Synthesis of N-arylsubstituted pyrrolidines and piperidines by reaction of anilines with \(\alpha,\omega\)-diols catalyzed by FeCl\(_3\)·6H\(_2\)O in carbon tetrachloride

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Abstract
N-Arylpyrrolidines and N-arylpiperidines were synthesized in 20-88% yields by the reaction of aniline and aniline derivatives with 1,4-butane- and 1,5-pentanediols in the presence of Fe-containing catalysts and carbon tetrachloride. 1,4-Butane- and 1,5-pentanediols are partially chlorinated under the reaction conditions to give chlorohydrins, which subsequently undergo N-heterocyclization with anilines to give N-arylpiperrolidines and N-arylpiperidines.

Keywords: N-heterocyclization, anilines, 1,4-butane- and 1,5-pentanediols, N-arylpiperrolidines, N-arylpiperidines, FeCl\(_3\)·6H\(_2\)O, chlorohydrin, catalysis, carbon tetrachloride

Introduction

Pyrrolidines and piperidines form a highly important class of secondary amines; they are present as structural parts in many pharmaceuticals, herbicides, fungicides, and dyes.\(^1\) A known method for the synthesis of cyclic amines of the pyrrolidine and piperidine series is based on aniline heterocyclization with \(\alpha,\omega\)-diols catalyzed by Ru metal complexes to give high yields of the target products.\(^2-6\) Presumably, the reaction mechanism includes dehydrogenation of one OH group of the diol to give the [Ru]-hydroxyaldehyde-H\(_2\) complex, which then condenses with aniline to give the Schiff base. The latter is hydrogenated affording amino alcohol, which undergoes intramolecular cyclization to yield N-substituted cyclic amine.\(^2\) Another publication\(^7\) describes the synthesis of N-phenylpyrrolidines by the reaction of anilines with 1,4-butanediol catalyzed by the iridium complex Ir[C\(_5\)(CH\(_3\))\(_5\)] in the presence of NaHCO\(_3\) as a base.
In this study, we ascertained that iron compounds and complexes serve as efficient catalysts for the synthesis of cyclic amines, N-arylpyrrolidines and N-arylpiperidines, by reactions of anilines with 1,4-butane- and 1,5-pentanediols. The reaction proceeds in carbon tetrachloride in the presence of the following iron compounds: FeCl$_3$, FeBr$_2$, FeCl$_3$·6H$_2$O, Fe(acac)$_3$, Fe$_2$(CO)$_9$, the catalyst of choice being FeCl$_3$·6H$_2$O.

**Results and Discussion**

It was found experimentally that the optimal catalyst and reactant molar ratios are as follows: [FeCl$_3$·6H$_2$O]:[RC$_6$H$_4$NH$_2$]:[diol]:[CCl$_4$] = 0.5:100:200:30. At 180 °C over a period of 6 h, the reactions give N-arylpyrrolidines 1-12 and N-arylpiperidines 13-24 in 5-88% yields. The highest yields of 88% and 85% were observed for unsubstituted aniline-derived products 1 and 13. Aniline derivatives were less active in this reaction irrespective of the electron-donating or electron-withdrawing properties of substituents. Therefore, our attempt to establish a correlation between the basicity (pK$_a$) and reactivity of substituted anilines was not a success. Most difficult was heterocyclization of 1,4-butane- and 1,5-pentanediols with p-anisidine (the yields were 18% for 12 and 5% for 24), the basicity of which (pK$_a$ = 5.29) differs little from the basicity of p-toluidine (pK$_a$ = 5.12), which forms cyclic amines 4 and 16 in 75 and 61% yields, respectively (Scheme 1).

![Scheme 1](image)

The abnormal behavior of p-anisidine may be due to the possibility of complex formation with the central atom of the catalyst involving the ether group or chelation by NH$_2$- and OMe-groups.

Note that in the absence of carbon tetrachloride, no reaction occurs. It is evident that CCl$_4$ is not only a solvent but also a reactant. Taking into account the probable participation of CCl$_4$,
three reaction pathways leading to $N$-phenylpyrrolidine can be conceived and are shown in the chart (Scheme 2).

![Scheme 2](image)

**Scheme 2**

First, $CCl_4$ can be hydrolyzed under the reaction conditions to give HCl, which can subsequently catalyze the reaction (pathway I – acid catalysis) (Scheme 3).

$$CCl_4 + 2H_2O \rightarrow 4HCl + CO_2$$

**Scheme 3**

This assumption was verified by experiments with authentic hydrochloric acid taken in a concentration of 15% comparable with the concentration released upon the formation of $N$-phenylpyrrolidine 1 from 1,4-butanediol, aniline, and $CCl_4$ under the action of the catalyst. As shown by the experiment, in the presence of HCl without a catalyst in the reaction mixture, the yield of $N$-phenylpyrrolidine 1 was only 14%. Hence, this pathway is unlikely.

According to gas chromatography/mass spectrometry analysis data, the reaction mixture contained 4-chlorobutanol 25, 1,4-dichlorobutane 26, and 4,4'-di(chlorobutyl) ether 27, which may participate in the formation of $N$-phenylpyrrolidine 1 (pathways II and III) (Scheme 4).

![Scheme 4](image)

**Scheme 4**

In view of the presence of 4-chloro-1-butanol 25 and considering published data, the process starts, most likely, with partial chlorination of 1,4-butanediol with $CCl_4$ to give chlorohydrin 25. The evolution of CO$_2$ was detected by test reaction with a calcium hydroxide solution (Scheme 5).
Scheme 5

The next step is the reaction of chlorohydrin 25 with aniline under the action of FeCl₃·6H₂O to give 4-(N-phenylamino)-1-butanol 28, which then undergoes intramolecular dehydration with evolution of 1 mole of water to afford N-phenylpyrrolidine 1 (Scheme 6).

Scheme 6

A control experiment with authentic chlorohydrin 25 in the presence of the FeCl₃·6H₂O catalyst resulted in the formation of N-phenylpyrrolidine 1 in a quantitative yield.

Note that under the reaction conditions a part of the formed chlorohydrin 25 that has not reacted with aniline can subsequently react with carbon tetrachloride yielding 1,4-dichlorobutane 26 and giving off two moles of water (Scheme 7).

Scheme 7

The second pathway is supported by the results of control experiment with aniline and a mixture of 4-chlorobutanol, 1,4-dichlorobutane, and 4,4'-dichlorodibutyl ether (2:1:5) carried out in the presence of the FeCl₃·6H₂O catalyst at 180 °C within 4 h. It was found that only 4-chloro-1-butanol 25 was consumed for the formation of N-phenylpyrrolidine (Scheme 8).
Scheme 8.
Conclusions

We propose a readily available catalyst, FeCl$_3$·6H$_2$O, for N-heterocyclization of anilines with 1,4-butane- and 1,5-pentanediols in the presence of CCl$_4$ giving N-aryl-substituted pyrrolidines and piperidines.

Experimental Section

General. $^1$H, $^{13}$C and $^{19}$F NMR spectra were measured on a Bruker Avance-400 spectrometer (400.13, 100.62 and 376.5 MHz, respectively) in CDCl$_3$, the chemical shifts are referred to TMS. Mass spectra were run on a Shimadzu GCMS-QP2010Plus GC/MS spectrometer (an SPB-5 capillary column, 30 m × 0.25 mm, helium as a carrier gas, temperature programming from 40 to 300°C at 8 °C/min, evaporation temperature 280 °C, temperature of the ion source 200°C, ionization energy 70 eV). Chromatographic analysis was carried out on a Shimadzu GC-9A, GC-2014 instrument [2 m × 3 mm column, silicone SE-30 (5%) on Chromaton N-AW-HMDS as the stationary phase, temperature programming from 50 to 270 °C at 8 °C/min, helium as the carrier gas (47 mL/min)]. The elemental composition of the samples was determined on a Karlo Erba 1106 elemental analyzer.

N-Arylpyrrolidines and N-arylpiperidines. General procedure. The reactions were carried out in a glass ampoule (V = 10 mL), placed in a stainless-steel micro autoclaves (V = 17 mL) under constant stirring and controlled heating. The ampoule was charged with FeCl$_3$·6H$_2$O (2.9 mg, 0.01 mmol), aniline (0.2 mL, 2.15 mmol), diol (1,4-butandiol 0.38 mL and 1,5-pentanediol 0.45 mL, 4.30 mmol) and carbon tetrachloride (0.06 mL, 0.65 mmol) in an argon flow. The sealed ampoule was placed in an autoclave. The autoclave was air-tightly closed and heated at 160-180 °C for 6-12 h under continuous stirring. After completion of the reaction, the autoclave was cooled to room temperature, the ampoule was opened, and the reaction mixture was treated with diluted (10%) hydrochloric acid. The water layer was separated, neutralized with 10% solution of sodium hydroxide, and extracted with dichloromethane. The organic layer was filtered and the solvent was distilled off. The residue was distilled in a vacuum or recrystallized from hexane.

$^N$-Phenylpyrrolidine (1). $^3$Yield 88%; colorless, oily liquid; bp 89-90 °C/1 mm (lit.$^3$ 86 °C/1 mm). $^1$H NMR (400.13 MHz, CDCl$_3$): δ 7.34 (m, 2H, C$_{3,5}$H), 6.78 (m, 1H, C$_4$H), 6.69 (d, J 8 Hz, 2H, C$_{2,6}$H), 3.38 (m, 4H, C$_{2,5}'$H$_2$), 2.09 (m, 4H, C$_{3,4}'$H$_2$); $^{13}$C NMR (100.62 MHz, CDCl$_3$): δ 148.06 (C$_1$), 129.22 (C$_{3,5}$), 115.53 (C$_4$), 111.81 (C$_{2,6}$), 47.72 (C$_{3,5}'$), 25.56 (C$_{3,4}'$); MS (EI, 70 eV): $m/z$ (%) 147 (94) [M$^+$], 146 (100), 119 (9), 104 (25), 91 (72), 77 (46), 65 (7), 51 (19).

$^N$-(2-Methylphenyl)pyrrolidine (2). $^9$Yield 50%; light yellow oily liquid; bp 121-123 °C/10 mm (lit.$^{10}$ 55 °C/0.38 mm). $^1$H NMR (400.13 MHz, CDCl$_3$): δ 7.20 (m, 1H, C$_1$H), 7.05 (m, 1H, C$_5$H), 6.93 (m, 1H, C$_6$H), 6.70 (m, 1H, C$_4$H), 3.32 (m, 4H, C$_{2,5}$H$_2$), 2.44 (s, 3H, C$_3$H$_3$), 2.04 (m,
$4H, C^{3,4}H_2$; $^{13}C$ NMR (100.62 MHz, CDCl$_3$): $\delta$ 148.14 (C$^1$), 131.92 (C$^3$), 129.20 (C$^5$), 126.56 (C$^6$), 121.68 (C$^2$), 116.59 (C$^6$), 49.74 (C$^{2,5}$), 24.52 (C$^{3,4}$), 20.35 (C$^7$).

$N$-(3-Methylphenyl)pyrrolidine (3).$^9$ Yield 63%; colorless, oily liquid; bp 85-86 °C/1 mm (lit.$^{10}$ 70 °C/0.64 mm). $^1$H NMR (400.13 MHz, CDCl$_3$): $\delta$ 7.24 (m, 1H, C$^3$H), 6.63 (d, J 8 Hz, 1H, C$^4$H), 6.53 (s, 1H, C$^5$H), 6.52 (d, J 8 Hz, 1H, C$^6$H), 3.39 (m, 4H, C$^{2,5}$H$_2$), 2.45 (s, 3H, C$^7$H$_3$), 2.09 (m, 4H, C$^{3,4}$H$_2$); $^{13}$C NMR (100.62 MHz, CDCl$_3$): $\delta$ 148.15 (C$^1$), 138.83 (C$^3$), 129.11 (C$^5$), 116.61 (C$^6$), 112.53 (C$^2$), 109.14 (C$^6$), 47.79 (C$^{2,5}$), 25.55 (C$^{3,4}$), 21.98 (C$^7$); MS (EI, 70 eV): m/z (%) 161 (72) [M+], 160 (100), 118 (22), 105 (69), 91 (56), 77 (14), 65 (34), 51 (11).

$N$-(4-Methylphenyl)pyrrolidine (4).$^{11}$ Yield 75%; yellow solid; mp 38-40 °C (lit.$^{12}$ 40–42 °C). $^1$H NMR (400.13 MHz, CDCl$_3$): $\delta$ 7.07 (d, J 8 Hz, 2H, C$^{3,5}$H), 6.56 (d, J 8 Hz, 2H, C$^{2,6}$H), 3.27 (m, 4H, C$^{2,5}$H$_2$), 2.28 (s, 3H, C$^7$H$_3$), 2.02 (m, 4H, C$^{3,4}$H$_2$); $^{13}$C NMR (100.62 MHz, CDCl$_3$): $\delta$ 145.85 (C$^1$), 129.68 (C$^{2,5}$), 124.98 (C$^4$), 112.19 (C$^{2,6}$), 48.26 (C$^{2,5}$), 25.39 (C$^{3,4}$), 20.36 (C$^7$); MS (EI, 70 eV): m/z (%) 161 (76) [M+], 160 (100), 118 (31), 105 (79), 91 (64), 89 (16), 77 (18), 65 (38), 51 (13).

$N$-(2-Ethylphenyl)pyrrolidine (5). Yield 47%; yellow oily liquid; bp 88-90 °C/0.8 mm. $^1$H NMR (400.13 MHz, CDCl$_3$): $\delta$ 7.22 (m, 1H, C$^3$H), 7.16 (m, 1H, C$^3$H), 6.99 (m, 1H, C$^6$H), 6.95 (m, 1H, C$^4$H), 3.20 (br s, 4H, C$^{2,5}$H$_2$), 2.75 (q, J 7.2 Hz, 2H, C$^7$H$_2$), 1.97 (br s, 4H, C$^{3,4}$H$_2$), 1.29 (t, J 7.2 Hz, 3H, C$^5$H$_3$); $^{13}$C NMR (100.62 MHz, CDCl$_3$): $\delta$ 135.50 (C$^1$), 129.39 (C$^3$), 128.35 (C$^6$), 126.18 (C$^4$), 120.97 (C$^2$), 116.66 (C$^6$), 51.62 (C$^{2,5}$), 25.33 (C$^{3,4}$), 24.93 (C$^7$), 14.39 (C$^8$); MS (EI, 70 eV): m/z (%) 175 (80) [M+], 174 (100), 160 (7), 146 (12), 134 (15), 119 (35), 91 (37), 65 (16); Anal. Calcd. for C$_{12}$H$_{11}$N: C, 82.23; H, 9.78; N, 7.99%. Found: C, 82.11; H, 9.83; N, 8.06%.

$N$-(2-Chlorophenyl)pyrrolidine (6).$^{10}$ Yield 51%; colorless, oily liquid; bp 78-80 °C/1 mm (lit.$^{10}$ 54 °C/0.20 mm). $^1$H NMR (400.13 MHz, CDCl$_3$): $\delta$ 7.29 (m, 1H, C$^3$H), 7.17 (m, 1H, C$^3$H), 7.00 (m, 1H, C$^4$H), 6.82 (m, 1H, C$^6$H), 3.41 (br s, 4H, C$^{2,5}$H$_2$), 1.97 (br s, 4H, C$^{3,4}$H$_2$); $^{13}$C NMR (100.62 MHz, CDCl$_3$): $\delta$ 146.98 (C$^1$), 131.29 (C$^3$), 127.29 (C$^5$), 126.44 (C$^4$), 123.59 (C$^2$), 120.91 (C$^6$), 51.26 (C$^{2,5}$), 25.20 (C$^{3,4}$); MS (EI, 70 eV): m/z (%) 181 (85) [M+], 183 (23), 182 (42), 180 (100), 140 (24), 138 (64), 125 (69), 111 (49), 91 (27).

$N$-(3-Chlorophenyl)pyrrolidine (7).$^9$ Yield 50%; yellow oily liquid; bp 92-93 °C/0.8 mm. $^1$H NMR (400.13 MHz, CDCl$_3$): $\delta$ 7.06 (m, 1H, C$^3$H), 6.55 (d, J 8 Hz, 1H, C$^4$H), 6.46 (s, 1H, C$^2$H), 6.37 (d, J 8 Hz, 1H, C$^6$H), 3.19 (br s, 4H, C$^{2,5}$H$_2$), 1.96 (br s, 4H, C$^{3,4}$H$_2$); $^{13}$C NMR (100.62 MHz, CDCl$_3$): $\delta$ 148.83 (C$^1$), 134.78 (C$^3$), 129.98 (C$^5$), 114.95 (C$^4$), 111.27 (C$^2$), 109.89 (C$^6$), 47.57 (C$^{2,5}$), 25.41 (C$^{3,4}$).

$N$-(4-Chlorophenyl)pyrrolidine (8).$^{10}$ Yield 60%; white solid; mp 83-85 °C (lit.$^{13}$ 84–85 °C). $^1$H NMR (400.13 MHz, CDCl$_3$): $\delta$ 7.14 (d, J 8 Hz, 2H, C$^{3,5}$H), 6.46 (d, J 8 Hz, 2H, C$^{2,6}$H), 3.25 (m, 4H, C$^{2,5}$H$_2$), 2.02 (m, 4H, C$^{3,4}$H$_2$); $^{13}$C NMR (100.62 MHz, CDCl$_3$): $\delta$ 146.51 (C$^1$), 128.90 (C$^{2,5}$), 120.04 (C$^4$), 112.73 (C$^{2,6}$), 47.78 (C$^{2,5}$), 25.56 (C$^{3,4}$); MS (EI, 70 eV): m/z (%) 181 (88) [M+], 183 (23), 182 (30), 180 (100), 138 (37), 127 (17), 125 (66), 110 (46), 91 (16), 89 (19), 75 (20).
N-(4-Fluorophenyl)pyrrolidine (9). Yield 45%; yellow oily liquid; bp 82-84 °C/1mm (lit. 14 130-132 °C/13 mm). 1H NMR (400.13 MHz, CDCl3): δ 6.96 (m, 2H, C3,5-H), 6.50 (m, 2H, C2,6-H), 3.25 (m, 4H, C2,5-H2), 2.02 (m, 2H, C3,4-H2); 13C NMR (100.62 MHz, CDCl3): δ 154.83 (d, C4, 72 Hz), 144.83 (C1), 115.43 (d, C2,6, J 8 Hz), 112.14 (d, C3,5, J 2 Hz), 48.18 (C2,5), 25.53 (C3,4); 19F NMR (376.5 MHz, CDCl3): δ -130.73; MS (EI, 70 eV): m/z (%) 165 (94) [M+], 164 (73), 136 (11), 122 (63), 109 (100), 95 (10).

N-(3-Hydroxyphenyl)pyrrolidine (10). Yield 42%; white solid; mp 134-135 °C (lit. 16 134 °C). 1H NMR (400.13 MHz, CDCl3): δ 7.07 (m, 1H, C5-H), 6.19 (m, 1H, C4-H), 6.18 (s, 1H, C2-H), 6.08 (m, 1H, C6-H), 3.25 (m, 4H, C2,5-H2), 1.99 (m, 4H, C3,4-H2); 13C NMR (100.62 MHz, CDCl3): δ 156.84 (C3), 149.52 (C1), 130.02 (C5), 104.61 (C4), 102.77 (C6), 98.90 (C2), 47.70 (C2,5), 25.40 (C3,4); MS (EI, 70 eV): m/z (%) 163 (93) [M+], 162 (100), 134 (17), 120 (17), 107 (55), 93 (21), 77 (10), 65 (30).

N-(3-Methoxyphenyl)pyrrolidine (11). Yield 24%; colorless, oily liquid; bp 109-110 °C/1 mm. 1H NMR (400.13 MHz, CDCl3): δ 7.18 (m, 1H, C5-H), 6.30 (m, 1H, C4-H), 6.18 (s, 1H, C2-H), 6.11 (m, 1H, C6-H), 3.85 (s, 3H, C3,5-H3), 3.32 (m, 4H, C2,5-H2), 2.03 (m, 4H, C3,4-H2); 13C NMR (100.62 MHz, CDCl3): δ 160.74 (C3), 149.50 (C1), 129.97 (C5), 105.08 (C4), 100.60 (C6), 98.02 (C2), 55.14 (C7), 47.72 (C2,5), 25.46 (C3,4); MS (EI, 70 eV): m/z (%) 177 (82) [M+], 176 (100), 121 (99), 107 (35), 92 (45), 77 (78), 64 (57), 41 (80), 39 (62).

N-(4-Methoxyphenyl)pyrrolidine (12). Yield 18%; white solid; mp 44-46 °C. 1H NMR (400.13 MHz, CDCl3): δ 6.87 (d, J 8 Hz, 2H, C3,5-H), 6.57 (d, J 8 Hz, 2H, C4,6-H), 3.77 (s, 3H, C3,5-H3), 3.23 (m, 4H, C2,5-H2), 2.01 (m, 4H, C3,4-H2); 13C NMR (100.62 MHz, CDCl3): δ 150.81 (C4), 143.24 (C1), 115.04 (C2,6), 112.70 (C3,5), 56.02 (C7), 48.31 (C2,5), 25.36 (C3,4); MS (EI, 70 eV): m/z (%) 177 (75) [M+], 162 (100), 134 (10), 120 (15), 92 (6), 77 (8), 65 (5), 57 (5).

N-Phenylpiperidine (13). Yield 85%; colorless oil; bp 73-74 °C/0.4 mm (lit. 3 86 °C/1 mm). 1H NMR (400.13 MHz, CDCl3): δ 7.30 (m, 2H, C4,5-H), 7.00 (d, J 8 Hz, 2H, C4,6-H), 6.88 (m, 1H, C4-H), 3.21 (m, 4H, C2,6-H2), 1.76 (m, 4H, C3,5-H2), 1.64 (m, 2H, C3,4-H2); 13C NMR (100.62 MHz, CDCl3): δ 152.22 (C1), 129.04 (C3,5), 119.36 (C4), 116.66 (C2,6), 50.81 (C2,5), 25.88 (C3,5), 24.34 (C4).

N-(2-Methylphenyl)piperidine (14). Yield 42%; light yellow oily liquid; bp 60-61 °C/0.6 mm (lit. 18 44 °C/0.2 mm). 1H NMR (400.13 MHz, CDCl3): δ 7.19 (m, 1H, C4-H), 7.14 (m, 1H, C5-H), 6.98 (m, 1H, C6-H), 6.87 (m, 1H, C4-H), 2.99 (br s, 4H, C2,5-H2), 2.31 (s, 3H, C3,5-H3), 1.86 (br s, 4H, C2,5-H2), 1.60 (m, 2H, C3,4-H2); 13C NMR (100.62 MHz, CDCl3): δ 149.87 (C1), 132.41 (C4), 131.56 (C5), 126.74 (C6), 124.31 (C2), 119.32 (C6), 54.08 (C2,6), 25.74 (C3,5), 23.76 (C4), 18.31 (C7); MS (EI, 70 eV): m/z (%) 175 (86) [M+], 174 (100), 146 (28), 132 (18), 118 (86), 91 (38).

N-(3-Methylphenyl)piperidine (15). Yield 47%; light yellow oily liquid; bp 95-97 °C/0.5 mm. 1H NMR (400.13 MHz, CDCl3): δ 7.17 (m, 1H, C5-H), 6.88 (d, J 8 Hz, 1H, C4-H), 6.53 (s, 1H, C4-H), 6.51 (m, 1H, C6-H), 3.25 (m, 4H, C2,5-H2), 2.33 (s, 3H, C3-H3), 2.22 (m, 4H, C3,5-H2), 1.63 (m, 2H, C3,4-H2); 13C NMR (100.62 MHz, CDCl3): δ 148.34 (C1), 139.45 (C4), 129.32 (C5), 124.56 (C6), 119.90 (C2), 115.62 (C6), 53.49 (C2,6), 24.69 (C3,5), 23.18 (C4), 21.64 (C7); MS (EI, 70 eV): m/z (%) 175 (81) [M+], 174 (100), 160 (7), 146 (12), 134 (15), 119 (36), 91 (38), 65 (16).
**N-(4-Methylphenyl)piperidine (16)**. Yield 61%; light yellow solid; mp 264-266 °C (lit. 265-267 °C). 1H NMR (400.13 MHz, CDCl3): δ 7.56 (d, J = 8 Hz, 1H, C\(^2\)-H), 7.11 (d, J = 8 Hz, 1H, C\(^4\)-H), 3.20 (m, 4H, C\(^2,6\)-H), 2.24 (s, 3H, C\(^3\)-H), 2.07 (m, 4H, C\(^5,5\)-H); 13C NMR (100.62 MHz, CDCl3): δ 142.18 (C\(^1\)), 137.94 (C\(^3\)), 129.92 (C\(^4\)), 120.42 (C\(^6\)), 56.15 (C\(^2,6\)), 23.17 (C\(^3,5\)), 21.94 (C\(^1\)), 20.86 (C\(^3\)); MS (EI, 70 eV): m/z (%): 175 (98) [M+], 174 (100), 160 (12), 146 (9), 134 (13), 119 (32), 91 (29), 64 (10).

**N-(2-Ethylphenyl)piperidine (17)**. Yield 38%; yellow oily liquid; bp 75-77 °C/1mm. 1H NMR (400.13 MHz, CDCl3): δ 7.27 (m, 1H, C\(^2\)-H), 7.19 (m, 1H, C\(^5\)-H), 7.11 (m, 1H, C\(^3\)-H), 7.06 (m, 1H, C\(^4\)-H), 2.77 (m, 4H, C\(^2,6\)-H), 2.57 (m, 2H, C\(^3\)-H), 1.80 (m, 4H, C\(^5,5\)-H), 1.61 (m, 2H, C\(^6\)-H), 1.30 (m, 3H, C\(^8\)-H); 13C NMR (100.62 MHz, CDCl3): δ 152.29 (C\(^1\)), 139.29 (C\(^3\)), 128.87 (C\(^5\)), 126.36 (C\(^6\)), 123.62 (C\(^2\)), 119.85 (C\(\delta\)), 54.36 (C\(^2,6\)), 26.61 (C\(^{3,5}\)), 24.66 (C\(\gamma\)), 24.36 (C\(\gamma\)), 14.89 (C\(\delta\)); Anal. Calcd. for C\(\text{H}_{11}\)N: C: 68.48; H: 10.12; N: 7.40%. Found: C: 82.61; H: 10.04; N: 7.35%.

**N-(2-Chlorophenyl)piperidine (18)**. Yield 33%; light yellow oily liquid; bp 89-90 °C/0.6 mm. 1H NMR (400.13 MHz, CDCl3): δ 7.39 (m, 1H, C\(^2\)-H), 7.26 (m, 1H, C\(^5\)-H), 7.08 (m, 1H, C\(^3\)-H), 7.00 (m, 1H, C\(^4\)-H), 3.02 (m, 4H, C\(^2,6\)-H), 1.79 (m, 4H, C\(^5,5\)-H), 1.63 (m, 2H, C\(^6\)-H); 13C NMR (100.62 MHz, CDCl3): δ 150.66 (C\(^1\)), 130.53 (C\(^3\)), 128.00 (C\(^5\)), 127.45 (C\(^5\)), 123.15 (C\(^4\)), 120.49 (C\(^6\)), 52.92 (C\(^2,6\)), 26.31 (C\(^{3,5}\)), 24.32 (C\(\gamma\)); Anal. Calcd. for C\(\text{H}_{11}\)ClN: C: 67.51; H: 7.21; N: 7.16%. Found: C: 67.62; H: 7.39; N: 7.03%.

**N-(3-Chlorophenyl)piperidine (19)**. Yield 35%; light yellow oily liquid; bp 82-83 °C/0.5 mm. 1H NMR (400.13 MHz, CDCl3): δ 7.15 (m, 1H, C\(^2\)-H), 7.04 (d, J = 8 Hz, 1H, C\(^4\)-H), 6.92 (s, 1H, C\(^3\)-H), 6.79 (d, J = 8 Hz, 1H, C\(^4\)-H), 3.18 (m, 4H, C\(^2,6\)-H), 1.71 (m, 4H, C\(^5,5\)-H), 1.60 (m, 2H, C\(^6\)-H); 13C NMR (100.62 MHz, CDCl3): δ 152.80 (C\(^1\)), 134.85 (C\(^3\)), 130.26 (C\(^5\)), 119.95 (C\(^4\)), 116.16 (C\(^2\)), 114.49 (C\(\delta\)), 50.34 (C\(^2,6\)), 25.52 (C\(^{3,5}\)), 24.14 (C\(\gamma\)).

**N-(4-Chlorophenyl)piperidine (20)**. Yield 40%; light yellow solid; mp 45-47 °C. 1H NMR (400.13 MHz, CDCl3): δ 7.21 (d, J = 8 Hz, 2H, C\(^3,5\)-H), 6.60 (d, J = 8 Hz, 2H, C\(^6\))-H), 3.14 (m, 4H, C\(^2,6\)-H), 1.75 (m, 4H, C\(^5,5\)-H), 1.60 (m, 2H, C\(^6\)-H); 13C NMR (100.62 MHz, CDCl3): δ 144.90 (C\(^1\)), 128.95 (C\(^3,5\)), 123.07 (C\(^4\)), 118.11 (C\(^2,6\)), 51.19 (C\(^2,6\)), 25.46 (C\(^{3,5}\)), 23.94 (C\(\gamma\)); MS (EI, 70 eV): m/z (%): 195 (91) [M+], 192 (36), 196 (41), 194 (100), 154 (25), 139 (42), 125 (14), 111 (50); Anal. Calcd. for C\(\text{H}_{14}\)ClN: C: 67.51; H: 7.21; N: 7.16%. Found: C: 67.38; H: 7.46; N: 7.23%.

**N-(4-Fluorophenyl)piperidine (21)**. Yield 35%; yellow oily liquid; bp 65-67 °C/1.5 mm (lit. 110-112 °C/16 mm). 1H NMR (400.13 MHz, CDCl3): δ 7.46 (br s, 2H, C\(^3,5\)-H), 6.95 (br s, 2H, C\(^6\)-H), 3.22 (br s, 4H, C\(^2,6\)-H), 1.93 (br s, 4H, C\(^5,5\)-H), 1.59 (br s, 2H, C\(^6\)-H); 13C NMR (100.62 MHz, CDCl3): δ 160.09 (d, C\(^2\), J = 244 Hz), 143.02 (C\(^1\)), 121.47 (d, C\(^2,6\), J = 21 Hz), 116.28 (d, C\(^3,5\), J = 22 Hz), 55.00 (C\(^2,6\)), 24.20 (C\(^{3,5}\)), 22.35 (C\(\gamma\)); 19F NMR (376.5 MHz, CDCl3): δ -116.13.

**N-(3-Hydroxyphenyl)piperidine (22)**. Yield 24%; white solid; mp 122-123 °C. 1H NMR (400.13 MHz, CDCl3): δ 7.10 (m, 1H, C\(^3\)-H), 6.54 (d, J = 8 Hz, 1H, C\(^4\)-H), 6.44 (s, 1H, C\(^2\)-H), 6.33 (m, 1H, C\(^6\)-H), 3.14 (m, 4H, C\(^2,6\)-H), 1.71 (m, 2H, C\(^6\)-H), 1.60 (m, 4H, C\(^5,5\)-H); 13C NMR (100.62 MHz, CDCl3): δ 156.77 (C\(^3\)), 153.40 (C\(^1\)), 129.88 (C\(^5\)), 108.99 (C\(^4\)), 106.64 (C\(\delta\)), 103.84
(С²), 50.71 (С²,6), 25.58 (С³,5), 24.25 (С′); MS (EI, 70 eV): m/z (%) 177 (61) [М+], 176 (86), 121 (99), 93 (55), 65 (87), 55 (54), 41 (73), 39 (100).

N-(3-Methoxyphenyl)piperidine (23). Yield 7%; light yellow oily liquid; 103-104 °C/0.4 mm. ¹H NMR (400.13 MHz, CDCl₃): δ 7.08 (m, 1H, С³), 6.52 (d, J 8 Hz, 1H, С′), 6.45 (s, 1H, С²), 6.33 (м, 1H, С⁵), 3.81 (s, 3H, С⁷), 3.15 (м, 4H, С₂,6⁴), 1.70 (m, 4H, С³,5⁵), 1.59 (m, 2H, С⁶); ¹³C NMR (100.62 MHz, CDCl₃): δ 160.45 (С⁴), 153.51 (С′), 130.01 (С⁵), 108.86 (С⁶), 106.44 (С⁴), 103.69 (С²), 55.16 (С⁷), 50.58 (С²,6⁴), 25.64 (С³,5⁵), 24.29 (С⁶); MS (EI, 70 eV): m/z (%) 191 (68) [М+], 190 (100), 135 (62), 92 (44), 77 (58), 65 (39), 55 (38), 41 (66), 39 (54).

N-(4-Methoxyphenyl)piperidine (24). Yield 5%; white solid; mp 64-65 °C. ¹H NMR (400.13 MHz, CDCl₃): δ 6.95 (d, J 8 Hz, 1H, С³,5), 6.83 (d, J 8 Hz, 1H, С²,6), 3.78 (s, 3H, С⁷), 3.03 (m, 4H, С₂,6⁴), 1.74 (m, 4H, С³,5⁵), 1.56 (m, 2H, С⁶); ¹³C NMR (100.62 MHz, CDCl₃): δ 153.90 (С⁴), 147.63 (С′), 115.35 (С³,5), 113.74 (С²,6), 57.82 (С⁵), 50.87 (С²,6⁴), 26.93 (С³,5⁵), 24.14 (С⁶); MS (EI, 70 eV): m/z (%) 191 (57) [М+], 190 (34), 176 (74), 135 (44), 120 (100), 92 (48), 77 (46), 65 (43), 55 (36), 41 (90), 39 (54).

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