CHAPTER IV

A Straight Forward Synthesis of 4-Aryl Substituted 2-quinolones *via* Pd-NHC Catalyzed Heck Reaction

IV.A. Introduction

Since Mizoroki and Heck independently reported the reaction of aryl halides with alkenes in the early 1970s,[1] the Mizoroki-Heck coupling has been employed in numerous applications, ranging from the synthesis of pharmaceuticals to that of fluorescent materials.[2] The Heck reaction tolerates almost any sensitive functionality such as unprotected amino, hydroxyl, aldehyde, ketone, carboxy, ester, cyano, and nitro groups[3] and because of its broad functional group tolerance, mild reaction conditions and performance with a variety of aryl halides and olefins make the Heck reaction very attractive in the field of synthetic organic chemistry. Usually, in order to achieve the highest efficiency of the palladium- catalyzed Mizoroki-Heck reaction, toxic, air-sensitive and expensive phosphine ligands are introduced to facilitate the corresponding transformations.[4,5]

However, after the isolation and characterization of the stable free *N*-heterocyclic carbene (NHC) by Arduengo and co-workers in 1991,[6] NHC has been used as phosphine surrogates. The potentiality of this class of compounds to serve as spectator ligands in transition-metal complexes was recognized in 1995 by Herrmann *et al*.[7] Soon thereafter, Enders *et al*.[8] developed first chiral palladium-NHC complex and it was applied as a catalyst for an enantioselective Heck-type reaction. In the year of 1998, Herrmann's group has reported a chelating palladium-NHC complex as the catalyst for Heck reaction.[9]

On other hand, the scaffold, 2-quinolone is present in several natural products and a wide variety of biologically active compounds.[10] These are well known for therapeutic values.[11] Besides that 2-quinolones also serve as crucial intermediates in numerous synthetic transformations. For example, these can readily be transformed into 2-(pseudo)/haloquinolines[12] which could act as a key material for accessing structurally diverse compound.[13] Substituted 4-aryl-2-quinolones, tipifarnib is known to act as an anticancer agent.[14] In addition, several synthesized products in this series are under clinical trial.[15] Various strategies, both metal free[16] and metal[17,18] catalyzed, are available in literature to access 2-quinolone structural motifs. However, the metal-catalyzed protocol proved to be a powerful and practical route for the syntheses of substituted 2-quinolones. Much attention has been paid for the palladium catalyzed syntheses of 2-quinolones. The domino Heck/Buchwald-Hartwig reaction of *o*-bromocinnamide with iodoarenes,[17b] cyclization of 3,3-diarylacrylamides followed by intramolecular C-H amination,[17c] carbonylative annulations of alkynes with anilines in

the presence of gaseous CO are frequently used techniques.[17d,17e] Very recent, Inamoto *et al*[17f] reported the synthesis of 4-aryl-2-quinolones *via* the Pd catalyzed sequential Heck reaction and intramolecular C-H amidation. Another alternative procedure, the oxidative carbonylation of 2-vinylanilines was developed by Alper's group.[17g] The ring closing metathesis (RCM) reaction of *N*-phenylacrylamide,[18a] indium catalyzed annulations of *N*-arylcarbamoyl chloride,[18b] copper catalyzed cyclization of 3,3-diarylacrylamides through C-H functionalization/C-N bond formation[18c] and nickel catalyzed cycloaddition of *o*-cyanophenylbenzamides with alkenes[18d] have also been reported to use for the synthesis of functionalized 2-quinolones.

IV.B. Present work: Background, objective and strategy

In Pd catalyzed synthesis of 4-aryl-2-quinolones, cinnamides are most commonly used starting compounds (figure-IV.1b-d). However, Cacchi's group for the first time described the synthesis of 4-aryl-2-quinolones from methyl β-(*o*- acetamidophenyl) acrylate instead of cinnamides (figure-IV.1a).[17h]

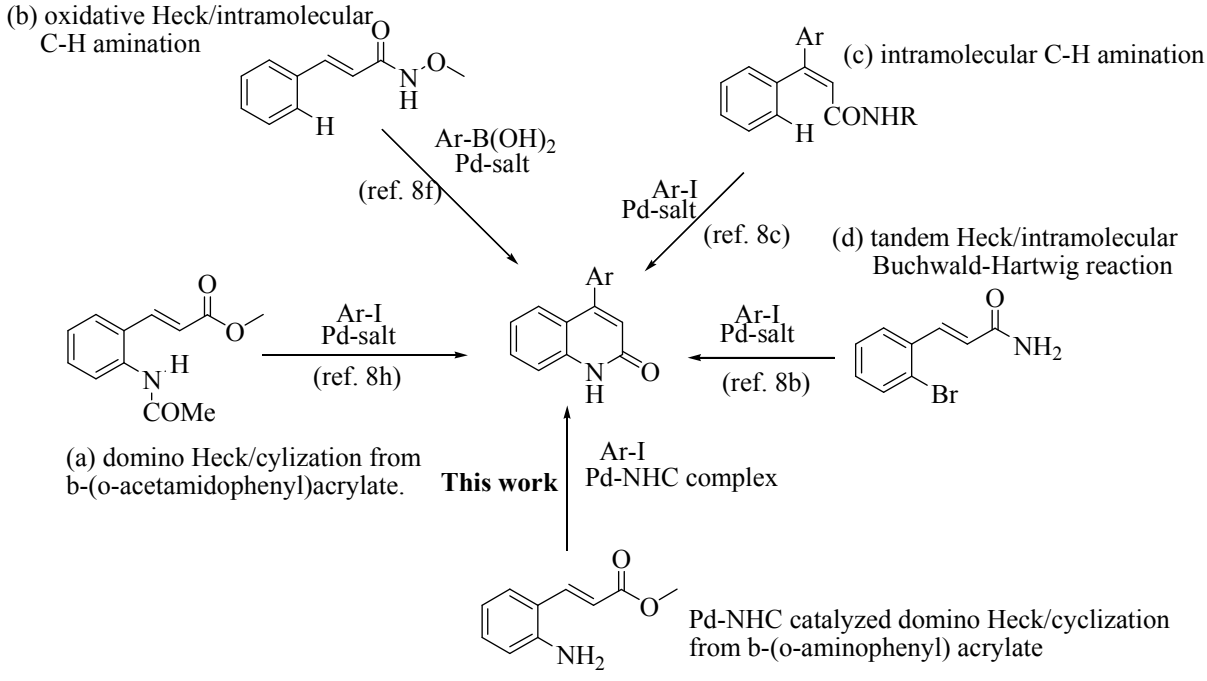


Figure-IV.1: Synthesis of 4-aryl-2-quinolones via palladium catalyzed process.

But in this case the amino group is to be protected before reaction otherwise it solely results in the unsubstituted 2-quinolone. In light of these successful precedents, we anticipated the Pd-NHC complex catalyzed Heck reaction of β-(*o*- aminophenyl) acrylate with arylhalide followed by the intramolecular cyclization would be an efficient protocol for the easy access structurally diverse 4-aryl-2-quinolones.

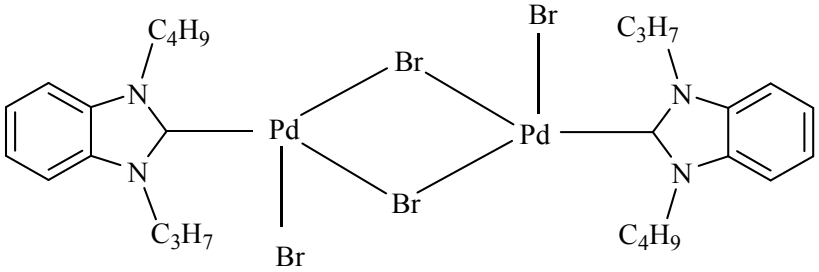


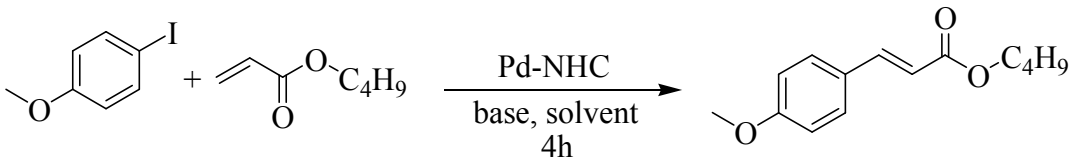
Figure-IV.2: Benzimidazole based Pd-NHC complex.

In earlier two chapter, we have demonstrated the benzimidazole based palladium-*N*-heterocyclic carbene (Pd-NHC) that effectively catalyzes the C-C cross-coupling reaction in a broad variety of substrates. In light of these achievement, we have explored Pd-NHC catalyzed Heck reaction and one-pot efficient protocol for the synthesis of 4-aryl-2-quinolones.

IV.C. Present work: Result and discussion

We began our study to find the suitable condition for Heck cross coupling reaction using our newly developed Pd-NHC catalyst. 4-iodoanisole and n-butylacrylate were selected as model coupling partners to screen the best reaction condition.

Table-IV.1: Optimization studies of reaction condition in Heck coupling between 4-iodoanisole and butylacrylate.[a]

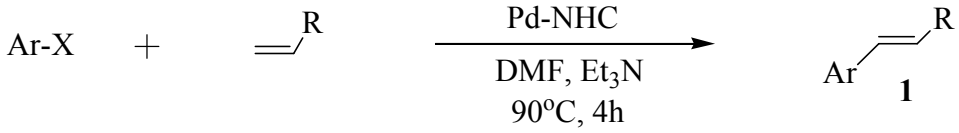


Entry	Solvent	Base	Temperature	Pd-NHC(mol%)	Yield(%)[b]
1	DMSO/H_2O	K_2CO_3	90°C	2	71
2	Acetone/H_2O	K_2CO_3	70°C	2	66
3	EtOH/H_2O	K_2CO_3	90°C	2	39
4[c]	H_2O	K_2CO_3	90°C	2	69
6	**DMF**	**Et_3N**	**90°C**	**1**	**91**
7	DMSO	Et_3N	90°C	1	81
8	DMF	K_2CO_3	90°C	1	83

[a]Reaction conditions: 4-iodoanisole (1 mmol), n-butylacrylate (1.5 mmol), base (2 mmol);
[b]Isolated yield after column chromatography; [c]2 mmol TBAB was added.

The details optimization results in respect of solvents and bases are given in table-1. The results clearly showed that the reaction responded well both in organic solvent as well as in water. But the combination of DMF as solvent and triethylamine as base was proved to be the best suited in the present study as it led to desire coupled product in 91% yield upon isolation (table-IV.1, entry-6). Notably, 1 mol% Pd-NHC catalyst was sufficient to catalyze the coupling reaction effectively.

Table-IV.2: Heck coupling of aryl halides with different olefins.[a]



Entry	Ar	R	X	Product	Yield(%)[c]
1	4-OCH_3 -C_6H_5	$CO_2C_4H_9$	I	**1a**	91
2	4-OCH_3 -C_6H_5	CN	I	**1b**	93
3	4-OCH_3 -C_6H_5	Ph	I	**1c**	94
4	4-CH_3 - C_6H_5	$CO_2C_4H_9$	I	**1d**	90
5	2-F -C_6H_5	$CO_2C_2H_5$	I	**1e**	97
6	4-Cl -C_6H_5	Ph	I	**1f**	94
7	2-CH_3 -C_6H_5	CN	I	**1g**	95
8	2-NH_2 -C_6H_5	CO_2CH_3	I	**1h**	95
9	1-Napthyl	$CO_2C_4H_9$	I	**1i**	98
10	2-OH-C_6H_5	$CO_2C_2H_5$	I	**1j**	93
11[b]	4-OCH_3 -C_6H_5	Ph	Br	**1c**	86
12[b]	4-F-C_6H_5	Ph	Br	**1k**	89
13[b]	4-$COCH_3$ -C_6H_5	Ph	Br	**1l**	76
14[b]	4-CN -C_6H_5	Ph	Br	**1m**	87

[a]Reaction conditions: aryl iodides (1 mmol), substituted alkenes (1.5 mmol), Et_3N (2 mmol), Pd-NHC (1 mol%, 0.0096g), DMF, 90^0C, 4 h; [b]K_2CO_3 used instead of Et_3N, 130°C, 6 h; [c]Isolated yield after column chromatoghrapy.

The results showed that aryl halides bearing electron withdrawing and donating groups worked well under this optimized conditions and leading to the corresponding products in excellent yield. Butylacrylate, acrylonitrile as well as styrene were efficiently participating in cross-coupling reaction with 4-iodoanisole and results in the desired coupled products in 91%, 93% and 94% yields (table-IV.2, entry-1, 2 and 3) respectively upon isolation. Comparatively sterically hindered aryl halides also underwent the reaction smoothly to furnish the desired coupled products in high yields

(table-IV.2, entry-5,7,8,10). On the other hand, aryl moiety containing sensitive functional groups such as $–NH_2$, -OH (table-IV.2, entry-8, 10) resulting the high yields of the coupled product. No such side product was detected in those cases. 1-iodonapthalene coupled with butylacrylate and furnished the desired product in 98% yield.

After successful completion of the Heck coupling reaction with aryliodides, we then explored the possibility to apply this technique in case of arylbromides. Accordingly, we attempted the Heck reaction between 4-bromoanisole and styrene at our optimized condition but the isolated yield of the desired coupled product was not satisfactory (table-IV.3, entry-1).

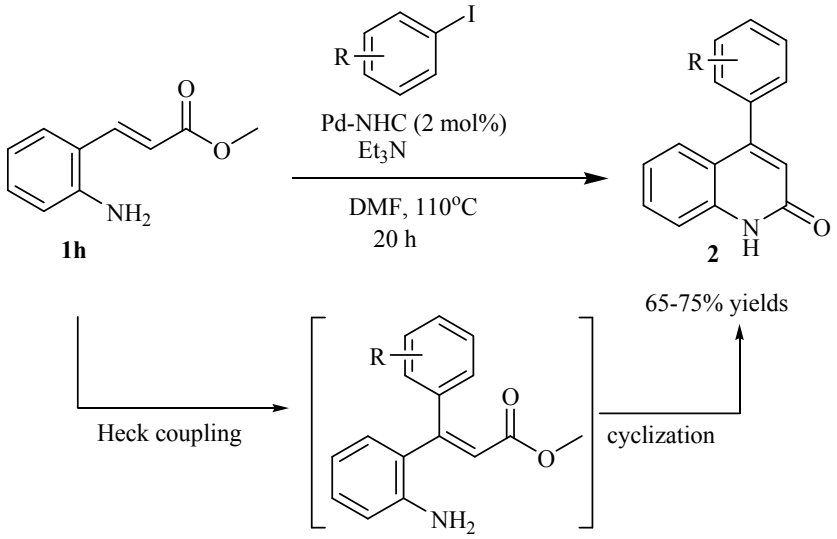
Table-IV.3: Optimization for reaction between 4-bromoanisole and styrene[a]

Entry	Base	Temp. (^oC)	Yield (%)[b]
1	Et_3N	90	35
2	Et_3N	110	42
3	Et_3N	130	65
4	K_2CO_3	130	86
5	Cs_2CO_3	130	N.R.
6	NaOAc	130	<20

[a]Reaction conditions: 4-bromoanisole (1 mmol), styrene (1.5 mmol), base (2 mmol), Pd-NHC (1 mol%, 0.0096g), DMF, 6 hr; [b]Isolated yield after column chromatography.

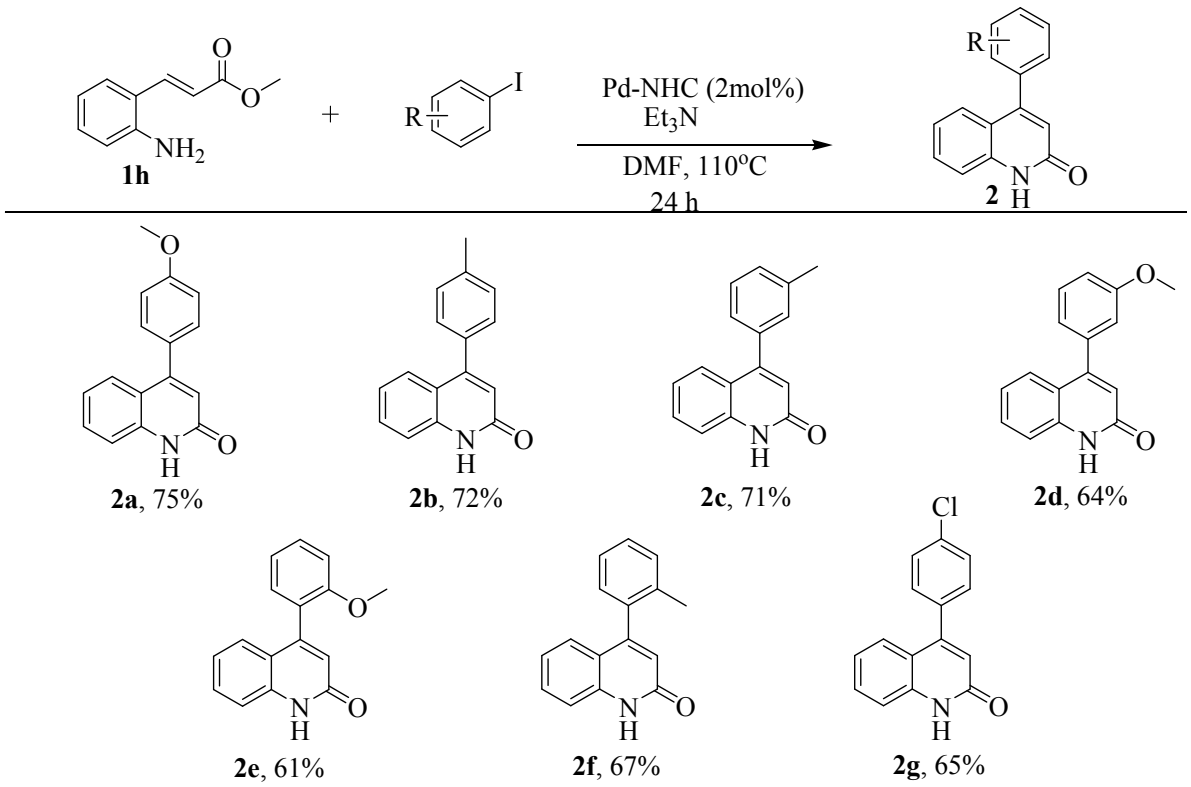
Then we improved the reaction condition and it was found that at 130^oC for 6 h in the presence of K_2CO_3 arylbromides were smoothly participating in the coupling reaction. Under this optimized condition various arylbromides were subjected to Heck coupling reaction with styrene (table-IV.2, entry-11 to 14). Both the electron rich and electron deficient arylbromides were smoothly coupled with styrene and the corresponding desired coupled products were isolated in high yields (table-IV.2, entry-11 to 14).

Several sensitive groups such as -CN, $COCH_3$ remain intact under this reaction condition and results in the high yield of the cross coupled products.



Scheme-IV.1: Synthesis of 4-aryl-2-quinolone *via* Heck coupling and cyclization reaction.

After that we turned to our main objective *i.e.* the synthesis of 4-aryl-2-quinolones (scheme-IV.1). Synthesis of 4-aryl-2-quinolones from the Heck coupled product methyl β-(*o*-aminophenyl) acrylate (**1h)** is a two step process *viz.* Heck cross coupling and cyclization reaction. We attempted to carry out both the reaction in one pot (scheme-IV.1). The β-(*o*-aminophenyl) acrylate (**1h)** was then treated with 4-iodoanisole in the presence of Pd-NHC catalyst and Et_3N in DMF. After refluxing the mixture at 110°C for 20 h the corresponding 4-aryl-2-quinolone (**2a**) was isolated in 75% yield.



Reaction conditions: **1h** (1 mmol), aryliodide (1.2 mmol), Et_3N (2 mmol), Pd-NHC (2 mol%, 0.0192g), DMF, 110°C, 20 h; Isolated yield after column chromatography.

Scheme-IV.2: Synthesis of structurally diverse 4-aryl-2-quinolones.

Very delightfully, we then applied this protocol with different aryl iodides for accessing of structurally diverse 4-aryl-2-quinolones (scheme-IV.2).

It was found from the results that aryliodides were efficiently participating in the reaction and resulted in the good yield of the corresponding 4-aryl-2-quinolones. A marginal difference in yield of the final product was observed for electron donating and withdrawing group present in the aryl moiety. A little dropped in yield in case of *o*-OCH_3/-CH_3 might be attributed for the steric effect. Electron deficient 4-chloroiodobenzene productively participating in the reaction to form the desired 4-(4-chlorophenyl)quinolin-2(*1H*)-one (**2g**) in 65% yield and notably chloro atom is well tolerated under this reaction condition.

IV.D. Conclusion

We have demonstrated an effective Pd-NHC catalyzed Heck coupling. In addition, we have also developed one pot protocol for the synthesis of the valuable 4-aryl-2-quinolone moieties. The process stands good with a range of arylhalides including electron deficient, electron rich as well as sterically hindered entities.

IV.E. Experimental

IV.E.1. General consideration

Unless stated otherwise, all reagents such as aryl halides, potassium carbonate, triethylamine, alkenes, and solvents were used as received from commercial suppliers. NMR spectra were recorded on 300 MHz spectrometer at 298 K and calibrations were done on the basis of solvent residual peak. Products were isolated using column chromatography on silica gel (60-120 mesh) and a mixture of petroleum ether (60-80^{o}C)/ethyl acetate was used as an eluent. Reaction progress was monitored by silica gel TLC.

IV.E.2. General procedure for Heck reaction

A mixture of aryl halide (1 mmol), alkene (1.5 mmol), base (2 mmol Et_3N for aryliodides and 2 mmol K_2CO_3 for arylbromides), Pd-NHC (1 mol%, 0.0096 g) and 3 mL DMF were taken in a 25 mL round bottom flask and the mixture was placed in a preheated oil bath at 90^{o}C for 4 h (at 130^{o}C for 6 h in case of arylbromides). Then the reaction mixture was diluted with water and extracted with DCM (3 x 10 mL). The combined organic layer was dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude residue was purified by silica gel column chromatography.

IV.E.3. Spectral analysis of Heck coupled product

n-Butyl-3-(4-methoxyphenyl)acrylate (1a)[19]

Yellowish liquid; ^{1}H NMR ($CDCl_3$, 300 MHz) δ : 0.96 (t, *J* = 7.2 Hz, 3H), 1.37-1.50 (m, 2H), 1.64-1.73 (m, 2H), 3.88 (s, 3H), 4.20 (t, *J* = 6.9 Hz, 2H), 6.31 (d, *J* = 16.2 Hz, 1H), 6.90 (d, *J* = 8.7 Hz, 2H), 7.48 (d, *J* = 9 Hz, 2H), 7.64 (d, *J* = 15.9 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75

MHz) δ : 13.78, 19.22, 30.80, 55.37, 64.28, 114.28, 115.73, 127.18, 129.70, 144.23, 161.30, 167.49.

3-(4-methoxyphenyl)acrylonitrile (1b)[20]

Yellowish liquid; ^{1}H NMR ($CDCl_3$, 300 MHz) δ : 3.84 (s, 3H), 5.71 (d, *J* = 16.8 Hz, 1H), 6.90-6.93 (m, 2H), 7.30-7.41(m, 4H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ : 55.42, 93.32, 114.48, 118.66, 126.31, 129.04, 150.01, 162.01.

1-(4-methoxystyryl)benzene (1c)[21]

White solid; m.p. 135-137^{o}C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ : 3.75 (s, 3H), 6.80-6.87 (m, 2H), 6.94 (d, *J* = 14.4 Hz, 1H), 7.13-7.18 (m, 2H), 7.21-7.29 (m, 3H), 7.35-7.42 (m, 3H); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 55.35, 114.14, 126.27, 126.62, 127.24, 127.74, 128.21, 128.67, 130.15, 137.65, 159.30.

n-Butyl-3-*p*-tolylacrylate (1d)[19]

Yellow liquid; ^{1}H NMR ($CDCl_3$, 300 MHz) δ : 0.96 (t, *J* = 7.2 Hz, 3H), 1.38-1.50 (m, 2H), 1.64-1.73 (m, 2H), 2.37 (s, 3H), 4.20 (t, *J* = 6.9 Hz, 2H), 6.39 (d, *J* = 15.9 Hz, 1H), 7.19 (d, *J* = 7.8 Hz, 2H), 7.42 (d, *J* = 8.1 Hz, 2H), 7.66 (d, *J* = 15.9 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 13.77, 19.21, 21.46, 30.79, 64.35, 117.18, 128.04, 129.60, 131.73, 140.61, 144.55, 167.32.

Ethyl-3-(2-fluorophenyl)acrylate (1e)[22]

Light yellow liquid; ^{1}H NMR ($CDCl_3$, 300 MHz) δ : 1.32 (t, *J* = 7.2 Hz, 3H), 4.25 (q, *J* = 7.2 Hz, 2H), 6.52 (d, *J* = 16.2 Hz, 1H), 7.03-7.16 (m, 1H), 7.29-7.36 (m,1H), 7.48-7.54 (m, 1H), 7.79 (d, *J* = 16.2 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 14.02, 60.34, 115.89 (d, $J_{C\text{-}F}$ = 21.82 Hz), 120.55 (d, $J_{C\text{-}F}$ = 6.52 Hz), 122.21 (d, $J_{C\text{-}F}$ = 11.7 Hz), 124.15 (d, $J_{C\text{-}F}$ = 3.67 Hz), 128.74 (d, $J_{C\text{-}F}$ = 2.77 Hz), 131.36 (d, $J_{C\text{-}F}$ = 8.7 Hz), 136.87 (d, $J_{C\text{-}F}$ = 2.85 Hz), 161.04 (d, $J_{C\text{-}F}$ = 252.37 Hz), 166.53.

1-(4-chlorostyryl)benzene (1f)[21]

White solid; m.p. 128-130^{o}C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ : 7.03 (d, *J* = 1.5 Hz, 2H), 7.20-7.49 (m, 9H); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 126.61, 127.39, 127.72, 127.93, 128.79, 128.89, 129.34, 133.20, 135.87, 137.01.

3-*o*-tolylacrlonitrile (1g)[20]

Light yellow liquid; ^{1}H NMR ($CDCl_3$, 300 MHz) δ : 2.37 (s, 3H), 5.76 (d, *J* = 16.5 Hz, 1H), 7.17-7.32 (m, 3H), 7.39-7.44 (m, 1H), 7.66 (d, *J* = 16.5 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 19.38, 96.95, 118.16, 125.30, 126.36, 130.75, 130.79, 132.29, 136.99, 148.21.

Methyl-3-(2-aminophenyl)acrylate (1h)[23]

Yellow solid; m.p. 59-61°C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ : 3.72 (s, 3H), 3.87 (s, 2H), 6.28 (d, *J* = 15.9 Hz, 1H), 6.61-6.71 (m, 2H), 7.06-7.12 (m, 1H), 7.30 (dd, *J* = 7.8, 1.5 Hz, 1H), 7.77 (d, *J* = 15.9 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 51.65, 116.82, 117.56, 118.93, 119.83, 128.06, 131.36, 140.37, 145.67, 167.76.

n-Butyl-3-(napthalen-1-yl)acrylate (1i)[19]

Light yellow liquid; ^{1}H NMR ($CDCl_3$, 300 MHz) δ : 0.97 (t, *J* = 7.2 Hz, 3H), 1.39-1.51 (m, 2H), 1.62-1.76 (m, 2H), 4.23 (t, *J* = 6.6 Hz, 2H), 6.51 (d, *J* = 15.6 Hz, 1H), 7.43-7.56 (m, 3H), 7.71 (d, *J* = 7.2 Hz, 1H), 7.75-7.85 (m, 2H), 8.16 (d, *J* = 8.1 Hz, 1H), 8.51 (d, *J* = 15.6 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 13.84, 19.29, 30.86, 64.57, 120.93, 123.40, 125.01, 125.47, 126.23, 126.87, 128.75, 130.49, 131.43, 131.82, 133.70, 141.60, 167.03.

Ethyl-3-(2-hydroxyphenyl)acrylate (1j)[24]

Light yellow liquid; ^{1}H NMR ($CDCl_3$, 300 MHz) δ : 1.35 (t, *J* = 7.2 Hz, 3H), 4.30 (q, *J* = 7.2 Hz, 2H), 6.67 (dd, *J* = 16.2, 1.2 Hz, 1H), 6.87-6.92 (m, 2H), 7.19-7.25 (m, 1H), 7.45 (dd, *J* = 8.1, 1.5 Hz, 2H), 8.08 (d, *J* = 16.2 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 14.31, 60.86, 116.50, 118.08, 120.52, 121.69, 129.20, 131.51, 141.15, 155.81, 168.96.

1-(4-fluorostyryl)benzene (1k)[21]

White solid; m.p. 122-124°C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ : 6.97-7.09 (m, 4H), 7.22-7.28 (m, 1H), 7.33-7.38 (m, 2H), 7.44-7.50 (m, 4H); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 115.67 (d, J_{C-F} = 21.5 Hz), 126.49, 127.48, 127.73, 128.03 (d, J_{C-F} = 7.9 Hz), 128.46, 128.77, 133.51 (d, J_{C-F} = 3.3 Hz), 137.17, 162.35 (d, J_{C-F} = 245.5 Hz).

1-(4-styrylphenyl)ethanone (1l)[21]

White solid; m.p. 141-143°C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ : 2.60 (s, 3H), 7.09-7.20 (m, 2H), 7.25-7.32 (m, 1H), 7.35-7.40 (m, 2H), 7.52-7.59 (m, 4H), 7.94 (d, *J* = 8.4 Hz); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 26.60, 126.51, 126.83, 127.45, 128.33, 128.81, 128.89, 131.48, 135.95, 136.70, 142.03, 197.52.

4-styrylbenzonitrile (1m)[21]

White solid; m.p. 114-116°C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ : 7.07 (d, *J* = 16.5 Hz, 1H), 7.20 (d, *J* = 16.5 Hz, 1H), 7.31-7.41 (m, 3H), 7.52-7.63 (m, 6H); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 110.62, 119.02, 126.75, 126.88, 126.94, 128.66, 128.87, 132.44, 132.48, 136.32, 141.86.

IV.E.4. General procedure for the synthesis of 4-aryl-2-quinolones (2)

A mixture of **1h** (1 mmol, 0.177 g), aryliodide (1 mmol), Et_3N (2 mmol, 0.202 g) and Pd-NHC (2 mol %) were taken in a 25 mL round bottom flask. Then 3 mL DMF was added into it and the mixture was stirred for 20 h at 110^oC. After cooling to room temperature, the reaction mixture was diluted with DCM and washed with water. The organic layer was dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography.

IV.E.5. Spectral analysis of 4-aryl-2-quinolones

4-(4-methoxyphenyl)quinolin-2-(*1H*)-one (2a)[17b]

White solid; m.p. 196-198^oC; ^1H NMR ($CDCl_3$, 300 MHz) δ : 3.99 (s, 3H), 6.81 (s, 1H), 7.14 (d, *J* = 8.7 Hz, 2H), 7.27-7.37 (m, 1H), 7.52 (d, *J* = 8.7 Hz, 2H), 7.65 (d, *J* = 6 Hz, 2H), 7.74 (d, *J* = 8.1 Hz, 1H), 12.7 (bs, 1H); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 55.41, 114.14, 116.80, 119.96, 120.08, 122.78, 126.86, 129.31, 130.24, 130.79, 138.74, 153.57, 160.26, 163.94.

4-*p*-tolylquinolin-2(*1H*)-one (2b)[17b]

White solid; m.p. 229-231^oC; ^1H NMR ($CDCl_3$, 300 MHz) δ : 2.46 (s, 3H), 6.71 (s, 1H), 7.14-7.19 (m, 1H), 7.31-7.39 (m, 4H), 7.50-7.61 (m, 3H), 13.00 (bs, 1H); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 21.36, 116.85, 119.76, 120.42, 122.61, 126.79, 128.84, 129.34, 130.71, 134.21, 138.86, 138.93, 153.69, 164.36.

4-*m*-tolylquinolin-2(*1H*)-one (2c)[17h]

White solid; m.p. 158-160^oC; ^1H NMR ($CDCl_3$, 300 MHz) δ : 2.45 (s, 3H), 6.72 (s, 1H), 7.17-7.22 (m, 1H), 7.26-7.32 (m, 3H), 7.41 (t, *J* = 7.8 Hz, 1H), 7.55-7.61 (m, 3H), 12.60 (bs, 1H); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 21.52, 116.81, 119.86, 120.21, 122.86, 125.98, 126.92, 128.54, 129.51, 129.66, 130.87, 136.94, 138.44, 138.65, 154.09, 163.93.

4-(3-methoxyphenyl)quinolin-2(*1H*)-one (2d)[17b]

White solid; m.p. 190-192^oC; ^1H NMR ($CDCl_3$, 300 MHz) δ : 3.87 (s, 3H), 6.74 (s, 1H), 7.02-7.07 (m, 3H), 7.18 (m, 1H), 7.43 (t, *J* = 7.8 Hz, 1H), 7.54-7.62 (m, 3H), 12.90 (bs, 1H); ^{13}C NMR ($CDCl_3$, 75MHz) δ : 55.41, 114.42, 114.45, 116.84, 119.63, 120.52, 121.28, 122.73, 126.77, 129.73, 130.81, 138.42, 138.86, 153.52, 159.66, 164.42.

4-(2-methoxyphenyl)quinolin-2(*1H*)-one (2e)

White solid; m.p. 210-212^oC; ^1H NMR ($CDCl_3$, 300 MHz) δ: 3.64 (s, 3H), 6.61 (s, 1H), 6.94-7.04 (m, 3H), 7.15-7.19 (m, 2H), 7.34-7.47 (m, 3H), 12.90 (bs, 1H); ^{13}C

NMR ($CDCl_3$, 75MHz) δ : 55.53, 111.10, 116.59, 120.12, 120.79, 121.55, 122.33, 126.08, 126.91, 130.27, 130.40, 130.55, 138.46, 151.13, 156.58, 164.57; MS (ESI+): m/z 251.80 $[M]^+$; elemental analysis calcd (%) for $C_{16}H_{13}NO_2$: C, 76.48; H, 5.21; N, 5.57, found C, 76.41; H, 5.15; N, 5.61.

4-*o*-tolylquinolin-2(*1H*)-one (2f)

White solid; m.p. 178-180^oC; ^1H NMR ($CDCl_3$, 300 MHz) δ : 2.05 (s, 3H), 6.56 (s, 1H), 6.99-7.06 (m, 2H), 7.11-7.16 (m, 1H), 7.22-7.32 (m, 3H), 7.39-7.49 (m, 2H), 12.92 (bs, 1H); ^{13}C NMR ($CDCl_3$, 75MHz) δ: 19.85, 116.67, 120.07, 120.91, 122.73, 125.93, 126.67, 128.65, 128.93, 130.29, 130.78, 135.68, 136.64, 138.59, 153.65, 164.55; MS (ESI+): m/z 235.80 $[M]^+$; elemental analysis calcd (%) for $C_{16}H_{13}NO$: C, 81.68; H, 5.57; N, 5.95, found C, 81.57; H, 5.51; N, 5.98.

4-(4-chlorophenyl)quinolin-2(*1H*)-one (2g)[17h]

White solid; m.p. 208-210^oC; ^1H NMR (DMSO-d_6, 300 MHz) δ : 6.30 (s, 1H), 7.00-7.06 (m, 1H), 7.22-7.30 (m, 2H), 7.38-7.48 (m, 5H), 11.80 (s,1H); ^{13}C NMR (DMSO-d_6, 75 MHz) δ : 116.29, 118.57, 121.92, 122.45, 126.44, 129.21, 131.08, 131.17, 134.09, 135.94, 139.73, 150.70, 161.66.

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