CHAPTER 2

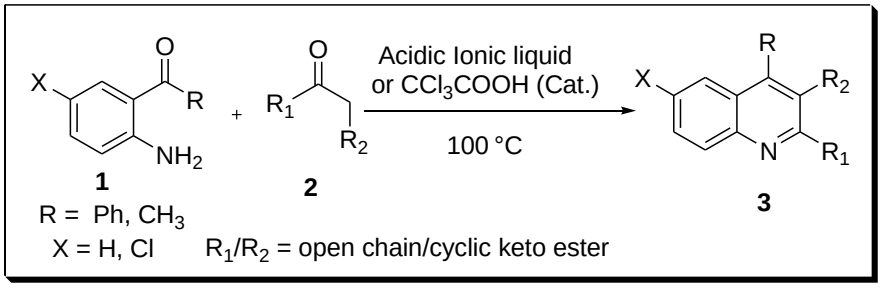
Synthesis, characterization and applications of Brønsted acidic ionic liquids (BAILs) as catalyst/medium for the preparation of quinoline derivatives

Section 2A:

Studies on Brønsted acidic imidazolium task-specific ionic liquids (TSILs) for the synthesis of quinoline derivatives via Friedländer annulation

2A.1 Introduction

Quinoline nucleus is one of the most biologically active compounds which possess various medicinal properties. The literature search revealed that organic reactions performed by using ionic liquids are gaining wide success from different point of view like time, cost, and environmental reason. The ionic liquid mediated Friedländer annulation seems to be one of the straightforward evergreen strategies for the synthesis of quinoline derivatives which commonly involves acid or base catalyzed thermal condensation of 2-aminoaryl ketone with carbonyl analogue possessing a reactive α-methylene group followed by cyclodehydration (**Scheme 2A.1**) [1]. A variety of metal salts have been employed as Lewis acid catalysts for the Friedländer synthesis in addition to traditional Brønsted acids as described in **Chapter 1** [2-5]. However, most of them are not fully satisfactory with respect to operational simplicity, use of large amount of relatively toxic or expensive non-reusable catalysts, volatile organic solvents and low yields. The unique properties of acidic ionic liquids make them as recyclable catalyst and medium in different types of organic transformation under various conditions [6-7]. Some ionic liquids act as medium for the Friedländer annulations in presence of added acid catalysts with longer reaction time, high temperature reaction and less product formation [8]. Few reports have described the dual applications of task-specific ILs as catalyst and medium in this synthesis with variation of reaction times which again depend on the acidity and thermal stability of acidic ILs [9]. The potential applications of $–SO_3H$ functionalized ILs in organic synthesis inspired us to study sulfoimidazolium ILs as catalyst or medium for the Friedländer annulations [10-12].



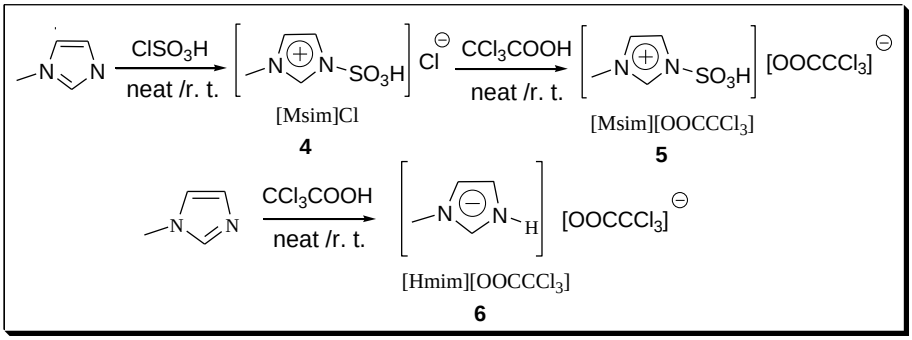
Scheme 2A.1 Preparation of quinoline derivatives

In this section, two sulfoimidazolium ILs 3-methyl-1-sulfonic acid imidazolium trichloroacetate ([Msim][OOCCCl$_3$]) (**5**) and 3-methyl-1-sulfonic acid imidazolium chloride ([Msim][Cl]) (**4**) were synthesized according to the **Scheme 2A.2.** After characterization of novel ([Msim][OOCCCl$_3$]) IL, the acidity and thermal stability of (**5**) was compared with known [Msim][Cl] and another new Brønsted acidic IL 1-methyl imidazoliumtrichloroacetate ([Hmim][OOCCCl$_3$]) (**6**) prepared from the reaction of trichloroacetic acid and 1-methylimidazole (**Scheme 2A.2**). By knowing the acidity and thermal stability of the three ILs, their catalytic performance were examined for the Friedländer synthesis of quinoline derivatives (**3**) by the condensation of 2-aminoacetophenone or benzophenone (**1**) derivatives with a variety of ketones and keto esters (**2**) and compared with CCl_3COOH catalyst at various condition (**Scheme 2A.1**).

2A.2 Results and discussion

2A.2.1 Synthesis and characterization of ionic liquids

Two novel ILs [Msim][OOCCCl$_3$] (**5**) and [Hmim][OOCCCl$_3$] (**6**) were prepared from the reaction of CCl_3COOH acid with [Msim][Cl] (**4**) ionic liquid and 1-methylimidazole respectively at room temperature stirring (**Scheme 2A.2**).



Scheme 2A.2 Synthetic approach of three ILs (**4**), (**5**) and (**6**)

2A.2.1a Spectral analysis

The synthesized ionic liquids were analysed by FT-IR, ^{1}H NMR, ^{13}C NMR and CHN techniques. The FT-IR spectra showed strong carbonyl absorption at 1639-1653 cm^{-1} for both ionic liquids due to carboxylate anions. The strong bands of [Msim][$OOCCCl_3$] IL at 1217, 1053 and 585 cm^{-1} were associated with the stretching and bending vibrations of –SO_3H group (**Figure 2A.1**). In the ^{1}H NMR spectra the –SO_3H acid proton appears at 14.1 ppm as singlet. The carbonyl and CCl_3 peaks of [$OOCCCl_3$] anions appeared at 162-163 ppm and 92 ppm respectively in the ^{13}C NMR spectra for both ILs. For [Hmim][$OOCCCl_3$] ionic liquid, the –N^{+}H proton observed at 4.14 ppm (s) in the ^{1}H NMR spectra. The elemental analysis data further confirmed the structure of two new ILs.

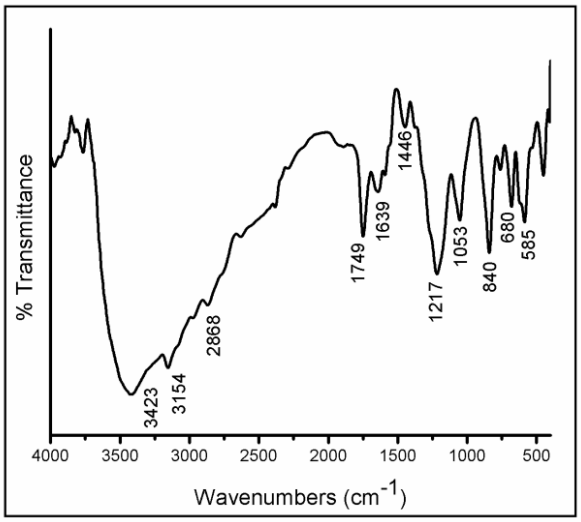


Figure 2A.1 FT-IR spectra of IL [Msim][$OOCCCl_3$]

2A.2.1b Thermal analysis

The TGA analyses of the three ILs (**4**, **5**, **6**) were performed on thermogravimetric analyser to observe the thermal stability. The TGA curve (**Figure 2A.2**) of [Hmim][$OOCCCl_3$] ionic liquid notifies weight loss about 90% in one step at 98.9 ºC. The reason for this weight loss may be decreasing the ionic bond strength of imidazolium cation and carboxylate anion with rising temperature than ambient condition which was completely decomposed around 100 ºC. A slight (approx. 15%) weight loss of [Msim][$OOCCCl_3$] below 100 ºC was observed which may be due to the elimination of absorbed water from the IL. From the analysis, it has been found that the thermal stability of [Msim][$OOCCCl_3$] ionic liquid is higher (273.7 ºC) than the stability of parent [Msim][Cl] ionic liquid (225.2 ºC) (**Figure 2A.2**).

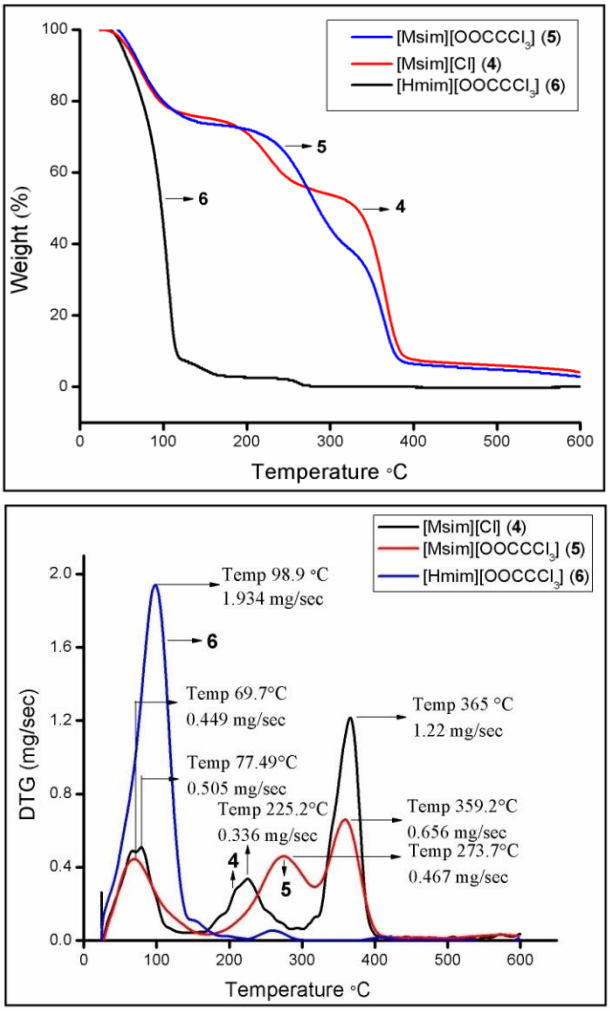


Figure 2A.2 TGA and DTGA diagram of ILs (**4**), (**5**) and (**6**)

2A.2.1c Acidity determination

In order to compare the acidity of the new ILs with the known [Msim][Cl] IL, an UV-Vis spectrophotometer was used through the Hammett method in presence of 4-nitroaniline as basic indicator [13-14]. The absorbance of the indicator decreases (**Figure 2A.3**) with increasing the acidities of the ionic liquids. The protonated form [HI^+] of the indicator did not appear in the spectra because of smaller molar absorptivity.

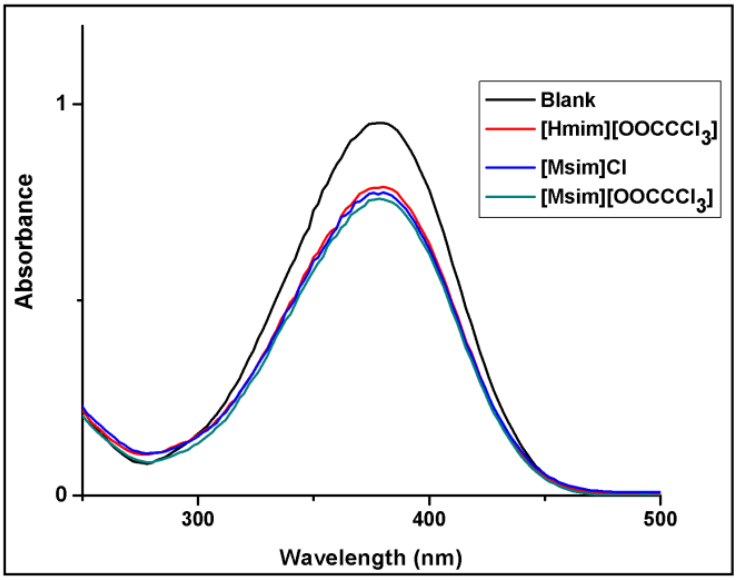


Figure 2A.3 Absorption spectra of 4-nitroaniline for various acidic ILs in ethanol

The Hammett function H_0 can be calculated from the observed absorption differences by using equation – (1).

$$H_0 = pK(I)aq + \log([I]/[IH^+]) \qquad (1)$$

Where p*K*(I)aq is the p*K*a value of the basic indicator in aqueous solution and [I] is the unprotonated basic indicator. Solution of both basic indicator 4-nitroaniline (5 mg/dm^3, p*K*a = 0.99) and IL (5 mmol/dm^3) in ethanol with similar concentration were prepared to determine the H_0 of the Brønsted acidic ILs. The indicator gives a maximal absorbance at 382 nm in ethanol. From the Hammett study the relative acidity of the three ILs was observed according to their decreasing order as follows: [Msim][$OOCCCl_3$] > [Msim][Cl] >

[Hmim][$OOCCCl_3$] which was also supported by the p*K*a values of the ILs (**Table 2A.1**). The acidity of chlorosulfonic acid based ionic liquids depends on the strength of ionic bond between [Msim] cation and anion which was found to be more with the stable carboxylate anion due to resonance.

Table 2A.1 Calculation of the Hammett Function for various ILs in ethanol

Entry	ILs	A_{max}	[I]%	[IH]%	H_0	p*K*a[a]
1	Blank	1.526	100.0	0	-	-
2	[Hmim][$OOCCCl_3$]	1.299	84.9	14.1	1.76	2.75
3	[Msim][Cl]	1.209	79.2	20.8	1.57	2.5
4	[Msim][$OOCCCl_3$]	1.196	78.4	21.6	1.54	2.25

[a] Indicator: 4-nitroaniline

2A.2.2 Applications of ILs for the quinoline synthesis

After observing the acidity of ILs, the efficiency of these acidic ILs was examined as medium or catalyst for the synthesis of quinolines. For the study, a typical reaction of 2-aminobenzophenone (1 mmol) and 5,5-dimethyl-1,3-cyclohexanedione (1 mmol) was carried out at different temperature range. The optimization results revealed that the role of sulfoimidazolium ionic liquids is more efficient as reaction medium for the model reaction at 100 ºC (**Table 2A.2**). The reaction afforded maximum yield by using 0.4 mmol (40 mol%) of strong acidic IL **5** in 45 min against 1.3 mmol of less acidic [Msim][Cl] ionic liquid within 70 min at 100 ºC (**Table 2A.2**, entry 1 and 2). Both the reaction rate and yield decreases by lowering the reaction temperature (**Table 2A.2**, entry 1 and 2). Since, the thermal analysis of less acidic IL [Hmim][$OOCCCl_3$] showed almost 90% weight loss around 100 ºC, thus it wasn't suitable to use as reaction medium above this temperature (**Table 2A.2**, entry 3). To explain the observed catalytic efficiency of the three ionic liquids only the small p*K*a differences are not sufficient for the model reaction of quinoline synthesis, although the optimization results supported the relative acidity in the same order as already determined by Hammett method

(**Table 2A.1**). Therefore, the task specific activities of these ILs as shown in **Table 2A.2** are mainly the function of concentration of ILs and their stability at high temperature. Since, the strong acidic sulfoimidazolium IL **5** was obtained from CCl_3COOH, therefore we were interested to know the catalytic activity of this acid under solvent-free method for the same reaction for comparison. The model reaction consumed 4 h reaction time to yield 96% product using 10 mol% of the acid catalyst (**Table 2A.2**, entry 4).

Table 2A.2 Optimization of the amount of acidic ILs/CCl_3COOH as catalyst at various temperatures

Entry	Catalysts	Amount mmol(g)	Time (min)	Temp. (ºC)	Yields **3** (%)
1	[Msim][$OOCCCl_3$]	1.5 (0.50)	20	100	100
		1.5 (0.50)	1.5h	80	65
		0.77 (0.25)	20	100	100
		0.40 (0.130)	45	100	100
		0.10 (0.032)	2.5h	100	70
2	[Msim][Cl]	2.5 (0.5)	40	100	100
		1.3 (0.25)	70	100	100
		0.76 (0.150)	3h	100	94
		2.5 (0.50)	2h	80	60
3	[Hmim][$OOCCCl_3$]	2 (0.50)	8h	70	20
		4 (1.0)	8h	70	30
4	CCl_3COOH	0.05/0.1/0.25	8h/4h/4h	100	70/96/96
		0.1	8h	80/60	70/40

The activity of IL methodology has also been compared for the model reaction with some literature procedures of conventional acid catalysts in **Table 2A.3**

which distinctly supported the dual behaviour of these ionic liquids in the quinoline synthesis.

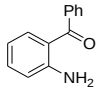
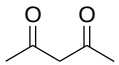
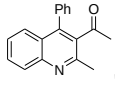
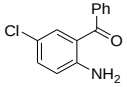
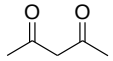
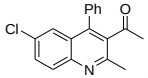
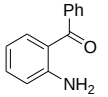
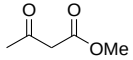
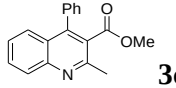
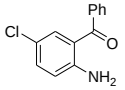
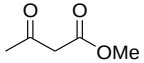
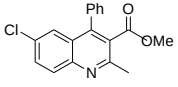
Table 2A.3 Comparison of the activity of ILs methodology with traditional acids

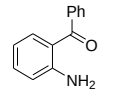
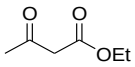
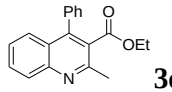
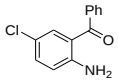
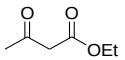
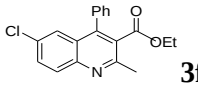
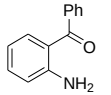
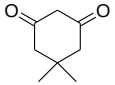
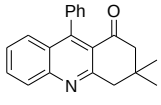
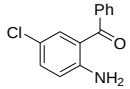
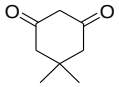
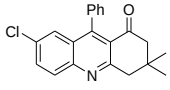
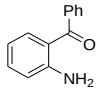
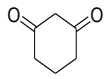
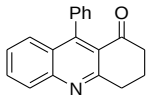
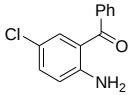
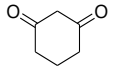
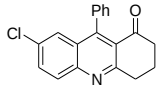
Entry	Catalyst/medium (Amount in mol%)	Time (Temp.°C)	Solvent	Yields % **3**	Recyclability [ref]
1	$Cu(OTf)_2$ (20)	5 h (25)	No	80	No [15]
2	TFA (10)	15 min (100)	No	92	No [16]
3	$Y(OTf)_3$ (20)	5 h (25)	CH_3CN	83	Yes [17]
4	Sulphamic acid (5)	90 min (70)	No	94	Yes [18]
5	Oxalic acid (10)	2 h (80)	No	89	No [19]
6	[Msim][$OOCCCl_3$] (40)	45 min (100)	No	100	Yes [present method]
7	[Msim][Cl] (1.3 mmol)	70 min (100)	No	100	Yes [present method]

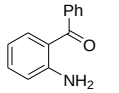
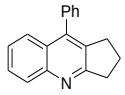
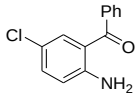
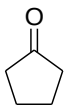
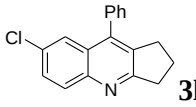
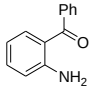
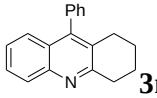
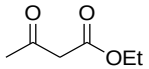
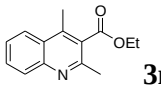
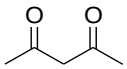
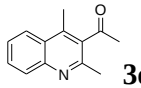
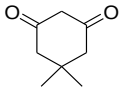
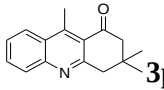
After optimizing the amounts of ionic liquids and CCl_3COOH, these conditions were extended to a variety of 2-aminoaryl ketones and β-keto esters (**Table 2A.4**). Various 1,3-diketones and esters reacted efficiently with 2-aminoaryl ketones to furnish the corresponding quinoline with 97-100% conversion in presence of 40 mol% of [Msim][$OOCCCl_3$] ionic liquid (**Table 2A.4**, entries 1-10, and 14-16). Subsequently, simple cyclic ketones also form excellent amount of products by reacting with substituted 2-aminoaryl ketones within the specified time with 98-100% conversion (**Table 2A.4**, entries 11-13, 17-18). The performance of [Msim][Cl] ionic liquid as acidic medium for the reaction also found to be identical with the ionic liquid [Msim][$OOCCCl_3$] under the optimized condition (**Table 2A.4**). These results indicate that the acidities of both ILs are sufficient to give significantly high yield of products with various types of carbonyl compounds containing α-methylene moiety under optimized reaction conditions irrespective of the nature of the 2-aminoaryl ketones within a very short period of time. The catalytic activity of

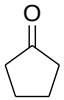
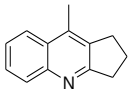
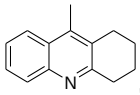
trichloroacetic acid was also found to be good with all systems under solvent-free condition except 2-aminoacetophenone (**Table 2A.4**, entries 14-18).

Table 2A.4 Syntheses of quinoline derivatives **3** under optimized conditions using ionic liquids and trichloroacetic acid as medium/catalyst at 100 ºC

Entry	2-Amino Arylketone	CH acid	Products **3**	Mp. °C (Found) (Reported)	Conversion (%) A/B/C[a,b] **3**	Yield (%)[c] A/B/C
1			 **3a**	111-112.7 (111-112) [19]	100/100/98	99/99/96
2			 **3b**	149.8-152.8 (151) [20]	100/99/97	99/98/95
3			 **3c**	104.6-105.8 (106-107) [21]	100/99/98	98/98/97
4			 **3d**	132-134 (133-135) [22]	100/98/98	96/95/96

5			 **3e**	98.6-100 (100-101) [23]	100/99/98	98/96/96
6			 **3f**	99.8-102 (108) [20]	100/99/96	99/98/94
7			 **3g**	189.7-192 (190-192) [19]	100/100/98	100/100/96
8			 **3h**	207.5-209 (208-209) [19]	100/98/98	100/97/94
9			 **3i**	157-158 (155-156) [19]	100/100/99	99/99/96
10			 **3j**	185-187 (185-186) [19]	100/99/97	98/97/95

11			 **3k**	133.4-134 (133-135) [23]	99/98/95	97/95/92
12			 **3l**	104.6-106 (106-107) [19]	100/99/96	99/97/93
13			 **3m**	139.5-141 (142-143) [23]	100/98/95	98/96/90
14			 **3n**	Oil [24]	98/98/50	98/99/48
15			 **3o**	Oil [25]	99/98/55	99/99/50
16			 **3p**	103.6-104 (105-106) [25]	97/95/55	97/98/52

17			 **3q**	58.7-60 (58-60) [25]	98/98/50	99/98/47
18			 **3r**	77-78 (75-77) [20]	100/98/50	100/99/50

[a] A: Using [Msim][$OOCCCl_3$] ionic liquid; B: using [Msim][Cl] ionic liquid and C: using trichloroacetic acid under solvent-free condition; [b] Conversion calculated with GC analysis; [c] Isolated yields

2A.2.3 Single crystal X-ray characterization of quinoline derivative

X-Ray single crystal structure analysis was performed on the quinoline derivative **3d** (**Table 2A.4**, entry 4) which indicated the presence of basic quinoline moiety in the molecule (**Figure 2A.4**). The crystallographic parameters of the compound **3d** are included in **Table 2A.5**.

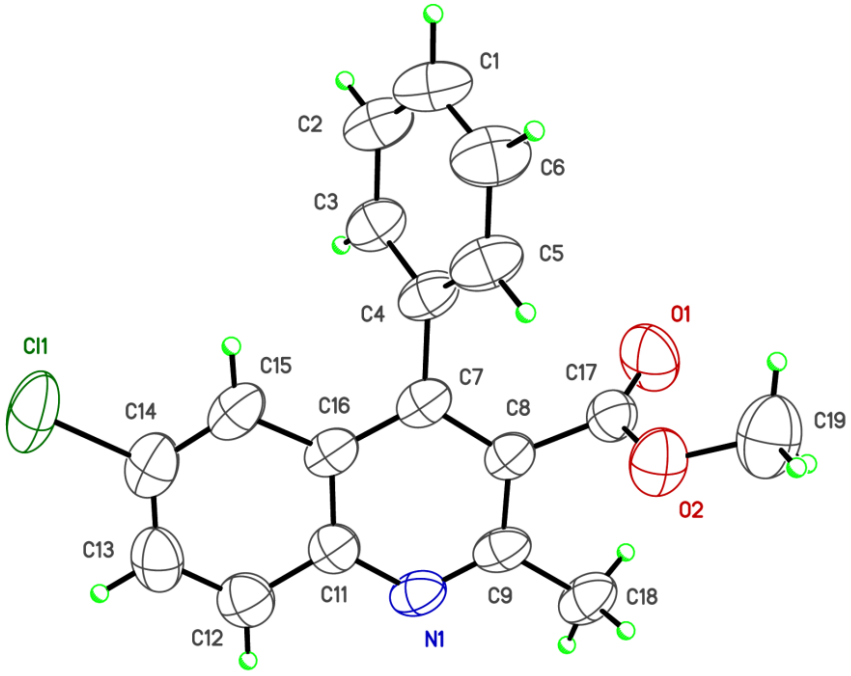


Figure 2A.4 ORTEP of quinoline derivative **3d** (CCDC-958618) with 50% probability ellipsoid

Table 2A.5 Crystallographic parameters of the compound **3d**

Parameter	Data	Parameter	Data
Chemical formula	$C_{18}H_{14}ClNO_2$	V/ Å^3	1538.09(16)
Formula weight	311.75	D_{calc}/g cm^{-3}	1.346
Crystal system	Monoclinic	μ /mm^{-1}	0.254

Space group	$P2_1/n$	Reflns collected	10168
T/K	296	Unique reflns	3096
a/Å	10.8381(6)	range *h*	-12 to 13
b/ Å	7.5433(4)	range *k*	-9 to 7
c/ Å	18.8677(13)	range *h*	-24 to 18
α/°	90	R1[I > 2(I)]	0.0458
β/°	94.346(3)	wR2 (all)	0.1363
γ/°	90	Goodness-of-fit	1.123
Z	4	Instrument	Bruker APEX-II CCD

2A.2.4 Reusability of ionic liquid and trichloroacetic acid

The reusability of the two acidic ILs and trichloroacetic acid were studied and represented by the bar diagram in **Figure 2A.5**.

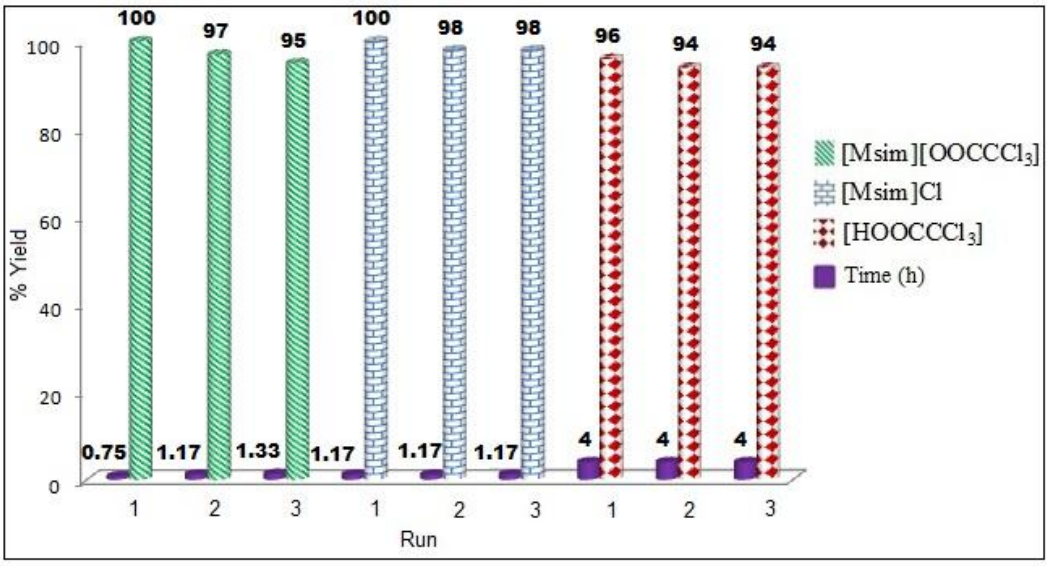


Figure 2A.5 Bar diagram for reusability of ILs and trichloroacertic acid

The two acidic ILs were easily recovered from the reaction mixture of 1st cycle of reactions and reused for two cycles with the model reaction between 2-amino-benzophenone (1 mmol) and 5,5-dimethyl-1,3-cyclohexane-dione (1 mmol) under optimized reaction condition. In this study, we observed slight loss in the activity of [Msim][$OOCCCl_3$] ionic liquid in next two runs of recycling as compared to 1st run.

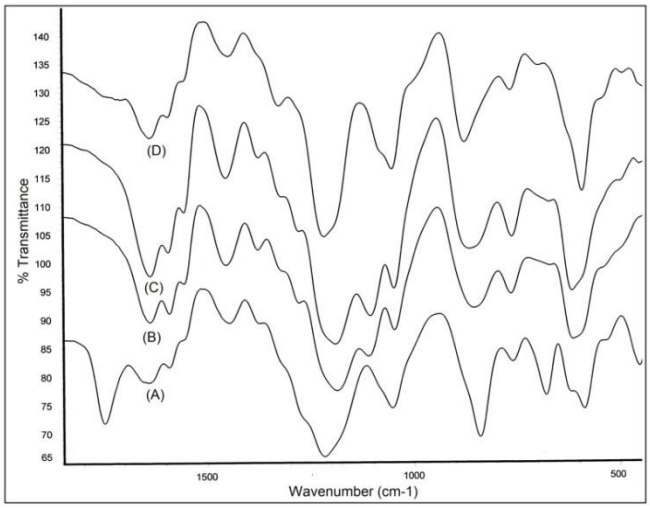
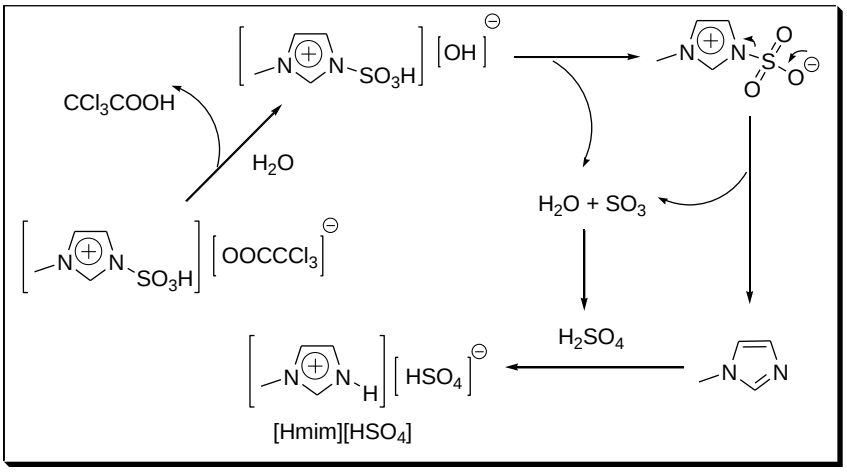


Figure 2A.6 FT-IR spectra of fresh and reused [Msim][$OOCCCl_3$] (A-C) and [Hmim][HSO_4] (D)

These results were again supported by the change in the FT-IR absorption bands of the fresh (A) and reused (B-C) spectra of [Msim][$OOCCCl_3$] ionic liquid in **Figure 2A.6**. The observed loss of activity can be explained by the proposed mechanism of formation of [Hmim][HSO_4] ionic liquid (**Scheme 2A.3**) within the reaction pot in presence of atmospheric moisture to some extent. The comparison of fingerprint region of reused spectra of ionic liquids were almost similar to those of [Hmim][HSO_4] ionic liquid (D). By using 0.4 mmol of [Hmim][HSO_4] IL for the same reaction produced only 50% of expected product during 2.5 h reaction time at 100 ºC in solvent-free medium. This observation didn't support the catalytic function of [Hmim][HSO_4] to give similar yield of products for the two recycling reactions with [Msim][$OOCCCl_3$]. Interestingly, the [Msim][Cl] ionic liquid retains its catalytic activity up to three cycles. The trichloroacetic acid

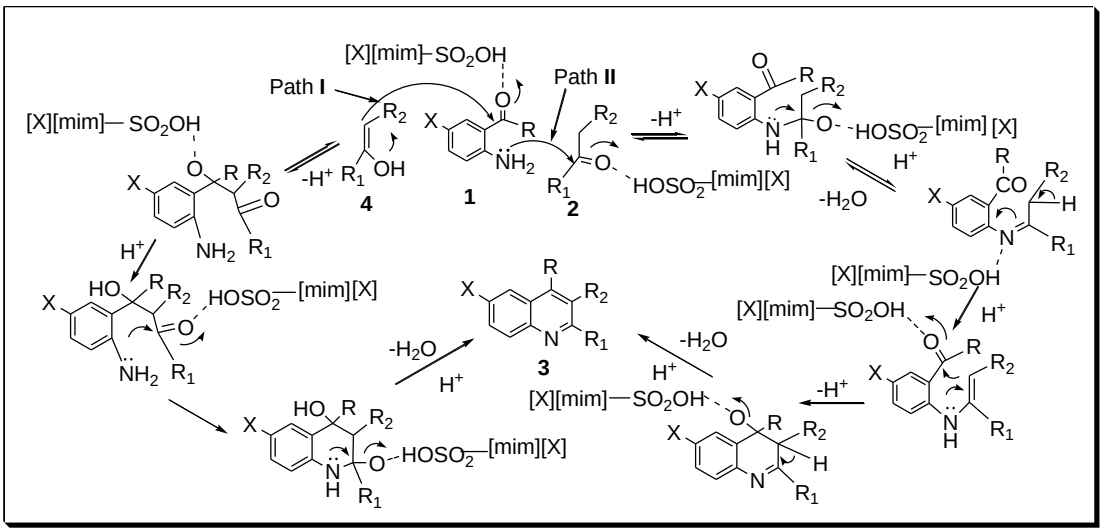
catalyst has been recycled for three times from the reaction mixture after regeneration from each cycle of the reaction under solvent-free method.



Scheme 2A.3 Plausible mechanism for the formation of [Hmim][HSO_4] ionic liquid

2A.2.5 Plausible mechanism of the quinoline synthesis

The ionic liquid catalyzed mechanism for this annulation can be proposed with the support of two different pathways **I** and **II** according to the **Scheme 2A.4** [4].



Scheme 2A.4 Proposed mechanism of Friedländer annulation

2A.3 Conclusion

This section emphasized on the synthesis, characterization and development of task-specific acidic ILs as catalyst or medium for the Friedländer annulation of quinoline. For this purpose three ILs were synthesized and compared their acidity by Hammett plot which was found to be the same order with the catalytic activity for quinoline synthesis under the optimized conditions. The novel two acidic ionic liquids (**5**, **6)** were characterized by NMR, FT-IR, elemental and thermal analysis. The weak acidic IL (**6**) didn't perform the reaction at high temperature because of less thermal stability around 100 °C. In this study, we also compared the acidity, stability and catalytic activity of new ILs with the reported [Msim][Cl]. The IL mediated annulation provides several advantages such as single product formation, high yields, easy work-up, short reaction time and recycling of ILs as medium/catalyst. Furthermore, as a Brønsted acid CCl_3COOH also selectively catalyzed the annulation reactions at 100 °C in absence of solvent with longer reaction time.

2A.4 Experimental section

2A.4.1 General information

The synthesized compounds were characterized by using FT-IR, ^{1}H NMR, ^{13}C NMR, TGA, DTGA, CHN analysis and comparison of melting point with reported data [19-25]. The acidity and p*K*a measurement of the the Brønsted acidic ILs were conducted according to the reported literature [13-14]. CCDC-958618 contains the supplementary crystallographic data of compound **3d** which can be obtained free of charge from the Cambridge Crystallographic Data Centre via http://www.ccdc.ac.uk/data_request/cif.

2A.4.2 General procedures for the synthesis of ionic liquids

3-Methyl-1-sulfonic acid imidazolium chloride [Msim][Cl] (**4**)

1-methylimidazole (5 mmol, 0.410 g) was placed in a round-bottomed flask (100 mL) with dry CH_2Cl_2 (50 mL), and then chlorosulfonic acid (5 mmol, 0.605 g) was added drop wise over a period of 5 min at room temperature. After that, the reaction mixture was stirred for 20 min and the settled CH_2Cl_2 layer was decanted. The residue was then washed with dry CH_2Cl_2 (3×10 mL) and dried under vacuum to furnish [Msim][Cl] as viscous colourless liquid in 97% yield, 0.965 g [27].

3-Methyl-1-sulfonic acid imidazolium trichloroacetate [Msim][$OOCCCl_3$] (**5**)

A mixture of [Msim][Cl] (5 mmol, 0.993 g) and trichloroacetic acid (5 mmol, 0.817 g) in a round bottomed flask (100 mL) was stirred for 2 h at room temperature. Afterward, to separate produced ionic liquid from unreacted acid washed with dry CH_2Cl_2 (3×20 mL) and dried under vacuum to provide the title ionic liquid as viscous oil (99% yield, 1.61 g).

1-Methyl-imidazolium trichloroacetate [Hmim][$OOCCCl_3$] (**6**)

In a round bottomed flask (50 mL), 1–methylimidazole (5 mmol, 0.410 g) and trichloroacetic acid (5 mmol, 0.817 g) was stirred with 50 mL dry CH_2Cl_2 at room temperature over a period of 2 h. After completion of the reaction, the crude ionic liquid was washed with dry CH_2Cl_2 (3×20 mL) and dried under vacuum to give the product as colourless viscous oil (97% yield, 1.19 g).

2A.4.3 General procedure for acidity determination and pKa of ionic liquids

UV-vis acidity evaluation of ILs: The solutions of ionic liquids and 4-nitroaniline as indicator were prepared in ethanol. Then measured the absorption value using UV visible spectrophotometer.

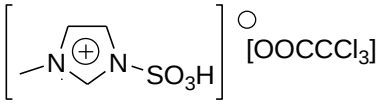
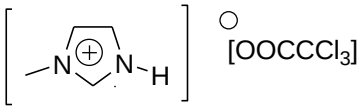
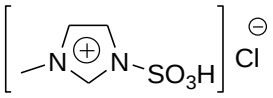
Determination of pKa of ionic liquids: For p*K*a determinations, stock solutions (0.01 mol/dm^3) of the ionic liquids were prepared in distilled water. The solutions were then titrated with aqueous KOH solution (0.100 mol/dm^3). The pH of the solution was measured using a calibrated glass electrode on a digital 802 pH meter at 295 K. The p*K*a for each compound was calculated by the procedure described by Albert and Serjeant [26].

2A.4.4 General procedure for the synthesis of quinoline derivatives 3

A mixture of 2-aminoaryl ketone (1.0 mmol), α-CH acid (1.0 mmol), and trichloroacetic acid (0.1 mmol) or ionic liquid (0.4 mmol of [Msim][OOCCCl$_3$] or 1.3 mmol of [Msim][Cl]) was heated in an oil bath for the specified time in absence of any solvent at 100 °C. For ionic liquid mediated reactions, after completion of the reaction as monitored by TLC, the product was extracted from the ionic liquid phases using ethylacetate (2×3 mL) as solvent. The product was isolated through distillation of ethylacetate solution under reduced pressure and the ionic liquid medium was again used for next cycle of reaction. The crude products, thus isolated were subjected to further purification by recrystallization from ethanol to get analytically pure product. Similarly, for the reaction of trichloroacetic acid as catalyst, after completion as monitored by TLC, the product was precipitated from an aqueous solution by dissolving trichloroacetic acid in water (3 mL). The solid product was filtered, washed with distilled water and recrystallized from ethanol. The trichloroacetic acid was obtained as residue from the aqueous filtrate by evaporation in a water bath.

2A.5 Spectral and elemental data of ILs and quinoline derivatives

2A.5.1 Spectral data of ionic liquids

IL	Spectral data
 3-Methyl-1-sulfonic acid imidazolium trichloroacetate ([Msim][$OOCCCl_3$]) **(5)**	Viscous colourless oil, 99% (1.61 g) yield FT-IR (KBr): 3423, 3154, 2868, 1749, 1639, 1591, 1446, 1217, 1053, 840, 760, 680, 586, 451 cm^{-1}; ^1H NMR (400MHz, DMSO-d_6): δ (ppm) = 3.78 (s, 3H), 7.55 (s, 2H), 8.91 (s, 1H), 14.07 (s, 1H); ^{13}C NMR (100MHz, DMSO-d_6): δ = 35.9, 92.0, 120.0, 123.6, 136.1, 163.1; Elemental analysis for $C_6H_7O_5SN_2Cl_3$: Cal. C 22.21, H 2.16, N 8.64; Found: C 22.24, H 2.21, N 8.68.
 1-Methyl-imidazolium trichloroacetate ([Hmim][$OOCCCl_3$]) **(6)**	Viscous colourless oil, 97% (1.19 g) yield FT-IR(KBr): 3422, 2866, 1653, 1518, 1422, 1363, 1284, 1233, 1085, 917, 825, 750, 665 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ (ppm) = 3.21 (s, 3H), 4.14 (s, 1H), 6.46 (s, 1H), 6.56 (s, 1H), 6.99 (s, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 32.9, 120.5, 128.5, 137.5, 162; Elemental analysis for: $C_6H_7O_2N_2Cl_3$: Cal. C 29.5, H 2.87, N 11.5; Found: C 29.52, H 2.90, N 11.5 8.
 3-Methyl-1-sulfonic acid imidazolium chloride ([Msim][Cl]) **(4)**	Viscous colourless oil, 97% (0.965 g) yield FT-IR (KBr): 3458, 3149, 1638, 1449, 1213, 1052, 868, 762, 589 cm^{-1}; ^1H NMR (400MHz, DMSO-d_6): δ (ppm) = 3.72 (s, 3H), 7.45 (s, 1H), 7.48 (s, 1H), 8.79 (s, 1H), 14.02 (s, 1H); ^{13}C NMR (100MHz, DMSO-d_6): δ = 36.8, 121.2, 124.9, 139.1; Elemental analysis for $C_4H_7ClN_2O_3S$: Cal. C 24.19, H 3.55, N 14.10; Found: C 24.30, H 3.61, N 13.99.

2A.5.2 Spectral data of synthesized quinoline compounds

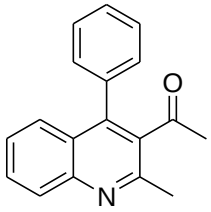
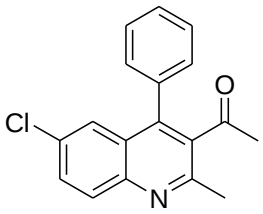
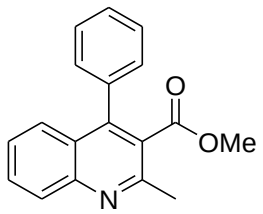
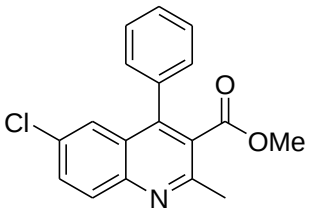
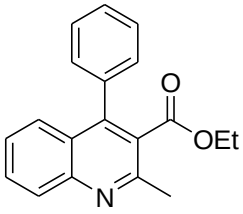
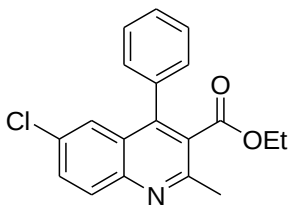
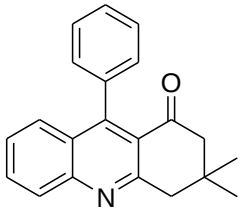
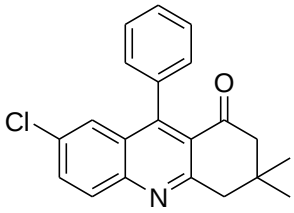
Compounds	Spectral data
 1-(2-Methyl-4-phenylquinoline-3-yl) ethanone **Table-2A.4**, entry-1, (**3a**)	Yellow solid, Mp. 111-112.7 °C FT-IR (KBr): 3424, 3065, 2910, 1687, 1560, 1482, 1390, 1212, 1169,1025, 956, 756, 702 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 2.01 (s, 3H), 2.7 (s , 3H) , 7.34-7.37 (m, 2H), 7.45 (t, *J* = 8.2 Hz, 1H), 7.51-7.52 (m, 3H), 7.61(d, *J* = 7.8Hz, 1H), 7.72 (t, *J* = 6.8Hz, 1H) , 8.07 (d, *J* = 8.2Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 23.9, 32.0, 125.1, 126.2, 126.6, 128.7, 128.9, 129.0, 130.1, 130.2, 135.3, 144.0, 147.6, 153.6, 205.7; Elemental analysis for $C_{18}H_{15}NO$: Cal. C 82.73, H 5.79, N 5.36; Found: C 82.70, H 5.82, N 5.38.
 1-(6-Chloro-2-methyl-4-phenylquinoline-3-yl) ethanone **Table-2A.4**, entry-2, (**3b**)	Yellow solid, Mp. 149.8-152.8 °C FT-IR (KBr): 3023, 2945, 1695,1470, 1380, 1220, 1075, 754, 692 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 2.03 (s, 3H), 2.71 (s, 3H), 7.37-7.93 (m, 8H); ^{13}C NMR (100MHz $CDCl_3$): δ = 23.8, 32.2, 124.8, 125.7, 128.8, 129.0, 129.7, 130.9, 132.2, 134.4, 135.6, 142.8, 145.7, 153.9, 203.2; Elemental analysis for $C_{18}H_{14}ClNO$: Cal. C 73.10, H 4.77, N 4.74; Found: C 73.08, H 4.79, N 4.72.
 Methyl-2-methyl-4-phenylquinoline-3-carboxylate	Yellow solid, Mp. 104.6-105.8 °C FT-IR (KBr): 3448, 3063, 2946, 1728, 1574, 1483, 1384,1295, 1227,1170, 1064, 966, 758, 696 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 2.78 (s, 3H), 3.58 (s, 3H), 7.35-7.37 (m, 2H), 7.41-7.50 (m, 4H), 7.58 (d, *J* = 8.2Hz, 1H), 7.72 (t, *J* = 6.8Hz, 1H), 8.07(d, *J* = 8.2Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 23.9,

Table-2A.4, entry-3, (**3c**)	52.3, 125.0, 126.5, 126.6, 128.4, 128.6,129.0, 129.3, 130.0,136.0, 146.5, 147.8, 154.6, 169.1; Elemental analysis for $C_{18}H_{15}NO_2$: Cal. C 77.96, H 5.45, N 5.05; Found: C 77.94, H 5.48, N 5.02.
 Methyl 6-chloro-2-methyl-4-phenylquinoline-3-carboxylate **Table-2A.4**, entry-4, (**3d**)	Yellow solid, Mp. 132-134 °C FT-IR (KBr) cm^{-1}: 3454, 3051, 2946, 1735, 1555, 1482, 1374, 1282, 1211, 1165, 1063, 825, 758, 710, 678; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 2.77 (s, 3H), 3.59 (s, 3H), 7.33-7.35 (m, 2H), 7.50-7.52 (m, 3H), 7.55-7.56 (m,1H), 7.65 (dd, *J* = 8.8, 2.2 Hz, 1H), 8.02 (d, *J* = 8.8Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 23.6, 52.5, 125.4, 126.0, 128.6, 129.0, 129.2, 130.0, 131.6, 145.7, 146.2, 155.0, 168.5; Elemental analysis for $C_{18}H_{14}ClNO_2$: Cal. C 69.35, H 4.53, N 4.49; Found C 69.30, H 4.58, N 4.45.
 Ethyl-2-methyl-4-phenylquinoline-3-carboxylate **Table-2A.4**, entry-5, (**3e**)	Yellow solid, Mp. 98.6-100 °C FT-IR (KBr) cm^{-1}: 3420, 2989, 1676, 1553, 1465, 1376, 1290, 1210, 1126, 1067, 839, 696, 548 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 0.96 (t, *J* = 7.2Hz, 3H), 2.80(s, 3H), 4.20 (q, *J* = 7.2Hz, 2H), 7.34-7.38 (m, 2H), 7.42-7.51 (m,4H), 7.59 (dd, *J* = 8.2, 1.0 Hz, 1H), 7.71(m, 1H), 8.09(d, *J* = 8.6 Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 13.7, 24.5, 61.6, 125.4, 126.7, 127.0, 127.6, 128.5, 128.9, 129.4, 130.5, 135.8, 146.3, 147.7, 154.6, 168.5; Elemental analysis for $C_{19}H_{17}NO_2$: Cal. C 78.33, H 5.88, N 4.81; Found C 78.30, H 5.91, N 4.78.
	Brown solid, Mp. 99.8-102 °C FT-IR (KBr) cm^{-1}: 3072, 2978, 2928, 1720, 1601, 1558, 1475, 1380, 1304, 1210, 1167, 1069, 887, 795, 612; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 0.95 (t, *J* = 6.8Hz, 3H), 2.79 (s, 3H), 4.04 (q, *J* = 6.8Hz, 2H),

Ethyl-6-chloro-2-methyl-4-phenylquinoline- 3-carboxylate **Table-2A.4**, entry-6, (**3f**)	7.34-7.37 (m,2H), 7.50-7.52 (m,3H), 7.54 (d, *J* = 2.8Hz, 1H), 7.65 (dd, *J* = 8.8, 2.8Hz, 1H), 8.02 (d, *J* = 8.8 Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 13.7, 23.8, 61.7, 125.4, 126.6, 128.5, 128.9, 129.3, 129.6, 131.0, 131.5, 132.6, 145.9,146.7, 155.1, 168.6; Elemental analysis for $C_{19}H_{16}ClNO_2$: Cal. C 70.05, H 4.95, N 4.30; Found C 70.02, H 4.99, N 4.24.
 3,3-Dimethyl-9-phenyl-1, 2,3,4 tetrahydro-1-acridinone **Table-2A.4**, entry-7, (**3g**)	Yellow solid , Mp. 189.7-192 °C FT-IR (KBr): 2937, 1682, 1553, 1479, 1383, 1286, 1215, 1129, 1033, 765, 693, 541 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) =1.16 (s, 6H), 2.57 (s, 2H), 3.28 (s, 2H), 7.17 (m, 2H), 7.38-7.42 (m, 1H), 7.47-7.51 (m, 4H), 7.77 (t, *J*= 7.2Hz, 1H), 8.06 (d, *J*= 8.6Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 28.3, 32.3, 48.4, 54.2,123, 126.4, 127.4, 127.5, 128, 128.1, 128.3,128.5,131.7, 139, 148.9, 151, 161.2, 198; Elemental analysis for $C_{21}H_{19}NO$: Cal. C 83.69, H 6.35, N 4.65; Found: C 83.65, H 6.37, N 4.63.
 7-Chloro-3,4-dihydro-3,3-dimethyl-9-phenylacridin-1-(2H)-one **Table-2A.4**, entry-8, (**3h**)	Yellow solid, Mp. 207.5-209 °C FT-IR (KBr): 3424, 2944, 1693, 1552, 1473, 1382, 1289, 1200, 1130, 1077, 837, 698, 547 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 1.16 (s, 6H), 2.57 (s, 2H), 3.26 (s, 2H), 7.15 (m, 2H), 7.43 (m, 1H), 7.50-7.52 (m, 3H), 7.67-7.69 (dd, *J* = 2.2, 2.6Hz, 1H), 7.99 (d, *J* = 8.6Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 28.4, 32.3, 48.4, 54.3,124,126.9, 127.9, 128, 128.4, 130.3, 132.5, 132.6, 137, 147.5, 150.2, 161.5, 197.8; Elemental analysis for $C_{21}H_{18}ClNO$: Cal. C 75.11, H 5.40, N 4.17; Found. C 75.09, H 5.45, N 4.12.

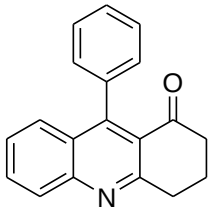
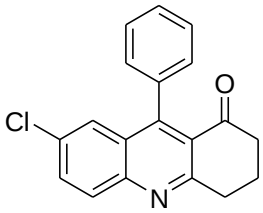
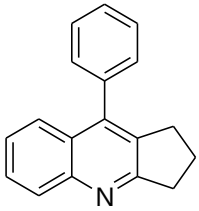
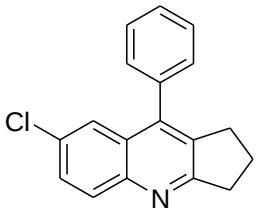
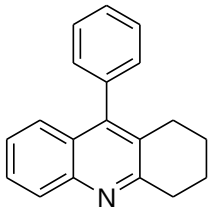
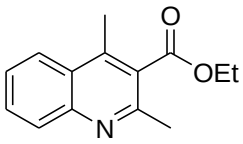
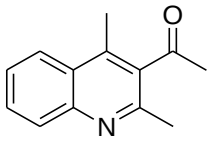
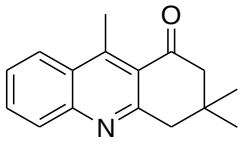
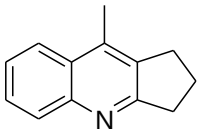
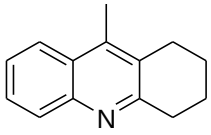
 9-Phenyl-1, 2,3,4-tetrahydro-1-acridinone **Table-2A.4**, entry-9, (**3i**)	Yellow solid, Mp. 157-158 °C FT- IR (KBr): 3433, 2945, 1684, 1552, 1481, 1385, 1289, 1215, 1154, 1015, 760, 704, 596, 531 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 2.25-2.26 (m, 2H), 2.70 (t, *J* = 6.8Hz, 2H), 3.38 (t, *J* = 6.4Hz, 2H), 7.19 (m, 2H), 7.38-7.40 (m, 1H), 7.45-7.50 (m,4H), 7.76 (t, *J* = 7.8Hz, 1H), 8.07 (d, *J*= 8.2Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 21.5, 34.7, 40.7, 126.5, 127.6, 128.1,128.2, 128.3, 128.6, 131.8,138, 148.8, 151.5, 162.3, 198; Elemental analysis for $C_{19}H_{15}NO$: Cal. C 83.49, H 5.53, N 5.12; Found. C 83.42, H 5.60, N 5.07.
 7-Chloro-3,4-dihydro-9-phenylacridin-1(2H)-one **Table-2A.4**, entry-10, (**3j**)	Yellow solid, Mp. 185-187 °C FT-IR (KBr): 3022, 2978, 2868, 1697, 1552, 1474, 1377, 1208, 1078, 1006, 974, 840, 693 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 2.28 (q, *J* = 6.6 Hz, 2H), 2.75 (t, *J* = 6.6 Hz, 2H), 3.38 (t, *J* = 6.8 Hz, 2H), 7.16-7.20 (m, 2H), 7.39 (s, 1H), 7.52-7.54 (m, 3H), 7.68 (d, *J* = 8.6Hz, 1H), 8.03 (d, *J* = 8.6Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 23.1, 32.5, 43.5, 122.6, 126.5, 127.6, 128.2, 129.4, 129.8, 132.5, 133.6, 138.3, 140.7, 148.6, 161.2, 197.3; Elemental analysis for $C_{19}H_{14}ClNO$: Cal. C 74.15, H 4.58, N 4.55; Found. C 74.12, H 4.60, N 4.57.
 9-Phenyl-2,3-dihydro-1-*H*-cyclopenta[*b*]quinoline	Yellow solid, Mp. 133.4-134 °C FT-IR (KBr): 3414, 2926, 1571, 1485, 1437, 1384, 1338, 1265, 1078, 1024, 763, 704, 601 cm^{-1}; ^{1}H NMR (400MHz $CDCl_3$): δ (ppm) = 2.15-2.19 (m, 2H), 2.89 (t, *J* = 7.2Hz, 2H), 3.22 (t, *J* = 7.8Hz, 2H), 7.36-7.40 (m, 3H), 7.47-7.54 (m,3H), 7.60-7.64 (m,2H), 8.06 (dd, *J* = 9.2, 0.8Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 23.6, 30.4, 35.3, 125.6, 125.7, 128.1,

Table-2A.4, entry-11, (**3k**)	128.3, 128.6, 128.9, 129.4, 133.7, 136.8, 143.1, 148.0, 167.5; Elemental analysis for $C_{18}H_{15}N$: Cal. C 88.13, H 6.16, N 5.71; Found. C 88.10, H 6.19, N 5.68.
 7-Chloro-9-phenyl-2,3 dihydro-1*H*-cyclopenta[*b*]quinoline **Table-2A.4**, entry-12, (**3l**)	Yellow solid, Mp. 104.6-106 ℃ FT-IR (KBr): 3060, 2958, 1606, 1487, 828, 715 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ (ppm) = 2.16-2.19 (m, 2H), 2.89 (t, *J* = 7.8Hz, 2H), 3.23 (t, *J* = 7.8Hz, 2H), 7.32-7.35 (m, 2H), 7.49-7.59 (m, 5H), 8.03 (d, *J* = 8.8Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 23.5, 30.4, 35.1, 124.6, 127.2, 128.4, 128.8, 129.2, 129.3, 130.1, 131.6, 134.9, 135.9, 142, 146, 167.7; Elemental analysis for $C_{18}H_{14}ClN$: Cal. C 77.28, H 5.04, N 5.01; Found. C 77.23, H 5.06, N 5.97.
 Phenyl-5,6,7,8-tertrahydroacridine **Table-2A.4**, entry-13, (**3m**)	Yellow solid, Mp. 139.5-141 ℃ FT-IR (KBr): 3420, 2978, 1568, 1430, 1136, 1025, 772, 609 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ (ppm) = 1.63-1.65 (m, 4H), 1.89-2.01 (m, 2H), 2.72-2.74 (m, 2H), 7.28-7.39 (m, 4H), 7.50-7.68 (m, 4H), 8.09 (d, *J* = 8.2Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 25.5, 28.4, 31.3, 32.2, 126.2, 128.0, 128.8, 129.3, 129.9, 131.2, 131.6, 138.1, 145.5, 146.9, 167.6; Elemental analysis for $C_{19}H_{17}N$: Cal. C 87.99, H 6.61, N 5.40; Found: C 87.97, H 6.64, N 5.38.
 Ethyl-2,4-dimethylquinoline-3-carboxylate **Table-2A.4**, entry-14, (**3n**)	Yellow oil FT-IR (KBr): 3021,2928, 1672, 1585, 1480, 1392, 1188, 1050, 768, 644 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ (ppm) = 1.43 (t, *J* = 7.2 Hz, 3H), 2.65 (s, 3H), 2.74 (s, 3H), 4.52 (q, *J* = 7.2 Hz, 2H), 7.52 (td, *J* = 8.0, 1.0Hz, 1H), 7.69 (td, *J* = 8.0, 1.0Hz, 1H), 8.01-8.05 (m, 2H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 15.2, 16.5, 23.8, 62.8, 124.6, 126.2, 126.8, 128.7, 129.6, 130.5, 142.4, 147.6, 154.5, 169.9; Elemental analysis

	for $C_{14}H_{15}NO_2$: Cal. C 73.34, H 6.59, N 6.11; Found: C 73.32, H 6.61, N 6.09.
 1-(2,4-Dimethyl quinolin-3-yl) ethanone **Table-2A.4**, entry-15, (**3o**)	Brown oil FT-IR (KBr): 3068, 2959, 1703, 1614, 1585, 1208, 758 cm^{-1} ; ^1H NMR (400MHz, $CDCl_3$): δ (ppm) = 2.59 (s, 6H), 2.64 (s, 3H), 7.56- 7.58 (m, 1H), 7.69-7.71 (m, 1H), 7.96-7.99 (m, 1H), 8.04-8.07 (m, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 15.4, 23.3, 32.7, 123.8, 126, 126.6,128.9, 130.1, 135.8, 139.3, 146.5, 152.6, 206.4; Elemental analysis for $C_{13}H_{13}NO$: Cal. C 78.36, H 6.58, N 7.03; Found: C 78.32, H 6.62, N 7.10.
 3,3,9-Trimethyl-1,2,3,4-tetrahydro-1-acridinone **Table-2A.4**, entry-16, (**3p**)	Yellow solid, Mp. 103.6-104 ℃ FT IR (KBr): 3079, 2989, 1714, 1669, 1584, 1179, 796 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ (ppm) = 1.15 (s, 6H), 2.67 (s, 2H), 3.08 (s, 3H), 3.22 (s, 2H), 7.58 (t, *J* = 7.2Hz, 1H), 7.78 (t, *J* = 7.2Hz, 1H), 8.05 (d, *J* = 8.2Hz, 1H), 8.22 (d, *J* = 8.2Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 16.1, 28.3, 32.1, 48.2 54.8, 124.2, 125.6, 126.6, 127.7, 131.7, 161.0, 200.4; Elemental analysis for $C_{16}H_{17}NO$: Cal. C 80.30, H 7.16, N 5.85; Found: C 80.28, H 7.18, N 5.83.
 2,3-Dihydro-9-methyl-1*H*-cyclopenta[*b*]quinoline **Table-2A.4**, entry-17, (**3q**)	Yellow solid, Mp. 58.7-60 °C FT IR (KBr): 3320, 2948, 1710, 1679, 1583, 1178, 768, 610 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ (ppm) = 2.10 (m, 2H), 2.46 (s, 3H), 2.77-2.79 (m, 2H), 2.90-2.92 (m, 2H), 7.40-7.59 (m, 2H), 7.87-7.89 (m, 1H), 8.03 (d, *J* = 8.2Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 18.9, 26.3, 27.1, 36.7, 124.8, 126.6, 128.2, 128.8, 132.6, 142.7, 146.5, 175.6. Elemental analysis for $C_{13}H_{13}N$: Cal. C 85.21, H 7.15, N 7.64; Found: C 85.28, H 7.19, N 7.73.

 9-Methyl-1,2,3,4-tertrahydroacridine **Table-2A.4**, entry-18, (**3r**)	Yellow solid, Mp. 77-78 °C FT-IR (KBr): 3432, 2929, 2859, 1612, 1558,1428, 1147, 1022, 765, 612 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 1.80-1.82 (m, 4H), 2.30 (s, 3H), 2.68 (t, *J* = 7.6Hz, 2H), 2.96 (t, *J* = 7.6Hz, 2H), 7.27-7.88 (m, 4H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 13.5, 23.7, 24.0, 26.1, 32.9, 122.7, 124.8, 126.5, 127.6, 128.3, 141.6, 146.0, 159.2; Elemental analysis for $C_{14}H_{15}N$: Cal. C 85.24, H 7.66, N 7.10; Found: C 85.29, H 7.70, N 7.15

References:

[1] Martins, M.A.P., et al. *Chem. Rev*. **108** (6), 2015--2050, 2008.

[2] Zolfigol, M.A., et al. *Catal.Commun.* **8** (8), 1214--1218, 2007.

[3] Ghassamipour, S. & Sardarian, A.R. *Tetrahedron Lett.* **50** (5), 514--519, 2009.

[4] Marco-Contelles, J., et al. *Chem. Rev*. **109** (6), 2652--2671, 2009 and references cited therein.

[5] Strekowski, L., et al. *J. Fluorine Chem.* **104** (2), 281--284, 2000.

[6] Wasserscheid, P. & Welton, T. *Ionic liquid in Synthesis*, Wiley VCH, Weinheim, 2008.

[7] Hallett, J.P. & Welton, T. *Chem. Rev.* **111** (5), 3508-3576, 2011.

[8] Wang, J., et al. *Can. J. Chem.* **82** (7), 1192--1196, 2004

[9] Sowmiah, S., et al. *Curr. Org. Synth.* **9** (1), 74--95, 2012.

[10] Cheng, G., et al. *Catal. Commun.* **10** (2), 201--204, 2008.

[11] Karimi, B. & Vafaeezadeh, M., et al. *Chem. Commun.* **48** (27), 3327--3329, 2012.

[12] Akbari, J., et al. *J. Comb. Chem.* **12** (1), 137--140, 2010.

[13] Wang, Y.-Y., et al. *Chin. J. Chem.* **26** (8), 1390--1394, 2008.

[14] Thomazeau, C., et al. *J. Am. Chem. Soc.* **125** (18), 5264--5265, 2003.

[15] Soleimani, E., et al. *Chem. Pharm. Bull.* **58** (2), 212--213, 2010.

[16] Shaabani, A., et al. *Synth. Commun.* **37** (4), 629--635, 2007.

[17] De, S.K. & Gibbs, R.A. *Tetra. Lett.* **46** (10), 1647--1949, 2005.

[18] Yadav, J.S., et al. *Tetrahedron Lett.* **46** (42), 7249--7253, 2005.

[19] Dabiri, M., et al. *Monatsh. Chem.* **138** (12), 1249--1252, 2007.

[20] Palimkar, S.S., et al. *J. Org. Chem.* **68** (24), 9371--9378, 2003.

[21] Zhou, T., et al. *Letters in Organic Chemistry* **5** (1), 47--50, 2008.

[22] Shaabani, A., et al. *Monatsh. Chem.* **137** (2), 181--184, 2006.

[23] Abdollahi-Alibeik, M. & Pouriayevali, M. Catal. Commun. **22**, 13--18, 2012.

[24] Desai, U.V., et al. *Arkivoc* (xv), 198--204, 2006.

[25] Wang, G.-W, et al. *Tetrahedron Lett.* **47** (7), 1059--1063, 2006.

[26] Albert, A. & Serjeant, E.P. *The Determination of Ionization Constants: A Laboratory Manual*, 3rd ed., Chapman and Hall, New York, 1984.

[27] Zolfigol, M.A., et al. *J. Iran. Chem. Soc.* **7** (3), 646--651, 2010.

Section 2B:

Studies on -SO_3H functionalized Brønsted acidic imidazolium ionic liquids (BAILs) for one pot synthesis of 2-styrylquinolines via Friedländer annulation followed by Knoevenagel condensation

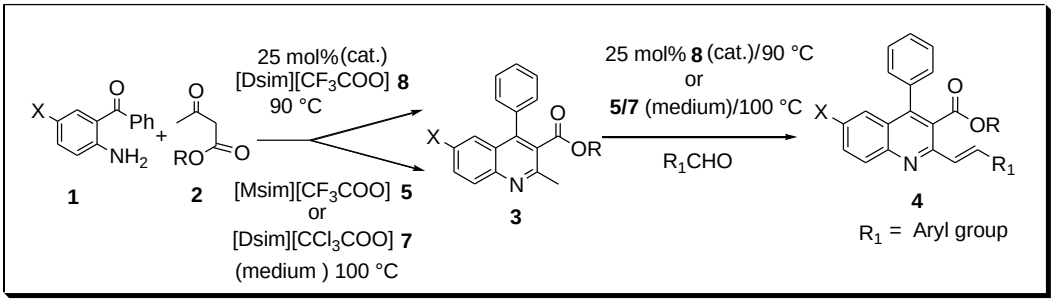
2B.1 Introduction

Designing of one pot multistep synthetic route is a sustainable structure development method in organic synthesis [1-2]. It makes provision for creating complex library of small organic molecules without isolating the intermediates involved in various steps with less chemical waste and greater economic benefit [3-4]. Styrylquinoline derivatives have shown extensive potential biological activities along with HIV-1 integrase inhibitor, lipoxygenase inhibitors and leukotriene d_4 antagonists as discussed in **Chapter 1** [5-8]. Several known methods are available for the direct introduction of alkyl substituent into the quinoline nucleus using organometallic compounds, active methylene compounds or Wittig reagents [9-12]. However, most of the methods for the synthesis of 2-styrylquinoline derivatives are acid or base catalyzed condensation of 2-methyl quinoline derivatives with excess amount of appropriate aldehydes in acetic anhydride at high temperature (100-140 °C) which produce only moderate yield of products after prolonged reaction time (20 h) [13]. Few modified procedures employed microwave energy to produce the title compound in good to moderate yields from 2-methyl quinoline using $ZnCl_2$, Ac_2O/SiO_2 as catalyst in neat conditions at high temperature [14-16]. They obtained the key intermediate quinalidine from Friedländer, Doebner–von Miller,

Combes, and Pfitzinger reactions [17-19]. Another two step method described the preparation of 2-styryl-1,2,3,4-tetrahydroquinolines via a vinylogous Povarov reaction followed by aromatization which isn't yet commonly applicable in terms of the substitution on the styryl side chains [20-22]. All these multistep protocols have some problems like formation of low yield of product, time consuming and produce side products. Dabiri *et al.* first employed one pot synthesis of 2-styrylquinolines in 1-methylimidazolium trifluoroacetate ionic liquid (IL) as dual catalyst-solvent system via Friedländer annulation of 2-aminoarylketone and methylketone followed by Knoevenagel reaction with aromatic aldehyde at 80 °C in 2 h [23]. Kumar *et al.* also exploited the synthesis of title compounds using this approach in presence of 10 mol% of $In(OTf)_3$ as catalyst at 100 °C within 2-4 h [24]. Both methods required longer reaction time to give good to excellent results. Although the reported IL method has several advantages such as simple method with high yields of product, no side product, recycling of acidic IL, but the major limitation is the use of stoichiometric amount of weak acidic IL and longer reaction time (2-4 h). As a consequence, there is a scope to use strong acidic ILs as reusable homogeneous catalytic system for the preparation of 2-styrylquinolines.

The $-SO_3H$ functionalized ionic liquids represent a class of strong task specific Brønsted acidic ILs and they have many applications as recyclable acid catalyst in organic reactions under mild conditions, which is rather difficult to obtain with other Lewis or Brønsted acid catalysts [25]. The acidity of such ILs can be varied with the incorporation of one or more $-SO_3H$ groups into the cations. By keeping view in this, in this section, a few catalytic $-SO_3H$ functionalized Brønsted acidic ionic liquids (BAILs) were designed for the synthesis of 2-styrylquinolines via one pot method (**Scheme 2B.1**). This study utilized four acidic sulfoimidazolium ILs such as 3-methyl-1-sulfoimidazolium trifluoroacetate ([Msim][$OOCCF_3$]) (**5**), 1,3-disulfoimidazoliumtosylate ([Dsim][OTs]) (**6**) and 1,3-disulfo-imidazolium carboxylate ILs ([Dsim][X]) {where X = [CCl_3COO] (**7**),

[CF_3COO] (**8**)} as catalyst/reaction medium. The three known ILs (**5**), (**7**) and (**8**) (**Figure 2B.1**) were prepared according to the reported methods in previous literature [26-27]. The novel IL 1,3-disulfoimidazoliumtosylate ([Dsim][OTs]) (**6**) was synthesized and characterized by various analytical methods before application as task specific ILs in 2-styrylquinoline synthesis.



Scheme 2B.1 Synthesis of 2-styrylquinoline derivatives

2B.2 Results and discussion

2B.2.1 Synthesis and characterization of ionic liquids

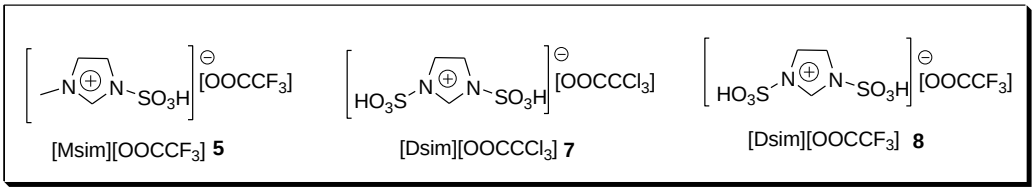
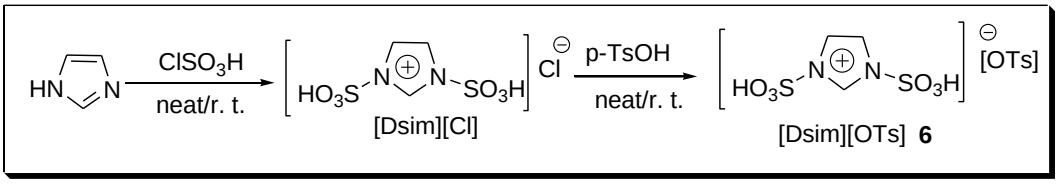


Figure 2B.1 Structure of three sulfoimidazolium BAILs

Initially the three sulfoimidazolium ionic liquids ([Msim][$OOCCF_3$]) (**5**), ([Dsim][$OOCCCl_3$]) (**7**) and ([Dsim][$OOCCF_3$]) (**8**) (**Figure 2B.1**) were synthesiszed from the reaction of 1-sulfo-3-methylimidazolium chloride ([Msim][Cl]) IL with CF_3COOH and 1,3-disulfo-imidazolium chloride ([Dsim][Cl]) with CCl_3COOH and CF_3COOH respectively as depicted by the procedures in section 2B.4.2. In addition, the IL [Dsim][OTs] (**6**) was prepared

from the reaction of [Dsim][Cl] IL and p-toluene sulfonic acid at room temperature stirring (**Scheme 2B.2**).



Scheme 2B.2 Synthesis of [Dsim][OTs] ionic liquid

2B.2.1a Spectral analysis

The FT-IR spectra of IL (**6**) indicated three absorption bands around 1208, 1048 and 582 cm^{-1} which were assigned for the stretching and bending vibrations of -SO_3H group (**Figure 2B.2**). It has another strong peak at 823 cm^{-1} corresponding to N-S stretching vibration. The ^1H NMR spectra of (**6**) has a proton singlet at 14.1 ppm for the -SO_3H acidic protons. The elemental analyses further confirmed the structure of the new IL ([Dsim][OTs]) (**6**).

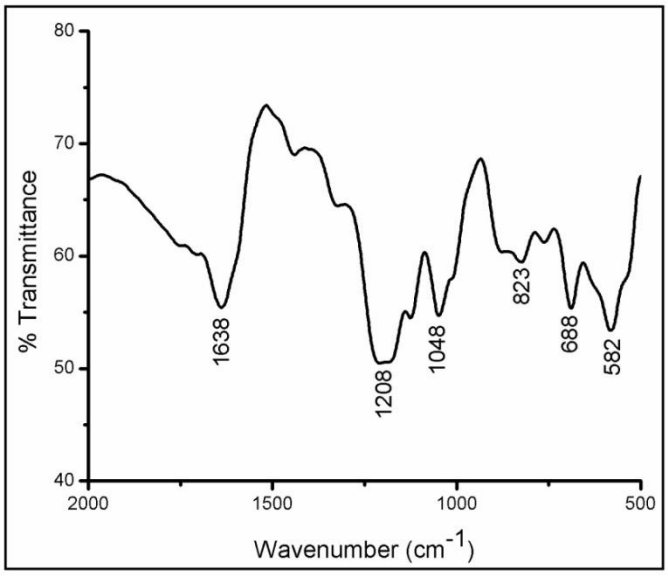


Figure 2B.2 FT-IR spectra of IL (**6**)

2B.2.1b Thermal analysis of ILs

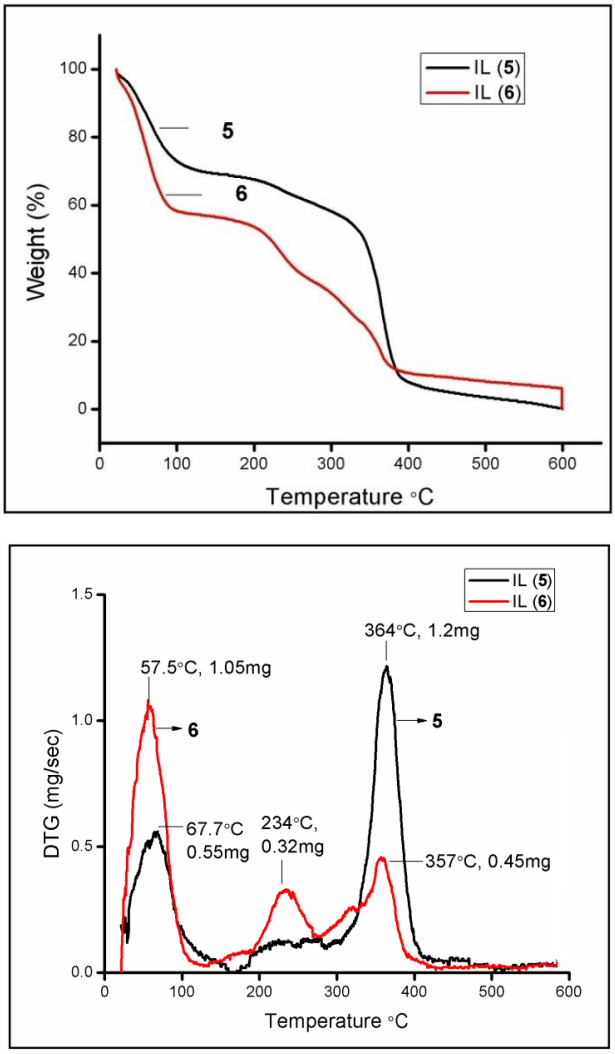


Figure 2B.3 TGA and DTGA analysis of the ionic liquids (**5**) and (**6**)

The thermal stability of ILs (**7**) and (**8**) were observed to be stable up to 260 °C from literature reports [26]. The stability of two ILs (**5**, **6**) was studied by thermogravimetric analysis (**Figure 2B.3**) and slight weight loss from IL (**5**) at 67.7 °C was observed which can be assigned for the elimination of absorbed water from the IL. In case of ionic liquid (**5**) higher thermal stability (364 °C) was observed. In contrast, the TGA curve of ([Dsim][OTs]) displays decomposition approximately 40% (1.05 mg) at 57.5 °C. The reason may be the weaker strength of ionic bond between imidazolium cation and tosylate anion in ([Dsim][OTs])

with increasing temperature and thus, the –OTs group can easily eliminate as strong leaving group from the IL by abstraction of proton from $–SO_3H$ group.

2B.2.1c UV-Visible study of ILs

The acidity of various acidic ILs can be easily expressed by Hammett function (H_0) using UV-Visible spectrophotometer according to equation (1) in presence of 4-nitroaniline as basic indicator [28-29].

$$H_0 = pK(I)aq + \log [I]/[IH]^+ \qquad (1)$$

In this equation, the p*K*a value of the basic indicator is represented by the term p*K*(I)aq in aqueous ethanol and [I] is the absorbance of basic indicator without protonation.

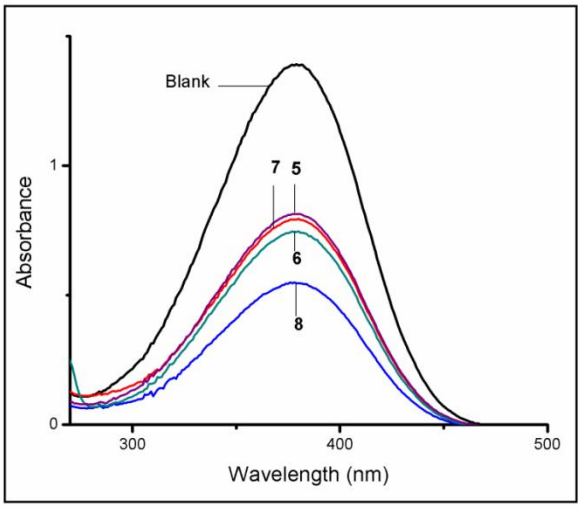


Figure 2B.4 Absorption spectra of basic indicator

By using this experiment, the acidities of four sulfoimidazolium BAILs (**5**), (**6**), (**7**) and (**8**) have been studied. The acidities were expressed in terms of Hammett function in **Table 2B.1** by the extent of protonation of the indicator with the decreasing absorbance [I] of basic indicator (**Figure 2B.4**). No absorption

observed for the protonated form $[HI]^+$ of the indicator due to smaller molar absorptivity. The procedure started with the mixing of basic indicator solution (5 mg/dm^3, p*K*a = 0.99) and ILs (5 mmol/dm^3) in ethanol with equal concentration which showed maximum absorbance at 378 nm.

Table 2B.1 Calculation of the Hammett Function for various ILs in ethanol

Entry	IL	A_{max}	[I]%	[IH]%	H_0[a]
1	Blank	1.394	100.0	0	-
2	[Msim][$OOCCF_3$] **5**	0.815	58.5	41.5	1.14
3	[Dsim][$OOCCCl_3$] **7**	0.798	57.2	42.8	1.12
4	[Dsim][OTs] **6**	0.743	53.3	46.7	1.05
5	[Dsim][$OOCCF_3$] **8**	0.541	38.8	61.2	0.79

[a] Indicator: 4-nitroaniline

The order of acidities of ILs was arranged in the decreasing trend by increasing the values of Hammett function (**Table 2B.1**) according to the Hammett plot (**Figure 2B.4**) as follows: ([Dsim][$OOCCF_3$]) > ([Dsim][OTs]) > ([Dsim][$OOCCCl_3$]) > ([Msim][$OOCCF_3$]).

2B.2.2 Applications of the ILs as catalyst in one pot synthesis of 2-styrylquinoline 4

Table 2B.2 includes the standardization results of 2-styrylquinoline **4a** starting from 2-aminobenzophenone (1 mmol), acetoacetic ester (1 mmol) and *p*-tolualdehyde (1 mmol) using the acidic ILs **(5/6/7/8)** as catalysts/medium at various temperature. As reaction medium, they produced 22-39% of 2-

methylquinoline **3a** at room temperature during 12 h stirring (**Table 2B.2**, entry 1). By increasing the reaction temperature to 100 °C, the reaction was completed to form **3a** within 10-40 min using 50 mol% of (**5**/**7**/**8**) ILs (**Table 2B.2**, entry 2) except (**6**) which decomposed at 57.7 °C in the TGA analysis. In next step, the crude intermediate **3a** produce 84-96% of **4a** after treatment with 1 mmol of *p*-toluadehyde at 100 °C (**Table 2B.2**, entry 3). The three ILs produced similar yields of **4a** at 90 °C (**Table 2B.2**, entry 4). Among the three ILs, the best catalytic activity was obtained from 25 mol% of (**8**) at 90 °C (**Table 2B.2**, entries 5-6). In addition, 50 mol% of weak acidic ILs (**5**) and (**7**) was optimized as reaction medium for the synthesis of **4a** at 90 °C (**Table 2B.2**, entry 4). Further the model reaction afforded 77-82% of **3a** at 1 h and 62-70% of **4a** with 25 mol% of (**8**) in methanol and water solvents during 4 h reflux. (**Table 2B.2**, entries 7, 8).

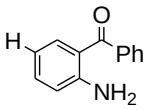
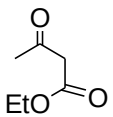
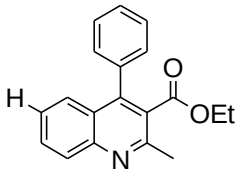
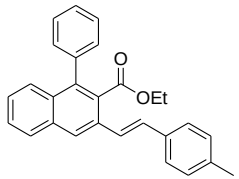
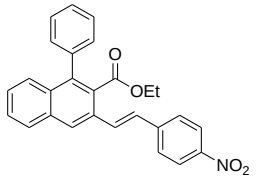
Table 2B.2 Optimization of the amount of ionic liquids and temperature for the synthesis of **3a** and **4a**

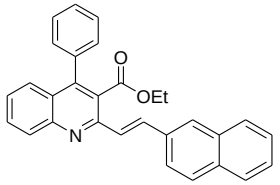
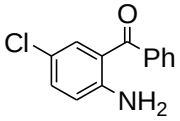
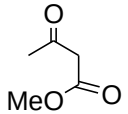
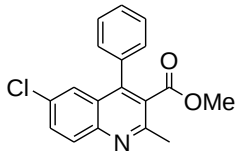
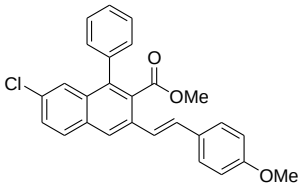
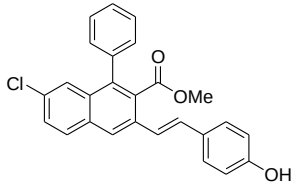
Entry	ILs (mol%)	Temp. (°C)	Time		% Yield of products [a,b]	
			3a(min) Step I	**4a**(h) Step II	**3a**	**4a**
1	**5**/**6**/**7**/**8**(100)	25	12 h	--	22/35/27/39	--
2	**5**/**7**/**8**(50)	100	40/25/10	--	97/97/98	--
3	**5**/**7**/**8**(50)	100	40/25/10	2/1.5/1	--	84/87/96
4	**5**/**7**/**8**(50)	90	40/30/10	2/1.5/1	--	83/85/95
5	**5**/**7**/**8**(25)	90	3 h/2.5 h/15	--	70/80/97	--
6	**8**(25)	90/80	15/35	1/85 min	--	94/83
7	**8**(25)	70/100	1 h	4	82/77	--
8	**8**(25)	70/100	1 h	4	--	70/62

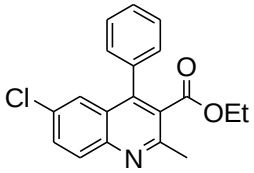
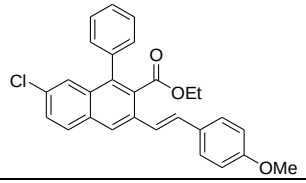
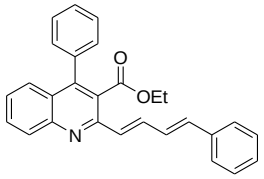
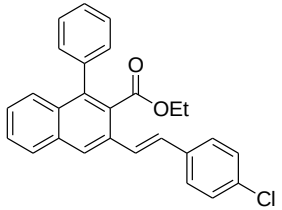
[a] Reactions were carried from the 1:1 ratio of 2-amino benzophenone and ethylacetoacetate using ionic liquid (**5**/**6**/**7**/**8**) followed by addition of 1 mmol of *p*-tolualdehyde; [b] Isolated yields

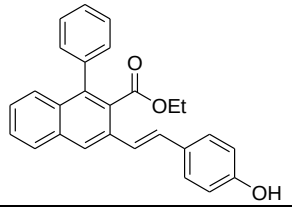
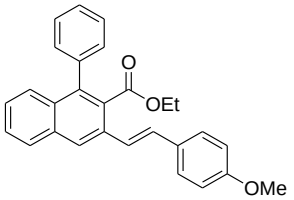
The standard reaction conditions were expanded to various 2-aminoaryl ketones and β-keto ester and substituted aromatic aldehydes. The results were summarized in **Table 2B.3**. The product formation was observed to be satisfactory within 1-2 h time in the 2nd step regardless of the nature of substituted aromatic aldehydes. By using IL [Msim][$OOCCF_3$] (**5**) the reactions provide 75-83% yield and using [Dsim][$OOCCCl_3$] (**7**) 79-85% yield was observed. The most active IL [Dsim][$OOCCF_3$] (**8**) afford maximum yield 88-95%. The condensation didn't occur with aliphatic aldehyde in presence of strong acidic IL (**8**) (**Table 2B.3**, entry 11).

Table 2B.3 Evaluation of the catalytic activity of ILs **5**, **7** and **8** for the synthesis of 2- styrylquinoline derivatives **4**

Entry	**1**	**2**	R_1CHO	Time (method)[a]		Product **4** Yield (%)[b] **5/7/8**	Mp. **4** [reported] °C
				3 **(**min**)**	**4** (h)		
1	 **1a**	 **2a**	4-$CH_3C_6H_4$-	40(I)/30(II)/15(III) **3a** 	2 /1.5/ 1	83/85/94 **4a** 	150.7-152.8
2	**1a**	**2a**	4-$NO_2C_6H_4$-	**3a**	2 /1.5/ 1	81/84/90 **4b** 	171.4-181.5

3	**1a**	**2a**	2-naphthyl-	**3a**	2 /1.5/ 1	80/84/88 **4c** 	158.6-159.2
4	 **1b**	 **2b**	4-$MeOC_6H_4$-	48(I)/40(II)/20(III) **3b** 	2 /1.5/ 1	80/83/95 **4d** 	167.6-172.4
5	**1b**	**2b**	4-HOC_6H_4-	**3b**	2 /1.5/ 1	78/81/93 **4e** 	182.7-184.3

6	**1b**	**2a**	4-$MeOC_6H_4$-	50(I)/45(II)/25(III) **3c** 	2 /1.5/ 1	75/80/92 **4f** 	145.7-147.2 [147-148] [23]
7	**1a**	**2a**	Ph-CH=CH-	**3a**	2 /1.5/ 1	81/84/90 **4g** 	169.6-173.7
8	**1a**	**2a**	4-ClC_6H_4-	**3a**	2 /1.5/ 1	75/79/94 **4h** 	150.5-154 [150-153] [23]

9	**1a**	**2a**	4-HOC_6H_4-	**3a**	2 /1.5/ 1	80/83/93 **4i** 	228-230.7 [232-234] [23]
10	**1a**	**2a**	4-$MeOC_6H_4$-	**3a**	2 /1.5/ 1	83/85/95 **4j** 	126.7-129
11	**1a**	**2a**	C_4H_9-	**3a** (III)	2 h	No reaction	----

[a] Method: (I) using 50 % of IL **5** at 90 °C, (II) using 50 mol% of IL **7** at 90 °C, (III) using 25 mol% of IL **8** at 90 °C; [b] Isolated yields

2B.2.3 Single crystal X-ray characterization of 2-styrylquinoline derivative

Single crystal X-ray analysis was performed on the 2-styrylquinoline derivative **4j** (**Table 2B.3**, entry 10) which confirmed the presence of basic 2-styrylquinoline moiety (**Figure 2B.5**) along with *anti*-conformation of two hydrogen atoms on the styrene double bond. The crystallographic parameters of the compound **4j** are included in **Table 2B.4**.

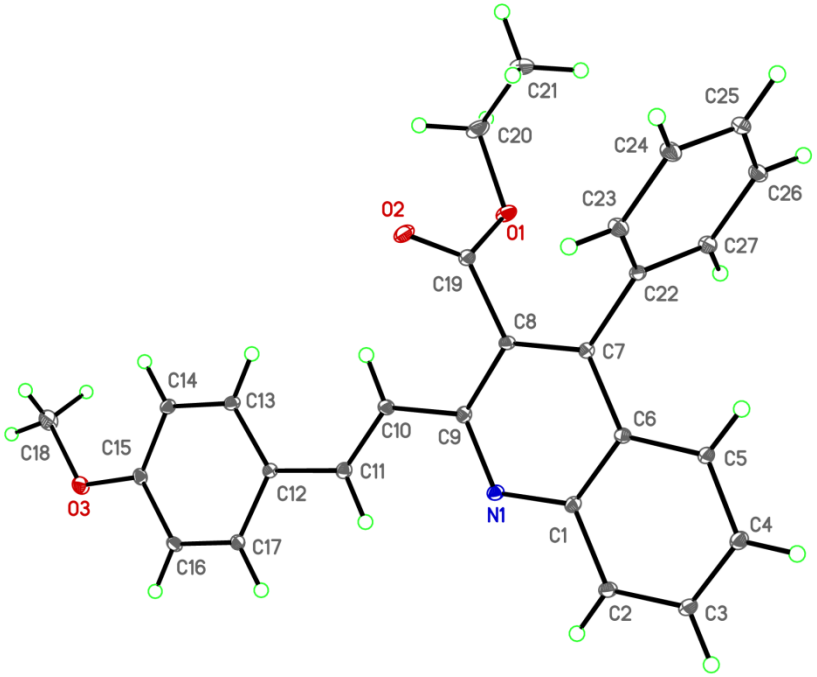


Figure 2B.5 Single crystal structure of **4j** with CCDC No.-1053069. The displacement ellipsoids are drawn at the 50% probability level and H atoms are represented by circles of arbitrary radii

Table 2B.4 Crystallographic parameters of the compound **4j**

	Compound **4j**		Compound **4j**
Chemical formula	$C_{27}H_{23}NO_3$	γ/°	90
Formula weight	409.46	Z	4
Crystal system	Monoclinic	V/ Å^3	2198.9(3)
Space group	$P2_1/c$	D_{calc}/g cm^{-3}	1.237

T/K	296(2)	μ /mm^{-1}	0.080
a/Å	12.9969(9)	Reflns collected	30670
b/ Å	15.4996(12)	Unique reflns	4318
c/ Å	12.1534(9)	R1[I > 2(I)]	0.0698
α/°	90	wR2 (all)	0.1856
β/°	116.085(5)	Goodness-of-fit	0.907

2B.2.4 Reusability of ionic liquid

The reusability of strong acidic ionic liquid catalyst (**8**) was performed up to 4th cycle for the preparation of **4a** from the mixture of 2-amino benzophenone (1 mmol), ethylacetoacetate (1 mmol) and *p*- tolualdehyde (1mmol) at 90 °C and it was expressed by the bar diagram (**Figure 2B.6**). From the figure it can be inferred that the IL can be reused for further reactions.

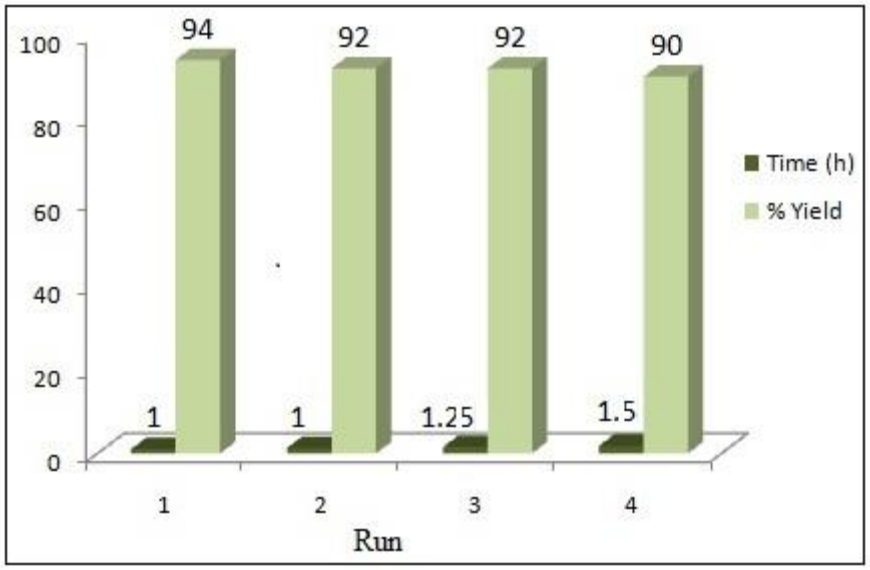
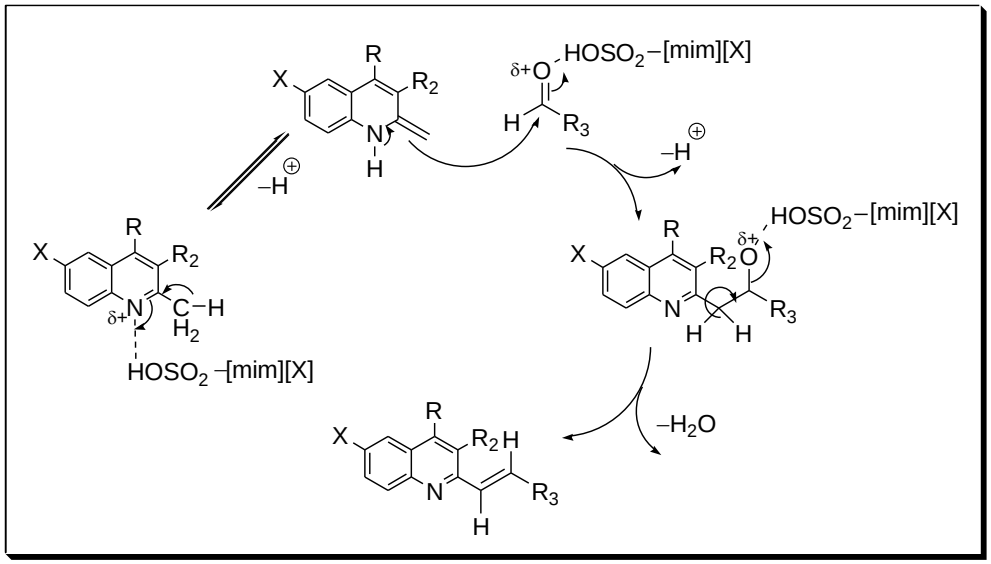


Figure 2B.6 Reusability of IL **8** as catalyst for the preparation of **4a**

2B.2.5 Plausible mechanism of the 2-styrylquinoline synthesis

The plausible mechanism of this synthesis can be expressed according to the following reaction **Scheme 2B.3.**



Scheme 2B.3 Proposed mechanism of Friedländer annulations

2B.3 Conclusion

This section describes the synthesis, characterization and utilization of four BAILs for the synthesis of 2-styrylquinoline derivatives. Three reported BAILs were synthesized along with one novel IL [Dsim][OTs.]. The thermal stability and acidity of these ILs were determined by using TGA analysis and UV spectrophotometer respectively. In addition, the novel IL was characterized by using FT-IR, ^{1}H NMR and ^{13}C NMR. After that the catalytic efficiency of these four sulfoimidazolium BAILs were studied for the one pot two step syntheses of 2-styrylquinolines. It was found that the new IL (**6**) decomposed at 57.5 °C and didn't catalyze the reaction under the optimized condition. The strong catalytic activity was observed for the IL (**8**) which generated excellent yield of product **4** at 90 °C under solvent-free condition in 1 h. The weak acidic ILs (**5**) and (**7**) promoted the reaction as reaction medium at the same temperature. In summary, the present procedure provides an efficient and improved method through single product formation, high yield, recycling of ILs and easy work up process.

2B.4 Experimental section

2B.4.1 General information

All the synthesized compounds were identified by using FT-IR, ^{1}H NMR, ^{13}C NMR, TGA, DTGA, CHN analyzer and melting point and comparison with reported data. The acidity measurement of the the Brønsted acidic ILs were done according to the reported literature methods [28-29]. The single crystal XRD data of compound **4j** was collected with CCDC No. -1053069 which contains the supplementary crystallographic information. This data can be obtained free of charge from the Cambridge Crystallographic Data Centre via www.ccdc.ac.uk./data/_request/cif.

2B.4.2 General procedures for the synthesis of ionic liquids

3-Methyl-1-sulfonic acid imidazolium trifluoroacetate ([Msim][$OOCCF_3$]) (**5**):

To a solution of [Msim][Cl] (5 mmol, 0.995 g) CF_3COOH solution (5 mmol, 0.57 g) in CH_2Cl_2 (10 mL) was added drop wise and the reaction mixture was stirred at 273 K for 10 min. The resulting reaction mixture was refluxed for 24 h. After completion of the reaction, solvent was removed by evaporation under reduced pressure. Further, residue was washed several times (5 times) with ethyl acetate to obtain [Msim][$OOCCF_3$] in 93% yield (1.28 g) [27].

1,3-Disulfo-imidazolium trichloroacetate ([Dsim][$OOCCCl_3$]) (**7)** & 1,3-disulfo-imidazolium trifluoroacetate [Dsim][$OOCCF_3$](**8**):

The synthesis of **7** and **8** ionic liquids consists of two steps which involves the preparation of 1,3-disulfonic acid imidazolium chloride and then treatment of this IL with the corresponding carboxylic acids according to the known methods [26, 30].

Step-I

In a round-bottomed flask (100 mL) containing imidazole (5 mmol, 0.340 g) in dry CH_2Cl_2 (50 mL), chlorosulfonic acid (1.19 g, 10.2 mmol) was added dropwise over a period of 20 min at room temperature. After the addition was

completed, the reaction mixture was stirred for 12 h under pressure of nitrogen (to remove the produced HCl), stand for 5 min, and the CH_2Cl_2 was decanted. The residue was washed with dry CH_2Cl_2 (3×10 mL) and dried under vacuum to give 1,3-disulfonicacid imidazolium chloride [Dsim][Cl] as a viscous pale yellow oil in 93% yield (1.26 g).

Step-II

These ionic liquids were prepared by mixing equal amount of (5 mmol, 1.32 g) [Dsim][Cl] ionic liquid and carboxylic acids [CCl_3COOH (0.816 g), CF_3COOH (0.57 g)] in dry dichloromethane (12 mL) in a 50 mL two necked round bottom flask and stirring at room temperature for 30 min. The HCl gas outlet was connected to a vacuum system through water and an alkali trap. The mixture was continued to stirring for one hour to complete the elimination of produced HCl gas and then diluted with 10 mL of dry CH_2Cl_2. The CH_2Cl_2 layer was decanted and washed the residue by more of it (3×10 mL). The ionic liquid residue was dried under vacuum to get **7**, **8** as reddish coloured viscous liquids with 97% (1.89 g) and 98% (1.67 g) yields respectively.

1,3-Disulfo-imidazolium tosylate [Dsim][OTs] (**6**):

In a 50 mL two necked round bottomed flask containing 5 mmol (1.32g) of [Dsim][Cl] ionic liquid, equal amount of p-toluene sulfonic acid (5 mmol, 0.86 g) was added over a period of 10 mins and then stirred at room temperature for 1 h. To remove the HCl gas produced during the period, an alkali trap was connected through a vacuum system. After completion of one hour stirring, the viscous reaction mixture was washed with dry CH_2Cl_2 (3×10 mL) and dried under reduced pressure to give [Dsim][OTs] as colourless oil with 97% (1.94 g) yield.

2B.4.3 General procedure for acidity determination and pKa of ionic liquids

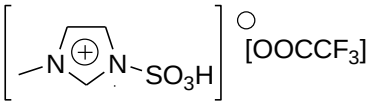
The detailed procedure of acidity determination by using UV spectrophotometer and the p*K*a calculation was described in **section 2A.4.3**.

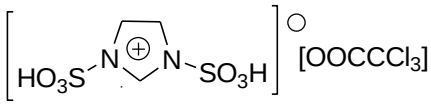
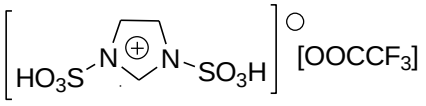
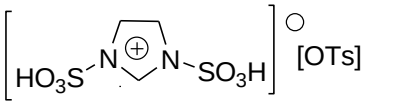
2B.4.4 Typical procedure for the synthesis of 2-styrylquinoline derivatives 4

A mixture of 2-aminoaryl ketone (1.0 mmol), β-keto ester (1.0 mmol) and 25 mol% of acidic ILs was heated in a 50 mL round-bottom flask at 90 °C for the specified time. After completion of the reaction as monitored by thin layer chromatography to the corresponding 2-methyl quinoline derivatives, 1 mmol of aromatic aldehyde was added to the reaction mixture. The reaction was again continued for the respective reaction time as represented in **Table 2B.3** at 90 °C for the formation of 2-styrylquinolines. The crude product was extracted from the ionic liquid phases using dichloromethane (2×3 mL) as solvent which was isolated from the dichloromethane solution after distillation under reduced pressure. The ionic liquid was retained as viscous layer in the reaction vessel and it was again utilized for next cycle of reaction. Further purification of the solid product was completed by recrystallization from ethanol to get analytically pure product.

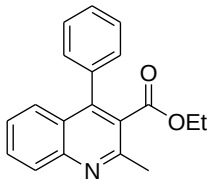
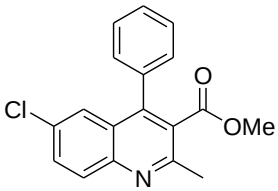
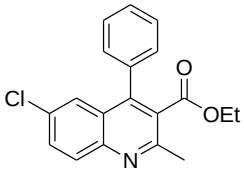
2B.5 Spectral and elemental data of ILs and 2-styrylquinoline derivatives

2B.5.1 Spectral data of ionic liquids

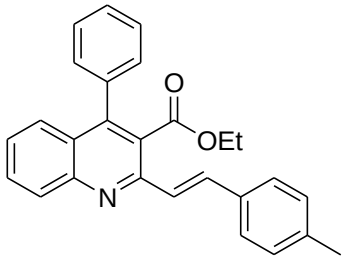
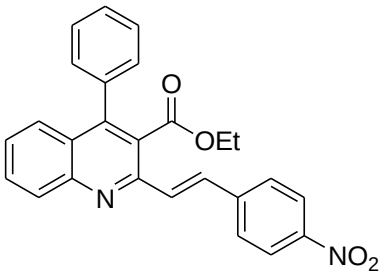
IL	Spectral data
 3-Methyl-1-sulfonic acid imidazolium trifluoroacetate ([Msim][$OOCCF_3$]) (**5**)	Viscous colourless oil, 93% (1.28 g) yield FT-IR (KBr) = 3238, 2978, 1770, 1612, 1450, 1174, 1051, 875, 763, 702, 585 cm^{-1}; ^1H NMR (400MHz, DMSO-d_6): δ (ppm) = 3.81 (s, 3H), 7.55 (s, 2H), 8.94 (s, 1H), 14.2 (s, 1H); ^{13}C NMR (100MHz, DMSO-d_6): δ = 34.9, 114.0, 116.9, 122.2, 127.6, 136.2, 158.7; Elemental analysis for: $C_6H_{10}F_3N_2O_5S$: Cal. C 25.8, H 3.61, N 10.0; Found: C 25.94, H 3.68, N 10.5.

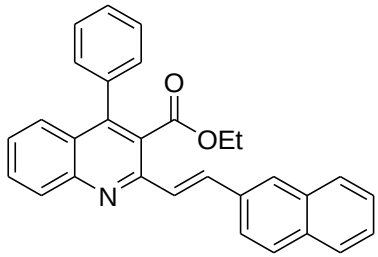
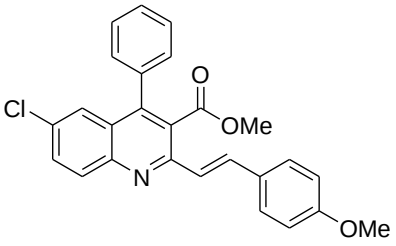
 1,3-Disulfo-imidazolium trichloroacetate ([Dsim][$OOCCCl_3$]) (**7**)	Reddish viscous liquid, 97% (1.89 g) yield FT-IR (KBr): 3413, 3312, 1752, 1634, 1594, 1427, 1187, 1051, 874, 760, 681, 591 cm^{-1}; ^1H NMR (400MHz, DMSO-d_6): δ (ppm) = 14.0 (s, 1H); 12.72 (s,1H), 8.81 (s, 1H), 7.48 (s, 2H), ^{13}C NMR (100MHz, DMSO-d_6): δ = 79.9, 121.1, 133.6, 163.0; Elemental analysis for $C_5H_5O_8S_2N_2Cl_3$: Cal. C 15.35, H 1.27, N 7.15; Found: C 15.40, H 1.33, N 7.22.
 1,3-Disulfo-imidazolium trifluoroacetate [Dsim][$OOCCF_3$] (**8**)	Reddish viscous liquid, 98% (1.67 g) yield FT-IR (KBr): 3415, 1748, 1645, 1582, 1438, 1180, 1049, 878, 758, 698, 581 cm^{-1}; ^1H NMR (400MHz, DMSO-d_6): δ (ppm) = 14.03 (s, 1H), 13.52 (s, 1H), 8.89 (s, 1H), 7.43 (s, 2H); ^{13}C NMR (100MHz, DMSO-d_6): δ = 62.9, 118.9, 138.2, 139.1, 158.9; Elemental analysis for $C_5H_5O_8S_2N_2F_3$: Cal. C 17.69, H 1.51, N 8.16; Found: C 17.76, H 1.58, N 8.22.
 1,3-Disulfo-imidazolium tosylate [Dsim][OTs] (**6**)	Viscous colourless oil, 97% (1.94 g) yield FT-IR (KBr): 3464, 1638, 1208, 1048, 823, 688, 582, 478, 418 cm^{-1}; ^1H NMR (400MHz, DMSO-d_6): δ (ppm) = 2.11 (s, 3H), 7.04 (s, 2H), 7.46-7.50 (m, 4H), 8.91 (s, 1H), 14.13 (s, 2H); ^{13}C NMR (100MHz, DMSO-d_6): δ = 21.2, 119.8, 125.9, 129, 134.6, 139.5, 139.7, 143.8, 144.1; Elemental analysis for $C_{10}H_{15}O_9S_3N_2$: Cal. C 29.77, H 3.75, N 6.94; Found: C 29.83, H 3.81, N 6.98.

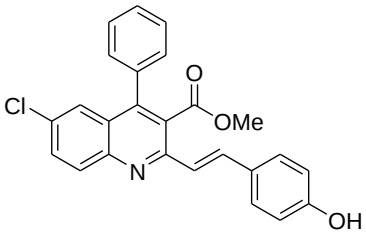
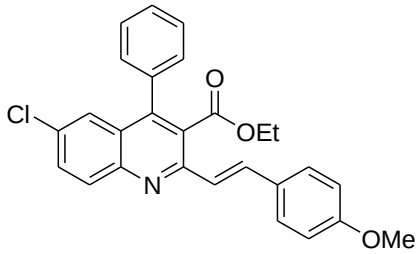
2B.5.2 Spectral data of quinoline derivatives

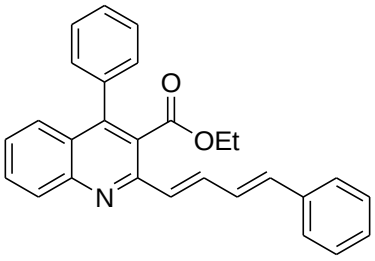
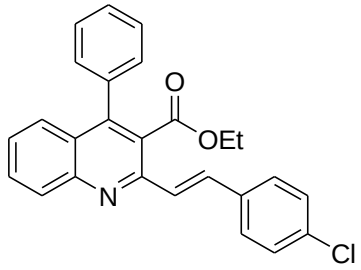
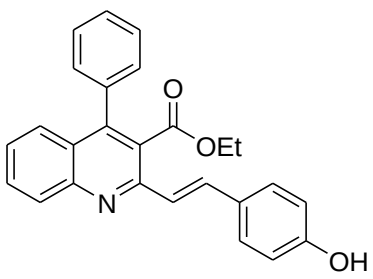
Compound	Spectral data
 Ethyl-2-methyl-4-phenylquinoline-3-carboxylate **Table-2B.3**, (**3a**)	Referred to Section 2A.5.2 (**Table 2A.4**, entry 5)
 Methyl-6-chloro-2-methyl-4-phenylquinoline-3-carboxylate **Table-2B.3**, (**3b**)	Referred to Section 2A.5.2 (**Table 2A.4**, entry 4)
 Ethyl-6-chloro-2-methyl-4-phenylquinoline-3-carboxylate **Table-2B.4**, (**3c**)	Referred to Section 2A.5.2 (**Table 2A.4**, entry 6)

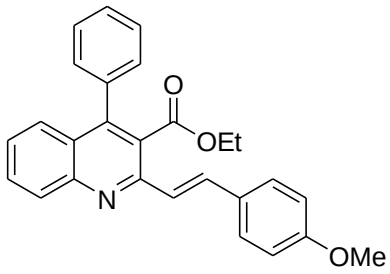
2B.5.3 Spectral data of 2-styrylquinoline derivatives

Compound	Spectral data
 (E)-ethyl 2-(4-methylstyryl)-4-phenylquinoline-3-carboxylate **Table-2B.3**, entry-1, (**4a**)	Yellow solid, Mp. 150.7-152.8 °C FT-IR (KBr): 3342, 2968, 1720, 1587, 1397, 1225, 1170, 1065, 963, 826, 757 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 0.97 (t, *J* = 7.4Hz, 3H), 2.37 (s, 3H), 4.09 (q, *J* = 6.9Hz, 2H), 7.20 (d, *J* = 7.8Hz, 2H), 7.34 (d, *J* = 15.6Hz, 1H), 7.38-7.44 (m, 3H), 7.48- 7.57 (m, 6H),7.74 (t, *J* = 6.9 Hz, 1H), 8.12 (d, *J* = 15.6 Hz, 1H), 8.19 (d, *J* = 8.3 Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 13.8, 21.5, 61.6, 123.5, 126.6, 126.7, 127.7, 128.3, 128.6, 129.4, 129.5, 130.6, 133.9, 146.0, 147.2, 139.0, 146.9, 148.0, 151.3, 168.4; Elemental analysis for $C_{27}H_{23}NO_2$: Cal. C 82.42, H 5.89, N 3.56; Found: C 82.44, H 5.91, N 3.54
 (E)-ethyl 2-(4-nitrostyryl)-4-phenylquinoline-3-carboxylate **Table-2B.3**, entry-2, (**4b**)	Yellow solid, Mp.171.4-181.5 °C FT-IR (KBr) : 3432, 3058, 2971, 1719, 1589, 1511, 1399, 1333, 1224, 1171, 1107, 1064, 974, 832, 760, 696 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 0.95 (t, *J* = 7.3Hz, 3H), 4.11 (q, *J* = 6.8Hz, 2H), 8.25 (d, *J* = 8.7 Hz, 2H), 8.19 (d, *J* = 9.1Hz, 2H), 8.12 (s, 1H), 7.74-7.79 (m 3H), 7.62 (d, *J* = 8.2 Hz, 1H), 7.45-7.51 (m, 4H), 7.36-7.40 (m, 2H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 13.6, 61.8, 124.2, 126.7, 128.1, 128.4, 128.7, 128.8, 129.5, 130.8, 133.7, 136.0, 143.1, 147.4, 147.5, 148.1, 150.1, 168.2; Elemental analysis for $C_{26}H_{20}N_2O_4$: Cal. C 73.57, H 4.75, N 6.60; Found: C 73.55, H 4.77, N 6.58

 Ethyl 2-[(E)-2-(naphthalene-3-yl)vinyl]-4-phenylquinoline-3-carboxylate **Table-2B.3**, entry-3, (**4c**)	Yellow solid, Mp. 158.6-159.2 °C FT-IR (KBr): 3451, 3242, 3048, 2927, 2377, 2271, 1624, 1582, 1504, 1434, 1362, 1301, 1265, 1168, 1098, 980, 865, 821, 742 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 0.92 (t, *J* = 6.9Hz, 3H), 4.05 (q, *J* = 6.9Hz, 2H), 7.28-7.43 (m, 9H), 7.52(d, *J* = 8.2Hz, 1H), 7.64-7.85 (m, 5H), 7.97 (s, 1H), 8.18 (d, *J* = 8.6 Hz, 1H), 8.26 (d, *J* = 15.6Hz, 1H); ^{13}C NMR (75MHz, $CDCl_3$): δ = 13.7, 61.6, 123.5, 123.8, 124.5, 125.7, 126.3, 126.6, 127.0, 127.3, 127.3, 127.7, 128.0, 128.3, 128.4, 128.6, 129.1, 129.4, 129.5, 130.5, 133.5, 134.1, 134.6, 135.7, 136.6, 143.4, 146.8, 148.1, 151.0, 168.2; Elemental analysis for $C_{30}H_{23}NO_2$: Cal. C 83.89, H 5.40, N 3.26; Found: C 83.86, H 5.44, N 3.22
 (E)-methyl-6-chloro-2-(4-methoxystyryl)-4-phenylquinoline-3-carboxylate **Table-2B.3**, entry-4, (**4d**)	Yellow solid, Mp. 143.7-146.9 °C FT-IR (KBr) :3431, 3059, 2946, 2838, 2379, 1730, 1565, 1509, 1476, 1437, 1391, 1313, 1223, 1159, 1073, 882, 831, 765, 704 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 3.60 (s, 3H), 3.85 (s,3H), 6.92 (d, *J* = 8.7Hz, 2H), 7.11 (d, *J* = 15.6 Hz, 1H), 7.36-7.38 (m, 2H), 7.51-7.53 (m, 4H), 7.57 (d, *J* = 8.7 Hz, 2H), 7.66 (dd, *J* = 9.2, 2.3Hz ,1H), 8.08-8.14 (m, 2H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 52.5, 55.5, 114.3, 125.4, 127.5, 128.6, 129.2, 129.3, 131.7, 132.5, 151.6, 160.6, 168.6; Elemental analysis for $C_{26}H_{20}ClNO_3$: Cal. C 72.64, H 4.69, N 3.26; Found: C 72.60, H 4.73, N 3.22

 (E)-methyl-6-chloro-2-(4-hydroxystyryl)-4-phenylquinoline-3-carboxylate **Table-2B.3**, entry-5, (**4e**)	Yellow solid, Mp. 182.7-184.3 °C FT-IR (KBr) : 3324, 2965, 1725, 1560, 1457, 1375, 1282, 1220, 1138, 1067, 962, 820, 685 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 3.59 (s, 3H), 6.63 (d, *J* = 8.2Hz, 1H), 6.86 (d, *J* = 8.2Hz, 1H), 6.96 (d, *J* = 8.2Hz, 1H), 7.05-7.25 (m, 2H), 7.35-7.37 (m, 2H), 7.45-7.60 (m, 4H), 7.63-7.75 (m, 1H), 7.98 (d, *J* =15.6Hz, 1H), 8.11 (d, *J* = 8.7Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 23.2, 52.4, 116.1, 125.4, 128.6, 129.1, 129.6, 129.7, 131.0, 151.4, 154.9, 156.6, 168.2; Elemental analysis for $C_{25}H_{18}ClNO_3$: Cal. C 72.20, H 4.36, N 3.37; Found: C 72.16, H 4.39, N 3.34
 (E)-ethyl-6-chloro-2-(4-methoxystyryl)-4-phenylquinoline-3-carboxylate **Table-2B.3**, entry-6, (**4f**)	Yellow solid, Mp 145.7-147.2 °C FT-IR (KBr) : 3334, 3052, 2977, 1727, 1566, 1476, 1436, 1381, 1275, 1219, 1150, 1070, 967, 829, 699 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 0.78 (t, *J* = 7.3Hz, 3H), 3.64 (s, 3H), 3.92 (q, *J* = 6.9 Hz, 2H), 6.65 (d, *J* = 8.7 Hz, 1H), 6.85 (d, *J* =8.3 Hz, 1H), 6.95 (d, *J* = 9.2Hz, 1H), 7.13-7.19 (m, 4H), 7.25-7.48 (m, 5H), 7.49 (d, *J* = 8.6 Hz, 1H), 7.76 (d, *J* = 8.7 Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 13.8, 43.2, 61.6, 113.7, 114.4, 114.5, 125.2, 125.9, 128.4, 128.6, 128.7, 128.9, 129.3, 129.6, 130.9, 132.5, 135.4, 156.9, 158.0, 168.2; Elemental analysis for $C_{27}H_{22}ClNO_3$: Cal. C 73.05, H 5.00, N 3.16; Found: C 73.00, H 5.04, N 3.21

 Ethyl 4-phenyl-2-(1E, 3E)-4-phenylbuta-1,3-dien-1-yl)quinoline-3-carboxylate **Table-2B.3**, entry-7, (**4g**)	Yellow solid, Mp 169.6-173.7 °C FT-IR (KBr): 3021, 2378, 1718, 1614, 1542, 1398, 1223, 1168, 1063, 989, 758, 694 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 0.87 (t, *J* = 6.9Hz, 3H), 4.01 (q, *J* = 6.9Hz, 2H), 6.85-7.10 (m, 4H), 7.19-7.48 (m, 11H), 7.67 (m, 2H), 7.96 (m,1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 13.8, 61.7, 126.6, 126.7, 127.0, 127.1, 128.3, 128.5, 128.7, 128.9, 129.7, 130.7, 136.0, 137.2, 137.3, 147.2, 148.7, 151.3, 168.6; Elemental analysis for $C_{28}H_{23}NO_2$: Cal. C 82.94, H 5.72, N 3.45; Found: C 82.90, H 5.75, N 3.42
 (E)-ethyl 2-(4-chlorotyryl)-4-phenylquinoline-3-carboxylate **Table-2B.3**, entry-8, (**4h**)	Brown solid, Mp.150.5-154 °C FT-IR (KBr) : 3296, 3052, 2977, 2668, 2550, 1929, 1702, 1573, 1483, 1404, 1296, 1233, 1175, 1127, 1070, 1008, 929, 851, 760, 694 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 0.94 (t, *J* = 6.9Hz, 3H), 4.08 (q, *J* = 6.9Hz, 2H), 7.32-7.59 (m, 12H), 7.75 (t, *J* = 7.3Hz, 1H), 8.10 (d, *J* = 15.6 Hz, 1H), 8.19 (d, *J* = 8.3 Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 13.9, 61.8, 125.2, 126.7, 127.1, 128.5, 128.7, 128.9, 129.8, 130.8, 134.6, 135.0, 135.3, 136.0, 147.1, 148.3, 150.9, 168.5; Elemental analysis for $C_{26}H_{20}ClNO_2$: Cal. C 75.45, H 4.87,N 3.38; Found: C 75.43, H 4.89, N 3.41
 (E)-ethyl 2-(4-hydroxystyryl)-4-	Yellow solid, Mp. 233-234 °C FT-IR (KBr) : 3324, 3050, 2981, 2377, 1722, 1564, 1503, 1439, 1392, 1290, 1223, 1166, 1062, 828, 762, 700 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 0.95 (t, *J* = 6.9Hz, 3H), 4.09 (q, *J* = 6.9Hz, 2H), 6.89 (d, *J* = 8.3Hz, 2H), 7.20 (d, *J* = 15.6 Hz, 1H), 7.35-7.51 (m,

phenylquinoline-3-carboxylate **Table-2B.3**, entry-9, (**4i**)	7H), 7.53-7.63 (m,2H), 7.75 (m, 1H), 8.09 (d, *J* = 15.6Hz, 1H), 8.19 (d, *J* = 8.2 Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 13.6, 61.6, 116.1, 121.2, 125.4, 126.3, 126.6, 127.5, 128.2, 128.5, 128.9, 129.2, 129.3, 130.6, 132.4, 135.4, 146.7, 147.5, 151.5, 157.2, 168.5; Elemental analysis for $C_{26}H_{21}NO_3$: Cal. C 78.97, H 5.35, N 3.54; Found: C 78.93, H 5.38,N 3.58
 (E)-ethyl 2-(4-methoxystyryl)-4-phenylquinoline-3-carboxylate **Table-2B.3**, entry-10, (**4j**)	Yellow solid, Mp.126.7-129 °C FT-IR (KBr) : 3320, 2975, 2375, 1716, 1557, 1429, 1385, 1282, 1220, 1165, 1057, 825, 758, 698 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ (ppm) = 0.97 (t, *J* = 7.4Hz, 3H), 3.8 (s, 3H), 4.11 (q, *J* = 7.3Hz, 2H), 6.93 (d, *J* = 8.7 Hz, 2H), 7.25-7.30 (m, 2H), 7.36-7.40 (m, 2H), 7.45-7.50 (m, 3H),7.54- 7.59 (m, 3H) , 7.76 (m, 1H), 8.07 (d, *J* = 15.6 Hz, 1H), 8.18(d, *J* = 8.4 Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ = 13.8, 55.4, 61.6, 114.3, 122.0, 126.6, 128.6, 129.2, 129.6, 129.7, 130.6, 133.0, 136.0, 147.9, 151.4, 157.6, 160.4, 168.4; Elemental analysis for $C_{27}H_{23}NO_3$: Cal. C 79.20, H 5.66, N 3.42; Found: C 79.18, H 5.68, N 3.40

References:

[1] Broadwater, S.J., et al. *Org. Biomol. Chem.* **3** (16), 2899--2906, 2005.

[2] Climent, M.J., et al. *Green Chem.* **12** (1), 99--107, 2010.

[3] Nordmann J. & Müller, T.J.J. *Org. Biomol. Chem.* **11** (38), 6556--6561, 2013.

[4] Ferguson, M., et al. *Green Chem.* **16** (3), 1374--1382, 2014.

[5] Normand-Bayle, M., et al. *Bioorg. Med. Chem. Lett.* **15** (18), 4019--4022, 2005.

[6] Ouali, M., et al. *J. Med. Chem.* **43** (10), 1949--1957, 2000.

[7] Zouhiri, F., et al. *Tetrahedron Lett.* **42** (46), 8189--8192, 2001

[8] Firley, D., et al. *J. Phys. Chem. B* **110** (1), 537--547, 2006.

[9] Taylor, E.C. & Martin, S.F. *J. Am. Chem. Soc.* **96** (26), 8095--8102, 1974.

[10] Ochiai, E. & Kuniyoshi, I. *Pharm. Bull.* **5** (4), 289--291, 1957.

[11] Cooper, G.H. & Rickard, R.L. *J. Chem. Soc. C* 772--776, 1971.

[12] Taylor, E.C. & Martin, S.F. *J. Am. Chem.Soc.* **94** (8), 2874--2875, 1972.

[13] Normand-Bayle, M., et al. *Bioorg. Med. Chem. Lett.* **15** (18), 4019--4022, 2005.

[14] Musiol, R., et al. *Monatsh. Chem.* **137** (9), 1211--1217, 2006.

[15] Li, V.M., et al. *Russ. J. Org. Chem.* **48** (6), 823--828, 2012.

[16] Staderini, M., et al. *Synlett* (17), 2577--2579, 2011.

[17] Cheng, C.-C. & Yan, S.-J. *Org. React.* **28** (2), 37--201, 2005.

[18] Bergstrom, F.W. *Chem. Rev.* **35** (2), 156, 1944.

[19] Jones, G. In *The Chemistry of Heterocyclic Compounds*, A. Weissberger, et al., eds., John Wiley and Sons: Chichester, 1977, 93--318.

[20] Sridharan, V., et al. *Tetrahedron* **65** (10), 2087--2096, 2009.

[21] Leonard, J.T. & Roy, K. *Eur. J. Med. Chem.***43** (1), 81--92, 2008.

[22] Makhija, M.T. *Curr. Med. Chem.* **13** (20), 2429--2441, 2006.

[23] Dabiri, M., et al. *Tetrahedron Lett.* **49** (37) 5366--5368, 2008.

[24] Kumar, D., et al. *RSC Adv.* **5** (4), 2920--2927, 2015.

[25] Olivier-Bourbigou H, et al. *App. Cat. A: Gen.* **373** (1-2), 1--56, 2010.

[26] Dutta, A.K., et al. *RSC Adv.* **4** (78), 41287--41291, 2014.

[27] Kore, R., et al. *J. Mo1. Catal. A: Chem.* **360**, 61--70, 2012.

[28] Wang, Y.-Y., et al. *Chin. J. Chem.* **26** (8), 1390--1394, 2008.

[29] Thomazeau, C., et al. *J. Am. Chem. Soc.* **125** (18), 5264--5265, 2003.

[30] Zolfigol, M.A., et al. *Appl. Catal. A* **400** (1-2), 70--81, 2011.