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A highly efficient regioselective one-pot synthesis of 2,3,6-trisubstituted pyridines and 2,7,7-trisubstituted tetrahydroquinolin-5-ones using $K_5CoW_{12}O_{40}\cdot 3H_2O$ as a heterogeneous recyclable catalyst

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Abstract—A systematic investigation into the regioselective one-pot, three-component condensation of enaminones **1a–g**, β-dicarbonyl compounds **2a–c**, and ammonium acetate in the presence of a catalytic amount of $K_5CoW_{12}O_{40}\cdot 3H_2O$ (0.01 equiv or 1.0 mol %) under solvent free conditions, as well as in refluxing isopropanol, has been reported. The reaction was highly efficient to produce 2,3,6-trisubstituted pyridines **3a–g**, **4a–g**, and novel 2,7,7-trisubstituted-5,6,7,8-tetrahydroquinoline-5-ones **5a–g** in excellent yields. The present procedure offers advantages of short reaction time, simple work-up, and the catalyst exhibited remarkable reusable activity.

1. Introduction

Synthesis of the pyridine ring system and its derivatives[1a–e] occupy an important place in the realm of natural and synthetic organic chemistry, due to their therapeutic and pharmacological properties. They have emerged as integral backbones of over 7000 existing drugs.[1a,2a–f] The pyridine ring is also an integral part of agrochemicals,[3a,b] preparative organic chemistry,[4] and in coordination chemistry.[5] In addition to these important biological applications, pyridine derivatives are ideal scaffolds for making libraries of drug-like compounds, and to generate libraries of inhibitors of HIV-1 protease[6a–c] and factor Xa. Thus, the synthesis of these heterocycles is of current importance. Previously, 2,3,6-trisubstituted pyridine derivatives were synthesized by the reaction of a 3-aminocrotonate with acetophenone Mannich base hydrochlorides in refluxing ethanol.[7,8] Further Bagley et al. explored the Bohlmann–Rahtz reaction by reacting 3-aminocrotonate with acetylenic ketones.[9] Recently, synthesis of these pyridines is reported by the reaction of enaminones with β-dicarbonyl compounds in the presence of ammonium acetate in refluxing acetic acid,[10] or by using Montmorillonite K10 in isopropanol.[11] However, these methods suffer from low yields, use of expensive or not readily available starting materials, and exhibit limited substrate tolerance. In view of these facts, development of an alternative one-pot procedure is crucial.[12]

The catalytic function of heteropoly compounds[13] (heteropoly acids and salts) has attracted much attention and they are used in solution as well as in the solid state. Due to their weak super-acidic and redox properties, low toxicity, ease of handling, low cost, stability, water tolerance, recoverability, and reusability, heteropoly compounds are useful as versatile catalysts in reactions requiring electrophilic catalysis.[14] The successful applications of potassium dodecatangestocobaltate trihydrate ($K_5CoW_{12}O_{40}\cdot 3H_2O$)[14b] as electron transfer catalyst for a wide variety of organic transformations[15] prompted us[16] to explore the potential of $K_5CoW_{12}O_{40}\cdot 3H_2O$ as catalyst for one-pot three-component heterocyclocondensation process. In this paper, we describe a general and practical route for the synthesis of 2,3,6-trisubstituted pyridines and 2,7,7-trisubstituted-5,6,7,8-tetrahydroquinoline-5-ones by the cyclocondensation of enaminones, β-dicarbonyl compounds, and ammonium acetate, using $K_5CoW_{12}O_{40}\cdot 3H_2O$ (1 mol %) as the catalyst.

2. Results and discussion

Enaminones,[17] being versatile substrates in the synthesis of heterocyclic compounds and drug intermediates, were chosen as starting material for the synthesis of 2,3,6-trisubstituted pyridines. They are generally prepared by the condensation of methyl aryl ketones with dimethylformamide

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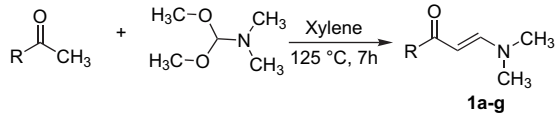
dimethylacetal in refluxing xylene[18] (Scheme 1, Table 1). Although the method is readily adopted, there is no general synthetic protocol for the preparation of enaminones. We present here a systematic procedure for the preparation of various enamino ketones **1a–g**. All the compounds were fully characterized by ^{1}H and ^{13}C NMR, IR and mass spectral data.



Scheme 1.

Table 1. Synthesis of enamino ketones **1a–g**

S. No.	R	Product	Yield[a] (%)	Mp (°C)	Ref.
1	C_6H_5	**1a**	90	86–88	18a
2	*p*-$CH_3C_6H_4$	**1b**	86	89–91	10
3	*p*-ClC_6H_4	**1c**	91	79–81	10
4	*p*-BrC_6H_4	**1d**	95	74–76	—
5	*p*-$NO_2C_6H_4$	**1e**	89	151–153	—
6	*p*-$CH_3OC_6H_4$	**1f**	83	98–100	10
7	1-Naphthyl	**1g**	89	Oil	—

[a] Isolated yields.

Initially, the reaction of 3-dimethylamino-1-(4-chlorophenyl)-prop-2-en-1-one **1c**, ethyl acetoacetate, and NH_4OAc was attempted under different sets of conditions (Table 2). Of all the above combinations, the reaction in IPA at reflux temperature (entry 3, Table 2) and under solvent free conditions (entry 8, Table 2) using 1 mol % of $K_5CoW_{12}O_{40}\cdot 3H_2O$ as the catalyst, is found to be a novel, one-pot combination that not only preserved the conditions of one-pot reaction, but also consistently produced excellent yields of the 2,3,6-trisubstituted pyridines (Scheme 2).

Table 2. Effect of reaction parameters on the synthesis of 2,3,6-trisubstituted pyridine **3c**

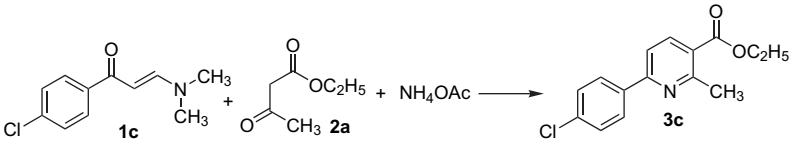
S. No.	Solvent	Catalyst	Temp (°C)	Time (min)	Yield[a] (%)
1	Acetic acid	Acetic acid[10]	118	60	84[10]
2	*iso*-Propanol	Montmorillonite K10[11]	82	240	79[11]
3	*iso*-Propanol	$K_5CoW_{12}O_{40}\cdot 3H_2O$	82	120	85
4	Ethanol	$K_5CoW_{12}O_{40}\cdot 3H_2O$	80	240	64
5	Methanol	$K_5CoW_{12}O_{40}\cdot 3H_2O$	64	240	52
6	*iso*-Propanol	$K_5CoW_{12}O_{40}\cdot 3H_2O$	25	240	0
7	Solvent-free	$K_5CoW_{12}O_{40}\cdot 3H_2O$	82	120	35
8	Solvent-free	$K_5CoW_{12}O_{40}\cdot 3H_2O$	115	30	95
9	Solvent-free	Silica-gel	115	120	41
10	Solvent-free	IR-120, H^+	115	120	45
11	Solvent-free	Dowex-50, H^+	115	120	43
12	Solvent-free	No catalyst	115	120	5[b]
13	*iso*-Propanol	No catalyst	82	1400	13[b]

[a] Isolated yields.
[b] Yield based on ^{1}H NMR.

In a typical experimental procedure, a mixture of ethyl acetoacetate **2a** or acetyl acetone **2b**, enaminone **1a–g**, and ammonium acetate was reacted in isopropanol (IPA) solvent (Method A, Table 3) and under solvent free conditions (Method B, Table 3), in the presence of a catalytic amount of $K_5CoW_{12}O_{40}\cdot 3H_2O$ (1 mol %). Decreased reaction times in solvent free conditions (Method B) compared to the reaction in IPA (Method A) is realized because of the increased reactivity of the reactant in the solid state, and the fact that water evaporates at the reaction temperatures. In order to improve the yields, we performed the reaction using different quantities of reagents. The best results were obtained with 0.01:1:1:2 ratios of $K_5CoW_{12}O_{40}\cdot 3H_2O$, enaminoketone, 1,3-dicarbonyl compound, and ammonium acetate, respectively (Scheme 3). To examine the reaction under traditional conditions, a solution of β-dicarbonyl compound **2a**,**b**, enaminone **1a–g**, ammonium acetate, and isopropanol was refluxed in the presence of a catalytic amount of $K_5CoW_{12}O_{40}\cdot 3H_2O$ (1 mol %) for a period of time (specified in Table 3) required to complete the reaction (TLC), resulting in the formation of trisubstituted pyridines. After completion of reaction the catalyst was recovered by simple filtration, and the trisubstituted pyridines **3a–g**, **4a–g** isolated from the filtrate by recrystallization in methanol. Under solvent free conditions, after completion of the reaction, as indicated by TLC, the reaction mixture was quenched with methanol, the catalyst was filtered out, and the methanol solution was cooled to afford 2,3,6-trisubstituted pyridines as pure products. Moreover the catalyst could be quantitatively recovered from the reaction mixture by using simple filtration of the contents and washing with solvent, and could be reused after thermal activation (80 °C). For example, the catalyst was reused in case of 4-nitrophenyl enaminoketone (entry 5, Table 3) more than five times with no loss of activity. To study the generality of the process, several examples illustrating the novelty for the synthesis of 2,3,6-trisubstituted pyridines studied, are summarized in Table 3.

Many of the pharmacologically relevant substitution patterns on the aromatic ring of trisubstituted pyridines could be introduced efficiently with a variety of enaminones in high yields and high purity. However, the nature of the functional group on the aromatic ring of the enaminones exerted a strong influence on the reaction time.

An increase of the reaction rate was observed with enaminones bearing electron-withdrawing groups in the *p*-position (entry 5, Table 3), in comparison to the unsubstituted enaminones. The presence of an electron donating (methoxy) group (entry 6, Table 3) decreased both the rate of reaction and the product yield. Acid sensitive β-dicarbonyl compounds such as acetyl acetone and ethyl acetoacetate worked well without the formation of any side products with variety of structurally and electronically divergent substituents of

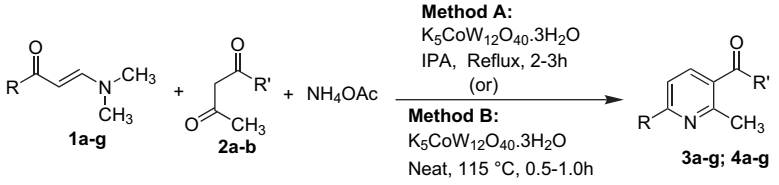


Scheme 2.

Table 3. Synthesis of 2,3,6-trisubstituted pyridines **3a–g** and **4a–g** using $K_5CoW_{12}O_{40}\cdot 3H_2O$ catalyst

Entry	R	R′	Product	Method A		Method B		Mp (°C)	Ref.
				Time (min)	Yield[a] (%)	Time (min)	Yield[a] (%)		
1	C_6H_5	OC_2H_5	**3a**	120	86	30	95	43–45	11
2	p-$CH_3C_6H_4$	OC_2H_5	**3b**	150	84	45	93	53–55	11
3	p-ClC_6H_4	OC_2H_5	**3c**	120	85	30	95	74–75	11
4	p-BrC_6H_4	OC_2H_5	**3d**	120	86	35	97	73–75	11
5	p-$NO_2C_6H_4$	OC_2H_5	**3e**	120	91[b]	30	98[b]	142	11
6	p-$CH_3OC_6H_4$	OC_2H_5	**3f**	150	83	45	92	48–50	11
7	1-Naphthyl	OC_2H_5	**3g**	150	85	45	94	Oil	—
8	C_6H_5	CH_3	**4a**	120	83	50	93	110	11
9	p-$CH_3C_6H_4$	CH_3	**4b**	180	81	60	90	82–84	—
10	p-ClC_6H_4	CH_3	**4c**	120	88	45	95	58–60	—
11	p-BrC_6H_4	CH_3	**4d**	120	89	45	96	76–78	—
12	p-$NO_2C_6H_4$	CH_3	**4e**	120	90, 89, 86[b]	30	97, 95, 92[b]	131	—
13	p-$CH_3OC_6H_4$	CH_3	**4f**	180	80	60	86	100	—
14	1-Naphthyl	CH_3	**4g**	180	86	60	93	Oil	—

[a] Isolated yield.
[b] The yields obtained after first, third, and fifth successive reuse of the catalyst.

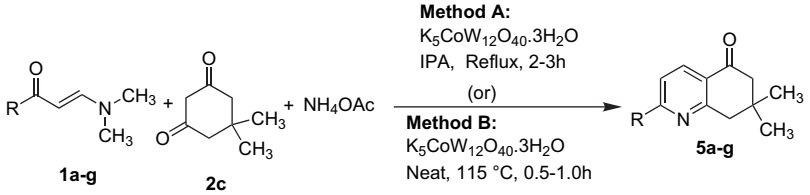


Scheme 3.

enaminones. Thus in the present protocol, variations in all components have been accommodated very comfortably.

In continuation of our synthetic experiments, we are delighted with a new series of 2,7,7-trisubstituted-5,6,7,8-tetrahydroquinoline-5-ones **5a–g** (Scheme 4) in excellent yields by the reaction of enaminones (**1a–g**), dimedone **2c**, and ammonium acetate in the presence of a catalytic amount of $K_5CoW_{12}O_{40}\cdot 3H_2O$ (1 mol %), under solvent free conditions (Method B, Table 4) as well as in refluxing isopropanol (Method A, Table 4). After completion of the reaction, the catalyst is recovered by simple filtration, and the tetrahydroquinoline-5-ones **5a–g** are isolated from the filtrate by recrystallization in methanol. The results are summarized in Table 4. All the products **5a–g** were fully characterized by ^1H and ^{13}C NMR spectroscopy, IR and mass spectral data (see Supplementary data). The use of just 1 mol % of $K_5CoW_{12}O_{40}\cdot 3H_2O$ is sufficient to push the reaction forward. Higher amounts of $K_5CoW_{12}O_{40}\cdot 3H_2O$ did not improve the result to a great extent. No additive or protic/Lewis acid is necessary in the procedure. The products obtained are of high purity (>95% by ^1H NMR spectroscopy). Another important aspect of this procedure is the survival of a variety of functional groups, such as NO_2, Cl, Br, OCH_3, and various dicarbonyl compounds, and the catalyst is reusable under the reaction conditions.

In conclusion, a series of 2,3,6-trisubstituted pyridines **3a–g**, **4a–g**, and tetrahydroquinoline-5-ones **5a–g** were synthesized efficiently by regioselective one-pot condensation of an enaminone **1**, β-dicarbonyl compound **2a**,**b** or dimedone **2c**, respectively, and ammonium acetate in the presence of a catalytic amount of $K_5CoW_{12}O_{40}\cdot 3H_2O$ (0.01 equiv or 1.0 mol %) in isopropanol and under solvent free conditions. The current protocol was applied successfully for the first time to the synthesis of tetrahydroquinoline-5-ones **5a–g** from enaminones **1**. The method has the ability to tolerate structurally and electronically divergent substituents, either in the enaminones or in the dicarbonyl compounds; variable reaction conditions, shorter reaction times, and simple work-up procedure are other advantages. Moreover, the catalyst exhibited remarkable reusable activity. Further, the present procedure is readily amenable to parallel synthesis and the generation of combinatorial 2,3,6-trisubstituted pyridine and 2,7,7-trisubstituted-5, 6,7,8-tetrahydroquinoline-5-one libraries.



Scheme 4.

Table 4. Reaction of enaminoketone and dimedone in the presence of $K_5CoW_{12}O_{40}\cdot 3H_2O$ catalyst

Entry	R	Product	Method A		Method B		Mp (°C)
			Time (min)	Yield[a] (%)	Time (min)	Yield[a] (%)	
1	C_6H_5	**5a**	150	90	45	94	67
2	*p*-$CH_3C_6H_4$	**5b**	180	88	60	91	120
3	*p*-ClC_6H_4	**5c**	150	92	50	97	105
4	*p*-BrC_6H_4	**5d**	150	92	45	96	132
5	*p*-$NO_2C_6H_4$	**5e**	120	93[b]	45	98[b]	182
6	*p*-$CH_3OC_6H_4$	**5f**	180	87	60	90	125
7	1-Naphthyl	**5g**	180	91	60	95	Oil

[a] Isolated yield.
[b] The catalyst was reused at least for five times.

3. Experimental section

3.1. General

All reagents and solvents were analytically pure, and were used without further purification. Anhydrous conditions were not required for this reaction. Melting points were measured with a Fischer–Johns melting point apparatus and are uncorrected. ^{1}H NMR spectra were taken in commercial deuterated solvents on a multinuclear spectrometer with all chemical shifts being reported in parts per million (δ) relative to internal tetramethylsilane (TMS, δ 0.0) or with the solvent reference relative to TMS employed as the internal standard $CDCl_3$ (δ 7.23 ppm). Data are reported as follows: chemical shifts (multiplicity [singlet (s), doublet (d), triplet (t), quartet (q), broad (br), and multiplet (m)], coupling constants [Hz], integration). ^{13}C NMR spectra were taken on a multinuclear spectrometer (50 MHz), and the chemical shifts are reported in parts per million (δ unit) downfield from tetramethylsilane as the internal standard ($CDCl_3$, δ 77.0). Infrared spectra were recorded as thin films on KBr plates with ν_{max} in inverse centimeters. Mass spectra were recorded under electron impact at 70 eV on Finnigan Mat 1020B mass spectrometer. Elemental analyses were performed on elemental analyzer Vario EL. Column chromatography was carried out using 60–120 mesh silica gel. Thin layer chromatography was performed on Merck 60 F-254 pre coated silica gel plates.

3.2. Preparation of potassium dodecatangestocobaltate trihydrate ($K_5CoW_{12}O_{40}\cdot 3H_2O$) catalyst[14]

Cobaltous acetate (5.0 g, 0.02 mol), sodium tangestate (39.6 g, 0.12 mol) was dissolved in acetic acid (5 mL) and H_2O at pH 6.5–7.5. This mixture was treated with KCl (26.0 g) followed by potassium persulfate (21.0 g) in H_2SO_4 (2 M, 80 mL); the precipitate was filtered, dried at 200 °C, and crystallized in MeOH gave potassium dodecatangestocobaltate trihydrate ($K_5CoW_{12}O_{40}\cdot 3H_2O$) as a light blue solid (32.3 g, 51%).

3.3. Representative procedure for the preparation of 1a–g

To a mixture of 4-nitroacetophenone (3.30 g, 20 mmol), in xylene (100 mL), was added dimethylformamide dimethylacetal (2.38 g, 20 mmol) and the reaction refluxed for 7 h (monitored by TLC). The xylene was distilled off and the product was triturated with petroleum ether. The resulting solid was filtered and washed with cold petroleum ether to afford the pure product **1e** as a yellowish brown solid (3.916 g, 89%).

3.3.1. 3-Dimethylamino-1-(phenyl)prop-2-enone 1a. Yield 90%, mp 86–88 °C (pet-ether, lit.[16a] 86–88 °C); IR (KBr) ν_{max} 3423, 3020, 2909, 2805, 1639, 1584, 1543, 1427, 1362, 1309, 1275, 1234, 1110, 1049, 1019, 852, 739, 6967; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 2.75–3.22 (6H, 2br s), 5.65 (1H, d, J=14.7 Hz), 7.40 (3H, m), 7.70 (1H, d, J=15.2 Hz), 7.85 (2H, m); MS (EI) *m/z* 175 (M^+, 34%), 158 (84), 98 (100), 91 (14), 77 (34), 55 (55), 51 (55). Anal. Calcd for $C_{11}H_{13}NO$: C, 75.40; H, 7.48; N, 7.99. Found: C, 75.31; H, 7.55; N, 8.01.

3.3.2. 3-Dimethylamino-1-(4-methylphenyl)prop-2-enone 1b. Yield 86%, mp 89–91 °C (pet-ether, lit.[10] 90–91 °C); IR (KBr) ν_{max} 3428, 2915, 2802, 1644, 1579, 1538, 1433, 1355, 1280, 1237, 1113, 1055, 975, 900, 780; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 2.40 (3H, s), 3.01 (6H, br 2 s), 5.68 (1H, d, J=12.8 Hz), 7.18 (2H, d, J=7.5 Hz), 7.75 (3H, m); MS (EI) *m/z* 189 (M^+, 33%), 172(87), 120 (26), 99 (100), 92 (26), 70 (43), 55 (52), 51 (31). Anal. Calcd for $C_{12}H_{15}NO$: C, 76.16; H, 7.99; N, 7.40. Found: C, 76.09; H, 7.91; N, 7.51.

3.3.3. 3-Dimethylamino-1-(4-chlorophenyl)prop-2-enone 1c. Yield 91%, mp 79–81 °C (pet-ether, lit.[10] 80–81 °C); IR (KBr) ν_{max} 3440, 2918, 2803, 1645, 1581, 1543, 1435, 1353, 1278, 1053, 899, 837, 787; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 2.82–3.32 (6H, br 2 s), 5.63 (1H, d, J=12.5 Hz), 7.35 (2H, d, J=8.5 Hz), 7.68–7.86 (3H, m); MS (EI) *m/z* 209 (M^+, 42%), 192 (81), 139 (26), 125 (11), 111 (15), 98 (100), 70 (21), 55 (12), 42 (20). Anal. Calcd for $C_{11}H_{12}ClNO$: C, 63.01; H, 5.77; N, 6.68. Found: C, 63.10; H, 5.66; N, 6.79.

3.3.4. 3-Dimethylamino-1-(4-bromophenyl)prop-2-enone 1d. Yield 95%, mp 74–76 °C; IR (KBr) ν_{max} 3446, 2912, 2805, 1640, 1578, 1540, 1438, 1356, 892, 805, 757; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 2.82–3.25 (6H, br 2 s), 5.60 (1H, d, J=12.2 Hz), 7.52 (2H, d, J=8.6 Hz), 7.70–7.80 (3H, m); ^{13}C NMR (50 MHz, $CDCl_3$) δ 36.9, 44.6, 91.2, 125.0, 128.8, 130.9, 138.9, 154.1, 186.6; MS (EI) *m/z* 253 (M^+, 32%), 238 (100), 183 (26), 157 (62), 55 (45). Anal. Calcd for $C_{11}H_{12}BrNO$: C, 51.99; H, 4.76; N, 5.51. Found: C, 51.87; H, 4.69; N, 5.59.

3.3.5. 3-Dimethylamino-1-(4-nitrophenyl)prop-2-enone 1e. Mp 151–153 °C (pet-ether); IR (KBr) ν_{max} 3423, 2921, 1643, 1552, 1512, 1438, 1345, 1055, 898, 860, 797; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 2.90 (3H, br s), 3.25 (3H, br s), 5.61 (1H, d, J=12.8 Hz), 7.78 (1H, d, J=12.1 Hz), 7.95 (2H, d, J=8.5 Hz), 8.22 (2H, d, J=8.5 Hz); ^{13}C NMR (50 MHz, $CDCl_3$) δ 37.2, 45.1, 91.7, 123.2, 128.1, 145.9, 148.8, 155.0, 185.8; MS (EI) *m/z* 220 (M^+, 32%), 204 (82), 157 (10), 70 (25), 55 (22), 44 (7). Anal. Calcd for $C_{11}H_{12}N_2O_3$: C, 59.99; H, 5.49; N, 12.72. Found: C, 59.86; H, 5.56; N, 12.80.

3.3.6. 3-Dimethylamino-1-(4-methoxyphenyl)prop-2-enone 1f. Yield 83%, mp 98–100 °C (pet-ether, lit.[10]

100 °C); IR (KBr) ν_{max} 2906, 2803, 1639, 1581, 1541, 1431, 1357, 1304, 1246, 1174, 1114, 1055, 1024, 902, 842, 772; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 3.01 (6H, br s), 3.85 (3H, s), 5.65 (1H, d, J=12.4 Hz), 6.85 (2H, d, J=8.8 Hz), 7.70 (1H, d, J=12.4 Hz), 7.85 (2H, d, J=8.8 Hz); MS (EI) m/z 205 (M^+, 46%), 188 (100), 162 (8), 135 (50), 98 (97), 92 (25). Anal. Calcd for $C_{12}H_{15}NO_2$: C, 70.22; H, 7.37; N, 6.82. Found: C, 70.09; H, 7.28; N, 6.87.

3.3.7. 3-Dimethylamino-1-(1-naphthyl)prop-2-enone 1g. Yield 89% (flash column chromatography on SiO_2, eluting with light petroleum–EtOAc (1:1), gave compound **1g** as a pale yellow oil); IR (KBr) ν_{max} 3446, 3051, 2922, 1641, 1555, 1423, 1349, 1273, 1094, 986, 900, 738, 627; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 2.80–3.20 (6H, br 2 s), 5.46 (1H, d, J=12.8 Hz), 7.40–7.58 (5H, m), 7.80 (2H, m), 8.24 (1H, d, J=9.0 Hz); MS (EI) m/z 225 (M^+, 6%), 169 (25), 141 (100), 125 (10), 115 (7), 105 (33), 83 (10), 57 (22), 43 (53). Anal. Calcd for $C_{15}H_{15}NO$: C, 79.97; H, 6.71; N, 6.22. Found: C, 79.86; H, 6.69; N, 6.30.

3.4. Representative procedure for the preparation of 3a–g

To a mixture of 3-dimethylamino-1-(4-nitrophenyl)prop-2-enone **1e** (0.550 g, 2.5 mmol), ethyl acetoacetate **2a** (0.325 g, 2.5 mmol), ammonium acetate (0.385 g, 5 mmol) in 5 mL of isopropanol (*Method A*) was added $K_5CoW_{12}O_{40}\cdot 3H_2O$ (0.080 g, 0.025 mmol, 1.0 mol %) and refluxed for 120 min (monitored by TLC). The resulting mixture was cooled to room temperature, the catalyst filtered off and washed with 5 mL of hot isopropanol. The IPA solution was concentrated on rotary evaporator and then recrystallized in methanol to afford pure product **3e** as pale yellowish solid (0.650 g, 91%). In solvent free conditions (*Method B*) the reaction mixture was stirred and heated at 115 °C for 30 min and the progress of the reaction was monitored by TLC. After completion, 5 mL of hot methanol was added to the reaction mixture; the catalyst was filtered off and washed with another 5 mL of hot methanol. The methanol solution was then cooled to afford pure product **3e** as pale yellowish solid (0.700 g, 98%). The filtered catalyst was reactivated by heating at 80 °C for 2 h and reused at least five times.

3.4.1. Ethyl (2-methyl-6-phenyl)nicotinate 3a. Yield 95%, mp 43–45 °C (MeOH, lit.[11] 43–45 °C); IR (KBr) ν_{max} 2991, 2928, 1715, 1581, 1451, 1269, 1088, 758, 691; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 1.42 (3H, t, J=7.1 Hz), 2.92 (3H, s), 4.38 (2H, q, J=7.1 Hz), 7.42 (3H, m), 7.60 (1H, d, J=8.1 Hz), 8.05 (2H, m), 8.22 (1H, d, J=8.3 Hz); ^{13}C NMR (50 MHz, $CDCl_3$) δ 14.1, 25.1, 60.9, 117.1, 123.5, 127.2, 128.6, 129.5, 138.4, 139.1, 158.9, 159.8, 166.5; MS (EI) m/z 241 (M^+, 100%), 213 (26), 196 (93), 169 (32), 155 (12), 141 (57), 128 (26), 115 (70), 98 (22), 84 (20), 77 (26), 57 (12), 51 (15). Anal. Calcd for $C_{15}H_{15}NO_2$: C, 74.67; H, 6.27; N, 5.81. Found: C, 74.59; H, 6.31; N, 5.93.

3.4.2. Ethyl (2-methyl-6-*p*-methylphenyl)nicotinate 3b. Yield 93%, mp 53–55 °C (MeOH, lit.[11] 53–54 °C) IR (KBr) ν_{max} 2983, 2928, 1714, 1581, 1451, 1269, 1184, 1090, 824, 780; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 1.41 (3H, t, J=7.5 Hz), 2.40 (3H, s), 2.88 (3H, s), 4.38 (2H, q, J=7.5 Hz), 7.22 (2H, d, J=7.5 Hz), 7.56 (1H, d, J=8.3 Hz), 7.95 (2H, d, J=8.3 Hz), 8.20 (1H, d, J=8.3 Hz); ^{13}C NMR (50 MHz, $CDCl_3$) δ 14.2, 21.2, 25.1, 60.9, 116.8, 123.2, 127.0, 129.4, 135.6, 139.0, 139.6, 158.9, 159.7, 166.5; MS (EI) m/z 255 (M^+, 100%), 210 (93), 183 (25), 167 (26), 129 (11), 115 (27), 91 (26), 63 (25). Anal. Calcd for $C_{16}H_{17}NO_2$: C, 75.27; H, 6.71; N, 5.49. Found: C, 75.19; H, 6.78; N, 5.55.

3.4.3. Ethyl (2-methyl-6-*p*-chlorophenyl)nicotinate 3c. Yield 96%, mp 74–75 °C (MeOH, lit.[11] 74–75 °C) IR (KBr) ν_{max} 2979, 2929, 1723, 1583, 1450, 1269, 1094, 1012, 827, 778; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 1.42 (3H, t, J=7.1 Hz), 2.88 (3H, s), 4.37 (2H, q, J=7.1 Hz), 7.40 (2H, d, J=8.6 Hz), 7.55 (1H, d, J=8.1 Hz), 8.00 (2H, d, J=8.6 Hz), 8.20 (1H, d, J=8.1 Hz); MS (EI) m/z 275 (M^+, 71%), 247 (25), 230 (100), 203 (38), 167 (62), 141 (47), 115 (47), 75 (47), 63 (40). Anal. Calcd for $C_{15}H_{14}ClNO_2$: C, 65.34; H, 5.12; N, 5.08. Found: C, 65.27; H, 5.17; N, 5.17.

3.4.4. Ethyl (2-methyl-6-*p*-bromophenyl)nicotinate 3d. Yield 97%, mp 73–75 °C (MeOH, lit.[11] 72–74 °C) IR (KBr) ν_{max} 2978, 2929, 1721, 1582, 1451, 1369, 1267, 1089, 1009, 826, 779; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 1.44 (3H, t, J=6.8 Hz), 2.89 (3H, s), 4.36 (2H, q, J=6.8 Hz), 7.55 (3H, m), 7.93 (2H, d, J=7.5 Hz), 8.20 (1H, d, J=8.3 Hz); MS (EI) m/z 319 (M^+, 96%), 317 (100), 275 (16), 275 (64), 274 (66), 249 (47), 247 (54), 182 (25), 167 (77), 155 (21), 141 (41), 126 (11), 115 (9), 83 (13), 75 (15), 63 (11), 39 (14). Anal. Calcd for $C_{15}H_{14}BrNO_2$: C, 56.27; H, 4.41; N, 4.37. Found: C, 56.31; H, 4.30; N, 4.31.

3.4.5. Ethyl (2-methyl-6-*p*-nitrophenyl)nicotinate 3e. Mp 142 °C (MeOH, lit. [11]71–73 °C); IR (KBr) ν_{max} 3094, 2974, 2928, 2849, 1719, 1580, 1517, 1436, 1371, 1340, 1260, 1160, 1087, 847, 791, 746; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 1.45 (3H, t, J=7.5 Hz), 2.92 (3H, s), 4.42 (2H, q, J=7.5 Hz), 7.70 (1H, d, J=8.3 Hz), 8.22–8.37 (5H, m); ^{13}C NMR (50 MHz, $CDCl_3$) δ 14.2, 25.0, 61.3, 117.9, 123.8, 125.0, 127.9, 139.5, 144.1, 148.4, 156.0, 160.2, 166.1; MS (EI) m/z 286 (M^+, 100%), 242 (88), 207 (55), 178 (27), 150 (91), 140 (26), 104 (32), 75 (28), 43 (60). Anal. Calcd for $C_{15}H_{14}N_2O_4$: C, 62.93; H, 4.93; N, 9.79. Found: C, 63.08; H, 4.86; N, 9.88.

3.4.6. Ethyl (2-methyl-6-*p*-methoxyphenyl)nicotinate 3f. Yield 92%, mp 48–50 °C (MeOH, lit.[11] 68–69 °C); IR (KBr) ν_{max} 3094, 2978, 2931, 2837, 1716, 1678, 1581, 1560, 1508, 1455, 1386, 1250, 1178, 1092, 1032, 828, 783; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 1.40 (3H, t, J=7.5 Hz), 2.89 (3H, s), 3.82 (3H, s), 4.35 (2H, q, J=7.5 Hz), 6.92 (2H, d, J=9.0 Hz), 7.50 (1H, d, J=8.3 Hz), 8.0 (2H, d, J=9.0 Hz), 8.19 (1H, d, J=8.3 Hz); MS (EI) m/z 271 (M^+, 100%), 244 (17), 227 (51), 200 (6), 150 (10), 136 (32), 105 (7), 77 (22), 63 (15). Anal. Calcd for $C_{16}H_{17}NO_3$: C, 70.83; H, 6.32; N, 5.16. Found: C, 70.76; H, 6.39; N, 5.09.

3.4.7. Ethyl (2-methyl-6-1-naphthyl)nicotinate 3g. Yield 94% (flash column chromatography on SiO_2, eluting with light petroleum–EtOAc (9:1), gave compound **3g** as a pale yellow oil); IR (film) ν_{max} 3052, 2979, 2931, 1721, 1584,

1556, 1508, 1445, 1390, 1269, 1148, 1081, 858, 782, 740; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 1.45 (3H, t, J=7.0 Hz), 2.98 (3H, s), 4.35 (2H, q, J=7.0 Hz), 7.42–7.65 (5H, m), 7.82–8.15 (3H, m), 8.32 (1H, d, J=8.5 Hz); MS (EI) m/z 291 (M^+, 11%), 263 (43), 219 (20), 128 (40), 113 (13), 105 (80), 86 (11), 77 (65), 58 (222), 44 (100). Anal. Calcd for $C_{19}H_{17}NO_2$: C, 78.33; H, 5.88; N, 4.81. Found: C, 78.27; H, 5.78; N, 4.90.

3.5. Representative procedure for the preparation of 4a–g

To a mixture of 3-dimethylamino-1-(4-nitrophenyl)-prop-2-en-1-one **1e** (0.550 g, 2.5 mmol), acetyl acetone **2b** (0.250 g, 2.5 mmol), ammonium acetate (0.385 g, 5 mmol) in isopropanol (5 mL) (*Method A*) was added $K_5CoW_{12}O_{40}\cdot 3H_2O$ (0.080 g, 0.025 mmol, 1.0 mol %) and refluxed for 120 min (monitored by TLC). The reaction mixture was worked up as represented above to yield product **4e** as pale yellowish solid (0.576 g, 90%). In solvent free conditions (*Method B*) the reaction mixture was stirred and heated at 115 °C for 30 min (monitored by TLC) and worked up as represented in the above procedure to afford pure pale yellow product **4e** (0.620 g, 97%).

3.5.1. 1-(2-Methyl-6-phenylpyridin-3-yl)ethanone 4a. Yield 93%, mp 110 °C (MeOH, lit.[11] 110 °C); IR (KBr) ν_{max} 2930, 1679, 1575, 1422, 1351, 1254, 742, 689; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 2.58 (3H, s), 2.82 (3H, s), 7.36–7.50 (3H, m), 7.62 (1H, d, J=8.3 Hz), 8.01–8.10 (3H, m); ^{13}C NMR (50 MHz, $CDCl_3$) δ 25.2, 29.1, 117.1, 127.2, 128.7, 129.6, 137.8, 138.3, 158.4, 158.5, 199.8; MS (EI) m/z 211 (M^+, 60%), 196 (100), 168 (40), 153 (10), 141 (57), 115 (15), 77 (11), 43 (20). Anal. Calcd for $C_{14}H_{13}NO$: C, 79.59; H, 6.20; N, 6.63. Found: C, 79.48; H, 6.19; N, 6.71.

3.5.2. 1-(2-Methyl-6-*p*-methylphenylpyridin-3-yl)ethanone 4b. Yield 90%, mp 82–84 °C (MeOH); IR (KBr) ν_{max} 2921, 1681, 1578, 1451, 1260, 1184, 818, 788, 763; ^{1}H NMR (200 MHz, $CDCl_3$, TMS) δ 2.45 (3H, s), 2.60 (3H, s), 2.85 (3H, s), 7.28 (2H, d, J=7.8 Hz), 7.60 (1H, d, J=7.8 Hz), 7.95–8.05 (3H, m); ^{13}C NMR (50 MHz, $CDCl_3$) δ 21.2, 25.2, 29.1, 116.7, 117.4, 126.7, 127.1, 128.3, 129.4, 137.8, 138.0, 158.5, 199.7; MS (EI) m/z 225 (M^+, 8%), 210 (7), 197 (46), 183 (100), 167 (19), 115 (13), 91 (33), 39 (42). Anal. Calcd for $C_{15}H_{15}NO$: C, 79.97; H, 6.71; N, 6.22. Found: C, 79.91; H, 6.80; N, 6.31.

3.5.3. 1-(2-Methyl-6-*p*-chlorophenylpyridin-3-yl)ethanone 4c. Yield 95%, mp 58–60 °C (MeOH); IR (KBr) ν_{max} 3077, 2994, 2967, 2925, 1677, 1577, 1488, 1430, 1351, 1260, 1180, 1089, 816, 763, 628; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 2.58 (3H, s), 2.82 (3H, s), 7.40 (2H, d, J=8.6 Hz), 7.58 (1H, d, J=7.7 Hz), 7.98–8.14 (3H, m); ^{13}C NMR (50 MHz, $CDCl_3$) δ 25.1, 29.0, 116.7, 128.3, 128.8, 130.7, 136.5, 137.8, 157.0, 158.4, 158.5, 199.5; MS (EI) m/z 245 (M^+, 56%), 230 (100), 202 (11), 167 (23). Anal. Calcd for $C_{14}H_{12}ClNO$: C, 68.44; H, 4.92; N, 5.70. Found: C, 68.39; H, 4.85; N, 5.81.

3.5.4. 1-(2-Methyl-6-*p*-bromophenylpyridin-3-yl)ethanone 4d. Yield 96%, mp 76–78 °C (MeOH); IR (KBr) ν_{max} 2925, 1678, 1576, 1485, 1430, 1352, 1256, 1005, 952, 816, 762; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 2.62 (3H, s), 2.86 (3H, s), 7.62 (3H, m), 7.96–8.10 (3H, m); ^{13}C NMR (50 MHz, $CDCl_3$) δ 25.1, 29.1, 116.8, 124.2, 128.6, 130.8, 131.8, 137.0, 137.8, 157.1, 158.4, 199.6; MS (EI) m/z 289 (M^+, 20%), 273 (35), 247 (100), 221 (17), 182 (15), 167 (57), 141 (37), 101 (61), 75 (88), 43 (83). Anal. Calcd for $C_{14}H_{12}BrNO$: C, 57.95; H, 4.17; N, 4.83. Found: C, 57.88; H, 4.23; N, 4.90.

3.5.5. 1-(2-Methyl-6-*p*-nitrophenylpyridin-3-yl)ethanone 4e. Mp 131 °C (MeOH); IR (KBr) ν_{max} 2925, 2851, 1719, 1682, 1581, 1517, 1428, 1341, 1261, 830, 739; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 2.62 (3H, s), 2.82 (3H, s), 7.72 (1H, d, J=7.5 Hz), 8.08 (1H, d, J=7.5 Hz), 8.25 (2H, d, J=9.0 Hz), 8.30 (2H, d, J=9.0 Hz); ^{13}C NMR (50 MHz, $CDCl_3$) δ 25.0, 29.3, 117.9, 123.9, 128.0, 131.9, 137.9, 144.0, 148.4, 155.6, 158.7, 199.7; MS (EI) m/z 256 (M^+, 7%), 241 (25), 167 (8), 148(9), 115 (8), 105 (100), 91 (32), 77 (80), 51 (44), 43 (54). Anal. Calcd for $C_{14}H_{12}N_2O_3$: C, 65.62; H, 4.72; N, 10.93. Found: C, 65.69; H, 4.66; N, 10.87.

3.5.6. 1-(2-Methyl-6-*p*-methoxyphenylpyridin-3-yl)ethanone 4f. Yield 86%, mp 100 °C (MeOH); IR (KBr) ν_{max} 2926, 2850, 1683, 1605, 1575, 1510, 1454, 1253, 1174, 1026, 826, 792; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 2.60 (3H, s), 2.72 (3H, s), 3.88 (3H, s), 6.95 (2H, d, J=9.0 Hz), 7.55 (1H, d, J=8.3 Hz), 7.95–8.05 (3H, m); ^{13}C NMR (50 MHz, $CDCl_3$) δ 25.3, 29.1, 55.3, 114.2, 116.2, 128.8, 128.2, 129.9, 131.0, 137.9, 158.6, 161.1, 199.7; MS (EI) m/z 241 (M^+, 43%), 226 (53), 199 (100), 184 (32), 156 (42), 141 (40), 128 (8), 43 (15). Anal. Calcd for $C_{15}H_{15}NO_2$: C, 74.67; H, 6.27; N, 5.81. Found: C, 74.59; H, 6.31; N, 5.79.

3.5.7. 1-(2-Methyl-6–1-naphthylpyridin-3-yl)ethanone 4g. Yield 93% (flash column chromatography on SiO_2, eluting with light petroleum, gave compound **4g** as a pale yellow oil); IR (film) ν_{max} 3054, 2924, 2852, 1685, 1585, 1580, 1553, 1433, 1353, 1260, 952, 801, 779; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 2.62 (3H, s), 2.85 (3H, s), 7.42–8.10 (9H, m); ^{13}C NMR (50 MHz, $CDCl_3$) δ 24.9, 29.3, 122.0, 124.4, 125.2, 125.3, 125.9, 126.5, 127.5, 128.3, 129.3, 130.9, 133.9, 137.2, 137.5, 158.1, 160.8, 200.1; MS (EI) m/z 261 (M^+, 100%), 247 (13), 204 (8), 190 (12), 177 (7), 156 (13), 142 (31), 128 (25), 110 (13), 77 (21), 58 (25), 44 (66). Anal. Calcd for $C_{18}H_{15}NO$: C, 82.73; H, 5.79; N, 5.36. Found: C, 82.64; H, 5.81; N, 5.41.

3.6. Representative procedure for the preparation of 5a–g

To a mixture of 3-dimethylamino-1-(4-nitrophenyl)-prop-2-enone **1e** (0.550 g, 2.5 mmol), dimedone **2c** (0.350 g, 2.5 mmol), ammonium acetate (0.385 g, 5 mmol) in isopropanol (5 mL) (*Method A*) was added $K_5CoW_{12}O_{40}\cdot 3H_2O$ (0.080 g, 0.025 mmol, 1.0 mol %) and refluxed for 120 min (monitored by TLC). The resulting mixture was worked out as described above to obtain pure **5e** as pale yellow compound (0.688 g, 93%). In solvent free conditions (*Method B*) the reaction mixture was stirred and heated at 115 °C for 45 min (monitored by TLC) and worked out as represented in the above procedure to afford pure pale yellow product **5e** (0.725 g, 98%).

3.6.1. 7,7-Dimethyl-5-oxo-2-(phenyl)-5,6,7,8-tetrahydroquinoline 5a. Yield 94%, mp 65–67 °C (MeOH); IR (KBr) ν_{max} 3059, 2950, 2867, 1678, 1581, 1446, 1395, 1304, 1186, 1122, 837, 778; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 1.15 (6H, s), 2.02 (2H, s), 3.08 (2H, s), 7.49 (3H, m), 7.70 (1H, d, J=7.5 Hz), 8.05 (2H, m), 8.26 (1H, d, J=8.3 Hz); ^{13}C NMR (50 MHz, $CDCl_3$) δ 25.2, 28.0, 32.6, 46.4, 51.7, 118.4, 125.2, 127.1, 128.5, 129.6, 136.7, 138.1, 160.6, 162.0, 197.3; MS (EI) m/z 251 (M^+, 76%), 236 (12), 223 (23), 208 (7), 195 (100), 167 (28), 141 (23), 77 (10). Anal. Calcd for $C_{17}H_{17}NO$: C, 81.24; H, 6.82; N, 5.57. Found: C, 81.19; H, 6.79; N, 5.66.

3.6.2. 7,7-Dimethyl-5-oxo-2-(4-methylphenyl)-5,6,7,8-tetrahydroquinoline 5b. Yield 91%, mp 120 °C (MeOH); IR (KBr) ν_{max} 3028, 2951, 2926, 2868, 1676, 1581, 1448, 1387, 1303, 1180, 802, 757; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 1.15 (6H, s), 2.42 (3H, s), 2.53 (2H, s), 3.10 (2H, s), 7.25 (2H, d, J=7.9 Hz), 7.65 (1H, d, J=8.3 Hz), 7.95 (2H, d, J=8.3 Hz), 8.25 (1H, d, J=8.3 Hz); ^{13}C NMR (50 MHz, $CDCl_3$) δ 21.1, 28.1, 32.7, 46.5, 51.9, 119.2, 125.1, 127.1, 129.9, 135.0, 139.9, 150.8, 160.8, 162.1, 197.5; MS (EI) m/z 265 (M^+, 40%), 236 (7), 209 (43), 181 (87), 154 (36), 140 (100), 71 (7), 43 (22). Anal. Calcd for $C_{18}H_{19}NO$: C, 81.47; H, 7.22; N, 5.28. Found: C, 81.39; H, 7.29; N, 5.31.

3.6.3. 7,7-Dimethyl-5-oxo-2-(4-chlorophenyl)-5,6,7,8-tetrahydroquinoline 5c. Yield 97%, mp 105 °C (MeOH); IR (KBr) ν_{max} 2954, 2929, 2867, 1683, 1576, 1416, 1300, 1090, 829, 807, 753; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 1.15 (6H, s), 2.52 (2H, s), 3.05 (2H, s), 7.42 (2H, d, J=8.6 Hz), 7.65 (1H, d, J=8.3 Hz), 8.0 (2H, d, J=8.8 Hz), 8.28 (1H, d, J=8.1 Hz); ^{13}C NMR (50 MHz, $CDCl_3$) δ 28.1, 32.8, 46.5, 51.9, 118.3, 125.6, 128.9, 129.5, 131.1, 135.3, 136.0, 136.6, 159.5, 162.3, 197.5; MS (EI) m/z 285 (M^+, 27%), 284 (25), 283 (82), 256 (31), 229 (100), 200 (17), 166 (95), 138 (32), 102 (20), 55 (31), 63 (37). Anal. Calcd for $C_{17}H_{16}ClNO$: C, 71.45; H, 5.64; N, 4.90. Found: C, 71.39; H, 5.59; N, 4.99.

3.6.4. 7,7-Dimethyl-5-oxo-2-(4-bromophenyl)-5,6,7,8-tetrahydroquinoline 5d. Yield 96%, mp 132 °C (MeOH); IR (KBr) ν_{max} 2953, 2928, 2867, 1678, 1574, 1413, 1378, 1299, 1070, 1008, 828, 806, 743; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 1.16 (6H, s), 2.52 (2H, s), 3.08 (2H, s), 7.59 (2H, d, J=9.0 Hz), 7.66 (1H, d, J=8.3 Hz), 7.95 (2H, d, J=8.3 Hz), 8.28 (1H, d, J=8.3 Hz); ^{13}C NMR (50 MHz, $CDCl_3$) δ 28.1, 32.8, 46.5, 51.9, 118.3, 124.5, 125.6, 128.8, 129.6, 131.8, 135.3, 137.1, 159.5, 162.3, 197.5; MS (EI) m/z 329 (M^+, 96%), 300 (18), 273 (93), 191 (8), 166 (100), 139 (32), 102 (26), 75 (28), 39 (95). Anal. Calcd for $C_{17}H_{16}BrNO$: C, 61.83; H, 4.88; N, 4.24. Found: C, 61.77; H, 4.91; N, 4.31.

3.6.5. 7,7-Dimethyl-5-oxo-2-(4-nitrophenyl)-5,6,7,8-tetrahydroquinoline 5e. Mp 182 °C (MeOH); IR (KBr) ν_{max} 3076, 2928, 2870, 1688, 1575, 1515, 1419, 1344, 835, 732; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 1.18 (6H, s), 2.59 (2H, s), 3.12 (2H, s), 7.80 (1H, d, J=8.3 Hz), 8.22–8.40 (5H, m); ^{13}C NMR (50 MHz, $CDCl_3$) δ 28.1, 32.8, 46.5, 51.9. 119.3, 123.8, 126.4, 128.1, 129.1, 135.6, 144.0, 148.5, 158.0, 162.5, 197.3; MS m/z 296 (M^+, 2%), 240 (3), 150 (100), 141 (20), 104 (73), 76 (31), 43 (100). Anal. Calcd for $C_{17}H_{16}N_2O_3$: C, 68.90; H, 5.44; N, 9.45. Found: C, 68.99; H, 5.36; N, 9.50.

3.6.6. 7,7-Dimethyl-5-oxo-2-(4-methoxyphenyl)-5,6,7,8-tetrahydroquinoline 5f. Yield 90%, mp 125 °C (MeOH); IR (KBr) ν_{max} 3071, 2959, 2932, 2840, 1676, 1580, 1510, 1447, 1307, 1254, 1173, 1028, 830, 809, 759; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 1.15 (6H, s), 2.52 (2H, s), 3.05 (2H, s), 3.90 (3H, s), 6.95 (2H, d, J=8.7 Hz), 7.65 (1H, d, J=8.0 Hz), 8.05 (2H, d, J=8.7 Hz), 8.25 (1H, d, J=8.0 Hz); ^{13}C NMR (50 MHz, $CDCl_3$) δ 28.2, 32.8, 46.6, 51.9, 55.2, 113.5, 114.1, 117.7, 124.8, 128.7, 130.4, 130.8, 135.0, 161.2, 162.2, 197.6; MS (EI) m/z 281 (M^+, 100%), 267 (6), 254 (8), 239 (8), 226 (61), 183 (11), 151 (28), 136 (95), 128 (22), 109 (10), 105 (10), 89 (35), 77 (44), 52 (35), 42 (55). Anal. Calcd for $C_{18}H_{19}NO_2$: C, 76.84; H, 6.81; N, 4.98. Found: C, 76.73; H, 6.88; N, 5.01.

3.6.7. 7,7-Dimethyl-5-oxo-2-(1-naphthyl)-5,6,7,8-tetrahydroquinoline 5g. Yield 95% (flash column chromatography on SiO_2, eluting with light petroleum, gave compound **5g** as pale yellow oil); IR (film) ν_{max} 3053, 2956, 2870, 1729, 1686, 1581, 1560, 1508, 1396, 1305, 1115, 848, 801, 778, 741, 663; ^{1}H NMR (300 MHz, $CDCl_3$, TMS) δ 1.20 (6H, s), 2.60 (2H, s), 3.15 (2H, s), 7.45–7.65 (5H, m), 7.85–7.95 (2H, m), 8.10 (1H, m), 835 (1H, d, J=8.3 Hz); ^{13}C NMR (50 MHz, $CDCl_3$) δ 28.2, 32.9, 46.5, 52.0, 123.5, 125.1, 125.2, 125.4, 125.9, 126.6, 127.7, 128.4, 129.5, 130.7, 133.9, 134.8, 137.5, 162.1, 163.3, 197.8; MS (EI) m/z 301 (M^+, 38%), 217 (11), 171 (16), 156 (50), 138 (11), 128 (71), 118 (57), 106 (46), 89 (27), 66 (51), 64 (93), 42 (100). Anal. Calcd for $C_{21}H_{19}NO$: C, 83.69; H, 6.35; N, 4.65. Found: C, 83.61; H, 6.41; N, 4.71.

Supplementary data

^{1}H NMR, ^{13}C NMR, EIMS, spectra for enaminones **1a–g**, 2,3,6-trisubstituted pyridines **3a–g** and **4a–g**, tetrahydroquinoline-5-ones **5a–g**. Supplementary data associated with this article can be found in the online version, at doi:10.1016/j.tet.2007.10.014.

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