

Imidazolium supported iron-chloroglycine complex, a good turnover recyclable catalyst for the solvent free synthesis of 3, 4-dihydropyrimidin-2(1H)-ones – promoted by ultrasound irradiation

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Abstract. A novel large band gap 1-glycyl-3-methyl imidazolium chloride-iron (III) complex [[Gmim]Cl-Fe(III)] was found to be a heterogeneous catalyst for an efficient and solvent free synthesis of 3,4-dihydropyrimidin-2(1H)-ones by condensation of substituted aldehydes, ethyl acetoacetate and urea (or) thiourea with tremendous yields in high turnover number (4.1×10^2 to 18.8×10^2) at ambient temperature using ultrasound irradiation as the activation mode of reaction. This operation formulates very interesting, ecological perspective due to simple reaction condition, isolation and purification of products. In addition, this methodology offers a competitive recyclability of the catalyst without a significant loss of its catalytic activity and could be readily reused, thus making this protocol more environmentally acceptable whilst no catalyst leaching was observed.

Keywords: Iron(III) complex; Multi-component reactions; Ultrasonication; Ionic liquid; Green approach.

Resumen.

Se descubrió que un complejo novedoso de banda ancha 1-glicil-3-metilimidazolio cloruro de hierro (III) [[Gmim] Cl-Fe (III)] es un catalizador heterogéneo para una síntesis eficiente y libre de solventes de 3,4-dihidropirimidin-2 (1H) -ones por condensación de aldehídos sustituidos, acetoacetato de etilo y tiourea urea (o) con tremendos rendimientos en alto número de recambio (4.1×10^2 a 18.8×10^2) a temperatura ambiente mediante irradiación con ultrasonido como modo de activación de reacción. Esta operación formula una perspectiva ecológica muy interesante debido a la condición de reacción simple, el aislamiento y la purificación de los productos. Además, esta metodología ofrece una reciclabilidad competitiva del catalizador sin una pérdida significativa de su actividad catalítica y podría reutilizarse fácilmente, lo que hace que este protocolo sea más aceptable para el medio ambiente sin que se observe lixiviación del catalizador.

Palabras clave: complejo de hierro (III); reacciones multi-componentes; ultrasonificación: líquido iónico; aproximamiento verde.

Introduction

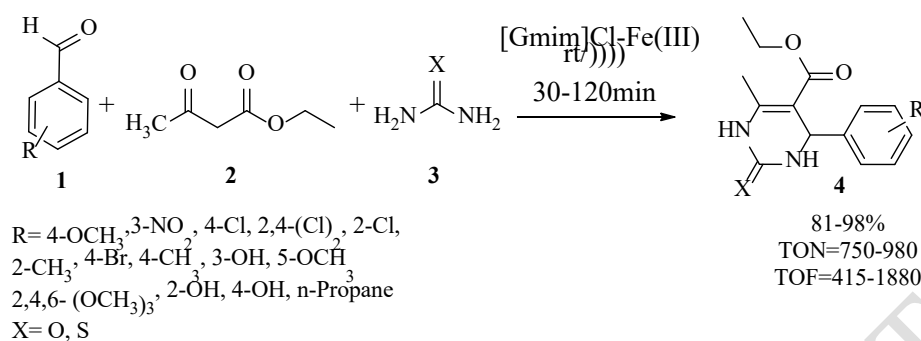
Multicomponent reactions (MCRs) are incredibly attractive tools towards obtain complex molecules from one-pot procedures. Dihydropyrimidinones (DHPMs) are their derivatives contain attracted significant interest since they exhibit promising activities as calcium channel blockers, antihypertensive agents, α -1a-antagonists in addition to neuropeptide Y antagonists. A few marine alkaloids containing the dihydropyrimidine core unit have interesting biological properties: batzelladine alkaloids have been found to be potent HIV gp-120-CD4 inhibitors. In recent times, dihydropyrimidinones have also been considered as a new lead for the growth of new anticancer drugs [1].

Ionic liquids contain emerged as a set of green solvents since last decade, with unique properties such as tunable polarity, high thermal stability, and immiscibility with a number of organic solvents, negligible vapor pressure and recyclability [2-6]. Recently, Vasundhara Singh *et al* was described Biginelli three component reactions under solvent free conditions by both thermally and in microwave conditions using [Bmim]HSO₄ as catalyst [7]. Devanand B. Shinde *et al* also followed one-pot synthesis of dihydropyrimidinones in [bmim] Cl·2AlCl₃ ionic liquids [8]. Moreover, Sergei G. Zlotin and Nina N. Makhova *et al* reported alkyl amine and alkyl imidazole salts with BF₄⁻, PF₆⁻, AlCl₄⁻ and Al₂Cl₇⁻ anions as mild acid catalysts in the three-component reaction of β -dicarbonyl compounds, including fluorinated ones, with aldehydes and urea [9]. Qin Wang *et al* was successfully employed [bmim]PF₆ as promoter for the Biginelli condensation of various aldehydes, urea and 1,3-dicarbonyl compounds to afford corresponding 3,4-dihydropyrimidinones in excellent yield and short duration under microwave irradiation [10]. Recently Brenno A.D. Neto *et al* was effectively employed imidazolium tagged iron catalyst for the Biginelli condensation reaction into excellent yield and short duration under room temperature [11].

Ultrasonic activation is based on cavitation effects leading to mass transfer improvement, towards promote powerful a green approach; which has been used progressively to speed up the synthesis of organic compounds toward increase the reaction rate and higher yield with shorter duration. Furthermore, this method considered as a processing help in terms of energy conservation along with waste minimization compared to conventional methods. Moreover, it is more convenient and easily controlled in the contemplation of green chemistry concepts [12-14].

Recently, iron complex has been used for several organic transformations such as the epoxidation of styrene [15], oxidation of alcohol [16-17], asymmetric synthesis [18-20], amination [21], and also for the Michael addition reactions [22-23]. However, optical properties of the metal complexes contain an interesting area of semiconducting along with optical materials because -CH=N group is isoelectronic with the -CH=CH group in these metal complexes with the incorporation of nitrogen atoms into the conjugated system. However, these materials possess large potential for device applications such as Schottky diode, light-emitted diode and optical sensor [24-27]. Therefore, it is important to investigate optical properties of them and obtain new optical materials based on metal complexes.

From above the open literature the development of benign, cost-effective and eco-friendly catalytic Biginelli reaction, based on iron functionalized ionic liquid is a major challenge. The objectives of the present study is develop an efficient synthetic process for the facile synthesis of 3, 4-dihydropyrimidin-2-(1*H*)-ones offer many advantages including high conversion, short duration and the involvement of non-toxic reagents conversion (Scheme 1).



Scheme 1. Synthesis of various 3,4-dihydropyrimidin-2-(1H)-ones using [Gmim]Cl-Fe(III) complex as a catalyst.

Experimental

The Ultrasonic irradiation experiments were carried out in a sonochemical apparatus SONIPRED-150. The frequency can be tuned between 18 and 27 kHz and the power can be varied up to a maximum output of 350 W. The ¹H-NMR spectra was recorded on a Bruker 500 MHz using CDCl₃ as the solvent and mass spectra were recorded on JEOL GC MATE II HRMS (EI) spectrometer. FT-IR was recorded on AVATRA 330 Spectrometer with DTGS detector. Column chromatography was performed on silica gel (200-300 mesh). Analytical thin-layer chromatography (TLC) was carried out on precoated silica gel GF-254 plates. All solvents and chemicals were commercially available and used without further purification unless otherwise stated.

Preparation of [Gmim]Cl-Fe(III) complex. [Gmim]Cl-Fe(III) complex was synthesized following the literature [28-29].

General procedure. A mixture of 4-methoxy benzaldehyde (1.22 g, 10.0 mmol), ethyl acetoacetate (1.28g, 10.0 mmol), urea (0.72g, 12.0 mmol) and [Gmim]Cl-Fe(III) (0.062g, 0.1 mmol) were added to a 50 mL round-bottomed flask. The mixture was continuously irradiated with a sonic horn at 20 kHz at 25°C for a period as indicated in (Table 3) (The reaction was monitored by TLC, until the aldehyde was disappeared). The product was extracted with diethyl ether (3 x 5 mL) and dried over MgSO₄ and evaporated under reduced pressure. The crude product obtained was purified by flash chromatography and further recrystallized from ethanol to obtain the pure product.

(4a) [30-32]: ¹H NMR (DMSO-d₆, 500MHz)δ (ppm): 9.80 (s, 2H), 7.35-7.21 (m, 5H), 5.15 (d, 1H), 3.98 (q, 2H), 2.25 (s, 3H), 1.09 (t, 3H); ¹³C-NMR: 165.8, 152.6, 148.8, 145.3, 128.8, 127.7, 126.7, 99.7, 59.6, 54.4, 18.2, 14.5.; HR-MS (EI) observed/theoretical: 260.4611/260.2884

(4b) [30-32]: ¹H NMR (DMSO-d₆, 500MHz)δ (ppm): 1.05 (t, 3H), 2.16 (s, 3H), 3.64 (s, 3H), 3.91 (q, 2H), 5.02(s, 1H), 7.06 (s,1H), 7.08 (d, 1H), 6.81 (d, 2H), 9.84 (s, 2H). ¹³C-NMR: 165.3, 158.4, 152.1, 147.9, 137.0, 127.3, 113.6, 99.5, 59.1, 55.0, 53.2, 17.7, 14.0. HRMS (EI) observed/theoretical: 290.291/290.1267

(4c) [30-32]: ¹H NMR (DMSO-d₆, 500MHz)δ (ppm): 9.82 (s, 2H), 7.67 (s, 2H), 7.20 (d, 2H), 5.12 (d, 1H), 3.93 (q, 2H), 2.24 (s, 3H), 1.09 (t, 3H); ¹³C-NMR: 167.3, 149.9, 148.8, 146.6, 144.8, 133.1, 129.3, 121.9, 120.7, 106.4, 61.7, 51.2, 20.5, 17.4.; HRMS (EI) observed/theoretical: 305.1010/305.1012

(4d) [30-32]: ¹H NMR (DMSO-d₆, 500MHz)δ (ppm): 9.76 (s, 2H), 7.78-7.83 (m, 4H), 5.18 (d, 1H), 3.84 (q, 2H), 2.28 (s, 3H), 1.20 (t, 3H); ¹³C-NMR: 167.9, 150.4, 146.5, 143.4, 132.4, 129.3, 129.1, 126.2, 126.0, 106.0, 61.9, 52.4, 20.4, 17.0.; HRMS (EI) observed/theoretical: 294.0770/294.7335

(4e) [30-32]: ^1H NMR (DMSO- d_6 , 500MHz) δ (ppm): 9.73 (s, 2H), 7.70 (s, 1H), 7.12-7.23 (m, 2H), 5.14 (d, 1H), 3.89 (q, 2H), 2.29 (s, 3H), 1.26 (t, 3H); ^{13}C -NMR: 167.7, 150.6, 147.5, 140.4, 133.5, 133.2, 130.6, 129.6, 126.2, 106.4, 61.9, 50.4, 20.6, 17.9.; HRMS (EI) observed/theoretical: 328.0381/329.1786

(4f) [30-32]: ^1H NMR (DMSO- d_6 , 500MHz) δ (ppm): 9.70 (s, 2H), 7.40 (m, 2H), 7.30 (m, 2H), 5.17 (d, 1H), 3.85 (q, 2H), 2.26 (s, 3H), 1.22 (t, 3H); ^{13}C -NMR: 167.1, 150.4, 147.0, 140.9, 132.5, 128.4, 128.6, 126.6, 126.2, 106.9, 60.9, 50.6, 21.0, 18.0.; HRMS (EI) observed/theoretical: 294.0771/294.2775.

(4g) [30-32]: ^1H NMR (DMSO- d_6 , 500MHz) δ (ppm): 9.69 (s, 2H), 7.36 (m, 2H), 7.14 (m, 1H), 5.19 (d, 1H), 3.89 (q, 2H), 2.41 (s, 3H), 2.23 (s, 3H), 1.27 (t, 3H); ^{13}C -NMR: 168.0, 150.4, 147.7, 142.9, 134.5, 130.2, 127.6, 126.5, 124.2, 106.9, 60.9, 50.6, 21.0, 19.6, 18.7.; HRMS (EI) observed/theoretical: 274.1317/274.3153

(4h) [30-32]: ^1H NMR (DMSO- d_6 , 500MHz) δ (ppm): 9.79 (s, 2H), 7.76 (d, 2H), 7.52 (s, 1H), 7.19 (d, 2H), 3.98 (q, 2H), 2.24 (s, 3H), 1.09 (t, 3H); ^{13}C -NMR: 165.8, 152.5, 149.3, 144.8, 131.9, 129.1, 120.9, 99.3, 59.8, 54.1, 18.4, 14.6; HRMS (EI) observed/theoretical: 339.0336/339.1845.

(4i) [30-32]: ^1H NMR (DMSO- d_6 , 500MHz) δ (ppm): 9.87 (s, 2H), 7.34-7.39 (m, 4H), 5.12 (d, 1H), 3.89 (q, 2H), 2.34 (m, 3H), 2.30 (s, 3H), 1.20 (t, 3H); ^{13}C -NMR: 167.7, 158.0, 147.8, 141.0, 134.2, 128.8, 128.3, 126.5, 106.0, 61.5, 52.0, 21.5, 20.0, 17.2.; HRMS (EI) observed/theoretical: 274.1318/274.3152.

(4j) [30-32]: ^1H NMR (DMSO- d_6 , 500MHz) δ (ppm): 9.87 (s, 2H), 7.06-7.15 (m, 4H), 5.16 (d, 1H), 5.35 (m, 1H), 3.82 (q, 2H), 2.34 (s, 3H), 1.21 (t, 3H); ^{13}C -NMR: 167.2, 156.3, 149.6, 147.0, 144.2, 129.8, 126.4, 112.6, 106.9, 61.5, 52.3, 21.5, 20.6, 17.2.; HRMS (EI) observed/theoretical: 276.1110/276.2878.

(4k) [30-32]: ^1H NMR (DMSO- d_6 , 500MHz) δ (ppm): 9.18 (s, 1H), 7.30-7.37 (m, 5H), 5.16 (s, 1H), 4.12 (m, 2H), 2.34 (m, 3H), 2.03 (s, 1H), 1.27 (m, 3H); ^{13}C -NMR: 174.8, 167.3, 160.6, 143.7, 129.8, 129.5, 126.4, 126.3, 106.9, 61.3, 58.3, 21.5, 14.9; HRMS (EI) observed/theoretical: 276.0930/276.3540.

(4l) [30-32]: ^1H NMR (DMSO- d_6 , 500MHz) δ (ppm): 9.39 (s, 1H), 7.02-7.14 (m, 4H), 5.16 (s, 1H), 4.12 (m, 2H), 3.86 (s, 3H), 2.34 (s, 3H), 2.01 (s, 1H), 1.31 (m, 3H); ^{13}C -NMR: 176.5, 167.8, 160.6, 156.7, 128.8, 128.5, 120.5, 113.6, 106.9, 67.0, 55.3, 53.7, 20.0, 17.9; HRMS (EI) observed/theoretical: 306.1037/306.3813.

(4m) [30-32]: ^1H NMR (DMSO- d_6 , 500MHz) δ (ppm): 10.81 (s, 1H), 9.00 (s, 1H), 6.43 (m, 2H), 4.16-4.18 (m, 3H), 3.80 (s, 9H), 2.30 (s, 3H), 1.32 (m, 3H); ^{13}C -NMR: 174.2, 167.9, 163.2, 160.3, 158.8, 158.2, 106.9, 104.2, 93.6, 93.1, 61.7, 56.3, 56.2, 55.8, 46.2, 18.4, 14.9; HRMS (EI) observed/theoretical: 366.1249/366.4321.

(4n) [30-32]: ^1H NMR (DMSO- d_6 , 500MHz) δ (ppm): 10.80 (s, 1H), 8.40 (s, 1H), 7.09 (m, 2H), 6.80 (m, 2H), 5.40 (s, 1H), 4.17-4.20 (m, 3H), 2.28 (s, 3H), 1.30 (m, 3H); ^{13}C -NMR: 174.7, 167.7, 160.8, 154.8, 128.4, 128.2, 122.8, 121.9, 115.8, 104.5, 60.6, 53.2, 19.8, 15.0; HRMS (EI) observed/theoretical: 292.0882/292.3534.

(4o) [30-32]: ^1H NMR (DMSO- d_6 , 500MHz) δ (ppm): 10.82 (s, 1H), 8.70 (s, 1H), 7.40 (m, 2H), 7.31 (m, 2H), 5.47 (s, 1H), 4.17 (m, 2H), 2.25 (s, 3H), 1.27 (m, 3H); ^{13}C -NMR: 174.0, 167.1, 160.0, 140.0, 132.8, 128.4, 128.2, 127.8, 127.3, 106.8, 61.6, 58.2, 18.8, 14.0; HRMS (EI) observed/theoretical: 310.0543/ 310.7991

(4p) [30-32]: ^1H NMR (DMSO- d_6 , 500MHz) δ (ppm): 10.75 (s, 1H), 8.50 (s, 1H), 7.10 (m, 2H), 6.98 (m, 2H), 5.37 (s, 1H), 4.22 (m, 2H), 2.20 (s, 3H), 1.32 (m, 3H); ^{13}C -NMR: 173.5, 166.8, 160.3, 156.7, 135.8, 126.4, 126.1, 115.8, 115.3, 106.0, 61.0, 58.8, 18.2, 14.6; HRMS (EI) observed/theoretical: 292.0882/292.3534.

(4q) [30-32]: ^1H NMR (DMSO- d_6 , 500MHz) δ (ppm): 10.70 (s, 1H), 8.59 (s, 1H), 7.11 (m, 1H), 6.90 (m, 2H), 6.72 (m, 1H), 5.30 (s, 1H), 4.20 (m, 2H), 2.17 (s, 3H), 1.28 (m, 3H); ^{13}C -NMR: 171.5, 167.8, 160.9, 157.7, 144.8, 129.4, 119.1, 113.8, 113.3, 106.5, 61.4, 58.0, 18.0, 14.3; HRMS (EI) observed/theoretical: 337.0732/337.3351

(4s) [30-32]: ¹H NMR (DMSO-d₆, 500MHz)δ (ppm): 10.79 (s, 1H), 8.74 (s, 1H), 4.20 (m, 2H), 3.34 (m, 1H), 2.17 (s, 3H), 1.28 (m, 3H), 1.50 (m, 2H), 1.32 (dd, 2H), 1.17 (dd, 2H), 1.05 (m, 3H); ¹³C-NMR: 171.0, 166.0, 147.7, 104.8, 63.4, 61.5, 38.0, 27.5, 22.6, 19.0, 14.7, 14.3; HRMS (EI) observed/theoretical: 256.1245/256.3644.

Results and Discussion

To evaluate the possibility of [Gmim]Cl-Fe(III) complex for a model reaction by a building block ratio of 1:1:1.2 of 4-methoxy benzaldehyde, ethyl acetoacetate and urea respectively to provide ethyl 4-(4-methoxyphenyl)-6-methyl-2-oxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate, was conducted in different solvents under with/without ultrasonic irradiation (Table 1). At first, we have complete this experiment under protic along with aprotic solvents such as methanol, ethanol (Table 1, entry 1 & 2) and CH₃CN, DCM, DMF and THF (Table 1, entries 3-7) the rate of reaction and product yield was found to be moderate under both conditions. After screening for diverse solvents, we turned our attention to a thorough exploration of the solvent free condition (Table 1, entry 8), which afforded the product not only in good yield other than also with higher reaction rate. We have also studied the sonochemical effect on model reaction by using diverse solvents. In all cases, the experimental results show that the reaction time is reduced along with the yield of the product is higher under sonication. Based on the results of this study, it seems that the ultrasound irradiation improves the reaction time and yield. The obtained results are summarized in (Table 1, entries 1-8).

Table 1. Effect of solvent on the synthesis of 3, 4-dihydropyrimidine-2(1H)-ones

S. No	Solvent	Without US condition ^a		With US condition ^b	
		Temp (°C)	Yield ^c (%)	Temp (°C)	Yield ^c (%)
1	Methanol	50	62	25	67
2	Ethanol	65	65	25	70
3	CH ₃ CN	60	50	25	67
4	DCM	35	53	25	59
5	DMF	100	48	25	51
6	CHCl ₃	50	58	25	63
7	THF	50	51	25	54
8	Solvent free	100	86	25	94

^aReaction condition: 4-methoxy benzaldehyde (10.0 mmol), ethyl acetoacetate (10.0 mmol), urea (12.0 mmol) and [Gmim]Cl-Fe (III) complex (0.1 mmol) ethyl 4-(4-methoxyphenyl)-6-methyl-2-oxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate under constant reflux at (100°C) for 24 hours. ^bReaction condition: 4-methoxy benzaldehyde (10.0 mmol), ethyl acetoacetate (10.0 mmol), urea (12.0 mmol) and [Gmim]Cl-Fe (III) complex (0.1 mmol) ethyl 4-(4-methoxyphenyl)-6-methyl-2-oxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate under ultrasonic waves for 30 min. ^cIsolated yield by flash chromatography.

Subsequently, we have included a number of catalysts on the model reaction. When the reaction was carried out in the presence of L-glycine, Chloroglycine, [Cemim]Br, [Aemim]Br, FeCl₃/[Cemim]Br also FeCl₃/[Aemim]Br with/ without ultrasonic irradiation, it trace to 55 % of product subsequent to 24 hours (Table 2, entries 1-6). However, when the same reaction was conducted under ultrasonic irradiation using [Gmim]Cl-Fe(III) as a catalyst it gave tremendous yield of product in short duration (Table 2, entry 7). Nearly similar yield was obtained when increasing the catalyst loading as well as duration (Table 2, entry 8 & 9).

Table 2. Preparation of 3, 4-dihydropyrimidine-2(1*H*)-one various catalysts

Entry	Catalyst	Without US	With US
		condition ^a	condition ^b
		Yield ^c (%)	Yield ^c (%)
1	L-glycine	--	--
2	Chloroglycine [Cl-gly]	12	15
3	[Cemim] Br	18	23
4	[Aemim] Br	27	30
5	FeCl ₃ / [Cemim] Br	48	55
6	FeCl ₃ / [Aemim] Br	55	60
7	[Gmim]Cl-Fe (III)	86	94
8	[Gmim]Cl-Fe (III) ^d	87	95
9	[Gmim]Cl-Fe (III) ^e	87	95

^aReaction condition: 4-methoxy benzaldehyde (10.0 mmol), ethyl acetoacetate (10.0 mmol), urea (12.0 mmol) and [Gmim]Cl-Fe (III) complex (0.1 mmol) ethyl 4-(4-methoxyphenyl)-6-methyl-2-oxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate under constant reflux at (100°C) for 24 hours. ^bReaction condition: 4-methoxy benzaldehyde (10.0 mmol), ethyl acetoacetate (10.0 mmol), urea (12.0 mmol) and [Gmim]Cl-Fe (III) complex (0.1 mmol) ethyl 4-(4-methoxyphenyl)-6-methyl-2-oxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate under ultrasonic waves for 30 min. ^c Isolated yield by flash chromatography. ^d About 0.2 mmol of [Gmim]Cl-Fe(III) was used. ^e Reaction time with and without US (45 min/ 30 hours).

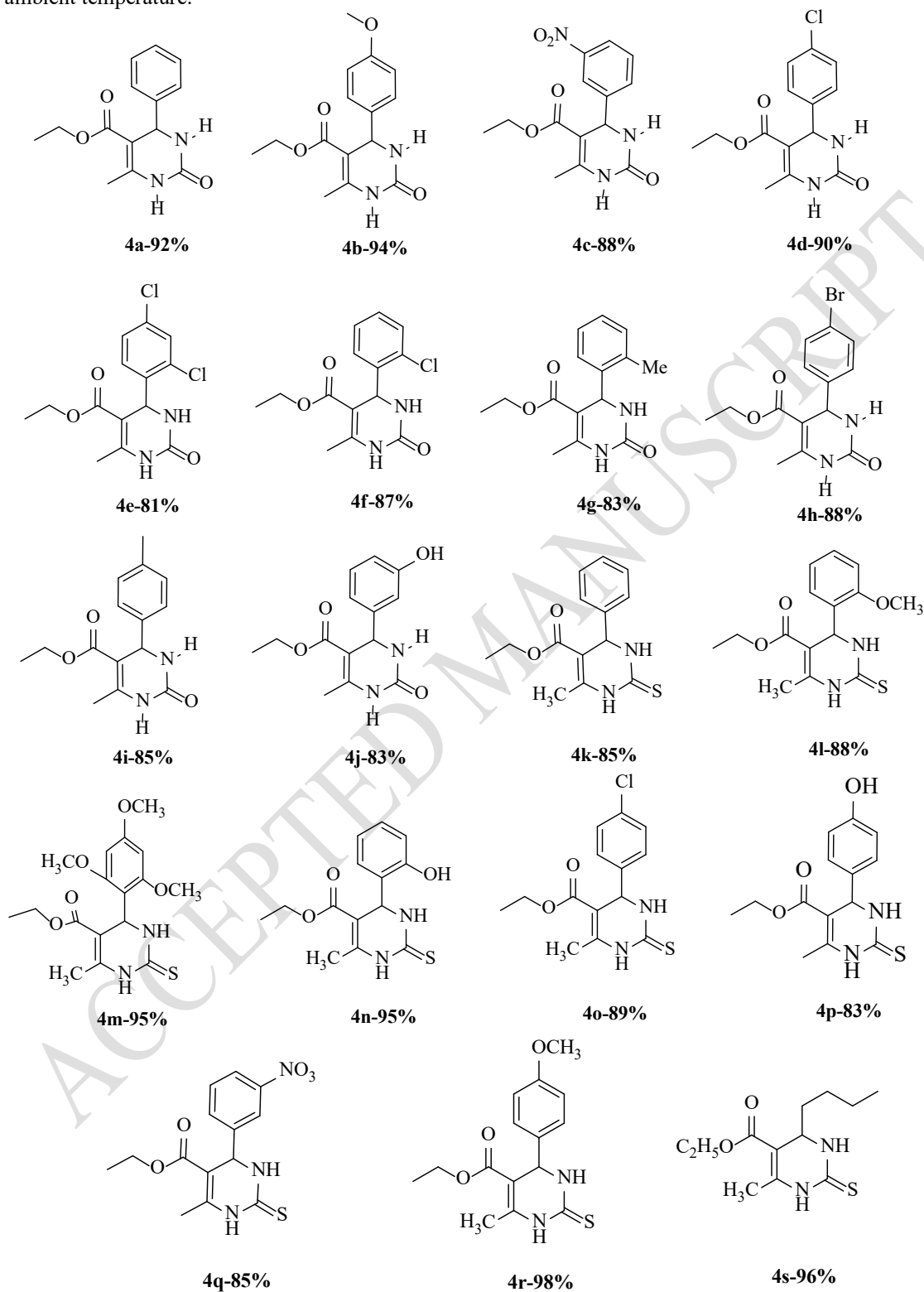
Having optimized the reaction conditions, the synthesis of substituted 3, 4-dihydropyrimidine-2(1*H*)-ones was synthesized by treating among a several aromatic aldehydes, ethyl acetoacetate and urea (or thiourea) using [Gmim]Cl-Fe(III) complex under ultrasound irradiation (20 kHz) on ambient temperature were examined (Scheme 2). The reaction condition was compatible with a variety of functional groups, ranging from the electron-withdrawing nitro groups to the halides. Definitely, it was observed that the oxidation prone groups (-OH, -OMe) were tolerated in this reaction. In general, the yield was high, regardless of the structural variations. Later, the recyclability of the used complex was studied for the synthesis of 3, 4-dihydropyrimidine- 2(1*H*)-ones. The catalytic system could be reused directly for the next cycle, after full extraction of the product three times with 5 mL diethyl ether per extraction and drying in vacuo. The results shown in Table 3 demonstrate that this catalytic system was readily recyclable for seven runs without any significant loss of catalytic activity.

Table 3. Successive trials by using reused [Gmim]Cl-Fe (III) catalyzed 3, 4-dihydropyrimidine- 2(1*H*)-ones employing ultrasound Irradiation as the activating mode ^a

Cycles	1	2	3	4	5	6	7
Yields ^b	94	94	92	92	91	90	88

^aReaction condition: 4-methoxy benzaldehyde (10.0 mmol), ethyl acetoacetate (10.0 mmol), urea (12.0 mmol) and [Gmim]Cl-Fe (III) complex (0.1 mmol) ethyl 4-(4-methoxyphenyl)-6-methyl-2-oxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate under ultrasonic waves. ^b Isolated yield by flash chromatography.

Scheme 2. The synthesis of substituted 3, 4-dihydropyrimidine-2(1H)-one under ultrasound irradiation at ambient temperature.



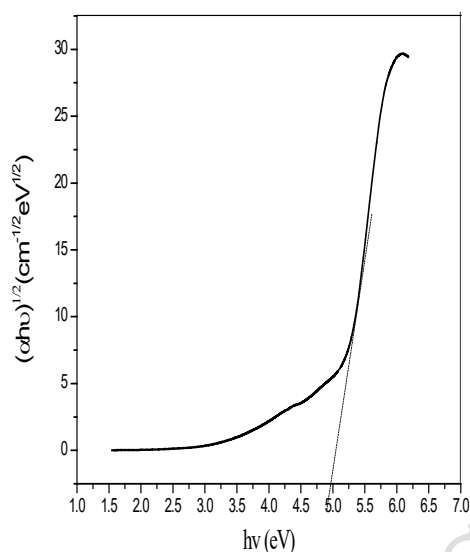


Fig. 1. The plots of $(\alpha hv)^{1/2}$ vs. $h\nu$ of [Gmim]Cl-Fe(III) complex.

Furthermore; Fe leaching was also studied by inductively coupled plasma-atomic emission spectroscopy (ICP-OES) analysis, indicating that the product mixture contained zero ppm of iron accounting for 0.1 mmol of the initially added amount of Fe. From those three experimental results, we believe that the no Fe leaching observed in Biginelli reaction, it's due to immobilized iron in amino acid functionalized ionic liquid binding site located on the surface, which acts as a ligand through metal–ligand interaction. The anchoring of Fe species by amino acid sites supported on ionic liquid minimizes catalyst deterioration and no metal leaching and therefore allows efficient catalyst recycling. The iron(III) complex stumble on superiority over most of the reported catalysts with many advantages: facile synthesis, thermal stability and structural versatility, easy handling, catalytic performance in air at 25°C, without any additives, no inert atmosphere required without leaching of catalyst. The possible mechanism for the reaction is shown in scheme 3. In the transition state I (TS I), the amino acid moiety of this catalyst interacts through hydrogen bonding with the acyl group of benzylideneurea while the neighboring primary amine activates ethyl acetoacetate involving an enamine intermediate. The obtained absolute configuration of DHPMs was explained by the transition state I, in which the imine was predominantly approached by the enamine intermediate generated from ethyl acetoacetate and the primary amine group of the [Gmim]Cl-Fe(III) catalyst. The attack of the enamine to the benzylidene urea was restricted by the complex scaffold of the catalyst. The mechanism indicates that the amino acid moiety and iron scaffold of this catalyst play a significant role in controlling the Biginelli reaction. The precise mechanism of the catalytic reaction needs to be elucidated, but it is noticeable that the mechanism is strongly modified depending of the iron catalyst employed, obtaining 3, 4-dihydropyrimidin-2(1*H*)-ones as the main product scheme 3.

The optical band gap (E_g). In the absorption method, an electron is excited from a lower to higher energy state by absorbing a photon of known energy and the transmitted radiation can decide the types of possible electron transitions. Primary absorption passes on to band-to-band and this absorption shows a sudden rise in the absorption, known as absorption edge, which can be used to determine the optical band gap ($E_g = hc/\lambda$).

To clarify the conductivity of the isolated complexes the optical band gap (E_g) of [Gmim]Cl-Fe(III) complex has been calculated from the following equations:

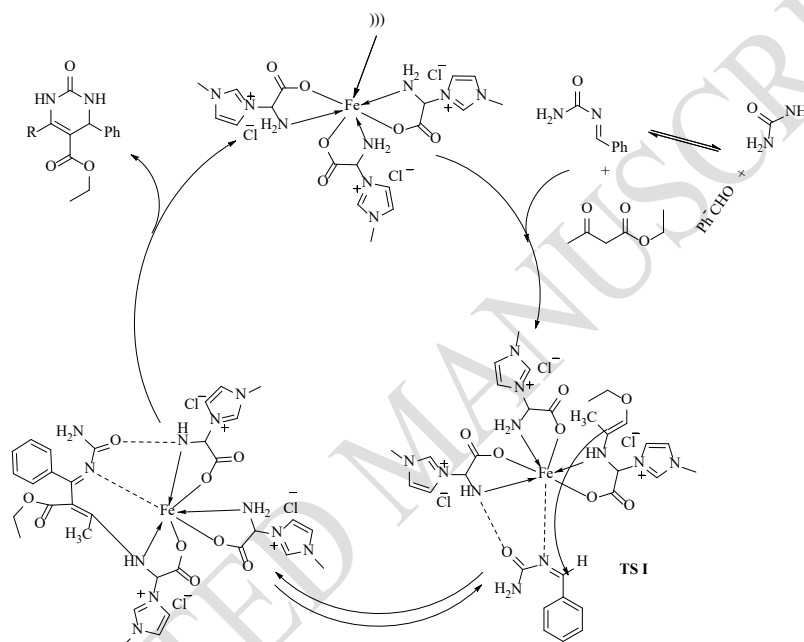
$$\alpha = 1/d \ln A,$$

where d is the width of the cell. The relation between the absorption coefficient and optical band gap

(E_g) is expressed to calculate the band gap of the compound by the following relation:

$$\alpha h\nu = A (hc - E_g)^m,$$

Where m is equal to 1/2 and 2 for direct and indirect transition, respectively, A is an energy independent constant. The values of α calculated from relation ($\alpha = 1/d \ln A$) was used to plot $(\alpha h\nu)^2$ vs. $h\nu$ (Fig. 2) from which a direct band gap was found by extrapolating the linear portion of the curve to $(\alpha h\nu)^2 = 0$. From the curve it is clear that the values of the direct band gap (E_g) equal 4.90eV in complex of [Gmim]Cl-Fe(III). There is a direct relation between the atomic number of the central atoms and (E_g) values, indicating that (E_g) depends on the fulfilled electronic configuration of the d orbital of the central ion. The band gap values suggest that this complex is insulator.



Scheme 3. Plausible reaction mechanism.

Conclusions

In summary, we have described a new green protocol to explore the use of ultrasound irradiation for the solvent free synthesis of 3, 4-dihydropyrimidin-2-(1*H*)-ones using 1-glycyl-3-methyl imidazolium chloride-iron(III) complex as a catalyst at ambient temperature within 30 min. The present methodology rendered several advantages such as simple procedure, easy work up and milder conditions. The reaction was tolerant of varying substitution patterns on the benzaldehyde components. It is noteworthy to mention that the complex could easily be recycled and reused without loss of activity. These advantages make the process highly valuable from the synthetic and environmental points of view. Further investigation on the application of this kind of catalyst is in progress in our laboratory.

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