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ARTICLE

Palladium-Catalyzed Decarboxylative, Decarbonylative and Dehydrogenative C(sp^2)-H Acylation at *Room Temperature*

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Over the past decades, an impressive array of C-H activation methodology have been developed for organic synthesis. However, due to the inherent inertness of the C-H bonds (e. g. ~ 110 kcal/mol for the cleavage of C(aryl)–H bonds) harsh reaction conditions have been realized to overcome high energetic transition states resulting in limited substrate scope and functional group tolerance. Therefore, development of mild C-H functionalization protocols are in high demand to exploit the full potential of C-H activation strategy in the synthesis of complex molecular framework. Although, electron-rich substrates undergo eletrophilic metalation under relatively mild conditions, eletron-deficient substrates procceds through a rate-limiting C-H insertion under forcing conditions at high temperature. In addition, stoichiometric amount of toxic silver salt is frequently used in palladium catalysis to facilitate the C-H activation process which is not acceptable from environmental and industrial standpoint. We report herein, a Pd(II)-catalyzed decarboxylative C-H acylation of 2-arylpyridines with α-ketocarboxylic acids under mild conditions. The present protocol does not require stoichiometric silver(I) salts as additives and proceeds smoothly at ambient temperature. A novel decarbonylative C-H acylation reaction has also been accomplished using aryl glyoxals as acyl surrogate. Finally, a practical C-H acylation via dehydrogenative pathway has been demonstrated using commercially available benzaldehydes and aqueous hydroperoxide. We also disclose that acetonitrile solvent is optimal for the acylation reaction at room temperature and has a prominent role on the reaction outcome. Control experiments suggest that the acylation reaction via decarboxylative, decarbonylative and dehdrogenative proceeds through radical pathway. Thus we disclose a practical protocol for the sp^2 C-H acylation reaction.

Introduction

Owing to the prevalence of benzophenones in natural products, pharmaceuticals and functionalized materials, the synthesis of functionalized carbonyl compounds is a sustained exertion in organic synthesis (Figure 1).[1] Typically, Lewis-acid promoted Friedel-Crafts acylation via electrophilic aromatic substitution generates isomeric mixtures and requires stroichiometric metal salts.[2] The reaction of Weinreb amides with Grignard reagents yields the carbonyl compounds with limited functional group tolerance.[3] Whereas, transition metal catalyzed cross-couplings are reported with relatively less nucleophilic organometallic reagents such as organozinc reagents and boronic acids.[4] As an alternative to air and moisture sensitive acyl chlorides which generate stoichiometric metal halide waste, thioesters is used in palladium-catalyzed Liebeskind-Srogl cross-coupling.[5] However, the reaction requires stoichiometric amount of copper complex as additive. Carbonylation of aryl halides with hazardous carbon monoxide requires special handling skills and laboratory set up.[6] Therefore, considering the stringent environmental factors (E factors) in chemical processes there is an urgent need for the development of practical and environmentally benign acylation reactions.

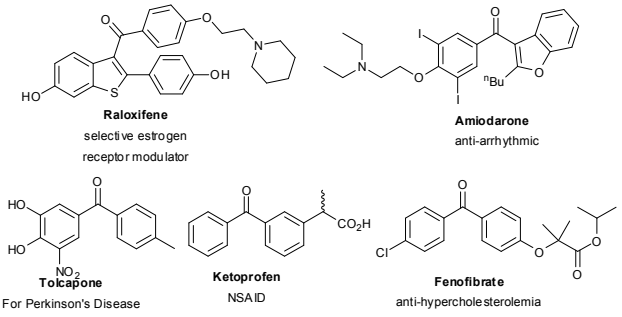

Figure 1 Some benzophenone containing drugs

Beyond typical cross-coupling approaches, the C-H activation strategy offers a unique opportunity to access carbonyl compounds without prefunctionalization steps.[7] Although an enormous effort has been dedicated for the development of C-H activation processes, significant challenges still remain unsolved. The harsh reaction

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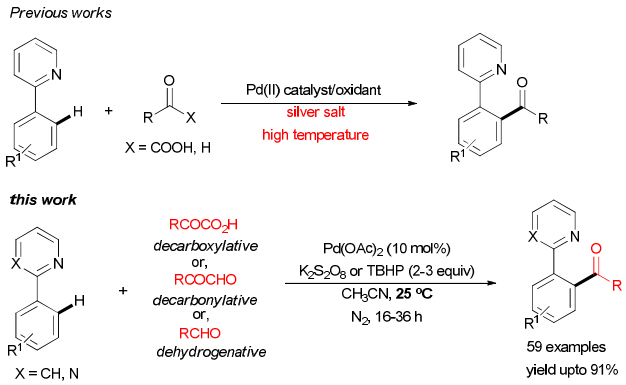
conditions, use of stoichiometric toxic silver(I) salts, high reaction temperature etc. limits their application in the synthesis of complex molecular architecture and industrial processes. Thus, developments of mild acylation reaction via C-H activation processes are in high demand.[8]

In recent years, decarboxylative cross-coupling has also been established as a modern strategy for C-C and C-heteroatom bond formation.[9] Inexpensive and readily available carboxylic acids are used as an alternative to expensive organometallic reagents and halides. Combining these two promising technologies, decarboxylative C-H functionalization has emerged as a fascinating field of research.[10] However, like C-H insertion, decarboxylative metalation is also a high energetic process and proceeds at elevated temperatures.[11] α-Oxocarboxylic acids undergo transition metal-catalyzed decarboxylation to provide acyl anion equivalent which been utilized in cross-coupling[12] and C-H acylation reaction to provide diaryl ketones.[13] Although decarboxylative C-H acylation of electron rich aniline derivatives or oximes proceed at ambient temperature through a facile electrophilic *ortho* metalation,[14] electron-deficient substrates require high temperature (110-140 °C) and stoichiometric silver(I) salt which is not acceptable from environmental and industrial viewpoint.[15] To the best of our knowledge, silver free decarboxylative acylation of electron-deficient 2-arylpyridine at room temperature has not been reported so far. As a part of our continuing research program for the development of cross-coupling reactions at mild conditions, we have reported decarboxylative Heck coupling at room temperature[16] and divergent synthesis of 2-arylindol and indolines via C-H activation.[17] Herein for the first time, we report a palladium-catalyzed decarboxylative C-H acylation of electron-deficient 2-



Scheme 1 C(sp^2)-H Acylation Reaction

arylpyridines system at *room temperature.* The present protocol does not require stoichiometric silver(I) salt and a dramatic influence of solvent was observed where acetonitrile was found to be optimal for this acylation reaction at ambient condition.[18] This room temperature acylation reaction was also demonstrated using phenylglyoxals and aldehydes as acylating agent via decarbonylative and dehydrogenative manifolds respectively.

Results and discussion

Initially, we started optimization for the decarboxylative acylation reaction at room temperature. A mixture of 2-phenylpyridine (**1a**) and phenylglyoxylic acid (**2a**) was stirred in the presence of 10 mol % palladium(II)acetate and 2.0 equiv of potassium persulfate ($K_2S_2O_8$) in diglyme solvent.[10k] The expected monoacylated product (**3a**) was obtained in 20% yield without any silver(I) salt added (entry 1, Table 1). Further screening of solvents showed that acetonitrile is superior to other solvents such as DMF, DMSO, toluene, acetic acid, 1,4-dioxane and DCE (entry 2-7, Table 1). Typically, silver salt is used in palladium catalysis for facile decarboxylation, carbonate or carboxylate anion source, halide scavenger and terminal oxidant for catalytic turnover.[19] However, contrary to our expectations, no desired product was isolated using silver salts such as Ag_2CO_3, Ag_2O etc. at room temperature although it is used as additive for this transformation at high temperature[15a] (entry 9-10, Table 1). Other common oxidants such as ammonium persulfate, (diacetoxyiodo)benzene (PIDA), *tert*-butyl hydroperoxide (in decane) and also molecular oxygen etc. were found to be inferior for this coupling reaction (entry 11-14, Table 1). Owing to the facile electrophilic palladation of cationic palladium salts, several Pd-complexes, such as $Pd(TFA)_2$, $Pd(MeCN)_2Cl_2$, $Pd(MeCN)_2(OTs)_2$, and $Pd(MeCN)_4(BF_4)_2$ were examined but provided lower yield (entry 15-18, Table 1). We also observed that silver nitrate as a catalyst was inactive for this transformation (entry 19, Table 1). Finally, in combination of 10 mol % $Pd(OAc)_2$ and 2.0 equiv of $K_2S_2O_8$ as oxidant using acetonitrile as a solvent provided excellent yield after stirring 16 h at room temperature (entry 8, Table 1). It is important to note that both $Pd(OAc)_2$ and $K_2S_2O_8$ are essential for this coupling reaction since no desired product was isolated while they were used separately (entry 20-21, Table 1). The yield of the acylation product was decreased to some extent under air (entry 22, Table 1) and no product was formed with oxygen purging (entry 23, Table 1). During optimization, it was found that moisture has negative impact on the reaction outcome presumably due to the formation of decarboxylative protonation product from phenylglyoxylic acid.

Next we explored the substrate scope under the optimized reaction conditions. A wide variety of phenylglyoxylic acids having electron-withdrawing and electron-donating substituents underwent decarboxylative coupling providing high to excellent yield (Scheme 2). Besides methoxy, alkyl, and

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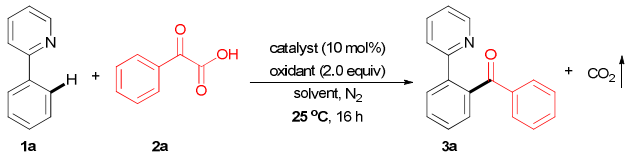
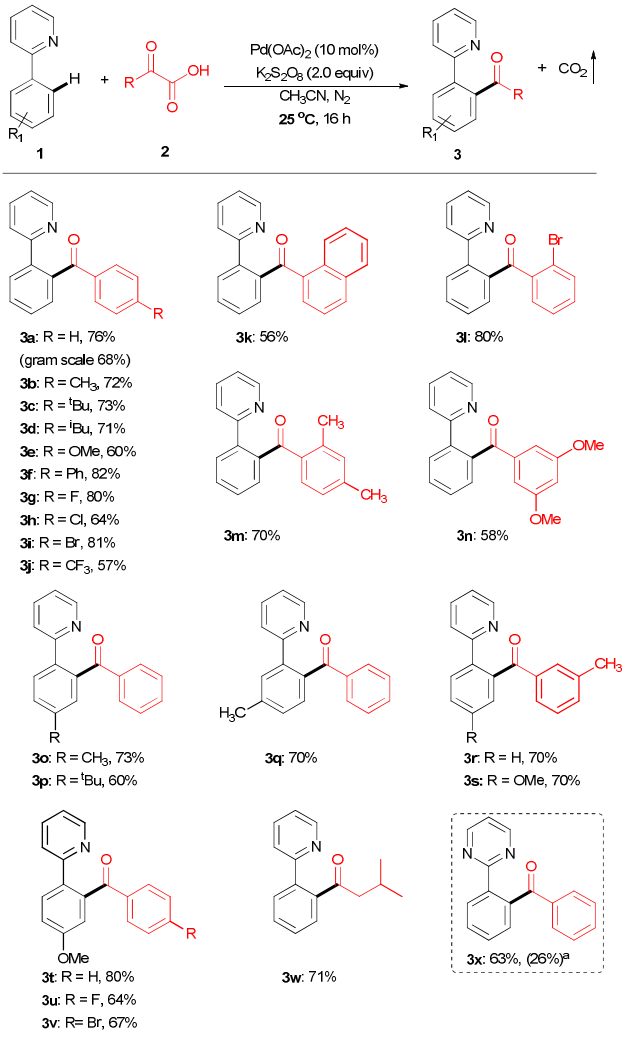
Table 1. Optimization of the reaction conditions[a,b]



entry	catalyst (10 mol %)	oxidant (2.0 equiv)	solvent	yield (%)[b]
1	$Pd(OAc)_2$	$K_2S_2O_8$	diglyme	20
2	$Pd(OAc)_2$	$K_2S_2O_8$	DMF	50
3	$Pd(OAc)_2$	$K_2S_2O_8$	DMSO	52
4	$Pd(OAc)_2$	$K_2S_2O_8$	Toluene	trace
5	$Pd(OAc)_2$	$K_2S_2O_8$	AcOH	25
6	$Pd(OAc)_2$	$K_2S_2O_8$	1,4-dioxane	14
7	$Pd(OAc)_2$	$K_2S_2O_8$	DCE	40
8	**$Pd(OAc)_2$**	**$K_2S_2O_8$**	**MeCN**	**76**
9	$Pd(OAc)_2$	Ag_2CO_3	MeCN	0
10	$Pd(OAc)_2$	Ag_2O	MeCN	0
11	$Pd(OAc)_2$	$(NH_4)_2S_2O_8$	MeCN	50
12	$Pd(OAc)_2$	PIDA	MeCN	26
13	$Pd(OAc)_2$	TBHP (in decane)	MeCN	0
14	$Pd(OAc)_2$	O_2	MeCN	0
15	$Pd(TFA)_2$	$K_2S_2O_8$	MeCN	70
16	$Pd(MeCN)_2Cl_2$	$K_2S_2O_8$	MeCN	8
17	$Pd(MeCN)_2(OTs)_2$	$K_2S_2O_8$	MeCN	65
18	$Pd(MeCN)_4(BF4)_2$	$K_2S_2O_8$	MeCN	57
19	$AgNO_3$	$K_2S_2O_8$	MeCN	0
20	$Pd(OAc)_2$	-	MeCN	0
21	-	$K_2S_2O_8$	MeCN	0
22[c]	$Pd(OAc)_2$	$K_2S_2O_8$	MeCN	67
23[d]	$Pd(OAc)_2$	$K_2S_2O_8$	MeCN	0

[a]All reactions were carried out in 0.1 mmol scale**, 1a** (1.0 equiv) and **2a** (1.5 equiv). [b]Yields refer to here are overall isolated yields. [c]Reaction was run under air. [d]Reaction was run under O_2.

aryl groups, halogens such as bromo (**3i, 3l, 3v,** Scheme 2), chloro (**3h**, Scheme 2), and fluoro (**3g**, Scheme 2) were also well tolerated in the reaction condition which are useful for further cross-coupling reactions. A strong electron-withdrawing group on α-keto acid afforded the acylated product in good yield (**3j**, Scheme 3). Interestingly, the α-keto acid with a naphthyl moiety furnished the desired product in good yield (**3k**, Scheme 2). The *ortho* substituted α-keto acid participated in the reaction with excellent yield (**3l**, Scheme 2). Disubstituted α-keto acids also participated in the reaction providing good yield (**3m**-**3n**, scheme 2). No significant influence of the electronic nature of the substituents on α-keto acids was observed on the reaction outcome. Similarly, substitutions on the 2-phenylpyridine moiety such as alkyl **(3o**-**3q**, Scheme 2), methoxy (**3s**-**3v**, Scheme 2) were tolerated in the reaction condition. In addition, aliphatic α- oxocarboxylic



Scheme 2 Substrate scope of 2-phenylpyridines and α-ketocarboxylic acids. The reaction was carried out in 0.2 mmol scale, **1** (1.0 equiv) and **2** (1.5-2.0 equiv). The yield referred to here is the average isolated yield of at least two experiments. [a]Diacylation occurred.

acid also afforded the desired product in good yield (**3w**, Scheme 2). Unfortunately, electron deficient groups like acyl, trifluromethyl on 2-phenylpyridine moiety did not furnish any acylated products. Other nitrogen directing groups like 2-phenoxypyridine, 1-phenyl-1*H*-pyrazole, acetophenone *O*-methyl oxime, and also 2-phenylbenzo[*d*]thiazole did not provide desired acylation products at room temperature. However, 2-phenylpyrimidine furnished a mixture of mono and diacylation product which was separated through column chromatography (mono:di = 2.5:1). To demonstrate the practical utility of this present protocol the reaction was performed in gram-scale providing the acylation product in comparable yields (**3a**, Scheme 2).

In recent years, decarbonylative cross-coupling reaction from carbonyl or carboxylic acid derivatives has emerged as a

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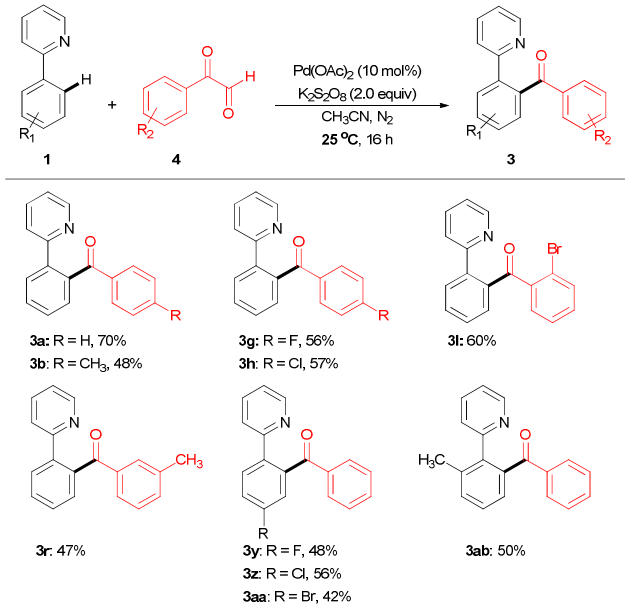
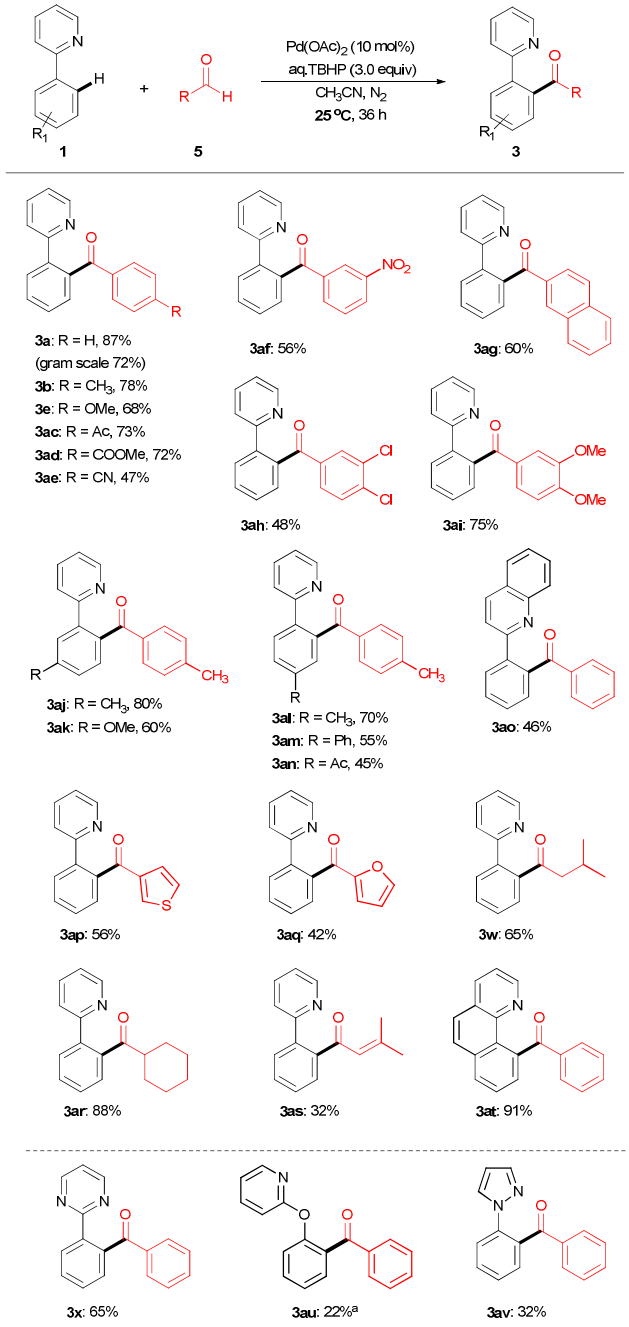
promising strategy in organic synthesis.[20] Initially, the transition metal undergoes oxidative addition to the activated carboxylic acid derivatives such as acid chlorides,[21] anhydrides,[22] esters[23] etc. to generate an acyl-metal species. Subsequently, aryl-metal species is formed through the extrusion of carbon monoxide. Unlike redox-neutral decarboxylative cross-coupling, no stoichiometric oxidant is required in the decarbonylative cross-coupling process. Although transition metal-catalyzed decarbonylative cross-coupling for arylation has been explored[24] but decarbonylative C-H acylation is not known. We hypothesized that glyoxals can be utilized in palladium-catalyzed decarbonylative C-H acylation reaction. To test, a mixture of 2-phenylpyridine, (**1a**) and phenylglyoxal (**4a**) was subjected under the optimized reaction conditions of decarboxylative acylation. Gratifyingly, the corresponding acylation product was isolated in 70% yield (**3a**, Scheme 3). However, the reaction under oxygen did not furnish any acylation product although dioxygen-mediated generation of alkyl radical from corresponding aldehydes is known at elevated temperature.[25] Other oxidants such as aq. TBHP or TBHP in decane even $(NH_4)_2S_2O_8$ were ineffective for this transformation. Surprisingly, a trace amount of acylation product was isolated in other solvents like DMSO, DMF, DCE and toluene. Therefore, we proceeded to examine the substrate scope under this condition. To our delight, a number of 2-phenylpyridine as well as phenylglyoxal with different substituents provided the corresponding acylated product with moderate to good yield (Scheme 3). It is noteworthy that halogenated and *ortho*-substituted 2-phynylpyridines also provided moderate yield of the acylation products which were ineffective under decarboxylative acylation protocol.



Scheme 3 Substrate scope of 2-phenylpyridines and 2-oxo-2-phenylacetaldehydes. The reaction was carried out in 0.2 mmol scale, 1 (1.0 equiv) and 4 (1.5 equiv). The yield referred to here is the average isolated yield of at least two experiments.



Scheme 4 Substrate scope of 2-phenylpyridines and aldehydes. The reaction was carried out in 0.2 mmol scale, **1** (1.0 equiv) and **5** (1.5 equiv). The yield referred to here is the average isolated yield of at least two experiments. [a]The reaction was run for 72 h.

Next we turned our attention to achieve acylation reaction with commercially available and inexpensive aldehydes as acylation agent. From literature, palladium-catalyzed C-H acylation of 2-phenylpyridine with aryl and alkyl aldehydes is

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known at high temperature.[26] However, aldehydes are converted to the corresponding acids by oxygen rapidly at high temperature and the yield is decreased.[26b,27] In addition, the oxidant TBHP is explosive at high temperature particularly in industrial-scale.[28] Keeping this in mind we intended to develop an acylation reaction with aldehydes at *room temperature*. Our initial trial reaction between 2-phenylpyridine (**1a**) and benzaldehyde (**5a**) under the previous optimized reaction conditions afforded acylated product in 35% yield (**3a**, Scheme 4). Considering the unique ability of *tert*-butylhydroperoxide (TBHP) to generate acyl radical from aldehydes,[29] we decided to use TBHP as oxidant in lieu of $K_2S_2O_8$. Surprisingly, the yield was improved to 55% with inexpensive aq. TBHP. Finally an excellent yield of the acylated product (**3a**) in 87% was isolated after stirring the reaction mixture for 36 h at room temperature with the combination of 10 mol % $Pd(OAc)_2$ and 3.0 equiv of aq. TBHP from 1.0 equiv of 2-phenylpyridine (**1a**) and 1.5 equiv of benzaldehyde (**5a**). However, 30% aq. H_2O_2 in lieu of aq. TBHP did not furnish any acylation product. To note, the reaction under air or oxygen provided lower (37%) or no yield thus the reaction vessel was purged with nitrogen. The reaction under neat condition also furnished inferior result (38%).

Subsequently, we explored the substrate scope under the optimized reaction conditions. A wide variety of functional groups on 2-phenylpyridine as well as on aldehyde were found to be compatible under this mild reaction protocol. Besides methoxy, alkyl, and aryl groups, halogens such as chloro (**3ah**, Scheme 4), ester (**3ad**, Scheme 4), cyano (**3ae**, Scheme 4), nitro (**3af**, Scheme 4) remain intact which are useful for further organic transformation. Interestingly, the acyl group on aldehyde (**3ac**, Scheme 4) is well-tolerated under the reaction conditions which demonstrate the mild nature of the conditions. Interestingly, the aldehyde with a naphthyl moiety furnished the desired product in good yields (**3ag**, Scheme 4). The electron deficient group like acyl on 2-phenylpyridine afforded the moderate yield (**3an**, Scheme 4) which was inferior in the decarboxylative acylation reaction. The reaction with 2-phenylquinoline afforded the acylation product in moderate yield (**3ao**, Scheme 4). Interestingly, the heterocyclic aldehydes, such as furan-2-carbaldehyde and thiophene-3-carbaldehyde provided moderate yield of the desired product (**3ap**-**3aq**, Scheme 4). In addition, aliphatic aldehydes also afforded the acylation product in moderate to excellent yield (**3w**-**3as**, Scheme 4). It is important to note that, benzo[*h*]quinoline worked extremely well in the reaction conditions to give the corresponding acylation product in excellent yield (**3at**, Scheme 4). Although, 2-phenoxypyridine, 1-phenyl-1H-pyrazole provided lower yield and unreacted starting material was recovered (**3au**-**3av**, Scheme 4) but 2-phenylpyrimidine furnished good yield (**3x**, Scheme 4) of the mono-acylation product. Finally, the reaction was reproduced in gram-scale providing comparable yield (**3a**, Scheme 4). Other *in situ* convertible acylating agents such as benzyl alcohol, benzyl amine, styrene and toluene did not furnish any acylated product with 2-phenylpyridine under the reaction conditions.

Investigation of the reaction mechanism

To gain insight into the reaction mechanism, we performed several control experiments. To check whether decarboxylative acylation reaction with phenylglyoxylic acid proceeds through radical or anionic pathway, radical scavenger 2,2,6,6-tetramethylpiperidinyl-1-oxy (TEMPO) experiment was performed. It was observed that the acylation reaction completely suppressed with 1.0 equiv of TEMPO. The TEMPO-acyl adduct, 2,2,6,6-tetramethylpiperidin-1-yl benzoate (**6a**) was detected in electrospray ionization (ESI) mass spectrometry of the crude reaction mixture. Further, it was isolated in 74% yield and well-charcterized by NMR and HRMS spectroscopy (Scheme 5a) (see the ESI). Thus the decarboxylative acylation reaction may proceed through radical pathway and the acyl radical may generate from the corresponding phenylglyoxylic acids with $K_2S_2O_8$ at room temperature. Similarly, acylation reaction with phenylglyoxal was also completely suppressed with 1.0 equiv of TEMPO and the TEMPO-acyl adduct (**6a**) was isolated in 56% yield (Scheme 5a). In addition, phenylglyoxal did not oxidized to the phenylglyoxylic acid under the reaction condition and remained intact (Scheme 5b). Therefore, the possibility of oxidation to the corresponding acid followed by decarboxylative acylation was ruled out rather an acyl radical may generate in the course of the reaction through decarbonylation of the arylglyoxal. Finally, dehydrogenative acylation reaction with benzaldehyde was also supressed substantially with 1.0 and 1.5 equiv of TEMPO and completely suppressed with 2.0 equiv of TEMPO. The TEMPO-acyl adduct (**6a**) was also isolated in 71% yield for further confirmation (Scheme 5a). Thus, dehydrogenative acylation may also proceed through radical pathway and the acyl radical intermediate may form from the corresponding benzaldehyde *via* TBHP oxidation. In the absence of $K_2S_2O_8$ no decarboxylative acylation product was isolated with 10 mol % or even with 1.0 equiv of $Pd(OAc)_2$ indicating that combination of palladium and $K_2S_2O_8$ is essential for the reaction to occur (Scheme 5c). Since palladium(II) acetate is known to form a dimeric complex with 2-phenylpyridine through C-H insertion,[30] a palladium dimer complex (**7a**) was prepared separately and subjected to the reaction conditions (Scheme 5d). Only a trace amount of product was detected suggesting that dimeric palladium species with 2-phenylpyridine may not form under the present reaction conditions whereas a monomeric palladium species may be involved.

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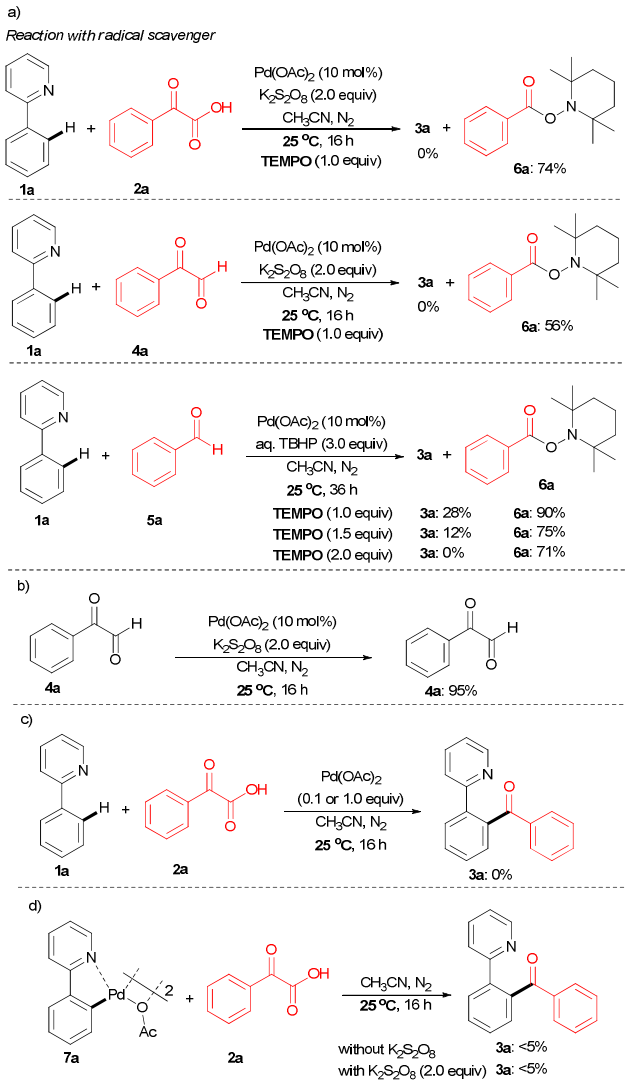
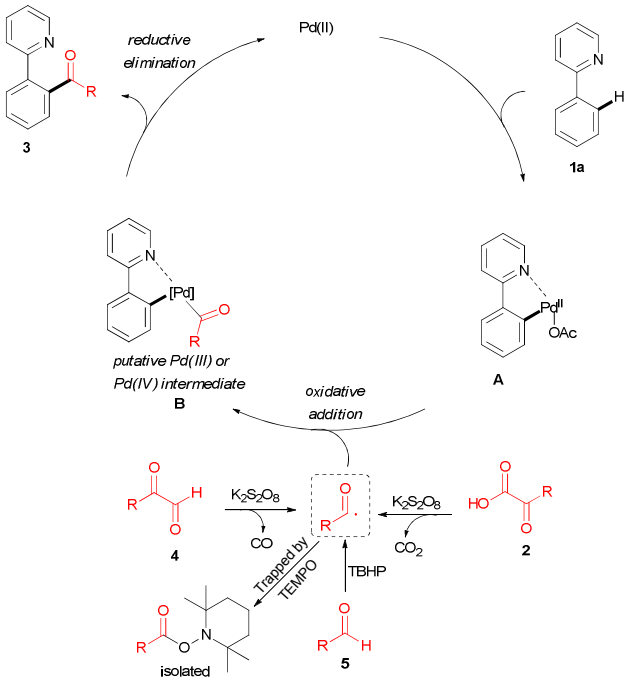


Scheme 5 Control experiments

From the control experiments and previous reported literatures,[29,31,32] we propose the reaction mechanism which has shown in Scheme 6. The pyridine-assisted cyclopalladation with Pd(II) *via* electrophilic palladation may generates the 5-membered palladacycle intermediate **A** (Scheme 6), which undergoes oxidative addition with acyl radical to yield cyclopalladated Pd(III) intermediate **B** (Scheme 6). Under visible light photoredox and palladium dual catalysis condition this putative Pd(III) is further oxidized to Pd(IV) with photoredox catalyst and/or oxidant.[8f,14b,32c,32d,33] However in these catalytic systems, the role of $K_2S_2O_8$ or TBHP in Pd(III)/Pd(IV) oxidation is not clear at this moment and warrants further investigation. The desired acylation product **3** may form through the facile reductive elimination of the intermediate **B** (Scheme 6) and the generation of Pd(II) catalyst for the subsequent runs.



Scheme 6 Plausible mechanism of C(sp^2)-H acylation

Conclusions

In conclusions, we have developed a mild reaction protocol for Pd(II)-catalyzed C(sp2)-H acylation using α-ketocarboxylic acids, phenylglyoxals and commercially available, inexpensive aldehydes via decarboxylative, decarbonylative and dehydrogenative manifolds respectively. The major advantages of the present protocol are- a) the reaction operates under mild conditions at *room temperature*; b) it does not require stoichiometric amount of toxic silver(I) salt for decarboxylation of the α-ketocarboxylic acid or as oxidant; c) acetonitrile was optimal for the acylation; d) gaseous CO_2, CO or water is formed as by-products avoiding rigorous separation technique; e) the present acylation reaction proceeds through radical pathway to provide mono acylation product at the *ortho* position selectively. This room temperature acylation reaction is scalable, energy efficient and avoids the accidental hazard due to explosion of peroxides at elevated temperature. Thus, we anticipate that this mild C-H acylation protocol will find its place in industrial application.

Experimental section

General information

Melting points were determined in open end-capillary tubes and are uncorrected. TLC was performed on silica gel plates (silica gel 60, f254), and the spots were visualized with UV light (254 and 365 nm) and $KMnO_4$ stain. ^1H and ^{13}C NMR spectra were recorded in $CDCl_3$ using TMS as the internal standard.

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HRMS (m/z) were measured using EI (magnetic sector, positive ion) and ESI (Q-TOF, positive ion) techniques. Infrared (IR) spectra were recorded on Fourier transform infrared spectroscopy; only intense peaks were reported.

General experimental procedure for the decarboxylative acylation reaction between 2-phenylpyridines and α-ketocarboxylic acids, **Scheme 2**.

To an oven-dried 10 mL sealed tube, a mixture of 2-phenylpyridines (0.2 mmol, 1.0 equiv), α-ketocarboxylic acids (0.3-0.4 mmol, 1.5-2.0 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II)acetate (4.6 mg, 0.02 mmol, 0.1 equiv) was taken and dry MeCN (3.0 mL) was added to it. After flushing with nitrogen for 30 seconds, immediately the vessel was sealed with a screw cap. The reaction mixture was allowed to stir for 16 h at room temperature. After that the reaction mixture was quenched with $NaHCO_3$ to remove the unreacted acids. Then the reaction mixture was poured into water (40 mL) and extracted with ethyl acetate (40 mL). The organic layer was washed with water (10 mL) and brine (10 mL), dried over anhydrous Na_2SO_4 and the solvent was evaporated under reduced pressure. The crude product was purified by column chromatography using ethyl acetate/hexane as eluent to afford the desired product.

To note: During optimization, it was found that α-ketocarboxylic acids are hygroscopic in nature thus water or moisture is detrimental to the reaction outcome. Therefore, so after flushing with nitrogen the reaction vessel was immediately sealed with a screw cap.

Phenyl(2-(pyridin-2-yl)phenyl)methanone, 3a, Scheme 2.[7d] The same general procedure was followed by using 2-phenylpyridine (31.0 mg, 0.2 mmol, 1.0 equiv), 2-oxo-2-phenylacetic acid (45 mg, 0.3 mmol, 1.5 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a white solid, (39.5 mg, 76%), mp 105-107 ^oC. ^1H NMR (600 MHz, $CDCl_3$): δ 8.36 (d, *J* = 4.2 Hz, 1H), 7.78 (d, *J* = 7.8 Hz, 1H), 7.70 (d, *J* = 7.8 Hz, 2H), 7.61 (t, *J* = 7.2 Hz, 1H), 7.50-7.56 (m, 4H), 7.39 (t, *J* = 7.2 Hz, 1H), 7.27 (t, *J* = 7.2 Hz, 2H), 7.01 (t, *J* = 4.8 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 198.2, 156.7, 149.0, 139.6, 139.5, 137.9, 136.3, 132.3, 130.2, 129.4, 129.1, 128.7, 128.5, 128.0, 122.6, 121.9; IR (neat): υ_{max} 1665, 1587, 1279, 929, 751, 703 cm^{-1}; HRMS (EI, m/z) calcd. for $C_{18}H_{13}NO$ $[M]^+$: 259.0997; found: 259.0979.

(2-(Pyridin-2-yl)phenyl)(*p*-tolyl)methanone, 3b, Scheme 2.[7d] The same general procedure was followed by using 2-phenylpyridine (31.0 mg, 0.2 mmol, 1.0 equiv), 2-oxo-2-(*p*-tolyl)acetic acid (49 mg, 0.3 mmol, 1.5 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a white solid, (39.0 mg, 72%), mp 97-99 ^oC. ^1H NMR (600 MHz, $CDCl_3$): δ 8.41 (d, *J* = 4.2 Hz, 1H), 7.78 (d, *J* = 7.2 Hz, 1H), 7.56-7.62 (m, 4H), 7.52 (d, *J* = 4.2 Hz, 2H), 7.49 (d, *J* = 8.4 Hz, 1H), 7.09 (d, *J* = 7.8 Hz, 2H), 7.03-7.06 (m, 1H), 2.33 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 197.9, 156.9, 149.1, 143.1, 139.7, 139.5, 136.2, 135.3, 130.0, 129.7, 128.92, 128.90, 128.8, 128.4, 122.8, 121.9, 21.6; IR (neat): υ_{max} 1662, 1604, 1433, 1284, 929, 751 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{19}H_{15}NONa$ $[M + Na]^+$: 296.1051; found: 296.1049.

(4-(*tert*-Butyl)phenyl)(2-(pyridin-2-yl)phenyl)methanone, 3c, Scheme 2.[34] The same general procedure was followed by using 2-phenylpyridine (31.0 mg, 0.2 mmol, 1.0 equiv), 2-(4-(tert-butyl)phenyl)-2-oxoacetic acid (62 mg, 0.3 mmol, 1.5 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a yellowish oil, (46.0 mg, 73%). ^1H NMR (300 MHz, $CDCl_3$): δ 8.40 (d, *J* = 4.2 Hz, 1H), 7.76 (d, *J* = 7.8 Hz, 1H), 7.65 (d, *J* = 8.4 Hz, 2H), 7.46-7.62 (m, 5H), 7.30 (d, *J* = 8.4 Hz, 2H), 7.00-7.04 (m, 1H), 1.27 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 197.9, 157.0, 156.0, 149.1, 139.7, 139.6, 136.2, 135.1, 130.0, 129.6, 129.0, 128.9, 128.2, 125.0, 122.9, 121.8, 35.0, 31.0; IR (neat): υ_{max} 2961, 1666, 1598, 1466, 1277, 753 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{22}H_{21}NONa$ $[M + Na]^+$: 338.1521; found: 338.1523.

(4-*iso*Butylphenyl)(2-(pyridin-2-yl)phenyl)methanone, 3d, Scheme 2. The same general procedure was followed by using 2-phenylpyridine (31.0 mg, 0.2 mmol, 1.0 equiv), 2-(4-*iso*butylphenyl)-2-oxoacetic acid (62 mg, 0.3 mmol, 1.5 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a colourless oil, (45.0 mg, 71%). ^1H NMR (600 MHz, $CDCl_3$): δ 8.39 (d, *J* = 4.2 Hz, 1H), 7.76 (d, *J* = 7.8 Hz, 1H), 7.51-7.62 (m, 6H), 7.45 (d, *J* = 7.8 Hz, 1H), 7.03 (d, *J* = 8.4 Hz, 2H), 7.00-7.02 (m, 1H), 2.43 (d, *J* = 7.2 H, 2H), 1.78-1.85 (m,1H), 0.84 (d, *J* = 6.6 Hz, 6H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 198.0, 157.0, 149.0, 146.8, 139.7, 139.6, 136.1, 135.5, 130.1, 129.5, 129.1, 128.9, 128.7, 128.4, 123.0, 121.8, 45.3, 30.1, 22.2; IR (neat): υ_{max} 2957, 1664, 1602, 1281, 930, 751 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{22}H_{21}NONa$ $[M + Na]^+$: 338.1521; found: 338.1520.

(4-Methoxyphenyl)(2-(pyridin-2-yl)phenyl)methanone, 3e, Scheme 2.[7d] The same general procedure was followed by using 2-phenylpyridine (31.0 mg, 0.2 mmol, 1.0 equiv), 2-(4-methoxyphenyl)-2-oxoacetic acid (54 mg, 0.3 mmol, 1.5 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a yellowish oil, (35.0 mg, 60%). ^1H NMR (600 MHz, $CDCl_3$): δ 8.44 (d, *J* = 4.8 Hz, 1H), 7.78 (d, *J* = 7.8 Hz, 1H), 7.68-7.70 (m, 2H), 7.56-7.62 (m, 2H), 7.52 (d, *J* = 4.2 Hz, 2H), 7.48 (d, *J* = 7.8 Hz, 1H), 7.05-7.07 (m, 1H), 6.76-6.79 (m,2H), 3.81 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 197.0, 163.0, 157.0, 149.1, 139.6, 139.5, 136.2, 131.9, 130.7, 129.9, 129.0, 128.8, 128.3, 123.0, 121.9, 113.3, 55.3; IR (neat): υ_{max}

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1658, 1597, 1464, 1256, 1027, 753 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{19}H_{15}NO_2Na$ $[M + Na]^+$: 312.1000; found: 312.0997.

(2,4-Dimethylphenyl)(2-(pyridin-2-yl)phenyl)methanone, 3m, Scheme 2. The same general procedure was followed by using 2-phenylpyridine (31.0 mg, 0.2 mmol, 1.0 equiv), 2-(2,4-dimethylphenyl)-2-oxoacetic acid (53.5 mg, 0.3 mmol, 1.5 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a light yellow oil, (40.0 mg, 70%). ^1H NMR (600 MHz, $CDCl_3$): δ 8.46-8.47 (m, 1H), 7.66-7.67 (m, 1H), 7.56-7.60 (m, 3H), 7.49-7.52 (m, 1H), 7.42 (d, *J* = 7.8 Hz, 1H), 7.11 (d, *J* = 8.4 Hz, 1H), 7.03-7.05 (m, 1H), 6.92 (s, 1H), 6.76 (d, *J* = 7.8 Hz, 1H), 2.56 (s, 3H), 2.24 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 199.5, 157.4, 148.7, 141.5, 141.0, 139.8, 139.4, 136.3, 135.2, 132.1, 131.2, 130.3, 129.6, 129.2, 128.4, 125.5, 122.8, 121.8, 21.3, 21.0; IR (neat): υ_{max} 2924, 1663, 1601, 1436, 1299, 753 cm^{-1}; HRMS (EI, m/z) calcd. for $C_{20}H_{17}NO$ $[M]^+$: 287.1310; found: 287.1305.

(3,5-Dimethoxyphenyl)(2-(pyridin-2-yl)phenyl)methanone, 3n, Scheme 2. The same general procedure was followed by using 2-phenylpyridine (31.0 mg, 0.2 mmol, 1.0 equiv), 2-(3,5-dimethoxyphenyl)-2-oxoacetic acid (63 mg, 0.3 mmol, 1.5 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a colourless oil, (37.0 mg, 58%). ^1H NMR (600 MHz, $CDCl_3$): δ 8.40 (d, *J* = 4.8 Hz, 1H), 7.77 (d, *J* = 7.8 Hz, 1H), 7.58-7.61 (m, 2H), 7.50-7.54 (m, 3H), 7.04-7.06 (m, 1H), 6.96 (d, *J* = 1.8 Hz, 2H), 6.50 (t, *J* = 2.4 Hz, 1H), 3.73 (s, 6H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 197.6, 160.3, 156.7, 149.0, 139.8, 139.5, 139.3, 136.3, 130.2, 129.1, 128.7, 128.4, 122.4, 122.0, 107.3, 105.0, 55.5; IR (neat): υ_{max} 1670, 1594, 1462, 1302, 1156, 1062, 753 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{20}H_{17}NO_3Na$ $[M + Na]^+$: 342.1106; found: 342.1007.

(5-Methoxy-2-(pyridin-2-yl)phenyl)(phenyl)methanone, 3t, Scheme 2.[26b] The same general procedure was followed by using 2-(4-methoxyphenyl)pyridine (37.0 mg, 0.2 mmol, 1.0 equiv), 2-oxo-2-phenylacetic acid (60 mg, 0.4 mmol, 2.0 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a white solid, (46.0 mg, 80%). mp 98-100 °C. ^1H NMR (600 MHz, $CDCl_3$): δ 8.32 (d, *J* = 4.8 Hz, 1H), 7.73 (d, *J* = 8.4 Hz, 1H), 7.70 (d, *J* = 7.2 Hz, 2H), 7.53 (td, *J* = 7.8 Hz, 1.2 Hz, 1H), 7.45 (d, *J* = 7.8 Hz, 1H), 7.38 (t, *J* = 7.2 Hz, 1H), 7.26-7.28 (m, 2H), 7.14 (dd, *J* = 8.4 Hz, 2.4 Hz, 1H), 7.06 (d, *J* = 2.4 Hz, 1H), 6.95-6.97 (m, 1H), 3.89 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 197.9, 159.8, 156.3, 148.8, 140.8, 137.7, 136.2, 132.3, 132.0, 129.9, 129.3, 128.0, 122.0, 121.3, 116.1, 114.0, 55.6; IR (neat): υ_{max} 1666, 1595, 1462, 1286, 1230, 741, 700 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{19}H_{15}NO_2Na$ $[M + Na]^+$: 312.1000; found: 312.1003.

(4-Fluorophenyl)(5-methoxy-2-(pyridin-2 yl)phenyl)methanone, 3u, Scheme 2. The same general procedure was followed by using 2-(4-methoxyphenyl)pyridine (37.0 mg, 0.2 mmol, 1.0 equiv), 2-(4-fluorophenyl)-2-oxoacetic acid (67 mg, 0.4 mmol, 2.0 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a white solid, (39.0 mg, 64%), mp 74-76 °C. ^1H NMR (600 MHz, $CDCl_3$): δ 8.31 (d, *J* = 4.8 Hz, 1H), 7.70-7.73 (m, 3H), 7.55 (td, *J* = 7.8 Hz, 1.8 Hz, 1H), 7.46 (d, *J* = 7.8 Hz, 1H), 7.14 (dd, *J* = 8.4 Hz, 2.4 Hz, 1H), 7.4 (d, *J* = 2.4 Hz, 1H), 6.98 (dd, *J* = 7.2 Hz, 4.8 Hz,1H), 6.93 (t, *J* = 8.4 Hz, 2H), 3.89 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 196.3, 165.1 (d, *J* = 252.0 Hz), 159.9, 156.1, 148.8, 140.5, 136.3, 134.2 (d, *J* = 3.0 Hz), 131.8 (d, *J* = 9.0 Hz), 129.9, 121.9, 121.4, 116.1, 115.1 (d, *J* = 21.0 Hz), 113.9, 55.6; IR (neat): υ_{max} 1668, 1596, 1464, 1289, 1230, 850 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{19}H_{14}FNO_2Na$ $[M + Na]^+$: 330.0906; found: 330.0872.

(4-Bromophenyl)(5-methoxy-2-(pyridin-2-yl)phenyl)methanone, 3v, Scheme 2. The same general procedure was followed by using 2-(4-methoxyphenyl)pyridine (37.0 mg, 0.2 mmol, 1.0 equiv), 2-(4-bromophenyl)-2-oxoacetic acid (92 mg, 0.4 mmol, 2.0 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a yellowish solid, (49.0 mg, 67%), mp 107-109 °C. ^1H NMR (600 MHz, $CDCl_3$): δ 8.28 (d, *J* = 4.8 Hz, 1H), 7.72 (d, *J* = 8.4 Hz, 1H), 7.55-7.57 (m, 3H), 7.48 (d, *J* = 7.8 Hz, 1H), 7.39 (d, *J* = 9.0 Hz, 2H), 7.13 (dd, *J* = 9.0 Hz, 3.0 Hz, 1H), 7.03 (d, *J* = 3.0 Hz, 1H), 6.98 (dd, *J* = 7.2 Hz, 4.8 Hz, 1H), 3.88 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 196.8, 159.9, 155.8, 148.7, 140.3, 136.7, 136.4, 131.7, 131.3, 130.7, 129.8, 127.2, 121.7, 121.5, 116.2, 113.9, 55.6; IR (neat): υ_{max} 1669, 1586, 1464, 1230, 841, 757 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{19}H_{14}BrNO_2Na$ $[M + Na]^+$: 390.0106; found: 390.0104.

For the spectroscopy data of compounds **3f**, **3g**, **3h**, **3i**, **3j**, **3k**, **3l**, **3o**, **3p**, **3q**, **3r**, **3s**, **3w** and **3x** see the ESI.

General experimental procedure for the decarbonylative acylation reaction between 2-phenylpyridines and phenylglyoxals, Scheme 3.

To an oven-dried 10 mL sealed tube, a mixture of 2-phenylpyridines (0.2 mmol, 1.0 equiv), phenylglyoxals (0.3 mmol, 1.5 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II)acetate (4.6 mg, 0.02 mmol, 0.1 equiv) was taken and dry MeCN (3.0 mL) was added to it. After flushing with nitrogen, immediately the vessel was sealed with a screw cap. The reaction mixture was allowed to stir for 16 h at room temperature. After that the reaction mixture was quenched with $NaHCO_3$. Then the reaction mixture was poured into water (40 mL) and extracted with ethyl acetate (40 mL). The organic layer was washed with water (10 mL) and brine (10 mL), dried over anhydrous Na_2SO_4 and the solvent was

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evaporated under reduced pressure. The crude product was purified by column chromatography using ethyl acetate/hexane as eluent to afford the desired product.

(5-fluoro-2-(pyridin-2-yl)phenyl)(phenyl)methanone, 3y, Scheme 3.[26b] The same general procedure was followed by using 2-(4-fluorophenyl)pyridine (35.0 mg, 0.2 mmol, 1.0 equiv), 2-oxo-2-phenylacetaldehyde (40 mg, 0.3 mmol, 1.5 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a white solid, (26.5 mg, 48%), mp 149-151 ^{o}C. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.36 (d, *J* = 4.8 Hz, 1H), 7.78 (dd, *J* = 8.4 Hz, 4.8 Hz, 1H), 7.69 (d, *J* = 7.8 Hz, 2H), 7.58 (td, *J* = 7.8 Hz, 1.2 Hz, 1H), 7.48 (d, *J* = 7.8 Hz, 1H), 7.42 (t, *J* = 7.2 Hz, 1H), 7.25-7.33 (m, 4H), 7.03 (dd, *J* = 6.6 Hz, 5.4 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 196.4, 162.6 (d, *J* = 249.0 Hz), 155.6, 148.9, 141.4 (d, *J* = 4.5 Hz), 137.2, 136.5, 135.5 (d, *J* = 1.5 Hz), 132.6, 130.6 (d, *J* = 7.5 Hz), 129.3, 128.1, 122.4, 122.0, 117.1 (d, *J* = 21.0 Hz), 116.1 (d, *J* = 22.5 Hz); IR (neat): υ_{max} 1661, 1588, 1279, 846, 789 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{18}H_{12}FNONa$ $[M + Na]^+$: 300.0801; found: 300.0802.

(5-chloro-2-(pyridin-2-yl)phenyl)(phenyl)methanone, 3z, Scheme 3.[15b] The same general procedure was followed by using 2-(4-chlorophenyl)pyridine (38.0 mg, 0.2 mmol, 1.0 equiv), 2-oxo-2-phenylacetaldehyde (40 mg, 0.3 mmol, 1.5 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a white solid, (33.0 mg, 56%), mp 113-115 ^{o}C. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.36 (d, *J* = 4.2 Hz, 1H), 7.74 (d, *J* = 8.4 Hz, 1H), 7.69 (dd, *J* = 8.4 Hz, 1.2 Hz, 2H), 7.57-7.61 (m, 2H), 7.52 (d, *J* = 1.8 Hz, 1H), 7.50 (d, *J* = 8.4 Hz, 1H), 7.40-7.43 (m, 1H), 7.30 (t, *J* = 7.8 Hz, 2H), 7.04-7.06 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 195.8, 155.4, 148.9, 141.0, 137.7, 137.2, 136.6, 134.9, 132.6, 130.2, 129.9, 129.3, 129.0, 128.2, 122.4, 122.2; IR (neat): υ_{max} 1688, 1588, 1458, 1276, 786 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{18}H_{12}ClNONa$ $[M + Na]^+$: 316.0505; found: 316.0502.

(5-bromo-2-(pyridin-2-yl)phenyl)(phenyl)methanone, 3aa, Scheme 3.[29a] The same general procedure was followed by using 2-(4-bromophenyl)pyridine (47.0 mg, 0.2 mmol, 1.0 equiv), 2-oxo-2-phenylacetaldehyde (40 mg, 0.3 mmol, 1.5 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a white solid, (28.5 mg, 42%), mp 109-111 ^{o}C. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.36 (d, *J* = 4.2 Hz, 1H), 7.74 (dd, *J* = 7.8 Hz, 1.8 Hz, 1H), 7.66-7.69 (m, 4H), 7.59 (td, *J* = 7.8 Hz, 1.8 Hz, 1H), 7.50 (d, *J* = 7.8 Hz, 1H), 7.42 (t, *J* = 7.2 Hz, 1H), 7.30 (t, *J* = 7.8 Hz, 2H), 7.04 (dd, *J* = 6.6 Hz, 4.8 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 196.2, 155.5, 149.0, 141.1, 138.2, 137.2, 136.6, 133.1, 132.6, 131.8, 130.1, 129.4, 128.2, 123.0, 122.4, 122.3; IR (neat): υ_{max} 1668, 1587, 1458, 1275, 786 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{18}H_{12}BrNONa$ $[M + Na]^+$: 360.0000, 361.9979; found: 359.9971, 361.9979.

(3-methyl-2-(pyridin-2-yl)phenyl)(phenyl)methanone, 3ab, Scheme 3.[26b] The same general procedure was followed by using 2-(o-tolyl)pyridine (34.0 mg, 0.2 mmol, 1.0 equiv), 2-oxo-2-phenylacetaldehyde (40 mg, 0.3 mmol, 1.5 equiv), potassium persulfate (108 mg, 0.4 mmol, 2.0 equiv) and palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a colourless oil, (27.0 mg, 50%). ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.49 (d, *J* = 4.2 Hz, 1H), 7.65 (d, *J* = 7.2 Hz, 2H), 7.60 (t, *J* = 7.2 Hz, 1H), 7.46 (d, *J* = 7.2 Hz, 1H), 7.40-7.43 (m, 2H), 7.37 (d, *J* = 7.2 Hz, 1H), 7.28-7.31 (m, 3H), 7.08 (dd, *J* = 6.6 Hz, 5.4 Hz, 1H), 2.30 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 198.2, 157.3, 148.7, 140.0, 137.6, 136.8, 136.1, 132.6, 132.5, 129.9, 129.8, 128.0, 127.9, 126.2, 125.3, 121.9, 20.1; IR (neat): υ_{max} 1666, 1589, 1282, 752, 707 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{19}H_{15}NONa$ $[M + Na]^+$: 296.1051; found: 296.1062.

General experimental procedure for the dehydrogenative acylation reaction between 2-phenylpyridines and aldehydes, Scheme 4.

To an oven-dried 7 mL clear vial, a mixture of 2-phenylpyridines (0.2 mmol, 1.0 equiv) and palladium(II)acetate (4.6 mg, 0.02 mmol, 0.1 equiv) was taken and dry MeCN (3.0 mL) was added to it. The corresponding aldehydes (0.3 mmol 1.5 equiv) were added to the reaction mixture. After flushing with nitrogen for 30 seconds, immediately the vessel was sealed with a screw cap. Then aq. TBHP (82 µL, 0.6 mmol, 3.0 equiv) was added to the reaction mixture via micro-litter syringe. The reaction mixture was allowed to stir for 36 h at room temperature. After completion (as indicated by TLC), the reaction mixture was quenched with $NaHCO_3$. Then the reaction mixture was poured into water (40 mL) and extracted with ethyl acetate (40 mL). The organic layer was washed with water (10 mL) and brine (10 mL), dried over anhydrous Na_2SO_4 and the solvent was evaporated under reduced pressure. The crude product was purified by column chromatography using ethyl acetate/hexane as eluent to afford the desired product.

Methyl 4-(2-(pyridin-2-yl)benzoyl)benzoate, 3ad, Scheme 4.[31a] The same general procedure was followed by using 2-phenylpyridine (31.0 mg, 0.2 mmol, 1.0 equiv), palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv), methyl 4-formylbenzoate (49 mg, 0.3 mmol, 1.5 equiv), and aq. *tert*-butyl hydroperoxide (82 µL, 0.6 mmol, 3.0 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a white solid, (45.5 mg, 72%). mp 100-102 ^{o}C. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.28-8.29 (m, 1H), 7.91 (d, *J* = 8.4 Hz, 2H), 7.78 (d, *J* = 7.2 Hz, 1H), 7.71 (d, *J* = 8.4 Hz, 2H), 7.61-7.64 (m, 1H), 7.54-7.59 (m, 4H), 6.98-7.00 (m, 1H), 3.89 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 197.4, 166.3, 156.1, 148.8, 141.6, 139.4, 139.0, 136.5, 132.8, 130.5, 129.2, 128.9, 128.8, 128.4, 122.2, 122.1, 52.3; IR (neat): υ_{max} 1717,

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1664, 1281, 1107, 743 cm^{-1}; HRMS (EI, m/z) calcd. for $C_{20}H_{15}NO_3$ $[M]^+$: 317.1052; found: 317.1053.

(3,4-Dichlorophenyl)(2-(pyridin-2-yl)phenyl)methanone, 3ah, Scheme 4. The same general procedure was followed by using 2-phenylpyridine (31.0 mg, 0.2 mmol, 1.0 equiv), palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv), 3,4-dichlorobenzaldehyde (52.5 mg, 0.3 mmol, 1.5 equiv), and aq. *tert*-butyl hydroperoxide (82 µL, 0.6 mmol, 3.0 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a white solid, (31.5 mg, 48%), mp 135-137 °C. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.33 (d, *J* = 4.2 Hz, 1H), 7.80 (d, *J* = 7.2 Hz, 1H), 7.78 (d, *J* = 1.8 Hz, 1H), 7.63-7.66 (m, 2H), 7.59 (d, *J* = 7.8 Hz, 1H), 7.55 (t, *J* = 7.2 Hz, 1H), 7.49-7.53 (m, 2H), 7.34 (d, *J* = 8.4 Hz, 1H), 7.06-7.08 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 195.7, 156.0, 148.8, 139.3, 138.5, 137.8, 136.6, 136.4, 132.5, 130.9, 130.6, 130.1, 129.0, 128.8, 128.4, 128.2, 122.2, 122.1; IR (neat): υ_{max} 1666, 1580, 1434, 1380, 1275, 955, 747 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{18}H_{11}Cl_2NONa$ $[M + Na]^+$: 350.0115; found: 350.0117.

(3,4-Dimethoxyphenyl)(2-(pyridin-2-yl)phenyl)methanone, 3ai, Scheme 4. The same general procedure was followed by using 2-phenylpyridine (31.0 mg, 0.2 mmol, 1.0 equiv), palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv), 3,4-dimethoxybenzaldehyde (50 mg, 0.3 mmol, 1.5 equiv), and aq. *tert*-butyl hydroperoxide (82 µL, 0.6 mmol, 3.0 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a white solid, (48.0 mg, 75%). mp 108-110 °C. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.42-8.43 (m, 1H), 7.77 (d, *J* = 7.8 Hz, 1H), 7.58-7.60 (m, 1H), 7.56 (td, *J* = 7.8 Hz, 1.8 Hz, 1H), 7.49-7.52 (m, 2H), 7.46 (d, *J* = 7.8 Hz, 1H), 7.44 (d, *J* = 1.8 Hz, 1H), 7.16 (dd, *J* = 8.4 Hz, 2.4 Hz, 1H), 7.03-7.05 (m, 1H), 6.66 (d, *J* = 8.4 Hz, 1H), 3.96 (s, 3H), 3.85 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 197.0, 157.0, 152.7, 149.2, 148.6, 139.51, 139.48, 136.2, 130.8, 130.0, 129.0, 128.9, 128.3, 125.2, 122.9, 121.9, 110.9, 109.6, 55.91, 55.89; IR (neat): υ_{max} 1656, 1588, 1511, 1269, 1128, 753 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{20}H_{17}NO_3Na$ $[M + Na]^+$: 342.1106; found: 342.1112.

(4-Methyl-2-(pyridin-2-yl)phenyl)(*p*-tolyl)methanone, 3aj, Scheme 4. The same general procedure was followed by using 2-(*m*-tolyl)pyridine (34.0 mg, 0.2 mmol, 1.0 equiv), palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv), 4-methylbenzaldehyde (36 µL, 0.3 mmol, 1.5 equiv), and aq. *tert*-butyl hydroperoxide (82 µL, 0.6 mmol, 3.0 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a white solid, (46.0 mg, 80%), mp 128-130 °C. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.42 (d, *J* = 4.2 Hz, 1H), 7.58-7.61 (m, 3H), 7.53 (td, *J* = 7.8 Hz, 1.8 Hz, 1H), 7.43 (t, *J* = 7.2 Hz, 2H), 7.32 (d, *J* = 7.8 Hz, 1H), 7.07 (d, *J* = 8.4 Hz, 2H), 7.01-7.03 (m, 1H), 2.50 (s, 3H), 2.31 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 198.0, 157.2, 149.1, 143.0, 140.3, 139.8, 136.8, 136.1, 135.4, 129.8, 129.7, 129.2, 129.0, 128.7, 123.1, 121.8, 21.6, 21.4; IR (neat): υ_{max} 1661, 1605, 1467, 1286, 931, 756 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{20}H_{17}NONa$ $[M + Na]^+$: 310.1208; found: 310.1217.

(4-Methoxy-2-(pyridin-2-yl)phenyl)(*p*-tolyl)methanone, 3ak, Scheme 4. The same general procedure was followed by using 2-(3-methoxyphenyl)pyridine (37.0 mg, 0.2 mmol, 1.0 equiv), palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv), 4-methylbenzaldehyde (36 µL, 0.3 mmol, 1.5 equiv), and aq. *tert*-butyl hydroperoxide (82 µL, 0.6 mmol, 3.0 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a colourless oil, (36.5 mg, 60%). ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.43-8.44 (m, 1H), 7.58 (d, *J* = 8.4 Hz, 2H), 7.52-7.55 (m, 2H), 7.39 (d, *J* = 7.8 Hz, 1H), 7.27 (d, *J* = 7.8 Hz, 1H), 7.02-7.07 (m, 4H), 3.93 (s, 3H), 2.31 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 197.3, 161.0, 157.2, 149.1, 142.9, 142.1, 136.1, 135.6, 132.0, 131.3, 129.8, 128.7, 123.4, 122.0, 114.6, 113.7, 55.5, 21.5; IR (neat): υ_{max} 2926, 1659, 1603, 1467, 1284, 1223, 1032, 758 cm^{-1}; HRMS (EI, m/z) calcd. for $C_{20}H_{17}NO_2$ $[M]^+$: 303.1259; found: 303.1256.

(4-(Pyridin-2-yl)-[1,1'-biphenyl]-3-yl)(*p*-tolyl)methanone, 3am, Scheme 4. The same general procedure was followed by using 2-([1,1'-biphenyl]-4-yl)pyridine (46.5 mg, 0.2 mmol, 1.0 equiv), palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv), 4-methylbenzaldehyde (36 µL, 0.3 mmol, 1.5 equiv), and aq. *tert*-butyl hydroperoxide (82 µL, 0.6 mmol, 3.0 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a white solid, (38.5 mg, 55%), mp 145-147 °C. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.42 (d, *J* = 4.2 Hz, 1H), 7.88 (d, *J* = 7.8 Hz, 1H), 7.84 (dd, *J* = 7.8 Hz, 1.8 Hz, 1H), 7.76 (d, *J* = 1.8 Hz, 1H), 7.67-7.69 (m, 4H), 7.59 (td, *J* = 7.8 Hz, 1.8 Hz, 1H), 7.55 (d, *J* = 7.8 Hz, 1H), 7.47 (t, *J* = 7.8 Hz, 2H), 7.39 (t, *J* = 7.2 Hz, 1H), 7.11 (d, *J* = 7.8 Hz, 2H), 7.04-7.06 (m, 1H), 2.34 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 197.9, 156.5, 149.1, 143.2, 141.2, 140.2, 139.7, 138.3, 136.3, 135.2, 129.8, 129.3, 128.9, 128.8, 128.5, 127.9, 127.5, 127.1, 122.6, 121.9, 21.6; IR (neat): υ_{max} 1662, 1596, 1462, 1245, 758 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{25}H_{19}NONa$ $[M + Na]^+$: 372.1364; found: 372.1364.

1-(3-(4-Methylbenzoyl)-4-(pyridin-2-yl)phenyl)ethanone, 3an, Scheme 4. The same general procedure was followed by using 1-(4-(pyridin-2-yl)phenyl)ethanone (39.5 mg, 0.2 mmol, 1.0 equiv), palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv), 4-methylbenzaldehyde (36 µL, 0.3 mmol, 1.5 equiv), and aq. *tert*-butyl hydroperoxide (82 µL, 0.6 mmol, 3.0 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a white solid, (28.0 mg, 45%), mp 89-91 °C. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.41-8.42 (m, 1H), 8.19 (dd, *J* = 7.8 Hz, 1.2 Hz, 1H), 8.07 (d, *J* = 1.8 Hz, 1H), 7.89 (d, *J* = 8.4 Hz, 1H), 7.59-7.64 (m, 3H), 7.55 (d, *J* = 7.8 Hz, 1H), 7.08-7.11 (m, 3H), 2.66 (s, 3H), 2.34 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 197.1, 197.0, 155.6, 149.2, 143.6, 143.5, 140.0, 136.6, 136.5, 134.8, 129.6, 129.5, 129.2, 128.9, 122.9, 122.6, 26.8, 21.6; IR (neat): υ_{max} 2925, 1682, 1599, 1300, 1243, 756 cm^{-1}; HRMS (EI, m/z) calcd. for $C_{21}H_{17}NO_2$ $[M]^+$: 315.1259; found: 315.1248.

(2-(Pyridin-2-yl)phenyl)(thiophen-3-yl)methanone, 3ap, Scheme 4. The same general procedure was followed by using 2-phenylpyridine (31.0 mg, 0.2 mmol, 1.0 equiv), palladium(II)

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acetate (4.5 mg, 0.02 mmol, 0.1 equiv), thiophene-3-carbaldehyde (26 µL, 0.3 mmol, 1.5 equiv), and aq. *tert*-butyl hydroperoxide (82 µL, 0.6 mmol, 3.0 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a colourless oil, (30.0 mg, 56%). ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.46 (d, *J* = 4.2 Hz, 1H), 7.77 (d, *J* = 7.2 Hz, 1H), 7.58-7.62 (m, 4H), 7.52 (t, *J* = 7.2 Hz, 1H), 7.49 (d, *J* = 7.8 Hz, 1H), 7.42 (d, *J* = 4.8 Hz, 1H), 7.15-7.16 (m, 1H), 7.07-7.09 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 191.8, 157.0, 149.2, 142.8, 140.0, 139.4, 136.3, 133.9, 130.3, 129.2, 128.7, 128.4, 127.6, 125.8, 122.9, 121.9; IR (neat): υ_{max} 1656, 1586, 1428, 1273, 858, 752 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{16}H_{11}NSONa$ $[M + Na]^+$: 288.0459; found: 288.0460.

3-Methyl-1-(2-(pyridin-2-yl)phenyl)but-2-en-1-one, 3as, Scheme 4. The same general procedure was followed by using 2-phenylpyridine (31.0 mg, 0.2 mmol, 1.0 equiv), palladium(II) acetate (4.5 mg, 0.02 mmol, 0.1 equiv), 3-methylbut-2-enal (29 µL, 0.3 mmol, 1.5 equiv), and aq. *tert*-butyl hydroperoxide (82 µL, 0.6 mmol, 3.0 equiv). Column chromatography (SiO_2, eluting with 7:3 hexane/ethyl acetate) afforded the desired product as a colourless oil, (15.0 mg, 76%). ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.64 (d, *J* = 4.8 Hz, 1H), 7.72 (td, *J* = 7.8 Hz, 1.8 Hz, 1H), 7.62 (d, *J* = 7.2 Hz, 1H), 7.58 (d, *J* = 7.8 Hz, 1H), 7.52-7.54 (m, 1H), 7.46-7.48 (m, 2H), 7.22-7.24 (m, 1H), 6.03 (s, 1H), 2.08 (s, 3H), 1.72 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 196.0, 158.1, 154.8, 149.2, 142.1, 139.4, 136.1, 130.1, 129.5, 128.4, 128.1, 125.3, 123.5, 122.0, 27.5, 20.7; IR (neat): υ_{max} 2926, 1666, 1615, 1434, 1236, 1012, 752 cm^{-1}; HRMS (ESI, m/z) calcd. for $C_{16}H_{15}NONa$ $[M + Na]^+$: 260.1051; found: 260.1057.

For the spectroscopy data of compounds **3ac**, **3ae**, **3af**, **3ag**, **3al**, **3ao**, **3aq**, **3ar**, **3at**, **3au** and **3av** see the ESI.

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Palladium-Catalyzed Decarboxylative, Decarbonylative and Dehydrogenative C(sp^2)-H Acylation at *Room Temperature*

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A practical and environmentally benign protocol for C(sp^2)-H acylation at room temperature has been achieved via entropically favourable decarboxylative, decarbonylative and cross-dehydrogenative manifolds.