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A sustainable approach towards the three-component $Yb(OTf)_3$ and taurinecatalyzed synthesis of bioactive 2-phenyl-1H-imidazole and pyrimido[4,5-*b*]quinoline

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Abstract: An efficient, convenient and environmentally benign one-pot three-component reaction for the synthesis of 2-phenyl-1*H*-imidazoleandpyrimido[4,5-*b*]quinoline derivatives as pharmacologically active compound. $Yb(OTf)_3$ and 2-aminoethanesulfonic acid in water an environmentally friendly catalyst and green solvent, is still highly desirable. Advantages of these protocols such as simple work-up procedure, short reaction times, excellent yields, and the use of nontoxic and inexpensive catalysts.

Keywords: Taurine; $Yb(OTf)_3$;2-phenyl-1*H*-imidazoles Pyrimido[4,5-*b*]quinoline; Multicomponentreaction

Introduction

Now a days, multicomponent reaction (MCR) has become a useful synthetic tool for the synthesis of medicinally potent heterocyclic compounds. These strategies combine three or more reactants in a single chemical step to obtain the desired products.[1]MCRs are a very efficient method from both economic and environmental standpoints, such as atom economy, simplicity of operation as well as simple reaction approach, decreased number of workups, purification and extraction processes, and decrease in waste generation, the overall reaction time is significantly reduced, and higher productyieldsareobtainedbecauseoftheir diverse therapeutic activities, including antiviral, anticancer, antibacterial, antihypertensive, antitumor, analgesic, antimicrobial, and adenosine tyrosine kinase inhibitor.[2–6]Pyrimido[4,5-b] quinolones and their derivatives are a class of naturally occurring compounds and widely used as chemotherapeutic agents, anticancer 5-fluorouracil, nitrendipine DHP-calcium antagonists,[7] methylthiouracil anti-thyroid agents,[8] and chloroquineflavouring agents.[9]

(**Figure 1**). In recent years imidazoles containing heterocycles that are of broad interest because of their diverse biological and medicinal applications.[10,11]The imidazole nucleus exists in various pharmacologically active compounds such as histamine and the related histidine hormone.[12,13]Noteworthy, imidazole nucleus can be found in a variety of several biological and drug molecules such as biotin, losartan, olmesartan, eprosartan, alpidem, flumazenil, and trifenagrel (**Figure 2**).[14–17]

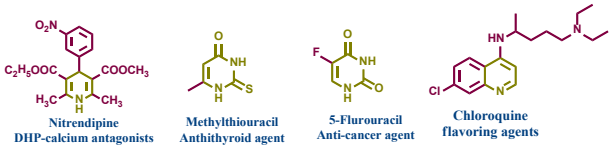


Figure 1 Pyrimido[4,5-*b*]quinoline incorporated bioactive molecules.

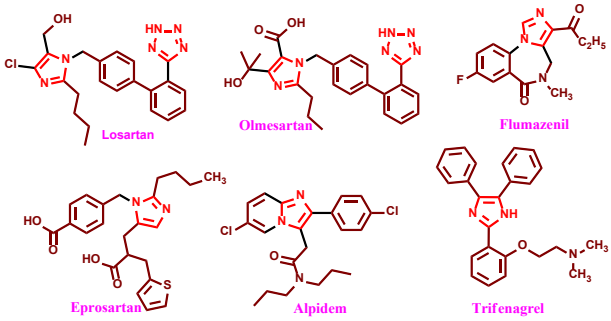


Figure 2 Imidazole-incorporated bioactive molecules.

A literature survey reveals that several methodologies have been developed for the synthesis of medicinally important substituted imidazole.[18–24] Many of these reported protocols are efficient, and some suffer from the drawbacks of tedious preparation of the catalyst, high reaction temperature, prolonged reaction time, low yields, expensive catalysts, etc. Taurine (2-aminoethanesulfonic acid) (**Figure 3**) is asemi-essential β-amino acidthat is abundantly found in high amounts in the human body and many living organisms, especially animals. It is structurally different from amino acidsinstead of a carboxylic acid group, taurine contains a sulfonic acid group. This difference increases its acidity, which is in the range of mineral acids (pKa1=41.5). In human beings, taurine exists in the bile it is present in one-tenth percent of total human weight. Taurine is a zwitterionic shape in water and is used in energy drinks, has a number of medicinal properties in the human body, and is also used in diet supplements.[25] There are very few published reports on 2-aminoethansulfonic acid as a catalyst. Jadhav *et al.*[6] recently used taurine as a green bio-organic catalyst to enhance the condensation and Knoevenagel reactions. The use of silica gel-supported 2-amiethansulfonic acid in the oxidation of sulfides to their corresponding disulfides has also been described. Lanthanide triflates are unique Lewis acids, mild and selective catalysts that have been extensively used to promote several carbon-carbon and heteroatom bond formation reactions effectively. Lanthanide triflates (**Figure 4**), an environmentally friendly catalyst and green solvents, is still highly desirable. Among them, ytterbium triflate is one of the most exploited lanthanide triflates for various organic transformations.

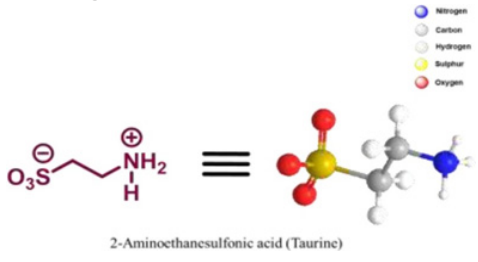
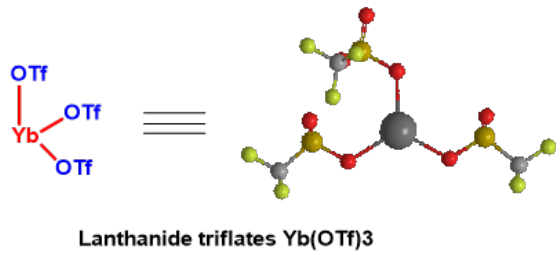


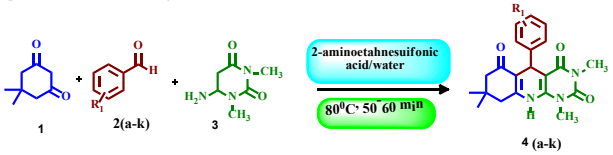
Figure 3



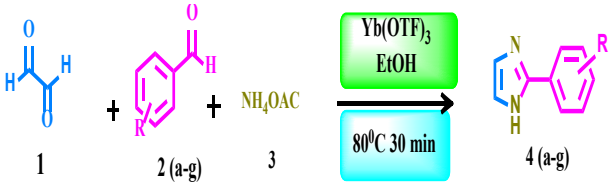
Lanthanide triflates Yb(OTf)3

Figure 4

Here, we develop a new three-component protocol for the synthesis of pyrimido[4,5-*b*]quinolones and 2-phenyl-1H-imidazole by a promoted by taurine and ytterbium triflate as a green catalyst.



Scheme 1 Synthesis of Taurine catalyzed for the synthesis of pyrimido[4,5-b] quinolines (1a-k).



Scheme 2 General Scheme for $Yb(OTf)_3$ catalysed for the synthesis of 2-phenyl-1*H*-imidazole.

Results and Discussion:

Considering the importance oftaurine catalyst in the multicomponent reaction. We have selected 6-amino-1,3-dimethyluracil, dimedone, and benzaldehyde as model substrates to identify the best reaction conditions. To optimize the reaction conditions, the initial reaction was carried out in the nonappearance of the Catalyst low yield of product was obtained even after 3 to 4 hours. To obtain a desired product, we have performed the reaction using various catalysts such as β-CD, γ-CD, cetyl trimethyl ammonium bromide (CTAB), p-toluene sulphonic acid (p-TSA), and taurine. Among them,an excellent result (91%) (**Table 1.1**) was obtained with taurine as the catalyst. Therefore taurine was selected as a bio-organic catalyst togive the synthesis of pyrimido[4,5-b] quinolines (4a) by easy workup after 50 min.

1.1 Efficiency comparison of various catalysts for the synthesis of pyrimido[4,5-*b*] quinolines (**8a**).

Entry	Catalyst	Time (min)	Yield[b] (%)
1	(without catalyst)	200	30
2	THAM	60	62
3	β-CD	120	58
4	γ-CD	120	63
5	CTAB	160	59
6	**Taurine**	**50**	**91**
7	p-TSA	160	40

[a]**Reaction condition**: 6-amino-1,3-dimethyluracil (1mmol), Aromatic benzaldehyde (1 mmol) and dimedone (1 mmol) & catalyst (20mol%) was heated at 80°C for 50–60 min. [b]**Isolated yield**.

The catalytic activity of taurine was checked by using different solvents as reactionmedia, such as ethanol, methanol CH_3CN, $CHCl_3$, DCM, H_2O-EtOH (1:1), and H_2O. In ethanol, a high amount of product was obtained, while in MeOH, CH_3CN, DCM, $CHCl_3$, DCM, and H_2O-EtOH (1:1) reaction gave a poor yield or no reaction of product. The best result was obtained by using H_2O as an environmentallygreen solvent to 91% yield (**Table 1.2**) of the titled product.

1.2 Screening the effect of solvent on the reaction in the presence of (10 mol %) of taurine at 80 °C.

Entry	Catalyst	Solvent	Time (min.)	Yield[b] (%)
1	Taurine	EtOH	60	72
2	Taurine	MeOH	90	55
3	Taurine	**H_2O**	**50**	**91**
4	Taurine	H_2O:EtOH (1:1)	60	68
5	Taurine	$CHCl_3$	60	No reaction
6	Taurine	CH_3CN	60	36
7	Taurine	DCM	60	No reaction

[a]**Reaction condition**: 6-amino-1,3-dimethyluracil (1mmol), Aromatic benzaldehyde (1 mmol) and dimedone (1 mmol) & catalyst (20mol%) was heated at 80^{0}C for 50–60 min. [b]Isolated yield.

To study the solubility of the catalyst and reactants, we examined the model reaction screening of various mol% of 2-aminoethansulfonic acids, such as 5, 10, 20, and 30. The product was obtained in 55%, 73%, 93%, and 90% yield, respectively. As shown in (**Table 1.3**) 20 mol% of taurine was sufficient to perform the reaction smoothly. To optimize different temperatures of model reaction, we have observed that as the temperature increased r.m., 40, 60, 80, and 100^{0}C, the product yield also increased. An excellent result was obtained in 80^{0}C furnishing the desired product (**Table 1.3**).

1.3 Optimization of reaction using different amounts of catalyst for the formation of pyrimido[4,5-*b*] quinolines at 80 °C .

Entry	Catayst	Time (min)	Yield[b]
1	-	200	30
2	Taurine (5 mol%)	50	55
3	Taurine (10 mol%)	50	73
4	Taurine (20 mol%) (RT, 40, 60, **80**, 100°C)	50	55, 70, 76, **93**, 84
5	Taurine (30 mol%)	50	90

[a]**Reaction condition**: 6-amino-1,3-dimethyluracil (1mmol), Aromatic benzaldehyde (1 mmol) and dimedone (1 mmol) & catalyst (20 mol%) was heated at 80^{0}C for 50–60 min. [b] **Isolated yield**. Bold values are for highlighting the good result.

It describes a study identifying the best reaction conditions for a specific methodology usingoxalaldehyde, ammonium acetate, and Aromatic benzaldehyde as model substrates.We have screened the different catalysts for **4a** synthesis to optimize the model reaction conditions. The product was obtained with a low yield and more time when the reaction was carried out without any catalyst. Further, the above model reaction was conducted with CTAB (cetyltrimethylammonium bromide) andprovided a better yield of 11a than p-TSA with 60% and 62%, respectively (**Table 1.4**). On the other hand, the reaction conducted with various triflates, among them $Yb(OTf)_3$ achieved excellent yield (92%) for the synthesis of the desired product.

1.4 Efficiency comparison of various catalysts for the synthesis of 2-phenyl-1*H*-imidazoles.

Entry	Catalyst	Time (min)	Yield[b] (%)
1	(without catalyst)	480	40
2	CTAB	400	60
3	β-CD	360	62
4	$Sc(OTf)_3$	120	70
5	$La(OTf)_3$	160	65
6	**$Yb(OTf)_3$**	**30**	**92**
7	p-TSA	260	54

[a]**Reaction condition**: Oxalaldehyde (1 mmol) ammonium acetate (3 mmol), benzaldehyde (1 mmol) & $Yb(OTf)_3$ (10 mol%) EtOH at 80˚C [b] **Isolated yield**.

We optimized various solvents such as CH_3COOH, DMFacetonitrileDCM, THF, and Toluenewith $Yb(OTf)_3$ as a

catalyst. In most of the solvents, low to moderate yields were obtained (**Table 1.5**). In ethanol, the reaction occurs smoothly with excellent yield obtained at reflux temperature.

1.5 Screening the effect of solvent on the reaction in the presence of (10 mol %) of $Yb(OTf)_3$ at 80 °C.

Entry	Catalyst	Solvent	Time (min.)	Yield[b] (%)
1	$Yb(OTf)_3$	CH_3COOH	100	72
2	$Yb(OTf)_3$	DMF	160	55
3	$Yb(OTf)_3$	CH_3CN	120	64
4	$Yb(OTf)_3$	DCM	120	70
5	$Yb(OTf)_3$	**EtOH**	**30**	**93**
6	$Yb(OTf)_3$	THF	90	78
7	$Yb(OTf)_3$	Toluene	120	30

[a] **Reaction condition**:Oxalaldehyde(1 mmol), ammonium acetate (3 mmol), benzaldehyde (1 mmol) & $Yb(OTf)_3$ (10 mol%) EtOH at 80˚C
[b] **Isolated yield**.

The reaction carried out efficiently may be due to the solubility of the catalyst and reactants. The optimization of catalyst concentration varies from 5, 10, 20, to 30 mol % for the model reaction, shown in Table (**1.6**). Among them, 20 mol% of $Yb(OTf)_3$in ethanolwas the best reaction condition for the described reaction (**Table 1.6**). We observe that yield of the reaction was increased with the increasing amount of catalyst.

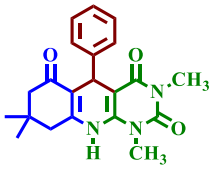
1.6 Optimization of reaction using different amounts of catalyst for the of $Yb(OTf)_3$ at 80 °C.

Entry	Catalyst	Time (min)	Yield[b]
1	$Yb(OTf)_3$ (5 mole%)	30	65
2	$Yb(OTf)_3$ (**10 mole%**) (RT, 40, 60, **80** °C)	30	57, 70, 77, **93**
3	$Yb(OTf)_3$ (20 mole%)	30	88
4	$Yb(OTf)_3$ (30 mole%)	30	90

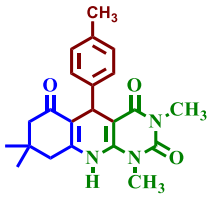
[a] **Reaction condition**: Oxalaldehyde (1 mmol), ammonium acetate (3 mmol), benzaldehyde (1 mmol), & $Yb(OTf)_3$ EtOH at 80˚C
[b] **Isolated yield**.

After the optimization of several reaction conditions such as solvent effect, catalyst, and amount of catalyst on model reaction for the synthesis of titled products, an excellent result was obtained in 10 mol% of $Yb(OTf)_3$in water, giving 93% yield in 30 min**.**

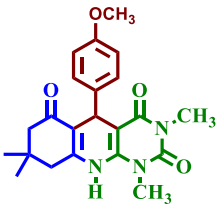
Table 1.7 Physical dataof pyrimido[4,5-*b*]quinolines (**4a-k**) and 2-phenyl-1*H*-imidazole (**4a-i**)



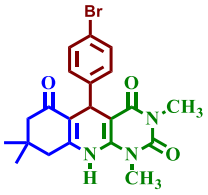
4a(50 min, 92%)
M.P. 272-274



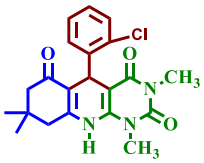
4b(55 min, 90%)
M.P. 308-310



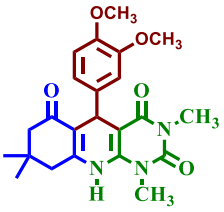
4c(52 min, 90%)
M.P. 302-304



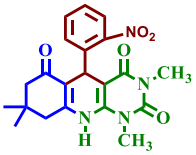
4d(55 min, 90%)
M.P. 232-234



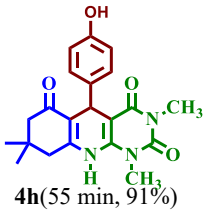
4e(52 min, 92%)
M.P. 326-328



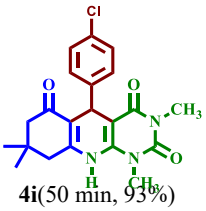
4f(58 min, 93%)
M.P. 307-309



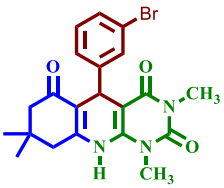
4g(48 min, 90%)
M.P. 282-284



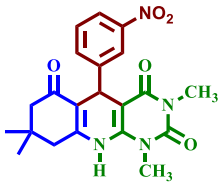
4h(55 min, 91%)
M.P. 316-318



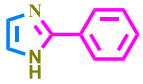
4i(50 min, 93%)
M.P. 294-296



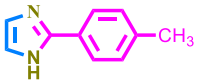
4j(58 min, 90%)
M.P. 283-285



4k(45 min, 89%)
M.P. 290-292

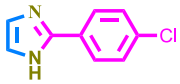


4a(30 min, 89%)
M.P. 144-146

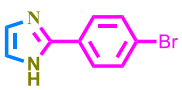


4b(30 min, 91%)
M.P. 224-226

4c(30 min, 93%)
M.P. 150-152

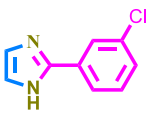


4d(30 min, 91%)
M.P. 244-246



4e(30 min, 86%)
M.P. 248-250

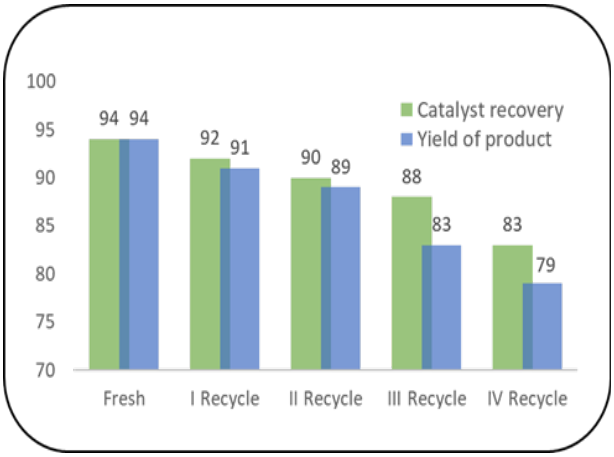
4f(30 min, 90%)
M.P. 312-314



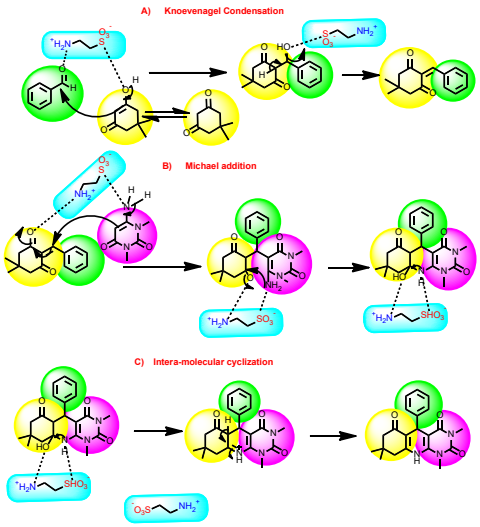
4g(30 min, 92%)
M.P. 131-133

Recovery of catalyst

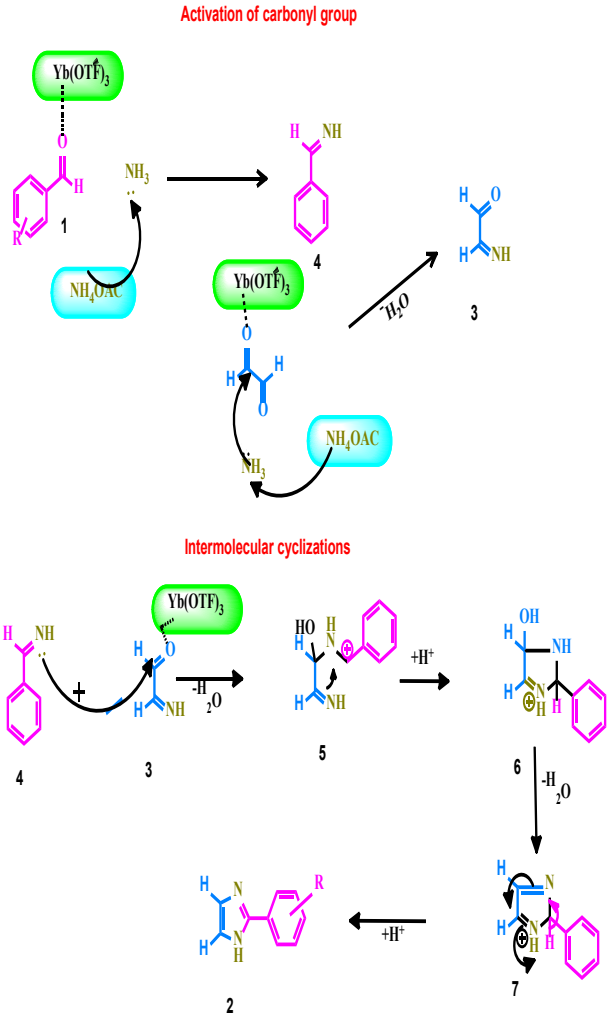
After the reaction was completed, the product was cooled to room temperature and simply separated using simple filtration. The catalyst 2-aminoethansulfonic acid is soluble in water then the filtered solution was evaporated to recycle the catalyst. The recycled catalyst was reused in the same reaction without losing catalytic activity. As we observed that the yields of pyrimido[4,5-*b*]quinolines slightly decreased after the third to the fourth recycle, as shown in their recyclability graph indicated in (**Figure 5**).



Plausible Reaction Mechanisms



Scheme 1 Proposed path for pyrimido[4,5-b]quinolone synthesis using taurine.



Scheme 2 Proposed path for2-phenyl-1*H*-imidazolessynthesis using $Yb(OTf)_3$.

Experimental
Materials and methods

All chemicals and solvents (analyticalgrade) were purchased from commercial suppliers and used without any further purification. Melting points were measured on a open capillary tube and are uncorrected. Progress of the reaction was monitored by Thin-

layerchromatographic analysis was carried out on precoated Mercksilica gel 60 F254 TLC aluminum sheets, and spots werevisualized under UV light at 254 nm and I2 vapor staining.IR spectra were obtained on a Brucker ALPHA [Eco-ATR] Spectrometer.^{1}H NMR spectra were respectively recorded Bruker SpectroSpin DPX-300spectrometer at 300 MHz & 400 MHz spectrometer using $CDCl_3$ as solvent at room temperature. Chemical shifts (δ) are reported in ppm with tetramethylsilane as internal standard.Splitting patterns are designated as follows: s (singlet), d (doublet), t (triplet), m (multiplet), 1H NMRchemical shift (δ) values are reported in parts per millionMass spectra were recorded on a Shimadzu QP-2000 ESI mass spectrometer.

Synthesis of 1,3,8,8-tetramethyl-5-phenyl-7,8,9,10-tetrahydropyrimido[4,5-b]quinoline-2,4,6(1H,3H,5H)-trione (4a-k).

A mixture of 6-amino-1,3-dimethyl uracil (1 mmol), dimedone (1 mmol), aromatic aldehyde (1 mmol), and 2-aminoethansulfonic acid (15 mol%) was heated at 80 ^{0}C for 50–60 min and progress of the reaction was monitored by thin layer chromatography using ethyl acetate: petroleum ether (30:70) as eluent.After completion of the reaction, the reaction mixture was cooledsolid2-aminoethansulfonic acid was obtained and the obtained solid 2-aminoethansulfonic acid was filtered. The solid obtained was filtered and washed by hot waterand dried. The resulting crude product was purified by recrystallized from ethanol to obtain the title product.

General procedure for the synthesis of 2-phenyl-1H-imidazole (4a-i).

oxalaldehyde (1.0 mmol) and Yb(OTf)3 (10 mol%) were added to a stirred mixture of aromatic aldehyde (1.0 mmol), ammonium acetate (0.5 mmol), and ethanol (6 mL) were added at room temperature to the reaction mixture, which was then stirred at 80 0C for a predetermined amount of time. To obtain the pure product, the resultant white solid was filtered, two or three times washed with water, and the filtrate containing the catalyst may be evaporated to produce a solid that could be recycled without losing its catalytic activity. The crude product was purified by recrystallization from ethanol to obtain the desired product.The synthesized compounds were confirmed by IR, Mass, 1H NMR spectral techniques, and melting point and are in good agreement with those reported in the literature.

The product was confirmed by IR, ^{1}H NMR, and mass spectroscopic analysis 1,3,8,8-tetramethyl-5-phenyl-7,8,9,10-tetrahydropyrimido[4,5-*b*]quinoline-2,4,6(1H,3H,5H)-trione (4a).

IR (ATR, υ cm^{-1}): 3410 (N-H), 1650 (C=O), 1705 (Ar-C=C), 1220 (C-N), 3070 (C-H); **^{1}H NMR** (400 MHz, DMSO-*d6* ppm): 9.12 (s1H, NH), 7.18-7.30 (m, 4H Ar-H), 7.11 (d, J = 7.1Hz Ar-H), 4.90 (s, 1H), 3.12-3.50 (s, 6H, NCH_3), 2.54-2.66 (s 2H), 2.10-2.26 (d, J =16 Hz, 2H), 1.02 (s, 6H, C-CH_3); **^{13}C NMR** (100MHz, DMSO-*d6* ppm): 195.0, 161.13, 151.02, 149.83, 144.15, 143.97, 135.24, 128.73, 128.03, 112.27, 90.76, 51.54, 33.81, 32.58, 31.18, 30.64, 29.59, 28.09, 26.92, 21.05; **Elemental analysis** Calculated. : $C_{21}H_{23}N_3O_3$: C, 69.02; H, 6.34; N, 11.50; Found C, 68.95; H, 11.45; N, 11.47.

1,3,8,8-tetramethyl-5-(p-tolyl)-7,8,9,10-tetrahydropyrimido[4,5-*b*]quinoline-2,4,6(1H,3H,5H)-trione (4b).

IR (ATR, υ cm^{-1}): 3420 (N-H), 1640 (C=O), 1580 (Ar-C=C), 1230 (C-N), 3040 (C-H); **^{1}H NMR** (400 MHz, DMSO-*d6* ppm): 9.02 (s, 1H, NH), 7.76 (m, 1H), 7.42-7.54 (d, J = 7.5 Hz, 2H, Ar-H), 7.30 (m, 1H, Ar-H), 5.64 (s, 1H), 3.06-3.46 (s, 6H, NCH_3), 2.60 (d, J = 5.6 Hz, 2H),2.34 (s, 3H, CH_3) 2.01-2.20 (d, J = 16.2 Hz, 2H), 1.01 (s, 6H, C-CH_3); **^{13}C NMR** (100 MHz, DMSO-*d6* ppm): 194.1, 162.3, 151.4, 149.4, 147.3, 141.5, 135.3, 128.8, 127.7, 127.3, 126.9, 111.8, 81.7, 51.2, 38.4, 40.2, 32.4, 30.9, 29.6, 28.1, 27.5, 21.4; **Elemental analysis** Calculated: $C_{22}H_{25}N_3O_3$: C, 69.64; H, 6.64; N, 11.07; Found C, 69.58; H, 6.57; N, 11.02.

5-(4-methoxyphenyl)-1,3,8,8-tetramethyl-7,8,9,10-tetrahydropyrimido[4,5-*b*]quinoline-2,4,6(1H,3H,5H)-trione (4c).

IR (ATR, υ cm^{-1}): 3245 (N-H), 1668 (C=O), 1656 (Ar-C=C), 1247 (C-N), 3160 (C-H); **^{1}H NMR** (400 MHz, DMSO-*d6* ppm): 8.96 (s, 1H, NH), 6.76-7.14 (d, J = 8.8 Hz, 4H, Ar-H), 4.80 (s, 1H), 3.70 (s, 3H, OCH_3), 3.12-3.48 (s, 6H, NCH_3), 2.60 (m, 2H), 2.08-2.20 (d, J = 16.0 Hz, 2H), 0.93-1.03 (s, C-CH_3, 6H); **^{13}C NMR** (100 MHz, DMSO-*d6* ppm): 194.3, 161.7, 151.6, 148.1, 147.8, 141.5, 136.3, 130.8, 129.7, 120.3, 118.9, 114.8, 113.1, 81.7, 51.4, 40.2, 38.4, 32.4, 30.9, 29.6, 28.1, 27.5; **Elemental analysis** Calculated: $C_{22}H_{25}N_3O_4$: C, 66.82; H, 6.37; N, 10.63; Found C, 66.78; H, 6.30; N, 10.60.

5-(4-bromophenyl)-1,3,8,8-tetramethyl-7,8,9,10-tetrahydropyrimido[4,5-*b*]quinoline-2,4,6(1H,3H,5H)-trione (4d).

IR (ATR, υ cm^{-1}): 3400 (N-H), 1660 (C=O), 1600 (Ar-C=C), 1250 (C-N), 3070 (C-H); **^{1}H NMR** (400 MHz, DMSO-*d6* ppm): 9.03 (s, 1H, NH), 7.20-7.38 (d, J = 8.2 Hz, 4H, Ar-H), 4.82 (s, 1H), 3.12-3.42 (s, 6H, NCH_3), 2.24 (s, 2H), 2.04-2.08 (s, 2H), 0.95-1.02 (s, 6H, C-CH_3); **^{13}C NMR** (100 MHz, DMSO-*d6* ppm): 194.2, 162.5, 151.3, 149.1, 147.4, 143.5, 132.3, 131.8, 131.5, 131.3, 130.9, 119.8, 112.1, 80.2, 51.3, 40.1, 39.4, 32.6, 30.7, 29.5, 27.8, 27.2; **Elemental analysis** Calculated: $C_{21}H_{22}BrN_3O_3$: C, 56.77; H, 4.99; N, 9.46; Found C, 56.71; H, 4.90; N, 9.40.

5-(2-chlorophenyl)-1,3,8,8-tetramethyl-7,8,9,10-tetrahydropyrimido[4,5-*b*]quinoline-2,4,6(1H,3H,5H)-trione (4e).

IR (ATR, υ cm^{-1}): 3250 (N-H), 1643 (C=O), 1605 (Ar-C=C), 1240 (C-N), 3120 (C-H); **^{1}H NMR** (400 MHz, DMSO-*d6* ppm): 9.01 (s, 1H, NH), 7.30 (d, J = 7.6 Hz 1H, Ar-H) 7.10-7.21 (m, 3H, Ar-H), 5.09 (s, 1H), 3.10-3.32 (s, 6H, NCH_3), 2.60 (s, 2H), 2.0-2.16 (d, J = 16.0 Hz, 2H), 0.95-1.02 (s, 6H, C-CH_3); **^{13}C NMR** (100 MHz, DMSO-*d6* ppm): 194.1, 162.4, 151.5, 149.5, 147.6, 143.7, 131.5, 128.8, 127.2, 126.8, 126.2, 111.8, 79.5, 51.2, 40.2, 34.8, 32.8, 30.8, 29.8, 27.4, 27.2**; Elemental analysis** Calculated: $C_{21}H_{22}ClN_3O_3$: C, 63.08; H, 5.55; N, 10.51; Found C, 63.04; H, 5.50; N, 10.46.

5-(3,4-dimethoxyphenyl)-1,3,8,8-tetramethyl-7,8,9,10-

tetrahydropyrimido[4,5-*b*]quinoline-2,4,6(1H,3H,5H)-trione (4f).

IR (ATR, υ cm^{-1}): 3294 (N-H), 3095 (C-H), 1665 (C=O), 1699 (Ar-C=C), 1239 (C-N); **^{1}H NMR** (400 MHz, DMSO-*d6* ppm): 8.91 (s, 1H, NH), 6.78-6.86 (m, 1H, Ar-H) 6.56 (m, Ar-H), 4.86 (s, 1H), 3.64-3.68 (s, 6H, OCH_3), 3.10-3.40 (s, 6H, NCH_3), 2.52 (s, 2H), 1.98-2.15 (d, J = 16.0 Hz, 2H), 0.85-1.02 (s, 6H, C-CH_3); **^{13}C NMR** (100 MHz, DMSO-*d6* ppm): 193.6, 162.4, 158.1, 151.7, 150.0, 149.1, 143.6, 132.9, 117.4, 111.4, 110.9, 109.2, 89.3, 55.6, 49.1, 32.6, 31.1, 29.3, 28.3, 27.8, 26.5, 25.3; **Elemental analysis** Calculated: $C_{23}H_{27}N_3O_5$: C, 64.93; H, 6.40; N, 9.88; Found C, 64.88; H, 6.35; N, 9.80.

1,3,8,8-tetramethyl-5-(2-nitrophenyl)-7,8,9,10-tetrahydropyrimido[4,5-*b*]quinoline-2,4,6(1H,3H,5H)-trione (4g).

IR (ATR, υ cm^{-1}): 3270 (N-H), 3056 (C-H), 1630 (C=O), 1701 (Ar-C=C), 1246 (C-N); **^{1}H NMR** (400 MHz, DMSO-*d6* ppm): 8.95 (s, 1H, NH), 7.50-7.52 (m, 2H, Ar-H) 7.29-7.40 (m, 2H, Ar-H), 5.72 (s, 1H), 3.64-3.68 (s, 6H, OCH_3), 3.02-3.42 (s, 6H, NCH_3), 2.58 (s, 2H), 1.95-2.18 (d, J = 16.0 Hz, 2H), 0.83-1.03 (s, 6H, C-CH_3); **^{13}C NMR** (100 MHz, DMSO-*d6* ppm): 194.7, 160.4, 152.1, 151.7, 150.5, 148.2, 144.6, 141.5, 132.9, 131.2, 127.4, 124.2, 111.4, 90.9, 51.6, 33.1, 32.2, 30.8, 30.3, 29.3, 28.2, 26.8; **Elemental analysis** Calculated: $C_{21}H_{22}N_4O_5$: C, 61.45; H, 5.40; N, 13.65; Found C, 61.40; H, 5.35; N, 13.59.

5-(4-hydroxyphenyl)-1,3,8,8-tetramethyl-7,8,9,10-tetrahydropyrimido[4,5-*b*]quinoline-2,4,6(1H,3H,5H)-trione (4h).

IR (ATR, υ cm^{-1}): 3397 (N-H), 3098 (C-H), 1658 (C=O), 1701 (Ar-C=C), 1246 (C-N); **^{1}H NMR** (400 MHz, DMSO-*d6* ppm): 9.07 (s, 1H, OH), 8.94 (s, 1H, NH), 6.50-7.00 (m, 3H, Ar-H) 4.72 (s, 1H), 3.12-3.43 (s, 6H, NCH_3), 2.54 (s, 2H), 2.10-2.20 (d, J = 16.0 Hz, 2H), 0.91-1.04 (s, 6H, C-CH_3); **^{13}C NMR** (100 MHz, DMSO-*d6* ppm): 194.3, 161.4, 155.6, 151.5, 149.7, 147.5, 138.2, 134.6, 131.5, 115.9, 115.2, 111.4, 80.9, 51.2, 39.5, 32.1, 31.2, 30.5, 29.8, 27.5, 27.2; **Elemental analysis** Calculated: $C_{21}H_{23}N_3O_4$: C, 66.13; H, 6.08; N, 11.02; Found C, 66.10; H, 6.05; N, 10.96.

5-(4-chlorophenyl)-1,3,8,8-tetramethyl-7,8,9,10-tetrahydropyrimido[4,5-*b*]quinoline-2,4,6(1H,3H,5H)-trione (4i).

IR (ATR, υ cm^{-1}): 3406 (N-H), 3088 (C-H), 1648 (C=O), 1706 (Ar-C=C), 1256 (C-N);**^{1}H NMR** (400 MHz, DMSO-*d6* ppm): 7.32 (s, 1H, NH), 7.10-7.26 (m, 4H, Ar-H) 4.86 (s, 1H), 3.06-3.41 (s, 6H, NCH_3), 2.48 (s, 2H), 2.0-2.18 (d, J = 16.0 Hz, 2H), 0.84-1.01 (s, 6H, C-CH_3); **^{13}C NMR** (100 MHz, DMSO-*d6* ppm): 194.3, 162.3, 151.4, 149.3, 147.3, 142.4, 131.3, 130.8, 130.2, 128.8, 128.2, 111.7, 79.9, 51.4, 40.0, 39.2, 32.7, 30.6, 29.7, 27.7, 27.1; **Elemental analysis** Calculated: $C_{21}H_{22}ClN_3O_3$: C, 63.08; H, 5.55; N, 10.51; Found C, 63.02; H, 5.45; N, 10.42.

5-(3-bromophenyl)-1,3,8,8-tetramethyl-7,8,9,10-tetrahydropyrimido[4,5-*b*]quinoline-2,4,6(1H,3H,5H)-trione (4j).

IR (ATR, υcm^{-1}): 3431 (N-H), 3097 (C-

H), 1660 (C=O), 1686 (Ar-C=C), 1208 (C-N); **^{1}H NMR** (400 MHz, DMSO-*d6* ppm): 9.05 (s, 1H, NH), 7.22-7.42 (d, J = 8.2 Hz, 4H, Ar-H), 4.76 (s, 1H), 3.14-3.44 (s, 6H, NCH_3), 2.26 (s, 2H), 2.06-2.10 (s, 2H), 0.96-1.04 (s, 6H, C-CH_3); **^{13}C NMR** (100 MHz, DMSO-*d6* ppm): 194.4, 162.6, 151.6, 149.5, 147.6, 144.5, 133.5, 129.3, 128.4, 126.7, 123.8, 112.6, 82.7, 51.7, 41.2, 40.4, 32.6, 30.9, 29.8, 28.1, 27.4; **Elemental analysis** Calculated: $C_{21}H_{22}BrN_3O_3$: C, 56.77; H, 4.99; N, 9.46; Found C, 56.73; H, 4.94; N, 9.43.

1,3,8,8-tetramethyl-5-(3-nitrophenyl)-7,8,9,10-tetrahydropyrimido[4,5-*b*] quinoline-2,4,6(1H,3H,5H)-trione (4k).

IR (ATR, υcm^{-1}): 3451 (N-H), 3087 (C-H), 1666 (C=O), 1691 (Ar-C=C), 1198 (C-N); **^{1}H NMR** (400 MHz, DMSO-*d6* ppm): 10.12 (s, NH), 7.90 (d, 1H, J = 8.0 Hz, Ar-H), 7.45 – 7.90 (m, 3H, Ar-H), 5.12 (s, 1H), 3.16 (m, 6H, NCH_3),1.90-2.40 (m, 4H), 0.95 (m, 6H, C-CH_3); **^{13}C NMR** (100MHz, DMSO-*d6* ppm): 194.74, 162.42, 150.10, 149.98, 147.48, 147.20, 145.95, 142.00, 134.25, 128.10, 122.71, 116.90, 113.70, 90.12, 51.40, 42.10, 38.40, 30.80, 29.90, 27.73, 25.81; **Elemental analysis** calculated for $C_{21}H_{22}N_4O_5$: C: 61.45; H: 5.40; N: 13.65; Found: C: 61.38; H: 5.32; N: 13.58.

2-phenyl-1*H*-imidazole (4a).

IR (ATR, υcm^{-1}): 3034 (N-H), 1566.20 (C=C), 1458 (Ar C=N),2912 (C-H);**^{1}H NMR** (400 MHz, Chloroform-d_6, ppm): 11.78(s,1H) 7.97 – 7.89 (m, 2H) 7.35-7.27 (m, 4H), 7.15-7.09 (m, 2H);**^{13}C NMR** (100 MHz, Chloroform-d_6, ppm): 123.04, 125.69, 128.63, 128.84, 130.20, 134.90, 147.2; **Elemental analysis** Calculated For $C_9H_8N_2$: C, 74.98; H, 5.59; N, 19.43; Found: C, 74.92; H, 5.54; N, 19.38.

2-(p-tolyl)-1*H*-imidazole (4b).

IR (ATR, υcm^{-1}): 3040 (N-H), 1568.20 (C=C), 1472 (Ar C=N), 2930 (C-H);**^{1}H NMR** (400 MHz, Chloroform-d_6, ppm): 11.28 (s, 1H) 8.52 – 7.29 (m, 4H) 7.09 (m, 2H), 2.32 (s, CH_3, 3H); **^{13}C NMR** (100 MHz, Chloroform-d_6, ppm): 146.30, 135.2, 131.7, 130.2, 129.4, 128.84, 126.4, 125.69, 124.78, 25.30; **Elemental analysis** Calculated For $C_{10}H_{10}N_2$: C, 75.92; H, 6.37; N, 17.71; Found: C, 75.85; H, 6.32; N, 17.65.

2-(4-methoxyphenyl)-1*H*-imidazole (4c).

IR (ATR, υcm^{-1}): 3034 (N-H), 1566.20 (C=C), 1458 (Ar C=N),2912 (C-H);**^{1}H NMR** (400 MHz, Chloroform-d_6, ppm): 10.78 (s, 1H) 7.57 – 7.55 (m, 1H) 7.46-7.42 (m, 1H), 7.38 (t, J = 7.8 Hz 4H), 6.98-6.94 (m, 1H); **^{13}C NMR** (100 MHz, Chloroform-d_6, ppm): 147.20, 134.90, 130.20, 128.84, 128.63, 125.69, 123.05; **Elemental analysis** Calculated For $C_9H_8N_2O$: C, 68.95; H, 5.79; N, 16.08; Found: C, 68.91; H, 5.74; N, 16.02.

2-(4-chlorophenyl)-1*H*-imidazole (4d).

IR (ATR, υcm^{-1}): 3048 (N-H), 1570.20 (C=C), 1452 (Ar C=N), 2924 (C-H);**^{1}H NMR** (400 MHz, Chloroform-d_6, ppm): 12.78(s, 1H) 8.01 – 7.89 (m, 2H) 7.55-7.35 (m, 2H), 7.09-7.02 (m, 2H); **^{13}C NMR** (100 MHz, Chloroform-d_6, ppm): 145.20, 133.90, 129.20, 127.84, 126.63, 124.69, 122.05; **Elemental analysis** Calculated For $C_9H_7ClN_2$: C, 60.52; H, 3.95; N, 15.68 Found: C, 60.49; H, 3.90;

N, 15.63.

2-(4-bromophenyl)-1*H*-imidazole (4e).

IR (ATR, υcm^{-1}): 3080 (N-H), 1586.20 (C=C), 1486 (Ar C=N), 2940 (C-H);**^{1}H NMR** (400 MHz, Chloroform-d): δ (ppm): 12.34 (s,1H) 7.66 – 7.68 (m, 4H) 7.09-7.02 (m, 2H); **^{13}C NMR** (100 MHz, Chloroform-d_6, ppm): 146.1, 133.7, 132.2, 130.4, 128.60, 125.50, 123.50, 122.7, 122; **Elemental analysis** Calculated For $C_9H_7BrN_2$: C, 48.46; H, 3.16; N, 12.56. Found: C, 48.42; H, 3.14; N, 12.52.

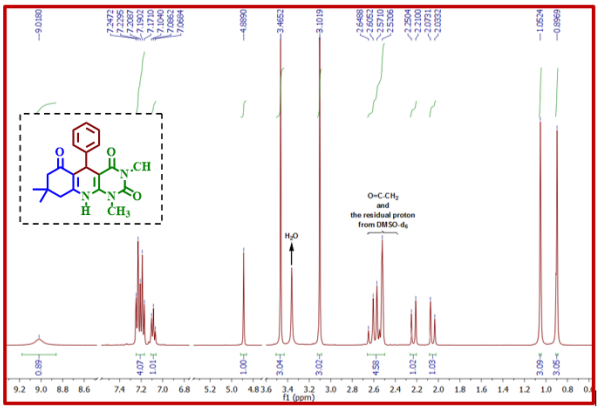
2-(4-nitrophenyl)-1*H*-imidazole (4f).

IR (ATR, υcm^{-1}): 3034 (N-H), 1566.20 (C=C), 1458 (Ar C=N),2912 (C-H);**^{1}H NMR** (400 MHz, Chloroform-d_6, ppm): 12.78 (s,1H) 8.58 – 8.32 (m, 2H) 8.28-8.02 (m, 2H), 7.09-7.02 (m, 2H); **^{13}C NMR** (100 MHz, Chloroform-d_6, ppm): 147.2, 144.1, 140.8, 128.4, 127.6, 125.50, 124.1, 123.7, 122.10; **Elemental analysis** Calculated For $C_9H_7N_3O$: C, 57.14; H, 3.73; N, 22.21; Found: C, 57.10; H, 3.70; N, 22.16.

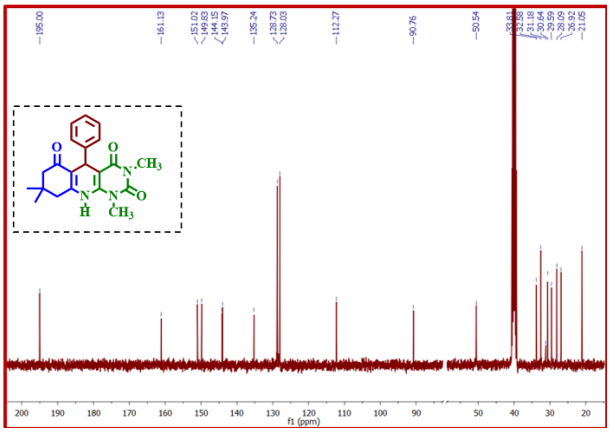
2-(3-chlorophenyl)-1*H*-imidazole (4g).

IR (ATR, υcm^{-1}): 3034 (N-H), 1566.20 (C=C), 1458 (Ar C=N),2912 (C-H);**^{1}H NMR** (400 MHz, Chloroform-d_6, ppm): 7.85 (s, 1H) 7.75 (d, J = 6.4 Hz, 2H) 7.30-7.25 (m, 2H), 7.20 (m, 2H); **^{13}C NMR** (100 MHz, Chloroform--d_6, ppm): 145.7, 134.90, 131.90, 130.20, 128.60, 125.50, 123.50; **Elemental analysis** Calculated For $C_9H_7ClN_2$: C, 60.52; H, 3.95; N, 15.68 Found: C, 60.47; H, 3.91; N, 15.65.

^{1}H NMR spectrum of compound (4a)



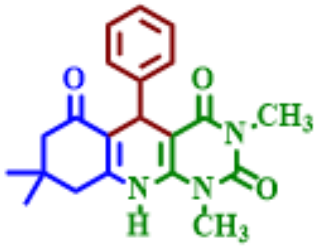
^{13}C NMR spectrum of compound (4a)



HRMS spectrum of compound (4a)

HRMS Facility, BITS Pilani, Pilani Campus
Compound Report

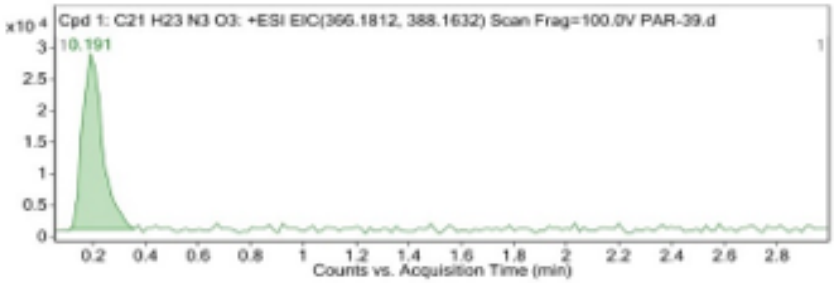
Data File	PAR-39.d
Sample Type	Sample
Instrument Name	Instrument 1
Acq Method	A_ACN_C_H2O_40_60_esi_positive_hrms.3min.m300720
IRM Calibration Status	Success
Comment	
Sample Group	
Stream Name	LC 1
Info.	
Acquisition SW Version	6200 series Q-TOF B.06



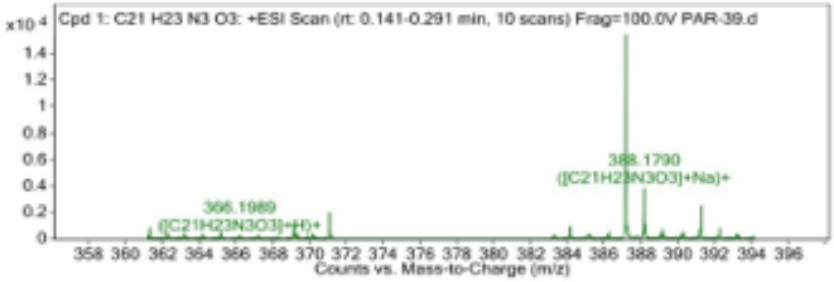
Compound Table

Compound Label	RT	Mass	Abund	Formula	Tgt Mass	Diff (ppm)
Cpd 1: C21 H23 N3 O3	0.191	365.1896	3810	C21 H23 N3 O3	365.1739	42.91

Compound Label	m/z	RT	Algorithm	Mass
Cpd 1: C21 H23 N3 O3	388.179	0.191	Find By Formula	365.1896



MS Zoomed Spectrum



MS Spectrum Peak List

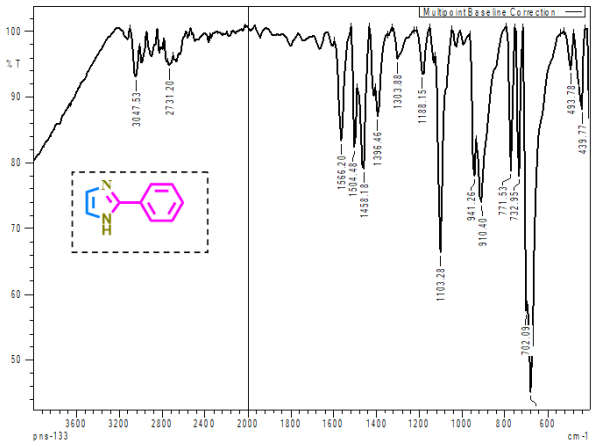
m/z	Calc m/z	Diff(ppm)	z	Abund	Formula	Ion
366.1989	366.1812	-48.27	1	213.75	C21H23N3O3	(M+H)+
388.179	388.1632	-40.83	1	3810.23	C21H23N3O3	(M+Na)+
389.1803	389.1663	-35.96	1	663.76	C21H23N3O3	(M+Na)+

Instrument Info : Agilent Technologies 6545 Q-TOF LC/MS

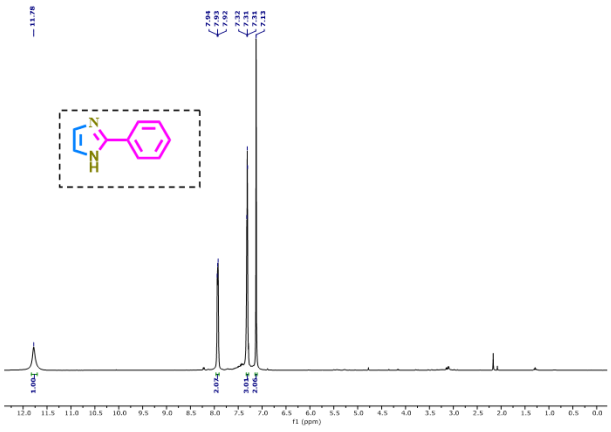
Note: Please acknowledge the work done by HRMS Facility at BITS Pilani, Pilani Campus funded by DST-FIST in your publication.

---End Of Report---

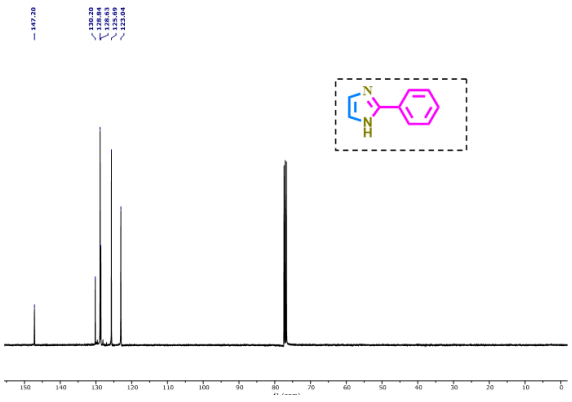
IR spectrum of compound (4a)



^{1}H NMR spectrum of compound (4a)



^{13}C NMR spectrum of compound (4a)



Conclusion:

In this research, we have developed a one-pot, three-component highly efficient and eco-friendly protocol for the synthesis ofpyrimido[4,5-b]quinoline and 2-phenyl-1H-imidazole derivatives catalysed by taurine and $Yb(OTf)_3$. The present protocol providesa number of advantages such as high atom economy, mild reaction conditions, clean reaction profiles, absence of tedious separation procedures, excellent yields. The present catalyst could be recovered and reused without loss of catalytic activity.

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