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Research Note

Preparation of 1-(benzothiazolylamino)methyl-2-naphthols using multi-SO₃H functionalized ionic liquid under solvent-free conditions

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 Benzothiazole;
 Ionic liquid.

Abstract. A one-pot, three-component condensation of aldehydes, 2-naphthol and 2-aminobenzothiazole in the presence of multi-SO₃H 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.

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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 regio-specific [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 anti-tumor 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 ([Hmp]HSO₄) [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-SO₃H functionalized ionic liquid under thermal and solvent-free conditions (Scheme 1).

Multi-SO₃H 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 ZrO₂, Fe₂O₃, ZnO, MgO, ZnCl₂, MgCl₂, CeCl₃·7H₂O, 1-butyl-3-methylimidazolium chloride ([bmim]Cl), 1,4-diazabicyclo[2.2.2]octane (DABCO), cyanuric chloride (C₃N₃Cl₃), N-bromosuccinimide (NBS) and multi-SO₃H functionalized ionic liquid were studied. Of these, multi-SO₃H functionalized ionic

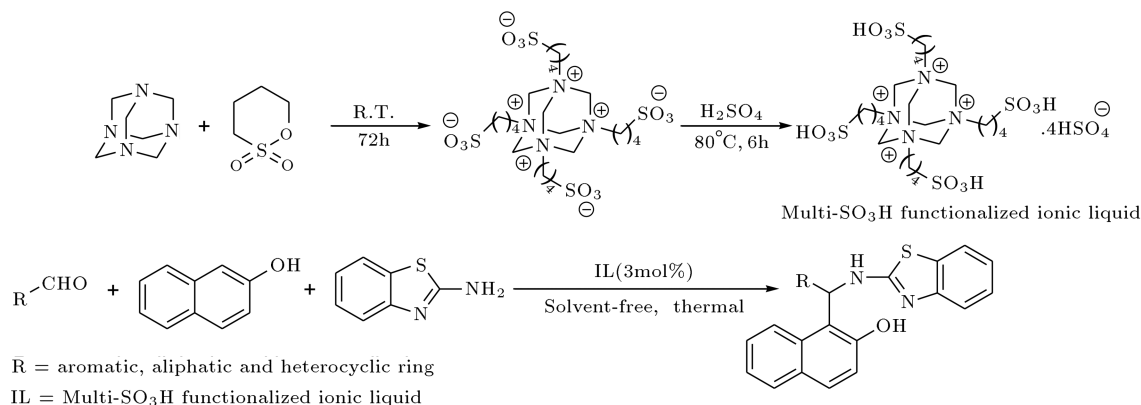
liquid was found to be the most effective for this conversion, and the best result was obtained by carrying out the reaction using 3 mol% of multi-SO₃H functionalized ionic liquid at 100°C under solvent-free conditions (Table 1, entry 7).

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-SO₃H 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-SO₃H 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 ₂ O 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 ₂ O (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 ₃ H ionic liquid (5 mol%)	70	15	70
13	Multi-SO ₃ H ionic liquid (5 mol%)	85	10	78
14	Multi-SO ₃ H ionic liquid (5 mol%)	100	9	84
15	Multi-SO ₃ H ionic liquid (5 mol%)	120	7	85
16	Multi-SO ₃ H ionic liquid (7 mol%)	100	8	80
17	Multi-SO ₃ H ionic liquid (10 mol%)	100	3	75
18	Multi-SO ₃ H ionic liquid (3 mol%)	100	5	87

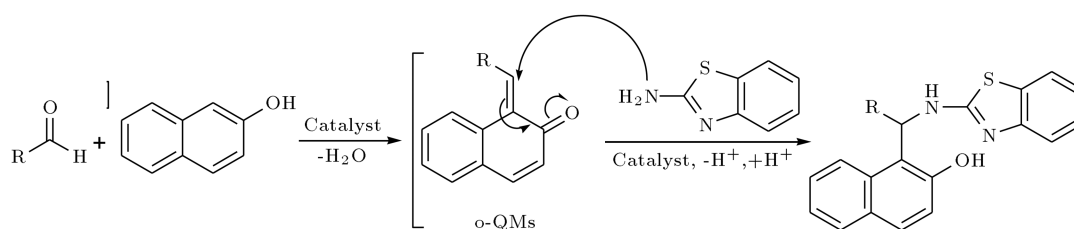
^a: Yields refer to isolated pure products.**Scheme 2.** Possible mechanism for one-pot preparation of 1-(benzothiazolylamino)methyl-2-naphthols catalyzed by multi-SO₃H functionalized ionic liquid.

Table 4. The results show that multi-SO₃H 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-SO₃H 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, ¹H NMR, ¹³C 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 Avance instrument. The spectra were measured

in DMSO-d₆ 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-SO₃H 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

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

quantitatively and in high purity, as assessed by mass balance [27].

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-SO₃H 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-SO ₃ H 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: ¹H NMR (400 MHz, DMSO-d₆): δ = 7.01 (1H, 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 (1H, d, J = 7.6 Hz), 8.06-8.15 (2H, m), 9.01 (1H, D₂O exchange, NH, d, J = 6.4 Hz), 10.24 (1H, D₂O exchange, OH, s) ppm; ¹³C NMR (100 MHz, DMSO-d₆): 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 C₂₈H₂₀N₂OS: 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)methyl)naphthalen-2-ol (Table 2, entry 19)

It was recrystallized from Acetone: ¹H NMR (400 MHz, DMSO-d₆): 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, D₂O exchange, NH, d, J = 7.2 Hz), 9.77 (1H, D₂O exchange, OH, s) ppm; ¹³C NMR (100 MHz, DMSO-d₆): 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 C₂₄H₁₆Cl₂N₂OS: 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: ¹H NMR (400 MHz, DMSO-d₆): 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, D₂O exchange, NH, s), 10.21 (1H, D₂O exchange, OH, s) ppm; ¹³C NMR (100 MHz, DMSO-d₆): 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 C₂₄H₁₇BrN₂OS: 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: ¹H NMR (400 MHz, DMSO-d₆): 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, D₂O exchange, NH, s), 9.62-10.28 (2H, D₂O exchange, 2OH, broad s) ppm; ¹³C NMR (100 MHz, DMSO-d₆): 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: 1H 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: 1H 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: 1H 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: 1H 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: 1H NMR (400 MHz, DMSO- d_6): 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-SO₃H 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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