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Research Note

Preparation of 1-(benzothiazolylamino)methyl -2-naphthols using multi-SO_3H functionalized ionic liquid under solvent-free conditions

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Ionic liquid.

Abstract. A one-pot, three-component condensation of aldehydes, 2-naphthol and 2-aminobenzothiazole in the presence of multi-SO_3H functionalized ionic liquid (synthesized from hexamethylenetetramine and 1,4-butane sulfonate), as an effective catalyst for the synthesis of 1-(benzothiazolylamino)methyl-2-naphthol derivatives, under thermal and solvent-free conditions, is described. These products involve two biologically active parts; Betti's base and benzothiazole. The present methodology offers several advantages, such as good yields, short reaction times, and easy work-up. The catalyst could be recycled and reused without substantial reduction in its catalytic activities.

1. Introduction

o-Quinone Methides (o-QMs) are highly reactive, transient species that have been applied as intermediates in the synthesis of several natural products, including flavonoids, isoflavans, chromenes and benzopyrans [1-4]. Because of their synthetic utility and biological importance, various methods have been reported for generating these extremely reactive intermediates that rely on the use of catalysts, acidic or basic conditions, high temperatures or long reaction times [5-8]. Until now, the ortho aldolization of phenols with aldehydes followed by Lewis acid-assisted water elimination is probably the most convenient path available. The o-QM thus generated then participates in a regiospecific [4+2] cycloaddition reaction with olefins, enol ethers or enamines, along with the formation of side products [9]. In recent years, trapping of o-QM by suitable nucleophiles has been used to provide a rapid access to novel Michael addition products [10].

Molecules featuring the benzothiazole structural motif play a key part in a wide variety of chemistries. Their diverse functions range from electron transfer facilitation in the firefly luciferine cycle, through antitumor and antidiabetic activity, to being an Alzheimer disease tracer and anticancer agent in the pharmaceutical chemistry [11]. The 2-aminobenzothiazole core, as a privileged scaffold, is found in many natural products and pharmaceuticals that exhibit remarkable biological activities [12,13].

In the context of sustainable chemistry, the implementation of methodologies giving selective access to elaborate scaffolds, while combining molecular diversity [14] with eco-compatibility, is a great challenge for organic chemists. Thanks to their ability to generate only one adduct from three or more reactants in a single operation with high atom economy [15] and bond forming efficiency, multi-component reactions

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(MCRs) [16] now constitute an established approach to reach this ideal goal. Due to environmental concerns, the investigation of greener alternatives to conventional organic solvents has resulted in considerable interest in the use of reusable room temperature ionic liquids (RTILs) [17]. Furthermore, the user friendly and adjustable properties of these salts have prompted numerous applications, not only as environmentally benign reaction media, but also as catalysts [18], task-specific reagents [19] and chirality transfer media [20]. From this perspective, combining the synthetic potential of MCRs with the dual properties of RTILs as solvents and promoters has resulted in the development of new and promising eco-compatible organic transformations.

Four reports appeared for the synthesis of 1-(benzothiazolylamino)methyl-2-naphthols using LiCl [21], heteropolyacid (HPA) [22], Sodium dodecyl sulfate [23] and methyl-2-pyrrolidonium hydrogen sulfate ([Hnmp]HSO_4) [24]. In continuation of our interest in the use of o-QM as an intermediate in the synthesis of organic molecules [25,26], herein, we report a green, one-pot, efficient synthesis of 1-(benzothiazolylamino)methyl-2-naphthols catalyzed by multi-SO_3H functionalized ionic liquid under thermal and solvent-free conditions (Scheme 1).

Multi-SO_3H functionalized strong Brønsted acidic ionic liquid has been prepared for the synthesis of biodiesel from rapeseed oil and ethanol [27].

2. Results and discussion

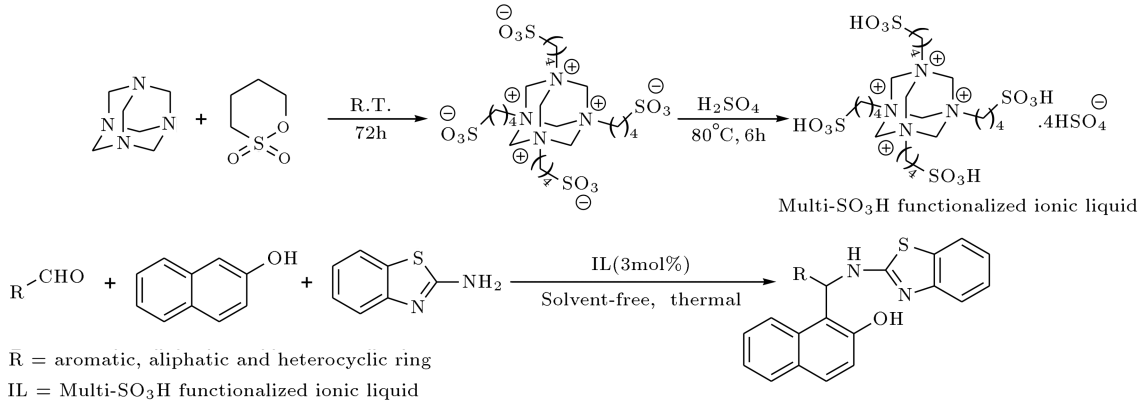
In an initial endeavor, we carried out the reaction of 4-chlorobenzaldehyde (1 equiv), 2-naphthol (1 equiv) and 2-aminobenzothiazole (1 equiv) as a model to optimize the reaction conditions. The effects of various catalysts, such as ZrO_2, Fe_2O_3, ZnO, MgO, $ZnCl_2$, $MgCl_2$, $CeCl_3.7H_2O$, 1-butyl-3-methylimidazolium chloride ([bmim]Cl), 1,4-diazabicyclo[2.2.2]octane (DABCO), cyanuric chloride ($C_3N_3Cl_3$), N-bromosuccinimide (NBS) and multi-SO_3H functionalized ionic liquid were studied. Of these, multi-SO_3H functionalized ionic liquid was found to be the most effective for this conversion, and the best result was obtained by carrying out the reaction using 3 mol% of multi-SO_3H functionalized ionic liquid at 100°C under solvent-free conditions (Table 1, entry 7).

Using these optimized reaction conditions, the generality of this reaction was examined using several types of aldehyde. As shown in Table 2, the direct three-component reactions worked well with a variety of heterocyclic aldehydes (Table 2, entries 17 and 25-26), aliphatic aldehyde (Table 2, entry 24) and aryl aldehydes, including those bearing electron-withdrawing and electron-donating groups, and the desired compounds were obtained in good yields. However, the yield of product was lower with aryl aldehydes containing electron-withdrawing substituents (Table 2, entries 14-16) compared with the others.

As reported in the literature [21-26], the reaction of 2-naphthol with aldehydes in the presence of an acid catalyst is known to give ortho-quinone methides (o-QMs). These o-QMs, generated in situ, react with 2-aminobenzothiazole to form the desired product (Scheme 2).

We also investigated the recycling of ionic liquids under solvent-free conditions using the model reaction of 4-methylbenzaldehyde, 2-aminobenzothiazole, and 2-naphthol in the presence of multi-SO_3H functionalized ionic liquid (3 mol%, 100°C, Table 2, entry 13). After completion of the reaction, water was added and the precipitated mixture was filtered off for separation of crude products. After washing the solid products with water completely, the water containing ionic liquid (IL is soluble in water) was evaporated under reduced pressure and the ionic liquid was recovered and reused (Table 3). The recovered catalysts were reused three runs without any loss of its activities.

In order to show the accessibility of the present work in comparison with four reported results in the literature, we summarized some of the results for the preparation of 1-((benzo[d]thiazol-2-ylamino)(aryl)-methyl)naphthalen-2-ol derivatives in

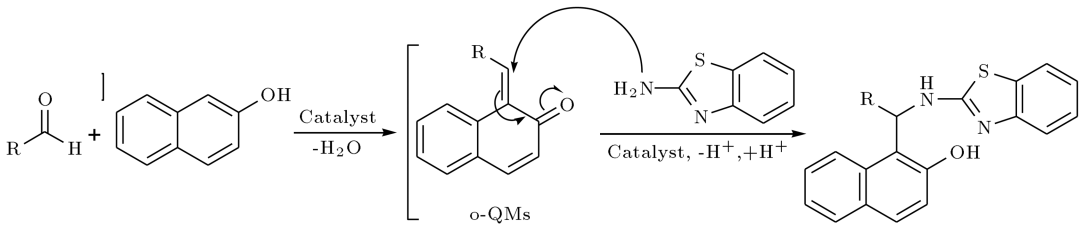


Scheme 1. Synthesis of 1-(benzothiazolylamino)methyl-2-naphthols catalyzed by multi-SO_3H functionalized ionic liquid.

Table 1. Optimization of the reaction condition for the preparation of 1-((benzo[d]thiazol-2-ylamino)(4-chlorophenyl)methyl)naphthalen-2-ol under solvent-free conditions.

Entry	Catalyst (mol%)	Temperature (°C)	Time (min)	Yield (%)[a]
1	ZrO_2 (10 mol%)	70	60	65
2	Fe_2O_3 (10 mol%)	70	60	43
3	ZnO (10 mol%)	70	25	51
4	MgO (10 mol%)	70	60	20
5	$ZnCl_2$ (10 mol%)	70	120	39
6	$MgCl_2$ (10 mol%)	70	19	71
7	$CeCl_3.7H_2O$ (10 mol%)	70	23	73
8	[bmim]Cl (10 mol%)	70	30	65
9	DABCO (10 mol%)	70	120	40
10	Cyanuric chloride (10 mol%)	70	18	55
11	NBS (10 mol%)	70	30	65
12	Multi-SO_3H ionic liquid (5 mol%)	70	15	70
13	Multi-SO_3H ionic liquid (5 mol%)	85	10	78
14	Multi-SO_3H ionic liquid (5 mol%)	100	9	84
15	Multi-SO_3H ionic liquid (5 mol%)	120	7	85
16	Multi-SO_3H ionic liquid (7 mol%)	100	8	80
17	Multi-SO_3H ionic liquid (10 mol%)	100	3	75
18	Multi-SO_3H ionic liquid (3 mol%)	100	5	87

[a]: Yields refer to isolated pure products.



Scheme 2. Possible mechanism for one-pot preparation of 1-(benzothiazolylamino)methyl-2-naphthols catalyzed by multi-SO_3H functionalized ionic liquid.

Table 4. The results show that multi-SO_3H functionalized ionic liquid under solvent-free conditions relative to LiCl [21], heteropolyacid (HPA) [22], and sodium dodecyl sulfate [23] are the most efficient catalysts, with respect to the reaction time and obtained yields.

3. Experimental

All reagents were purchased from Merck and Aldrich and used without further purification. Multi-SO_3H functionalized ionic liquid was prepared according to the reported procedure [27]. All yields refer to isolated products after purification. Products were characterized by comparison of spectroscopic data (IR, ^{1}H NMR, ^{13}C NMR spectra) and melting points with authentic samples. Elemental analyses for C, H, and N were performed using a Heraeus CHN-O-Rapid analyzer. The NMR spectra were recorded on a Bruker DRX-400 Avanve instrument. The spectra were measured in DMSO-d_6 relative to TMS (0.00 ppm). IR spectra were recorded on a JASCO FT-IR 460plus spectrophotometer. All compounds were solid, and solid state IR spectra were recorded using the KBr disk technique. 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 SIL G/UV 254 plates.

3.1. Synthesis of the catalyst

3.1.1. Preparation of zwitterions

Hexamethylenetetramine and 1,4-butane sulfonate were mixed together without solvent and stirred magnetically for 72 h at room temperature (25°C). Then, a white solid zwitterion was formed and the solid was washed repeatedly with ethyl ether. After being dried in vacuum (110°C, 0.01 Torr), the white solid

Table 2. Preparation of substituted 1-(benzothiazolylamino)methyl-2-naphthols.

Entry	Aldehyde	Time (min)/ yield (%)[a]	M.p. (°C)/Lit. M.p.[ref]
1	Benzaldehyde	5/91	202-204/202-203 [24]
2	2-Chlorobenzaldehyde	5/84	187-189/189-190 [24]
3	3-Chlorobenzaldehyde	6/90	193-195/192-194 [23]
4	4-Chlorobenzaldehyde	5/87	208-210/209-210 [21]
5	2,4-Dichlorobenzaldehyde	6/81	206-208/206-207 [24]
6	4-Fluorobenzaldehyde	5/90	184-186/176-178 [23]
7	3-Bromobenzaldehyde	6/93	203-205/202-204 [23]
8	2-Methoxybenzaldehyde	5/89	168-170/165-167 [23]
9	3-Methoxybenzaldehyde	7/86	184-186/184-186 [23]
10	4-Methoxybenzaldehyde	7/87	173-175/175-176 [21]
11	2,4-Dimethoxybenzaldehyde	8/84	160-162/161-163 [23]
12	4-Hydroxy-3-methoxybenzaldehyde	8/80	192-194/194-195 [24]
13	4-Methylbenzaldehyde	7/93	183-185/182-183 [21]
14	2-Nitrobenzaldehyde	10/69	212-214/215-216 [24]
15	3-Nitrobenzaldehyde	30/57	193-195/191-194 [23]
16	4-Nitrobenzaldehyde	30/54	187-189/189-191 [23]
17	Pyridine-4-carbaldehyde	10[b]/87	210-212/209-211 [23]
18	1-Naphthaldehyde	6/92	203-205/New product
19	2,6-Dichlorobenzaldehyde	6/88	193-195/New product
20	4-Bromobenzaldehyde	8/92	200-202/New product
21	5-Bromo-2-hydroxybenzaldehyde	8/87	183-185/New product
22	2,3-Dimethoxybenzaldehyde	10/83	201-203/New product
23	2-Methylbenzaldehyde	5/94	191-193/New product
24	3-Phenylpropanal	5/94	192-194/New product
25	Thiophene-2-carbaldehyde	6[b]/90	191-193/New product
26	Pyridine-3-carbaldehyde	10[b]/88	189-191/New product

[a]: Yields refer to isolated pure products; [b]: Reaction was carried out at 80°C.

zwitterion was obtained in a good yield (> 90%) and with sufficient purity [27].

3.1.2. Preparation of multi-SO_3H functionalized ionic liquid

A stoichiometric amount of sulfuric acid was added to the above obtained zwitterion and the mixture was stirred for 6 h at 80°C to form the ionic liquid. The IL phase was then washed repeatedly with toluene and ether to remove non-ionic residues, and dried in vacuum (110°C, 0.01 Torr). The product was formed quantitatively and in high purity, as assessed by mass balance [27].

Table 3. The recycling of the ionic liquids as catalyst in the reaction of 4-methylbenzaldehyde, 2-aminobenzothiazole, and 2-naphthol.

Run	The catalyst recovery (yield %)	Product (yield%)
1	95	93
2	93	90
3	91	89

3.2. General procedure for the preparation of 1-(benzothiazolylamino)methyl-2-naphthols

To a mixture of 2-naphthol (1 mmol), aldehyde (1 mmol), and 2-aminobenzothiazole (1 mmol), ionic liquid (3 mol%) was added. The mixture was stirred at 100°C (or 80°C for heterocyclic aldehydes) in an oil bath and the reaction was followed by TLC. After completion, the mixture was cooled to room temperature, and then water was added to remove IL from the reaction mixture. (Due to the fact that the catalyst was soluble in water, it could be recycled off the filtrate by evaporation of water. The separated catalyst was washed with diethyl ether, dried at 50°C under vacuum for 1 h and was reused in another reaction. The catalyst could be reused at least three times without significant loss of activity.) The solid

Table 4. Comparison of the results of multi-SO_3H functionalized ionic liquid under solvent-free conditions relative to LiCl [21], heteropolyacid (HPA) [22], and Sodium Dodecyl Sulfate (SDS) [23] in the synthesis 1-((benzo[d]thiazol-2-ylamino)(aryl)methyl)naphthalen-2-ol derivatives.

Entry	Catalyst	Conditions	Time	Yield (%)[a]
1	(HPAs) (0.09 g)	Ultrasound, Water (3 ml), 45°C	80-120 min	64-91
2	LiCl (0.5 g, 71 mmol)	Water (5 ml), 90°C	5-7 h	88-96
3	SDS (2equiv)	Water (3 ml), 100°C	1-5 h	71-93
4	Multi-SO3H functionalized ionic liquid (3 mol%)	Solvent-free, 100°C	5-30 min	54-94 (Present work)

[a]: Yields refer to isolated pure products.

product was purified by recrystallization or column chromatography. Spectral data for novel products are given below.

3.2.1. 1-(benzo[d]thiazol-2-ylamino)(naphthalen-1-yl) methyl)naphthalen-2-ol (Table 2, entry 18)

It was recrystallized from Acetic acid: ^{1}H NMR (400 MHz, DMSO-d_6): δ = 7.01 (^{1}H, t, J = 7.6 Hz), 7.15-7.36 (5H, m), 7.39-7.52 (3H, m), 7.62-7.66 (2H, m), 7.76-7.88 (4H, m), 7.95 (^{1}H, d, J = 7.6 Hz), 8.06-8.15 (2H, m), 9.01 (^{1}H, D_2O exchange, NH, d, J = 6.4 Hz), 10.24 (^{1}H, D_2O exchange, OH, s) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 52.6, 118.3, 118.6, 118.9, 119.0, 121.4 (2C), 122.8, 124.0, 125.5, 125.7, 125.9, 126.0, 126.6, 126.7, 128.1, 129.1, 129.2, 129.2, 130.2, 131.2, 131.6, 133.3, 134.1, 137.6, 152.8, 153.8, 165.8 ppm; IR (KBr, cm^{-1}): 3314, 3059, 1626, 1597, 1538, 1517, 1447, 1435, 1301, 1268, 1070, 808, 776; MS m/z (%): 432 (M^+, 3), 29 (7), 282 (28), 281 (59), 274 (20), 273 (100), 252 (16), 233 (15), 232 (67), 189 (9), 161 (11), 159 (12), 150 (16), 135 (36), 119 (15), 105 (18), 95 (15), 69 (12), 55 (12), 43 (46); Anal. Calcd for $C_{28}H_{20}N_2OS$: C, 77.75; H, 4.66; N, 6.48; S, 7.41. Found: C, 77.32; H, 4.96; N, 6.75; S, 7.25%.

3.2.2. 1-((benzo[d]thiazol-2-ylamino)(2,6-dichlorophenyl)me thyl)naphthalen-2-ol (Table 2, entry 19)

It was recrystallized from Acetone: ^{1}H NMR (400 MHz, DMSO-d_6): δ = 6.99-7.21 (2H, m), 7.21-7.41 (7H, m), 7.47 (1H, t, J = 8.0 Hz), 7.67 (1H, d, J = 8.0 Hz), 7.78 (1H, d, J = 8.8 Hz), 7.84 (1H, d, J = 8.0 Hz), 7.97 (1H, d, J = 8.8 Hz), 8.82 (1H, D_2O exchange, NH, d, J = 7.2 Hz), 9.77 (1H, D_2O exchange, OH, s) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 54.2, 115.6, 117.8, 118.7, 119.5, 121.4, 122.5, 122.9, 125.9, 126.2, 127.5, 128.7, 129.2, 129.6, 130.4, 131.1, 133.8, 135.5, 137.4, 152.8, 154.4, 165.0 ppm; IR (KBr, cm^{-1}): 3309, 3061, 1631, 1596, 1548, 1515, 1449, 1435, 1277, 1185, 1113, 809, 707; MS m/z (%): 452 (M^++1, 0.9), 450 (M^+1, 1.8), 408 (30), 271 (44), 267 (99), 266 (76), 265 (100), 230 (16), 202 (33), 201 (19), 200 (21), 150 (46), 144 (23), 123 (11), 115 (23), 108 (11), 96 (11), 69 (9), 63 (10); Anal. Calcd for $C_{24}H_{16}Cl_2N_2OS$: C, 63.86; H, 3.57; N, 6.21; S, 7.10. Found: C, 63.42; H, 3.62; N, 6.31; S, 7.24%.

3.2.3. 1-((benzo[d]thiazol-2-ylamino)(4-bromophenyl) methyl)naphthalen-2-ol (Table 2, entry 20)

It was recrystallized from Acetic acid/Ethanol: ^{1}H NMR (400 MHz, DMSO-d_6): δ = 7.04 (1H, t, J = 7.6 Hz), 6.98-7.30 (6H, m), 7.36-7.42 (2H, m), 7.44-7.50 (2H, m), 7.69 (1H, d, J = 7.6 Hz), 7.79-7.85 (3H, m), 8.84 (1H, D_2O exchange, NH, s), 10.21 (1H, D_2O exchange, OH, s) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 53.1, 118.6, 118.7, 118.8, 119.6, 121.4, 121.6, 123.0, 124.1, 125.9, 126.9, 128.8 (2C), 129.1, 130.3, 131.3, 131.4, 132.5, 142.7, 152.5, 153.7, 166.6 ppm; IR (KBr, cm^{-1}): 3375, 3057, 1627, 1543, 1484, 1436, 1332, 1270, 1251, 1207, 1072, 1010, 819, 751; MS m/z (%): 462 (2), 460 (2), 317 (20), 315 (18), 311 (18), 309 (17), 273 (13), 271 (34), 267 (34), 266 (21), 265 (94), 231 (91), 202 (51), 201 (20), 200 (26), 150 (100), 144 (35), 135 (19), 123 (15), 115 (27), 108 (16), 96 (14), 69 (15), 63 (11); Anal. Calcd for $C_{24}H_{17}BrN_2OS$: C, 62.48; H, 3.71; N, 6.07; S, 6.95. Found: C, 62.97; H, 3.75; N, 5.92; S, 6.81%.

3.2.4. 1-((benzo[d]thiazol-2-ylamino) (5-bromo-2-hydroxyphenyl)methyl)naphthalen-2-ol (Table 2, entry 21)

It was recrystallized from Acetic acid: ^{1}H NMR (400 MHz, DMSO-d_6): δ = 6.70 (1H, d, J = 8.4 Hz), 6.99 (1H, t, J = 7.6 Hz), 7.13-7.39 (7H, m), 7.46 (1H, t, J = 8.0 Hz), 7.63-7.68 (2H, m), 7.74 (1H, d, J = 8.8 Hz), 7.79 (1H, d, J = 8.0 Hz), 8.26 (1H, d, J = 8.4 Hz), 8.72 (1H, D_2O exchange, NH, s), 9.62-10.28 (2H, D_2O exchange, 2OH, broad s) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 50.5, 110.3, 117.6, 117.8, 118.4, 118.8, 121.4, 121.7, 123.1, 123.4, 126.2, 126.8, 128.7, 129.0, 129.9, 130.6, 130.8, 130.9, 131.5, 132.9, 152.2, 153.4, 154.4, 166.3 ppm; IR (KBr, cm^{-1}): 3355, 3208, 3061, 1628, 1575, 1537, 1467, 1435, 1339, 1311, 1267, 1214, 1107, 807, 747; MS m/z (%): 478 (2), 476 (2), 454 (31), 452 (39), 373 (8), 334 (38), 332 (38), 317 (75), 315

(64), 311 (65), 309 (64), 253 (28), 230 (24), 202 (11), 150 (55), 144 (64), 136 (37), 135 (100), 123 (12), 115 (39), 108 (27), 96 (22), 63 (19), 50 (10), 45 (7); Anal. Calcd for $C_{24}H_{17}BrN_2O_2S$: C, 60.38; H, 3.59; N, 5.87; S, 6.72. Found: C, 60.79; H, 3.72; N, 5.54; S, 6.51%.

3.2.5. 1-((benzo[d]thiazol-2-ylamino)(2,3-dimethoxyphenyl)methyl) naphthalen-2-ol (Table 2, entry 22)

It was purified by column chromatography EtOAc/Hexane: ^{1}H NMR (400 MHz, DMSO-d_6): δ = 3.24 (3H, s), 3.75 (3H, s), 6.91 (1H, d, J = 8.0 Hz), 6.95-7.04 (2H, m), 7.15-7.30 (4H, m), 7.32-7.45 (3H, m), 7.65 (1H, d, J = 7.6 Hz), 7.72-7.82 (2H, m), 8.18 (1H, d, J = 8.8 Hz), 8.71 (1H, D_2O exchange, NH, d, J = 8.0 Hz), 9.97 (1H, D_2O exchange, OH, s) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 50.8, 56.1, 59.8, 111.8, 118.5, 118.9, 119.5, 120.8, 121.2, 121.3, 122.4, 123.5, 123.7, 125.8, 126.4, 128.6, 128.9, 129.5, 131.1, 133.1, 136.4, 146.6, 152.8, 152.8, 154.6, 166.1 ppm; IR (KBr, cm^{-1}): 3328, 3066, 2993, 2961, 2932, 1631, 1594, 1571, 1544, 1516, 1475, 1447, 1337, 1294, 1274, 1209, 1091, 1036, 1004, 813, 751, 740; MS m/z (%): 442 (M^+, 1), 268 (6), 267 (32), 262 (32), 261 (98), 246 (13), 218 (27), 189 (20), 150 (100), 144 (15), 123 (18), 115 (12), 96 (19), 82 (8), 69 (17), 63 (10), 57 (9), 43 (8); Anal. Calcd for $C_{26}H_{22}N_2O_3S$: C, 70.57; H, 5.01; N, 6.33; S, 7.25. Found: C, 70.11; H, 5.28; N, 6.54; S, 7.63%.

3.2.6. 1-((benzo[d]thiazol-2-ylamino)(o-tolyl)methyl)naphthalen-2-ol (Table 2, entry 23)

It was recrystallized from Acetone: ^{1}H NMR (400 MHz, DMSO-d_6): δ = 2.10 (3H, s), 6.97 (1H, t, J = 7.6 Hz), 7.11-7.30 (7H, m), 7.30-7.41 (3H, m), 7.59 (1H, d, J = 8.0 Hz), 7.72-7.80 (2H, m), 7.96 (1H, d, J = 8.4 Hz), 8.81 (1H, D_2O exchange, NH, s), 10.08 (1H, D_2O exchange, OH, s) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 19.5, 53.1, 117.4, 118.5, 118.6, 121.3, 121.5, 123.0, 123.9, 125.9, 126.1, 126.7, 127.4, 127.5, 129.0, 129.1, 130.1, 130.7, 131.1, 133.0, 136.6, 139.8, 152.5, 153.7, 166.0 ppm; IR (KBr, cm^{-1}): 3389, 3328, 3061, 1706, 1623, 1594, 1536, 1451, 1433, 1271, 819, 750; MS m/z (%): 396 (M^+, 5), 245 (16), 230 (24), 231 (100), 229 (21), 215 (26), 203 (18), 202 (44), 189 (12), 150 (66), 149 (31), 123 (16), 122 (18), 115 (28), 105 (25), 91 (19), 69 (17), 63 (17), 43 (24); Anal. Calcd for $C_{25}H_{20}N_2OS$: C, 75.73; H, 5.08; N, 7.07; S, 8.09. Found: C, 75.95; H, 5.22; N, 6.89; S, 7.78%.

3.2.7. 1-(1-(benzo[d]thiazol-2-ylamino)-3-phenylpropyl)naphthalen-2-ol (Table 2, entry 24)

It was recrystallized from Acetic acid/Ethanol: ^{1}H NMR (400 MHz, DMSO-d_6): δ = 2.22-2.29 (1H, m), 2.54-2.62 (2H, m), 2.79-2.87 (1H, m), 5.78 (1H, s), 6.95 (1H, t, J = 7.6 Hz), 7.13-7.33 (9H, m), 7.46 (1H, t, J = 7.6 Hz), 7.61 (1H, d, J = 7.6 Hz), 7.71 (1H, d, J = 8.8 Hz), 7.78 (1H, d, J = 8.0 Hz), 8.23 (1H, s), 8.63 (1H, D_2O exchange, NH, s), 10.01 (1H, D_2O exchange, OH, s) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 33.0, 36.3, 52.1, 118.2, 119.0, 121.0, 121.3, 122.8, 123.4, 125.9, 126.2, 126.6, 128.8 (4C), 129.1, 129.4, 130.8, 132.8, 142.1, 152.8, 153.8, 166.7 ppm; IR (KBr, cm^{-1}): 3337, 3056, 3026, 2940, 2851, 1625, 1597, 1543, 1514, 1458, 1433, 1337, 1270, 819, 744; MS m/z (%): 410 (M^+, 4), 319 (5), 305 (14), 260 (13), 231 (30), 215 (12), 202 (19), 181 (15), 169 (26), 150 (99), 144 (25), 141 (23), 139 (26), 128 (42), 115 (70), 108 (20), 91 (100), 77 (29), 65 (25), 43 (21); Anal. Calcd for $C_{26}H_{22}N_2OS$: C, 76.07; H, 5.40; N, 6.82; S, 7.81. Found: C, 75.85; H, 5.53; N, 6.82; S, 7.78%.

3.2.8. 1-((benzo[d]thiazol-2-ylamino)(thiophen-2-yl) methyl)naphthalen-2-ol (Table 2, entry 25)

It was purified by column chromatography EtOAc/Hexane: ^{1}H NMR (400 MHz, DMSO-d_6): δ = 6.81-7.05 (3H, m), 7.19-7.51 (7H, m), 7.69 (1H, d, J = 6.0 Hz), 7.80-7.83 (2H, m), 8.03 (1H, s), 8.97 (1H, D_2O exchange, NH, s), 10.27 (1H, D_2O exchange, OH, s) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 50.8, 118.6, 118.7, 118.8, 121.4, 121.6, 123.0, 124.1, 124.6, 125.0, 126.0, 126.8, 127.1, 129.1 (2C), 130.3, 131.3, 132.5, 147.3, 152.4, 153.5, 166.4 ppm; IR (KBr, cm^{-1}): 3379, 3056, 1630, 1593, 1541, 1469, 1453, 1437, 1332, 1271, 1200, 838, 812, 752, 701; MS m/z (%): 388 (M^+, 2), 243 (8), 239 (18), 238 (68), 237 (100), 221 (13), 209 (19), 208 (24), 176 (8), 165 (19), 163 (10), 152 (10), 151 (11), 150 (52), 139 (9), 123 (9), 96 (10), 69 (10), 45 (6); Anal. Calcd for $C_{22}H_{16}N_2OS_2$: C, 68.01; H, 4.15; N, 7.21; S, 16.51. Found: C, 68.24; H, 4.18; N, 6.97; S, 16.93%.

3.2.9. 1-((benzo[d]thiazol-2-ylamino)(pyridin-3-yl)methyl)naphthalen-2-ol (Table 2, entry 26)

It was purified by column chromatography EtOAc/Hexane: ^{1}H NMR (400 MHz, DMSO-$_{d6}$): δ = 7.01-7.07 (1H, m), 7.19-7.43 (7H, m), 7.60-7.73 (2H, m), 7.82-7.93 (3H, m), 8.33-8.48 (2H, m), 8.89 (1H, D_2O exchange, NH, s), 10.26 (1H, D_2O exchange, OH, s) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 51.9, 118.2, 118.7, 118.9, 121.4, 121.7, 123.1, 123.7, 123.8, 126.0, 127.0, 129.1, 129.2, 130.5, 131.3, 132.4, 134.3, 138.5, 147.9, 148.1, 152.5, 153.8, 166.6 ppm; IR (KBr, cm^{-1}): 3382, 3168, 3055, 2975, 1626, 1596, 1541, 1453, 1435, 1313, 1270, 1106, 1031, 813, 725; MS m/z (%): 383 (M^+, 2), 243 (5), 239 (31), 238 (91), 237 (100), 234 (11), 233 (14), 232 (29), 221 (16), 209 (15), 208 (18), 176 (12), 165 (16), 152 (14), 151 (15), 150 (59), 144 (11), 123 (11), 115 (12), 96 (11), 69 (12), 63 (7), 57 (8), 43 (6);Anal. Calcd for $C_{23}H_{17}N_3OS$: C, 72.04;

H, 4.47; N, 10.96; S, 8.36. Found: C, 72.11; H, 4.28; N, 11.53; S, 7.92%.

4. Conclusions

In summary, we have developed a highly efficient synthesis of 1-(benzothiazolylamino)methyl-2-naphthol derivatives from aldehydes, 2-naphthol and 2-aminobenzothiazole under solvent-free conditions in the presence of multi-SO_3H functionalized ionic liquid (synthesized from hexamethylenetetramine and 1,4-butane sulfonate) as a catalyst. These products have two biologically active parts; Betti's base and benzothiazole. Simplicity, good yields, purity of product, efficiency of catalyst and clean reaction are the salient features of this method. The catalyst could be recycled and reused without substantial reduction in its catalytic activities.

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References

1. Chiang, Y., Kresge, A.J. and Zhu, Y. "Reactive intermediates. Some chemistry of quinone methides", *Pure. Appl. Chem.*, **72**(12), pp. 2299-2308 (2000).
2. Mashraqui, S.H., Patil, M.B., Mistry, H.D., Ghadigaonkar, S. and Meetsmay, A. "A three-component reaction of phenol, aldehyde, and active methylene substrate under Lewis acid catalysis: successful trapping of *o*-quinone methide to afford benzopyran systems", *Chem. Lett.*, **33**(8), pp. 1058-1059 (2004).
3. Adler, M.J. and Baldwin, S.W. "Direct, regioselective synthesis of 2,2-dimethyl-2H-chromenes. Total syntheses of octandrenolone and precocenes I and II", *Tetrahedron Lett.*, **50**(36), pp. 5075-5079 (2009).
4. Yadav, J.S., Subba-Reddy, B.V., Sadashiv, K. and Padmavani, B. "[4+2] cycloaddition of ortho-quinone methides promoted by ionic liquids: An efficient and mild protocol for the synthesis of tetrahydropyranobenzopyrans", *Adv. Synth. Catal.*, **346**(6), pp. 607-610 (2004).
5. Sugimoto, H., Nakamura, S. and Ohwada, T. "Generation and application of o-Quinone methides bearing various substituents on the benzene ring", *Adv. Synth. Catal.*, **349**(4-5), pp. 669-679 (2007).
6. Wan, P., Barker, B., Diao, L., Fischer, M. and Shi, Y. "1995 merck frosst award lecture quinone methides: Relevant intermediates in organic chemistry", *Can. J. Chem.* **74**(4), pp. 465-475 (1996).
7. Barrero, A.F., Qulez del Moral, J.F., Herrador, M.M., Arteaga. P., Cortes, M., Benites, J. and Rosellon, A. "Mild and rapid method for the generation of o-quinone methide intermediates. Synthesis of puupehedione analogues", *Tetrahedron*, **62**(25), pp. 6012 (2006).
8. Rodriguez, R., Adlington, R. M., Moses, J. E., Cowley, A. and Baldwin, J. E. "A new and efficient method for o-quinone methide intermediate generation: Application to the biomimetic synthesis of (±)-Alboatrin", *Org. Lett.*, **6**(20), 3617-3619 (2004).
9. Inoue, T., Inoue, S. and Sato, K. "A New synthesis of o-quinonemethides and their inter- and intramolecular cyclization reactions" *Bull. Chem. Soc. Jpn.*, **63**(4), pp. 1062-1068 (1990).
10. Mattson, A.E. and Scheidt, K.A. "Nucleophilic acylation of o-quinone methides: An umpolung strategy for the synthesis of α-aryl ketones and benzofurans" *J. Am. Chem. Soc.*, **129**(15), pp. 4508-4509 (2007).
11. Huang, S.T., Hsei, I.J. and Chen, C. "Synthesis and anticancer evaluation of bis(benzimidazoles), bis(benzoxazoles), and benzothiazoles", *Bioorg. Med. Chem.*, **14**(17), pp. 6106- 6119 (2006).
12. Paget, C.J., Kisner, K., Stone, R.L, and DeLong, D.C. "Heterocyclic substituted ureas. II. Immunosuppressive and antiviral activity of benzothiazole and benzoxazoleureas", *J. Med. Chem.*, **12**(6), pp. 1016-1018 (1969).
13. Young, R.C., Mitchell, R.C., Brown, T.H., Ganellin C.R., Griffiths. R., Jones, M., Rana, K.K, Saunders, D., Smith, I.R., Sore, N.E. and Wilks, T.J, "Development of a new physicochemical model for brain penetration and its application to the design of centrally acting H2 receptor histamine antagonists", *J. Med. Chem.*, **31**(3), pp. 656-671 (1988).
14. Nielsen, T.E. and Schreiber, S.L. "Towards the optimal screening collection: A synthesis strategy", *Angew. Chem. Int. Ed.*, **47**(1), pp. 48-56 (2008).
15. Trost, B.M. "On inventing reactions for atom economy", *Acc. Chem. Res.*, **35**(9), pp. 695- 705 (2002).
16. Lieby-Muller, F., Simon, C., Constantieux. T. and Rodriguez, J. "Current developments in Michael addition-based multicomponent domino reactions involving 1,3-dicarbonyls and derivatives", *QSAR Comb. Sci.*, **25**(5-6), pp. 432-438 (2006).
17. Hallet, J.P. and Welton, T. "Room-temperature ionic liquids: Solvents for synthesis and catalysis. 2.", *Chem. Rev.*, **111**(5), pp. 3508-3576 (2011).
18. Durand, J., Teuma, E. and Gomez, M. "Ionic liquids as a medium for enantioselective catalysis", *CR. Chim.*, **10**(3), pp. 152-177 (2007).
19. Ni, B. and Headley, A.D. "Ionic-Liquid-Supported (ILS) catalysts for asymmetric organic synthesis", *Chem. Eur. J.*, **16**(15), pp. 4426-4436 (2010).
20. Baudequin, C., Bregeon, D., Levillain, J., Guillen, F., Plaquevent, J.C. and Gaumont A.C. "Chiral ionic liquids, a renewal for the chemistry of chiral solvents? Design, synthesis and applications for chiral recognition and asymmetric synthesis", *Tetrahedron Asymmetry*, **16**(24), pp. 3921-3945 (2005).

21. Shaabani, A., Rahmati, A. and Farhangi, E. "Water promoted one-pot synthesis of 2′-aminobenzothiazolomethyl naphthols and 5-(2′-aminobenzothiazolomethyl)-6-hydroxyquinolines" *Tetrahedron Lett.*, **48**(41), pp. 7291-7294 (2007).

22. Ohanian, A., Javanshir, S., Heravi, M.M. and Bamoharram, F.F. "One-pot synthesis of 2′-aminobenzothiazolomethyl naphtols in water catalyzed by Wells-Dawson heteropolyacid", *13th International Electronic Conference on Synthetic Organic Chemistry (ECSOC-13)*, a037 (2009).

23. Kumar, A., Rao, M.S. and Rao, V.K. "Sodium dodecyl sulfate-assisted synthesis of 1-(Benzothiazolylamino)methyl-2-naphthols in water", *Aust. J. Chem.*, **63**(11), pp. 1538-1540 (2010).

24. Yi, Y. and Hong-Yunv, G. "One-pot synthesis of 2 -aminobenzothiazolo-arylmethyl-2-naphthols in Ionic Liquid of [Hnmp]HSO_4 under solvent-free conditions", *Chin. J. Org. Chem.*, **31**(1), pp. 96-100 (2011).

25. Shaterian, H.R., Ghashang, M. and Hassankhani, A. "One-pot synthesis of aryl 14H-dibenzoa,j]xanthene leuco-dye derivatives", *Dyes Pigments*, **76**(2), pp. 564-568 (2008).

26. Shaterian, H.R., Yarahmadi, H. and Ghashang, M. "Silica supported perchloric acid ($HClO_4$-SiO_2): An efficient and recyclable heterogeneous catalyst for the one-pot synthesis of amidoalkyl naphthols", *Tetrahedron*, **64**(7), pp. 1263-1269 (2008).

27. Liang, X. and Yang, J. "Synthesis of a novel multi-SO_3H functionalized ionic liquid and its catalytic activities for biodiesel synthesis", *Green. Chem.*, **12**(2), pp. 201-204 (2010).

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