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2,3-Diarylquinoxaline directed mono *ortho*-aroylation via cross-dehydrogenative coupling using aromatic aldehydes or alkylbenzenes as aroyl surrogate

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ABSTRACT

2,3-Diarylquinoxaline directed mono *ortho*-aroylation protocol has been developed using aromatic aldehydes or alkybenzenes as aroyl surrogates. Out of the four available *ortho* sp^2 C–H bonds in the two aryl rings of 2,3-diarylquinoxaline one of the C–H bond is selectively *ortho*-aroylated. The reaction proceeds via the aroyl radical path in the case of aromatic aldehydes while the alkylbenzenes follow either an aroyl radical or a benzyl radical path. Varieties of functional groups present as substituents in 2,3-diarylquinoxalines, aromatic aldehydes and alkylbenzenes are tolerated under the present reaction conditions.

1. Introduction

Recently a number of C–H bond functionalization methods are available to synthetic organic community. Functionalizations of such ubiquitous C–H bonds build complex molecular architecture through the construction of C–C and C–X (X=heteroatoms) bonds.[1] The two most commonly adopted approaches are the directing group assisted C–H functionalization[1g,l,2] and the cross-dehydrogenative coupling (CDC).[3] In the later approach both the coupling partners are attached through their C–H bonds, whereas in the former only *ortho* C–H bonds are functionalized via the chelation of metals through heteroatoms, such as nitrogen and oxygen. These two techniques make the synthetic tools highly appreciable due to the requirement of minimal steps and atom economy point of view. In this perspective Pd-catalyzed *ortho* C–H functionalizations have been successfully employed for the synthesis of aryl ketones.[4] Due to the use of stoichiometric amount of reagents the classical Friedel–Craft acylation[5] has been lately replaced by transition metal catalyzed cross-coupling processes.[6] To avoid the substrate pre-functionalization in the cross-coupling reactions C–H functionalizations have come into salvage. Substrates having different directing groups, such as 2-arylpyridine,[4a,7] 2-arylbenzazoles,[8] anilides,[4b,9] *o*-methyl oxime,[10] and benzamides[11] have been successfully *ortho* aroylated using aromatic aldehydes or alcohols as aroyl surrogates. Recently, ligand directed decarboxylation of alpha-keto acids strategies have been used for the *ortho*-aroylations.[4c–e,12] Following our approach of directing group assisted *ortho*-aroylation using alkylbenzenes as aroyl surrogates[4f] several other similar reports have emerged in the literature.[4g,h,13]

Quinoxaline is an important pharmacophoric unit possessing diverse biologically activities and are potentially useful in materials science.[14] Thus, any derivatization of 2,3-diarylquinoxaline is expected to generate further interests. There are three instances of *ortho*-functionalization of 2,3-diarylquinoxaline moiety viz. acetoxylation,[15] fluorination[16] and nitration.[17] Till to date there is no precedence of *ortho*-aroylation of this important scaffold using any of the aroyl surrogates via the CDC approach.

2. Results and discussion

In light of the above-mentioned *ortho*-aroylation processes, an initial trial was attempted with the model substrate 2,3-diphenylquinoxaline (**1**) through a chelation-assisted CDC approach. 2,3-Diphenylquinoxaline (**1**) (1 equiv) was treated with benzaldehyde (1.2 equiv) in the presence of $Pd(OAc)_2$ (2 mol %) and *tert*-butyl hydroperoxide (TBHP in decane) (1 equiv) in 1,2-dichloroethane (DCE) (2 mL) at 110 °C, which yielded the product (**1a**) in an isolated yield of 35% (Table 1, entry 1). The formation of mono *ortho*-aroylation of 2,3-diphenylquinoxaline was confirmed by spectroscopic data analysis (see Supplementary data). To

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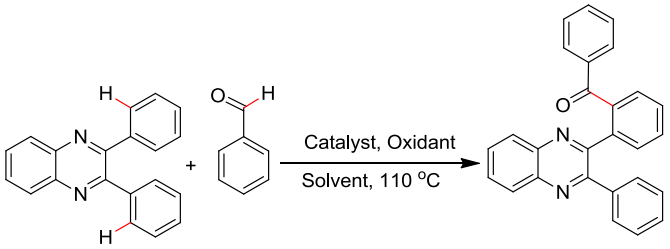
Table 1
Screening of reaction conditions



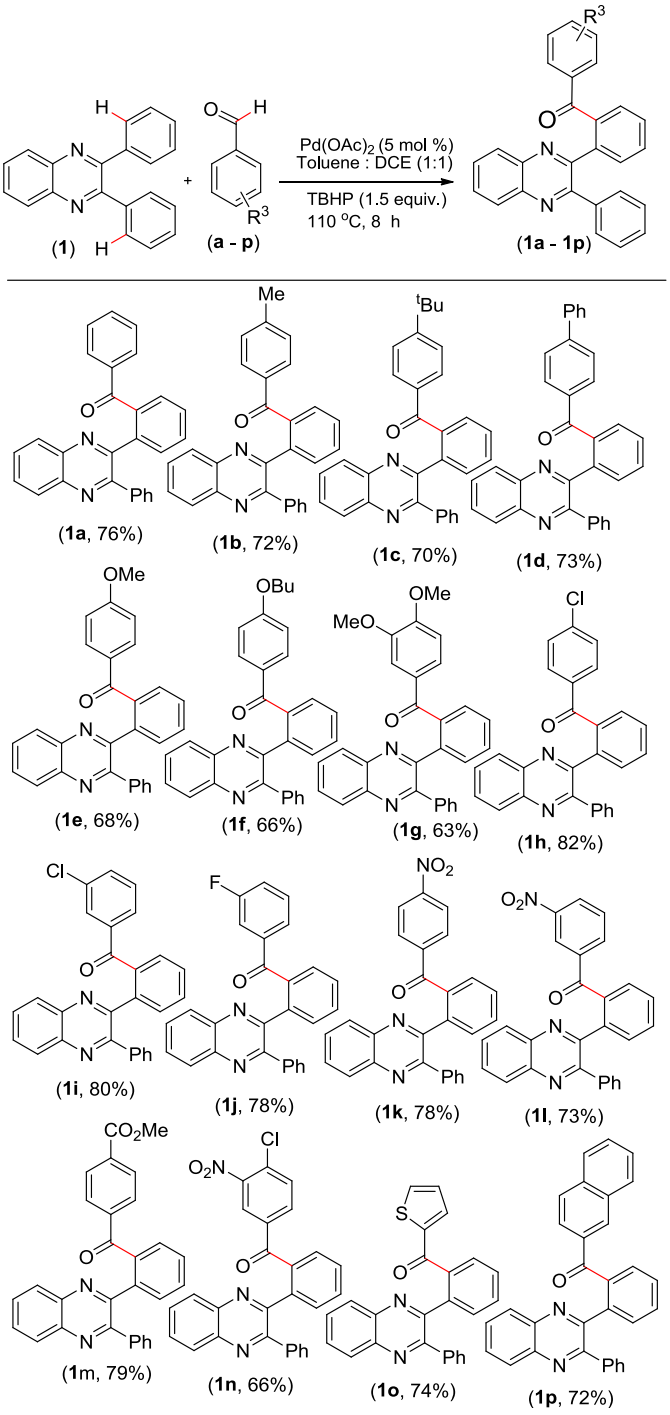
Entry	Catalyst (mol %)	Solvent	Oxidant	Yield (%)[a]
1	$Pd(OAc)_2$ (2.0)	DCE	TBHP	35
2	$Pd(OAc)_2$ (2.0)	DMF	TBHP	00
3	$Pd(OAc)_2$ (2.0)	DMSO	TBHP	00
4	$Pd(OAc)_2$ (2.0)	Cyclohexane	TBHP	32
5	$Pd(OAc)_2$ (2.0)	*o*-Xylene	TBHP	41
6	$Pd(OAc)_2$ (2.0)	Dioxane	TBHP	42
7	$Pd(OAc)_2$ (2.0)	Toluene	TBHP	50
8	$Pd(OAc)_2$ (2.0)	Toluene:DCE	TBHP	58[b]
9	$Pd(OAc)_2$ (5.0)	Toluene:DCE	TBHP	67[b]
10	$Pd(OAc)_2$ (10.0)	Toluene:DCE	TBHP	72[b]
11	$PdBr_2$ (5.0)	Toluene:DCE	TBHP	10[b]
12	$PdCl_2$ (5.0)	Toluene:DCE	TBHP	7[b]
13	$Pd(TFA)_2$ (5.0)	Toluene:DCE	TBHP	46[b]
14	$Pd(OAc)_2$ (5.0)	Toluene:DCE	$(PhCO_2)_2$	00[b]
15	$Pd(OAc)_2$ (5.0)	Toluene:DCE	$K_2S_2O_8$	00[b]
16	$Pd(OAc)_2$ (5.0)	Toluene:DCE	TBHP	70[c]
17	$Pd(OAc)_2$ (5.0)	Toluene:DCE	TBHP	76[d]

[a] Isolated yield after 8 h, TBHP was added in four equal lots at 1.5 h interval.
[b] 1:1 ratio of toluene and DCE.
[c] 1.2 equiv of TBHP.
[d] 1.5 equiv of TBHP.

improve the yield of the product, other reaction parameters, such as solvent, catalyst, oxidants and their quantities were varied. The use of polar aprotic solvents, such as DMF or DMSO failed to give any traces of product (Table 1, entries 2 and 3). Solvent toluene was found to be better compared to cyclohexane, *o*-xylene and dioxane tested (Table 1, entries 4–7).

A careful scrutiny of the literature revealed that toluene to be the most appropriate solvent towards Pd-catalyzed *ortho*-aroylation[4b,8a,9a,b,10] while for *ortho*-C–H functionalization of 2,3-diphenylquinoxaline DCE to be the most effective solvent.[15–17] Therefore we contemplate that the use of mixed solvents might improve the product yield. Interestingly, the use of mixture of toluene:DCE (in 1:1 ratio) gave an improved yield of 58% (Table 1, entry 8). The yield improved up to 67% when the catalyst loading was increased to 5 mol % (Table 1, entry 9). However, no significant improvement in the yield (72%) was observed even when the catalyst loading was increased to 10 mol % (Table 1, entry 10). Other palladium catalysts, such as $PdCl_2$ and $PdBr_2$ in lieu of $Pd(OAc)_2$ were found to give inferior yields (Table 1, entries 11 and 12). The catalyst $Pd(TFA)_2$ was good but slightly less effective compared to $Pd(OAc)_2$ (Table 1 entry 13). Changing the oxidant from TBHP to benzoyl peroxide and $K_2S_2O_8$ gave no desired *ortho*-aroylated product (Table 1, entries 14 and 15) suggesting the superiority of TBHP as the oxidant. Interestingly, increasing the oxidant (TBHP) quantity from 1 to 1.2 equiv and further to 1.5 equiv improved the yield to 70% and 76%, respectively (Table 1, entries 16 and 17). Thus, after a series of experimentations catalyst $Pd(OAc)_2$ (5 mol %), oxidant TBHP (1.5 equiv) and aroyl source aldehyde (1.2 equiv) in an equivolume mixture of toluene and 1,2-dichloroethane (2 mL) was found to be the best condition and was subsequently implemented for further reactions.

Using the above optimized condition this methodology was further applied to 2,3-diphenylquinoxaline (**1**) with a variety of aromatic aldehydes. Both activated and deactivated aromatic aldehydes coupled efficiently with 2,3-diphenylquinoxaline (**1**) giving the desired *ortho*-aroylated products in good to moderate yields. Aldehydes containing moderately electron-donating groups, such as *p*-Me (**b**), *p*-^{t}Bu (**c**) and *p*-Ph (**d**) afforded aroylated products (**1b**), (**1c**) and (**1d**), respectively in good yields (Scheme 1). The transformation was equally successful for aromatic aldehydes possessing electron-donating substituents, such as *p*-OMe (**e**), *p*-OBu (**f**) and 3,4-di-OMe (**g**) giving the products (**1e**), (**1f**) and (**1g**), respectively in moderate yields. The structure of mono-*ortho*-aroylated product (**1e**) was further confirmed by X-ray crystallographic analysis as shown in Fig. 1.



Scheme 1. Scope of aldehydes in Pd-catalyzed *ortho*-aroylation of 2,3-diphenylquinoxaline. Confirmed by IR, ^{1}H NMR and ^{13}C NMR spectroscopy. Yields after silica gel column chromatography.

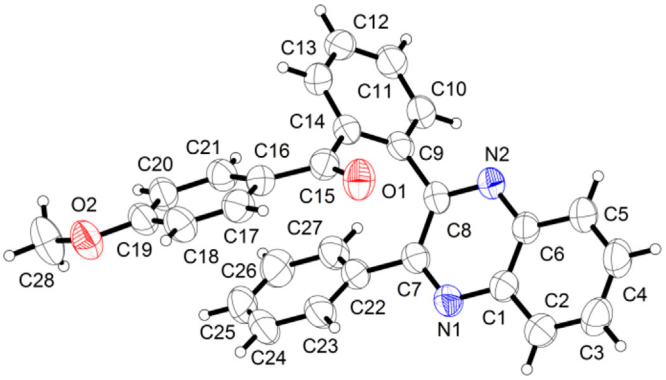
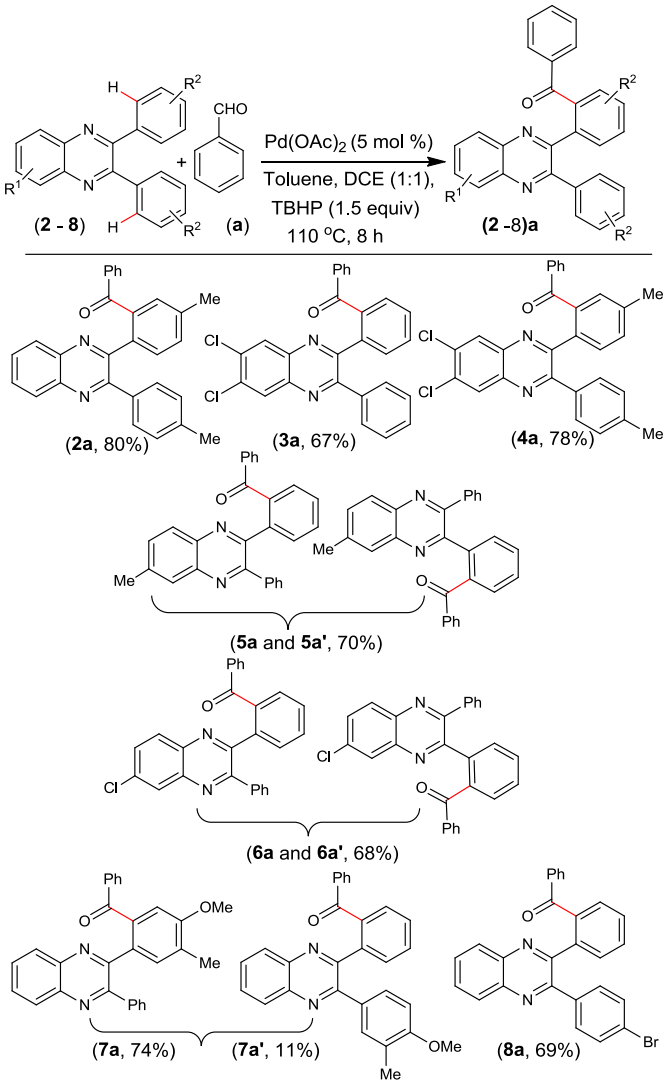


Fig. 1. ORTEP view of compound **1e**.

Aromatic aldehydes possessing weekly electron-withdrawing groups, such as *p*-Cl (**h**), *m*-Cl (**i**) and *m*-F (**j**) also underwent efficient conversion giving corresponding *ortho*-aroylated products (**1h**), (**1i**) and (**1j**), respectively in good yields. Aldehydes possessing strongly electron-withdrawing groups, such as *p*-NO_2 (**k**), *m*-NO_2 (**l**) and *p*-CO_2Me (**m**) served as good aroyl sources and provided the desired *ortho*-aroylated products (**1k**), (**1l**) and (**1m**), respectively in good yields. Aromatic aldehydes possessing two electron-withdrawing groups as in 4-Cl–3-NO_2 benzaldehyde (**n**) gave slightly lower yield of product (**1n**) when employed as an aroyl surrogate. Heteroaromatic aldehyde (**o**) and fused aromatic aldehyde (**p**) also afforded good yields of their respective *ortho*-aroylated products (**1o**) and (**1p**) when reacted with 2,3-diphenylquinoxaline (**1**) under the optimized condition (Scheme 1).

This selective *ortho*-aroylation strategy was further extended to other substituted 2,3-diphenylquinoxalines keeping benzaldehydes as fixed aroylating partner (Scheme 2). 2,3-Diphenyl substituted-quinoxaline containing electron-donating group (–Me) in its aryl rings gave excellent yield of the desire aroylated product (**2a**) when reacted with benzaldehyde under the reaction conditions. Chloro substituents present in the quinoxaline ring as in (**3**) on reaction with benzaldehyde (**a**) afforded decent yield (67%) of the mono-*ortho*-aroylated product (**3a**). However 2,3-aryl ring bearing methyl groups and the quinoxaline possessing chloro groups as in (**4**) afforded better yield of mono-*ortho*-aroylated product (**4a**). Methyl substituted unsymmetrical 2,3-diphenylquinoxaline (**5**) upon reaction with benzaldehyde gave an inseparable regioisomeric mono *ortho*-aroylated products **5a**/**5a**′ in the ratio of 5:4 as can be judged from its ^1H and ^{13}C NMR spectra. However it was not possible to assign the exact regioisomers (**5a** or **5a**′) from its ^1H and ^{13}C NMR spectra. The chloro substituted unsymmetrical 2,3-diphenylquinoxaline (**6**) also gave identical results and the two regioisomers **6a**/**6a**′ were obtained in the ratio of 5:3. Further *ortho*-aroylation reactions were performed using unsymmetrically substituted 2,3-diarylquinoxalines with benzaldehyde as the aroylating source. In case of substrate (**7**) containing two electron-donating substituents (–Me and –OMe) in one of the phenyl ring provided regioisomeric mono *ortho*-aroylated products (**7a** and **7a**′) in the ratio of 6.7:1 suggesting the preferential oxidative palladation at the more electron rich aryl ring. For substrate (**8**) containing weakly electron-withdrawing substituent (–Br) in one of the phenyl ring of 2,3-diarylquinoxaline *ortho*-aroylation takes place at the other electron neutral phenyl ring giving product (**8a**) exclusively reconfirming the preferential *ortho*-aroylation at comparatively electron rich phenyl ring.

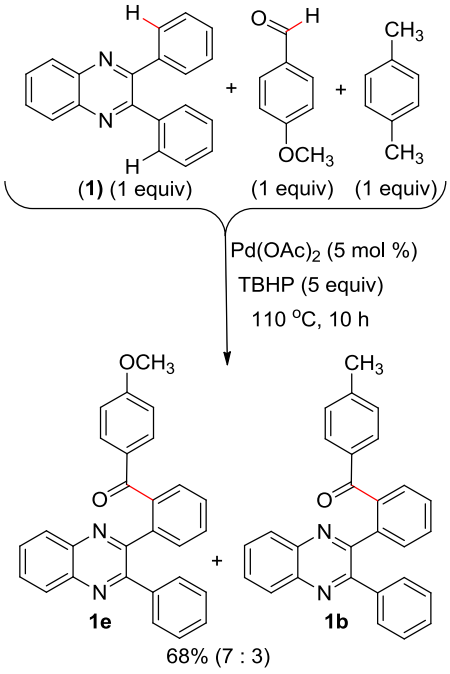
Recently the inert alkylbenzenes have been exploited as excellent aroyl surrogates by us[4f] and several others.[4g,h,13a,b] Although in present reaction alkylbenzene (toluene) has been used



Scheme 2. Scope of 2,3-diphenylquinoxaline in Pd-catalyzed *ortho*-aroylation with benzaldehyde. Confirmed by IR, ^1H NMR and ^{13}C NMR spectroscopy. Yields after silica gel column chromatography.

as the solvent in presence of aromatic aldehyde but no *ortho*-aroylated product derived from toluene was observed in any of the reactions. This is possibly due to the presence of sub-stoichiometric amount of aromatic aldehydes (1.2 equiv) with respect to the substrate quinoxalines in the reaction. These observations suggest that perhaps the aromatic aldehyde is a facile aroyl source compared to alkylbenzene. To confirm this 2,3-diphenylquinoxaline (**1**) was treated with an equimolar mixture of *p*-methoxy benzaldehyde (1 equiv) and *p*-xylene (1 equiv) under the experimental conditions. The progress of the reaction was monitored by TLC and GC over a period of 10 h. During the first 1 h product derived from *p*-methoxy benzaldehyde (**1e**) was formed with no traces of (**1b**) (Scheme 3). After 2 h aroylated products derived from *p*-xylene (**1b**) was observed in about 10% yield. At the end of the reaction (10 h) products (**1e**) and (**1b**) were isolated in the ratio of 7:3 in overall 68% yield, there by suggesting the higher *ortho*-aroylating ability of aromatic aldehyde over alkylbenzene.

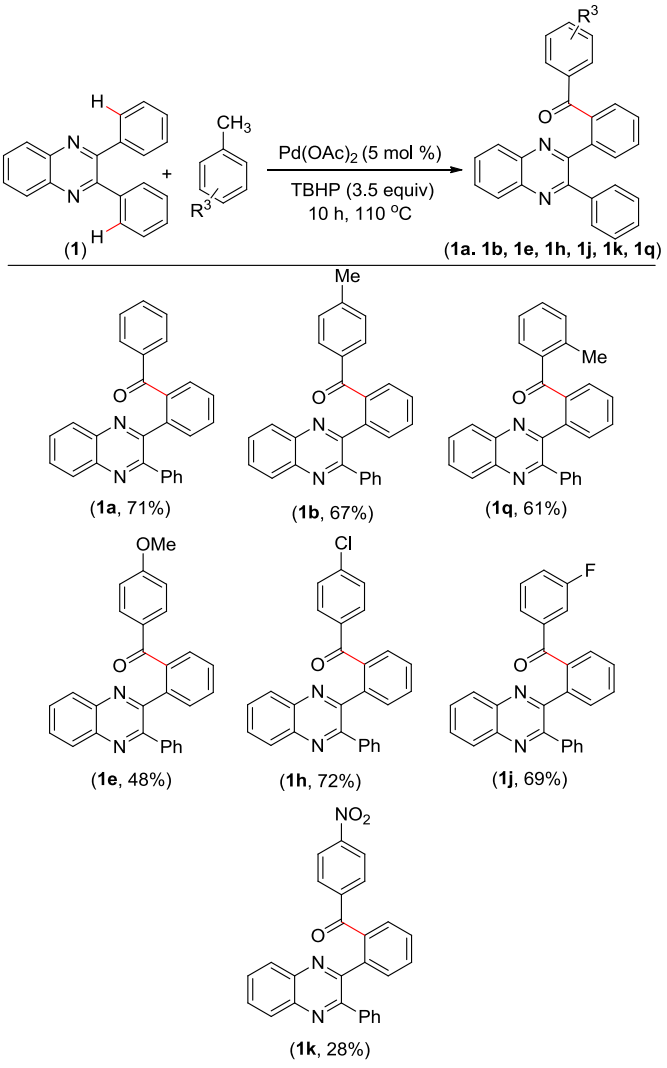
Taking cues from this and from our previous work[4f] under the forcing conditions alkylbenzenes may serve as aroyl surrogate towards *ortho*-aroylation of 2,3-diphenylquinoxalines. Thus, in the absence of aldehyde using toluene as the aroyl source as well as



Scheme 3. Competitive reaction of aromatic aldehyde and alkylbenzene.

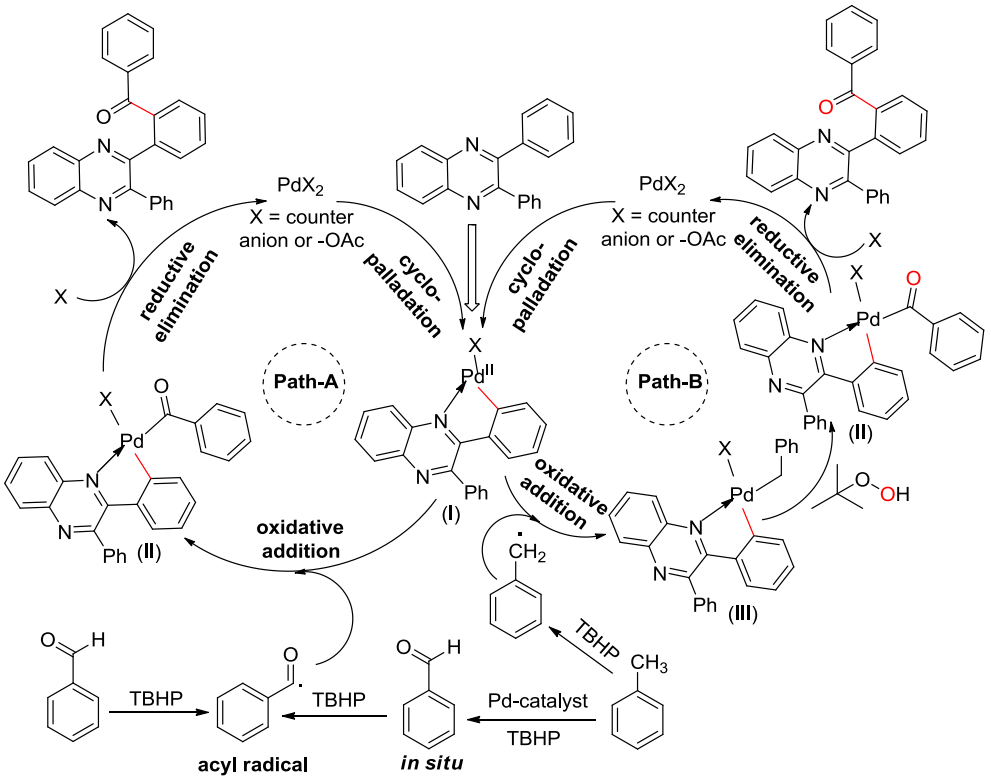
a solvent under the present optimized condition the product (**1a**) was obtained in 22% yield. Interestingly when the oxidant (TBHP) quantity was increased to 3.5 equiv from 1.5 equiv and toluene was used as the sole solvent in place of toluene/DCE mixture the yield of the product improved to 71% whereas using 2 or 3 equiv of oxidant (TBHP) the yields obtained were 41% and 63%, respectively. However increasing the oxidant quantity to 4 equiv and even to 5 equiv no significant improvement in the yield was observed. Thus in lieu of aromatic aldehydes various alkylbenzenes were reacted with 2,3-diphenylquinoxaline (**1**) and the results are summarized in Scheme 4. Alkylbenzenes, such as *p*-xylene, *o*-xylene served as good aroyl sources giving *ortho*-aroylated products (**1b**) and (**1q**), respectively. Alkylbenzene possessing electron-donating group as in *p*-methoxy toluene gave low yield (46%) of *ortho*-aroylated product (**1e**). This methodology was also equally successful for alkylbenzene possessing weakly electron-withdrawing groups. Thus *p*-chlorotoluene and *m*-fluorotoluene both gave good yields of their *ortho*-aroylated products (**1h**) and (**1j**), respectively (Scheme 4). Alkylbenzene possessing strongly electron-withdrawing groups, such as *p*-nitrotoluene provided *ortho*-aroylated product (**1k**) in a meager yield of 28%. This is in part due to the inheterogenity of the reaction mixture because of the insolubility of *p*-nitrotoluene in the reaction medium. When 1,2 dicholoroethane was used as the solvent for the above reaction no doubt the reaction mixture was homogeneous but the transformation was not at all effective. It may be mentioned here that the yields obtained using alkylbenzenes were slightly lower as compared to the use of analogous aromatic aldehydes.

To ascertain the nature of the mechanism(s) involved in each of these reactions a series of experiments were performed. Rate retardation with <10% conversion was observed when the reaction was performed in the presence of a radical scavenger 2,2,6,6-tetramethylpiperidine-1-oxyl (TEMPO, 1 equiv). This suggests the radical nature of the reactions for both aroyl surrogates viz. aromatic aldehyde and alkylbenzene. A mechanism similar to *ortho*-aroylation of 2-arylbenzazole (and other directing groups) using aryl aldehyde as aroyl surrogate can be proposed for this reactions as shown in Scheme 5, path-A.[8a,9a,10] Cyclopalladation of 2,3-diphenylquinoxaline leads to the formation of intermediate (**I**)



Scheme 4. Scope of alkylbenzenes in Pd-catalyzed *ortho*-aroylation with quinoxalines. Confirmed by IR, ^{1}HNMR and ^{13}CNMR spectroscopy. Isolated yield.

followed by the oxidative addition of the in situ generated aroyl radical obtained from aryl aldehyde and to form a dimeric $Pd^{(III)}$[18] intermediate (**II**). In the final stage reductive elimination gave *ortho*-aroylated product regenerating the active Pd^{II} species for further catalytic cycle (Scheme 5, path-A). Using toluene as the aroyl equivalent it is expected that the reaction may proceed via the sequential oxidation of toluene to benzyl alcohol and to aldehyde, which then enters in to the catalytic path-A (Scheme 5) giving *ortho*-aroylated product. Alternatively, the mechanism is expected to proceed similar to the one recently proposed by us during analogous substrate directed *ortho*-aroylation where a benzyl radical insertion followed by the benzylic oxidation has been proposed.[4f] In the later case the *o*-palladated intermediate (**I**) undergoes oxidative addition with the benzylic radical[19] generated in situ by the action of toluene and TBHP to give intermediate (**III**). Further oxidation at the benzylic carbon of intermediate (**III**) with TBHP provides intermediate (**II**) (path-B, Scheme 5). Reductive elimination of the Pd-catalyst from the intermediate (**II**) provides *ortho*-aroylated product. No di-*ortho*-aroylation was observed in the second *ortho* position of the aryl ring or in the two available *ortho* positions of the second aryl ring even with an excess of aroylating source, which may be due to the loss of planarity of the pendant aryl rings with respect to the quinoxaline moiety. The out of the plane orientation of the two aryl rings can be clearly seen from one of the mono-*ortho*-aroylated product (**1e**) as shown in Fig. 1.



Scheme 5. Plausible mechanistic cycle.

3. Conclusions

In conclusion, we have developed a selective mono *ortho*-aroylation protocol for 2,3-diphenylquinoxaline employing Pd-catalyst in the presence of oxidant TBHP in an air atmosphere using aryl aldehyde or alkylbenzene as aroyl precursors. This is the first such aroylation protocol for 2,3-diphenylquinoxaline. Using aldehyde as aroyl surrogate the reaction goes via aroyl radical path while the use of alkylbenzene as aroyl surrogate it can proceed either via an aroyl radical or by a benzyl radical path.

4. Experimental section

4.1. General remarks

All the reagents were commercial grade and purified according to the established procedures. Organic extracts were dried over anhydrous sodium sulfate. Solvents were removed in a rotary evaporator under reduced pressure. Silica gel (60–120 mesh size) was used for the column chromatography. Reactions were monitored by TLC on silica gel 60 F_{254} (0.25 mm). NMR spectra were recorded in $CDCl_3$ with tetramethylsilane as the internal standard for ^1H NMR (400 and 600 MHz) $CDCl_3$ solvent as the internal standard for ^{13}C NMR (100 and 150 MHz). MS spectra were recorded using ESI mode. IR spectra were recorded in KBr or neat.

4.2. Synthesis of phenyl(2-(3-phenylquinoxalin-2-yl)phenyl) methanone (1a) from 2,3-diphenylquinoxaline (1) and benzaldehyde

In an oven-dried 25 mL round bottom flask containing 1 mL each of toluene and dichloroethane (DCE), 2,3-diphenylquinoxaline (**1**) (0.141 g, 0.5 mmol), benzaldehyde (0.064 g, 0.6 mmol) and $Pd(OAc)_2$ (0.006 g, 0.025 mmol) was added sequentially. Then reaction mixture was kept in an oil bath preheated to 110 °C. TBHP (0.75 mmol) was added in four equal lots at an intervals of 1.5 h. The progress of the reaction was monitored by TLC after each addition. After completion of the reaction (8 h) the reaction mixture was cooled to room temperature and was admixed with water (5 mL). The product was extracted with ethyl acetate (3×10 mL) and the combined organic layer was washed with saturated sodium bicarbonate solution (5 mL), dried over anhydrous sodium sulfate (Na_2SO_4) and evaporated under reduced pressure. The crude product so obtained was purified by silica gel column chromatography (hexane/ethyl acetate, 10:0.8) to give pure phenyl(2-(3-phenylquinoxalin-2-yl)phenyl)methanone (**1a**) (0.147 g, yield 76%). The identity and purity of the product was confirmed by spectroscopic analysis.

4.3. Synthesis of phenyl(2-(3-phenylquinoxalin-2-yl)phenyl) methanone (1a) from 2,3-diphenylquinoxaline (1) and toluene

In an oven-dried 25 mL round bottom flask containing 2 mL of toluene, 2,3-diphenylquinoxaline (**1**) (0.141 g, 0.5 mmol) and $Pd(OAc)_2$ (0.006 g, 0.025 mmol) was added in sequence. The reaction mixture was the kept in an oil bath preheated to 110 °C. TBHP (1.75 mmol) was added in four equal lots at an intervals of 2 h. The progress of the reaction was monitored by TLC after each addition. After completion of the reaction (10 h) the reaction mixture was cooled to room temperature and was admixed with water (5 mL). The product was extracted with ethyl acetate (3×10 mL). The combined organic layer was washed with saturated sodium bicarbonate solution (5 mL), dried over anhydrous sodium sulfate (Na_2SO_4) and evaporated under reduced pressure. The crude product so obtained was purified by silica gel column chromatography (hexane/ethyl acetate, 10:0.8) to give pure phenyl(2-(3-phenylquinoxalin-2-yl)phenyl)methanone (**1a**) (0.137 g, yield 71%). The identity and purity of the product was confirmed by spectroscopic analysis.

*4.3.1. Phenyl(2-(3-phenylquinoxalin-2-yl)phenyl)methanone (**1a**).* The general procedure was followed. The product was purified by column chromatography (8% EtOAc/hexane) to give the title compound **1a** (147 mg, 76%) as Gummy; R_f (10% EtOAc/hexane) 0.45; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.13 (d, 1H, J=9.2 Hz, Ar. C–H), 8.01 (d, 1H, J=8.0 Hz, Ar. C–H), 7.75–7.69 (m, 2H, Ar. C–H), 7.66 (d, 1H, J=7.6 Hz, Ar. C–H), 7.61–7.57 (m, 1H, Ar. C–H), 7.45–7.39 (m, 7H, Ar. C–H), 7.28 (t, 2H, J=9.0 Hz, Ar. C–H), 7.23 (d, 1H, J=7.2 Hz, Ar. C–H), 7.16 (t, 2H, J=7.4 Hz, Ar. C–H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 196.5, 153.8, 153.4, 141.4, 141.0, 140.9, 138.8, 138.5, 137.1, 132.6, 131.6, 131.3, 130.3, 130.2, 130.1, 129.9, 129.8, 129.3, 129.1, 128.8, 128.3, 127.9; ν_{max} (KBr): 3052, 2922, 2851, 1789, 1736, 1658, 1597, 1572, 1475, 1446, 1393, 1342, 1315, 1291, 1269, 1218, 1059, 1025, 977, 937, 919, 761; HRMS (ESI) calcd for $C_{27}H_{18}N_2O$ ($M+H^+$) 387.1492, found 387.1485.

*4.3.2. (2-(3-Phenylquinoxalin-2-yl)phenyl)(p-tolyl)methanone (**1b**).* The general procedure was followed. The product was purified by column chromatography (6% EtOAc/hexane) to give the title compound **1b** (144 mg, 72%) as Gummy; R_f (10% EtOAc/hexane) 0.56; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.10 (d, 1H, J=7.2 Hz, Ar. C–H), 7.98 (d, 1H, J=7.2 Hz, Ar. C–H), 7.72–7.66 (m, 2H, Ar. C–H), 7.59 (d, 1H, J=7.6 Hz, Ar. C–H), 7.56–7.52 (m, 1H, Ar. C–H), 7.43–7.41 (m, 4H, Ar. C–H), 7.31 (d, 2H, J=8.4 Hz, Ar. C–H), 7.22 (d, 1H, J=5.6 Hz, Ar. C–H), 7.17–7.11 (m, 2H, Ar. C–H), 7.07 (d, 2H, J=8.0 Hz, Ar. C–H), 2.34 (s, 3H, Ar–CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 196.4, 153.9, 153.5, 143.4, 141.4, 141.1, 140.9, 139.2, 138.6, 134.7, 131.6, 131.1, 130.4, 130.3, 130.0, 129.8, 129.4, 129.2, 128.9, 128.8, 128.3, 127.9, 21.8; ν_{max} (KBr): 3054, 2912, 2846, 1659, 1602, 1443, 1399, 1338, 1262, 1050, 1024, 927, 801, 771; Anal. Calcd for $C_{28}H_{20}N_2O$: C 83.98, H 5.03, N 6.99; found: C 84.17, H 5.11, N 7.06.

*4.3.3. (4-(tert-Butyl)phenyl)(2-(3-phenylquinoxalin-2-yl)phenyl) methanone (**1c**).* The general procedure was followed. The product was purified by column chromatography (5% EtOAc/hexane) to give the title compound **1c** (155 mg, 70%) as Gummy; R_f (10% EtOAc/hexane) 0.67; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.11 (d, 1H, J=6.8 Hz, Ar. C–H), 8.02 (d, 1H, J=6.8 Hz, Ar. C–H), 7.74–7.68 (m, 2H, Ar. C–H), 7.66 (d, 1H, J=7.6 Hz, Ar. C–H), 7.59 (t, 1H, J=7.2 Hz, Ar. C–H), 7.49–7.45 (m, 2H, Ar. C–H), 7.41 (d, 2H, J=7.6 Hz, Ar. C–H), 7.36 (d, 2H, J=6.4 Hz, Ar. C–H), 7.27 (d, 2H, J=7.2 Hz, Ar. C–H), 7.21 (d, 1H, J=6.4 Hz, Ar. C–H), 7.14 (t, 2H, J=7.2 Hz, Ar. C–H), 1.28 (s, 9H, 3× aliphatic-CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 196.2, 156.3, 154.0, 153.6, 141.5, 141.1, 140.9, 139.2, 138.5, 134.4, 131.6, 131.3, 130.4, 130.2, 130.0, 129.8, 129.4, 129.3, 128.9, 128.3, 128.1, 124.9, 35.2, 31.2; ν_{max} (KBr): 3057, 2961, 2862, 1728, 1657, 1603, 1476, 1462, 1396, 1343, 1311, 1289, 1268, 1103, 1056, 1025, 977, 931, 845, 789, 763; HRMS (ESI) calcd for $C_{31}H_{26}N_2O$ ($M+H^+$) 443.2118, found 443.2110.

*4.3.4. [1,1′-Biphenyl]-4-yl(2-(3-phenylquinoxalin-2-yl)phenyl)methanone (**1d**).* The general procedure was followed. The product was purified by column chromatography (6% EtOAc/hexane) to give the title compound **1d** (168 mg, 73%) as Gummy; R_f (10% EtOAc/hexane) 0.50; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.13 (d, 1H, J=6.8 Hz, Ar. C–H), 8.03 (d, 1H, J=8.8 Hz, Ar. C–H), 7.75–7.70 (m, 2H, Ar. C–H), 7.67 (d, 1H, J=7.6 Hz, Ar. C–H), 7.62 (d, 1H, J=7.2 Hz, Ar. C–H), 7.58 (d, 3H, J=7.2 Hz, Ar. C–H), 7.53–7.45 (m, 10H, Ar. C–H), 7.39 (t, 1H, J=7.4 Hz, Ar. C–H), 7.25 (t, 1H, J=7.2 Hz, Ar. C–H), 7.17 (t, 1H, J=7.4 Hz, Ar. C–H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 196.1, 153.8, 153.5, 145.3, 141.4, 141.1, 140.9, 140.1, 138.9, 138.5, 135.8, 131.7, 131.3, 130.7, 130.4, 130.2, 130.1, 129.9, 129.4, 129.2, 129.1, 128.9, 128.3, 128.1, 127.4, 126.7; ν_{max} (KBr): 3054, 2956, 2920, 2851, 1651, 1603, 1478, 1397, 1344, 1311, 1275, 1215, 1155, 1056, 1026, 976, 934, 853, 798, 760; Anal. Calcd for $C_{33}H_{22}N_2O$: C 85.69, H 4.79, N 6.06; found: C 85.91, H 4.88, N 6.17.

*4.3.5. (4-Methoxyphenyl)(2-(3-phenylquinoxalin-2-yl)phenyl)methanone (**1e**).* The general procedure was followed. The product was purified by column chromatography (8% EtOAc/hexane) to give the title compound **1e** (141 mg, 68%) as Solid mp 112.8 °C; R_f (10% EtOAc/hexane) 0.33; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.13 (d, 1H, J=7.6 Hz, Ar. C–H), 8.06 (d, 1H, J=8.8 Hz, Ar. C–H), 8.00 (d, 1H, J=7.6 Hz, Ar. C–H), 7.75–7.68 (m, 2H, Ar. C–H), 7.62 (d, 1H, J=7.6 Hz, Ar. C–H), 7.58–7.54 (m, 1H, Ar. C–H), 7.44 (d, 4H, J=6.8 Hz, Ar. C–H), 7.22 (d, 1H, J=7.6 Hz, Ar. C–H), 7.16 (t, 2H, J=7.2 Hz, Ar. C–H), 6.95 (d, 1H, J=8.8 Hz, Ar. C–H), 6.78 (d, 2H, J=8.8 Hz, Ar. C–H), 3.83 (s, 3H, Ar–OCH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 195.3, 163.3, 153.9, 153.5, 141.4, 141.1, 140.7, 139.3, 138.5, 132.5, 132.4, 131.6, 130.3, 129.9, 129.8, 129.3, 129.2, 128.8, 128.2, 127.9, 113.8, 113.3, 55.6; ν_{max} (KBr): 2923, 2835, 2362, 1637, 1595, 1572, 1418, 1341, 1286, 1257, 1176, 1152, 1059, 1026, 924, 845, 775; HRMS (ESI) calcd for $C_{28}H_{20}N_2O_2$ ($M+H^+$) 417.1598, found 417.1603.

*4.3.6. (4-Butoxyphenyl)(2-(3-phenylquinoxalin-2-yl)phenyl)methanone (**1f**).* The general procedure was followed. The product was purified by column chromatography (6% EtOAc/hexane) to give the title compound **1f** (150 mg, 66%) as Gummy; R_f (10% EtOAc/hexane) 0.52; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.10 (d, 1H, J=7.6 Hz, Ar. C–H), 7.98 (d, 1H, J=7.6 Hz, Ar. C–H), 7.72–7.65 (m, 2H, Ar. C–H), 7.59 (d, 1H, J=7.6 Hz, Ar. C–H), 7.54–7.51 (m, 1H, Ar. C–H), 7.43–7.39 (m, 6H, Ar. C–H), 7.20 (d, 1H, J=7.2 Hz, Ar. C–H), 7.14 (t, 2H, J=7.0 Hz, Ar. C–H), 6.64 (d, 2H, J=9.2 Hz, Ar. C–H), 3.96 (t, 2H, J=6.4 Hz, Ar–OCH_2–), 1.79–1.72 (m, 2H, aliphatic-CH_2–), 1.51–1.43 (m, 2H, aliphatic-CH_2–), 0.97 (t, 3H, J=7.4 Hz, aliphatic-CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 195.3, 162.9, 154.0, 153.5, 141.4, 141.1, 140.8, 139.5, 138.6, 132.6, 131.6, 130.9, 130.4, 130.0, 129.8, 129.4, 129.3, 128.9, 128.3, 127.9, 113.8, 68.1, 31.3, 19.4, 13.9; ν_{max} (KBr): 3063, 2948, 2867, 1661, 1598, 1573, 1506, 1469, 1418, 1395, 1345, 1280, 1247, 1178, 1151, 1109, 1068, 1025, 977, 929, 841, 766; Anal. Calcd for $C_{31}H_{26}N_2O_2$: C 81.20, H 5.72, N 6.11; found: C 81.37, H 5.85, N 6.21.

*4.3.7. (3,4-Dimethoxyphenyl)(2-(3-phenylquinoxalin-2-yl)phenyl) methanone (**1g**).* The general procedure was followed. The product was purified by column chromatography (10% EtOAc/hexane) to give the title compound **1g** (140 mg, 63%) as Gummy; R_f (10% EtOAc/hexane) 0.09; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.05 (d, 1H, J=8.0 Hz, Ar. C–H), 7.93 (d, 1H, J=7.2 Hz, Ar. C–H), 7.67–7.61 (m, 2H, Ar. C–H), 7.54–7.46 (m, 2H, Ar. C–H), 7.42–7.35 (m, 4H, Ar. C–H), 7.19–7.09 (m, 4H, Ar. C–H), 6.93 (d, 1H, J=8.4 Hz, Ar. C–H), 6.63 (d, 1H, J=8.4 Hz, Ar. C–H), 3.83 (s, 3H, Ar–OCH_3), 3.76 (s, 3H, Ar–OCH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 195.3, 153.9, 153.5, 153.1, 148.7, 141.4, 141.1, 140.9, 139.3, 138.6, 131.6, 130.9, 130.4, 130.0, 129.9, 129.4, 129.2, 128.9, 128.2, 127.9, 125.8, 111.8, 109.7, 56.2, 56.0; ν_{max} (KBr): 3054, 2950, 2929, 2829, 1638, 1578, 1511, 1459, 1452, 1417, 1343, 1292, 1267, 1233, 1180, 1134, 1059, 1027, 978, 799, 763; HRMS (ESI) calcd for $C_{29}H_{22}N_2O_3$ ($M+H^+$) 447.1703, found 447.1694.

*4.3.8. (4-Chlorophenyl)(2-(3-phenylquinoxalin-2-yl)phenyl)methanone (**1h**).* The general procedure was followed. The product was purified by column chromatography (5% EtOAc/hexane) to give the title compound **1h** (172 mg, 82%) as Gummy; R_f (10% EtOAc/hexane) 0.58; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.14 (d, 1H, J=8.6 Hz, Ar. C–H), 8.01 (d, 1H, J=8.6 Hz, Ar. C–H), 7.77–7.70 (m, 2H, Ar. C–H), 7.67 (d, 1H, J=6.8 Hz, Ar. C–H), 7.61 (t, 1H, J=7.6 Hz, Ar. C–H), 7.47–7.39 (m, 4H, Ar. C–H), 7.34 (d, 2H, J=8.4 Hz, Ar. C–H), 7.27 (d, 3H, J=7.2 Hz, Ar. C–H), 7.17 (t, 2H, J=7.6 Hz, Ar. C–H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 195.4, 153.6, 153.4, 141.4, 141.1, 140.9, 139.9, 138.5, 135.5, 131.8, 131.6, 131.5, 130.4, 130.2, 130.0, 129.9, 129.4, 129.2, 128.9, 128.6, 128.4, 128.1; ν_{max} (KBr): 3058, 2918, 2845, 1661, 1585, 1479, 1443, 1398, 1343, 1270, 1218, 1174, 1090, 1054, 977, 929, 849, 771; HRMS (ESI) calcd for $C_{27}H_{17}ClN_2O$ ($M+H^+$) 421.1102, found 421.1094.

*4.3.9. (3-Chlorophenyl)(2-(3-phenylquinoxalin-2-yl)phenyl)methanone (**1i**).* The general procedure was followed. The product was

purified by column chromatography (6% EtOAc/hexane) to give the title compound **1i** (168 mg, 80%) as Gummy; R_f (10% EtOAc/hexane) 0.56; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.14 (d, 1H, J=6.8 Hz, Ar. C–H), 8.06 (d, 1H, J=7.6 Hz, Ar. C–H), 7.77–7.71 (m, 3H, Ar. C–H), 7.65 (t, 1H, J=7.4 Hz, Ar. C–H), 7.47 (t, 1H, J=7.6 Hz, Ar. C–H), 7.43 (s, 1H, Ar. C–H), 7.41–7.37 (m, 3H, Ar. C–H), 7.31 (t, 2H, J=8.4 Hz, Ar. C–H), 7.26 (t, 2H, J=2.8 Hz, Ar. C–H), 7.22–7.16 (m, 2H, Ar. C–H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 195.0, 153.5, 153.3, 141.4, 141.1, 141.0, 138.6, 138.4, 138.1, 134.1, 132.6, 131.9, 130.4, 130.2, 129.9, 129.4, 129.2, 129.0, 128.3, 128.2, 127.9; ν_{max} (KBr): 3053, 2918, 2845, 1660, 1591, 1568, 1477, 1440, 1418, 1390, 1344, 1289, 1257, 1219, 1154, 1071, 1054, 1025, 977, 939, 769; HRMS (ESI) calcd for $C_{27}H_{17}ClN_2O$ ($M+H^+$) 421.1102, found 421.1106.

*4.3.10. (3-Fluorophenyl)(2-(3-phenylquinoxalin-2-yl)phenyl)methanone (**1j**).* The general procedure was followed. The product was purified by column chromatography (6% EtOAc/hexane) to give the title compound **1j** (157 mg, 78%) as Gummy; R_f (10% EtOAc/hexane) 0.52; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.12 (d, 1H, J=8.0 Hz, Ar. C–H), 8.03 (d, 1H, J=8.0 Hz, Ar. C–H), 7.76–7.72 (m, 2H, Ar. C–H), 7.69 (s, 1H, Ar. C–H), 7.63 (t, 1H, J=6.7 Hz, Ar. C–H), 7.46 (t, 1H, J=7.6 Hz, Ar. C–H), 7.40 (t, 3H, J=7.6 Hz, Ar. C–H), 7.26–7.23 (m, 2H, Ar. C–H), 7.19 (d, 2H, J=9.2 Hz, Ar. C–H), 7.15 (d, 2H, J=7.2 Hz, Ar. C–H), 7.02 (d, 1H, J=9.2 Hz, Ar. C–H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 195.2, 163.5, 161.0, 153.6, 153.4, 141.5, 141.1, 141.0, 139.2, 138.5, 138.3, 131.9, 131.7, 130.4, 130.2, 130.0, 129.8, 129.7, 129.4, 129.2, 128.9, 128.4, 128.2, 125.8, 119.8, 119.6, 116.8, 116.6; ν_{max} (KBr): 3060, 2923, 1840, 1731, 1660, 1585, 1478, 1441, 1394, 1344, 1292, 1270, 1205, 1128, 1056, 1025, 977, 861, 840, 800, 769; HRMS (ESI) calcd for $C_{27}H_{17}FN_2O$ ($M+H^+$) 405.1402, found 405.1390.

*4.3.11. (4-Nitrophenyl)(2-(3-phenylquinoxalin-2-yl)phenyl)methanone (**1k**).* The general procedure was followed. The product was purified by column chromatography (8% EtOAc/hexane) to give the title compound **1k** (168 mg, 78%) as Gummy; R_f (10% EtOAc/hexane) 0.39; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.14 (d, 2H, J=8.8 Hz, Ar. C–H), 8.01 (d, 1H, J=8.0 Hz, Ar. C–H), 7.79–7.73 (m, 3H, Ar. C–H), 7.67 (t, 1H, J=7.6 Hz, Ar. C–H), 7.52–7.47 (m, 3H, Ar. C–H), 7.40 (d, 2H, J=6.8 Hz, Ar. C–H), 7.37 (t, 2H, J=7.0 Hz, Ar. C–H), 7.29 (d, 1H, J=6.4 Hz, Ar. C–H), 7.18 (t, 2H, J=7.4 Hz, Ar. C–H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 194.8, 153.1, 149.9, 142.1, 141.4, 141.1, 138.5, 137.7, 132.3, 132.1, 130.8, 130.4, 130.3, 130.2, 129.9, 129.4, 129.1, 128.5, 128.4, 123.2; ν_{max} (KBr): 3060, 2924, 2851, 1731, 1663, 1602, 1523, 1474, 1446, 1393, 1345, 1314, 1265, 1104, 1054, 1025, 977, 932, 864, 851, 771; HRMS (ESI) calcd for $C_{27}H_{17}N_3O_3$ ($M+H^+$) 432.1343, found 432.1333.

*4.3.12. (3-Nitrophenyl)(2-(3-phenylquinoxalin-2-yl)phenyl)methanone (**1l**).* The general procedure was followed. The product was purified by column chromatography (8% EtOAc/hexane) to give the title compound **1l** (157 mg, 73%) as Gummy; R_f (10% EtOAc/hexane) 0.31; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.29 (d, 1H, J=8.4 Hz, Ar. C–H), 8.11 (d, 1H, J=6.4 Hz, Ar. C–H), 8.03 (d, 1H, J=6.8 Hz, Ar. C–H), 7.98 (s, 1H, Ar. C–H), 7.79 (d, 2H, J=7.2 Hz, Ar. C–H), 7.75–7.69 (m, 3H, Ar. C–H), 7.52–7.47 (m, 2H, Ar. C–H), 7.37–7.33 (m, 3H, Ar. C–H), 7.15–7.09 (m, 3H, Ar. C–H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 193.9, 153.2, 147.7, 141.5, 141.1, 138.3, 137.4, 135.3, 132.4, 132.2, 130.5, 130.4, 130.2, 129.7, 129.5, 129.2, 129.0, 128.5, 128.4, 127.0, 124.9; ν_{max} (KBr): 3060, 2956, 2917, 2846, 1665, 1610, 1528, 1476, 1393, 1344, 1297, 1256, 1215, 1080, 1059, 1023, 971, 910, 768; HRMS (ESI) calcd for $C_{27}H_{17}N_3O_3$ ($M+H^+$) 432.1343, found 432.1336.

*4.3.13. Methyl 4-(2-(3-phenylquinoxalin-2-yl)benzoyl)benzoate (**1m**).* The general procedure was followed. The product was purified by column chromatography (8% EtOAc/hexane) to give the title compound **1m** (175 mg, 79%) as Gummy; R_f (10% EtOAc/hexane) 0.35; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.06 (d, 1H, J=7.6 Hz, Ar. C–H), 7.93 (d, 1H, J=7.2 Hz, Ar. C–H), 7.88 (d, 2H, J=6.8 Hz, Ar. C–H), 7.69–7.64 (m, 2H, Ar. C–H), 7.61 (d, 1H, J=7.6 Hz, Ar. C–H), 7.55 (t, 1H, J=7.4 Hz, Ar. C–H), 7.41–7.31 (m, 6H, Ar. C–H), 7.19 (t, 1H, J=7.0 Hz, Ar. C–H), 7.09 (t, 2H, J=7.0 Hz, Ar. C–H), 3.87 (s, 3H, Ar–CO_2CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 195.9, 166.4, 155.2, 153.5, 153.4, 141.5, 141.1, 141.0, 140.7, 138.6, 133.4, 131.9, 130.4, 130.2, 130.0, 129.9, 129.4, 129.3, 129.2, 128.9, 128.4, 128.2, 52.6; ν_{max} (KBr): 3058, 2949, 2840, 1723, 1661, 1476, 1435, 1404, 1344, 1274, 1104, 1056, 1018, 977, 931, 868, 798, 768; Anal. Calcd for $C_{29}H_{20}N_2O_3$: C 78.36, H 4.54, N 6.30; found: C 78.51, H 4.63, N 6.42.

*4.3.14. (4-Chloro-3-nitrophenyl)(2-(3-phenylquinoxalin-2-yl)phenyl)methanone (**1n**).* The general procedure was followed. The product was purified by column chromatography (8% EtOAc/hexane) to give the title compound **1n** (153 mg, 66%) as Gummy; R_f (10% EtOAc/hexane) 0.37; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.13 (d, 1H, J=6.8 Hz, Ar. C–H), 8.04 (d, 1H, J=7.6 Hz, Ar. C–H), 7.78 (t, 1H, J=7.0 Hz, Ar. C–H), 7.76–7.73 (m, 2H, Ar. C–H), 7.69 (t, 1H, J=7.6 Hz, Ar. C–H), 7.61–7.57 (m, 2H, Ar. C–H), 7.49 (t, 2H, J=6.8 Hz, Ar. C–H), 7.34–7.32 (m, 3H, Ar. C–H), 7.19 (t, 1H, J=7.2 Hz, Ar. C–H), 7.12 (t, 2H, J=7.4 Hz, Ar. C–H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 192.9, 153.1, 147.4, 141.5, 141.1, 138.4, 137.0, 136.4, 133.6, 132.6, 132.3, 131.9, 131.3, 130.6, 130.5, 130.3, 129.5, 129.2, 129.1, 128.6, 128.5, 126.8; ν_{max} (KBr): 3060, 2926, 2851, 1728, 1664, 1596, 1535, 1390, 1344, 1294, 1273, 1246, 1047, 1023, 977, 949, 908, 770; HRMS (ESI) calcd for $C_{27}H_{16}ClN_3O_3$ ($M+H^+$) 466.0953, found 466.0949.

*4.3.15. (2-(3-Phenylquinoxalin-2-yl)phenyl)(thiophen-2-yl)methanone (**1o**).* The general procedure was followed. The product was purified by column chromatography (8% EtOAc/hexane) to give the title compound **1o** (145 mg, 74%) as Gummy; R_f (10% EtOAc/hexane) 0.37; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.13 (d, 1H, J=8.0 Hz, Ar. C–H), 8.03 (d, 1H, J=8.4 Hz, Ar. C–H), 7.75–7.70 (m, 2H, Ar. C–H), 7.67 (d, 1H, J=8.0 Hz, Ar. C–H), 7.62–7.56 (m, 3H, Ar. C–H), 7.46 (t, 1H, J=7.4 Hz, Ar. C–H), 7.37 (d, 2H, J=8.4 Hz, Ar. C–H), 7.13 (t, 1H, J=6.6 Hz, Ar. C–H), 7.07 (d, 2H, J=7.6 Hz, Ar. C–H), 7.03 (t, 1H, J=3.6 Hz, Ar. C–H), 6.93 (t, 1H, J=4.2 Hz, Ar. C–H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 188.2, 153.7, 153.5, 143.8, 141.5, 141.2, 140.5, 138.7, 138.3, 135.3, 134.4, 131.9, 131.5, 130.4, 130.1, 129.9, 129.5, 129.4, 129.3, 128.8, 128.2, 128.1, 127.8; ν_{max} (KBr): 3059, 2913, 2851, 1621, 1515, 1474, 1409, 1353, 1342, 1297, 1052, 1023, 976, 845, 760; HRMS (ESI) calcd for $C_{25}H_{16}N_2OS$ ($M+H^+$) 393.1056, found 393.1051.

*4.3.16. Naphthalen-2-yl(2-(3-phenylquinoxalin-2-yl)phenyl)methanone (**1p**).* The general procedure was followed. The product was purified by column chromatography (6% EtOAc/hexane) to give the title compound **1p** (157 mg, 72%) as Gummy; R_f (10% EtOAc/hexane) 0.48; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.08 (d, 1H, J=6.4 Hz, Ar. C–H), 7.99 (d, 1H, J=7.6 Hz, Ar. C–H), 7.82 (d, 1H, J=8.0 Hz, Ar. C–H), 7.75 (d, 2H, J=8.4 Hz, Ar. C–H), 7.74 (s, 1H, Ar. C–H), 7.72–7.66 (m, 3H, Ar. C–H), 7.65–7.59 (m, 2H, Ar. C–H), 7.56 (t, 1H, J=7.4 Hz, Ar. C–H), 7.52–7.46 (m, 3H, Ar. C–H), 7.42 (d, 2H, J=6.8 Hz, Ar. C–H), 7.13–7.07 (m, 3H, Ar. C–H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 196.5, 153.9, 153.5, 141.4, 141.1, 139.1, 138.6, 135.4, 134.4, 132.3, 132.1, 131.7, 131.4, 130.4, 130.0, 129.8, 129.6, 129.4, 129.2, 128.9, 128.4, 128.2, 128.1, 127.8, 126.7, 125.3; ν_{max} (KBr): 3056, 2956, 2922, 2846, 1651, 1625, 1594, 1569, 1476, 1462, 1393, 1344, 1292, 1278, 1232, 1149, 1122, 1100, 1055, 1024, 977, 921, 905, 823, 789, 753; HRMS (ESI) calcd for $C_{31}H_{20}N_2O$ ($M+H^+$) 437.1648, found 437.1639.

*4.3.17. (5-Methyl-2-(3-(p-tolyl)quinoxalin-2-yl)phenyl)(phenyl)methanone (**2a**).* The general procedure was followed. The product was purified by column chromatography (5% EtOAc/hexane) to give the title compound **2a** (165 mg, 80%) as Gummy; R_f (10% EtOAc/hexane) 0.59; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.07 (d, 1H, J=8.4 Hz, Ar.

C–H), 7.98 (d, 1H, *J*=7.2 Hz, Ar. C–H), 7.71–7.64 (m, 2H, Ar. C–H), 7.55 (d, 1H, *J*=7.6 Hz, Ar. C–H), 7.44–7.38 (m, 4H, Ar. C–H), 7.29–7.25 (m, 4H, Ar. C–H), 7.22 (s, 1H, Ar. C–H), 6.93 (d, 2H, *J*=8.0 Hz, Ar. C–H), 2.39 (s, 3H, Ar–CH_3), 2.27 (s, 3H, Ar–CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 196.5, 153.7, 153.5, 141.3, 140.9, 138.8, 138.7, 138.2, 137.9, 137.1, 135.7, 132.4, 131.9, 131.5, 130.6, 130.3, 130.0, 129.7, 129.5, 129.2, 129.1, 128.9, 127.8, 21.3; ν_{max} (KBr): 3038, 2912, 1656, 1593, 1443, 1401, 1341, 1286, 1267, 1179, 1050, 996, 828, 779, 696; Anal. Calcd for $C_{29}H_{22}N_2O$: C 84.03, H 5.35, N 6.76; found: C 84.15, H 5.42, N 6.85.

*4.3.18. (2-(6,7-Dichloro-3-phenylquinoxalin-2-yl)phenyl)(phenyl) methanone (**3a**).* The general procedure was followed. The product was purified by column chromatography (4% EtOAc/hexane) to give the title compound **3a** (152 mg, 67%) as Gummy; R_f (10% EtOAc/hexane) 0.81; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.24 (s, 1H, Ar. C–H), 8.12 (s, 1H, Ar. C–H), 7.61–7.59 (m, 2H, Ar. C–H), 7.49 (d, 1H, *J*=7.2 Hz, Ar. C–H), 7.47–7.45 (m, 2H, Ar. C–H), 7.41–7.39 (m, 4H, Ar. C–H), 7.31 (t, 2H, *J*=7.6 Hz, Ar. C–H), 7.25 (t, 1H, *J*=7.2 Hz, Ar. C–H), 7.16 (t, 2H, *J*=6.6 Hz, Ar. C–H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 196.4, 155.2, 154.6, 140.4, 140.1, 139.8, 138.7, 137.8, 136.9, 134.4, 134.2, 132.8, 131.5, 130.4, 130.3, 130.1, 129.9, 129.8, 129.3, 128.3, 128.1; ν_{max} (KBr): 3059, 2956, 2917, 2846, 1655, 1596, 1574, 1441, 1389, 1337, 1315, 1271, 1190, 1152, 1103, 1075, 1056, 1024, 962, 926, 881, 831, 763, 725; HRMS (ESI) calcd for $C_{27}H_{16}Cl_2N_2O$ (M+H^+) 455.0712, found 455.0709.

*4.3.19. (2-(6,7-Dichloro-3-(p-tolyl)quinoxalin-2-yl)-5-methylphenyl)(phenyl)methanone (**4a**).* The general procedure was followed. The product was purified by column chromatography (4% EtOAc/hexane) to give the title compound **4a** (188 mg, 78%) as Gummy; R_f (10% EtOAc/hexane) 0.89; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.12 (s, 1H, Ar. C–H), 8.02 (s, 1H, Ar. C–H), 7.45 (d, 1H, *J*=7.6 Hz, Ar. C–H), 7.39 (t, 1H, *J*=7.4 Hz, Ar. C–H), 7.34–7.30 (m, 3H, Ar. C–H), 7.23–7.16 (m, 5H, Ar. C–H), 6.68 (d, 2H, *J*=7.6 Hz, Ar. C–H), 2.33 (s, 3H, Ar–CH_3), 2.20 (s, 3H, Ar–CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 196.5, 155.2, 154.7, 140.1, 139.8, 139.4, 138.8, 138.5, 137.7, 136.9, 135.1, 134.2, 133.9, 132.7, 132.2, 131.5, 130.9, 130.3, 130.1, 129.9, 129.8, 129.1, 127.9, 21.4; ν_{max} (KBr): 3054, 3027, 2920, 2846, 1736, 1655, 1596, 1447, 1386, 1336, 1315, 1293, 1270, 1210, 1182, 1105, 1050, 1020, 963, 880, 824, 800, 759, 715; HRMS (ESI) calcd for $C_{29}H_{20}Cl_2N_2O$ (M+H^+) 483.1025, found 483.1017.

*4.3.20. (2-(6-Methyl-3-phenylquinoxalin-2-yl)phenyl)(phenyl)methanone and (2-(7-methyl-3-phenylquinoxalin-2-yl)phenyl)(phenyl) methanone (**5a** and **5a′**).* The general procedure was followed. The product was purified by column chromatography (6% EtOAc/hexane) to give the title compound **5a** and **5a′** (140 mg, 70%) as Gummy; R_f (10% EtOAc/hexane) 0.55; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.99 (d, 1H, *J*=8.8 Hz, Ar. C–H), 7.88–7.86 (m, 2H, Ar. C–H), 7.76 (s, 1H, Ar. C–H), 7.62–7.59 (m, 2H, Ar. C–H), 7.57–7.50 (m, 5H, Ar. C–H), 7.45–7.38 (m, 12H, Ar. C–H), 7.29–7.24 (m, 5H, Ar. C–H), 7.20 (d, 2H, *J*=7.2 Hz, Ar. C–H), 7.15–7.12 (m, 4H, Ar. C–H), 2.56 (s, 3H, Ar–CH_3), 2.54 (s, 3H, Ar–CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 196.5, 153.5, 153.2, 152.7, 152.5, 141.3, 141.0, 140.9, 140.8, 140.4, 140.2, 139.8, 139.5, 138.8, 138.6, 137.1, 132.5, 132.3, 132.1, 131.6, 131.2, 130.2, 130.1, 129.9, 128.8, 128.7, 128.6, 128.2, 128.1, 127.9, 127.8, 21.9; IR (KBr, cm^{-1}): 3056, 3021, 2919, 2857, 1734, 1685, 1619, 1596, 1578, 1486, 1446, 1343, 1314, 1269, 1203, 1178, 1154, 1137, 1074, 1056, 1025, 979, 937, 925, 829, 805, 765, 753, 730; HRMS (ESI) calcd for $C_{28}H_{20}N_2O$ (M+H^+) 401.1648, found 401.1653.

*4.3.21. (2-(6-Chloro-3-phenylquinoxalin-2-yl)phenyl)(phenyl)methanone and (2-(7-chloro-3-phenylquinoxalin-2-yl)phenyl)(phenyl) methanone (**6a** and **6a′**).* The general procedure was followed. The product was purified by column chromatography (5% EtOAc/hexane) to give the title compound **6a** and **6a′** (143 mg, 68%) as Gummy; R_f (10% EtOAc/hexane) 0.74; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.05 (s, 1H, Ar. C–H), 7.99 (d, 1H, *J*=9.2 Hz, Ar. C–H), 7.92 (s, 1H, Ar. C–H), 7.87 (d, 1H, *J*=8.8 Hz, Ar. C–H), 7.61–7.58 (m, 2H, Ar. C–H), 7.56–7.49 (m, 4H, Ar. C–H), 7.42–7.37 (m, 6H, Ar. C–H), 7.34–7.30 (m, 7H, Ar. C–H), 7.23 (t, 4H, *J*=7.6 Hz, Ar. C–H), 7.19–7.16 (m, 3H, Ar. C–H), 7.10–7.07 (m, 4H, Ar. C–H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 196.5, 154.9, 154.3, 154.1, 153.6, 141.6, 141.3, 140.6, 139.9, 139.5, 138.7, 138.1, 138.0, 136.9, 135.6, 135.5, 132.7, 131.5, 131.4, 130.9, 130.8, 130.6, 130.3, 130.1, 129.1, 129.0, 128.3, 128.2, 128.0; IR (KBr, cm^{-1}): 3058, 2919, 1850, 1736, 1656, 1596, 1577, 1466, 1446, 1388, 1341, 1314, 1270, 1192, 1174, 1152, 1067, 1025, 978, 926, 876, 833, 804, 763, 727; HRMS (ESI) calcd for $C_{27}H_{17}ClN_2O$ (M+H^+) 421.1102, found 421.1110.

*4.3.22. (5-Methoxy-4-methyl-2(3-phenylquinoxalin-2-yl)phenyl)(-phenyl)methanone (**7a**).* The general procedure was followed. The product was purified by column chromatography (6% EtOAc/hexane) to give the title compound **7a** (159 mg, 74%) as Gummy; R_f (10% EtOAc/hexane) 0.27; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.09–8.05 (m, 2H, Ar. C–H), 7.72–7.67 (m, 2H, Ar. C–H), 7.52 (s, 1H, Ar. C–H), 7.38–7.31 (m, 6H, Ar. C–H), 7.21 (d, 2H, *J*=7.6 Hz, Ar. C–H), 7.18–7.13 (m, 2H, Ar. C–H), 6.85 (s, 1H, Ar. C–H), 3.76 (s, 3H, Ar–OCH_3), 2.33 (s, 3H, Ar–CH_3); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 196.1, 157.3, 153.7, 153.6, 141.1, 141.0, 138.6, 137.4, 137.2, 133.7, 132.8, 132.3, 130.8, 130.3, 129.9, 129.7, 129.2, 128.9, 128.7, 128.2, 127.8, 111.8, 55.7, 16.5; IR (KBr, cm^{-1}): 3442, 3058, 2961, 2924, 2841, 1657, 1598, 1564, 1502, 1478, 1562, 1446, 1339, 1271, 1242, 1220, 1171, 1127, 1110, 1055, 1027, 1013, 968, 907, 872, 813, 766, 732; HRMS (ESI) calcd for $C_{29}H_{22}N_2O_2$ (M+H^+) 431.1759, found 431.1766.

*4.3.23. (2-(3-(4-Methoxy-3-methylphenyl)quinoxalin-2-yl)phenyl)(-phenyl)methanone (**7a′**).* The general procedure was followed. The product was purified by column chromatography (6% EtOAc/hexane) to give the title compound **7a′** (23 mg, 11%) as Gummy; R_f (10% EtOAc/hexane) 0.22; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.10 (d, 1H, *J*=8.4 Hz, Ar. C–H), 8.05 (d, 1H, *J*=8.4 Hz, Ar. C–H), 7.78 (d, 1H, *J*=7.2 Hz, Ar. C–H), 7.74–7.69 (m, 2H, Ar. C–H), 7.66 (t, 1H, *J*=7.2 Hz, Ar. C–H), 7.47–7.43 (m, 3H, Ar. C–H), 7.36 (d, 2H, *J*=7.2 Hz, Ar. C–H), 7.27 (d, 2H, *J*=7.6 Hz, Ar. C–H), 7.16 (s, 1H, Ar. C–H), 7.07 (d, 1H, *J*=8.4 Hz, Ar. C–H), 6.52 (d, 1H, *J*=8.8 Hz, Ar. C–H), 3.76 (s, 3H, Ar–OCH_3), 1.91 (s, 3H, Ar–CH_3); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 195.7, 158.6, 153.9, 153.5, 141.6, 141.4, 141.0, 136.9, 132.9, 132.6, 131.8, 130.4, 130.2, 130.1, 129.9, 129.6, 129.5, 129.3, 129.2, 127.9, 127.8, 126.9, 109.5, 55.5, 16.1; IR (KBr, cm^{-1}): 3442, 3054, 2958, 2923, 2843, 1658, 1609, 1558, 1506, 1447, 1384, 1343, 1268, 1253, 1173, 1134, 1030, 927, 807, 765, 764, 737; HRMS (ESI) calcd for $C_{29}H_{22}N_2O_2$ (M+H^+) 431.1759, found 431.1764.

*4.3.24. (2-(3-(4-Bromophenyl)quinoxalin-2-yl)phenyl)(phenyl) methanone (**8a**).* The general procedure was followed. The product was purified by column chromatography (6% EtOAc/hexane) to give the title compound **8a** (160 mg, 69%) as Gummy; R_f (10% EtOAc/hexane) 0.40; ^{1}H NMR ($CDCl_3$, 600 MHz): δ 8.12 (d, 1H, *J*=8.4 Hz, Ar. C–H), 8.04 (d, 1H, *J*=7.2 Hz, Ar. C–H), 7.76–7.69 (m, 2H, Ar. C–H), 7.69 (d, 1H, *J*=7.8 Hz, Ar. C–H), 7.65–7.62 (m, 1H, Ar. C–H), 7.51 (t, 1H, *J*=7.5 Hz, Ar. C–H), 7.49–7.43(m, 3H, Ar. C–H), 7.41 (d, 2H, *J*=7.8 Hz, Ar. C–H), 7.35 (t, 2H, *J*=7.8 Hz, Ar. C–H), 7.28–7.23 (m, 3H, Ar–CH_3); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 196.4, 153.7, 152.4, 141.4, 141.3, 140.8, 137.5, 136.8, 132.9, 132.1, 131.8, 131.7, 131.5, 130.4, 130.3, 130.2, 130.1, 129.4, 129.3, 128.4, 128.2, 128.1, 123.8; IR (KBr, cm^{-1}): 3440, 3059, 2961, 2923, 2846, 1657, 1596, 1579, 1489, 1478, 1448, 1343, 1316, 1290, 1270, 1220, 1071, 1056, 1037, 1025, 1011, 977, 937, 927, 835, 807, 762, 733; HRMS (ESI) calcd for $C_{27}H_{17}BrN_2O$ (M+H^+) 465.0602, found 465.0608.

*4.3.25. (2-(3-Phenylquinoxalin-2-yl)phenyl)(o-tolyl)methanone (**1q**).* The general procedure was followed. The product was purified by column chromatography (5% EtOAc/hexane) to give the title compound **1q** (122 mg, 61%) as Gummy; R_f (10% EtOAc/hexane) 0.63; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.16 (d, 1H, J=8.8 Hz, Ar. C–H), 8.09 (d, 1H, J=6.8 Hz, Ar. C–H), 8.00 (d, 1H, J=6.4 Hz, Ar. C–H), 7.76–7.72 (m, 2H, Ar. C–H), 7.62–7.57 (m, 2H, Ar. C–H), 7.35–7.29 (m, 3H, Ar. C–H), 7.26–7.20 (m, 3H, Ar. C–H), 7.14 (d, 2H, J=6.8 Hz, Ar. C–H), 7.00 (t, 2H, J=7.2 Hz, Ar. C–H), 2.24 (s, 3H, Ar–CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 198.3, 154.4, 153.4, 141.3, 141.0, 140.9, 139.2, 138.8, 138.2, 137.5, 131.8, 131.7, 131.5, 131.0, 130.8, 130.3, 129.9, 129.7, 129.3, 129.1, 128.7, 128.3, 128.2, 124.8, 20.2; IR (KBr, cm^{-1}): 3049, 2961, 2921, 2851, 1742, 1659, 1593, 1563, 1454, 1342, 1297, 1260, 1215, 1098, 1025, 977, 927, 802, 763, 731; HRMS (ESI) calcd for $C_{28}H_{20}N_2O$ ($M+H^+$) 401.1648, found 401.1642.

4.4. Crystallographic description

Crystal data were collected with Bruker Smart Apex-II CCD diffractometer using graphite monochromated MoKα radiation (λ=0.71073 Å) at 298 K. Cell parameters were retrieved using SMART[20] software and refined with SAINT[21] on all observed reflections. Data reduction was performed with the SAINT software and corrected for Lorentz and polarization effects. Absorption corrections were applied with the program SADABS. The structure was solved by direct methods implemented in SHELX-97[22] program and refined by full-matrix least-squares methods on F^2. All non-hydrogen atomic positions were located in difference Fourier maps and refined anisotropically. The hydrogen atoms were placed in their geometrically generated positions. Colourless crystals were isolated in rectangular shape from acetonitrile at room temperature.

CCDC number for compound **1e**: CCDC 956425. This data can be obtained free of charge from the Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/datarequest/cif.

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Supplementary data

X-ray crystallographic data (CIF file) of **1e** as well as copies of ^{1}H and ^{13}C NMR spectra of products are available. Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.tet.2014.02.034.

References and notes

1. (a) Kakiuchi, F.; Murai, S. *Acc. Chem. Res.* **2002**, *35*, 826; (b) Dyker, G. *Handbook of C–H Transformations*; Wiley-VCH: Weinheim, Germany, 2005; (c) Godula, K.; Sames, D. *Science* **2006**, *312*, 67; (d) Campeau, L.-C.; Fagnou, K. *Chem. Soc. Rev.* **2007**, *36*, 1058; (e) Seregin, I. V.; Gevorgyan, V. *Chem. Soc. Rev.* **2007**, *36*, 1173; (f) Stuart, D. R.; Fagnou, K. *Science* **2007**, *316*, 1172; (g) Daugulis, O.; Do, H.-Q.; Shabashov, D. *Acc. Chem. Res.* **2009**, *42*, 1074; (h) Phipps, R. J.; Gaunt, M. J. *Science* **2009**, *323*, 159; (i) Chen, X.; Engle, K. M.; Wang, D.-H.; Yu, J.-Q. *Angew. Chem., Int. Ed.* **2009**, *48*, 5094; (j) Ackermann, L.; Vicente, R.; Kapdi, A. R. *Angew. Chem., Int. Ed.* **2009**, *48*, 9792; (k) Mkhalid, I. A. I.; Barnard, J. H.; Marder, T. B.; Murphy, J. M.; Hartwig, J. F. *Chem. Rev.* **2010**, *110*, 890; (l) Colby, D. A.; Bergman, R. G.; Ellman, J. A. *Chem. Rev.* **2010**, *110*, 624; (m) Bellina, F.; Rossi, R. *Chem. Rev.* **2010**, *110*, 1082; (n) Xu, L.-M.; Li, B.-J.; Yang, Z.; Shi, Z.-J. *Chem. Soc. Rev.* **2010**, *39*, 712; (o) Wang, D.-H.; Engle, K. M.; Shi, B.-F.; Yu, J.-Q. *Science* **2010**, *327*, 315; (p) Ackermann, L. *Chem. Rev.* **2011**, *111*, 1315; (q) Sun, C.-L.; Li, B.-J.; Shi, Z.-J. *Chem. Rev.* **2011**, *111*, 1293; (r) Verdernikov, A. N. *Acc. Chem. Res.* **2012**, *45*, 803; (s) Engle, K. M.; Yu, J.-Q. *J. Org. Chem.* **2013**, *78*, 8927.
2. (a) Chatani, N. *Directed Metallation*; Springer: Berlin, Germany, 2008.
3. (a) Li, C. J. *Acc. Chem. Res.* **2009**, *42*, 335; (b) Liu, Z.; Zhang, J.; Chen, S.; Shi, E.; Xu, Y.; Wan, X. *Angew. Chem., Int. Ed.* **2012**, *51*, 3231; (c) Ashenhurst, J. A. *Chem. Soc. Rev.* **2010**, *39*, 540; (d) Shi, E.; Shao, Y.; Chen, S.; Hu, H.; Liu, Z.; Zhang, J.; Wan, X. *Org. Lett.* **2012**, *14*, 3384.
4. (a) Jia, X.; Zhang, S.; Wang, W.; Luo, F.; Cheng, J. *Org. Lett.* **2009**, *11*, 3120; (b) Li, C.; Wang, L.; Li, P.; Zhou, W. *Chem.—Eur. J.* **2011**, *17*, 10208; (c) Fang, P.; Li, M.; Ge, H. *J. Am. Chem. Soc.* **2010**, *132*, 11898; (d) Kim, M.; Park, J.; Sharma, S.; Kim, A.; Park, E.; Kwak, J. H.; Jung, Y. H.; Kim, I. S. *Chem. Commun.* **2013**, 925; (e) Pan, C.-D.; Jin, H.-M.; Liu, X.; Cheng, Y.-X.; Zhu, C.-J. *Chem. Commun.* **2013**, 2933; (f) Guin, S.; Rout, S. K.; Banerjee, A.; Nandi, S.; Patel, B. K. *Org. Lett.* **2012**, *14*, 5294; (g) Wu, Y.; Choy, P. Y.; Mao, F.; Kwong, F. Y. *Chem. Commun.* **2013**, 689; (h) Yin, Z.; Sun, P. *J. Org. Chem.* **2012**, *77*, 11339; (i) Pan, C.; Jia, X.; Cheng, J. *Synthesis* **2012**, 677; (j) Wu, Y.; Wang, J.; Mao, F.; Kwong, F. Y. *Chem.—Asian J.* **2013**, http://dx.doi.org/10.1002/asia. 201300990; (k) Li, H; Li, P.; Wang, L. *Org. Lett.* **2013**, *15*, 620.
5. Olah, G. A. *Friedel–Crafts Chemistry*; Wiley: New York, NY, 1973.
6. (a) Goossen, L. J.; Ghosh, K. *Eur. J. Org. Chem.* **2002**, 3254; (b) Qin, C.; Chen, J.; Wu, H.; Cheng, J.; Zhang, Q.; Zuo, B.; Su, W.; Ding, J. *Tetrahedron Lett.* **2008**, *49*, 1884; (c) Lindh, J.; Sjoberg, J. R.; Larhed, M. *Angew. Chem.* **2010**, *49*, 7733; (d) Liu, J.; Zhou, X.; Rao, H.; Xiao, F.; Li, C.-J.; Deng, G.-J. *Chem.—Eur. J.* **2011**, *17*, 7996; (e) Mootz, D.; Deeg, A. *J. Am. Chem. Soc.* **1992**, *114*, 5887; (f) Chatani, N.; Asaumi, T.; Ikeda, T.; Yorimitsu, S.; Ishii, Y.; Kakiuchi, F.; Murai, S. *J. Am. Chem. Soc.* **2000**, *122*, 12882.
7. (a) Basle', O.; Bidange, J.; Shuai, Q.; Li, C.-J. *Adv. Synth. Catal.* **2010**, *352*, 1145; (b) Xiao, F.; Shuai, Q.; Zhao, F.; Basle', O.; Deng, G.; Li, C.-J. *Org. Lett.* **2011**, *13*, 1614; (c) Lu, J.; Zhang, H.; Chen, X.; Liu, H.; Jiang, Y.; Fu, H. *Adv. Synth. Catal.* **2013**, *355*, 529.
8. (a) Banerjee, A.; Santra, S. K.; Guin, S.; Rout, S. K.; Patel, B. K. *Eur. J. Org. Chem.* **2013**, 1367; (b) Ding, Q.; Ji, H.; Ye, C.; Wang, J.; Wang, J.; Zhou, L.; Peng, Y. *Tetrahedron* **2013**, *69*, 8661.
9. (a) Wu, Y.; Li, B.; Mao, F.; Li, X.; Kwong, F. Y. *Org. Lett.* **2011**, *13*, 3258; (b) Chan, C.-W.; Zhou, Z.; Yu, W.-Y. *Adv. Synth. Catal.* **2011**, *353*, 2999; (c) Yuan, Y.; Chen, D.; Wang, X. *Adv. Synth. Catal.* **2011**, *353*, 3373; (d) Szabó, F.; Daru, J.; Simkó, D.; Nagy, T. Z.; Stirling, A.; Novák, Z. *Adv. Synth. Catal.* **2013**, *355*, 685; (e) Sharma, S.; Khan, I. A.; Saxena, A. K. *Adv. Synth. Catal.* **2013**, *355*, 673; (f) Sharma, S.; Park, J.; Park, E.; Kim, A.; Kim, M.; Kwak, J. H.; Jung, Y. H.; Kim, I. S. *Adv. Synth. Catal.* **2013**, *355*, 332; (g) Park, J.; Kim, A.; Sharma, S.; Kim, M.; Park, E.; Jeon, Y.; Lee, Y.; Kwak, J. H.; Jung, Y. H.; Kim, I. S. *Org. Biomol. Chem.* **2013**, *11*, 2766.
10. Chan, C.-W.; Zhou, Z.; Chan, A. S. C.; Yu, W.-Y. *Org. Lett.* **2010**, *12*, 3926.
11. Park, J.; Park, E.; Kim, A.; Lee, Y.; Chi, K. W.; Kwak, J. H.; Jung, Y. H.; Kim, I. S. *Org. Lett.* **2011**, *13*, 4390.
12. (a) Wang, H.; Guo, L.-N.; Duan, X.-H. *Org. Lett.* **2012**, *14*, 4358; (b) Park, J.; Kim, M.; Sharma, S.; Park, E.; Kim, A.; Lee, S. H.; Kwak, J. H.; Jung, Y. H.; Kim, I. S. *Chem. Commun.* **2013**, 1654; (c) Sharma, S.; Kim, A.; Park, E.; Park, J.; Kim, M.; Kwak, J. H.; Lee, S. H.; Jung, Y. H.; Kim, I. S. *Adv. Synth. Catal.* **2013**, *355*, 667; (d) Yao, J.; Feng, R.; Wu, Z.; Liu, Z.; Zhang, Y. *Adv. Synth. Catal.* **2013**, *355*, 1517; (e) Miao, J.; Ge, H. *Org. Lett.* **2013**, *15*, 2930; (f) Yang, Z.; Chen, X.; Liu, J.; Gui, Q.; Xie, K.; Li, M.; Tan, Z. *Chem. Commun.* **2013**, 1560.
13. (a) Wu, Y.; Choy, P. Y.; Mao, F.; Kwong, F. Y. *Chem. Commun.* **2013**, 689; (b) Xu, Z.; Xiang, B.; Sun, P. *RSC Adv.* **2013**, *3*, 1679.
14. (a) Thomas, K. R. J.; Velusamy, M.; Lin, J. T.; Chuen, C.-H.; Tao, Y.-T. *Chem. Mater.* **2005**, *17*, 1860; (b) Katoh, A.; Yoshida, T.; Ohkanda, J. *Heterocycles* **2000**, *52*, 911; (c) Seitz, L. E.; Suling, W. J.; Reynolds, R. C. *J. Med. Chem.* **2002**, *45*, 5604; (d) Louis, S.; Marc, M. G.; Jory, J. W.; Joseph, P. B. *J. Org. Chem.* **2003**, *68*, 4179; (e) Jonathan, L. S.; Hiromitsu, M.; Toshihisa, M.; Vincent, M. L.; Hiroyuki, F. *J. Am. Chem. Soc.* **2002**, *124*, 13474.
15. Yadav, J. S.; Ramesh, K.; Reddy, B. V. S. *Synlett* **2011**, 169.
16. Lou, S.-J.; Xu, D.-Q.; Xia, A.-B.; Wang, Y.-F.; Liu, Y.-K.; Du, X.-H.; Xu, Z.-Y. *Chem. Commun.* **2013**, 6218.
17. Liu, Y.-K.; Lou, S.-J.; Xu, D.-Q.; Xu, Z.-Y. *Chem.—Eur. J.* **2010**, *16*, 13590.
18. (a) Powers, D. C.; Geibel, M. A. L.; Klein, J. E. M. N.; Ritter, T. *J. Am. Chem. Soc.* **2009**, *131*, 17050; (b) Powers, D. C.; Ritter, T. *Nat. Chem.* **2009**, *1*, 302.
19. Catino, A. J.; Nichols, J. M.; Choi, H.; Gottipamula, S.; Doyle, M. P. *Org. Lett.* **2005**, *7*, 5167.
20. SMART V 4.043 Software for the CCD Detector System; Siemens Analytical Instruments Division: Madison, WI, 1995.
21. SAINT V 4.035 Software for the CCD Detector System; Siemens Analytical Instruments Division: Madison, WI, 1995.
22. Sheldrick, G. M. *SHELXL-97, Program for the Refinement of Crystal Structures*; University of Göttingen: Göttingen, Germany, 1997.