[1,1′-Bis(diphenylphosphino)ferrocene]dichloropalladium/1,1′-Bis(diphenylphosphino)ferrocene Catalyzed Synthesis of 2,3-Diamino-1,4-naphthoquinones

Xiao Lei Wang,[a] Xiu Fang Zheng,[a] Lei Wang,[a] John Reiner,*[a] Wei Lin Xie,[b] Jun Biao Chang*[a,b]

[a] School of Pharmaceutical Science and Technology, Tianjin University, 300072 Tianjin, P. R. of China
Fax +86(22)27890968; E-mail: jreiner@tju.edu.cn

[b] School of Pharmaceuticals, Xinxiang Medical College, 453003 Xinxiang, P. R. of China

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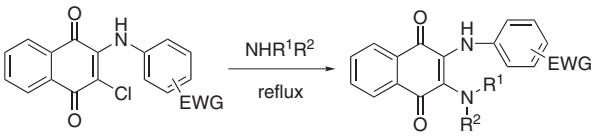
Abstract: A general method for the synthesis of 2,3-diamino-1,4-naphthoquinone derivatives via the palladium-catalyzed coupling of 2-amino-3-chloro-1,4-naphthoquinones with amines is described. The scope and limitations of the coupling process using [1,1′-bis(diphenylphosphino)ferrocene]dichloropalladium [$PdCl_2$(dppf)], combined with 1,1′-bis(diphenylphosphino)ferrocene (dppf) as a ligand and sodium *tert*-butoxide as base were investigated, and found to catalyze efficiently the coupling of 2-(arylamino)-3-chloro-1,4-naphthoquinones with primary aryl- and alkylamines. A series of novel 2,3-diamino-1,4-naphthoquinone derivatives previously unavailable were obtained by application of this procedure.

Key words: catalysis, quinones, aminations, palladium, amines

Mono- and diaminonaphthoquinone structures are important in a wide variety of natural products (such as kinamycin, awamycin, and damavaricin)[1] and they have been used as key synthetic intermediates for the construction of biologically important compounds associated with antitrypanosomal,[2] antimalarial,[3] antitumor,[4] and antineoplastic[5] activities. In most cases, the biological activity is related to the ability of quinones to accept one or two electrons to form the corresponding radical anion or dianion species as well the acid–base properties of the compounds. The electron-withdrawing or -donating substituents at the quinone moiety thus play an important role in the variable capacity of quinones to accept electrons. In addition, they have found widespread industrial applications in color chemistry and hair dying,[6] and as photostabilizers.[7] Although monoaminonaphthoquinones can be easily obtained either by the 1,4-addition of amines to 1,4-naphthoquinone followed by air oxidation[8] or by nucleophilic addition–elimination reaction of amines with 2-halo-1,4-naphthoquinone,[9] until now there have been no efficient methods reported for the synthesis of 2,3-diamino-1,4-naphthoquinones due to the deactivating effect of an amino substituent to nucleophilic addition of a second amino group.[10] Successful attempts to introduce a second amine to 2-amino-3-chloro-1,4-naphthoquinones have been limited to electron-poor amino-substituted naphthoquinones that condensed with an excess of a liquid alkylamine at high temperatures (Scheme 1).[11] When 2-anilino-3-chloro-1,4-naphthoquinone reacted with butylamine in boiling ethanol most of the starting material was recovered together with a small amount of 2-(butylamino)-3-chloro-1,4-naphthoquinone.[10c] These drawbacks make these methods synthetically unattractive.



EWG = SO_3H, COOR, I

NHR^1R^2 = Me_2NH, Et_2NH, piperidine, morpholine

Scheme 1 Literature reported synthesis of diaminonaphthoquinones.

The transition-metal-catalyzed amination of aryl halides has developed rapidly in the past few years and has proven to be a powerful method for the synthesis of various substituted amines.[12] Considering the major effect of the use of palladium complexes in related C–N bond formation processes discussed in the literature, it seemed reasonable that the amination of halo-substituted 1,4-naphthoquinones could be performed using a related method. The coupling of 2,3-dichloro-1,4-naphthoquinone with nitro-substituted anilines has been applied successfully to the synthesis of 2-(nitroanilino)-3-chloro-1,4-naphthoquinones, which were difficult to obtain by other methods.[9c] In the coupling reactions a trace of the corresponding symmetric 2,3-bis(nitroanilino)-1,4-naphthoquinone can also be detected, which informed us of the possibility of synthesizing asymmetric 2,3-diamino-1,4-naphthoquinones by the amination of 2-amino-3-chloro-1,4-naphthoquinones. Herein, we describe a detailed study on the synthesis of 2,3-diamino-1,4-naphthoquinones by the coupling of 2-amino-3-chloro-1,4-naphthoquinones with a series of amines catalyzed by [1,1′-bis(diphenylphosphino)ferrocene]dichloropalladium/1,1′-bis(diphenylphosphino)ferrocene [$PdCl_2$(dppf)/dppf] (Scheme 2).

A number of catalyst precursors and ligands (Table 1) that have been reported to successfully catalyze the amination of aryl halides were screened in the coupling between 2-anilino-3-chloro-1,4-naphthoquinone (**1**) and 4-chloroaniline with sodium *tert*-butoxide as base in refluxing tet-

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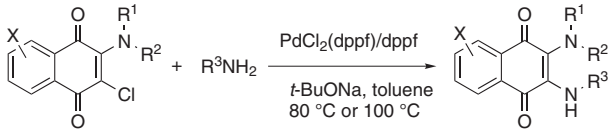
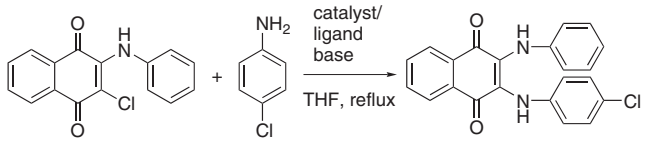


X = H, NO_2, NH_2, Cl, OH
R^1, R^2, R^3 = alkyl or aryl groups

Scheme 2 $PdCl_2$(dppf)/dppf catalyzed coupling of 2-amino-3-chloro-1,4-naphthoquinones with amines.

rahydrofuran.[13] All the catalysts and ligands in Table 1 failed to catalyze the coupling reaction with the exception of $Pd_2(dba)_3$/dppe and $PdCl_2$(dppf)/dppf, the latter gave a better yield of the coupled product **17**. To optimize the reaction conditions, a variety of solvents such as toluene, 1,4-dioxane, acetonitrile, *n*-hexane, and *N*,*N*-dimethylformamide, and bases such as sodium hydroxide, potassium hydroxide, cesium carbonate, and sodium hydride were examined together with the stoichiometry of amine, base, catalyst, and ligand, and the reaction temperature, for the coupling reaction between 2-anilino-3-chloro-1,4-naphthoquinone (**1**) and 4-chloroaniline. The best conditions were found to be those using the amine (1.5 equiv), sodium *tert*-butoxide (1.5 equiv) as base, $PdCl_2$(dppf) (5 mol%), and dppf (5 mol%) (relative to 2-anilino-3-chloro-1,4-naphthoquinone) with toluene as the solvent at 100 °C.

Table 1 Catalysts, Ligands and Bases Examined for Optimization of the Coupling Conditions[a]



1 **17**

Entry	Catalyst	Ligand	Base	Yield (%)
1	$NiCl_2$(dppf)	dppf	NaH/*t*-BuOH	–[b]
2	$Ni(acac)_2$	IPr·HCl[c]	NaH/*t*-BuOH	–[b]
3	$Ni(OAc)_2$	bipy	NaH/*t*-BuOH	–[b]
4	$Pd(PPh_3)_4$	PPh_3	*t*-BuONa	–[b]
5	$Pd_2(dba)_3$	IPr·HCl[c]	*t*-BuONa	–[b]
6	$Pd_2(dba)_3$	dppe	*t*-BuONa	60
7	$PdCl_2$(dppf)	dppf	*t*-BuONa	80

[a] Reaction conditions: **1** (0.7 mmol), *p*-chloroaniline (1.1 mmol), base (1.1 mmol), catalyst (0.035 mmol), and ligand (0.035 mmol), THF (5 mL), reflux.
[b] No desired product detected.
[c] 1,3-Bis(2,6-diisopropylphenyl)imidazolium chloride.

To investigate the scope of this amination reaction, we studied the $PdCl_2$(dppf)/dppf catalyzed coupling of different 2-(arylamino)-3-chloro-1,4-naphthoquinones with anilines. Table 2 indicates the results of these coupling reactions with a structurally and electronically diverse set of 2-(arylamino)-3-chloro-1,4-naphthoquinones **1**–**10** and arylamines under the optimized conditions. The coupling reaction provides a general route to the corresponding 2,3-bis(arylamino)-1,4-naphthoquinones **16**–**29** in good to excellent yield. 2-Arylamino-3-chloro-1,4-naphthoquinones with electron-donating groups on the aniline moiety are less reactive in the coupling reaction as indicated by the extended reaction time and comparatively lower yields (Table 2, entries 6, 7). Electron-donating substituents on the benzenoid moiety of naphthoquinone are similarly deactivating in the coupling reaction (Table 2, entries 10, 11, 14). The nitro and chloro groups in the benzenoid moiety of naphthoquinone can also be substituted by the corresponding amines under the coupling conditions; 2,3,5-trianilino-1,4-naphthoquinone (**46**) has been observed as a side product (Table 2, entries 9, 13).

N-Methylaniline and morpholine are inefficient in the coupling with 2-anilino-3-chloro-1,4-naphthoquinone (**1**), which results in the formation of trace amounts only of the corresponding 2,3-diamino-1,4-naphthoquinones **23** and **38** (experiments not reported) and incomplete reaction even after extended reaction time (20 h). This may be a consequence of the steric bulk on the nitrogen atom inhibiting the substitution of the *tert*-butoxy group from the intermediate *tert*-butoxy–palladium complex, which is necessary for the transamination step.[8a] Since the monoamination of 2,3-dichloro-1,4-naphthoquinone with secondary amines works well, this shortcoming can be easily overcome by inverting the reaction sequence for the introduction of the two amines. For example, 2-anilino-3-(*N*-methylanilino)-1,4-naphthoquinone (**23**) was prepared by the coupling of 2-chloro-3-(*N*-methylanilino)-1,4-naphthoquinone (**5**) with aniline in good yield (Table 2, entry 8) and 2-anilino-3-morpholino-1,4-naphthoquinone (**38**) was prepared by the coupling of 2-chloro-3-morpholino-1,4-naphthoquinone (**14**) with aniline (Table 3, entry 10). The inefficiency of the coupling using secondary amines may indicate that the steric bulk on the nitrogen atom of the amines plays an important role in the amination reaction.

Given the success of the $PdCl_2$(dppf)/dppf combination for the amination of 2-(arylamino)-3-chloro-1,4-naphthoquinones with anilines, we were interested in extending the scope and generality of this method to the coupling of 2-(arylamino)-3-chloro-1,4-naphthoquinones with alkylamines and 2-(alkylamino)-3-chloro-1,4-naphthoquinones with anilines (Table 3). Coupling of **1** with butylamine under the standard conditions [$PdCl_2$(dppf) (5 mol%), dppf (5 mol%), toluene, 100 °C] afforded 2-anilino-3-(butylamino)-1,4-naphthoquinone (**31**) in a moderate 50% yield. The main byproduct observed was 2-anilino-1,4-naphthoquinone resulting from reduction of the chloride. Re-evaluating the relative importance of the amount of $PdCl_2$(dppf)/dppf and the reaction temperature, the use of 10 mol% $PdCl_2$(dppf) and 10 mol% dppf at 80 °C, resulted in a higher yield of the aminated product **31** (Table 3, entry 2).

Table 2 Coupling of 2-(Arylamino)-3-chloro-1,4-naphthoquinones with Arylamines[a]

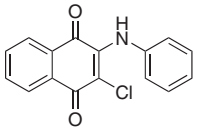
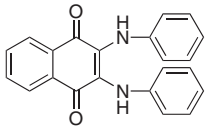
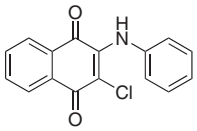
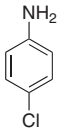
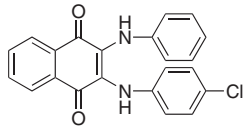
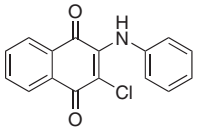
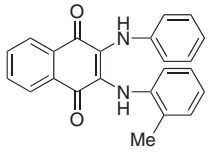
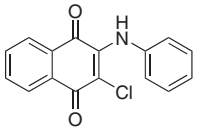
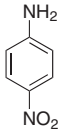
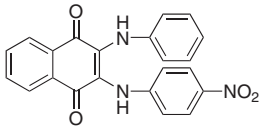
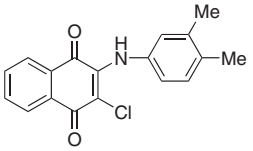
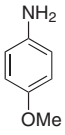
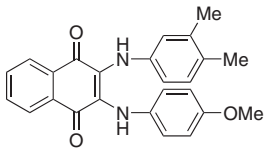
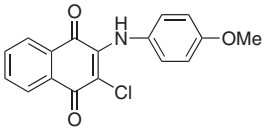
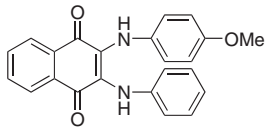
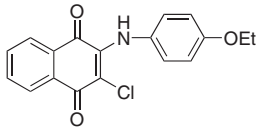
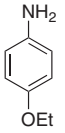
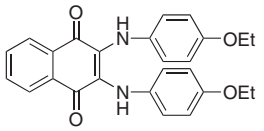
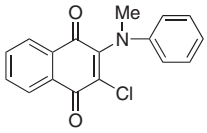
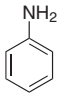
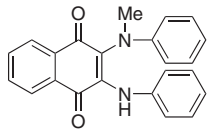
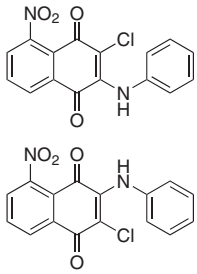
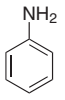
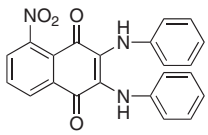
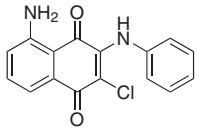
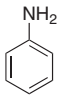
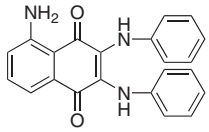
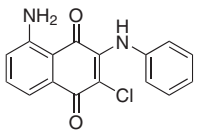
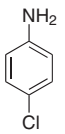
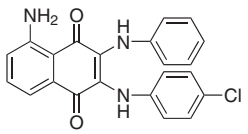
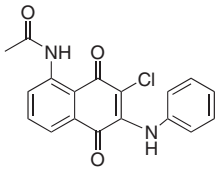
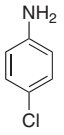
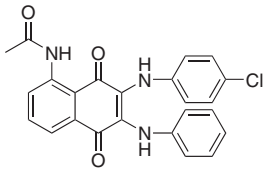
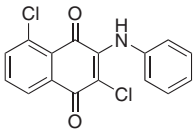
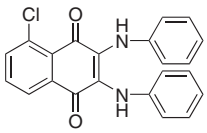
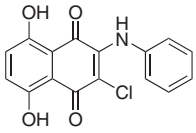
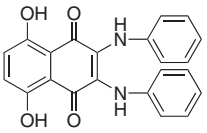
Entry	Quinone		Amine	Time (h)	Product		Yield[b] (%)
1		**1**		2		**16**	94
2		**1**		3		**17**	90
3		**1**		2		**18**	85
4		**1**		4		**19**	90
5		**2**		2		**20**	83
6		**3**		6		**21**	75
7		**4**		10		**22**	70
8		**5**		7		**23**	75
9[c]		**6**		2		**24**	80
10		**7**		5		**25**	65
11		**7**		6		**26**	70

Table 2 Coupling of 2-(Arylamino)-3-chloro-1,4-naphthoquinones with Arylamines[a] (continued)

Entry	Quinone		Amine	Time (h)	Product		Yield[b] (%)
12		**8**		8		**27**	75
13[d]		**9**		2		**28**	67
14		**10**		30		**29**	27

[a] Reaction conditions: see experimental section.
[b] Isolated yield.
[c] 2,3,5-Trianilino-1,4-naphthoquinone (**46**) was obtained in 10% yield.
[d] 2,3,5-Trianilino-1,4-naphthoquinone (**46**) was obtained in 21% yield.

By using a higher catalyst loading and a lower temperature, a wide range of 2-(alkylamino)-3-(arylamino)-1,4-naphthoquinones **30**–**40** are available in moderate to good yields. Compared to the coupling between 2-(arylamino)-3-chloro-1,4-naphthoquinones and alkylamines, the coupling of 2-(alkylamino)-3-chloro-1,4-naphthoquinones with arylamines was found to be less effective (compare Table 3, entries 2 and 7). A possible explanation for this result is that alkylamines are more electron donating than arylamines and will consequently have a greater deactivating effect on the chloro-1,4-naphthoquinone in the catalyst oxidative addition step. Better yields resulting from amination of 2-chloro-3-morpholino-1,4-naphthoquinone (**14**, Table 3, entry 10, 11) may also be attributed to the lower electron-donating properties of the morpholino group.

Table 3 Coupling of 2-(Arylamino)-3-chloro-1,4-naphthoquinones with Alkylamines and Coupling of 2-(Alkylamino)-3-chloro-1,4-naphthoquinones with Arylamines[a]

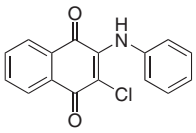
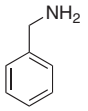
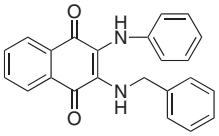
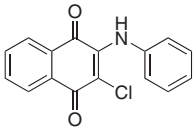
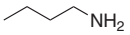
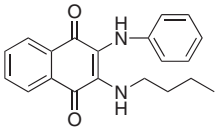
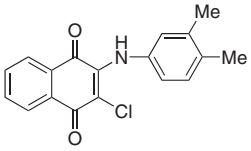
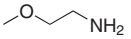
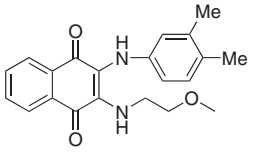
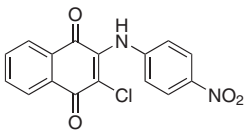
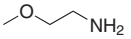
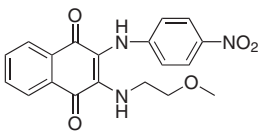
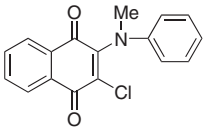
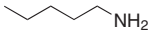
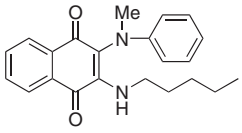
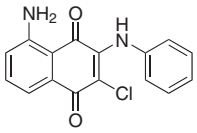
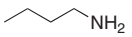
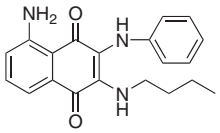
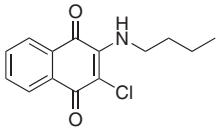
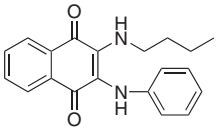
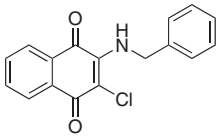
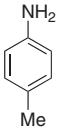
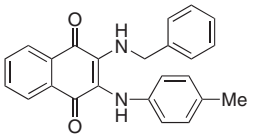
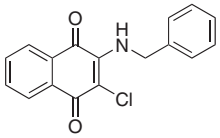
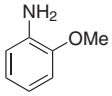
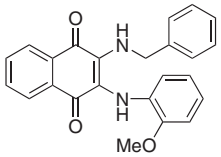
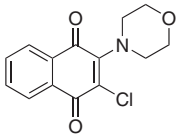
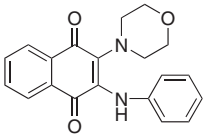
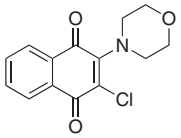
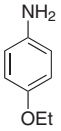
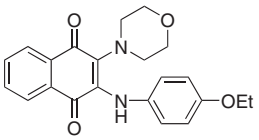
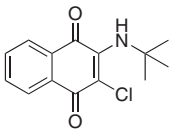
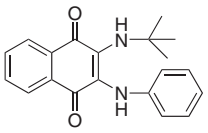
Entry	Quinone		Amine	Time (h)	Product		Yield[b] (%)
1		**1**		1		**30**	70
2		**1**		1		**31**	75
3		**2**		2		**32**	40
4		**11**		3		**33**	57

Table 3 Coupling of 2-(Arylamino)-3-chloro-1,4-naphthoquinones with Alkylamines and Coupling of 2-(Alkylamino)-3-chloro-1,4-naphthoquinones with Arylamines[a] (continued)

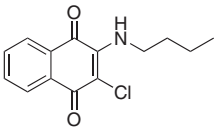
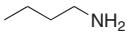
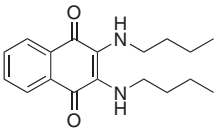
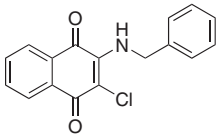
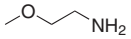
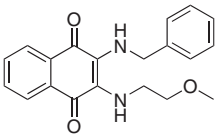
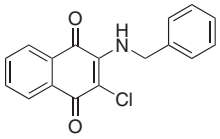
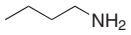
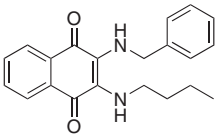
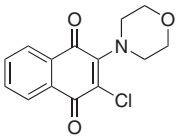
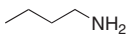
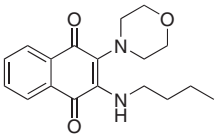
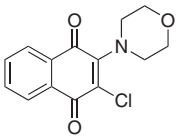
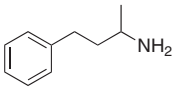
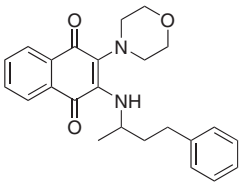
Entry	Quinone		Amine	Time (h)	Product		Yield[b] (%)
5		**5**		6		**34**	62
6		**7**		8		**35**	42
7		**12**		3		**31**	55
8		**13**		4		**36**	40
9		**13**		6		**37**	45
10		**14**		5		**38**	66
11		**14**		9		**39**	70
12		**15**		6		**40**	58

[a] Reaction conditions: see experimental section.
[b] Isolated yield.

Finally, coupling of 2-(alkylamino)-3-chloro-1,4-naphthoquinones **12**–**14** with alkylamines afforded lower yields of 2,3-bis(alkylamino)-1,4-naphthoquinones **41**–**45** (Table 4). This may be due to two factors: (1) the strong electron-donating effect of the first alkylamino group deactivates the chloroquinone and (2) the alkylamine coupling partner containing a β-hydrogen may promote the formation of the dehalogenated byproduct. In the case of 2-(butylamino)-3-chloro-1,4-naphthoquinone (**12**) aminations with butylamine and 2-methoxyethylamine (experiments not reported) as examples showed a slower reaction rate. Extending the reaction time in order to complete the reaction failed to improve the yield, and, contrary to our expectations, the yield of the desired coupling product diminished and the main product was the dehalogenated product. In such cases, a controlled reaction time of three hours was used and TLC analysis indicated a better ratio of coupled product to dehalogenated byproduct. In addition, another possibility for the lower yield of the coupling reaction using primary alkylamines (Table 3, entries 1–6 and Table 4) may be due to the formation of catalytically inactive bis(amine) complexes, which may also explain the requirement for higher catalyst and ligand loading.[14]

In summary, the synthesis of diverse 2,3-diamino-1,4-naphthoquinones via a palladium-catalyzed coupling

Table 4 Coupling of 2-(Alkylamino)-3-chloro-1,4-naphthoquinones with Alkylamines[a]

Entry	Quinone		Amine	Time (h)	Product		Yield[a] (%)
1		**12**		3		**41**	20
2		**13**		3		**42**	20
3		**13**		3		**43**	18
4		**14**		5		**44**	65
5		**14**		12		**45**	40

[a] Reaction conditions: see experimental section.
[b] Isolated yield.

methodology has been developed. The $PdCl_2$(dppf)/dppf catalyst combined with sodium *tert*-butoxide proved to be efficient for the amination of 2-(arylamino)-3-chloro-1,4-naphthoquinones regardless of the substitution pattern of the aryl chloride and is applicable to a variety of electron-rich, electron-poor, and neutral anilines as well as primary alkylamines. A series of novel, previously unobtainable, 2,3-diamino-1,4-naphthoquinone derivatives were obtained by application of this procedure.

Toluene was distilled from CaH_2. *t*-BuONa, 2,3-dichloro-1,4-naphthoquinone, all amines and all other solvents were commercially available and were used without further purification; dppf,[15] $PdCl_2$(dppf),[16] $NiCl_2$(dppf),[17] dppe,[18] IPr·HCl,[19] and all the 2-amino-3-chloro-1,4-naphthoquinones[20] were prepared according to the literature. ^{1}H (500 MHz) and ^{13}C NMR (125 MHz) spectra were recorded on a Varian Inova 500 MHz. Mps are not corrected. HRMS were recorded on a Waters Micromass GCT apparatus, or IonSpec 4.7 Tesla FTMS, or Q-TOF micro (Waters) apparatus.

2,3-Bis(arylamino)-1,4-naphthoquinones; General Procedure
A mixture of 2-(arylamino)-3-chloro-1,4-naphthoquinone (200 mg), *t*-BuONa (1.5 equiv), $PdCl_2$(dppf) (5 mol%), dppf (5 mol%), and the corresponding arylamine (1.5 equiv) in toluene (5 mL) in an oven-dried round-bottom flask was heated at 100 °C under N_2 with magnetic stirring. The progress of the reaction was monitored by TLC (EtOAc–PE). When the reaction was complete, it was concentrated in vacuo. The crude mixture thus obtained was purified by chromatography (EtOAc–PE, 5:95 to 20:80) to give the corresponding 2,3-bis(arylamino)-1,4-naphthoquinone.

2-(Alkylamino)-3-(arylamino)-1,4-naphthoquinones and 2,3-Bis(alkylamino)-1,4-naphthoquinones; General Procedure
A mixture of 2-amino-3-chloro-1,4-naphthoquinone (200 mg), *t*-BuONa (1.5 equiv), $PdCl_2$(dppf) (10 mol%), dppf (10 mol%), and the corresponding arylamine (1.5 equiv) in toluene (5 mL) was heated at 80 °C under N_2 in an oven-dried round-bottom flask with magnetic stirring. The progress of the reaction was monitored by TLC (EtOAc–PE). When the reaction was complete, the reaction mixture was concentrated in vacuo. The crude mixture thus obtained was purified by chromatography (EtOAc–PE, 2:98 to 20:80) to give the corresponding 2,3-diamino-1,4-naphthoquinone.

2,3-Dianilino-1,4-naphthoquinone (16)
Dark blue solid; mp 232–233 °C.

^{1}H NMR (500 MHz, DMSO-d_6): δ = 8.02 (dd, *J* = 5.5, 3.5 Hz, 2 H), 7.80 (dd, *J* = 5.5, 3.5 Hz, 2 H), 6.84–6.87 (m, 4 H), 6.64 (t, *J* = 7.5 Hz, 2 H), 6.38 (d, *J* = 7.5 Hz, 4 H).

^{13}C NMR (125 MHz, DMSO-d_6): δ = 181.56, 138.49, 134.36, 131.89, 127.53, 126.35, 124.82, 120.97, 119.94.

HRMS (EI): *m*/*z* $[M + H]^+$ calcd for $C_{22}H_{17}N_2O_2$: 341.1285; found: 341.1288.

2-Anilino-3-(4-chloroanilino)-1,4-naphthoquinone (17)
Dark blue solid; mp 203–205 °C.

^{1}H NMR (500 MHz, DMSO-d_6): δ = 8.01–8.03 (m, 2 H), 7.79–7.81 (m, 2 H), 6.85–6.9 (m, 4 H), 6.69 (t, *J* = 7.5 Hz, 1 H), 6.39 (dd, *J* = 7.5, 1.0 Hz, 2 H), 6.34 (dd, *J* = 6.5, 2.0 Hz, 2 H).

^{13}C NMR (125 MHz, DMSO-d_6): δ = 181.66, 181.45, 138.16, 137.53, 134.44, 134.33, 131.92, 131.82, 127.55, 127.21, 126.38, 126.37, 125.24, 124.47, 124.14, 121.30, 121.18, 120.22.

2-Anilino-3-(2-methylanilino)-1,4-naphthoquinone (18)
Dark blue solid; mp 206–208 °C.

^{1}H NMR (500 MHz, DMSO-d_6): δ = 8.03 (t, *J* = 4.5 Hz, 2 H), 7.81 (t, *J* = 4.5 Hz, 2 H), 6.86–6.91 (m, 3 H), 6.60–6.66 (m, 3 H), 6.30–6.39 (m, 3 H), 1.92 (s, 3 H).

^{13}C NMR (125 MHz, DMSO-d_6): δ = 181.56, 181.49, 138.75, 136.06, 134.55, 134.37, 131.95, 131.69, 129.39, 128.56, 127.62, 126.43, 126.40, 125.43, 125.38, 124.17, 122.38, 120.95, 120.51, 119.43, 18.23.

HRMS (EI): *m*/*z* [M + H]$^+$ calcd for $C_{23}H_{19}N_2O_2$: 355.1441; found: 355.1447.

2-Anilino-3-(4-nitroanilino)-1,4-naphthoquinone (19)
Dark red solid; mp 198–220 °C.

^{1}H NMR (500 MHz, DMSO-d_6): δ = 8.04–8.09 (m, 2 H), 7.81–7.87 (m, 2 H), 7.74 (d, *J* = 9.0 Hz, 2 H), 6.91 (t, *J* = 8.0 Hz, 2 H), 6.79 (t, *J* = 7.5 Hz, 1 H), 6.56 (d, *J* = 7.5 Hz, 2 H), 6.39 (d, *J* = 7.5 Hz, 2 H).

^{13}C NMR (125 MHz, DMSO-d_6): δ = 182.21, 180.79, 147.07, 138.77, 137.04, 134.98, 134.05, 132.25, 131.44, 131.28, 127.47, 126.61, 126.42, 124.46, 122.88, 122.28, 119.58, 116.55.

HRMS (EI): *m*/*z* [M + H]$^+$ calcd for $C_{22}H_{16}N_3O_4$: 386.1135; found: 386.1145.

2-(3,4-Dimethylanilino)-3-(4-methoxyanilino)-1,4-naphthoquinone (20)
Dark green solid; mp 185–187 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.06–8.08 (m, 2 H), 7.63–7.65 (m, 2 H), 7.13 (s, 1 H), 7.07 (s, 1 H), 6.68 (d, *J* = 7.5 Hz, 1 H), 6.44–6.47 (m, 2 H), 6.24–6.26 (m, 2 H), 6.09–6.11 (m, 2 H), 3.70 (s, 3 H), 2.09 (s, 3 H), 2.03 (s, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 181.64, 181.52, 155.44, 135.62, 135.45, 133.59, 133.49, 131.85, 131.78, 130.84, 130.26, 128.64, 126.36, 124.30, 123.32, 122.35, 122.05, 118.04, 112.84, 55.80, 19.82, 19.24.

HRMS (EI): *m*/*z* [M + H]$^+$ calcd for $C_{25}H_{23}N_2O_3$: 399.1703; found: 399.1714.

2-Anilino-3-(4-methoxyanilino)-1,4-naphthoquinone (21)
Dark green solid; mp 190–191 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.06–8.09 (m, 2 H), 7.62–7.66 (m, 2 H), 7.26 (s, 1 H), 7.14 (s, 1 H), 6.93 (t, *J* = 8.0 Hz, 2 H), 6.74 (t, *J* = 7.5 Hz, 1 H), 6.45–6.48 (m, 2 H), 6.30–6.34 (m, 4 H), 3.68 (s, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 181.49, 181.11, 155.30, 137.77, 133.50, 133.20, 131.64, 131.38, 130.21, 127.45, 126.18, 126.15, 124.91, 122.26, 122.19, 121.49, 119.78, 112.73, 55.54.

HRMS (EI): *m*/*z* [M + H]$^+$ calcd for $C_{23}H_{19}N_2O_3$: 371.1390; found: 371.1392.

2,3-Bis(4-ethoxyanilino)-1,4-naphthoquinone (22)
Dark green solid; mp 168–169 °C.

^{1}H NMR (500 MHz, DMSO-d_6): δ = 7.98 (dd, *J* = 5.5, 3.5 Hz, 2 H), 7.76 (dd, *J* = 5.5, 3.0 Hz, 2 H), 6.45 (d, *J* = 9.0 Hz, 4 H), 6.27 (d, *J* = 9.0 Hz, 4 H), 3.86 (q, *J* = 7.0 Hz, 4 H), 1.25 (t, *J* = 7.0 Hz, 6 H).

^{13}C NMR (125 MHz, DMSO-d_6): δ = 181.33, 153.61, 134.17, 131.95, 131.82, 126.20, 124.32, 121.41, 113.80, 63.85, 15.27.

2-Anilino-3-(*N*-methylanilino)-1,4-naphthoquinone (23)
Dark green solid; mp 163–166 °C.

^{1}H NMR (500 MHz, DMSO-d_6): δ = 8.05 (dd, *J* = 8.0, 1.0 Hz, 1 H), 7.94 (dd, *J* = 7.5, 1.0 Hz, 1 H), 7.85 (td, *J* = 7.5, 1.5 Hz, 1 H), 7.79 (td, *J* = 7.5, 1.5 Hz, 1 H), 6.92–7.02 (m, 5 H), 6.79–6.81 (m, 2 H), 6.60 (t, *J* = 7.5 Hz, 1 H), 6.31 (d, *J* = 7.5 Hz, 2 H), 2.71 (s, 3 H).

^{13}C NMR (125 MHz, DMSO-d_6): δ = 182.93, 180.07, 146.10, 140.17, 139.09, 135.31, 133.42, 133.29, 131.13, 128.86, 127.61, 126.50, 124.67, 124.06, 124.00, 117.58, 113.54, 40.27, 40.10, 39.94, 39.77, 39.60, 37.75.

HRMS (EI): *m*/*z* [M + H]$^+$ calcd for $C_{23}H_{19}N_2O_2$: 355.1441; found: 355.1449.

2,3-Dianilino-5-nitro-1,4-naphthoquinone (24)
Dark purple solid; mp 238–240 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.27 (dd, *J* = 7.5, 1.0 Hz, 1 H), 7.78 (t, *J* = 7.5 Hz, 1 H), 7.60 (dd, *J* = 8.0, 1.5 Hz, 1 H), 7.27 (s, 1 H), 7.19 (s, 1 H), 6.89–6.94 (m, 4 H), 6.75–6.79 (m, 2 H), 6.34 (d, *J* = 7.5 Hz, 2 H), 6.30 (d, *J* = 8.0 Hz, 2 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 179.43, 177.62, 148.58, 136.86, 136.81, 134.45, 132.70, 128.58, 127.79, 127.76, 127.15, 123.81, 123.71, 122.71, 122.64, 122.51, 120.74, 120.69.

HRMS (EI): *m*/*z* [M + H]$^+$ calcd for $C_{22}H_{16}N_3O_4$: 386.1135; found: 386.1136.

5-Amino-2,3-dianilino-1,4-naphthoquinone (25)
Brown solid; mp 192–193 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.50 (dd, *J* = 7.5, 1.0 Hz, 1 H), 7.43 (s, 1 H), 7.34 (t, *J* = 8.0 Hz, 1 H), 7.10 (s, 1 H), 6.85–6.92 (m, 5 H), 6.57–6.75 (m, 4 H), 6.38 (dd, *J* = 8.5, 1.0 Hz, 2 H), 6.33 (d, *J* = 8.5 Hz, 2 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 183.38, 181.22, 149.74, 137.79, 137.07, 134.20, 132.47, 127.36, 127.23, 124.63, 123.14, 122.09, 121.73, 121.11, 120.51, 119.73, 117.22, 110.66.

HRMS (EI): *m*/*z* [M]$^+$ calcd for $C_{22}H_{17}N_3O_2$: 355.1321; found: 355.1326.

5-Amino-2-anilino-3-(4-chloroanilino)-1,4-naphthoquinone (26)
Brown solid; mp 209–211 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.51 (dd, *J* = 7.5, 1.5 Hz, 1 H), 7.46 (s, 1 H), 7.37 (t, *J* = 8.0 Hz, 1 H), 7.02 (s, 1 H), 6.95 (t, *J* = 8.0 Hz, 2 H), 6.84–6.89 (m, 3 H), 6.79 (t, *J* = 7.5 Hz, 1 H), 6.60 (br s, 2 H), 6.40 (d, *J* = 7.5 Hz, 2 H), 6.23 (d, *J* = 8.5 Hz, 2 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 183.47, 181.31, 150.11, 137.02, 136.71, 134.62, 132.66, 127.62, 127.56, 126.43, 125.26, 123.44, 122.45, 121.85, 121.10, 121.03, 117.57, 110.82.

5-Acetamido-2-anilino-3-(4-chloroanilino)-1,4-naphthoquinone (27)
Dark green solid; mp 210–211 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 12.03 (s, 1 H), 9.01 (dd, *J* = 8.5, 1.5 Hz, 1 H), 7.87 (dd, *J* = 7.5, 1.5 Hz, 1 H), 7.63 (t, *J* = 8.0 Hz, 1 H), 7.33 (s, 1 H), 7.13 (s, 1 H), 6.95–6.98 (m, 2 H), 6.87–6.89 (m, 2 H), 6.82 (t, *J* = 7.5 Hz, 1 H), 6.38 (d, *J* = 7.5 Hz, 2 H), 6.23 (d, *J* = 8.5 Hz, 2 H), 2.30 (s, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 184.86, 181.07, 169.96, 141.48, 136.68, 136.06, 135.20, 131.76, 127.74, 127.70, 127.19, 126.36, 124.10, 122.86, 122.79, 122.27, 121.32, 121.13, 115.17, 25.91.

2,3-Dianilino-5-chloro-1,4-naphthoquinone (28)
Dark blue solid; mp 180–182 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.12 (dd, *J* = 7.5, 1.5 Hz, 1 H), 7.66 (dd, *J* = 8.0, 1.5 Hz, 1 H), 7.56 (t, *J* = 8.0 Hz, 1 H), 7.41 (s, 1 H), 7.14 (s, 1 H), 6.90–6.93 (m, 4 H), 6.73–6.78 (m, 2 H), 6.32–6.36 (m, 4 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 180.14, 180.09, 137.44, 137.29, 137.06, 134.67, 134.37, 133.59, 127.73, 127.64, 127.62, 126.08, 124.87, 122.38, 122.02, 120.79, 120.54, 120.30.

HRMS (EI): *m*/*z* [M + H]$^+$ calcd for $C_{22}H_{16}ClN_2O_2$: 375.0895; found: 375.0893.

2,3-Dianilino-5,8-dihydroxy-1,4-naphthoquinone (29)
Brown solid; mp 241–242 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 12.34 (s, 1 H), 7.26 (d, *J* = 9.0 Hz, 2 H), 7.18 (s, 2 H), 6.92 (t, *J* = 7.5 Hz, 4 H), 6.77 (t, *J* = 7.5 Hz, 2 H), 6.35 (d, *J* = 8.0 Hz, 4 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 184.14, 157.13, 137.04, 129.19, 127.72, 123.86, 122.43, 120.66, 110.68.

2,3,5-Trianilino-1,4-naphthoquinone (46)
Dark green solid; mp 233–234 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 10.91 (s, 1 H), 7.57 (dd, *J* = 6.5, 2.5 Hz, 1 H), 7.35–7.43 (m, 5 H), 7.18–7.29 (m, 3 H), 7.13 (s, 1 H), 6.88–6.93 (m, 4 H), 6.70–6.76 (m, 2 H), 6.39 (d, *J* = 7.5 Hz, 2 H), 6.34 (d, *J* = 8.0 Hz, 2 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 183.75, 181.35, 148.33, 139.60, 137.99, 137.41, 134.59, 132.98, 129.82, 127.66, 127.56, 125.30, 124.82, 124.43, 122.53, 122.04, 121.56, 120.75, 120.35, 120.13, 118.06, 111.49.

HRMS (EI): *m*/*z* [M]$^+$ calcd for $C_{28}H_{21}N_3O_2$: 431.1634; found: 431.1631.

2-Anilino-3-(benzylamino)-1,4-naphthoquinone (30)
Dark purple solid; mp 156–158 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.01–8.04 (m, 2 H), 7.58–7.66 (m, 2 H), 7.19–7.29 (m, 5 H), 7.01–7.03 (m, 2 H), 6.94 (t, *J* = 7.5 Hz, 1 H), 6.81 (d, *J* = 7.5 Hz, 2 H), 6.63 (s, 1 H), 5.85 (t, *J* = 6.5 Hz, 1 H), 4.08 (d, *J* = 7.0 Hz, 2 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 182.07, 181.53, 142.83, 139.04, 135.63, 134.21, 133.10, 132.06, 131.13, 129.29, 128.83, 128.00, 127.71, 126.54, 126.39, 121.64, 121.09, 117.33, 47.27.

HRMS (EI): *m*/*z* [M + H]$^+$ calcd for $C_{23}H_{19}N_2O_2$: 355.1441; found: 355.1431.

2-Anilino-3-(butylamino)-1,4-naphthoquinone (31)
Dark purple solid; mp 85–86 °C.

^{1}H NMR (500 MHz, DMSO-d_6): δ = 7.98 (dd, *J* = 7.0, 0.5 Hz, 1 H), 7.95 (dd, *J* = 7.0, 0.5 Hz, 1 H), 7.80 (td, *J* = 7.5, 1.5 Hz, 1 H), 7.13 (td, *J* = 7.5, 1.5 Hz, 1 H), 7.16 (t, *J* = 9.0 Hz, 2 H), 6.68–6.74 (m, 3 H), 3.12 (t, *J* = 7.5 Hz, 2 H), 1.34 (quint, *J* = 7.5 Hz, 2 H), 1.10 (sextet, *J* = 7.5 Hz, 2 H), 0.73 (t, *J* = 7.5 Hz, 3 H).

^{13}C NMR (125 MHz, DMSO-d_6): δ = 182.73, 180.51, 146.44, 141.06, 135.23, 133.27, 132.77, 131.01, 129.38, 126.49, 126.13, 118.83, 117.70, 115.31, 42.64, 32.75, 19.97, 14.18.

HRMS (EI): *m*/*z* [M + H]$^+$ calcd for $C_{20}H_{21}N_2O_2$: 321.1598; found: 321.1605.

2-(3,4-Dimethylanilino)-3-[(2-methoxyethyl)amino]-1,4-naphthoquinone (32)
Dark blue solid; mp 108–110 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.01 (dd, *J* = 7.5, 1.0 Hz, 2 H), 7.55–7.63 (m, 2 H), 6.96 (d, *J* = 8.0 Hz, 1 H), 6.56 (d, *J* = 2.0 Hz, 1 H), 6.47 (dd, *J* = 8.0, 2.5 Hz, 1 H), 5.91 (s, br, 1 H), 3.25 (s, 3 H), 3.21 (s, 4 H), 2.19 (s, 3 H), 2.16 (s, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 181.75, 181.11, 140.67, 136.96, 135.59, 133.75, 132.62, 131.92, 131.00, 129.89, 128.70, 126.14, 125.99, 121.39, 118.57, 114.42, 71.51, 58.67, 42.39, 19.96, 18.88.

2-(4-Nitroanilino)-3-[(2-methoxyethyl)amino]-1,4-naphthoquinone (33)
Dark red solid; mp 162–163 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.13 (d, *J* = 9.0 Hz, 2 H), 8.09 (d, *J* = 7.5 Hz, 2 H), 7.72 (t, *J* = 7.5 Hz, 1 H), 7.64 (t, *J* = 7.5 Hz, 1 H), 6.74 (s, 1 H), 6.70 (d, *J* = 9.0 Hz, 2 H), 6.24 (s, 1 H), 3.31–3.37 (m, 7 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 181.67, 180.46, 150.15, 140.42, 139.60, 134.73, 132.93, 132.05, 130.46, 126.68, 126.42, 125.82, 116.65, 114.68, 71.08, 58.96, 42.68.

2-(*N*-Methylanilino)-3-(pentylamino)-1,4-naphthoquinone (34)
Dark red solid; mp 146–148 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.06 (dt, *J* = 7.5, 1.5 Hz, 2 H), 7.70 (td, *J* = 7.5, 1.5 Hz, 1 H), 7.61 (td, *J* = 7.5, 1.5 Hz, 1 H), 7.18–7.21 (m, 2 H), 6.69–6.75 (m, 3 H), 5.89 (br s, 1 H), 3.30–3.32 (m, 2 H), 3.19 (s, 3 H), 1.49–1.54 (m, 2 H), 1.20–1.23 (m, 4 H), 0.84 (t, *J* = 7.0 Hz, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 183.19, 180.10, 149.07, 145.29, 134.87, 133.36, 131.99, 130.36, 129.15, 126.48, 126.25, 120.98, 117.51, 112.52, 43.49, 39.63, 29.99, 28.93, 22.25, 13.89.

HRMS (EI): *m*/*z* [M + H]$^+$ calcd for $C_{22}H_{25}N_2O_2$: 349.1911; found: 349.1907.

5-Amino-2-anilino-3-(butylamino)-1,4-naphthoquinone (35)
Brown solid; mp 102–104 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.44 (dd, *J* = 7.5, 1.0 Hz, 1 H), 7.20–7.29 (m, 3 H), 6.82–6.88 (m, 2 H), 6.64–6.74 (m, 3 H), 6.49 (s, br, 2 H), 5.40 (t, *J* = 6.0 Hz, 1 H), 2.90 (q, *J* = 7.0 Hz, 2 H), 1.23–1.29 (m, 2 H), 1.10–1.17 (m, 2 H), 0.74 (t, *J* = 7.5 Hz, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 184.01, 182.06, 149.27, 143.02, 135.06, 133.29, 132.09, 128.78, 123.65, 121.17, 120.31, 117.17, 116.92, 111.01, 42.47, 32.52, 19.75, 13.65.

HRMS (EI): *m*/*z* [M + H]$^+$ calcd for $C_{20}H_{22}N_3O_2$: 336.1707; found: 336.1726.

2-(Benzylamino)-3-(4-methylanilino)-1,4-naphthoquinone (36)
Dark purple solid; mp 85–87 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.99–8.01 (m, 2 H), 7.55–7.62 (m, 2 H), 7.17–7.22 (m, 3 H), 7.07 (d, *J* = 8.0 Hz, 2 H), 7.01 (d, *J* = 8.0 Hz, 2 H), 6.73 (d, *J* = 8.5 Hz, 2 H), 4.06 (s, 2 H), 2.29 (s, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 181.70, 181.28, 139.78, 138.92, 134.59, 133.75, 132.80, 131.74, 130.96, 130.34, 129.46, 128.49, 127.70, 127.33, 126.18, 126.06, 122.17, 117.41, 47.07, 20.63.

2-(Benzylamino)-3-(2-methoxyanilino)-1,4-naphthoquinone (37)
Dark purple solid; mp 126–129 °C.

^{1}H NMR (500 MHz, DMSO-d_6): δ = 7.97 (dd, *J* = 7.5, 1.5 Hz, 1 H), 7.90 (dd, *J* = 7.5, 1.5 Hz, 1 H), 7.72–7.80 (m, 2 H), 7.25 (t, *J* = 7.5 Hz, 2 H), 7.13–7.19 (m, 3 H), 7.01 (dd, *J* = 6.0, 3.5 Hz, 1 H), 6.82 (dd, *J* = 6.0, 4.0 Hz, 2 H), 6.42 (dd, *J* = 6.0, 3.5 Hz, 1 H), 4.13 (s, 2 H), 3.92 (s, 3 H).

^{13}C NMR (125 MHz, DMSO-d_6): δ = 182.23, 180.66, 148.10, 140.47, 139.09, 135.19, 134.10, 133.75, 132.07, 131.04, 128.95, 127.92, 127.64, 126.64, 126.18, 121.34, 120.22, 119.48, 114.46, 111.08, 56.40, 46.01.

HRMS (EI): *m*/*z* [M + H]$^+$ calcd for $C_{24}H_{21}N_2O_3$: 385.1547; found: 385.1546.

2-Anilino-3-morpholino-1,4-naphthoquinone (38)
Dark blue solid; mp 106–108 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.02 (dd, *J* = 7.5, 1.5 Hz, 2 H), 7.66 (td, *J* = 7.0, 1.0 Hz, 1 H), 7.61 (td, *J* = 7.5, 1.0 Hz, 1 H), 7.26–7.30 (m, 2 H), 7,23 (s, 1 H), 7.04–7.07 (m, 1 H), 6.91 (dd, *J* = 7.5, 0.5 Hz, 2 H), 3.31 (t, *J* = 4.5 Hz, 4 H), 3.18 (t, *J* = 4.5 Hz, 4 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 182.69, 182.15, 139.05, 134.08, 132.93, 131.93, 131.55, 130.65, 128.53, 126.60, 125.91, 123.34, 121.34, 66.88, 49.01.

HRMS (EI): *m*/*z* [M]$^+$ calcd for $C_{20}H_{18}N_2O_3$: 334.1317; found: 334.1318.

2-(4-Ethoxyanilino)-3-morpholino-1,4-naphthoquinone (39)
Black solid; mp 125–127 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.98–8.01 (m, 2 H), 7.65 (td, *J* = 7.5, 1.0 Hz, 1 H), 7.58 (td, *J* = 7.5, 1.5 Hz, 1 H), 7.23 (s, 1 H), 6.81–6.87 (m, 4 H), 4.01 (q, *J* = 7.0 Hz, 2 H), 3.27 (t, *J* = 5.0 Hz, 4 H), 3.12 (t, *J* = 5.0 Hz, 4 H), 1.42 (t, *J* = 7.0 Hz, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 182.65, 181.68, 155.53, 133.92, 133.42, 132.87, 132.39, 131.70, 130.35, 129.91, 126.22, 125.64, 123.24, 114.03, 77.30, 77.05, 76.79, 66.59, 63.76, 48.94, 14.84.

2-Anilino-3-(*tert*-butylamino)-1,4-naphthoquinone (40)
Dark purple solid; mp 119–121 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.03 (m, 2 H), 7.62–7.65 (m, 2 H), 7.24–7.27 (m, 2 H), 6.94 (t, *J* = 7.5 Hz, 1 H), 6.81 (d, *J* = 8.0 Hz, 2 H), 6.76 (s, 1 H), 4.66 (s, 1 H), 1.09 (s, 9 H).

^{13}C NMR (125 MHz, CDCl3): δ = 182.97, 182.15, 140.69, 134.57, 133.63, 133.40, 131.85, 131.75, 128.63, 128.00, 126.60, 126.23, 121.69, 119.52, 56.14, 30.55.

HRMS (EI): *m*/*z* [M]$^+$ calcd for $C_{20}H_{20}N_2O_2$: 320.1525; found: 320.1525.

2,3-Bis(butylamino)-1,4-naphthoquinone (41)
Dark purple solid; mp 43–44 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.97 (dd, *J* = 5.5, 3.0 Hz, 2 H), 7.57 (dd, *J* = 5.5, 3.0 Hz, 2 H), 4.82 (s, br, 2 H), 3.13 (t, *J* = 7.5 Hz, 4 H), 1.47–1.53 (m, 4 H), 1.37 (sextet, *J* = 7.0 Hz, 4 H), 0.91 (t, *J* = 7.5 Hz, 6 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 181.77, 132.94, 132.26, 131.40, 125.83, 43.25, 32.76, 20.12, 13.91.

2-(Benzylamino)-3-[(2-methoxyethyl)amino]-1,4-naphthoquinone (42)
Dark purple solid; mp 85–86 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.93–7.98 (m, 2 H), 7.55–7.58 (m, 2 H), 7.20–7.29 (m, 5 H), 5.28 (s, br, 1 H), 5.19 (br s, 1 H), 4.31 (s, 2 H), 3.43–3.49 (m, 4 H), 3.34 (s, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 181.62, 139.30, 133.07, 133.00, 132.68, 131.70, 131.27, 131.21, 128.57, 127.63, 127.25, 125.93, 125.89, 71.86, 58.89, 47.10, 43.07.

HRMS (EI): *m*/*z* [M]$^+$ calcd for $C_{20}H_{20}N_2O_3$: 336.1474; found: 336.1473.

2-(Benzylamino)-3-(butylamino)-1,4-naphthoquinone (43)
Dark purple solid; mp 61–62 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.93–7.98 (m, 2 H), 7.55–7.58 (m, 2 H), 7.20–7.31 (m, 5 H), 5.07 (s, br, 2 H), 4.30 (s, 2 H), 3.24 (t, *J* = 7.5 Hz, 2 H), 1.50–1.56 (m, 2 H), 1.32–1.40 (m, 2 H), 0.90 (m, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 181.92, 181.54, 139.44, 133.13, 133.05, 132.92, 131.36, 131.28, 131.20, 128.56, 127.58, 127.22, 125.90, 47.07, 43.33, 32.77, 20.11, 13.88.

2-(Butylamino)-3-morpholino-1,4-naphthoquinone (44)
Dark red solid; mp 108–109 °C.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.03 (dd, *J* = 7.5, 1.0 Hz, 1 H), 7.95 (dd, *J* = 7.5, 1.0 Hz, 1 H), 7.68 (td, *J* = 7.5, 1.0 Hz, 1 H), 7.55 (td, *J* = 7.5, 1.0 Hz, 1 H), 6.10 (s, 1 H), 3.83 (q, *J* = 7.0 Hz, 2 H), 3.76 (t, *J* = 5.0 Hz, 4 H), 3.23 (s, 4 H), 1.60–1.66 (m, 2 H), 1.41–1.48 (m, 2 H), 0.98 (t, *J* = 7.5 Hz, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 183.84, 181.09, 145.04, 134.50, 133.61, 131.64, 130.32, 125.86, 125.79, 125.71, 67.35, 50.75, 44.93, 32.87, 20.10, 13.87.

HRMS (EI): *m*/*z* [M]$^+$ calcd for $C_{18}H_{22}N_2O_3$: 314.1630; found: 314.1628.

2-[(2-Methyl-3-phenylpropyl)amino]-3-morpholino-1,4-naphthoquinone (45)
Dark oil.

^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.03 (dd, *J* = 8.0, 1.0 Hz, 1 H), 7.97 (dd, *J* = 7.5, 1.0 Hz, 1 H), 7.68 (td, *J* = 7.5, 1.0 Hz, 1 H), 7.56 (td, *J* = 7.5, 1.5 Hz, 1 H), 7.24–7.27 (m, 2 H), 7.14–7.18 (m, 3 H), 5.94 (d, *J* = 8.5 Hz, 1 H), 4.75–4.80 (m, 1 H), 3.58–3.61 (m, 4 H), 3.15 (br s, 4 H), 2.66–2.78 (m, 2 H), 1.84–1.98 (m, 2 H), 1.25 (d, *J* = 6.5 Hz, 3 H).

^{13}C NMR (125 MHz, $CDCl_3$): δ = 183.79, 181.29, 144.02, 141.04, 134.55, 133.62, 131.69, 130.23, 128.53, 128.26, 126.11, 125.93, 125.84, 125.25, 67.36, 50.61, 48.57, 39.15, 32.38, 22.32.

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