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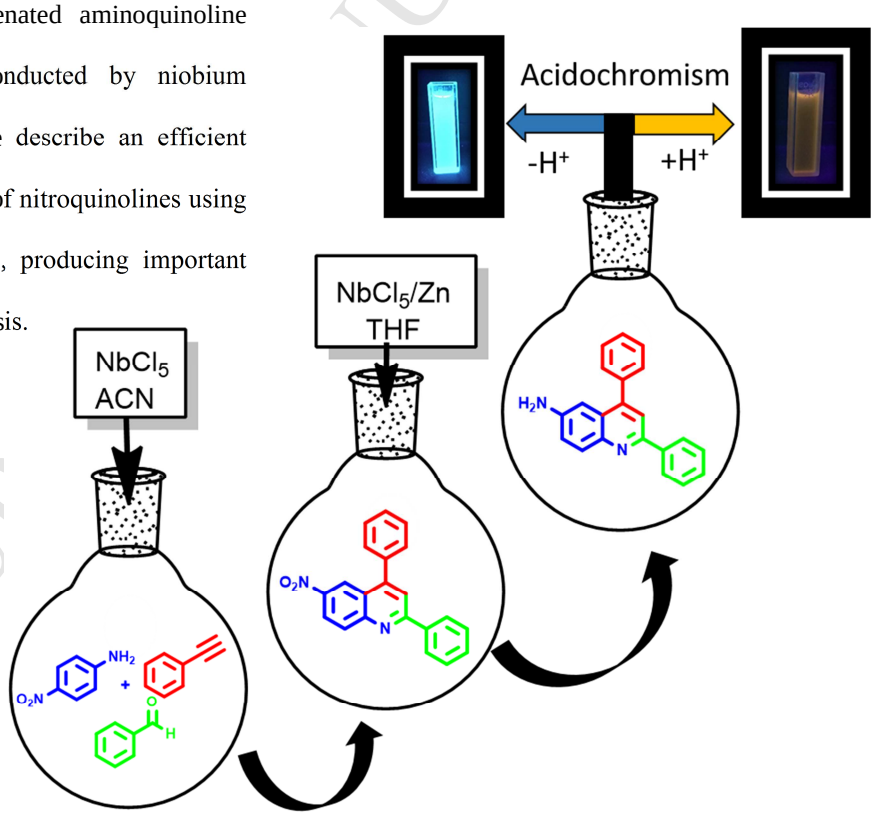
$NbCl_5$ a multifunctional reagent for the synthesis of new halogenated aminoquinoline compounds through innovative One-pot reaction and the acidochromism effect.

Giovanny Carvalho dos Santos, Vitor Fernandes Moreno, Paula Beatriz Oshiro and Luiz Carlos da Silva-Filho*

Laboratory of Organic Synthesis and Processes (LOSP), São Paulo State University (UNESP), Department of Chemistry, School of Sciences, 17033-360, Bauru, São Paulo, Brazil

Fax +55(14) 31036099:*e-mail: lcsilva@fc.unesp.br

Abstract: This paper describes an original one-pot way to synthesize nine new halogenated aminoquinoline derivatives using reactions conducted by niobium pentachloride. Subsequently, we describe an efficient and selective reduction reaction of nitroquinolines using niobium pentachloride and zinc, producing important compounds in the organic synthesis. The results showed that it is an important tool to synthesize these compounds, besides being time- and resources-saving and generating good yields. A quick study of acidochromism was performed.



Keywords: Niobium Pentachloride, One-Pot Reactions, Aminoquinoline Derivatives, Selective Reduction Reactions.

1. Introduction

The growing interest in niobium compounds for organic synthesis and catalysis is highlighted by the commercially available niobium pentachloride ($NbCl_5$), which is highly electrophilic, making it possible to act as a Lewis acid [1]. Among the recent applications of $NbCl_5$ in the organic synthesis and catalysis, there are: synthesis of β-mercapto compounds, 3,4-dihydropyrimidinones (Biginelli reaction), 1,3-dicarbonyl compounds with amines condensation and β-keto esters, catalysis and promotion of Friedel-Crafts acylation, acetylation of alcohols and phenols, Mannich-type reactions, Knoevenagel condensation, aldol and aza-aldolic reactions, Sakurai reaction, cross-coupling reactions, carbonyl compounds coupling reactions, reduction reactions, cycloaddition and cyclization, multicomponent reactions, one-pot and polymerization reactions, and also transesterification/esterification of microalgae to biodiesel production, Diels-Alder reactions, among others [2-4]. Furthermore, in the last years, $NbCl_5$ has been used by our group and has proven to be an efficient and versatile catalyst in synthetic methodologies in several reactions to synthesize important compounds: isoquinuclidine, xanthenedione, 4*H*-pyran, fluorescein, methoxylated phloroglucinol, chromeno[4,3-b]chromene, quinoline, xanthene and tetraaryl-1,4-dihydropyrrolo-[3,2-b]pyrrole derivatives [5].

One type of these important compounds is the quinoline derivatives, which are important N-based heterocyclic compounds that are characterized by a benzene ring fused to a pyridine ring. These molecules have been an important subject to numerous research groups. Several authors highlight the importance of quinoline derivatives for having many biological applications against several diseases and for its use in polymer chemistry, organic electronics and optoelectronics [6]. Among these uses, the authors also mention the manufacturing of dyes, food colorants, pH indicators and their use as corrosion inhibitors [6].

With this great potential of applicability for the quinoline derivatives, research groups have invested in the synthesis of this heterocyclic compound. Our research group has recently described the synthesis of aminoquinoline derivatives (two-steps) through multicomponent reaction (MCR) catalyzed by Niobium Pentachloride, followed by a reduction of the nitro group with Pd/C and hydrazine [7]. But this method shows a Pd-catalyzed hydrogenolysis of compounds with carbon-halogen bonds with

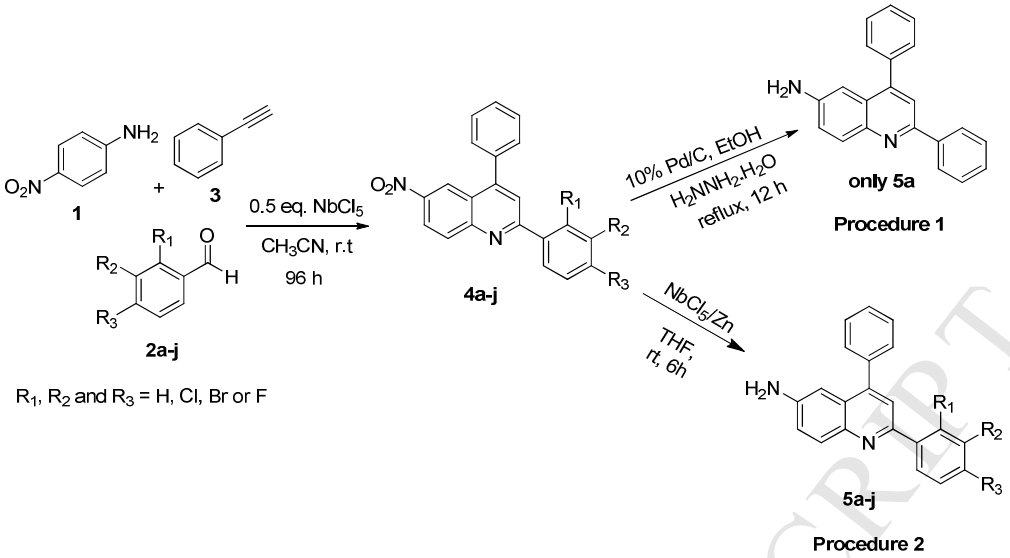
hydrazine as a hydrogen donor. In the literature we know about several methods to reduce nitro compounds to their respective amines, but many of them are not selective to any group [8].

Bearing this in mind, this study has shown that the conversion of halogenated nitroquinolines with fluorides, bromides and chlorides into their corresponding aminoquinolines is possible, based on a report of Yoo and co-workers [9] that described the use of the $NbCl_5$/In system as a reagent for the chemoselective reduction of aromatic nitrocompounds [9]. Here we use zinc instead of indium to reduce the production cost of the final molecule. In addition, we describe a new method for directly obtaining unpublished halogenated aminoquinoline derivatives in a one-pot reaction using the $NbCl_5$/Zn system.

2. Results and discussion

2.1. Two steps synthesis of aminoquinoline derivatives.

In a recent work, we studied the synthesis of nitroquinoline derivatives by MCRs using $NbCl_5$ as promoter, showing good yields for the production of the nitroquinoline derivative, regardless of the benzaldehyde derivatives used [7]. The MCRs were conducted between *p*-nitroaniline (**1**) (1.0 eq.), benzaldehyde derivatives (**2a-j)** (1.0 eq.) and phenylacetylene (**3**) (1.0 eq.) under air atmosphere, room temperature, constant stirring and using anhydrous acetonitrile (CH_3CN) as solvent. $NbCl_5$ was used in the proportion of 50% for each mol of benzaldehyde derivative used. The reduction of the nitro group in the nitroquinoline derivatives was conducted with hydrazine monohydrate in the presence of 10% Pd/C (**Procedure 1**), but these reaction conditions resulted in the dehalogenation of the products, obtaining only the compound **5a** as product [7]. In this present work, we decided to test the $NbCl_5$/Zinc system in the reduction of the nitro group (**Procedure 2**). Procedure 2 is selective and the halogen bond (-Br, -Cl and –F) with aromatic ring remained unaffected. This method shows that it is possible to obtain new aminoquinoline with its halogen substituent. The reduction of the nitro group in all nitroquinoline derivatives (**5a-j**) was successfully obtained and presented reasonable yields without the removal of the halogen (**Scheme 1**).



Scheme 1 Synthesis of aminoquinolines **5a-j** in two ways

The results are summarized in **Table 1** and show the difference of yields between the procedures.

Table 1 Benzaldehyde derivatives used and reaction yields

Aldehyde	R_1	R_2	R_3	R_4	R_5	Aminoquinoline Yield(%)[a,b]	Aminoquinoline Yield (%)[a,c]
2a	H	H	H	H	H	92 (**5a**)	63 (**5a**)
2b	F	H	H	H	H	91 (**5a**) and 0 (**5b**)	67 (only **5b**)
2c	Cl	H	H	H	H	94 (**5a**) and 0 (**5c**)	69 (only **5c**)
2d	Br	H	H	H	H	93 (**5a**) and 0 (**5d**)	68 (only **5d**)
2e	H	F	H	H	H	84 (**5a**) and 0 (**5e**)	61 (only **5e**)
2f	H	Cl	H	H	H	92 (**5a**) and 0 (**5f**)	53 (only **5f**)
2g	H	Br	H	H	H	90 (**5a**) and 0 (**5f**)	51 (only **5g**)
2h	H	H	F	H	H	84 (**5a**) and 0 (**5h**)	62 (only **5h**)
2i	H	H	Cl	H	H	80 (**5a**) and 0 (**5i**)	46 (only **5i**)
2j	H	H	Br	H	H	87 (**5a**) and 0 (**5j**)	32 (only **5j**)

[a]Yields of isolated products after recrystallization
[b]Method with Pd/C and hydrazine
[c]Method with $NbCl_5$ and zinc

Although the yields were not very good when the reduction method with the $NbCl_5$/Zn system was used, we were able to observe the formation of the respective aminoquinoline derivatives (**5b-j**)

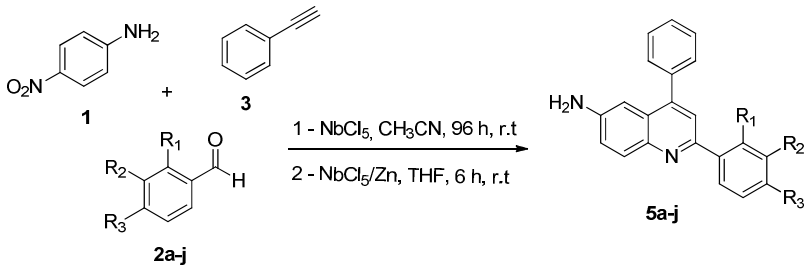
containing the halogens while, when the Pd/C system was used, only the formation of aminoquinoline **5a** was verified, independent of the nitroquinoline derivative used, probably due to its reductive reactional condition, which also resulted in the dehalogenation of the products. In general, higher yields were observed when the halogens were in the *ortho* position, followed by *meta* position and finally the *para* position. With some exceptions, in the general behavior regarding which halogen was used, we have the best yields with F, Cl and Br, respectively. These results can be explained by the bond strength of the halogens [10].

The reduction process of the nitroquinoline derivatives occurs by the generation of low-valent niobium complexes, formed from the reduction of $NbCl_5$ by using zinc metal. Previous experiments showed us that $NbCl_5$ or Zn separately do not initiate the reaction [9]. Therefore, we need the formation of a $NbCl_5$/Zn system in order to reduce the nitro group, which occurs by the reductive cleavage of polarized N-O bonds that are polarized by a single electron transfer (SET) process.

The chemical structures of the resulting new halogenated aminoquinoline derivatives were confirmed by ^{1}H NMR, ^{13}C NMR, IR and HRMS spectra. In order to emphasize the importance of halogenated quinolines, we highlight that these compounds have become important intermediates in metal-catalyzed carbon–carbon bond formation to promote the synthesis novel substituted quinoline derivatives to act as monomers in polymerization reactions and with potential applications in pharmaceuticals and materials [11]. In addition, the halogenated quinoline shows potent antibacterial activities against a broad spectrum of pathogenic bacteria, including multidrug-resistant clinical isolates [12].

2.2. One-pot synthesis of aminoquinoline derivatives.

In order to improve the synthesis of aminoquinoline derivatives, a new method was performed to directly obtain these compounds by One-pot reaction using $NbCl_5$ in the two steps of the synthesis. Firstly, the synthesis of the nitroquinoline derivatives (**4a-j**) was performed in the same reaction conditions described previously. After 96 hours of reaction, the solution containing the reducing system ($NbCl_5$/Zn) was added directly to the reaction medium and, after 6 hours, the formation of aminoquinoline derivatives (**5a-j**) with excellent yields was verified. The results obtained are described in Scheme 2 and Table 2.



Scheme 2 Synthesis of aminoquinolines **5a-j**

Table 2 MCR and One-pot reaction yields

Aldehyde	R_1	R_2	R_3	R_4	R_5	Aminoquinoline Yield (%)[a] (One-pot reaction)	Overall Yield of reactions in two steps (%)
2[a]	H	H	H	H	H	90 (**5a**)	59 (**5a**)
2b	F	H	H	H	H	92 (**5b**)	58 (**5b**)
2c	Cl	H	H	H	H	86 (**5c**)	63 (**5c**)
2d	Br	H	H	H	H	87 (**5d**)	55 (**5d**)
2e	H	F	H	H	H	92 (**5e**)	45 (**5e**)
2f	H	Cl	H	H	H	89 (**5f**)	52 (**5f**)
2g	H	Br	H	H	H	90 (**5g**)	40 (**5g**)
2h	H	H	F	H	H	93 (**5h**)	60 (**5h**)
2i	H	H	Cl	H	H	91 (**5i**)	39 (**5i**)
2j	H	H	Br	H	H	88 (**5j**)	31 (**5j**)

[a]Yields of isolated products after chromatography column by one-pot reaction.

The results show us that this is an important methodology to directly produce aminoquinoline derivatives with good yields for the halogenated aminoquinolines. In the two-step method, the first with the MCR followed by extraction and isolation of the product, the second using the compound isolated for the reduction of the nitro group, we observed a reasonable overall yield (see comparison in table 2), in addition to reducing the time and solvents spent in the extraction process and purification. On the other hand, using the new one-pot methodology, we observed good yields and time- and resource-saving during the synthesis. As to the results, the yields of the halogens in *para* position are, in general, higher than those in the *meta* and *ortho* positions, respectively. Regarding the type of halogen, the fluorine as substituent presents the best results.

Due to the several examples of the application of 2,4-disubstituted quinolines, the one-pot synthesis shows to be an important method due to its simple and low-cost methodology in obtaining these derivatives. The chemical structures of the resulting halogenated aminoquinoline derivatives were confirmed by ^{1}H NMR, ^{13}C NMR, IR and HRMS spectra.

2.3. Photophysical Properties

2.3.1. UV-Vis Absorption Properties

In this study, we add different halogens (F, Cl, Br) substituents at *ortho*, *meta* and *para* positions to examine the effects on absorption. The absorption spectra of ethanolic solutions ($5x10^{-5}$ mol.L^{-1}) of aminoquinoline derivatives are depicted in **Fig. 1**

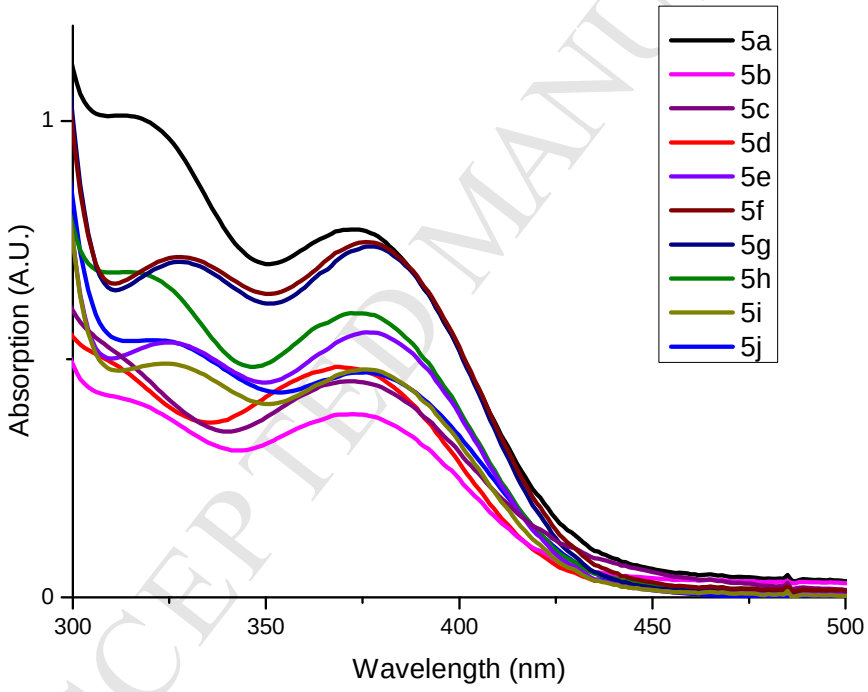


Figure 1: UV-Vis absorption of halogenated aminoquinoline derivatives (**5a–j**) in ethanol

As shown in the others papers [12-13], the absorption spectra of the halogenated aminoquinoline derivatives in ethanol are characterized by strong absorption peaks centered at approximately 300–330 nm and 369–378 nm attributed to π-π* and n-π* transitions. Visually we did not observe many differences in shape and shift of the spectrum, the greatest differences are in the intensity. The data of UV-Vis absorption are summarized in **Table 3** in $5x10^{-5}$ mol. L^{-1} EtOH solution.

Table 3: Maximum absorption wavelength (λmax) for halogenated aminoquinoline derivatives

Aldehyde	R_1	R_2	R_3	R_4	R_5	λmax(nm) ethanol
2a	H	H	H	H	H	375
2b	F	H	H	H	H	372
2c	Cl	H	H	H	H	372
2d	Br	H	H	H	H	369
2e	H	F	H	H	H	376
2f	H	Cl	H	H	H	377
2g	H	Br	H	H	H	378
2h	H	H	F	H	H	373
2i	H	H	Cl	H	H	376
2j	H	H	Br	H	H	376

The difference in shift among the halogenated aminoquinoline derivatives is not very significant. In spite of this it is possible to observe a tendency between which is the halogen and in which position is inserted in the ring. In general, the lowest absorption values are observed for the *ortho* position, in the sequence we have the *para* position and finally the *meta* position presents the largest displacement for the red region, these work for all the halogens. Bromine substituent has the lowest absorption wavelength value in the *ortho* position (**5d**) and the highest value in the *meta* position (**5g**). These new halogen-containing compounds can be used as important starting materials for the synthesis of more complex molecules.

2.3.2. Acidochromism effect in UV-Vis Absorption Properties

We have known that these derivatives show a slight solvatocromism (Fig S1 in Support Information and ref [13]). Here we added HCl to the compound **5a** solubilized in ethanol to know the effect of protonation on the molecule. We have been observed a protonation of nitrogen based heterocycles in Figure 2 [14]. The addition changed the color of solution from light yellow to orange in visible light and from blue to orange color in UV light irradiation (365 nm).

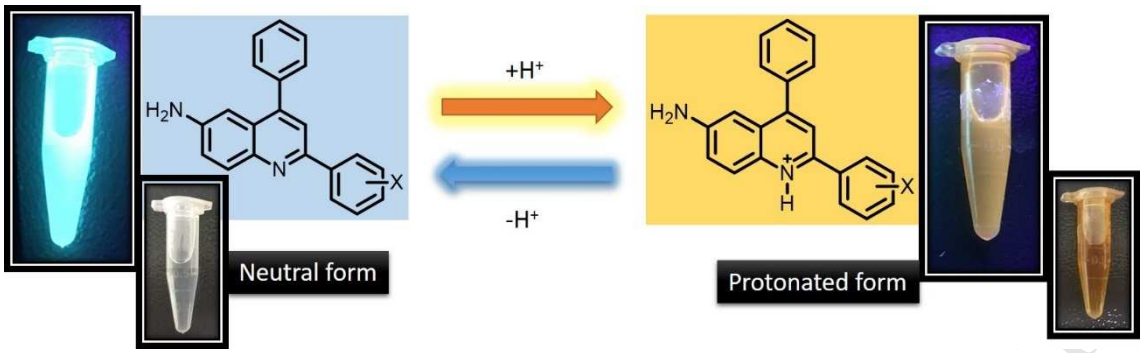


Figure 2: Effect of nitrogen protonation of quinoline backbone

The addition of HCl caused a batochromism (red shift) of 72nm as observed. To this effect is given the name of positive acidochromism, where a strong transfer of charge is possible, as mechanistically suggested in Figure 3. The addition of ammonium hydroxide had no change at the spectra. All the compounds (**5a-j**) have shown the same behavior in acidic and basic media.

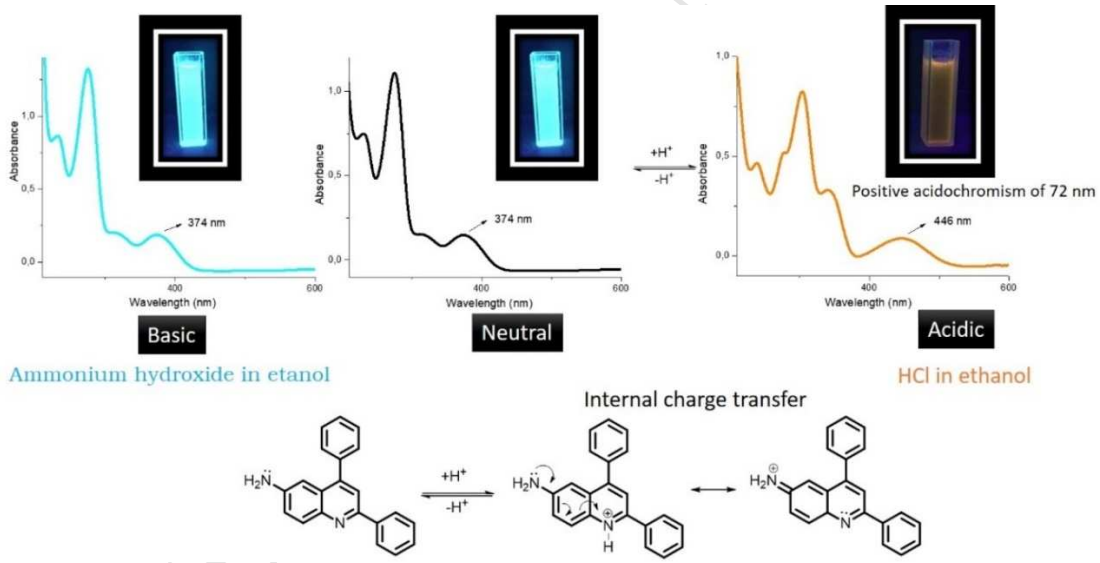


Figure 3: Absorption spectra of compound **5a** and mechanism of charge tranfer.

3. Conclusion

We found a new method for obtaining aminoquinoline compounds using $NbCl_5$ that proved to be an excellent reagent for one-pot reactions. All the reactions were conducted at low cost, in mild conditions and with good yields. Here, a quick study of acidochromism was performed and a positive acidochromism was observed when we added HCl. Considering the unquestionable importance of quinoline derivatives in different areas, such as the development of pharmaceuticals, dyes, chemical polymers and in electronic devices, this methodology developed here proves to be important for a fast and efficient study about these molecules.

4. Experimental section

4.1. General

All reactions were performed under air atmosphere, unless otherwise specified. Acetonitrile was distilled from calcium hydride. All commercially available reagents were used without further purification. The $NbCl_5$ used was supplied by Companhia Brasileira de Metalurgia e Mineração (CBMM). Thin-layer chromatography was performed on 0.2 mm Merck $60F_{254}$ silica gel aluminum sheets, which were visualized with UV-365nm irradiation. Bruker DRX 400 spectrometer was employed for the NMR spectra ($CDCl_3$ solutions) using tetramethylsilane as internal reference for ^1H and $CDCl_3$ as an internal reference for ^{13}C. A model 4600 Jasco FTIR was used to record IR spectra (KBr pellets). HRMS analyses were recorded in a micrOTOF (Bruker), with ESI-TOF detector working on positive mode.

4.2. General Procedure for the synthesis of nitroquinoline derivatives

The complete synthesis and full spectral characterization (NMR, MS, IR and other techniques) of nitro compounds were reported previously [7].

4.3. Procedure 1 for the synthesis of aminoquinoline derivatives from nitroquinolines

An ethanol suspension (20.0 mL) of nitroquinoline derivative (1.0 mmol) was heated to 50.0 °C in the presence of 10%Pd/C and 2.00 mL of hydrazine monohydrate was added to this suspension after 30 min. The reaction mixture became clear as the reaction proceeded. It was then kept at reflux for another 12 hours. After the reaction was complete, the mixture was filtered over Celite twice to remove the Pd/C

catalyst. Ethanol was removed under reduced pressure. The crude product was recrystallized from isopropanol. Note: the crystals grew slowly [15].

4.4. Procedure 2 for the synthesis of aminoquinoline derivatives from nitroquinolines

Niobium pentachloride (270 mg, 1.0 mmol), zinc powder (460 mg, 4.0 mmol) and THF (3 mL) were mixed and the resulting mixture was sonicated for 30 min at room temperature. A black solution of the complex was obtained. A nitroquinoline derivative (0.5 mmol) was added to this solution. The reaction mixture was stirred for 6h at room temperature. After the reaction was over, as indicated by TLC, water was added and then the organic extract was obtained with ethyl acetate. The combined organic extract was washed with brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The crude product was purified by silica gel column chromatography (hexane:ethyl acetate = 2:1) to yield the aminoquinoline derivative [9].

4.5. Procedure for direct synthesis of aminoquinoline (One-pot reaction)

In a solution of $NbCl_5$ (50 mol%) in 7.0 mL of anhydrous acetonitrile, maintained at room temperature under air atmosphere, we added a solution of *p*-nitroaniline (1.0 mmol), phenylacetylene (1.0 mmol) and benzaldehyde derivatives **(2a-j)** (1.0 mmol) in 3.0 mL of anhydrous acetonitrile. The reaction mixture was quenched with water (3.0 mL) after 96 hours. Separately, niobium pentachloride (270 mg, 1.0 mmol), zinc powder (460 mg, 4.0 mmol) and THF (3 mL) were mixed and the resulting mixture was sonicated for 30 min at room temperature. A black solution of the complex was obtained. This solution was added to the reaction flask. The reaction mixture was stirred for 6h at room temperature. After the reaction was over, as indicated by TLC, water was added and then the organic extract was obtained with ethyl acetate. The combined organic extract was washed with brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The crude product was purified by silica gel column chromatography (hexane:ethyl acetate = 2:1) to yield the aminoquinoline derivative.

4.5.1. 6-amino-2,4-diphenylquinoline (5a) [7]: Yellowish-white solid. **mp/ºC** =148 – 151 °C. **^{1}H NMR** (400 MHz, $CDCl_3$): δ8.16 (d, *J*=1.5 Hz, 2H), 8.14 (s, 1H), 7.72 (s, 1H), 7.56 (d, *J*=4.5 Hz, 4H), 7.44-7.53 (m, 4H), 7.20 (dd, *J*=8.8, 2.5 Hz, 1H), 6.99 (d, *J*=2.5 Hz, 1H), 3.94 (s, 2H) ppm;**^{13}C NMR** (125 MHz, $CDCl_3$): δ 105.7, 116.7, 119.6, 121.4, 127.1, 128.1, 128.5, 128.7, 128.7, 129.4, 131.3, 138.9, 139.9,

143.9, 144.6, 146.7, 153.4 ppm. **IR** (neat): ν_{max}= 698, 763, 1031, 1258, 1377, 1550, 1619, 1671, 2857, 2926, 3303, 3438 cm^{-1};**ESI-HRMS:***m/z* calcd for $C_{21}H_{17}N_2$ $[M + H]^+$: 297.1386; found 297.1388.

4.5.2. 2-(2-fluorophenyl)-6-amine-4-phenylquinoline (5b): Brown foam. **^{1}H NMR** ($CDCl_3$, 400MHz): δ = 8.02-8.07 (m, 2H), 7.68 (d, *J* = 2.5 Hz, 1H), 7.45-7.54 (m, 5H), 7.35-7.37 (m, 1H), 7.24-7.29 (m, 1H), 7.12-7.17 (m, 2H), 6.98 (d, *J* = 2.5 Hz, 1H), 3.85 (s, 2H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 161.9, 159.4, 149.9, 146.1, 145.0, 143.9, 138.8, 131.3, 130.2, 129.5, 128.5, 128.1, 127.3, 124.6, 123.0, 121.5, 116.3, 116.0, 105.6 ppm. **IR**: ν_{max}= 698, 763, 1031, 1258, 1377, 1550, 1619, 1671, 2857, 2926, 3303, 3438 cm^{-1}. **ESI-HRMS**: *m/z* calcd for $C_{21}H_{16}FN_2$ $[M + H]^+$: 315.1292; found 315.1294

4.5.3. 2-(2-chlorophenyl)-6-amine-4-phenylquinoline (5c): Brown foam**.** **^{1}H NMR** ($CDCl_3$, 400MHz): δ = 8.13-8.15 (m, 2H), 8.07 (d, *J* = 9.0 Hz, 1H), 7.71 (s, 1H), 7.51-7.56 (m, 7H), 7.19 (dd, *J* = 9.0, 2.5 Hz, 1H), 6.99 (d, *J* = 2.5 Hz, 1H), 3.87 (s, 2H). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 171.1, 153.3, 145.5, 145.1, 143.7, 139.8, 138.7, 132.5, 131.7, 131.3, 130.0, 129.5, 128.5, 128.1, 127.1, 123.2, 121.4, 105.5 ppm. **IR**: ν_{max}= 698, 771, 835, 1027, 1081, 1220, 1328, 1483, 1589, 3103 cm^{-1}. **ESI-HRMS**: *m/z* calcd for $C_{21}H_{16}ClN_2$ $[M + H]^+$: 331.0996; found 331.0992.

4.5.4. 2-(2-bromophenyl)-6-amine-4-phenylquinoline (5d): Brown foam. **^{1}H RMN** ($CDCl_3$, 400 MHz): δ = 8.05 (d, *J* = 8.8 Hz, 1H); 7,70 (s, 1H); 7.69-7.67 (m, 2H); 7.58–7.44 (m, 6H); 7.29–7.25 (m, 1H); 7.20 (dd, *J* = 8.8, 2.5 Hz, 1H); 7.05 (d, *J* = 2.5 Hz, 1H); 3,92 (s, 2H) ppm. **^{13}C RMN** (125 MHz, $CDCl_3$): δ = 105.6, 121.4, 122.1, 123.2, 127.1, 127.6, 128.1, 128.5, 129.5,129.6, 131.3, 131.6, 133.2, 138.6, 141.82, 143.5, 145.1, 145.5, 154.6 ppm. **IR**: ν_{max}= 698, 763, 830, 956, 1091, 1297, 1492, 1619, 2366, 3045, 3294, 3442 cm^{-1}. **ESI-HRMS:** *m/z* calcd for $C_{21}H_{16}BrN_2$ $[M + H]^+$: 375.0491; found 375.0493.

4.5.5. 2-(3-fluororophenyl)-6-amine-4-phenylquinoline (5e): Brown foam. **^{1}H NMR** ($CDCl_3$, 400MHz): δ = 7.79 (d, *J*= 9.0 Hz, 1H), 7.62-7.67 (m, 2H), 7.41 (s, 1H), 7.17-7.30 (m, 6H), 6.83-6.92 (m, 2H), 6.71 (d, *J* = 2.5 Hz, 1H), 3.67 (s, 2H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 164.6, 151.9, 146.9, 145.0, 143.8, 142.4, 138.8, 131.4, 130.2, 129.4, 128.6, 128.2, 127.5, 122.7, 121.7, 119.4, 115.6, 114.2, 105.6 ppm. **IR**: ν_{max}= 698, 762, 1215, 1374, 1491, 1623, 1736,2364, 2971, 3030, 3307, 3448 cm^{-1}. **ESI-HRMS:** *m/z* calcd for $C_{21}H_{16}FN_2$ $[M + H]^+$: 315.1292; found 315.1273.

4.5.6. 2-(3-chlorophenyl)-6-amine-4-phenylquinoline (5f): Brown foam. **^{1}H NMR** ($CDCl_3$, 400MHz): δ = 7.81-7.84 (m, 2H), 7.77 (d, *J* = 9.0 Hz, 1H), 7.39 (s, 1H), 7.18-7.28 (m, 7H), 6.91 (dd, *J* =

9.0, 2.5 Hz, 1H), 6.71 (d, *J* = 2.5 Hz, 1H), 3.66 (s, 2H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 152.1, 146.9, 144.9, 143.9, 138.9, 134.8, 131.3, 129.4, 128.9, 128.6, 128.4, 128.2, 127.3, 121.6, 119.2, 105.7 ppm. **IR**: ν_{max}= 648, 698, 764, 832, 1030, 1296, 1491, 1622, 3206, 3314 cm^{-1}. **ESI-HRMS**: *m/z* calcd for $C_{21}H_{16}ClN_2$ $[M + H]^+$: 331.0996; found 331.0992.

4.5.7. 2-(3-bromophenyl)-6-amine-4-phenylquinoline (5g): Brown foam. **^{1}H NMR** ($CDCl_3$, 400MHz): δ = 8.07 (t, *J* = 1.8 Hz, 1H), 7.77-7.87 (m, 2H), 7.39 (s, 1H), 7.24-7.29 (m, 6H), 7.09 (t, *J* = 7.8 Hz, 1H), 6.91 (dd, *J* = 9.0, 2.5 Hz, 1H), 6.71 (d, *J* = 2.5 Hz, 1H), 3,64 (s, 2H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 151.6, 146.9, 145.1, 143.8, 142.0, 138.8, 131.6, 131.4, 130.3, 130.2, 129.4, 128.6, 128.2, 127.5, 125.6, 123.1, 121.7, 119.3, 105.6 ppm. **IR**: ν_{max}= 698, 763, 834, 1028, 1295, 1491, 1621, 3211, 3314, 3440 cm^{-1}. **ESI-HRMS**: *m/z* calcd for $C_{21}H_{16}BrN_2$ $[M + H]^+$: 375.0491; found 375.0493.

4.5.8. 2-(4-fluorophenyl)-6-amine-4-phenylquinoline (5h): Brown foam. **^{1}H NMR** ($CDCl_3$, 400MHz): δ = 7.86-7.89 (m, 2H), 7.77 (d, *J* = 9.0 Hz, 1H), 7.38 (s, 1H), 7.23-7.28 (m, 5H), 6.89-6.94 (m, 3H), 6.71 (d, *J* = 2.5 Hz, 1H), 3.63 (s, 2H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 169.5, 154.0, 153.9, 151.9, 134.4, 134.2, 130.8, 129.4, 129.2, 125.3, 125.1, 125.0, 124.1, 118.9, 94.1 ppm. **IR**: ν_{max}= 698, 771, 835, 1027, 1081, 1220, 1328, 1483, 1589, 3103 cm^{-1}. **ESI-HRMS:** *m/z* calcd for $C_{21}H_{16}FN_2$ $[M + H]^+$: 315.1292; found 315.1293.

4.5.9. 2-(4-chlorophenyl)-6-amine-4-phenylquinoline (5i): Brown foam. **^{1}H NMR** ($CDCl_3$, 400MHz): δ = 7.93 (s, 1H), 7.73-7.80 (m, 2H), 7.40 (s, 1H), 7.13-7.28 (m, 7H), 6.9 (dd, *J* = 9.0, 2.5 Hz, 1H), 6.71 (d, *J* = 2.5 Hz, 1H), 3.66 (s, 2H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 151.6, 148.9, 145.2, 143.8, 141.7, 138.8, 134.8, 134.4, 129.9, 129.4, 128.6, 128.2, 127.3, 125.2, 121.7, 119.3, 105.5 ppm. **IR**: ν_{max}= 698, 771, 835, 1027, 1081, 1220, 1328, 1483, 1589, 3103 cm^{-1}. **ESI-HRMS**: *m/z* calcd for $C_{21}H_{16}ClN_2$ $[M + H]^+$: 331.0996; found 331.0991.

4.5.10. 2-(4-bromophenyl)-6-amine-4-phenylquinoline (5j): Brown foam. **^{1}H NMR** ($CDCl_3$, 400MHz): δ = 7.78-7.82 (m, 1H), 7.75 (d, *J* = 2.5 Hz, 1H), 7.39 (s, 1H), 7.34-7.37 (m, 2H), 7.22-7.31 (m, 5H), 7,05 (s, 1H), 6.92 (dd, *J* = 9.0, 2.5 Hz, 1H), 6.71-6.74 (d, 2.5Hz, 1H), 3.66 (s, 2H) ppm. **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 169.1, 153.2, 153.3, 152.6, 134.6, 131.4, 129.3, 126.6, 126.5, 125.2, 124.5, 124.4, 124.1, 124.0, 91.5 ppm. **IR**: ν_{max}= 699, 959, 1094, 1253, 1515, 1623, 3329, 3420 cm^{-1}. **ESI-HRMS**: *m/z* calcd for $C_{21}H_{16}BrN_2$ $[M + H]^+$: 375.0491; found 375.0493.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at XXX

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