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Dehydrogenative Synthesis of Quinolines, 2-Aminoquinolines and Quinazolines using Singlet Di-radical Ni(II)-Catalysts

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Abstract. Simple, straightforward and atom economic methods for the synthesis of quinolines, 2-aminoquinolines and quinazolines via bio-mimetic dehydrogenative condensation/coupling reactions, catalyzed by well defined inexpensive and easy to prepare singlet di-radical Ni(II)-catalysts featuring two antiferromagnetically coupled singlet di-radical diamine type ligands are described. Various polysubstituted quinolines, 2-aminoquinolines and quinazolines were synthesized in moderate to good yields from different low-cost and readily accessible starting materials. Several control experiments were carried out to get insight into the reaction mechanism which shows that the nickel and the coordinated diamine ligands participate in a synergistic way during the dehydrogenation of alcohols.

Introduction. Nitrogen-heterocycles are ubiquitous in nature and constitute the backbone of numerous natural products, pharmaceutically important molecules and organic functional materials.[1] Among various nitrogen-heterocycles known, Quinolines, 2-Aminoquinolines and Quinazolines are important structural motifs found in a myriad of pharmacologically active and biologically relevant compounds.[2] They exhibit wide range of pharmacological and biological activities such as antibacterial,[3] antiinflammatory,[4] anticonvulsant,[5] antimalarial,[6] antiasthmatic,[7] anti-Alzheimer,[8] and anticancer[9] activities.

Over the decades significant advances have been made for the synthesis of these heterocycles via the classical metal-free methods as well as several metal-catalyzed multi-component coupling reactions were developed.[10,11] In-spite of notable progress, the developed protocols are mostly associated with multi step reaction sequences, generation of copious waste and almost always require pre-functionalized starting materials. Therefore, development of new alternative efficient and environmentally benign atom economic synthetic methods involving cheap and easily available starting materials for the construction of these nitrogen-heterocycles are desirable.

In this regard, the dehydrogenative functionalization of alcohols offers an environmentally benign and atom economic synthetic method for the benign construction of complex organic molecules, including N-heterocycles, from sustainable and abundant alcohols.[12-26] Presently, the chemistry of dehydrogenative functionalization of alcohols is undergoing a renaissance and a significant progress has been made on developing new catalysts and catalytic methodologies to achieve efficient dehydrogenative functionalization of alcohols to various value added products.[12-26] In the last one decade, several research groups made notable contribution for the synthesis of various useful organic materials including N-heterocycles such as pyrroles,[13] pyridines,[14] pyrimidines,[15] quinolines,[16] quinazolinones,[17] quinazolines,[18] etc. via this dehydrogenative coupling approach. Other than organo-heterocycles, some reports have come up in recent times for the dehydrogenative synthesis of other useful organic materials such as amines,[19] imines,[20] amides,[21] and esters.[22]

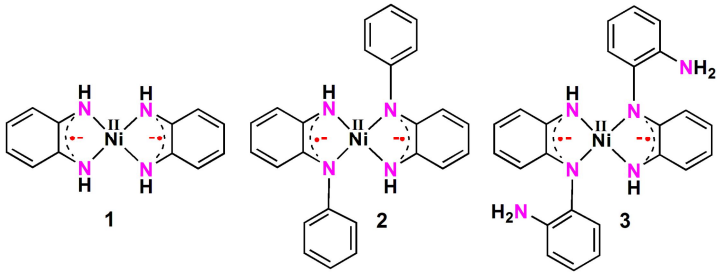
Despite of the significant advances on dehydrogenative functionalization of alcohols to various value added complex organic molecules including N-heterocycles, the catalysts mostly used during dehydrogenation reactions are of precious metals such as Ru, Rh, and Ir.[12-22] Therefore, in terms of sustainability, these expensive noble metals ought to be replaced by

inexpensive and environmentally benign earth-abundant first-row base metals such as Mn, Fe, Co, and Ni.[23-26]

Recently, we reported [Ni^{II}(MeTAA)] (tetramethyltetraaza[14]annulene (MeTAA)) catalyzed synthesis of quinazoline,[26a] quinazolin-4(3H)-one,[26b] and quinoline,[26c] through dehydrogenative condensation/coupling reactions. The [Ni^{II}(MeTAA)] catalyzed dehydrogenation of alcohols proceeds via the formation of transient nickel hydride intermediate involving exclusively metal centered redox events which are usually energetically uphill and hence almost always require high temperature.[26] In this regard, the bio-inspired catalysis utilizing transition metal complexes featuring redox noninnocent scaffolds offer an attractive alternative where the high energetic metal centered redox events may be avoided during catalysis via the synergistic participation of both metal and coordinated ligand centered redox or in some cases via exclusive ligand centered redox events.[27,28] The synergistic participation of copper and the coordinated phenoxyl radical in dehydrogenation of alcohols catalyzed by metallozyme Galactose Oxidase (GO) under biological conditions is noteworthy to mention.[28b]

Herein we report a new bio-mimetic method for the construction of various polysubstituted quinolines, 2-aminoquinolines and quinazolines through dehydrogenative condensation/coupling of 2-aminobenzylalcohols with ketones (for quinolines); 2-phenylacetonitrile (for 2-aminoquinolines) and nitriles (for quinazolines) respectively, catalyzed by well defined singlet di-radical Ni(II)-complexes featuring two simple diamine type of ligands where all or part of the redox events are expected to take place at the ligands.[29] We envisaged that a Ni(II)-ion coordinated to a one electron oxidized semiquinone radical ligand can possibly mimic the activity of the metalloenzyme GO during the dehydrogenation of alcohols. The nickel bound ligand centered radical would trap the α-CH atom of any alcohol (similar to that of phenoxyl radical in GO) affording nickel bound ketyl radical intermediate which then upon intermolecular electron transfer can produce the desired aldehydes. In the subsequent steps, base promoted intermolecular/intramolecular condensation of 2-aminobenzaldehyde with the other coupling partners would afford the desired nitrogen heterocycles; quinolines, 2-aminoquinolines and quinazolines respectively. Various polysubstituted quinolines, 2-aminoquinolines and quinazolines were synthesized in moderate to good yields from readily accessible starting materials under relatively mild reaction conditions (<100 °C).

Result and Discussion. Three tetracoordinated singlet di-radical Ni(II)-complexes bearing two antiferromagnetically coupled one-electron oxidized redox noninnocent ligands $(L^{1-3})^{\bullet-}$ with the valence configuration of $[Ni^{II}\{(L^{1-3})^{\bullet-}\}_2]$ were used in this study to synthesize quinoline, 2-aminoquinoline and quinazolines (Scheme 1).[29] In catalyst **1**, two one electron oxidized *o*-phenylenediamine ($\mathbf{L}^1$) ligands are coordinated to the nickel center in a square planer geometry,[29a] whereas in catalyst **2**, the coordinated ligands are two one electron oxidized N-phenyl-*o*-phenylenediamine ($\mathbf{L}^2$).[29b] In catalyst **3**, two one electron oxidized tridentate N-(2-aminophenyl)benzene-1,2-diamine ($\mathbf{L}^3$) ligands are coordinated to the nickel center in a bidentate fashion with one pendant amine arm from each of the ligands.[29c] All these complexes were prepared following the available literature methodes.[29]



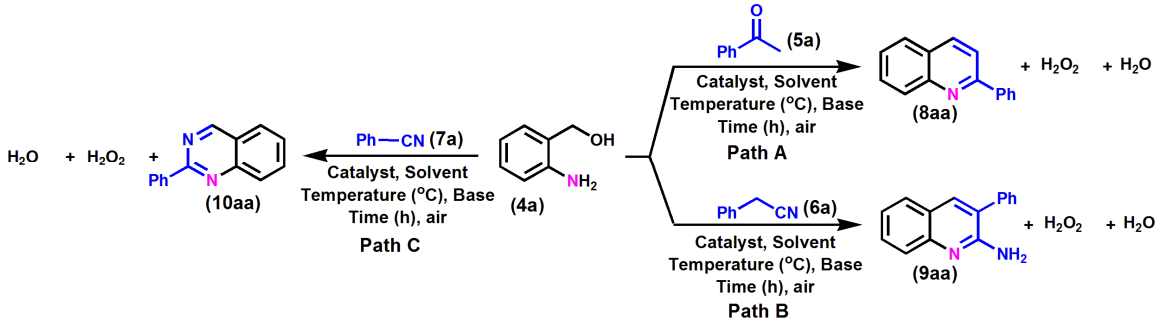
Scheme 1. Ni(II)-complexes used as catalysts.

Initially the reactions of 2-aminobenzylalcohol (**4a**) with acetophenone (**5a**), 2-phenylacetonitrile (**6a**) and benzonitrile (**7a**) respectively, were studied separately under different reaction conditions to get the optimal reaction parameters for the synthesis of quinolines, 2-aminoquinolines and quinazolines catalyzed by **3**. Since the catalysts used in this study are all air stable, we opted to carry out the catalytic reactions under aerial conditions. Optimization of the reaction conditions revealed that these reactions proceed efficiently in toluene or xylene in presence of an inorganic base like KO^{t}Bu or NaO^{t}Bu. Poor yields were obtained in polar solvents such as MeOH, acetonitrile, etc; no desired product was obtained in absence of base. Highest yield of quinoline (**8aa**) (85%) was obtained when the reaction was carried out in toluene at 80 °C for 10h (Table 1, entry 1). However, 2-aminoquinoline (**9aa**) and quinazoline (**10aa**) required slightly higher temperature and prolong reaction time. At 95 °C in toluene 65% of 2-aminoquinoline (**9aa**) was obtained in 30h whereas 82% of quinazoline (**10aa**) was isolated at 90 °C in toluene (Table 1, entry 7, 13). A catalyst loading of 4.0 mol% has been found to be

sufficient to bring about the highest yields of **8aa** in presence of 0.5 equiv. of KO^tBu. Slightly higher base loading (0.75 equiv.) is required to obtain the highest yields of **9aa**, and **10aa** respectively. Increasing the temperature or base loading did not lead to any noticeable increase in yields, however, decreasing the temperature or base loading below 0.5 equiv. significantly diminish the yields.

In presence of only base, quinoline (**8aa**), 2-aminoquinoline (**9aa**) and quinazoline (**10aa**) were not obtained. Catalysts **1** and **2** were found to be comparably less effective than catalyst **3** (Table 1, entries 15, 16). In presence of other nickel(II) salts such as $Ni(ClO_4)_2.6H_2O$ and $NiCl_2.6H_2O$, desired products were obtained in trace amounts (Table 1, entries 22, 23).

Table 1. Optimization of the Reaction Conditions.[a-c]



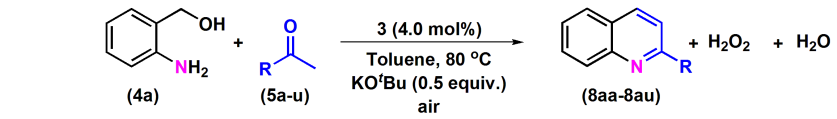
Entry	Ni-catalyst (mol%)	Solvent	Base	Temperature (°C)	Yield (%)		
					8aa	**9aa**	**10aa**
1	**3** (4.0 mol%)	toluene	KO^{t}Bu	80	85	45	78
2	**3** (4.0 mol%)	toluene	NaO^{t}Bu	80	74	48	70
3	**3** (4.0 mol%)	toluene	KOH	80	72	41	69
4	**3** (4.0 mol%)	toluene	NaOH	80	70	40	67
5	**3** (4.0 mol%)	toluene	K_3PO_4	80	trace	trace	trace
6	**3** (4.0 mol%)	toluene	NEt_3	80	NR	NR	NR
7	**3** (4.0 mol%)	toluene	KO^{t}Bu	90	85	49	82
8	**3** (4.0 mol%)	xylene	KO^{t}Bu	80	85	44	77
9	**3** (4.0 mol%)	acetonitr	KO^{t}Bu	80	trace	trace	trace
10	**3** (4.0 mol%)	ethanol	KO^{t}Bu	80	NR	trace	trace
11	**3** (4.0 mol%)	THF	KO^{t}Bu	80	NR	trace	trace
12	**3** (4.0 mol%)	DMF	KO^{t}Bu	80	NR	trace	trace
13	**3** (4.0 mol%)	toluene	KO^{t}Bu	95	83	65	82
14	**3** (4.0 mol%)	xylene	KO^{t}Bu	120	80	60	80
15	**1** (4.0 mol%)	toluene	KO^{t}Bu	100	56	25	40
16	**2** (4.0 mol%)	xylene	KO^{t}Bu	120	43	30	47
17	-	toluene	KO^{t}Bu	100	NR	NR	NR
18	**3** (4.0 mol%)	toluene	-	100	NR	NR	NR
19	-	toluene	KO^{t}Bu	80	trace	-	-
20	-	toluene	KO^{t}Bu	95	-	NR	-
21	-	toluene	KO^{t}Bu	90	-	-	NR
22	$Ni(ClO_4)_2.6H_2O$ (10 mol%)	toluene	KO^{t}Bu	100	trace	trace	trace
23	$NiCl_2.6H_2O$ (10 mol%)	toluene	KO^{t}Bu	100	trace	trace	trace

[a]Stoichiometry : **Path A** : 2-aminobenzylalcohol (**4a**) (1.0 mmol), acetophenone (**5a**) (1.0 mmol), base (0.50 mmol, 0.5equiv.), time 10h; **Path B**: 2-aminobenzylalcohol (**4a**) (1.0 mmol), 2-phenylacetonitrile (**6a**) (1.0 mmol), base (0.75 mmol, 0.75 equiv.), time 30h; **Path C**: 2-aminobenzylalcohol (**4a**) (1.0 mmol), benzonitrile (7a) (1.0 mmol), base (0.75 mmol, 0.75 equiv.), time 30h; [b]solvent : 5.0 mL; [c]Isolated yields after column chromatography.

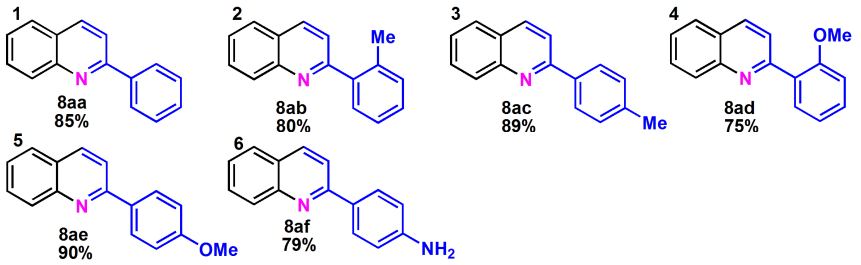
With the optimal conditions in hand we explored the scope and the versatility of the present nickel-catalyzed dehydrogenative coupling reactions. Initially we studied the reaction of 2-aminobenzylalcohol and ketones catalyzed by **3** (Table 2). A wide variety of ketones bearing various functionalities such as aryl, alkyl, naphthyl, and heterocycles were found to be compatible under our optimal reaction conditions. Reactions proceeded efficiently with acetophenones having both electron withdrawing and donating functionalities. For example, 2-aminobenzylalcohol (**4a**) when reacted with 2′-methylacetophenone (**5b**) and 4′-methylacetophenone (**5c**) respectively, under our optimal conditions produced **8ab** and **8ac** in 80% and 89% yields respectively (Table 2, entry 2, 3). The presence of amino group was also tolerated under our optimal reaction conditions yielding the desired quinoline, **8af** in 79% yield (Table 2, entry 6).

Reactions also proceeded with acetophenones containing electron withdrawing functionalities. 2′-haloacetophenones (**5g**, **5i**) produced the corresponding quinolines **8ag** and **8ai** in 65 and 77% yields respectively. 2-aminobenzylalcohol (**4a**) when reacted with the corresponding 4′-haloacetophenones (**5h**, **5j**, **5l**) under our optimal reaction conditions produced the corresponding quinolines **8ah**, **8aj** and **8al** in 69, 74 and 57% yields respectively (Table 2, entries 8, 10, 12). 3′-bromoacetophenone (**5k**) was also tolerated under our optimal reaction conditions to afford the desired quinoline, **8ak** in 64% isolated yield. However, the desired quinolines were obtained in moderate yields (Table 2, entries 13-15) in presence of strong electron withdrawing groups like $-CF_3$, $-NO_2$ etc. Reactions also proceeded with ketones bearing heterocycle functionalities as the coupling partners. 1-(pyridin-3-yl)ethanone (**5r**), 1-(thiophen-2-yl)ethanone (**5p**) when reacted separately under the optimal reaction conditions with 2-aminobenzylalcohol (**4a**) produced **8ar** and **8ap** in 89 and 84% yields respectively (Table 2, entries 16-18). Reactions also proceeded with non-methyl and aliphatic ketones. Using non-methyl ketones, quinolines, **8as** and **8at** were isolated in 88 and 90% yields respectively (Table 2, entries 19, 20). Using aliphatic ketone, cyclopropylethanone (**5u**) the corresponding quinoline, **8au** was obtained in 70% isolated yield (Table 2, entry 21).

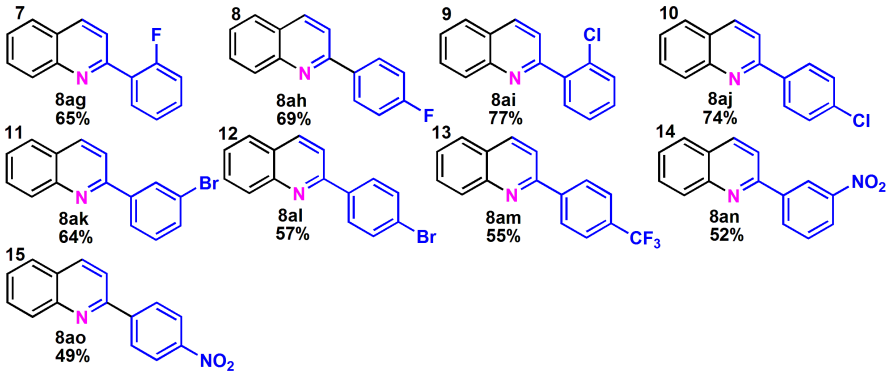
Table 2. Synthesis of Polysubstituted Quinolines via Dehydrogenative Coupling of Various Ketones with 2-Aminobenzylalcohol Catalyzed by 3.[a-e]



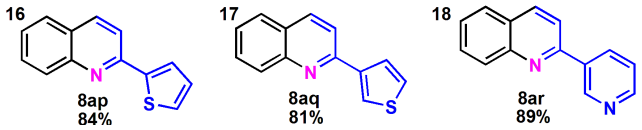
Aryl Ketones containing Electon Donating Groups



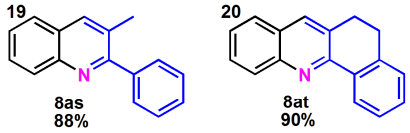
Aryl Ketones containing Electon Withdrawing Groups



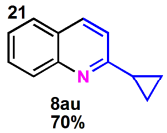
Ketones containing Heterocyclic Functionalities



Nonmethyl Ketones and Alcohols



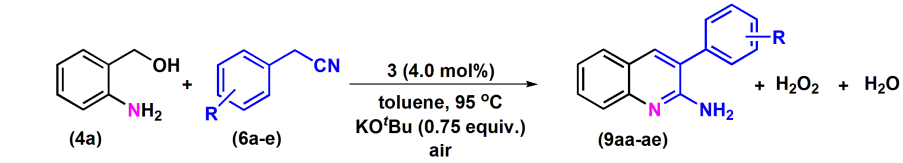
Aliphatic Ketones



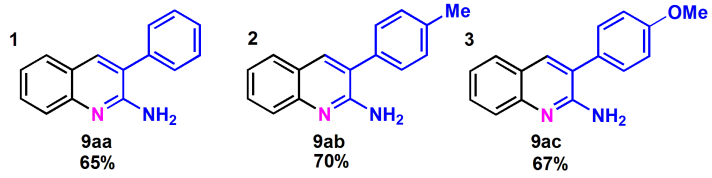
[a]Stoichiometry: 2-aminobenzyl alcohol (4a) (1.0 mmol); ketone (5a-u) (1.0 mmol); Catalyst 3 (4.0 mol%);base (0.5 mmol, 0.5 eqiv.); [b]Solvent: toluene 5 ml, [c]Temperature: 80°C; [d]Time: 10 h; [e]Isolated yields after column chromatography.

Next, we explored the substrate scope of the dehydrogenative coupling of 2-aminobenzylalcohol (**4a**) and 2-phenylacetonitrile, catalyzed by **3** (Table 3) to synthesize various polysubstituted 2-aminoquinolines. As was observed during quinoline synthesis, 2-phenylacetonitrile containing electron withdrawing and donating functionalities were found to be suitable producing the desired 2-aminoquinolines in 65-73% yields. For example, 2-*p*-tolylacetonitrile (**6b**) and 2-(4-methoxyphenyl)acetonitrile (**6c**) afforded the corresponding 2-aminoquinolines **9ab** and **9ac** in 70 and 67% yields respectively (Table 3, entry 2, 3). Reactions proceeded also with 2-phenylacetonitriles containing electron withdrawing halogens (Table 3, entries 4-5).

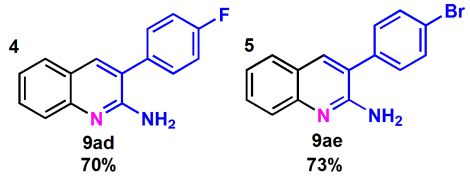
Table 3. Synthesis of Polysubstituted 2-Aminoquinolines via Dehydrogenative Coupling of Various 2-phenylacetonitriles with 2-Aminobenzylalcohol Catalyzed by **3**.[a-e]



2-phenylacetonitrile containing Electon Donating Groups



2-phenylacetonitrile containing Electron Withdrawing Groups



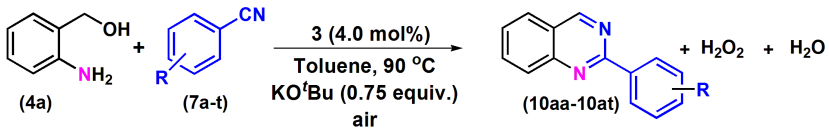
[a]Stoichiometry: 2-aminobenzyl alcohol (4a) (1.0 mmol); 2-phenylacetonitrile (6a-e) (1.0 mmol), Catalyst 3 (4.0 mol%); base (0.75 mmol, 0.75 eqiv.); [b]Solvent:toluene 5 ml; [c]Temperature: 95°C ; [d]Time: 30 h; [e]Isolated yields after column chromatography.

To explore the substrate scope and versatility of the dehydrogenative synthesis of quinazolines catalyzed by **3**, 2-aminobenzylalcohol (**4a**) was reacted with various substituted benzonitriles under the optimal reaction conditions (Table 4). To our delight, the dehydrogenative coupling reactions proceeded smoothly with benzonitriles having both electron

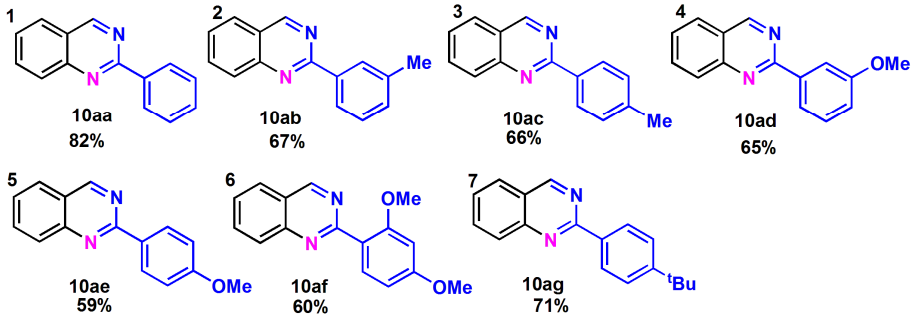
withdrawing and donating groups. The corresponding quinazolines were isolated in moderate to good yields. Quinazolines were isolated in slightly higher yields with substrates containing electron withdrawing functionalities compared to the substrates bearing electron donating groups. For example, benzonitriles bearing methyl groups at the *meta*- or *para*- positions produced the corresponding quinazolines, **10ab** and **10ac** in 67 and 66% (Table 4, entries 2, 3) yields respectively.

Quinazolines were also isolated in good yields when benzonitriles having electron withdrawing functionalities were used as the substrates. Benzonitriles having halogens (Cl, Br) at different positions of the phenyl ring were also found to be compatible producing the desired quinazolines **10ah**-**10am** in 72-84% yields respectively (Table 4, entries 8-13). Benzonitriles containing multiple electron withdrawing functionalities were also tolerated under our optimal reaction conditions. The reaction of 2-aminobenzylalcohol (**4a**) with 3, 5-difluorobenzonitrile (**7n**) under the optimal reaction conditions produced 2-(3,5-difluorophenyl)quinazoline (**10an**) in 88% yield (Table 4, entry 14). Benzonitriles containing -CF_3 groups were also found to be suitable; afforded the desired quinazoline, **10ao** in 85% yields (Table 4, entry 15). Quinazolines were also obtained in moderate to good yields starting from nitriles bearing heterocyclic functionalities (Table 4, entries 17-19). Reaction also proceeded with long chain alkyl nitrile, albeit required slightly prolonged reaction time and the corresponding quinazoline was isolated in moderate yield (Table 4, entry 20).

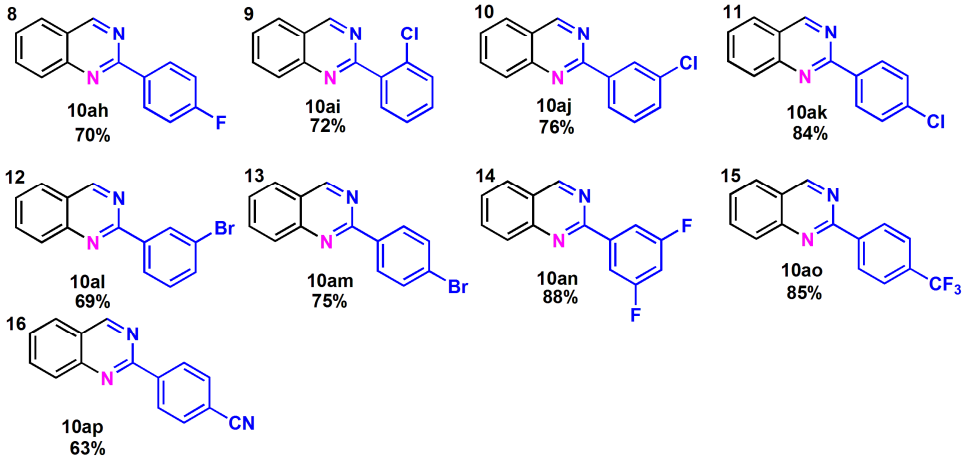
Table 4. Synthesis of Polysubstituted Quinazolines via Dehydrogenative Coupling of Various Nitriles with 2-Aminobenzylalcohol Catalyzed by **3**.[a-e]



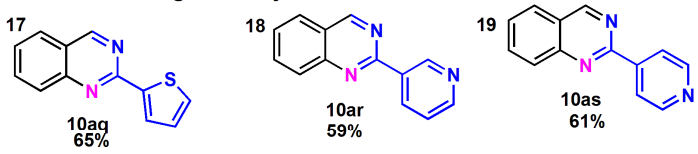
Aryl Nitriles containing Electon Donating Groups



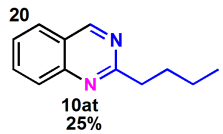
Aryl Nitriles containing Electron Withdrawing Groups



Nitriles containing Heterocyclic Functionalities



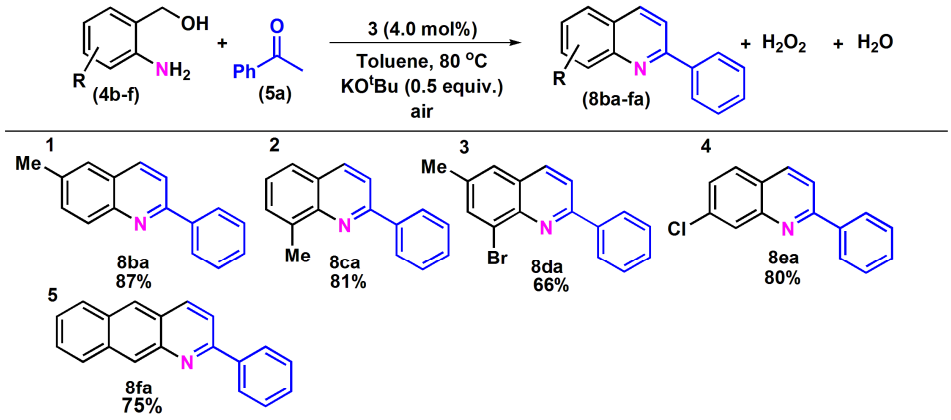
Aliphatic Nitriles



[a]Stoichiometry:2-aminobenzyl alcohol (4a) (1.0 mmol); nitriles(7a-t) (1.0 mmol);Catalyst 3 (4 mol%); base (0.75 mmol, 0.75 eqiv.); [b]Solvent:toluene 5 ml, [c]Temperature: 90°C; [d]Time:30 h; [e]Isolated yields after column chromatography.

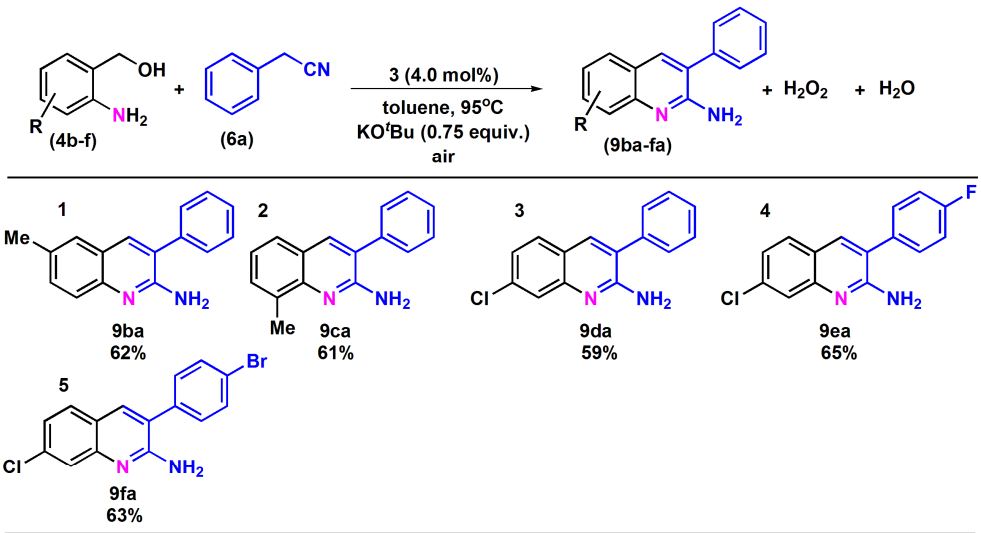
To explore the versatility and expand the substrate scope of the present nickel catalyzed dehydrogenative coupling reactions, several substituted 2-aminobenzylalcohols were reacted separately with acetophenone (**5a**), 2-phenylacetonitrile (**6a**) and benzonitrile (**7a**) under our optimal conditions (Table 5-7). To our delight, quinolines (**8ba-8fa**), 2-aminoquinolines (**9ba-9fa**) and quinazolines (**10ba-10fa**) were obtained in 66-87% (quinolines); 59-65% (2-aminoquinolines); and 78-84% (quinazolines) yields respectively starting from 2-aminobenzylalcohols containing electron donating or electron withdrawing functionalities. Reactions also proceeded with 2-aminobenzylalcohols containing both electron donating and electron withdrawing groups.

Table 5. Synthesis of Polysubstituted Quinolines via Dehydrogenative Coupling of Acetophenone with Various 2-Aminobenzylalcohol Catalyzed by **3**.[a-e]



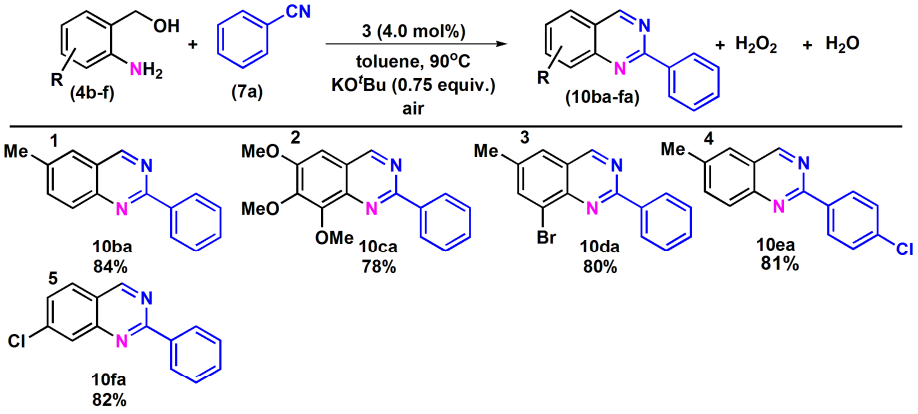
[a]Stoichiometry: 2-aminobenzyl alcohol (4b-f) (1.0 mmol); acetophenone (5a) (1.0 mmol); catalyst 3 (4.0 mol%);base (0.5 mmol, 0.5 eqiv.); [b]Solvent: toluene 5 ml, [c]Temperature: 80°C , [d]Time: 10h ; [e]Isolated yields after column chromatography.

Table 6. Synthesis of Polysubstituted 2-Aminoquinolines via Dehydrogenative Coupling of 2-phenylacetonitrile with Various 2-Aminobenzylalcohol Catalyzed by **3**.[a-e]



[a]Stoichiometry: 2-aminobenzyl alcohol (4b-f) (1.0 mmol); 2-phenylacetonitrile (6a) (1.0 mmol); catalyst 3(4.0 mol%); base (0.75 mmol, 0.75 eqiv.); [b]Solvent: toluene 5 ml, [c]Temperature: 95°C, [d]Time: 30 h; [e]Isolated yields after column chromatography.

Table 7. Synthesis of Polysubstituted Quinazolines via Dehydrogenative Coupling of Benzonitrile with Various 2-Aminobenzylalcohol Catalyzed by **3**.[a-e]



[a]Stoichiometry: 2-aminobenzyl alcohol (4b-f) (1.0 mmol); benzonitrile (7a) (1.0 mmol); catalyst 3 (4.0 mol%), base (0.75 mmol, 0.75 eqiv.); [b]Solvent: toluene 5 ml, [c]Temperature: 90°C; [d]Time: 30 h; [e]Isolated yields after column chromatography.

To gain insight into the reaction mechanism, several control experiments were performed under the optimal conditions. Initial mechanistic investigations were focused on to explore the plausible pathways of alcohol dehydrogenation reaction catalyzed by **3**.

Since the catalysts used in this study are all singlet di-radical Ni(II)-complexes containing two antiferromagnetically coupled ligand centered radicals, the dehydrogenation of alcohols as

well as the dehydrogenative coupling reactions mentioned above were carried out in presence of a radical scavenger 2,2-diphenyl-1-picrylhydrazyl (DPPH) to check the involvement of organic radical during catalytic turnover. In presence of one equivalent DPPH, only 5% of the aldehyde was obtained as the dehydrogenation product of the alcohol and no products were obtained in all the above mentioned dehydrogenative coupling reactions.

The color of the catalysts **2** and **3** immediately changes upon addition of K^{t}BuO. Since, other than acting as base, alkali metal tertiary butoxides, are known to be capable of acting as a reducing agent,[30] the observed color change may be because of simple deprotonation of any of the -NH group of the coordinated ligand or it may be because of the reduction of the coordinated ligands. Therefore, to check whether the origin of the color changes observed upon addition of K^{t}BuO is because of reduction of the catalyst, the reaction mixtures containing K^{t}BuO and catalyst **2** or **3** were studied by EPR. Both the reaction mixtures showed very weak EPR signals representing at most a tiny amount of the bulk of the nickel complex when treated with K^{t}BuO (see SI). Hence, the color change seems to be because of deprotonation of any of the -NH arms of the coordinated ligand and possibly the deprotonated complex [**3**]$^-$ acts as the active catalyst. Notably, when the dehydrogenation of benzylalcohol was carried out in a stoichiometric manner using the preformed [**3**]$^-$ as the catalyst, in absence of any added base, 92% of the dehydrogenated product was isolated indicating the active role of the deprotonated complex [**3**]$^-$ during catalysis.

Next, intermolecular transfer hydrogenation experiments were performed in presence of easily reducible substrates to test the possibility of H_2 evolution during dehydrogenation of alcohols. Notably, no transfer hydrogenation was observed during the dehydrogenation of 1-phenylethanol (**11a**) in presence of 4-methoxybenzaldehyde (**11b**) under closed conditions in presence of argon. Moreover, the dehydrogenated product, acetophenone (**5a**) was obtained in trace amount (See SI). On the other hand, when the same transfer hydrogenation reaction was carried out under aerial conditions, the yield of the dehydrogenated product, acetophenone (**5a**) increases to 85%. In presence of air, no transfer hydrogenation was observed, rather H_2O_2 was detected as the hydrogenated product of molecular oxygen (Figure S1).

Attempts were made to quantify the liberated H_2O_2 under aerial conditions. Under optimized catalytic conditions in presence of 0.5 equiv. of KO^{t}Bu, 0.68 equiv. of H_2O_2 was detected with respect to the alcohol. In presence of 1.0 equiv. of KO^{t}Bu the amount of H_2O_2 becomes almost half (0.48 equiv.) with respect to 1-phenyl ethanol, indicating the incorporation

of only one hydrogen atom of the 1-phenylethanol to H_2O_2. On the other hand, the stoichiometric reaction, using [**3**]$^-$ as the catalyst, in absence of any added base afforded 0.82 equiv. of H_2O_2, indicating that almost two hydrogen atoms of the alcohol (-OH and C-H) are incorporated in H_2O_2. Overall, in presence of excess base (deprotonating agent), H_2O_2 was found to form in 0.48 equiv. whereas in absence of base using [**3**]$^-$, almost one equivalent H_2O_2 was obtained which indeed indicates that the deprotonated complex [**3**]$^-$ can also act as an deprotonating agent. Therefore, under the optimal catalytic conditions, it is believed that both the added base as well as the active catalyst [**3**]$^-$ act as the deprotonating agent.

To further confirm the role of [**3**]$^-$ during the deprotonation of alcohols, a stoichiometric reaction was carried out between [**3**]$^-$ and D_2-1-phenylethanol under inert conditions. IR spectroscopic analysis of the reaction mixture shows an absorption band at 2163 cm^{-1} indicating N-D stretching. The stoichiometric dehydrogenation of D_1-1-phenylethanol also showed N-D stretching at 2162 cm^{-1} which indeed confirmed that the C-D bond in 1-phenyl ethanol is cleaved and the deuterium is transferred to the coordinated ligand forming N-D bond. Since, the catalyst **3** used herein is a singlet di-radical species containing two antiferromagnetically coupled ligand centered radicals, the transfer of hydrogen atom from the alcohol to the coordinated ligand may indeed take place either via the1e$^-$ hydrogen atom transfer process (HAT) forming ketyl radical intermediate[28a] or via 2e$^-$ hydride transfer pathway forming a transient nickel-hydride intermediate followed by hydrogen atom walking mechanism.[28f]

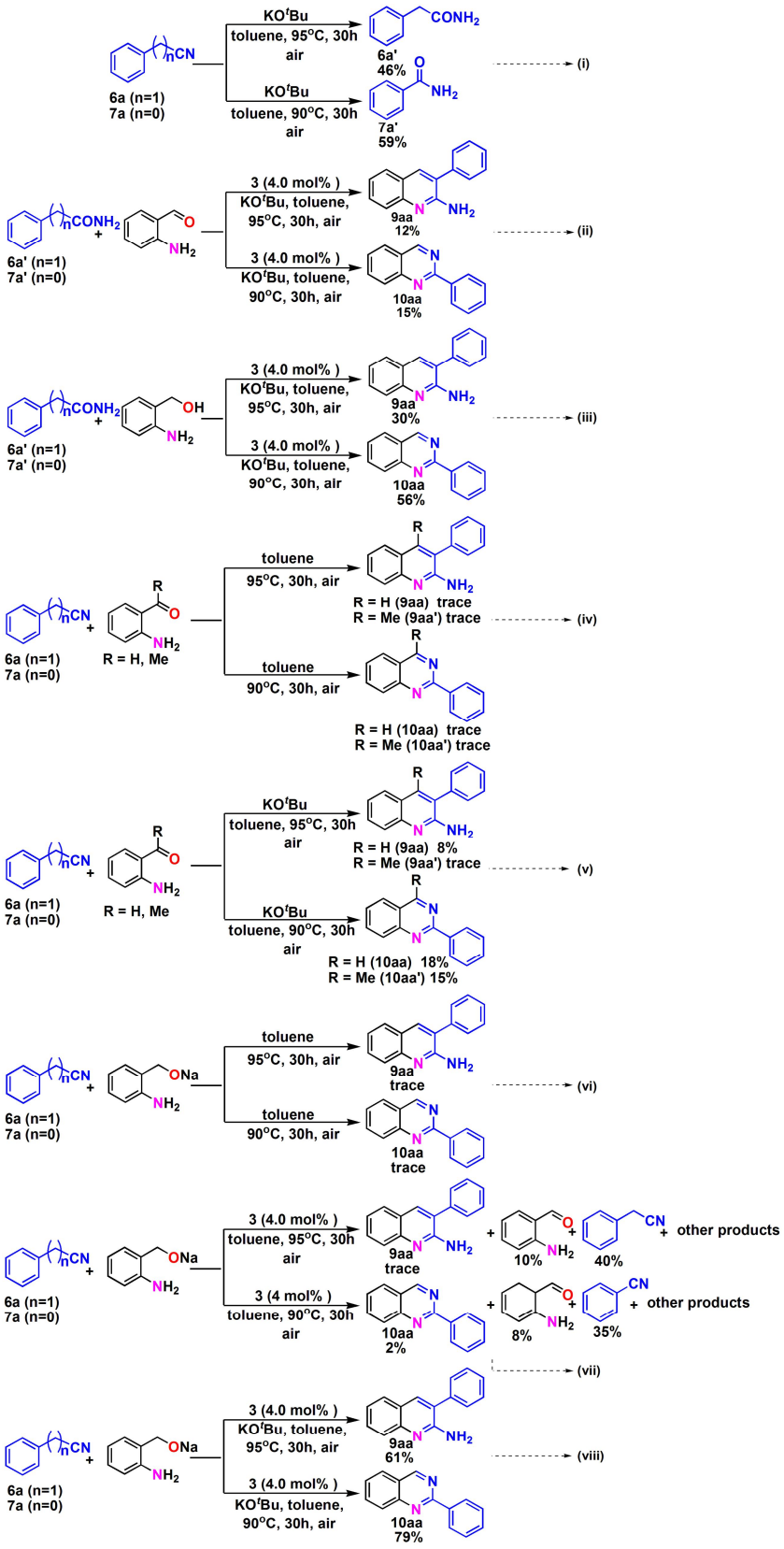
To probe the 1e$^-$ hydrogen atom transfer process (HAT) vs. 2e$^-$ hydride transfer pathway the radical clock substrate cyclobutanol was subjected to dehydrogenation under our optimal reaction conditions using **3** as the catalyst. Formation of multiple ring opening products points to the possibility of HAT process rather than hydride transfer as also evident from the fact that in presence of radical scavenger like DPPH, the yield of the product decreases significantly.

Once we understood the plausible mechanistic pathway for the dehydrogenation of alcohols catalyzed by **3**, our next control experiments were focused on to explore the plausible mechanistic pathways for the dehydrogenative coupling reactions. The dehydrogenative coupling of alcohols with carbonyl species having active methylene group is known to proceed through the base mediated formation of α, β-unsaturated ketones followed by intramolecular cyclodehydration to produce quinolines.[26c] The dehydrogenative coupling of nitriles with alcohols is reported to proceed through the formation of amidine intermediate which upon subsequent dehydrogenation followed by intramolecular condensation affords quinazolines.[18a]

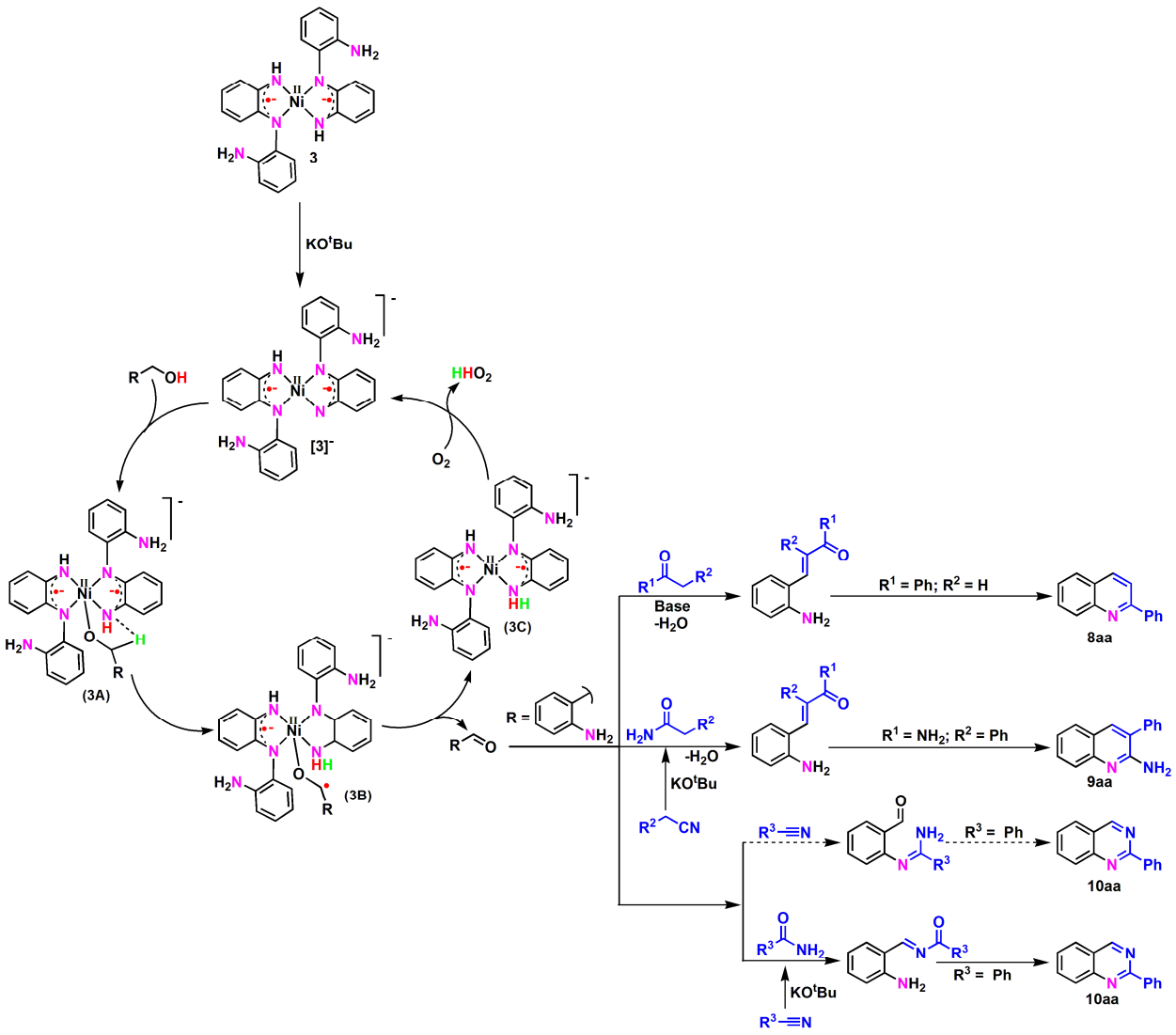
However, in our recent report we shown that in presence of KO^{t}Bu, nitriles can be converted to the corresponding amides which upon base promoted intermolecular condensation followed by cyclization can also produce quinazolines.[26a]

Control experiments showed that under our optimal reaction conditions, in presence of 0.75 equiv. of KO^{t}Bu, 46% 2-phenylacetamide (**6a'**) was isolated from 2-phenylacetonitrile (**6a**) (Scheme 2, equation (i)). On the other hand, 59% of benzamide (**7a'**) was isolated from benzonitrile (**7a**) under our optimal reaction conditions. Therefore, the dehydrogenative coupling of 2-aminobenzylalcohol with 2-phenylacetonitriles or benzonitriles can either proceed via amidine intermediate or the direct condensation of in-situ formed 2-aminobenzaldehyde (dehydrogenated product of 2-aminbenzylalcohol) and amide (formed from nitriles) can also lead to the formation of 2-aminoquinolines and quinazolines. It is worthy to mention here that the direct condensation of preformed 2-aminobenzaldehyde with 2-phenylacetamide (**6a'**) and benzamide (**7a'**) respectively produce the corresponding 2-aminoquinoline (**9aa**) and 2-phenylquinazoline (**10aa**) in 12% and 15% isolated yields respectively (Scheme 2, equation (ii)).[26a]

However, the direct reactions of 2-aminobenzaldehyde with benzonitrile and 2-phenylacetonitrile respectively, in absence of base (KO^{t}Bu), afforded 2-aminoquinolines (**9aa**) or 2-phenyl quinazoline (**10aa**) in trace amounts (Scheme 2, equation (vi)). Similarly, 2-aminoquinoline (**9aa**) and 2-phenyl quinazoline (**10aa**) were also obtained in trace amounts from the reactions of the Na-salt of 2-aminobenzylalcohol with 2-phenylacetonitrile and benzonitrile respectively in absence of KO^{t}Bu under the optimal reaction conditions (Scheme 2, equation (iv)). However, the same reactions of the Na-salt of 2-aminobenzylalcohol with 2-phenylacetonitrile or benzonitrile in presence of 0.75 equiv. of KO^{t}Bu, under the optimal reaction conditions, afforded 61% of **9aa** and 79% of **10aa** (Scheme 2, equation (viii)).



Scheme 2. Mechanistic investigation during dehydrogenative coupling of 2-aminobenzylalcohol and benzonitrile catalyzed by **3**.



Scheme 3. Proposed mechanism.

In accordance with available literature and above experimental results a possible mechanism for the present dehydrogenative coupling of 2-aminobenzylalcohols with carbonyls, 2-phenylacetonitriels and nitriles, catalyzed by the singlet di-radical Ni(II)-catalyst **3** is shown in Scheme 3. The reaction proceeds via the initial base promoted deprotonation of one of the coordinated ligand in **3** to form the deprotonated complex [**3**]$^-$ which then acts as the active catalyst. The catalytic reaction begins with the deprotonation of the alcohol followed by the formation of nickel-alkoxy intermediate **3A**. As evident from the control reactions, other than base the deprotonated complex [**3**]$^-$ can also abstract the OH proton of the alcohols. In the next step hydrogen atom abstraction from the nickel-alkoxy intermediate produces an O-coordinated ketyl radical intermediate (**3B**) which upon rapid one-electron oxidation produce the desired 2-aminobenzaldehydes.

2-aminobenzaldehyde, thus formed, undergoes base promoted cross-aldol condensation with ketones (preformed or formed in-situ from 2-phenylacetonitrile) to form the α, ß-unsaturated ketones. Intramolecular cyclodehydration of these α, ß-unsaturated ketones then produce the desired quinolines and 2-aminoquinolines. Base mediated condensation 2-aminobenzyldehyde with benzamide (formed in-situ from benzonitrile) afforded the quinazolines. Formation of quinazoline via amidine intermediate as reported by others seems less likely, however, cannot be ignored.

Conclusion. In summary the present work provides a simple, straightforward and atom economic alternative approach to access quinolines, 2-aminoquinolines and quinazolines via bio-mimetic dehydrogenative coupling of various cheap and easily accessible starting precursors, catalyzed by well defined cheap and earth abundant singlet di-radical Ni(II)-catalysts featuring two antiferromagnetically coupled singlet di-radical diamine type ligands. A wide variety of quinolines, 2-aminoquinolines and quinazolines were synthesized in moderate to good yields under aerial conditions. Mechanistic studies showed that during dehydrogenation of alcohols, both nickel and the coordinated redox active ligand act in a synergistic manner.

Experimental Section.

General Information. Unless otherwise mentioned, all the reagents and starting materials were commercially available and used without further purification. Solvents were dried prior to use following the available standard procedures. Bruker DPX-300 (300 MHz) and Bruker DPX-400 (400 MHz) spectrometers were used for NMR experiments using $SiMe_4$ (tetramethylsilane) as the internal standard. GF254 silica gel plates (0.25 mm thickness) were used for TLC and Merck 60 silica gel of 60-120 mesh was used for column chromatography. Micromass Q-TOF mass spectrometer (serial no. YA 263) was used to collect the ESI mass spectra.

Synthesis of Catalysts. The catalysts **1-3** were prepared following the available literature methodes.[29]

General Procedure for Synthesis of Quinolines via Dehydrogenative Coupling of 2-Aminobenzylalcohol with Ketones. Under air, in an oven dried 50 mL bound-bottom flask, a mixture of 2-aminobenzylalcohol (1.0 mmol), KO^tBu (0.50 mmol) and catalyst **3** were taken. A

magnetic stir bar was then inserted to the round-bottom flask and using a syringe, acetophenone (1.0 mmol) dissolved in 5.0 mL dry toluene was added to the reaction vessel. The round-bottom flask containing the reaction mixture was then placed in an oil bath and heated at 80°C. The reaction was monitored through TLC. Once the reaction was complete after 10h, the reaction mixture was cooled to room temperature and the solvent was evaporated to dryness using rotary vacuum evaporator. The residue was purified by flash column chromatography using petroleum ether/ethyl acetate (20:1) as eluent.

General Procedure for Synthesis of 2-Aminoquinolines via Dehydrogenative Coupling of 2-Aminobenzylalcohol with 2-Phenylaetonitriles. Under air, a mixture of 2-aminobenzylalcohol (1.0 mmol), KO^{t}Bu (0.75 mmol) and catalyst **3** were taken in an oven-dried 50 mL round-bottom flask containing a magnetic stir bar. Using a syringe, 2-phenylacetonitrile (1.0 mmol) dissolved in 5.0 mL dry toluene was added to the reaction vessel. The round-bottom flask containing the reaction mixture was then placed in an oil bath and heated at 95^{o}C. The reaction was monitored through TLC. After 30h, the reaction mixture was cooled to room temperature and the solvent was evaporated to dryness using rotary vacuum evaporator. The residue was purified by flash column chromatography (silica gel) using petroleum ether/ ethyl acetate (3:1) as eluent**.**

General Procedure for Synthesis of Quinazolin by Dehydrogenative Coupling of 2-Aminobenzylalcohol with Nitriles. Under air, a mixture of 2-aminobenzylalcohol (1.0 mmol), KO^{t}Bu (0.75 mmol) and catalyst **3** were taken in an oven-dried 50 mL round-bottom flask containing a magnetic stir bar. Using a syringe, nitriles (1.0 mmol) dissolved in 5.0 mL dry toluene were added to the reaction vessel. The round-bottom flask containing the reaction mixture was then placed in an oil bath and heated at 90^{o}C. The reaction was monitored through TLC. After 30h, the reaction mixture was cooled to room temperature and the solvent was evaporated to dryness using rotary vacuum evaporator. The residue was purified by flash column chromatography (silica gel) using petroleum ether/ ethyl acetate (19:1) as eluent.

Characterization Data of the Isolated Compounds.

2-Phenylquinoline (8aa).[10d, 26c] Eluent: petroleum ether/ethyl acetate (20: 1). White solid (85%, 174 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.25- 8.16 (m, 4H), 7.90-7.83 (m, 2H), 7.76-7.70 (m, 1H), 7.56-7.47 (m, 4H). $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ (ppm) = 157.5, 148.4,

139.8, 136.9, 129.9, 129.7, 129.6, 128.9, 127.7, 127.6, 127.3, 126.4, 119.1. HRMS (ESI, positive ions): m/z calcd for $C_{15}H_{12}N^+$ [M + H^+] 206.0964, found 206.0977.

2-*o*-Tolylquinoline (8ab).[26c] Eluent: petroleum ether/ethyl acetate (20:1). White solid (80%, 175 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.18 - 8.13 (t, *J* = 9.5 Hz, 2H), 7.80 (d, *J* = 8.0 Hz, 1H), 7.72 - 7.68 (m, 1H), 7.53 - 7.48 (m, 3H), 7.31-7.29 (m, 3H), 2.40 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 160.3, 147.9, 140.7, 136.1, 136.0, 130.9, 129.8, 129.7, 129.6, 128.6, 127.6, 126.8, 126.5, 126.1, 122.4, 20.4.

2-*p*-Tolylquinoline (8ac).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). White solid (89% 195 mg). ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) = 8.21 – 8.16 (t, *J* = 9.0 Hz, 2H), 8.08 (d, *J* = 6.6 Hz, 2H), 7.88 -7.80 (m,2H), 7.75 – 7.70 (t, *J* = 7.0 Hz, 1H), 7.54 – 7.49 (t, *J* = 7.6 Hz, 1H), 7.34 (d, *J* =8.1 Hz, 2H), 2.44 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) =157.5, 148.4, 139.7, 137.1, 139.8, 129.7, 129.5, 127.6, 127.4, 126.2, 119.0, 21.6.

2-(2-Methoxyphenyl)quinoline (8ad).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). Yellow liquid (75%, 176 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.07 (d, *J* = 8.0 Hz, 1H), 8.00 (d, *J* = 8.0 Hz, 1H), 7.77-7.74 (m, 2H), 7.68 (d, *J* = 8.0 Hz, 1H), 7.69-7.56 (m, 1H), 7.40-7.37 (t, *J* = 8.0 Hz, 1H), 7.31-7.27 (m, 1H), 7.03-6.99 (t, *J* = 8.0 Hz, 1H), 6.90- 6.88 (d, *J* = 8.0 Hz, 1H), 3.71 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 157.2, 157.2, 148.3, 135.1, 131.5, 130.4, 129.7, 129.6, 129.3, 127.4, 127.1, 126.2, 123.5, 121.3, 111.5, 55.6.

2-(4-Methoxyphenyl)quinoline (8ae).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). White solid (90%, 212 mg). ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) = 8.20 - 8.13 (m, 4H), 7.85-7.79 (t, *J* = 7.5 Hz, 2H), 7.74-7.68 (t, *J* = 9.3 Hz, 1H), 7.52-7.48 (t, *J* = 7.5 Hz, 1H), 7.06 (d, *J* = 9.4 Hz, 2H), 3.90 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 161.0, 157.2, 148.6, 136.9, 132.4, 129.9, 129.7, 129.1, 127.6, 127.1, 126.0, 118.7, 114.4, 55.6. HRMS (ESI, positive ions): m/z calcd for $C_{16}H_{14}NO^+$ [M + H^+] 236.10699, found 236.1060.

4-(Quinolin-2-yl)benzenamine (8af).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). Yellow solid (79%, 174 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.10 (d, *J* = 8.0 Hz, 2H), 8.01 (d, *J* = 8.0 Hz, 2H), 7.78- 7.74 (m, 2H), 7.69- 7.65 (m, 1H), 7.47-7.43 (m, 1H), 6.78 (d, *J* = 8.0 Hz, 2H), 3.85 (br. s, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 157.3, 148.2, 148.1, 136.4, 130.7, 129.4, 129.0, 128.7, 127.4, 126.7, 125.5, 118.3, 115.0.

2-(2-Fluorophenyl)quinoline (8ag).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). Yellow liquid (65% , 145 mg). ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) =8.19-8.14 (m, 2H), 8.11-8.07 (m, 1H), 7.88-7.78 (m, 2H), 7.74-7.70 (m, 1H), 7.55-7.51 (m, 1H), 7.44-7.38 (m, 1H), 7.32-7.28 (m,

1H), 7.21-7.16 (m, 1H). $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm) =160.8 (d, *J* = 248.1 Hz), 148.3, 136.2, 131.5, 130.9, 130.8, 129.7(d, *J* = 3.9 Hz), 127.5, 127.2, 126.7, 124.7, 124.7, 122.5, 122.4, 116.3(d, *J* = 22.0 Hz). HRMS (ESI, positive ions): m/z calcd for $C_{15}H_{11}FN^+$ [M + H^+] 224.087, found 224.0886.

2-(4-Fluorophenyl)quinoline (8ah).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). White solid (69%, 154 mg). ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) = 8.23-8.15 (m, 4H), 7.83 (d, *J* = 12.2 Hz, 2H), 7.76-7.71(t, *J*=7.5 Hz, 1H), 7.56-7.51 (t, *J*=7.5 Hz, 1H), 7.26-7.19 (m, 2H). $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm) = 161.8, 156.4, 148.4, 137.0, 135.9, 129.9, 129.8, 129.5 (d, *J* = 13.9 Hz), 127.6, 127.2, 126.5, 118.8, 115.9 (d, *J* = 24.3 Hz) .

2-(2-Chlorophenyl)quinoline (8ai).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). White solid (77% , 185 mg). ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) = 8.23-8.18 (t, *J* = 8.7 Hz, 2H), 7.85 (d, *J* = 8.0 Hz, 1H), 7.75-7.70 (m, 3H), 7.59–7.50 (m, 2H), 7.43-7.36 (m, 2H). $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm) = 157.4, 148.1, 139.7, 135.7, 132.4, 131.8, 130.1, 129.9, 129.7, 129.7, 127.6, 127.2, 127.2, 126.8, 122.8.

2-(4-Chlorophenyl)quinoline (8aj).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). White solid (74%, 177 mg). ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) = 8.19-8.08 (m, 4H), 7.80-7.70 (m, 3H), 7.54-7.46 (m, 3H). $^{13}C\{^{1}H\}$ NMR (75 MHz, $CDCl_3$): δ (ppm) = 155.9, 148.1, 137.9, 137.1, 135.7, 129.9, 129.6, 129.1, 128.9, 127.5, 127.3, 126.6, 118.6. HRMS (ESI, positive ions): m/z calcd for $C_{15}H_{11}ClN^+$ [M + H^+] 240.0575, found 240.0552.

2-(3-Bromophenyl)quinoline (8ak).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). White solid (64%, 181 mg). ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) = 8.26 (s, 1H), 8.12-8.06 (m, 2H), 7.96 (d, *J* = 9.0 Hz, 1H), 7.72-7.61 (m, 3H), 7.49-7.41 (m, 2H), 7.30-7.25 (t, *J* = 6.0 Hz,1H). $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$): δ (ppm) = 155.5, 148.2, 141.6, 136.9, 132.2, 130.6, 130.3, 129.9, 129.7, 127.5, 127.3,126.6, 126.0, 123.1, 118.6. HRMS (ESI, positive ions): m/z calcd for $C_{15}H_{11}BrN^+$ [M + H^+] 284.0069, found 284.0059.

2-(4-Bromophenyl)quinoline (8al).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). White solid (57% , 162 mg). ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) = 8.17 (d, *J*= 8.7 Hz, 2H), 8.04 (d, *J*= 8.1 Hz, 2H), 7.79-7.75 (m, 2H), 7.72 (d, *J*= 7.5 Hz, 1H), 7.64-7.49 (m, 3H). $^{13}C\{^{1}H\}$ NMR (75 MHz, $CDCl_3$): δ (ppm) = 156.0, 148.3, 138.6, 137.0, 132.0, 131.9, 129.9, 129.8, 129.8, 129.2, 127.6, 127.3, 126.6, 124.0, 118.5.

2-(4-(Trifluoromethyl)phenyl)quinoline (8am).[26c] Eluent: petroleum ether/ethyl acetate (20: 1). White solid (55%, 150 mg). ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) = 8.28-8.23 (m, 2H), 8.20 (d,

J = 8.3 Hz, 2H), 7.86-7.82 (m, 2H), 7.79-7.73 (m, 3H), 7.59-7.53 (t, *J*= 7.8 Hz, 1H). ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$): δ (ppm) = 155.7, 148.4, 143.1, 137.3, 131.4, 130.1, 129.9, 127.9, 127.6, 127.5, 126.9, 126.1, 125.9-125.8 (q, J_{C-F} = 4.0 Hz), 118.8. HRMS (ESI, positive ions): m/z calcd for $C_{16}H_{11}F_3N^+$ [M + H^+] 274.0838, found 274.0847.

2-(3-Nitrophenyl)quinoline (8an).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). White solid (52%, 130 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.99 (s, 1H), 8.50 (d, *J*= 8.0 Hz, 1H), 8.25 (d, *J*= 8.0 Hz, 2H), 8.13 (d, *J*= 8.0 Hz, 1H), 7.88 (d, *J*= 8.0 Hz,1H), 7.81 (d, *J*= 8.0 Hz, 1H), 7.74-7.70 (t, *J*= 8.0 Hz, 1H), 7.67-7.63 (t, *J*= 8.0 Hz, 1H), 7.54-7.51 (t, *J*= 8.0 Hz,1H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): δ (ppm) = 154.3, 148.3, 141.2, 137.5, 133.9, 130.2, 129.9, 129.8, 127.6, 127.4, 127.1, 123.9, 123.2, 122.4, 118.4.

2-(4-Nitrophenyl)quinoline (8ao).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). White solid (49%,123 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.07-8.03 (t, *J*= 7.8 Hz, 2H), 7.95 (d, *J*= 8.8 Hz, 2H), 7.73-7.69 (m, 2H), 7.63-7.59 (m, 1H), 7.39-7.37 (t, *J*= 8.0 Hz, 1H), 6.73 (d, *J*= 8.0 Hz, 2H). ^{13}C {^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 157.2, 148.3, 147.8, 136.5, 129.9, 129.5, 129.3, 128.8, 127.4, 126.8, 125.6, 118.5, 115.3.

2-(Thiophen-2-yl)quinoline (8ap).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). White solid (84%, 177 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.07 (d, *J*= 8.0 Hz, 1H), 8.00 (d, *J*= 8.0 Hz, 1H), 7.69-7.62(m, 4H), 7.43-7.39 (m, 2H), 7.09 -7.08(m, 1H). HRMS (ESI, positive ions): m/z calcd for $C_{13}H_{10}SN^+$ [M + H^+] 212.0528, found 212.0527.

2-(Thiophen-3-yl)quinoline (8aq).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). White solid (81% , 171 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.10(d, *J*= 8.0 Hz, 1H), 8.04 (d, *J*= 8.4 Hz, 1H), 7.98-7.97 (m, 1H), 7.85-7.84 (dd, *J*= 1.12, 4.40 Hz, 1H), 7.71-7.65 (m, 3H), 7.45- 7.42 (m, 1H), 7.39-7.37 (m, 1H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 153.2, 148.2, 142.6, 136.7, 129.7, 129.4, 127.5, 127.1, 126.8, 126.4, 126.1, 124.7, 119.1.

2-(Pyridin-3-yl)quinoline (8ar).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). White solid (89%, 184 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.34 (d, *J*=1.8 Hz, 1H), 8.68-8.66 (dd, *J*= 1.6, 4.6 Hz, 1H), 8.45- 8.42 (m, 1H), 8.16- 8.13 (dd, *J*= 2.72, 8.40 Hz, 2H), 7.78-7.72 (m, 2H), 7.73-7.68 (m, 1H), 7.52-7.48(m, 1H), 7.40-7.37 (m,1H) .

3-Methyl-2-phenylquinoline (8as).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). Yellow oil (88% , 193 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.03 (d, *J*= 8.0 Hz, 1H), 7.88 (s, 1H), 7.65 (d, *J*=7.6 Hz, 1H), 7.56-7.52 (t, *J*= 6.9 Hz, 1H), 7.48 (d, *J*= 8.0 Hz, 2H), 7.41-7.32 (m, 4H), 2.34 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 160.5, 146.6, 140.9, 136.8, 129.3,

129.2, 128.9, 128.8, 128.3, 128.2, 127.6, 126.7, 126.4, 20.6. HRMS (ESI, positive ions): m/z calcd for $C_{16}H_{14}N^+$ [M + H^+] 220.1121 found 220.1128.

5,6-Dihydrobenzo[c]acridine (8at).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). White solid (90% , 208 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.35 (d, *J*= 7.96, 1H), 9.15 (s, 1H), 8.59 (s, 1H), 7.91 (d, *J*= 8.0 Hz, 1H), 7.76 (d, *J*= 8.0 Hz, 1H), 7.60 (d, *J*= 6.0 Hz, 1H),7.41 (s, 2H), 7.25 (d, *J*= 3.2 Hz, 1H), 3.12 (s, 2H), 2.92 (s, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 150.0, 143.1, 141.6, 138.3, 134.3, 133.5,132.1, 129.8, 129.3, 128.8, 128.4, 127.7, 127.4, 125.6, 122.1, 27.8, 27.7. HRMS (ESI, positive ions): m/z calcd for $C_{17}H_{14}N^+$ [M + H^+] 232.11208 found 232.1127.

2-Cyclopropylquinoline (8au).[26c] Eluent: petroleum ether/ethyl acetate (20 : 1). White solid (70% , 118 mg). ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) = 8.01-7.92 (m, 2H), 7.71-7.61 (m, 2H), 7.43-7.38 (t, *J*= 7.3 Hz, 1H), 7.12 (d, *J*= 8.0 Hz, 1H), 2.25-2.19 (m, 1H), 1.18-1.08 (m, 4H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 163.4, 147.9, 135.8, 129.3, 128.6, 127.5, 126.7, 125.2, 119.4, 18.1, 10.4.

3-(Phenyl)quinoline-2-amine (9aa). Eluent: petroleum ether/ethyl acetate (3:1). White solid (65%, 143 mg). M.p: 108-110^{o}C; ^{1}H NMR ($CDCl_3$, 300 MHz): δ (ppm) = 7.78 (s, 1H), 7.70-7.62 (m, 2H), 7.58-7.46 (m, 5H), 7.44-7.41 (m, 1H), 7.29-7.24 (t, *J* = 7.7 Hz, 1H), 5.06 (s, 2H).^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 154.2, 145.6, 136.4, 136.3, 128.7, 128.1, 127.8, 127.2, 126.5, 124.1, 124.1, 123.0, 121.8. HRMS (ESI, positive ions): m/z calcd for $C_{15}H_{13}N_2^+$ [M + H^+] 221.1073, found 221.1076.

3-(*p*-Tolyl)quinoline-2-amine (9ab). Eluent: petroleum ether/ethyl acetate (3:1). White solid (70%, 164 mg). M.p : 123-125^{o}C ; ^{1}H NMR ($CDCl_3$, 300 MHz): δ (ppm) = 7.67 (s, 1H), 7.61-7.53 (m, 2H), 7.49-7.43 (m, 1H), 7.32 (d, *J* = 7.8 Hz, 2H), 7.22-7.14 (m, 3H), 5.06 (s, 2H), 2.34 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 154.4, 145.8, 137.1, 136.1, 133.4, 128.8, 128.5, 127.7, 126.4, 124.3, 124.0, 123.1, 121.7, 20.2. HRMS (ESI, positive ions): m/z calcd for $C_{16}H_{15}N_2^+$ [M + H^+] 235.1229, found 235.1219

3-(4-Methoxyphenyl)quinoline-2-amine (9ac). Eluent: petroleum ether/ethyl acetate (3:1). White solid (67%,167 mg). M.p:136-138^{o}C; ^{1}H NMR ($CDCl_3$, 300 MHz): δ (ppm) = 7.67 (s, 1H), 7.62-7.53 (m, 2H), 7.49-7.44 (t, *J* = 6.0 Hz, 1H), 7.36 (d, *J* = 8.7 Hz, 2H), 7.20-7.15(m, 1H), 6.94 (d, *J* = 9.0 Hz, 2H), 4.99 (s, 2H), 3.78 (s, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 158.7, 154.4, 136.5, 129.1, 128.8, 128.1, 126.4, 123.9, 123.6, 122.9, 122.0, 113.6,

113.0, 54.4. HRMS (ESI, positive ions): m/z calcd for $C_{16}H_{15}N_2O^+$ [M + H^+] 251.1179, found 251.1158.

3-(4-Fluorophenyl)quinoline-2-amine (9ad). Eluent: petroleum ether/ethyl acetate (3:1). White solid (70%, 166 mg). M.p: 176-178^oC ^1H NMR ($CDCl_3$, 400 MHz): δ (ppm) = 7.77 (s, 1H), 7.70 (d, *J* = 7.2 Hz, 1H), 7.65 (d, *J* = 8.0 Hz, 1H), 7.58 (t, *J* = 7.2 Hz, 1H), 7.51-7.48 (m, 2H), 7.30-7.26 (m, 1H), 7.19 (t, *J* = 8.4 Hz, 2H), 4.99 (s, 2H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm) = 161.7 (d, *J*= 243.9 Hz), 154.1, 145.5, 138.3, 136.7, 132.2, 129.7 (d, *J*= 8.3 Hz), 129.1, 126.5, 124.1, 122.9 (d, *J*= 11.0 Hz), 122.1, 115.3 (d, *J*= 22.2 Hz). HRMS (ESI, positive ions): m/z calcd for $C_{15}H_{12}FN_2^+$ [M + H^+] 239.0979, found 239.0958.

3-(4-Bromophenyl)quinoline-2-amine (9ae). Eluent: petroleum ether/ethyl acetate (3:1). White solid (73%, 218 mg). M.p: 167-169^{o}C; ^1H NMR ($CDCl_3$, 400 MHz): δ (ppm) = 7.76 (s, 1H), 7.69 (d, *J* = 8.0 Hz, 1H), 7.65- 7.61 (m, 3H), 7.60-7.56 (m, 1H), 7.40-7.39 (m, 2H), 7.30-7.27 (m, 1H), 4.95 (s, 2H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm) = 153.7, 146.2, 136.4, 135.4, 131.3, 129.6, 128.9, 126.5, 124.6, 123.0, 122.7, 121.9, 121.4. HRMS (ESI, positive ions): m/z calcd for $C_{15}H_{12}BrN_2^+$ [M + H^+] 299.0178, found 299.0158.

2-Phenylquinazoline (10aa).[18a,26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (82% , 169 mg). ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.45 (s, 1H), 8.63-8.61 (m, 2H), 8.08 (d, *J* = 8 Hz, 1H), 7.91-7.87 (m, 2H), 7.61-7.50 (m, 4H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm) = 160.0, 159.4, 149.7, 137.0, 133.1, 129.6, 127.6, 127.5, 126.2, 126.1, 122.5.

2-*m*-Tolylquinazoline (10ab).[26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (67%, 148 mg). ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.37 (s, 1H), 8.34 (d, *J* = 10.4 Hz, 2H), 8.00 (d, *J* = 8.0 Hz, 1H), 7.83-7.79 (m, 2H), 7.53-7.49 (t, *J* = 7.4 Hz, 1H), 7.37- 7.33 (t, *J* = 7.5 Hz, 1H), 7.24 (d, *J* = 7.4 Hz, 1H), 2.40 (s, 3H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm)= 161.2, 160.5, 150.8, 138.3, 137.9, 134.1, 131.5, 129.1, 128.6, 127.2, 127.1, 125.8, 123.6, 21.5.

2-*p*-Tolylquinazoline (10ac).[26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (66%, 145 mg). ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.34 (s, 1H), 8.43- 8.41 (m, 2H), 7.98 -7.96 (m, 1H), 7.80 - 7.76 (m, 2H), 7.50 - 7.46 (m, 1H), 7.25 (d, *J* = 8.0 Hz, 2H), 2.351 (s, 3H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm)= 160.1, 159.4, 149.7, 139.8, 134.3, 132.9, 128.4, 127.5, 126.1, 125.9, 122.4, 20.5.

2-(3-Methoxyphenyl)quinazoline (10ad).[26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (65%, 154 mg). ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.34 (s, 1H), 8.14 -8.09 (m, 2H),

7.98 (d, *J* = 8 Hz, 1H), 7.80 - 7.76 (m, 2H), 7.50 -7.47 (m, 1H), 7.37 - 7.33 (t, *J* = 7.96 Hz, 1H), 6.98 - 6.96 (m, 1H), 3.84 (d, *J* = 8.0 Hz, 3H). $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm)= 160.8, 160.5, 160.0, 150.7, 139.5, 134.1, 129.7, 128.7, 127.3, 127.1, 123.7, 121.2, 117.3, 112.9, 55.5.

2-(4-Methoxyphenyl)quinazoline (10ae).[26a] Eluent: petroleum ether/ethyl acetate (17:1). White solid (59%, 139 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.41 (s, 1H), 8.58 (d, *J* = 7.8 Hz, 2H), 8.04 (d, *J* = 7.58 Hz, 1H), 7.88 (d, *J* = 7.1 Hz, 2H), 7.57 (d, *J* = 7.8 Hz, 1H), 7.05 (d, *J* = 8.4 Hz, 2H), 3.89 (s, 1H). $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm)= 161.8, 160.9, 160.4, 150.8, 134.0, 130.7, 130.2, 128.4, 127.1, 126.8, 123.3, 113.9, 55.4.

2-(2, 4-dimethoxyphenyl)quinazoline (10af).[26a] Eluent: petroleum ether/ethyl acetate (9:1). White solid (60% 184 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.40 (s, 1H), 8.01 (d, *J* = 8.4 Hz, 1H), 7.85-7.76 (m, 3H), 7.55-7.51 (t, *J* = 7.7 Hz, 1H), 6.58-6.54 (m, 2H), 3.99 (d, *J* = 2.0 Hz, 6H). $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm)= 162.2, 162.1, 160.0, 159.2, 150.7, 134.0, 133.2, 128.4, 127.2, 127.1, 122.9, 121.8, 105.0, 99.4, 56.1, 55.5.

2-(4-Tert-butylphenyl)quinazoline (10ag).[26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (71%, 186 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.35 (s, 1H), 8.45 (d, *J* = 8 Hz, 2H), 7.98 (d, *J* = 8 Hz, 1H), 7.81-7.77 (t, *J* = 8 Hz, 2H), 7.50-7.46 (m, 3H), 1.30 (s, 9H).

2-(4-Fluorophenyl)quinazoline (10ah).[11g,26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (70%, 157 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ(ppm) = 9.43 (s,1H), 8.63-8.59 (m, 2H), 8.04 (d, *J* = 8 Hz, 1H), 7.89-7.85 (m, 2H), 7.59-7.56 (t, *J* = 8 Hz, 1H), 7.25-7.16 (m, 2H). $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$): δ(ppm)=164.7 (d, *J* = 248.7 Hz), 160.5, 160.1, 150.7, 134.2, 130.7, 130.6, 128.5, 127.3, 127.1, 123.5, 115.6 (d, *J* = 21.4 Hz).

2-(2-Chlorophenyl)quinazoline (10ai).[26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (72%, 173 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.45 (s, 1H), 8.06 (d, *J* = 8 Hz, 1H), 7.93-7.87 (m, 2H), 7.76-7.74 (m, 1H), 7.65-7.61 (t, *J* = 8 Hz, 1H), 7.48-7.45 (m, 1H), 7.35-7.32 (m, 2H).

2-(3-Chlorophenyl)quinazoline (10aj).[26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (76%, 183 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.34 (s, 1H), 8.55 (d, *J* = 2 Hz, 1H), 8.44 - 8.41 (m, 1H), 7.99 (d, *J* = 4.0 Hz, 1H), 7.85 - 7.81 (m, 2H), 7.56 - 7.53 (m, 1H), 7.40 - 7.35 (m, 2H). $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm) = 160.6, 159.7, 150.6, 139.8, 134.8, 134.3, 130.5, 129.8, 128.6, 127.6, 127.1, 126.6, 123.7.

2-(4-Chlorophenyl)quinazoline (10ak).[18a,26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (84%, 202 mg). ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) = 9.48-9.43 (m, 1H), 8.63-8.55 (m, 2H), 8.12-8.05 (m, 1H), 7.97-7.90 (m, 2H), 7.68-7.61 (m, 1H), 7.59-7.48 (m, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 160.5, 160.0, 150.6, 136.8, 136.5, 134.2, 129.9, 128.8, 128.6, 127.5, 127.1, 123.6.

2-(3-Bromophenyl)quinazoline (10al).[26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (69%, 197 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.33 (s, 1H), 8.67 (s, 1H), 8.45 (d, *J* = 8 Hz, 1H), 7.97 (d, *J* = 8 Hz, 1H), 7.82-7.79 (m, 2H), 7.54-7.50 (m, 2H), 7.31-7.27 (s, 1H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 160.5, 159.5, 150.6, 140.1, 134.3, 133.5, 131.6, 130.2, 128.7, 127.6, 127.1, 127.1, 123.7, 122.9.

2-(4-Bromophenyl)quinazoline (10am).[18a,26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (75%, 214 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.35 (s, 1H), 8.43-8.39 (m, 2H), 7.98 (d, *J* = 8 Hz, 1H), 7.84-7.80 (m, 2H), 7.59-7.51 (m, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 160.5, 160.1, 150.7, 136.9, 134.3, 131.8, 130.2, 128.6, 127.5, 127.2, 125.4, 123.7.

2-(3,5-Difluorophenyl)quinazoline (10an).[26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (88%, 213 mg). ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) = 9.47 (d, *J*= 10.6 Hz, 1H), 8.21-8.07 (m, 3H), 7.99-7.93 (m, 2H), 7.72-7.66 (m, 1H), 7.00-7.94 (m, 1H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 164.5 (d, *J* = 13.0 Hz) , 162.08 (d, *J* = 11.9 Hz), 160.6, 158.7, 150.5, 141.6 (t, *J* = 10.0 Hz) , 134.5, 128.7, 127.9, 127.2, 123.9, 111.5-111.2 (m), 105.99-105.48 (m).

2-(4-(Trifluoromethyl)phenyl)quinazoline (10ao).[18a,26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (85%, 233 mg). ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) = 9.53 (d, *J* = 18.9 Hz, 1H), 8.84-8.75(dd, *J* = 7.9 Hz, 19.0 Hz, 2H), 8.21-8.11 (dd, *J* = 8.7 Hz, 19.0 Hz, 1H), 8.05-7.96 (m, 2H), 7.88-7.82 (t, *J* = 12 Hz, 1H), 7.79-7.68 (m, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 160.7, 159.6, 150.7, 141.4, 134.4, 132.3, 131.9, 128.9, 128.8, 127.9, 127.2, 125.6-125.5 (q, $J_{C\text{-}F}$ = 4.0 Hz), 123.8. HRMS (ESI, positive ions): m/z calcd for $C_{15}H_{10}F_3N_2^+$ [M + H^+] 275.0791, found 275.0795.

3-(Quinazolin-2-yl)benzonitrile (10ap).[11g] Eluent: petroleum ether/ethyl acetate (9:1). Yellow solid (63%, 146 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 9.42 (s, 1H), 8.69-8.67 (m, 2H), 8.04 (d, *J*= 8.0 Hz, 1H), 7.91-7.87 (m, 2H), 7.75 (m, 2H), 7.64-7.60 (m, 1H)). ^{13}C{^{1}H} NMR

(100 MHz, $CDCl_3$): δ (ppm) = 160.7, 159.1, 150.6, 142.1, 134.5, 132.4, 129.0, 128.8, 128.2, 127.2, 123.9, 118.9, 113.8.

2-(Thiophen-2-yl)quinazoline (10aq).[11g,18a,26a] Eluent: petroleum ether/ethyl acetate (17:1). White solid (65%, 138 mg). ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) = 9.27 (s, 1H), 8.07 (d, *J* = 3.6 Hz, 1H), 7.92 (d, *J* = 8.0 Hz, 1H), 7.81-7.78 (m, 2H), 7.48 (t, *J* = 8.0 Hz, 1H), 7.44 (d, *J* = 4.9 Hz, 1H), 7.11 (t, *J* = 4.0 Hz, 1H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 160.5, 157.8, 150.6, 143.8, 134.4, 129.9, 129.3, 128.4, 128.2, 127.3, 127.0, 123.3.

2-(Pyridin-3-yl)quinazoline (10ar).[11g] Eluent: petroleum ether/ethyl acetate (17:1). Yellow solid (59%, 122 mg). ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) = 9.73 (s, 1H), 9.39 (s, 1H), 8.79 (d, *J* = 8 Hz, 1H), 8.64 (d, *J* = 4.0 Hz, 1H), 8.02 (d, *J* = 8 Hz, 1H), 7.86 (m, 2H), 7.58 (t, *J* = 7.28 Hz, 1H), 7.39-7.36 (m, 1H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) = 160.7, 159.2, 151.1, 150.6, 150.2, 135.8, 134.5, 129.3, 128.7, 127.8, 127.2, 123.8, 123.5.

2-(Pyridin-4-yl)quinazoline (10as).[11g,26a] Eluent: petroleum ether/ethyl acetate (17:1). Yellow solid (61%, 126 mg). ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) = 9.43 (s, 1H), 8.74 (s, 2H), 8.40 (s, 2H), 8.06 (d, *J* = 8.0 Hz, 1H), 7.91- 7.87 (m, 2H), 7.64-7.60 (m, 1H).

2-Butylquinazoline (10at).[18a, 26a] Eluent: petroleum ether/ethyl acetate (20:1). yellow oil (25%, 47 mg). ^{1}H NMR ($CDCl_3$, 300 MHz) δ (ppm) = 9.37 (s, 1H), 7.97-7.91 (m, 1H), 7.84-7.79 (m, 2H), 7.53-7.50 (m, 1H), 3.61-3.56 (m, 2H), 1.99-1.94 (m, 2H), 1.61-1.53 (t, *J*= 8.73 Hz, 2H) 0.83-0.79 (t, *J* = 7.47 Hz, 3H).

6-Methyl-2-phenylquinoline (8ba).[26c] Eluent: petroleum ether/ethyl acetate (19 : 1). White solid (87%, 191 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 8.12 (d, *J* = 7.8 Hz, 2H), 8.07-8.02 (t, *J* = 8.8 Hz, 2H), 7.75 (d, *J* = 8.3 Hz, 1H), 7.52-7.47 (m, 4H), 7.44-7.42 (m,1H), 2.49 (s, 3H).

8-Methyl-2-phenylquinoline (8ca).[26c] Eluent: petroleum ether/ethyl acetate (19 : 1). Pale-yellow oil (81%, 178 mg). ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) =8.12 (d, *J* = 7.20 Hz, 2H), 7.97 (d, *J* = 8.88 Hz, 1H), 7.71 (d, *J* =8.88 Hz, 1H), 7.48 (d, *J* = 7.76 Hz, 1H), 7.43-7.37 (m, 3H),7.33-7.29 (m, 1H), 7.27-7.29 (m, 1H), 2.78 (s, 3H).

8-Bromo-6-methyl-2-phenylquinoline (8da).[26c] Eluent: petroleum ether/ethyl acetate (19 : 1). White solid (66%, 197 mg). ^{1}H NMR(400 MHz, $CDCl_3$): δ (ppm) = 8.16-8.14 (dd, *J* = 1.28, 8.84 Hz, 2H), 7.85 (d, *J* = 8.88 Hz, 1H), 7.73-7.68 (m, 2H), 7.41-7.37 (m, 2H), 7.35-7.30 (m, 2H), 2.32 (s, 3H).

7-Chloro-2-phenylquinoline (8ea).[26c] Eluent: petroleum ether/ethyl acetate (19 : 1). White solid (80%, 192 mg).^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) = 8.19-8.14 (m, 3H), 8.09 (d, *J* = 8.73 Hz,

1H), 7.80 (d, *J* = 7.29 Hz, 1H), 7.67 (d, *J*= 8.73 Hz, 1H), 7.57-7.49 (m, 3H), 7.45-7.42 (dd, *J*= 2.16, 8.73 Hz, 1H). $^{13}C\{^{1}H\}$ NMR (75 MHz, $CDCl_3$): δ (ppm) = 158.2, 148.7, 139.2, 136.5, 135.5, 129.7, 128.9, 128.7, 127.7, 127.3, 125.6, 119.1. HRMS (ESI, positive ions): m/z calcd for $C_{15}H_{11}ClN^+$ [M + H^+] 240.0575, found 240.0563.

2-Phenylbenzo[g]quinoline (8fa).[26c] Eluent: petroleum ether/ethyl acetate (19 : 1). White solid (75%, 191 mg).^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 8.77 (s, 1H), 8.38 (d, *J* = 8.72 Hz, 2H), 8.23 (d, *J* = 5.84 Hz, 2H), 8.10 (d, *J* = 6.76 Hz, 1H), 8.03 (d, *J* = 7.76 Hz, 1H), 7.88 (d, *J* = 8.72 Hz, 1H), 7.58-7.49 (m, 5H).

6-Methyl-3-(phenyl)quinoline-2-amine (9ba). Eluent: petroleum ether/ethyl acetate (3:1). White solid (62%, 145 mg). M.p: 128-130^{o}C . ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) = 7.57 (s, 1H), 7.49 (d, *J* = 8.0 Hz, 1H), 7.37-7.34 (m, 5H), 7.28-7.26 (m,2H), 5.29 (s, 2H), 2.33 (s,3H). $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm) = 154.8, 144.7, 137.5, 137.1, 132.4, 131.9, 129.2, 128.9, 128.3, 126.7, 125.1, 124.7, 123.9, 21.2. HRMS (ESI, positive ions): m/z calcd for $C_{16}H_{15}N_2^+$ [M + H^+] 235.1229, found 235.1229.

8-Methyl-3-(phenyl)quinoline-2-amine (9ca). Eluent: petroleum ether/ethyl acetate (3:1). Yellow oil (61%, 143 mg). ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) = 7.64 (s, 1H), 7.42-7.38 (m, 3H), 7.36-7.35 (m, 2H), 7.32-7.30 (m, 2H), 7.05 (t, *J* = 8 Hz, 1H), 4.89 (s, 2H), 2.58 (s, 3H). $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm) = 153.5, 145.1, 136.8, 136.6, 132.6, 128.9, 128.1, 127.9, 127.1, 124.5, 123.5, 123.0, 121.4, 17.0. HRMS (ESI, positive ions): m/z calcd for $C_{16}H_{15}N_2^+$ [M + H^+] 235.1229, found 235.1229.

7-Chloro-3-(phenyl)quinoline-2-amine (9da). Eluent: petroleum ether/ethyl acetate (3:1). White solid. (59%, 150 mg). M.p: 140-142^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) = 7.72 (s, 1H), 7.66-7.62 (m, 1H), 7.53 (d, *J* = 8 Hz, 1H), 7.49 (d, *J* = 8 Hz, 4H), 7.47-7.41 (m, 1H), 7.21-7.18 (dd, *J* = 2.0, 8.8 Hz, 1H), 5.21 (s, 2H); $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm) = 155.9, 147.7, 137.2, 136.9, 135.3, 129.3, 128.8,128.6, 128.4, 125.2, 124.7, 123.5, 122.5. HRMS (ESI, positive ions): m/z calcd for $C_{15}H_{12}ClN_2^+$ [M + H^+] 255.0683, found 255.0679.

7-Chloro-3-(4-fluorophenyl)quinoline-2-amine (9ea). Eluent: petroleum ether/ethyl acetate (3:1). White solid (65%, 177 mg). M.p: 180-182 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) = 7.63 (s, 1H), 7.58 (s, 1H), 7.46 (d, *J* = 8.0 Hz, 1H), 7.41-7.38 (m, 2H), 7.14- 7.09 (m, 3H), 5.13 (s, 2H). $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$): δ (ppm) =155.9, 147.5, 137.1, 135.5, 133.0, 132.9, 130.7 (d, *J* = 9.0 Hz), 128.6, 124.6, 124.1, 123.7, 122.4, 116.3 (d, *J* = 21.0 Hz). HRMS (ESI, positive ions): m/z calcd for $C_{15}H_{11}ClFN_2^+$ [M + H^+] 273.0589, found 273.0587.

3-(4-Bromophenyl)-7-chloroquinoline-2-amine (9fa). Eluent: petroleum ether/ethyl acetate (3:1). White solid (63%, 210 mg). M.p: 175-177^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ (ppm) = 7.71 (s, 1H), 7.66-7.62 (m, 3H), 7.53 (d, *J* = 8 Hz, 1H), 7.35 (d, *J* = 8.0 Hz, 2H), 7.22 (d, *J* = 8.0 Hz, 1H), 6.21 (br.s, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ (ppm) = 155.9, 145.7, 137.7, 136.3, 135.2, 132.6, 130.5, 128.7, 124.4, 124.0, 123.0, 122.8, 121.7. HRMS (ESI, positive ions): m/z calcd for $C_{15}H_{11}BrClN_2^+$ [M + H$^+$] 332.9789, found 332.9791.

6-Methyl-2-phenyl quinazoline (10ba).[18a,26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (84%, 185 mg). ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) = 9.30 (s, 1H), 8.53-8.51 (dd, *J*= 1.6 Hz, 8.4 Hz, 2H), 7.91 (d, *J* = 8.8 Hz, 1H), 7.67-7.64 (dd, *J* = 1.6 Hz, 8.8 Hz, 1H), 7.60 (s, 1H), 7.48-7.41 (m, 3H), 2.49 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) = 160.4, 159.8, 149.4, 138.2, 137.5, 136.4, 128.6, 128.4, 128.3, 125.8, 123.6, 21.7. HRMS (ESI, positive ions): m/z calcd for $C_{15}H_{13}N_2^+$ [M + H$^+$] 221.1073, found 221.1052.

6,7,8-trimethoxy-2-phenylquinazoline (10ca).[26a] Eluent: petroleum ether/ethyl acetate (19:1). pale yellow oil (78%, 231 mg). ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) = 9.22 (s, 1H), 8.54 (d, *J* = 5.56 Hz, 1H), 7.46-7.41 (m, 4H), 6.90 (s, 1H), 4.24 (d, *J* = 16.0 Hz, 3H), 4.05 (d, *J* = 11.08 Hz, 3H), 3.95 (d, *J* = 11.08 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) = 158.3, 153.5, 146.7, 138.2, 130.3, 128.6, 128.2, 120.9, 100.1, 61.6, 60.5, 56.2.

8-Bromo-6-methyl-2-phenylquinazoline (10da).[26a] Eluent: petroleum ether/ethyl acetate (24:1). White solid (80%, 239 mg); ^{1}H NMR ($CDCl_3$, 300 MHz) δ (ppm) = 9.30 (s, 1H), 8.69-8.67 (m, 2H), 8.03 (s, 1H), 7.59 (s, 1H), 7.54-7.51 (m, 3H), 2.52 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) = 161.0, 160.3, 146.7, 139.5, 138.5, 137.7, 130.9, 128.8, 128.6, 125.6, 124.6, 123.8, 21.5.

2-(4-Chlorophenyl)-6-methylquinazoline (10ea).[18a,26a] Eluent: petroleum ether/ethyl acetate (19:1). White solid (81%, 206 mg). ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) = 9.34 (s, 1H), 8.53 (d, *J* = 8.8 Hz, 2H), 7.95 (d, *J* = 7.8 Hz, 1H), 7.73 (d, *J* = 8.8 Hz,1H), 7.66 (s, 1H), 7.49 (d, *J* = 8.8 Hz, 2H), 2.56 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) = 159.8, 159.4, 149.3, 137.7, 136.7, 136.6, 129.7, 128.8, 128.2, 125.8, 123.6, 21.7.

7-Chloro-2-phenyl quinazoline (10fa).[26a] Eluent: petroleum ether/ethyl acetate (24:1). White solid (82%, 197 mg). ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) = 9.34 (s,1H), 8.53-8.50 (m, 2H), 7.99 (d, *J*= 1.3 Hz, 1H), 7.76 (d, *J* = 8.6 Hz, 1H), 7.47-7.44 (m, 4H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) = 161.8, 160.2, 151.3, 140.3, 137.6, 130.9, 128.7, 128.4, 128.4, 127.8, 121.9. HRMS (ESI, positive ions): m/z calcd for $C_{14}H_{10}ClN_2^+$ [M + H$^+$] 241.0527, found 241.0517.

2-Phenylacetamide (6a'). Eluent: petroleum ether/ethyl acetate (2:1). White solid. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) = 7.40 - 7.36 (m, 2H), 7.34-7.28 (m, 3H), 5.89 (br.s., 1H), 5.47 (br.s., 1H), 3.60 (s, 2H).

Benzamide (7a'). Eluent: petroleum ether/ethyl acetate (3:1). White solid. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) = 7.76 - 7.74 (m, 2H), 7.47 -7.44 (m, 1H), 7.39 - 7.35 (t, *J* = 8.0 Hz, 2H), 6.29 (br.s., 2H).

ASSOCIATED CONTENT

Supporting Information. The Supporting Information is available free of charge on the ACS Publications website www.pubs.acs.org. ^{1}H and ^{13}C NMR spectral data (PDF).

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Notes

The authors declare no competing financial interest.

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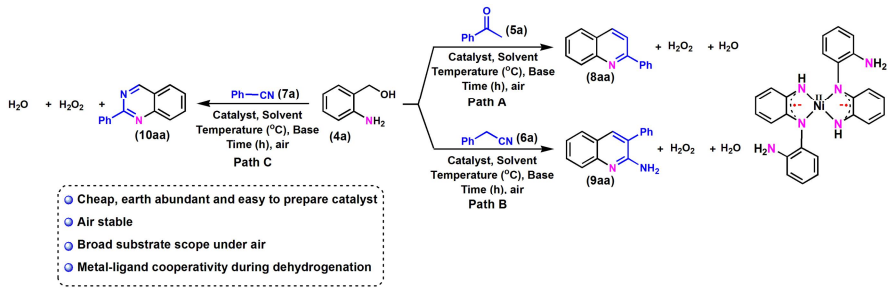
(5a)
Catalyst, Solvent
Temperature (°C), Base
Time (h), air
Path A
(8aa)
+ H2O2 + H2O
Ph—CN (7a)
Catalyst, Solvent
Temperature (°C), Base
Time (h), air
Path C
(10aa)
H2O + H2O2 +
(4a)
Ph—CN (6a)
Catalyst, Solvent
Temperature (°C), Base
Time (h), air
Path B
(9aa)
+ H2O2 + H2O
Ni
Cheap, earth abundant and easy to prepare catalyst
Air stable
Broad substrate scope under air
Metal-ligand cooperativity during dehydrogenation