Chem Sci Trans., 2012, **1(1),** 73-84 Chemical Science Transactions
DOI:10.7598/cst2012.139 ISSN: 2278-3458

RESEARCH ARTICLE

Three-Component Synthesis of *α*-Amidoalkyl-*β*-naphthols and *α*-Carbamato-alkyl-*β*–naphthols Catalyzed by P_2O_5/SiO_2

HAMID REZA SHATERIAN*, KOBRA AZIZI and NAFISEH FAHIMI

Department of Chemistry, Faculty of Sciences, University of Sistan and Baluchestan, PO Box 98135-674, Zahedan, Iran

hrshaterian@chem.usb.ac.ir

Received 6 May 2012 / Accepted 18 May 2012

Abstract: A convenient and efficient solvent-free procedure via a three-component reaction of aldehydes, *β*–naphthol, and amides or carbamates for preparation of *α*-amidoalkyl-*β*-naphthols and α-carbamato-alkyl-*β*–naphthols in the presence of green catalytic amount of phosphorus pentoxide supported on silica gel (P_2O_5/SiO_2) is described. The use of non-toxic and inexpensive materials, simple and clean work-up, short reaction times and good yields of the products are the advantages of this method.

Keywords: *α*-Amidoalkyl-*β*-naphthols, *α*-Carbamato-alkyl-*β*–naphthols, Heterogeneous catalyst, P_2O_5/SiO_2; Solvent-free

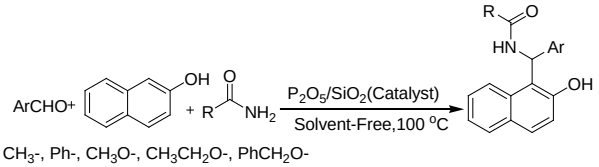
Introduction

The development of cleaner technologies is a major subject in green chemistry[1]. Among the several aspects of green chemistry, the reduction or replacement of volatile organic solvents from the reaction medium is of greatest concern[2]. Heterogeneous organic reactions and solvent-free reactions have many advantages such as reduced pollution, low costs, simplicity in process with ease handling of catalyst, cleaner reactions, easier work up, decreasing corrosive problems, reduced reaction times and eco-friendliness[3]. These considerations are currently driving our efforts to develop heterogeneous organic transformations.

Phosphorus pentoxide is a white, flammable, dangerous, corrosive to metal and extremely deliquescent compound[4a]. It reacts vigorously with water and water-containing substances, liberates much heat and may even cause fire[4]. Phosphorus pentoxide-methanesulfonic acid was used for the first time as a convenient alternative to polyphosphoric acid by Eaton *et al* to escape the difficulties encountered with polyphosphoric acid (PPA)[5]. Then, P_2O_5 supported on SiO_2 as an inexpensive, heterogeneous stable, free flowing, and white powder was prepared[6a]. It has the advantage of being easily removed from the organic product by simple filtration and also this reagent is improved storage stability in moisture in comparison to P_2O_5, which is very sensitive to moisture and also it showed much more reactivity than unsupported P_2O_5[6]. This heterogeneous catalyst has been used in several organic reactions such as Fries rearrangement[7], nitration of aromatic compounds[8], protection and deprotection of aldehydes[9], or alcohols[10], Beckmann or Schmidt rearrangements[11], preparation of bisindolylmethanes[12], solvent-free synthesis of *N*–sulfonyl imines[13] and Ritter reaction[14].

α-Amidomethyl-*β*-naphthols and *α*-carbamato-alkyl-*β*–naphthols as precursors were used for preparation of a variety of biologically important natural products and potent drugs including a number of nucleoside antibiotics and HIV protease inhibitors, such as ritonavir and lipinavir[15]. They can be converted into important 'drug like' *α*-amino-methyl-*β*-naphthol derivatives by amide hydrolysis[16]. The hypotensive and bradycardiac effects of these compounds have been evaluated[17]. The intramolecular cyclization of amidoalkyl naphthols by Vilsmeier reagent produced 1,3-oxazines[18]. The synthesis of 1,3-oxazines has attracted attention because of their potential as antibiotics[15], antitumor agents[19], anticonvulsants[20], anti-psychotic agents[21], anti-malarial[22], antianginal[23], anti-hypertensive[24], and potent anti-rheumatic agents[25].

In continuation of our research on application of heterogeneous catalysts in organic reactions[26], we have employed silica supported P_2O_5 in preparation of *α*-amidoalkyl-*β*-naphthols and *α*-carbamato-alkyl-*β*–naphthols (Scheme 1).



Scheme 1. Preparation of *α*-amidoalkyl-*β*-naphthols and *α*-carbamato-alkyl-*β*–naphthols

Experimental

All reagents were purchased from Merck and Sigma-Aldrich and used without further purification. P_2O_5/SiO_2 was prepared according to the reported procedure[13]. All yields refer to isolated products after purification. Products were characterized by comparison physical data with authentic samples and spectroscopic data (IR and NMR). The NMR spectra were recorded on a Bruker Avance DPX 500 MHz instrument. The spectra were measured in DMSO relative to TMS (0.00 ppm). IR spectra were recorded on a JASCO FT-IR 460 plus spectrophotometer. Mass spectra were recorded on an Agilent technologies 5973 network mass selective detector (MSD) operating at an ionization potential of 70 eV. Melting points were determined in open capillaries with a BUCHI 510 melting point apparatus. TLC was performed on Silica–gel polygram SILG/UV 254 plates.

General procedure for the synthesis of α-amidoalkyl-β-naphthol and α-carbamato-alkyl-β–naphthol derivatives

A stirred mixture of arylaldehydes (10 mmol), *β*-naphthol (10 mmol), amide or carbamat (12 mmol), and P_2O_5/SiO_2 (800 mg, 7% w/w, 3.7 mol%) was reacted in an oil bath at 100 ^oC for the appropriated times (Tables 3, 4). Completion of the reaction was indicated by TLC. After completion of the reaction, it was cooled to room temperature and the crude solid product was solved in ethylacetate and filtered for separation of the catalyst. The catalyst was washed four times with ethyl acetate (4×5 mL) and then recovered catalyst was dried in oven at 100 ^oC for 3 h. The filtrate organic solution was concentrated. The solid product was purified by recrystallization procedure in aqueous EtOH (15 %).

All the products were characterized by comparison of their spectroscopic and physical data with the authentic samples[26a,27-29,34,35]. The spectral data of new products are given below:

N-(1-(2-Hydroxynaphthalen-1-yl)-3-phenylpropyl)acetamide (Table 3, Entry 17)

Mp: 185-186 ^oC; ^1H NMR (500 MHz, DMSO-d_6): δ = 1.85 (s, 3H), 2.07-2.12 (m, 1H), 2.33-2.37 (m, 1H), 2.43-2.49 (m, 1H), 2.65-2.69 (m, 1H), 5.77-5.81 (m, 1H), 7.13-7.17(m, 4H),

7.22-7.26 (m, 3H), 7.37 (t, *J* = 7.6 Hz, 1H), 7.66 (d, *J* = 8.8 Hz, 1H), 7.75 (d, *J* = 7.8 Hz, 1H), 7.99 (brd, *J* = 8.2 Hz, 1H), 8.10 (brs, 1H), 9.87 (s ,1H) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): δ = 22.7, 32.5, 35.6, 45.7, 118.6, 119.6, 122.2, 122.3, 122.5, 125.6, 126.0, 128.1 (2C), 128.2 (2C), 128.3, 128.4, 132.2, 141.8, 153.0, 168.5 ppm; IR (KBr, cm^{-1}): 3421, 3230, 2922, 1638, 1516, 1438, 1334, 810, 741; MS (EI, 70 eV) *m/z* (%) = 319 (M+, 28), 281 (9), 260 (7), 214 (23), 186 (8), 172 (100), 156 (17), 141 (16), 127 (21), 115 (22), 91 (56), 43 (49); Anal. Calcd for: $C_{21}H_{21}NO_2$: C, 79.98; H, 6.63; N, 4.39%. Found: C, 79.95; H, 6.67; N, 4.40%.

Methyl(4-cyanophenyl)(2-hydroxynaphthtalen-1-yl)-methyl carbamate (Table 4, Entry 18)

Mp: 233-234 ^{o}C; ^{1}H NMR (500 MHz, DMSO-d_6): δ=3.57 (s, 3H), 6.89 (d, *J* = 8.3 Hz, 1H), 7.18 (d, *J* = 8.8 Hz, 1H), 7.27 (t, *J* = 7.38 Hz, 1H), 7.38 (t, *J* = 9.2 Hz, 3H), 7.71 (d, *J* = 1.4 Hz, 2H), 7.73-7.79 (m, 3H), 7.83 (brs,1H), 10.17 (s, 1H) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): δ = 50.3, 51.7, 109.0, 117.9, 118.3, 118.8, 122.6, 122.7, 126.7, 126.9 (2C), 128.3, 128.6, 129.7, 131.9, 132.0 (2C), 148.4, 153.0, 156.6 ppm; IR (KBr, cm^{-1}): 3417, 3171, 2227, 1678, 1629, 1607, 1516, 1439, 1327, 1277, 1234, 1199, 1137, 1066, 1040, 956, 855, 832, 806, 745; MS (EI, 70 eV) *m/z* (%) = 332 (M+, 12), 300 (3), 271 (4), 258 (14), 257 (60), 256 (100), 242 (6), 227 (9), 204 (4), 170 (3), 144 (3), 129 (5), 115 (8), 59 (4), 45 (2); Anal. Calcd for: $C_{20}H_{16}N_2O_3$: C, 72.28; H, 4.85; N, 8.43%. Found: C, 72.30; H, 4.83; N, 8.41%.

Methyl(3-methoxyphenyl)(2-hydroxynaphthtalen-1-yl)methylcarbamate (Table 4, Entry 19)

Mp: 180-182 ^{o}C; ^{1}H NMR (500 MHz, DMSO-d_6): δ=3.56 (s, 3H), 3.65 (s, 3H), 6.73-6.77 (m, 2H), 6.80-6.83 (m, 2H), 7.15 (t, *J* = 8.9 Hz, 1H), 7.20 (d, *J* = 8.8 Hz, 1H), 7.26 (t, *J* = 7.3 Hz, 1H), 7.38 (brt, *J* = 7.1Hz, 1H), 7.67 (brs, 1H), 7.75 (d, *J* = 8.8 Hz, 1H), 7.79 (d, *J* = 7.95 Hz, 1H), 7.90 (brs, 1H), 10.09 (s, 1H) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): δ=50.3, 51.6, 54.8, 111.0, 112.4, 118.4, 118.8, 122.4, 122.9, 126.4, 128.3, 128.5, 129.1, 129.2, 129.3, 132.0, 144.0, 152.8, 156.5, 159.1 ppm; IR (KBr, cm^{-1}): 3421, 3353, 1689, 1600, 1516, 1489, 1330, 1274, 1241, 1164, 1049, 1035, 812, 779, 742; MS (EI, 70 eV) *m/z* (%) = 337 (M+,19), 316 (30), 262 (50), 261 (56), 217 (9), 202 (5), 183 (13), 115 (8), 91 (6), 65 (6); Anal. Calcd for: $C_{20}H_{19}NO_4$: C, 71.20; H, 5.68; N, 4.15%. Found: C, 71.25; H, 5.65; N, 4.17%.

Ethyl(4-nitrophenyl)(2-hydroxynaphthtalen-1-yl) methylcarbamate (Table 4, Entry 20)

Mp: 222-223 ^{o}C; ^{1}H NMR (500 MHz, DMSO-d_6): δ=1.15 (t, *J* = 6.9, 3H), 3.96-4.05 (m, 2H), 6.83 (d, *J* = 8.5 Hz, 1H), 7.19-7.22 (m, 3H), 7.27 (t, *J* = 7.3 Hz,1H), 7.32 (d, *J* = 8.6 Hz, 2H), 7.39 (brt, *J* = 7.1 Hz, 1H), 7.62 (brs, 1H), 7.75-7.80 (m, 2H),7.88 (brs, 1H), 10.14 (s, 1H) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): δ= 14.6, 49.7, 60.1, 118.4, 118.5, 122.5, 122.8, 126.6, 127.8, 128.0 (2C), 128.3 (2C), 128.5, 129.4, 130.9, 131.9, 141.5, 152.8, 156.1 ppm; IR (KBr, cm^{-1}): 3429, 3185, 3067, 2978, 1685, 1516, 1349, 1267, 1236, 1146, 1070, 1049, 852, 821, 708; MS (EI, 70 eV) *m/z* (%) = 367 (M+1, 5), 366 (M+, 21), 334 (17), 320 (7), 291 (15), 276 (25), 260 (98), 230 (100), 202 (28), 144 (14), 115 (22), 45 (9); Anal. Calcd for: $C_{20}H_{18}N_2O_5$: C, 65.57; H, 4.95; N, 7.65%. Found: C, 65.51; H, 4.97; N, 7.64%.

Ethyl(4-chlorophenyl)(2-hydroxynaphthtalen-1-yl) methylcarbamate (Table 4, Entry 21)

Mp: 220-221 ^{o}C; ^{1}H NMR(500MHz, DMSO-d_6): δ= 1.16 (t, J= 6.8 Hz, 3H), 3.98-4.07 (m, 2H), 6.93 (d, *J* = 8.2 Hz, 1H), 7.19 (d, *J* = 8.8 Hz, 1H), 7.28 (t, *J* = 7.3 Hz, 1H), 7.40 (brt, *J* = 7.3 Hz, 1H), 7.45 (d, *J* = 8.5 Hz, 2H), 7.76-7.82 (m, 3H), 7.89 (brs, 1H), 8.14 (d, *J* = 8.7 Hz, 2H), 10.19 (s, 1H) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): δ= 14.5, 50.0, 60.3, 118.0, 118.3, 122.6, 122.7, 123.3 (2C), 126.8, 127.1(2C), 128.3, 128.6, 129.8, 131.8, 146.0, 150.7, 153.0, 156.2;

IR(KBr, cm^{-1}): 3423, 3187, 1678, 1628, 1578, 1516, 1489, 1477, 1329, 1274, 1231, 1171, 1144, 1088, 1069, 1001, 940, 814, 751; MS (EI, 70 eV) *m/z* (%) = 357 (M+2, 3), 355 (M+, 8), 334(6), 281(16), 265 (51), 231 (100), 202 (16), 138 (6), 115 (9), 97 (7), 83 (8), 57 (11), 43 (11); Anal. Calcd for: $C_{20}H_{18}ClNO_3$: C, 65.71; H, 5.10; N, 3.94%. Found: C, 65.70; H, 5.09; N, 3.90%.

Ethyl(phenyl)(2-hydroxynaphthtalen-1-yl) methylcarbamate (Table 4, Entry 22)

Mp: 203-204 ^oC; ^1H NMR (500MHZ, DMSO-d_6): δ= 1.17 (t, *J* = 6.9 Hz, 3H), 4.04 (q, *J* = 7.4, 2H), 6.89 (brd, *J* = 9.8 Hz, 1H), 7.15-7.19 (m, 1H), 7.24 (d, *J* = 9.2 Hz, 1H), 7.26 (t, *J* = 4.6 Hz, 4H), 7.29 (d, *J* = 7.5 Hz, 1H), 7.41 (brt, *J* = 7.8 Hz, 1H), 7.56 (brs, 1H), 7.78 (d, *J* = 8.4 Hz, 1H), 7.82 (d, *J* = 8.0 Hz, 1H), 7.96 (d, *J* = 7.6 Hz, 1H), 10.13 (s, 1H) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): δ= 14.5, 50.3, 60.0, 118.4, 118.9, 122.4, 122.8, 125.9 (2C), 126.2, 126.5, 128.0(2C), 128.3, 128.5, 129.2, 132.0, 142.4, 152.8, 156.0 ppm; IR (KBr, cm^{-1}):3424, 3169, 3033, 2993, 1672, 1518, 1437, 1331, 1272, 1042, 939, 814, 742, 695 ; MS (EI, 70 eV) *m/z* (%) = 321 (M+, 21), 275 (5), 233 (24), 232 (94), 231 (100), 202 (16), 144 (15), 115 (18), 104 (12), 77 (10), 45 (6); Anal. Calcd for: $C_{20}H_{19}NO_3$: C, 74.75; H, 5.96; N, 4.36%. Found: C, 74.73; H, 5.94; N, 4.35%.

Ethyl(2,4-dimethoxyphenyl)(2-hydroxynaphthtalen-1-yl) methylcarbamate (Table 4, Entry 23)

Mp: 217-218 ^oC; ^1H NMR (500MHz, DMSO-d_6): δ= 1.15 (t, *J* = 7.0 Hz, 3H), 3.57 (s, 3H), 3.66 (s, 3H), 4.00 (q, *J* = 7.2 Hz, 2H), 6.73-675 (m, 1H), 6.81 (d, *J* = 7.7 Hz, 1H), 7.04 (d, *J* = 9.3 Hz, 1H), 7.18 (d, *J* = 8.6 Hz, 2H), 7.28 (t, *J* = 7.4 Hz, 1H), 7.42 (brs, 1H), 7.47 (t, *J* = 7.6 Hz, 1H), 7.72 (d, *J* = 8.8 Hz, 1H), 7.77 (d, *J* = 7.9 Hz, 1H), 8.25 (d, *J* = 8.7 Hz, 1H), 10.06 (s, 1H) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): δ= 14.5, 18.5, 55.2, 55.9, 56.0, 59.8, 111.5, 111.9, 115.3, 118.6, 118.8, 122.3, 123.2, 125.9, 128.1, 128.2, 128.8, 131.4, 132.2, 150.5, 152.8, 152.9, 155.4 ppm; IR (KBr, cm^{-1}):3425, 3226, 2997, 1678, 1515, 1498, 1317, 1275, 1210, 1148, 1026, 794, 749; MS (EI, 70 eV) *m/z* (%) = 382 (M+1, 9), 381(M+, 30), 308 (9), 293 (11), 276 (11), 263 (130, 262 (91), 261 (100), 238 (12), 218 (30), 189 (9), 144 (10), 115 (12), 45 (6); Anal. Calcd for: $C_{22}H_{23}NO_5$: C, 69.28; H, 6.08; N, 3.67%. Found: C, 69.25; H, 6.10; N, 3.64%.

Benzyl(4-cyanophenyl)(2-hydroxynaphthalen-1-yl)methylcarbamate (Table 4, Entry 24)

Mp: 202-203 ^oC; ^1H NMR (500 MHZ, DMSO-d_6): δ = 5.08 (d, *J* = 12.3 Hz, 1H), 5.13 (d, *J* = 12.6 Hz, 1H), 6.98 (d, *J* = 8.2 Hz, 1H), 7.24 (d, *J* = 8.8 Hz, 1H), 7.28-7.44 (m, 9H), 7.74 (d, *J* = 8.3 Hz, 2H), 7.77-7.83(m, 2H), 7.93(brs, 2H), 10.20 (s, 1H) ppm; ^{13}C NMR (125 MHz, DMSO-d_6): δ=50.3, 65.8, 109.1, 117.9, 118.3, 118.8, 122.5, 122.7, 126.7 (2C), 126.9, 127.6, 127.7, 128.2 (2C), 128.3 (2C), 128.6, 129.7, 131.9 (2C), 132.0, 136.8, 148.3, 153.0, 156.1ppm; IR (KBr, cm^{-1}): 3424, 3204, 2231, 1678, 1509, 1439, 1320, 1273, 1067, 943, 857, 814, 746, 700; MS (EI, 70 eV) *m/z* (%) = 408 (M+, 6), 273 (7), 256 (44), 227 (7), 144 (32), 115 (25), 91 (100), 65 (12), 51 (10); Anal. Calcd for: $C_{26}H_{20}N_2O_3$: C, 76.45; H, 4.94; N, 6.86%. Found: C, 76.48; H, 4.90; N, 6.88%.

Results and Discussion

In our initial experiments, the condensation of benzaldehyde, β-naphthol and acetamide (molar ratio 1:1:1.2) was performed in the presence of 80 mg of the catalyst, (7% w/w, 3.7 mol%)[12] at various temperatures under solvent-free conditions (Table 1). Table 1 clearly demonstrates that 100 ^oC is an effective temperature in terms of reaction time and yield obtained. However, reaction rate accelerate in 110 and 120 ^oC, but the yield increase slightly (1%).

Table 1. Optimization of temperature in the reaction of *β*-naphthol, benzaldehyde, acetamide in the presence of P_2O_5/SiO_2 (80 mg) as catalyst under solvent-free conditions at different temperature

Entry	Temperatere, ^oC	Time, min	Yield, %[a]
1	60	9	55
2	80	5	70
3	90	3.5	80
4	100	3	94
5	110	2.5	95
6	120	1.5	95

[a]*Yields refer to isolated pure product*

To optimize the catalyst in the mentioned reaction, we have carried out a model study with benzaldehyde, *β*-naphthol and acetamide with different amount of P_2O_5/SiO_2 as catalyst under solvent-free conditions at 100 ^oC (Table 2). It was found that 80 mg of the catalyst showed maximum yield (94%) in minimum time (5 min). A further increasing of the catalyst (100, 150 mg) causes the reaction performed at the short reaction times (4, 2 min), but decrease the yield of the product. Thus, 80 mg of the catalyst was found to be the optimal quantity and sufficient to push the reaction forward (Table 2).

Table 2. Optimization of amount of P_2O_5/SiO_2 as the catalyst in the reaction of β-naphthol, benzaldehyde and acetamide under solvent-free conditions

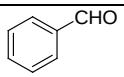
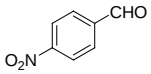
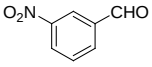
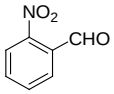
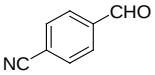
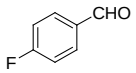
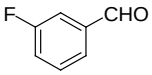
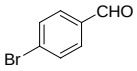
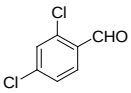
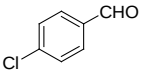
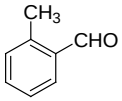
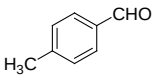
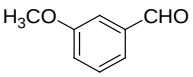
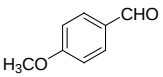
Entry	Catalyst, mg	Time, min	Yield, %[a]
1	50	10	65
2	60	9	72
3	70	8	80
4	80	5	94
5	100	4	90
6	150	2	85

[a]*Yields refer to isolated pure product*

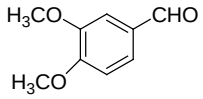
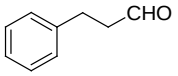
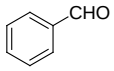
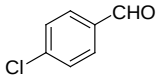
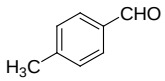
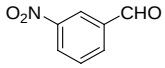
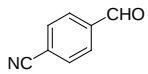
Using these optimized reaction conditions (80 mg of P_2O_5/SiO_2 at 100 ^oC, under solvent-free conditions), the scope and efficiency of the reaction were explored for the synthesis of a wide variety of substituted *α*-amidoalkyl-*β*-naphthols using various aryl aldehydes, 2-naphthol and amides. The results are summarized in Table 3.

In all the cases the corresponding *α*-amidoalkyl-*β*-naphthols were obtained in good to excellent yields. However, with aromatic aldehydes with electron-withdrawing groups as substrates, the reaction time is shorter than those with electron-donating groups. Though *meta*- and *para*-substituted aromatic aldehydes gave good results, *ortho*-substituted aromatic aldehyde (*o*-methylbenzaldehyde) gave corresponding products in shorter time than other positions because of the steric effects. Interestingly, 3-phenylpropinaldehyde also gave the desired product in excellent yield. On the other hand, reactions with n-heptaldehyde and *n*-octanaldehyde provided corresponding α-amidoalkyl-β-naphthols with <10% yields, the reactions didn't completed after 24 h and almost 90% of aldehydes were intact without formation aldol condensation products (Table 3, entries 23, 24). We also use benzamide instead of acetamide in the mentioned reaction (Table 3, entries 18-22), the *α*-benzamido-alkyl-*β*-naphthol derivatives were obtained in excellent yield with short reaction times.

Table 3. Three-compnent synthesis of *α*-amidoalkyl-*β*-naphthol drivatives through direct condensation of *β*-naphthol, aldehyde and amides (molar ratio: 1/1/1.2) catalyzed by P_2O_5/SiO_2 (80 mg) under solvent free conditions at 100 ^oC

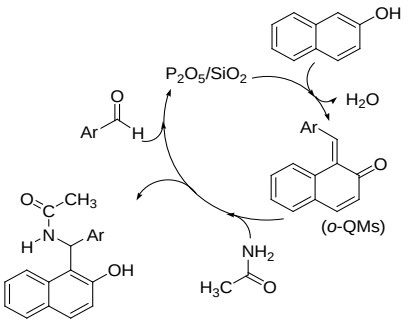
Entry	Substrate	R	Time, min	Yield, %[a]	Found M.P.(^oC)/ [Lit. M.P (^oC)][Ref.]
1		Me	5	94	242-243[245-246][26a] [241-243][27]
2		Me	3	77	242-243[248-250][26a] [241-243][27]
3		Me	8	87	242-243[241-242][26a] [182-184][27]
4		Me	4	85	180-182[179-182][26a] [180-182][27]
5		Me	5	82	262-263[261-262][28]
6		Me	7	83	239-240[230-232][26a] [209-210][27]
7		Me	6	80	248-249[248-249][26a]
8		Me	10	84	229-231[227-229][26a]
9		Me	5	78	212-213[213-215][26a]
10		Me	8	78	205-206[201-203][26a] [198-199][27]
11		Me	12	76	229-230[223-225][26a] [224-227][27]
12		Me	17	83	230-231[199-202][26a]
13		Me	30	80	215-216[222-223][26a]
14		Me	10	70	215-216 [201-204][26a]
15		Me	47	54	180-182 [183-185][26a] [184-186][27]

Contd…

16		Me	40	79	235-236 [235-237][26a] [235-236][27]
17		Me	60	60	185-186[The Product was synthesized for the first time]
18		Ph	2	80	234-235 [233-235][29]
19		Ph	5	85	227-229 [225-227][29]
20		Ph	7	79	177-179 [175-177][29]
21		Ph	1.5	90	215-217 [216-217][29]
22		Ph	2	93	176-177 [176-178][28]
23	$CH_3(CH_2)_5CHO$	Me	24 h	<10	-
24	$CH_3(CH_2)_6CHO$	Me	24h	<10	-

[a]Yields refer to the isolated pure products. The desired pure products were characterized by comparison of their physical data (melting points, IR, ^1H and ^{13}C NMR) with those of known compounds.[26a, 27-29] The reaction was carried out under thermal solvent-free conditions in an oil bath at 100 ^oC

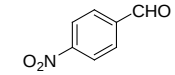
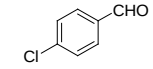
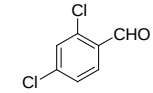
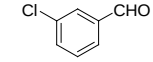
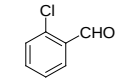
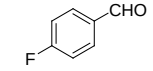
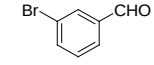
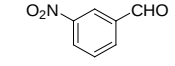
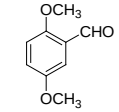
The suggested mechanism is described in Scheme 2. As reported in literature[27], the reaction of *β*-naphthol with aromatic aldehydes in the presence of acid catalyst is known to give *ortho*-quinone methides (*o*-QMs) as a highly reactive and ephemeral intermediate. The same *o*-QMs, generated in-situ, have been reacted with acetamide to form α-amidoalkyl-*β*-naphthol derivatives (Scheme 2). A reasonable explanation for this result can be given by considering the nucleophilic addition to *o*-QM intermediate favorable via conjugate addition on *α, β*-unsaturated carbonyl group that aromatizes naphthalene ring of this intermediate. The electron withdrawing groups (EWD) substituted on benzaldehyde in *o*-QM intermediate increase the rate of 1,4-nucleophilic addition reaction because of alkene LUMO is at lower energy in the neighboring withdrawing groups than electron donating groups (EDG)[26a]. The reactions of aliphatic aldehydes (Table 3, entry 23,24) instead of aromatic aldehydes weren't completed and give the desired products with low yield as well as the known catalysts, such as $K_5CoW_{12}O_{40}.3H_2O$[30], *p*-TSA[31], sulfamic acid[32] and cation-exchange resins[33] probably due to less stability of *o*-QMs from aliphatic aldehydes.



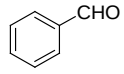
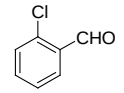
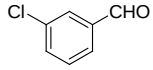
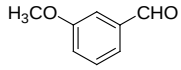
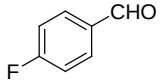
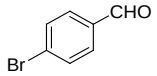
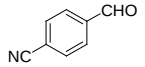
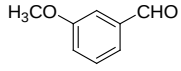
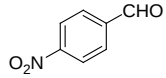
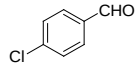
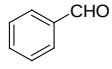
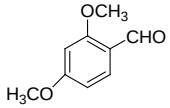
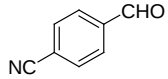
Scheme 2. The suggested mechanism for preparation of *α*-amidoalkyl-*β*-naphthols

In continuation of our research, we try to prepare *α*-carbamato-alkyl-*β*–naphthols in a one-pot and three componet reaction using benzaldehydes, *β*-naphthol and carbomates in the presence of P_2O_5/SiO_2 (80 mg) as catalyst under solvent-free conditions at 100 ^oC. We extended our study with different aromatic aldehydes to prepare a series of *α*-carbamato-alkyl-*β*–naphthols. Table 4 summarized some of these results.

Table 4. Preparation of *α*-carbamato-alkyl-*β*–naphthols catalyzed by P_2O_5/SiO_2 (80 mg) under solvent-free conditions at 100 ^oC

Entry	Substrate	R	Time, min	Yield, %[a]	Found M.P.(^oC)/ [Lit. M.P (^oC)][Ref.]
1		CH_3O	10	90	215-217 [217-218][34]
2		CH_3O	8	88	207-208 [205-207][34]
3		CH_3O	8	88	200-202 [198-200][34]
4		CH_3O	7	80	192dec [192dec][34]
5		CH_3O	8	78	198-200 [196-198][34]
6		CH_3O	9	89	183-185 [182-184][35]
7		CH_3O	8	90	204-205 [202-204][35]
8		CH_3O	8	92	194-195 [193-195][35]
9		CH_3O	7	82	254dec [252dec][34]
10		CH_3O	15	90	216dec [215dec][34]

Contd…

11		$PhCH_2O$	12	92	180-181 [179-180][34]
12		$PhCH_2O$	10	87	163-165 [163-165][34]
13		$PhCH_2O$	10	80	203dec [203dec][34]
14		$PhCH_2O$	20	83	184-185 [182-184][34]
15		$PhCH_2O$	12	75	185-186 [185-186][34]
16		CH_3O	8	90	196-198 [195-197][34]
17		CH_3O	9	92	233-234 [The Product was synthesized for the first time]
18		CH_3O	15	89	180-182 [The Product was synthesized for the first time]
19		CH_3CH_2O	8	93	222-223 [The Product was synthesized for the first time]
20		CH_3CH_2O	9	95	220-221 [The Product was synthesized for the first time]
21		CH_3CH_2O	10	90	203-204 [The Product was synthesized for the first time]
22		CH_3CH_2O	17	90	217-218 [The Product was synthesized for the first time]
23		$PhCH_2O$	12	88	202-203 [The Product was synthesized for the first time]

[a]*Yields refer to the isolated pure products. The desired pure products were characterized by comparison of their physical data (melting points, IR, ^1H and ^{13}C NMR) with those of known compounds.[34-35] The reaction was carried out under thermal solvent-free conditions in an oil bath at 100 ^oC*

In order to show the accessibility of the present work in comparison with the reported results in the literature such as $Ce(SO_4)_2$[27], I_2[36], $H_3Mo_{12}O_{40}P$[37], Montmorrillonite k10 clay[38], $K_5CoW_{12}O_{40}.3H_2O$[29] and $Fe(HSO_4)_3$[39], $HClO_4/SiO_2$[16], we summarized some of the results for the preparation of α-amidoalkyl-β-naphthols in Table 5, which shows that P_2O_5/SiO_2 is the most efficient catalyst with respect to the reaction time and temperature and exhibits broad applicability in terms of yield.

Table 5. Comparison results of P_2O_5/SiO_2 with $Ce(SO_4)_2$, I_2, Montmorrillonite k10 clay, $K_5CoW_{12}O_{40}.3H_2O$, $H_3Mo_{12}O_{40}P$, $Fe(HSO_4)_3$ and $HClO_4/SiO_2$ in the synthesis of *α*-amidoalkyl-*β*-naphthols

Entry	Catalyst	Molar ratio aldehyde/*β*-naphthol/(catalyst)	Conditions	Time	Yield, %
1	$Ce(SO_4)_2$	1/1/ (1 mol %)	Reflux in acetonitrile	36 h	72
2	I_2	1/1/ (5 mol %)	Solvent-free	5.5 h	85
3	$H_3Mo_{12}O_{40}P$	1/1(6.6 mol %)	Reflux in ethyl acetate	3.5 h	95
4	$K_5CoW_{12}O_{40}.3H_2O$	1/1/(0.01g)	Solvent-free	2 h	90
5	Montmorrillonite K10 clay	1/1/(0.1g)	Solvent-free	1.5 h	89
6	$Fe(HSO_4)_3$	1/1/ (5 mol %)	Solvent-free	65 min	83
7	$HClO_4/SiO_2$	1/1/ (0.6 mol %)	Solvent-free	40 min	89
8	P_2O_5/SiO_2	1/1/ (0.08 g, 3.7 mol%), (present work)	Solvent-free	5 min	94

[a]*Based on the reaction of β-naphthol, benzaldehyde and acetamide*

We also investigated the recycling of the catalyst under solvent-free conditions using a model reaction of benzaldehyde, *β*-naphthol and acetamide. After completion of the reaction, the reaction was cooled to room temperature, and the crude solid product was dissolved in ethylacetate. The mixture was filtered for separation of the catalyst. The catalyst was washed four times with ethyl acetate (4×5 mL) ethylacetate. The recovered catalyst was dried in vacuum and was used for the subsequent catalytic runs. The catalytic system worked well up to five catalytic runs. Catalytic cycles with respect to 94% yield (Table 3, entry 1). The recovered catalyst was reused five times without any loss of its activities.

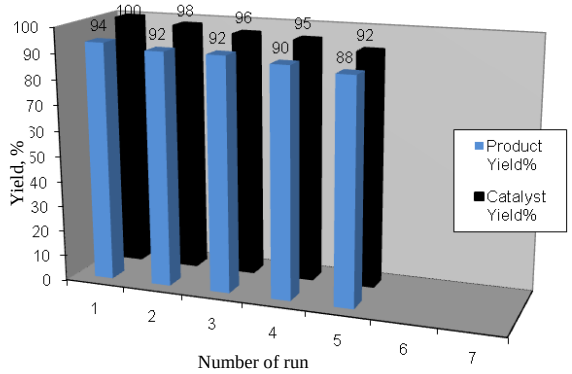


Figure 1. The investigation of the recycling of P_2O_5/SiO_2

Conclusion

We have developed a green and straightforward protocol for the synthesis of *α*-amidoalkyl-*β*-naphthols and and *α*-carbamato-alkyl-*β*–naphthols using P_2O_5/SiO_2 as catalytic medium under solvent-free conditions. This procedure provides several advantages such as cleaner reactions, easier workup, reduced reaction times, reusable catalyst and eco-friendly promising strategy.

Acknowledgement

We are thankful to the University of Sistan and Baluchestan Research Council for the partial support of this work.

References

1. Paul T A, Irvin J L and Kathryn E P, Green Chemistry Education: Changing the course of chemistry*;* Oxford University press, USA, 2009.
2. Istran T H and Paul A, *Chem Rev.*, 2007, **107**, 2169-2173.
3. Tanabe K, Misono M, Ono Y and Hattori H, New Solid Acids and Bases: Their Catalytic Properties; Kodansha L T D, Tokyo. Elsevier Science Publishers B V, Amesterdam, Netherlands, 1989**.**
4. (a) Corbridge D E C, Phosphorus: An Outline of its Chemistry, Biochemistry, and Technology 5th Edition Elsevier: Amsterdam., Netherlands,1978**.**; (b) Patnaik P A, Comprehensive Guide to the Hazardous Properties of Chemical substances, John Wiley & Sons: New York, 2007.
5. Eaton P E, Carlson G R and Lee J T, *J Org Chem.*, 1973, **38**, 4071-4073.
6. (a) Eshghi H, Rafei M and Karimi M H, *Synth Commun***.,** 2001, **31**, 771-774; (b) Tamaddon F, Khoobi M and Keshavarz E, *Tetrahedron Lett***.,** 2007, **48**, 3643–3646.
7. Eshghi H, Rafei M, Gordi Z and Bohloli M, *J Chem Res (S).*, 2003, 763.
8. Hajipour A R and Ruoho A E, *Tetrahedron Lett.*, 2005, **46**, 8307-8310.
9. Eshghi H and Gordi Z, *Phosphorus, Sulfur Silicon, Relat Elem.*, 2005, **180**, 1553–1557.
10. Eshghi H and Shafieyoon P, *Phosphorous, Sulfur Silicon, Relat Elem.*, 2004, **179**, 2149–2159.
11. Eshghi H and Hassankhani A, *Synth Commun*., 2006, **36**, 2211–2216.
12. Hasaninejad A R, Zare A, Sharghi H, Niknam K and Shekouhy M, *Arkivoc*, 2007, **xiv**, 39–50.
13. Hasaninejad A R, Zare A, Sharghi H and Shekouhy M, *Arkivoc*, 2008, **ii**, 64–67.
14. Tamaddon F, Khoobi M and Keshavarz E, *Tetrahedron Lett.*, 2007, **48**, 3643-3646.
15. Wang Y F, Izawa T, Kobayashi S and Ohono M, *J Am Chem Soc*., 1982, **104**, 64-65.
16. Shaterian H R,Yarahmadi H and Ghashang M, *Tetrahedron*, 2008, **64**, 1263-1269.
17. Shen A, Chen C L and Lin C, *J Physiol.*, 1992, **35**, 45.
18. Damodiran M, Panneer Selvam N and Perumal P T, *Tetrahedron Lett*., 2009, **50**, 5474-5478.
19. (a) Wani M C, Taylor H L and Wall M E, *J Chem Soc Chem Commun.*, 1973, 390.; (b) Johnson P Y and Silver R, *J Heterocycl Chem.*, 1975, **10**, 1029-1030.; (c) Renullard S, Rebhun L I; Havic G A and Kupchan S.M, *Sci.*, 1975, **189**, 1002-1005.
20. Mosher H S, Frankel M B and Gregory M, *J Am Chem Soc.*, 1953, **75**, 5326-5328.
21. Peglion J L, Vian J, Despaux N, Audinot V and Millan M, *Bioorg Med Chem Lett.*, 1997, **7**, 881-886.
22. Ren H, Grady S, Gamenara D, Heinzen H, Moyna P, Croft S, Kendrick H, Yardley V and Moyna G, *Bioorg Med Chem Lett.*, 2001, **11**, 1851-1854.
23. Benedini F, Bertolini G, Cereda R, Doná G, Gromo G, Levi S, Mizrahi J and Sala A, *J Med Chem.*, 1995, **38**, 130-136.
24. Clark R D, Caroon J M, Kluge A F, Repke D B, Roszkowski A P, Strosberg A M, Baker S, Bitter S M and Okada M D, *J Med Chem.*, 1983, **26**, 657-661.
25. Dingermann T, Steinhilber D and Folkers G, In Molecular Biology in Medicinal Chemistry; Wiley VCH., Verlag GmbH & KGaA, Weinheim, Germany, 2004.

26. (a) Shaterian H R and Yarahmadi H, *Tetrahedron Lett.*. 2008, **49**, 1297-1300; (b) Shaterian H R and Yarahmadi H, *Arkivoc*, 2008**, ii**, 105-114; (c) Shaterian H R; Ghashang M and Hassankhani A, *Dyes Pigments*, 2008, **76**, 564-568; (d) Shaterian H R, Hosseinian A and Ghashang M, *Synth Commun.*, 2008, **38**, 4097-4106. (e) Shaterian H R, Hosseinian A and Ghashang M, *Synth Commun*., 2008**,** 19, 3375-3389.
27. Selvam N P and Perumal P T, *Tetrahedron Lett.*, 2006, **47**, 7481-7483.
28. Mahdavinia G H, Bigdeli M A and Heravi M M, *Chinese Chem lett.*, 2008, **19**, 1171-1174.
29. Shaterian H, Amirzadeh A, Khorami F and Ghashang M, *Synth Commun.*, 2008, **38**, 2983-2994.
30. Nagarapu L, Baseeruddin M, Apuri S and Kantevari S, *Catal Commun.*, 2007, **8**, 1729–1734.
31. Khodaei M M, Khosropour A R and Moghanian H, *Synlett.*, 2006, **6**, 916-920.
32. Nagawade R R and Shinde D B, *Chinese J Chem.*, 2007, **25**, 1710-1714.
33. Sachin B P, Pankajkumar R S, Mandar P S and Shriniwas D S, *Synth Commun.*, 2007, **37**,.1659-1664.
34. Shaterian H R Hosseinian A and Ghashang M, *Tetrahedron Lett.*, 2008, **49**, 5804-5805.
35. Dabiri M, Delbari A S and Bazgir A, *Hetrocycl.***,** 2007, **71**, 543-548.
36. Nagawade R R and Shinde D B, *Mendeleev Commun*., 2007, **17**, 299-300.
37. Jiang W-Q, An L-T and Zou J-P, *Chin J Chem.*, 2008, **26**, 1697-1701.
38. Kantevari S, Vuppalapati S V N, Nagarapu L, *Catal Commun.*, 2007, **8**, 1857-1862.
39. Shaterian H R, Yarahmadi H and Ghashang M, *Bioorg Med Chem Lett.*, 2008, **18**, 788-792.