

# **Recyclable Ru/C catalyzed oxidative cyanation of tertiary amines with TBHP**

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### General Information:

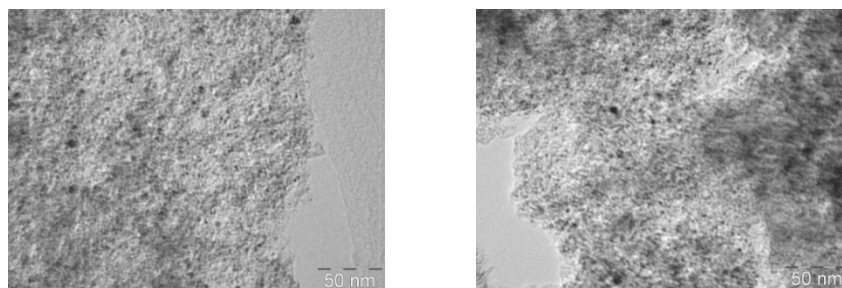
$^1\text{H}$  NMR and  $^{13}\text{C}$  NMR (Avance 300, Innova 400 MHz and Bruker Gemini 200 MHz) spectra were recorded in  $\text{CDCl}_3$ . Chemical shifts ( $\delta$ ) were reported in ppm, and spin-spin coupling constants ( $J$ ) were in Hz. Melting points were determined on a Fischer-Johns melting point apparatus. IR and MS were recorded on a Thermo Nicolet Nexus 670 FT-IR spectrometer and Finnegan MAT 1020 mass spectrometer operating at 70 eV.

### Representative experimental procedure for oxidative cyanation of tertiary amines:

The reaction was carried in a 25 mL round bottom flask equipped with magnetic stir bar charged with *N,N*-dimethylaniline (1 mmol), ethyl cyanoformate (2 mmol), 5–6 M TBHP solution in decane (2.5 mmol), methanol (3 mL) and Ru/C (20 mg) catalyst. The resulting reaction mixture was stirred at 60 °C for 6h. The reaction progress was monitored by TLC. After the reaction, Ru/C was separated by centrifugation and the solvent was evaporated and the crude product was purified by column chromatography. The identity and purity of the product was confirmed by  $^1\text{H}$  NMR,  $^{13}\text{C}$  NMR and ESI-MS.

### Recycling of the catalyst:

After the reaction was complete, the reaction mixture was allowed to cool, and Ru/C was removed by centrifugation. After each cycle, the catalyst was recovered by simple centrifugation, washing with ethyl acetate followed by acetone and then drying in vacuo. The recovered Ru/C was used directly in the next cycle. The native and used Ru/C were analyzed by TEM analysis. It was observed from the TEM studies that the used Ru/C was intact in size and shape even after four cycles compared to the native catalyst.

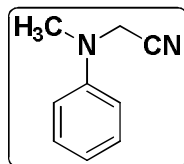


(a)

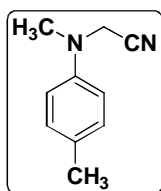
(b)

TEM images of (a) native Ru/C (b) after four cycles Ru/C

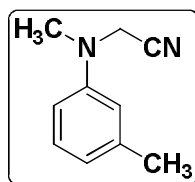
### Spectroscopic Data:



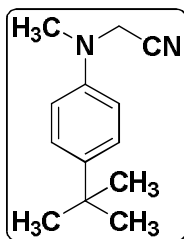
**2-(methyl(phenyl)amino)acetonitrile (Table 3, entry 1)**<sup>1</sup>: <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ 7.30 - 7.21 (m, 2H), 6.93 - 6.80 (m, 3H), 4.13 (s, 2H), 3.01 (s, 3H). <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>): δ 147.7, 129.4, 120.3, 114.9, 96.1, 42.2, 39.2. ESI- MS: *m/z* 147 [M+1].



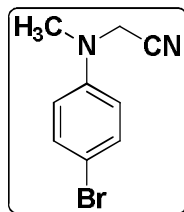
**2-(methyl(p-tolyl)amino)acetonitrile (Table 3, entry 2)**<sup>1</sup>: <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ 7.08 - 7.05 (m, 2H), 6.76 - 6.74 (m, 2H), 4.08 (s, 2H), 2.96 (s, 3H), 2.28 (s, 3H). <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>): δ 145.6, 129.8, 129.7, 115.4, 115.3, 42.6, 39.3, 20.2. ESI- MS: *m/z* 161 [M+1].



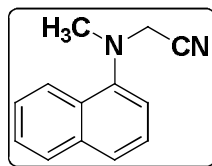
**2-(methyl(m-tolyl)amino)acetonitrile (Table 3, entry 3)**<sup>1</sup>: <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ 7.16 - 7.10 (m, 1H), 6.72 - 6.59 (m, 3H), 4.10 (s, 2H), 2.98 (s, 3H), 2.33 (s, 3H). <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>): δ 147.7, 139.1, 129.1, 120.9, 115.5, 111.9, 42.1, 39.1, 21.6. ESI- MS: *m/z* 161 [M+1].



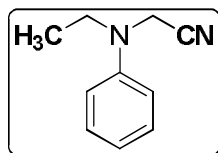
**2-((4-(tert-butyl)phenyl)(methyl)amino)acetonitrile (Table 3, entry 4)**<sup>3</sup>: <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ 7.29 - 7.24 (m, 2H), 6.79 - 6.76 (m, 2H), 4.09 (s, 2H), 2.97 (s, 3H), 1.29 (s, 9H). <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>): δ 145.5, 143.0, 126.2, 115.0, 42.5, 39.3, 34.0, 31.5. ESI- MS: *m/z* 203 [M+1].



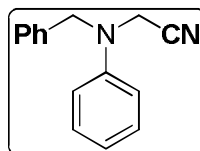
**2-((4-bromophenyl)(methyl)amino)acetonitrile (Table 3, entry 5)<sup>1</sup>:** <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ 7.40 - 7.34 (m, 2H), 6.74 - 6.68 (m, 2H), 4.10 (s, 2H), 2.99 (s, 3H),. <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>): δ 146.7, 132.2, 116.3, 115.0, 112.5, 42.1, 39.3. ESI- MS: *m/z* 225 [M+1].



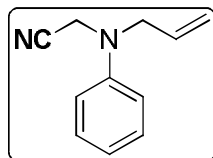
**2-(methyl(naphthalen-1-yl)amino)acetonitrile (Table 3, entry 6):** <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ 8.07 - 8.04 (m, 1H), 7.85 - 7.76 (m, 1H), 7.66 - 7.55 (m, 1H), 7.50 - 7.21 (m, 4H), 4.05 (s, 2H), 3.04 (s, 3H). <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>): δ 146.2, 134.8, 128.7, 128.7, 126.1, 125.4, 122.7, 117.1, 115.0, 46.1, 41.3. ESI- MS: *m/z* 197 [M+1].



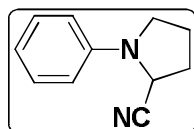
**2-(ethyl(phenyl)amino)acetonitrile (Table 3, entry 7)<sup>2</sup>:** <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ 7.32 - 7.17 (m, 2H), 6.91 - 6.75 (m, 3H), 4.09 (s, 2H), 3.41 (q, *J* = 7.1 Hz, 2H), 1.25 (*J* = 7.1 Hz, 3H). <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>): δ 146.8, 129.5, 120.0, 116.0, 115.1, 114.0, 46.2, 39.5, 12.2. ESI- MS: *m/z* 161 [M+1].



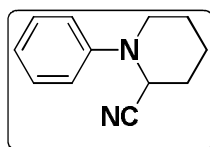
**2-(benzyl(phenyl)amino)acetonitrile (Table 3, entry 8):** <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ 7.44 - 7.21 (m, 7H), 6.96 - 6.84 (m, 3H), 4.49 (s, 1H), 4.02 (s, 1H). <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>): δ 147.9, 136.7, 129.5, 128.9, 127.8, 127.6, 120.7, 115.7, 114.1, 55.7, 39.4. ESI- MS: *m/z* 223 [M+1].



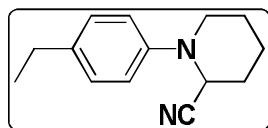
**2-(allyl(phenyl)amino)acetonitrile (Table 3, entry 9):**  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.28 - 7.21 (m, 2H), 6.93 - 6.80 (m, 3H), 5.96 - 5.79 (m, 1H), 5.37 - 5.26 (m, 2H), 4.09 (s, 2H), 3.93 (d,  $J = 5.2$  Hz, 2H).  $^{13}\text{C}$  NMR (75 MHz,  $\text{CDCl}_3$ ):  $\delta$  147.4, 132.9, 129.5, 120.4, 115.3, 96.2, 54.5, 39.3. ESI- MS:  $m/z$  173 [M+1].



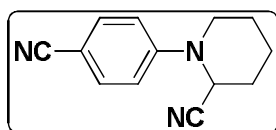
**1-phenylpyrrolidine-2-carbonitrile (Table 3, entry 10)<sup>2</sup>:**  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.37 - 7.21 (m, 2H), 6.98 - 6.81 (m, 1H), 6.74 - 6.62 (m, 2H), 4.43 (d,  $J = 6.9$  Hz, 1H), 3.50 - 3.33 (m, 2H), 2.49 - 2.10 (m, 4H). ESI- MS:  $m/z$  173 [M+1].



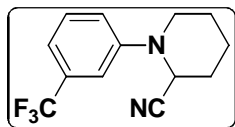
**1-phenylpiperidine-2-carbonitrile (Table 3, entry 11)<sup>2</sup>:**  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ ): 7.29 - 7.24 (m, 2H), 6.97 - 6.94 (m, 3H), 4.55 (s, 1H), 3.39 (d,  $J = 12.2$  Hz, 1H), 3.05 (t,  $J = 11.7$  Hz, 1H), 2.03 - 1.55 (m, 6H). ESI- MS:  $m/z$  187 [M+1].



**1-(4-ethylphenyl)piperidine-2-carbonitrile (Table 3, entry 12):**  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.12 (d,  $J = 8.5$  Hz, 2H), 6.91 (d,  $J = 8.5$  Hz, 2H), 4.55 (s, 1H), 3.39 - 3.29 (m, 1H), 3.07 - 2.93 (m, 1H), 2.57 (q,  $J = 7.5$  Hz, 2H), 2.01 - 1.59 (m, 6H), 1.20 (t,  $J = 7.5$  Hz, 3H).  $^{13}\text{C}$  NMR (75 MHz,  $\text{CDCl}_3$ ):  $\delta$  147.6, 138.0, 128.5, 118.4, 117.1, 52.4, 46.7, 29.1, 27.9, 25.0, 20.1, 15.5. ESI- MS:  $m/z$  215 [M+1].

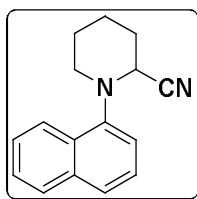


**1-(4-cyanophenyl)piperidine-2-carbonitrile (Table 3, entry 13):**  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.56 (d,  $J = 8.8$  Hz, 2H), 6.9 (d,  $J = 8.8$  Hz, 2H), 4.76 (s, 1H), 3.64 (d,  $J = 12.1$  Hz, 1H), 3.05 (t,  $J = 12.1$  Hz, 1H), 2.16 - 1.56 (m, 6H).  $^{13}\text{C}$  NMR (75 MHz,  $\text{CDCl}_3$ ):  $\delta$  152.3, 133.5, 119.1, 116.6, 103.5, 49.3, 45.6, 28.8, 24.6, 19.8. ESI- MS:  $m/z$  212 [M+1].



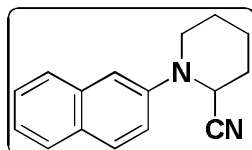
**1-(3-(trifluoromethyl)phenyl)piperidine-2-carbonitrile (Table 3, entry**

**14):**  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ )  $\delta$  7.43 - 7.39 (m, 1H), 7.24 - 7.14 (m, 3H), 4.65 (s, 1H), 3.50 - 3.47 (m, 1H), 3.09 - 3.02 (m, 1H), 2.12 - 1.95 (m, 2H), 1.90 - 1.83 (m, 2H), 1.79 - 1.63 (m, 2H).  $^{13}\text{C}$  NMR (75 MHz,  $\text{CDCl}_3$ ):  $\delta$  150.0, 129.9, 120.8, 118.5, 116.7, 114.9, 51.5, 46.4, 29.6, 24.9, 19.9. ESI- MS:  $m/z$  255 [M+1].



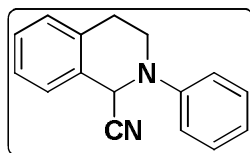
**1-(naphthalen-1-yl)piperidine-2-carbonitrile (Table 3, entry 15):**  $^1\text{H}$  NMR

(300 MHz,  $\text{CDCl}_3$ )  $\delta$  8.06 - 7.96 (m, 1H), 7.88 - 7.79 (m, 1H), 7.68 - 7.60 (m, 1H), 7.53 - 7.40 (m, 3H), 7.38 - 7.22 (m, 1H), 4.40 (s, 1H), 3.45 - 3.31 (m, 1H), 3.17 - 3.13 (m, 1H), 2.33 - 2.09 (m, 1H), 2.08 - 1.69 (m, 5H).  $^{13}\text{C}$  NMR (75 MHz,  $\text{CDCl}_3$ ):  $\delta$  146.8, 134.6, 128.6, 125.8, 125.1, 122.2, 117.4, 54.5, 48.2, 29.3, 25.5, 20.3. EI-MS:  $m/z$  237 [M+1].



**1-(naphthalen-2-yl)piperidine-2-carbonitrile (Table 3, entry 16):**  $^1\text{H}$

NMR (300 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.77 - 7.73 (m, 3H), 7.46 - 7.15 (m, 4H), 4.75 (s, 1H), 3.59 (d,  $J$  = 11.3 Hz, 1H), 3.16 - 3.04 (m, 1H), 2.15 - 1.55 (m, 6H).  $^{13}\text{C}$  NMR (75 MHz,  $\text{CDCl}_3$ ):  $\delta$  147.2, 134.1, 129.0, 127.3, 127.1, 126.4, 124.3, 120.0, 113.3, 51.9, 46.6, 29.1, 25.0, 20.1. ESI- MS:  $m/z$  237 [M+1].



**2-phenyl-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (Table 3, entry**

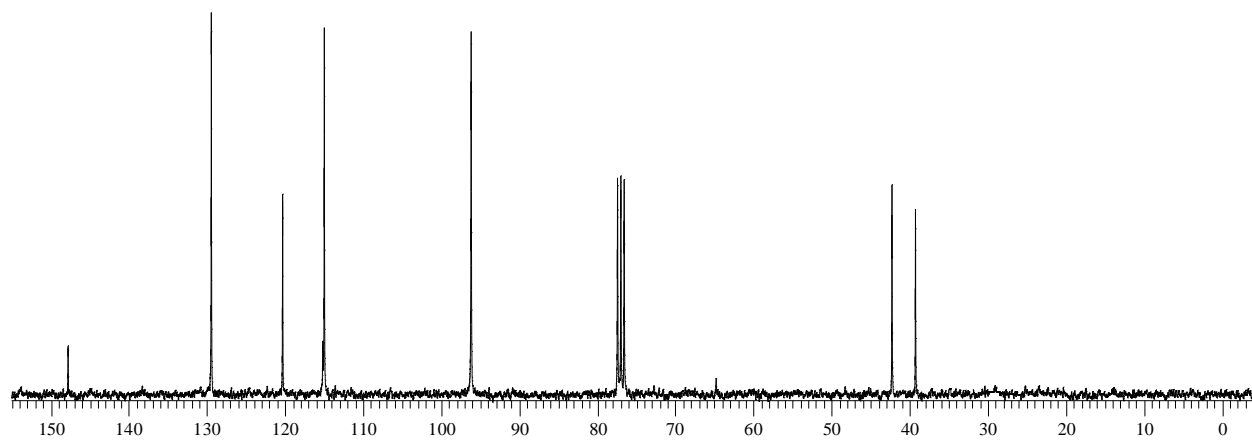
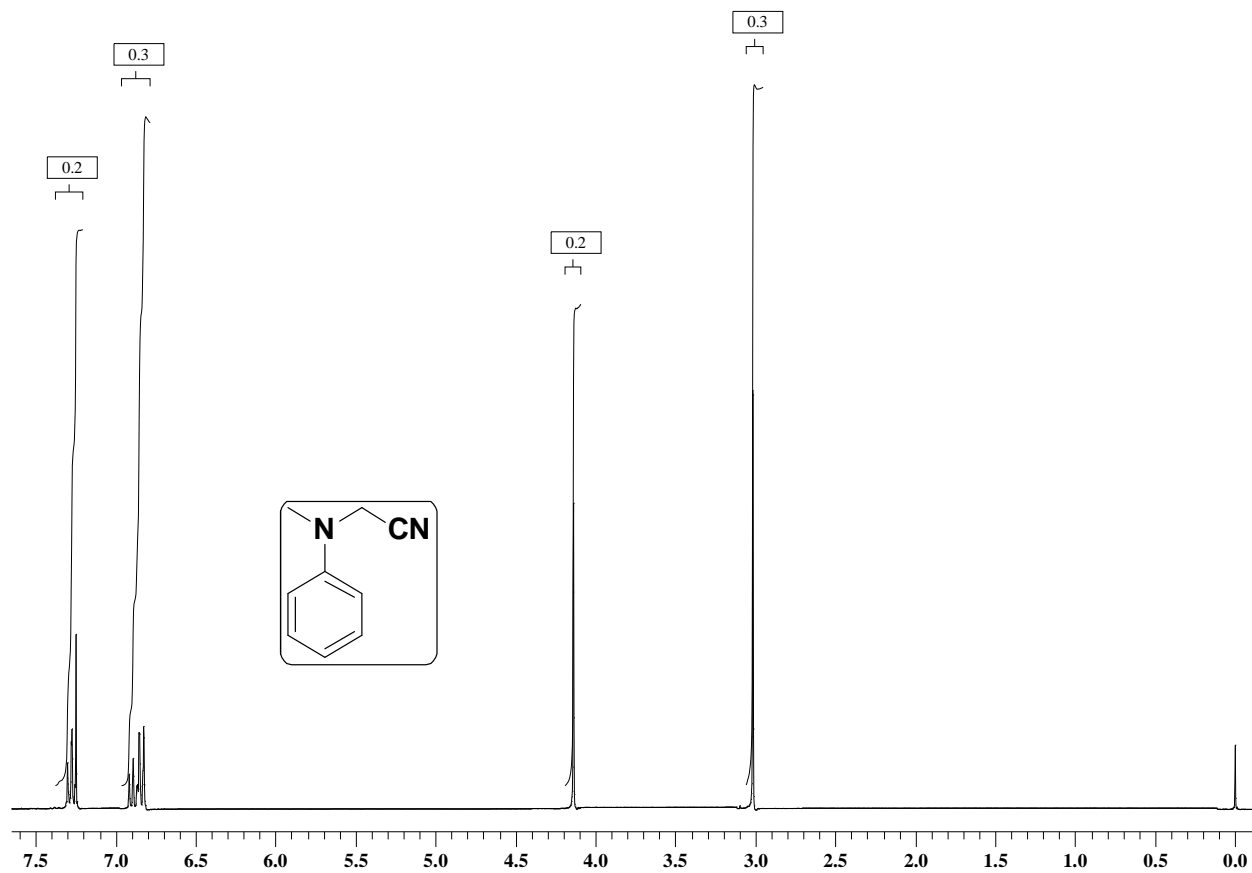
**17):**  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.34 - 7.17 (m, 6H), 7.05 - 6.94 (m, 3H), 5.43 (s, 1H), 3.77 - 3.67 (m, 1H), 3.52 - 3.38 (m, 1H), 3.19 - 3.05 (m, 1H), 2.96 - 2.91 (m, 1H).  $^{13}\text{C}$  NMR (75 MHz,  $\text{CDCl}_3$ ):  $\delta$  148.4, 134.5, 129.5, 128.7, 128.7, 127.1, 122.0, 117.7, 53.2, 44.2, 28.6. ESI- MS:  $m/z$  235 [M+1].

## References:

1. S. I. Murahashi, T. Nakae, H. Terai and N. Komiya, *J. Am. Chem. Soc.*, 2008, **130**, 11005.
2. Y. Zhang, Y. Peng, M. Zhang and Y. Cheng, *Chem. Commun.*, 2011, **47**, 2354.
3. S. Singhal, S. J. Jain and B. Sain, *Chem. Commun.*, 2009, 2371.

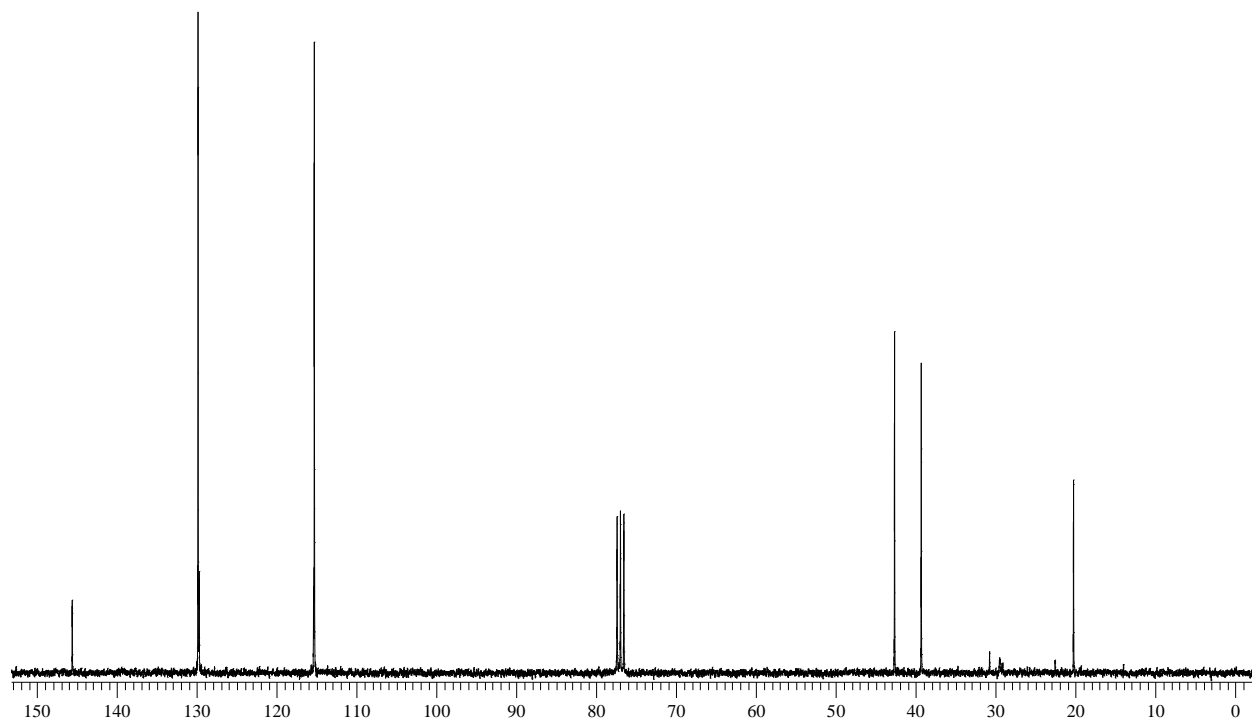
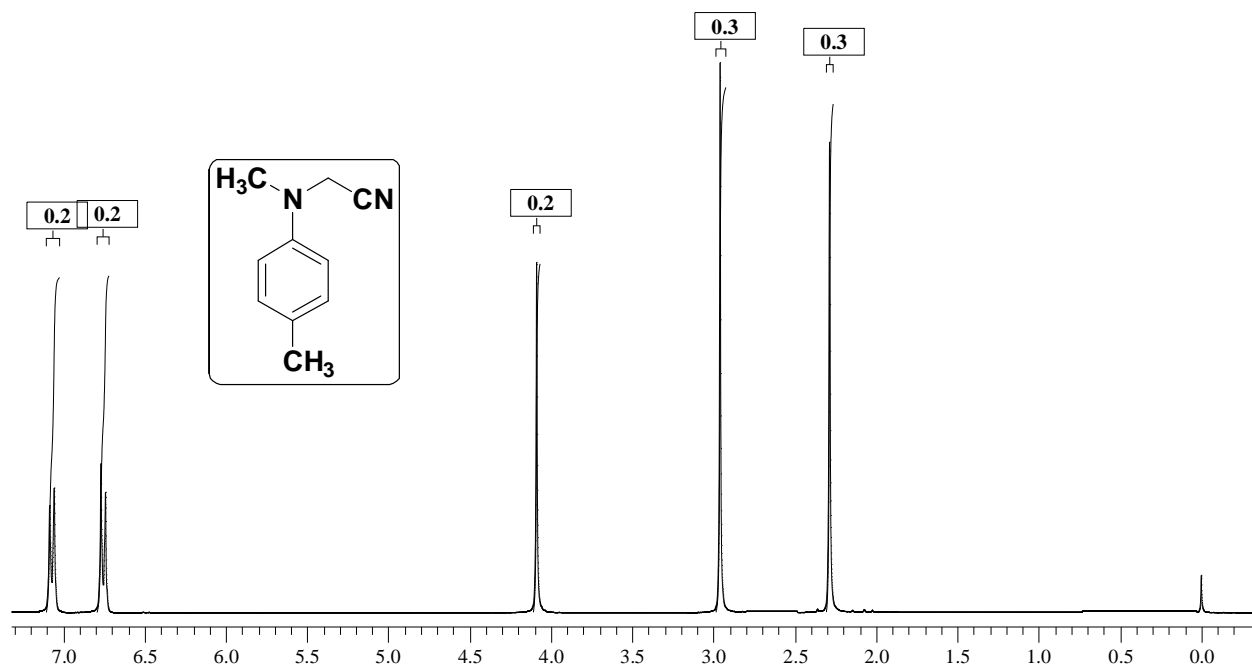
## Copies of $^1\text{H}$ NMR and $^{13}\text{C}$ NMR of Compounds:

### 2-(methyl(phenyl)amino)acetonitrile (Table 3, entry 1):

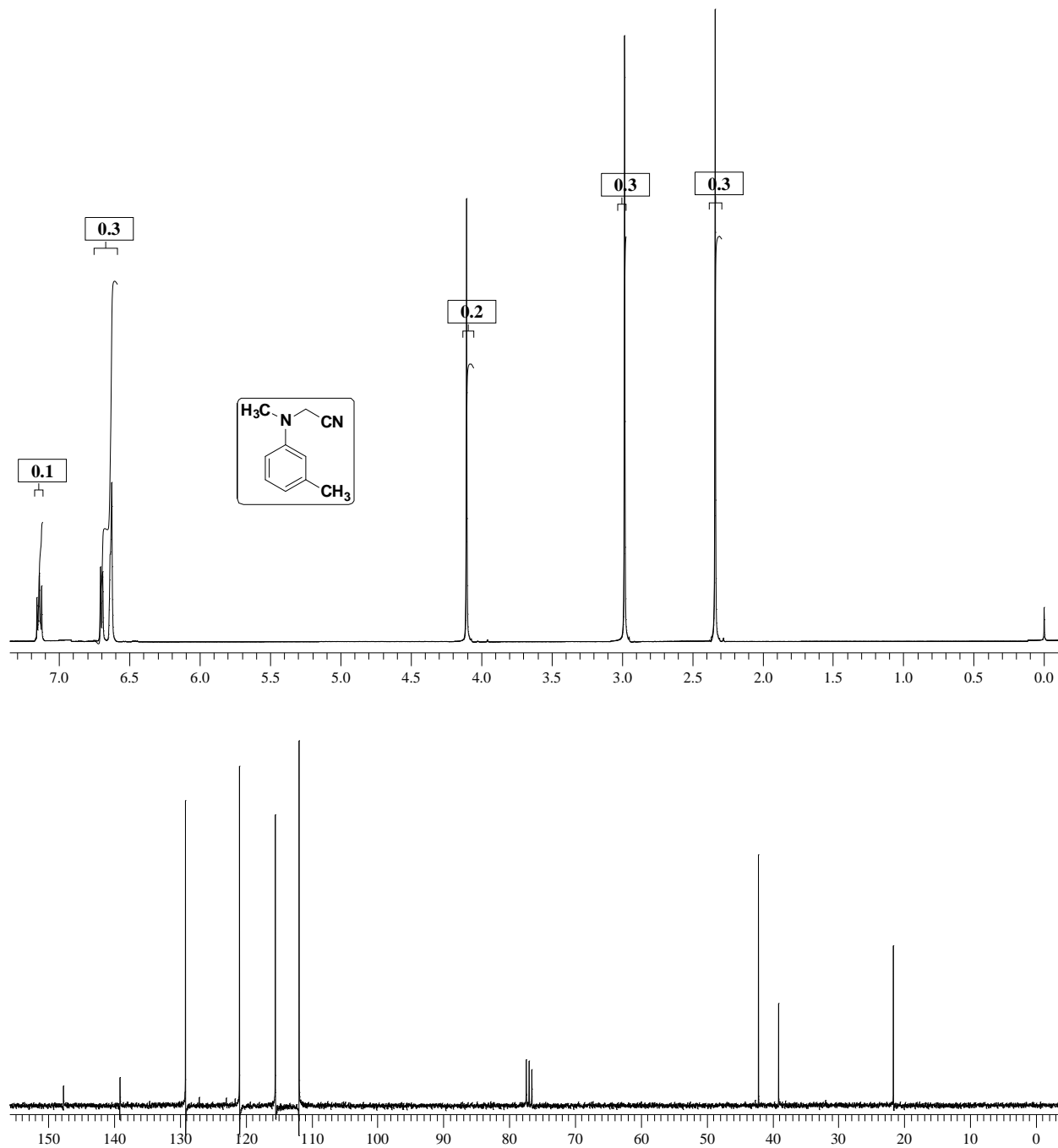




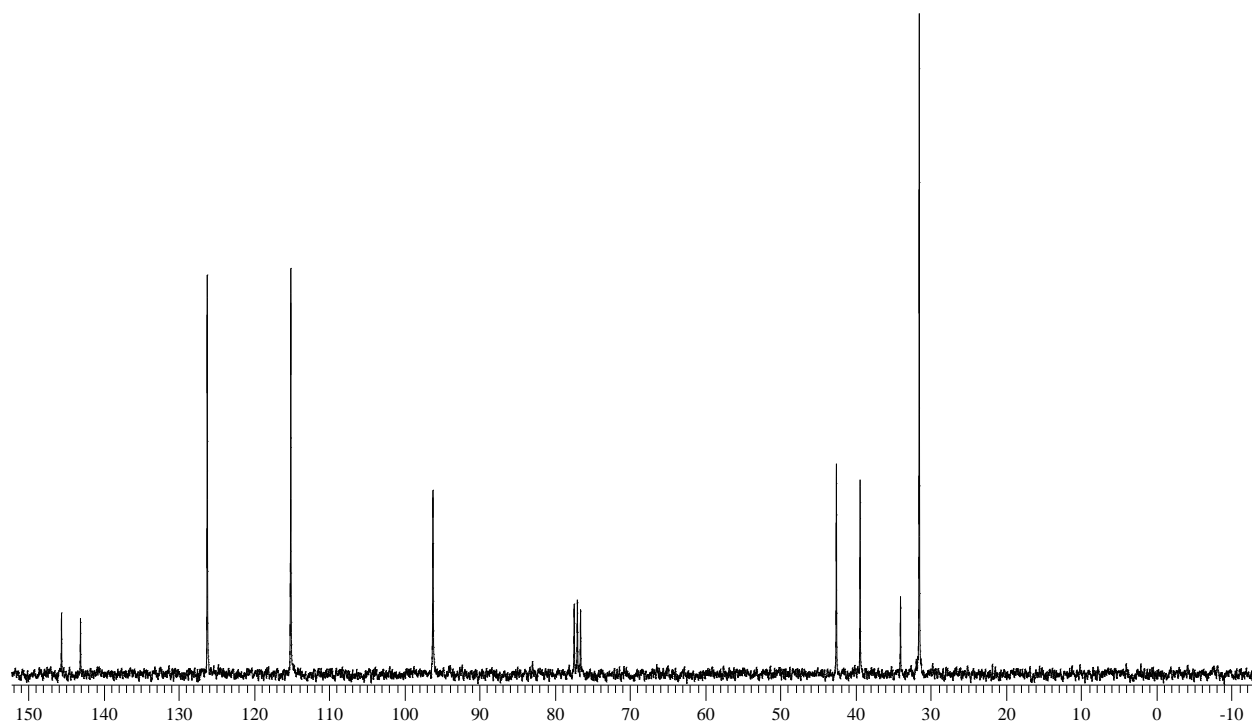
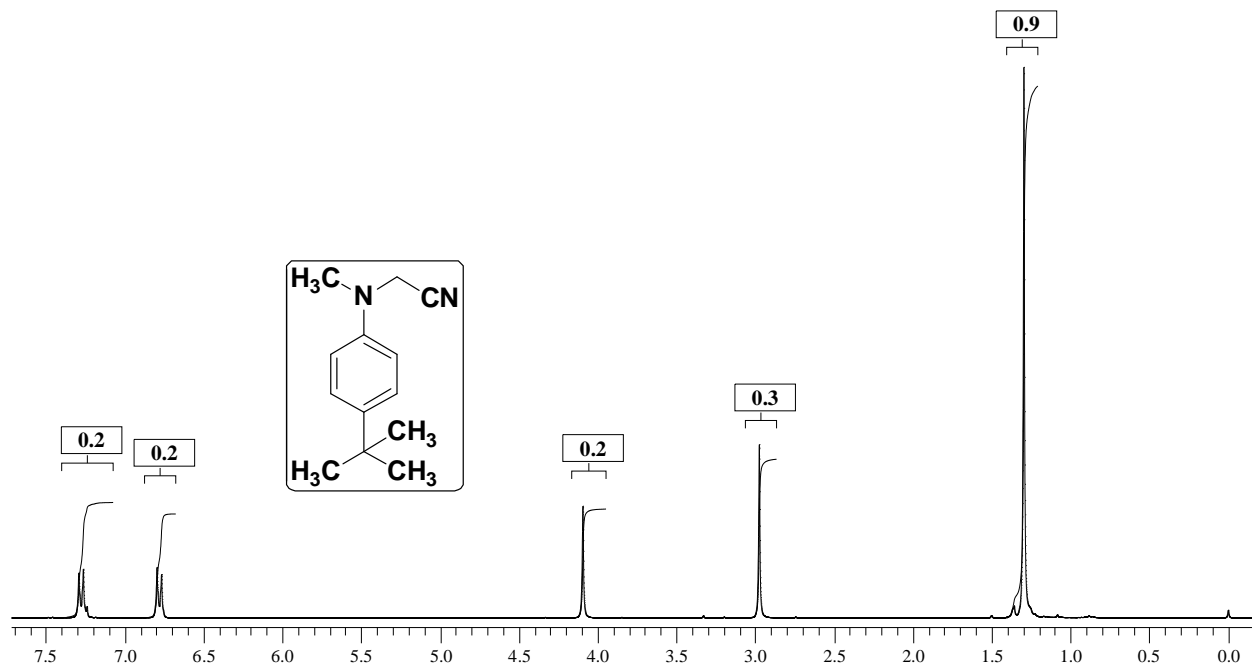
**2-(methyl(p-tyl)amino)acetonitrile (Table 3, entry 2):**



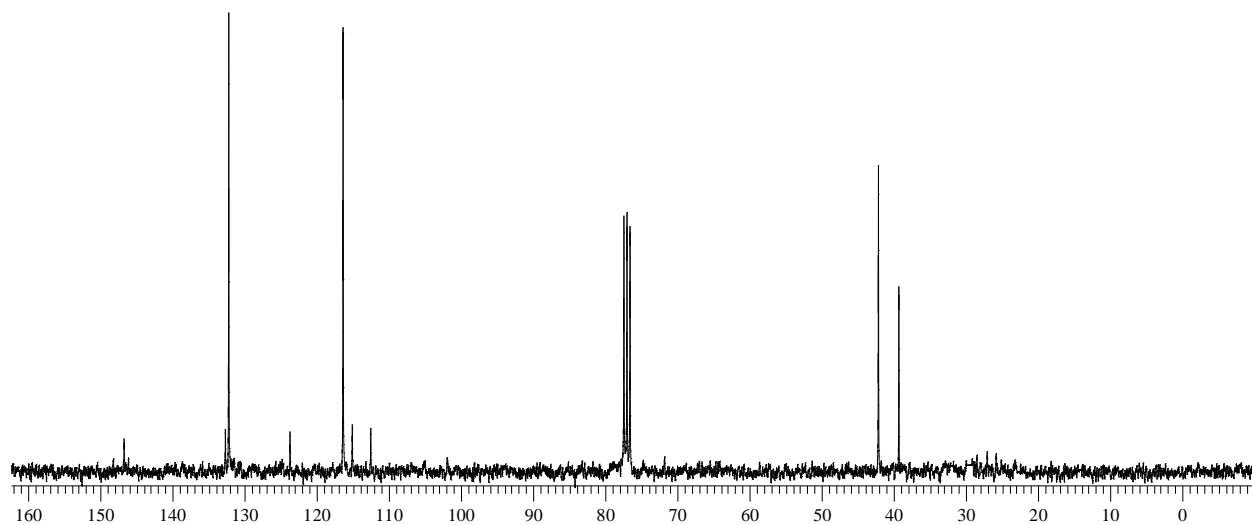
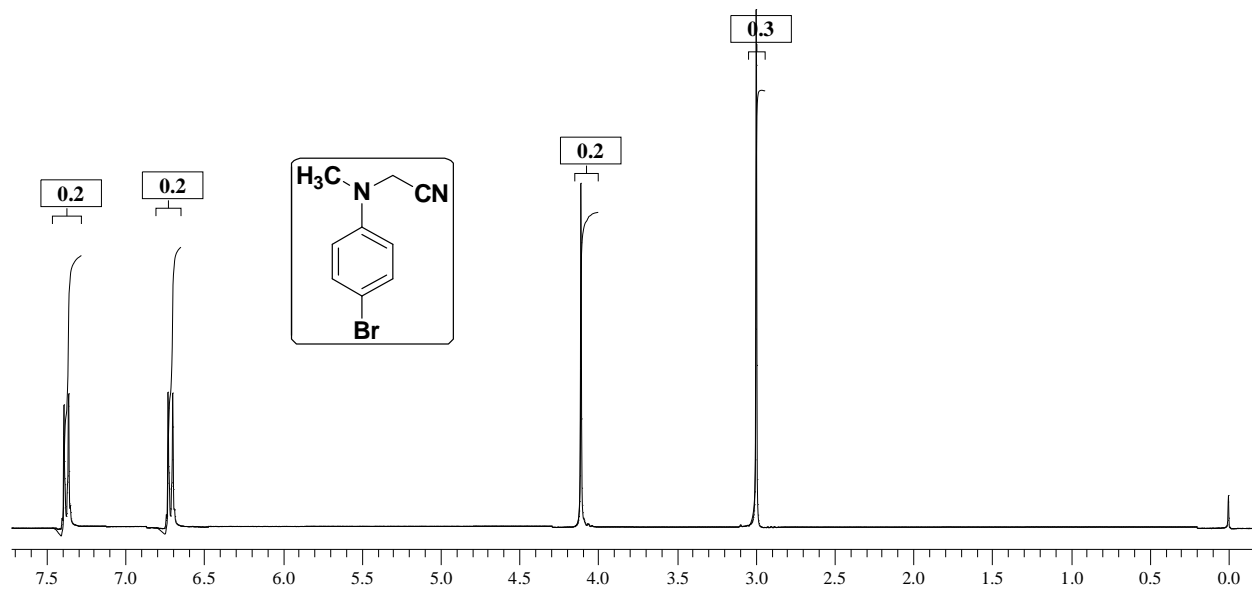
**2-(methyl(m-tolyl)amino)acetonitrile (Table 3, entry 3):**



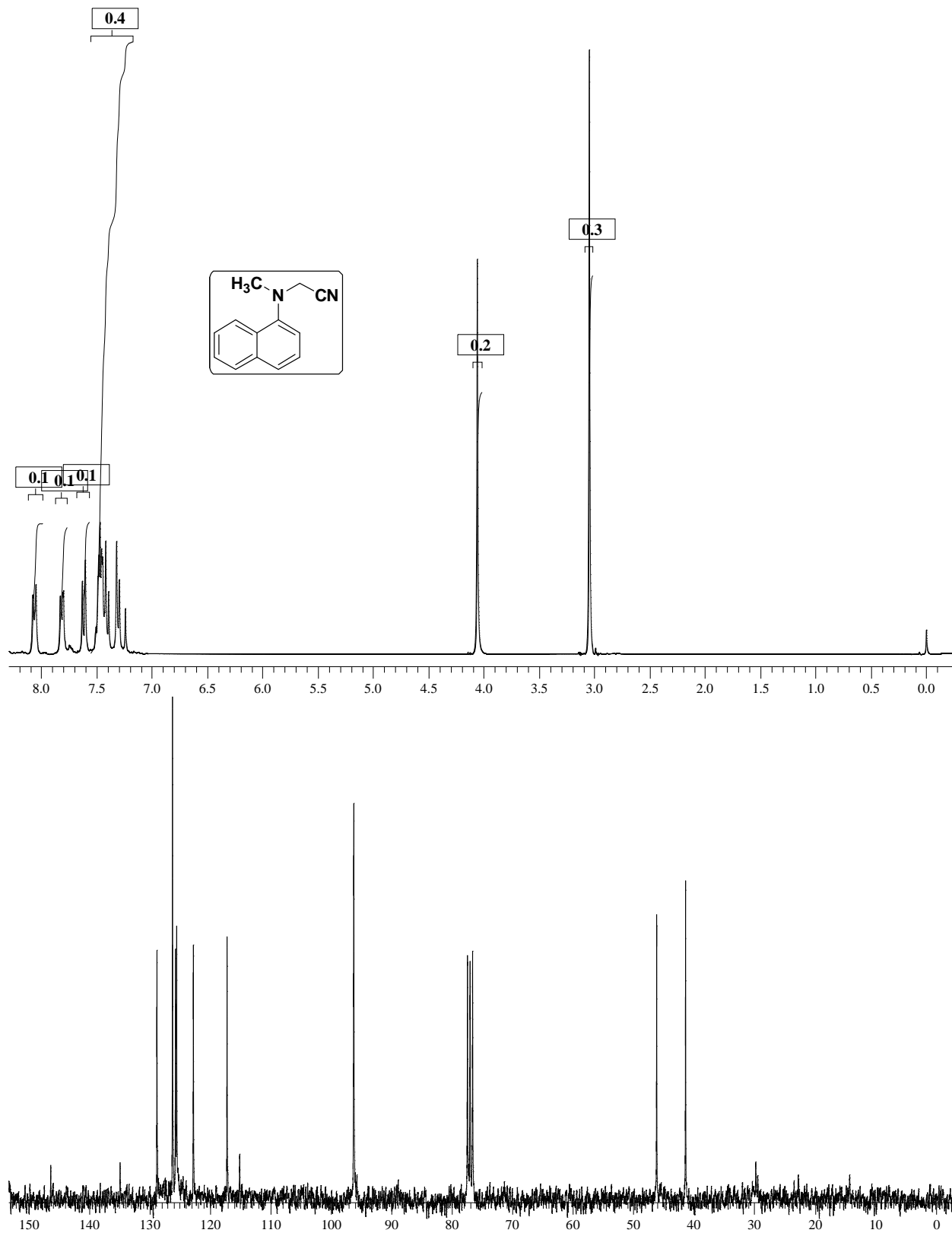
**2-((4-(tert-butyl)phenyl)(methyl)amino)acetonitrile (Table 3, entry 4):**



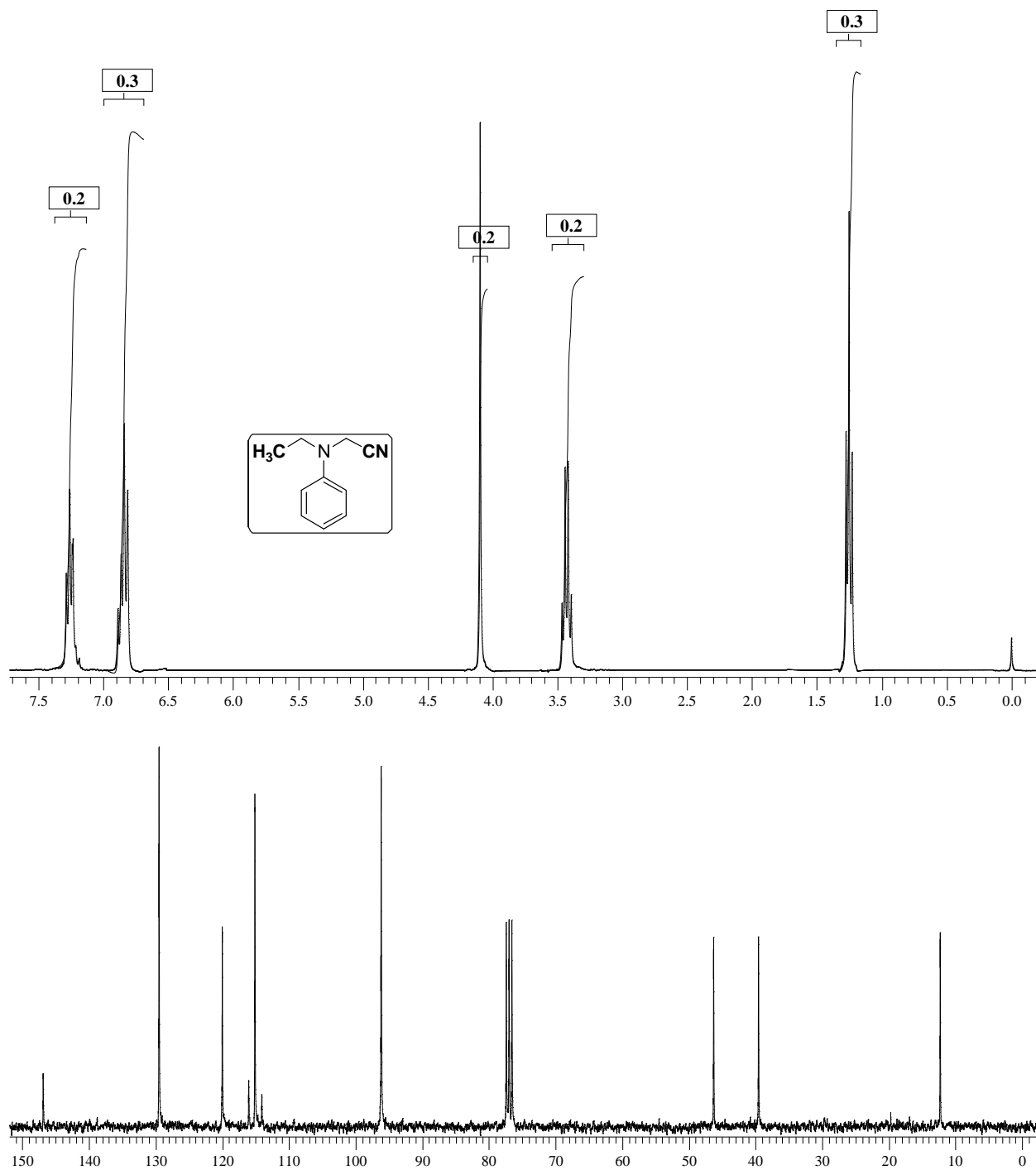
**2-((4-bromophenyl)(methyl)amino)acetonitrile (Table 3, entry 5):**



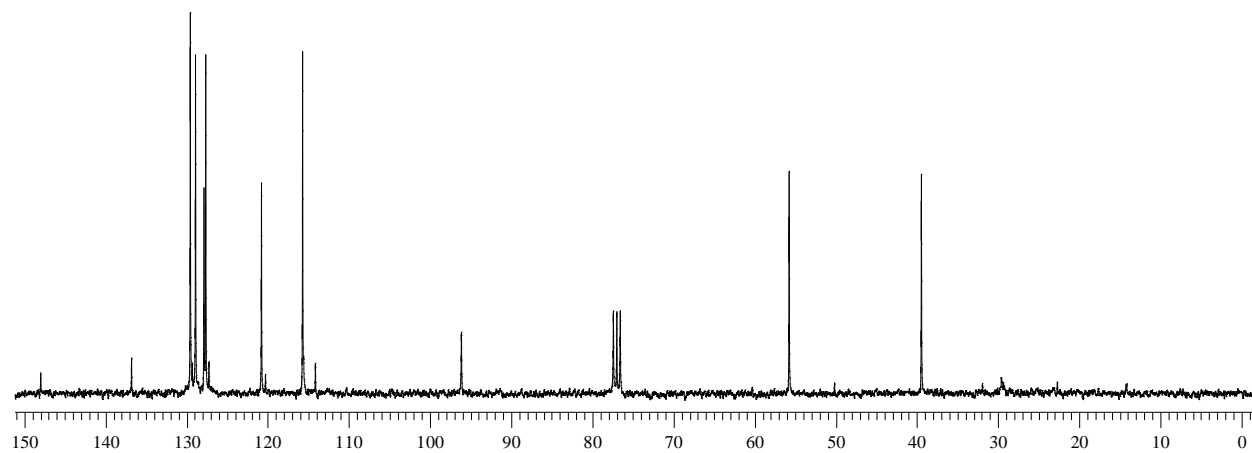
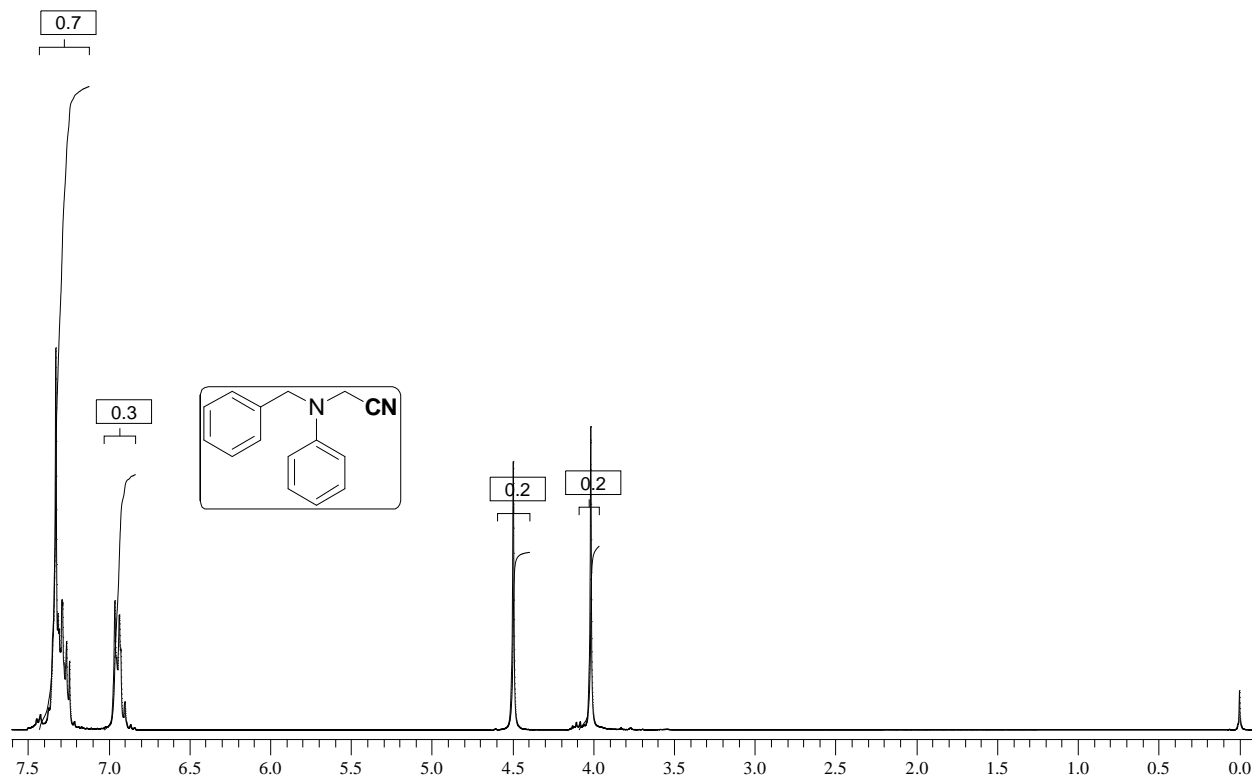
**2-(methyl(naphthalen-1-yl)amino)acetonitrile (Table 3, entry 6):**



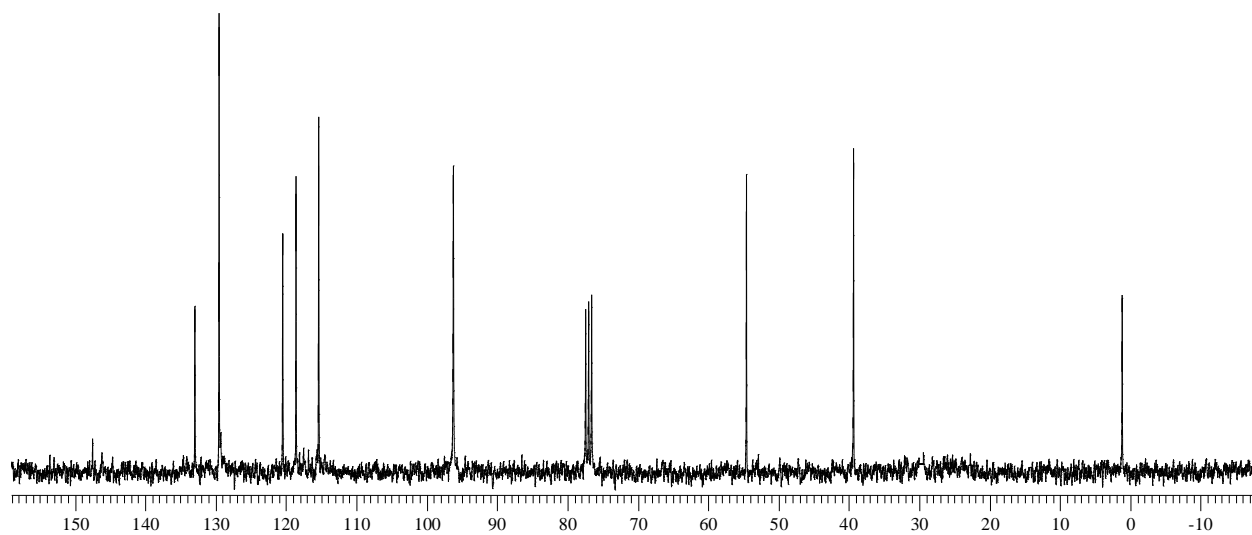
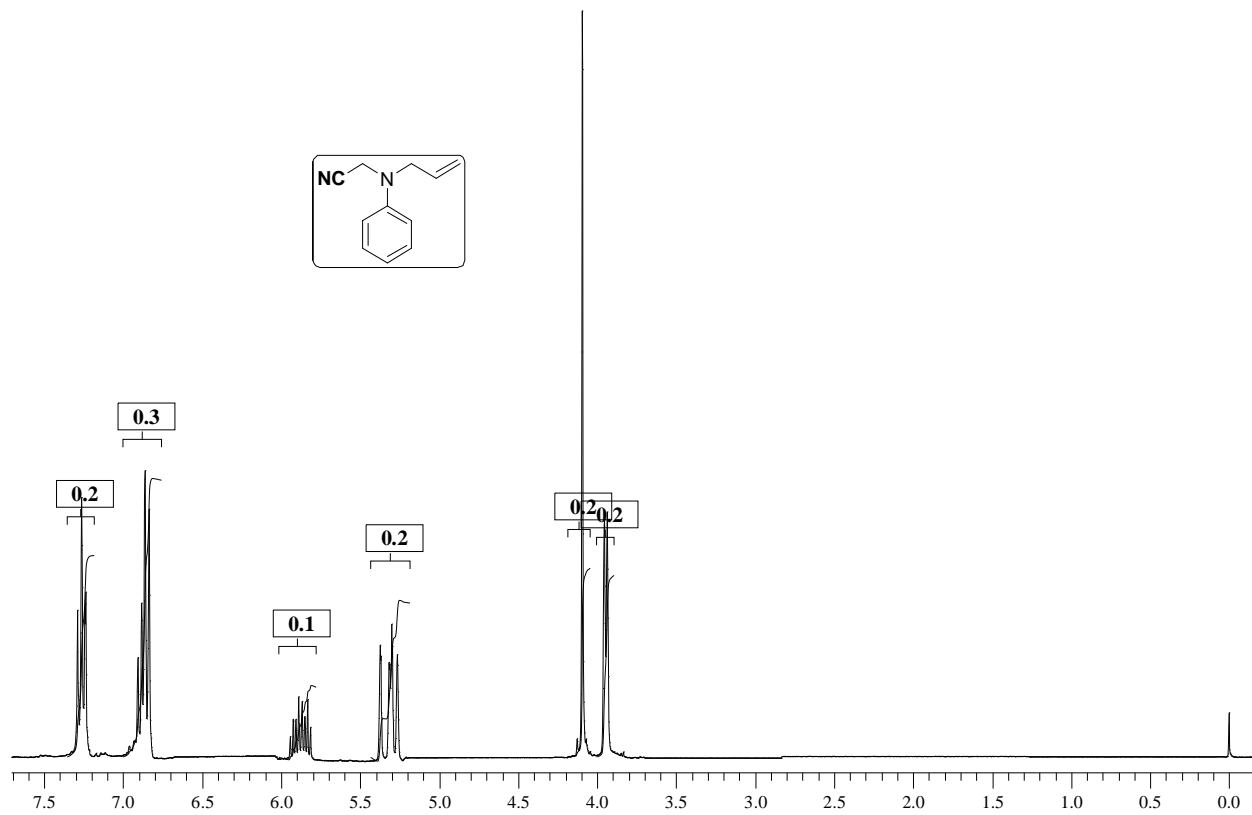
**2-(ethyl(phenyl)amino)acetonitrile (Table 3, entry 7):**



**2-(benzyl(phenyl)amino)acetonitrile (Table 3, entry 8):**

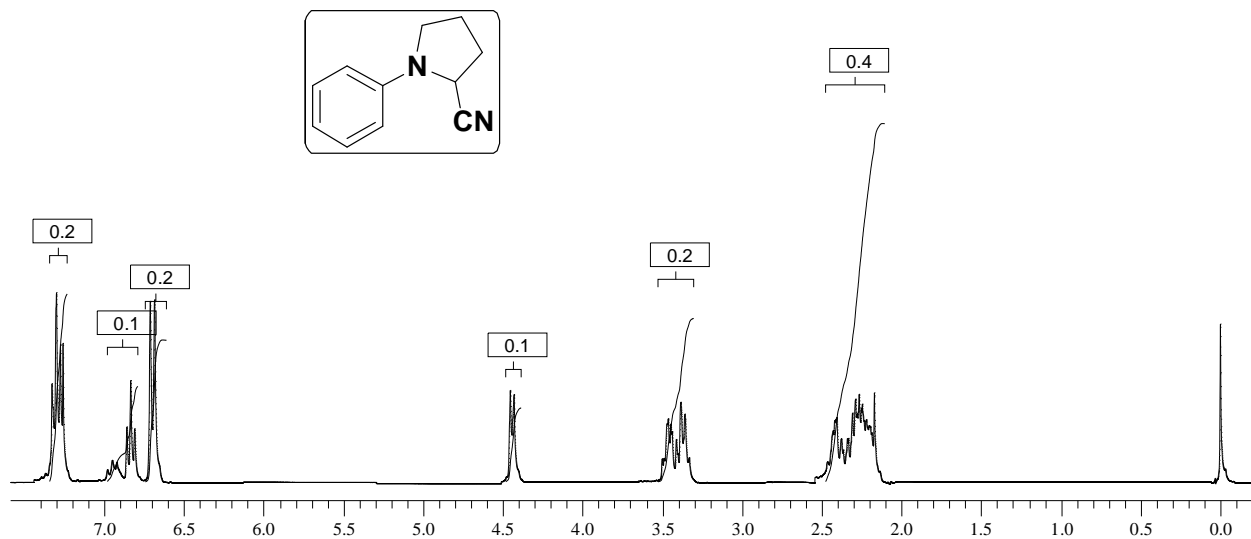


**2-(allyl(phenyl)amino)acetonitrile (Table 3, entry 9):**

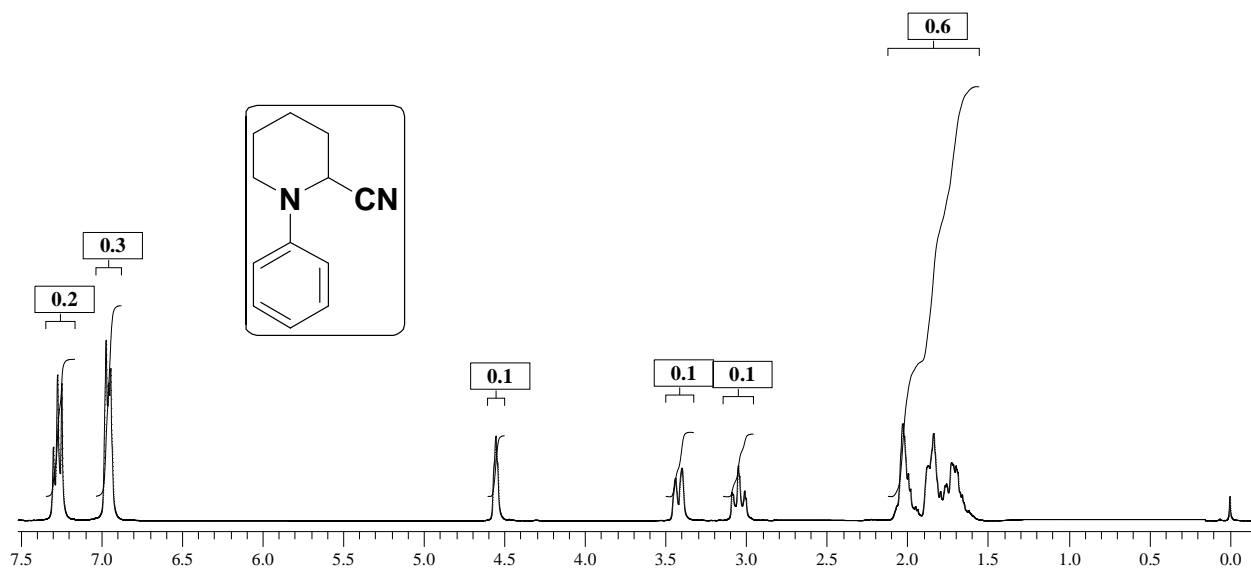




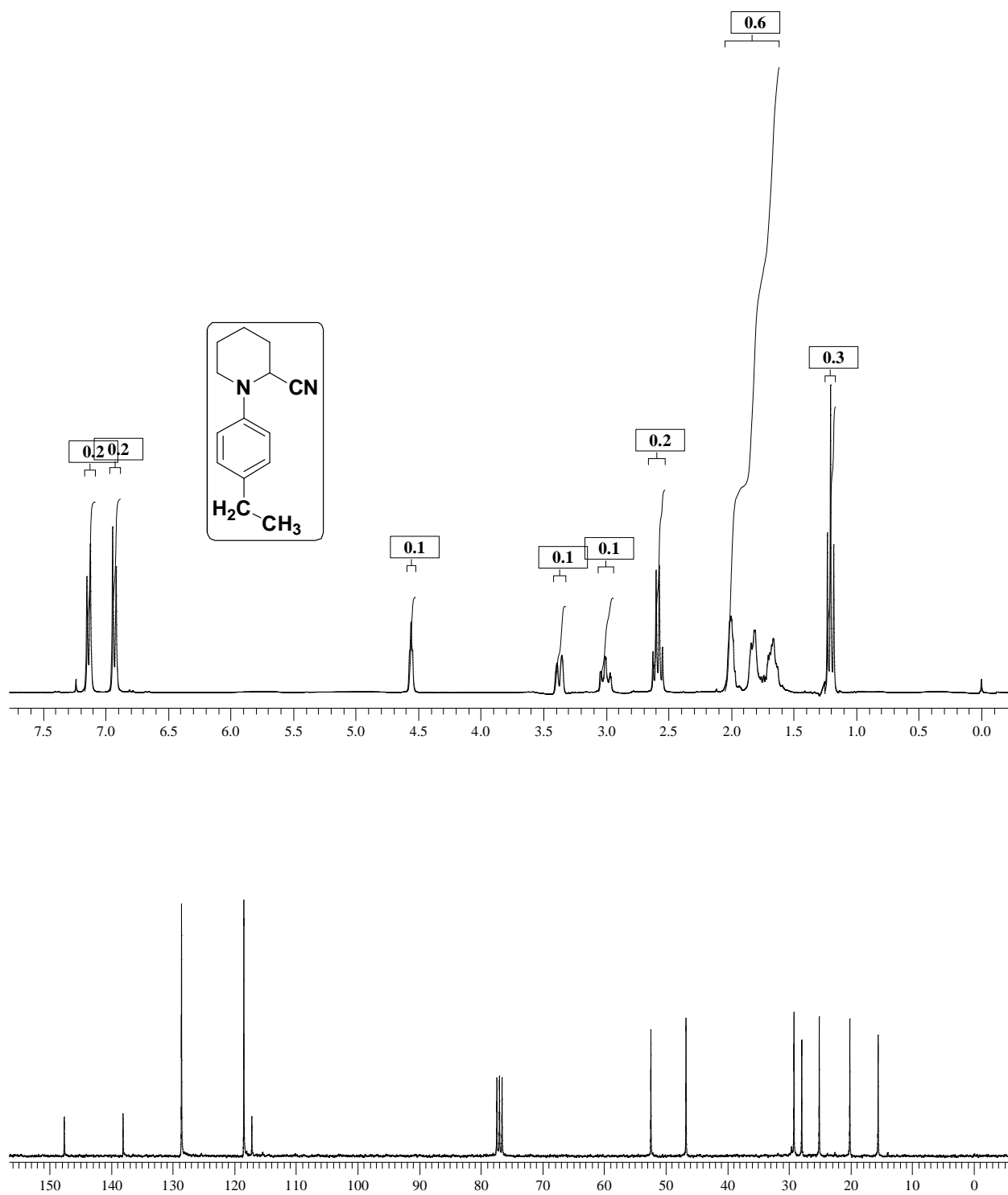
### 1-phenylpyrrolidine-2-carbonitrile (Table 3, entry 10):



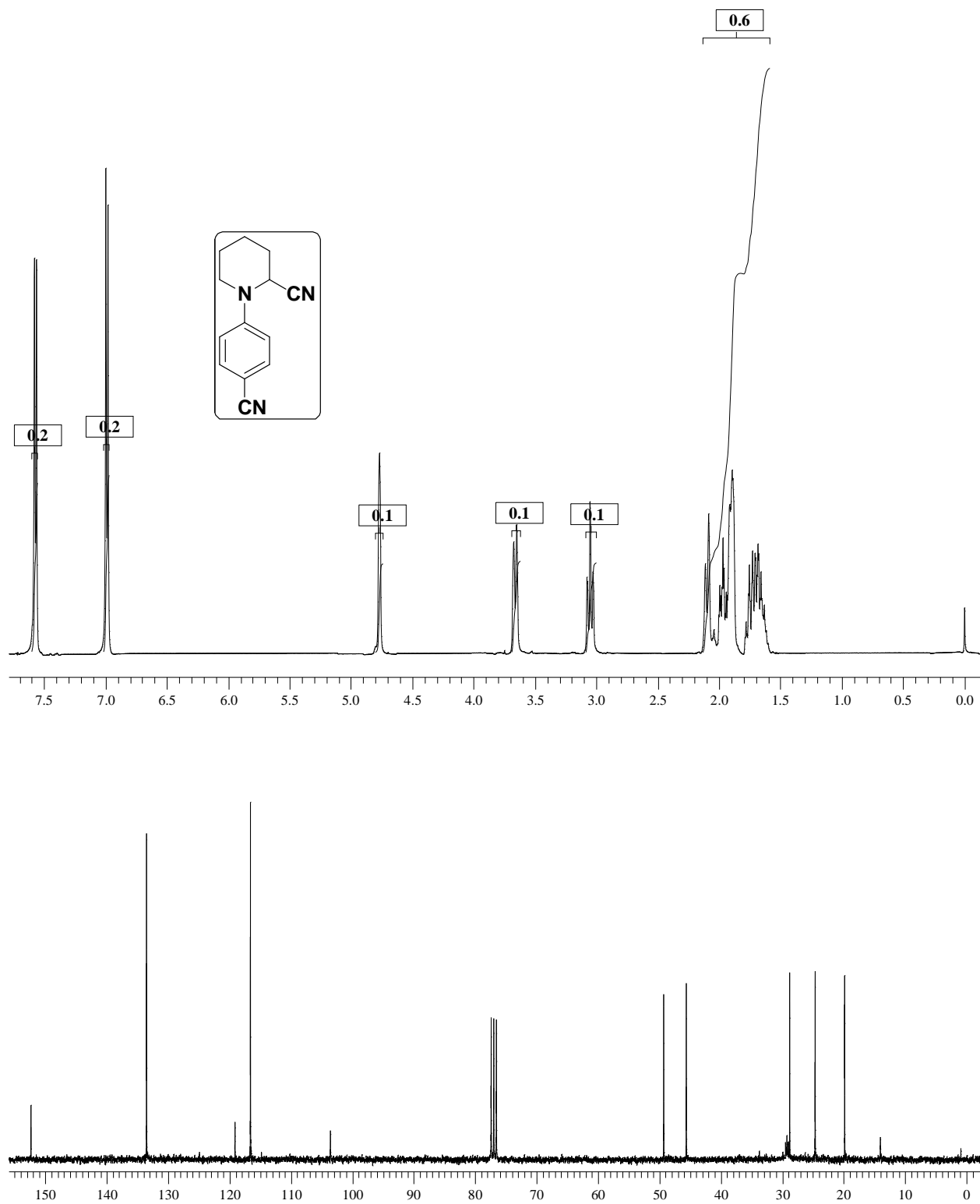
### 1-phenylpiperidine-2-carbonitrile (Table 3, entry 11):



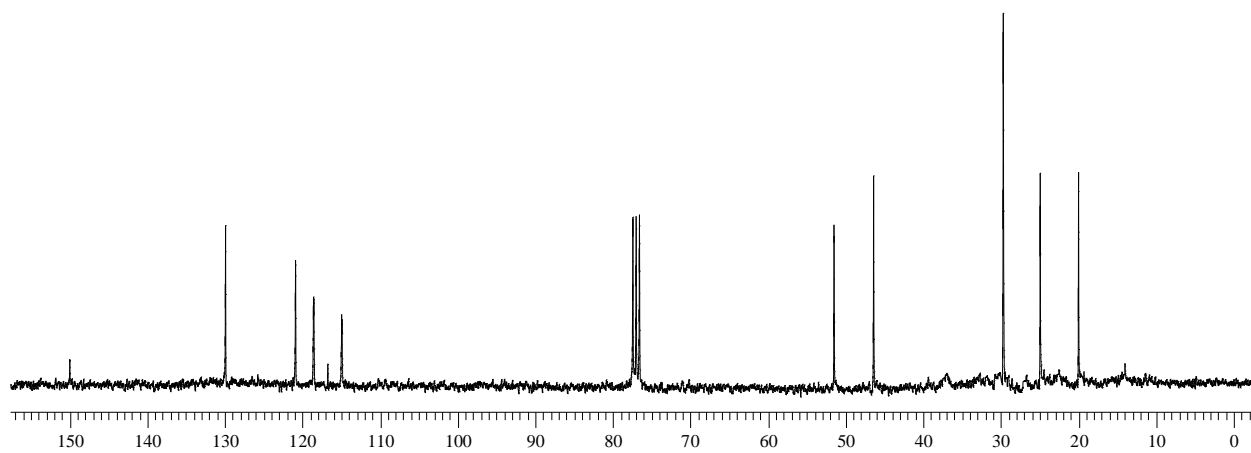
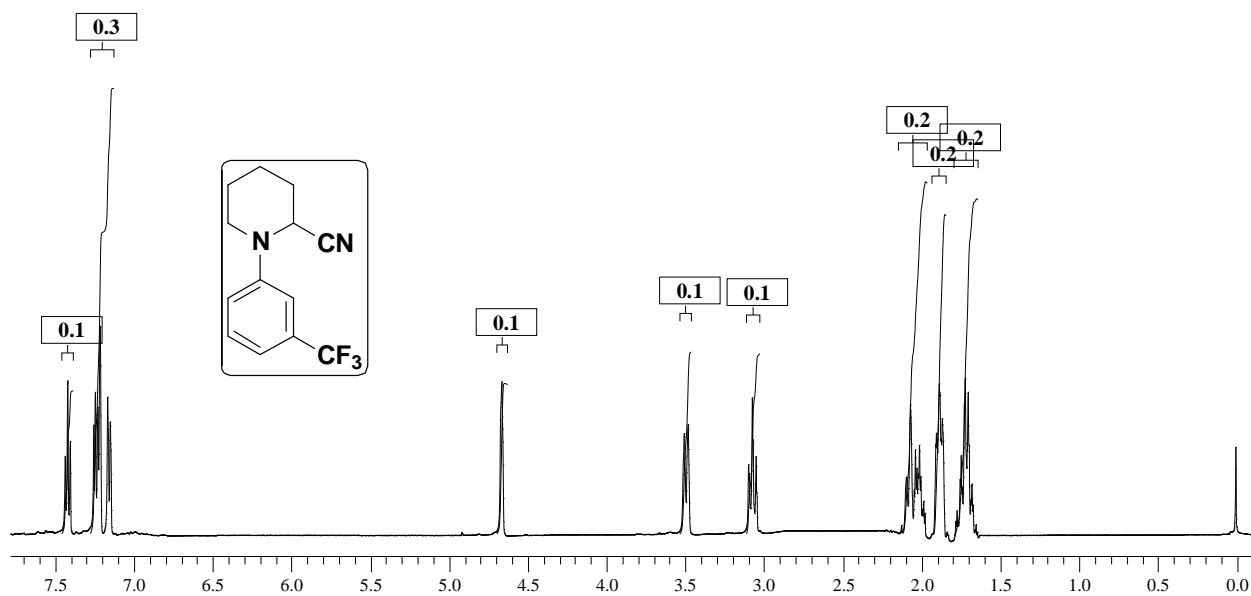
**1-(4-ethylphenyl)piperidine-2-carbonitrile (Table 3, entry 12):**



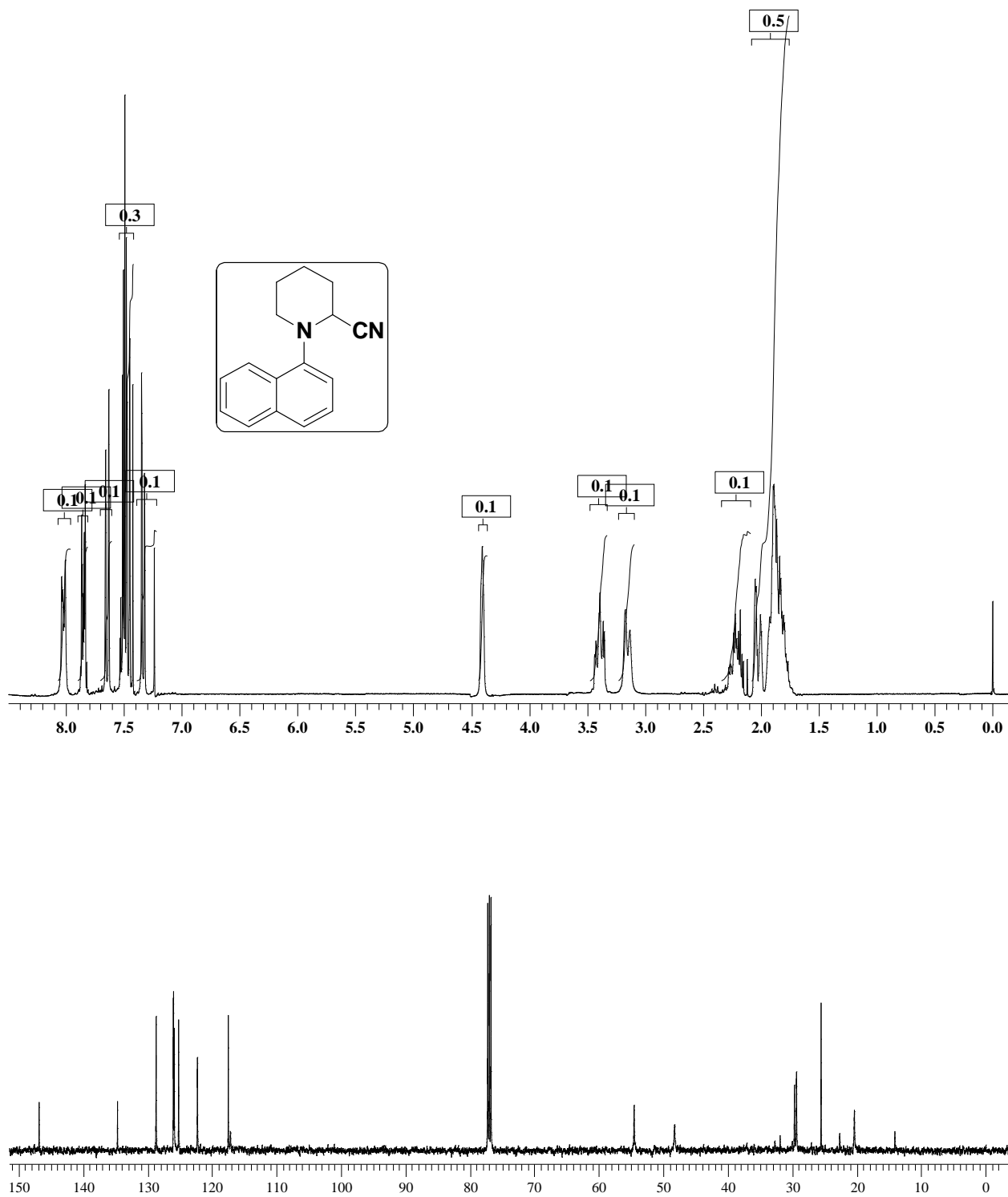
**1-(4-cyanophenyl)piperidine-2-carbonitrile (Table 3, entry 13):**



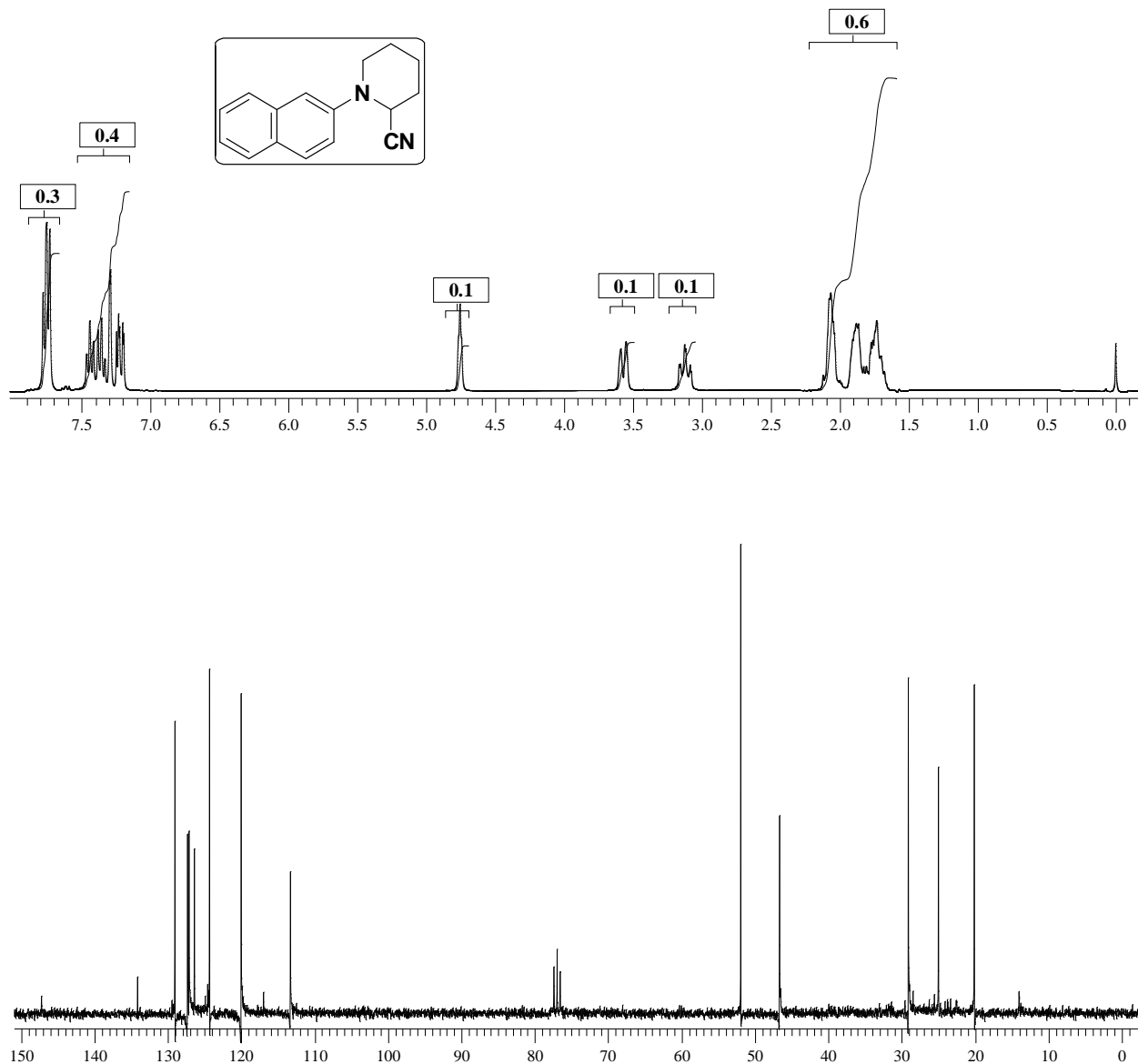
**1-(3-(trifluoromethyl)phenyl)piperidine-2-carbonitrile (Table 3, entry 14):**



### 1-(naphthalen-1-yl)piperidine-2-carbonitrile (Table 3, entry 15):



**1-(naphthalen-2-yl)piperidine-2-carbonitrile (Table 3, entry 16):**



**2-phenyl-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (Table 3, entry 17):**

