

Electronic Supporting information

Stabilization of copper nanoparticles onto the double Schiff-base-functionalized ZSM-5 for A³ coupling reaction catalysis aiming under mild conditions

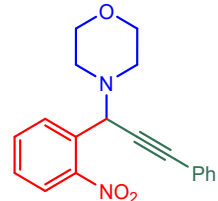
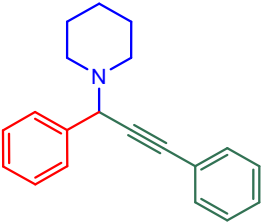
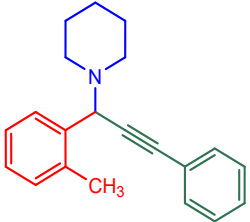
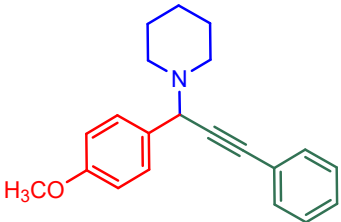
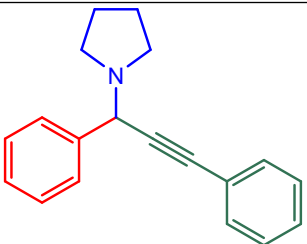
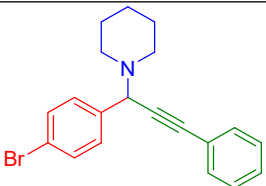
Leila Mohammadi^a, Mojtaba Hosseinifard^{b*}, Mohammad Reza Vaezi^{a*}, Sadegh Rostamnia^c

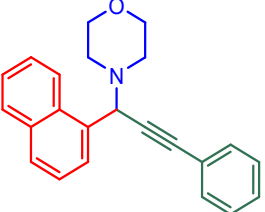
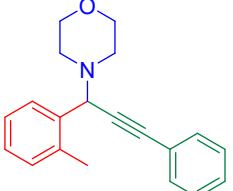
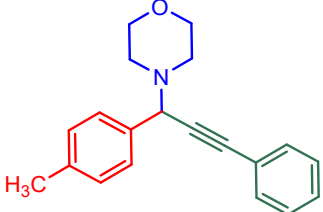
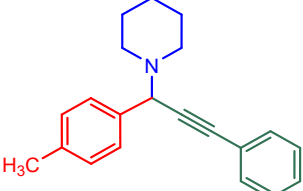
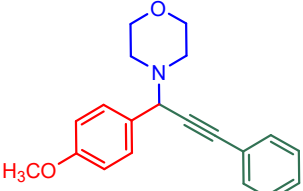
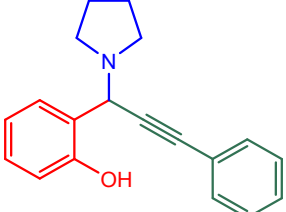
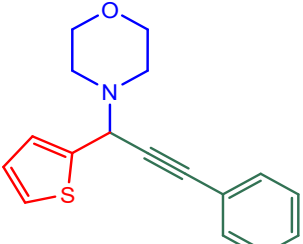
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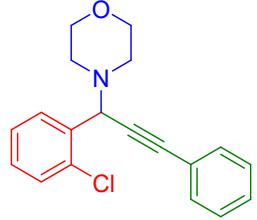
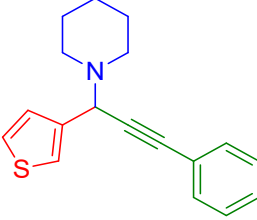
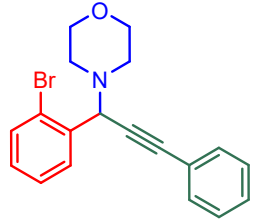
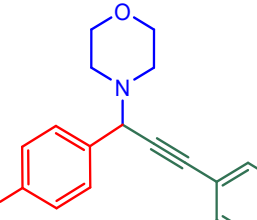
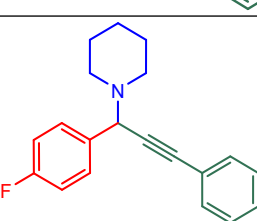
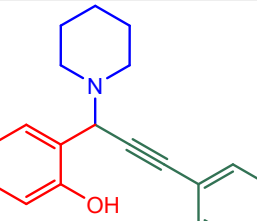
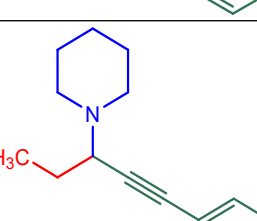
^b*Department of Energy, Materials and Energy Research Center, Karaj, Iran. E-mail: m.hosseini@merc.ac.ir*

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Table S1. investigation of the effects on catalyst efficiency

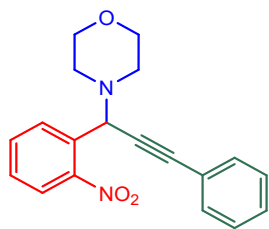
Entrance	Product	Time (min)	ZSM-5@Cu Yield (%)	ZSM-5@ATPS@Cu Yield (%)	ZSM-5@ATPS@2-aminopyridine/terephthalaldehyde@Cu Final Catalyst Yield (%)
1		120	85	88	99
2		120	82	85	98
3		120	76	79	91
4		120	75	77	90
5		120	77	80	93
6		120	81	83	95

7		120	80	81	92
8		120	78	79	91
9		120	78	79	92
10		120	80	81	94
11		120	78	79	90
12		120	84	85	95
13		120	75	76	93

14		120	76	77	92
15		120	79	79	94
16		120	79	79	93
17		120	83	84	95
18		120	84	85	96
19		120	85	85	97
20		120	67	68	85

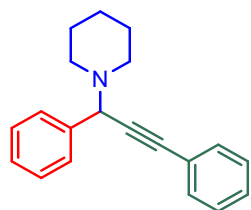
Reaction conditions: 1 mmol of morpholine, 1 mmol of benzaldehyde, and 1.1 mmol of phenylacetylene.

1-(1-(2-nitrophenyl)-3-phenylprop-2-ynyl) morpholine



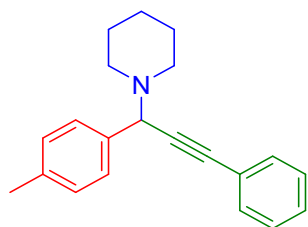
$^1\text{H NMR}$ (400 MHz, CDCl_3): δ 2.43 (s, 2H), 2.62 (s, 2H), 3.63 (s, 4H), 5.65 (s, 1H), 7.26-7.56 (m, 7H), 7.71 (d, $J = 7.5$ Hz, 1H), 7.95 (d, $J = 7.2$ Hz, 1H). $^{13}\text{C NMR}$ (100 MHz, CDCl_3): δ 49, 57.3, 66.3, 81.4, 90.1, 121.9, 123.8, 127.9, 128.1, 128.3, 129.6, 130.9, 131.3, 131.6, 149.4.

2-(1,3-diphenylprop-2-yn-1-yl) piperidine



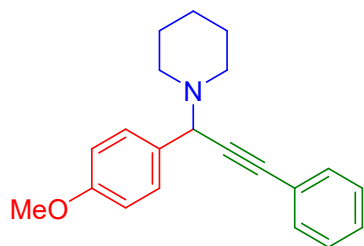
$^1\text{H NMR}$ (CDCl_3 , 400 MHz): δ 7.70-7.64 (m, 2H), 7.58-7.53 (m, 2H), 7.43-7.34 (m, 6H), 4.91 (s, 1H), 2.65 (t, 4H), 1.73-1.59 (m, 4H), 1.50-1.48 (m, 2H). $^{13}\text{C NMR}$ (CDCl_3 , 100 MHz): δ 138.00, 131.85, 128.74, 128.33, 128.19, 128.15, 127.68, 123.20, 88.08, 85.69, 62.33, 50.63, 25.94, 24.31.

3-(3-phenyl-1-(p-tolyl) prop-2-yn-1-yl) piperidine



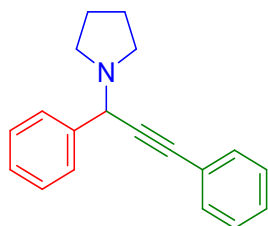
$^1\text{H NMR}$ (CDCl_3 , 400 MHz): δ 7.59-7.54 (m, 4H), 7.39-7.35 (m, 3H), 7.22 (d, 2H, $J=8$), 4.89 (s, 1H), 2.66 (t, 4H), 2.40 (s, 3H), 1.73-1.60 (m, 4H), 1.51-1.49 (m, 2H). $^{13}\text{C NMR}$ (CDCl_3 , 100 MHz): δ 137.40, 134.90, 131.85, 128.87, 128.72, 128.33, 128.16, 123.27, 87.90, 85.96, 62.08, 50.61, 25.92, 24.34, 21.19.

4-(1-(4-methoxyphenyl)-3-phenylprop-2-yn-1-yl) piperidine



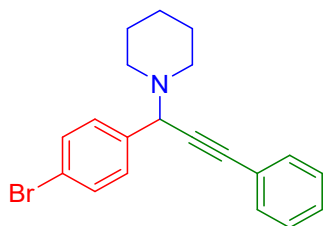
^1H NMR (CDCl_3 , 400 MHz): δ 7.59-7.55 (m, 4H), 7.38-7.36 (m, 3H), 6.94 (d, 2H, $J=8$), 4.80 (s, 1H), 3.86 (s, 3H), 2.60 (br, 4H), 1.67-1.47 (m, 6H). ^{13}C NMR (CDCl_3 , 100 MHz): δ 159.00, 131.83, 130.67, 129.71, 128.31, 128.05, 123.41, 113.41, 87.65, 86.43, 61.80, 55.31, 50.64, 26.20, 24.51.

5-(1,(3-diphenylprop-2-yn-1-yl) pyrrolidine



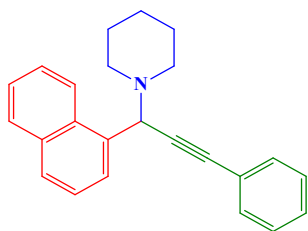
^1H NMR (CDCl_3 , 400 MHz): δ 7.66 (t, 2H), 7.55-7.53 (m, 2H), 7.45-7.34 (m, 6H), 5.06 (s, 1H), 2.85-2.72 (m, 4H), 2.03-1.82 (m, 4H). ^{13}C NMR (CDCl_3 , 100 MHz): δ 138.69, 131.84, 128.51, 128.37, 128.34, 128.03, 127.87, 123.03, 87.29, 86.07, 58.97, 50.19, 23.52.

6-(1-(4-bromophenyl)-3-phenylprop-2-yn-1-yl) piperidine



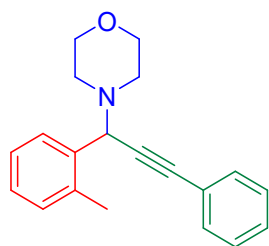
^1H NMR (CDCl_3 , 400 MHz): δ 7.69 (d, 1H, $J=8$), 7.58-7.50 (m, 5H), 7.37 (t, 3H), 4.79 (s, 1H), 2.58 (t, 4H), 1.70-1.57 (m, 4H), 1.50-1.38 (m, 2H). ^{13}C NMR (CDCl_3 , 100 MHz): δ 137.83, 131.85, 131.18, 130.24, 129.06, 128.36, 128.26, 88.30, 85.29, 61.79, 50.67, 26.14, 24.39.

7-(1-(naphthalen-3-yl)-3-phenylprop-2-ynyl) piperidine



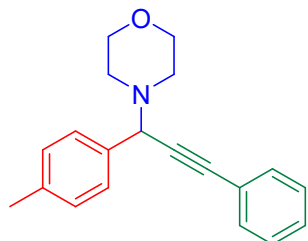
^1H NMR (400 MHz, CDCl_3 , ppm): δ 1.47-1.51 (m, 2H), 1.60-1.67 (m, 4H), 2.64 (t, 4H), 4.97 (s, 1H), 7.36-7.40 (m, 3H), 7.48-7.52 (m, 2H), 7.58-7.61 (m, 2H), 7.79 (dd, $J^1=J^2=8.4$ Hz, 1H), 7.85-7.91 (m, 3H), 8.11 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3 , ppm) δ 24.4, 26.2, 50.8, 62.5, 86, 88.1, 123.3, 125.8, 125.9, 126.7, 127.2, 127.5, 127.7, 128.1, 128.12, 131.8, 132.9, 133.1, 136.3.

8-(3-phenyl-1-(o-tolyl) prop-2-yn-1-yl) morpholine



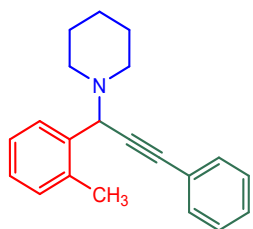
^1H NMR (400 MHz, Chloroform-*d*) δ 7.76 – 7.71 (m, 1H), 7.58 – 7.53 (m, 2H), 7.39 – 7.32 (m, 3H), 7.23 (dd, $J = 5.8, 3.7$ Hz, 3H), 4.91 (s, 1H), 3.77 – 3.64 (m, 4H), 2.66 (t, $J = 4.7$ Hz, 4H), 2.51 (s, 3H). ^{13}C NMR (75 MHz, Chloroform-*d*) δ 137.6, 135.8, 131.8, 130.8, 129.1, 128.4, 128.2, 127.9, 125.4, 123.1, 88.7, 85.1, 67.3, 59.9, 49.8, 19.2.

9-(3-phenyl-1-(p-tolyl) prop-2-yn-1-yl) morpholine



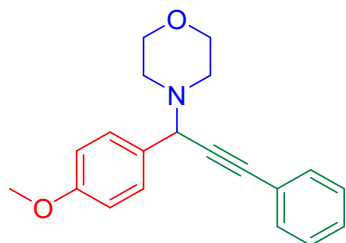
^1H NMR (400 MHz, Chloroform-*d*) δ 7.50 (q, $J = 3.5$ Hz, 4H), 7.31 (t, $J = 4.6$ Hz, 3H), 7.20 – 7.13 (m, 2H), 4.74 (d, $J = 3.4$ Hz, 1H), 3.72 (d, $J = 4.9$ Hz, 4H), 2.62 (t, $J = 4.6$ Hz, 4H), 2.34 (s, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 137.5, 134.8, 131.8, 129.0, 128.6, 128.3, 128.2, 123.0, 88.3, 85.34, 67.2, 61.8, 49.9, 21.2.

10-(3-phenyl-1-(p-tolyl) prop-2-yn-1-yl)piperidine



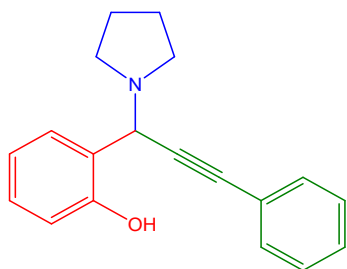
^1H NMR (CDCl_3 , 400 MHz): δ 7.59-7.54 (m, 4H), 7.39-7.35 (m, 3H), 7.22 (d, 2H, $J=8$), 4.89 (s, 1H), 2.66 (t, 4H), 2.40 (s, 3H), 1.73-1.60 (m, 4H), 1.51-1.49 (m, 2H). ^{13}C NMR (CDCl_3 , 100 MHz): δ 137.40, 134.90, 131.85, 128.87, 128.72, 128.33, 128.16, 123.27, 87.90, 85.96, 62.08, 50.61, 25.92, 24.34, 21.19.

11-(1-(4-methoxyphenyl)-3-phenylprop-2-yn-1-yl) morpholine



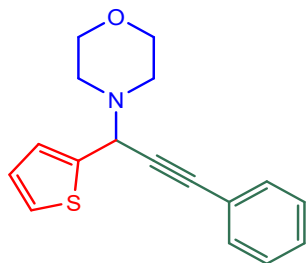
^1H NMR (300 MHz, Chloroform-*d*) δ 7.57 (t, $J = 1.2$ Hz, 1H), 7.54 (ddd, $J = 6.0, 2.5, 1.6$ Hz, 3H), 7.37 – 7.31 (m, 3H), 6.95 – 6.89 (m, 2H), 4.76 (s, 1H), 3.81 (s, 3H), 3.75 (td, $J = 5.1, 3.0$ Hz, 4H), 2.64 (dt, $J = 5.2, 3.3$ Hz, 4H). ^{13}C NMR (75 MHz, Chloroform-*d*) δ 159.2, 131.8, 129.8, 129.7, 128.3, 128.2, 123.0, 113.6, 88.3, 85.40, 67.1, 61.4, 55.3, 49.8.

12-(3-phenyl-1-(pyrrolidin-1-yl) prop-2-ynyl) phenol



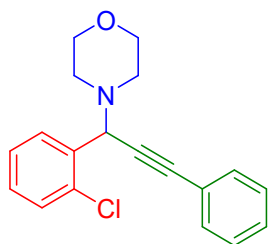
^1H NMR (400 MHz, CDCl_3): δ 1.87-1.89 (m, 4H), 2.78-2.88 (m, 4H), 5.29 (s, 1H), 6.82-6.87 (m, 2H), 7.19-7.27 (m, 1H), 7.34-7.37 (m, 3H), 7.51-7.54 (m, 3H). ^{13}C NMR (100 MHz, CDCl_3): δ 23.8, 48.9, 57.1, 83, 89, 116.2, 118.9, 122.2, 122.6, 127.8, 128.4, 128.5, 128.8, 129.9, 131.9, 157.6.

13-(3-phenyl-1-(thiophen-2-yl) prop-2-yn-1-yl)morpholine



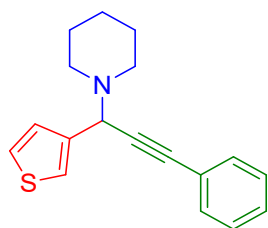
^1H NMR (CDCl_3 , 400 MHz): δ 7.57-7.53 (m, 2H), 7.38-7.28 (m, 5H), 7.02-7.00 (m, 1H), 5.05 (s, 1H), 3.84-3.77 (m, 4H), 2.79-2.68 (m, 4H). ^{13}C NMR (CDCl_3 , 100 MHz): δ 142.66, 131.89, 128.49, 128.38, 126.51, 126.38, 125.89, 122.66, 87.64, 84.25, 67.12, 57.79, 49.64.

14-(1-(2-chlorophenyl)-3-phenylprop-2-yn-1-yl) morpholine



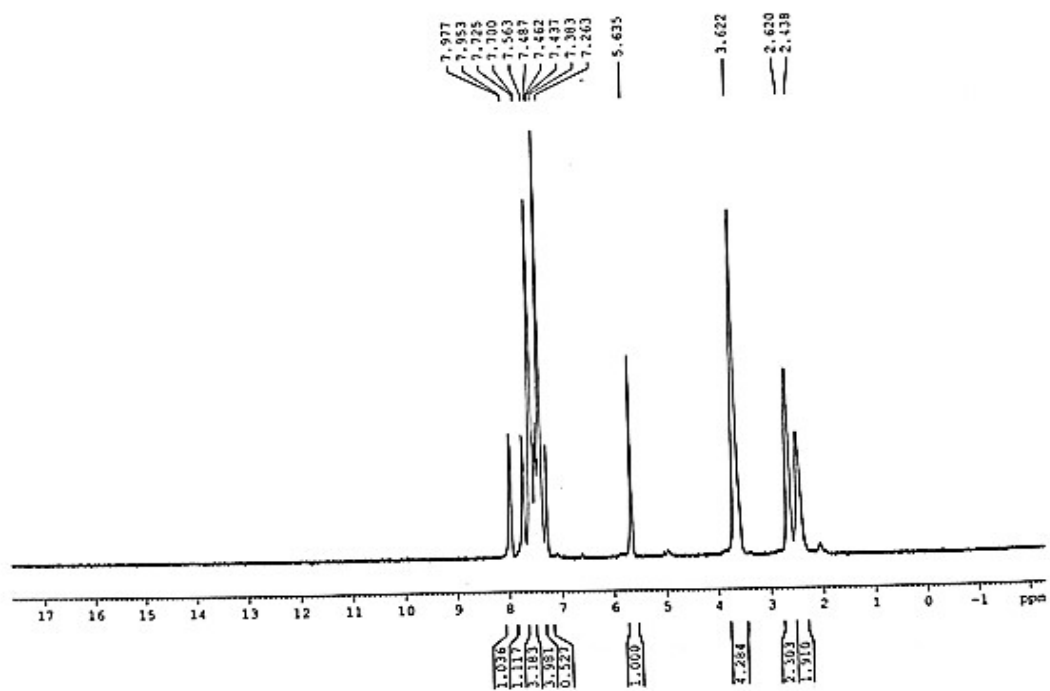
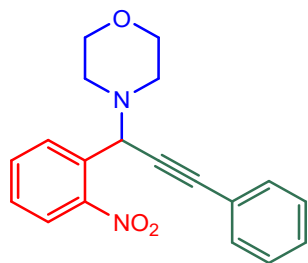
^1H NMR (CDCl_3 , 400 MHz): δ 7.81 (d, 1H, $J=8$), 7.56-7.53 (m, 2H), 7.48-7.42 (m, 1H), 7.39-7.28 (m, 5H), 5.18 (s, 1H), 3.79-3.75 (m, 4H), 2.73 (br, 4H). ^{13}C NMR (CDCl_3 , 100 MHz): δ 135.51, 134.68, 131.86, 130.62, 129.95, 129.22, 128.44, 128.38, 126.42, 122.78, 88.42, 84.65, 67.11, 58.96, 49.85.

15-(3-phenyl-1-(thiophen-3-yl) prop-2-yn-1-yl) piperidine:



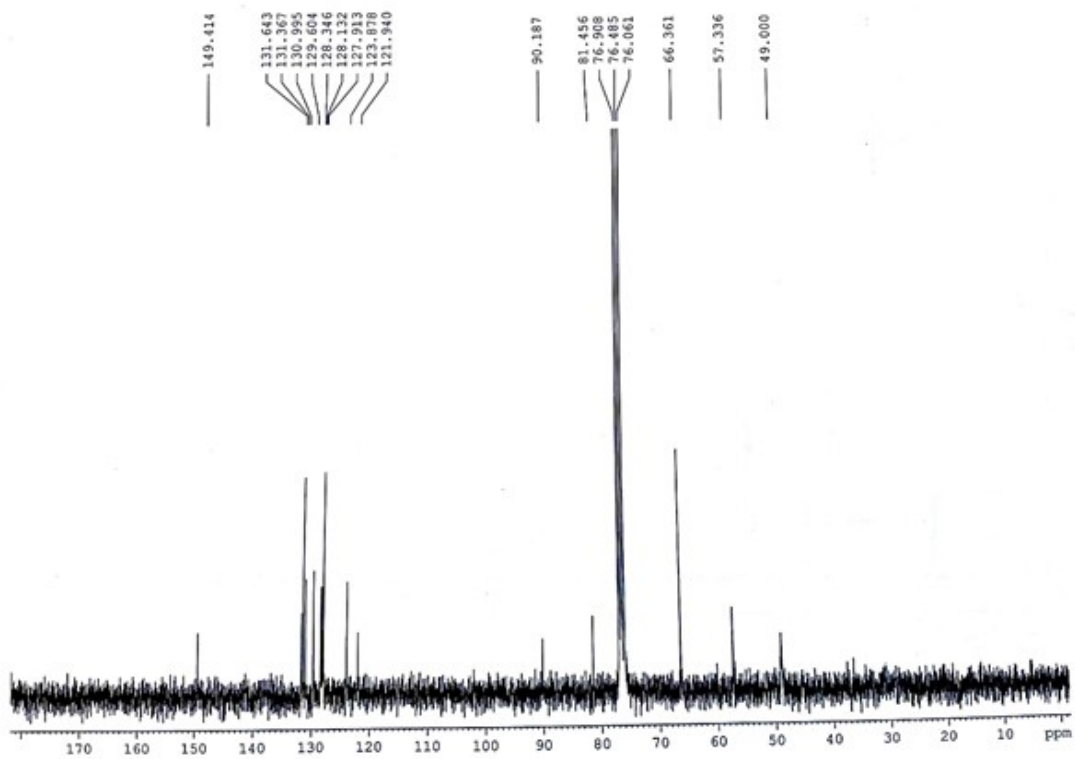
^1H NMR (CDCl_3 , 400 MHz): δ 7.57-7.55 (m, 2H), 7.46 (s, 1H), 7.41-7.29 (m, 5H), 4.88 (s, 1H), 2.62 (br, 4H), 1.83-1.60 (m, 4H), 1.51-1.49 (m, 2H). ^{13}C NMR (CDCl_3 , 100 MHz): δ 140.29, 131.86, 128.34, 128.15, 127.94, 125.39, 123.29, 123.26, 86.68, 86.22, 58.31, 50.62, 26.20, 24.48.

1-(1-(2-nitrophenyl)-3-phenylprop-2-yn-1-yl) morpholine



¹H NMR

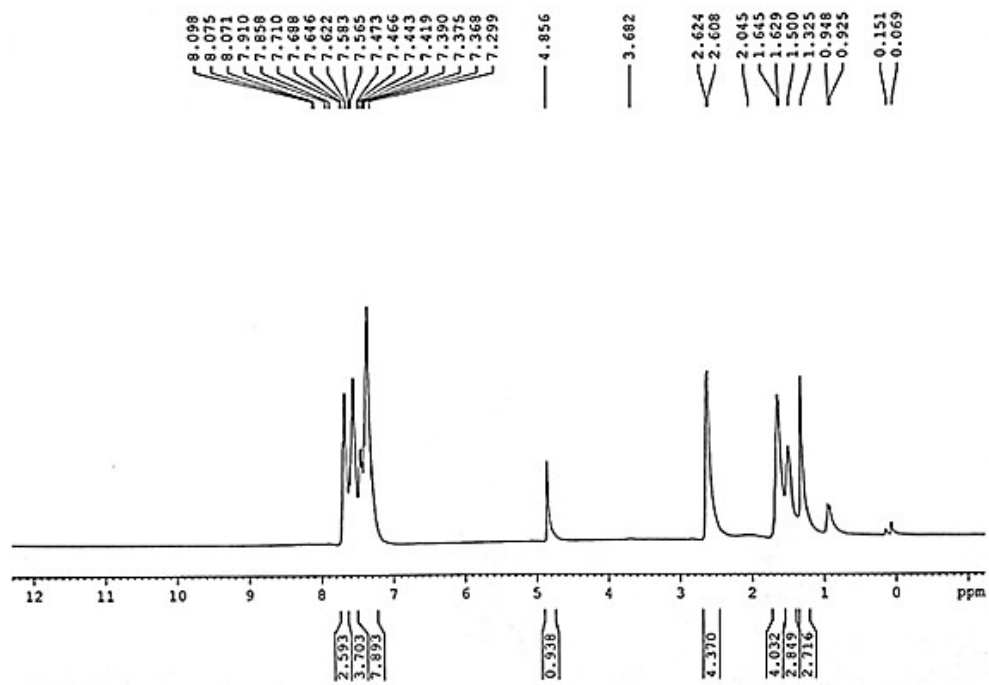
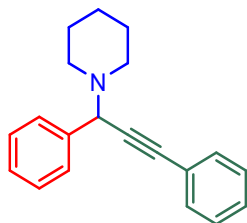
4-(1-(2-nitrophenyl)-3-phenylprop-2-yn-1-yl)morpholine



^{13}C NMR

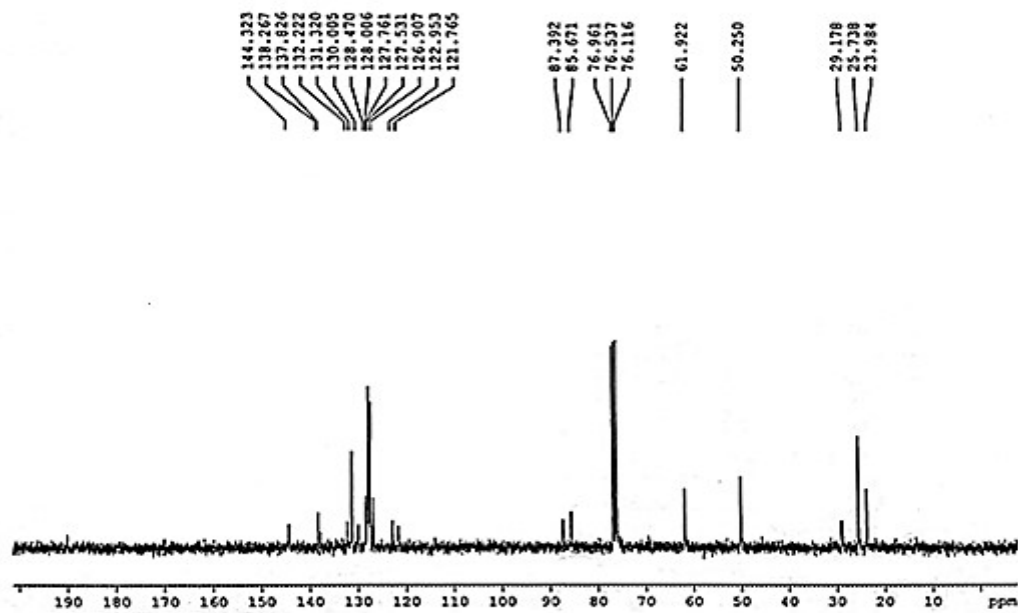
4-(1-(2-nitrophenyl)-3-phenylprop-2-yn-1-yl) morpholine

2-(1,3-diphenylprop-2-yn-1-yl) piperidine



¹H NMR

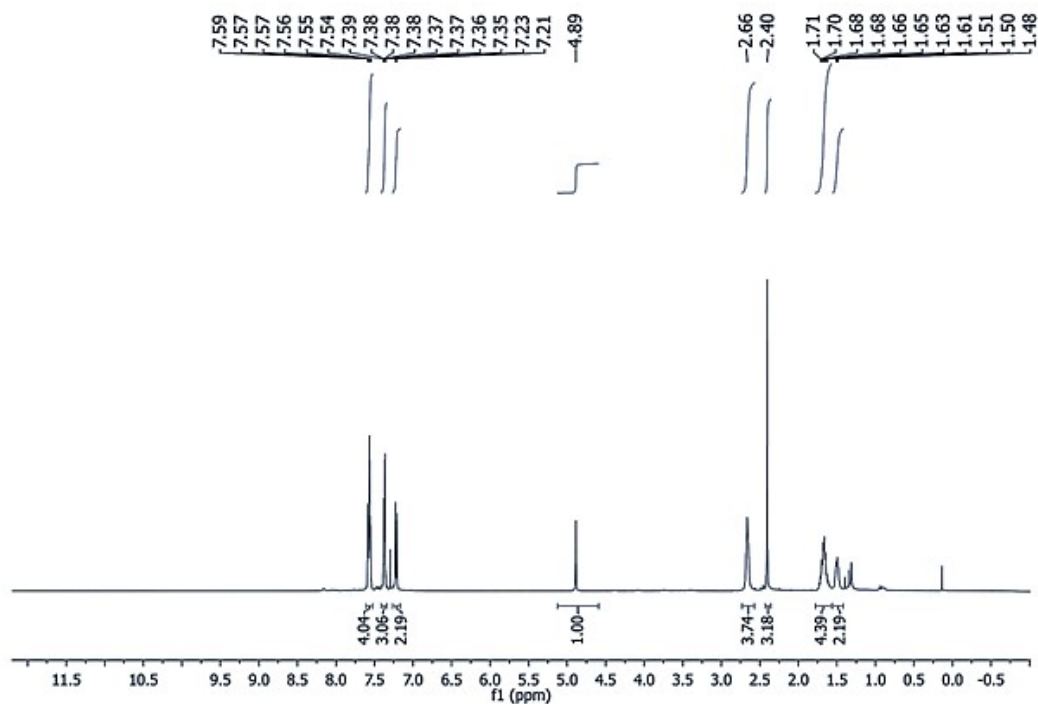
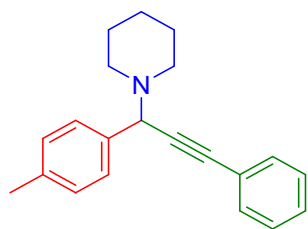
1-(1,3-diphenylprop-2-yn-1-yl) piperidine



¹³CNMR

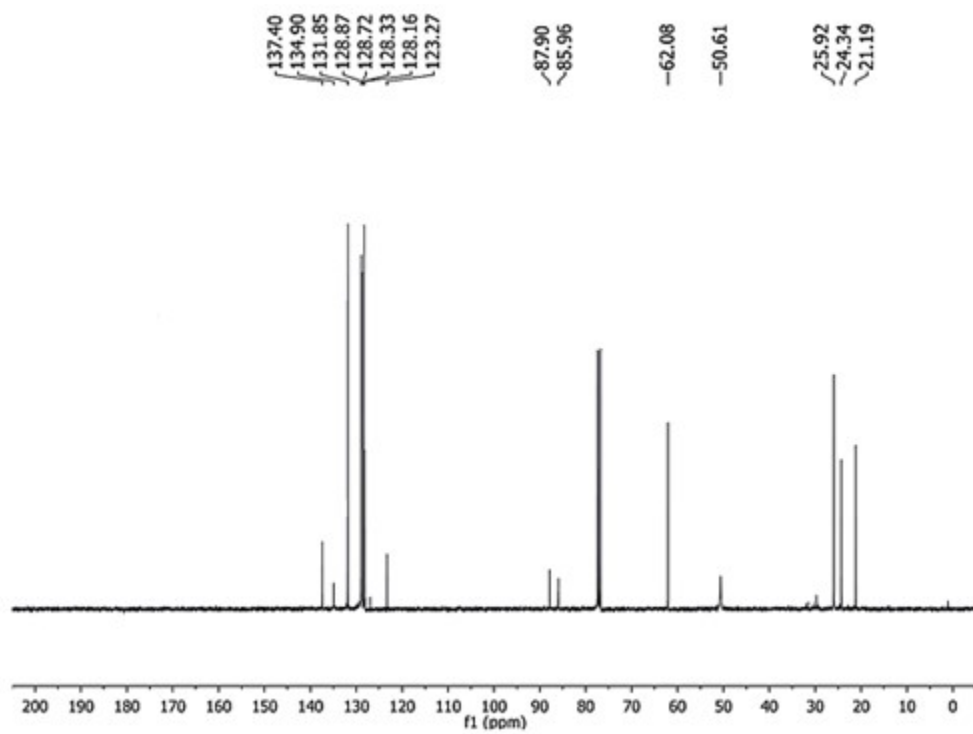
1-(1,3-diphenylprop-2-yn-1-yl) piperidine

3-(3-phenyl-1-(p-tolyl) prop-2-yn-1-yl)piperidine



¹H NMR

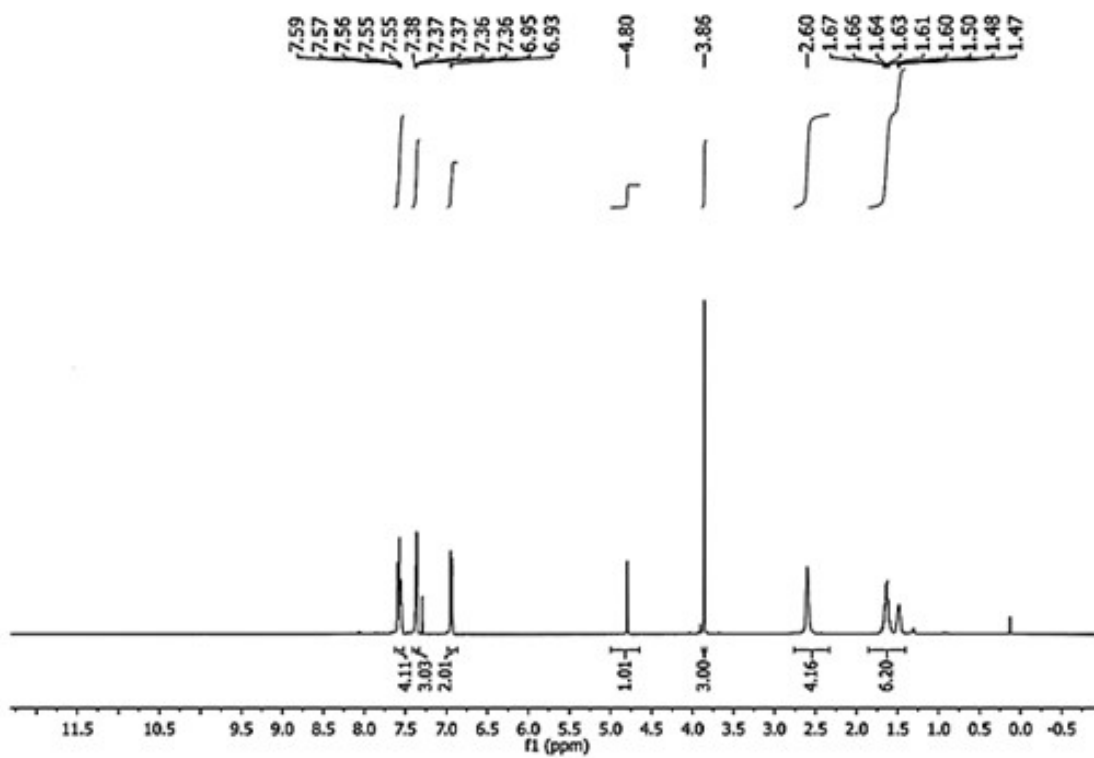
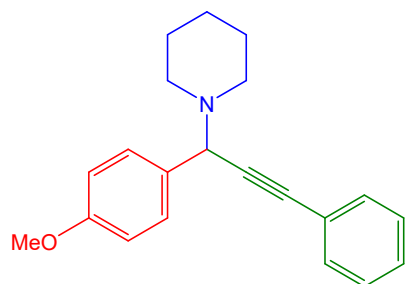
1-(3-phenyl-1-(p-tolyl) prop-2-yn-1-yl)piperidine



¹³C NMR

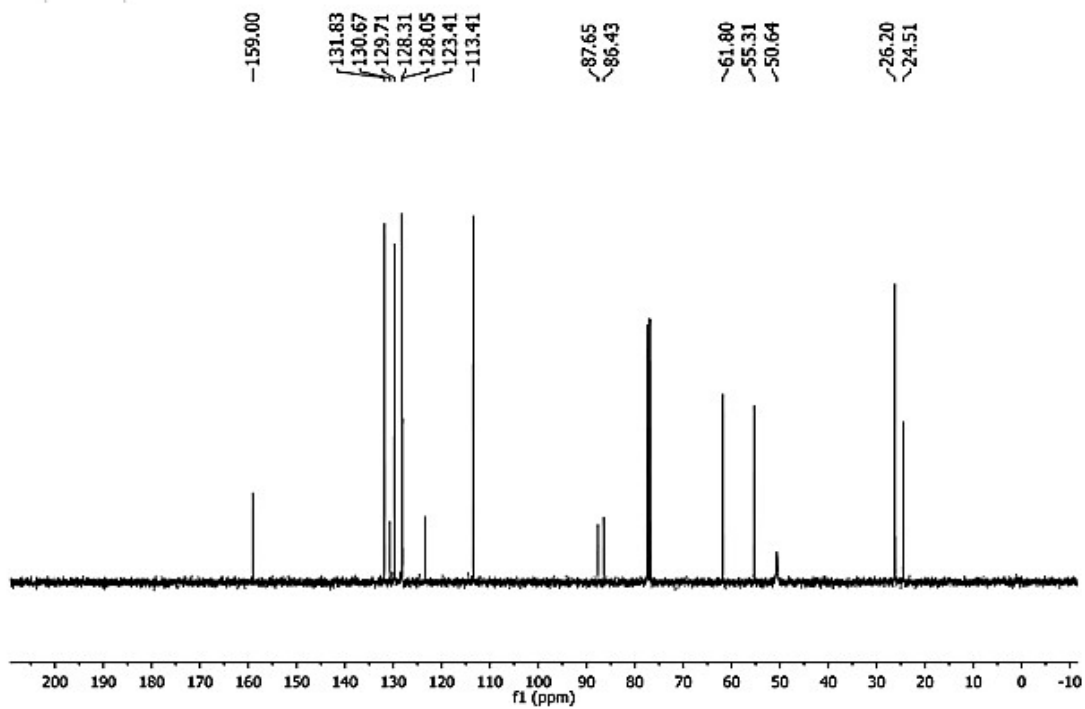
1-(3-phenyl-1-(p-tolyl) prop-2-yn-1-yl)piperidine

4-(1-(4-methoxyphenyl)-3-phenylprop-2-yn-1-yl) piperidine



¹H NMR

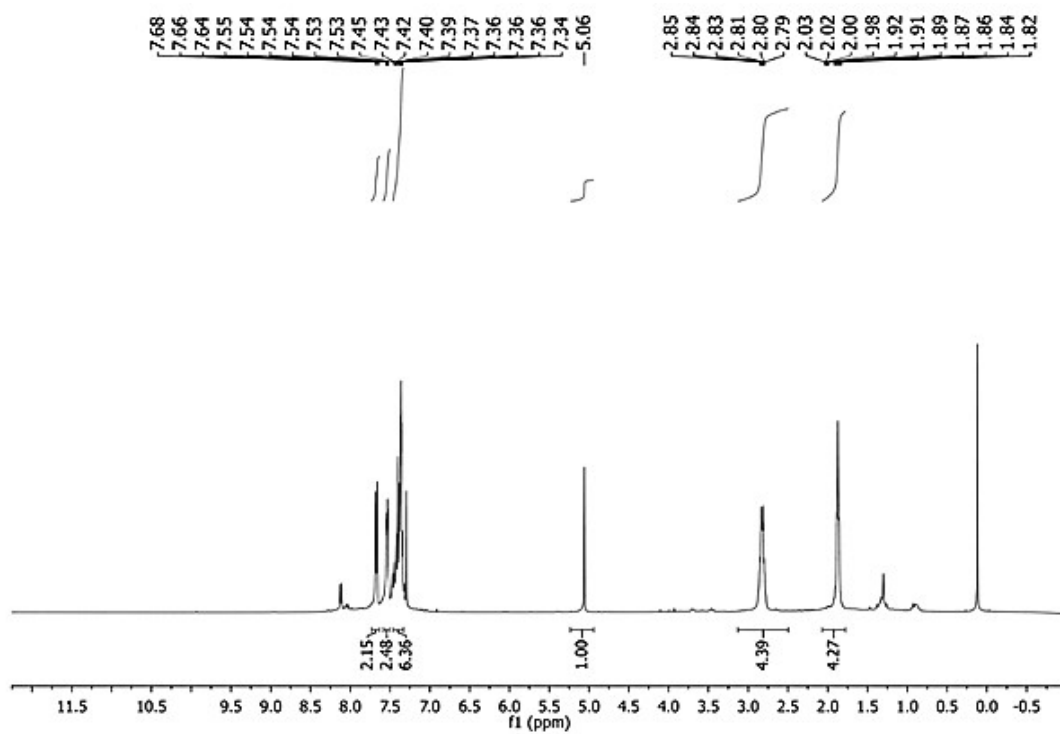
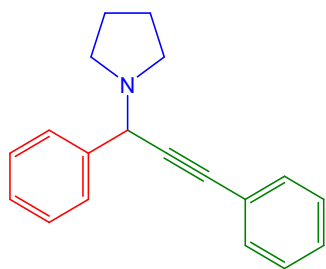
1-(1-(4-methoxyphenyl)-3-phenylprop-2-yn-1-yl) piperidine



^{13}C NMR

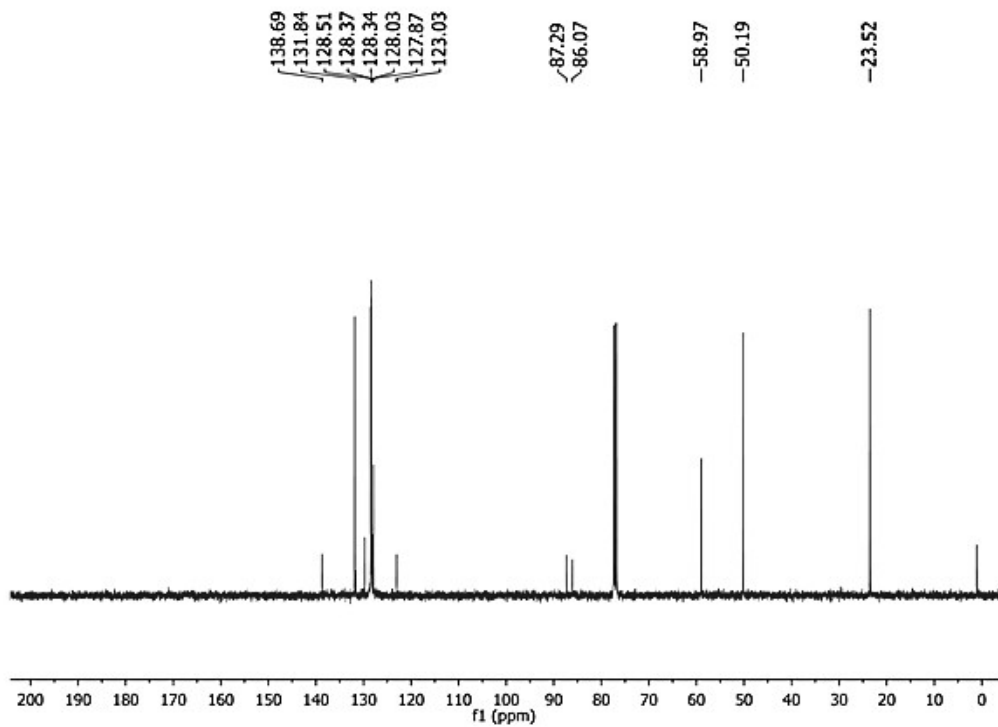
1-(1-(4-methoxyphenyl)-3-phenylprop-2-yn-1-yl) piperidine

5. 1-(1,3-diphenylprop-2-yn-1-yl) pyrrolidine



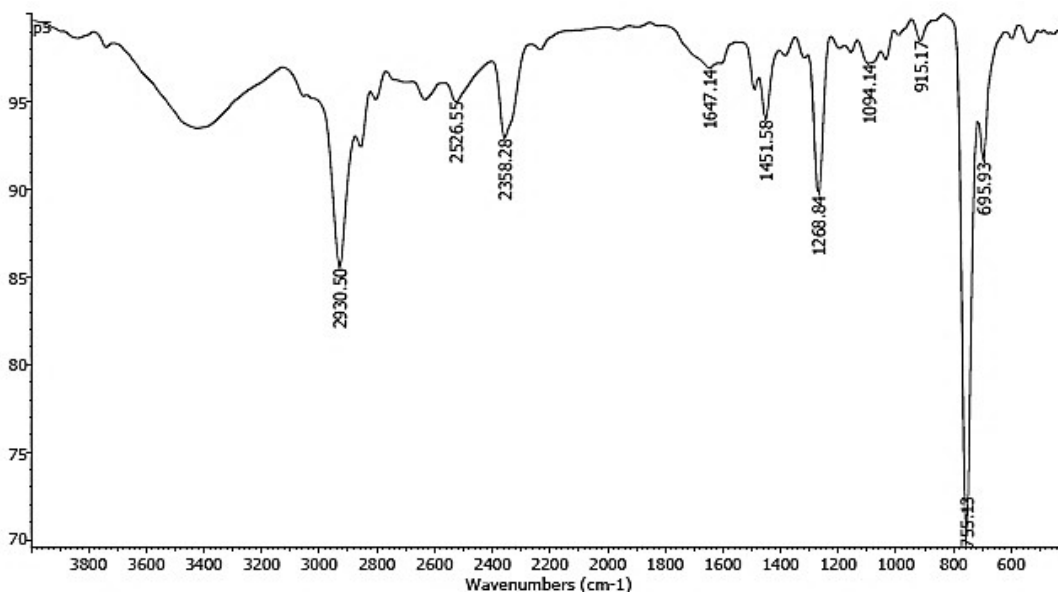
¹H NMR

1-(1,3-diphenylprop-2-yn-1-yl) pyrrolidine



¹³C NMR

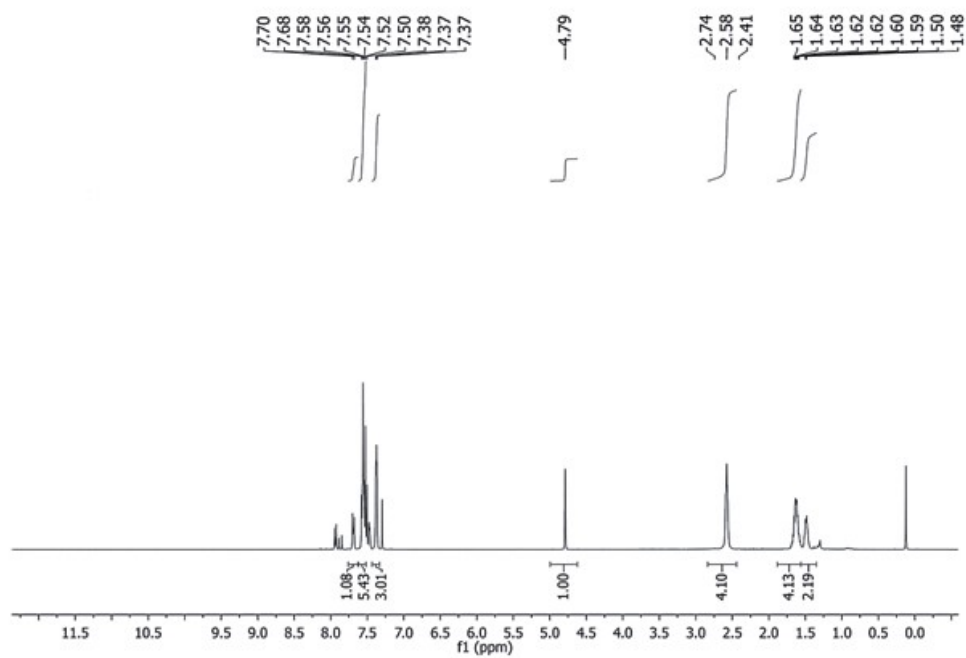
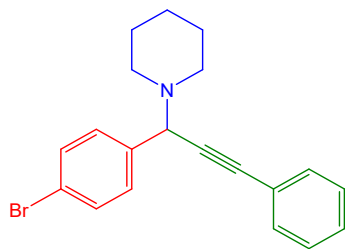
1-(1,3-diphenylprop-2-yn-1-yl) pyrrolidine



FT-IR

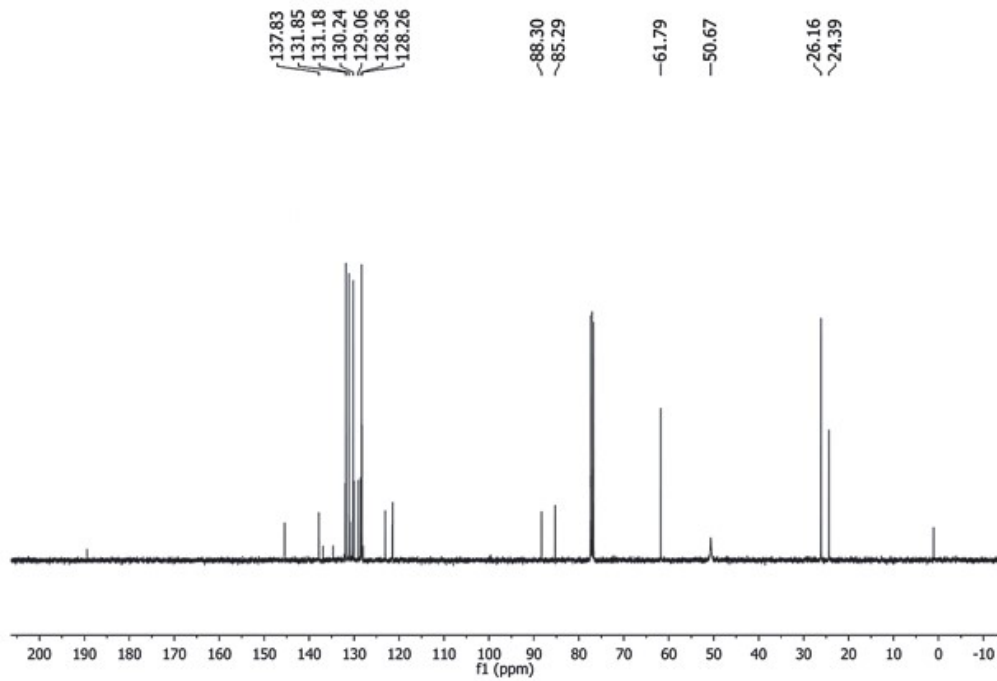
1-(1,3-diphenylprop-2-yn-1-yl) pyrrolidine

6-(1-(4-bromophenyl)-3-phenylprop-2-yn-1-yl) piperidine



¹H NMR

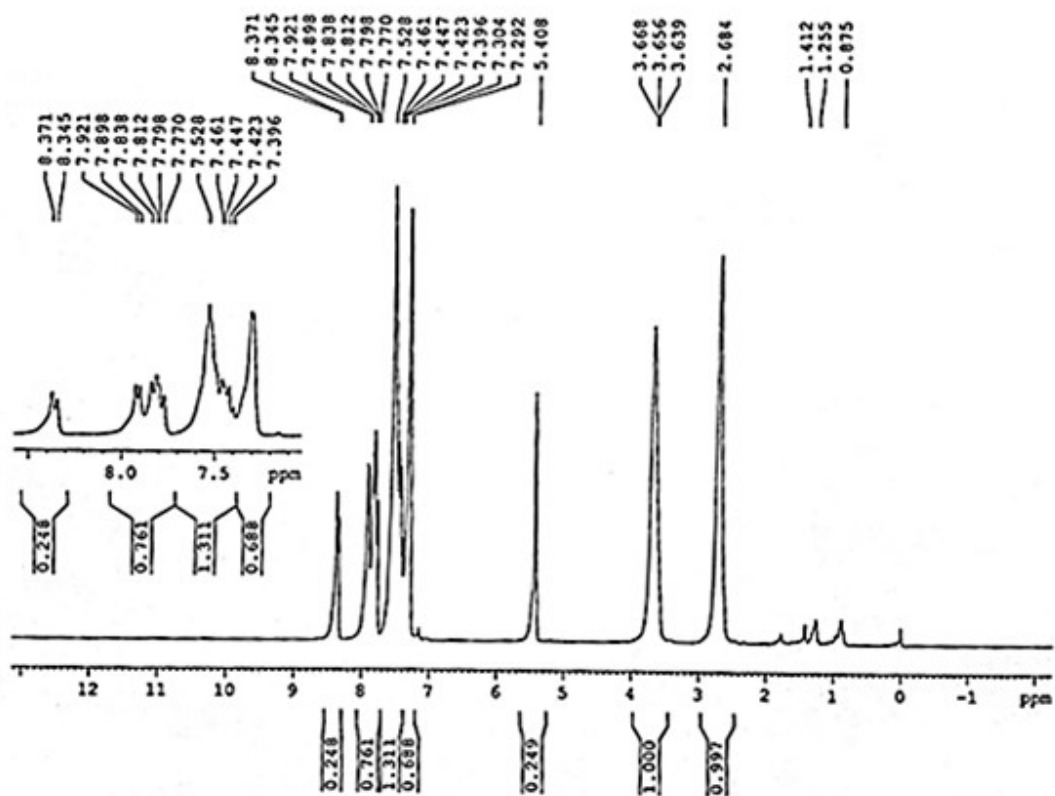
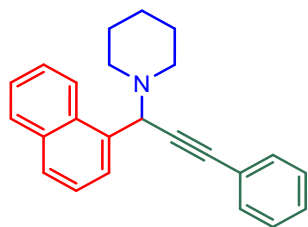
1-(1-(4-bromophenyl)-3-phenylprop-2-yn-1-yl) piperidine



¹³C NMR

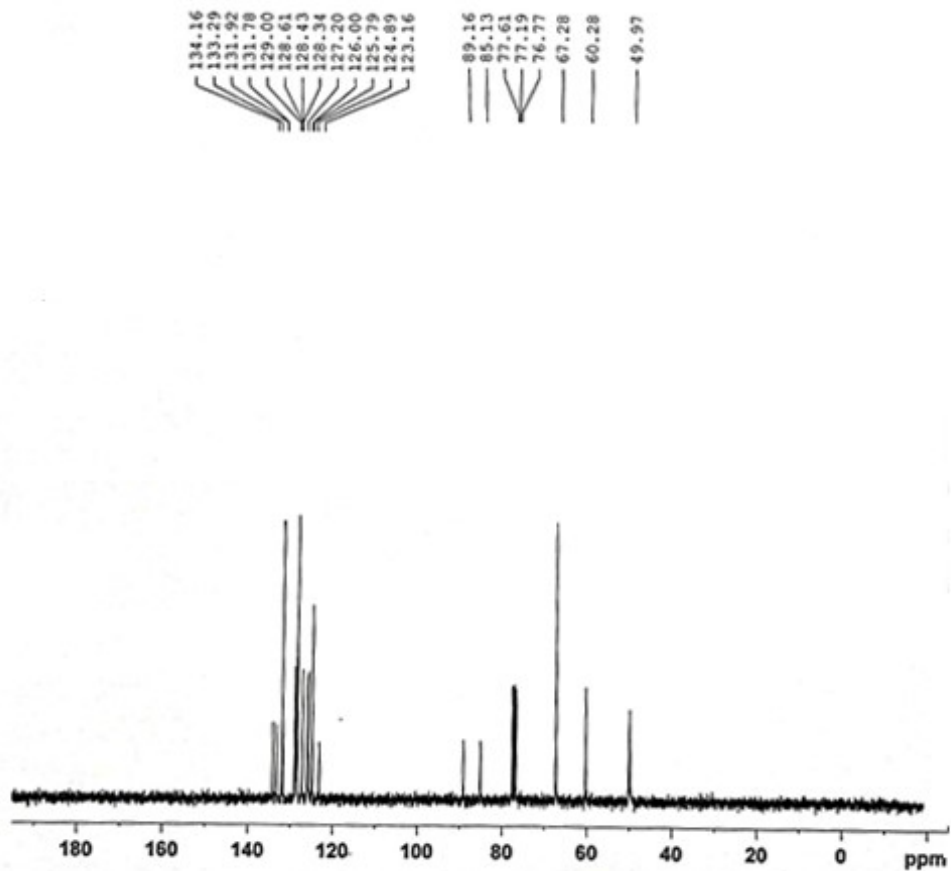
1-(1-(4-bromophenyl)-3-phenylprop-2-yn-1-yl) piperidine

7-(1-(naphthalen-1-yl)-3-phenylprop-2-yn-1-yl) piperidine



¹H NMR

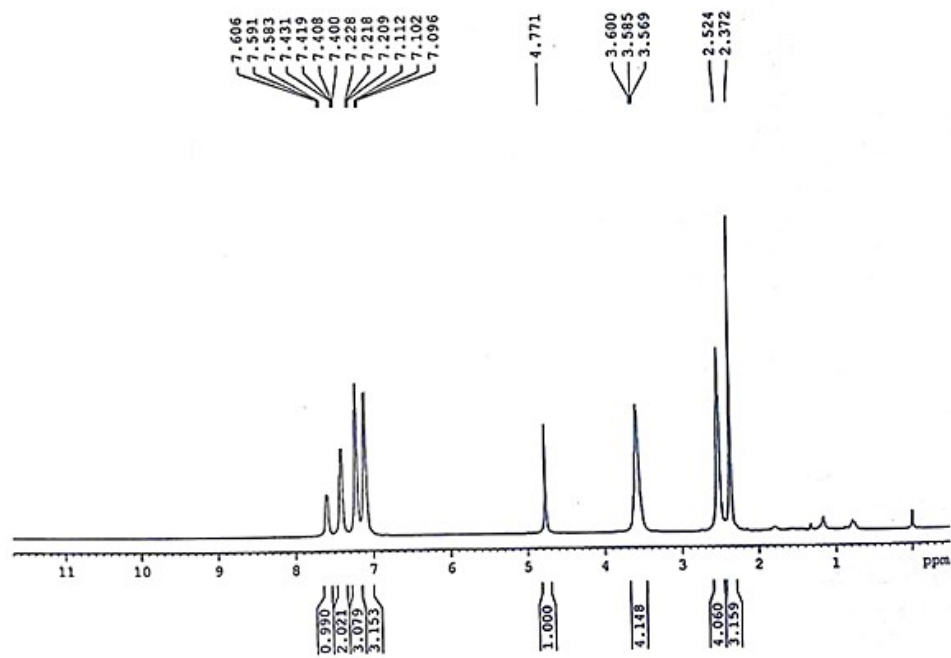
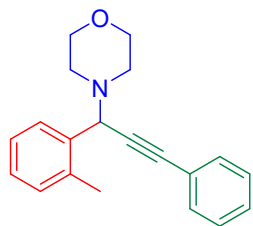
1-(1-(naphthalen-1-yl)-3-phenylprop-2-yn-1-yl) piperidine



^{13}C NMR

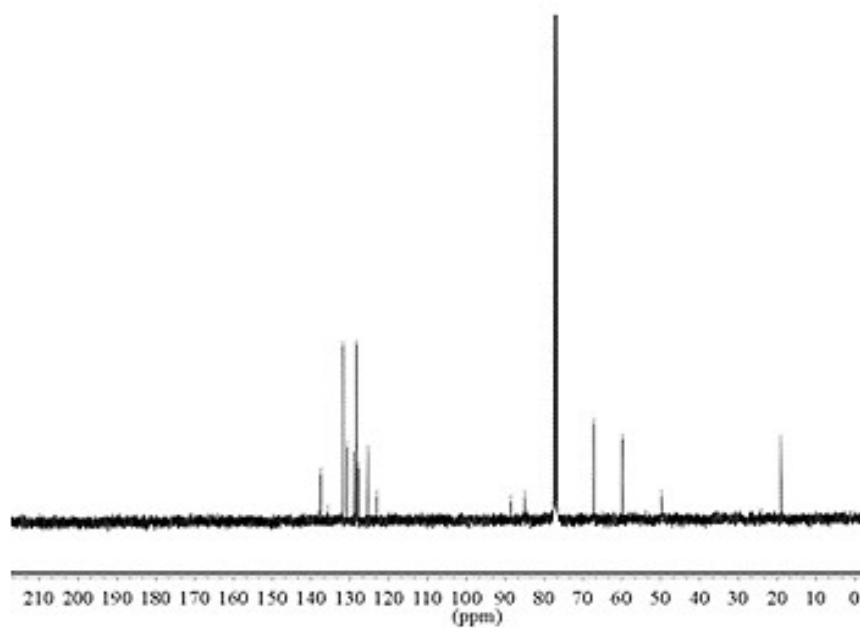
1-(1-(naphthalen-1-yl)-3-phenylprop-2-yn-1-yl) piperidine

8-(3-phenyl-1-(o-tolyl) prop-2-yn-1-yl) morpholine



¹H NMR

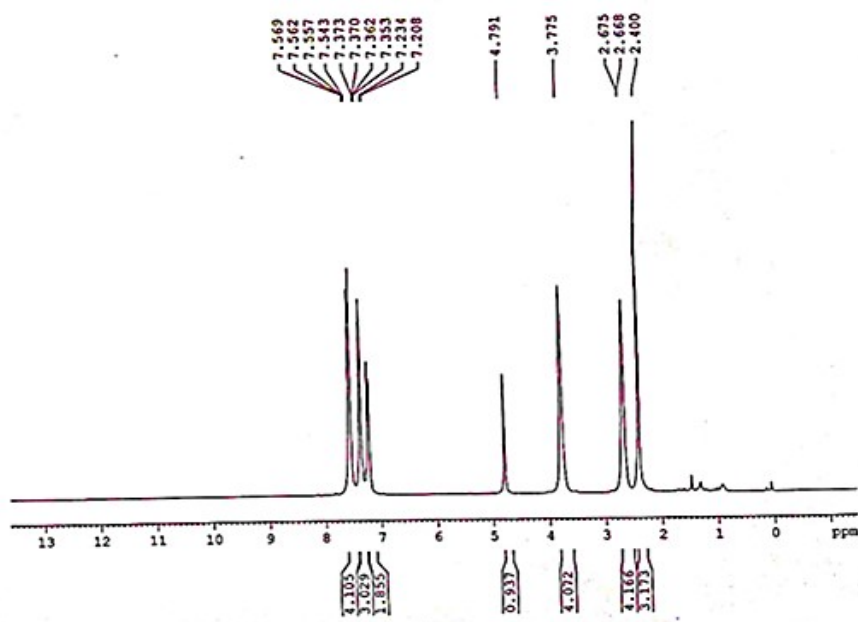
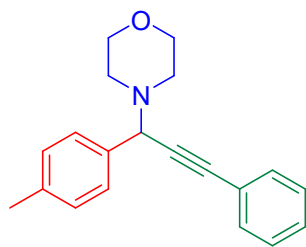
4-(3-phenyl-1-(o-tolyl) prop-2-yn-1-yl) morpholine



^{13}C NMR

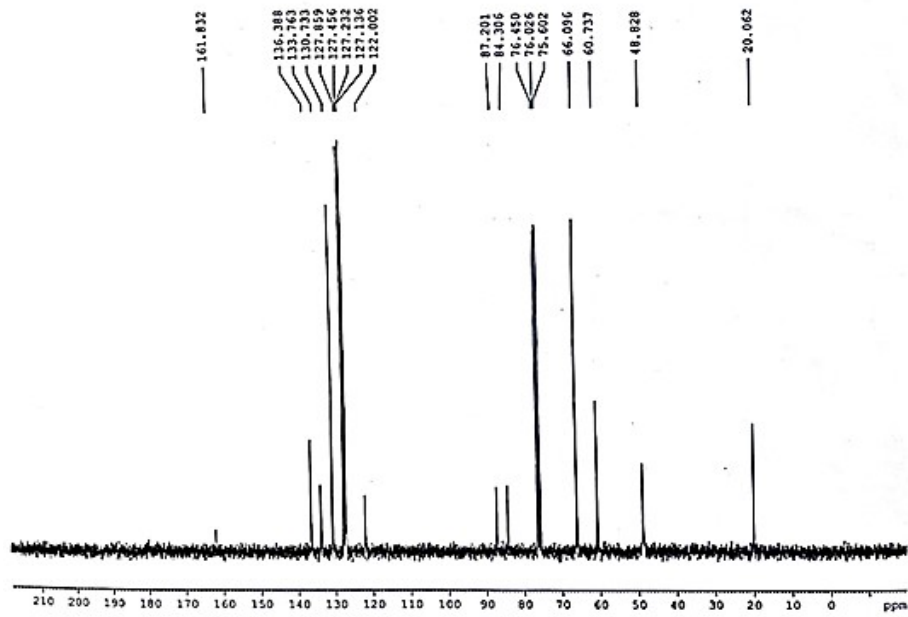
4-(3-phenyl-1-(o-tolyl) prop-2-yn-1-yl) morpholine

9-(3-phenyl-1-(p-tolyl) prop-2-yn-1-yl)morpholine



¹H NMR

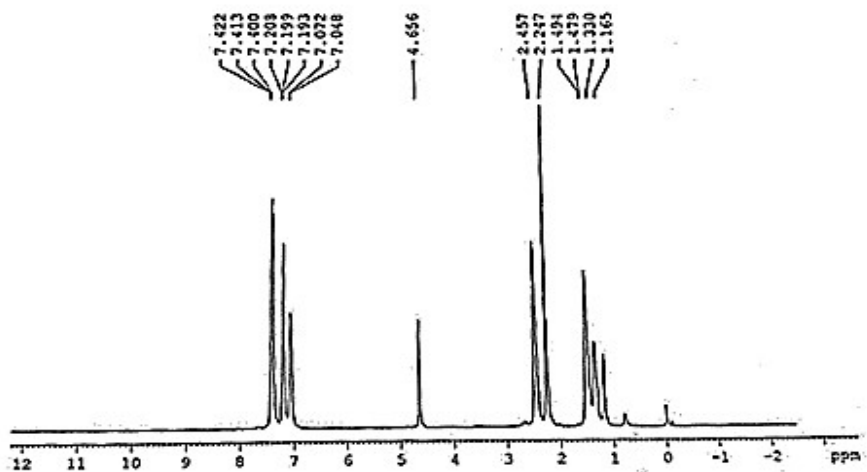
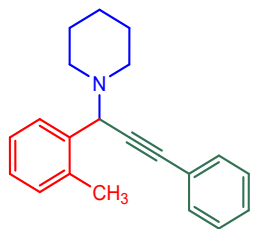
4-(3-phenyl-1-(p-tolyl) prop-2-yn-1-yl)morpholine



¹³C NMR

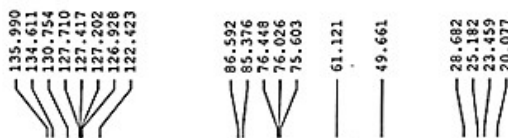
4-(3-phenyl-1-(p-tolyl) prop-2-yn-1-yl) morpholine

10-(3-phenyl-1-(o-tolyl) prop-2-yn-1-yl)piperidine



¹H NMR

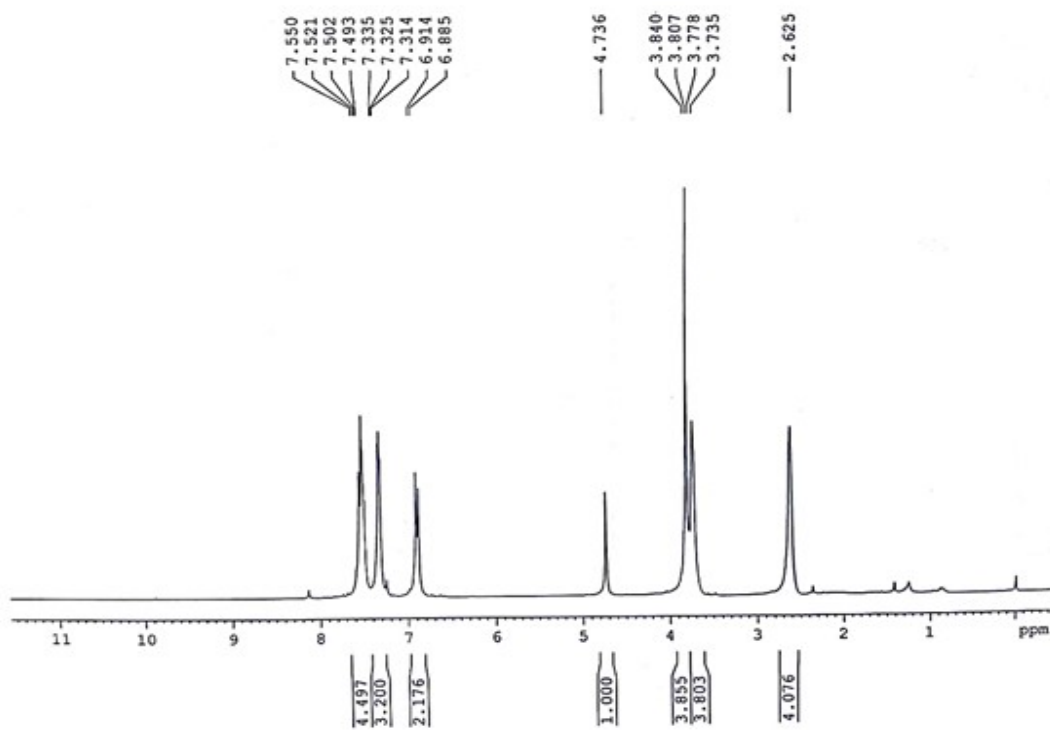
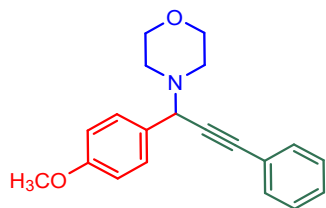
1-(3-phenyl-1-(o-tolyl) prop-2-yn-1-yl)piperidine



¹³C NMR

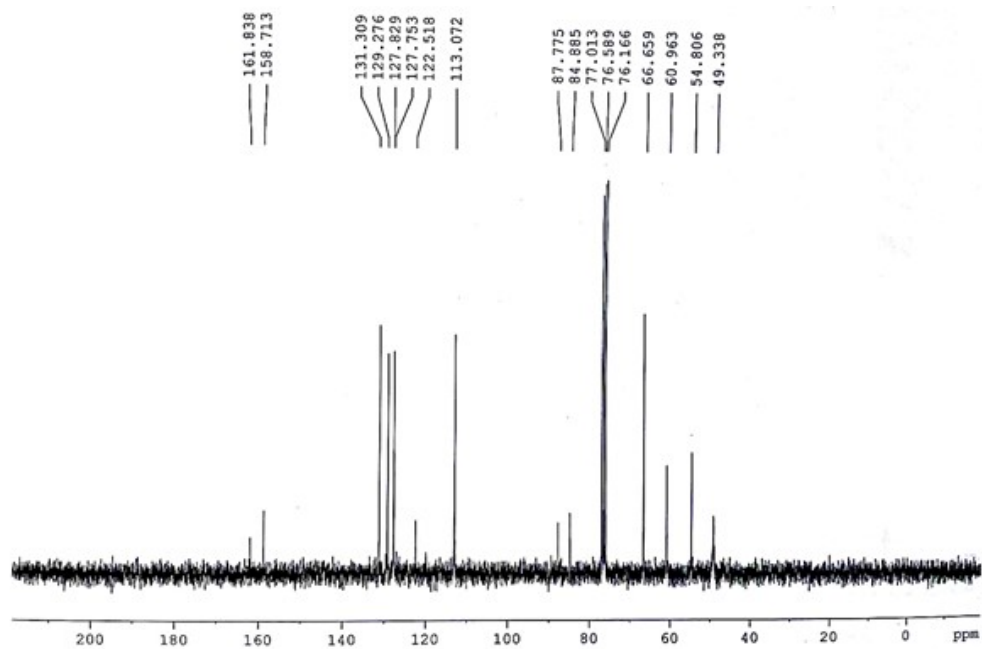
1-(3-phenyl-1-(o-tolyl) prop-2-yn-1-yl)piperidine

11-(1-(4-methoxyphenyl)-3-phenylprop-2-yn-1-yl) morpholine



¹H NMR

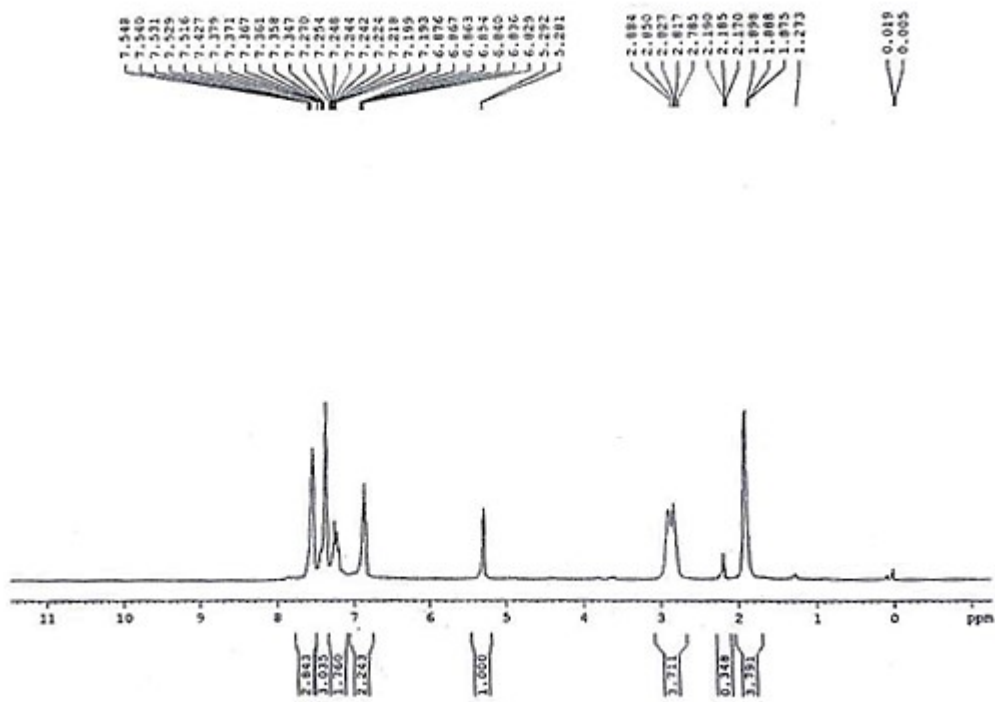
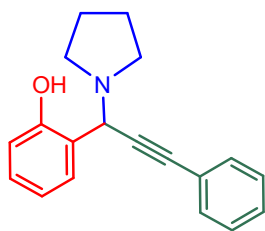
4-(1-(4-methoxyphenyl)-3-phenylprop-2-yn-1-yl) morpholine



^{13}C NMR

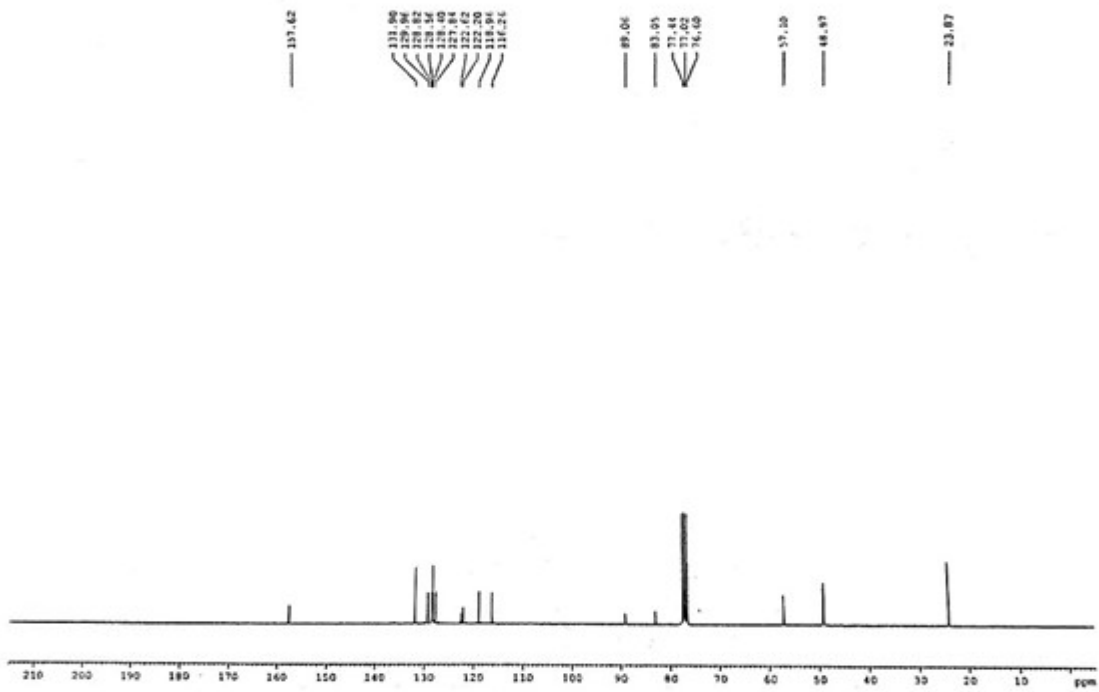
4-(1-(4-methoxyphenyl)-3-phenylprop-2-yn-1-yl) morpholine

12-(3-phenyl-1-(pyrrolidin-1-yl) prop-2-yn-1-yl)phenol



¹H NMR

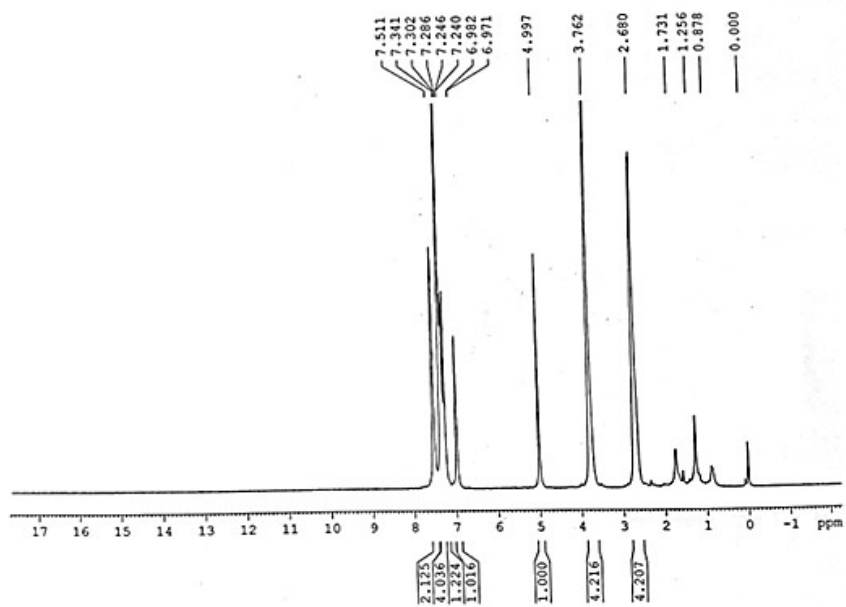
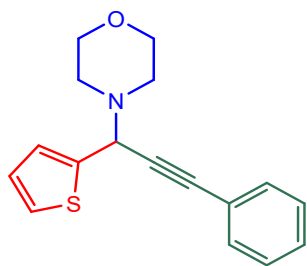
2-(3-phenyl-1-(pyrrolidin-1-yl) prop-2-yn-1-yl)phenol



^{13}C NMR

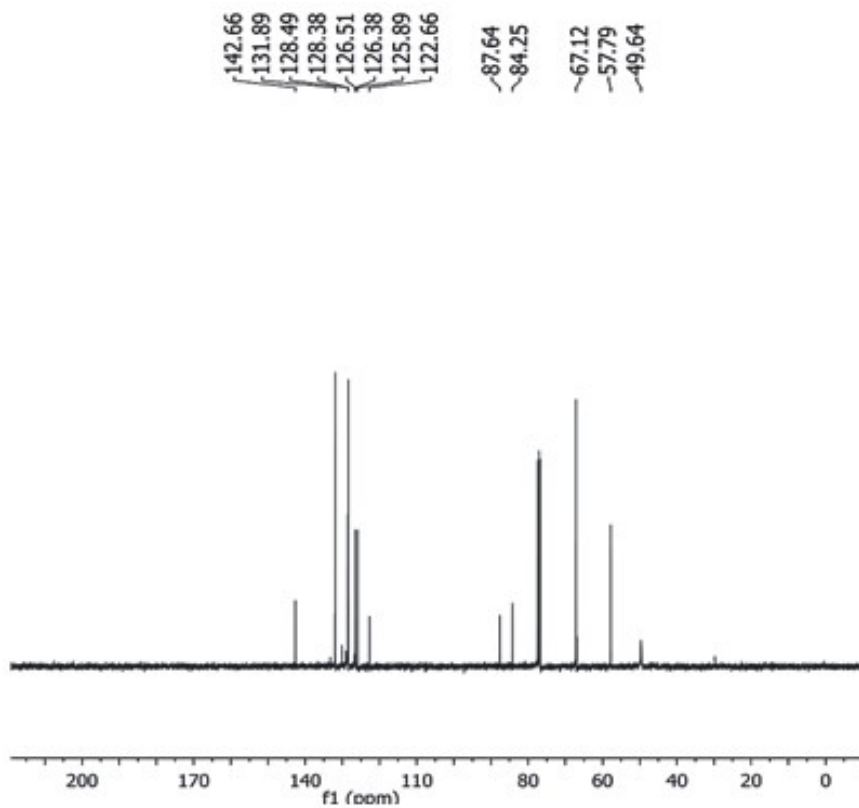
2-(3-phenyl-1-(pyrrolidin-1-yl) prop-2-yn-1-yl)phenol

13-(3-phenyl-1-(thiophen-2-yl) prop-2-yn-1-yl)morpholine



¹H NMR

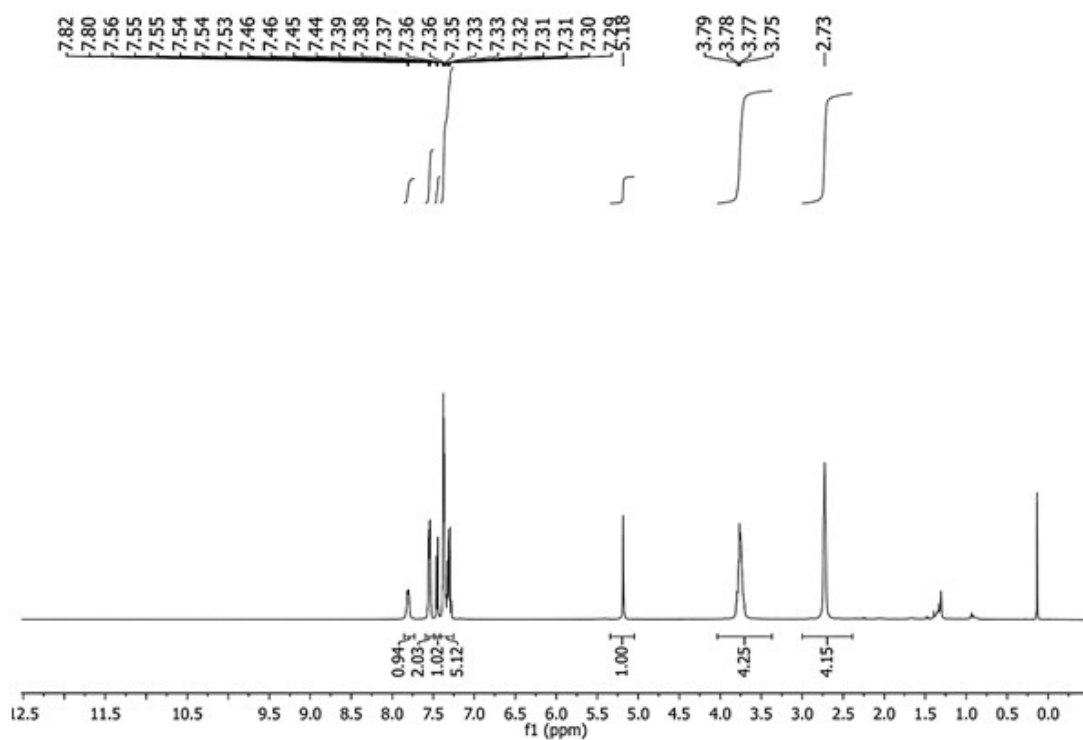
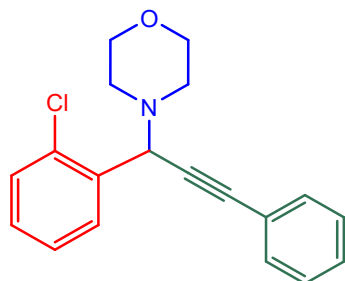
4-(3-phenyl-1-(thiophen-2-yl) prop-2-yn-1-yl)morpholine



¹³C NMR

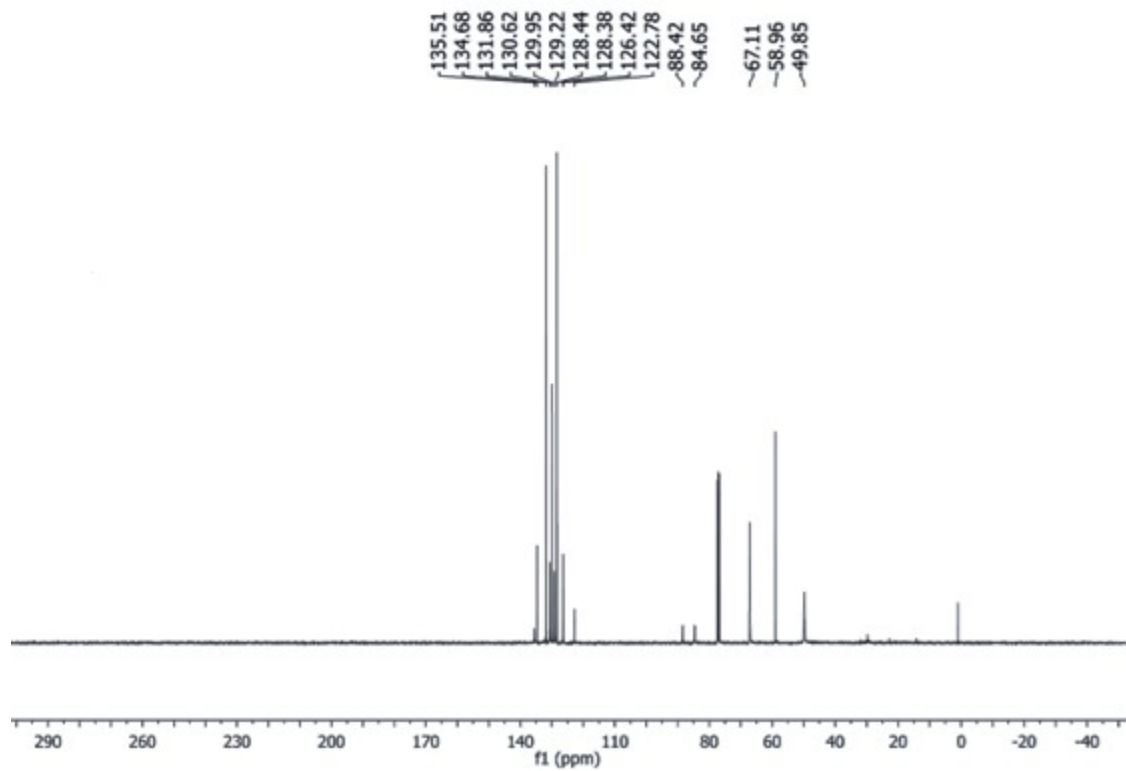
4-(3-phenyl-1-(thiophen-2-yl)prop-2-yn-1-yl)morpholine

14-(1-(2-chlorophenyl)-3-phenylprop-2-yn-1-yl) morpholine



¹H NMR

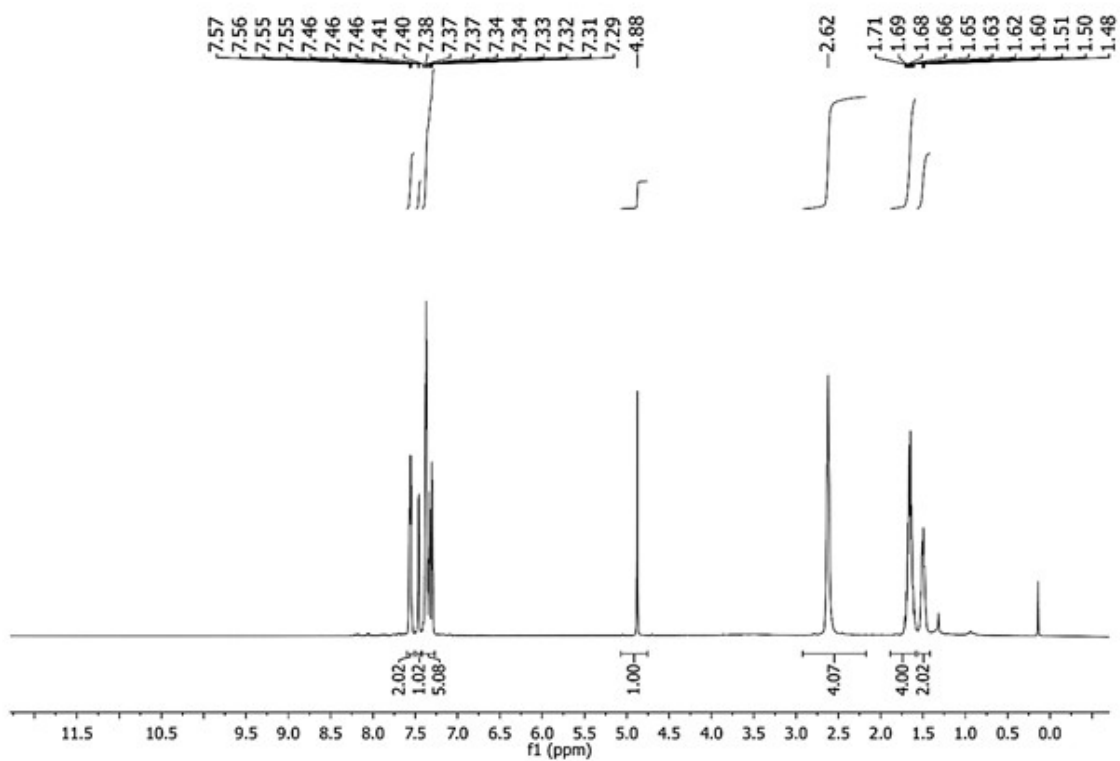
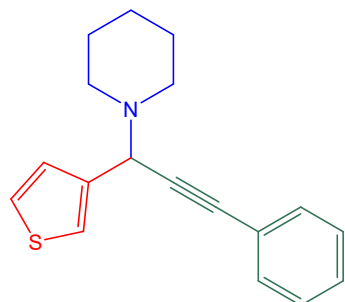
4-(1-(2-chlorophenyl)-3-phenylprop-2-yn-1-yl) morpholine



¹³C NMR

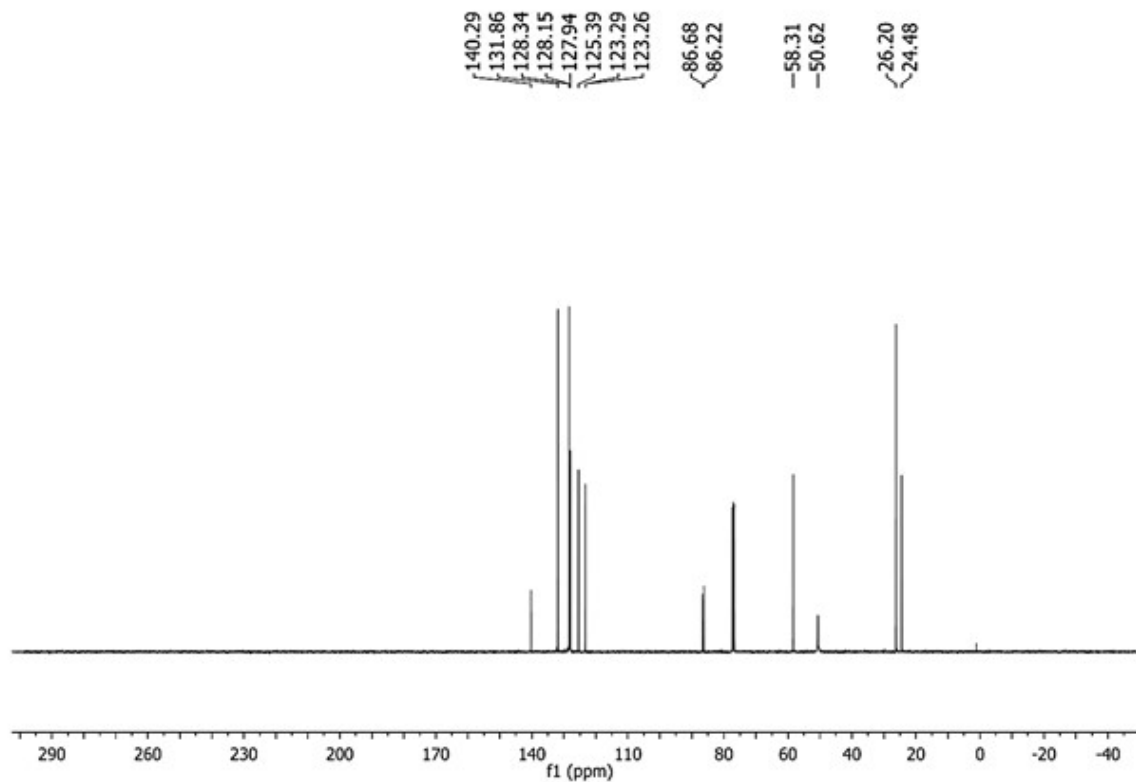
4-(1-(2-chlorophenyl)-3-phenylprop-2-yn-1-yl) morpholine

15-(3-phenyl-1-(thiophen-3-yl)prop-2-yn-1-yl)piperidine



¹H NMR

1-(3-phenyl-1-(thiophen-3-yl) prop-2-yn-1-yl)piperidine



¹³C NMR

1-(3-phenyl-1-(thiophen-3-yl) prop-2-yn-1-yl) piperidine

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