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# $FeCl_3$-Catalyzed Synthesis of 2-Methyl-4-Substituted-1,2,3,4-Tetrahydroquinoline Derivatives by the Imino Diels-Alder Reaction

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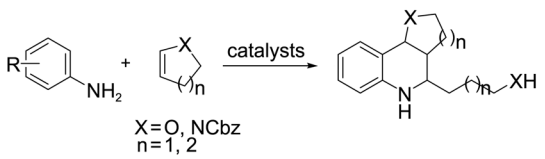
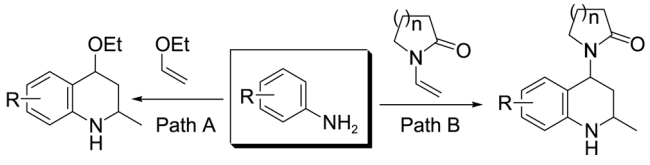
The tetrahydroquinoline nucleus is present in many natural products and these products exhibit a broad range of biological activities.[1] The imino Diels-Alder reaction between *N*-arylimines and dienophiles is a powerful synthetic tool for the construction of nitrogen-containing heterocyclic compounds including tetrahydroquinoline derivatives.[2] Using an imino Diels-Alder reaction as a key step, a number of methods for the synthesis of tricyclic compounds bearing the tetrahydroquinoline moiety, starting from substituted anilines with 2,3-dihydrofuran or 3,4-dihydro-2*H*-pyran or *N*-protected 2-pyrroline, have been reported (Scheme 1). These reactions have been extensively studied with the use of a variety of Lewis acids such as $LiClO_4$,[3] $BF_3{\cdot}OEt_2$,[4] $CuCl_2$,[5] $SmI_2$,[6] $InCl_3$,[7] $SbCl_3$,[8] $GbCl_3$,[9] $ZrCl_4$,[10] and Brønsted acids such as TFA,[11] *p*-TsOH,[12] $KHSO_4$,[13] and oxalic acid.[14]

Recently, several methods for the synthesis of 2-methyl-4-substituted-1,2,3,4-tetrahydroquinoline derivatives through imino Diels-Alder reactions have been developed (Scheme 2). These methods involve coupling reactions of substituted anilines with vinyl ether (Path A)[15] or *N*-vinyl lactams (Path B).[16,17] These reactions have been accomplished using catalysts such as cerium ammonium nitrate,[15] copper dipyridine dichloride,[16] and 4-nitro phthalic acid.[17]

Although several methods for the synthesis of 2-methyl-4-substituted-1,2,3,4-tetrahydroquinoline derivatives have been reported,[15-17] there is still demand for simpler, less toxic, more cost effective, and more environmentally benign catalysts. In a related work, an $FeCl_3$/NaI mediated reaction of aryl azides with 3,4-dihydro-2*H*-pyran for the synthesis of tricyclic compounds involving the tetrahydroquinoline moiety has been described as a stoichiometric reaction.[18] Our interest in developing a mild and efficient synthetic method that provides a variety of 2-methyl-4-substituted-1,2,3,4-tetrahydroquinoline derivatives has led us to looking into more convenient and safely usable catalysts. Among these, we think iron(III) chloride is a viable alternative, and may be a promising catalyst for the synthesis of 2-methyl-4-substituted-1,2,3,4-tetrahydroquinoline derivatives due to its easy availability, low price, sustainability, non-toxicity, and environmentally friendly properties.[19] We report herein an $FeCl_3$-catalyzed one-pot synthesis of biologically interesting 2-methyl-4-substituted-1,2,3,4-tetrahydroquinoline derivatives.




**Scheme 1**



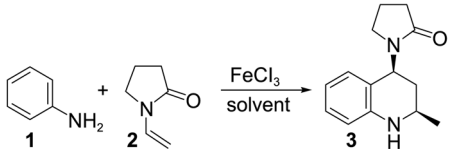

**Scheme 2**

## Results and Discussion

The reaction of aniline (**1**, 1.0 mmol) with *N*-vinylpyrrolidinone (**2**, 3.0 mmol) was first examined in the presence of 20 mol % $FeCl_3$ in several solvents (Table 1). Across the range of solvents tested, the best yield was obtained in acetonitrile, with 74% yield. Interestingly, in this case, only *cis*-adduct was produced. The *cis*-stereochemistry of compound **3** was determined by $^1$H NMR analysis and compared directly with the reported data.[15-17]

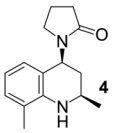
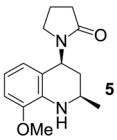
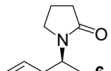
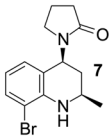
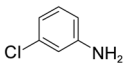
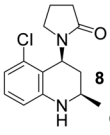
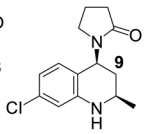
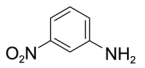
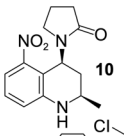
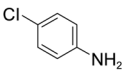
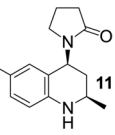
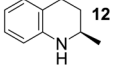
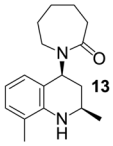
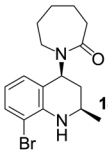
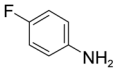
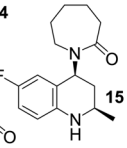
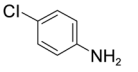
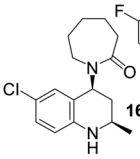
In order to extend the utility of this methodology, further reactions of a series of substituted anilines with *N*-vinylpyrrolidinone and *N*-vinylcaprolactam were examined. These reactions were carried out in the presence of 20 mol % of $FeCl_3$ in acetonitrile using the conditions described above. The results are summarized in Table 2. The reactions worked

**Table 1.** Reaction of aniline (**1**) with *N*-vinylpyrrolidinone (**2**) in the presence of $FeCl_3$ in several solvents

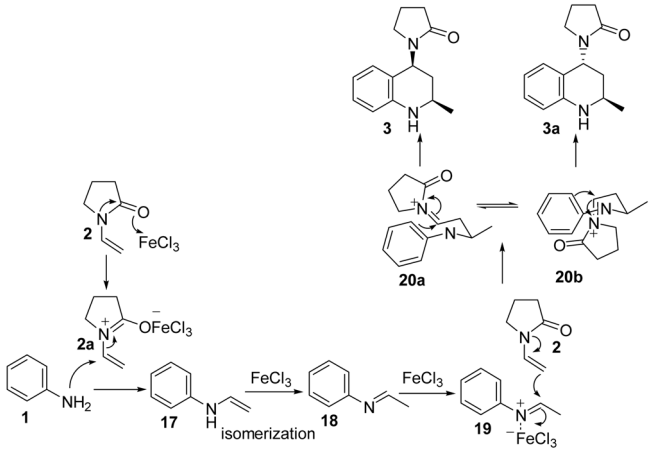



| Entry | $FeCl_3$ (mol %) | Solvent | Condition | Yield (%) |
|---|---|---|---|---|
| 1 | 20 | toluene | reflux, 20 h | 40 |
| 2 | 20 | THF | reflux, 8 h | 68 |
| 3 | 20 | acetonitrile | reflux, 8 h | 74 |
| 4 | 20 | DMF | 100 °C, 10 h | 34 |
| 5 | 20 | DMSO | 100 °C, 10 h | 39 |

**Table 2.** $FeCl_3$-catalyzed synthesis of a variety of 2-methyl-4-sustituted tetrahydroquinoline derivatives

| Entry | Starting material | *N*-vinyl Compound | Time (h) | Product | Yield (%) |
|---|---|---|---|---|---|
| 1 |  |  | 10 |  **4** | 71 |
| 2 |  | | 10 |  **5** | 66 |
| 3 |  | | 10 |  **6** | 72 |
| 4 |  | | 8 |  **7** | 90 |
| 5 |  | | 10 |  **8**  **9** | 72 |
| 6 |  | | 8 |  **10** | 88 |
| 7 |  | | 8 |  **11** | 84 |
| 8 |  |  | 10 |  **12** | 80 |
| 9 |  | | 8 |  **13** | 85 |
| 10 |  | | 8 |  **14** | 85 |
| 11 |  | | 8 |  **15** | 88 |
| 12 |  | | 10 |  **16** | 80 |

well with substituted anilines bearing either electron-donating or -withdrawing groups on the benzene ring. For example, the treatment of *o*-substituted anilines with *N*-vinylpyrrolidinone provided products **4-7** in 71, 66, 72, and 90% yield, respectively (entries 1-4). Importantly, reactions of *m*-substituted anilines with *N*-vinylpyrrolidinone have not been reported so far. With 3-chloroaniline, inseparable two regioisomers **8** and **9** as a 5:95 ratio were produced in 72% yield (entry 5), whereas reaction with 3-nitroaniline gave **10** in 88% yield, without any detection of other regioisomer (entry 6). Interestingly, **10** was cyclized at the hindered site between the amino and nitro groups. Their structural assignment and the ratio of regioisomers of **8** and **9** were based on $^1$H NMR spectroscopic data. The $^1$H NMR spectrum of **8** showed 3 peaks on the benzene ring at δ 6.91(d, $J$ = 7.8 Hz), 6.65 (t, $J$ = 7.8 Hz), and 6.41 (d, $J$ = 7.8 Hz), whereas **9** exhibited 3 peaks at δ 6.69 (d, $J$ = 8.1 Hz), 6.57 (dd, $J$ = 8.1, 1.8 Hz), and 6.44 (d, 1.8 Hz). *p*-Substituted aniline reacted smoothly with *N*-vinylpyrrolidinone to give the corresponding tetrahydroquinoline **11** in 84% yield, respectively (entry 7). With other *N*-vinylcaprolactam, the desired products **12-16** were produced in 80-88% yield (entries 8-12). These reactions provided rapid access to various 2-methyl-4-substituted tetrahydroquinoline derivatives **4-16** in good yields.




**Scheme 3**

The formation of **3** can be explained by the proposed mechanism as shown in Scheme 3. The aniline (**1**) is first reacted with *N*-vinylpyrrolidinone in the presence of $FeCl_3$ to give *N*-vinylaniline (**17**), which undergoes isomerization to afford enamine **18**. Next, the $FeCl_3$-catalyzed imino Diels-Alder reaction of **19** to *N*-vinylpyrrolidinone (**2**) gives product **3**. The imino Diels-Alder reaction is known to proceed *via* a stepwise mechanism,[20] so the generation of two intermediates, **20a** and **20b**, with the pseudoequatorial conformation adopted by the methyl group in the chair-like transition state is expected. In the final cyclization step, *cis*-stereochemistry may be observed due to there being a greater preference for an equatorial arrangement of the iminium ion **20a** than for intermediate **20b**.

In summary, efficient one-pot multi-component reactions of substituted anilines with *N*-vinylpyrrolidinone or *N*-vinylcaprolactam were developed in the presence of 20 mol % of $FeCl_3$ in acetonitrile. These reactions provided rapid access to a variety of 2-methyl-4-substituted tetrahydroquinoline derivatives in good yields.

## Experimental

**General Procedure for the Synthesis of 2-Methyl-4-amino-1,2,3,4-tetrahydroquinolines.** A mixture of the substituted anilines (1.0 mmol), *N*-vinyl-2-pyrrolidinone (3.0 mmol) or *N*-vinylcaprolactam (3.0 mmol) and $FeCl_3$ (32 mg, 0.2 mmol) in acetonitrile (10 mL) was refluxed, and the reaction progress was monitored by TLC. When the reaction was completed, the reaction was quenched with saturated aqueous $NaHCO_3$ solution (30 mL) and extracted ethyl acetate (3 × 30 mL). The combined organic layer was wash-

ed with water (30 mL), dried over anhydrous $Na_2SO_4$, and concentrated. The crude material was purified by column chromatography to give products.

***cis*-1-(2-Methyl-1,2,3,4-tetrahydroquinoline-4-yl) pyrrolidin-2-one (3):** Yield (74%). mp 74-76 ºC; $^1$H NMR (600 MHz, $CDCl_3$) δ 6.96 (1H, t, $J$ = 7.8 Hz), 6.77 (1H, d, $J$ = 7.8 Hz), 6.60 (1H, d, $J$ = 7.8 Hz), 6.47 (1H, d, $J$ = 7.8 Hz), 5.51 (1H, dd, $J$ = 12.0, 6.0 Hz), 3.70 (1H, br s), 3.54-3.49 (1H, m), 3.21-3.16 (1H, m), 3.12-3.08 (1H. m), 2.50-2.40 (2H, m), 2.00-1.92 (2H, m), 1.91-1.88 (1H, m), 1.70-1.64 (1H, m), 1.17 (3H, d, $J$ = 6.0 Hz); $^{13}$C NMR (150 MHz, $CDCl_3$) δ 175.7, 145.9, 128.0, 126.7, 118.8, 117.7, 114.6, 48.0, 46.9, 42.2, 34.1, 31.4, 22.3, 18.2; IR (KBr) 3332, 2953, 1673, 1491, 1285, 1031, 756 cm$^{-1}$.

***cis*-1-(2,8-Dimethyl-1,2,3,4-tetrahydroquinoline-4-yl) pyrrolidin-2-one (4):** Yield (71%). mp 129-131 ºC; $^1$H NMR (300 MHz, acetone-$d_6$) δ 6.71 (1H, d, $J$ = 7.5 Hz), 6.51 (1H, d, $J$ = 7.5 Hz), 6.36 (1H, t, $J$ = 7.5 Hz), 5.31 (1H, dd, $J$ = 12.0, 6.0 Hz), 4.13 (1H, br s), 3.48-3.39 (1H, m), 3.14-3.06 (1H, m), 2.95-2.88 (1H, m), 2.27-2.19 (2H, m), 1.94 (3H, s), 1.90-1.82 (2H, m), 1.74-1.66 (1H, m), 1.63-1.51 (1H, m), 1.13 (3H, d, $J$ = 6.3 Hz); $^{13}$C NMR (75 MHz, acetone-$d_6$): δ 175.9, 146.0, 130.4, 125.6, 123.1, 120.2, 117.9, 49.6, 48.6, 43.2, 35.6, 32.3, 23.2, 19.6, 18.2; IR (KBr) 3346, 2923, 1676, 1475, 1429, 1300, 1268, 1197, 1164, 1102, 763 cm$^{-1}$.

***cis*-1-(8-Methoxy-2-methyl-1,2,3,4-tetrahydroquinoline-4-yl)pyrrolidin-2-one (5):** Yield (66%). mp 78-79 ºC; $^1$H NMR (300 MHz, $CDCl_3$) δ 6.62-6.57 (2H, m), 6.47 (1H, d, $J$ = 7.5 Hz), 5.57 (1H, dd, $J$ = 12.0, 6.3 Hz), 4.16 (1H, br s), 3.81 (3H, s), 3.56-3,.47 (1H, m), 3.27-3.03 (2H, m), 2.49-2,43 (2H, m), 2.00-1.92 (2H, m), 1.92-1.81 (1H, m), 1.77-1.65 (1H, m), 1.24 (3H, d, $J$ = 6.3 Hz); $^{13}$C NMR (75 MHz, $CDCl_3$) δ 175.8, 146.4, 136.0, 119.3, 118.9, 116.9, 108.4, 55.5, 48.2, 46.8, 42.5, 34.1, 31.6, 22.4, 18.3; IR (KBr) 3327, 2973, 2919, 1678, 1609, 1584, 1503, 1460, 1430, 1376, 1335, 1291, 1272, 1252, 1235, 1166, 1083, 1063, 968, 844, 767, 787, 767, 743 cm$^{-1}$.

***cis*-1-(8-Fluoro-2-methyl-1,2,3,4-tetrahydroquinoline-4-yl) pyrrolidin-2-one (6):** Yield (72%). mp 96-97 ºC; $^1$H NMR (300 MHz, acetone-$d_6$) δ 6.76-6.70 (1H, m), 6.50 (1H, d, $J$ = 7.5 Hz), 6.45-6.38 (1H, m), 5.34 (1H, dd, $J$ = 12.0, 6.0 Hz), 4.75 (1H, br s), 3.55-3.49 (1H, m), 3.23-3.15 (1H, m), 3.00-2.95 (1H, m), 2.29-2.23 (2H, m), 1.97-1.86 (2H, m), 1.80-1.73 (1H, m), 1.71-1.59 (1H, m), 1.18 (3H, d, $J$ = 6.0 Hz); $^{13}$C NMR (75 MHz, $CDCl_3$) δ 174.6, 150.7 (d, $J$ = 236 Hz), 134.9 (d, $J$ = 12.8 Hz), 121.7 (d, $J$ = 3.0 Hz), 115.6 (d, $J$ = 7.5 Hz), 113.2, 112.9, 47.6, 46.8, 41.7, 33.8, 30.7, 21.4, 18.1; IR (KBr) 3319, 2969, 1674, 1624, 1503, 1457, 1316, 1274, 1229, 1164, 970, 783, 720 cm$^{-1}$.

***cis*-1-(8-Bromo-2-methyl-1,2,3,4-tetrahydroquinoline-4-yl) pyrrolidin-2-one (7):** Yield (90%). mp 127-128 ºC; $^1$H NMR (300 MHz, acetone-$d_6$) δ 7.12 (1H, d, $J$ = 7.8 Hz), 6.65 (1H, d, $J$ = 7.8 Hz), 6.36 (1H, t, $J$ = 7.8 Hz), 5.30 (1H, dd, $J$ =12.0, 6.0 Hz), 4.50 (1H, br s), 3.57-3.51 (1H, m), 3.20-3.11 (1H, m), 2.97-2.90 (1H, m), 2.26-2.16 (2H, m), 1.93-1.83 (2H, m), 1.78-1.71 (1H, m), 1.67-1.55 (1H, m), 1.18 (3H, d, $J$ = 6.3 Hz); $^{13}$C NMR (75 MHz, acetone-$d_6$) δ 176.1, 144.7, 132.7, 127.3, 122.8, 118.9, 109.7, 49.5, 48.5, 43.4, 35.1, 32.2, 23.0, 19.6; IR (KBr) 3329, 2963, 1678, 1598, 1499, 1459, 1376, 1339, 1294, 1165, 1135, 972, 795, 762, 733 cm$^{-1}$.

***cis*-1-(5-Chloro-2-methyl-1,2,3,4-tetrahydroquinoline-4-yl) pyrrolidin-2-one (8) and *cis*-1-(7-Chloro-2-methyl-1,2,3,4-tetrahydroquinoline-4-yl) pyrrolidin-2-one (9):** Yield of **8** and **9** (5:95 ratio, 72%). **Compound 8** (minor): $^1$H NMR (300 MHz, $CDCl_3$) δ 6.91 (1H, d, $J$ = 7.8 Hz), 6.65 (1H, d, $J$ = 7.8 Hz), 6.41 (1H, t, $J$ = 7.8 Hz), 5.26-5.22 (1H, m), 3.78 (1H, br s), 3.35-3.28 (1H, m), 3.12-3.06 (1H, m), 2.96-2.79 (1H, m), 2.41-2.35 (2H, m), 2.25-2.15 (1H, m), 2.04-1.87 (3H, m), 1.18 (3H, d, $J$ = 6.3 Hz). Compound **9** (major): δ 6.69 (1H, d, $J$ = 8.1 Hz), 6.57 (1H, dd, $J$ = 8.1, 1.8 Hz), 6.44 (1H, d, $J$ = 1.8 Hz), 5.46 (1H, dd, $J$ = 12.0, 6.0 Hz), 3.78 ( 1H, br s), 3.60-3.49 (1H, m), 3.25-3.14 (1H, m), 3.11-3.06 (1H, m), 2.50-2.44 (2H, m), 2.05-1.96 (2H, m), 1.92-1.87 (1H, m), 1.72-1.56 (1H, m), 1.19 (3H, d, $J$ = 6.3 Hz); $^{13}$C NMR (75 MHz, $CDCl_3$) δ 175.9, 162.5, 147.0, 133.6, 128.1, 117.7, 114.2, 47.8, 47.1, 42.3, 33.9, 31.6, 22.4, 18.4; IR (KBr) 3333, 3269, 2960, 1663, 1602, 1492, 1423, 1338, 1311, 1288, 1267, 1198, 1166, 1126, 1088, 919, 908, 849 cm$^{-1}$.

***cis*-1-(2-Methyl-5-nitro-1,2,3,4-tetrahydroquinoline-4-yl) pyrrolidin-2-one (10):** Yield (88%). mp 228-229 ºC; $^1$H NMR (300 MHz, $CDCl_3$) δ 7.06 (1H, dd, $J$ = 8.1, 7.8 Hz), 6.84 (1H, d, $J$ = 7.8 Hz), 6.67 (1H, d, $J$ = 8.1 Hz), 5.69 (1H, dd, $J$ = 11.1, 7.2 Hz), 4.16 (1H, br s), 3.50-3.43 (1H, m), 3.14-3.06 (1H, m), 2.92-2.85 (1H, m), 2.39-2.14 (2H, m), 2.07-2.00 (1H, m), 1.92-1.81 (2H, m), 1.64-1.52 (1H, m), 1.21 (3H, d, $J$ = 6.3 Hz); $^{13}$C NMR (75 MHz, $CDCl_3$) δ 174.8, 162.3, 147.8, 128.4, 118.1, 112.7, 111.6, 46.0, 45.7, 42.7, 33.3, 30.7, 21.5, 17.9; IR (KBr) 3267, 2961, 1667, 1609, 1527, 1449, 1330, 1287, 1197, 1076, 978, 779, 726 cm$^{-1}$.

***cis*-1-(6-Chloro-2-methyl-1,2,3,4-tetrahydroquinoline-4-yl) pyrrolidin-2-one (11):** Yield (84%). mp 142-143 ºC; $^1$H NMR (300 MHz, $CDCl_3$) δ 6.88 (1H, d, $J$ = 8.5 Hz), 6.70 (1H, s), 6.38 (1H, d, $J$ = 8.5 Hz, 5.43 (1H, dd, $J$ = 12.0, 6.0 Hz), 3.88 (1H, br s ), 3.50-3.44 (1H, m), 3.22-3.04 (2H, m), 2.54-2.38 (2H, m), 2.03-1.93 (2H, m), 1.88-1.82 (1H, m), 1.69-1.57 (1H, m), 1.15 ( 3H, d, $J$ = 6.0 Hz); $^{13}$C NMR (75 MHz, $CDCl_3$) δ 175.9, 144.6, 128.1, 126.3, 122.3, 120.5, 115.9, 47.9, 47.0, 42.3, 33.7, 31.4, 22.2, 18.3; IR (KBr) 3334, 1666, 1602, 1488, 1437, 1350, 1312, 1293, 1200, 882, 821 cm$^{-1}$.

***cis*-1-(2-Methyl-1,2,3,4-tetrahydroquinoline-4-yl) azepan-2-one (12):** Yield (80%). mp 128-130 ºC; $^1$H NMR (300 MHz, $CDCl_3$) δ 6.96 (1H, dd, $J$ = 7.8, 7.5 Hz) , 6.84 (1H, d, $J$ = 7.8 Hz), 6.61 (1H, dd, $J$ = 7.8, 7.5 Hz), 6.48 (1H, d, $J$ = 7.5 Hz), 6.00 (1H, dd , $J$ = 12.0, 6.3 Hz), 3.69 (1H, br s), 3.55-3.44 (1H, m), 3.13-2.94 (2H, m), 2.63-2.60 (2H, m), 2.01-1.94 (1H, m), 1.82-1.66 (3H, m), 1.64-1.52 (3H, m), 1.42-1.35 (1H, m), 1.19 (3H, d, $J$ = 6.3 Hz); $^{13}$C NMR (75 MHz, $CDCl_3$) δ 176.9, 146.7, 128.0, 127.5, 120.3, 118.0, 114.8, 51.3, 47.2, 44.9, 37.7, 35.0, 30.2, 29.7, 23.8, 22.5; IR (KBr): 3326, 2929, 1628, 1490, 1443, 1340, 1196, 973, 912,

845, 735 $cm^{-1}$.

***cis*-1-(2,8-Dimethyl-1,2,3,4-tetrahydroquinoline-4-yl) azepan-2-one (13):** Yield (85%). mp 158-160 °C; $^1H$ NMR (300 MHz, $CDCl_3$) δ 6.84 (1H, d, *J* = 7.2 Hz), 6.72 (1H, d, *J* = 7.8 Hz), 6.53 (1H, dd, *J* = 7.8, 7.2 Hz), 6.00 (1H, dd, *J* = 11.7, 6.0 Hz), 3.52 (1H, br s), 3.49-3.45 (1H, m), 3.01-2.90 (2H, m), 2.60-2.57 (2H, m), 2.04 (3H, s), 1.96-1.93 (1H, m), 1.79-1.52 (6H, m), 1.39-1.32 (1H, m), 1.21 (3H, d, *J* = 6.3 Hz); $^{13}C$ NMR (75 MHz, $CDCl_3$) δ 176.5, 144.5, 128.8, 125.1, 121.4, 119.4, 117.0, 51.3, 47.0, 44.6, 37.5, 34.6, 30.0, 29.5, 23.5, 22.4, 17.3; IR (KBr) 3355, 2927, 1630, 1474, 1445, 1337, 1293, 1189, 1083, 972, 845, 751 $cm^{-1}$.

***cis*-1-(8-Bromo-2-methyl-,2,3,4-tetrahydroquinoline-4-yl) azepan-2-one (14):** Yield (85%). mp 159-160 °C; $^1H$ NMR (300 MHz, $CDCl_3$) δ 7.20 (1H, d, *J* = 7.8 Hz), 6.77 (1H, d, *J* = 7.8 Hz), 6.53 (1H, t, *J* = 7.8 Hz), 6.00 (1H, dd, *J* = 12.0, 6.0 Hz), 4.30 (1H, br s), 3.55-3.50 (1H, m), 3.12-2.90 (2H, m), 2.65-2.52 (2H, m), 1.94-1.91 (1H, m), 1.81-1.53 (6H, m), 1.40-1.32 (1H, m), 1.24 (3H, d, *J* = 6.3 Hz); $^{13}C$ NMR (75 MHz, $CDCl_3$) δ 176.7, 143.4, 131.2, 126.4, 121.7, 117.9, 109.0, 51.3, 47.1, 44.8, 37.5, 34.4, 30.1, 29.6, 23.6, 22.2; IR (KBr) 3401, 2929, 1634, 1490, 1454, 1339, 1293, 1195, 1144, 1085, 972, 734 $cm^{-1}$.

***cis*-1-(6-Fluoro-2-methyl-1,2,3,4-tetrahydroquinoline-4-yl) azepan-2-one (15):** Yield (88%). mp 96-98 °C; $^1H$ NMR δ 6.70-6.64 (1H, m), 6.57-6.53 (1H, m), 6.43-6.40 (1H, m), 5.95 (1H, dd, *J* = 11.7, 6.0 Hz), 3.68 (1H, br s), 3.47-3.41 (1H, m), 3.14-3.06 (1H, m), 2.99-2.92 (1H, m), 2.62-2.58 (2H, m), 1.99-1.92 (1H, m), 1.81-1.70 (3H, m), 1.61-1.49 (3H, m), 1.41-1.34 (1H, m), 1.16 (3H, d, *J* = 6.3 Hz); $^{13}C$ NMR (75 MHz, $CDCl_3$) δ 176.7, 156.1 (d, *J* = 234 Hz), 142.9, 121.7, 115.7 (d, *J* = 7.5 Hz), 114.8 (d, *J* = 22.5 Hz), 113.5 (d, *J* = 22.5 Hz), 51.2, 47.4, 44.9, 37.6, 34.6, 30.1, 29.7, 23.7, 22.4; IR (KBr) 3331, 2932, 1632, 1498, 1445, 1343, 1259, 1220, 1191, 1147, 1088, 974, 911, 813, 739 $cm^{-1}$.

***cis*-1-(6-Chloro-2-methyl-1,2,3,4-tetrahydroquinoline-4-yl) azepan-2-one (16):** Yield (80%). mp 141-142 °C; $^1H$ NMR (300 MHz, $CDCl_3$) δ 6.91 (1H, dd, *J* = 8.7, 2.4 Hz), 6.79 (1H, d, *J* = 2.4 Hz), 6.41 (1H, d, *J* = 8.7 Hz), 5.96 (1H, dd, *J* = 12.0, 6.0 Hz), 3.77 (1H, br s), 3.55-3.46 (1H, m), 3.19-3.10 (1H, m), 3.00-2.94 (1H, m), 2.71-2.57 (2H, m), 2.02-1.94 (1H, m), 1.87-1.73 (3H, m), 1.63-1.51 (3H, m), 1.43-1.36 (1H, m), 1.18 (3H, d, *J* = 6.3 Hz); $^{13}C$ NMR (75 MHz, $CDCl_3$) δ 176.7, 144.9, 127.8, 126.8, 122.4, 121.7, 115.7, 50.9, 47.0, 44.7, 37.5, 34.4, 30.0, 29.6, 23.5, 22.2; IR (KBr) 3332, 2931, 1627, 1487, 1444, 1343, 1303, 1259, 1196, 1091, 973, 814, 735 $cm^{-1}$.

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