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Regioselective α-arylation of coumarins and 2-pyridones with phenylhydrazines under transition-metal-free condition

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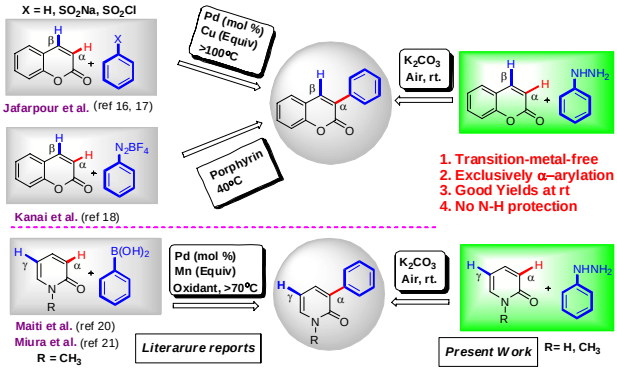
A facile regioselective metal-free direct α-arylation of coumarins and 2-pyridones is achieved by the reaction of coumarins and 2-pyridones with phenylhydrazine in good yields. The reaction proceeds at room temperature under mild conditions using inexpensive reagents and without the need of step intensive activating groups. The methodology is operationally simple, practically viable and also allows the coupling of similar nitrogen heterocycle aza-coumarin without prerequisite N-protection.

The metal-free direct C-H arylation processes have started to emerge as a straightforward, atom-economical and environment-friendly research.[1] These methods are an alternative to metal-catalyzed processes, which are associated with limitations such as step and cost intensive procedures along with the use of toxic, sensitive and environmentally hazardous metals and ligands.[2] In recent past, radical C-H functionalization of innately reactive heterocycles has re-emerged as avenue for selective, early or late stage functionalization of pharmaceutically important precursors and products.[3] Radical-mediated metal-free C-H arylations have been achieved substantially utilizing a variety of aryl coupling partners[4] and among the notable radical-mediated aryl coupling partners, base-mediated arylhydrazine derived aryl radicals have emerged as powerful synthetic intermediate towards the direct C-H arylation under oxidative conditions with limited substrate scope.[5] However, the utility of these intermediates with robust control of regioselectivity in oxidative C-H arylation reactions of biologically prominent and synthetically useful motifs is highly challenging and valuable.

3-Arylcoumarins and 3-aryl-2-pyridones are important scaffolds present in many natural products and bioactive compounds.[6] In particular, α-arylated coumarin derivatives have been shown to be potent, selective monoamine oxidase B inhibitors,[7] active in neurological disorders[8] and inhibitors of HIV-1 replication (Figure 2).[9] Furthermore, 3-arylcoumarins are also important class of fluorophores and found their application as fluorescent labels in complex biological systems.[10] On the other hand, the 3-aryl-2-pyridones, which is key pharmacophore of pharmaceutically important molecules such as Perampanel, and PD180970 (figure 1).[11] Despite the importance of 3-aryl coumarins and 3-aryl-2-pyridones as biologically active scaffolds, the α-arylation of coumarins and 2-pyridones are difficult due to regioselectivity bias of β-arylation of coumarins and γ-arylation of 2-pyridones, which is expected in Heck-type reaction.[12] Radical mediated C-H arylation methods proved as a convenient method because of the inherent reactivity of heterocycles towards aryl radical species. The α-regioselectivity in case of coumarins/aza-coumarins and 2-pyridones towards aryl radical is due to the formation of resonance stabilized benzylic radical[13] and allylic radical[14] intermediates respectively. Herein, we report a K_2CO_3/air promoted regioselective method for direct α-arylation of biologically prominent heterocycles such as coumarins, 2-pyridones and aza-coumarins without prerequisite N-protection under metal and ligand-free condition.



Scheme 1 Strategic approaches for the synthesis of 3-Arylcoumarins and 3-Aryl-2-pyridones.

Mostly the α-arylation of coumarins was achieved either from suitable phenyl substituted precursors[15] or require prefunctionalization at α-position such as in palladium-catalyzed Suzuki coupling of 3-halo coumarin with arylboronic acid[16] and palladium-catalyzed decarboxylative coupling of coumarin-3-carboxylic acid with haloarenes.[17] The most notable methodologies for regioselective α-arylation were

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[c] † Electronic Supplementary Information (ESI) available: Experimental procedures, data and NMR spectra of all the final compounds. See DOI: 10.1039/b000000x/

desulfitative coupling of coumarins with arenesulfonyl chloride,[18] dehydrogenative cross-coupling of coumarins with arenes via two-fold C-H activation under Palladium catalyst[19] and recently Kanai and co-workers reported porphyrin-mediated Meerwein arylation of coumarins which suffer from some disadvantages such as synthesis and solubility of organic electron mediators and use of unstable and explosive arylcoupling partners (arenediazonium salts).[13] In recent years, only a few reports are available for metal-catalyzed regioselective α-arylation of N-protected 2-pyridones (i) Suzuki-coupling of 5-halouracil with arylboronic acid by Wnuk group,[20] (ii) iron-catalyzed regioselective direct α-arylation of N-alkyl-2-pyridones with aryl boronic acid using $K_2S_2O_8$ as an oxidant and K_2CO_3 as base at 70°C by Maiti group,[21] and manganese-mediated α-selective direct arylation of N-alkyl-2-pyridone with arylboronic acid under N_2 condition at 90°C by Miura group.[14] Although all the above methodologies have been utilized effectively for α-arylation of coumarins and 2-pyridones, but are limited by the prefunctionalization, use of transition-metals (Cu or Ag was used in equivalents), use of ligands, high temperatures and low yields (Schema 1). Thus, the development of an efficient transition-metal-free methodology towards regioselective α-arylation of coumarins and 2-pyridones is highly desirable.

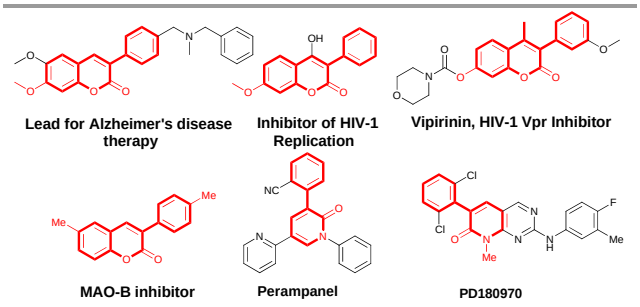
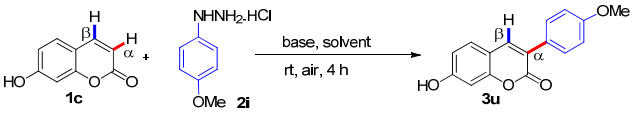


Figure 1 3-arylcoumarin and 3-aryl-2-pyridone based bioactive molecules.

As part of our continuous efforts for the development of efficient C-H arylation and coupling processes for biologically important motifs,[5c,22] we pursued the synthetic challenge to identify a practically viable metal-free regioselective α-arylation of coumarin and 2-pyridone with phenylhydrazines. We initially investigated the α-arylation of 7-hydroxy coumarin **1c** with 4-methoxy phenylhydrazine **2i** in the presence of K_2CO_3 in DMSO (dimethyl sulfoxide) at room temperature under air for 4 hours. To our delight, the reaction yielded only α-arylated product **3u** with 85% yield (Table 1, entry **1**) and no C-4 arylated product was observed.

Encouraged by above promising results in hand, further a set of experiments was performed to optimize the reaction conditions with various bases and oxidants (Table 1). We screened different bases such as Na_2CO_3, Ag_2CO_3, Cs_2CO_3, NaOEt and K^{t}OBt (Table 1, entries **2-6**) and none of them were found to be better than K_2CO_3. The efficiency of other oxidants such as (diacetoxyiodo)benzene (PIDA), *tert*-butyl hydroperoxide (TBHP), $K_2S_2O_8$, di-tert-butyl peroxide (DTBP) and molecular iodine were checked, however, none of them were found to give better yield than K_2CO_3/air system (Table 1, entries **7-11** versus entry **1**). In the absence of K_2CO_3 no product was observed (Table 1, entry **12**), which clearly indicated that the base is essential for this reaction. Different solvents other than DMSO were also screened such as DMF (dimethylformamide), DMA (dimethylacetamide), NMP (N-methylpyrrolidone) and MeOH (methanol) but all of them produced lower yield of product **3u** (Table 1, entries **1** and **13-16**). To check the essentiality of air as an oxidant in this transformation, we performed the reaction with degassed DMSO under N_2 atmosphere. The yield of product **3u** decreased to 24%, which clearly indicated that oxygen is crucial for the reaction (Table 1, entry **17**). In the presence of O_2 (ballon) similar yield of product **3u** was observed (Table 1, entry **18**).

Table 1 Optimization of the reaction conditions[a]



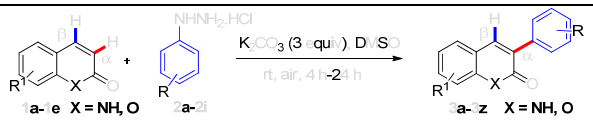
Entry	Base (3 equiv)	Solvent	Yield[b] (%)
1	**K_2CO_3**	**DMSO**	**85**
2	Na_2CO_3	DMSO	30
3	Ag_2CO_3	DMSO	35
4	Cs_2CO_3	DMSO	60
5	NaOEt	DMSO	55
6	K^{t}OBt	DMSO	30
7	PIDA	DMSO	35
8	TBHP	DMSO	20[c]
9	$K_2S_2O_8$	DMSO	30
10	DTBP	DMSO	-
11	I_2	DMSO	-
12	-	DMSO	-
13	K_2CO_3	DMF	35
14	K_2CO_3	DMA	30
15	K_2CO_3	NMP	20
16	K_2CO_3	MeOH	43
17	K_2CO_3	DMSO	24[d]
18	K_2CO_3	DMSO	84[e]

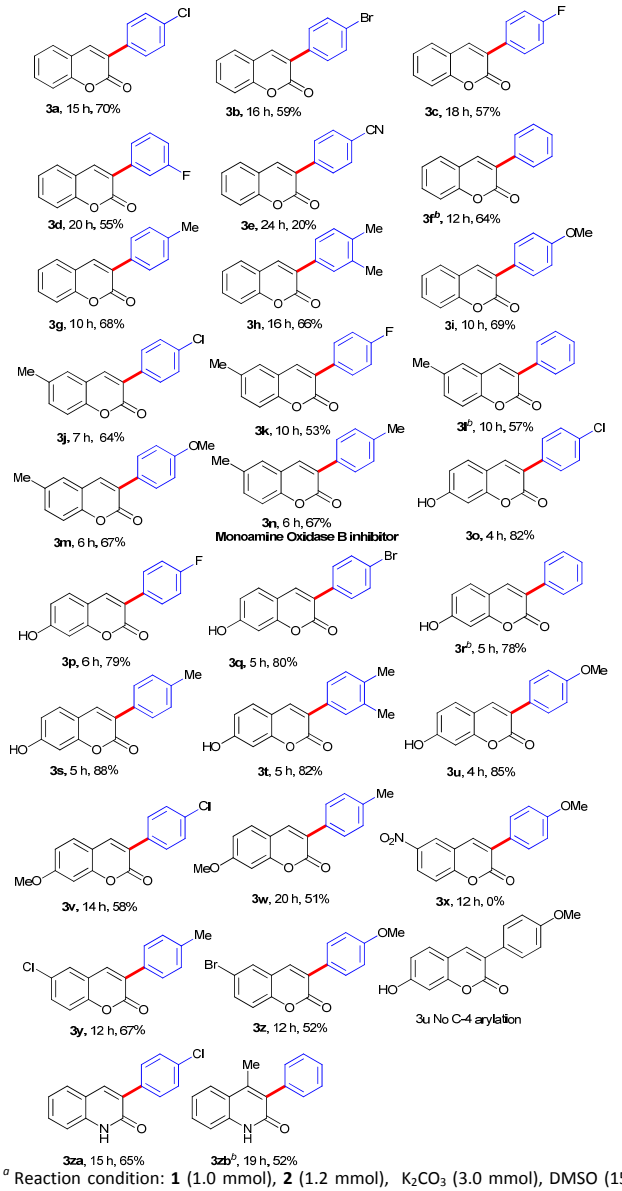
[a] Reaction condition: **1c** (1.0 mmol), **2h** (1.2 mmol), K_2CO_3 (3.0 mmol), DMSO (15 mL) at rt. [b] Isolated yield. [c] 70% aq. TBHP was used. [d] Under nitrogen atmosphere. [e] Under O_2 atmosphere.

After optimization results in hand, we turned our attention towards the scope of the substrate in metal-free regioselective α-arylation of coumarins with various phenylhydrazines. The phenylhydrazines having electron-withdrawing groups such as 4-F, 4-Cl, 4-Br, 3F (Table 2, product **3a**-**3d**) and electron-donating groups such as 4-Me, 3,4-diMe, 4-OMe (Table 2, product **3g**-**3i**) respectively on the aromatic ring, afforded the α-arylated products in good to excellent yields. However, 4-cyano substituted phenylhydrazine produced the α-arylated product in 20% yield (Table 2, product **3e**). Electron donating groups (such as OMe, Me) at C-4 of phenylhydrazine reduce the reaction time (Table 2, products 3g & 3i), however 4-CN function in the phenylhydrazine afforded only 20% yield in 24 h (Table 2, product 3e) and further no product was observed in

the case of 4-nitrophenylhydrazine even after prolonged reaction time.

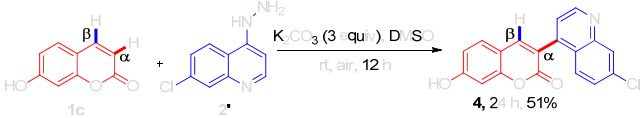
Table 2 Scope of regioselective α-arylation of coumarin and aza-coumarin[a]





[a] Reaction condition: **1** (1.0 mmol), **2** (1.2 mmol), K_2CO_3 (3.0 mmol), DMSO (15 mL) at rt. Isolated yields are given . [b] Phenylhydrazine was used as free base.

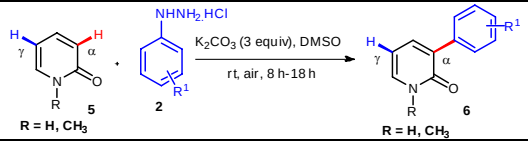
Further, the scope of the methodology was investigated with respect to coumarins. The coumarin moiety bearing electron-donating groups such as methyl, methoxy and hydroxyl at the C-6 or C-7 position afforded their corresponding α-arylated products in moderate to good yields (Table 2, products **3j-3w**), however the reaction time in case of hydroxyl substituted coumarins at C-7 was considerably less (4-6 h) (Table 2, products 3o-3u) as compared to C-7 methoxy (14-20 h) (Table 2, products 3v & 3w) and C-6 methyl (6-10 h) (Table 2, products (Table 2, products 3j-3n) substituted coumarins. Notably, the nitro group at 6-position of coumarin did not furnish the α-arylated product (Table 2, product **3x**). The C-6 halogen (Cl and Br) containing coumarins with C-4 electron-donating (methyl and methoxy) phenylhydrazines afforded α-arylated product 67% and 52% respectively (Table 2, product **3y** and **3z**), however the substrates possessing electron withdrawing groups (Cl and Br) both on C-6 of coumarins and C-4 of arylhydrazines, drastically affect the reaction outcome where no product was observed. To check the feasibility of regioselective arylation on aza-coumarins, we tested the reaction of unprotected 2-hydroxyqyinolines with phenylhydrazines under optimized condition. Pleasingly, the reaction proceeded smoothly without N-protection and afforded regioselectively α-arylated products in moderate yields (Table 2, products **3za** and **3zb**).

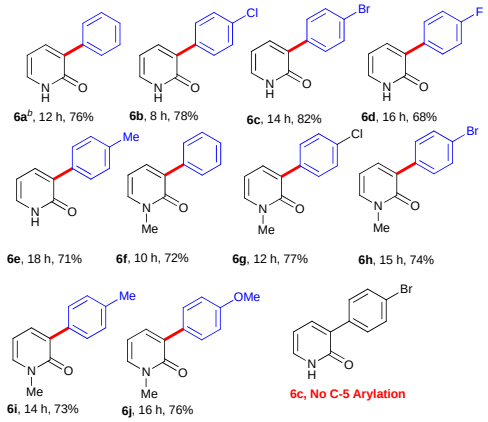


Scheme 2 Synthesis of 3-(7-chloroquinolin-4-yl)-7-hydroxy-2H-chromen-2-one.

Subsequently, the compatibility of present methodology was further tested with heteroaromatic hydrazine, since the heteroaromatic substitutions on bioactive molecules impart desirable pharmacological and pharmacokinetic properties. To achieve the unique substitution at α-position, we attempted the reaction of 4-hydrazinoquinoline with 7-hydroxycoumarin under the optimized condition. To our delight, the reaction afforded the compound **4** α-(7-chloroquinolin-4-yl)-7-hydroxy-2H-chromen-2-one, a unique hybrid of quinoline and coumarin in 51% yield (Scheme 2).

Table 3 Scope of regioselective α-arylation of 2-pyridone[a]

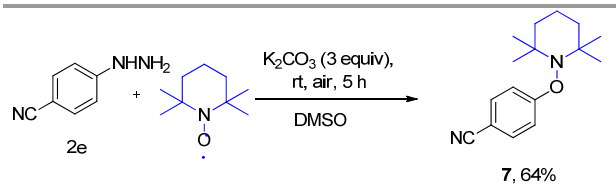




[a] Reaction condition: **5** (1.0 mmol), **2** (1.2 mmol), K_2CO_3 (3.0 mmol), DMSO (15 mL) at rt. Isolated yields are given .[b] Phenylhydrazine was used as free base.

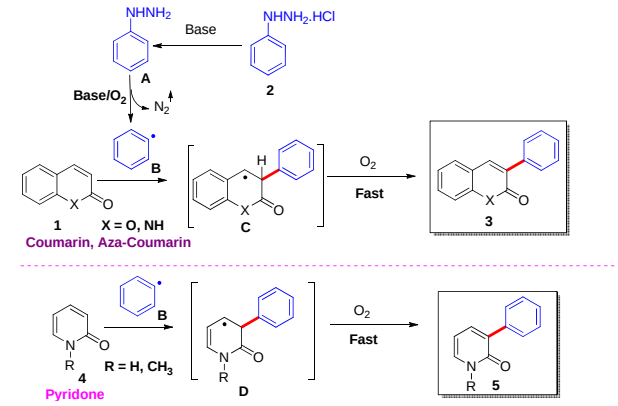
Successful installation of α-arylation in aza-coumarins inspired us to expand the applicability of the method towards metal-free regioselective arylation of the 2-pyridone moiety. To the best of our knowledge, this is the first metal-free report for α-C-H arylation of 2-pyridone. Gratifyingly the reaction of 2-pyridones with phenylhydrazines afforded exclusively α-arylated products in good to excellent yields (Table 3, product **6a-6j**). It was noteworthy that the reaction proceeded with or without N-H protection of 2-pyridones at room temperature and also compatible with both electron withdrawing and electron donating substitutions on phenylhydrazine.

To gain insight into the mechanism, we performed control experiment for radical trapping. The reaction of 2,2,6,6-tetramethylpiperidine-1-oxyl (TEMPO) with 4-cyano phenylhydrazine **2e** afforded adduct 4-((2,2,6,6-tetramethylpiperidin-1-yl)oxy)benzonitrile **7** in 64% yield **(**Scheme 3**).**



Scheme 3 Radical trapping experiment with TEMPO.

Based on our experiment, previous literature reports[14,20,23-27] and our previous work,[5c] a possible mechanism has been proposed in Scheme 3. Initially, the treatment of phenylhydrazine hydrochloride with base afforded Phenylhydrazine [**A**], which further undergoes oxidation in the presence of Base/O_2 to form aryl radical [**B**][24,27] by removal of N_2 and then aryl radical addition to coumarin/aza-coumarin (**1**) and 2-pyridone (**4**) afforded benzylic radical[13] intermediates [**C**] and allylic radical[14] intermediate [**D**] respectively, which were stabilized by resonance. Upon further oxidation,[26] intermediates [**C**] and [**D**] leads to α-arylated product of coumarin, aza-coumarin (**3**) and pyridone (**5**) (Scheme 4).



Scheme 4 Plausible mechanism.

Conclusions

In conclusion, we have achieved a transition-metal-free regioselective α-arylation of coumarins, 2-pyridones and aza-coumarin via base/air-promoted denitrogenative coupling of phenylhydrazines in moderate to good yields. High functional group tolerability with excellent regioselectivity and room temperature reaction condition are salient features of the present strategy.

Experimental

General Information

All glass apparatus were oven dried prior to use. ^{1}H NMR and ^{13}C NMR spectra were recorded on Bruker Avance-400 using $CDCl_3$ and DMSO-d_6 as solvent and tetramethylsilane as internal reference. Splitting patterns are described as singlet (s), doublet (d), triplet (t), multiplet (m) and broad (br). IR spectra were recorded on a FT-IR spectrophotometer and melting points were determined on melting point apparatus and are uncorrected. Electrospray ionization mass spectrometry (ESI-MS) was obtained on Thermo LCQ Advantage Max Spectrometer and HRMS was recorded on Agilent 6520 Q-TOF. Reactions were monitored on silica gel TLC plates (coated with TLC grade silica gel, obtained from Merck). Detecting agents used (for TLC) were: iodine vapors and/or spraying with an aq. solution of vanillin in 10% sulfuric acid followed by heating at 100°C. Column chromatography was performed over silica gel (230-400 Mesh) by using Smart flash EPCLC AI-700X YAMAZEN with minimal amount of solvent. All chemicals and reagents were obtained from Aldrich , Lancaster, Alfa Aesar and were used without further purification.

General Experimental Procedures

Representative procedure for the synthesis of product 3a

A solution of coumarin **1a** (146 mg, 1.0 mmol), phenylhydrazine **2a** (215 mg, 1.2 mmol) and potassium carbonate (408 mg, 3.0 mmol) in dimethyl sulphoxide (15 mL) was stirred at room temperature for 15 hours. Next, the reaction was diluted with water (80 mL) and the aqueous layer was extracted with ethyl acetate (3×20 mL). The organic layer was further dried over sodium sulphate (anhydrous) and concentrated under reduced pressure to give crude product, which upon purification by column chromatography over silica gel (gradient elution with Hexane: ethyl acetate, 9:1 to 7:3) afforded the desired product 179 mg (70%) of **3a** as white solid. The remaining reactions were carried out following this procedure for products **3b-3zb.**

Representative procedure for the synthesis of product 6b

A solution of 2-pyridone **5a** (95 mg, 1.0 mmol), phenylhydrazine **2b** (215 mg, 1.2 mmol) and potassium carbonate (408 mg, 3.0 mmol) in dimethyl sulphoxide (15 mL)

was stirred at room temperature for 8 hours. Next, the reaction was diluted with water (80 mL) and the aqueous layer was extracted with ethyl acetate (3×20 mL). The organic layer was further dried over sodium sulphate (anhydrous) and concentrated under reduced pressure to give crude product, which was further purified by column chromatography over silica gel to afford the desired product 160 mg (78%) of **6b** as white solid. The remaining reactions were carried out following this procedure for products **6a and 6c—6j.**

Representative for the synthesis of product 7

A solution of phenylhydrazine **2e** (169 mg, 1.0 mmol), 4-((2,2,6,6-tetramethylpiperidin-1-yl)oxy)benzonitrile (234 mg, 1.5 mmol) and potassium carbonate (408 mg, 3.0 mmol) in dimethyl sulphoxide (20 mL) was stirred at room temperature for 5 hours. Next, the reaction was diluted with water (100 mL) and the aqueous layer was extracted with ethyl acetate (3×20 mL). The organic layer was further dried over sodium sulphate (anhydrous) and concentrated under reduced pressure to give crude product, which was further purified by column chromatography over silica gel to afford the desired product 165 mg (64%) of **7** as white solid.

Compound Characterization Data

3-(4-chlorophenyl)-2H-chromen-2-one (3a).[28]
Yield 70% as white solid: mp 180-182°C; FT-IR (KBr, cm^{-1}) 3019, 1618, 1210, 1076; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29-7.33 (m, 1H), 7.36-7.39 (m, 1H), 7.41-7.44 (m, 2H), 7.53-7.57 (m, 2H), 7.66-7.68 (m, 2H), 7.82 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 116.54 (CH), 119.51 (C), 124.63 (CH), 127.20 (C), 127.98 (CH), 128.71 (2×CH), 129.85 (2×CH), 131.68 (CH), 133.10 (C), 134.96 (C), 139.91 (CH), 153.58 (C), 160.34 (C); ESI-MS (m/z) 257 $(M+H)^+$; HRMS (ESI) calculated for $C_{15}H_{10}ClO_2$ $(M+H)^+$ 257.0369, found 257.0367.

3-(4-bromophenyl)-2H-chromen-2-one (3b).[28]
Yield 59% as light yellow solid: mp 190-192°C; FT-IR (KBr, cm^{-1}) 3019, 1610, 1215, 1069; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29-7.33 (m, 1H), 7.36-7.39 (m, 1H), 7.53-7.62 (m, 6H), 7.82 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 116.55 (CH), 119.50 (C), 123.21 (C), 124.65 (CH), 127.23 (C), 127.99 (CH), 130.12 (2×CH), 131.67 (2×CH), 131.72 (CH), 133.57 (C), 139.93 (CH), 153.58 (C), 160.27 (C); ESI-MS (m/z) 301 $(M+H)^+$; HRMS (ESI) calculated for $C_{15}H_{10}BrO_2$ $(M+H)^+$ 300.9864 found 300.9862.

3-(4-fluorophenyl)-2H-chromen-2-one (3c).[28]
Yield 57% as white solid: mp 158-160°C; FT-IR (KBr, cm^{-1}) 3021, 1609, 1215, 1113; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.11-7.17 (m, 2H) 7.29-7.33 (m, 1H), 7.37-7.39 (m, 1H), 7.52-7.56 (m, 2H), 7.69-7.72 (m, 2H), 7.79 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 115.60 (d, J = 21.47 Hz, 2×CH), 116.49 (CH), 119.58 (C), 124.59 (CH), 127.32 (C), 127.91 (CH), 130.47 (d, J = 8.15 Hz, 2×CH), 130.71 (C), 131.52 (CH), 139.69 (CH), 153.51 (C), 160.55 (C), 164.33 (d, J = 247.39 Hz, C-F); ESI-MS (m/z) 241 $(M+H)^+$; HRMS (ESI) calculated for $C_{15}H_{10}FO_2$ $(M+H)^+$ 241.0665 found 241.0668.

3-(3-fluorophenyl)-2H-chromen-2-one (3d).[29]
Yield 55% as white solid: mp 152-154°C; FT-IR (KBr, cm^{-1}) 3019, 1610, 1215, 1069; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.08-7.13 (m, 1H), 7.29-7.33 (m, 1H), 7.37-7.44 (m, 2H), 7.45-7.51 (m, 2H), 7.53-7.57 (m, 2H), 7.84 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 115.81 (d, J = 22.85 Hz, CH), 115.89 (d, J = 21.04 Hz, CH), 116.54 (CH), 119.42 (C), 124.19 (d, J = 2.86 Hz, CH), 124.65 (CH), 127.06 (C), 128.08 (CH), 130.03 (d, J = 8.37 Hz, CH), 131.82 (CH), 136.74 (d, J = 8.28 Hz, C), 140.40 (CH), 153.62 (C), 160.20 (C), 163.90 (d, J = 244.27 Hz, C-F); ESI-MS (m/z) 241 $(M+H)^+$; HRMS (ESI) calculated for $C_{15}H_{10}FO_2$ $(M+H)^+$ 241.0665 found 241.0659.

4-(2-oxo-2H-chromen-3-yl)benzonitrile (3e).[30]
Yield 20% as white solid: mp 152-154°C; FT-IR (KBr, cm^{-1}) 3019, 2230, 1614, 1215, 1068; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.31-7.41 (m, 2H), 7.57-7.62 (m, 2H), 7.72-7.76 (m, 2H), 7.83-7.87 (m, 2H), 7.89 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 112.46 (C), 116.68 (CH), 118.51 (C), 119.19 (C), 124.85 (CH), 126.47 (C), 128.29 (CH), 129.20 (2×CH), 132.22 (2×CH), 132.41 (CH), 139.18 (C), 141.31 (CH), 153.82 (C), 159.87 (C); ESI-MS (m/z) 248 $(M+H)^+$; HRMS (ESI) calculated for $C_{16}H_{10}NO_2$ $(M+H)^+$ 248.0712 found 248.0687.

3-phenyl-2H-chromen-2-one (3f).[28]
Yield 64% as white solid: mp 135-137°C; FT-IR (KBr, cm^{-1}) 3019, 1613, 1215, 1069; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28-7.32 (m, 1H), 7.37-7.48 (m, 4H), 7.51-7.56 (m, 2H), 7.69-7.72 (m, 2H), 7.82 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 116.49 (CH), 119.71 (C), 124.50 (CH), 127.91 (CH), 128.42 (C), 128.49 (2×CH), 128.55 (2×CH), 128.88 (CH), 131.41 (CH), 134.73 (C), 139.86 (CH), 153.56 (C), 160.60 (C); ESI-MS (m/z) 223 $(M+H)^+$; HRMS (ESI) calculated for $C_{15}H_{11}O_2$ $(M+H)^+$ 223.0759 found 223.0763.

3-(p-tolyl)-2H-chromen-2-one (3g).[28]
Yield 68% as white solid: mp 150-152°C; FT-IR (KBr, cm^{-1}) 3019, 1618, 1210, 1076; ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.41 (s, 3H), 7.27-7.32 (m, 3H), 7.37 (d, J = 8.2 Hz, 1H), 7.51-7.55 (m, 2H), 7.62 (d, J = 7.76 Hz, 2H), 7.79 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.30 (CH_3) 116.44 (CH), 119.80 (C), 124.44 (CH), 127.80 (CH), 128.41 (C & 2×CH), 129.19 (2×CH), 131.19 (CH), 131.83 (C), 138.94 (C), 139.19 (CH), 153.46 (C), 160.69 (C); ESI-MS (m/z) 237 $(M+H)^+$; HRMS (ESI) calculated for $C_{16}H_{13}O_2$ $(M+H)^+$ 237.0916 found 237.0897.

3-(3,4-dimethylphenyl)-2H-chromen-2-one (3h).
Yield 66% as light yellow solid: mp 110-112°C; FT-IR (KBr, cm^{-1}) 3019, 1609, 1215, 1069; ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.31 (s, 3H), 2.33 (s, 3H), 7.21 (d, J = 7.80 Hz, 1H), 7.27-7.31 (m, 1H), 7.35-7.37 (m, 1H), 7.43-7.46 (m, 1H), 7.48-7.54 (m, 3H), 7.78 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 19.61 (CH_3), 19.89 (CH_3), 116.42 (CH), 119.83 (C), 124.40 (CH), 125.99 (CH), 127.77 (CH), 128.50 (C), 129.61 (CH), 129.76 (CH), 131.11 (CH), 132.26 (C), 136.69 (C), 137.65 (C), 139.12 (CH), 153.44 (C), 160.72 (C); ESI-MS (m/z) 251 $(M+H)^+$; HRMS (ESI) calculated for $C_{17}H_{15}O_2$ $(M+H)^+$ 251.1072 found 251.1069.

3-(4-methoxyphenyl)-2H-chromen-2-one (3i).[28]
Yield 69% as white solid: mp 140-142°C; FT-IR (KBr, cm^{-1}) 3019, 1610, 1215, 1026; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.86 (s, 3H), 6.97-6.99 (m, 2H), 7.27-7.31 (m, 1H), 7.35-7.37 (m, 1H), 7.49-7.54 (m, 2H), 7.66-7.69 (m, 2H), 7.76 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 55.38 (CH_3), 113.94 (2×CH), 116.40 (CH), 119.87

(C), 124.43 (CH), 127.10 (C), 127.70 (CH), 127.91 (C), 129.85 (2×CH), 131.01 (CH), 138.48 (CH), 153.33 (C), 160.19 (C), 160.80 (C); ESI-MS (m/z) 253 $(M+H)^+$; HRMS (ESI) calculated for $C_{16}H_{13}O_3$ $(M+H)^+$ 253.0865 found 253.0855.

3-(4-chlorophenyl)-6-methyl-2H-chromen-2-one (3j).

Yield 64% as white solid: mp 158-160°C; FT-IR (KBr, cm^{-1}) 3021, 1612, 1215, 1026; ^1H NMR (400 MHz, $CDCl_3$) δ 2.43 (s, 3H), 7.25-7.27 (m, 1H), 7.33-7.36 (m, 2H), 7.39-7.43 (m, 2H), 7.64-7.67 (m, 2H), 7.75 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 20.80 (CH_3), 116.25 (CH), 119.25 (C), 127.03 (C), 127.75 (CH), 128.68 (2×CH), 129.85 (2×CH), 132.75 (CH), 133.27 (C), 134.33 (C), 134.85 (C), 139.95 (CH), 151.73 (C), 160.57 (C); ESI-MS (m/z) 271 $(M+H)^+$; HRMS (ESI) calculated for $C_{16}H_{12}ClO_2$ $(M+H)^+$ 271.0526 found 271.0518.

3-(4-fluorophenyl)-6-methyl-2H-chromen-2-one (3k).

Yield 53% as white solid: mp 158-160°C; FT-IR (KBr, cm^{-1}) 3019, 1603, 1215, 1084; ^1H NMR (400 MHz, $CDCl_3$) δ 2.42 (s, 3H), 7.11-7.15 (m, 2H), 7.25-7.27 (m, 1H), 7.32-7.35 (m, 2H), 7.67-7.71 (m, 2H), 7.73 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 20.80 (CH_3), 115.57 (d, J = 21.49 Hz, 2×CH), 116.22 (CH), 119.32 (C), 127.19 (C), 127.67 (CH), 130.45 (d, J = 8.17 Hz, 2×CH), 130.87 (C), 132.57 (CH), 134.28 (C), 139.70 (CH), 151.67 (C), 160.76 (C), 164.29 (d, J = 247.4 Hz, C-F); ESI-MS (m/z) 255 $(M+H)^+$; HRMS (ESI) calculated for $C_{16}H_{12}FO_2$ $(M+H)^+$ 255.0821 found 255.0823.

6-methyl-3-phenyl-2H-chromen-2-one (3l).[28]

Yield 57% as light brown solid: mp 140-142°C; FT-IR (KBr, cm^{-1}) 3019, 1613, 1215, 1070; ^1H NMR (400 MHz, $CDCl_3$) δ 2.43 (s, 3H), 7.28 (s, 1H), 7.33-7.35 (m, 2H), 7.38-7.47 (m, 3H), 7.68-7.71 (m, 2H), 7.76 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 20.80 (CH_3), 116.20 (CH), 119.45 (C), 127.69 (CH), 128.26 (C), 128.47 (2×CH), 128.55 (2×CH), 128.78 (CH), 132.46 (CH), 134.17 (C), 134.90 (C), 139.89 (CH), 151.71 (C), 160.82 (C); ESI-MS (m/z) 237 $(M+H)^+$; HRMS (ESI) calculated for $C_{16}H_{13}O_2$ $(M+H)^+$ 237.0916 found 237.0900.

3-(4-methoxyphenyl)-6-methyl-2H-chromen-2-one (3m).[19]

Yield 67% as white solid: mp 134-136°C; FT-IR (KBr, cm^{-1}) 3019, 1611, 1215, 1069; ^1H NMR (400 MHz, $CDCl_3$) δ 2.38 (s, 3H), 3.82 (s, 3H), 6.92-6.96 (m, 2H), 7.20-7.23 (m, 1H), 7.27-7.28 (m, 2H), 7.62-7.65 (m, 2H), 7.67 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 20.80 (CH_3), 55.38 (CH_3), 113.92 (2×CH), 116.11 (CH), 119.60 (C), 127.26 (C), 127.50 (CH), 127.76 (C), 129.83 (2×CH), 132.07 (CH), 134.08 (C), 138.53 (CH), 151.48 (C), 160.12 (C), 161.03 (C); ESI-MS (m/z) 267 $(M+H)^+$; HRMS (ESI) calculated for $C_{17}H_{15}O_3$ $(M+H)^+$ 267.1021 found 267.1012.

6-methyl-3-(p-tolyl)-2H-chromen-2-one (3n).[7b]

Yield 67% as light yellow solid: mp 138-140°C; FT-IR (KBr, cm^{-1}) 3019, 1621, 1215, 1112; ^1H NMR (400 MHz, $CDCl_3$) δ 2.39 (s, 3H), 2.41 (s, 3H), 7.23-7.25 (m, 3H), 7.30-7.32 (m, 2H), 7.59 (d, J = 8.16 Hz, 2H), 7.72 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 20.79 (CH_3), 21.29 (CH_3), 116.14 (CH), 119.53 (C), 127.60 (CH), 128.19 (C), 128.41 (2×CH), 129.16 (2×CH), 131.99 (C), 132.24 (CH), 134.09 (C), 138.82 (C), 139.22 (CH), 151.61 (C), 160.90 (C); ESI-MS (m/z) 251 $(M+H)^+$; HRMS (ESI) calculated for $C_{17}H_{15}O_2$ $(M+H)^+$ 251.1072 found 251.1073.

3-(4-chlorophenyl)-7-hydroxy-2H-chromen-2-one (3o).[31]

Yield 82% as light yellow solid: mp 252-254°C; FT-IR (KBr, cm^{-1}) 3401, 3019, 1602, 1215, 1069; ^1H NMR (400 MHz, DMSO-d_6) δ 6.75 (d, J = 2.16 Hz , 1H), 6.82-6.84 (dd, J = 8.48, 2.24 Hz, 1H), 7.49-7.51 (m, 2H), 7.60 (d, J = 8.56 Hz, 1H), 7.72-7.75 (m, 2H), 8.19 (s, 1H), 10.65 (s, 1H); ^{13}C NMR (DMSO-d_6) δ 102.21 (CH), 112.35 (C), 113.96 (CH), 121.29 (C), 128.63 (2×CH), 130.46 (2×CH), 130.58 (CH), 133.13 (C), 134.39 (C), 141.85 (CH), 155.47 (C), 160.38 (C), 161.93 (C); ESI-MS (m/z) 273 $(M+H)^+$; HRMS (ESI) calculated for $C_{15}H_{10}ClO_3$ $(M+H)^+$ 273.0318, found 273.0291.

3-(4-fluorophenyl)-7-hydroxy-2H-chromen-2-one (3p).[32]

Yield 79% as light yellow solid: mp 245-247°C; FT-IR (KBr, cm^{-1}) 3394, 3019, 1608, 1215, 1024; ^1H NMR (400 MHz, DMSO-d_6) δ 6.75 (d, J = 2.24 Hz , 1H), 6.81-6.84 (dd, J = 8.52, 2.28 Hz, 1H), 7.25-7.29 (m, 2H), 7.59 (d, J = 8.56 Hz , 1H), 7.72-7.76 (m, 2H), 8.15 (s, 1H), 10.60 (s, 1H); ^{13}C NMR (DMSO-d_6) δ 102.19 (CH), 112.39 (C), 113.90 (CH), 115.60 (d, J = 21.31 Hz, 2×CH), 121.63 (C), 130.45 (CH), 130.89 (d, J = 8.1 Hz, 2×CH), 131.92 (C), 141.54 (CH), 155.38 (C), 160.56 (C), 161.75 (C), 163.55 (d, J = 243.92 Hz, C-F); ESI-MS (m/z) 257 $(M+H)^+$; HRMS (ESI) calculated for $C_{15}H_{10}FO_3$ $(M+H)^+$ 257.0614 found 257.0593.

3-(4-bromophenyl)-7-hydroxy-2H-chromen-2-one (3q).[33]

Yield 80% as light yellow solid: mp 228-230°C; FT-IR (KBr, cm^{-1}) 3410, 3019, 1602, 1215, 1084; ^1H NMR (400 MHz, DMSO-d_6) δ 6.75 (d, J = 2.16 Hz , 1H), 6.81-6.84 (dd, J = 8.48, 2.24 Hz, 1H), 7.59-7.68 (m, 5H), 8.20 (s, 1H), 10.65 (s, 1H); ^{13}C NMR (DMSO-d_6) δ 102.22 (CH), 112.37 (C), 113.98 (CH), 121.35 (C), 121.75 (C), 130.60 (CH), 130.76 (2×CH), 131.57 (2×CH), 134.77 (C), 141.86 (CH), 155.48 (C), 160.33 (C), 161.95 (C); ESI-MS (m/z) 317 $(M+H)^+$; HRMS (ESI) calculated for $C_{15}H_{10}BrO_3$ $(M+H)^+$ 316.9813 found 316.9806.

7-hydroxy-3-phenyl-2H-chromen-2-one (3r).[19]

Yield 78% as light yellow solid: mp 180-182°C; FT-IR (KBr, cm^{-1}) 3400, 3019, 1611, 1215, 1069; ^1H NMR (400 MHz, DMSO-d_6) δ 6.76 (d, J = 2.12 Hz, 1H), 6.81-6.84 (dd, J = 8.48, 2.28 Hz, 1H), 7.36-7.46 (m, 3H), 7.60 (d, J = 8.52 Hz, 1H), 7.68-7.70 (m, 2H), 8.15 (s, 1H), 10.59 (s, 1H); ^{13}C NMR (DMSO-d_6) δ 102.19 (CH), 112.47 (C), 113.86 (CH), 122.66 (C), 128.47 (CH), 128.63 (2×CH), 128.73 (2×CH), 130.46 (CH), 135.58 (C), 141.58 (CH), 155.40 (C), 160.54 (C), 161.72 (C); ESI-MS (m/z) 239 $(M+H)^+$; HRMS (ESI) calculated for $C_{15}H_{11}O_3$ $(M+H)^+$ 239.0708 found 239.0738.

7-hydroxy-3-(p-tolyl)-2H-chromen-2-one (3s).[34]

Yield 88% as light yellow solid: mp 242-244°C; FT-IR (KBr, cm^{-1}) 3400, 3019, 1602, 1215, 1084; ^1H NMR (400 MHz, DMSO-d_6) δ 2.34 (s, 3H), 6.74 (d, J = 2.24 Hz , 1H), 6.80-6.83 (dd, J = 8.48, 2.28 Hz , 1H), 7.24 (d, J = 7.96 Hz , 2H), 7.58-7.60 (dd, J = 8.52, 2.08 Hz, 3H), 8.11 (s, 1H), 10.56 (s, 1H); ^{13}C NMR (DMSO-d_6) δ 21.26 (CH_3) 102.16 (CH), 112.51 (C), 113.81 (CH), 122.57 (C), 128.56 (2×CH), 129.21 (2×CH), 130.33 (CH), 132.65 (C), 137.90 (C), 140.91 (CH), 155.27 (C), 160.58 (C), 161.56 (C); ESI-MS (m/z) 253 $(M+H)^+$; HRMS (ESI) calculated for $C_{16}H_{13}O_3$ $(M+H)^+$ 253.0865 found 253.0846.

3-(3,4-dimethylphenyl)-7-hydroxy-2H-chromen-2-one (3t).

Yield 82% as light brown solid: mp 210-212°C; FT-IR (KBr, cm^{-1}) 3399, 3019, 1602, 1215, 1084; ^1H NMR (400 MHz, DMSO-d_6) δ 2.25 (s, 3H), 2.26 (s, 3H), 6.74 (d, J = 2.12 Hz, 1H), 6.79-6.82

(dd, *J* = 8.48, 2.24 Hz , 1H), 7.18 (d, *J* = 7.88 Hz, 1H), 7.41-7.47 (m, 2H), 7.59 (d, *J* = 8.52 Hz, 1H), 8.09 (s, 1H), 10.56 (s, 1H); ^{13}C NMR (DMSO-d_6) δ 19.61 (CH_3), 19.93 (CH_3) 102.15 (CH), 112.53 (C), 113.79 (CH), 122.69 (C), 126.12 (CH), 129.62 (CH), 129.71 (CH), 130.28 (CH), 133.00 (C), 136.34 (C), 136.66 (C), 140.80 (CH), 155.24 (C), 160.57 (C), 161.50 (C); ESI-MS (m/z) 267 $(M+H)^+$; HRMS (ESI) calculated for $C_{17}H_{15}O_3$ $(M+H)^+$ 267.1021 found 267.1018.

7-hydroxy-3-(4-methoxyphenyl)-2H-chromen-2-one (3u).[35]

Yield 85% as light brown solid: mp 220-222°C; FT-IR (KBr, cm^{-1}) 3408, 3019, 1611, 1215, 1069; ^{1}H NMR (400 MHz, DMSO-d_6) *δ* 3.79 (s, 3H), 6.74 (d, *J* = 2.16 Hz, 1H), 6.79-6.82 (dd, *J* = 8.48, 2.28 Hz, 1H), 6.98-7.01 (m, 2H), 7.59 (d, *J* = 8.56 Hz, 1H), 7.63-7.67 (m, 2H), 8.08 (s, 1H), 10.53 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) *δ* 55.65 (CH_3) 102.15 (CH), 112.58 (C), 113.77 (CH), 114.08 (2×CH), 122.32 (C), 127.78 (C), 129.96 (2×CH), 130.17 (CH), 140.19 (CH), 155.12 (C), 159.62 (C), 160.68 (C), 161.37 (C); ESI-MS (m/z) 269 $(M+H)^+$; HRMS (ESI) calculated for $C_{16}H_{13}O_4$ $(M+H)^+$ 269.0814 found 269.0773.

3-(4-chlorophenyl)-7-methoxy-2H-chromen-2-one (3v).[33]

Yield 58% as white solid: mp 158-160°C; FT-IR (KBr, cm^{-1}) 3020, 1613, 1215, 1076; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 3.89 (s, 3H), 6.86-6.89 (m, 2H), 7.39-7.45 (m, 3H), 7.63-7.66 (m, 2H), 7.76 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 55.84 (CH_3), 100.47 (CH), 112.97 (CH), 113.18 (C), 123.58 (C), 128.63 (2×CH), 128.94 (CH), 129.69 (2×CH), 133.44 (C), 134.45 (C), 140.08 (CH), 155.41 (C), 160.66 (C), 162.87 (C); ESI-MS (m/z) 287 $(M+H)^+$; HRMS (ESI) calculated for $C_{16}H_{12}ClO_3$ $(M+H)^+$ 287.0475 found 287.0473.

7-methoxy-3-(p-tolyl)-2H-chromen-2-one (3w).[19]

Yield 51% as white solid: mp 105-107°C; FT-IR (KBr, cm^{-1}) 3019, 1618, 1215, 1069; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 2.42 (s, 3H), 3.91 (s, 3H), 6.88-6.90 (m, 2H), 7.26-7.28 (m, 2H), 7.43-7.46 (m, 1H), 7.60-7.62 (m, 2H), 7.76 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 21.26 (CH_3), 55.79 (CH_3), 100.43 (CH), 112.73 (CH), 113.46 (C), 124.86 (C), 128.27 (2×CH), 128.73 (CH), 129.13 (2×CH), 132.14 (C), 138.44 (C), 139.39 (CH), 155.23 (C), 161.00 (C), 162.49 (C); ESI-MS (m/z) 267 $(M+H)^+$; HRMS (ESI) calculated for $C_{17}H_{15}O_3$ $(M + H)^+$ 267.1021 found 267.1010.

6-chloro-3-(p-tolyl)-2H-chromen-2-one (3y).[36]

Yield 67% as white solid: mp 176-178°C; FT-IR (KBr, cm^{-1}) 3019, 1621, 1230, 1071; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 2.43 (s, 3H), 7.28-7.34 (m, 3H), 7.47-7.49 (dd, *J* = 8.76, 2.4 Hz, 1H), 7.54 (d, *J* = 2.36 Hz, 1H), 7.62 (d, *J* = 8.12 Hz, 1H), 7.72 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 21.32 (CH_3), 117.85 (CH), 120.83 (C), 126.97 (CH), 128.42 (2×CH), 129.27 (2×CH), 129.50 (C), 129.67 (C), 131.06 (CH), 131.35 (C), 137.72 (CH), 139.38. (C), 151.78 (C), 160.09 (C); ESI-MS (m/z) 271 $(M+H)^+$; HRMS (ESI) calculated for $C_{16}H_{12}ClO_3$ $(M + H)^+$ 271.0526 found 271.0522.

6-bromo-3-(4-methoxyphenyl)-2H-chromen-2-one (3z).[37]

Yield 52% as white solid: mp 197-199°C; FT-IR (KBr, cm^{-1}) 3019, 1615, 1228, 1067; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 3.89 (s, 3H), 7.01 (d, *J* = 8.80 Hz, 2H), 7.28-7.29 (brd, 1H), 7.59-7.62 (dd, *J* = 8.71, 2.12 Hz, 1H), 7.68-7.70 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 55.41 (CH_3), 114.03 (2×CH), 116.98 (C), 118.12 (CH), 121.43 (C), 126.57 (C), 129.04 (C), 129.91 (C & 2×CH), 133.69 (CH), 136.83 (C), 152.11 (C), 160.47 (C); ESI-MS (m/z) 331 $(M+H)^+$; HRMS (ESI) calculated for $C_{16}H_{12}BrO_3$ $(M + H)^+$ 330.9970 found 330.9971.

3-(4-chlorophenyl)quinolin-2(1H)-one (3za).[38]

Yield 65% as white solid: mp 252-254°C; FT-IR (KBr, cm^{-1}) 3410, 3019, 1656; ^{1}H NMR (400 MHz, DMSO-d_6) *δ* 7.18-7.22 (m, 1H), 7.34 (d, *J* = 8.2 Hz, 1H), 7.48-7.53 (m, 3H), 7.73 (d, *J* = 7.16 Hz, 1H), 7.80-7.83 (m, 2H), 8.16 (s, 1H), 11.99 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) *δ* 115.20 (CH), 119.91 (C), 122.45 (CH), 128.40 (2×CH), 128.69 (CH), 130.54 (C), 130.90 (3×CH), 132.97 (C), 135.50 (C), 138.36 (CH), 138.91 (C), 161.33 (C); ESI-MS (m/z) 236 $(M+H)^+$; HRMS (ESI) calculated for $C_{15}H_{11}ClNO$ $(M+H)^+$ 256.0529 found 256.0525.

4-methyl-3-phenylquinolin-2(1H)-one (3zb).[39]

Yield 52% as white solid: mp 240-242°C; FT-IR (KBr, cm^{-1}) 3408, 3019, 1646; ^{1}H NMR (400 MHz, DMSO-d_6) *δ* 2.25 (s, 3H), 7.19-7.25 (m, 3H), 7.33-7.38 (m, 2H), 7.41-7.45 (m, 2H), 7.49-7.53 (m, 1H), 7.77-7.79 (dd, *J* = 8.12, 0.96 Hz, 1H), 11.78 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) *δ* 17.02 (CH_3), 115.60 (CH), 120.36 (C), 122.25 (CH), 125.70 (CH), 127.62 (CH), 128.29 (2×CH), 130.45 (CH), 130.74 (2×CH), 132.46 (C), 136.76 (C), 138.27 (C), 143.71 (C), 161.47 (C); ESI-MS (m/z) 236 $(M+H)^+$; HRMS (ESI) calculated for $C_{16}H_{14}NO$ $(M+H)^+$ 236.1075 found 236.1068.

3-(7-chloroquinolin-4-yl)-7-hydroxy-2H-chromen-2-one (4).

Yield 51% as light yellow solid: mp 225-230°C; FT-IR (KBr, cm^{-1}) 3409, 3019, 1644, 1215, 1069; ^{1}H NMR (400 MHz, DMSO-d_6) *δ* 6.85-6.98 (m, 2H), 7.61-7.66 (m, 3H), 7.97 (d, *J* = 9.12 Hz , 1H), 8.17 (d, *J* = 14.68 Hz, 2H), 9.01 (d, *J* = 3.84 Hz, 1H), 10.80 (brd, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) *δ* 102.53 (CH), 111.97 (C), 114.06 (CH), 120.02 (C), 123.26 (CH), 125.47 (C), 127.76 (CH), 128.36 (CH), 128.64 (CH), 130.85 (CH), 134.60 (C), 142.71 (C), 145.11 (CH), 148.74 (C), 152.01 (CH), 156.23 (C), 160.18 (C), 162.45 (C); ESI-MS (m/z) 324 $(M+H)^+$; HRMS (ESI) calculated for $C_{18}H_{11}ClNO_3$ $(M+H)^+$ 324.0427 found 324.0429.

3-phenylpyridin-2(*1H*)-one (6a).

Yield 76% as white solid: mp 197-199°C; FT-IR (KBr, cm^{-1}) 3402, 3019, 1641; ^{1}H NMR (400 MHz, DMSO-d_6) *δ* 6.29 (t, *J* = 6.68 Hz, 1H), 7.28-7.31 (m, 1H), 7.36-7.39 (m, 3H), 7.62-7.64 (dd, *J* = 6.88, 2.0 Hz, 1H), 7.69-7.72 (m, 2H), 11.77 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) *δ* 105.85 (CH), 127.66 (CH), 128.32 (2×CH), 128.58 (2×CH), 130.43 (C), 135.15 (CH), 137.27 (C), 139.16 (CH), 161.70 (C); ESI-MS (m/z) 172 $(M+H)^+$; HRMS (ESI) calculated for $C_{11}H_{10}NO$ $(M+H)^+$ 172.0762 found 172.0756.

3-(4-chlorophenyl)pyridin-2(*1H*)-one (6b).

Yield 78% as white solid: mp 182-184°C; FT-IR (KBr, cm^{-1}) 3409, 3019, 1631; ^{1}H NMR (400 MHz, DMSO-d_6) *δ* 6.29 (t, *J* = 6.72 Hz, 1H), 7.39-7.44 (m, 3H), 7.67-7.69 (dd, *J* = 6.96, 2.08 Hz, 1H), 7.78 (d, *J* = 8.6 Hz, 2H), 11.84 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6): *δ* 105.90 (CH), 128.31 (2×CH), 128.88 (C), 130.27 (2×CH), 132.27 (C), 135.61 (CH), 136.01 (C), 139.37 (CH), 161.52 (C); ESI-MS (m/z) 206 $(M+H)^+$; HRMS (ESI) calculated for $C_{11}H_9ClNO$ $(M+H)^+$ 206.0373 found 206.0369.

3-(4-bromophenyl)pyridin-2(1H)-one (6c).

Yield 82% as light brown solid: mp 245-247°C; FT-IR (KBr, cm^{-1}) 3412, 3020, 1652; ^{1}H NMR (400 MHz, DMSO-d_6) *δ* 6.29 (t, *J* = 6.8 Hz, 1H), 7.39-7.42 (dd, *J* = 6.4, 2.04 Hz, 1H), 7.54-7.58 (m, 2H), 7.67-7.73 (m, 3H), 11.84 (s, 1H): ^{13}C NMR (100 MHz, DMSO-d_6) *δ* 106.00 (CH), 120.88 (C), 128.93 (C), 130.61 (2×CH),

131.26 (2×CH), 135.63 (CH), 136.37 (C), 139.43 (CH), 161.49 (C), ESI-MS (m/z) 250 $(M+H)^+$; HRMS (ESI) calculated for $C_{11}H_9BrNO$ $(M+H)^+$ 249.9868 found 249.9860.

3-(4-fluorophenyl)pyridin-2(1H)-one (6d).

Yield 68% as white solid: mp 218-220°C; FT-IR (KBr, cm^{-1}) 3418, 3019, 1632; ^1H NMR (400 MHz, DMSO-d_6) δ 6.29 (t, J = 6.68 Hz, 1H), 7.17-7.22 (m, 2H), 7.37-7.39 (dd, J = 6.4, 2.0 Hz, 1H), 7.63-7.65 (dd, J = 6.92, 2.0 Hz, 1H), 7.75-7.79 (m, 2H), 11.80 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 105.88 (CH), 115.21 (d, J = 21.03 Hz, 2×CH), 129.28 (C), 130.60 (d, J = 7.89 Hz, 2×CH), 133.57 (C), 135.21 (CH), 139.10 (CH), 161.65 (C), 163.11 (d, J = 242.77 Hz, C-F); ESI-MS (m/z) 190 $(M+H)^+$; HRMS (ESI) calculated for $C_{11}H_9FNO$ $(M+H)^+$ 190.0668 found 190.0667.

3-(p-tolyl)pyridin-2(1H)-one (6e).[21]

Yield 71% as light yellow solid: mp 191-194°C; FT-IR (KBr, cm^{-1}) 3412, 3019, 1636; ^1H NMR (400 MHz, DMSO-d_6) δ 2.31 (s, 3H),) 6.27 (t, J = 6.76 Hz, 1H), 7.18 (d, J = 7.92 Hz, 2H), 7.34-7.36 (dd, J = 6.4, 2.08 Hz, 1H), 7.59-7.63 (m,3H), 11.72 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 21.25 (CH_3), 105.84 (CH), 128.42 (2×CH), 128.90 (2×CH), 130.36 (C), 134.36 (C), 134.77 (CH), 136.91 (C), 138.62 (CH), 161.75 (C); ESI-MS (m/z) 186 $(M+H)^+$; HRMS (ESI) calculated for $C_{12}H_{12}NO$ $(M+H)^+$ 186.0919 found 186.0913.

1-methyl-3-phenylpyridin-2(1H)-one (6f).[21]

Yield 72% as white solid: mp 127-129°C; FT-IR (KBr, cm^{-1}) 3019, 1641; ^1H NMR (400 MHz, $CDCl_3$) δ 3.61 (s, 3H), 6.25 (t, J = 6.8 Hz, 1H), 7.29-7.34 (m, 2H), 7.37-7.41 (m, 2H), 7.47-7.49 (dd, J = 6.88, 2.0 Hz, 1H), 7.67-7.70 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 38.20 (CH_3), 105.82 (CH), 127.65 (CH), 128.09 (2×CH), 128.61 (2×CH), 131.64 (C), 136.85 (C), 137.41 (CH), 137.59 (CH), 161.95 (C), ESI-MS (m/z) 186 $(M+H)^+$; HRMS (ESI) calculated for $C_{12}H_{12}NO$ $(M+H)^+$ 186.0919 found 186.0907.

1-methyl-3-phenylpyridin-2(1*H*)-one (6g).[21]

Yield 77% as white solid: mp 135-137°C; FT-IR (KBr, cm^{-1}) 3019, 1646; ^1H NMR (400 MHz, $CDCl_3$) δ 3.61 (s, 3H), 6.25 (t, J = 6.84 Hz, 1H), 7.31-7.33 (dd, J = 6.68, 2.0 Hz, 1H), 7.36 (d, J = 8.64 Hz, 2H), 7.46-7.48 (dd, J = 7.0, 2.04 Hz, 1H), 7.65 (d, J = 8.64 Hz, 2H): ^{13}C NMR (100 MHz, $CDCl_3$) δ 38.25 (CH_3), 105.84 (CH), 128.25 (2×CH), 129.89 (2×CH), 130.34 (C), 133.52 (C), 135.23 (CH), 137.57 (CH), 137.76 (C), 161.74 (C), ESI-MS (m/z) 206 $(M+H)^+$; HRMS (ESI) calculated for $C_{12}H_{11}ClNO$ $(M+H)^+$ 220.0529 found 220.0517.

3-(4-bromophenyl)-1-methylpyridin-2(1H)-one (6h).[14]

Yield 74% as light brown solid: mp 144-146°C; FT-IR (KBr, cm^{-1}) 3021, 1656; ^1H NMR (400 MHz, $CDCl_3$) δ 3.61 (s, 3H), 6.25 (t, J = 6.88 Hz, 1H), 7.31-7.33 (dd, J = 6.68, 2.0 Hz, 1H), 7.46-7.48 (dd, J = 7.0, 2.04 Hz, 1H), 7.49-7.53 (m, 2H), 7.57-7.60 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 38.27 (CH_3), 105.86 (CH), 121.77 (C), 130.21 (2×CH), 130.37 (C), 131.22 (2×CH), 135.70 (C), 137.57 (CH), 137.80 (CH), 161.68 (C); ESI-MS (m/z) 264 $(M+H)^+$; HRMS (ESI) calculated for $C_{12}H_{11}BrNO$ $(M+H)^+$ 264.0024 found 264.0020.

1-methyl-3-(p-tolyl)pyridin-2(1H)-one (6i).[21]

Yield 73% as light yellow solid: mp 136-138°C; FT-IR (KBr, cm^{-1}) 3019, 1652; ^1H NMR (400 MHz, DMSO-d_6) δ 2.32 (s, 3H), 3.49 (s, 3H), 6.29 (t, J = 6.84 Hz, 1H), 7.18 (d, J = 7.92 Hz, 2H), 7.55-7.59 (m, 3H), 7.69-7.71 (dd, J = 6.68, 2.04 Hz, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 21.24 (CH_3), 37.91 (CH_3), 105.59 (CH), 128.61 (2×CH), 128.90 (2×CH), 129.67 (C), 134.55 (C), 136.96 (C), 137.75 (CH), 139.30 (CH), 161.36 (C), ESI-MS (m/z) 200 $(M+H)^+$; HRMS (ESI) calculated for $C_{13}H_{14}NO$ $(M+H)^+$ 200.1075 found 200.1067.

3-(4-methoxyphenyl)-1-methylpyridin-2(1H)-one (6j).[21]

Yield 76% as white solid: mp 110-112°C; FT-IR (KBr, cm^{-1}) 3020, 1657; ^1H NMR (400 MHz, $CDCl_3$) δ 3.45 (s, 3H), 3.68 (s, 3H), 6.07 (t, J = 6.8 Hz, 1H), 6.76-6.79 (m, 2H), 7.09-7.12 (m, 1H), 7.28-7.30 (dd, J = 6.96, 2.24 Hz, 1H), 7.49-7.52 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 38.20 (CH_3), 55.32 (CH_3), 105.90 (CH), 113.56 (2×CH), 129.30 (C), 129.79 (2×CH), 131.23 (C), 136.66 (2×CH), 139.79 (CH), 159.25 (C), 162.09 (C); ESI-MS (m/z) 216 $(M+H)^+$; HRMS (ESI) calculated for $C_{13}H_{14}NO_2$ $(M+H)^+$ 216.1025 found 216.1012.

4-((2,2,6,6-tetramethylpiperidin-1-yl)oxy)benzonitrile (7).[40]

Yield 64% as white solid: mp 78-81°C; FT-IR (KBr, cm^{-1}) 3019, 2231, 1591; ^1H NMR (400 MHz, $CDCl_3$) δ 0.99 (s, 6H), 1.25 (s, 6H), 1.44-1.49 (m, 1H), 1.59-1.66 (m, 5H), 7.28 (s, 2H), 7.54 (d, J = 9.12 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 16.90 (CH_2), 20.46 (4×CH_3), 32.31 (CH_2), 39.69 (CH_2), 60.76 (2×C), 103.21 (C), 114.89 (2×CH), 119.61 (C), 133.52 (2×CH), 166.91 (C).

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Regioselective α-arylation of coumarins and 2-pyridones with phenylhydrazines under transition-metal-free condition

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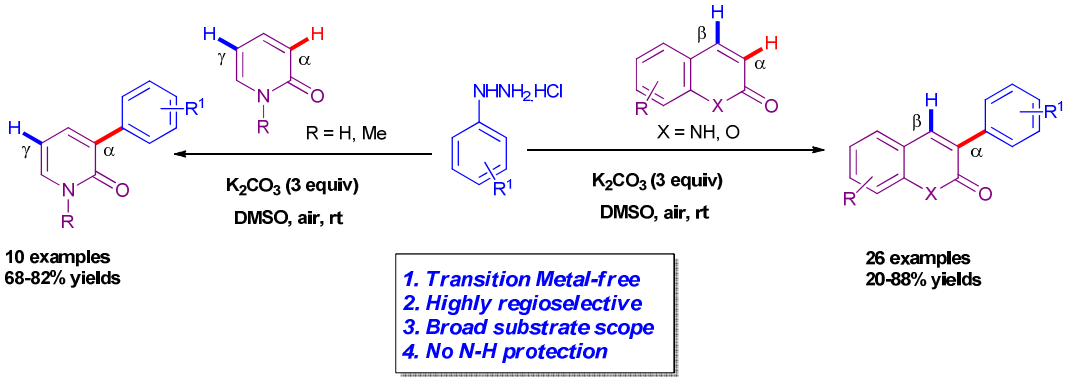

A transition-metal-free regioselective α-arylation of coumarins and 2-pyridones have been accomplished by the reaction of phenylhydrazines with coumarins or 2-pyridones. The reaction conditions are mild (Base/air system) and atom economical with broad substrate scope.