



## Original Research Article

# One-pot synthesis of 1-amidoalkyl-2-naphthols catalyzed by nano-graphene oxide under solvent-free conditions

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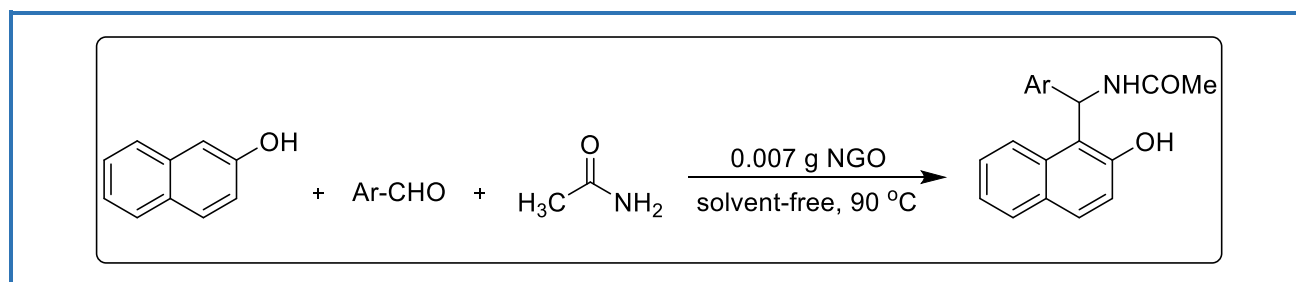
Solvent-free conditions

## ABSTRACT

An efficient and eco-friendly procedure for the synthesis of 1-amidoalkyl-2-naphthols by the one-pot three-component reaction of various aldehydes, 2-naphthol and acetamide catalyzed by nano-graphene oxide under solvent-free conditions has been described. The presented method has several advantages such as high yields, easy purification, mild reaction conditions, easy work-up, survival of different functional groups, and short reaction times. Moreover, nano-graphene oxide is an easily synthesized, cheap, air and moisture stable, heterogeneous and green catalyst. The catalyst could simply be separated and recovered from the reaction mixture and reused in subsequent reactions without significant loss in activity.

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## Graphical Abstract



## Introduction

Green chemistry is a concept that has been receiving great attention in recent years by chemists and researchers. It focuses on technological approaches to pollution prevention by the designing processes and products that minimize the use and production of hazardous chemicals, and also avoiding the use of organic solvents and using alternative safer solvents. Optimal use of material and energy, and an efficient waste management can be recognized as important factors for environmental protection. In order to realize this goal, in recent decades, reactions under solvent-free conditions are very much considered [1–3]. Performing a reaction under solvent-free conditions has many advantages such as reduced pollution, environmentally friendly reaction conditions, low cost, simple operation, easy work-up, short reaction time, high product yield and green aspects by avoiding hazardous organic solvents.

1-amidoalkyl-2-naphthols are precursors for the synthesis of oxazines which are present in variety of biologically important natural products and potent drugs; including, a number of nucleoside antibiotics and HIV protease inhibitors, such as ritonavir and lipinavir [4–6]. In recent years, several methods have been reported for the synthesis of amidoalkyl-naphthols using various catalysts such as  $I_2$  [7, 8], montmorillonite  $K_{10}$  [9],  $HClO_4 \cdot SiO_2$  [10, 11], silica chloride [12], potassium hydrogen sulphate [13], dodecylphosphonic acid (DDA) [14], bismuth (III) nitrate pentahydrate [15], nano sulphated zirconia [16], antimony (III) acetate [17], and Ag nanoparticles [18]. These procedures, however, suffer from some drawbacks such as the use of toxic, highly acidic and expensive catalysts and require prolonged reaction times. Furthermore, the yields of corresponding amidoalkyl-naphthols are not always satisfactory.

Recently, a two-dimensional single-layered nano-graphene oxide has attracted a tremendous amount of attention because of its remarkable properties such as low cost, easy of synthesis, high stability to ambient conditions and novel layered structures [19–21]. Nano-graphene oxide (NGO) exhibits a hydrophilic nature owing to the wide range of oxygen-carrying functional groups on its basal planes and edges [22, 23]. Nano-graphene oxide has been used as catalyst in various organic reactions such as oxidation of sulphides and thiols [24], oxidation of benzyl alcohols [25], ring opening of epoxides [26], Michael addition reactions [27], synthesis of aldehydes or ketones [28], Friedel-Crafts reactions [29], and addition of indoles to  $\alpha$ ,  $\beta$ -unsaturated ketones [30].

Based on our earlier success in the synthesis of organic compounds in the presence of heterogeneous catalysts [31–33], we wish to report a new method for the synthesis of 1-amidoalkyl-2-naphthols in the presence of catalytic amounts of nano-graphene oxide under solvent-free conditions.

## Experimental

### *Materials and methods*

All materials were purchased from Fluka, Aldrich and Merck and used without further purification. The products were characterized by comparing their physical properties and spectroscopic data with those reported in the literature. Infrared (IR) spectra were recorded on KBr Pellets on a Shimadzu IR Presting-21 spectrophotometer in the range of 4000–400  $\text{cm}^{-1}$ . NMR spectra were recorded in  $\text{DMSO-}d_6$  on a Bruker Advanced DPX 400 MHz spectrometer using TMS as an internal reference. Melting points were obtained in open capillary tubes and were measured on a Buchi melting point B-540 B.V.CHI apparatus.

### *Preparation of the catalyst*

Nano-graphene oxide was prepared by a modified Hummer's method [34]. Briefly, 23 mL of 98%  $\text{H}_2\text{SO}_4$  and 100 mg of  $\text{NaNO}_3$  were added to 1 g of graphite, followed by stirring at room temperature over a 24 h. Subsequently, the mixture was kept below 5 °C by ice bath, and 3 g of  $\text{KMnO}_4$  was slowly added into the mixture. After being heated to 35–40 °C, the mixture was stirred for another 30 min. Then, 10 mL of 30%  $\text{H}_2\text{O}_2$  was added into the mixture to stop the reaction. Finally, the unexploited graphite in the resulting mixture was removed by centrifugation.

### *General procedure for the synthesis of 1-amidoalkyl-2-naphthols*

A mixture of aldehydes (1 mmol), 2-naphthol (1 mmol), acetamide (1.2 mmol) and nano-graphene oxide (0.007 g) was heated at 90 °C for an appropriate time under solvent-free conditions. The progress of the reaction was monitored by TLC (*n*-hexane: ethyl acetate 1:2). After completion of the reaction, the mixture was washed with ethyl acetate and the crude product was recrystallized by ethanol in order to obtain the pure 1-amidoalkyl-2-naphthol derivatives in 80–96% yields.

### *Selected spectroscopic data*

#### *N-(5-ethyl-2-hydroxyphenyl)((2-hydroxynaphthalen-1-yl)methyl)acetamide (7)*

Mp 208–210 °C, IR (KBr) ( $\nu_{\text{max}}/\text{cm}^{-1}$ ): 3347, 3321, and 1635.  $^1\text{H}$  NMR (400 MHz,  $\text{DMSO-}d_6$ ):  $\delta$  1.3 (3H, t,  $\text{CH}_3$ ), 2.2 (3H, s,  $\text{CH}_3$ ), 2.6 (2H, q,  $\text{CH}_2$ ), 5.0 (2H, broad s, OH), 5.79 (1H, s, CH), 6.16 (1H, d, CH), 7.04–7.74 (9H, m, ArH). 8.0 (1H, s, NH).  $^{13}\text{C}$  NMR (100 MHz,  $\text{DMSO-}d_6$ ):  $\delta$  13.2, 23.6, 32.7, 48.5, 112.1, 115.3, 118.7, 119.6, 121.0, 122.0, 123.9, 126.3, 128.3, 129.2, 129.4, 130.1, 133.0, 143.0, 151.8, 152.1, 173.0.

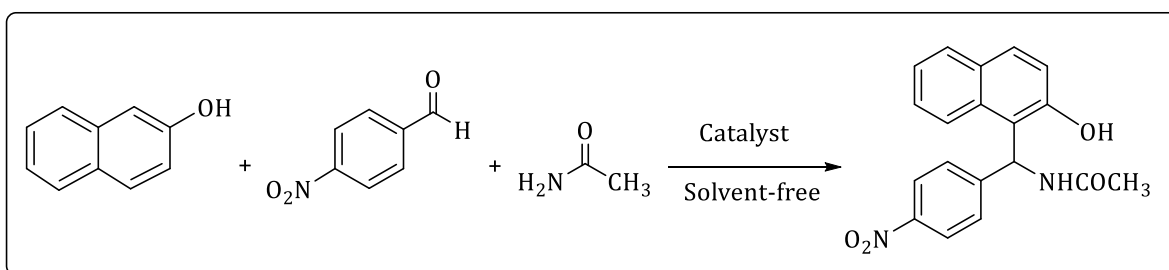
#### *N-(2-hydroxynaphthalen-1-yl)((3-hydroxyphenyl)methyl)acetamide (13)*

Mp 212–214 °C, IR (KBr) ( $\nu_{\max}$ /  $\text{cm}^{-1}$ ): 3314, 3310, and 1620.  $^1\text{H}$  NMR (400 MHz,  $\text{DMSO-}d_6$ ):  $\delta$  2.02 (3H, s,  $\text{CH}_3$ ), 5.0 (2H, broad s, OH), 6.06 (1H, s, CH), 6.84–7.46 (10H, m, ArH), 8.21 (1H, s, NH).  $^{13}\text{C}$  NMR (100 MHz,  $\text{DMSO-}d_6$ ):  $\delta$  23.6, 48.5, 48.5, 115.5, 118.7, 122.6, 123.9, 126.0, 126.3, 128.3, 129.1, 129.6, 130.5, 133.7, 144.0, 145.0, 152.8, 153.1, 175.1.

## Results and Discussion

The problems in the reported protocols such as prolonged reaction time and poor yields prompted us to develop a new and rapid method offering excellent yields using a solid-phase basic green catalyst for the synthesis of 1-amidoalkyl-2-naphthols. To find the best reaction conditions, the reaction of 2-naphthol (1 mmol), 4-nitrobenzaldehyde (1 mmol) and acetamide (1.2 mmol) was done under various conditions and different quantities of nano-graphene oxide (Scheme 1).

In order to establish the better catalytic activity of nano-graphene oxide we compared the reaction using other catalysts at 90 °C and for 10 min under solvent-free conditions. The results are listed in Table 1. As shown in Table 1, the reaction in the presence of nano-graphene oxide gave the best yield of corresponding product.



**Scheme 1.**

**Table 1.** Investigation of catalytic strength of various catalyst in the reaction of 2-naphthol, 4-nitrobenzaldehyde and acetamide under solvent-free conditions at 90 °C for 10 minutes

Entry	Catalyst	Yield (%)	Entry	Catalyst	Yield (%)
1	-	20	8	$\text{NaHSO}_4 \cdot \text{H}_2\text{O}$	62
2	$\text{Ce}(\text{SO}_4)_2$	20	9	$\text{Al}(\text{H}_2\text{PO}_4)_3$	65
3	$\text{I}_2$	25	10	<i>p</i> -TSA	48
4	K-10 clay	36	11	Sulfamic acid	55
5	Antimony(III) acetate	80	12	Silica sulfuric acid	60
6	$\text{FeCl}_3 \cdot \text{SiO}_2$	50	13	Silver nanoparticles	75
7	$\text{HClO}_4 \cdot \text{SiO}_2$	60	14	Nano-graphene oxide	98

To determine the optimum quantity of nano-graphene oxide, the reaction was carried out using different quantities of nano-graphene oxide (Table 2). It was found that 0.007 g of catalyst is sufficient for this transformation (Table 2, entry 4).

The above reaction was also examined in various solvents under thermal conditions (Table 3). The results showed that although this reaction proceeded in EtOH and EtOAc under reflux conditions, the best result was obtained under solvent-free condition at 90 °C (Table 3, entry 5).

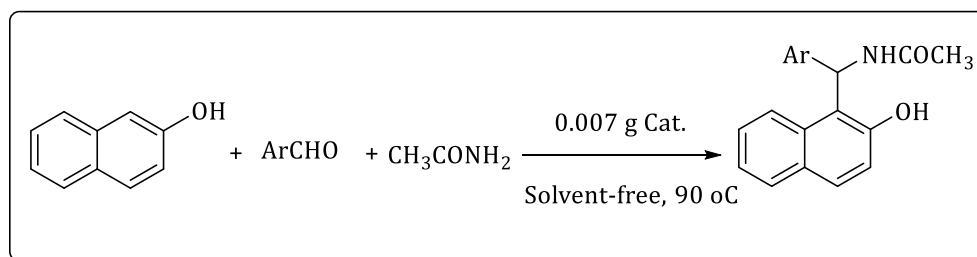
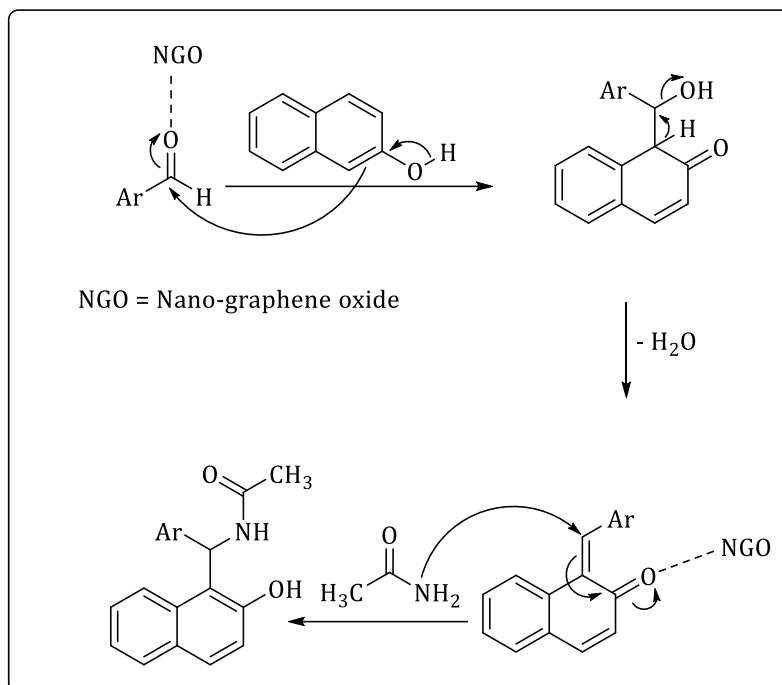
**Table 2.** Optimization amount of nano-graphene oxide for the synthesis of 1-amidoalkyl-2-naphthols

Entry	Catalyst (g)	Time (min)	Yield (%)
1	-	10	0
2	0.003	10	65
3	0.005	10	84
4	0.007	10	96
5	0.01	10	95

**Table 3.** Optimization of the reaction conditions

Entry	Solvent	Temperature (°C)	Time (min)	Yield (%)
1	EtOH	reflux	120	25
2	EtOAc	reflux	120	55
3	CHCl <sub>3</sub>	reflux	120	0
4	H <sub>2</sub> O	reflux	120	0
5	Neat	90 °C	10	96
6	Neat	40 °C	10	15
7	Neat	60 °C	10	70
8	Neat	80 °C	10	80

According to the best conditions, the various 1-amidoalkyl-2-naphthols were synthesized *via* the condensation of 2-naphthol with acetamide and various aldehydes (Scheme 2, Table 4). It is noteworthy that the reaction with aldehydes containing electron-withdrawing groups such as 4-nitrobenzaldehyde was accomplished in shorter time than those with electron-donating groups. As per earlier report [35], the lower energy of LUMO of the alkene containing electron-withdrawing groups (a carbonyl group as in *ortho*-quinone methides intermediate) as compared to that of alkene containing electron-donating groups may be responsible for making the present reaction faster. These are in accordance with the proposed mechanism (Scheme 3).

**Scheme 2.****Scheme 3.** Proposed mechanism for the synthesis of 1-amidoalkyl-2-naphthols

To examine the reusability, the catalyst was extracted from the reaction mixture of 4-nitrobenzaldehyde, 2-naphthol and acetamide, washed with methanol or acetone, dried in the air, and reused as such in subsequent experiments (up to five cycles) under similar reaction conditions. The yields of the product remained comparable in all experiments (96, 94, 93, 91, and 88% in cycles 1–5, respectively), indicating that the catalyst can be recycled for at least five times without significant loss of activity (Table 5).

**Table 4.** Synthesis of 1-amidoalkyl-2-naphthols in the presence of nano-graphene oxide under solvent-free conditions at 90 °C

Entry	Ar	Time (min)	Yield (%) <sup>a, b</sup>	M.p. (°C)		Ref.
				Found	Reported	

1	2-NO <sub>2</sub> C <sub>6</sub> H <sub>4</sub>	11	95	260-262	263-265	[12]
2	3-NO <sub>2</sub> C <sub>6</sub> H <sub>4</sub>	10	95	254-256	252-256	[12]
3	4-NO <sub>2</sub> C <sub>6</sub> H <sub>4</sub>	10	96	243-245	242-243	[12]
4	3-ClC <sub>6</sub> H <sub>4</sub>	12	91	238-240	237-238	[12]
5	4-ClC <sub>6</sub> H <sub>4</sub>	12	89	228-230	226-228	[12]
6	2-OHC <sub>6</sub> H <sub>4</sub>	16	89	214-216	215-217	[12]
7	2-OH-5-CH <sub>2</sub> CH <sub>3</sub> C <sub>6</sub> H <sub>3</sub>	14	91	208-210	-	-
8	4-OH-3-CH <sub>3</sub> OC <sub>6</sub> H <sub>3</sub>	15	87	213-214	212	[12]
9	4-CH <sub>3</sub> C <sub>6</sub> H <sub>4</sub>	17	80	211-213	-	-
10	2-OH-3-CH <sub>3</sub> OC <sub>6</sub> H <sub>3</sub>	13	90	160-162	157-159	[12]
11	4-CH <sub>3</sub> CO <sub>2</sub> C <sub>6</sub> H <sub>4</sub>	12	90	221-223	220-222	[12]
12	4-NHCH <sub>3</sub> C <sub>6</sub> H <sub>4</sub>	17	83	122-124	121-123	[12]
13	3-OHC <sub>6</sub> H <sub>4</sub>	14	90	212-214	-	-

<sup>a</sup> All products were characterized by IR, and <sup>1</sup>H and <sup>13</sup>C NMR, and their spectra were compared with those of the authentic samples

<sup>b</sup> Isolated yields

**Table 5.** Catalyst reusability in the reaction of 4-nitrobenzaldehyde, 2-naphthol and acetamide under solvent-free conditions at 90 °C

Run	1	2	3	4	5
Time (min)	10	10	10	10	10
Yield (%)	96	94	93	91	88

## Conclusions

In conclusion, we have developed a new procedure for the synthesis of 1-amidoalkyl-2-naphthols using nano-graphene oxide as an inexpensive and effective catalyst under solvent-free conditions. The important features of this procedure are mild reaction conditions, easy work-up, high yields of products, green aspects such as avoiding hazardous organic solvents, toxic catalysts and waste, ease of recovery and reuse of the catalyst.

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## Disclosure Statement

No potential conflict of interest was reported by the authors.

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## References

- [1]. Varma R.S. *Green Chem.*, 1999, **1**:43
- [2]. Tanaka K., Toda F. *Chem. Rev.*, 2000, **100**:1025
- [3]. Singh M.S., Chowdhury S. *RSC Adv.*, 2012, **2**:4547
- [4]. Seebach D., Matthews J.L. *J. Chem. Soc. Chem. Commun.*, 1997, **21**:2015
- [5]. Wang Y.F., Izawa T., Kobayashi S., Ohno M. *J. Am. Chem. Soc.*, 1982, **104**:6465
- [6]. Knapp S. *Chem. Rev.*, 1995, **95**:1859
- [7]. Das B., Laxminarayana K., Ravikanth B., Rao B. *J. Mol. Catal. A: Chem.*, 2007, **261**:180
- [8]. Nagawade R.R., Shinde D.E. *Mendeleev Commun.*, 2007, **17**:299
- [9]. Kantevari S., Vuppalapati S.V.N., Nagarapu L. *Catal. Commun.*, 2008, **8**:1857
- [10]. Shaterian H.R., Yarahmadi H., Ghashang M. *Tetrahedron*, 2008, **64**:1263
- [11]. Mahdavinia G.H., Bigdeli M.A., Heravi M.M. *Chin. Chem. Lett.*, 2008, **19**:1171
- [12]. Datta B., Pasha M.A. *Ultrason. Sonochem.*, 2011, **18**:624
- [13]. Cai X., Guo H., Xie B. *Int. J. Chem.*, 2011, **3**:119
- [14]. Zandi M., Sardarian A.R. *Comptes Rendus Chim.*, 2012, **15**:365
- [15]. Wang M., Liang Y., Zhang T., Gao J. *Chin. Chem. Lett.*, 2012, **23**:65
- [16]. Zali A., Shokrolahi A. *Chin. Chem. Lett.*, 2012, **23**:269
- [17]. Hakimi F. *J. Chem. Res.*, 2016, **40**:489
- [18]. Hakimi F. *Synth. React. Inorg. Met. Org. Chem.*, 2017, **47**:994
- [19]. Dikin D.A., Stankovich S., Zimney E.J., Piner R.D., Dommert G.H.B., Evmenenko G., Nguyen S.T., Ruoff R.S. *Nature*, 2007, **448**:457
- [20]. Gomez-Navarro C., Burghard M., Kern K. *Nano Lett.*, 2008, **8**:2045
- [21]. Guo H.L., Wang X.F., Qian Q.Y., Wang F.B., Xia X.H. *ACS Nano*, 2009, **3**:2653
- [22]. Dreyer D.R., Park S., Bielawski C.W., Ruoff R.S. *Chem. Soc. Rev.*, 2010, **39**:228
- [23]. Compton O.C., Nguyen S.T. *Small*, 2010, **6**:711
- [24]. Mungse H.P., Verma S., Kumar N., Sain B., Khtri O.P. *J. Mater. Chem.*, 2012, **22**:5427
- [25]. Dreyer D.R., Jia H.P., Todd A.D., Geng J., Bielawski C.W. *Org. Biomol. Chem.*, 2011, **9**:7292



- [26]. Jia H.P., Dreyer D.R., Bielawski C.W. *Tetrahedron*, 2011, **67**:4431
- [27]. Dreyer D.R., Jia H.P., Bielawski C.W. *Angew. Chem. Int. Ed.*, 2010, **49**:6813
- [28]. Dhakshinamoorthy A., Alvaro M.S., Concepcion P., Fornes V., Garcia H. *Chem. Commun.*, 2012, **48**:5443
- [29]. Verma S., Mungse H.P., Kumar N., Choudhary S., Jain S.L., Sain B., Khatri O.P. *Chem. Commun.*, 2011, **47**:12673
- [30]. Kumar V., Rao K.R. *Tetrahedron Lett.*, 2011, **52**:5188
- [31]. Ayashi N., Fallah-Mehrjardi M., Kiasat A.R. *Org. Chem. Res.*, 2017, **3**:25
- [32]. Ayashi N., Fallah-Mehrjardi M., Kiasat A.R. *Russ. J. Org. Chem.*, 2017, **53**:846
- [33]. Beyki M., Fallah-Mehrjardi M. *Org. Chem. Res.*, 2017, **3**:103
- [34]. Liu S., Tian J., Wang L., Sun X. *Carbon*, 2011, **49**:3158
- [35]. Shaterian H.R., Yarahmadi H. *Tetrahedron Lett.*, 2008, **49**:1297

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