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HIGH-YIELDING MICROWAVE ASSISTED SYNTHESIS OF QUINOLINE AND DIHYDROQUINOLINE DERIVATIVES UNDER SOLVENT-FREE CONDITIONS

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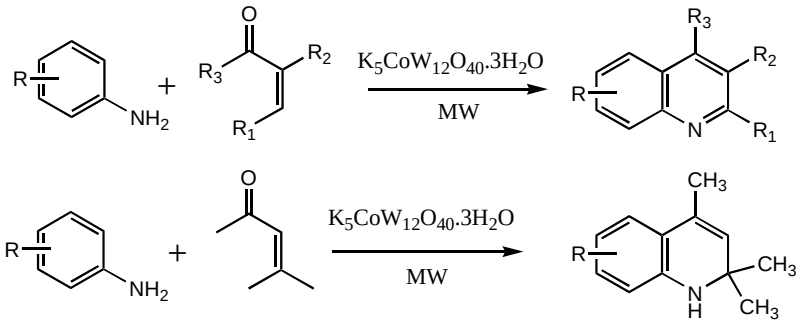
Abstract- A mild and efficient solvent-free method has been developed by two different approaches for the synthesis of quinoline and dihydroquinoline derivatives: (i) one-pot reaction of anilines with alkyl vinyl ketones (Skraup reaction) (ii) between various acetophenones and 2-aminoacetophenone (Friedländer reaction) using stable and effective heterogeneous catalyst potassium dodecatangestocobaltate (25 mol %) (PDTC) under microwave irradiation in high yields.

INTRODUCTION

Quinolines and its derivatives display a wide spectrum of biological activities such as antimalarial, antibacterial, antidiabetic, and anti-inflammatory behavior.[1] Furthermore cytotoxic agents like benzo[5,6]pyrrolizino[1,2-*b*]quinolines, antitumor agents like camptothecin also contain the quinoline ring system.[2] Recently quinolines are also shown for their formation of conjugated molecules and polymers that combine enhanced electronic, optoelectronic, or nonlinear optical properties with excellent mechanical properties.[3,4] The structural core of quinolines has generally been synthesized by various conventional routes such as Skraup, Döbner-von Miller, and Friedländer syntheses. Quinolines can be prepared from aminoarenes and olefins using transition metal complexes as catalysts.[5] The Skraup reaction is venerable reaction and it is one of the most simple and straightforward methods for synthesizing quinolines.[6] Classically, the process involves a series of reactions brought about by heating a primary aromatic amine, in which at least one position ortho to the amino group is unsubstituted, with glycerol, sulfuric acid, and an oxidizing agent. However, it requires a large amount of sulfuric acid at temperatures above 150^0C and the reaction is often violent. Further, the disposal of acid waste leads to

environmental pollution. Since then, several methods have been developed for the synthesis of quinolines; but most of these methods suffer from one or the other limitations such as drastic reaction conditions,[7a,c,e,f] undesired side products, generality,[7b,d,e] low yield,[7a,c,e,g] and expensive transition metal-catalyzed reagents.[7h,i] Consequently, there is scope for further renovation toward mild reaction conditions, increased variation of the substituents in both components, and better yields.

In recent years, much attention has focused on microwave-assisted organic reactions[8] in the absence of solvent. Often, thermal demanding reactions take hours in solution, and may require repetitive treatments with excess reagents to drive them to completion. However, with microwave irradiation these same reactions may be completed in few minutes. In continuation of our ongoing efforts in this area,[9] we envisioned the applicability of potassium dodecatangestocobaltate trihydrate ($K_5CoW_{12}O_{40}.3H_2O$, PDTC)[10] was found to be the most suitable catalyst for the synthesis of substituted quinolines or dihydroquinolines from readily available anilines and alkyl vinyl ketones under microwave irradiation because of its availability, low cost and ease of recycling (Scheme 1). In a typical general experimental procedure involves the irradiation of a mixture of the aniline and alkyl vinyl ketone by microwave in a domestic microwave oven for a certain period of time as required to complete the reaction (TLC), resulting in the formation of substituted quinolines (Scheme 1).



Scheme 1

The reaction mixture was then eluted with ethyl acetate and the extract was washed with brine, dried and evaporated to obtain the crude material, which was purified by column chromatography over silica gel. Preliminary optimization of reaction conditions was performed using 2,3,4-trimethoxyaniline and methyl vinyl ketone (Entry 5 in Table 3). Optimal conditions for the synthesis were found to be 10 –15 min reaction time using 500 W of microwave irradiation power. We first examined the reaction time and temperature effects when 25 mol% of PDTC was used under microwave irradiation. As time increased, the reaction temperature also increased and the maximum yield (88%) was obtained after 15 min as illustrated in Table 1, Entry 3. The temperature was one of the key factors that improved the yields but a longer time and a higher temperature did not increase the yield (Table 1, Entry 4).

Table 1. Optimization of the reaction time in the synthesis of substiuted quinoline (**2e**) under microwave irradiation or conventional heating in a thermostated oil bath (scale = 3 mmol, ratio of aniline:alkyl vinyl ketone:PDTC = 1:1.5:0.25)

Entry	Time (min)	Temp.(0^0C)[a]	Yield (%)	
			Microwave[b]	Conventional
1	5	75	32	
2	10	100	65	
3	15	110	88	27[c]
4	20	130	85	

[a] Temperature of reaction mixture was recorded after the microwave irradiation at the given reaction time. [b] The reactions were carried out in a 2450 MHz commercial microwave oven (BatliboiEddy, model # FR-5054-D). [c] Oil bath temperature = 110^0C.

In order to evaluate the influence of PDTC, the reactions were carried out using different PDTC equivalents. It should be pointed out that cyclization is enhanced by PDTC as shown in Table 2. In the absence of PDTC, microwave irradiation effect was not observed in the synthesis of quinolines at 110^0C Table 2, Entry 1). However, when 25 mol % of PDTC was added, the yield was increased up to 88 % Table 2, Entry 3). PDTC in excess of 25 mol % did not help to increase the yield Table 2, Entry 5).

Table 2. Optimization of the PDTC equivalents and reaction time in the synthesis of substiuted quinoline (**2e**) under microwave irradiation (scale = 3 mmol, ratio of aniline:alkyl vinyl ketone = 1 equiv.:1.5 equiv.)

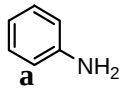
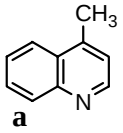
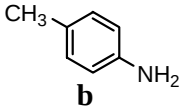
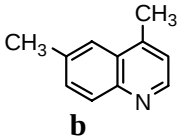
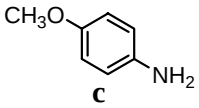
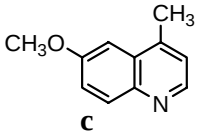
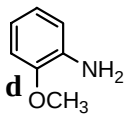
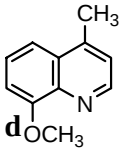
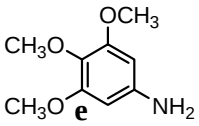
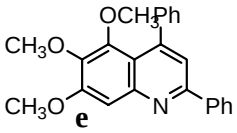
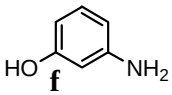
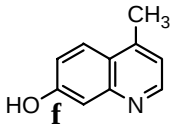
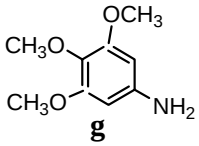
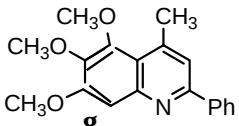
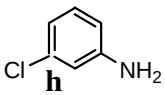
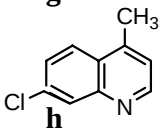
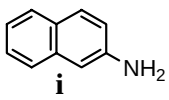
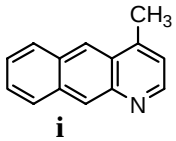
Entry	PDTC (mol %)	Time (min)	Yield (%)	
			Microwave	Conventional
1	0	5	15	2[a]
2	5.0	5	32	–
3	10.0	15	65	15[a]
4	25.0	15	88	27[a]
5	50.00	25	85	38[b]
6	75.0	360	83	

[a] Oil bath temperatre = 110^0C. [b]Oil bath temperature = 130^0C.

To check the possibility of intervention of specific (non purely thermal) microwave effects, the reaction has also been examined using a pre-heated oil bath for the same duration and at the same final temperature as measured at the end of exposure during the microwave-assisted synthesis. It was found that reaction proceeded slowly with 15-27 % yield in 15 min (Table 2, Entries 3 and 4) whereas 38 % of diphenylquinolines was obtained after 360 min under conventional heating at 130^0C (Table 2, Entry 6).

In an effort to optimize this process, a wide range of substituted anilines and structurally diverse alkyl vinyl ketones were subjected to this procedure to produce the corresponding quinolines or dihydroquinolines in moderate to high yields without side products (Table 3).

Table 3. $K_5CoW_{12}O_{40}.3H_2O$-catalyzed synthesis of quinolines under solvent-free conditions

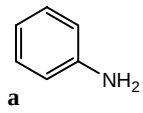
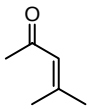
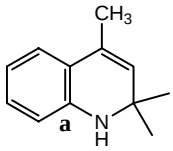
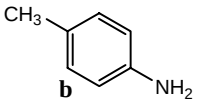
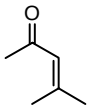
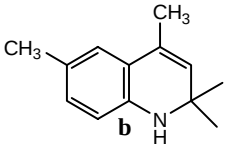
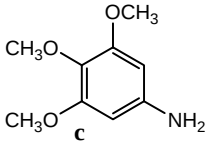
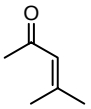
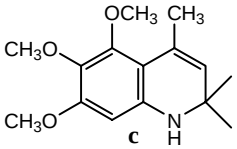
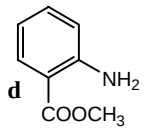
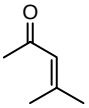
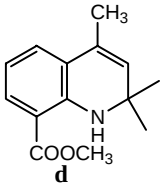
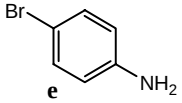
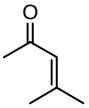
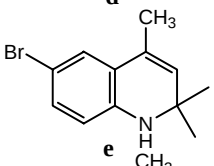
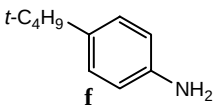
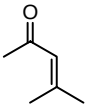
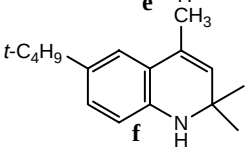
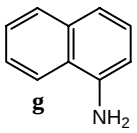
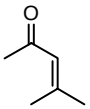
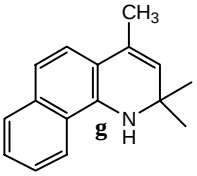
Entry	Substrate R (**1**)	R_1	R_2	R_3	Time (min.)	Product (**2**)[a]	Yield (%)[b]
1	 **a**	H	H	CH_3	8	 **a**	75
2	 **b**	H	H	CH_3	10	 **b**	78
3	 **c**	H	H	CH_3	10	 **c**	85
4	 **d**	H	H	CH_3	12	 **d**	81
5	 **e**	Ph	H	Ph	10	 **e**	88
6	 **f**	H	H	CH_3	15	 **f**	80
7	 **g**	Ph	H	CH_3	12	 **g**	82
8	 **h**	H	H	CH_3	10	 **h**	74
9	 **i**	H	H	CH_3	10	 **i**	77

[a]All the Products were characterized by IR, ^{1}HNMR, ^{13}CNMR and MS spectra.
[b] Yields refer to pure isolated products.

However, use of a β-substituted alkyl vinyl ketone such as mesityl oxide leads to the formation of a dihydroquinoline ring. This may be because of the presence of two methyl groups at the carbon adjacent to NH prevents aromatization to the quinoline ring. The results are depicted in Table 4. It is noteworthy to mention here that the yield of this reaction strongly depends on the relative amount of the starting materials used (a 2:1 molar ratio of the alkyl vinyl ketone versus aniline gave the optimal yield (65-88%)

of substituted quinoline). Furthermore, the reaction remains incomplete with lower amounts of the oxidant even after extended exposure to microwaves. *It is essential to work in an open vessel to enable the low volatile formed either from the reaction mixture or excess alkyl vinyl ketones to escape from the reaction*

Table 4. $K_5CoW_{12}O_{40}.3H_2O$-catalyzed synthesis of dihydroquinolines

Entry	Aniline R (**1**)	Alkyl vinyl ketone	Time (min.)	Product (**2**)	Yield (%)[a]
1	 **a**		15	 **a**	78
2	 **b**		20	 **b**	65
3	 **c**		15	 **c**	80
4	 **d**		25	 **d**	68
5	 **e**		20	 **e**	72
6	 **f**		15	 **f**	67
7	 **g**		15	 **g**	75

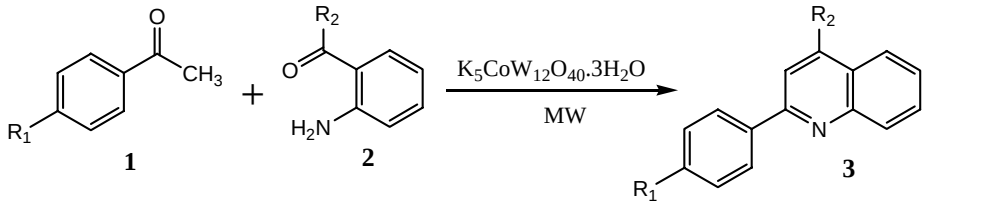
[a] Yeilds refer to those of pure isolated products fully characterized by spectral (IR, ^1H,^{13}C NMR and MS spectra) and analytical data.

mixture. Synthesis of these compounds using analogue methodology, employing conventional heating, requires a large excess of highly toxic anilines.

To investigate further the scope and limitations of the above optimal condition, quinoline and dihydroquinoline derivatives was synthesized. The results from Table 3 reveal that the microwave-assisted synthesis provides an efficient way to access a variety of 4-substituted quinolines under solvent-free conditions. In general, the yields of quinolines are not affected by the nature of substituents on the

aniline and alkyl vinyl ketone. In the case of *m*-substituted anilines, only one regioisomeric quinoline corresponding to the *p*-cyclization is formed. Presumably, this process involves Michael addition of the aniline to the vinyl ketone[11] followed by subsequent cyclization and aromatization under the catalysis of $K_5CoW_{12}O_{40}.3H_2O$.[12] However, this reaction does not proceed with acrolein (or vinyl aldehyde in general) yielding instead the corresponding imine. Another important aspect of this procedure is survival of functional groups such as OCH_3, CN under the reaction conditions. By conventional heating method (oil bath) at 110^0C in place of microwave activation induces considerable polymerization of vinyl ketones reducing the yield of quinolines drastically.

We have also studied Friedländer[13] coupling condensation reaction by using the same catalyst $K_5CoW_{12}O_{40}.3H_2O$ between various acetophenones and 2-aminoacetophenone or benzophenone under microwave irradiation to obtain quinoline derivatives (Scheme 2). We first examined the reaction time and temperature effects when 25mol % of catalyst $K_5CoW_{12}O_{40}.3H_2O$ was used under microwave irradiation. As time increased, the reaction temperature also increased and the maximum yield (78%) was obtained after 10 min at 110^oC as shown in Scheme 2 **3b**. The temperature was one of the important factors that improved the yields but a longer time and a higher temperature did not increase the yield.



a: R_1 = Cl, R_2 = Ph (65%)
b: R_1 = CH_3, R_2 = Ph (78%)

Scheme 2

In summary, microwave-assisted solvent-free reactions were employed to synthesize quinoline derivatives. The method not only offers substantial improvement in yield over conventional heating methods but also eliminates the use of hazardous solvents and excess expensive acid catalyst. Advantages of this method include the fact that it is environmentally benign, an economical procedure, has a short reaction time and involves inexpensive reagents and can be effectively applied to large-scale synthesis of quinolines in high yields.

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EXPERIMENTAL

Reagents and all solvents were analytically pure grade and were used without further purification. Anhydrous conditions were not required for this reaction. ^{1}H NMR spectra were recorded on Varian FT-200 MHz (Gemini) in $CDCl_3$. Chemicals shifts are reported in parts per million (δ) relative to

tetramethylsilane (δ 0.0) as an internal standard. Mass spectra were recorded under electron impact at 70eV on Finnigan Mat 1020B mass spectrometer. Melting points were recorded on Büchi 535 and are uncorrected. 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 silica gel plates.

A typical procedure for 2,4,-diphenyl-5,6,7-trimethoxyquinoline synthesis is as follows: A mixture of 3,4,5-trimethoxyaniline (3.66 g, 20 mmol) and 1,3-diphenylprop-2-en-1-one (6.24 g, 30 mmol) was added to potassium dodecatangestocobaltate (80 mg, 0.01 mmol) and the whole mixture was stirred for few minutes for uniform mixing. This mass was then irradiated by microwave in a domestic microwave oven (BatliboiEddy, model # FR-5054-D) at 500W for 2 min intervals. After this heating, a period of 30 sec was allowed for cooling to prevent excess heating. This process was repeated 5-8 times (i.e. total of 10-15 min). The reaction mixture is allowed to attain room temperature, the solid mass was dissolved in ethyl acetate (2x15 mL), filtered to separate the catalyst and the crude product quinoline (**2e**, Table 3) isolated in pure form by passing through a silica gel column chromatography (petroleum ether-ethyl acetate 9:1) as a yellow oil (6.52 g, 88%). IR 3024, 1616, 1519 cm^{-1}; ^{1}HNMR ($CDCl_3$): δ 3.22 (s, 3H), 3.91(s, 3H), 4.06(s, 3H), 7.38-7.55(m, 11H), 8.12(d, *J* = 4.4 Hz, 1H). ^{13}CNMR ($CDCl_3$): δ 56.0, 60.6, 61.0, 96.2, 105.5, 119.7, 126.9, 127.1, 127.4, 128.4, 128.7, 129.1, 139.5, 142.3, 147.2, 147.6, 148.7, 155.7; EIMS: *m/z* (%) 371 (M^+, 62), 324(8), 117(100), 84(44), 47(21). Anal. Calcd for $C_{24}H_{21}NO_3$: C, 77.60; H. 5.70; N, 3.77. Found: C, 77.45; H, 5.59; N, 3.73.

4,6-Dimethylquinoline (**2b**, Table 3). Yellow oil (85%); 3000, 1625, 1500 cm^{-1}; ^{1}HNMR δ 2.58 (s, 3H), 2.67 (s, 3H), 7.12 (d, *J* = 4.1 Hz, 1H), 7.58 (d, *J* = 8.5 Hz, 1H), 7.78 (s, 1H), 8.02 (d, *J* = 8.5 Hz, 1H), 8.73 (d, *J* = 4.1 Hz, 1H). ^{13}CNMR ($CDCl_3$): δ 18.4, 21.6, 121.8, 122.6, 128.5, 128.9, 131.3, 136.2, 144.0, 145.6, 148.8; EIMS: *m/z* (%) 157 (M^+, 38), 117(100), 106 (12), 84(100), 77 (10), 51 (28), 49 (93). Anal. Calcd for $C_{11}H_{11}N$: C, 84.04; H. 7.05; N, 8.91. Found: C, 83.93; H, 7.02; N, 8.85.

6-Methoxy-4-methylquinoline (**2c**, Table 3). Yellow oil (85%); IR 3017, 1615, 1500 cm^{-1}; ^{1}HNMR δ 2.45 (s, 3H), 3.88 (s, 3H), 7.15-7.19 (m, 2H), 7.36 (d, *J* = 9.0 Hz, 1H), 8.02 (d, *J* = 9.0 Hz, 1H), 8.61 (d, *J* = 4.4Hz). ^{13}CNMR δ 17.4, 53.6, 110.0, 112.0, 120.2, 127.5, 127.7, 141.2, 142.0, 146.2, 156.0. Anal. Calcd for $C_{11}H_{11}NO$: C, 76.28; H. 6.40; N, 8.09. Found: C, 76.23; H, 6.32; N, 8.01.

8-Methoxy-4-methylquinoline (**2d**, Table 3). Yellow oil (81%); IR 3085, 1620, 1520 cm^{-1}; ^{1}HNMR δ 2.69 (s, 3H), 3.90 (s, 3H), 7.18-7.22 (m, 2H), 7.45 (t, *J* = 6.0 Hz, 1H), 8.02 (d, *J* = 6.0 Hz, 1H), 8.75 (d, *J*

= 4.5Hz, 1H); ^{13}CNMR ($CDCl_3$): δ 17.9, 54.0, 109.3, 118.0, 122.5, 125.4, 128.1, 135.8, 140.2, 148.0, 155.2. Anal. Calcd for $C_{11}H_{11}NO$: C, 76.28; H. 6.40; N, 8.09. Found: C, 76.18; H, 6.33; N, 8.04.

7-Hydroxy-4-methylquinoline (**2f**, Table 3). Yellow oil (65%); IR 3380, 1610, 1505cm-1; ^{1}HNMR δ 2.72 (s, 3H), 7.28 (m, 2H), 7.52 (d, *J* = 9.0 Hz, 1H), 7.95 (d, *J* = 9.0 Hz, 1H), 8.11 (d, *J* = 1.2 Hz, 1H), 8.76 (d, *J* = 6.0 Hz, 1H). ^{13}CNMR ($CDCl_3$): δ 8.76 (d, *J* = 6.0 Hz, 1H). ^{13}CNMR ($CDCl_3$): δ 17.4, 110.0, 121.5, 122.0, 127.2, 131.8, 140.0, 142.2, 150.0, 155.4. Anal. Calcd for $C_{10}H_9NO$: C, 75.45; H. 5.70; N, 8.80. Found: C, 75.36; H, 5.67; N, 8.72.

2-Phenyl-4-methyl-5,6,7-trimethoxyquinoline (**2g**, Table 3). Yellow oil (82%); IR 3020, 1615, 1525 cm^{-1}; ^{1}HNMR ($CDCl_3$): δ 2.75 (s, 3H), 3.21 (s, 3H), 3.89 (s, 3H), 4.02 (s, 3H), 7.38-7.55 (m, 6H), 8.12 (d, *J* = 4.4 Hz, 1H). EIMS: *m/z* (%) 309 (M^+, 100), 294(45), 266(100), 84(38), 251(27), 180(26), 141(35), 71(48), 57(81), 43(78). Anal. Calcd for $C_{19}H_{19}NO_3$: C, 73.76; H. 6.19; N, 4.53. Found: C, 73.69; H, 6.14; N, 4.50.

7-Chloro-4-methylquinoline (**2h**, Table 3). Yellow oil (74%); IR 3020, 1600, 1510 cm^{-1}; ^{1}HNMR δ 2.70 (s, 3H), 7.28 (d, *J* = 4.2 Hz, 1H), 7.55 (dd, *J* = 9.0, 1.8 Hz, 1H), 7.95 (d, *J* = 9.0 Hz, 1H), 8.14 (d, *J* = 1.8 Hz, 1H), 8.75 (d, *J* = 4.2 Hz, 1H). ^{13}CNMR ($CDCl_3$): δ 18.5, 121.0, 125.5, 127.4, 128.0, 129.2, 135.4, 145.0, 147.2, 150.4. Anal. Calcd for $C_{10}H_8NCl$: C, 67.62; H. 4.54; N, 7.89. Found: C, 67.58; H, 4.51; N, 7.82.

4-Methyl-7,8-benzoquinoline (**2i**, Table 3). Yellow oil (77%); IR 3040, 1600, 1510 cm^{-1}; ^{1}HNMR δ 2.75 (s, 3H), 7.31 (d, *J* = 4.5 Hz, 1H), 7.68-7.85 (m, 5H), 8.82 (d, *J* = 4.5 Hz, 1H), 9.28 (d, *J* = 8.1 Hz, 1H); ^{13}CNMR ($CDCl_3$): δ 19.5, 121.9, 122.7, 123.9, 125.0, 125.5, 126.4, 126.6, 127.5, 128.0, 133.0, 138.0, 147.0, 147.8. Anal. Calcd for $C_{14}H_{11}N$: C, 87.01; H. 5.74; N, 7.25. Found: C, 86.96; H, 5.68; N, 7.23.

2,2,4-Trimethyl-1,2-dihydroquinoline (**2a**, Table 4). colorless oil (78%); IR 3355 cm^{-1}; ^{1}HNMR δ 1.25 (s, 6H), 1.98 (d, *J* = 1.3 Hz, 3H), 5.25 (s, 1H), 6.45 (dt, *J* = 1.1, 7.5 Hz, 1H), 6.65 (dt, *J* = 1.1, 7.5 Hz, 1H), 7.01 (dt, *J* = 1.4, 7.6 Hz, 1H), 7.08 (dd, *J* = 1.4, 7.6 Hz, 1H); ^{13}CNMR ($CDCl_3$): δ 19.1, 31.0 (2C), 52.2, 113.3, 117.5, 122.0, 123.8, 128.5 (2C), 129.1, 130.2, 141.6. Anal. Calcd for $C_{12}H_{15}N$: C, 83.19; H. 8.73; N, 8.08. Found: C, 83.06; H, 8.62; N, 7.98.

2,2,3,6-Tetramethyl-1,2-dihydroquinoline (**2b**, Table 4). colorless oil (65%); IR 3365 cm^{-1}; ^{1}HNMR δ 1.25 (s, 6H), 1.98 (d, *J* = 1.0 Hz, 3H), 2.25 (s, 3H), 5.30 (d, *J* = 1.0 Hz, 1H), 6.35 (d, *J* = 7.8 Hz, 1H), 6.76

(dd, *J* = 2.3, 7.8 Hz, 1H), 6.88 (s, 1H); ^{13}CNMR ($CDCl_3$): δ 19.1, 21.0, 31.4 (2C), 52.1, 96.3, 113.2, 124.5, 126.8, 129.8, 129.2, 129.3, 141.6. Anal. Calcd for $C_{13}H_{17}N$: C, 83.37; H. 9.15; N, 7.48. Found: C, 83.22; H, 8.97; N, 7.34.

2,2,4-Trimethyl-5,6,7-trimethoxydihydroquinoline (**2c**, Table 4). Yellow crystal (80%), (recrystallization solvent EtOAc-hexane). mp 93-95^{0}C; IR 3385, 1600 cm^{-1}; ^{1}HNMR δ 1.22 (s, 6H), 2.12 (s, 3H), 3.42-3.64 (br s, 1H), 3.72 (s, 3H), 3.76 (s, 3H), 3.85 (s, 3H), 5.12 (s, 1H), 5.78 (s, 1H). ^{13}CNMR ($CDCl_3$): δ 22.1, 29.7 (2C), 50.9, 55.7, 60.9, 61.0, 93.7, 108.6, 127.9, 128.6, 134.6, 141.0, 153.2. EIMS: *m/z* (%) 263 (M^+, 5), 249(100), 218(45), 190(28), 147(23), 118 (15). Anal. Calcd for $C_{15}H_{21}NO_3$: C, 68.41; H. 8.04; N, 5.32. Found: C, 68.29; H, 7.92; N, 5.26.

8-Carbomethoxy-2,2,4-trimethyl-1,2-dihydroquinoline (**2d**, Table 4). colorless oil (68%); IR 3327, 1680 cm^{-1}; ^{1}HNMR δ 1.21 (s, 6H), 1.95 (s, 3H), 3.42-3.64 (br s, 1H), 3.81 (s, 3H), 5.30 (s, 1H), 6.43 (t, *J* 7.3 Hz, 1H), 7.15 (d, *J* = 7.3 Hz, 1H), 7.62 (d, *J* = 8.2 Hz, 1H), 7.90 (bs, 1H). ^{13}CNMR ($CDCl_3$): δ 19.6, 33.0 (2C), 51.6, 52.1, 96.4, 114.5, 122.5, 128.0, 128.2, 129.0, 131.0, 147.8, 169.5. Anal. Calcd for $C_{14}H_{17}NO_2$: C, 72.70; H. 7.41; N, 6.06. Found: C, 72.58; H, 7.35; N, 6.03.

6-Bromo-2,2,4-trimethyl-1,2-dihydroquinoline (**2e**, Table 4). Pale yellow crystal (72%); (recrystallization solvent EtOAc-hexane). mp 76-78^{0}C; IR 3370, 755 cm^{-1}; ^{1}HNMR δ 1.23 (s, 6H), 2.25 (s, 3H), 3.45-3.48 (br s, 1H), 5.29 (s, 1H), 6.29 (d, *J* = 8.3 Hz, 1H), 7.05 (dd, *J* = 2.3, 8.3 Hz, 1H), 7.10 (d, *J* = 2.2 Hz, 1H), ^{13}CNMR ($CDCl_3$): δ 19.0, 31.0 (2C), 52.2, 109.0, 114.5, 122.5, 126.7, 128.2, 129.0, 131.0, 142.8. Anal. Calcd for $C_{12}H_{14}NBr$: C, 57.16; H. 5.60; N, 5.55. Found: C, 57.06; H, 5.51; N, 5.49.

6-*tert*-Butyl-2,2,4-trimethyl-1,2-dihydroquinoline (**2f**, Table 4). Pale yellow oil (67%); IR 3350, 750 cm^{-1}; ^{1}HNMR δ 1.23 (s, 6H), 1.27 (s, 9H), 2.01(s, 3H), 5.25 (s, 1H), 6.34 (d, *J* = 8.3 Hz, 1H), 6.96 (dd, *J* = 2.3, 8.3 Hz, 1H), 7.02 (s, 1H); EIMS: *m/z* (%) 229 (M^+, 5), 214(100), 198(27), 86(13). Anal. Calcd for $C_{16}H_{23}N$: C, 83.78; H. 10.11; N, 6.11. Found: C, 83.55; H, 9.85; N, 6.06.

2,2,4-Trimethyl-1,2-dihydro[7,8]benzoquinoline (**2g**, Table 4). Colourless oil (75%); IR 3417, cm^{-1}; ^{1}HNMR δ 1.25 (s, 6H), 2.25 (s, 3H), 5.31 (s, 1H), 7.26 (d, *J* = 8.5 Hz, 1H), 7.42-7.46 (m, 3H), 7.77-7.80 (m, 2H). ^{13}CNMR ($CDCl_3$): δ 19.5, 31.4(2C), 52.3, 116.0, 116.5, 120.5, 122.5, 123.0, 125.2, 125.7, 126.7, 129.0, 123.0, 134.2, 138.8. Anal. Calcd for $C_{16}H_{17}N$: C, 86.05; H. 7.67; N, 6.27. Found: C, 85.85; H, 7.52; N, 6.23.

2-(*p*-Chlorophenyl)-4-phenylquinoline (**3a**): yellow crystal (65%). (recrystallization solvent EtOAc-hexane). mp 106-108^{0}C; .^{1}HNMR δ 7.38-7.61 (m, 8H), 7.66-7.78 (m, 2H), 7.84-7.92 (m, 1H), 8.12-8.204 (m, 3H); ^{13}CNMR ($CDCl_3$): δ 118.1, 125.0, 125.2, 126.5, 127.77 (8C), 134.8, 137.2, 137.3, 148.6, 150.0, 154.7, 196.0. EIMS: *m/z* (%) 315 (M^+, 100), 202(15), 154(11), 139 (85), 111 (33), 43 (9). Anal. Calcd for $C_{22}H_{17}N$: C, 89.46; H. 5.80; N, 4.74. Found: C, 89.27; H, 5.69; N, 4.71.

2-(*p*-Methylphenyl)-4-phenylquinoline (**3b**): yellow crystal (78%). (recrystallization solvent EtOAc-hexane). mp 74-76^{0}C; ^{1}HNMR δ 2.41 (s, 3H), 7.21-7.65 (m, 9H), 7.67-7.92 (m, 4H), 8.06-8.25 (m, 4H); ^{13}CNMR ($CDCl_3$): δ 22.5, 118.5, 126.2, 127.1, 127.7 (8C), 135.3, 137.2, 138.9, 140.2, 143.7, 149.8, 158.2, 170.0, 198.5. EIMS: *m/z* (%) 295 (M^+, 100), 202(7). Anal. Calcd for $C_{21}H_{14}NCl$: C, 80.10; H. 4.45; N, 4.44. Found: C, 79.46; H, 4.50; N, 4.39.

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