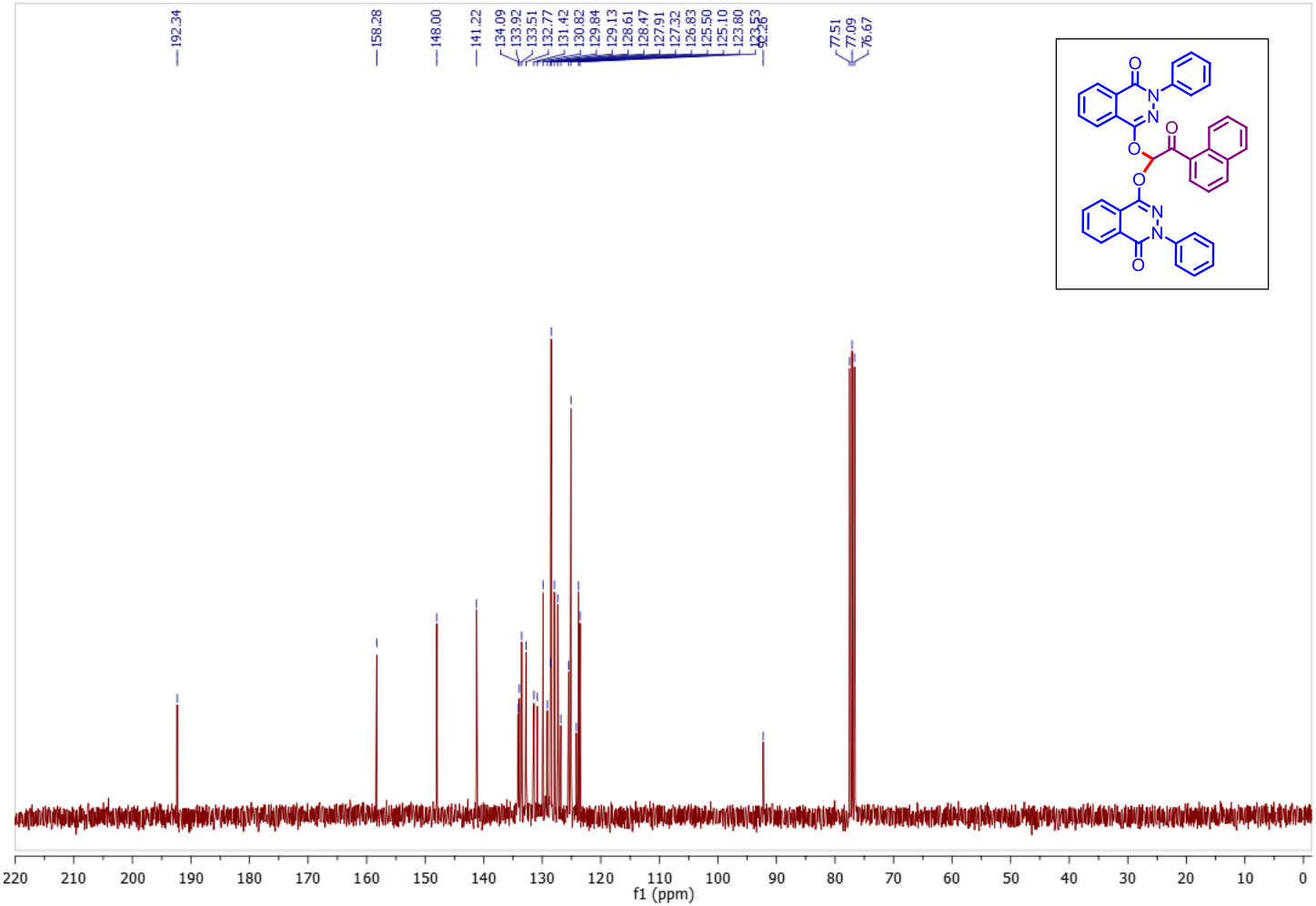
4,4'-((2-(4-nitrophenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3f): ^{13}C NMR (75 MHz, $CDCl_3$):



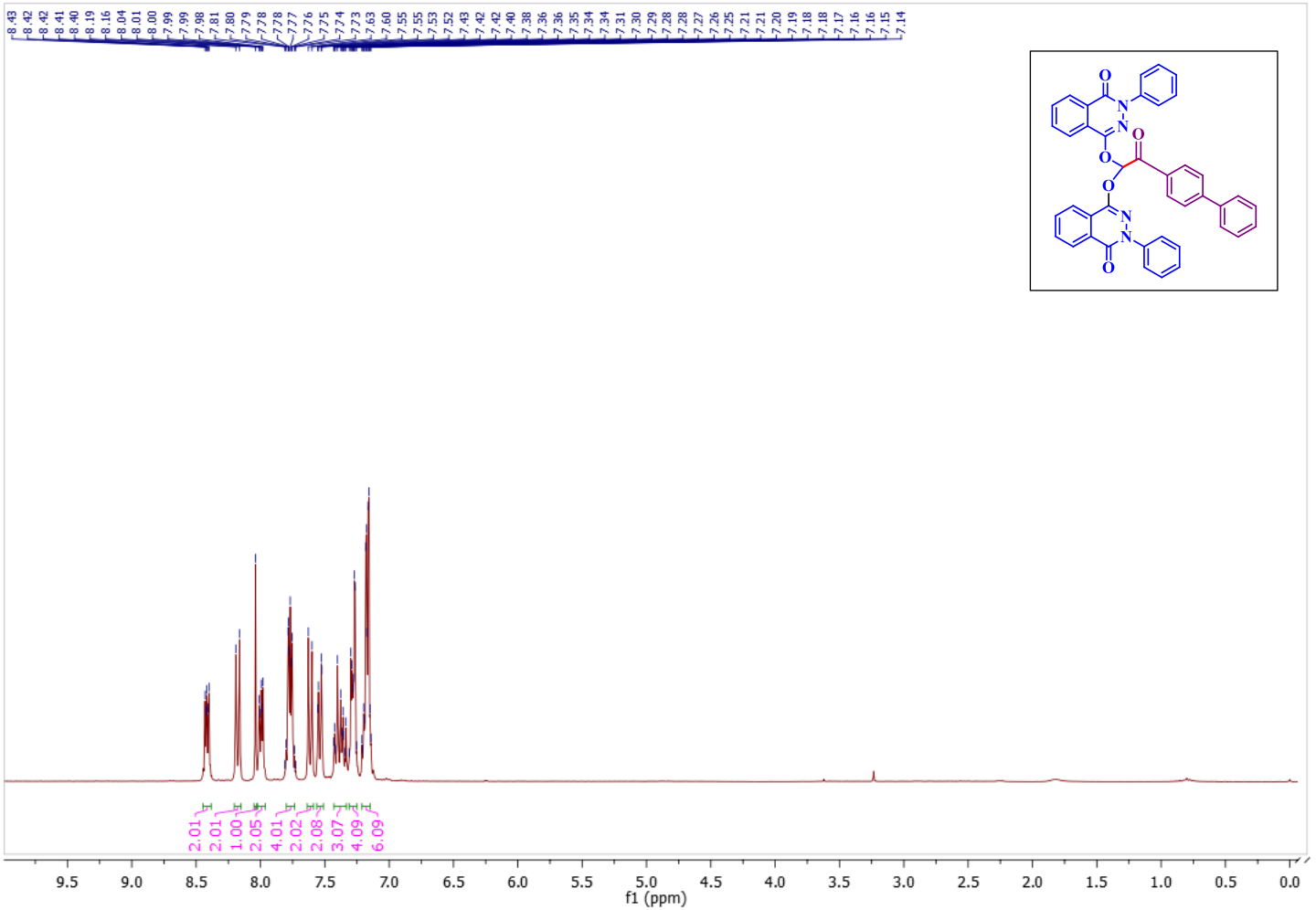
4,4'-((2-(naphthalen-1-yl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3g): ^{1}H NMR (300 MHz, $CDCl_3$):



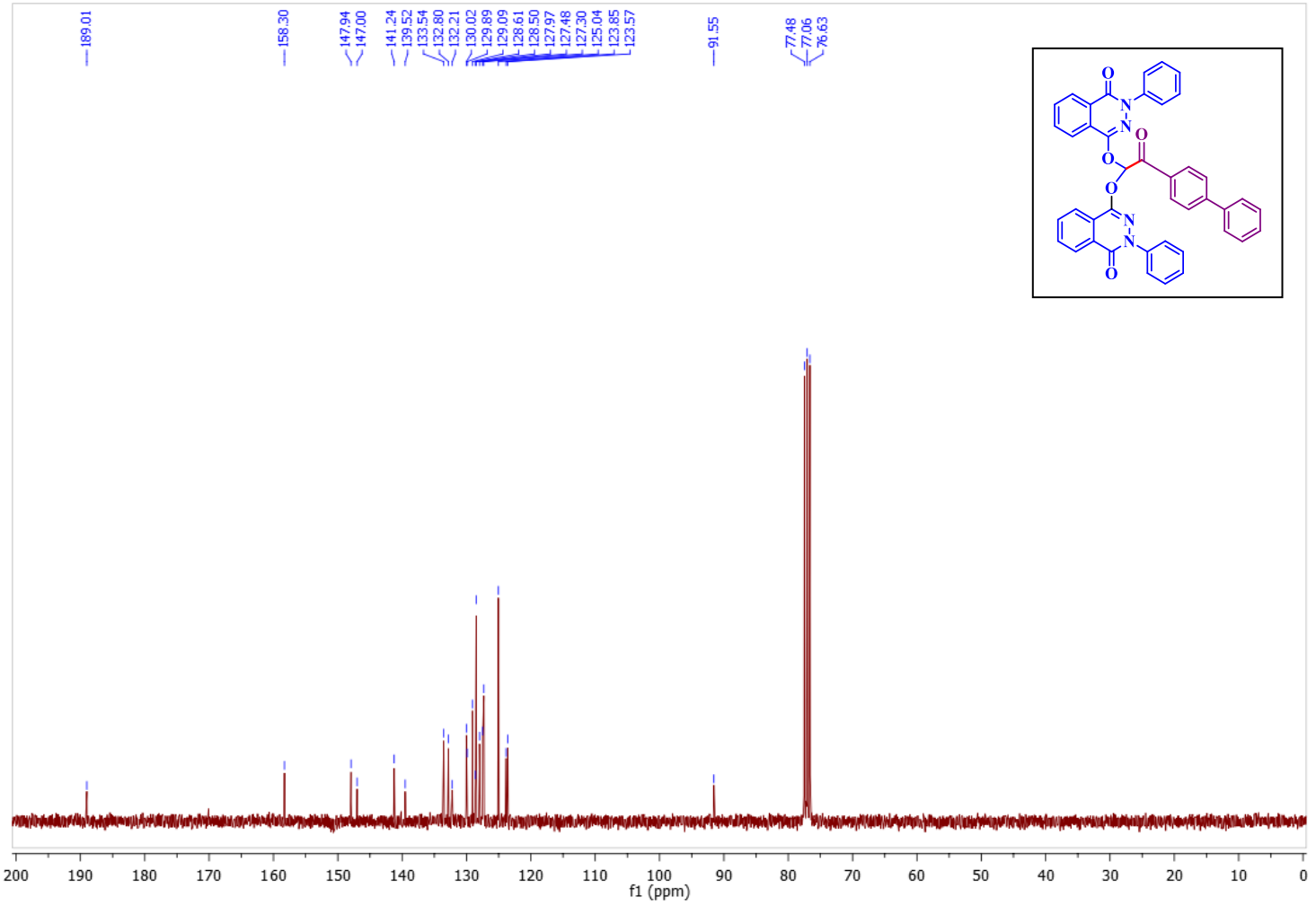
4,4'-((2-(naphthalen-1-yl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3g): ^{13}C NMR (75 MHz, $CDCl_3$):



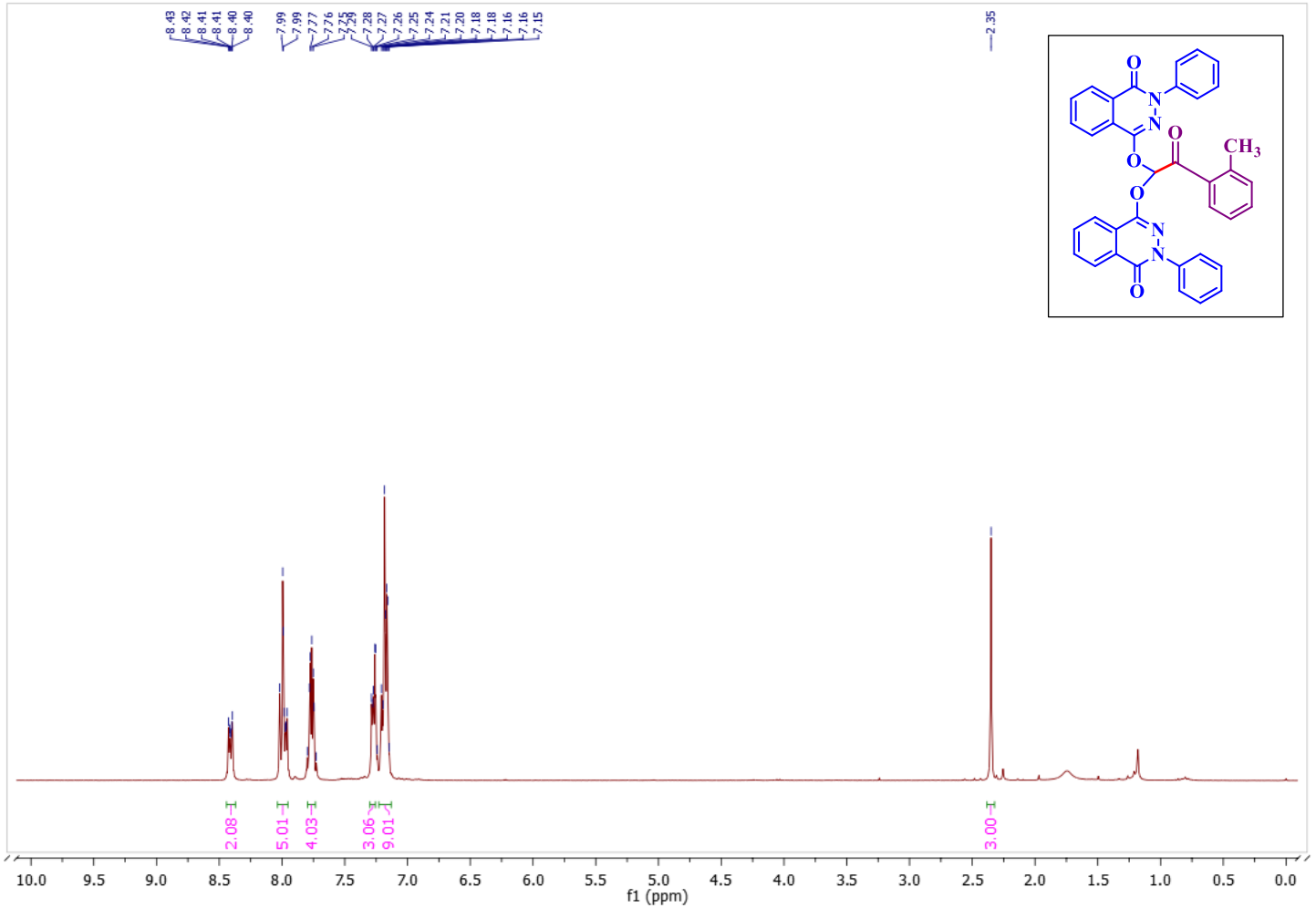
4,4'-((2-([1,1'-biphenyl]-4-yl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3h): ^{1}H NMR (300 MHz, $CDCl_3$):



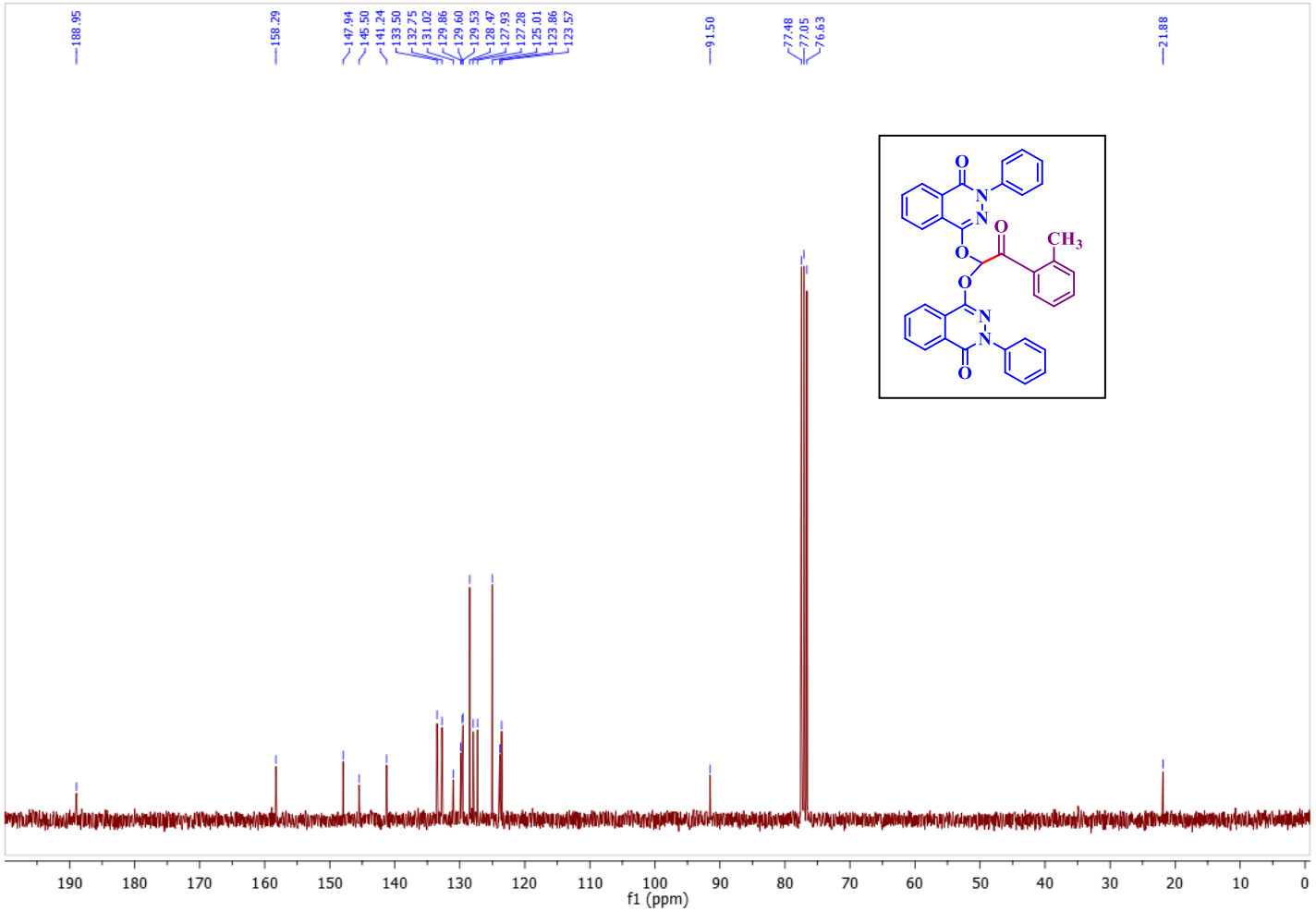
4,4'-((2-([1,1'-biphenyl]-4-yl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3h): ^{13}C NMR (75 MHz, $CDCl_3$):



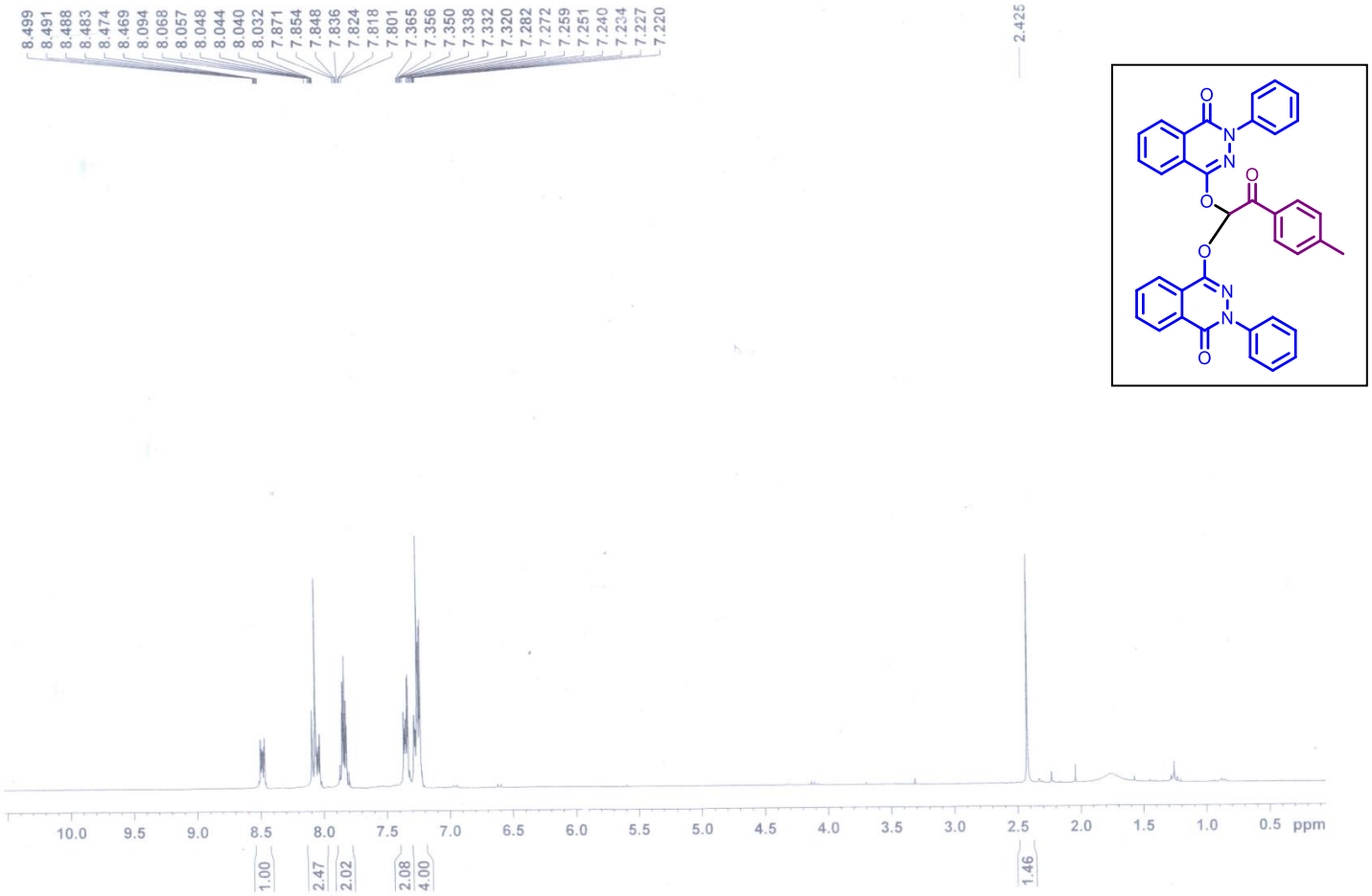
4,4'-((2-oxo-2-(o-tolyl)ethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3i): ^{1}H NMR (300 MHz, $CDCl_3$):



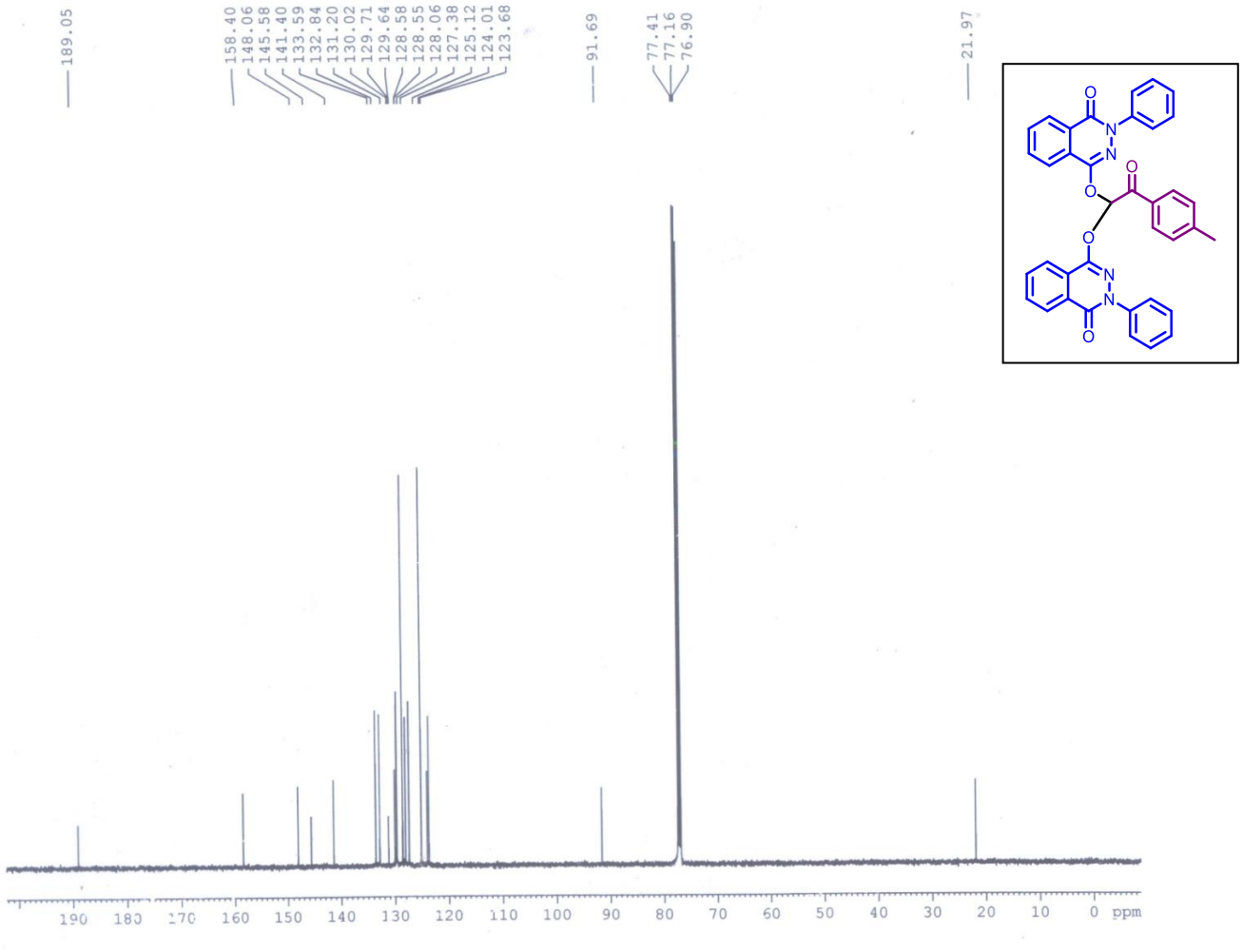
4,4'-((2-oxo-2-(o-tolyl)ethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3i): ^{13}C NMR (75 MHz, $CDCl_3$):



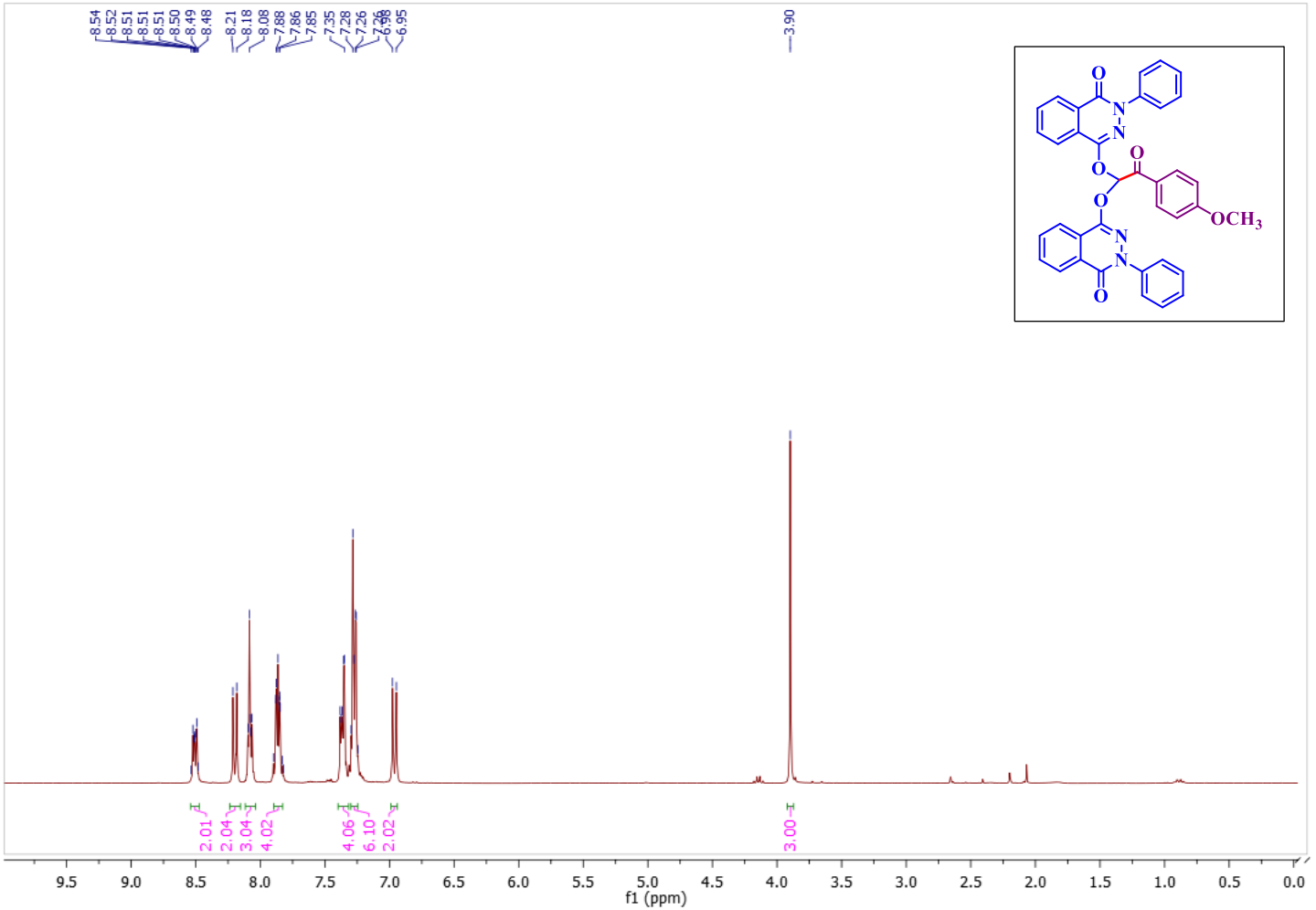
4,4'-((2-oxo-2-(p-tolyl)ethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3j): ^{1}H NMR (500 MHz, $CDCl_3$):



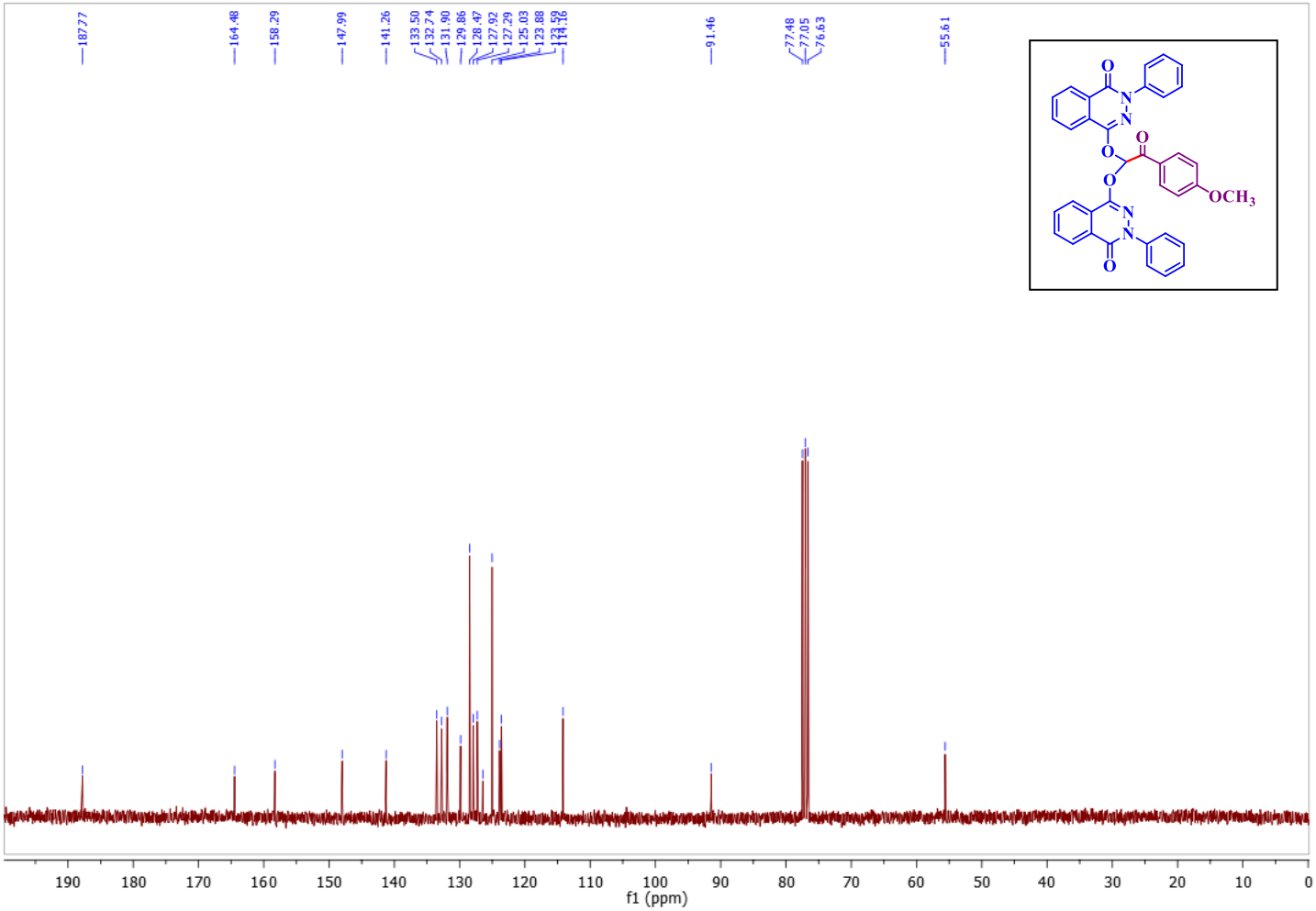
4,4'-((2-oxo-2-(p-tolyl)ethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3j): ^{13}C NMR (125 MHz, $CDCl_3$):



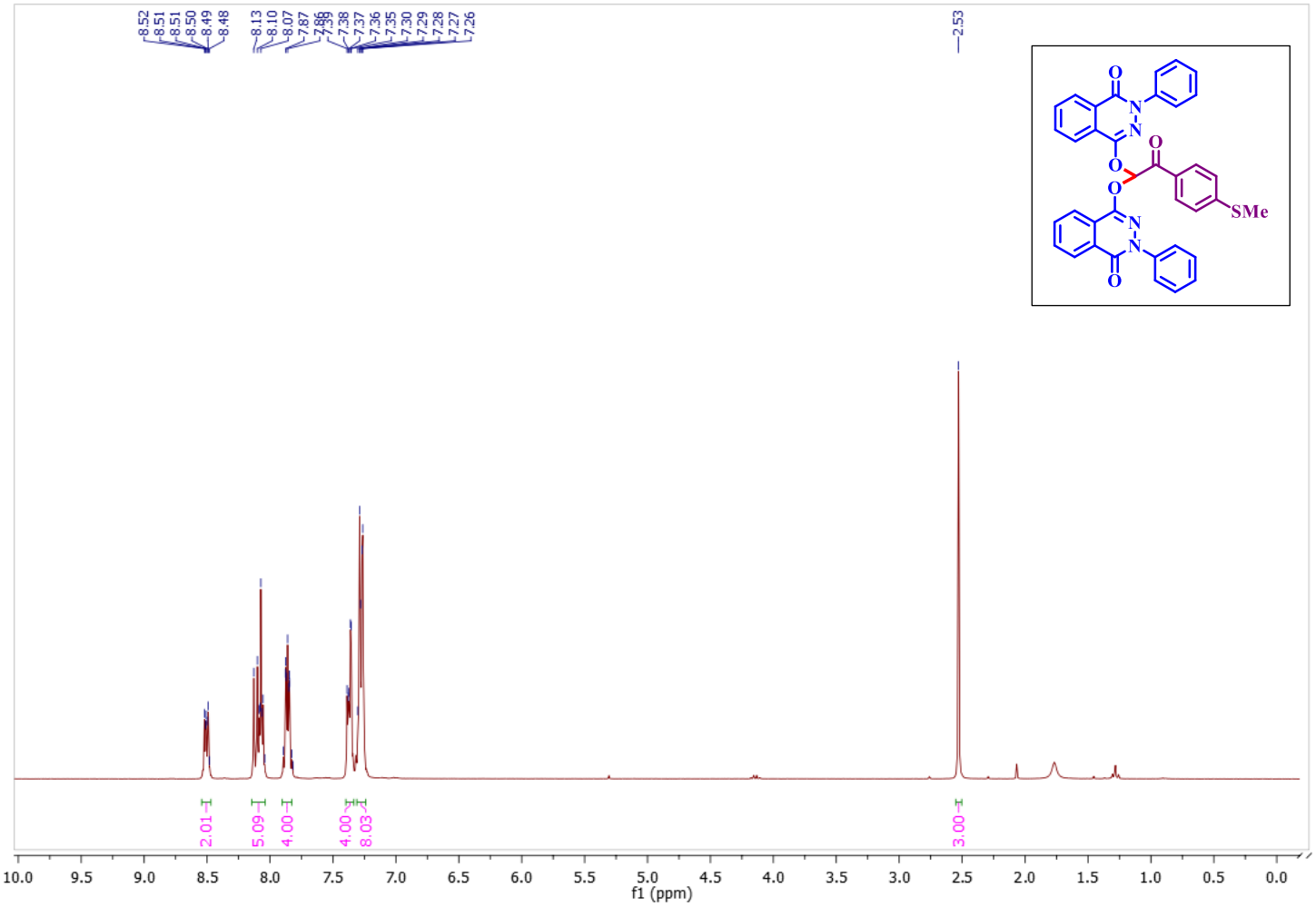
4,4'-((2-(4-methoxyphenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3k): ^{1}H NMR (300 MHz, $CDCl_3$):



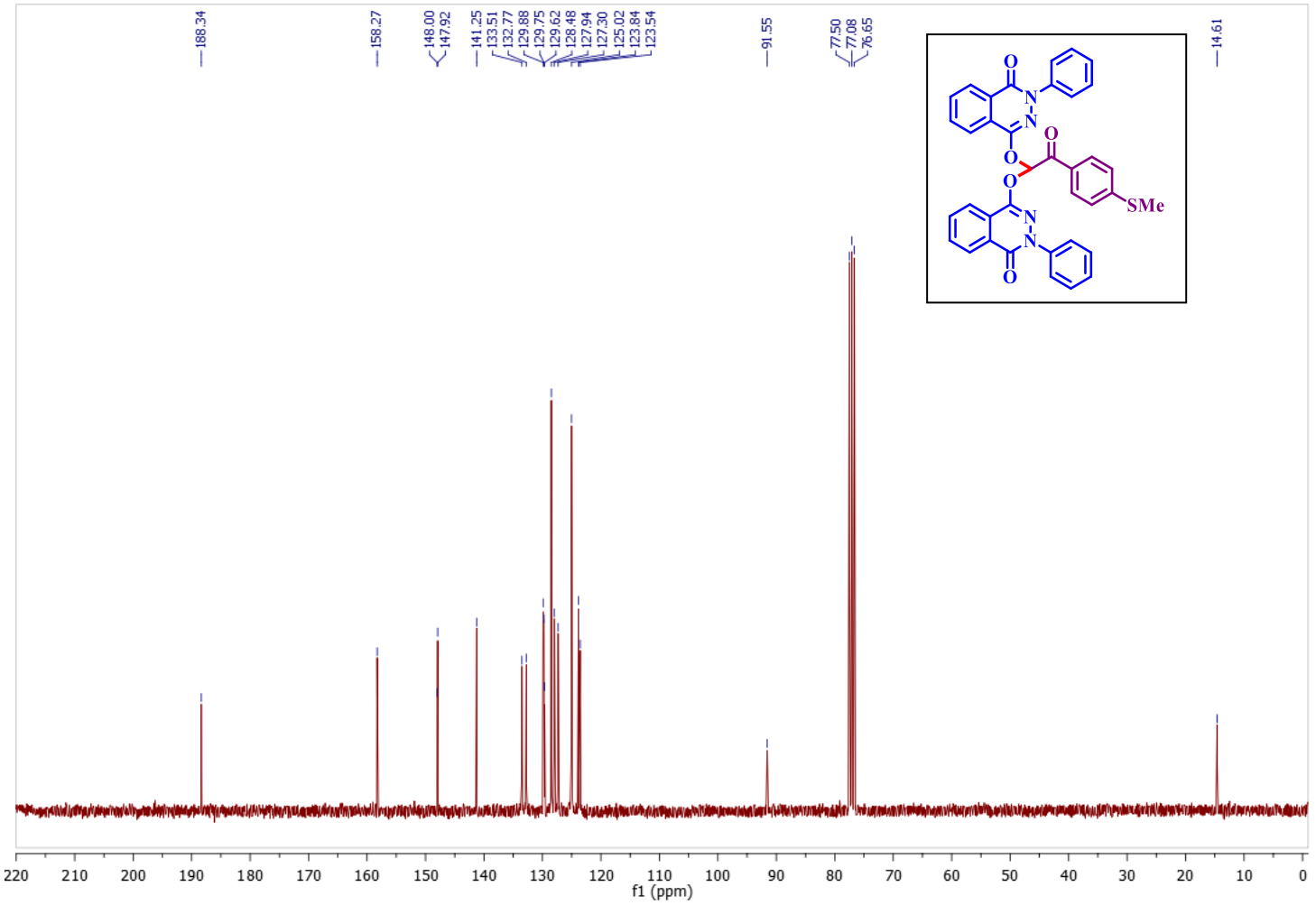
4,4'-((2-(4-methoxyphenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3k): ^{13}C NMR (75 MHz, $CDCl_3$):



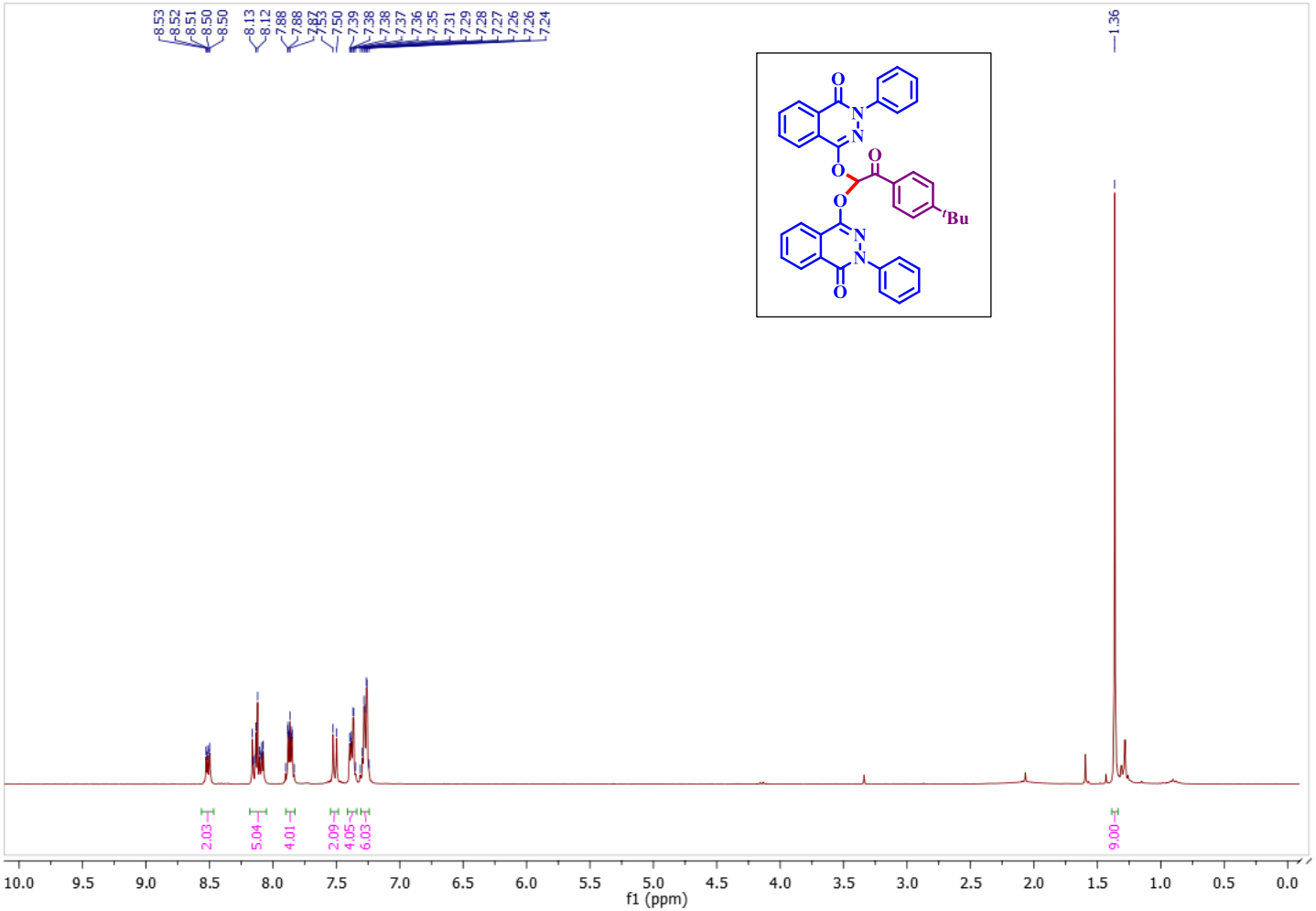
4,4'-((2-(4-(methylthio)phenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3l): ^{1}H NMR (300 MHz, $CDCl_3$):



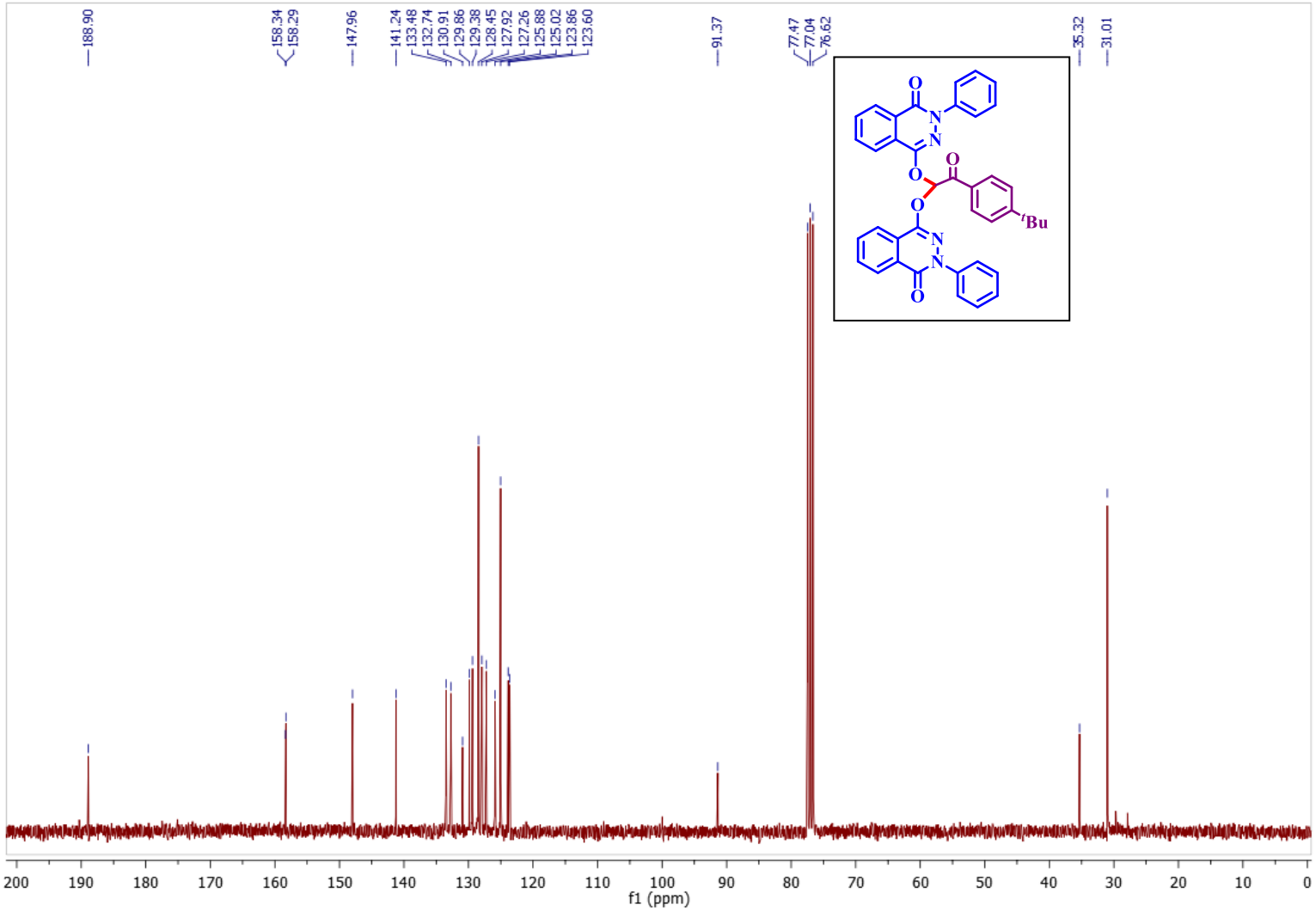
4,4'-((2-(4-(methylthio)phenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3l): ^{13}C NMR (75 MHz, $CDCl_3$):



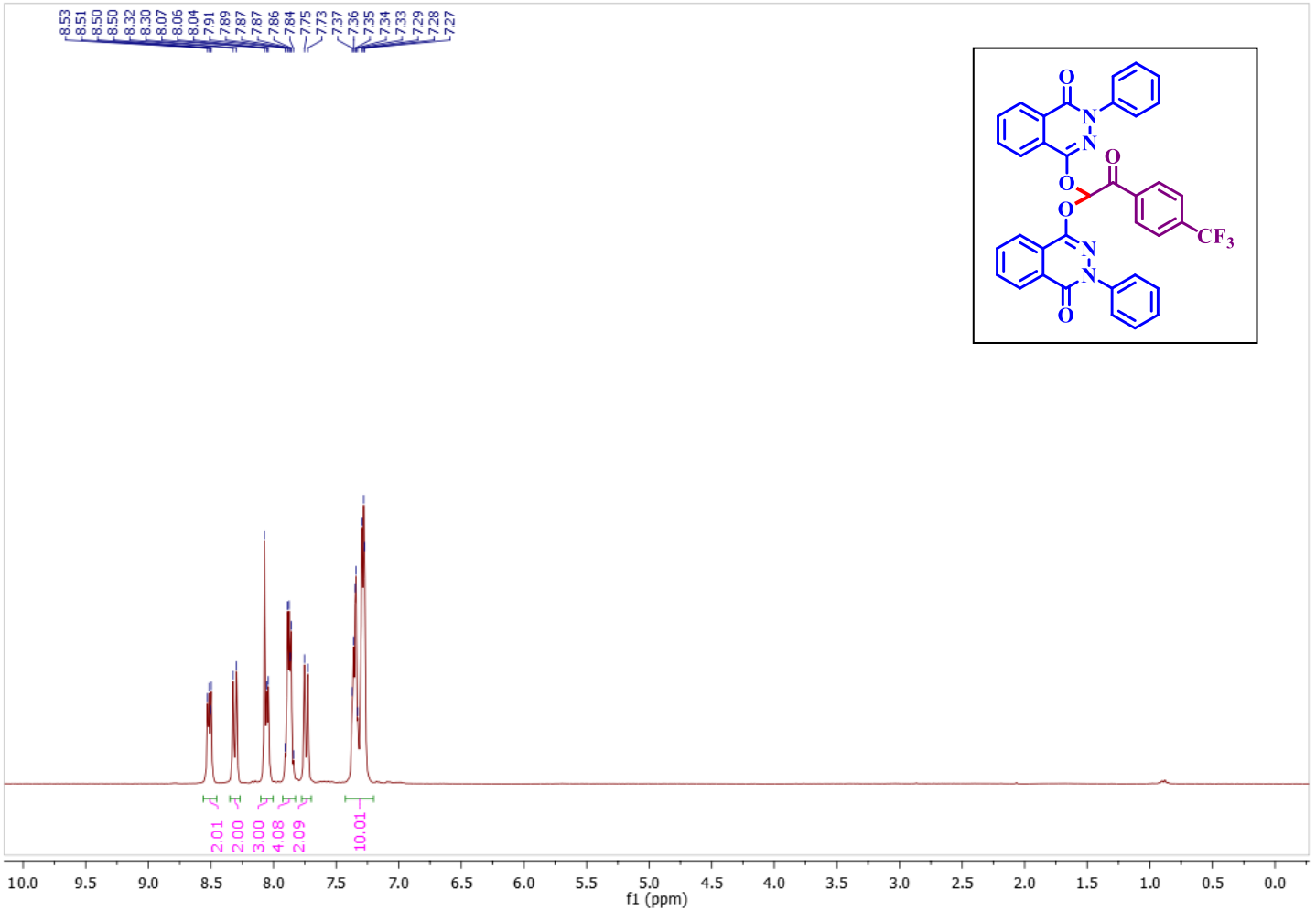
4,4'-((2-(4-(tert-butyl)phenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3m): ^{1}H NMR (300 MHz, $CDCl_3$):



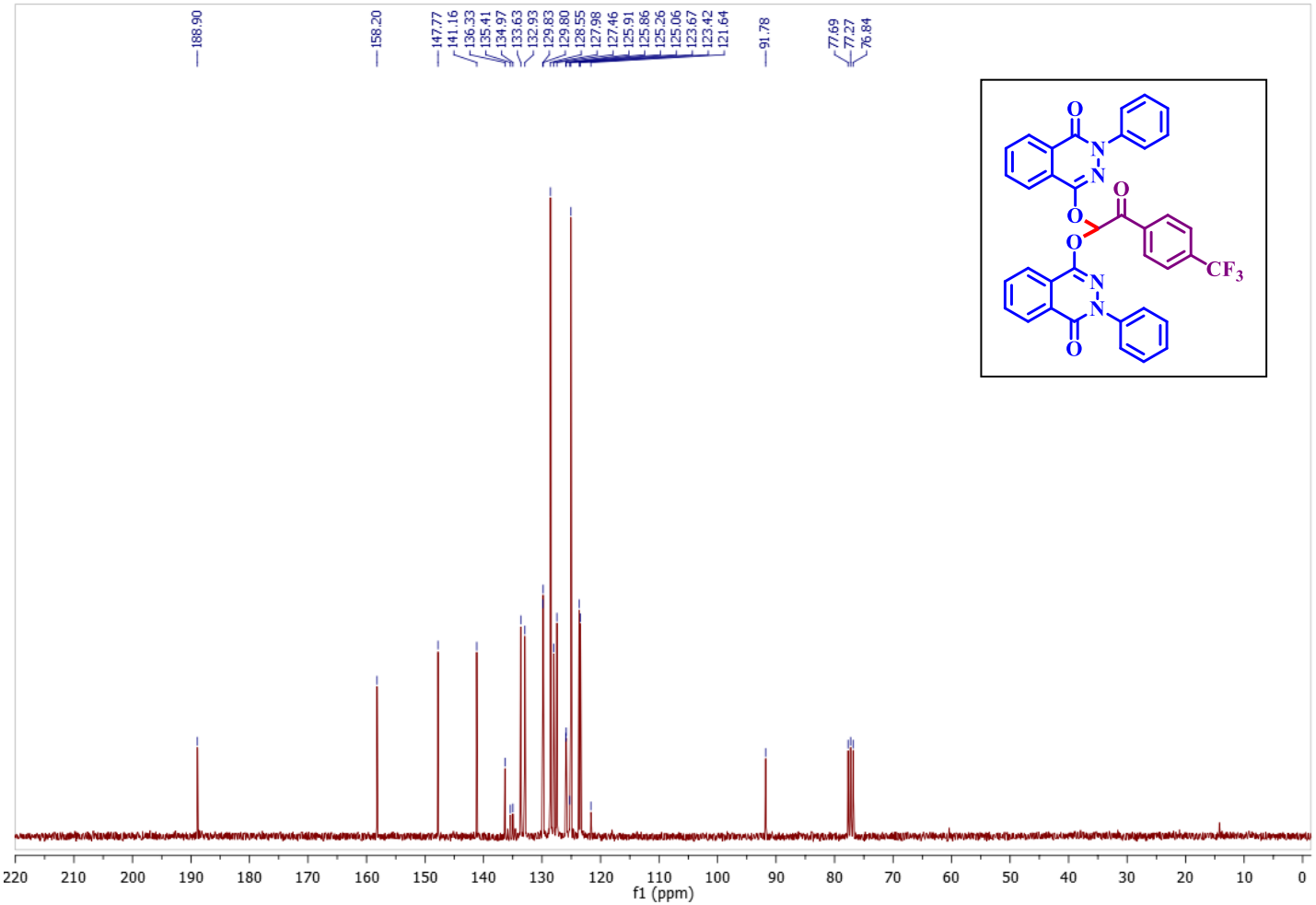
4,4'-((2-(4-(tert-butyl)phenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3m): ^{13}C NMR (75 MHz, $CDCl_3$):



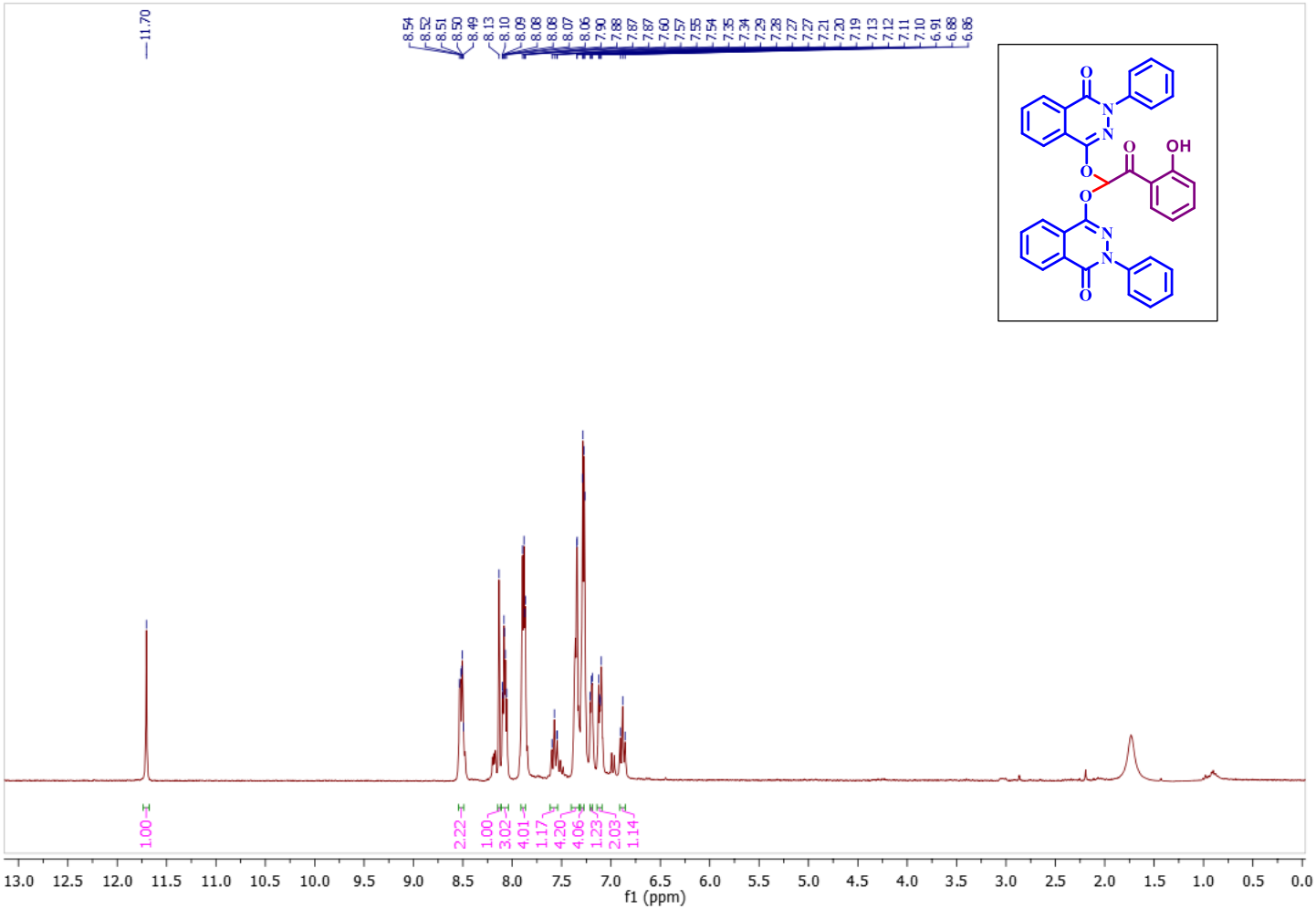
4,4'-((2-oxo-2-(4-(trifluoromethyl)phenyl)ethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3n): ^{1}H NMR (300 MHz, $CDCl_3$):



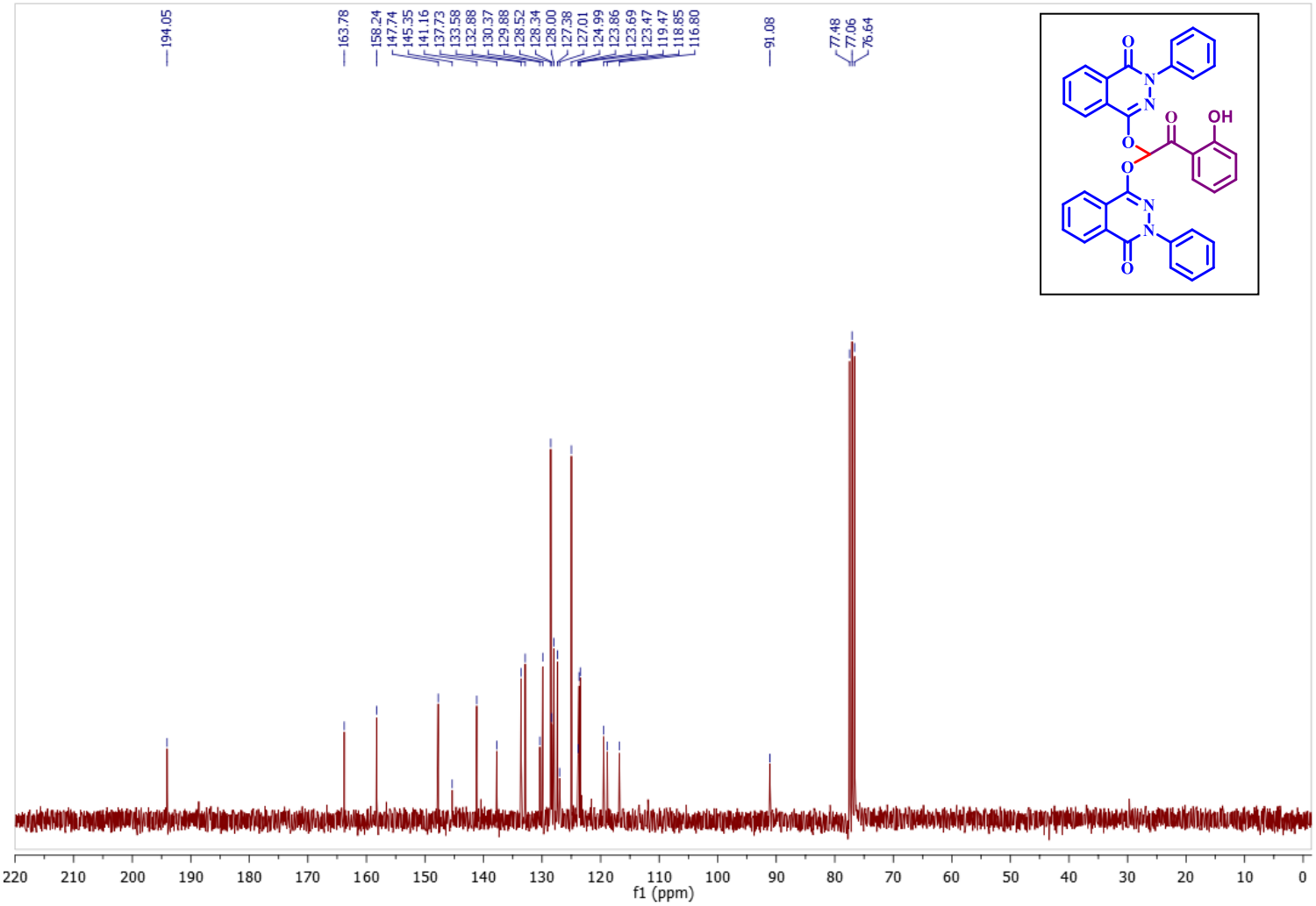
4,4'-((2-oxo-2-(4-(trifluoromethyl)phenyl)ethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3n): ^{13}C NMR (75 MHz, $CDCl_3$):



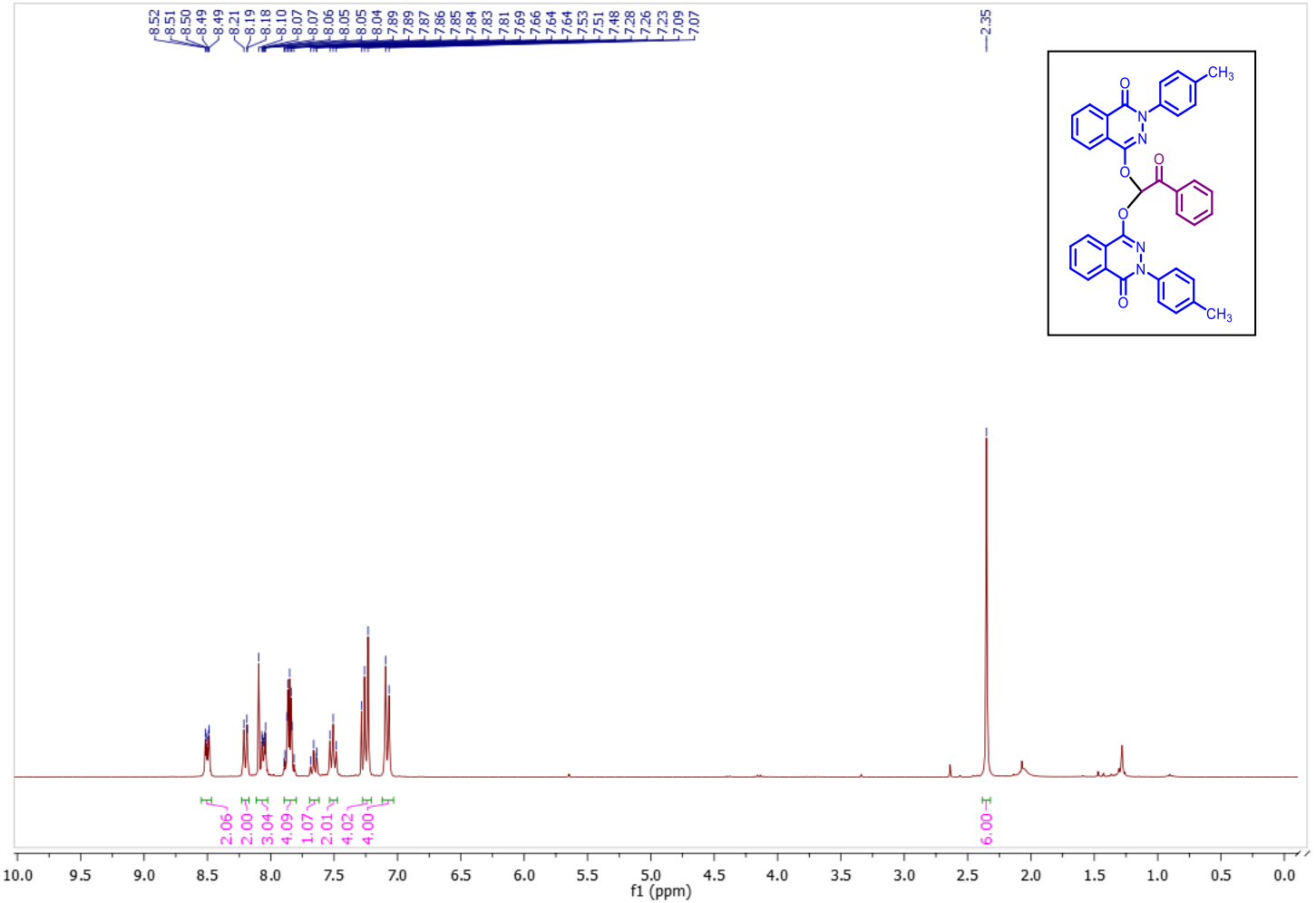
4,4'-((2-(2-hydroxyphenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3o): ^{1}H NMR (300 MHz, $CDCl_3$):



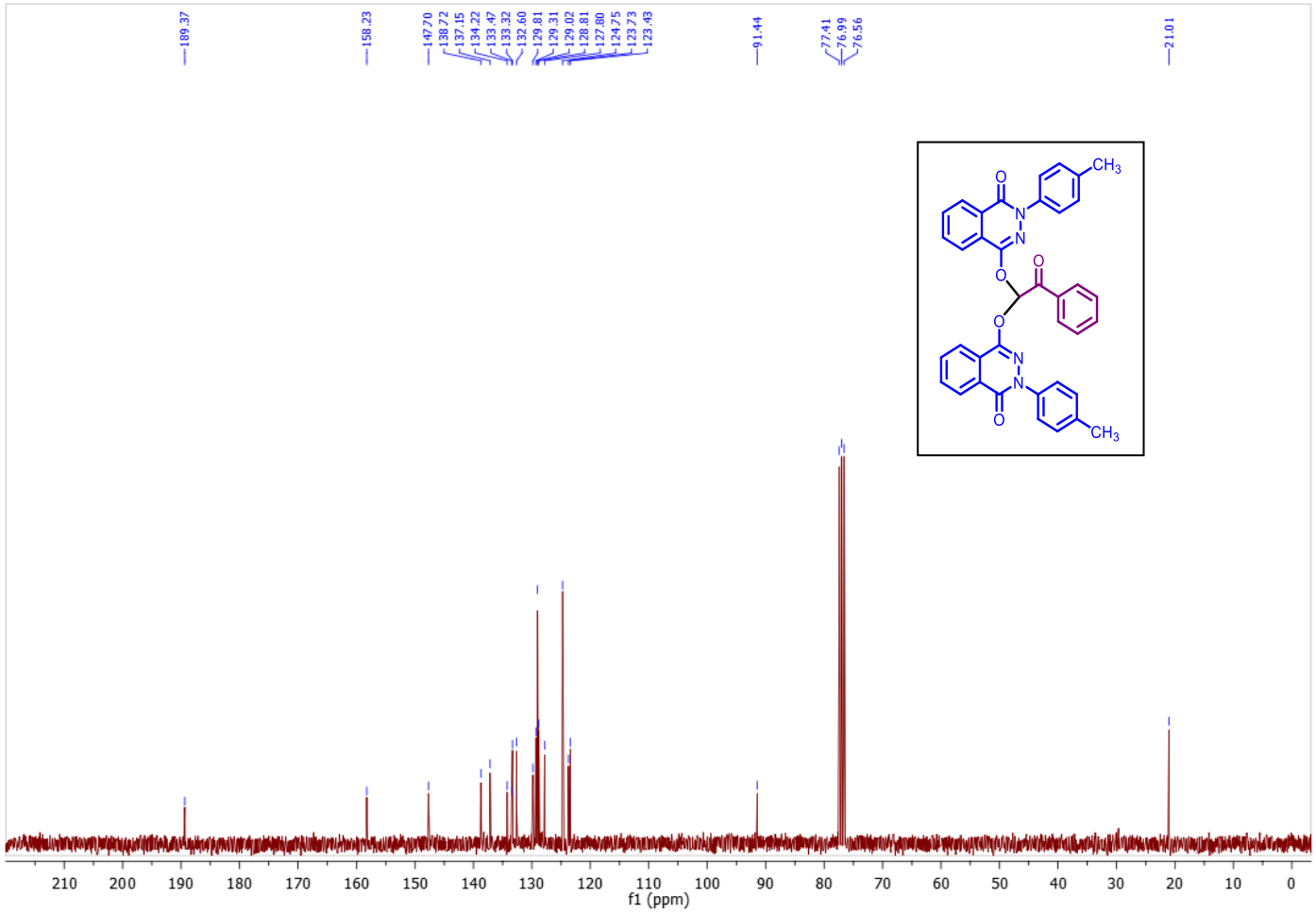
4,4'-((2-(2-hydroxyphenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3o): ^{13}C NMR (75 MHz, $CDCl_3$):



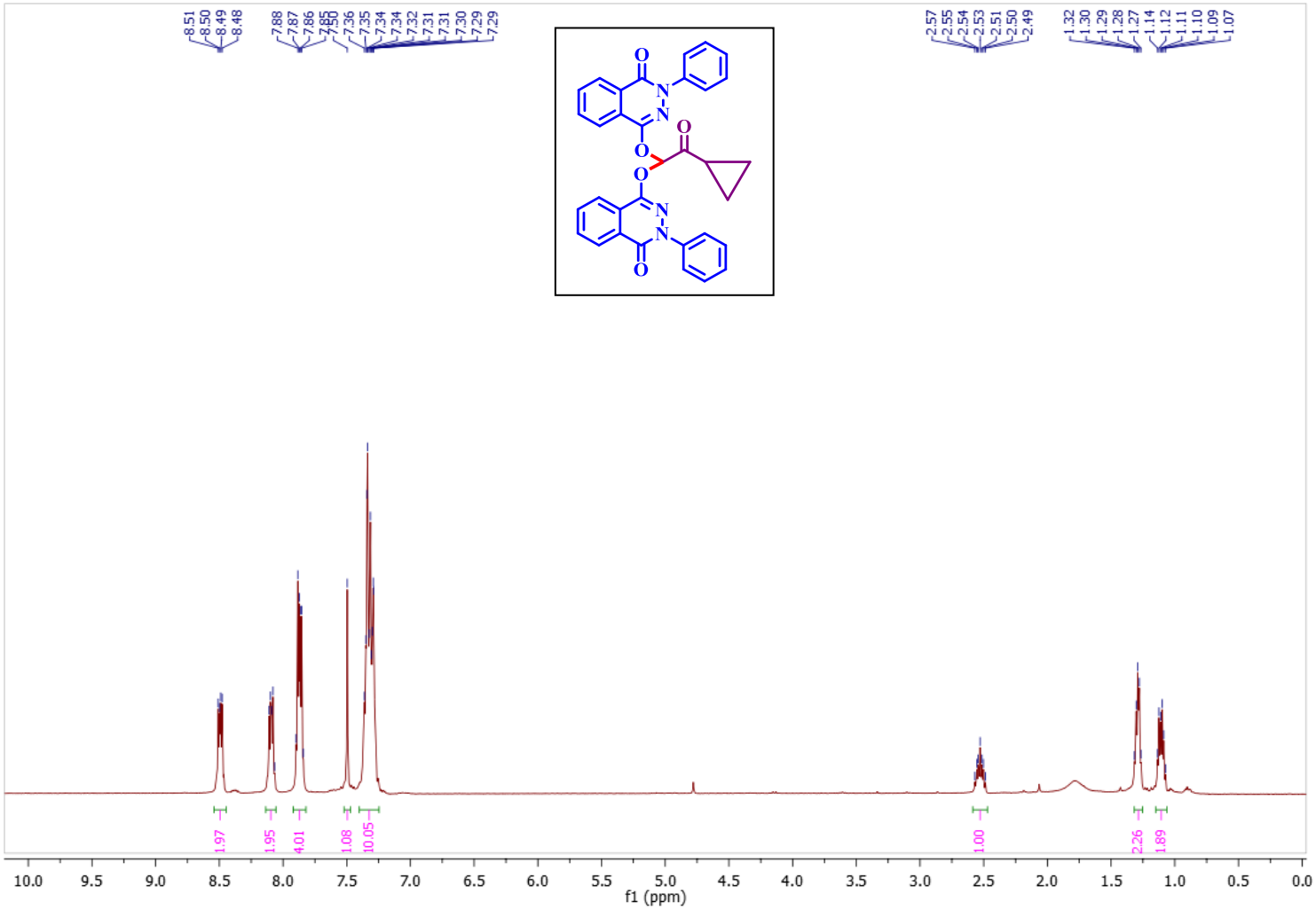
4,4'-((2-oxo-2-phenylethane-1,1-diyl)bis(oxy))bis(2-(p-tolyl)phthalazin-1(2*H*)-one) (3p): ^{1}H NMR (300 MHz, $CDCl_3$):



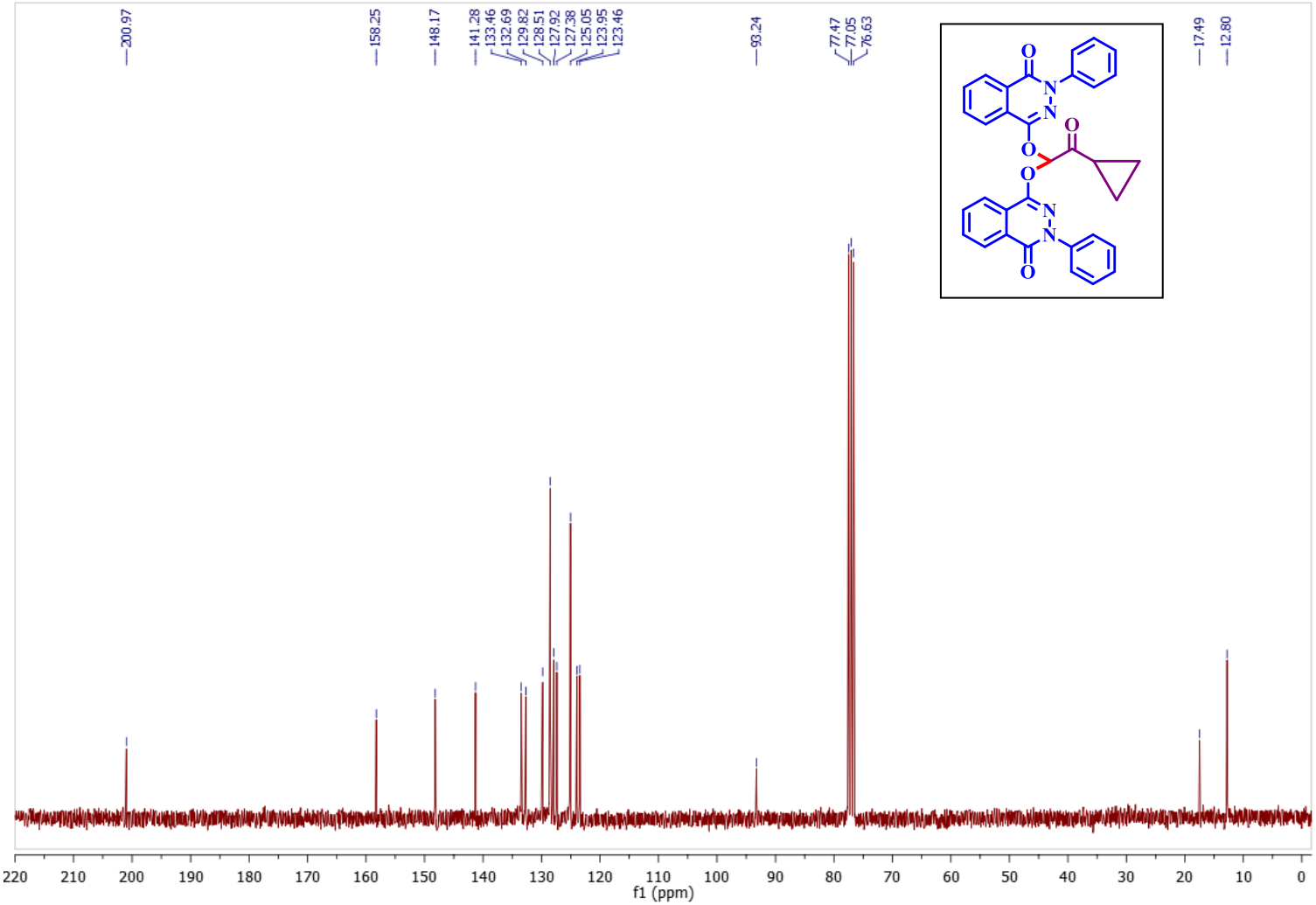
4,4'-((2-oxo-2-phenylethane-1,1-diyl)bis(oxy))bis(2-(p-tolyl)phthalazin-1(2*H*)-one) (3p): ^{13}C NMR (75 MHz, $CDCl_3$):



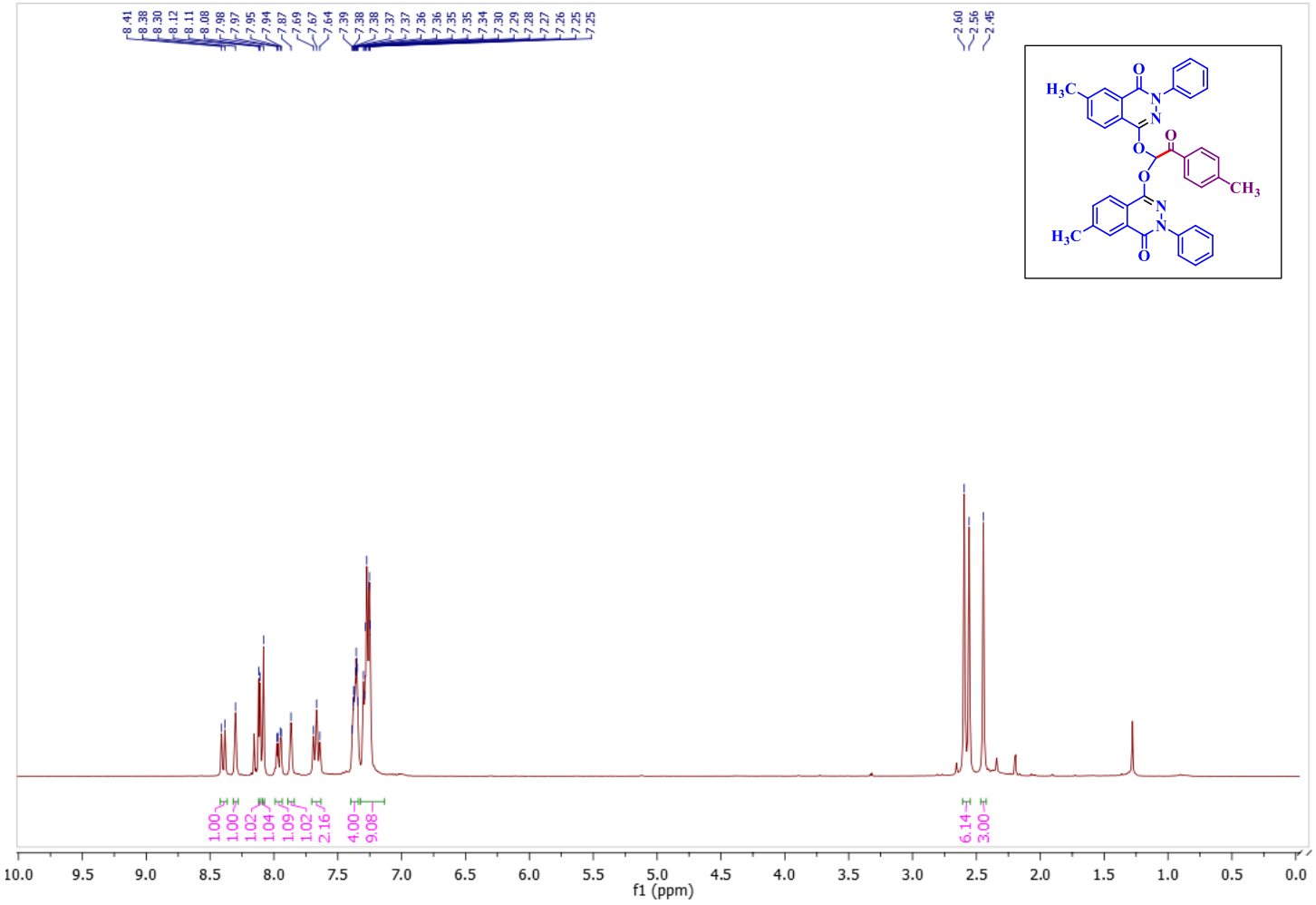
4,4'-((2-cyclopropyl-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3q): ^{1}H NMR (300 MHz, $CDCl_3$):



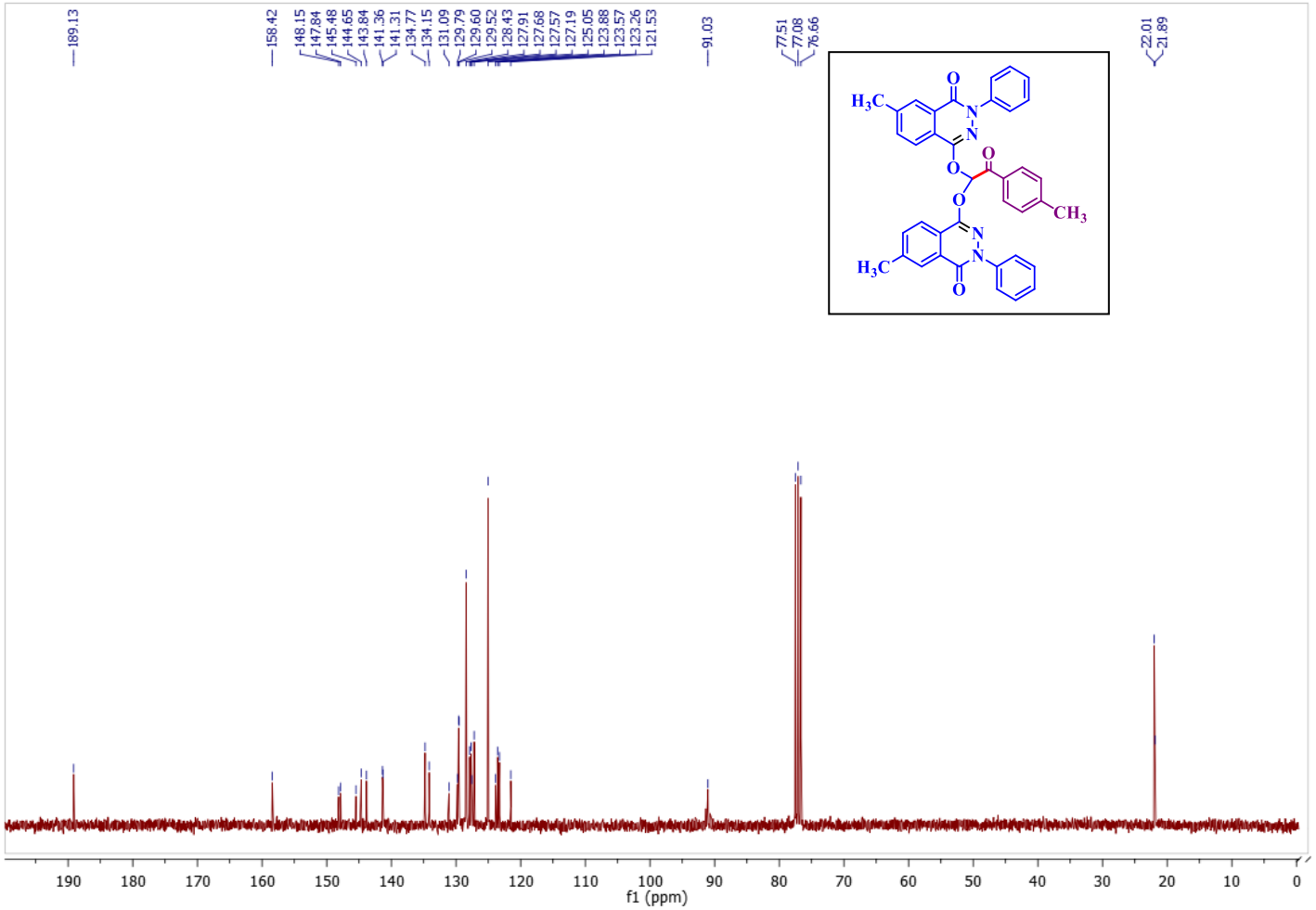
4,4'-((2-cyclopropyl-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one)) (3q): ^{13}C NMR (75 MHz, $CDCl_3$):



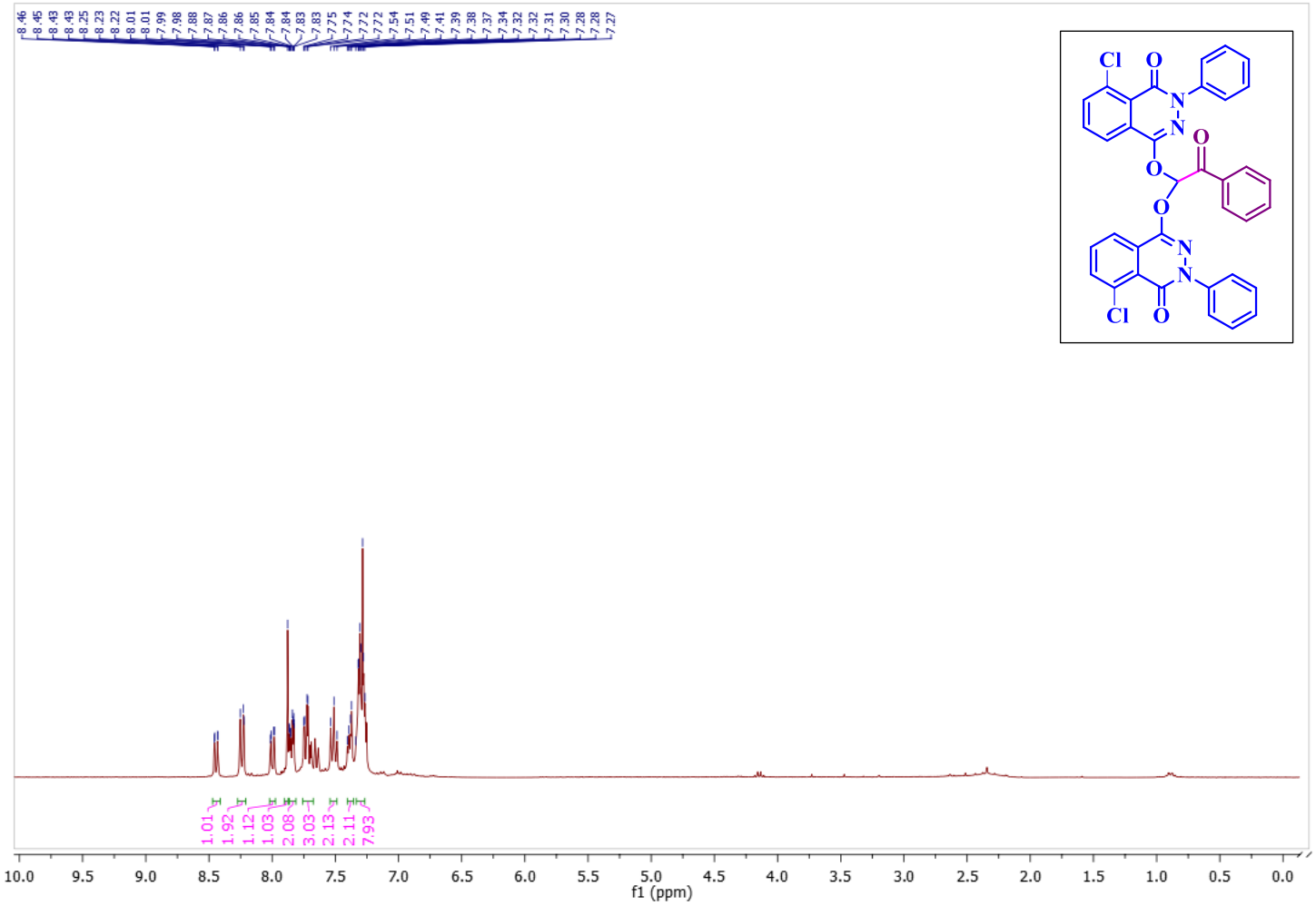
4,4'-((2-oxo-2-(p-tolyl)ethane-1,1-diyl)bis(oxy))bis(7-methyl-2-phenylphthalazin-1(2*H*)-one) (3r): ^{1}H NMR (300 MHz, $CDCl_3$):



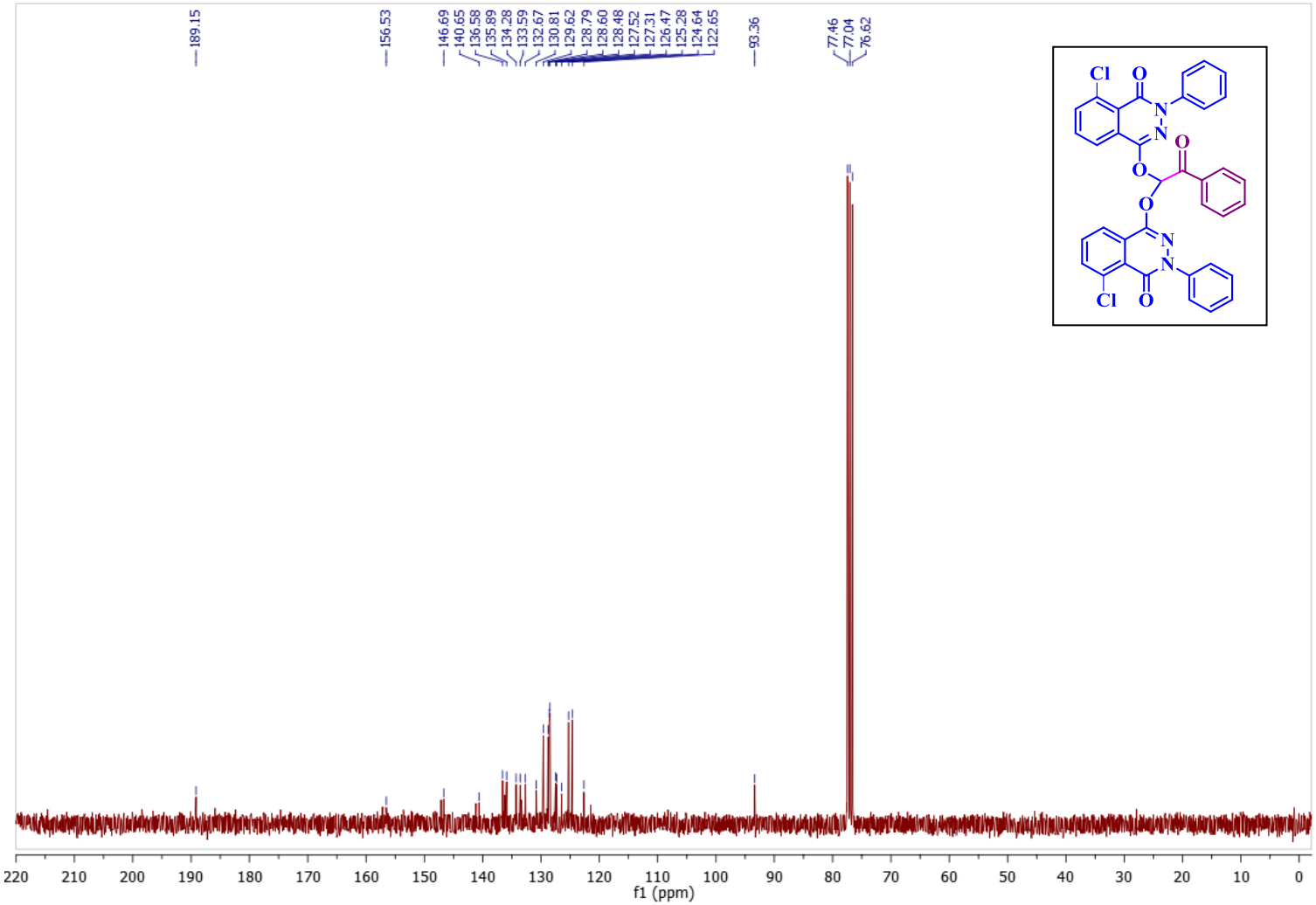
4,4'-((2-oxo-2-(p-tolyl)ethane-1,1-diyl)bis(oxy))bis(7-methyl-2-phenylphthalazin-1(2*H*)-one) (3r): ^{13}C NMR (75 MHz, $CDCl_3$):



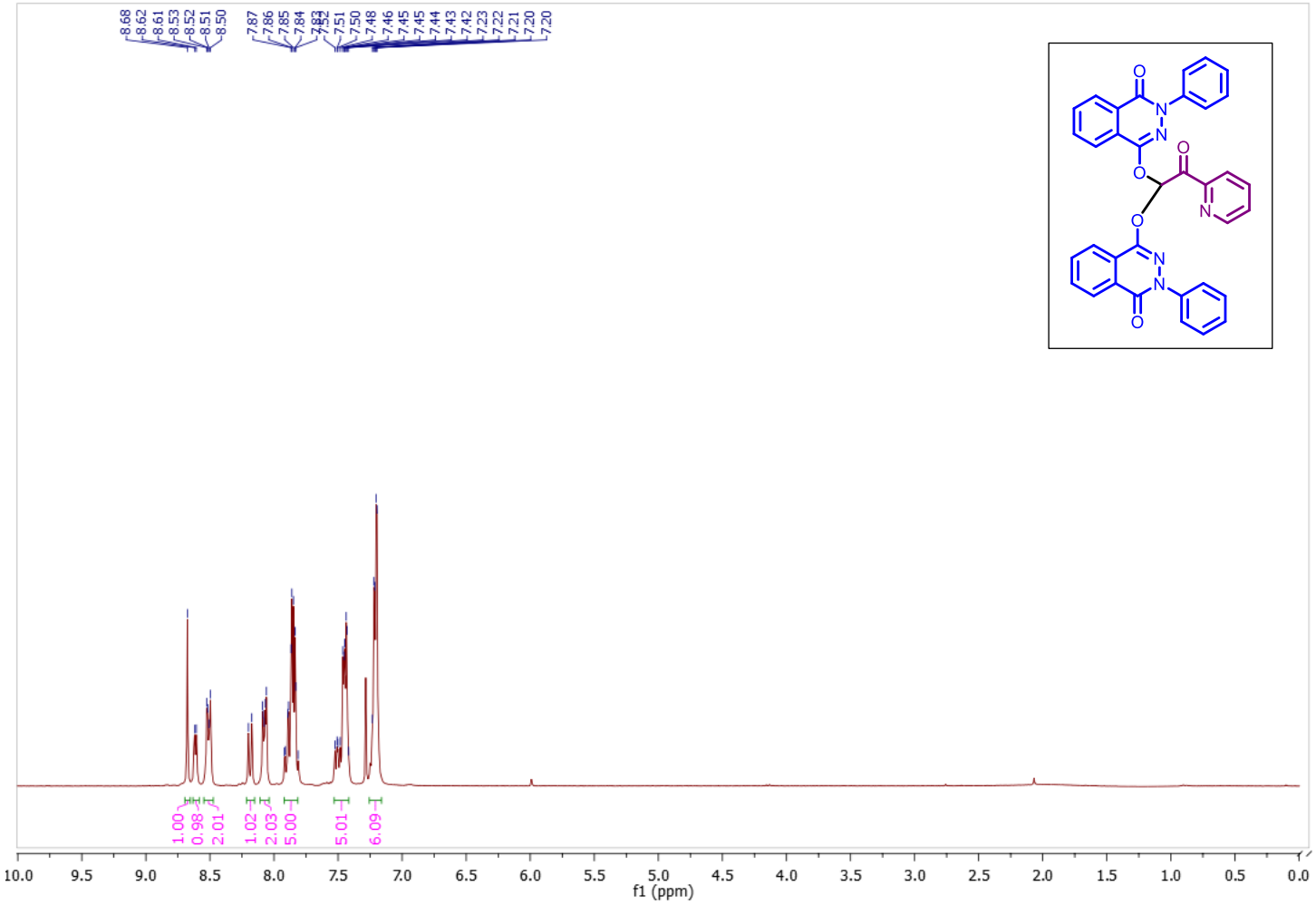
4,4'-((2-oxo-2-phenylethane-1,1-diyl)bis(oxy))bis(8-chloro-2-phenylphthalazin-1(2*H*)-one) (3s): ^{1}H NMR (300 MHz, $CDCl_3$):



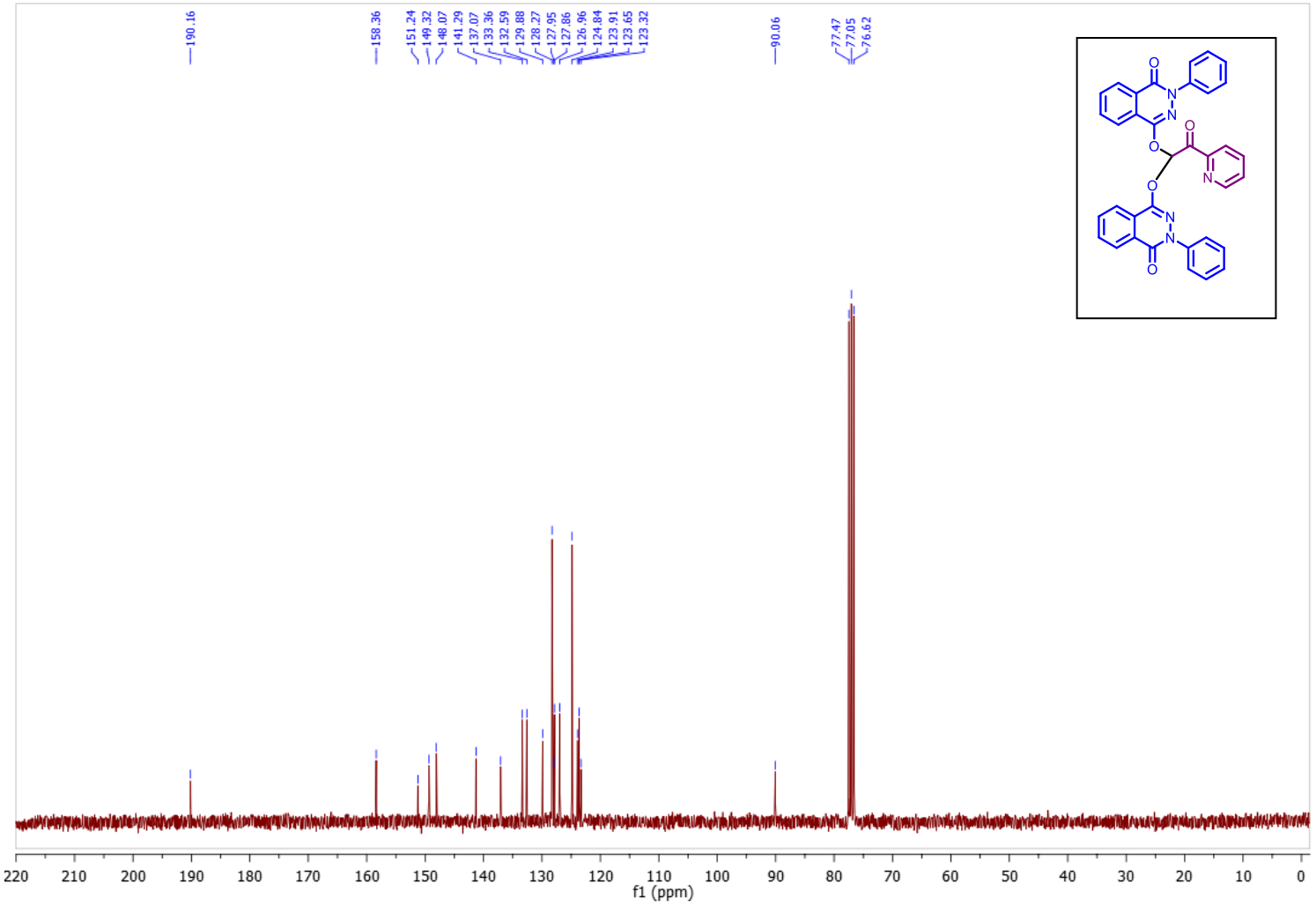
4,4'-((2-oxo-2-phenylethane-1,1-diyl)bis(oxy))bis(8-chloro-2-phenylphthalazin-1(2*H*)-one) (3s): ^{13}C NMR (75 MHz, $CDCl_3$):



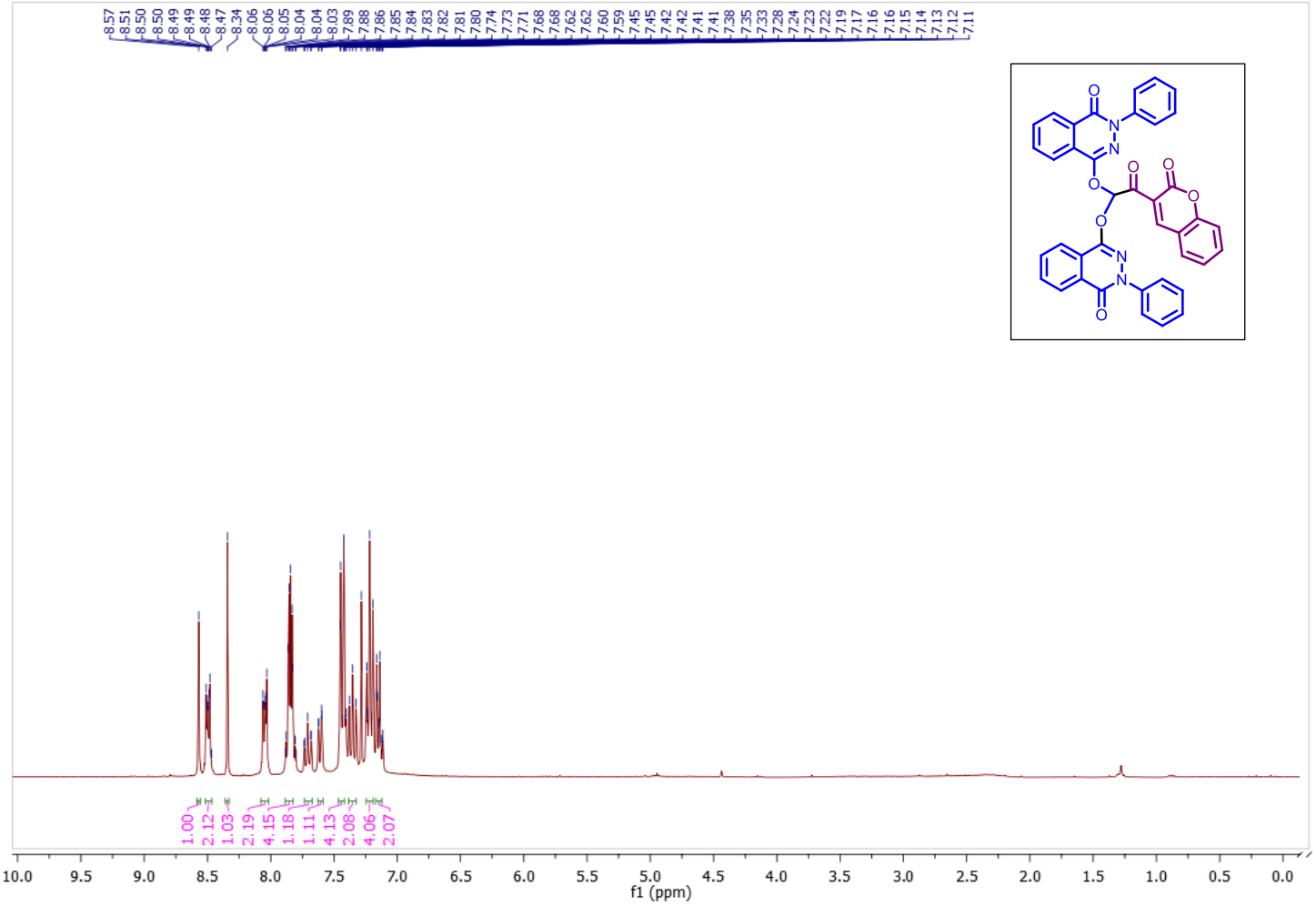
4,4'-((2-oxo-2-(pyridin-2-yl)ethane-1,1-diyl)bis(oxy))bis(2 phenylphthalazin-1(2*H*)-one) (3t): ^{1}H NMR (300 MHz, $CDCl_3$):



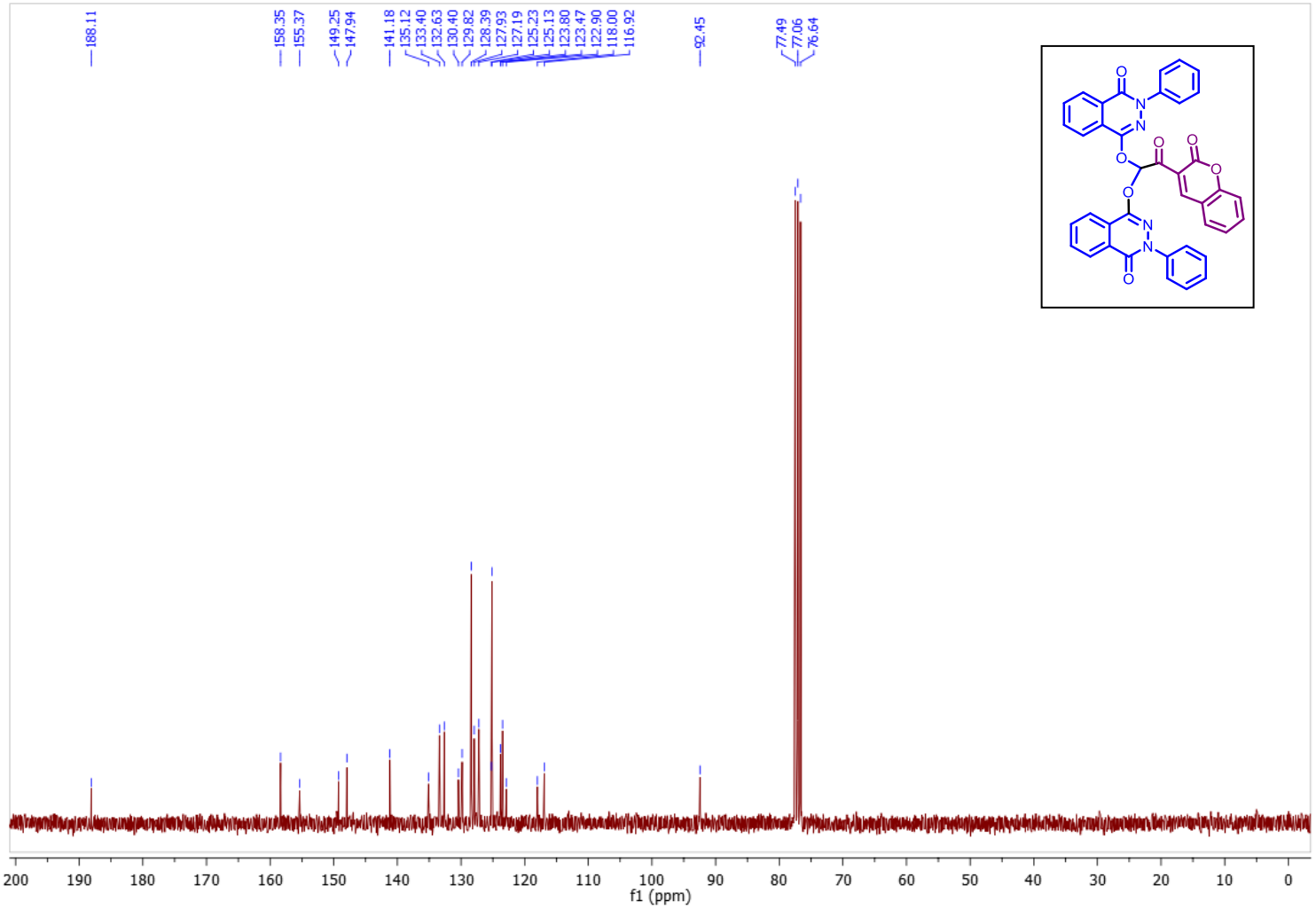
4,4'-((2-oxo-2-(pyridin-2-yl)ethane-1,1-diyl)bis(oxy))bis(2 phenylphthalazin-1(2*H*)-one) (3t): ^{13}C NMR (75 MHz, $CDCl_3$):



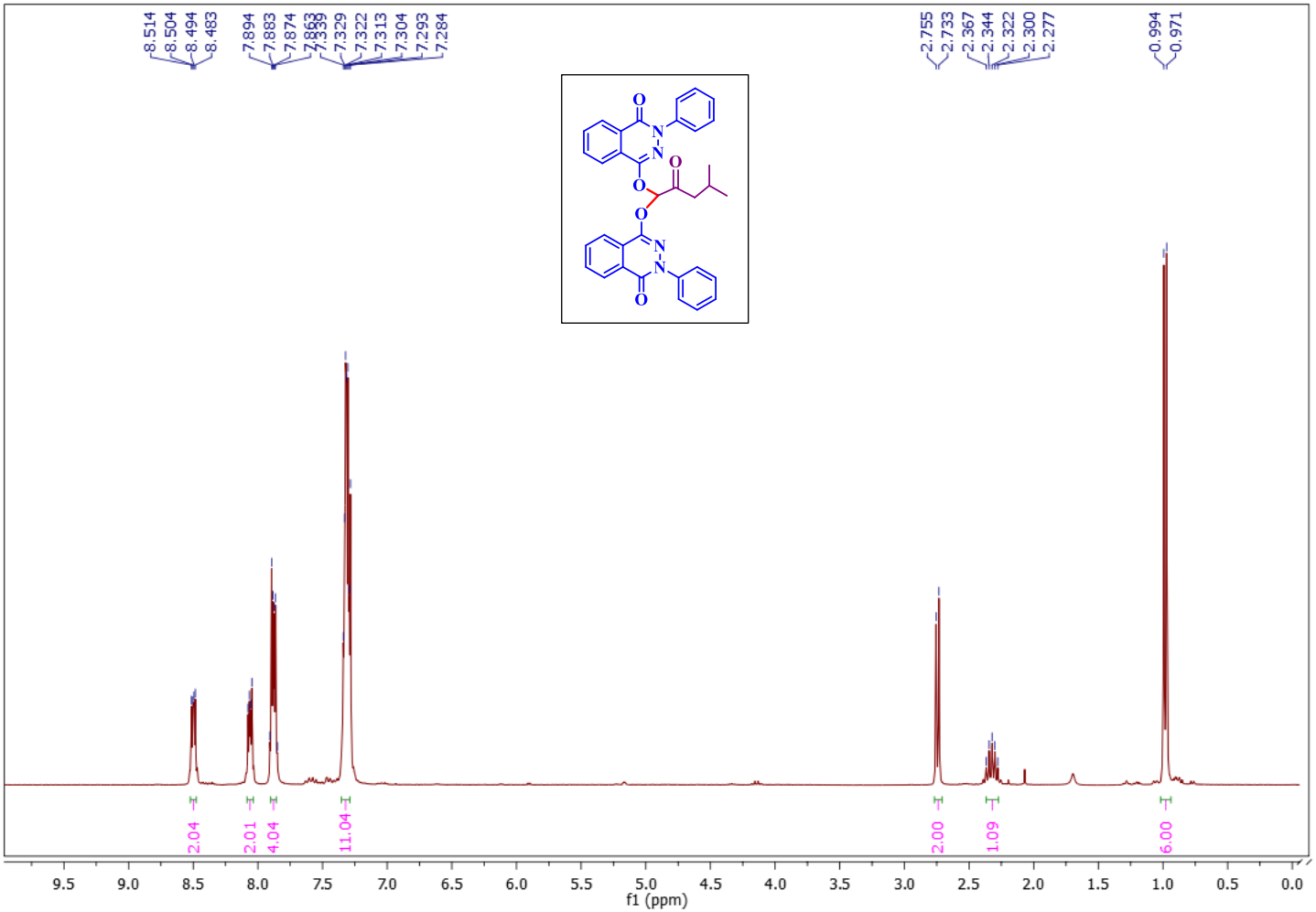
4,4'-((2-oxo-2-(2-oxo-2H-chromen-3-yl)ethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3u): ^{1}H NMR (300 MHz, $CDCl_3$):



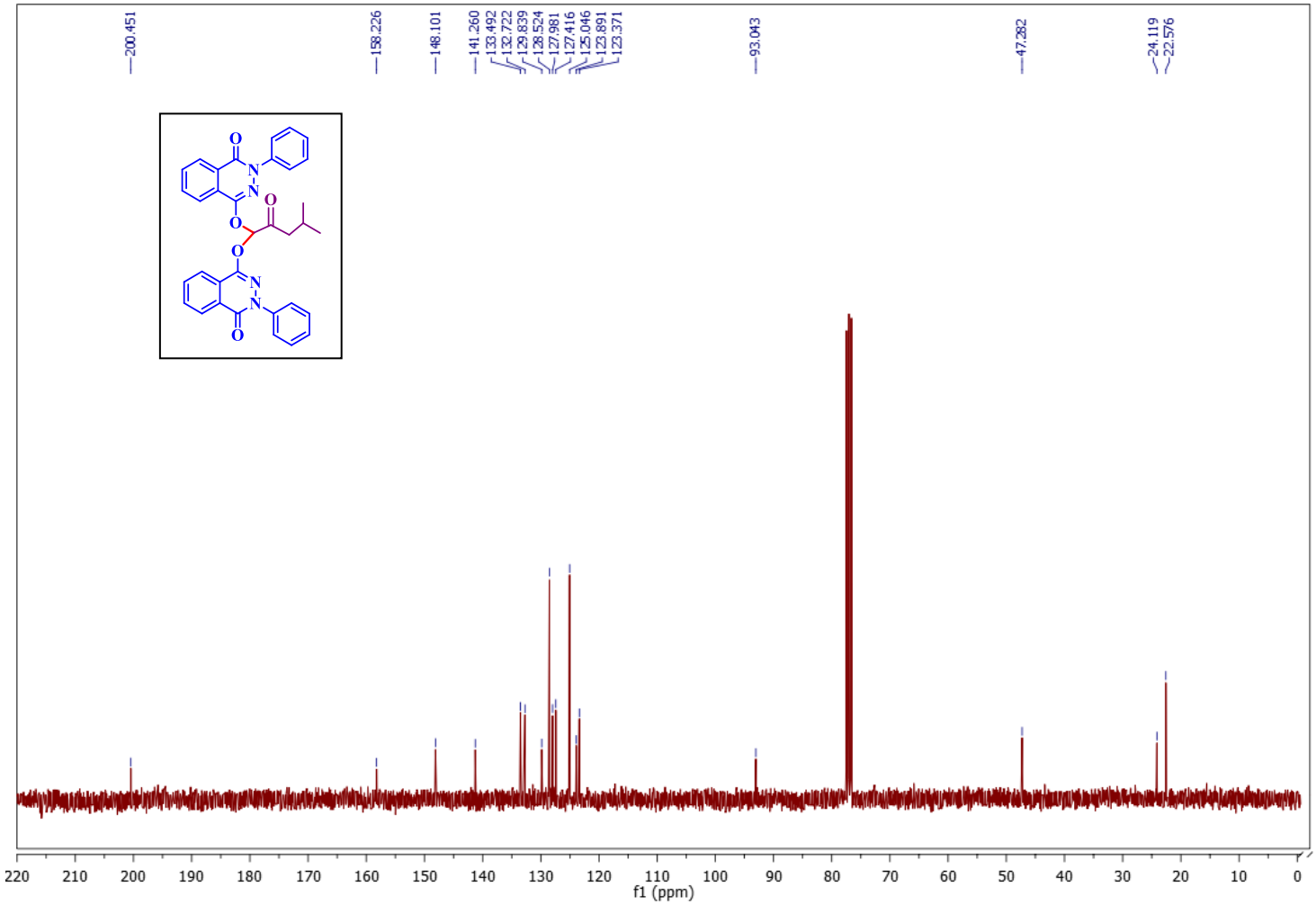
4,4'-((2-oxo-2-(2-oxo-2H-chromen-3-yl)ethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3u): ^{13}C NMR (75 MHz, $CDCl_3$):



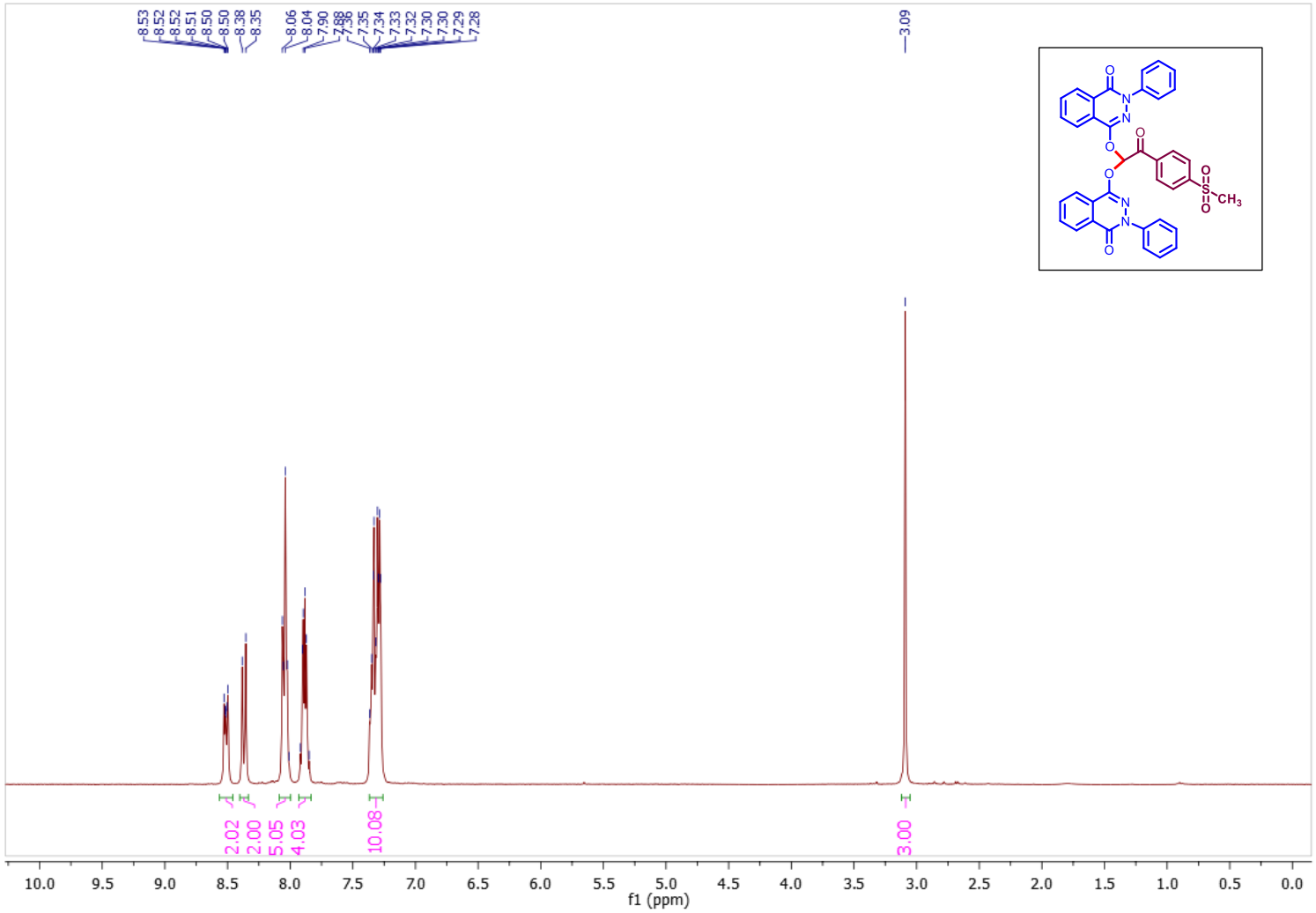
4,4'-((4-methyl-2-oxopentane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3v): ^{1}H NMR (300 MHz, $CDCl_3$):



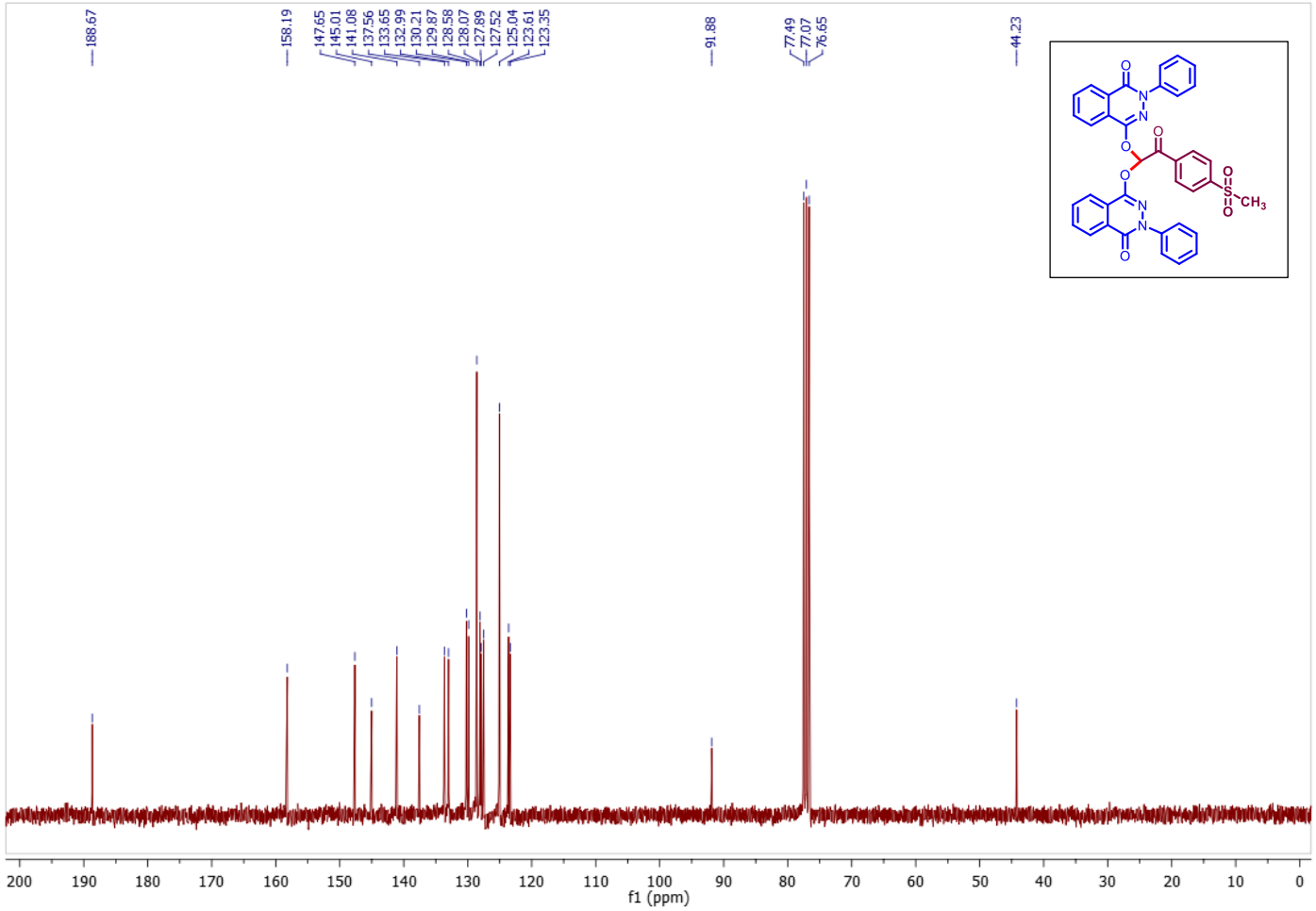
4,4'-((4-methyl-2-oxopentane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2*H*)-one) (3v): ^{13}C NMR (75 MHz, $CDCl_3$):



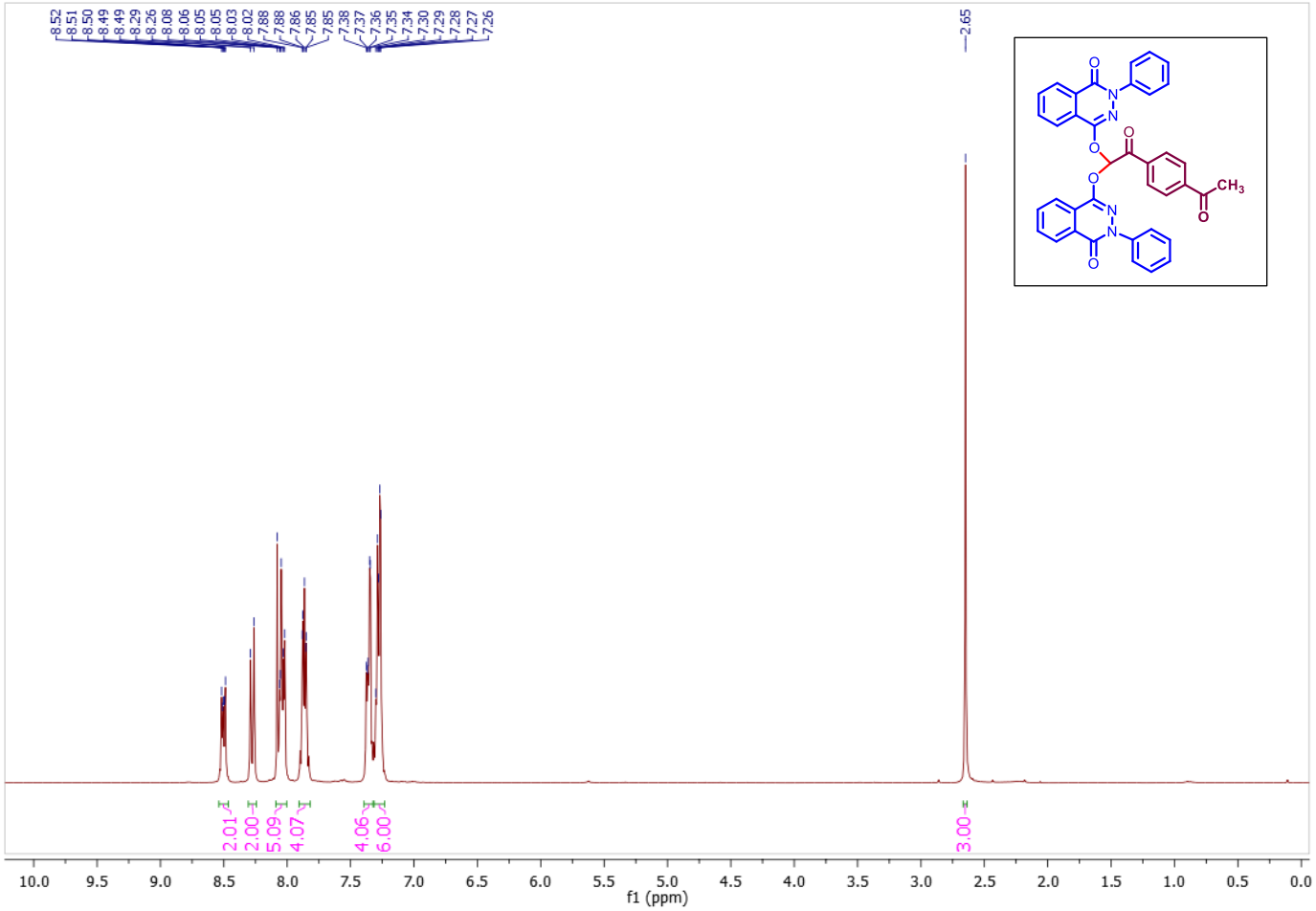
4,4'-((2-(4-(methylsulfonyl)phenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2H)-one) (3w): ^{1}H NMR (300 MHz, $CDCl_3$):



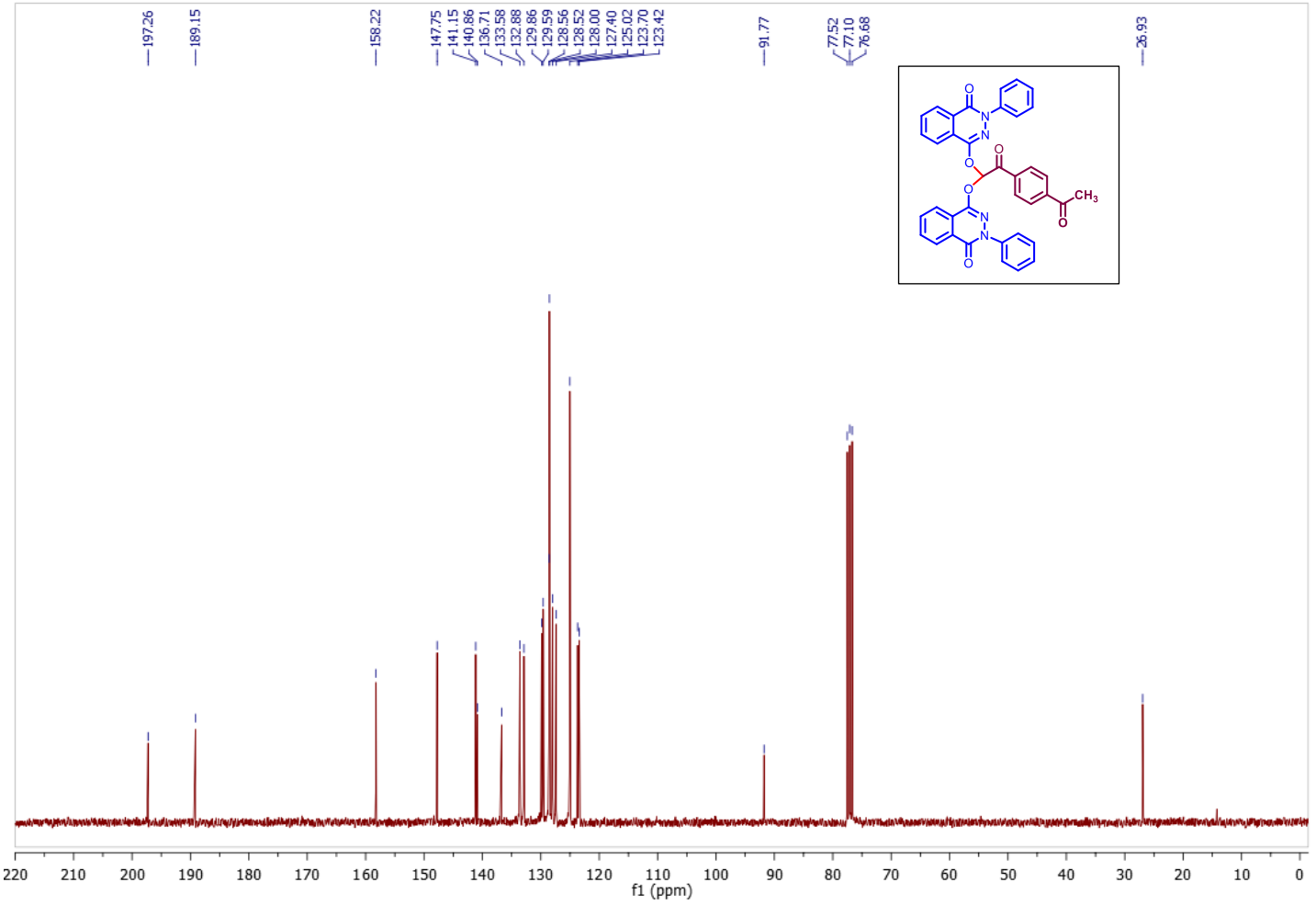
4,4'-((2-(4-(methylsulfonyl)phenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2H)-one) (3w): ^{13}C NMR (75 MHz, $CDCl_3$):



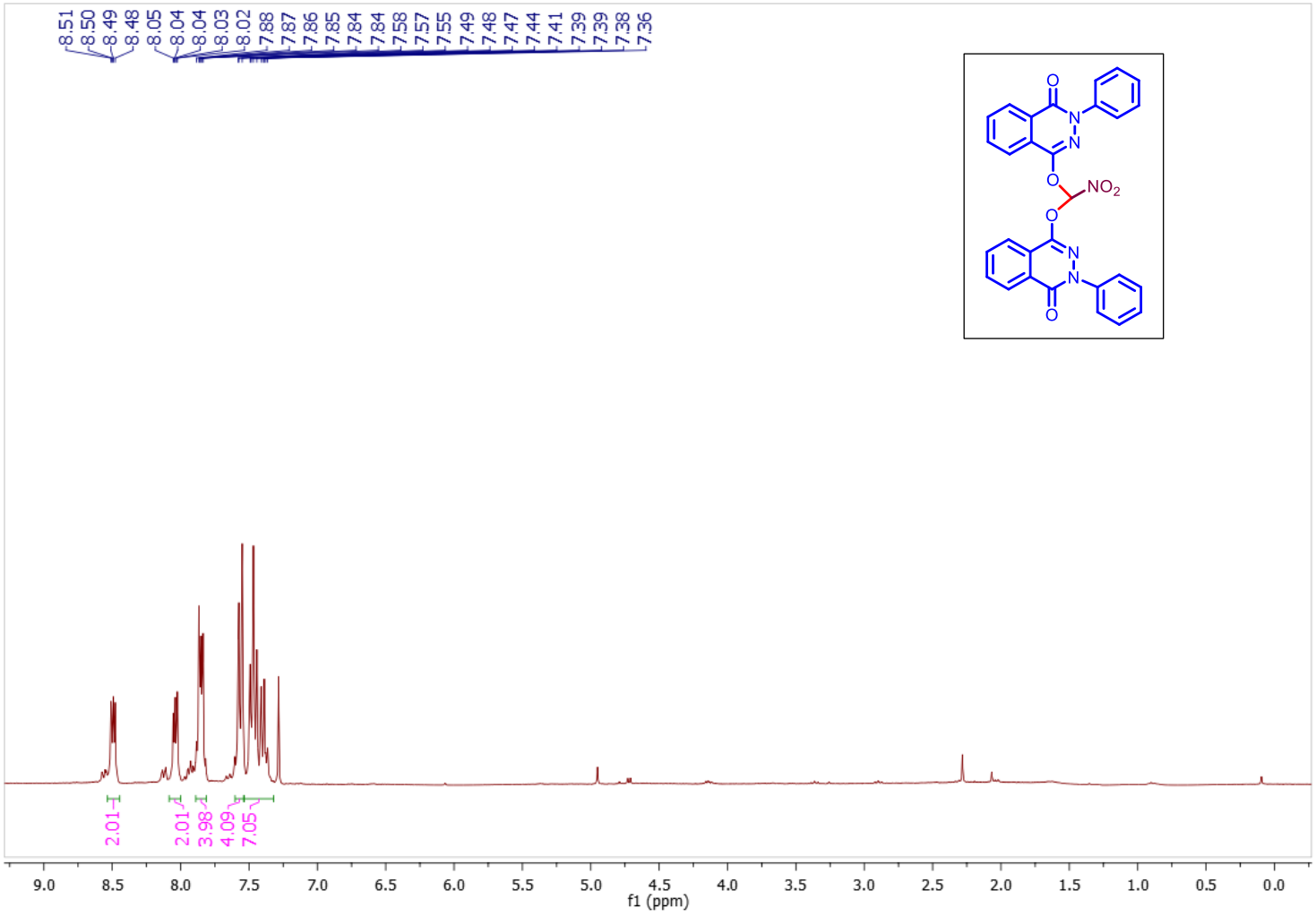
4,4'-((2-(4-acetylphenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2H)-one) (3x): ^{1}H NMR (300 MHz, $CDCl_3$):



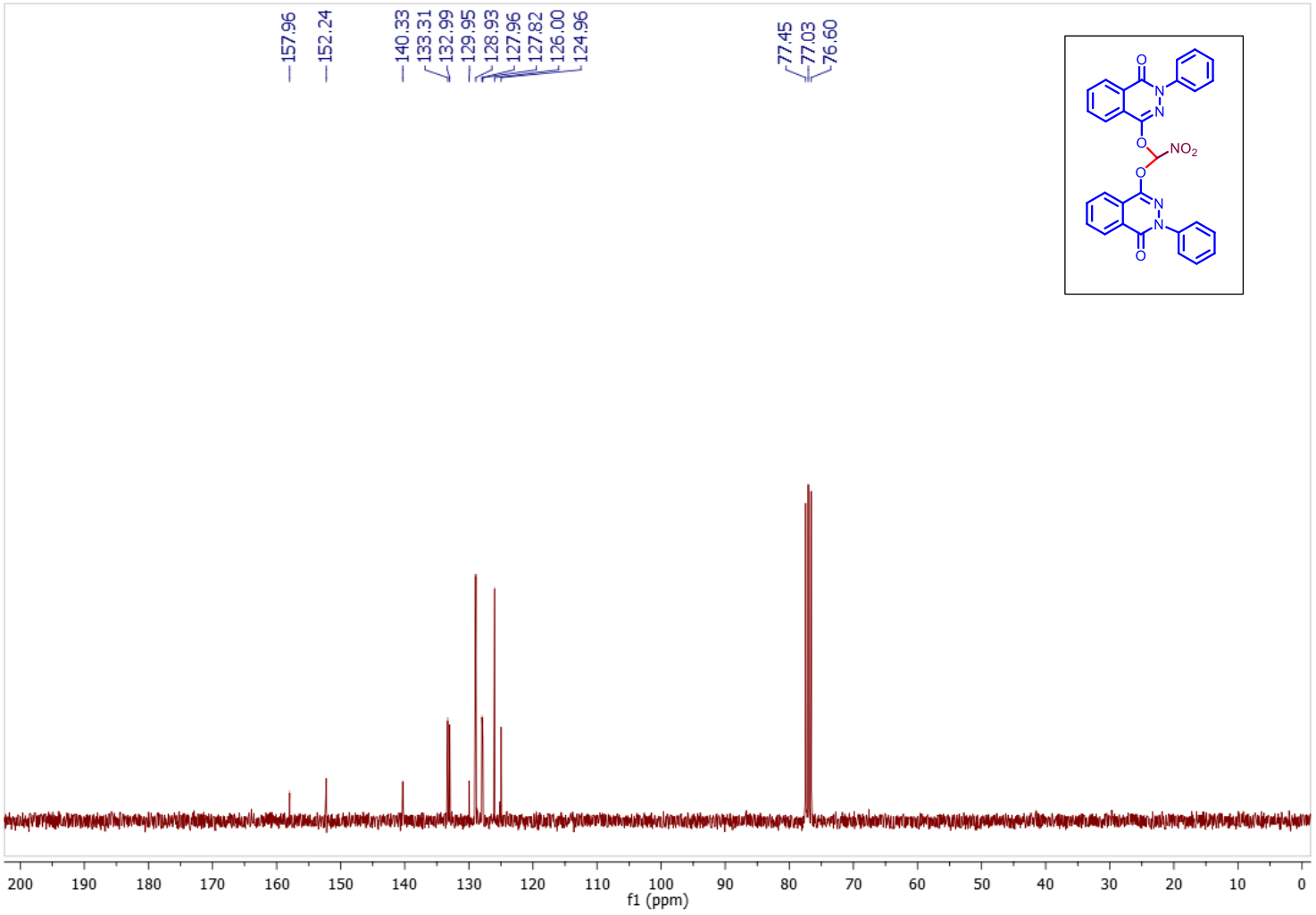
4,4'-((2-(4-acetylphenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2H)-one) (3x):): ^{13}C NMR (75 MHz, $CDCl_3$):



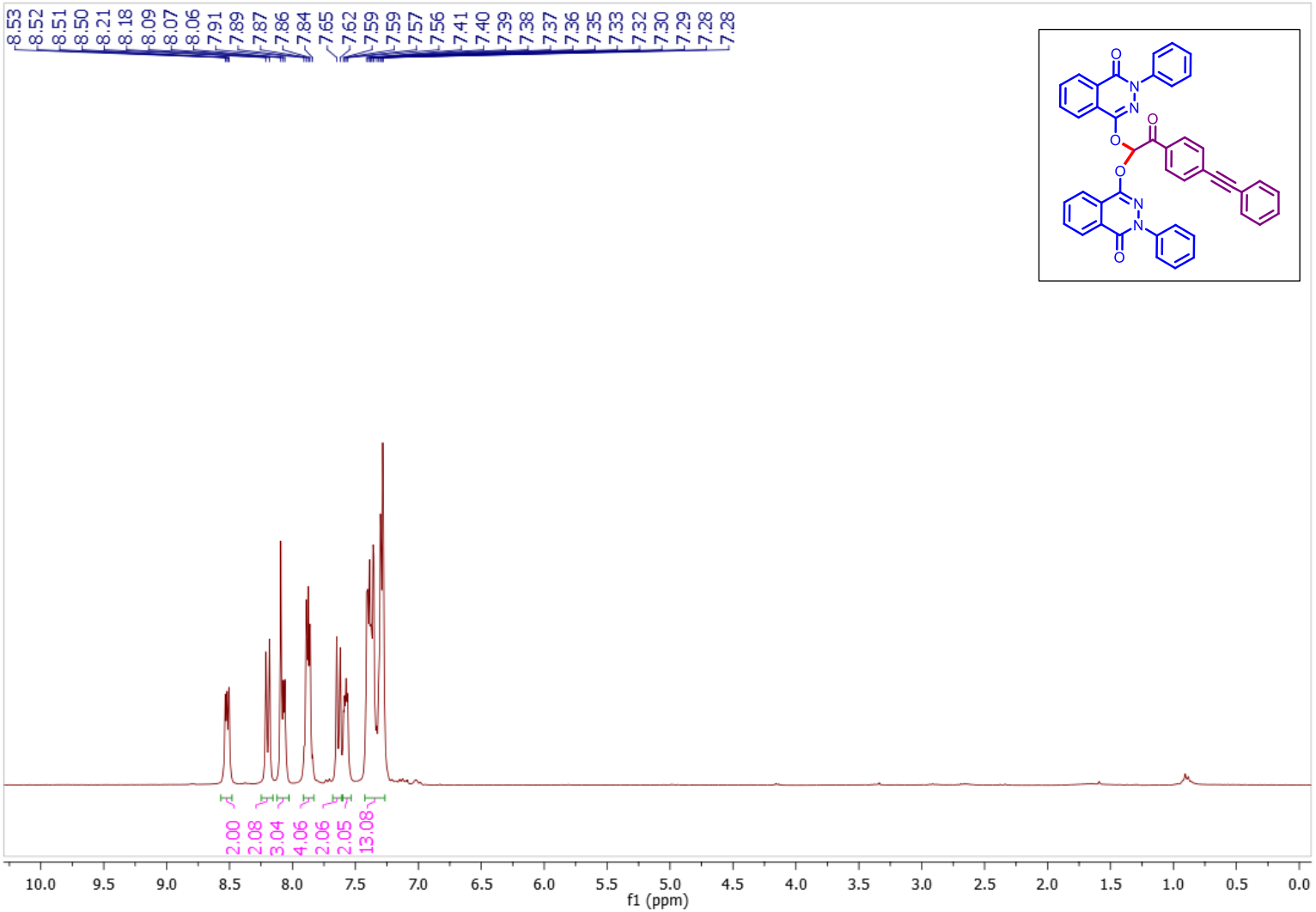
4,4'-((nitromethylene)bis(oxy))bis(2-phenylphthalazin-1(2H)-one) (3y): ^{1}H NMR (300 MHz, $CDCl_3$):



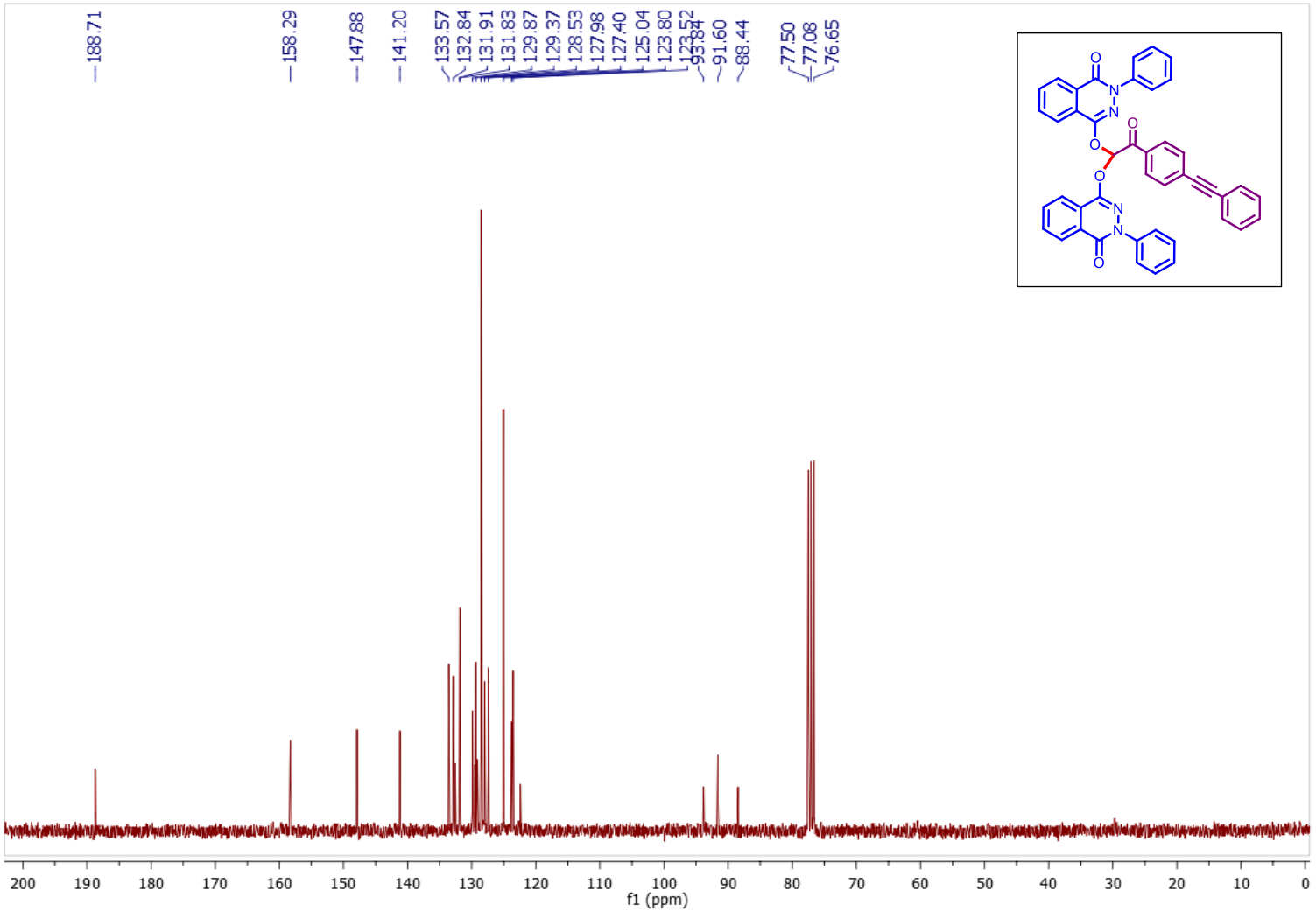
4,4'-((nitromethylene)bis(oxy))bis(2-phenylphthalazin-1(2H)-one) (3y): ^{13}C NMR (75 MHz, $CDCl_3$):



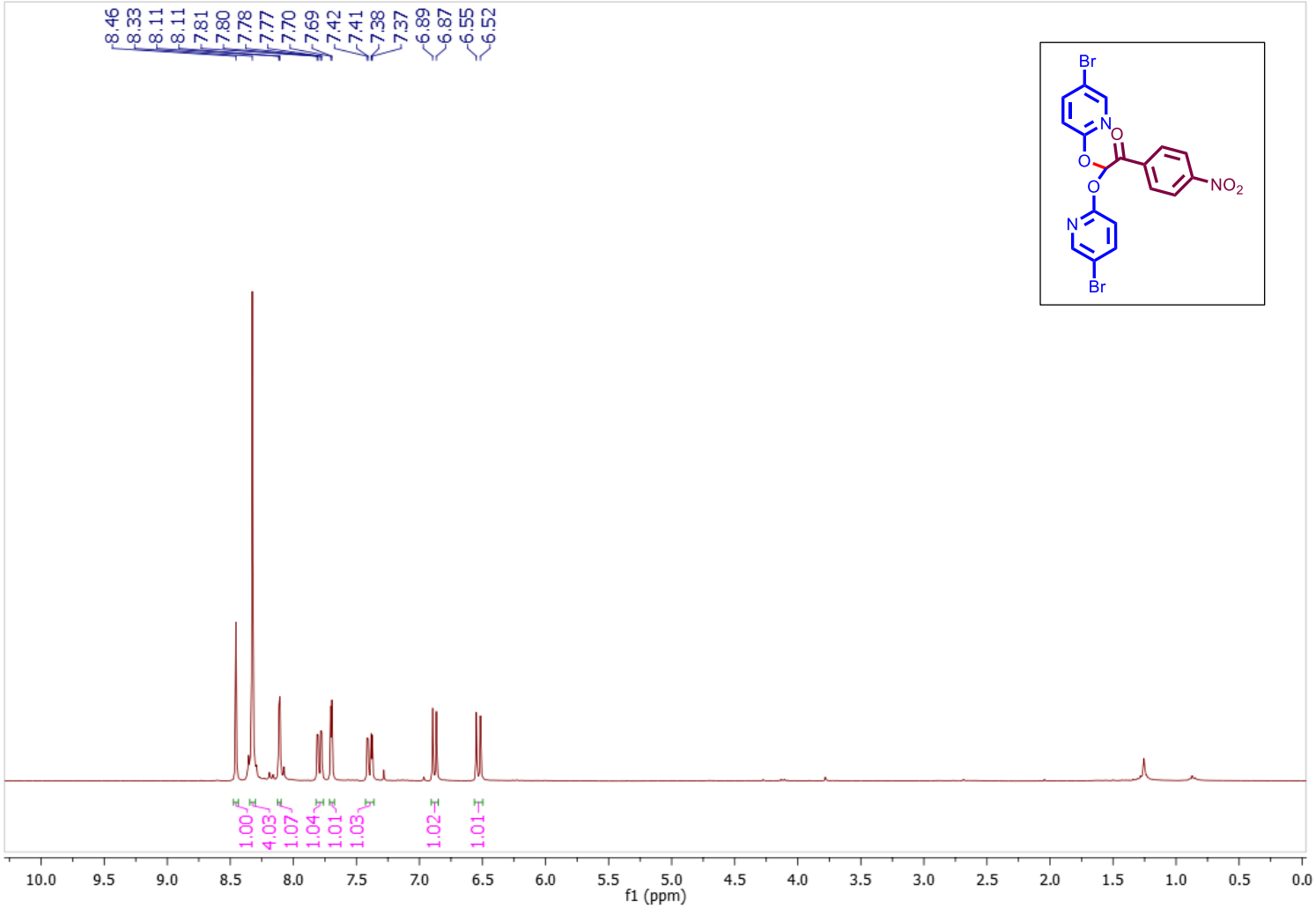
4,4'-((2-oxo-2-(4-(phenylethynyl)phenyl)ethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2H)-one) (3z): ^{1}H NMR (300 MHz, $CDCl_3$):



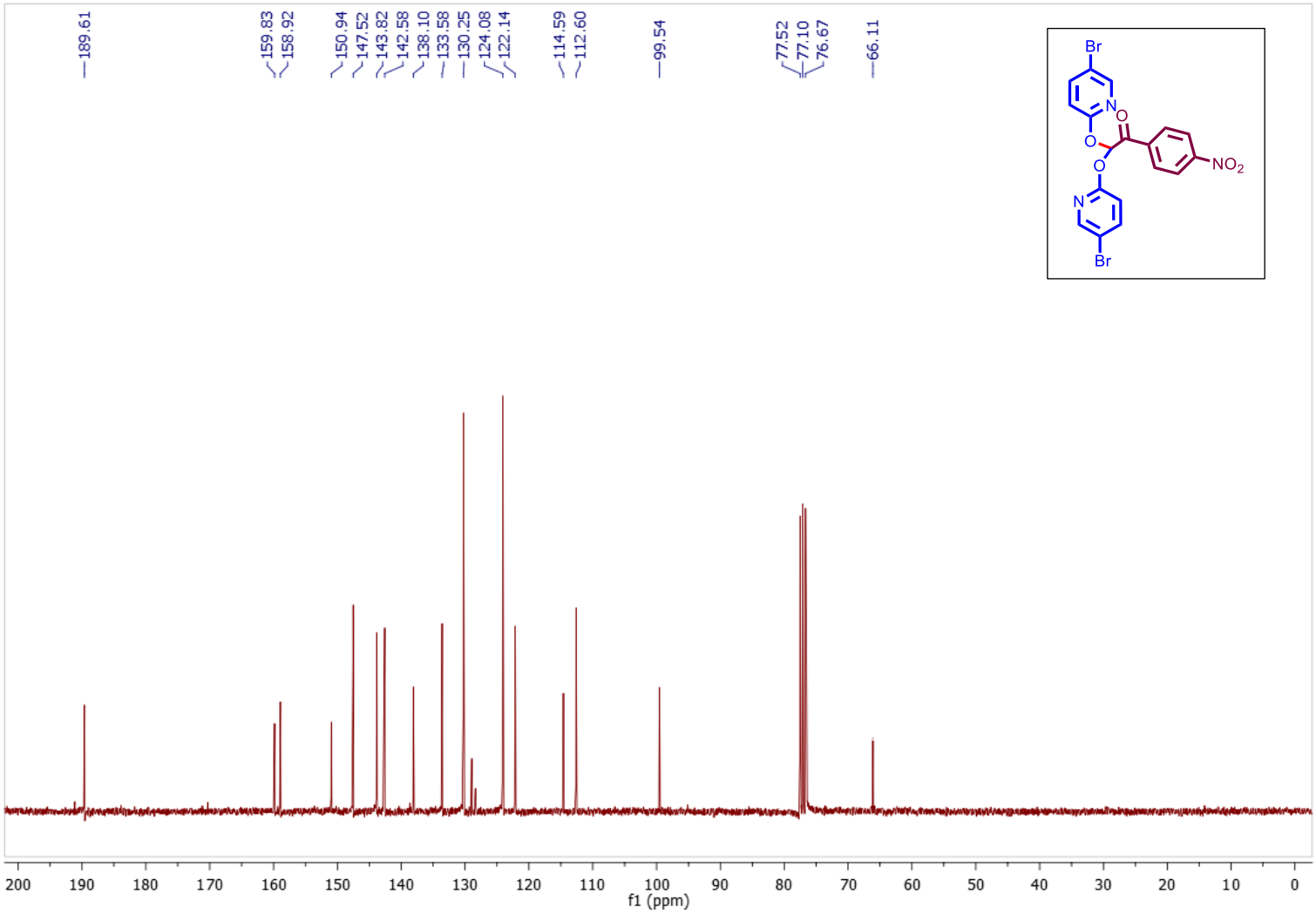
4,4'-((2-oxo-2-(4-(phenylethynyl)phenyl)ethane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2H)-one) (3z): ^{13}C NMR (75 MHz, $CDCl_3$):



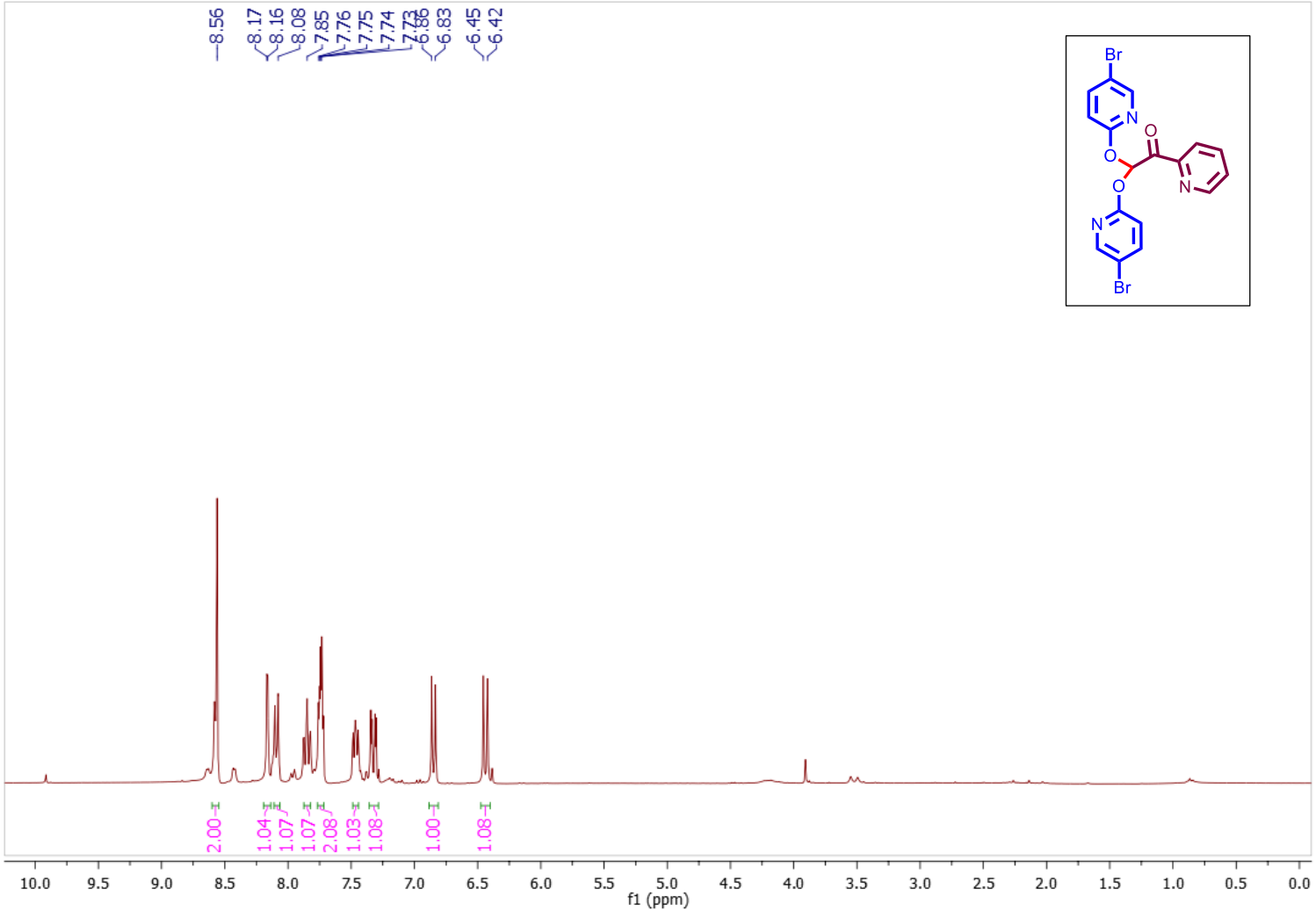
2,2-bis((5-bromopyridin-2-yl)oxy)-1-(4-nitrophenyl)ethan-1-one (3za): ^{1}H NMR (300 MHz, $CDCl_3$):



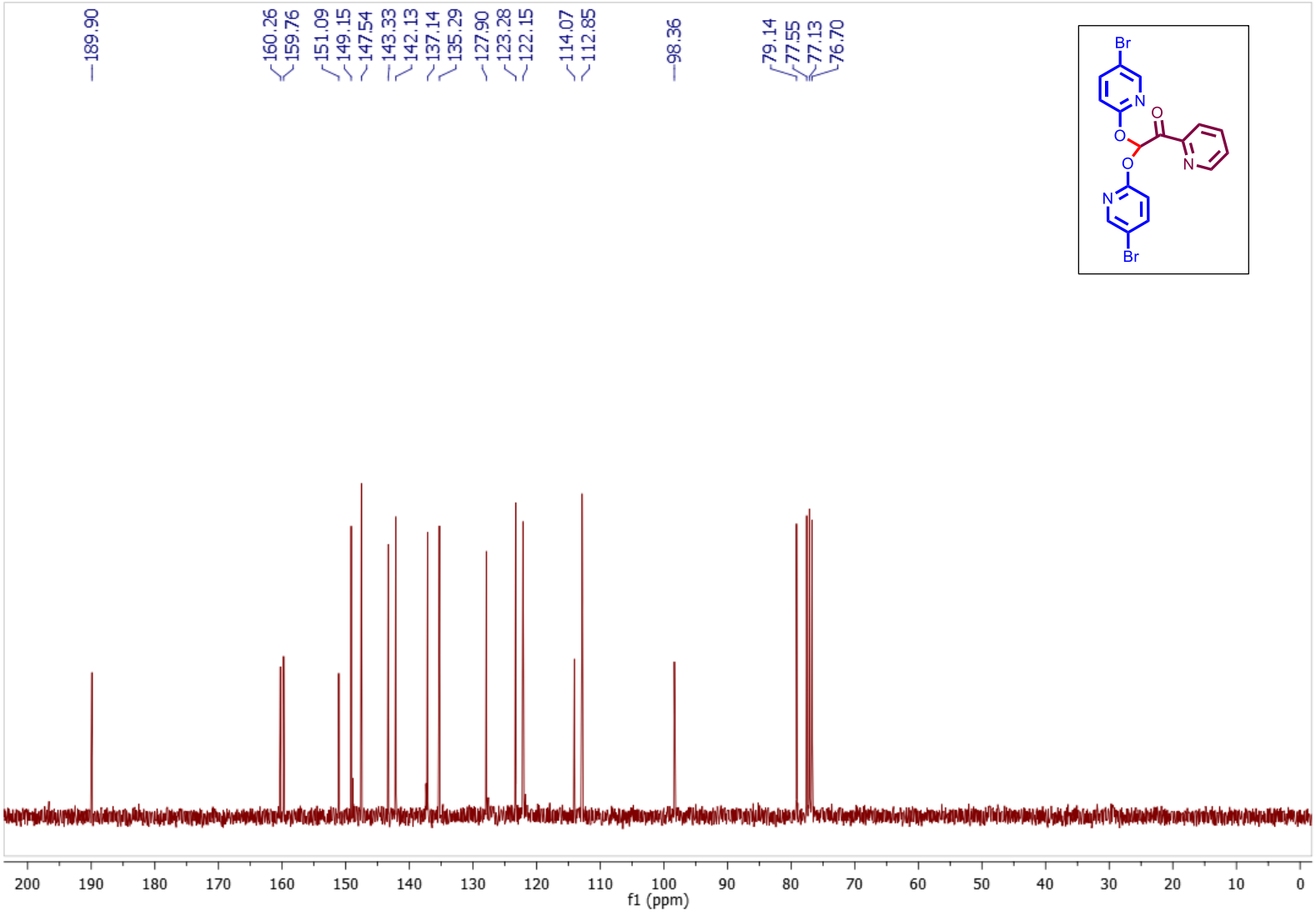
2,2-bis((5-bromopyridin-2-yl)oxy)-1-(4-nitrophenyl)ethan-1-one (3za): ^{1}H NMR (300 MHz, $CDCl_3$): ^{13}C NMR (75 MHz, $CDCl_3$):



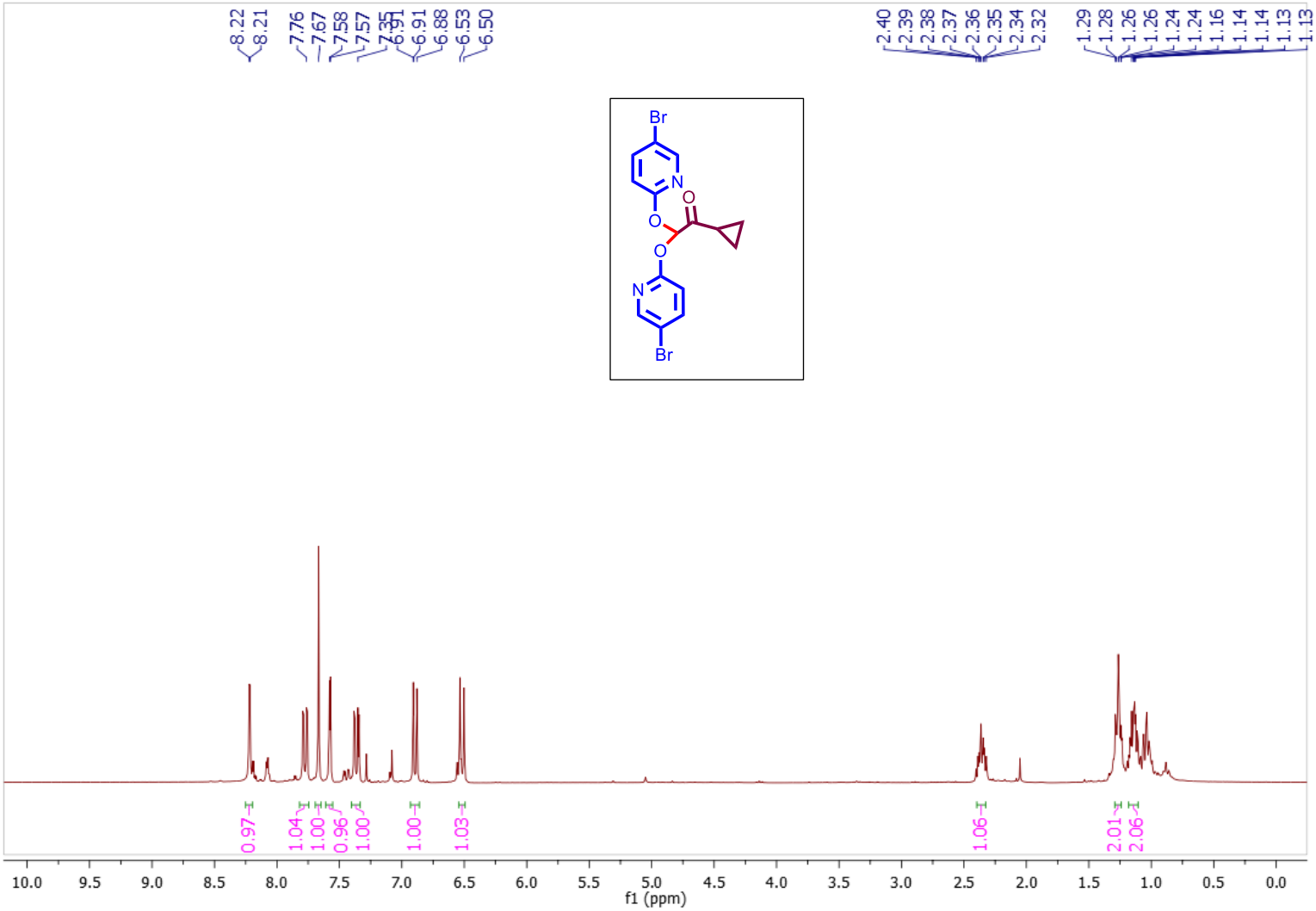
2,2-bis((5-bromopyridin-2-yl)oxy)-1-(pyridin-2-yl)ethan-1-one (3zb): ^{1}H NMR (300 MHz, $CDCl_3$):



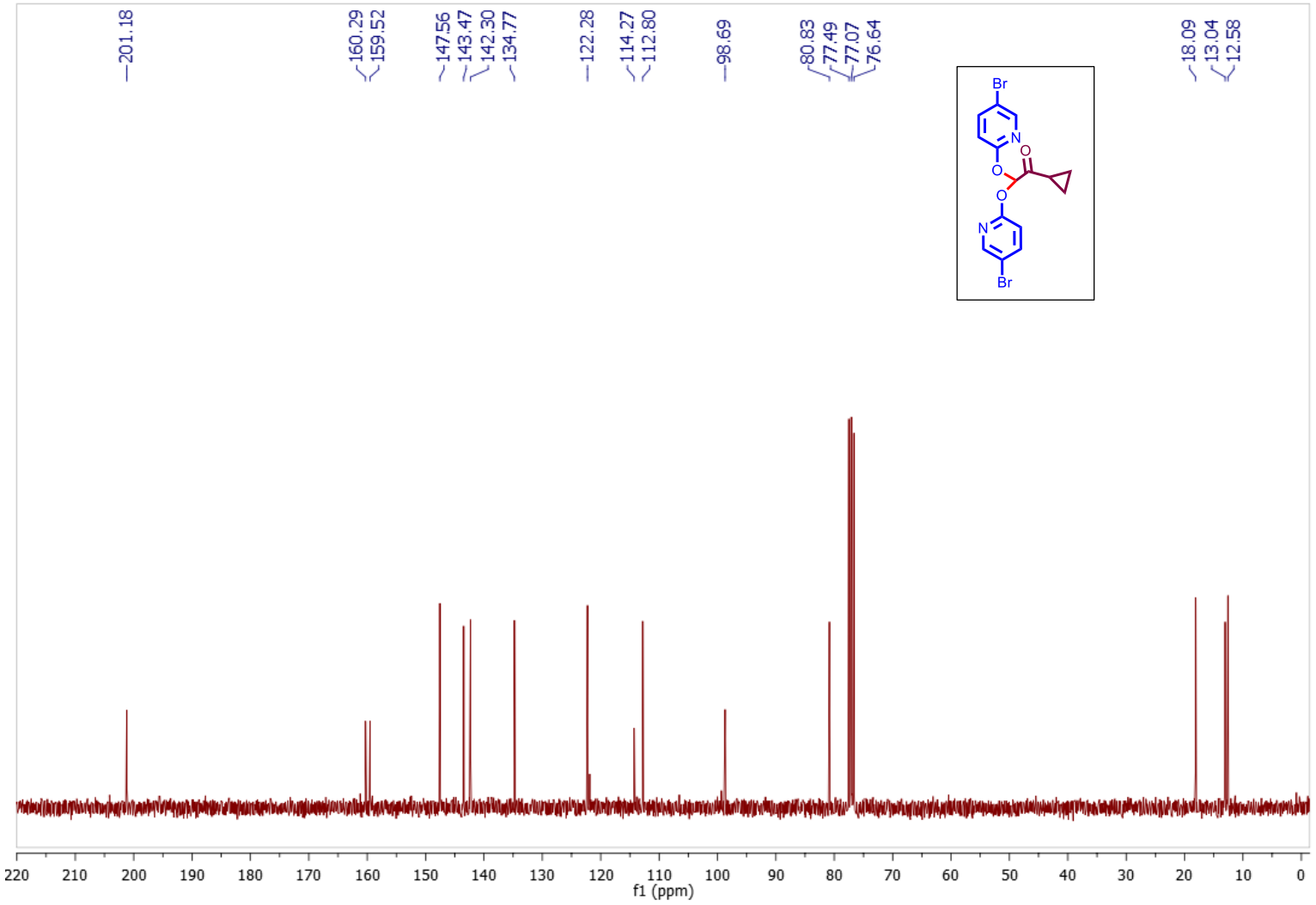
2,2-bis((5-bromopyridin-2-yl)oxy)-1-(pyridin-2-yl)ethan-1-one (3zb): ^{13}C NMR (75 MHz, $CDCl_3$):



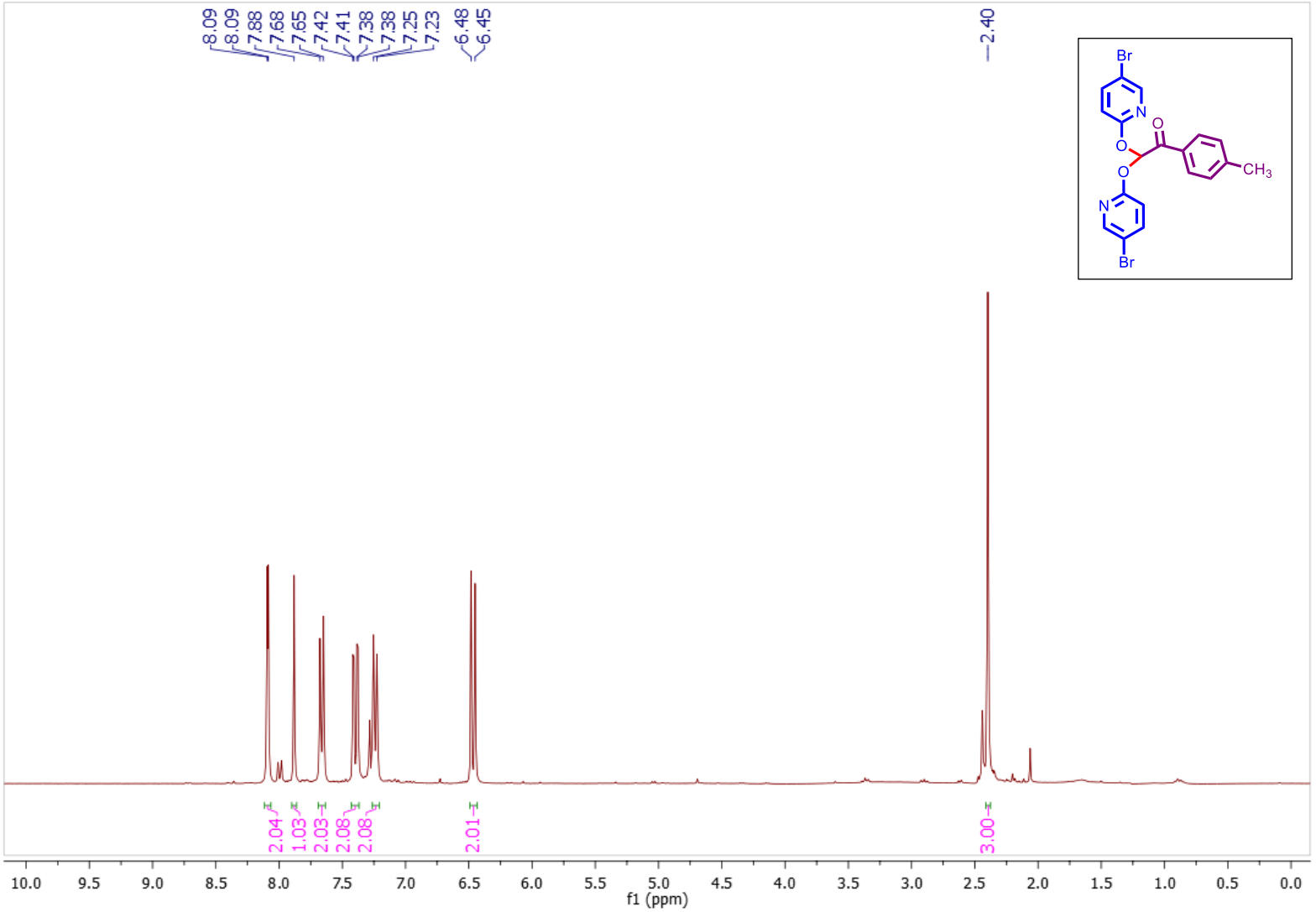
2,2-bis((5-bromopyridin-2-yl)oxy)-1-cyclopropylethan-1-one (3zc): ^{1}H NMR (300 MHz, $CDCl_3$):



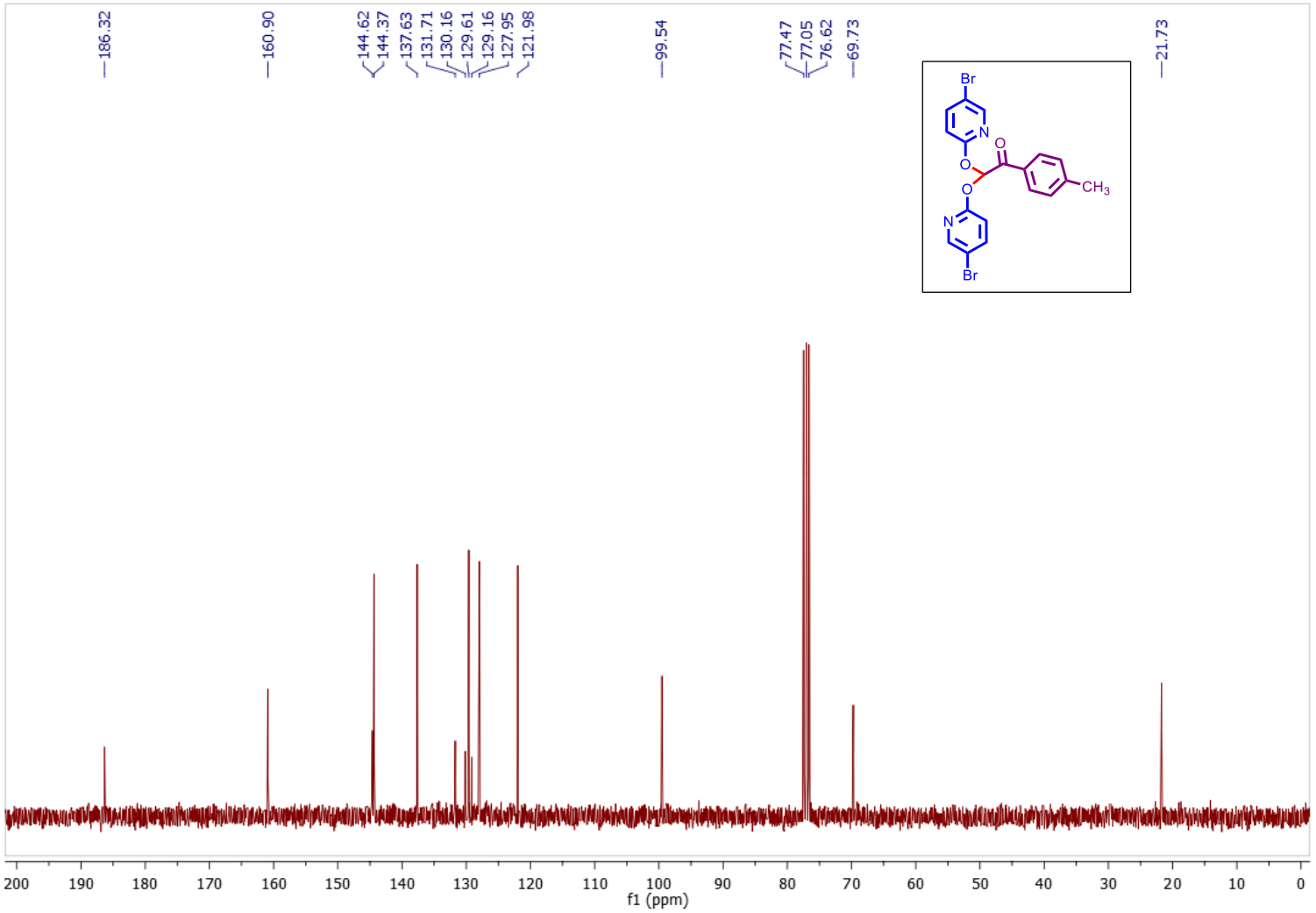
2,2-bis((5-bromopyridin-2-yl)oxy)-1-cyclopropylethan-1-one (3zc): ^{1}H NMR (300 MHz, $CDCl_3$): ^{13}C NMR (75 MHz, $CDCl_3$):



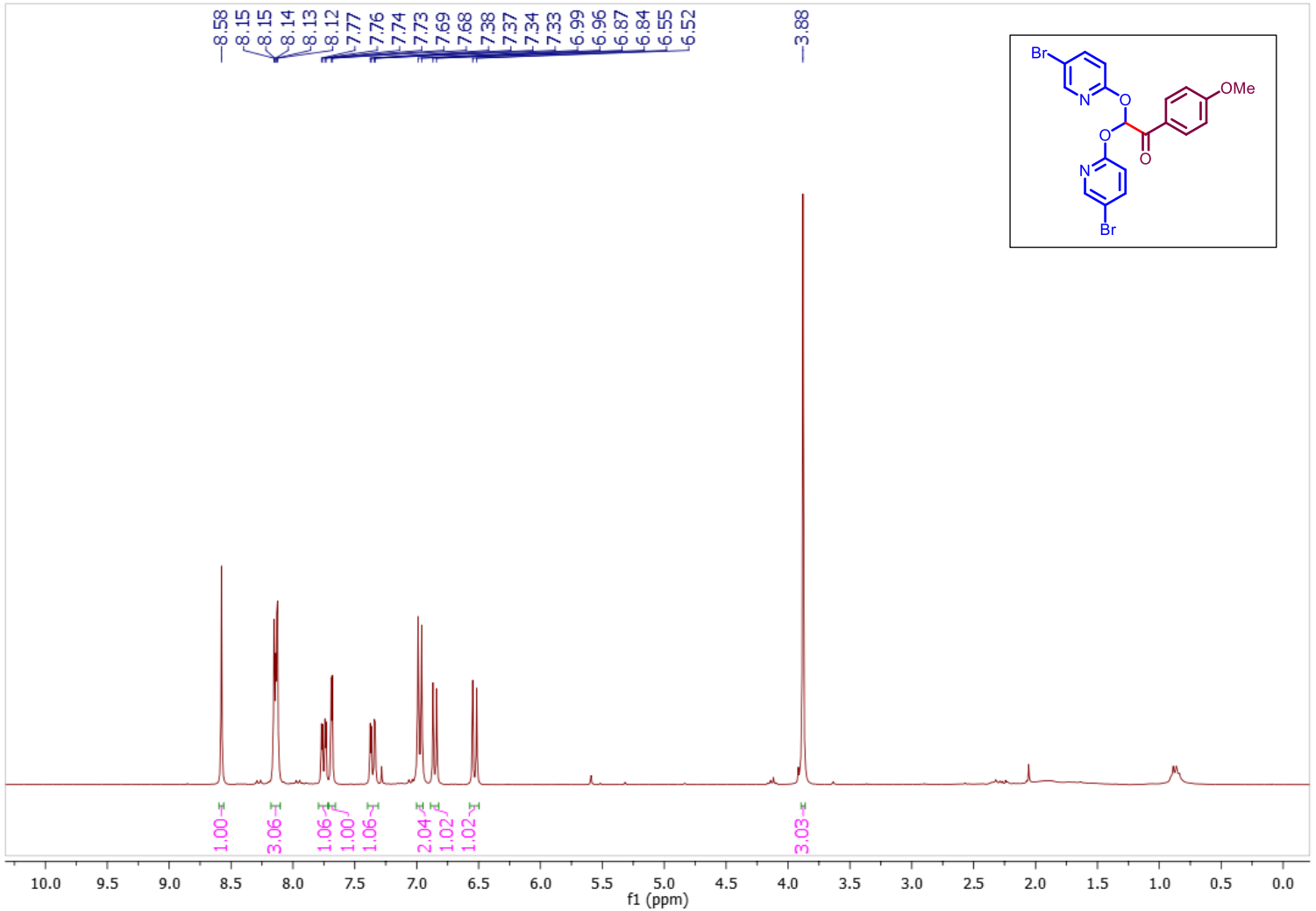
2,2-bis((5-bromopyridin-2-yl)oxy)-1-(p-tolyl)ethan-1-one (3zd): ^{1}H NMR (300 MHz, $CDCl_3$):



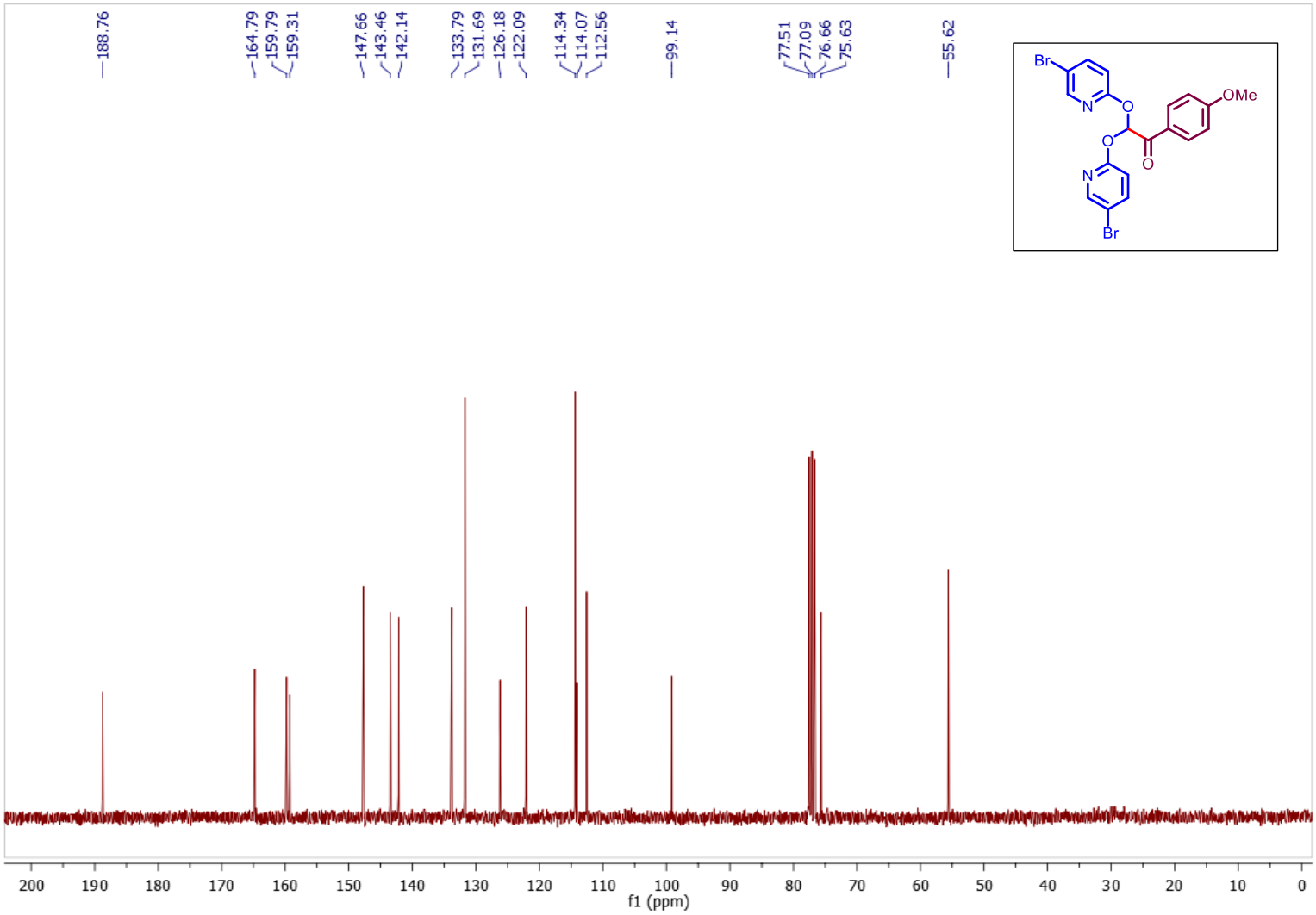
2,2-bis((5-bromopyridin-2-yl)oxy)-1-(p-tolyl)ethan-1-one (3zd): ^{13}C NMR (75 MHz, $CDCl_3$):



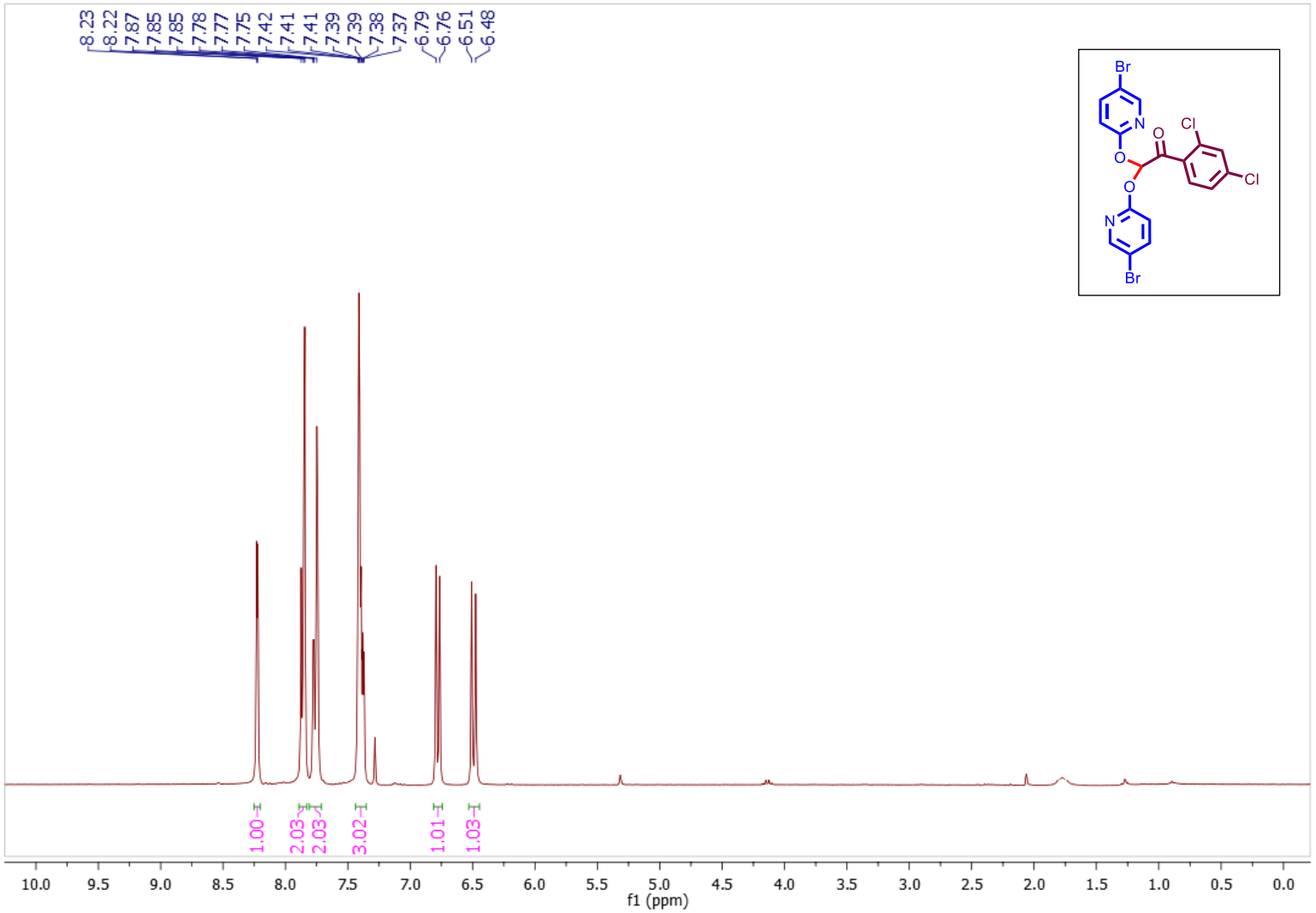
2,2-bis((5-bromopyridin-2-yl)oxy)-1-(4-methoxyphenyl)ethan-1-one (3ze): ^{1}H NMR (300 MHz, $CDCl_3$):



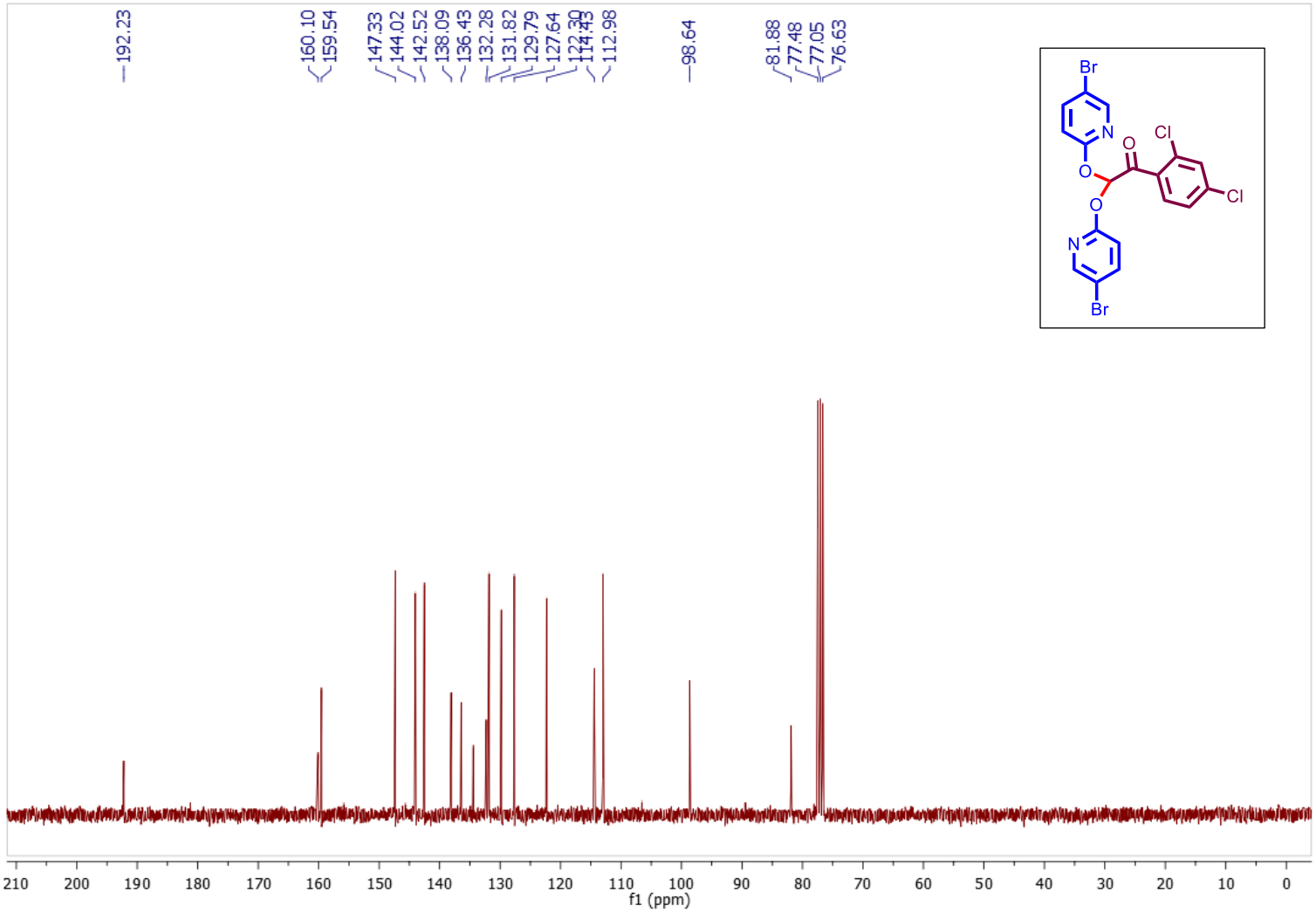
2,2-bis((5-bromopyridin-2-yl)oxy)-1-(4-methoxyphenyl)ethan-1-one (3ze): ^{13}C NMR (75 MHz, $CDCl_3$):



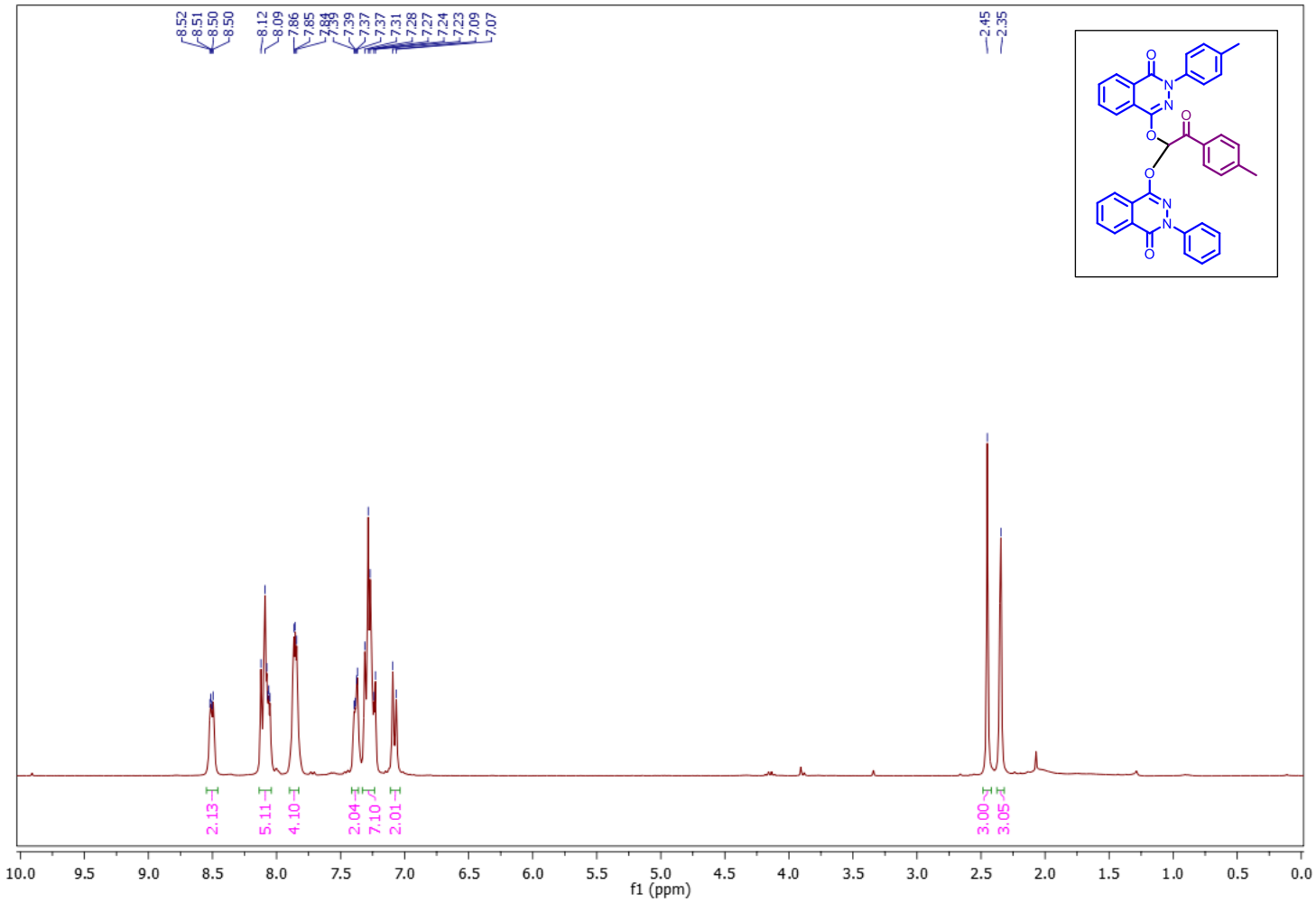
2,2-bis((5-bromopyridin-2-yl)oxy)-1-(2,4-dichlorophenyl)ethan-1-one (3zf): ^{1}H NMR (300 MHz, $CDCl_3$):



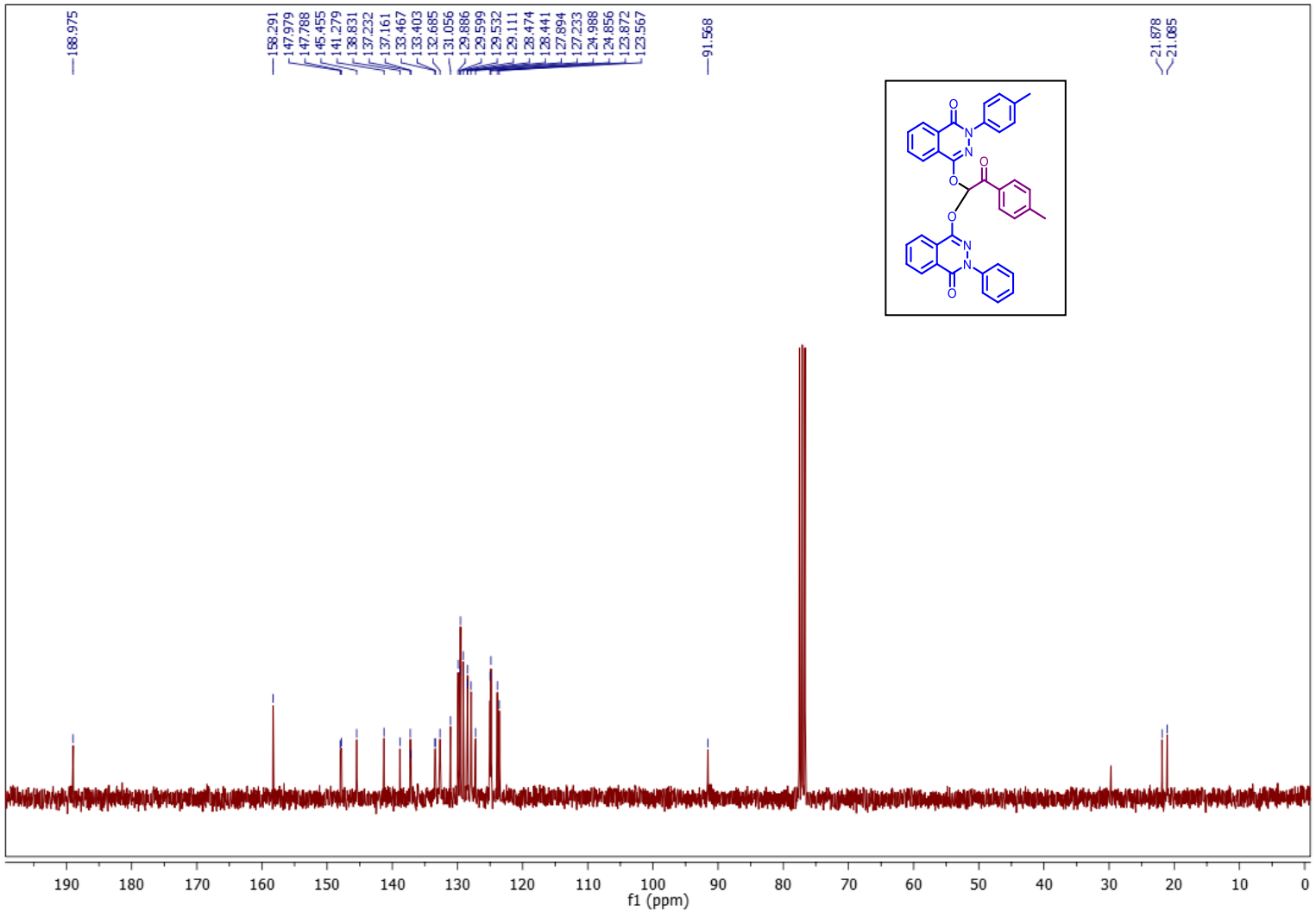
2,2-bis((5-bromopyridin-2-yl)oxy)-1-(2,4-dichlorophenyl)ethan-1-one (3zf): ^{1}H NMR (300 MHz, $CDCl_3$): ^{13}C NMR (75 MHz, $CDCl_3$):



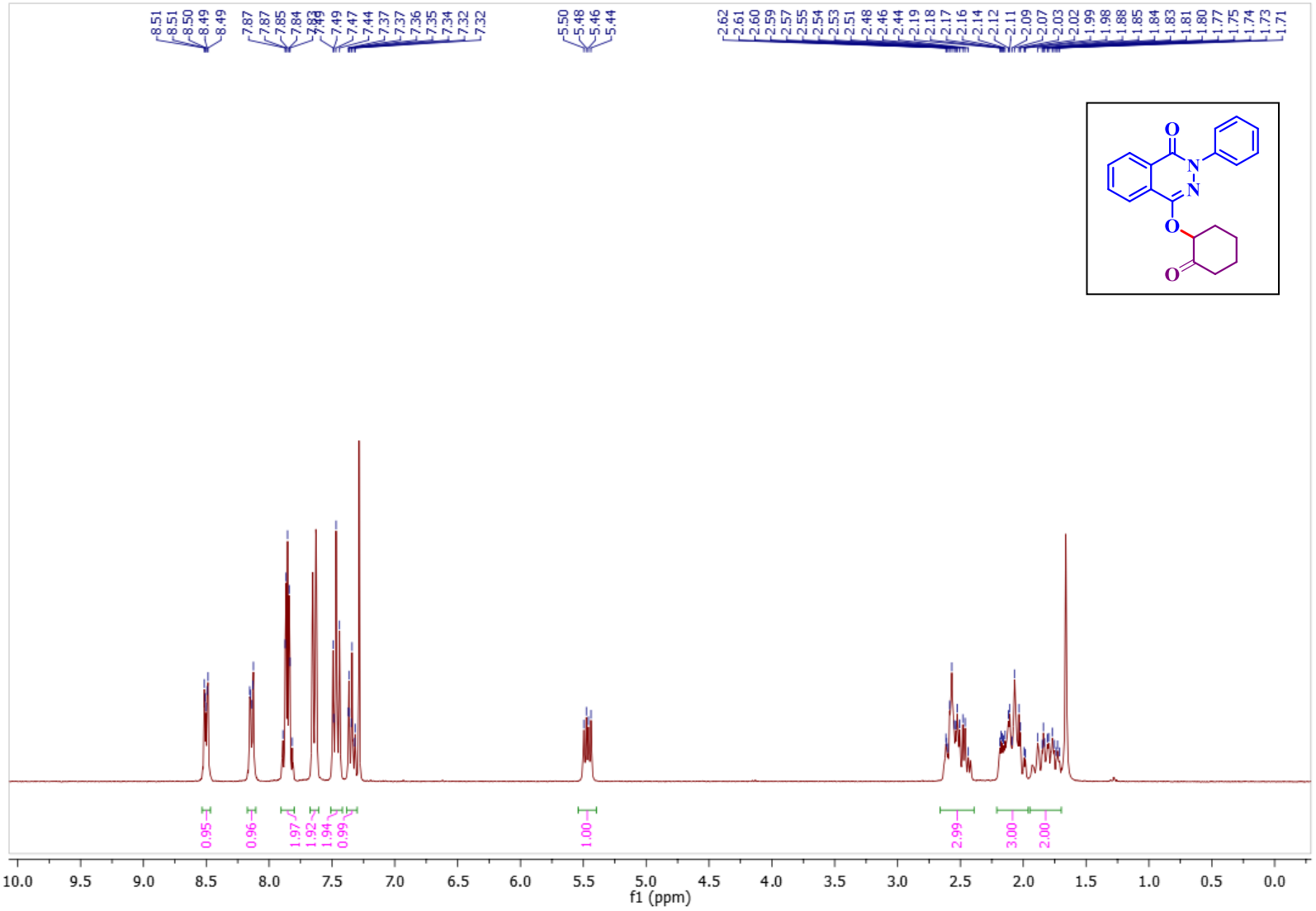
4-(2-oxo-1-((4-oxo-3-(p-tolyl)-3,4-dihydrophthalazin-1-yl)oxy)-2-(p-tolyl)ethoxy)-2-phenylphthalazin-1(2*H*)-one (3zg): ^{1}H NMR (300 MHz, $CDCl_3$):



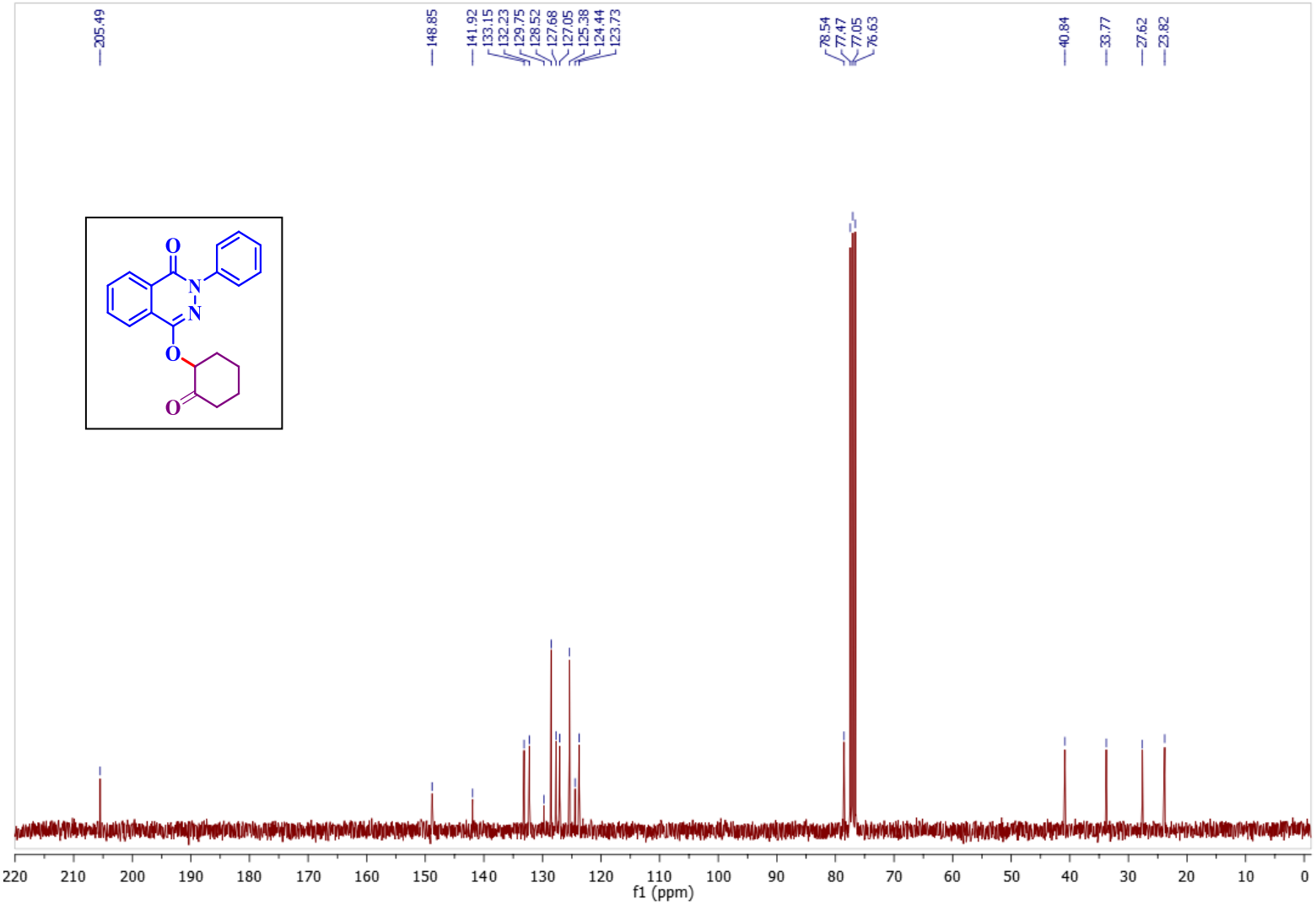
4-(2-oxo-1-((4-oxo-3-(p-tolyl)-3,4-dihydrophthalazin-1-yl)oxy)-2-(p-tolyl)ethoxy)-2-phenylphthalazin-1(2*H*)-one (3y): ^{13}C NMR (75 MHz, $CDCl_3$):



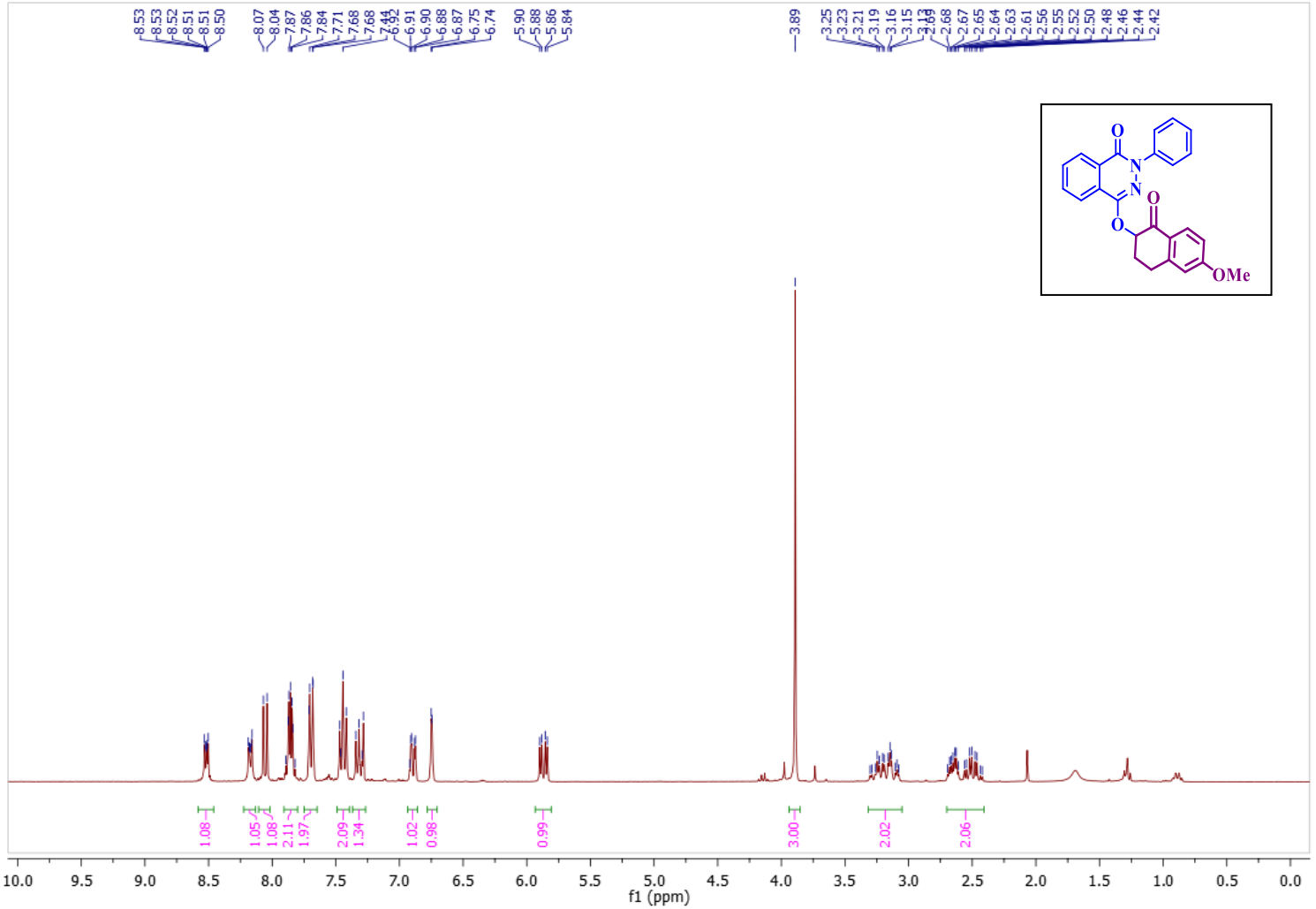
4-((2-oxocyclohexyl)oxy)-2-phenylphthalazin-1(2*H*)-one: (3ab): ^{1}H NMR (300 MHz, $CDCl_3$):



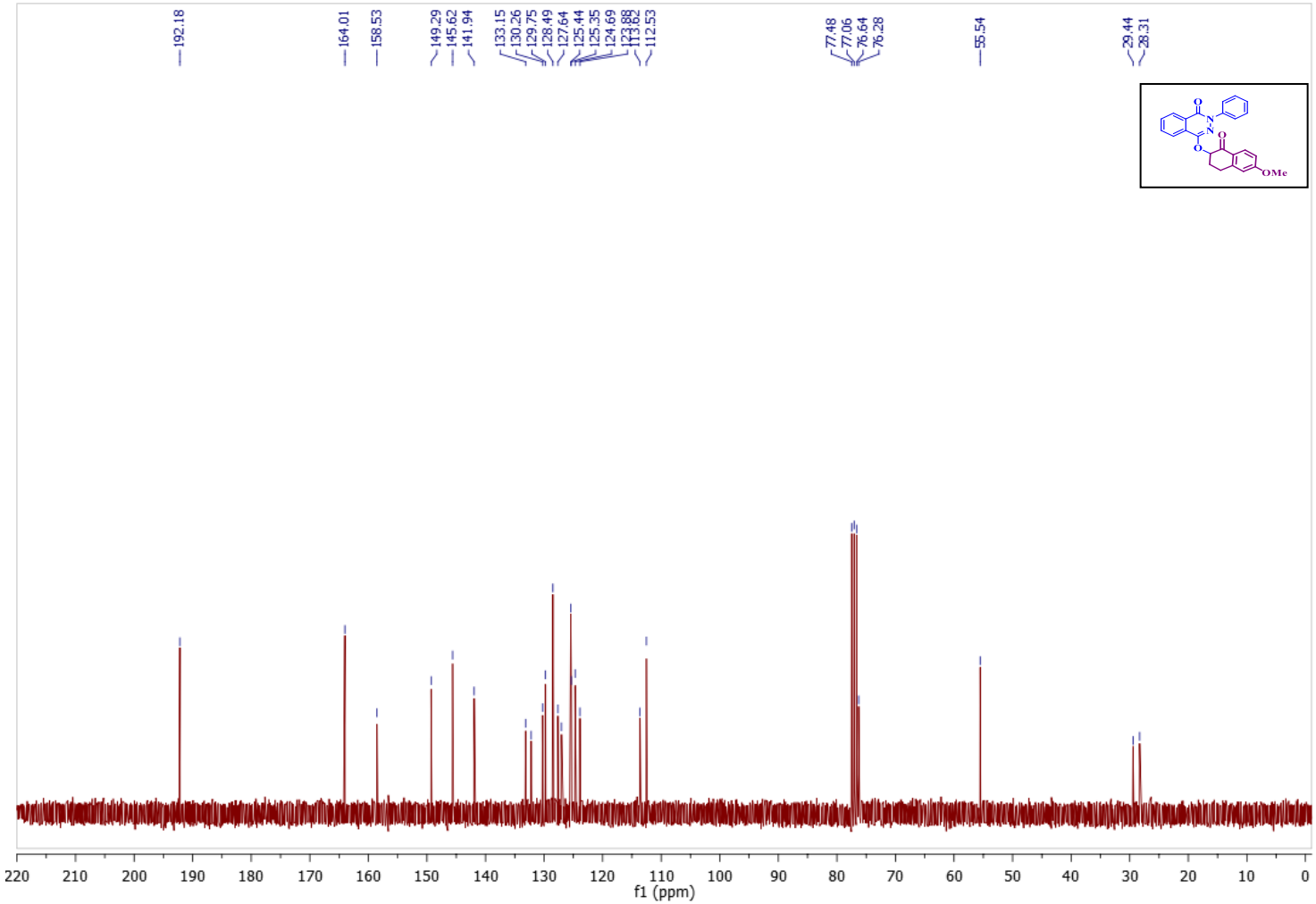
4-((2-oxocyclohexyl)oxy)-2-phenylphthalazin-1(2*H*)-one: (3ab): ^{13}C NMR (75 MHz, $CDCl_3$):



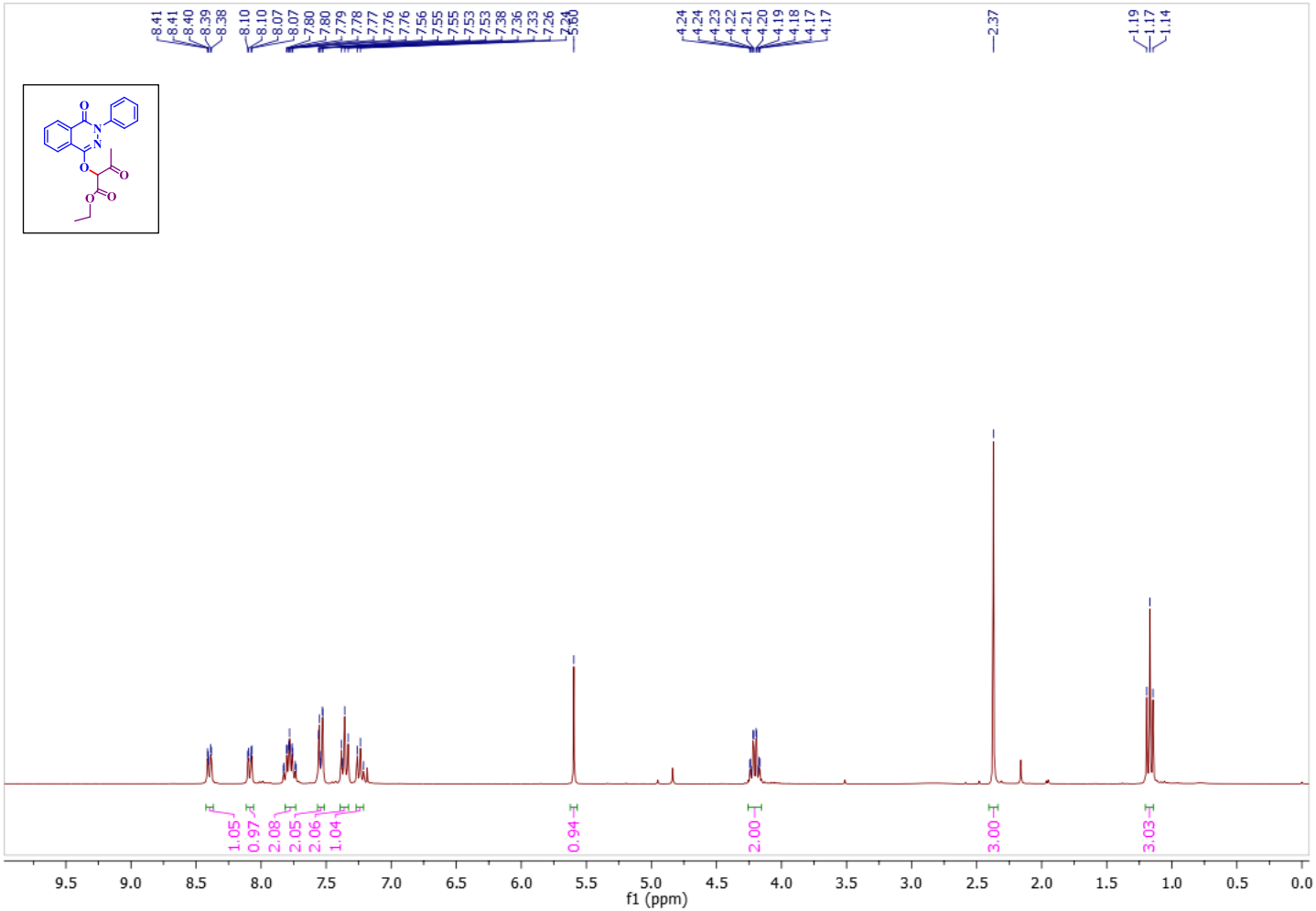
4-((6-methoxy-1-oxo-1,2,3,4-tetrahydronaphthalen-2-yl)oxy)-2-phenylphthalazin-1(2*H*)-one (3ac): ^{1}H NMR (300 MHz, $CDCl_3$):



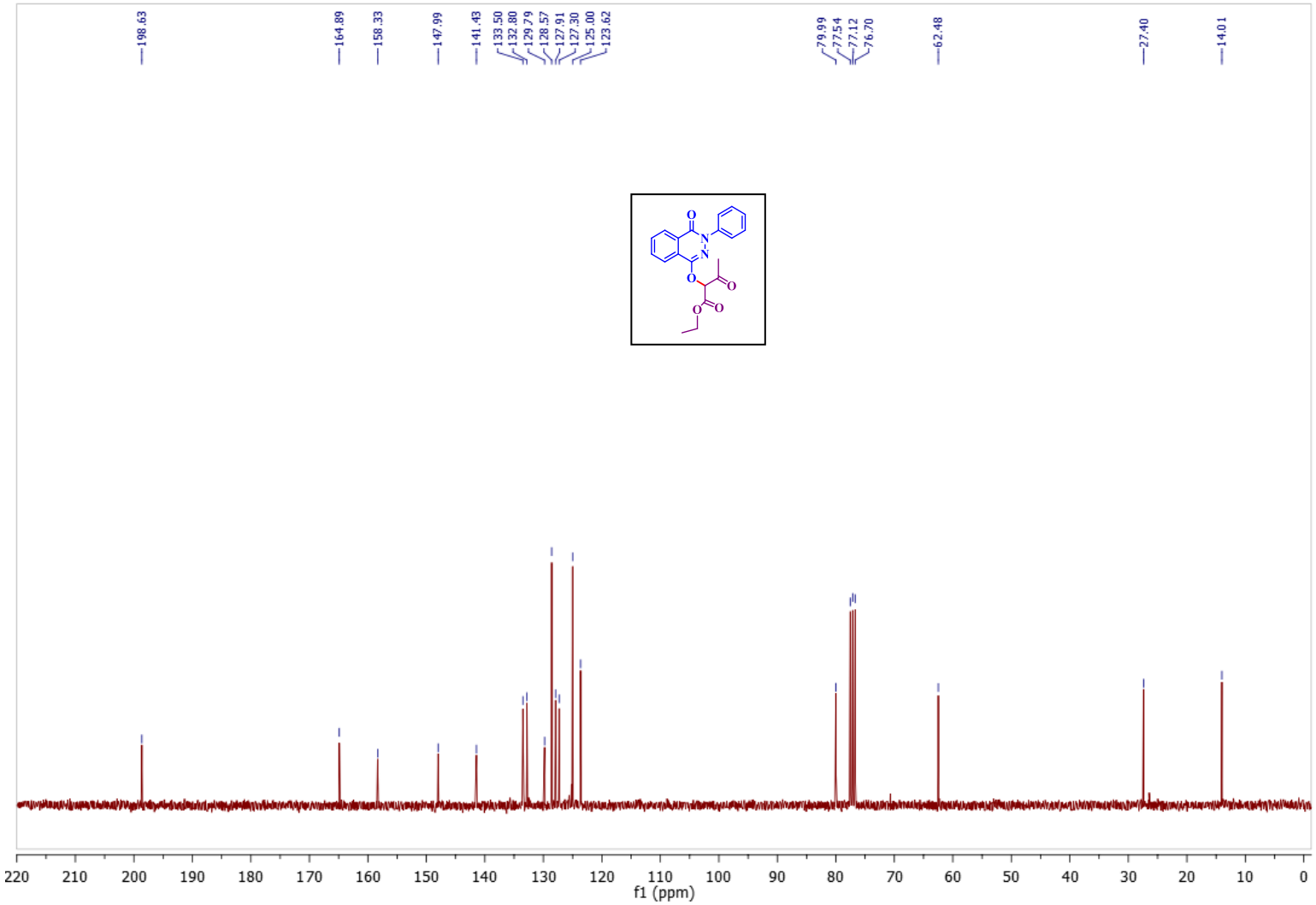
4-((6-methoxy-1-oxo-1,2,3,4-tetrahydronaphthalen-2-yl)oxy)-2-phenylphthalazin-1(2*H*)-one (3ac):^{13}C NMR (75 MHz, $CDCl_3$):



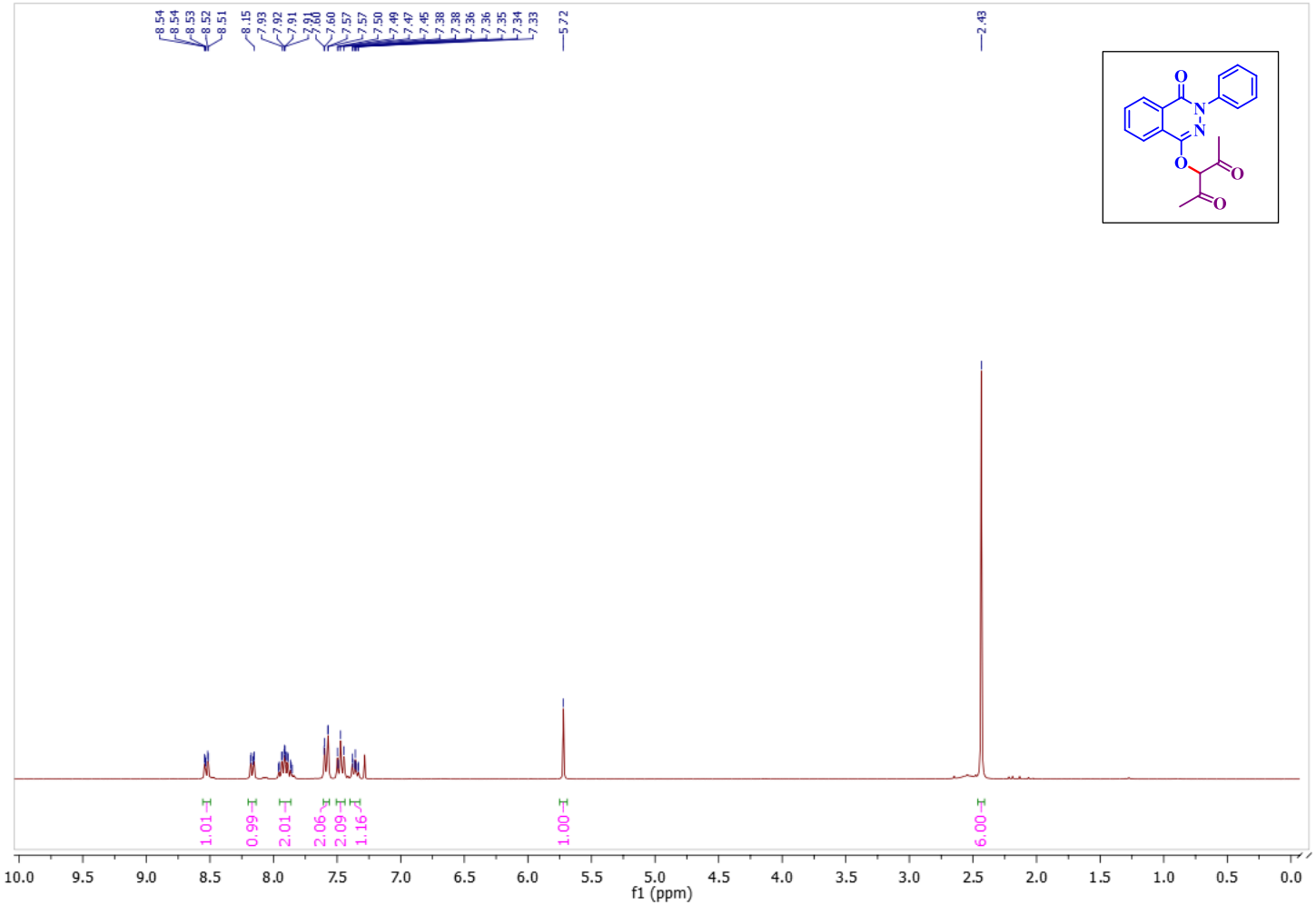
ethyl 3-oxo-2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)butanoate (3ad):^{1}H NMR (300 MHz, $CDCl_3$):



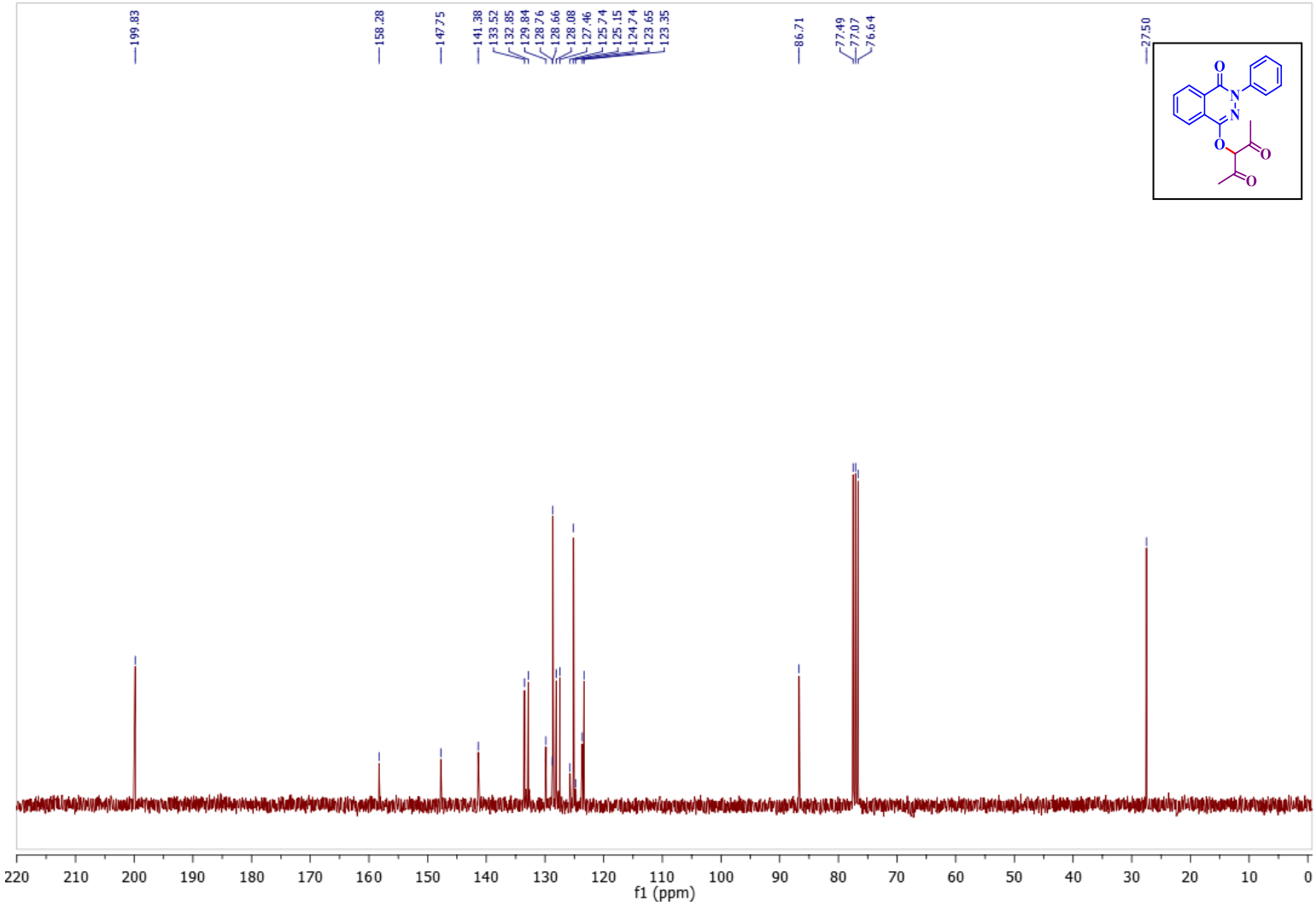
ethyl 3-oxo-2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)butanoate (3ad):^{13}C NMR (75 MHz, $CDCl_3$):



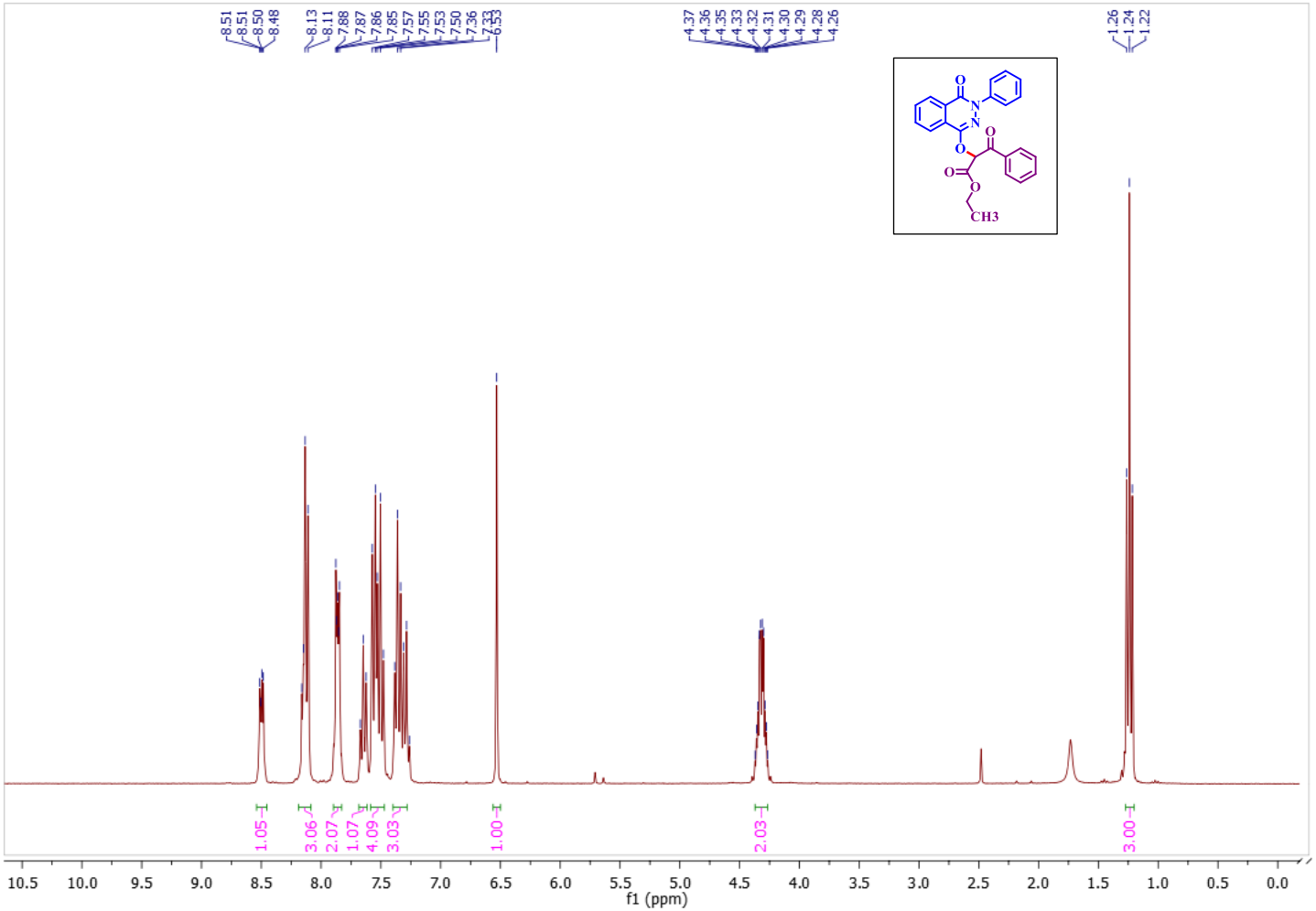
3-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)pentane-2,4-dione (3ae): ^{1}H NMR (300 MHz, $CDCl_3$):



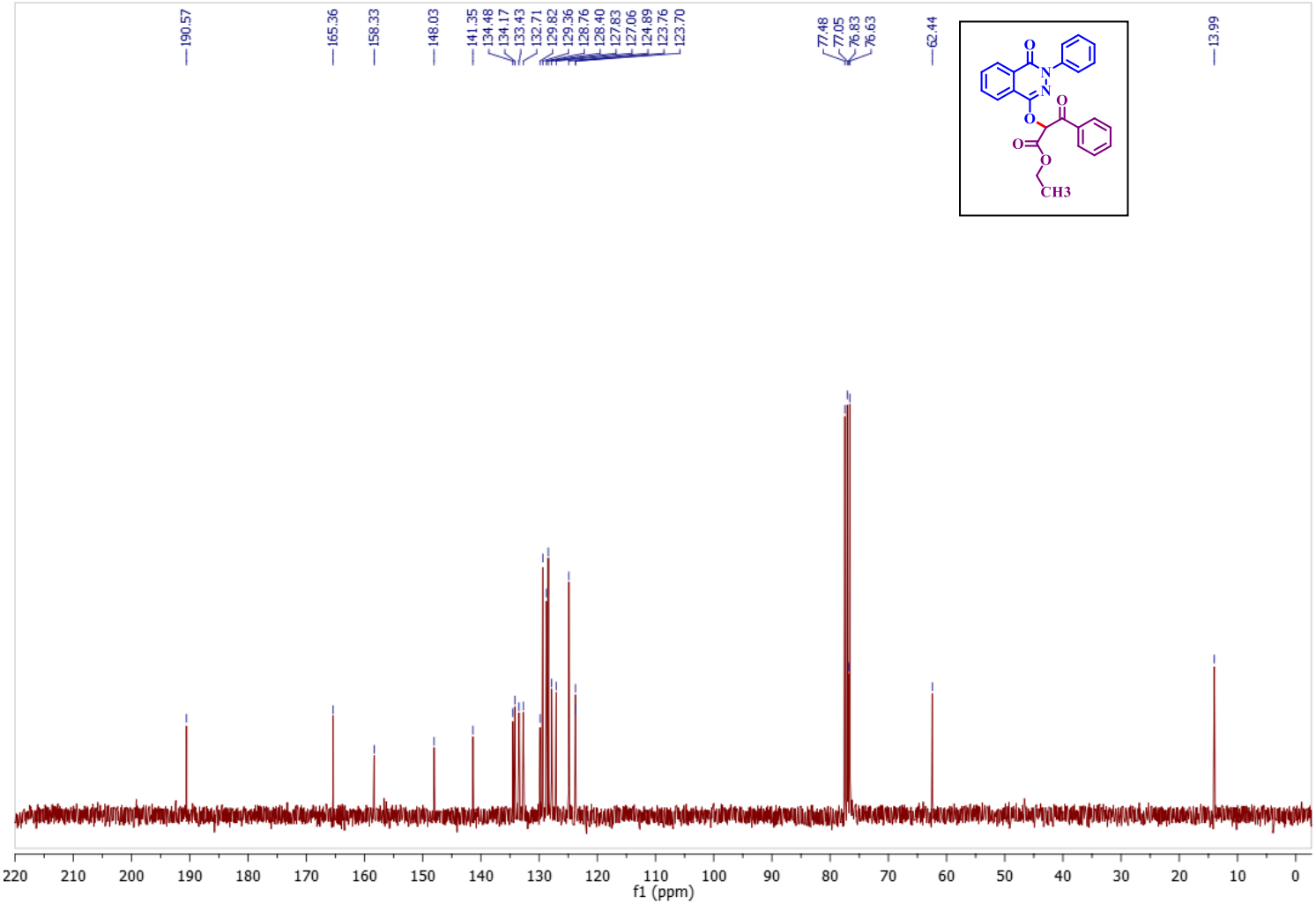
3-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)pentane-2,4-dione (3ae): ^{1}H NMR (300 MHz, $CDCl_3$):



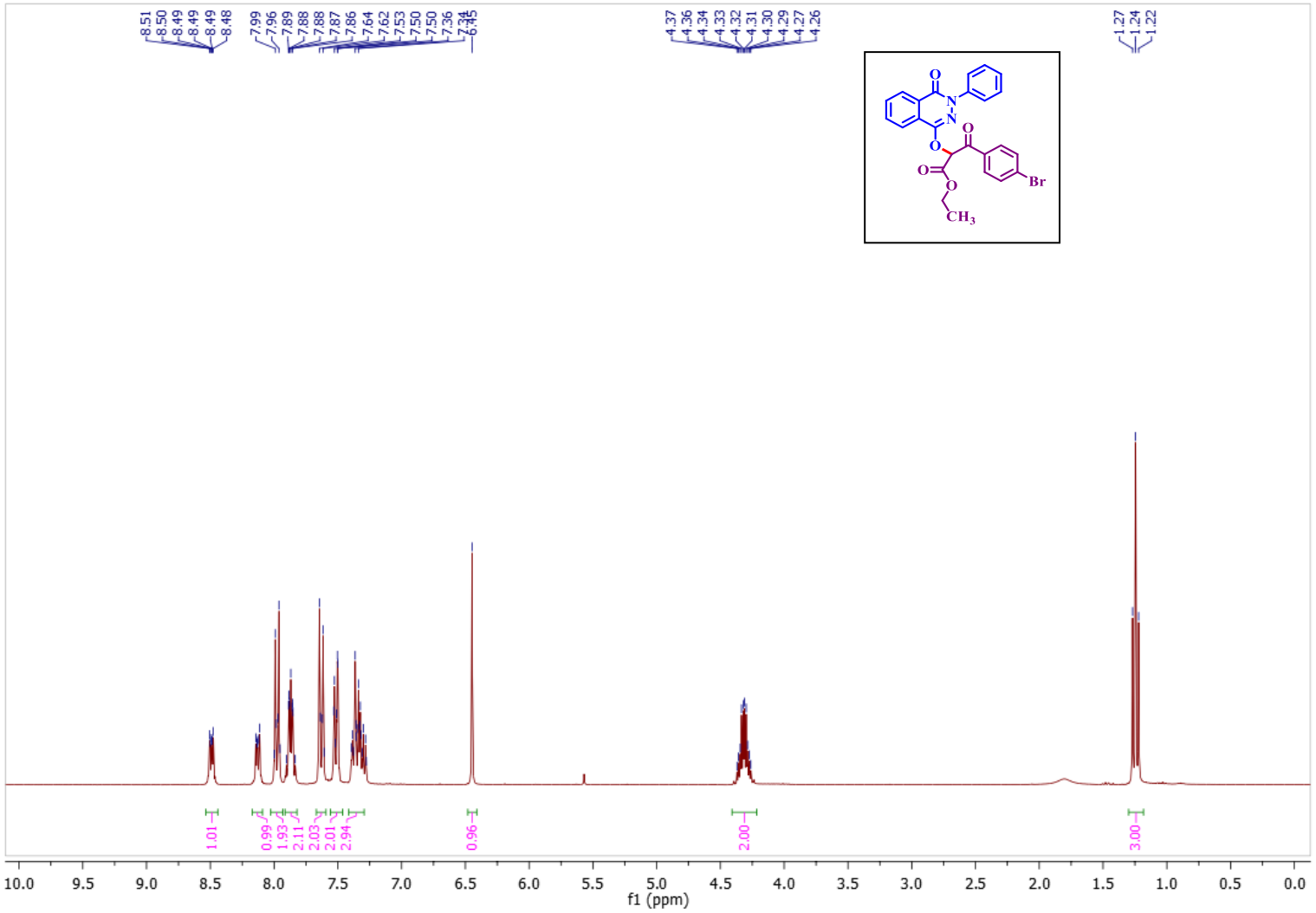
ethyl 3-oxo-2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)-3-phenylpropanoate (3af): ^{1}H NMR (300 MHz, $CDCl_3$):



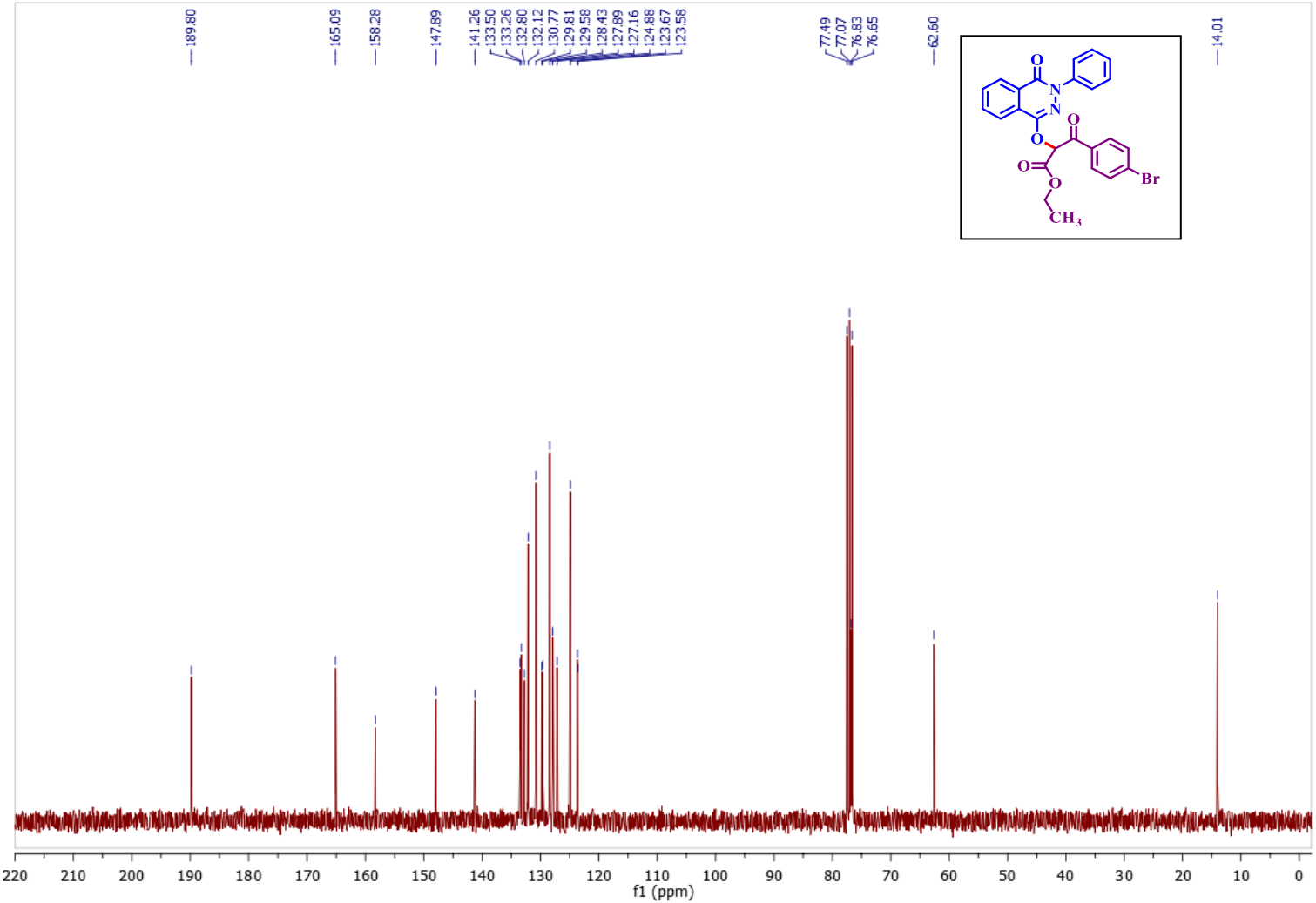
ethyl 3-oxo-2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)-3-phenylpropanoate (3af): ^{1}H NMR (300 MHz, $CDCl_3$):



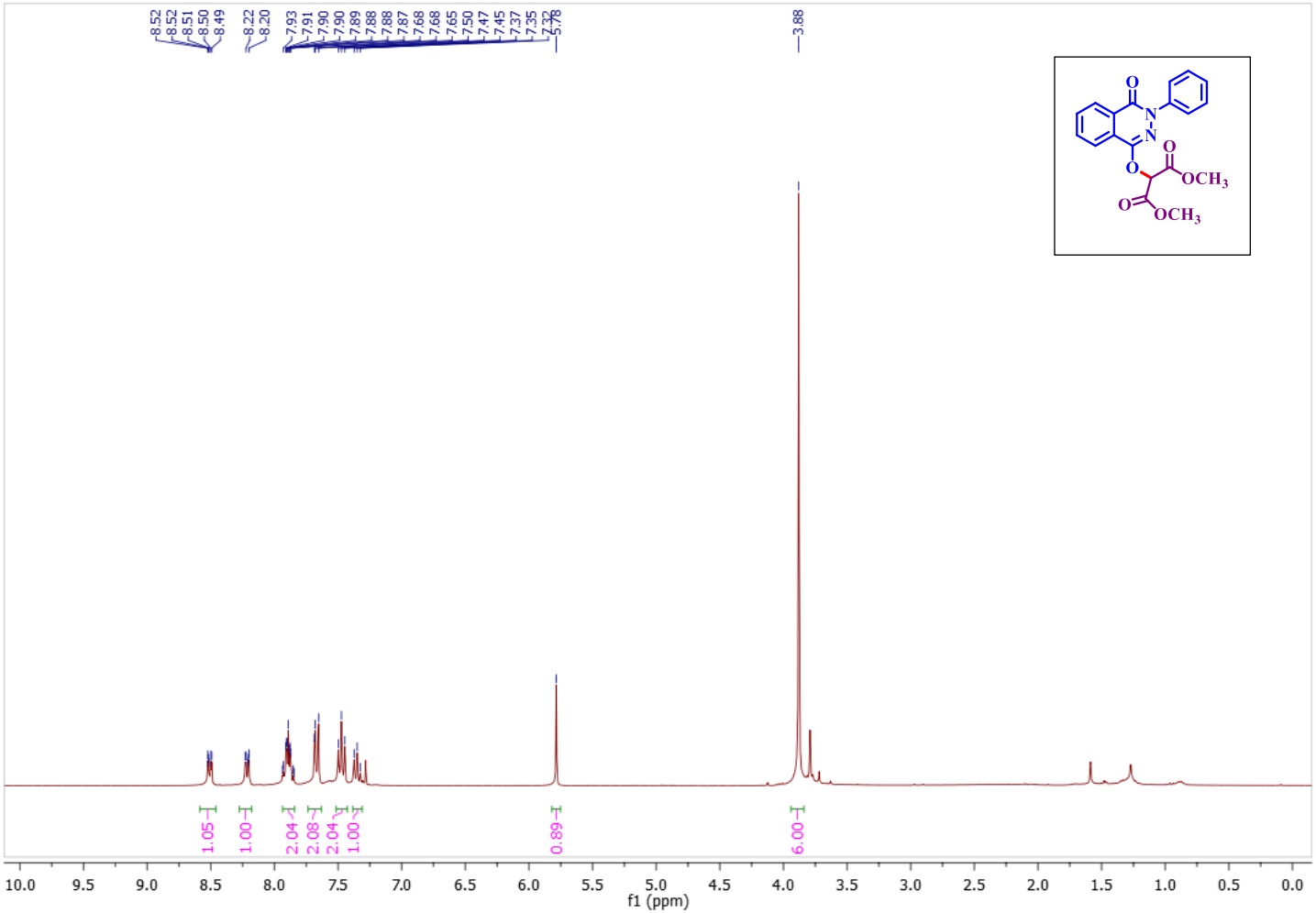
ethyl 3-(4-bromophenyl)-3-oxo-2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)propanoate (3ag): ^{1}H NMR (300 MHz, $CDCl_3$):



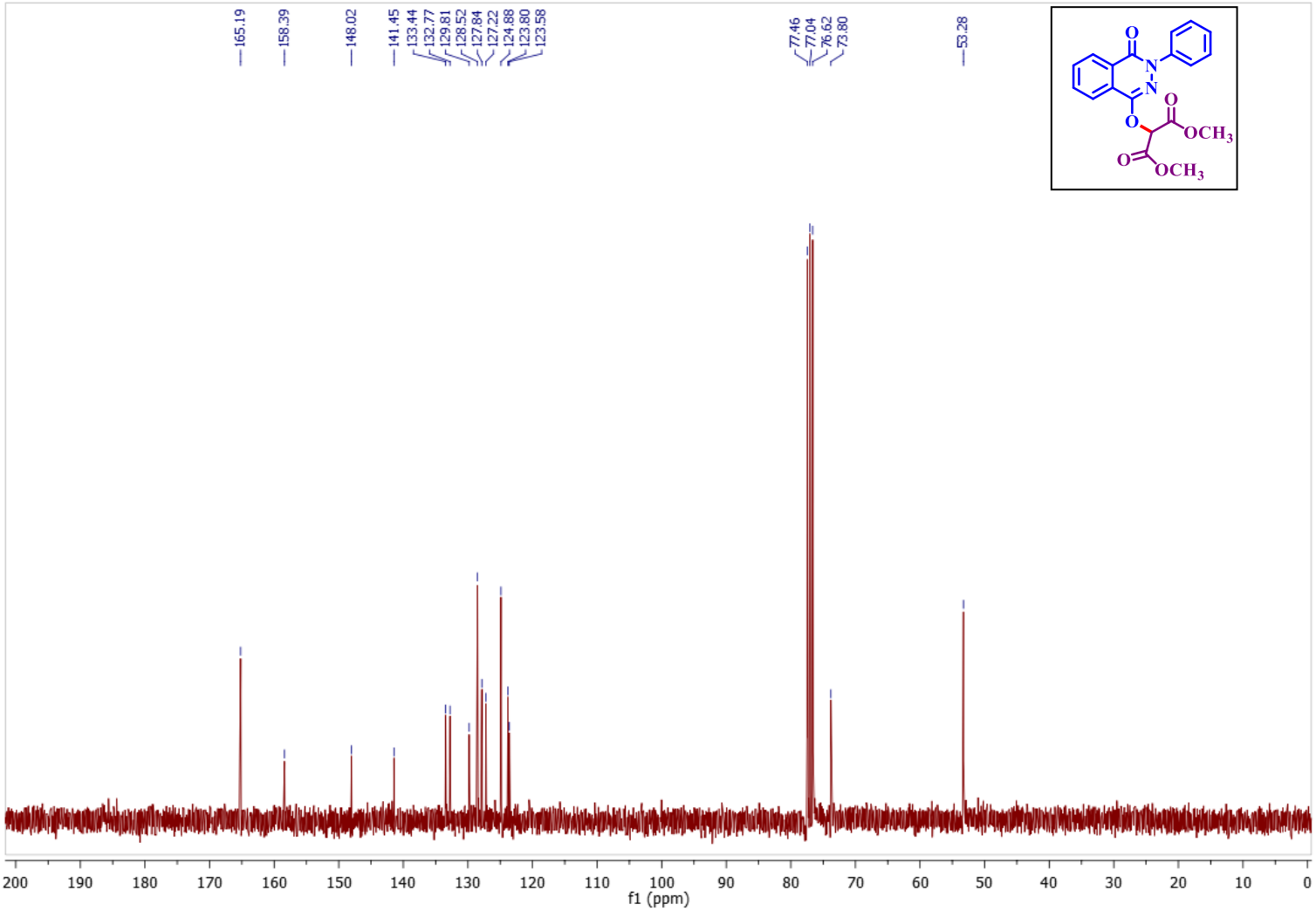
ethyl 3-(4-bromophenyl)-3-oxo-2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)propanoate (3ag): ^{13}C NMR (75 MHz, $CDCl_3$):



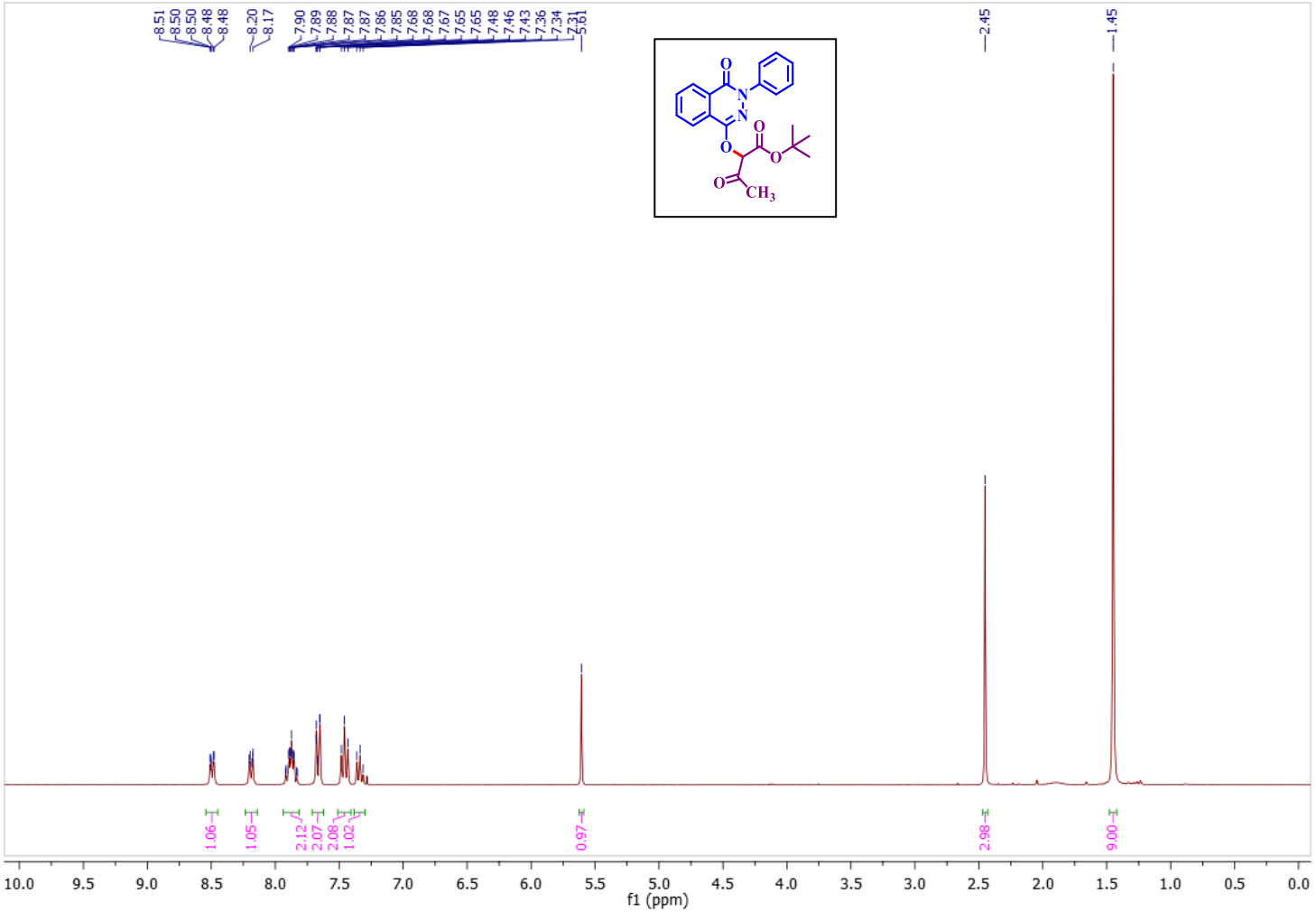
dimethyl 2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)malonate (3ah): ^{1}H NMR (300 MHz, $CDCl_3$):



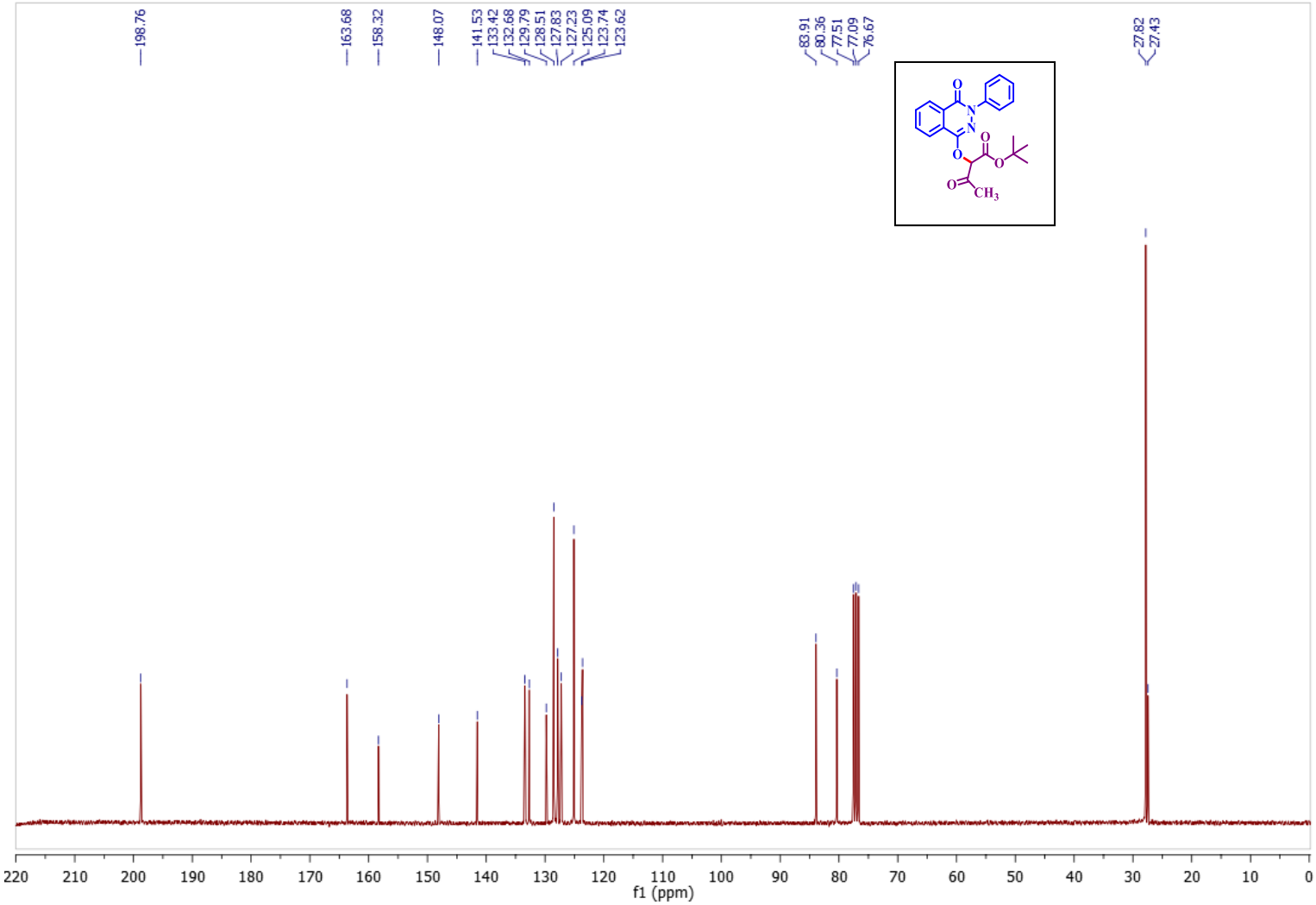
dimethyl 2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)malonate (3ah): ^{13}C NMR (75 MHz, $CDCl_3$):



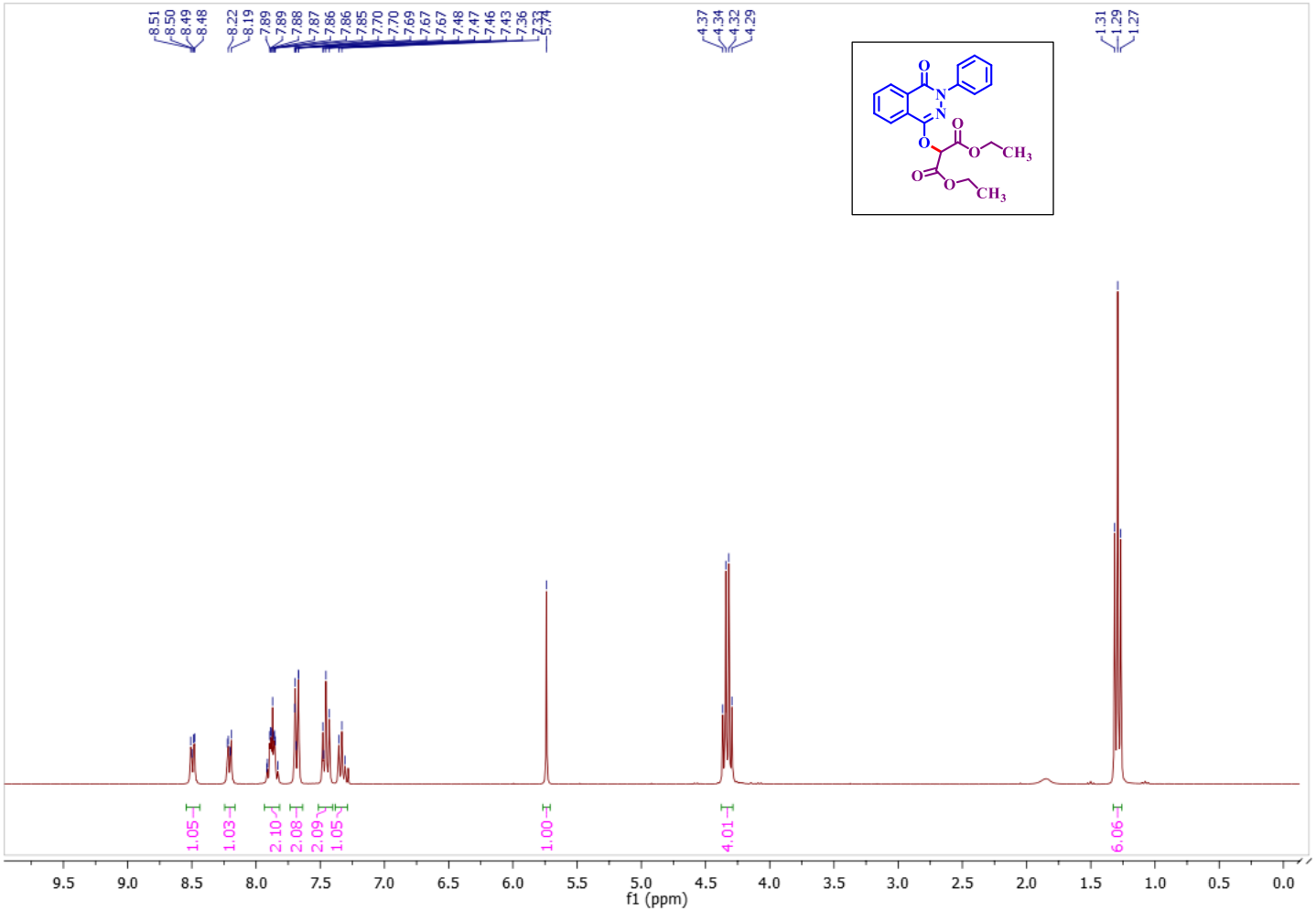
tert-butyl 3-oxo-2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)butanoate (3ai): ^{1}H NMR (300 MHz, $CDCl_3$):



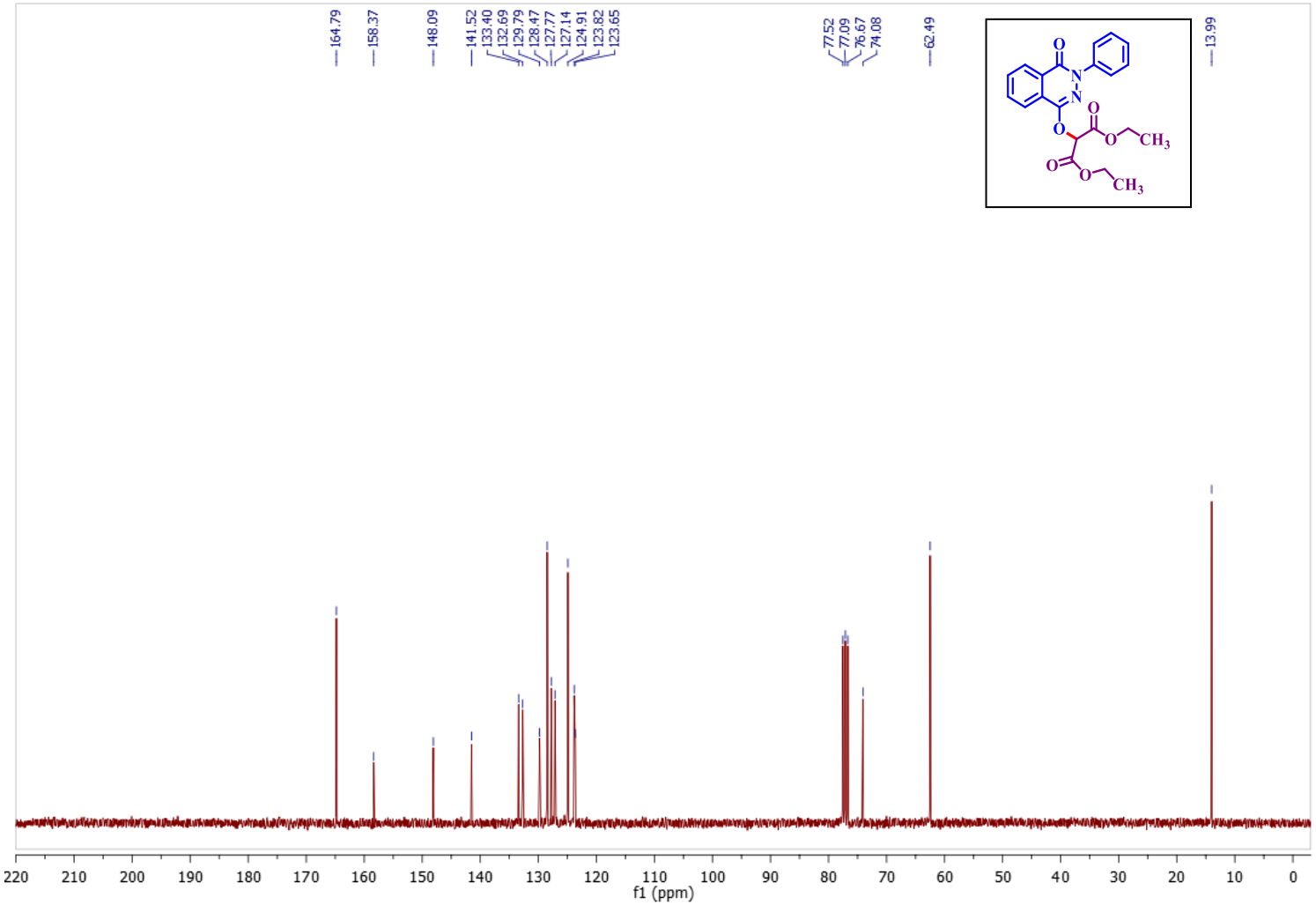
tert-butyl 3-oxo-2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)butanoate (3ai): ^{13}C NMR (75 MHz, $CDCl_3$):



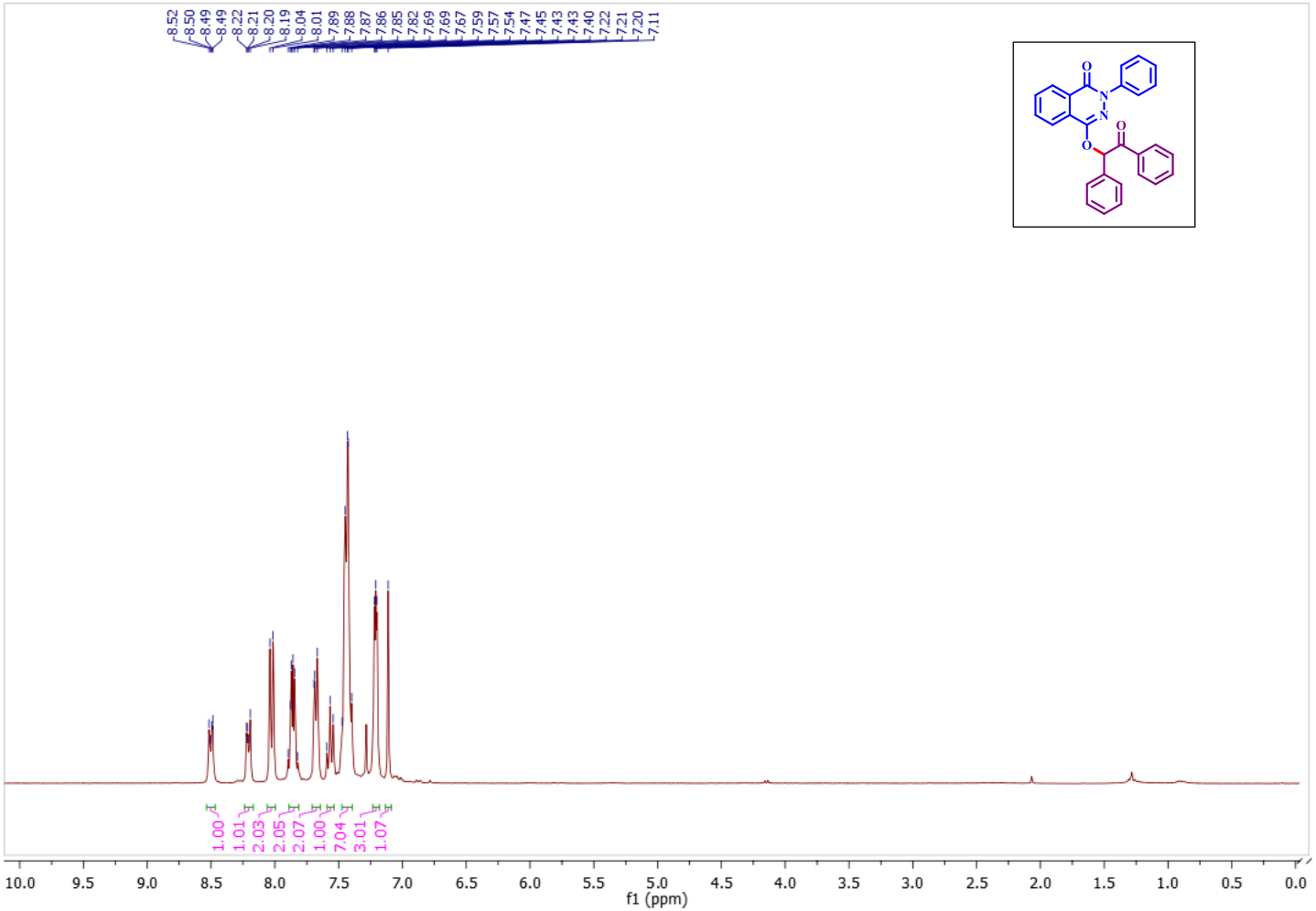
diethyl 2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)malonate (3aj): ^{1}H NMR (300 MHz, $CDCl_3$):



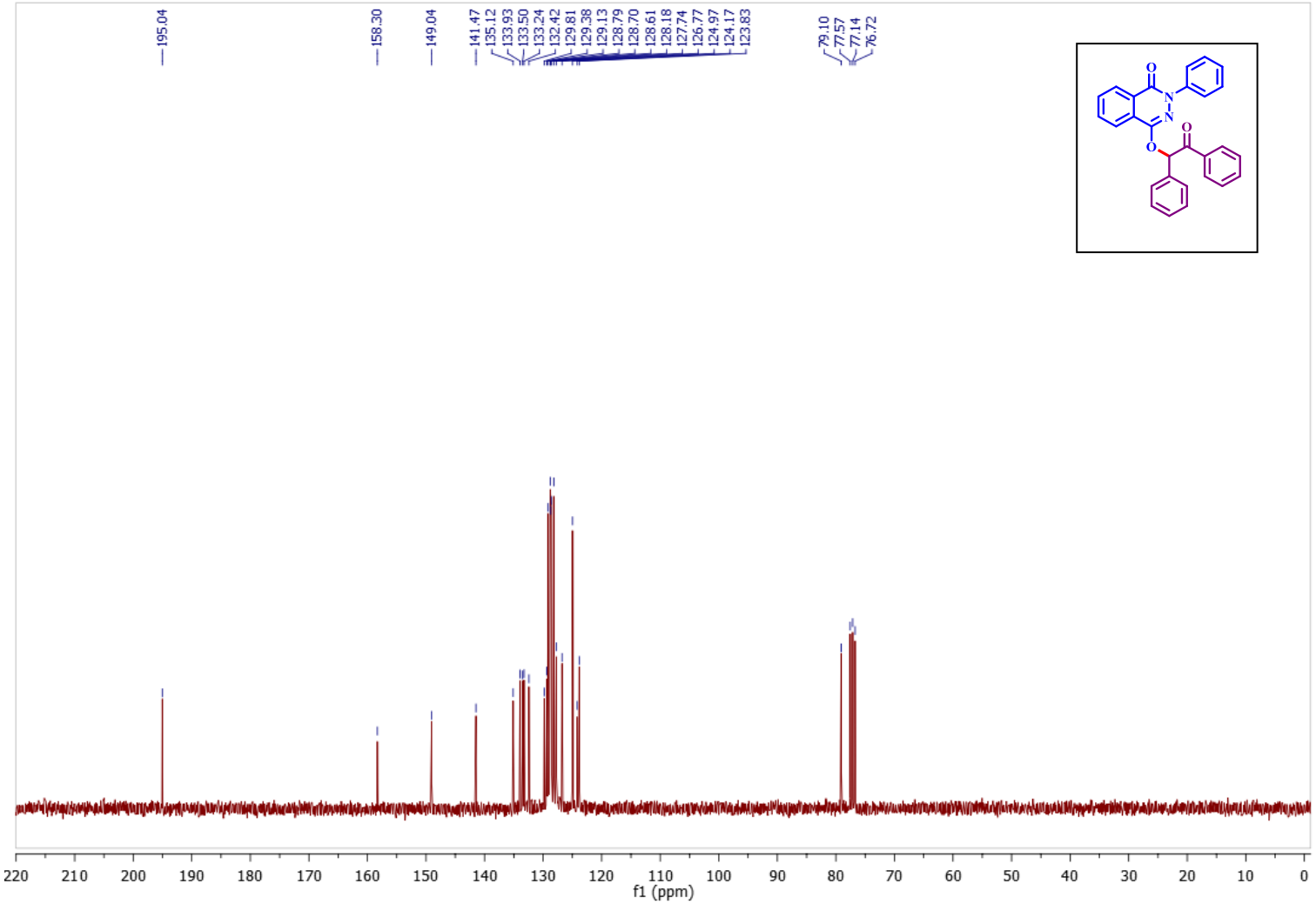
diethyl 2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)malonate (3aj): ^{13}C NMR (75 MHz, $CDCl_3$):



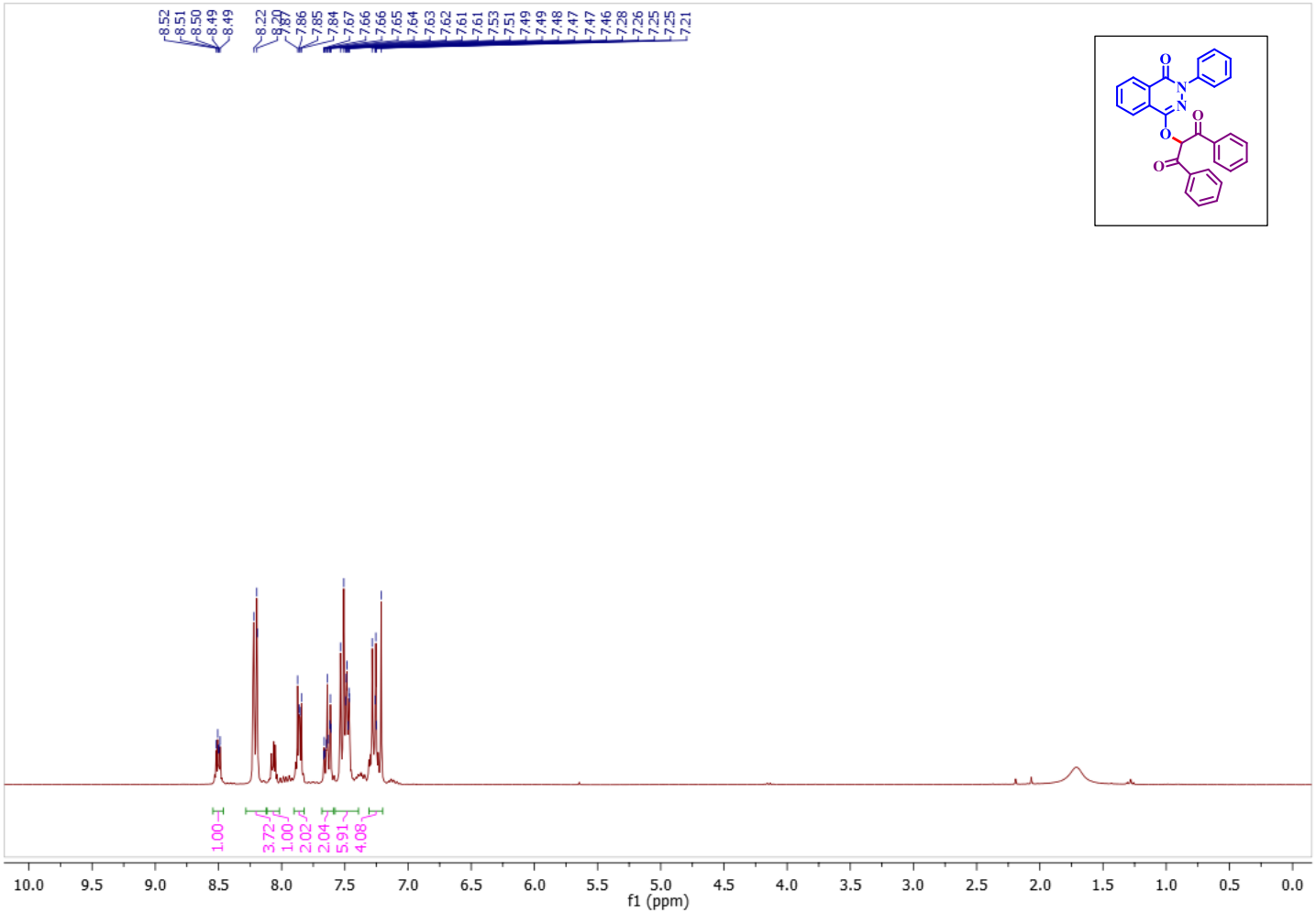
4-(2-oxo-1,2-diphenylethoxy)-2-phenylphthalazin-1(2*H*)-one (3ak): ^{1}H NMR (300 MHz, $CDCl_3$):



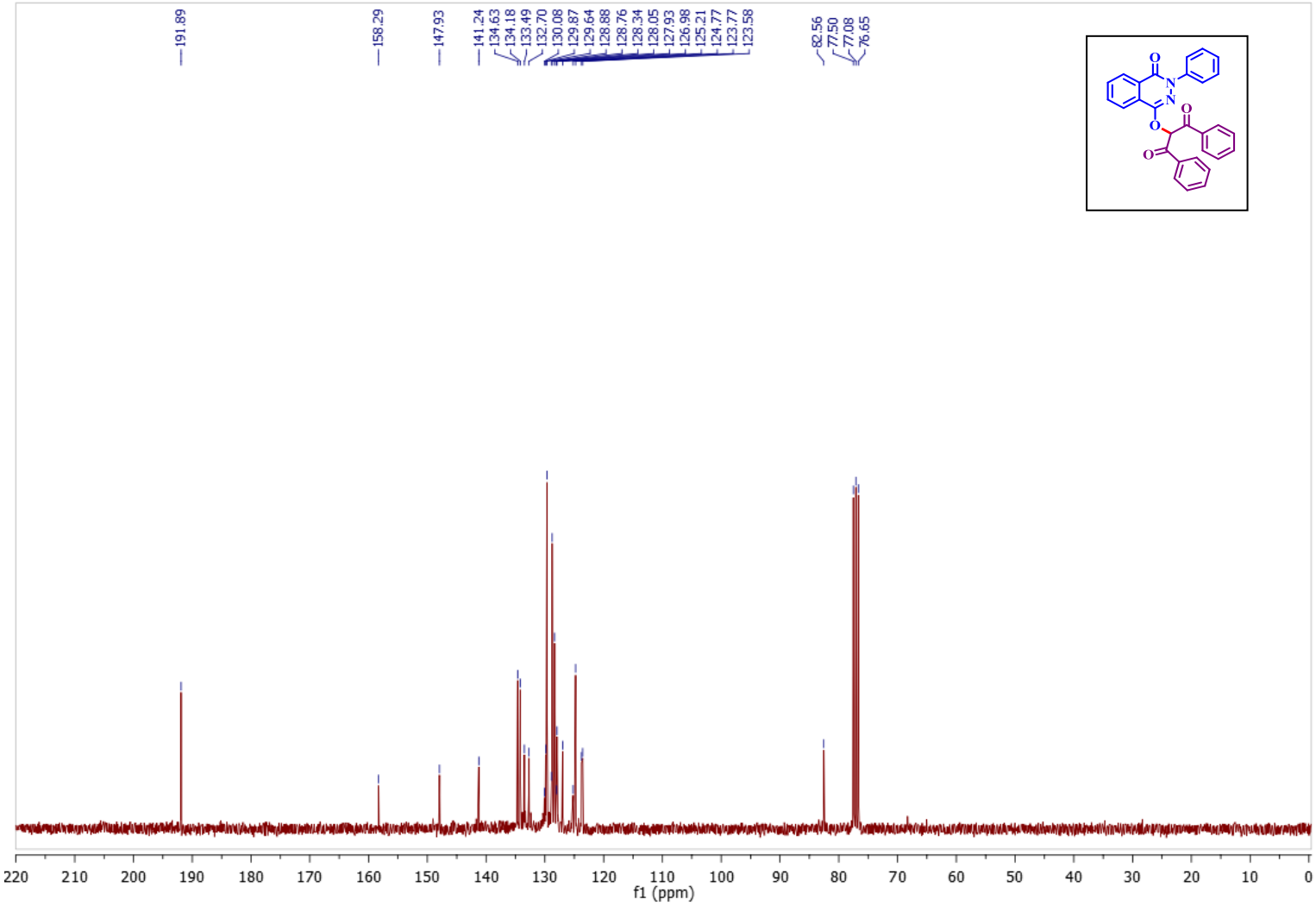
4-(2-oxo-1,2-diphenylethoxy)-2-phenylphthalazin-1(2*H*)-one (3ak): ^{13}C NMR (75 MHz, $CDCl_3$):



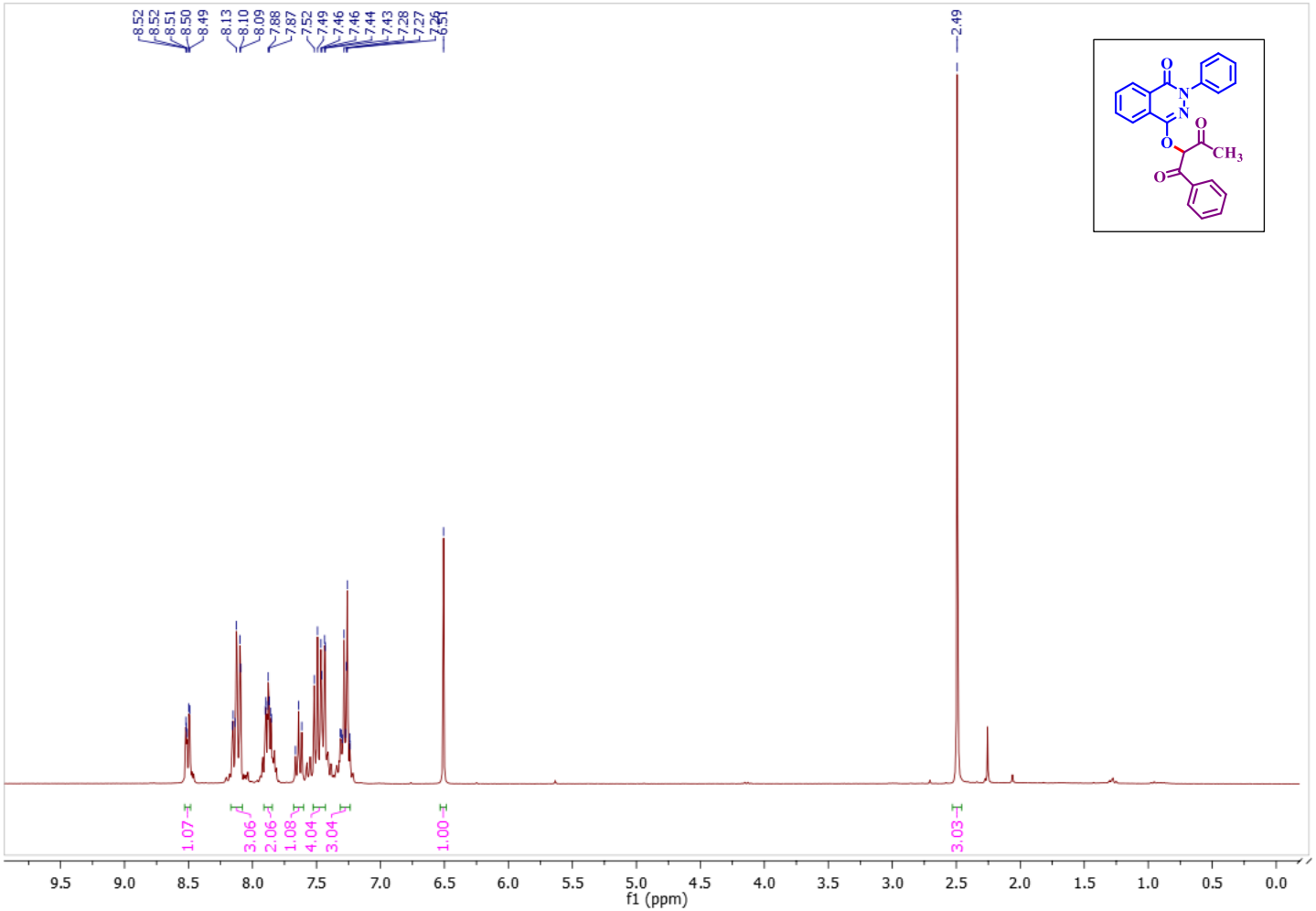
2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)-1,3-diphenylpropane-1,3-dione (3al): ^{1}H NMR (300 MHz, $CDCl_3$):



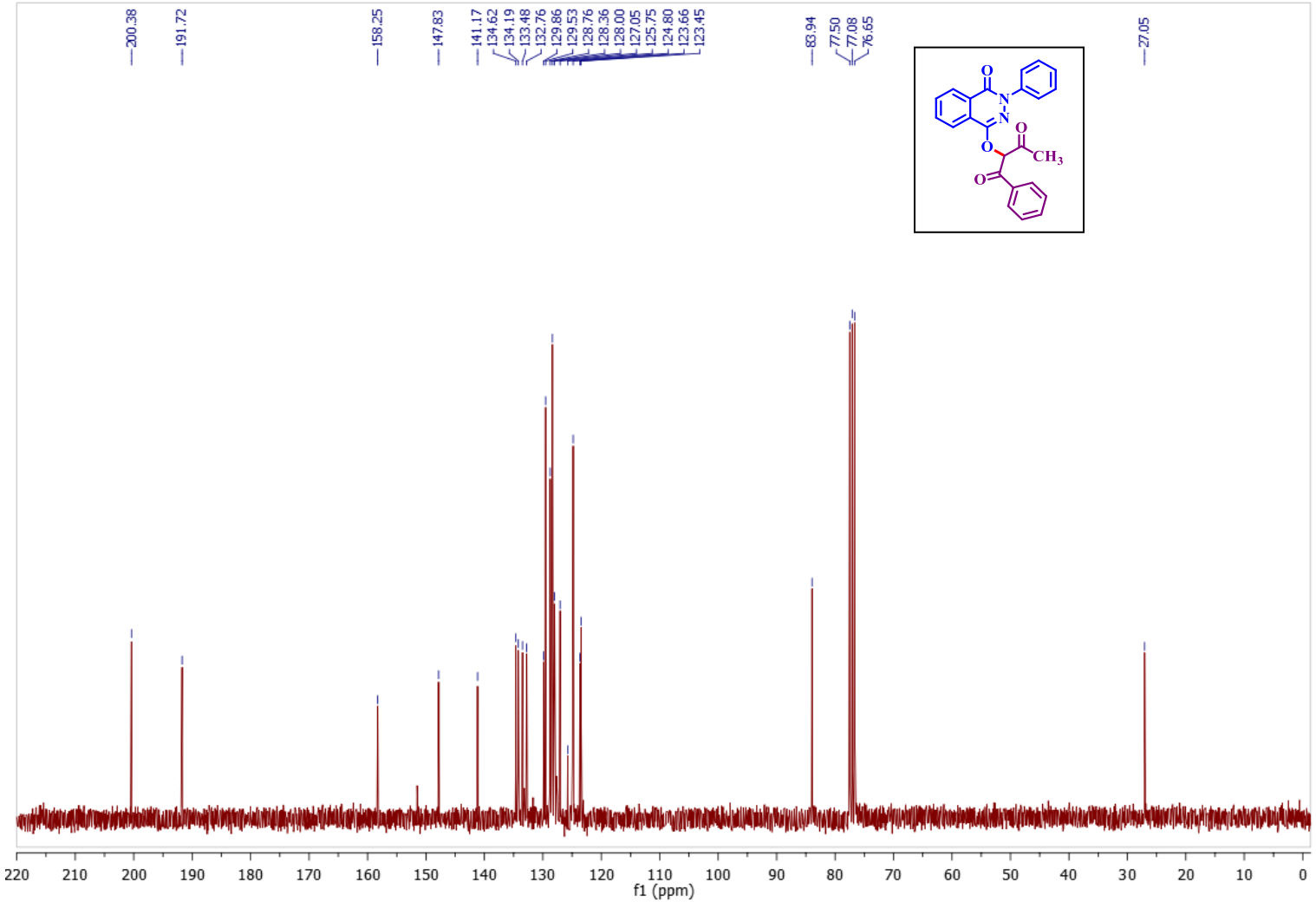
2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)-1,3-diphenylpropane-1,3-dione (3al): ^{13}C NMR (75 MHz, $CDCl_3$):



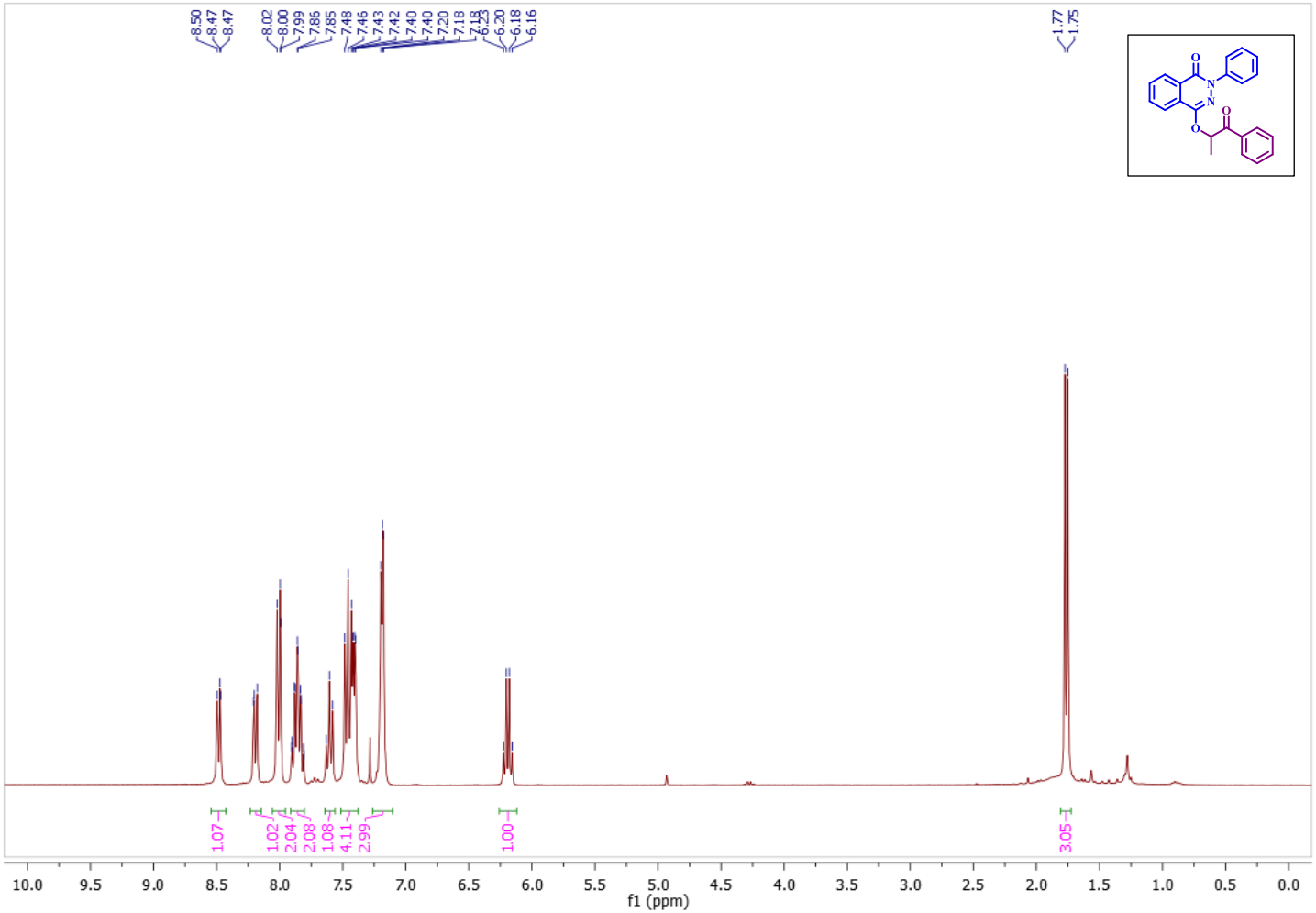
2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)-1-phenylbutane-1,3-dione (3am): ^{1}H NMR (300 MHz, $CDCl_3$):



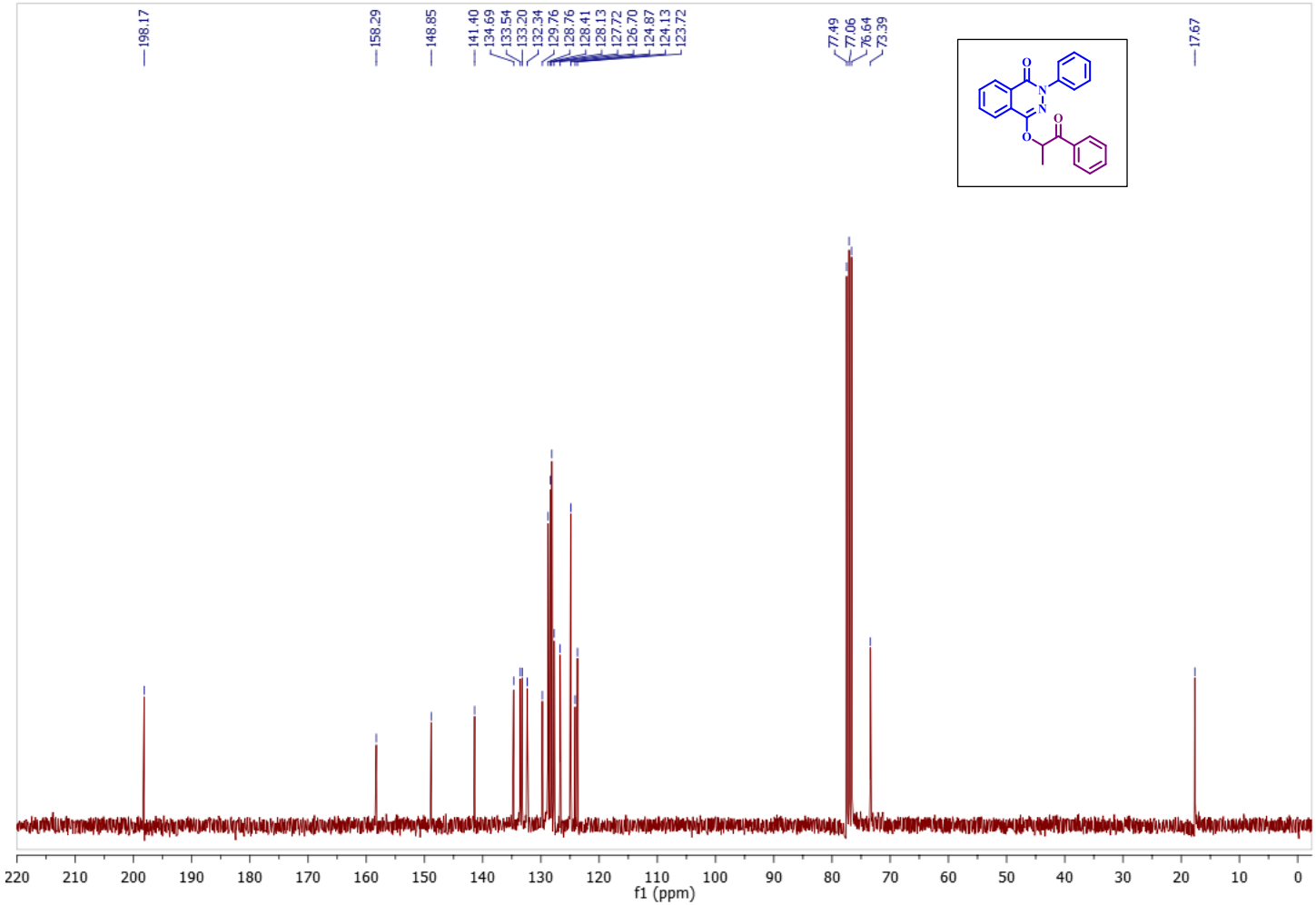
2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)-1-phenylbutane-1,3-dione (3am): ^{13}C NMR (75 MHz, $CDCl_3$):



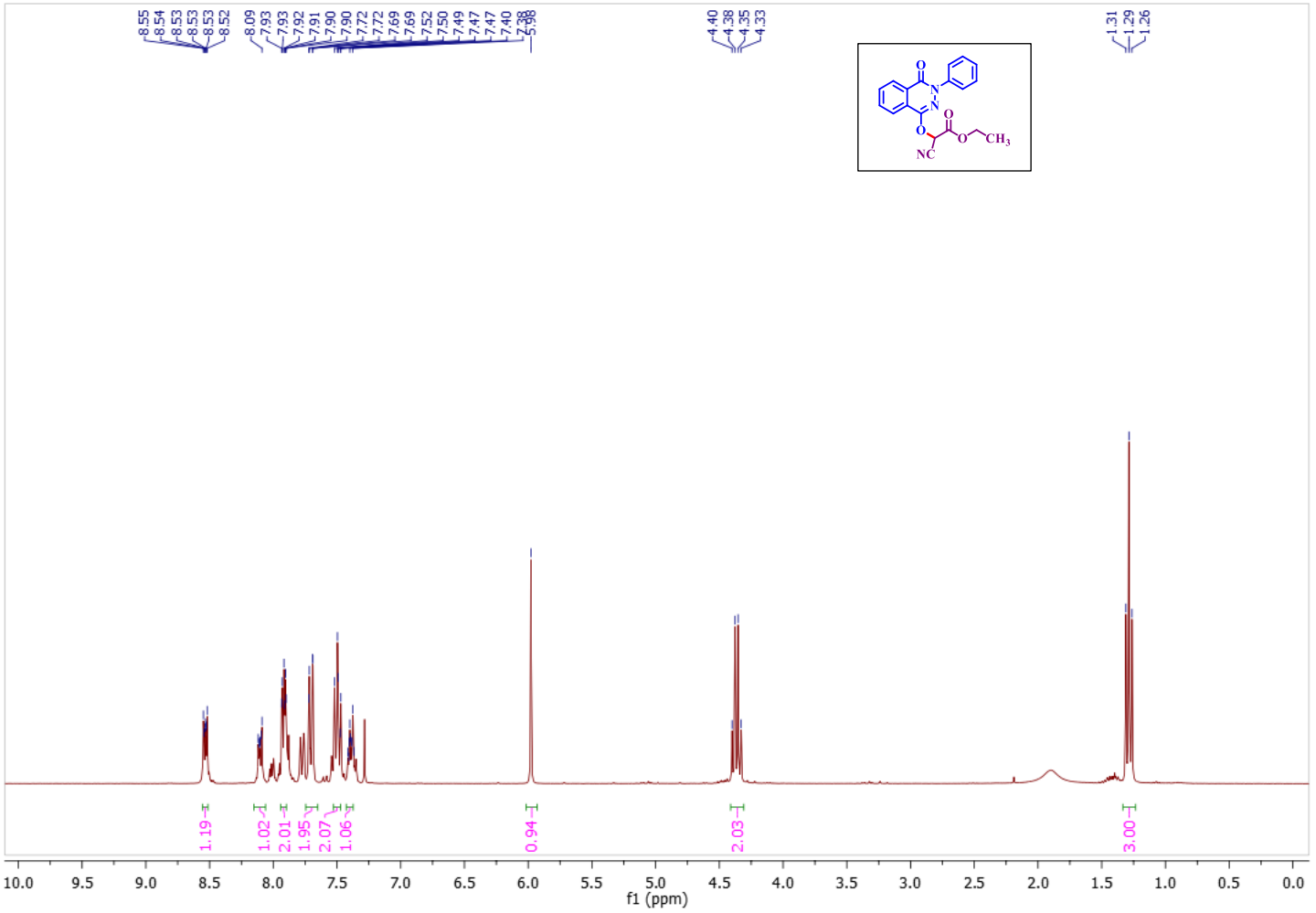
4-((1-oxo-1-phenylpropan-2-yl)oxy)-2-phenylphthalazin-1(2*H*)-one (3an): ^{1}H NMR (300 MHz, $CDCl_3$):



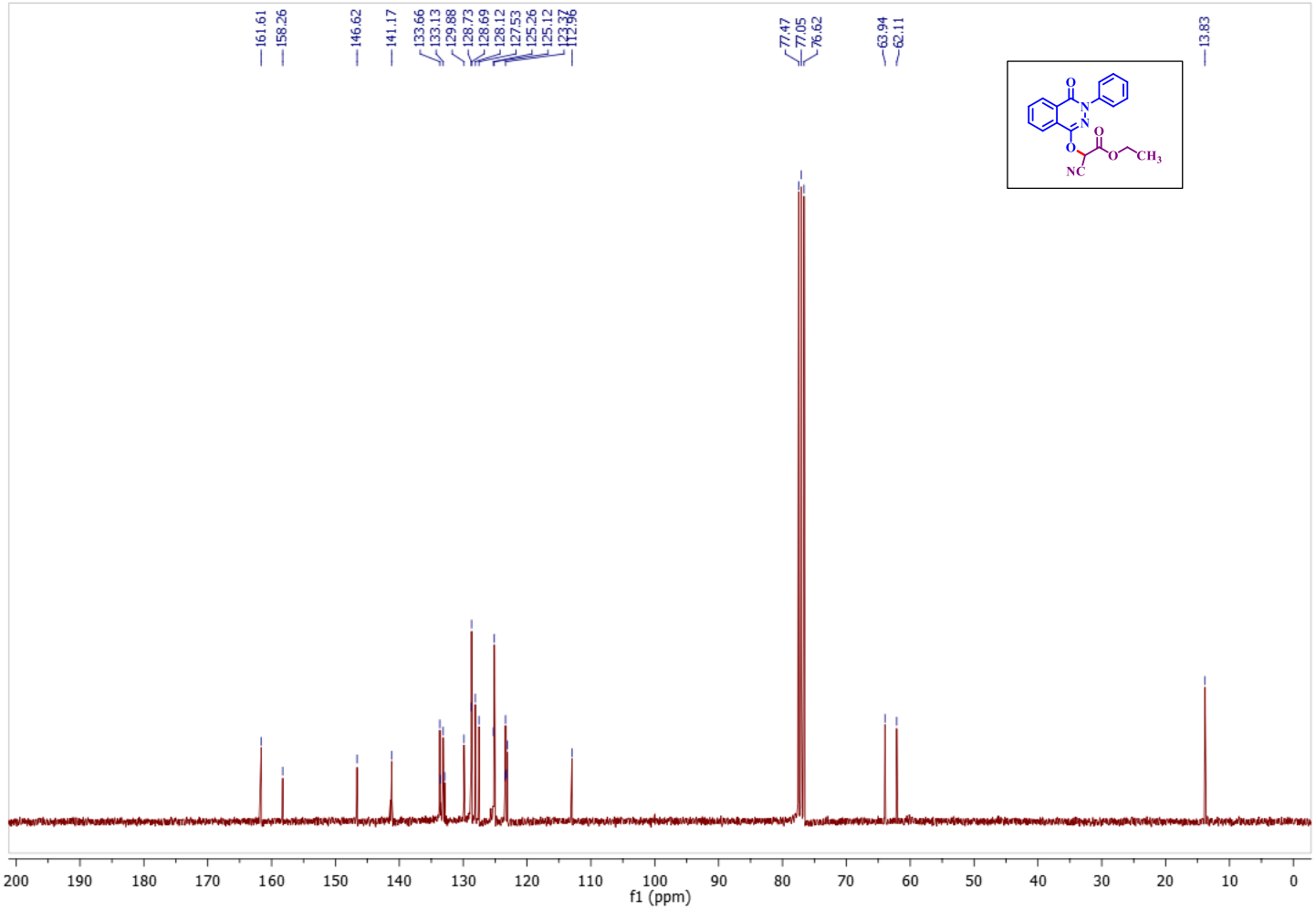
4-((1-oxo-1-phenylpropan-2-yl)oxy)-2-phenylphthalazin-1(2*H*)-one (3an): ^{13}C NMR (75 MHz, $CDCl_3$):



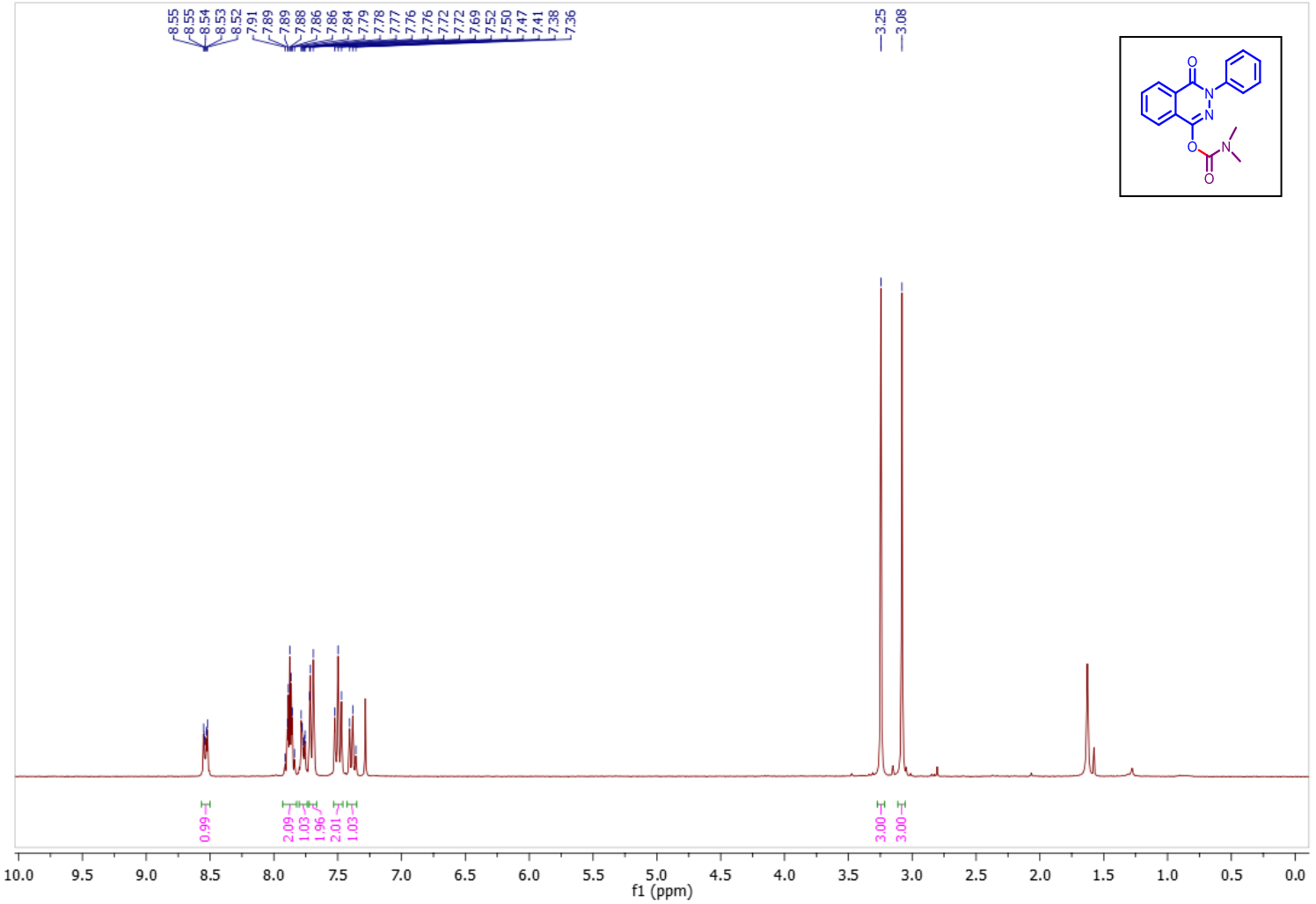
ethyl 2-cyano-2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)acetate (3ao): ^{1}H NMR (300 MHz, $CDCl_3$):



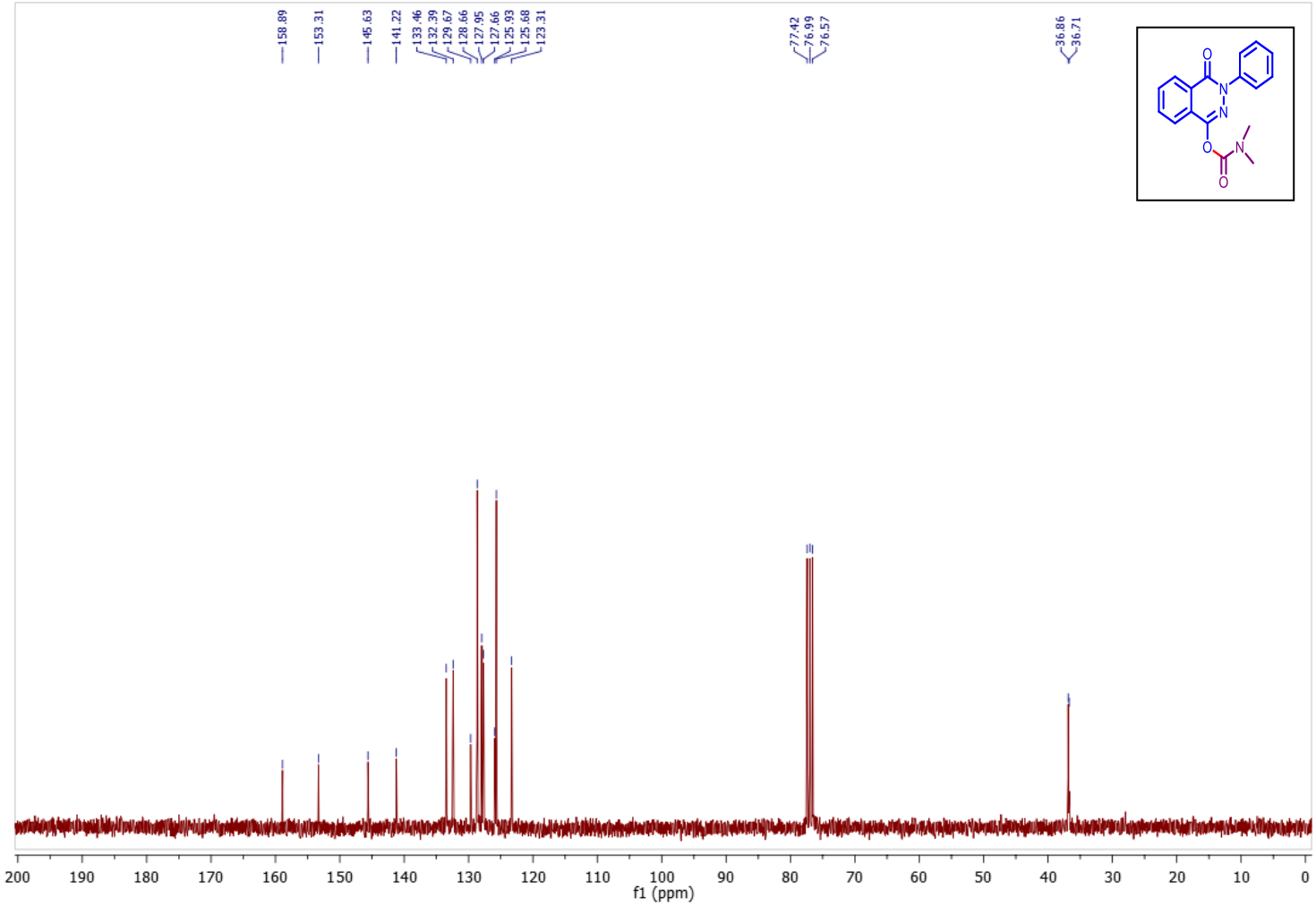
ethyl 2-cyano-2-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)acetate (3ao): ^{13}C NMR (75 MHz, $CDCl_3$):



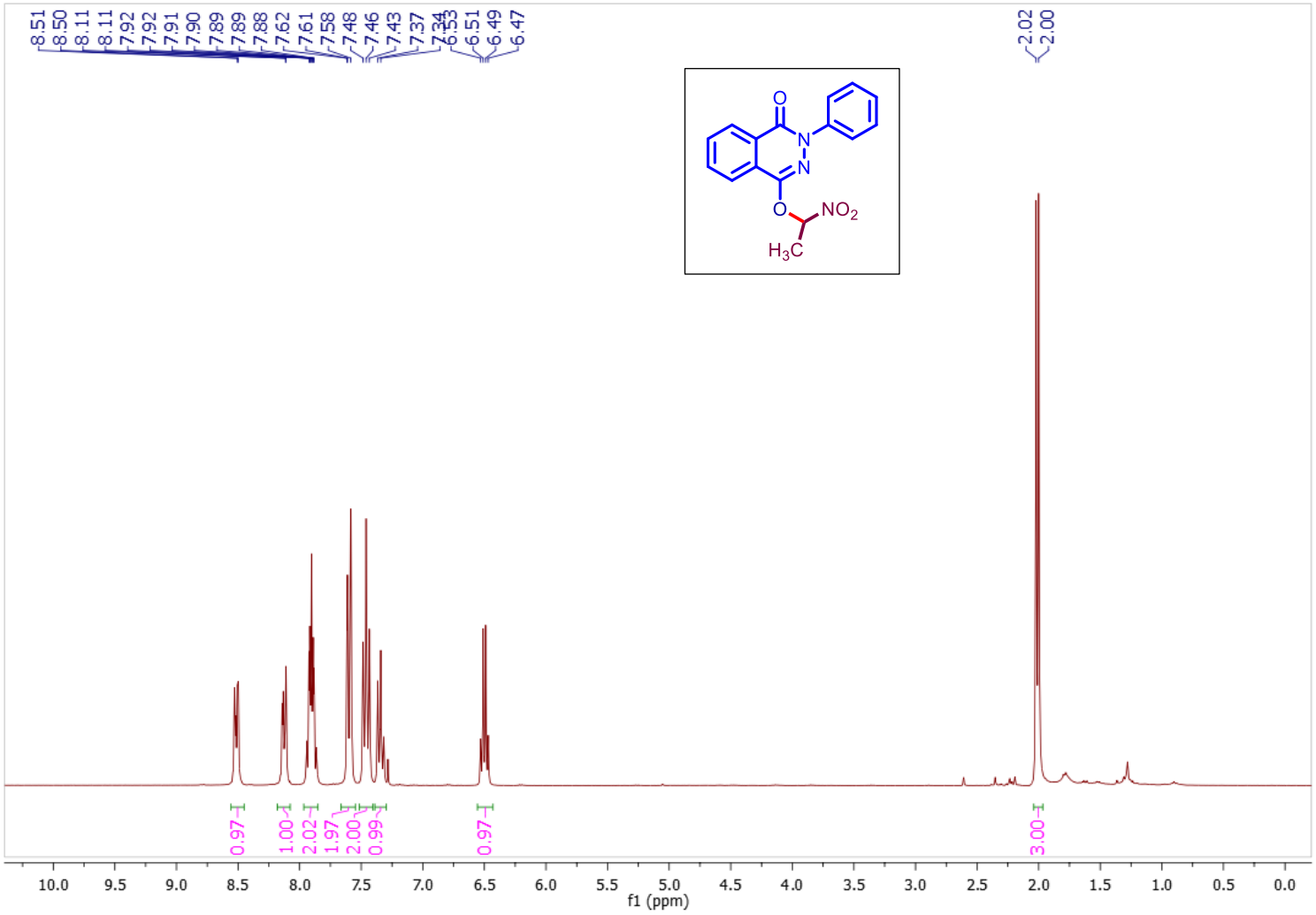
4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl dimethylcarbamate (3ap): ^{1}H NMR (300 MHz, $CDCl_3$):



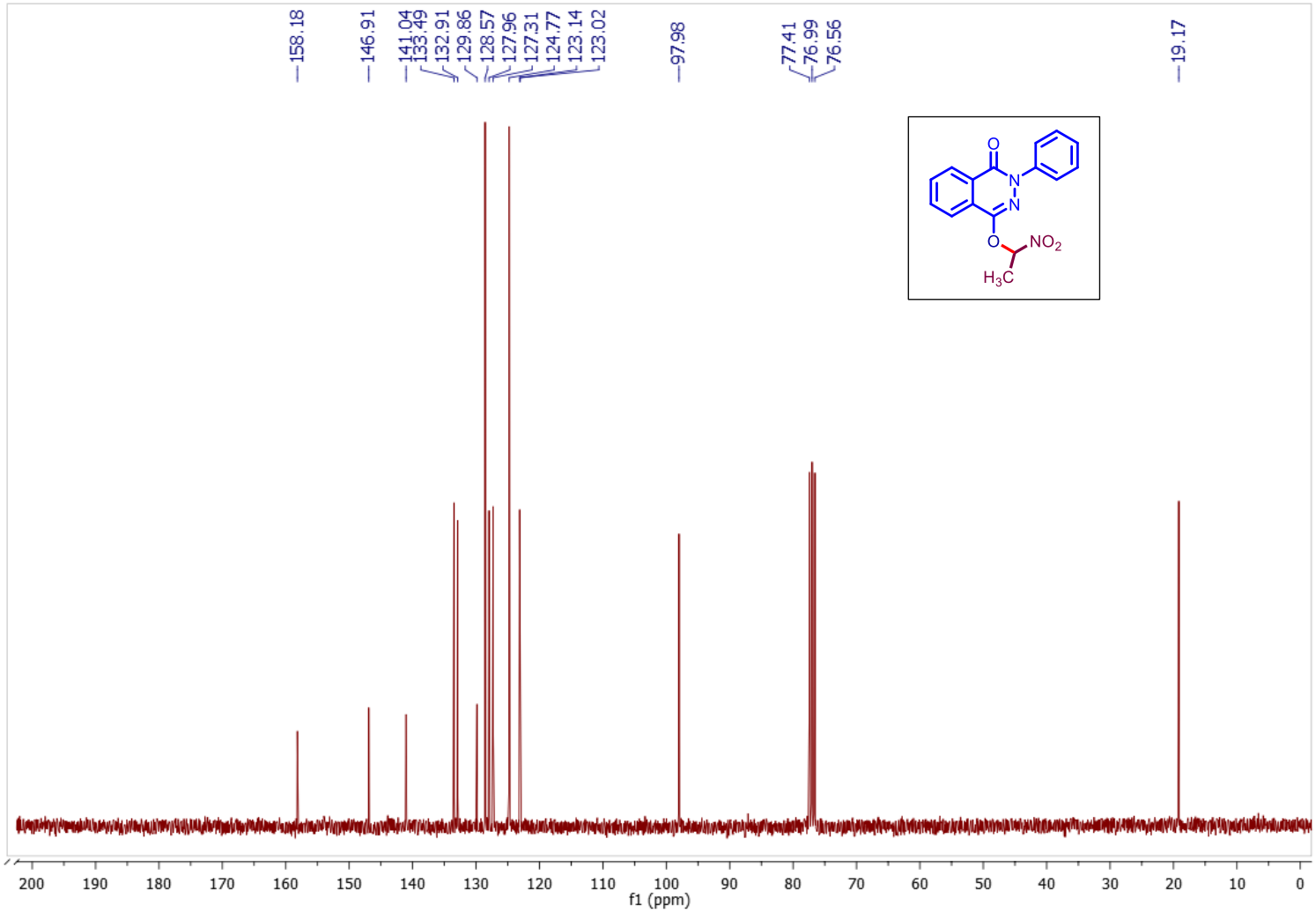
4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl dimethylcarbamate (3ap): ^{13}C NMR (75 MHz, $CDCl_3$):



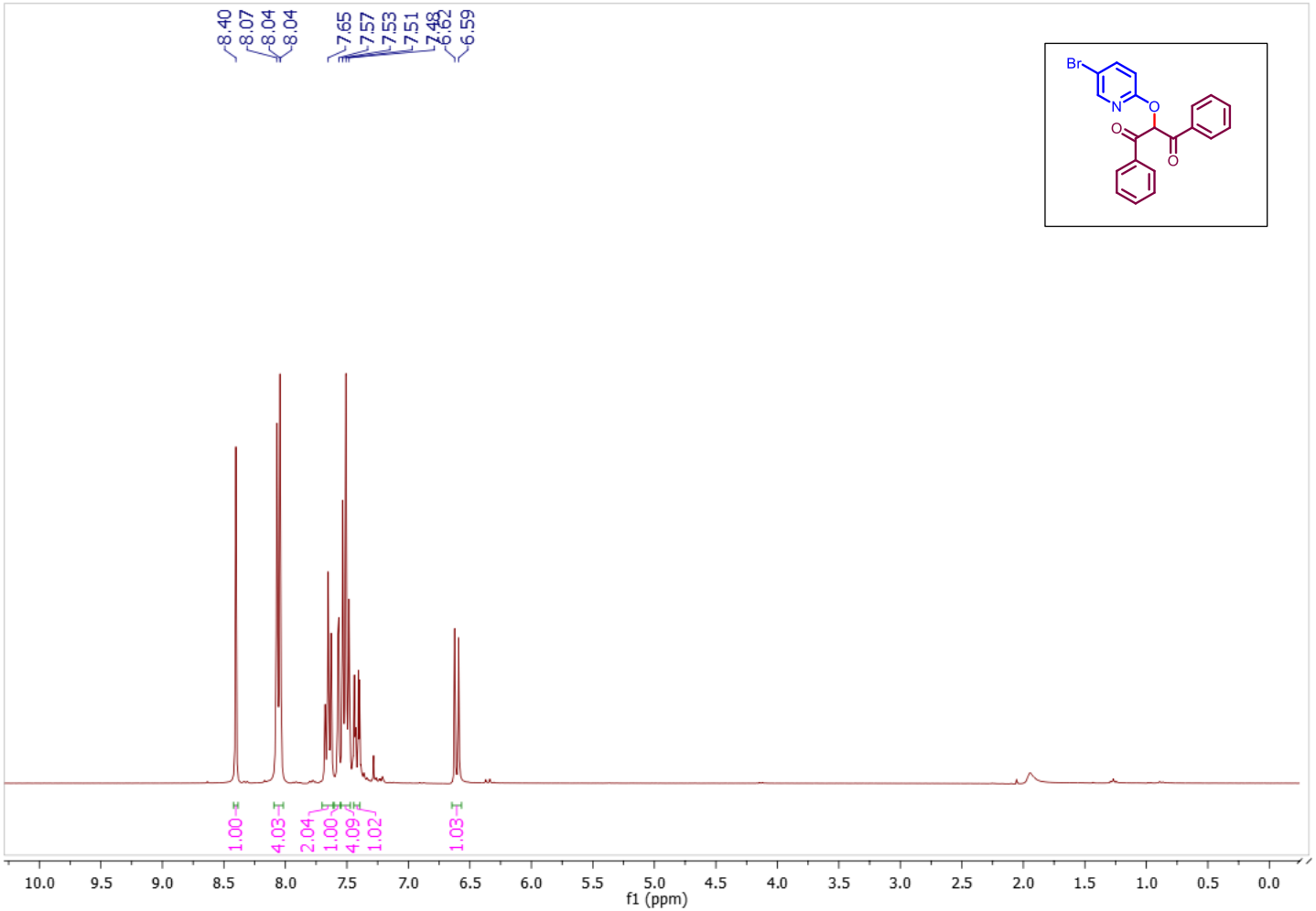
4-(1-nitroethoxy)-2-phenylphthalazin-1(2H)-one (3aq): ^{1}H NMR (300 MHz, $CDCl_3$):



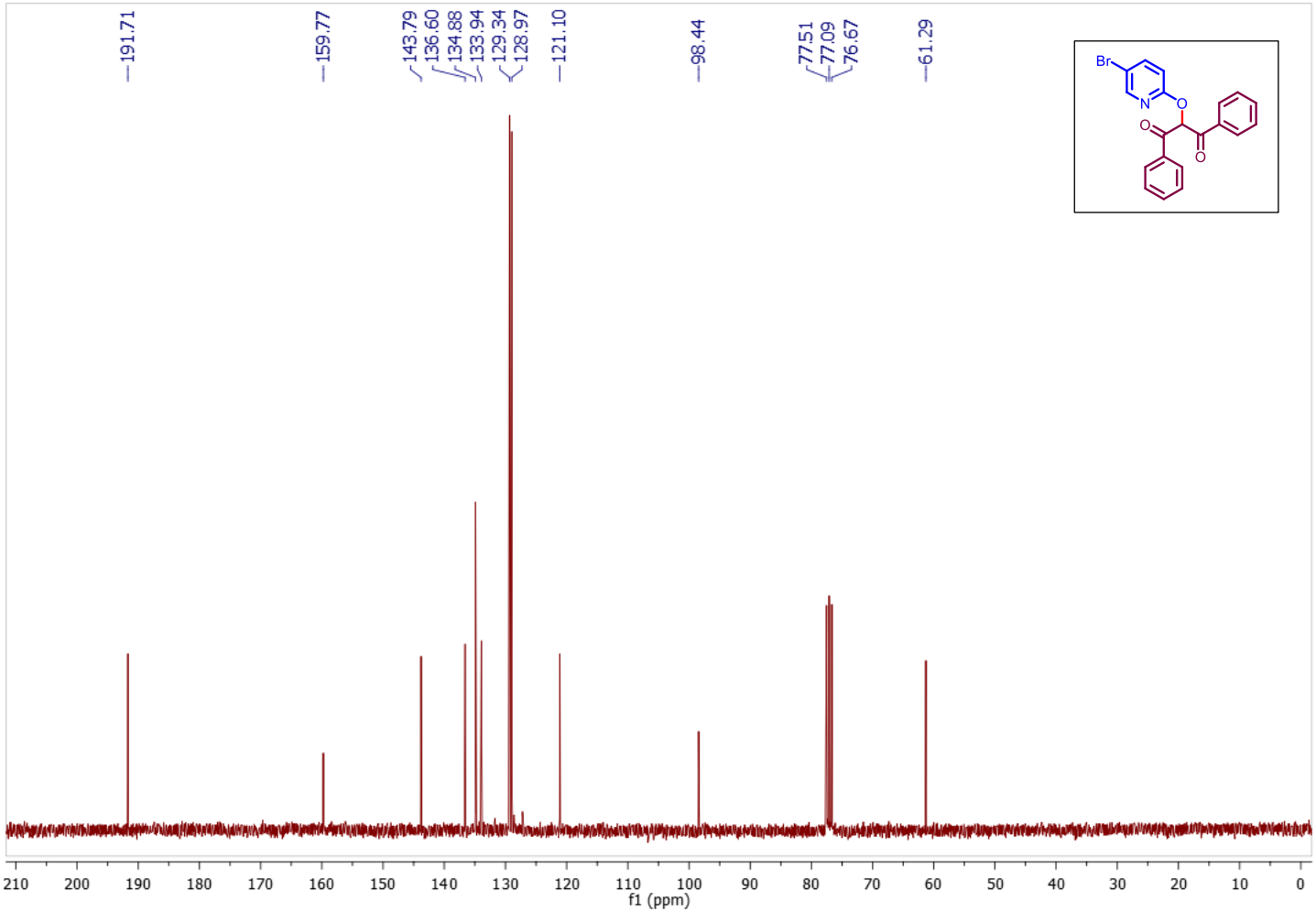
4-(1-nitroethoxy)-2-phenylphthalazin-1(2H)-one (3aq): ^{13}C NMR (75 MHz, $CDCl_3$):



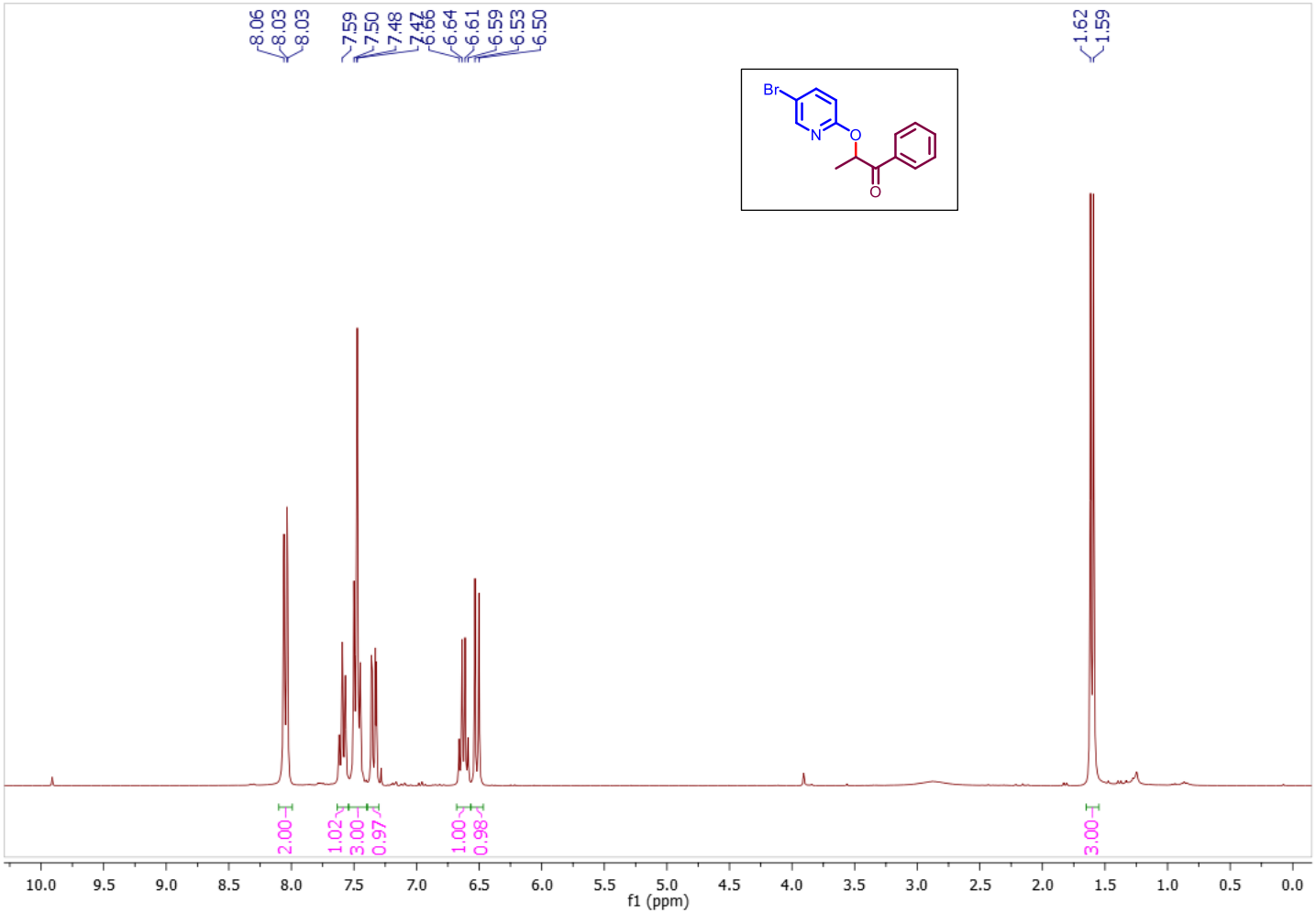
2-((5-bromopyridin-2-yl)oxy)-1,3-diphenylpropane-1,3-dione (3ar): ^{1}H NMR (300 MHz, $CDCl_3$):



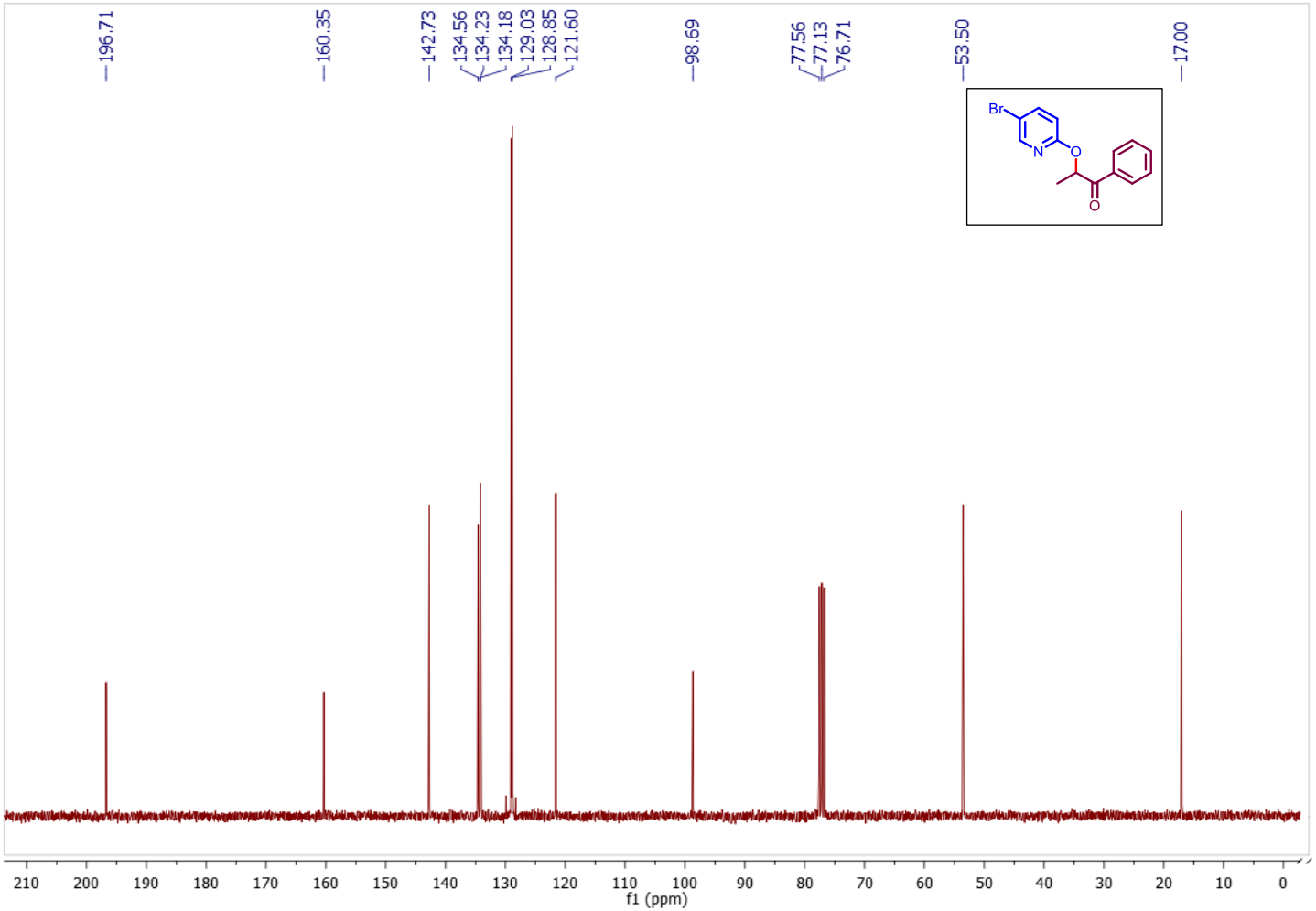
2-((5-bromopyridin-2-yl)oxy)-1,3-diphenylpropane-1,3-dione (3ar): ^{13}C NMR (75 MHz, $CDCl_3$):



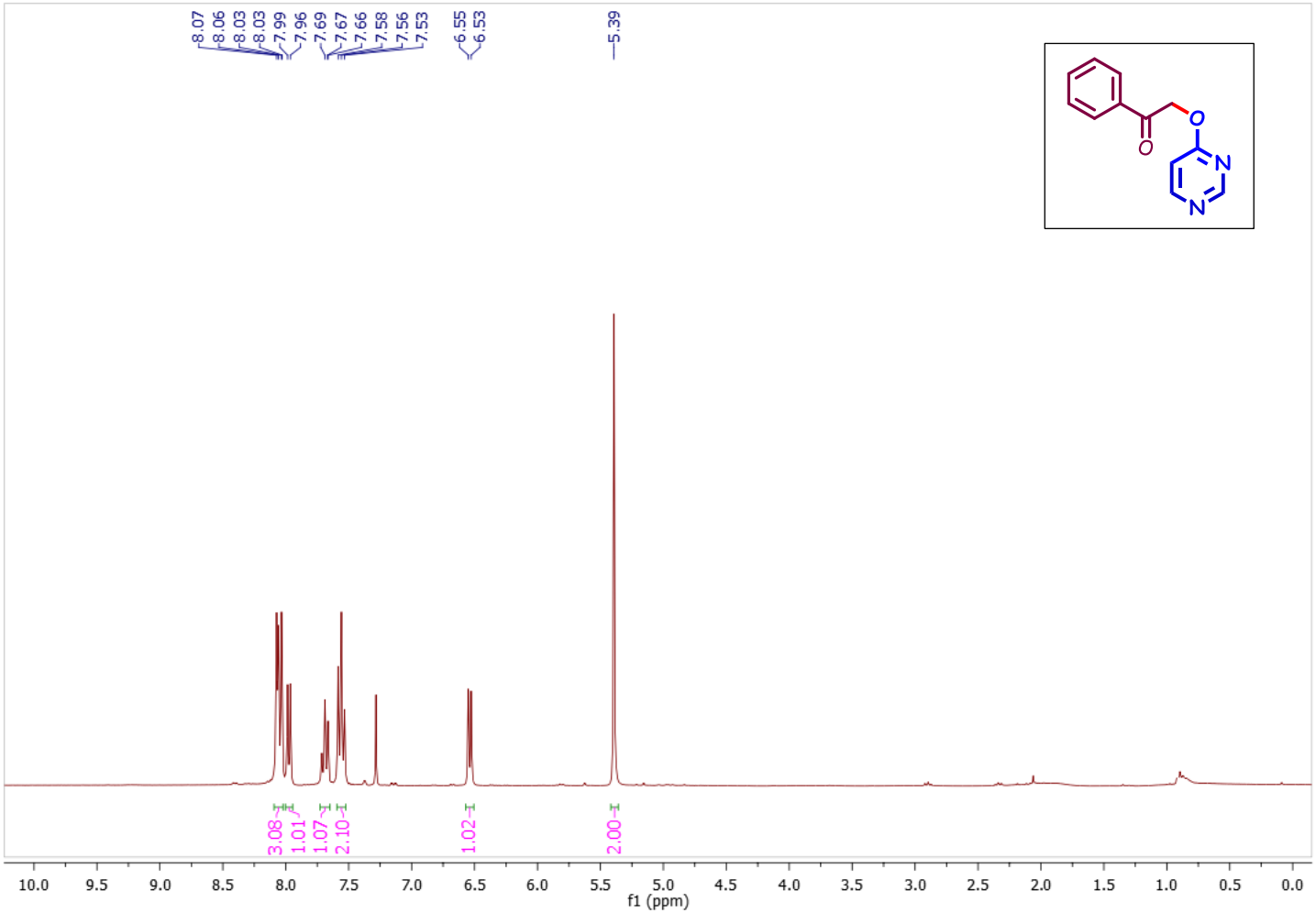
2-((5-bromopyridin-2-yl)oxy)-1-phenylpropan-1-one (3as): ^{1}H NMR (300 MHz, $CDCl_3$):



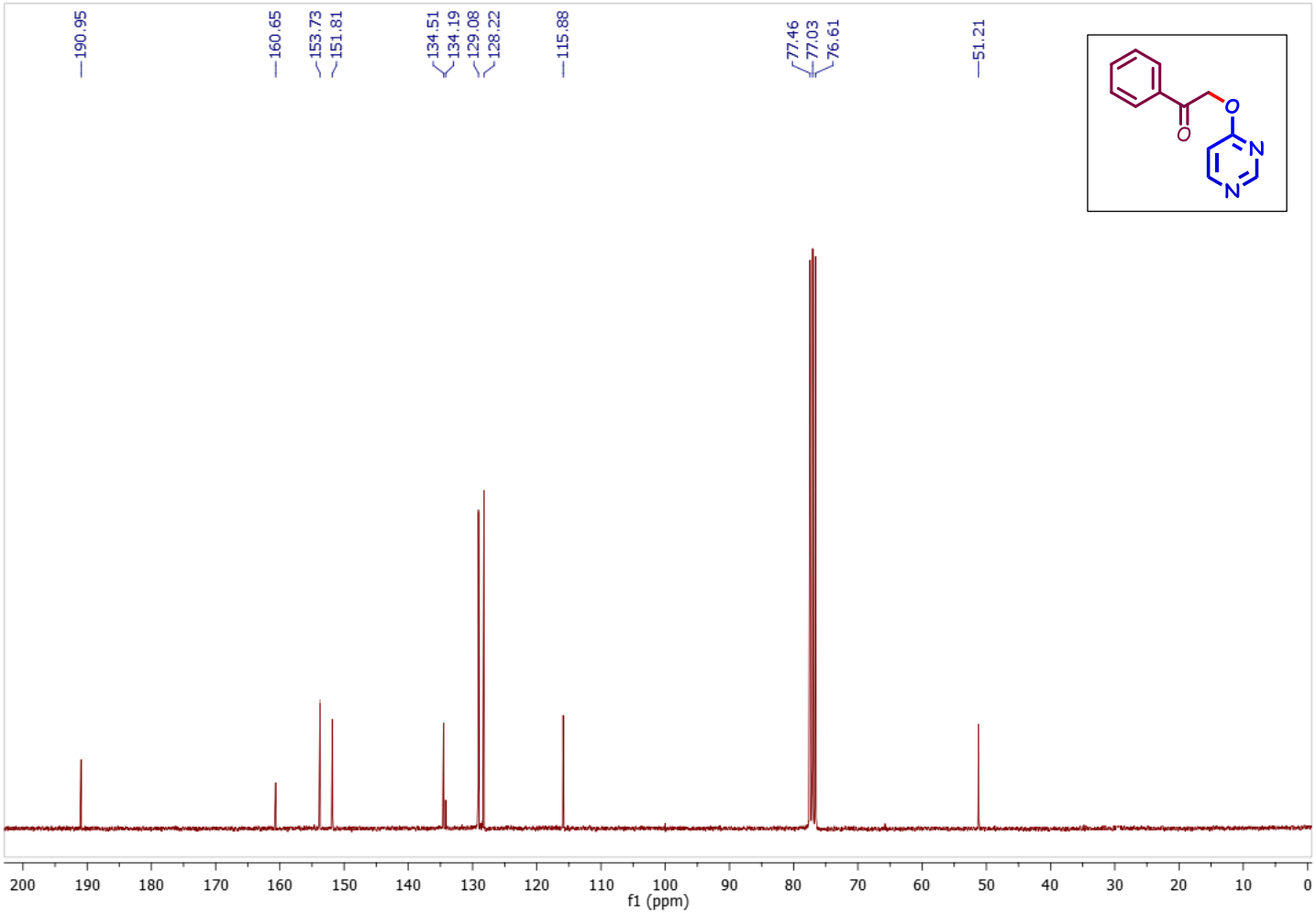
2-((5-bromopyridin-2-yl)oxy)-1-phenylpropan-1-one (3as): ^{13}C NMR (75 MHz, $CDCl_3$):



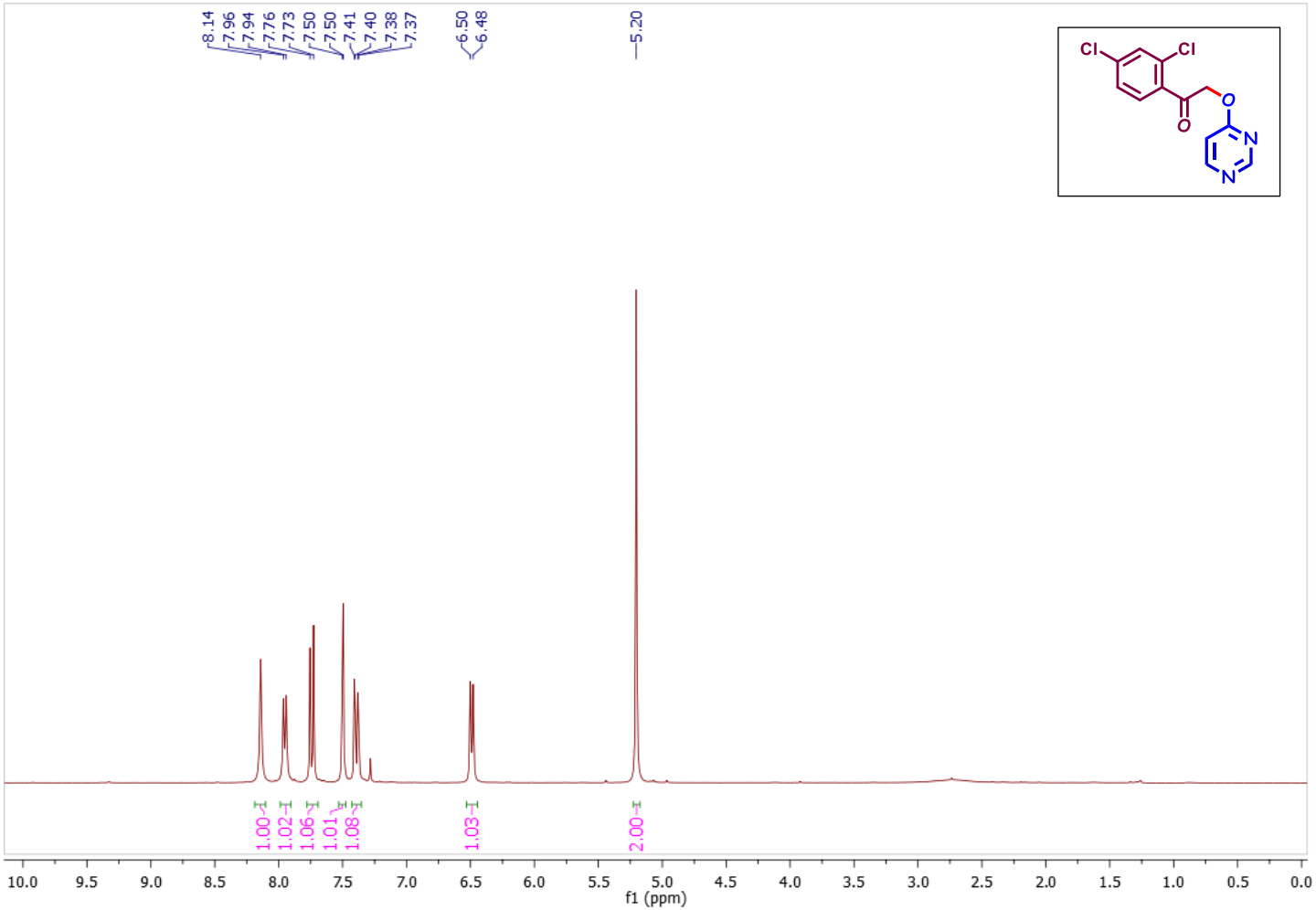
1-phenyl-2-(pyrimidin-4-yloxy)ethan-1-one (3at): ^{1}H NMR (300 MHz, $CDCl_3$):



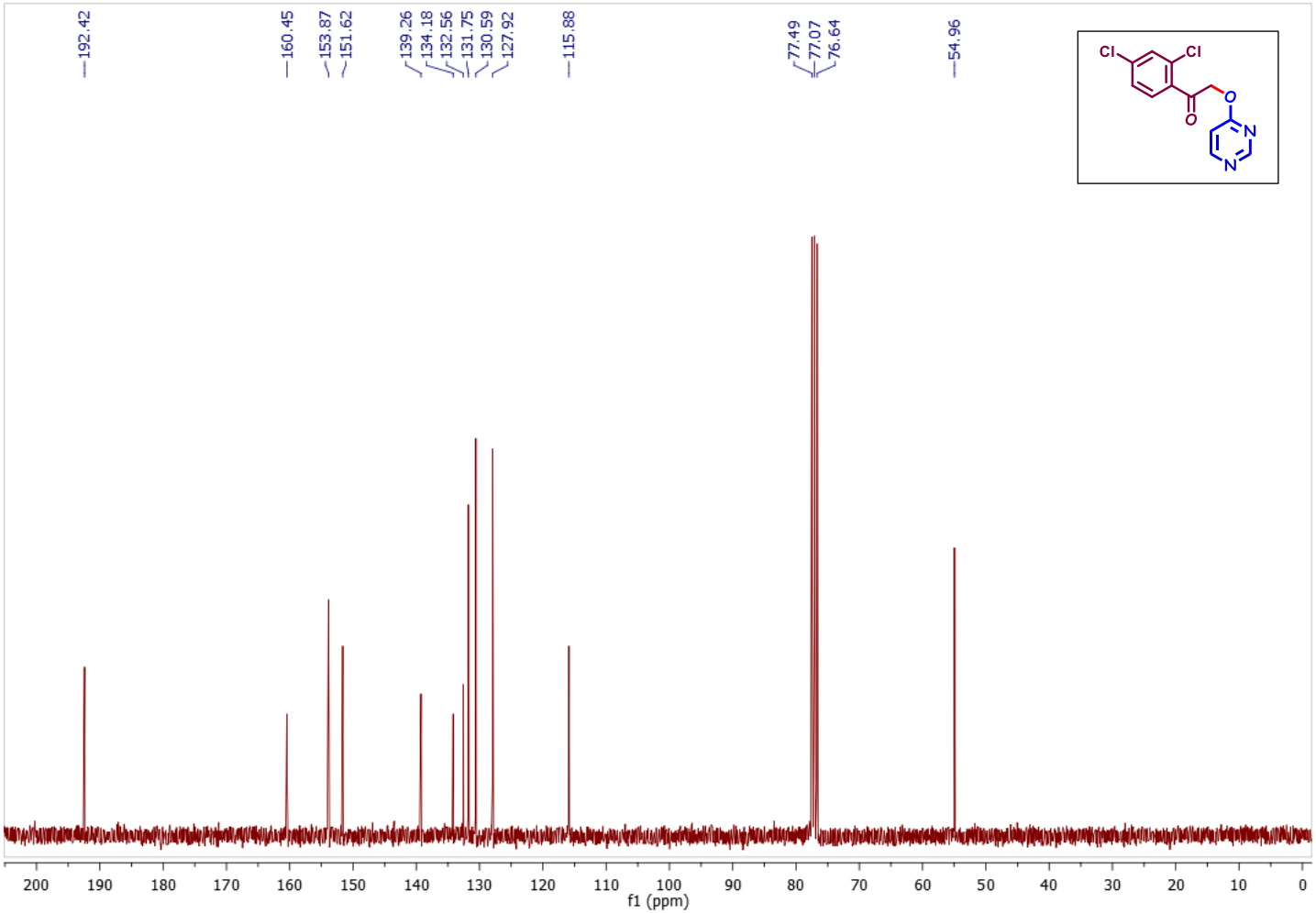
1-phenyl-2-(pyrimidin-4-yloxy)ethan-1-one (3at): ^{13}C NMR (75 MHz, $CDCl_3$):



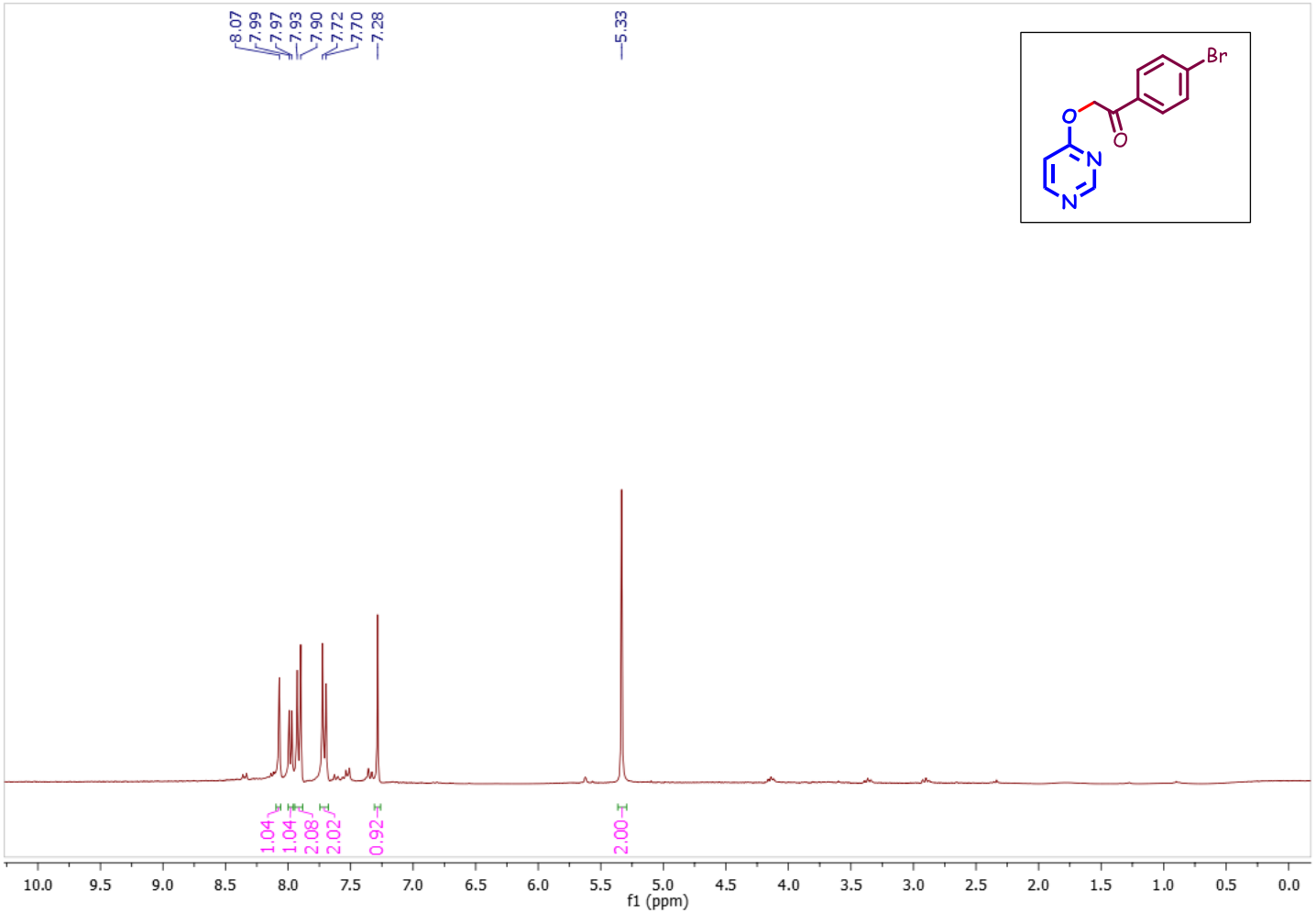
1-(2,4-dichlorophenyl)-2-(pyrimidin-4-yloxy)ethan-1-one (3au): ^{1}H NMR (300 MHz, $CDCl_3$):



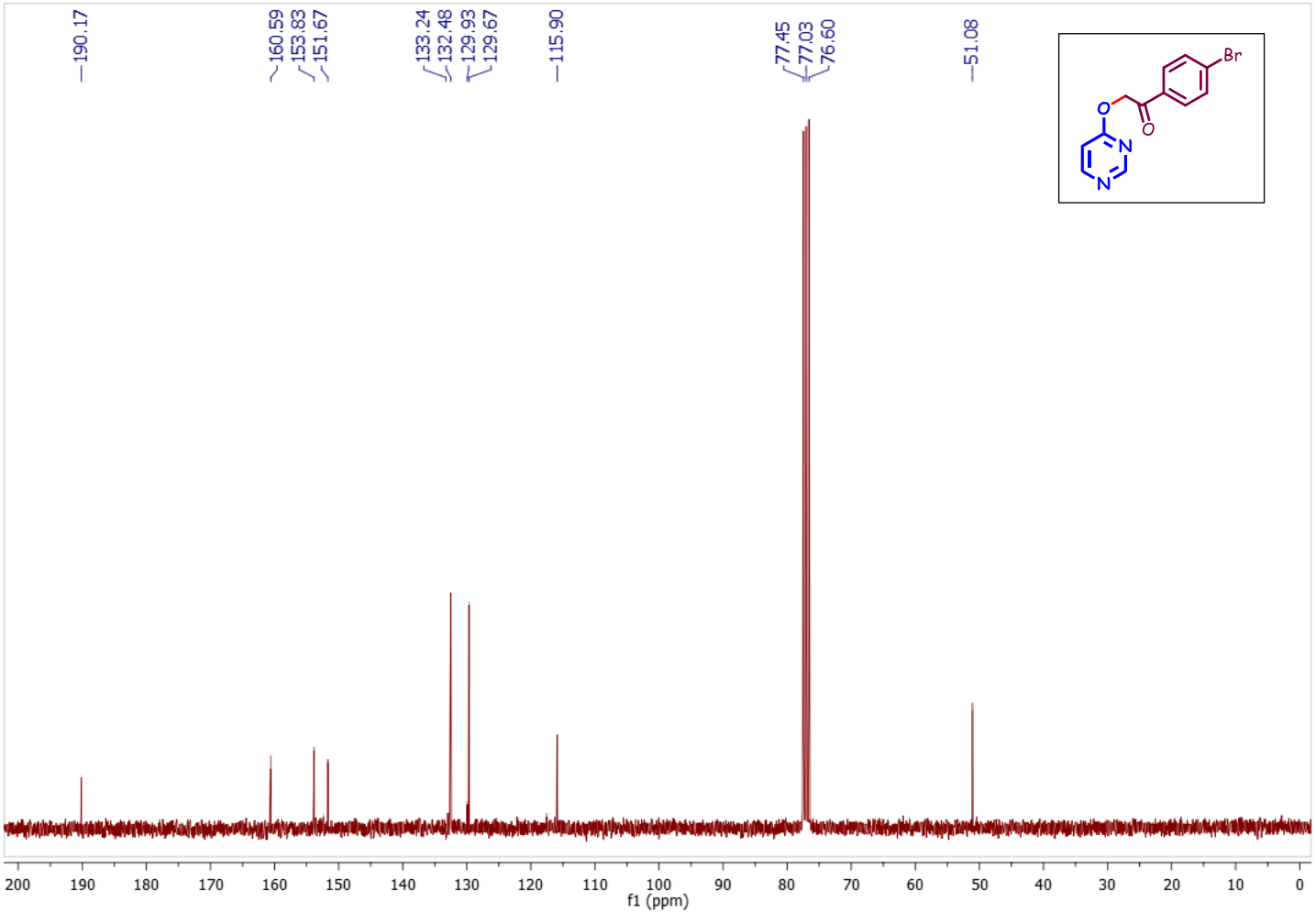
1-(2,4-dichlorophenyl)-2-(pyrimidin-4-yloxy)ethan-1-one (3au): ^{13}C NMR (75 MHz, $CDCl_3$):



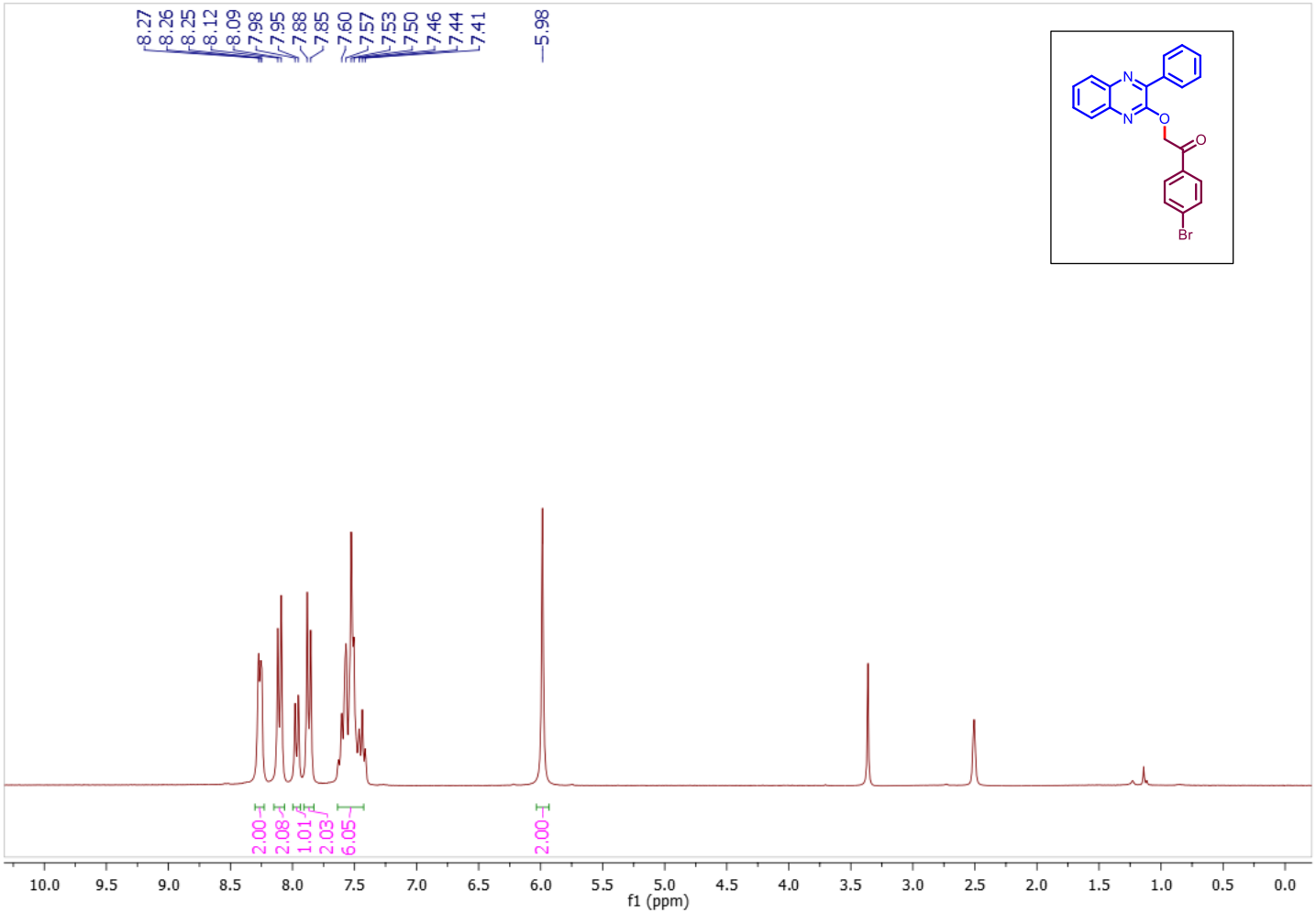
1-(4-bromophenyl)-2-(pyrimidin-4-yloxy)ethan-1-one (3av): ^{1}H NMR (300 MHz, $CDCl_3$):



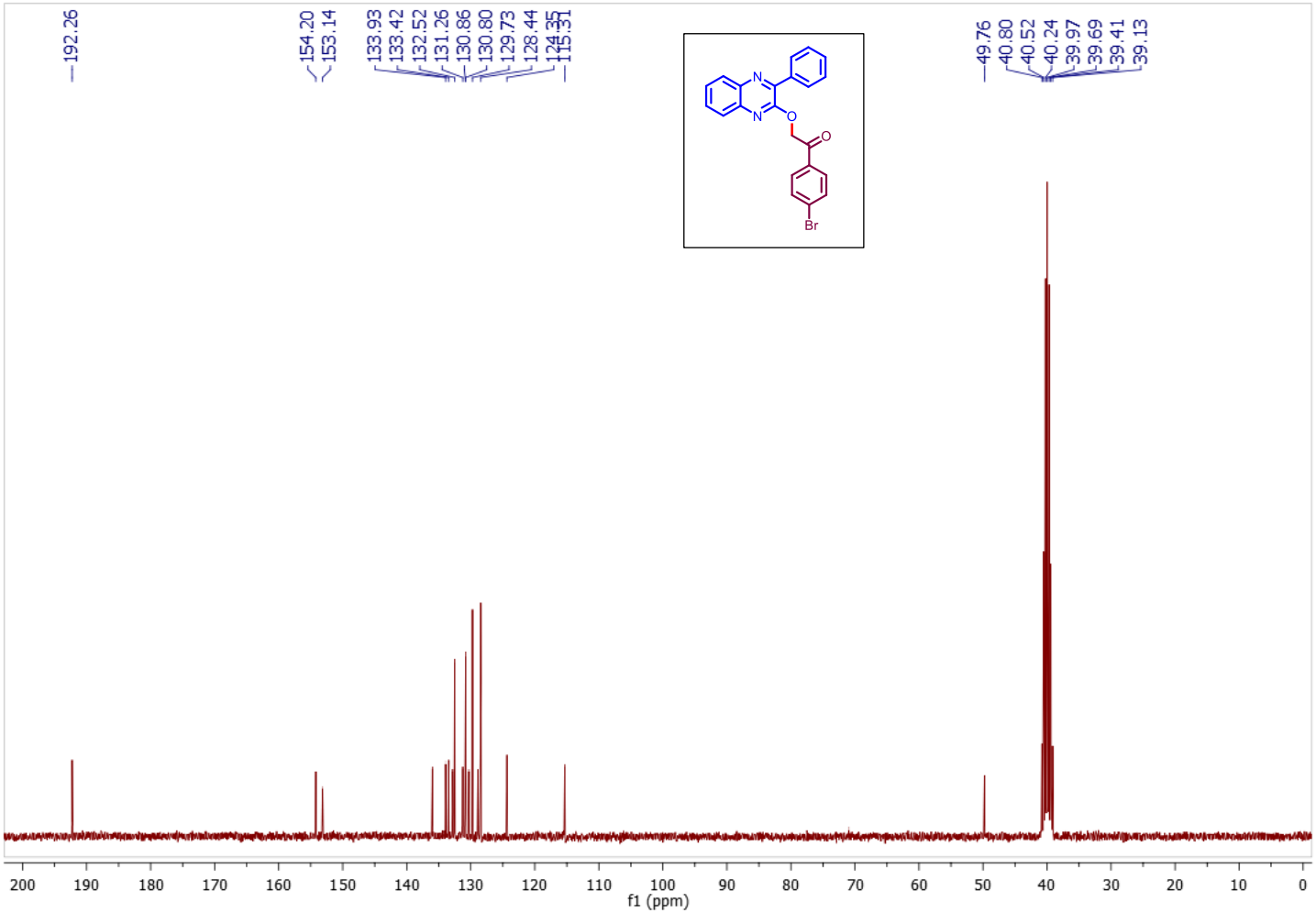
1-(4-bromophenyl)-2-(pyrimidin-4-yloxy)ethan-1-one (3av): ^{13}C NMR (75 MHz, $CDCl_3$):



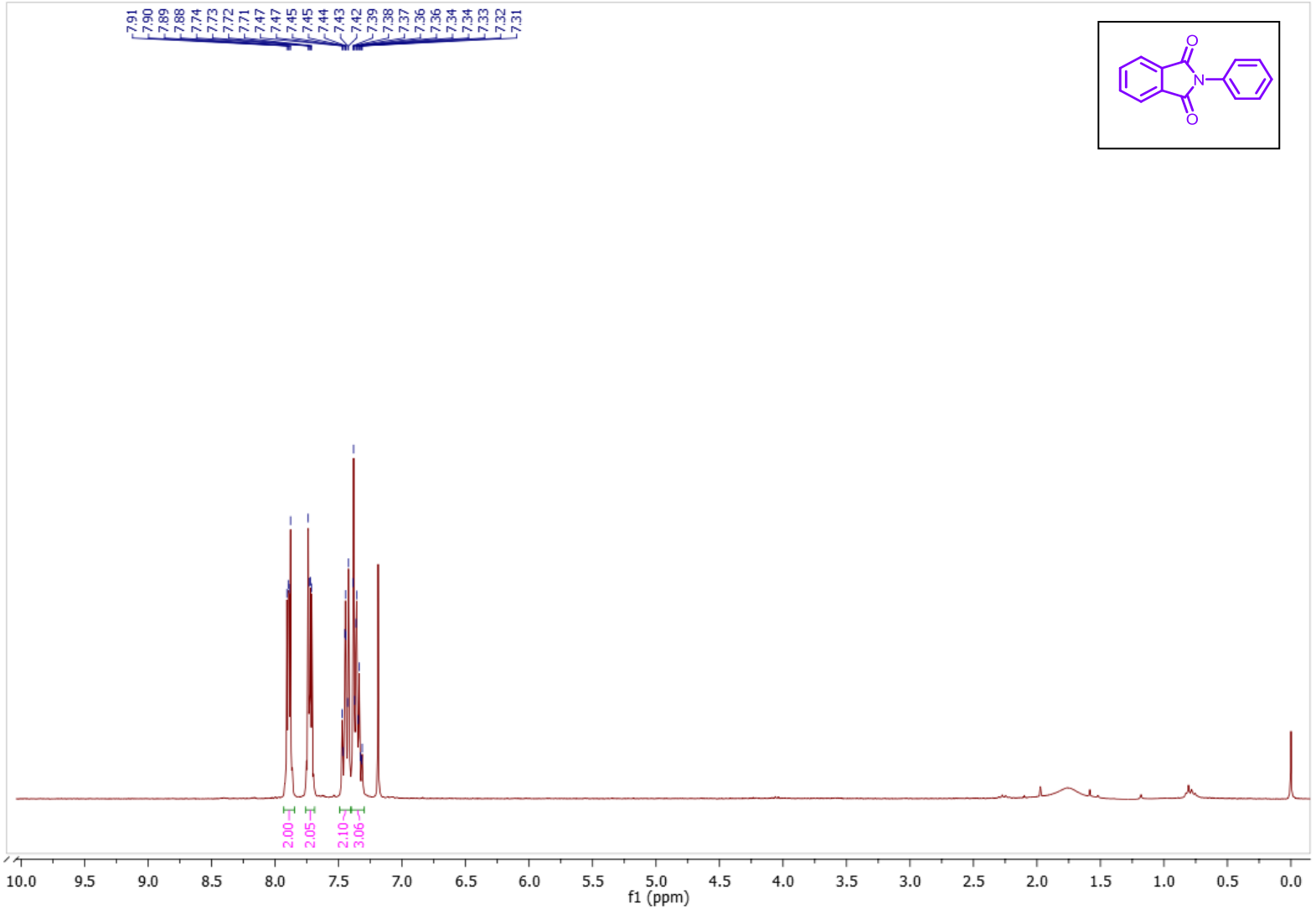
1-(4-bromophenyl)-2-((3-phenylquinoxalin-2-yl)oxy)ethan-1-one (3aw): ^{1}H NMR (300 MHz, DMSO-d$_6$):



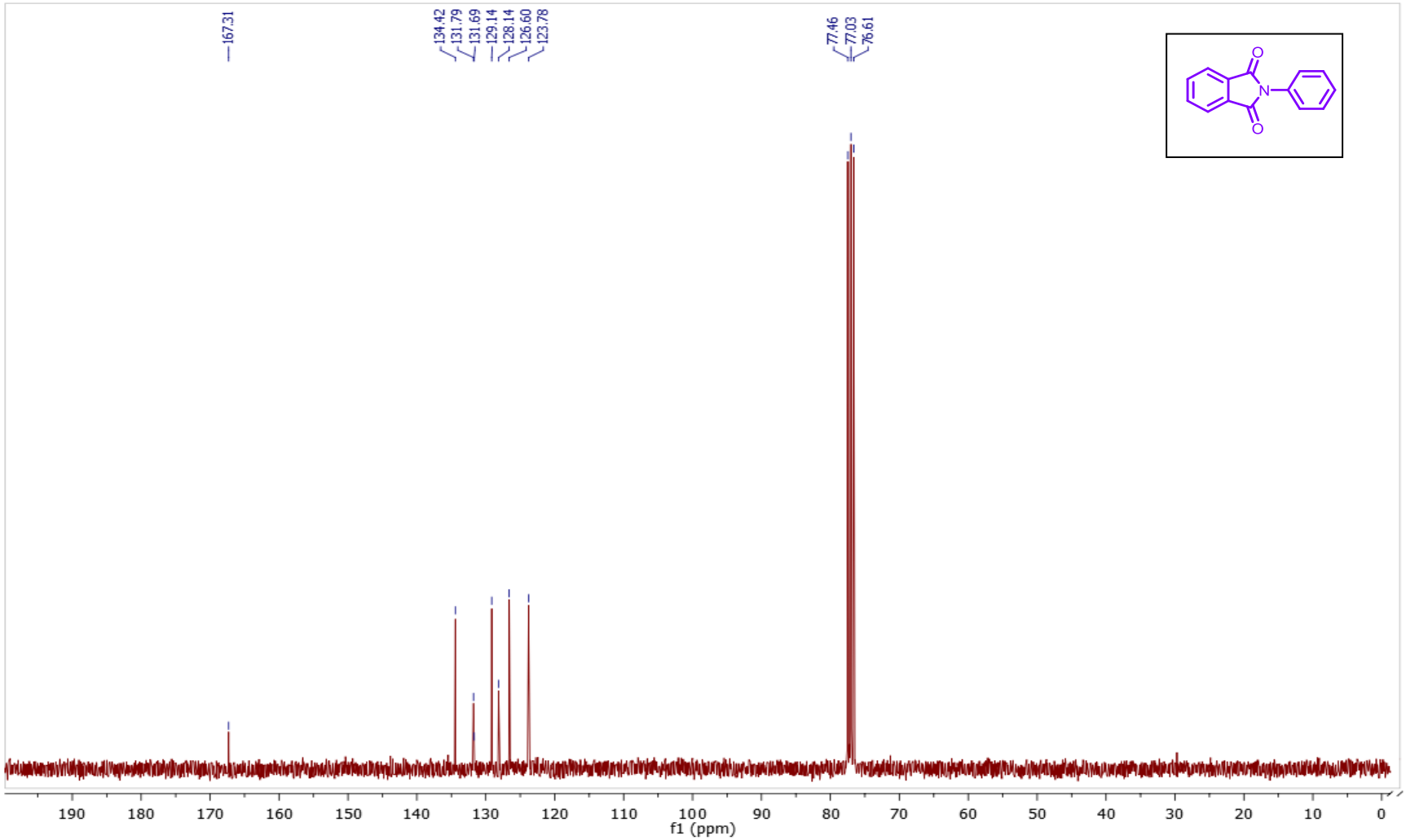
1-(4-bromophenyl)-2-((3-phenylquinoxalin-2-yl)oxy)ethan-1-one (3aw): ^{13}C NMR (75 MHz, DMSO-*d*$_6$):



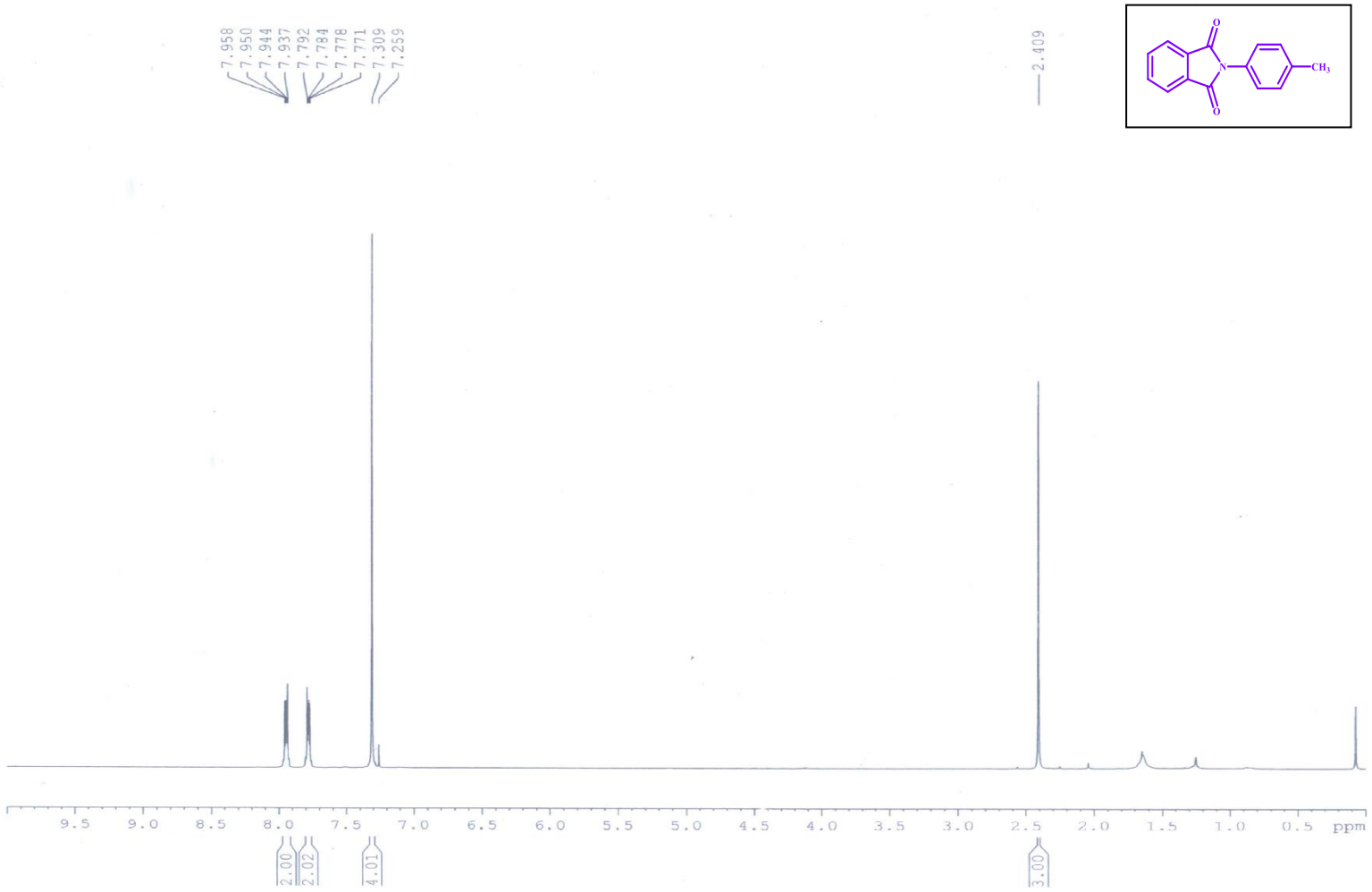
2-phenylisoindoline-1,3-dione(4a): ^{1}H NMR (300 MHz, CDCl3):



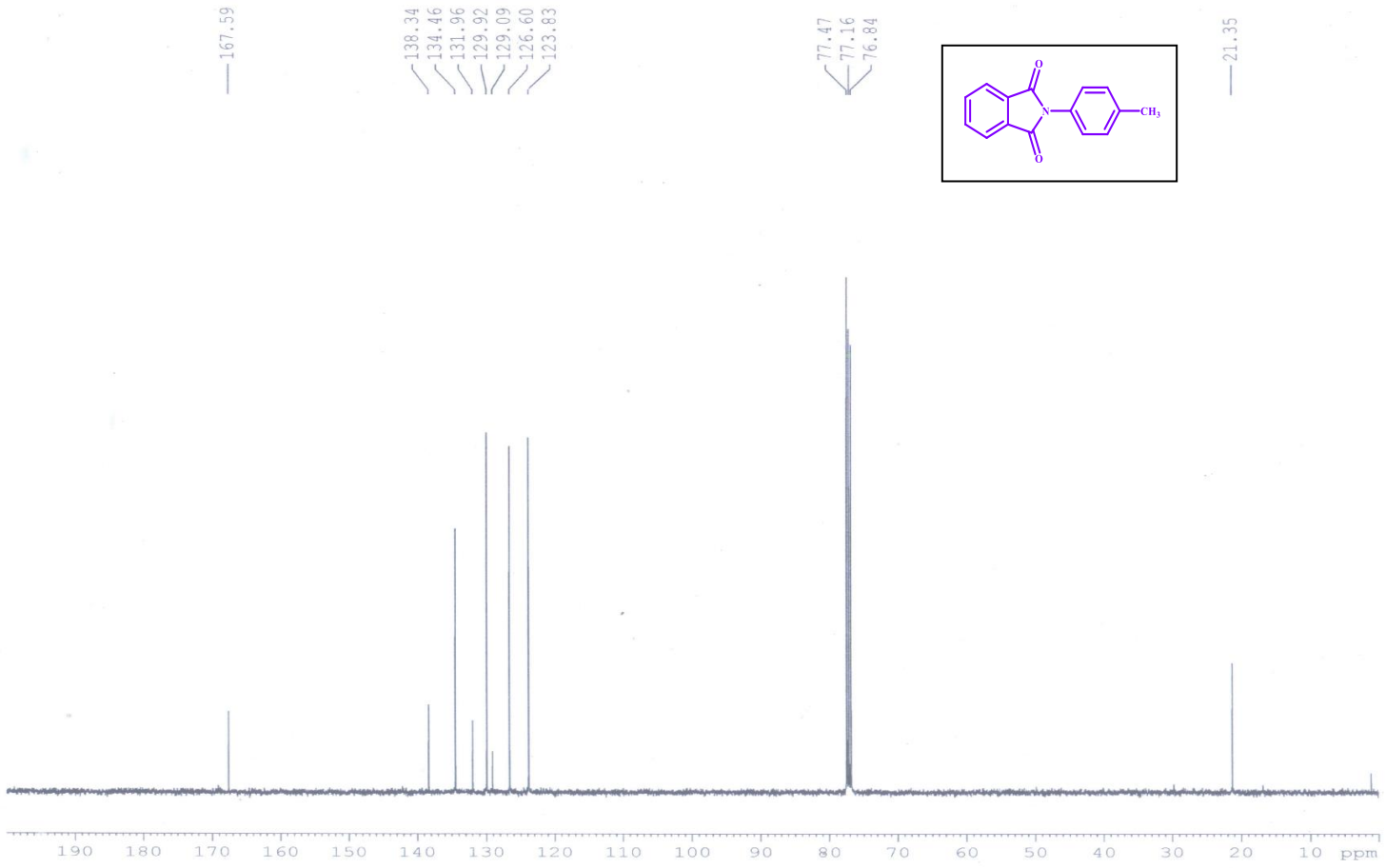
2-phenylisoindoline-1,3-dione(4a): ^{13}C NMR (75 MHz, CDCl3):



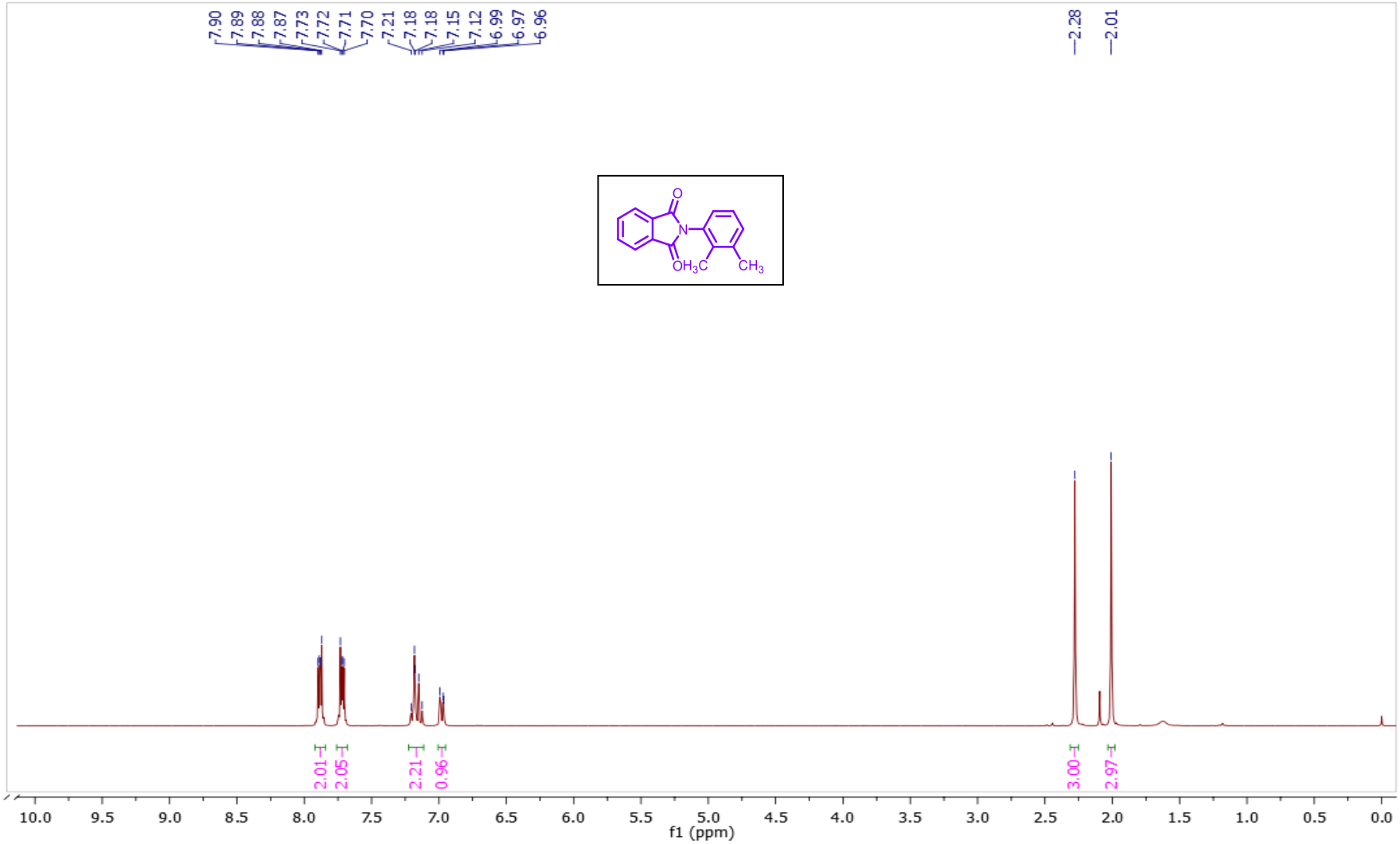
2-(p-tolyl)isoindoline-1,3-dione(4b): ^{1}H NMR (400 MHz, CDCl3):



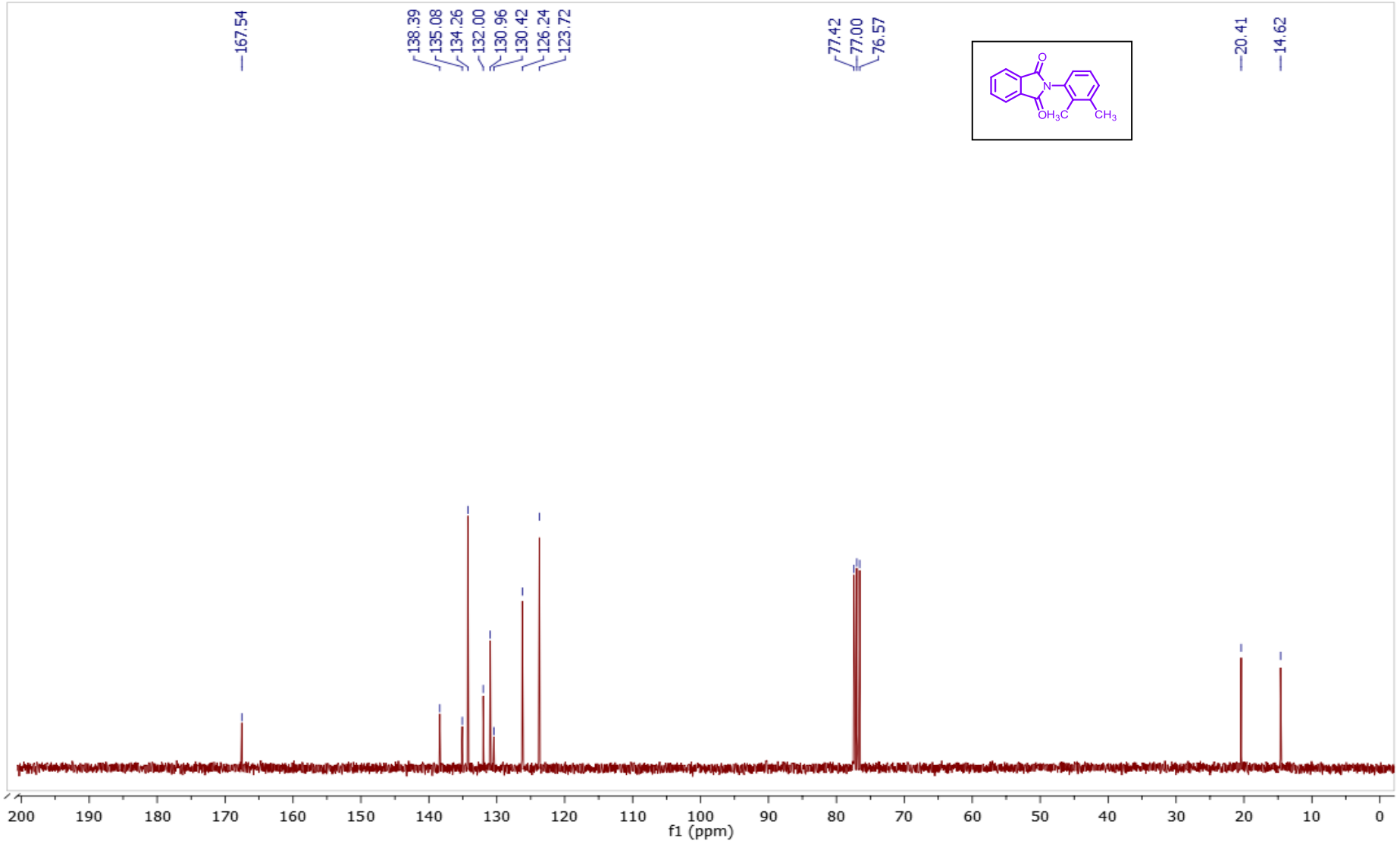
2-(p-tolyl)isoindoline-1,3-dione(4b): ^{13}C NMR (100 MHz, CDCl3):



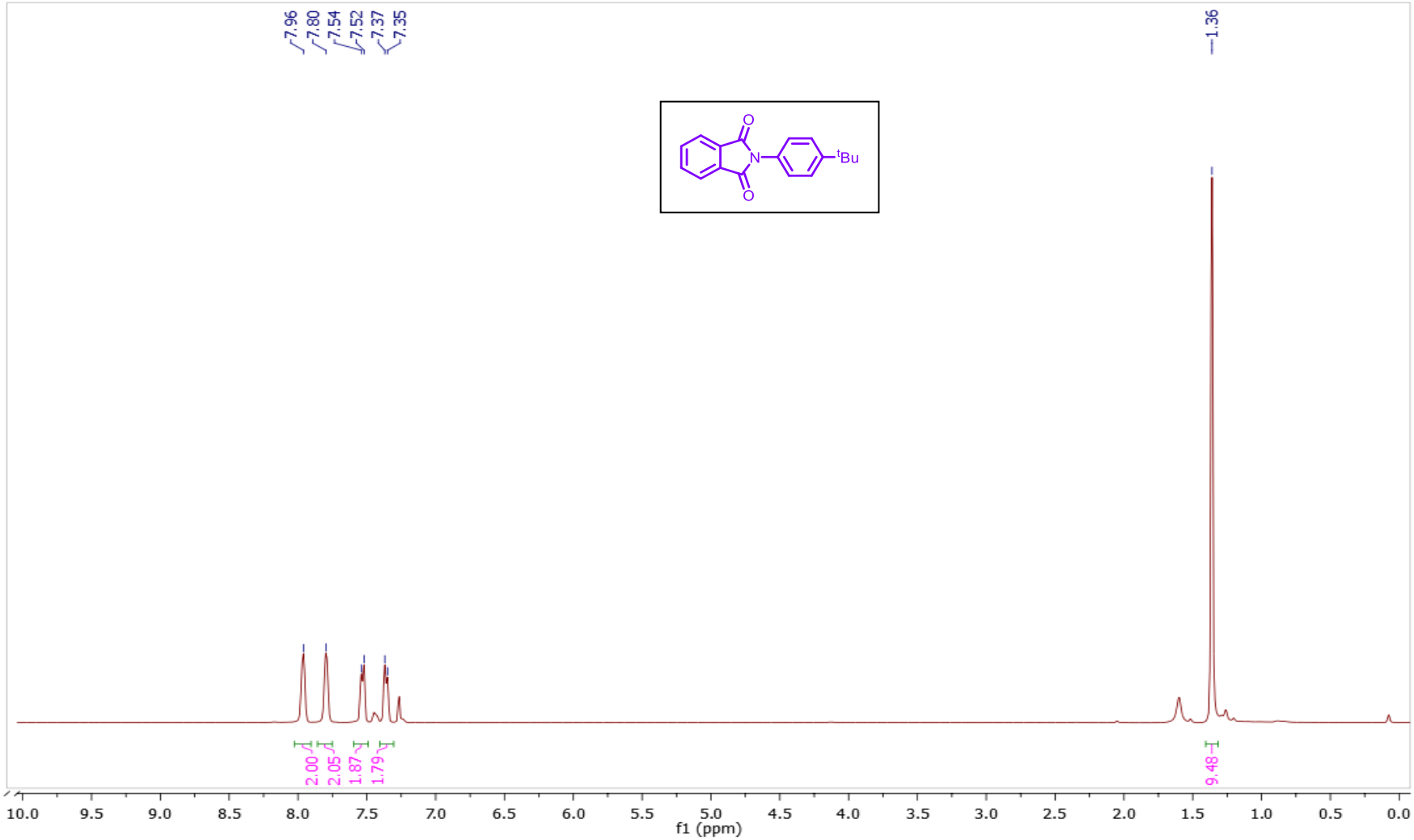
2-(2,3-dimethylphenyl)isoindoline-1,3-dione (4c): ^{1}H NMR (300 MHz, CDCl3):



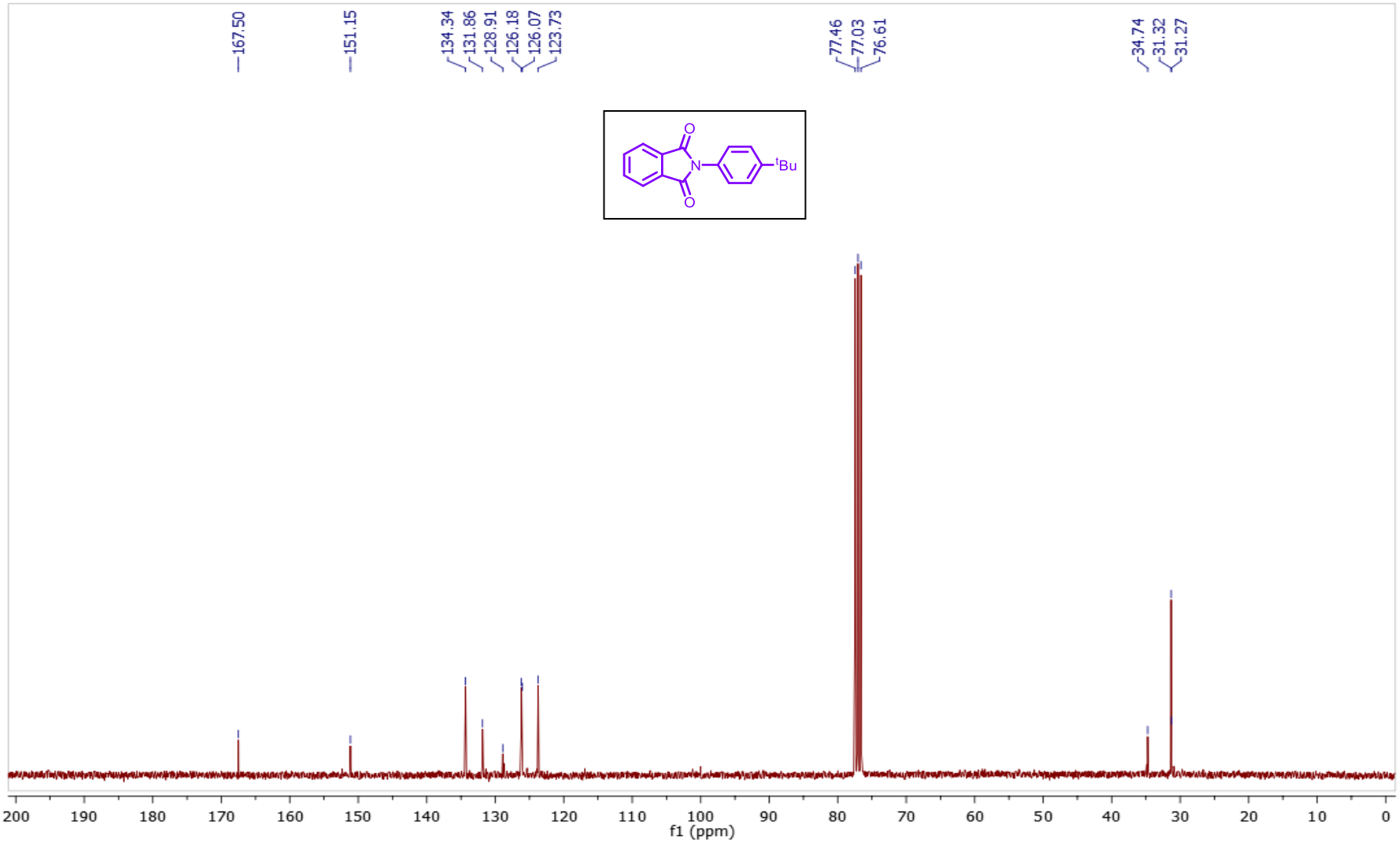
2-(2,3-dimethylphenyl)isoindoline-1,3-dione (4c): ^{13}C NMR (75 MHz, CDCl3):



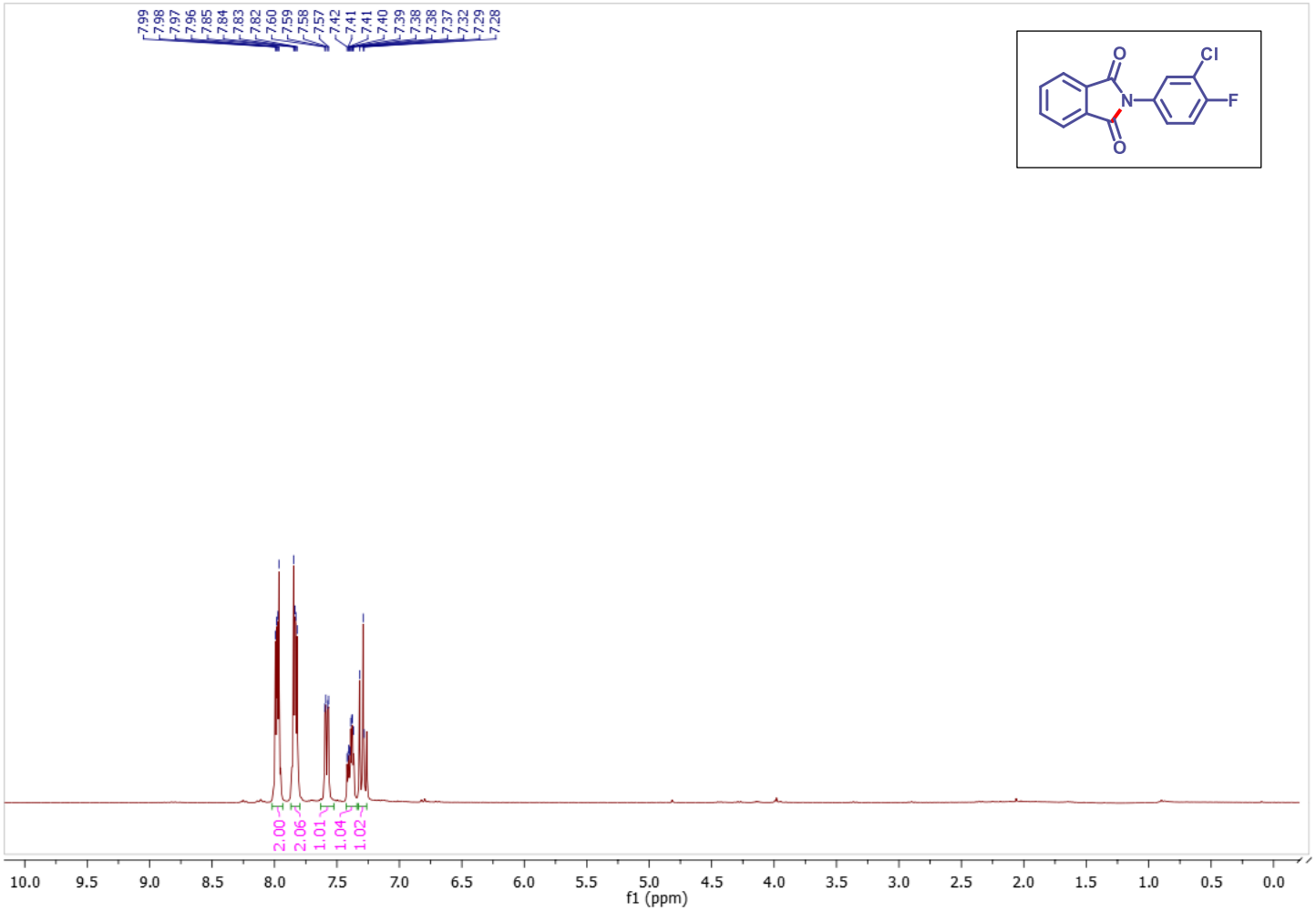
2-(4-(tert-butyl)phenyl)isoindoline-1,3-dione (4d): ^{1}H NMR (400 MHz, CDCl3):



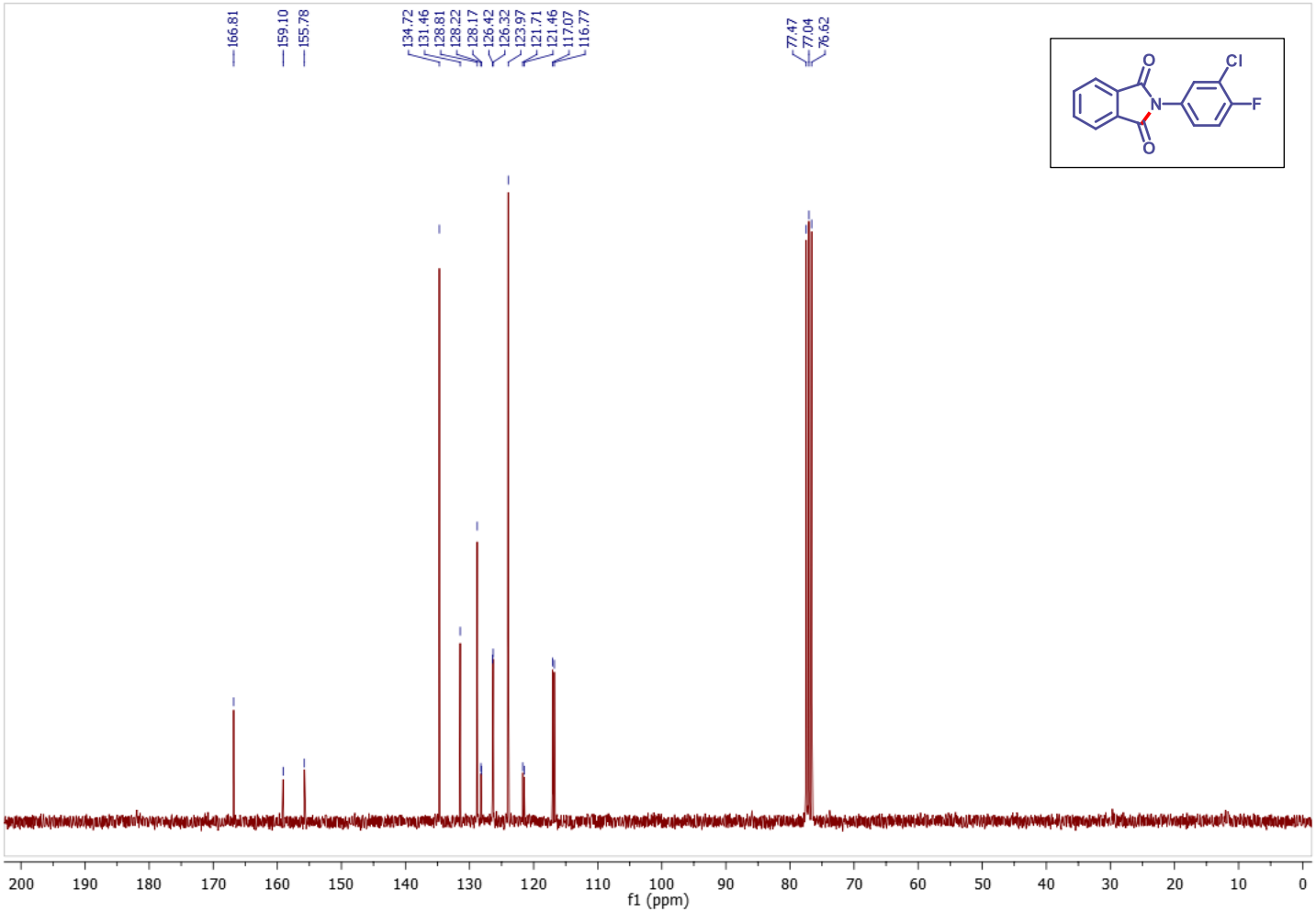
2-(4-(tert-butyl)phenyl)isoindoline-1,3-dione (4d): ^{13}C NMR (75 MHz, CDCl3):



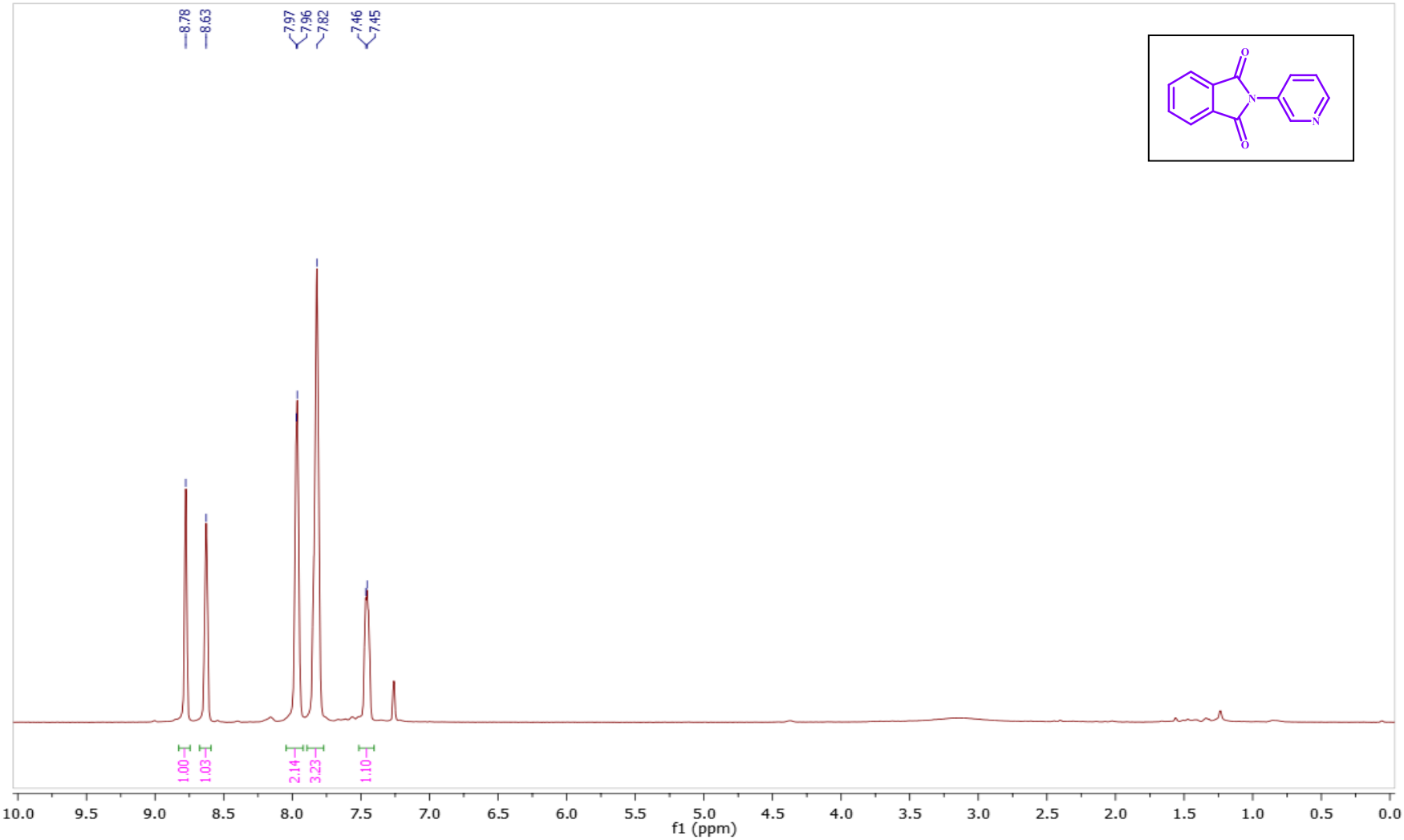
2-(3-chloro-4-fluorophenyl)isoindoline-1,3-dione (4e): ^{1}H NMR (300 MHz, CDCl3):



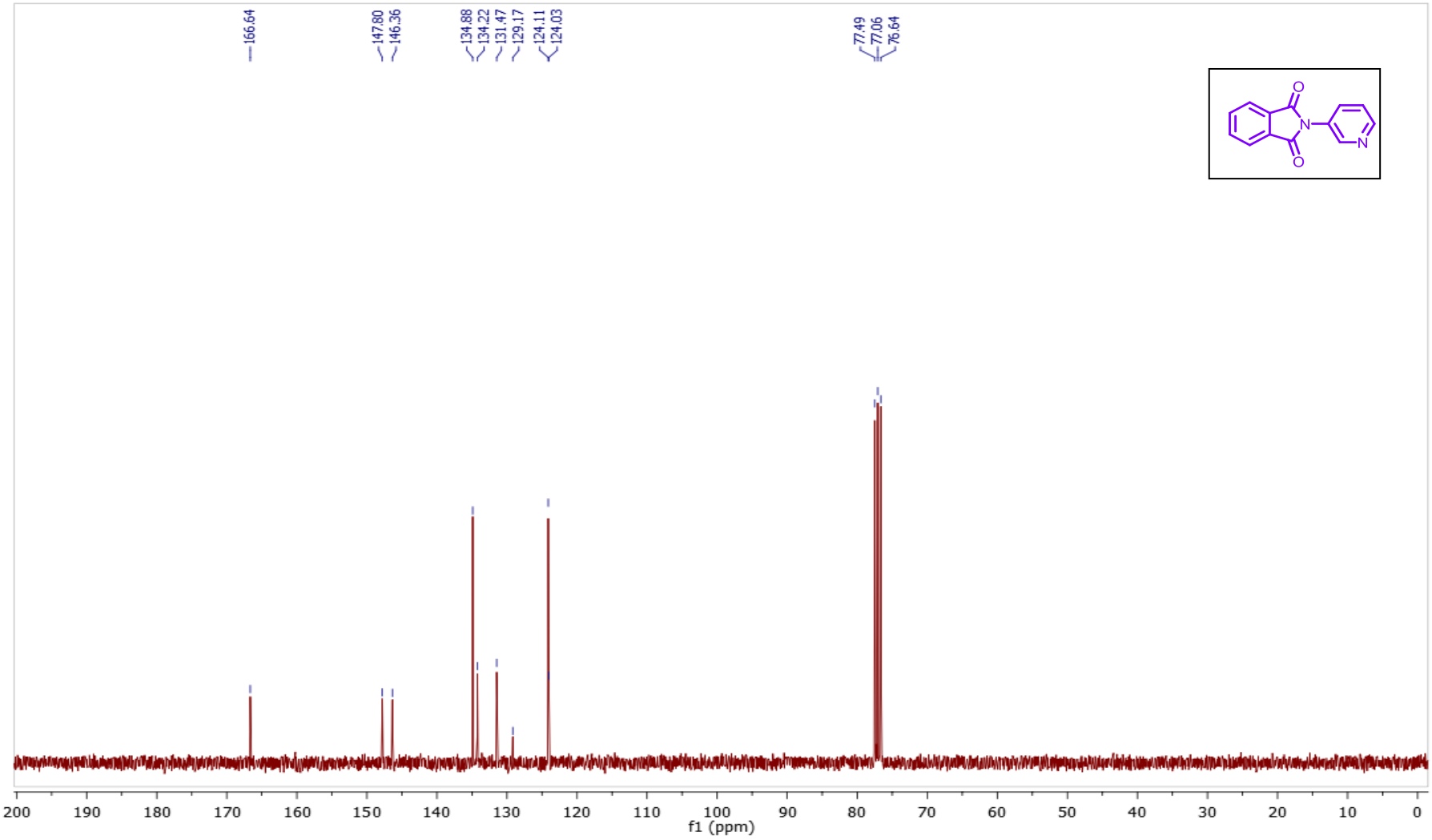
2-(3-chloro-4-fluorophenyl)isoindoline-1,3-dione (4e): ^{13}C NMR (75 MHz, CDCl3):



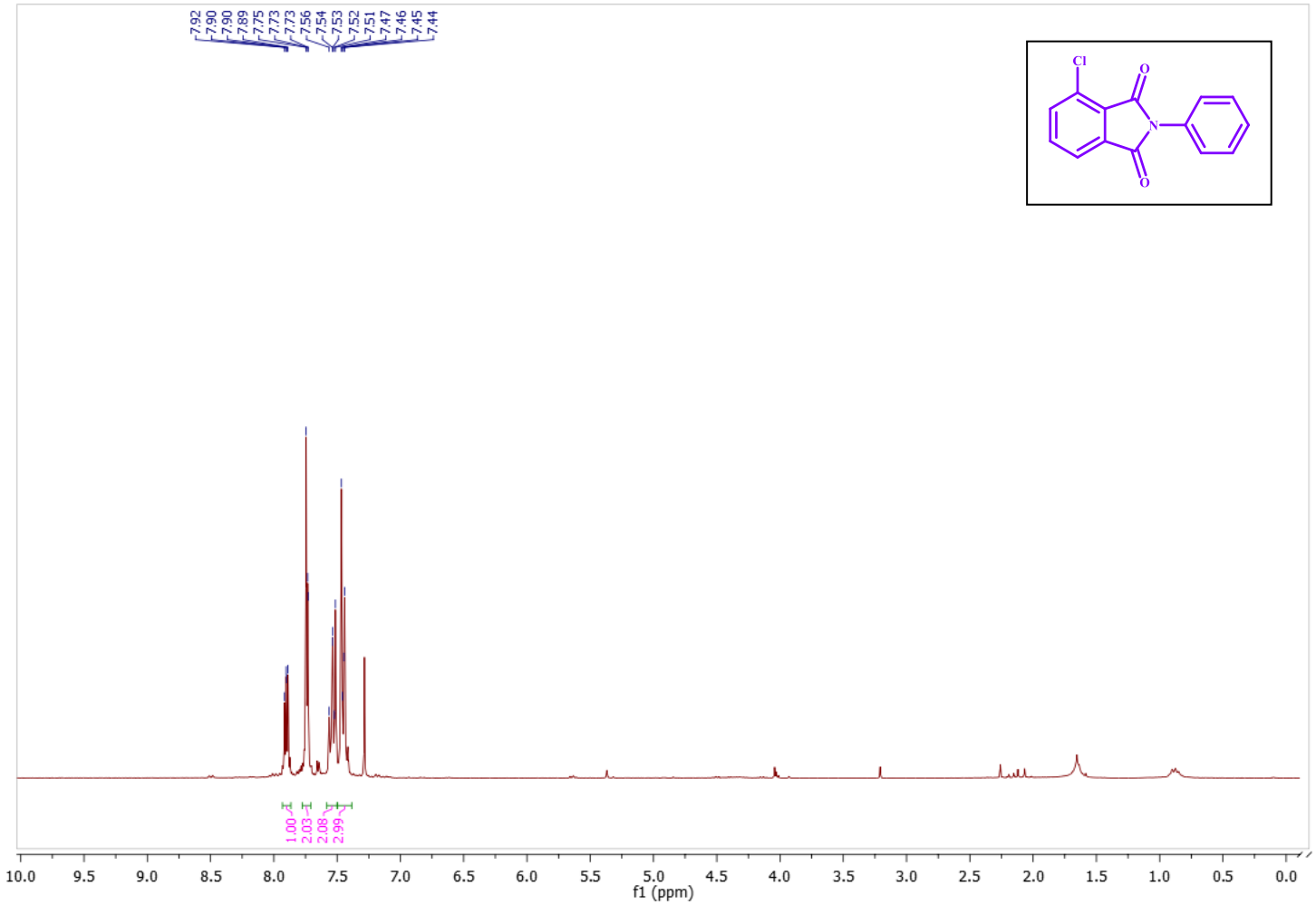
2-(pyridin-3-yl)isoindoline-1,3-dione (4f): 1H NMR (400 MHz, CDCl3):



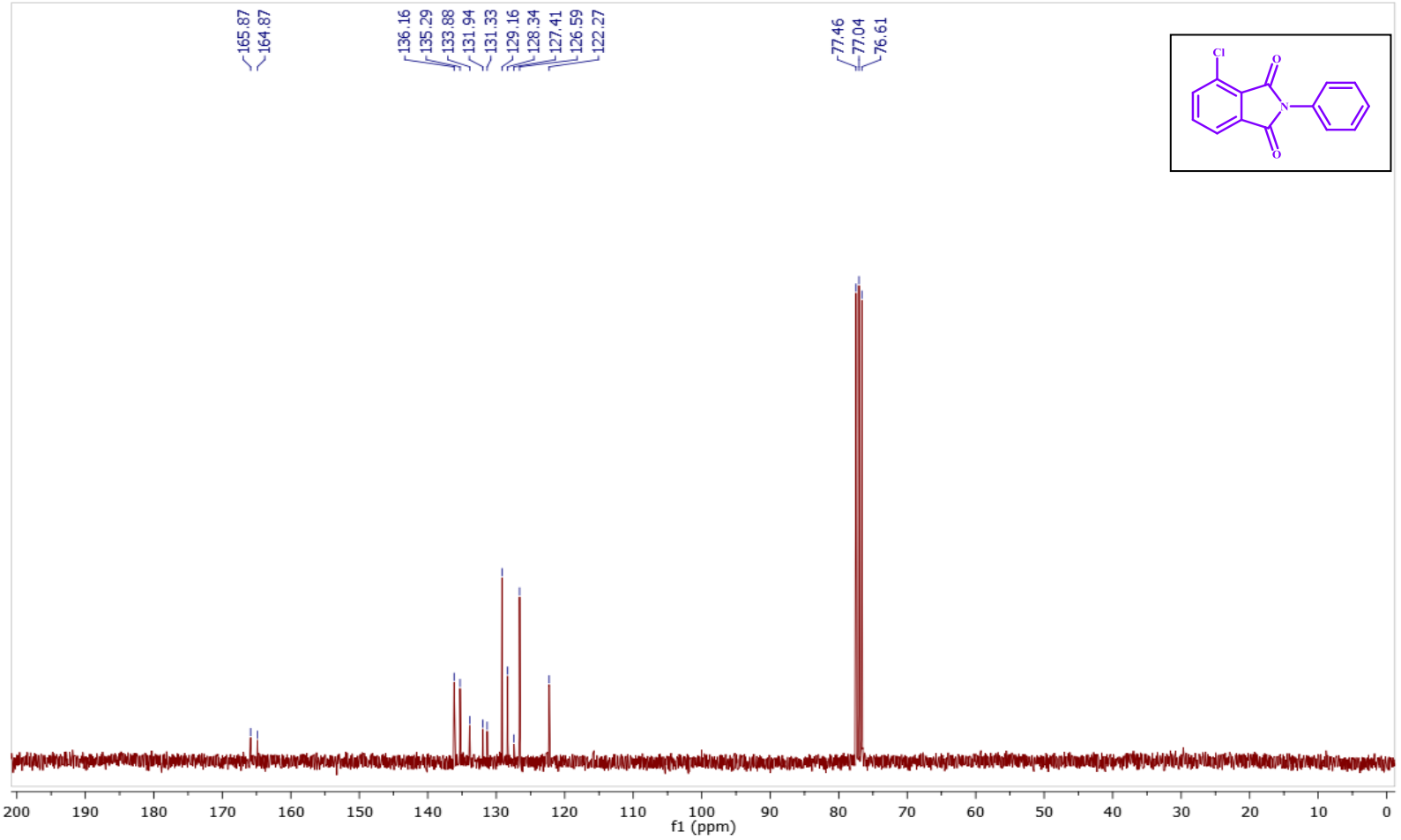
2-(pyridin-3-yl)isoindoline-1,3-dione (4f): 13C NMR (75 MHz, CDCl3):



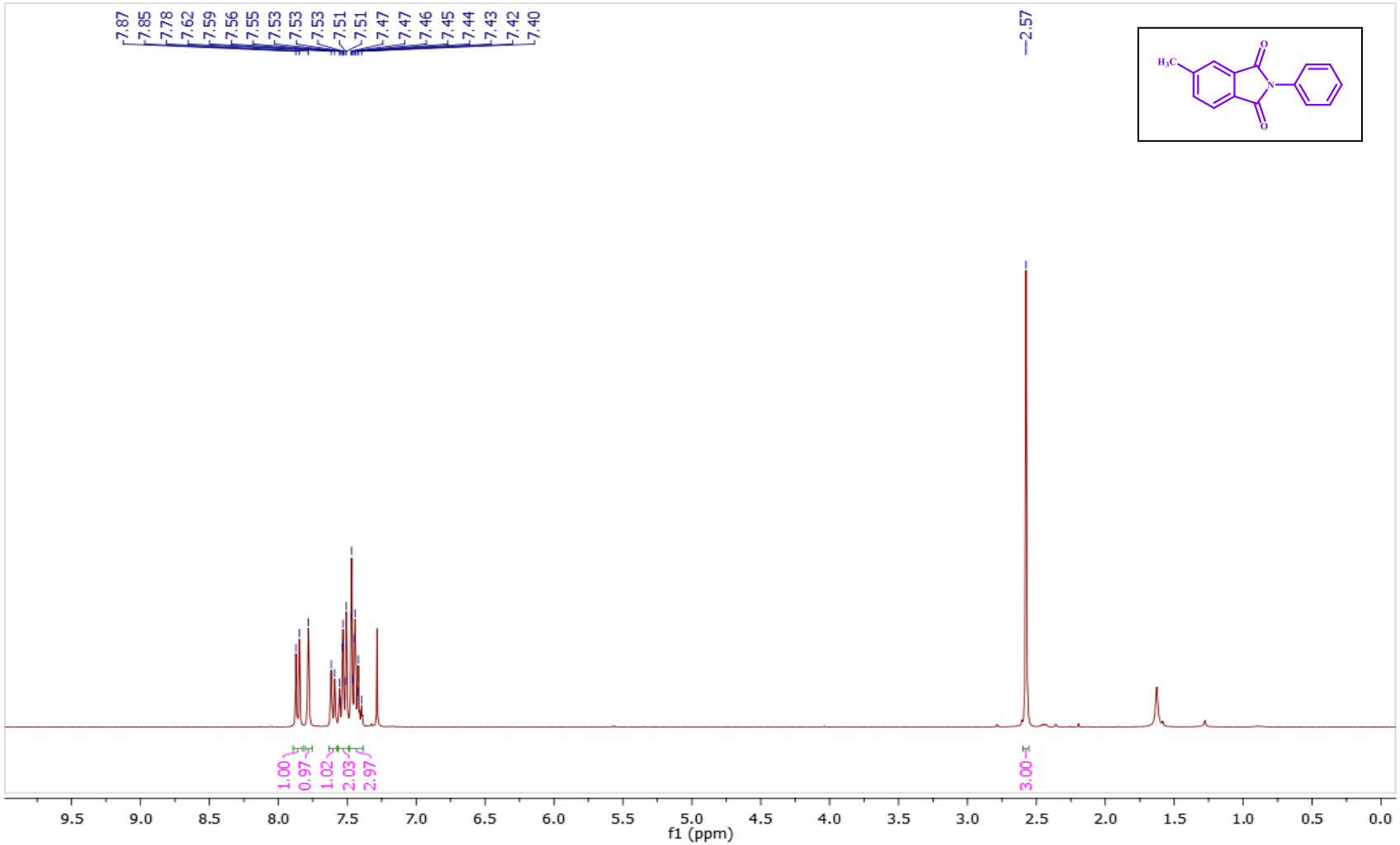
4-chloro-2-phenylisoindoline-1,3-dione (4g): ^{1}H NMR (300 MHz, CDCl3):



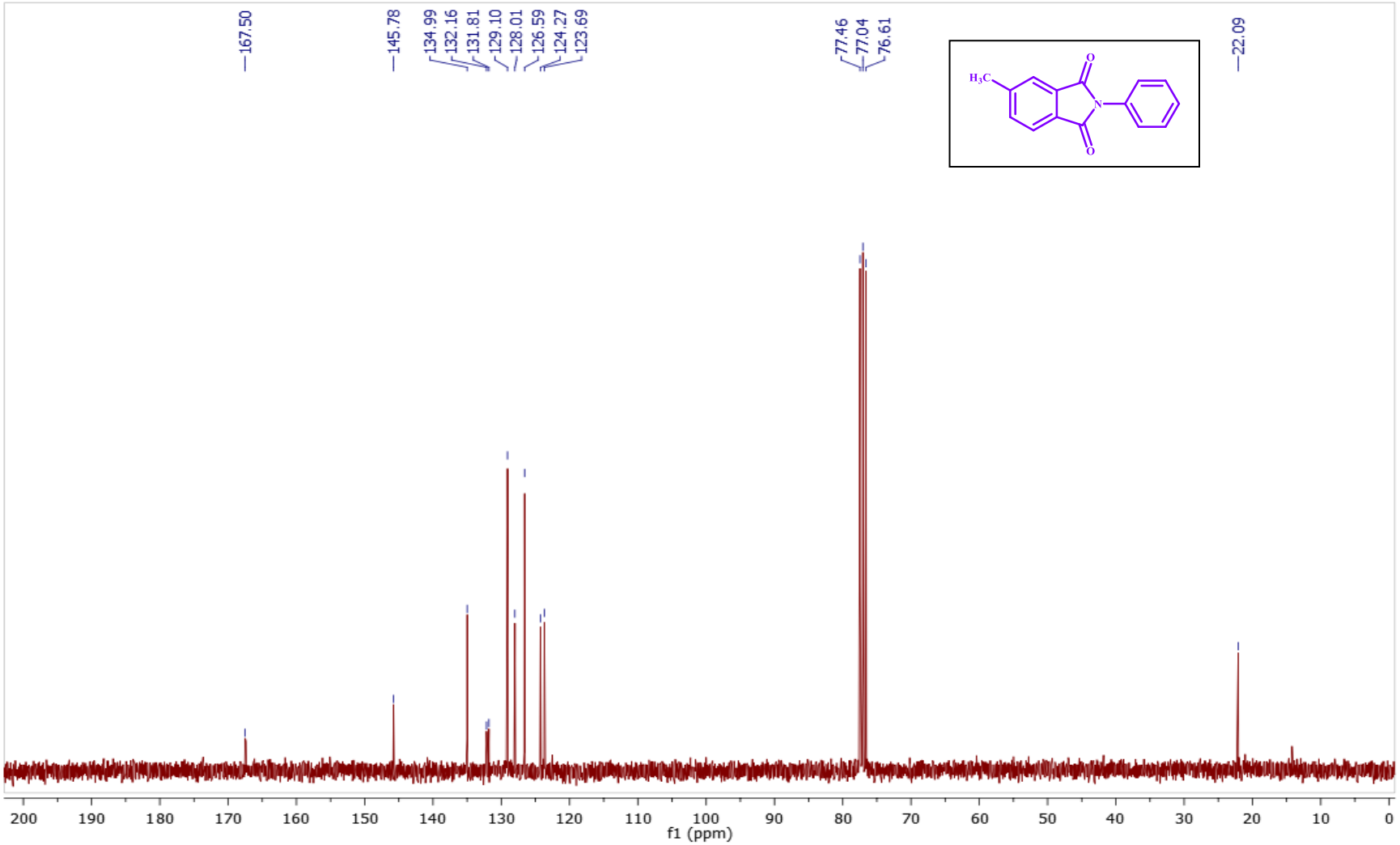
4-chloro-2-phenylisoindoline-1,3-dione (4g): ^{13}C NMR (75 MHz, CDCl3):



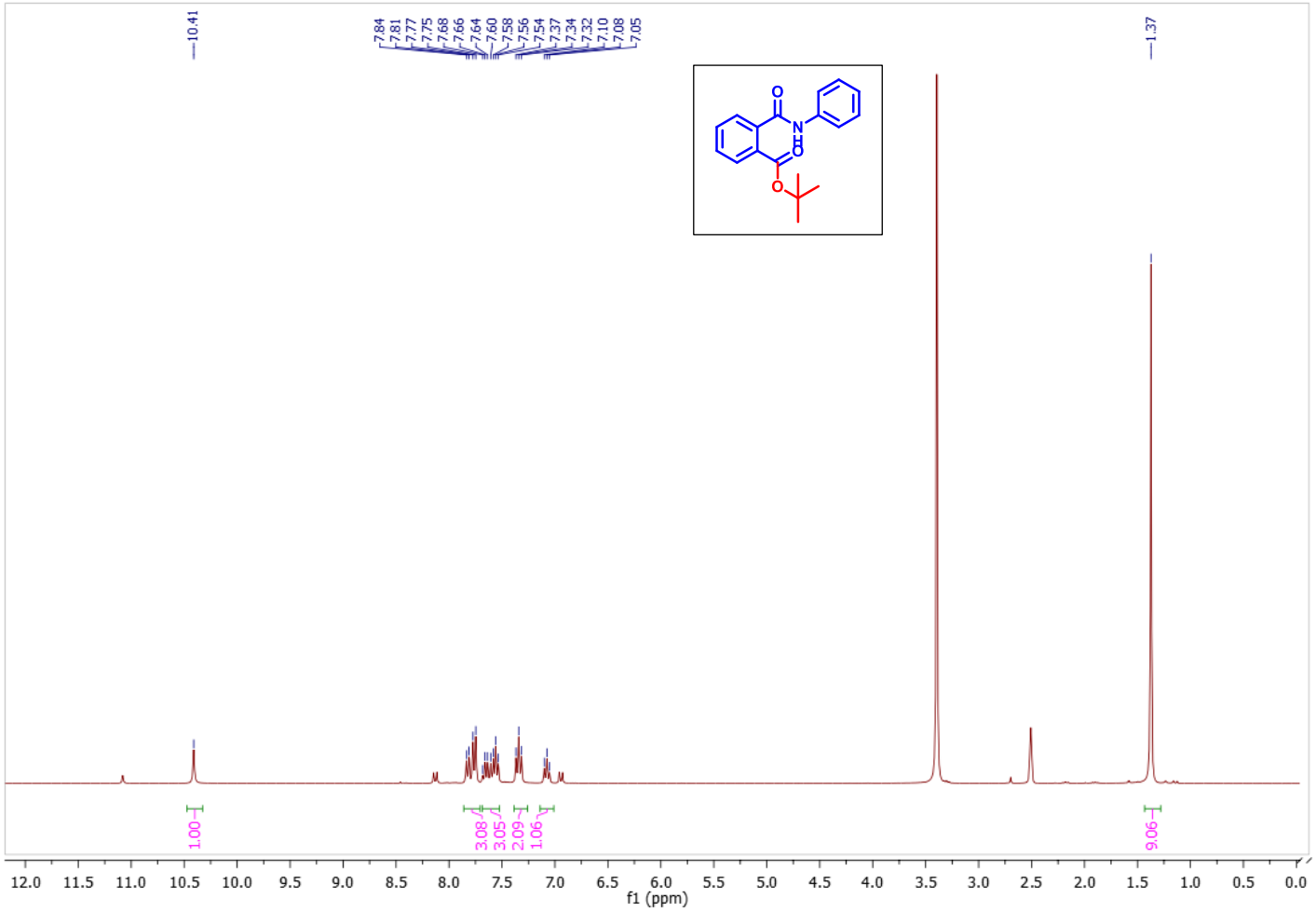
5-methyl-2-phenylisoindoline-1,3-dione (4h): ^{1}H NMR (300 MHz, CDCl3):



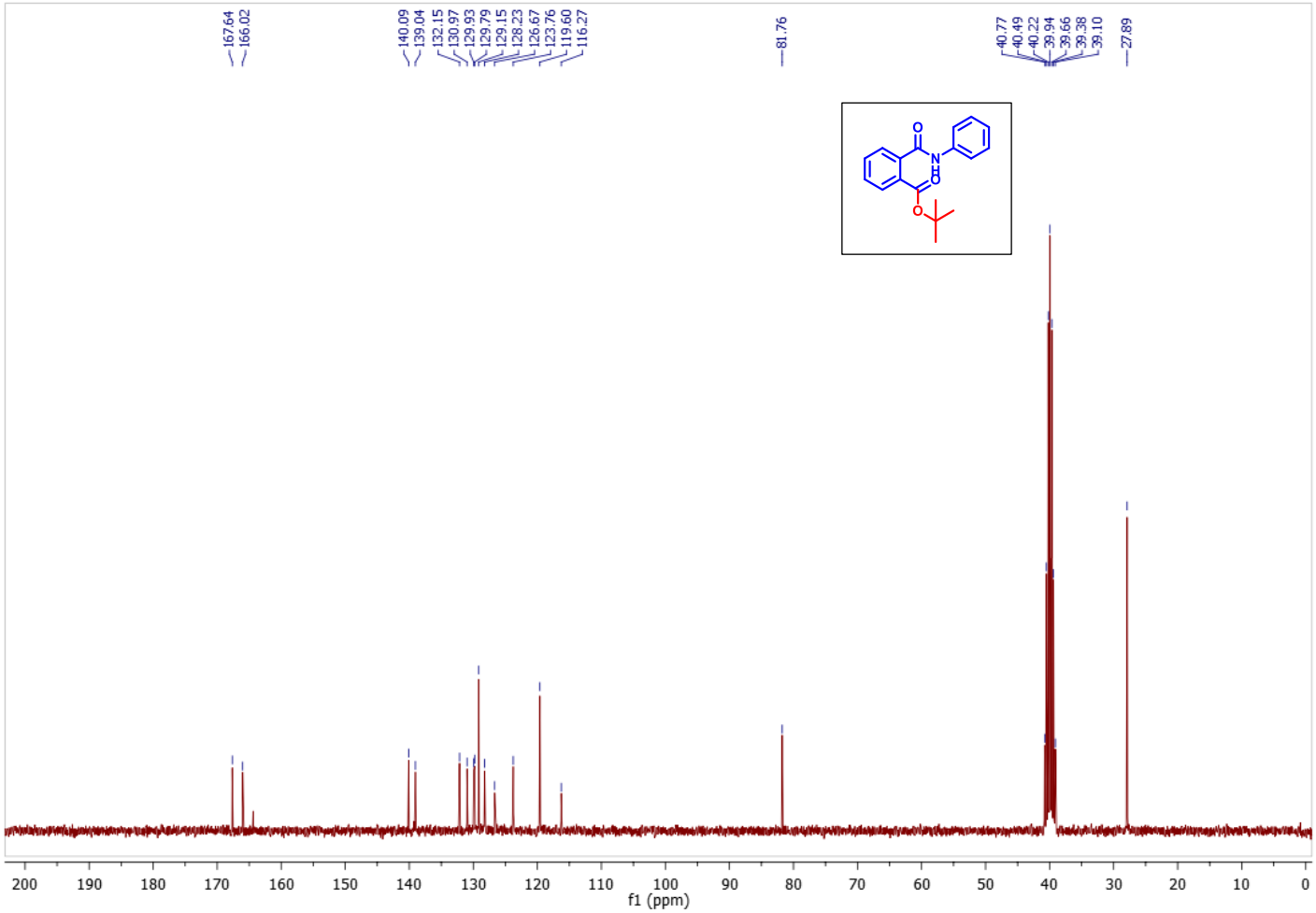
5-methyl-2-phenylisoindoline-1,3-dione (4h): ^{13}C NMR (75 MHz, CDCl3):



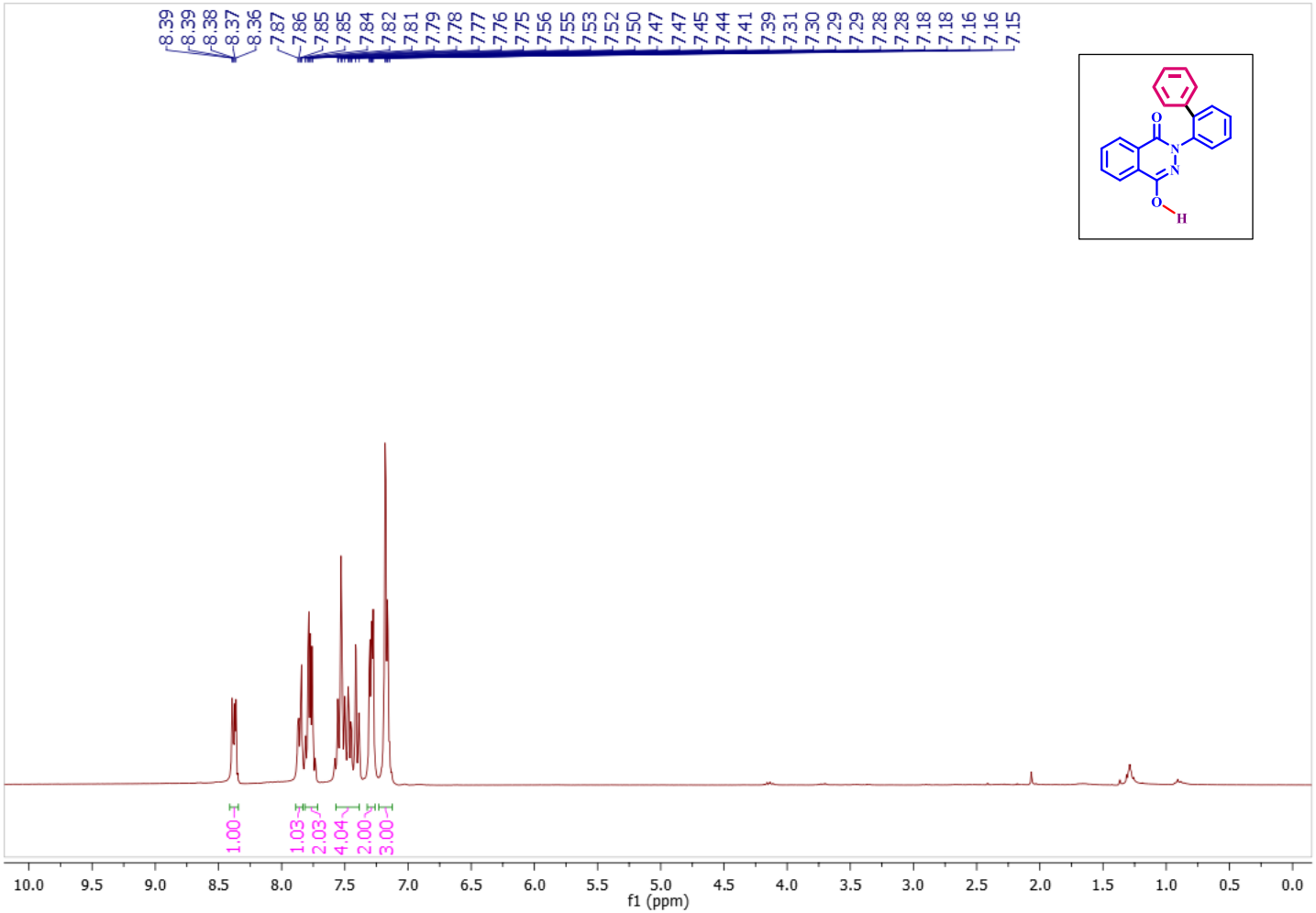
tert-butyl 2-(phenylcarbamoyl)benzoate (4′): ^{1}H NMR (300 MHz, DMSO-*d*$_6$):



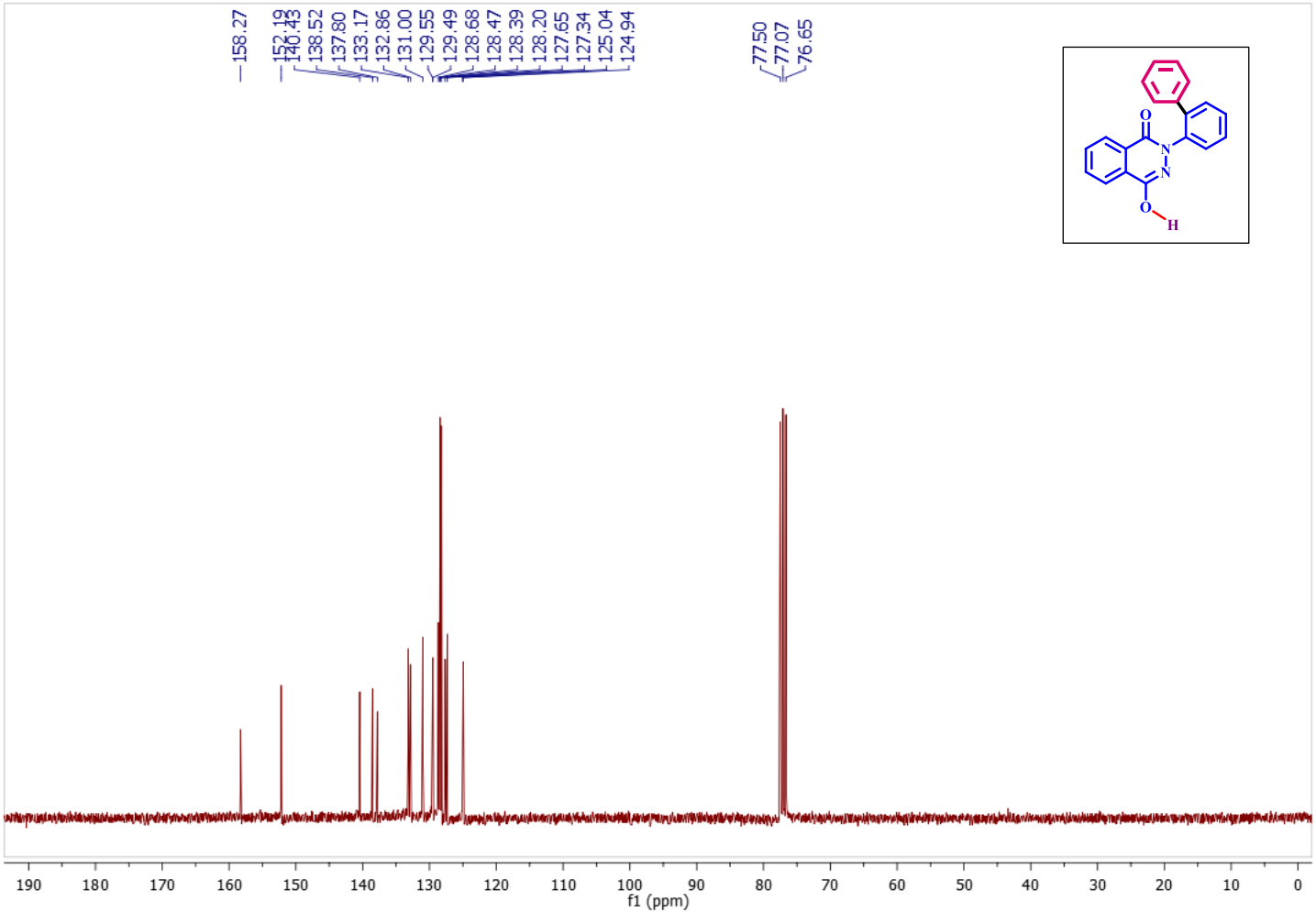
tert-butyl 2-(phenylcarbamoyl)benzoate (4′): ^{13}C NMR (75 MHz, DMSO-d_6):



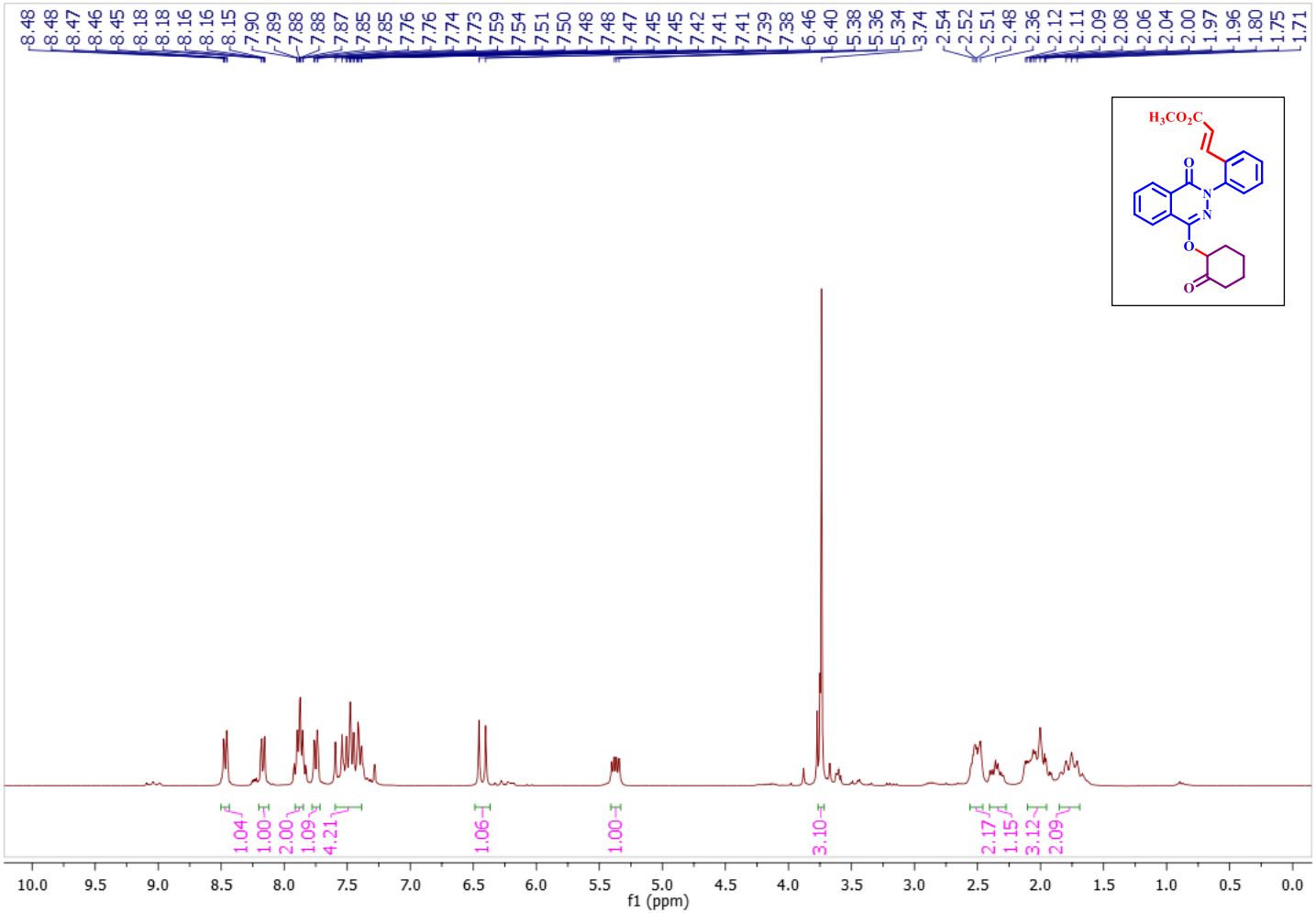
2-([1,1'-biphenyl]-2-yl)-4-hydroxyphthalazin-1(2H)-one (5): ^{1}H NMR (300 MHz, CDCl3):



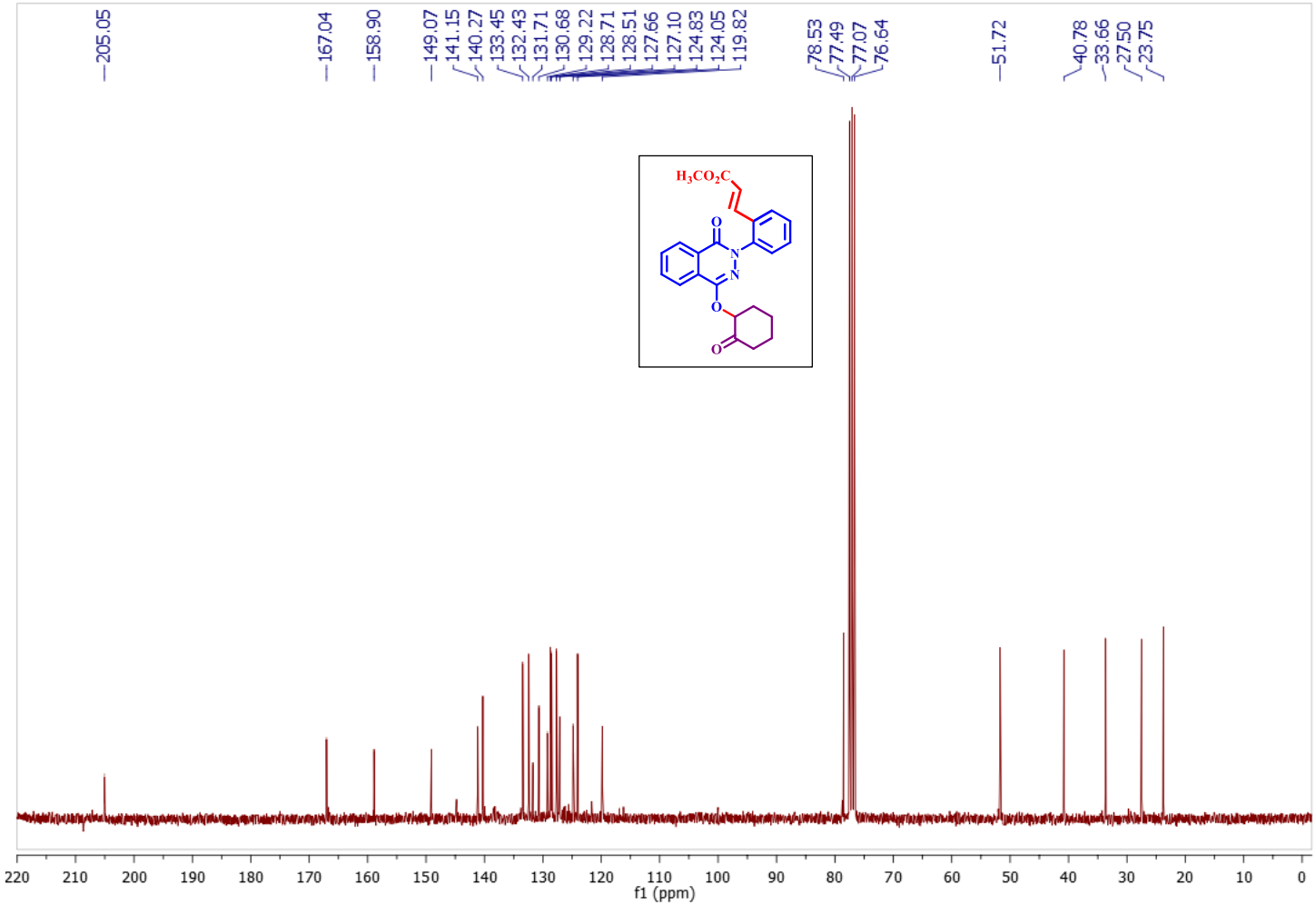
2-([1,1'-biphenyl]-2-yl)-4-hydroxyphthalazin-1(2*H*)-one (5): ^{13}C NMR (75 MHz, CDCl3):



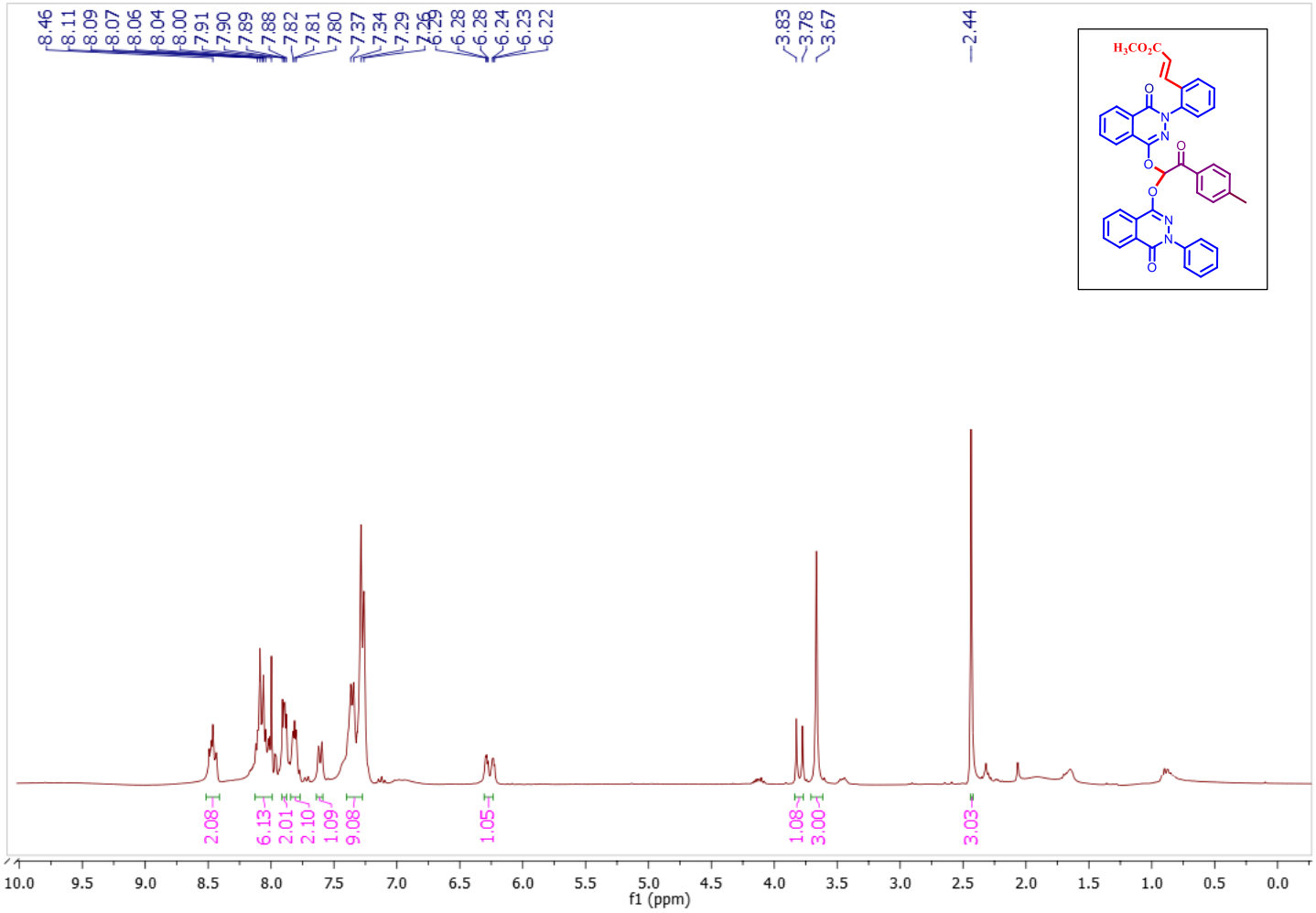
methyl (E)-3-(2-(1-oxo-4-((2-oxocyclohexyl)oxy)phthalazin-2(1*H*)-yl)phenyl)acrylate (6): ^{1}H NMR (300 MHz, CDCl3):



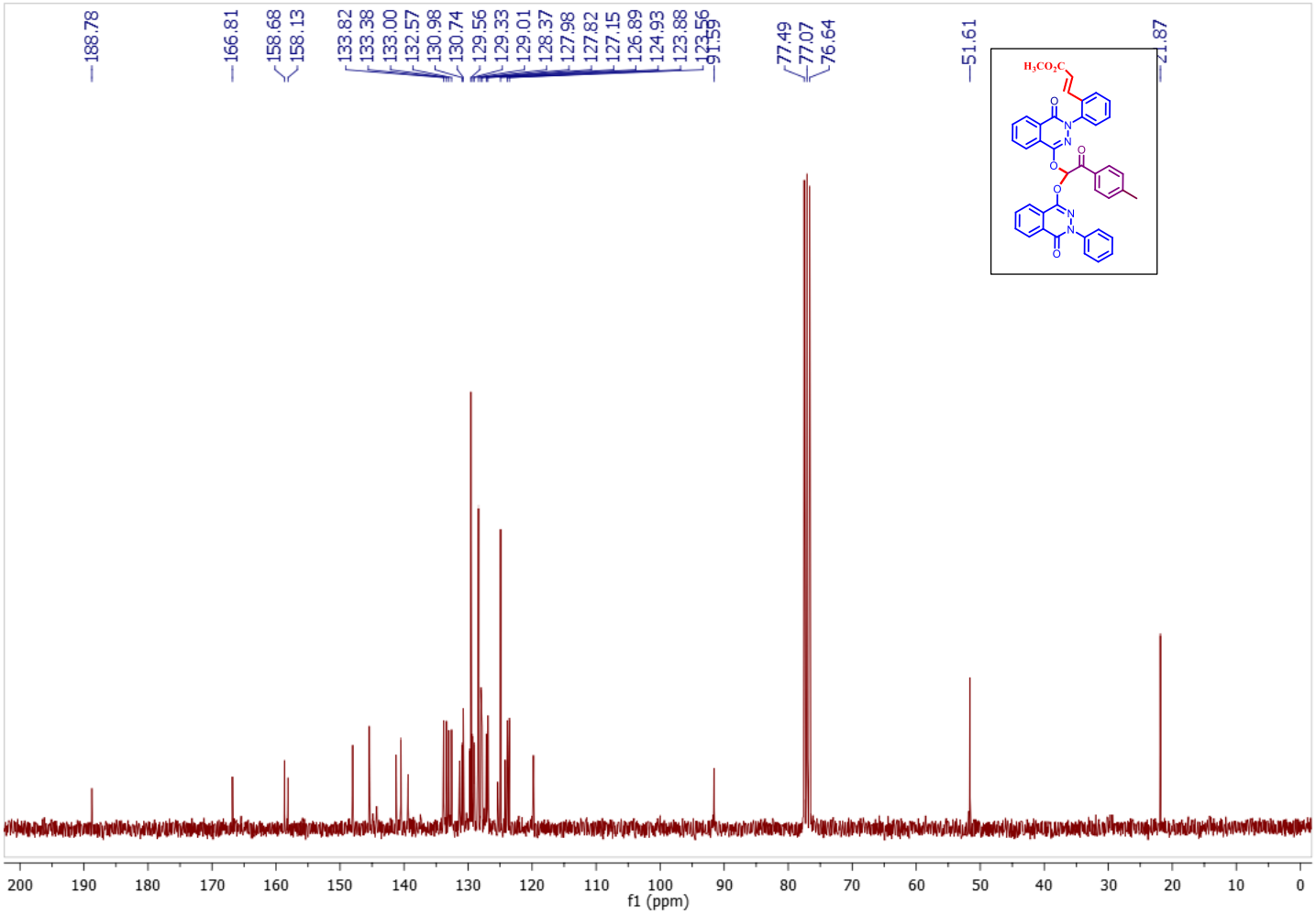
methyl (E)-3-(2-(1-oxo-4-((2-oxocyclohexyl)oxy)phthalazin-2(1*H*)-yl)phenyl)acrylate (6): ^{13}C NMR (75 MHz, CDCl3):



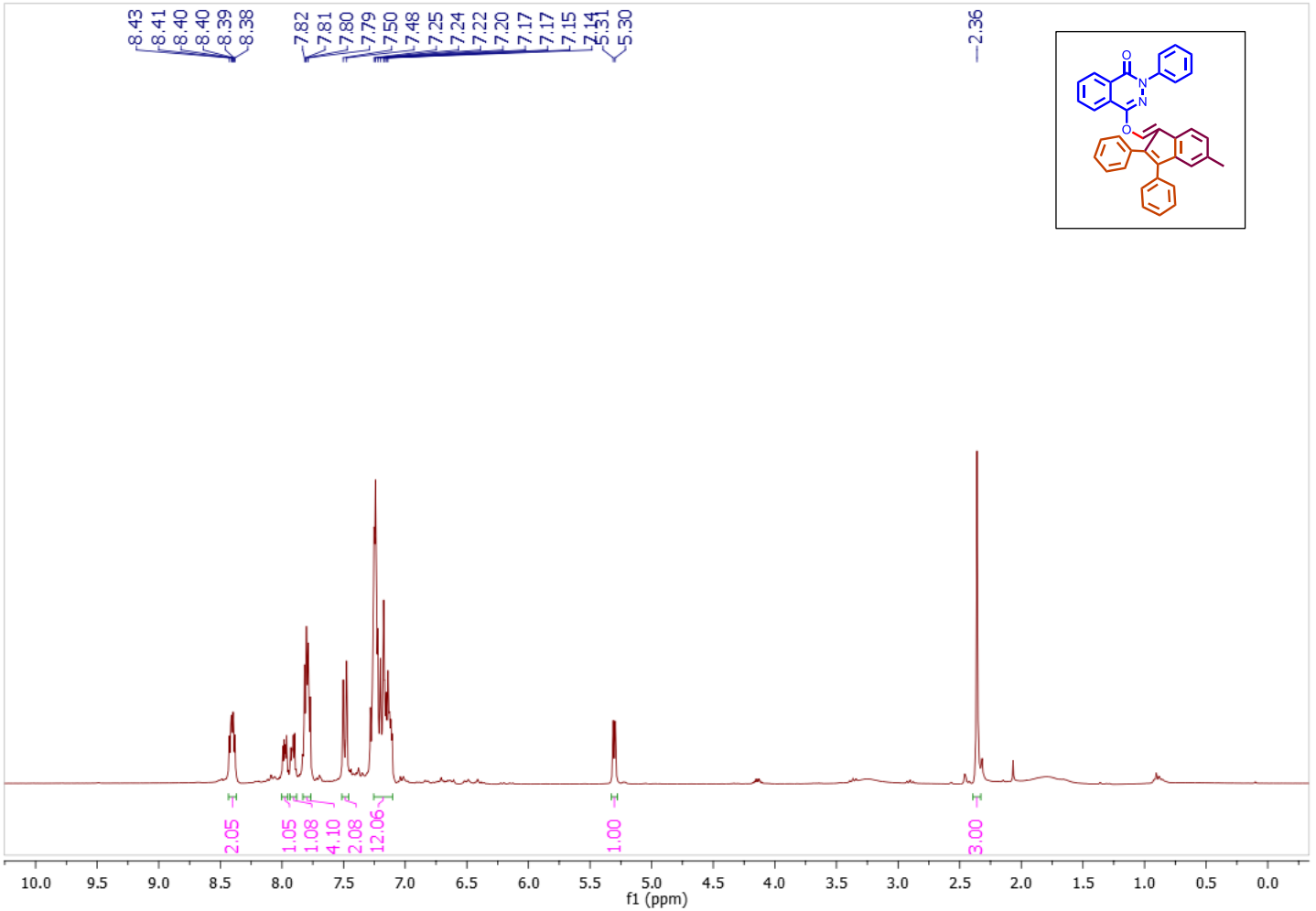
methyl (E)-3-(2-(1-oxo-4-(2-oxo-1-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)-2-(p-tolyl)ethoxy)phthalazin-2(1*H*)-yl)phenyl)acrylate (7): ^{1}H NMR (300 MHz, CDCl3):



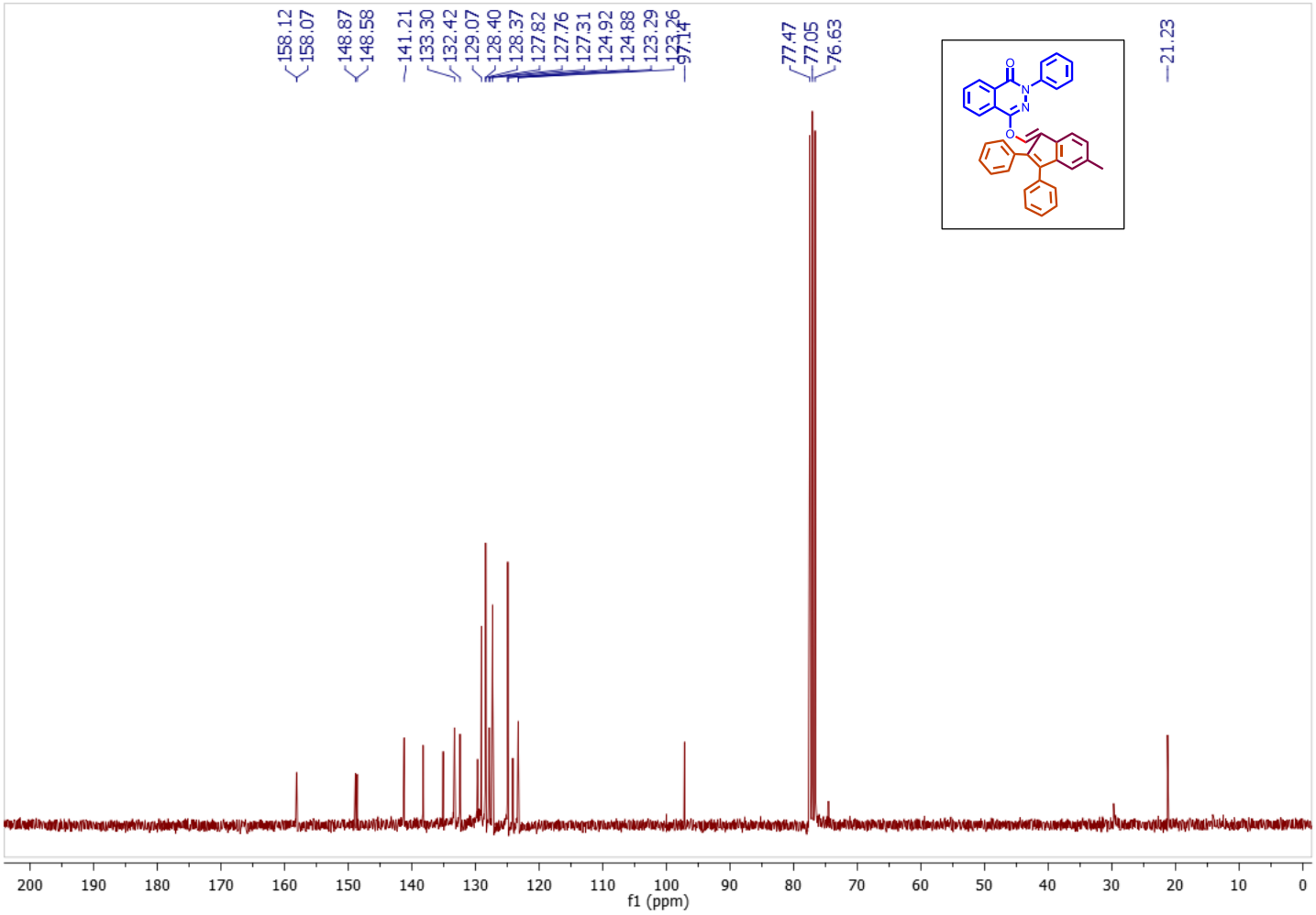
methyl (E)-3-(2-(1-oxo-4-(2-oxo-1-((4-oxo-3-phenyl-3,4-dihydrophthalazin-1-yl)oxy)-2-(p-tolyl)ethoxy)phthalazin-2(1*H*)-yl)phenyl)acrylate (7): ^{13}C NMR (75 MHz, CDCl3):



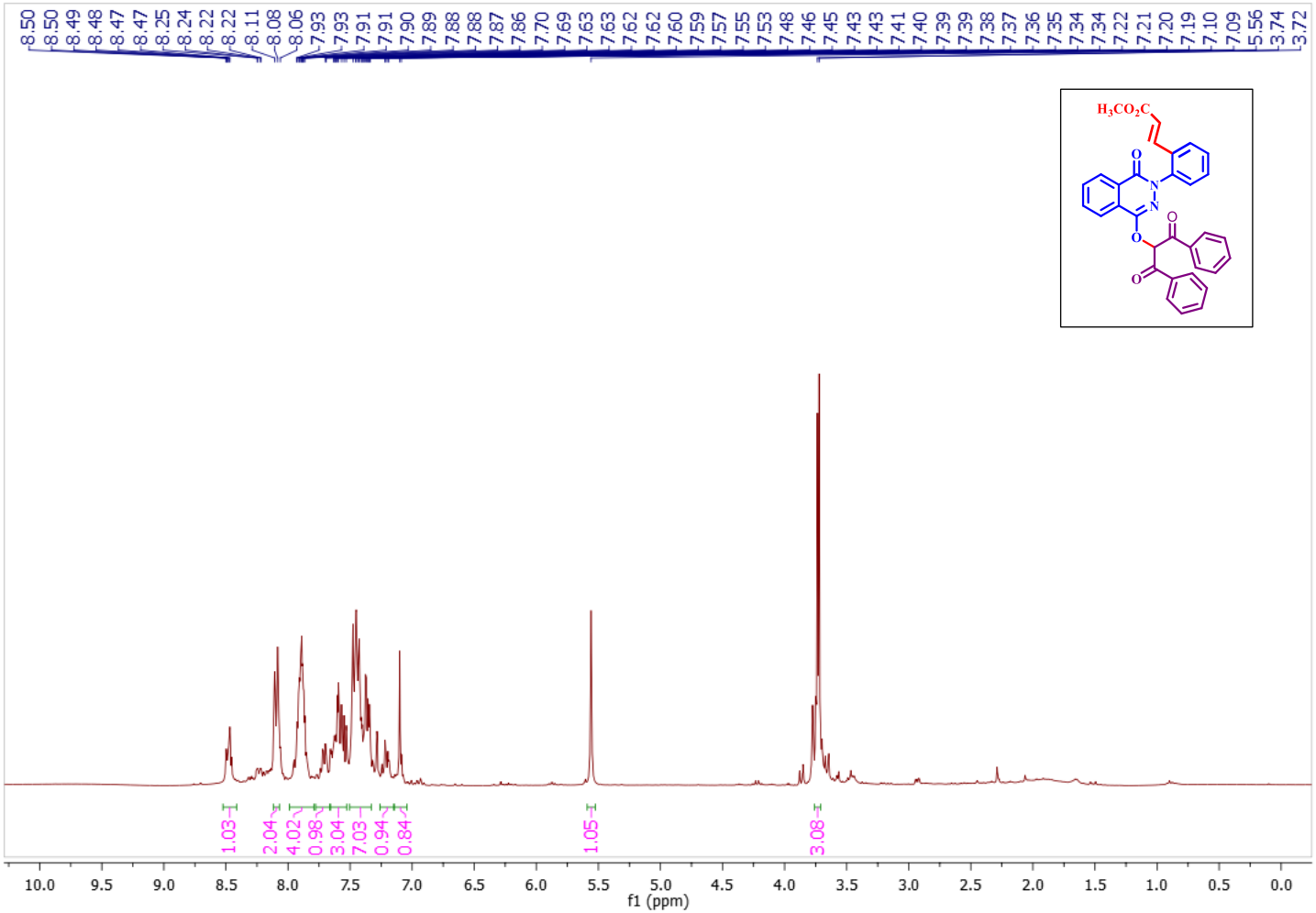
(E)-4-((5-methyl-2,3-diphenyl-1H-inden-1-ylidene)methoxy)-2-phenylphthalazin-1(2*H*)-one (8): ^{1}H NMR (300 MHz, CDCl3):



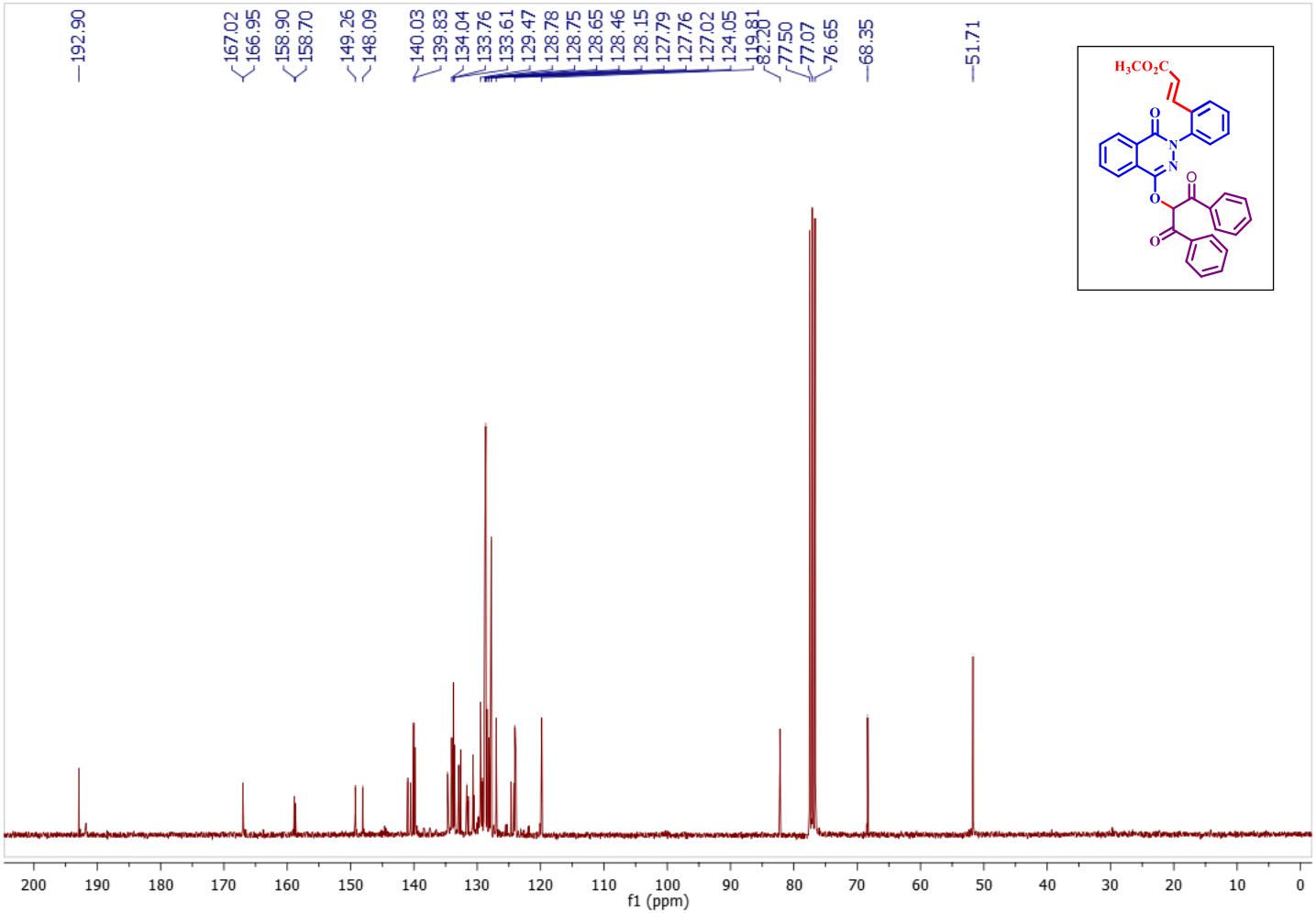
(E)-4-((5-methyl-2,3-diphenyl-1H-inden-1-ylidene)methoxy)-2-phenylphthalazin-1(2*H*)-one (8): ^{1}H NMR (300 MHz, CDCl3): ^{13}C NMR (75 MHz, CDCl3):



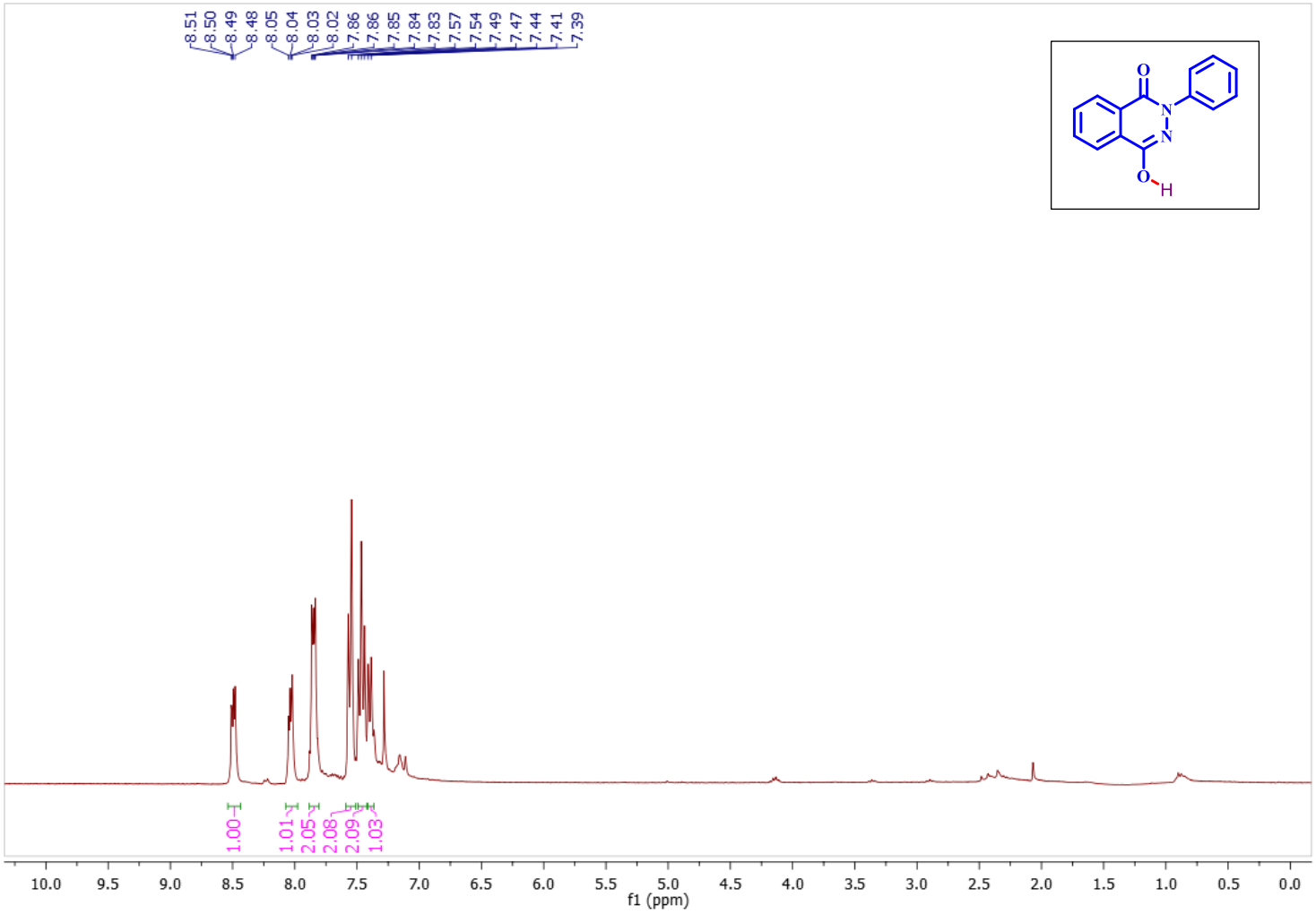
methyl (E)-3-(2-(4-((1,3-dioxo-1,3-diphenylpropan-2-yl)oxy)-1-oxophthalazin-2(1*H*)-yl)phenyl)acrylate (9): ^{1}H NMR (300 MHz, CDCl3):



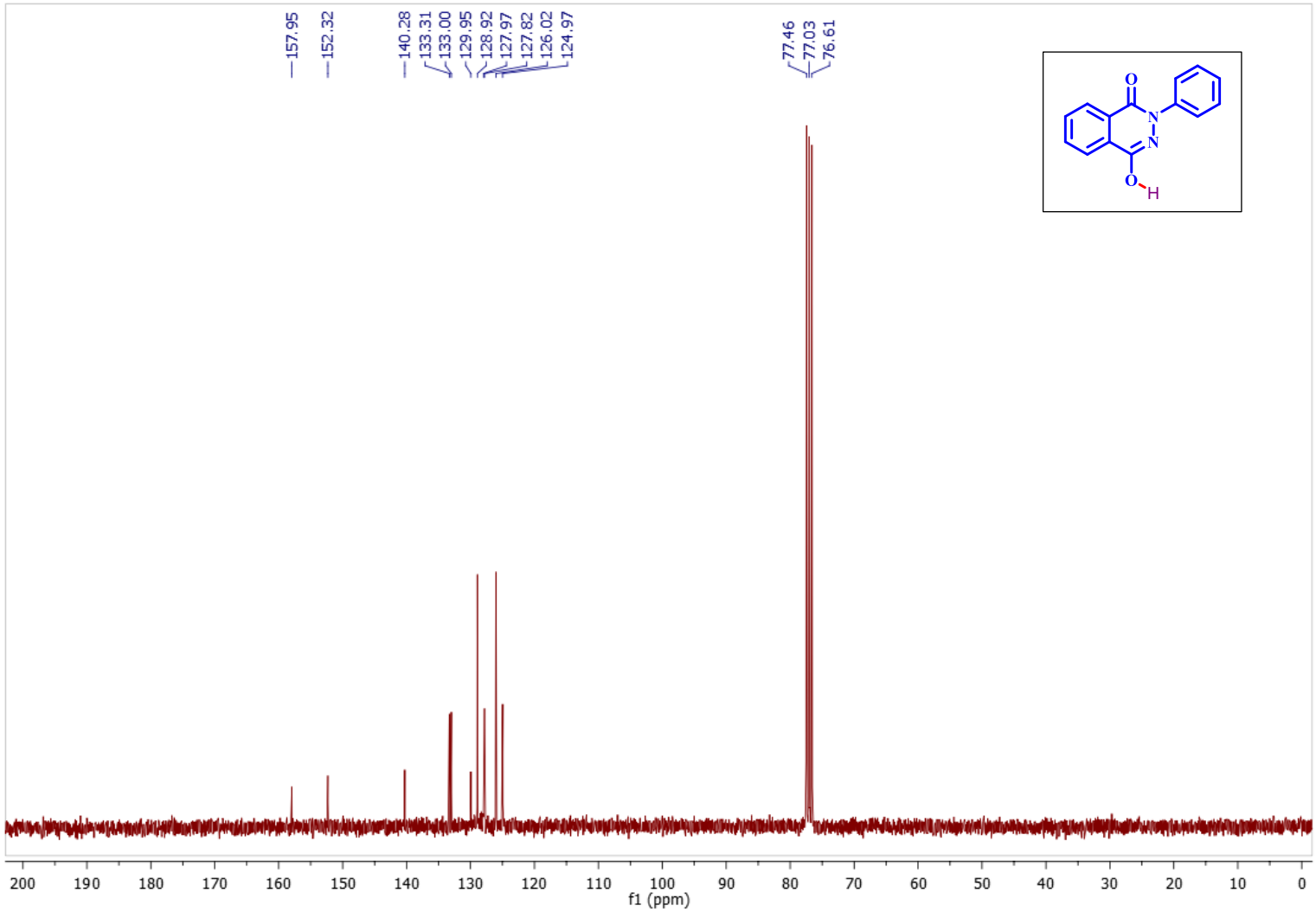
methyl (E)-3-(2-(4-((1,3-dioxo-1,3-diphenylpropan-2-yl)oxy)-1-oxophthalazin-2(1*H*)-yl)phenyl)acrylate (9): ^{13}C NMR (75 MHz, CDCl3):



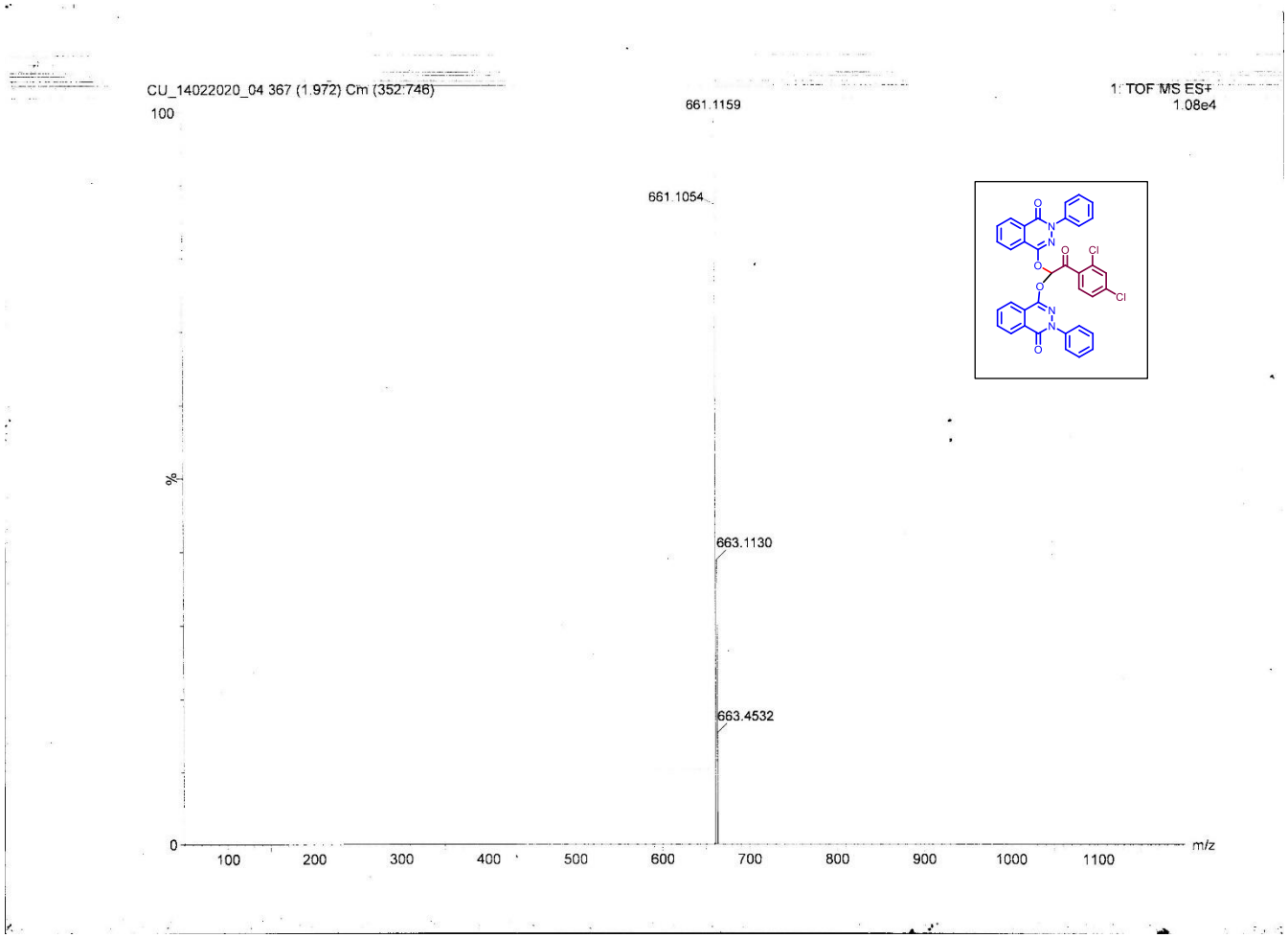
4-hydroxy-2-phenylphthalazin-1(2*H*)-one (1a): ^{1}H NMR (300 MHz, CDCl3):



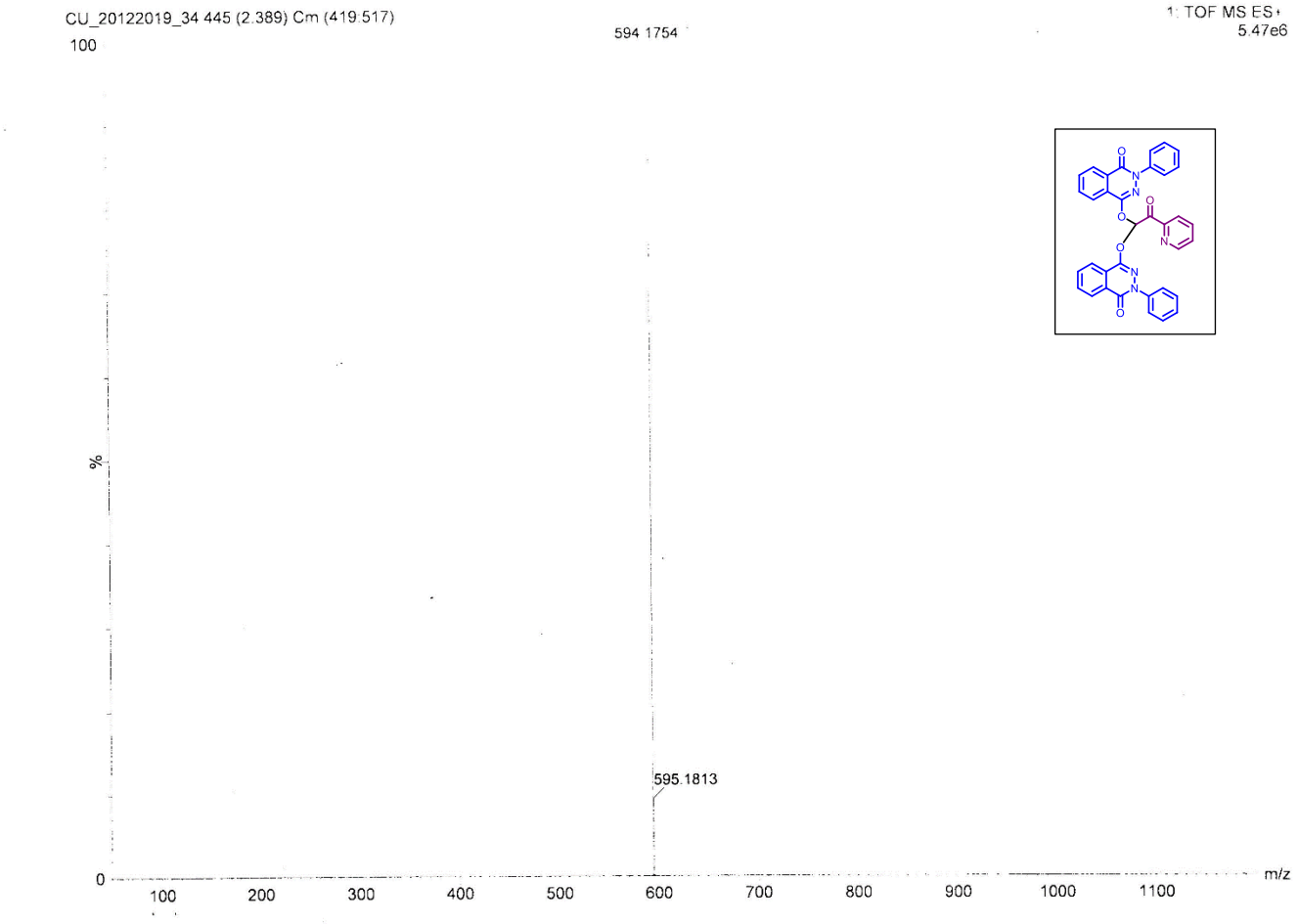
4-hydroxy-2-phenylphthalazin-1(2*H*)-one (1a): ^{13}C NMR (75 MHz, CDCl3):



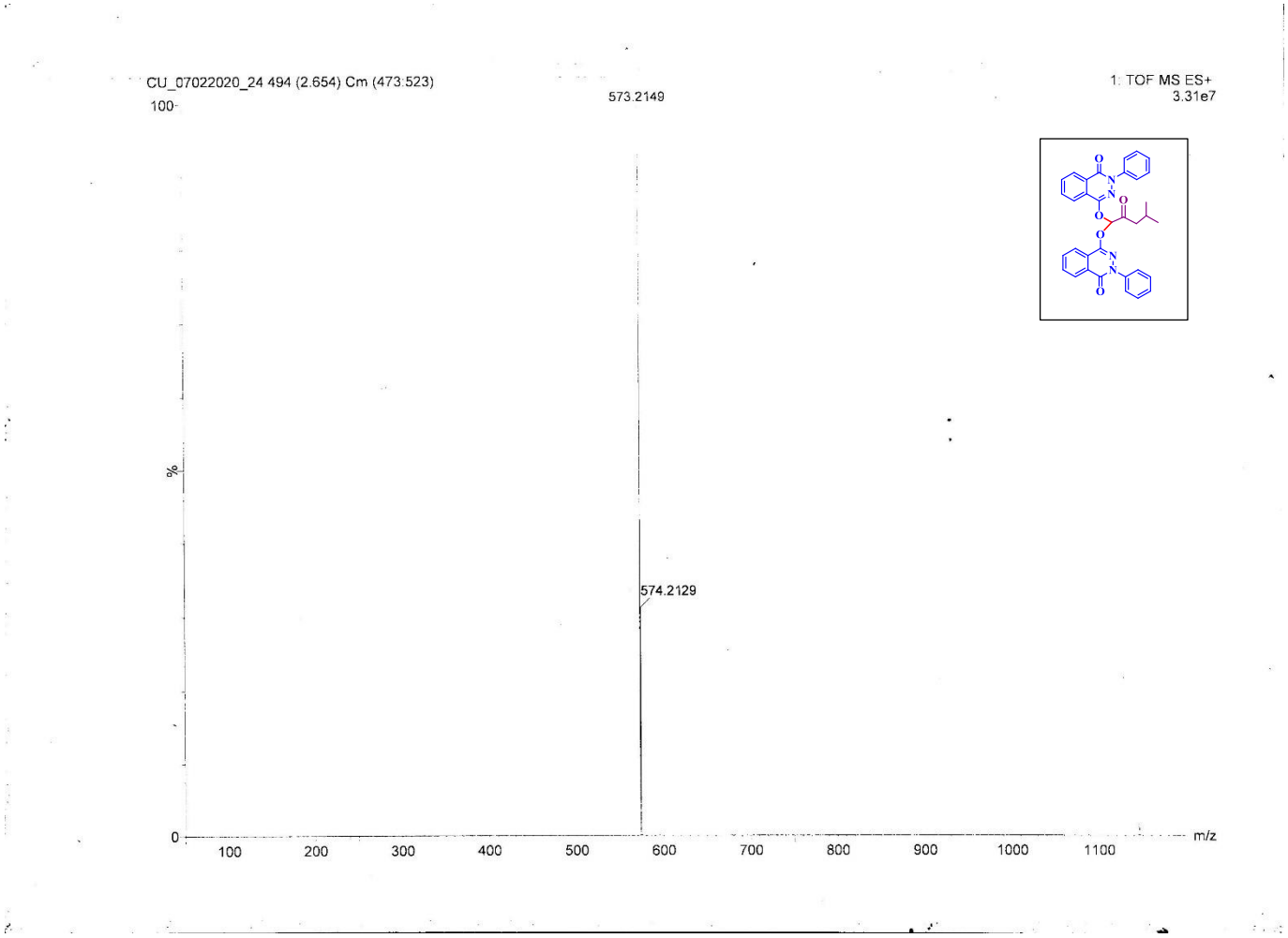
HRMS Sepctra of 4,4'-((2-(2,4-dichlorophenyl)-2-oxoethane-1,1-diyl)bis(oxy))bis(2 phenylphthalazin-1(2H)-one) (3e): $[C_{36}H_{22}Cl_2N_4O_5+H]^+$



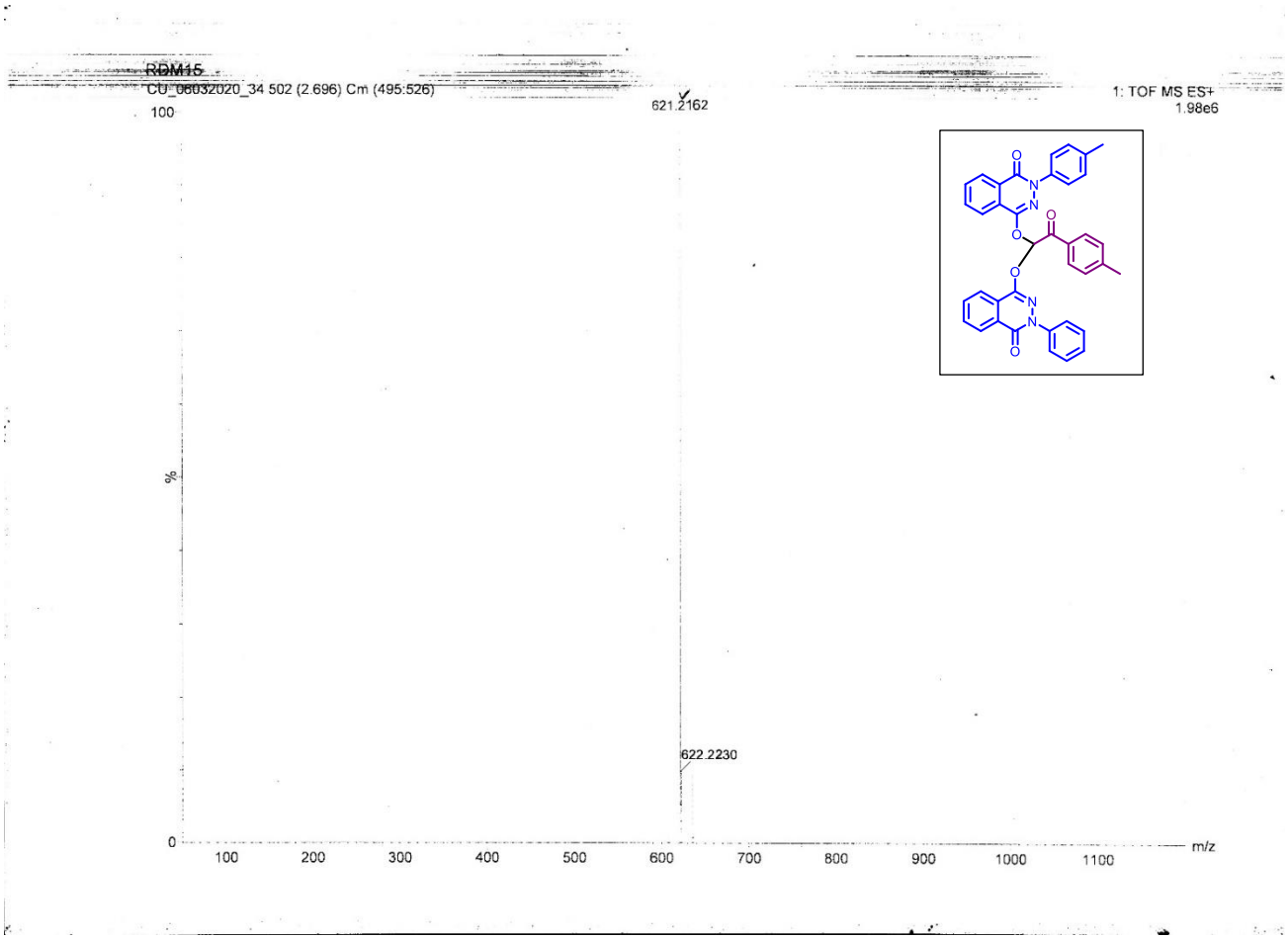
HRMS Sepctra of 4,4'-((2-oxo-2-(pyridin-2-yl)ethane-1,1-diyl)bis(oxy))bis(2 phenylphthalazin-1(2H)-one) (3t): $[C_{35}H_{23}N_5O_5+H]^+$:



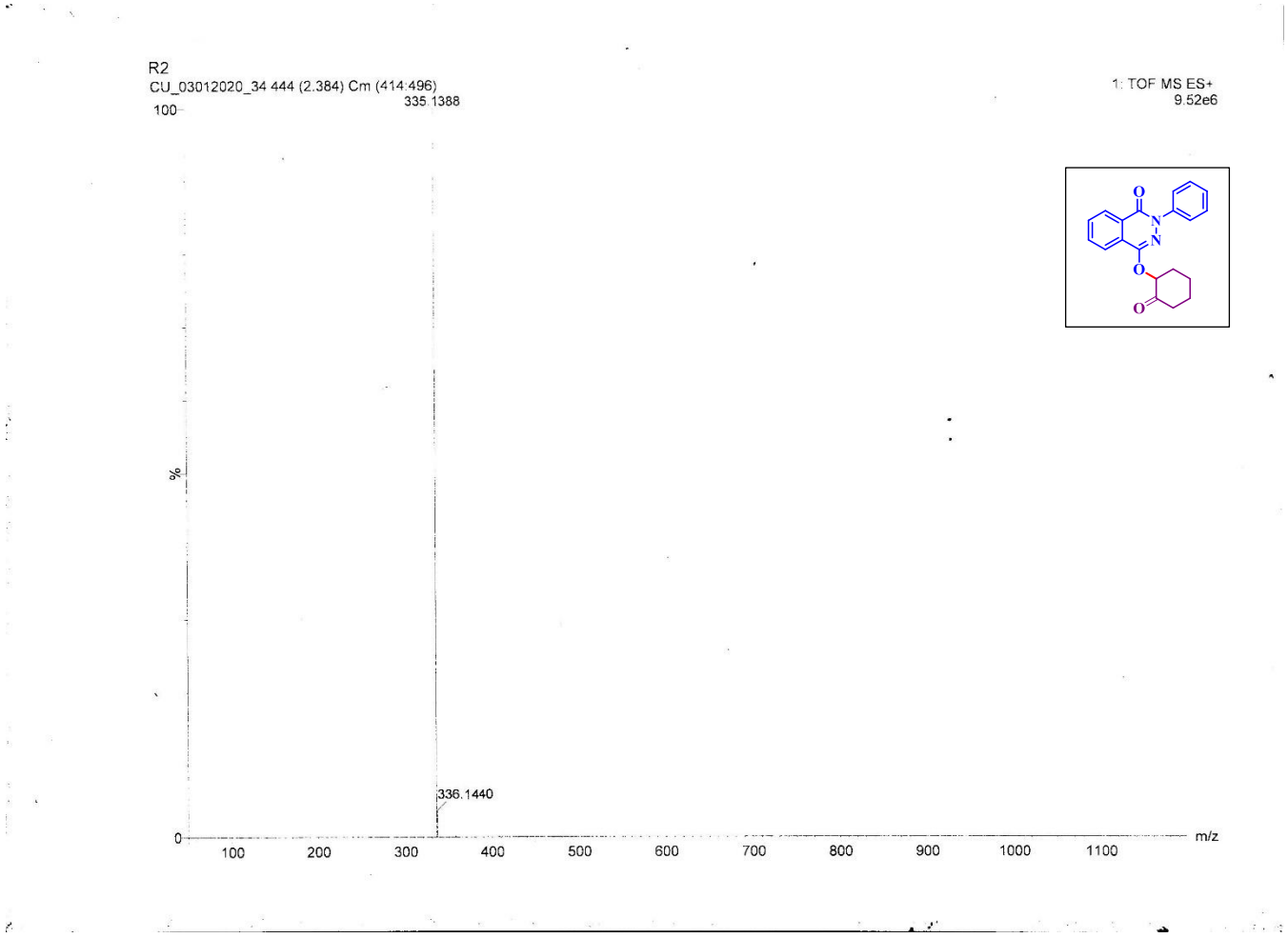
HRMS Sepctra of 4,4'-((4-methyl-2-oxopentane-1,1-diyl)bis(oxy))bis(2-phenylphthalazin-1(2H)-one) (3v): $[C_{34}H_{28}N_4O_5+H]^+$:



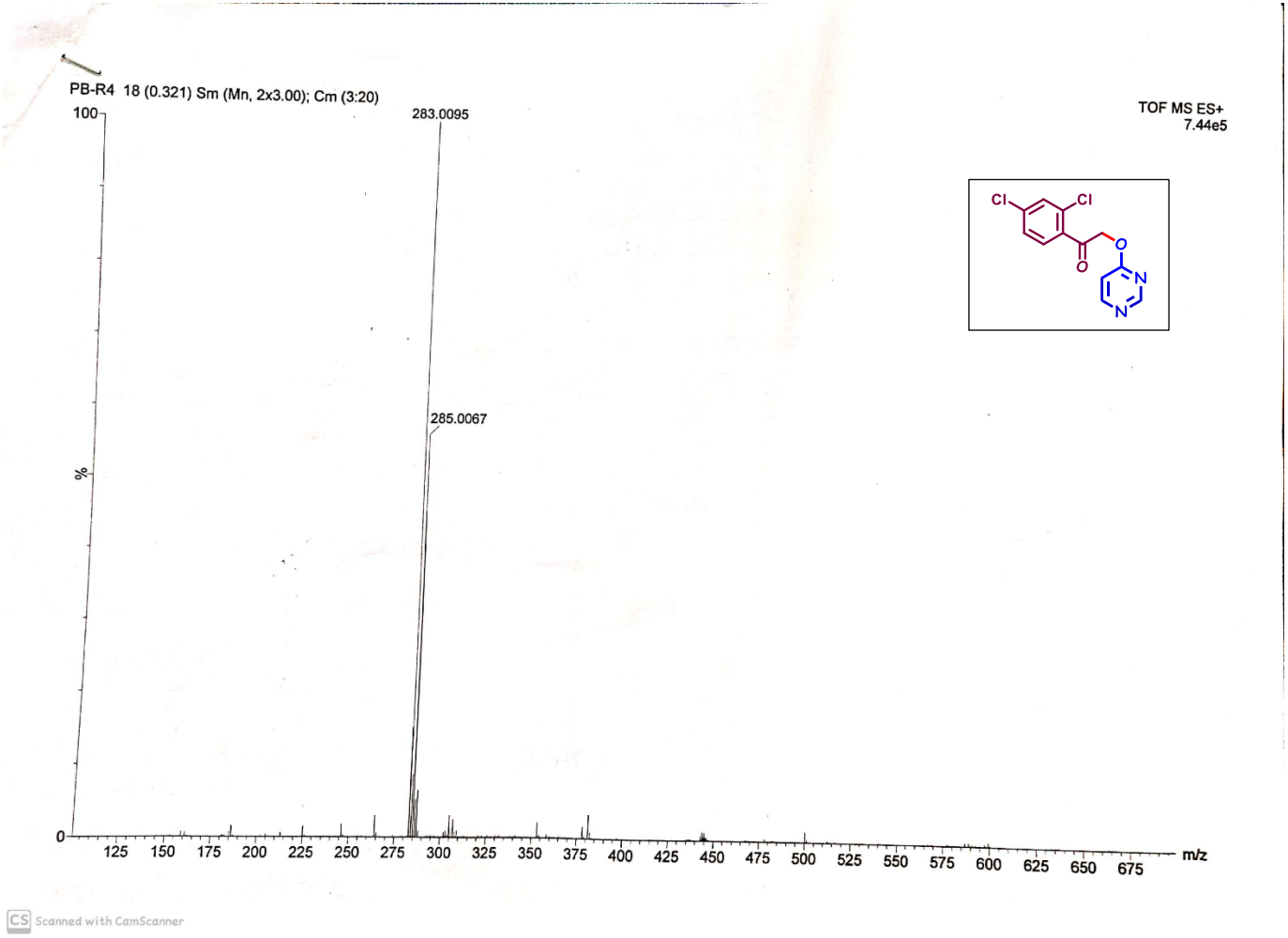
HRMS Sepctra of 4-(2-oxo-1-((4-oxo-3-(p-tolyl)-3,4-dihydrophthalazin-1-yl)oxy)-2-(p-tolyl)ethoxy)-2-phenylphthalazin-1(2H)-one (3zg): $[C_{38}H_{28}N_4O_5+H]^+$:



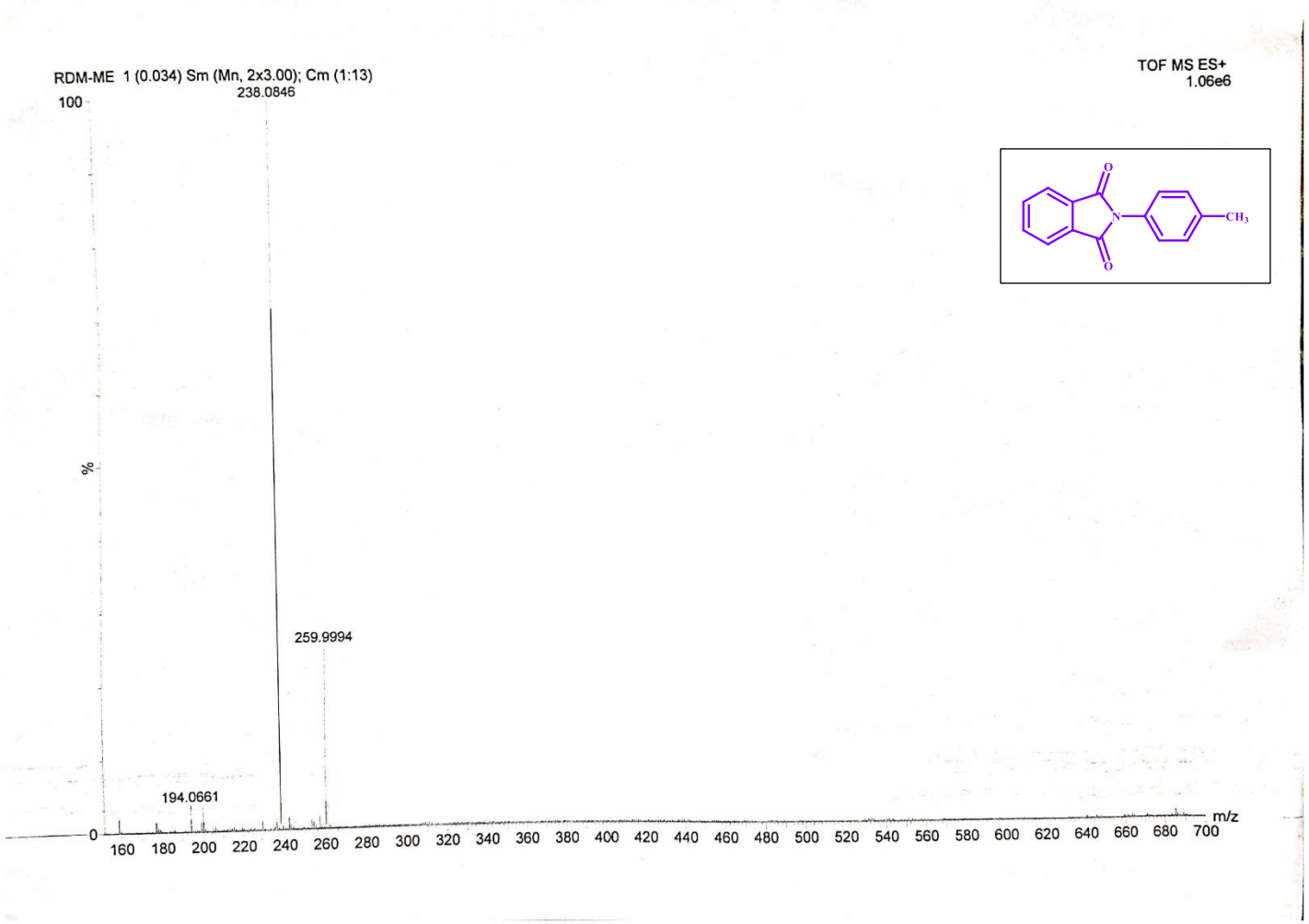
HRMS Sepctra of 4-((2-oxocyclohexyl)oxy)-2-phenylphthalazin-1(2*H*)-one: (3ab): $[C_{20}H_{18}N_2O_3+H]^+$:



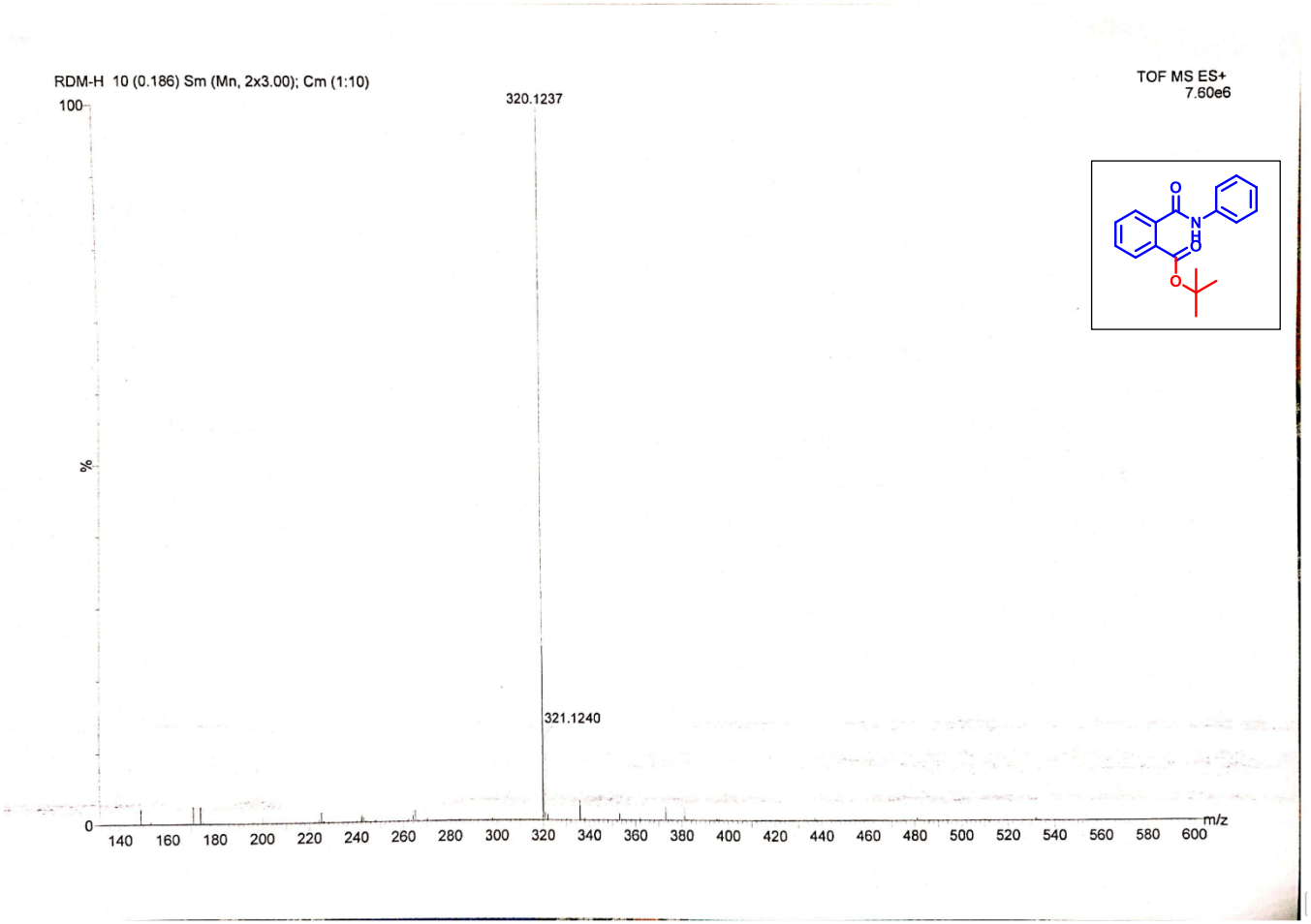
HRMS Sepctra of 1-(2,4-dichlorophenyl)-2-(pyrimidin-4-yloxy)ethan-1-one (3au): $[C_{12}H_8Cl_2N_2O_2+H]^+$:



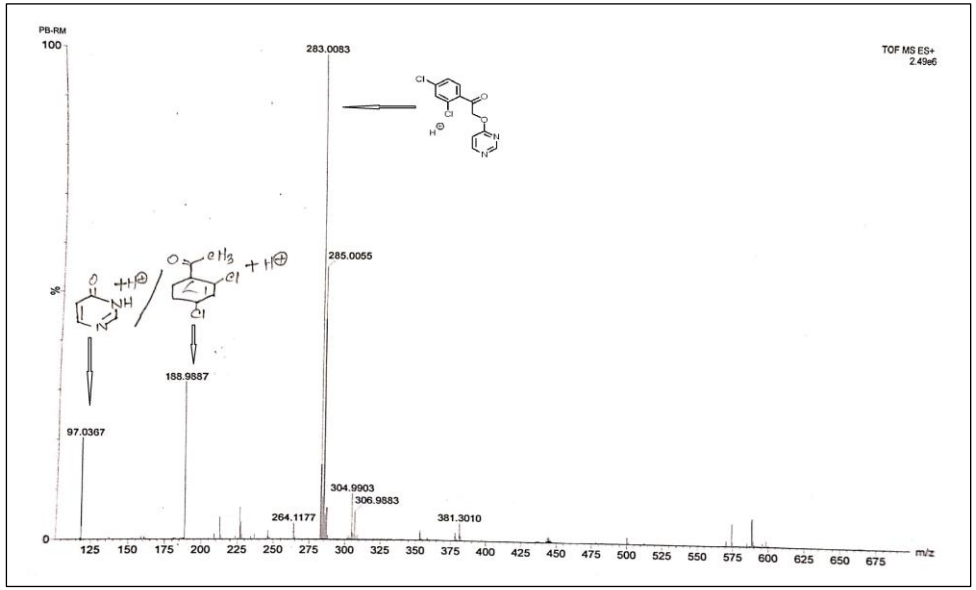
HRMS Sepctra of 2-(p-tolyl)isoindoline-1,3-dione (4b): $[C_{15}H_{11}NO_2+H]^+$:



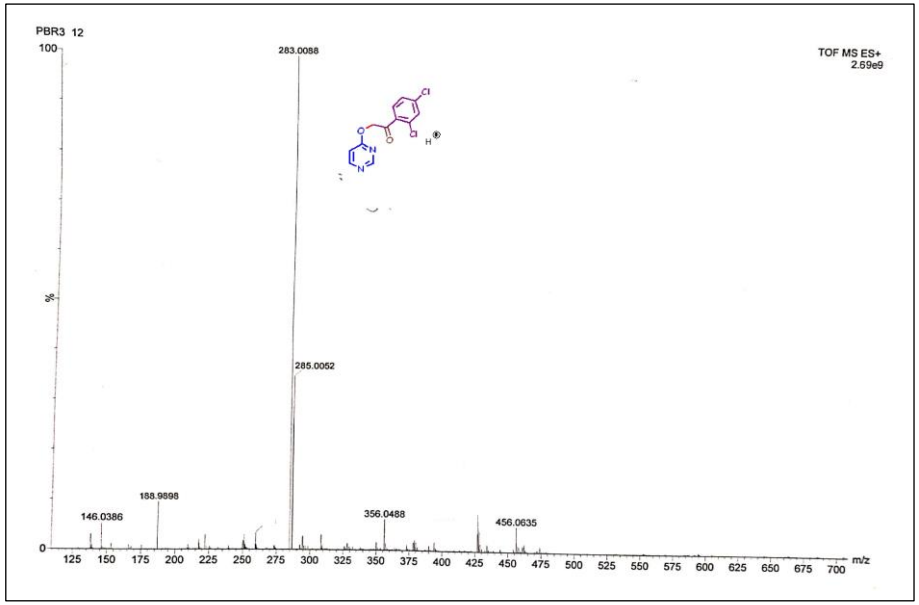
HRMS Sepctra of tert-butyl 2-(phenylcarbamoyl)benzoate (4′): $[C_{18}H_{19}NO_3 + Na]^+$:



HRMS analysis of reaction mixture (RM-3) after 5hr. (I) and 8hr. (II) of oxidative C(sp^3)-O cross coupling reaction of Pyrimidinone (1r) with 2, 4- dichloro acetophenone (2e):



After 5 hr. (I)



After 8 hr. (II)