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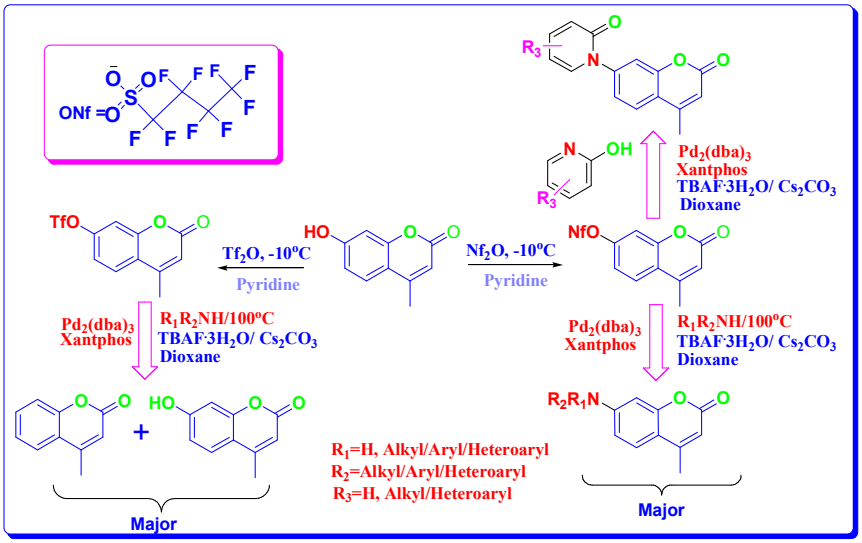
GRAPHICAL ABSTRACT



A rapid approach for the synthesis of an array of 4-methyl-7-substituted coumarins has been developed.

A rapid and modified approach for C-7 amination and amidation of 4-methyl-7-nonafluorobutylsulfonyloxy coumarins under microwave irradiation

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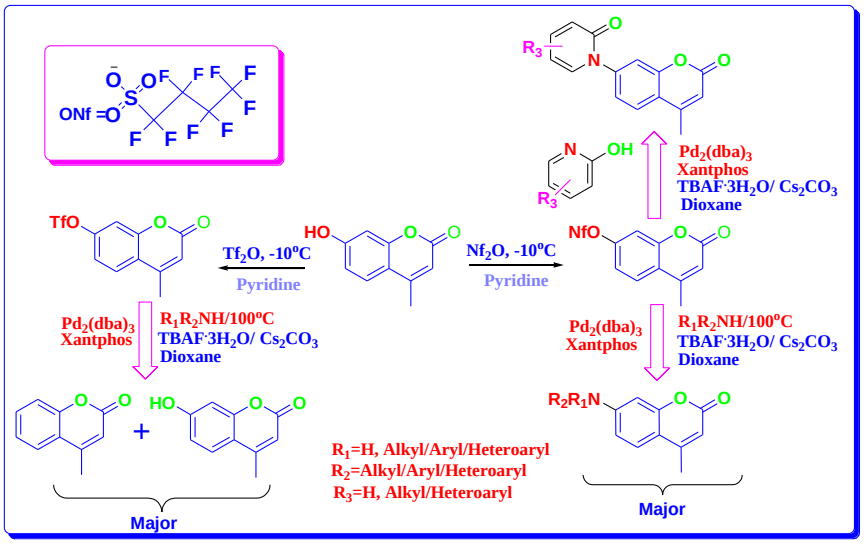


ABSTRACT

A facile, efficient and reliable access for the synthesis of an array of 4-methyl-7-(alkyl/aryl/heteroaryl) amino and amido coumarins have been developed by treating 4-methyl-7-nonafluorobutylsulfonyloxy coumarin with various amines and pyridones in presence of catalyst combination of $Pd_2(dba)_3$/Xantphos under microwave irradiation. Nonaflates coupled efficiently to give the diaryl amines in acceptable to excellent yields whereas the corresponding triflate was unstable yielding the detriflated product as well as the hydrolyzed product as competing side products along with the desired product. Wide bite angle (108°) of Xantphos, employment of Cs_2CO_3 as a mild base and the utilization of $TBAF{\cdot}3H_2O$ as an additive were proved to be the key for success of the reaction.

KEYWORDS

Coumarin, Nonaflate, Palladium-catalyzed amination, Microwave, Bite angle

Introduction

The Buchwald-Hartwig cross-coupling reaction between amines and organic halides or triflates has emerged as one of the foremost methods for the creation of C(sp^2)-N bonds under mild conditions.[1] The reaction provides an efficient pathway to a range of pharmaceuticals, natural products, dyes and polymers and hence has significantly extended its scope in recent years.[2] The development of more efficient ligands by Buchwald and co-workers[3] has considerably increased the extent of these reactions and has found widespread use in pharmaceutical industries.[4] The metal catalyzed cross-coupling reactions are considerably slow and usually take hours or days for complete conversion of reactants which is too long for medicinal chemistry research programs in which large libraries of compounds have to be made within a short period of time.[5] The microwave assisted organic synthesis (MAOS) has indisputably became a powerful tool in drug discovery laboratories these days for the construction of versatile chemical entities due often to superior reaction rates, selectivity and product yields as compared to standard thermal conditions.[6] It is well documented that microwave assistance can lead to enormous rate enhancement compared to conventional heating by significantly shortening the reaction times. Moreover, a better reproducibility, greater yields and less side reactions have often been observed when compared to standard heating methodologies.[7]

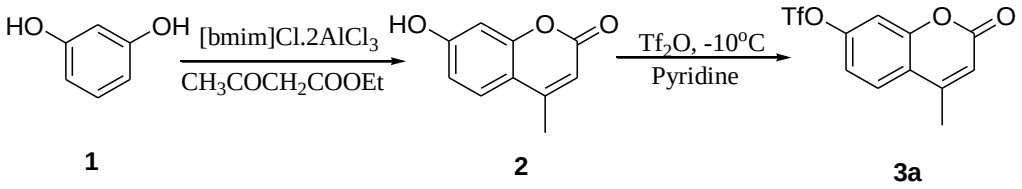
Coumarins are an important class of benzopyrones that are widely distributed throughout the plant kingdom either in free or combined state.[8] They represent one of the most active classes of compounds and possess a wide spectrum of pharmacological activities.[9] Coumarin derivatives have various therapeutic applications including photo chemotherapy, anti-tumor, anti-HIV therapy,[10] and are also active as anti-bacterial,[11,12] anti-inflammatory[13] and anti-viral agents.[14] In addition, coumarins are found to be lipid lowering agents with moderate triglyceride lowering activity[15] whereas hydroxycoumarins are powerful chain breaking anti-oxidants which prevent free radical injury.[16,17] The diverse biological activities of coumarins as anticoagulants and antithrombotics are extensively reported in literature.[18] The coumarin motif is present within the chemical structure of pharmaceutical drugs such as warfarin, acenocoumarol, carbochromen etc. and in antibiotics such as novobiocin, clorobiocin and coumermycin A_1.[19] Coumarin derivatives

have also been used as luminescent probes, triplet sensitizers and photostable laser dyes.[20] For the past 20 years, these varied applications of coumarins have encouraged many researchers to synthesize and evaluate the pharmacological profile of new coumarin derivatives.[21]

The diverse applications of coumarins in various areas of chemistry have been well reported in literature. Furthermore, the structure activity relationship (SAR) studies of various heteroaryl/aryl coumarins have revealed that the presence of substituted heteroaryl/aryl groups in the coumarin moiety is an indispensable feature for their active pharmacological properties.[22] However, the instability (lactone ring cleavage) of the coumarin nuclei in basic as well as prolonged heating conditions is broadly reported in literature.[22,23] As a continuation of our ongoing research program in medicinal chemistry,[24] we were interested in the synthesis of some substituted amino and amido coumarins which may possess significant biological activity. Continuing with our ongoing studies on microwave assisted synthesis[25] and considering the instability of coumarin nuclei to prolonged heating conditions, we decided to utilize the microwave irradiation for the synthesis of various amino and amido coumarins in view of the fact that the reaction could reach to completion within minutes as compared to classical heating. In this letter, we report a rapid and novel access for the synthesis of a variety of 4-methyl-7-(alkyl/aryl/heteroaryl) amino and amido coumarins **4a-t** by utilizing the palladium catalyzed cross-coupling of 4-methyl-7-nonafluorobutylsulfonyloxycoumarins **3b** with various aryl/heteroaryl amines under microwave irradiation.

Results and discussions

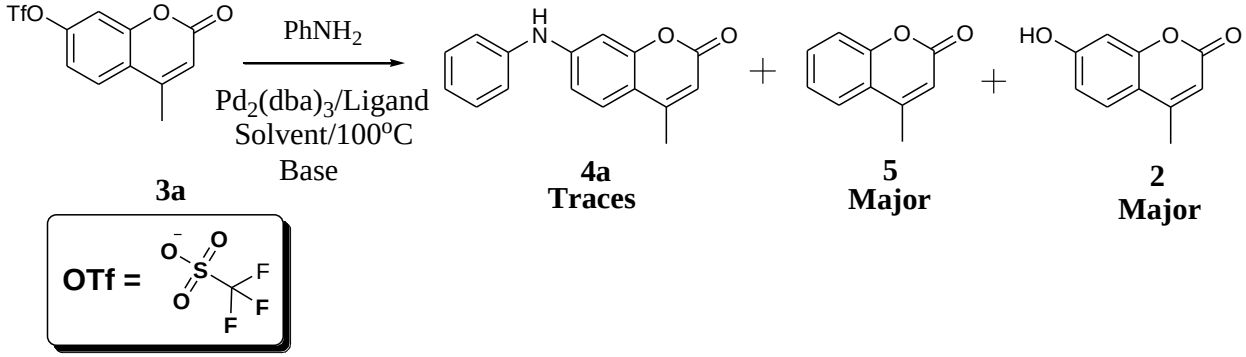
The parent coumarin scaffold **2** was synthesized using the modified Pechmann cyclization condition **(Scheme 1)** in which resorcinol **1** was treated with ethyl acetoacetate in 1-Butyl-3-methylimidazolium chloroaluminate at 30 °C for 20 min.[26] The obtained hydroxy coumarin **2** was then converted to corresponding triflate **3a** by treating it with trifluoromethane sulfonic anhydride in pyridine at -10 °C for 2 h. The intermediate thus obtained was then subjected to Buchwald-Hartwig amination with the intention of synthesizing a series of novel 4-methyl-7-(heteroaryl) amino/ amidocoumarins of considerable pharmacological relevance.



1 **2** **3a**

Scheme 1: Synthesis of 4-methyl-7-trifluoromethylsulfonyloxy coumarin intermediate

Initially, we carried out the reaction optimization by treating triflate **3a** with aniline as the product formation could be easily identified by TLC and LC-MS. The identification of an effective catalyst combination is a major task in Buchwald coupling since a variety of catalysts in combination with various ligands have been developed hitherto.[17,27] An extensive literature survey revealed that the amination can be successfully carried out with $Pd_2(dba)_3$ or $Pd(OAc)_2$ in combination with various ligands like BINAP, dppf, Xantphos, DPEphos etc.[28] We started our initial screening in $Pd_2(dba)_3$ since the obtained results could be easily reproducible with quantitative yields and are more efficient even though it is a little time consuming.[18a,d,29] Various *in situ* generated catalyst combinations and bases were tried in dioxane and the reaction was carried out at 120 °C for 30 min at 110 W in a microwave oven **(Table 1)**. To our disappointment, in most of the cases we found the detriflated product **5** as the major product (>50 %) with only traces of required product **4a (Scheme 2)**.



3a **4a Traces** **5 Major** **2 Major**

Scheme 2: Buchwald coupling of 4-methyl-7-trifluoromethylsulfonyloxy coumarin intermediate with aniline

The triflate **3a** was proved to be unstable and subsequent C-O bond cleavage occurred even within 30 min. of the commencement of the reaction. Even though we could see a little amount of product mass (15 %) when Xantphos was used as a ligand and Cs_2CO_3 as base in dioxane, the saponified product **2** of the triflate was obtained as a major product **(Table 1, Entry 3)**. Although

the use of hydrated tetrabutyl ammonium fluoride ($TBAF{\cdot}3H_2O$) as an additive with Cs_2CO_3 and Xantphos suppressed the triflate saponification to some extent, the detriflated product **5** prevailed as a major competitor **(Table 1, Entry 5)**. Neither decreasing the reaction time nor the temperature gave acceptable conversion **(Table 1, Entries 6, 7)**. Among the various bases screened (Cs_2CO_3, K_3PO_4, NaO*t*Bu, NaOH), Cs_2CO_3, albeit in low yield, gave better conversions. The observed decomposition of aryl triflate could be plausibly due to the unstable nature of intermediate Pd(II) complex that is expected to arise from initial oxidative addition of the triflate to Pd(0).[30] It is presumed that the base promoted nucleophilic attack at the sulfur atom is too high in triflates which apparently caused the undesired phenol formation and resulted in lower yields of desired product.[31]

Table 1. Effect of various ligands and bases in the coupling of triflate **3a** with aniline

Entry	Catalyst	Ligand	Base	Solvent	Yield 5 (%)	Yield 2 (%)	Yield 4a (%)
1	$Pd_2(dba)_3$	BINAP	Cs_2CO_3	Dioxane	85	traces	Nil
2	$Pd_2(dba)_3$	dppf	Cs_2CO_3	Dioxane	76	<10	traces
3	$Pd_2(dba)_3$	Xantphos	Cs_2CO_3	Dioxane	28	45	15
4	$Pd_2(dba)_3$	DPEphos	Cs_2CO_3	Dioxane	50	32	traces
5	$Pd_2(dba)_3$	Xantphos	Cs_2CO_3	Dioxane	35	23	30[b]
6	$Pd_2(dba)_3$	Xantphos	Cs_2CO_3	Dioxane	traces	20	40[b,c]
7	$Pd_2(dba)_3$	Xantphos	Cs_2CO_3	Dioxane	traces	18	45[b,d]

Reaction conditions: 4-methyl-7-trifluoromethylsulfonyloxy coumarin **3a** (1 mmol), aniline (1.3 mmol), $Pd_2(dba)_3$ (5 mol %), ligand (0.1 mmol), base (2 mmol), dioxane, microwave irradiated at 110 W at 120 °C for 30 min.
[b] 1 mmol of $TBAF{\cdot}3H_2O$ used as an additive.
[c] Reaction carried out for 15 min.
[d] Reaction carried out at 100 °C.

In order to circumvent the problems caused by instability and saponification of triflate, we tried the reaction optimization with corresponding nonaflates. The 4-methyl-7-nonafluorobutylsulfonyloxy coumarin intermediate **3b** was synthesized by the reaction of hydroxy intermediate **2** with nonafluorobutane sulfonic anhydride in pyridine at -10 °C for 1 h **(Scheme 3)**. Nonaflates are reported to be more stable than corresponding triflates and hence can be stored for longer periods.[31a,32] They are slightly more reactive than corresponding triflates and are considered as a practical alternative to triflates.[33] The strong electron-withdrawing property of the perfluorinated alkyl chain in combination with the SO_2 moiety dramatically enhances the

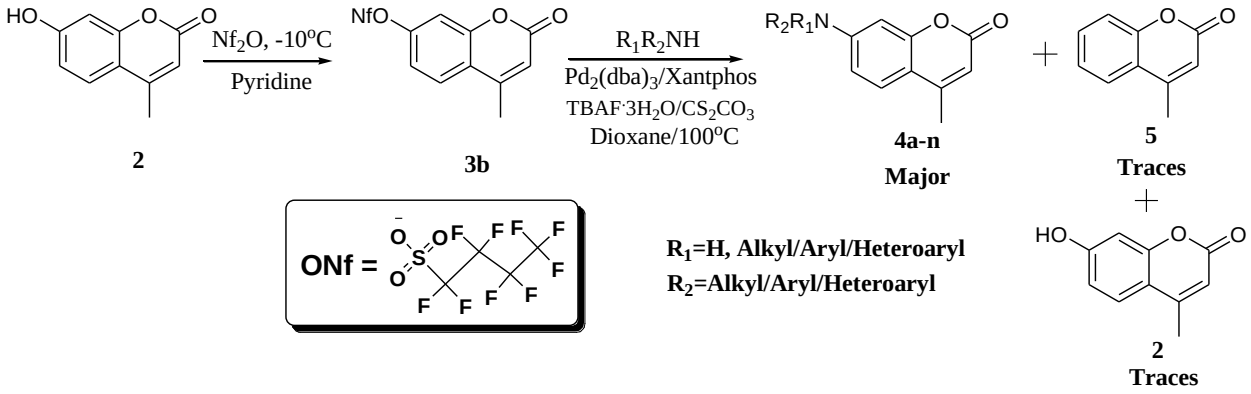
reactivity of nonaflates and hence is an ideal tool for creating a good leaving group.[34] Moreover, it has been reported that the nonaflates are less prone to O-S bond cleavage than corresponding triflates which subsequently causes the hydrolysis.[35] Owing to these observations, we treated the nonaflate **3b** with aniline in different $Pd_2(dba)_3$/ligand combinations and Cs_2CO_3 as base in various solvents and the reaction was carried out in a microwave oven at 120 °C at 110 W for 30 min **(Table 2)**.

Table 2. Effect of various ligands and bases in the coupling of nonaflate **3b** with aniline

Entry	Catalyst	Ligand	Base	Solvent	Yield 5 (%)	Yield 2 (%)	Yield 4a (%)
1	$Pd_2(dba)_3$	BINAP	Cs_2CO_3	Dioxane	28	18	48
2	$Pd_2(dba)_3$	dppf	Cs_2CO_3	Dioxane	15	76	traces
3	$Pd_2(dba)_3$	DPEphos	Cs_2CO_3	Dioxane	24	20	35
4	$Pd_2(dba)_3$	Xantphos	Cs_2CO_3	Dioxane	traces	35	60
5	$Pd_2(dba)_3$	Xantphos	Cs_2CO_3	NMP	15	35	42
6	$Pd_2(dba)_3$	Xantphos	Cs_2CO_3	DMF	traces	44	30
7	$Pd_2(dba)_3$	Xantphos	Cs_2CO_3	Dioxane	15	Traces	75[b]
8	$Pd_2(dba)_3$	Xantphos	Cs_2CO_3	Dioxane	traces	Traces	96[c,d]

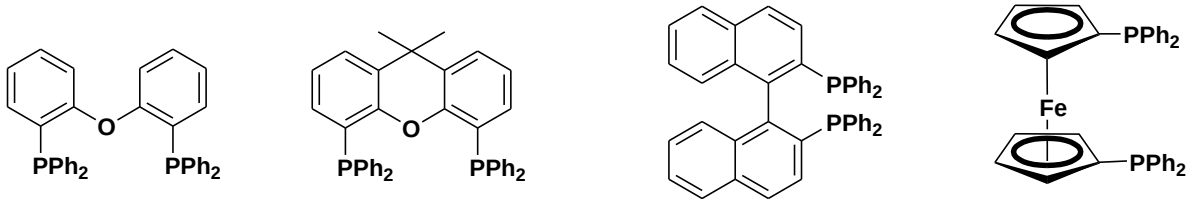
Reaction conditions: 4-methyl-7-nonafluorobutylsulfonyloxy coumarin **3b** (1 mmol), aniline (1.3 mmol), $Pd_2(dba)_3$ (5 mol %), ligand (0.1 mmol), Cs_2CO_3 (2 mmol), solvent, microwave irradiated at 110 W at 120 °C for 30 min.
[b] 1 mmol of TBAF·$3H_2O$ used as an additive.
[c] Reaction carried out at 100 °C.
[d] 2 mmol of TBAF·$3H_2O$ used.

We observed that the reaction conditions and nature of catalyst have a determining influence on this coupling reaction. $Pd_2(dba)_3$/Xantphos catalytic system were found to be essential for better conversions and polar solvents like DMF, NMP were found to be ineffective **(Table 2, Entries 1-6)**. To our delight, we could see the product in considerably better yield when Cs_2CO_3 was used as a base along with the catalytic system in dioxane but still the hydrolyzed compound **2** remained as a competitive side-product **(Table 2, Entry 4)**. Fortunately, we obtained the product in an acceptable yield when TBAF·$3H_2O$ (1 equiv.) was used as an additive along with Cs_2CO_3 in dioxane which significantly reduced the hydrolysis of the nonaflate **(Table 2, Entry 7)**. Finally, addition of one more equivalent of TBAF·$3H_2O$ and reducing the reaction temperature to 100 °C procured the required diaryl amine **4a** in 96 % yield with 92 % of isolated yield **(Table 2, Entry 8)**.



Scheme 3: Synthesis of 4-methyl-7-nonafluorobutylsulfonyloxycoumarin intermediate and its Buchwald coupling with various amines

In the present study, the ligands having bite angle less than that of Xantphos (108°) proved to be inefficient **(Table 2, Entries 1-3)**. The superiority of Xantphos to other ligands might be attributed to the wide bite angle characteristic **(Fig 1)** of the ligand which increased the steric bulk and enhanced the reductive elimination step by forming a cis complex in the catalytic cycle.[36] Increase in the solvation of $TBAF{\cdot}3H_2O$ in the reaction medium when its stoichiometric ratio was increased could be the prominent feature for the complete suppression of hydrolysis of the nonaflate.[31b,c] In the current work, hydrated TBAF considerably reduced the saponification of the nonaflates when compared to triflates which is in agreement with earlier observations.[31b,c]



DPEphos (104°) **Xantphos (108°)** **BINAP(93°)** **dppf (99°)**

Fig 1: Structure of various ligands screened and their bite angles

Our subsequent efforts were to study the effect of the base in the reaction system. Keeping this in mind, we explored the reaction by varying the bases and by keeping all the other parameters constant **(Table 3)**. Among the various bases screened, Cs_2CO_3 gave excellent conversions which could be attributed to the unique properties of cesium cation like high ionic

radius, low charge density and high polarizibility.[25c] The usage of strong bases like NaO*t*Bu and NaOH caused the substantial cleavage of the lactone ring **(Table 3, Entries 4, 5)**.

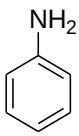
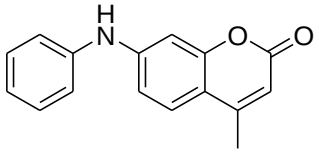
Table 3. Effect of various bases in the Buchwald coupling reaction

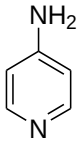
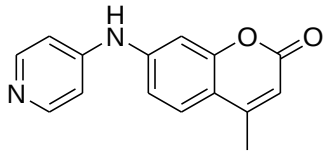
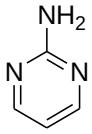
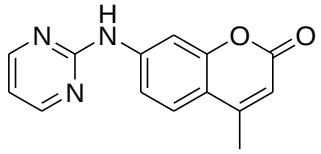
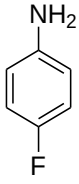
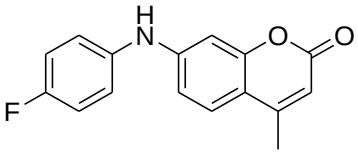
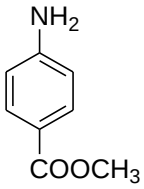
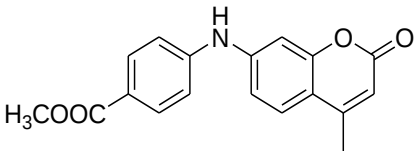
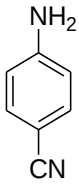
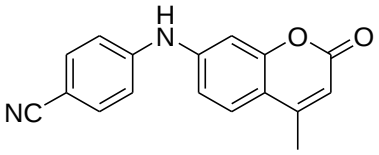
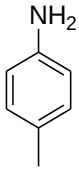
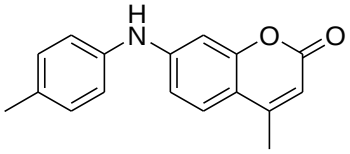
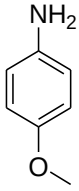
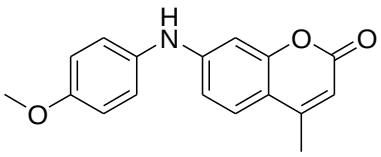
Entry	Base	Yield[b] (%)
1	K_2CO_3	18
2	$NaHCO_3$	25
3	Na_2CO_3	20
4	NaOH	traces
5	NaO*t*Bu	traces
6	K_3PO_4	48
7	CsOAc	78
8	Cs_2CO_3	92

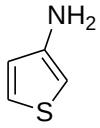
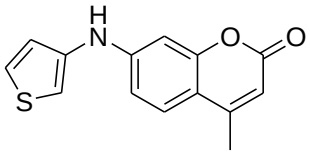
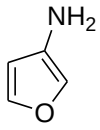
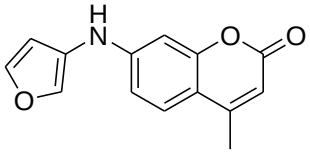
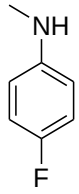
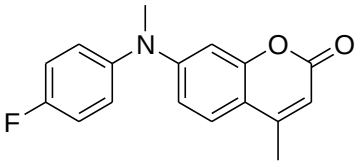
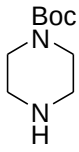
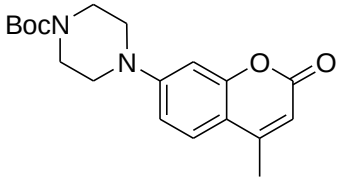
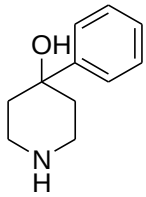
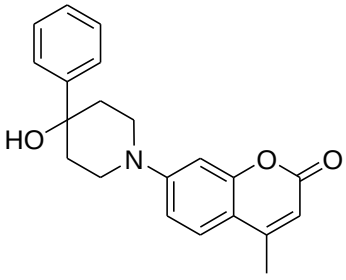
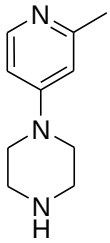
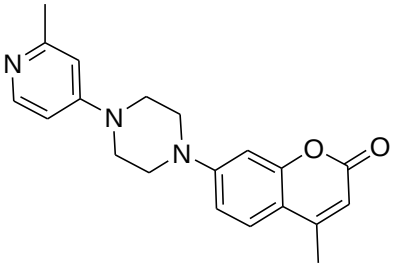
Reaction conditions: 4-methyl-7-nonafluorobutylsulfonyloxy coumarin **3b** (1 mmol), aniline (1.3 mmol), $Pd_2(dba)_3$ (5 mol %), Xantphos (0.1 mmol), base (2 mmol), $TBAF{\cdot}3H_2O$ (2 mmol), dioxane, microwave irradiated at 110 W at 100 °C for 30 min.
[b] Isolated yield.

With the optimized condition in hands, we shifted our attention to evaluate the generality of the developed protocol. A series of primary and secondary amines with various electronic and steric characteristics were effectively coupled with the nonaflate and our results are summarized in **Table 4**. Electron withdrawing amines gave slightly lesser yields even after 1h whereas electron donating amines gave exceptional yields to produce the corresponding diaryl amines **(Table 4, Entries 4-8)**. The presence of electron-withdrawing groups might have reduced the nucleophilicity of the nitrogen in amines which considerably decreased the formation of coupled product. Sterically hindered amines gave slightly lesser yields even after continuing the reaction for 1h. **(Table 4, Entries 12-14)**. Aliphatic primary amines didn't furnish any coupled product with the nonaflate in the optimized conditions and was proved to be inert.

Table 4. Buchwald coupling of the nonaflate intermediate with various amines

Entry	Nonaflate (3)	Amine (2)	Product	Yield[b] (%)
1	**3b**	 **2a**	 **4a**	92

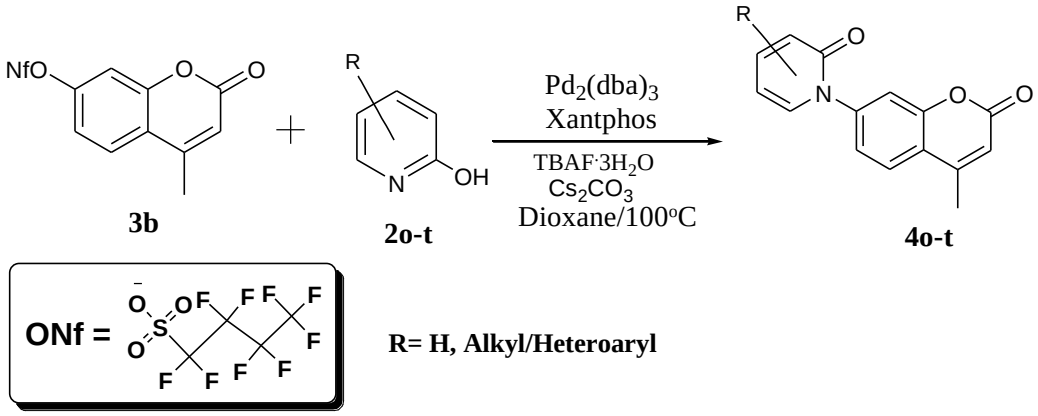
2	**3b**	 **2b**	 **4b**	94
3	**3b**	 **2c**	 **4c**	91
4	**3b**	 **2d**	 **4d**	82
5	**3b**	 **2e**	 **4e**	79
6	**3b**	 **2f**	 **4f**	76
7	**3b**	 **2g**	 **4g**	87
8	**3b**	 **2h**	 **4h**	90

9	**3b**	 **2i**	 **4i**	92
10	**3b**	 **2j**	 **4j**	88
11	**3b**	 **2k**	 **4k**	82
12	**3b**	 **2l**	 **4l**	79
13	**3b**	 **2m**	 **4m**	80
14	**3b**	 **2n**	 **4n**	82

Reaction conditions: 4-methyl-7-nonafluorobutylsulfonyloxy coumarin **3b** (1 mmol), amine (1.3 mmol), $Pd_2(dba)_3$ (5 mol %), Xantphos (0.1 mmol), Cs_2CO_3 (2 mmol), $TBAF{\cdot}3H_2O$ (2 mmol), dioxane, microwave irradiated at 110 W at 100 °C for 30 min.

[b] Isolated yield.

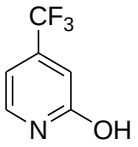
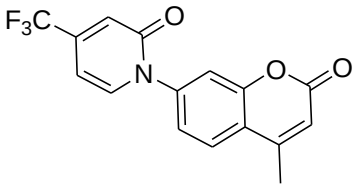
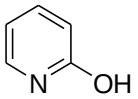
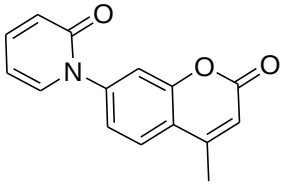
Our next attention was to elaborate the substrate scope by extending the reaction for the synthesis of cyclic amides. Keeping this in mind, we applied the optimized condition to a variety of heteroannulated pyridones **(Scheme 4)** and our results are depicted in **Table 5**.

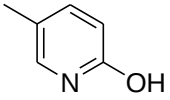
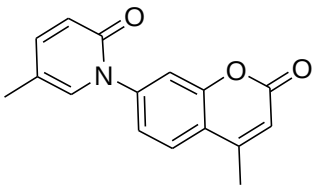
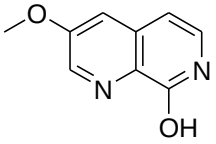
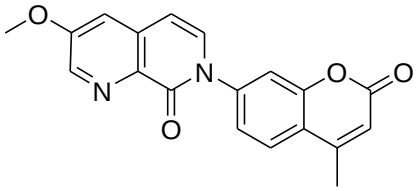
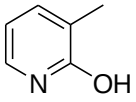
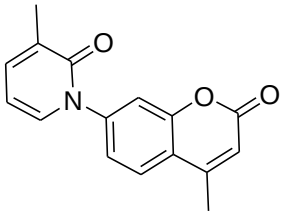
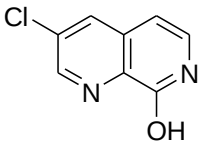
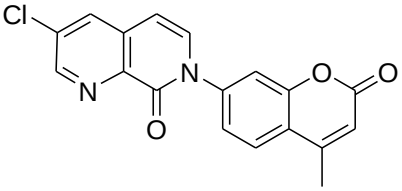


Scheme 4: Buchwald coupling of 4-methyl-7-nonafluorobutylsulfonyloxycoumarin intermediate with various pyridones

Gratifyingly, under these conditions, all the pyridones coupled well enough to procure the cyclic amides at C-7 position of coumarins. Sterically hindered pyridones rendered the lactams in comparatively smaller yields than that of other pyridones as expected **(Table 5, Entries 4 & 6)**.

Table 5. Buchwald coupling of the nonaflate intermediate with various pyridones

Entry	Nonaflate (3)	Pyridones (2)	Product	Yield[b] (%)
1	**3b**	 **2o**	 **4o**	91
2	**3b**	 **2p**	 **4p**	90

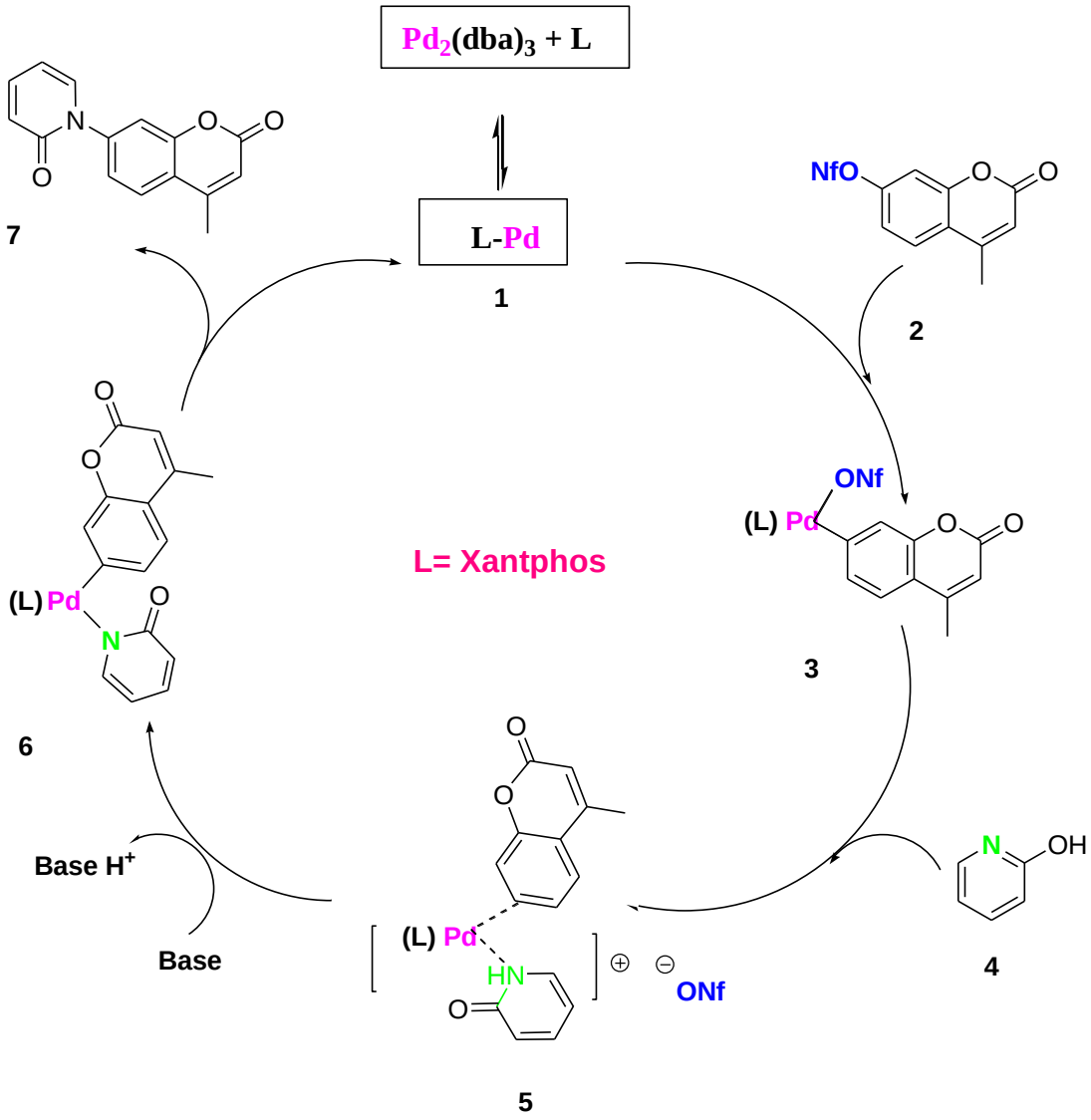
3	**3b**	 **2q**	 **4q**	87
4	**3b**	 **2r**	 **4r**	82
5	**3b**	 **2s**	 **4s**	93
6	**3b**	 **2t**	 **4t**	77

Reaction conditions: 4-methyl-7-nonafluorobutylsulfonyloxy coumarin **3b** (1 mmol), pyridone (1.3 mmol), $Pd_2(dba)_3$ (5 mol %), Xantphos (0.1 mmol), $TBAF{\cdot}3H_2O$ (2 mmol), Cs_2CO_3 (2 mmol), dioxane, microwave irradiated at 110 W at 100 °C for 30 min.

[b] Isolated yield.

A plausible mechanism[37] of the coupling reaction of pyridone with nonaflate has been proposed **(Scheme 5)**. The first step in the catalytic cycle is the formation of a true catalytic species (a coordinatively unsaturated electron rich palladium complex) which undergoes oxidative addition with coumarin nonflate to yield oxidative adduct complex **3**. The subsequent step involves the complexation of pyridone with this palladium complex which increases the acidity of pyridone proton resulting in its deprotonation by Cs_2CO_3 to yield the complex **6**. Finally, it undergoes reductive elimination to form the coupled diaryl amines and completes the catalytic cycle.

Although the effect of TBAF in these reactions is quite unclear, it is speculated that TBAF possess some critical beneficial roles such as the stabilization of low-coordinated Pd(II) species **3** and **6** that are expected to form during the coupling process and acts as a phase-transfer catalyst in order to enhance the desired product formation.[38]



Scheme 5: Proposed mechanism of the coupling reaction

Conclusion

We have achieved an efficient, modified and concise protocol for C-7 amination and amidation of 4-methyl-7-nonafluorobutylsulfonyloxy coumarins by the *in situ* generation of a Pd/Xantphos catalyst system in presence of Cs_2CO_3 and TBAF·$3H_2O$ under microwave irradiation. The nonaflates proved to be superior than corresponding triflates in terms of reactivity and stability to hydrolysis. The use of Cs_2CO_3 as a mild base which broadened the substrate scope and utilization of hydrated TBAF as an additive which significantly suppressed the nonaflate hydrolysis were proved to be the key for success of the reaction. This method provided a facile and reliable access to a variety of pharmacologically relevant coumarins and could be extended for the coupling of other densely functionalized heterocycles. The biological screening of the newly synthesized molecules will be done in due course and will be communicated shortly as a continuation of the current work.

Experimental

General information

All solvents and reagents were obtained from commercial suppliers and used without any further purification unless otherwise noted. All the reactions were carried out under the inert atmosphere of argon. Analytical TLC was performed on pre-coated aluminum sheets of silica (60 F254 nm) and visualized by short-wave UV light at λ 254. Melting points were determined on an EZ - Melt automated melting point apparatus. ^{1}H NMR spectra were recorded at 400 MHz and 300 MHz using an internal deuterium lock. Chemical shifts were measured in δ (ppm). Data is presented as follows: chemical shift, multiplicity, coupling constant (*J*) in Hz, and integration. The following abbreviations are used for the splitting patterns: s for singlet, d for doublet, t for triplet, m for multiplet and br for broad. ^{13}C NMR spectra were recorded at 100 MHz using an internal deuterium lock. ^{19}F NMR spectra were recorded at 376.5 MHz in $CFCl_3$ using an internal deuterium lock. LC-MS analyses were performed using ESI/APCI, with an ATLANTIS C18 (50X4.6 mm - 5µm) column and a flow rate of 1.2 mL/min.

Procedure for the synthesis of 4-methyl-7-nonafluorobutylsulfonyloxy coumarin 3b

To a solution of 4-methyl-7-hydroxy coumarin (**2**, 1 equiv) in DCM, was added pyridine (2 equiv) at -10 °C, followed by the addition of nonafluorobutane sulfonic anhydride (1.2 equiv)

drop wise. Reaction mixture was warmed to 0 °C and stirred for 1 h. Reaction mass was then diluted with DCM, bi-phased with water and extracted, organic layer was washed with $NaHCO_3$, brine solution and dried over Na_2SO_4 and distilled under reduced pressure. Crude compound was purified by column chromatography packed with 60-120 silica gel and eluted with 15 to 20 % ethyl acetate in petroleum ether to obtain the titled compound **3b** as colorless solid in 87 % yield. MP: 86-88 °C; ^{1}H NMR (300MHz, $CDCl_3$): δ 2.47,d, *J*=1.08 Hz,3H,CH_3; δ 6.37,1H,ArH; δ 7.23-7.29,m,2H,ArH; δ 7.69,d, *J*=8.67 Hz,1H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 23.2,CH_3; δ 115.3, δ 116.5, δ 116.9,m,CF_2; δ 118.9,m,CF_2; δ 126.7,m,CF_3; δ 132.2, δ 154.1-154.7 (2 peaks), δ 156.3,m,SO_2CF_2; δ 163.4,CO; ^{19}F NMR (376.5 MHz, $CDCl_3$): δ -125.32 to -125.22,m; δ -120.77 to -120.68,m; δ -112.97 to -112.87,m; δ -80.59 to -80.52,m; LC-MS: Calculated 394.2, Observed 395.2.

General procedure for the synthesis of substituted diaryl amines 4a-t

To a solution of 4-methyl-7-nonafluorobutylsulfonyloxy coumarin (**3b**, 1 equiv) in dioxane, were added a premixed solution of $Pd_2(dba)_3$ (5 mol %) and Xantphos (0.1 equiv) in dioxane. The solution was purged with argon and stirred at room temperature for 10 min, at which time the amine/pyridone (1.3 equiv), Cs_2CO_3 (2 equiv) and $TBAF{\cdot}3H_2O$ (2 equiv) were added. The reaction solution was purged again with argon and then placed in the microwave and heated for 20–30 min. at 100 °C at 110 W. When TLC and LC-MS showed full consumption of starting materials, the reaction mixture was filtered, diluted with ethyl acetate, separated the ethyl acetate layer, given water wash, brine wash, dried over anhydrous sodium sulfate and distilled in vacuo to get the crude material. The crude product was purified by column chromatography and eluted in varying polarities to obtain the substituted diaryl amines **4a-t**.

4-Methyl-7-(phenylamino)-2H-chromen-2-one (4a)

MP: 78-80 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.49,d, *J*=1.28 Hz,3H,CH_3; δ 3.94,br,1H,NH; δ 6.49,s,1H,ArH; δ 7.59-7.61,dd, J_1=1.72 Hz J_2=8.12 Hz,2H,ArH; δ 7.64-7.67,dd, J_1=1.00 Hz J_2=8.48 Hz,2H,ArH; δ 7.71-7.73,d, *J*=7.8 Hz,1H,ArH; δ 7.82-7.86,m,1H,ArH; δ 7.92-8.05,m,2H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 24.7,CH_3; δ 107.7, δ 110.5, δ 113.5, δ 117.9, δ

124.7, δ 125.6, δ 131.4, δ 132.7, δ 140.8, δ 141.7, δ 144.4, δ 148.3, δ 158.1,CO; LC-MS: Calculated 251.1, Observed 252.1; Anal. calcd for $C_{16}H_{13}NO_2$: C, 76.48; H, 5.21; N, 5.57 %, found: C, 76.39; H, 5.26; N, 5.53 %.

4-Methyl-7-(pyridine-4-ylamino)-2H-chromen-2-one (4b)

MP: 79-81 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.40,d, *J*=2.08 Hz,3H,CH_3; δ 3.94,br,1H,NH; δ 7.15-7.18,dd, J_1=2.96 Hz J_2=7.92 Hz,1H,ArH; δ 7.25-7.28,m,2H,ArH; δ 7.35-7.37,d, *J*=8.24 Hz,1H,ArH; δ 7.83-7.90,m,2H,ArH; δ 8.26-8.28,dd, J_1=1.4 Hz J_2=8.16 Hz,1H,ArH; δ 8.40-8.42,d, *J*=8.92 Hz,1H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 24.7,CH_3; δ 110.2, δ 117.9, δ 118.8, δ 118.7, δ 125.8, δ 129.9, δ 132.9, δ 136.2, δ 141.8, δ 146.6, δ 155.4, δ 157.6,CO; LC-MS: Calculated 252.2, Observed 253.2; Anal. calcd for $C_{15}H_{12}N_2O_2$: C, 71.42; H, 4.79; N, 11.10 %, found: C, 71.36; H, 4.87; N, 11.08 %.

4-Methyl-7-(pyrimidin-2-ylamino)-2H-chromen-2-one (4c)

MP: 81-84 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.36,d, *J*=1.16 Hz,3H,CH_3; δ 3.83,br,1H,NH; δ 6.38,s,1H,ArH; δ 6.64-6.66,dd, J_1=1.76 Hz J_2=7.84 Hz,1H,ArH; δ 6.83-6.84,d, *J*=3.36 Hz,1H,ArH; δ 7.27-7.29,m,2H,ArH; δ 7.87-7.89,dd, J_1=1.44 Hz J_2=8.48 Hz,2H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 24.7,CH_3; δ 110.7, δ 113.8, δ 118.0, δ 121.5, δ 125.8, δ 132.7, δ 140.1, δ 141.9, δ 146.5, δ 154.9, δ 159.1,CO; δ 160.6; LC-MS: Calculated 253.1, Observed 254.1; Anal. calcd for $C_{14}H_{11}N_3O_2$: C, 66.40; H, 4.38; N, 16.59 %, found: C, 66.48; H, 4.38; N, 16.54 %.

7-(4-Fluorophenylamino)-4-methyl-2H-chromen-2-one (4d)

MP: 83-85 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.47,d, *J*=1.56 Hz,3H,CH_3; δ 3.96,br,1H,NH; δ 6.33,s,1H,ArH; δ 7.27-7.29,m,2H,ArH; δ 7.44-7.47,m,2H,ArH; δ 7.76-7.80,m,2H,ArH; δ 8.04,d, *J*=8.20 Hz,1H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 24.7,CH_3; δ 110.6, δ 113.8, δ 118.0, δ 121.5, δ 125.8, δ 132.7, δ 140.2, δ 141.9, δ 146.5, δ 148.5, δ 154.9,m,CF; δ 160.1,CO; LC-MS: Calculated 269.2, Observed 270.2; Anal. calcd for $C_{16}H_{12}FNO_2$: C, 71.37; H, 4.49; N, 5.20 %, found: C, 71.49; H, 4.41; N, 5.17 %.

Methyl 4-(4-methyl-2-oxo-2H-chromen-7-ylamino)benzoate (4e)

MP: 96-98 °C; ^{1}H NMR (300MHz, $CDCl_3$): δ 2.49,d, *J*=1.17 Hz,3H,CH_3; δ 3.88,br,1H,NH; δ 3.96,s,3H,OCH_3; δ 6.34,s,1H,ArH; δ 7.47-7.51,m,3H,ArH; δ 7.64-7.72,m,3H,ArH; δ 8.14-8.17,dd, J_1=1.68 Hz J_2=6.51 Hz,1H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 23.2,CH_3; δ 54.3,CH_3(ester); δ 111.4, δ 112.6, δ 114.5, δ 117.8, δ 121.1, δ 121.8, δ 129.8, δ 133.1, δ 142.2, δ 146.4, δ 154.2, δ 156.1, δ 159.8,CO; 165.4,CO(ester); LC-MS: Calculated 309.1, Observed 310.1; Anal. calcd for $C_{18}H_{15}NO_4$: C, 69.89; H, 4.89; N, 4.53 %, found: C, 69.94; H, 4.86; N, 4.51 %.

4-(4-Methyl-2-oxo-2H-chromen-7-ylamino)benzonotrile (4f)

MP: 85-87 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.49,d, *J*=1.52 Hz,3H,CH_3; δ 3.95,br,1H,NH; δ 6.49,s,1H,ArH; δ 7.59-7.64,m,2H,ArH; δ 7.71,d, *J*=7.8 Hz,1H,ArH; δ 7.82-7.86,dd, J_1=1.24 Hz J_2=7.72 Hz,2H,ArH; δ 8.02,d, *J*=7.76 Hz,2H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 24.7,CH_3; δ 108.5, δ 109.8, δ 117.9, δ 118.8, δ 125.9, δ 129.8,CN; δ 132.9, δ 136.2, δ 141.6, δ 141.8, δ 146.3, δ 146.6, δ 155.4, δ 156.6, δ 159.5,CO; LC-MS: Calculated 276.2, Observed 277.2; Anal. calcd for $C_{17}H_{12}N_2O_2$: C, 73.90; H, 4.38; N, 10.14 %, found: C, 73.99; H, 4.34; N, 10.11 %.

7-(p-Tolylamino)-4-methyl-2H-chromen-2-one (4g)

MP: 84-86 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.49,d, *J*=1.64 Hz,3H,CH_3; δ 3.14,s,3H,CH_3; δ 3.76,br,1H,NH; δ 6.49,s,1H,ArH; δ 6.84-6.89,m,2H,ArH; δ 6.96-6.99,dd, J_1=1.24 Hz J_2=7.76 Hz,2H,ArH; δ 7.46-7.49,dd, J_1=1.36 Hz J_2=7.92 Hz,2H,ArH; δ 7.78,d, *J*=7.76 Hz,1H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 23.4,CH_3; δ 26.2,CH_3; δ 111.1, δ 112.2, δ 114.3, δ 117.8, δ 121.8, δ 129.7, δ 131.1, δ 133.2, δ 139.6, δ 142.4, δ 154.3, δ 155.8, δ 159.5,CO; LC-MS: Calculated 265.1, Observed 266.1; Anal. calcd for $C_{17}H_{15}NO_2$: C, 76.96; H, 5.70; N, 5.28 %, found: C, 77.02; H, 5.68; N, 5.22 %.

7-(4-Methoxyphenylamino)-4-methyl-2H-chromen-2-one (4h)

MP: 88-90 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.49,d, *J*=1.56 Hz,3H,CH_3; δ 3.88,br,1H,NH; δ 3.93,s,3H,OCH_3; δ 6.34,s,1H,ArH; δ 7.54-7.59,m,3H,ArH; δ 7.64-7.72,m,3H,ArH; δ 8.14-8.17,dd, J_1=2.24 Hz J_2=8.68 Hz,1H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 21.1,CH_3; δ 55.8,OCH_3; δ 110.2, δ 117.9, δ 118.8, δ 125.9, δ 129.8, δ 132.9, δ 136.8, δ 141.6, δ 141.8, δ

146.0, δ 146.6, δ 155.5, δ 156.3, δ 159.5,CO; LC-MS: Calculated 281.2, Observed 282.2; Anal. calcd for $C_{17}H_{15}NO_3$: C, 72.58; H, 5.37; N, 4.98 %, found: C, 72.71; H, 5.28; N, 4.94 %.

4-Methyl-7-(thiophen-3-ylamino)-2H-chromen-2-one (4i)

MP: 74-76 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.47,d, *J*=1.12 Hz,3H,CH_3; δ 3.82,br,1H,NH; δ 6.27,s,1H,ArH; δ 6.52-6.55,dd, J_1=1.72 Hz J_2=3.32 Hz,1H,ArH; δ 6.81,d, *J*=3.32 Hz,2H,ArH; δ 7.23-7.26,m,1H,ArH; δ 7.54-7.59,m,2H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 23.2,CH_3; δ 105.6, δ 108.7, δ 113.6, δ 114.9, δ 115.4, δ 123.6, δ 127.8, δ 129.5, δ 129.9, δ 144.7, δ 153.6, δ 155.5, δ 159.4,CO; LC-MS: Calculated 257.1, Observed 258.1; Anal. calcd for $C_{14}H_{11}NO_2S$: C, 65.35; H, 4.31; N, 5.44 %, found: C, 65.38; H, 4.31; N, 5.41 %.

7-(Furan-3-ylamino)-4-methyl-2H-chromen-2-one (4j)

MP: 77-79 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.47,d, *J*=1.16 Hz,3H,CH_3; δ 3.84,br,1H,NH; δ 6.29,s,1H,ArH; δ 6.54-6.56,dd, J_1=1.76 Hz J_2=3.36 Hz,1H,ArH; δ 6.83,d, *J*=3.36 Hz,2H,ArH; δ 7.27-7.29,m,1H,ArH; δ 7.57-7.61,m,2H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 24.8,CH_3; δ 110.7, δ 116.5, δ 118.4, δ 126.9, δ 127.8, δ 127.6, δ 129.1, δ 131.9, δ 135.4, δ 143.4, δ 148.3, δ 148.9, δ 158.1,CO; LC-MS: Calculated 241.2, Observed 242.2; Anal. calcd for $C_{14}H_{11}NO_3$: C, 69.70; H, 4.60; N, 5.81 %, found: C, 69.84; H, 4.52; N, 5.77 %.

7-(N-(4-fluorophenyl)-N-methylamino)-4-methyl-2H-chromen-2-one (4k)

MP: 87-89 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.49,d, *J*=1.68 Hz,3H,CH_3; δ 3.55,s,3H,NCH_3; δ 6.33,s,1H,ArH; δ 7.24-7.29,m,2H,ArH; δ 6.71-6.73,dd, J_1=1.48 Hz J_2=8.56 Hz,2H,ArH; δ 7.05-7.08,dd, J_1=1.76 Hz J_2=7.96 Hz,2H,ArH; δ 7.26,d, *J*=8.72 Hz,1H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 23.4,CH_3; δ 43.9,NCH_3; δ 111.7, δ 112.8, δ 114.8, δ 118.1, δ 118.7, δ 123.1, δ 130.1, δ 147.2, δ 150.9, δ 153.6, δ 154.9,m,CF; δ 155.8, δ 159.8,CO; LC-MS: Calculated 283.1, Observed 284.1; Anal. calcd for $C_{17}H_{14}FNO_2$: C, 72.07; H, 4.98; N, 4.94 %, found: C, 72.12; H, 4.96; N, 4.92 %.

Tert-butyl 4-(4-methyl-2-oxo-2H-chromen-7-yl)piperazine-1-carboxylate (4l)

MP: 112-114 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 1.53,s,9H,*t*-Bu; δ 2.49,d, *J*=1.08 Hz,3H,CH_3; δ 3.61-3.69,m,4H,CH_2; δ 3.69-3.73,m,4H,CH_2; δ 6.79,s,1H,ArH; δ 7.22-7.28,m,2H,ArH; δ 7.46,d, *J*=8.84 Hz,1H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 23.2,CH_3; δ 30.7,Boc CH_3; δ 50.8,CH_2; δ 51.7,CH_2; δ 81.9,Boc C; δ 106.9, δ 112.8, δ 113.3, δ 114.7, δ 129.9, δ 151.5, δ 153.4, δ 154.9, δ 156.4,Boc CO; δ 159.5,CO; LC-MS: Calculated 334.2, Observed 245.2; Anal. calcd for $C_{19}H_{24}N_2O_4$: C, 66.26; H, 7.02; N, 8.13 %, found: C, 66.38; H, 7.12; N, 8.17 %.

7-(4-Hydroxy-4-phenylpiperidin-1-yl)-4-methyl-2H-chromen-2-one (4m)

MP: 106-108 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.49,d, *J*=1.64 Hz,3H,CH_3; δ 2.51-2.54,m,4H,CH_2; δ 2.62,s,1H,OH; δ 3.36-3.41,m,4H,CH_2; 6.39,s,1H,ArH; δ 6.85-6.89,m,2H,ArH; δ 7.57,d, *J*=8.84 Hz,1H,ArH; δ 7.72-7.74,m,5H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 24.7,CH_3; δ 40.3, δ 45.8, δ 76.6, δ 106.9, δ 112.8, δ 113.3, δ 114.7, δ 128.4, δ 129.9, δ 130.5, δ 131.2, δ142.3, δ 151.4, δ 153.3, δ 155.1, δ 159.6,CO; LC-MS: Calculated 335.2, Observed 336.2; Anal. calcd for $C_{21}H_{21}NO_3$: C, 75.20; H, 6.31; N, 4.18 %, found: C, 75.34; H, 6.27; N, 4.12 %.

4-Methyl-7-(4-(2-methylpyridin-4-yl)piperazin-1-yl)-2H-chromen-2-one (4n)

MP: 112-114 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.18,d, *J*=2.4 Hz,3H,CH_3; δ 2.48,s,3H,CH_3; δ 3.40-3.52,m,8H,CH_2; δ 6.91,s,1H,ArH; δ 7.00-7.02,d, *J*=7.6 Hz,1H,ArH; δ 7.10-7.14,dd, J_1=2.8 Hz J_2=7.6 Hz,1H,ArH; δ 8.20-8.21,d, *J*=6.8 Hz,1H,ArH; δ 7.27-7.34,m,2H,ArH; δ 8.46,d, *J*=7.2 Hz,1H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 23.4,CH_3; δ 27.3,CH_3; δ 31.7, δ 44.6, δ 51.7, δ 106.9, δ 113.5, δ 113.7, δ 115.4, δ 122.6, δ 124.7, δ 129.8, δ 151.2, δ 151.4, δ 153.2, δ 154.9, δ 159.5, δ 160.4, δ 163.3,CO; LC-MS: Calculated 335.1, Observed 336.1; Anal. calcd for $C_{20}H_{21}N_3O_2$: C, 71.62; H, 6.31; N, 12.53 %, found: C, 71.68; H, 6.27; N, 12.51 %.

4-(Trifluoromethyl)-1-(4-methyl-2-oxo-2H-chromen-7-yl)pyridin-2(1H)-one (4o)

MP: 92-94 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.49,d, *J*=1.76 Hz,3H,CH_3; δ 6.21,d, *J*=7.80 Hz,1H,ArH; δ 6.33,s,1H,ArH; δ 7.34,s,1H,ArH; δ 7.46-7.49,m,4H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 24.7,CH_3; δ 108.5, δ 110.8, δ 113.8, δ 117.6, δ 121.5, δ 125.8, δ 132.7, δ 140.2, δ 141.9,m,CF_3; δ 146.5, δ 148.5, δ 154.9, δ 160.7,CO (Pyridone); δ 163.1,CO; LC-MS: Calculated

321.2, Observed 322.2; Anal. calcd for $C_{16}H_{10}F_3NO_3$: C, 59.82; H, 3.14; N, 4.36 %, found: C, 59.96; H, 3.04; N, 4.34 %.

1-(4-Methyl-2-oxo-2H-chromen-7-yl)pyridin-2(1H)-one (4p)

MP: 79-82 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.41,d, *J*=2.08 Hz,3H,CH_3; δ 7.15-7.18,dd, J_1=1.76 Hz J_2=7.92 Hz,1H,ArH; δ 7.27,s,1H,ArH; δ 7.35,d, *J*=8.24 Hz,2H,ArH; δ 7.83-7.90,m,2H,ArH; δ 8.26-8.28,m,2H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 24.7,CH_3; δ 110.0, δ 116.6, δ 117.9, δ 125.6, δ 131.4, δ 132.7, δ 140.5, δ 140.8, δ 141.7, δ 144.4, δ 146.6, δ 149.9, δ 158.0,CO (Pyridone); δ 160.6,CO; LC-MS: Calculated 253.2, Observed 254.2; Anal. calcd for $C_{15}H_{11}NO_3$: C, 71.14; H, 4.38; N, 5.53 %, found: C, 71.24; H, 4.36; N, 5.47 %.

3-Methyl-1-(4-methyl-2-oxo-2H-chromen-7-yl)pyridin-2(1H)-one (4q)

MP: 82-84 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.43,d, *J*=2.16 Hz,3H,CH_3; δ 2.47,s,3H,CH_3; δ 6.43,s,1H,ArH; δ 7.15,d, *J*=8.04 Hz,1H,ArH; δ 7.25-7.29,m,1H,ArH; δ 7.68-7.71,dd, J_1=1.96 Hz J_2=8.04 Hz,1H,ArH; δ 7.83-7.86,dd, J_1=2.12 Hz J_2=8.28 Hz,1H,ArH; δ 8.19-8.25,m,2H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 18.2,CH_3; δ 24.7,CH_3; δ 107.7, δ 109.2, δ 123.6, δ 127.3, δ 135.7, δ 137.1, δ 143.8, δ 148.3, δ 148.9, δ 149.7, δ 155.1, δ 160.8,CO (Pyridone); δ 162.9,CO; LC-MS: Calculated 267.3, Observed 268.3; Anal. calcd for $C_{16}H_{13}NO_3$: C, 71.90; H, 4.90; N, 5.24 %, found: C, 71.98; H, 4.86; N, 5.22 %.

3-Methoxy-7-(4-methyl-2-oxo-2H-chromen-7-yl)-1,7-naphthyridin-8(7H)-one (4r)

MP: 120-122 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.49,d, *J*=2.24 Hz,3H,CH_3; δ 4.11,s,3H,OCH_3; δ 7.14-7.17,dd, J_1=2.96 Hz J_2=7.92 Hz,2H,ArH; δ 7.27,s,1H,ArH; δ 7.36,d, *J*=7.24 Hz,1H,ArH; δ 7.52,d, *J*=7.64 Hz,1H,ArH; δ 7.80-7.82,dd, J_1=1.12 Hz J_2=7.88 Hz,2H,ArH; δ 8.20-8.28,d, *J*=6.84 Hz,1H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 24.7,CH_3; δ 30.5,OCH_3; δ 110.2, δ 117.9, δ 118.8, δ 125.9, δ 129.8, δ 132.9, δ 136.2, δ 141.6, δ 141.8, δ 146.4, δ 146.6, δ 154.7, δ 155.4, δ 156.6,CO (Pyridone); δ 159.5,CO; LC-MS: Calculated 334.2, Observed 335.2; Anal. calcd for $C_{19}H_{14}N_2O_4$: C, 68.26; H, 4.22; N, 8.38 %, found: C, 68.38; H, 4.18; N, 8.32 %.

5-Methyl-1-(4-methyl-2-oxo-2H-chromen-7-yl)pyridin-2(1H)-one (4s)

MP: 82-84 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.40,d, *J*=2.24 Hz,3H,CH_3; δ 2.41,s,3H,CH_3; δ 6.41,s,1H,ArH; δ 7.13-7.16,dd, J_1=1.36 Hz J_2=7.92 Hz,1H,ArH; δ 7.22-7.27,m,1H,ArH; δ 7.66-7.69,dd, J_1=2.04 Hz J_2=8.12 Hz,1H,ArH; δ 7.81-7.83,dd, J_1=1.4 Hz J_2=7.88 Hz,1H,ArH; δ 8.20-8.25,m,2H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 18.5,CH_3; δ 24.7,CH_3; δ 110.2, δ 117.9, δ 118.8, δ 125.9, δ 129.8, δ 132.9, δ 136.2, δ 141.6, δ 141.8, δ 146.3, δ 146.6, δ 155.4, δ 156.6,CO (Pyridone); δ 159.5,CO; LC-MS: Calculated 267.3, Observed 268.3; Anal. calcd for $C_{16}H_{13}NO_3$: C, 71.90; H, 4.90; N, 5.24 %, found: C, 71.95; H, 4.90; N, 5.20 %.

3-Chloro-7-(4-methyl-2-oxo-2H-chromen-7-yl)-1,7-naphthyridin-8(7H)-one (4t)

MP: 116-118 °C; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.49,d, *J*=2.36 Hz,3H,CH_3; δ 6.34,s,1H,ArH; δ 6.47-6.53,m,2H,ArH; δ 7.37-7.41,m,2H,ArH; δ 7.54-7.56,dd, J_1=2.24 Hz J_2=8.04 Hz,1H,ArH; δ 8.72,s,1H,ArH; δ 9.21,s,1H,ArH; ^{13}C NMR (100MHz, $CDCl_3$): δ 23.4,CH_3; δ 109.9, δ 114.3, δ 114.5, δ 119.0, δ 120.5, δ 129.3, δ 133.2, δ 134.7, δ 136.2, δ 139.1, δ 141.3, δ 149.7, δ 152.2, δ 152.7, δ 155.1, δ 162.8,CO (Pyridone); δ 163.6,CO; LC-MS: Calculated 338.2, Observed 339.2 & 341.2; Anal. calcd for $C_{18}H_{11}ClN_2O_3$: C, 63.82; H, 3.27; N, 8.27 %, found: C, 63.94; H, 3.23; N, 8.21 %.

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