Synthesis of 1,4-Disubstituted 1,2,3-Triazoles by Use of Copper(I) and Amino Acids Ionic Liquid Catalytic System

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Abstract: An efficient and green one-pot synthesis of 1,4-disubstituted 1,2,3-triazoles from aryl iodides and alkyl chlorides, sodium azide, and terminal alkynes catalyzed by copper(I) and amino acid ionic liquid (AAIL) in [BMIM]BF_4 was developed. The reactions proceeded smoothly to generate the corresponding products in high yields. In addition, CuI, AAIL, and [BMIM]BF_4 could be recovered for six consecutive trials without significant loss of activity.

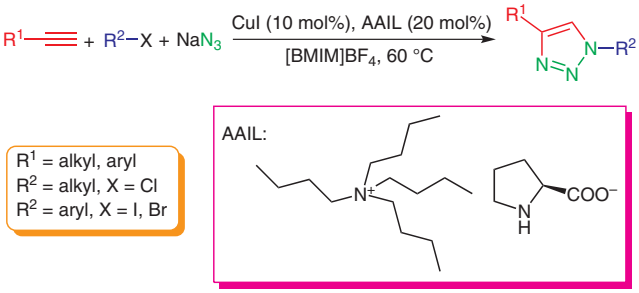
Key words: click reaction, triazoles, ionic liquids, amino acid, copper

'Click chemistry', introduced by Sharpless and co-workers,[1] is a newer approach to the synthesis of drug-like molecules that can accelerate the drug discovery process by utilizing a few practical and reliable reactions. The click reaction has wide scope and is easy to perform, uses only readily available reagents, and is insensitive to oxygen and water. Nowadays this concept has found wide use in drug discovery process and biochemistry.[2]

Of the reactions comprising click chemistry, the perfect example is the Huisgen 1,3-dipolar cycloaddition of alkynes to azides to form 1,4-disubsituted-1,2,3-triazoles.[3] The copper(I)-catalyzed reaction is mild and very efficient.[4] The azide and alkyne functional groups are largely inert towards biological molecules and aqueous environments, which allows the use of the Huisgen 1,3-dipolar cycloaddition in target guided synthesis[5] and activity-based protein profiling.[6] The products of these reactions, 1,2,3-triazoles have similarities to the ubiquitous amide moiety found in nature, but unlike amides, is not susceptible to cleavage. Additionally, they are nearly impossible to be oxidized or reduced. Thus, they have been widely used as synthetic intermediates and in industrial applications, such as dyes, anticorrosive agents, photostabilizers, photographic materials, and agrochemicals. For the click reaction, the catalysts might be copper(0) nanosize clusters,[7] or appropriate copper(I) salts (CuI or CuBr) with triphenylphosphine,[8] iminopyridine,[9] or mono-4 or polydentate[10,11] nitrogen ligands. Our group also developed this type of reaction with use of a silica-supported copper(I) catalyst[12] and in water under transition-metal-catalyst-free reaction conditions.[13] In these previous work 1,4-disubstituted 1,2,3-triazoles were derived from alkynes, sodium azide, and benzyl and alkyl halides, but rarely from aryl halides.[14]

As efficient catalysts, copper and its salts have been widely used in various of reactions such as Ullmann reaction,[15] substitution,[16] Diels–Alder reaction,[17] asymmetric allylic alkylation,[18] 1,3-dipolar cycloaddition,[19] and so on. Most recently, copper/amino acid systems have been widely used in catalyzing cross-couplings, such as C–N bond,[20a] C–O bond,[20b] C–S bond,[20c] C–C bond[20d] formation reactions, under mild reaction conditions. In these reactions, amino acids were found to be the efficient ligands.[21] Ionic liquids (ILs) have received more attention as eco-friendly, reusable and alternative reaction media in organic synthesis because of their unique properties.[22] Much more attention has been focused on functionalized ionic liquids (FILs), that is to say, through incorporation of additional functional groups as a part of the cation and/or anion, the so-called task-specific ionic liquids (TSILs) and their applications in chemical research. Ohno and his co-worker have developed amino acid ionic liquids and demonstrated their properties.[23] When the amino acids served as anions in ionic liquids, they can also play an important role of N,O-ligand.

Here we wish to disclose our results about an efficient and green one-pot synthesis of 1,4-disubstituted 1,2,3-triazoles from aryl iodides and alkyl chlorides, sodium azide, and terminal alkynes catalyzed by copper(I) and amino acid ionic liquid (AAIL) in [BMIM]BF_4 (Scheme 1). The reactions proceeded smoothly to generate the corresponding products in high yields. It is important to note that CuI, AAIL, and [BMIM]BF_4 could be recovered by general treatment of the reaction solution and reused for six consecutive trials without significant loss of activity.



Scheme 1 CuI and AAIL catalyzed 'click reaction'

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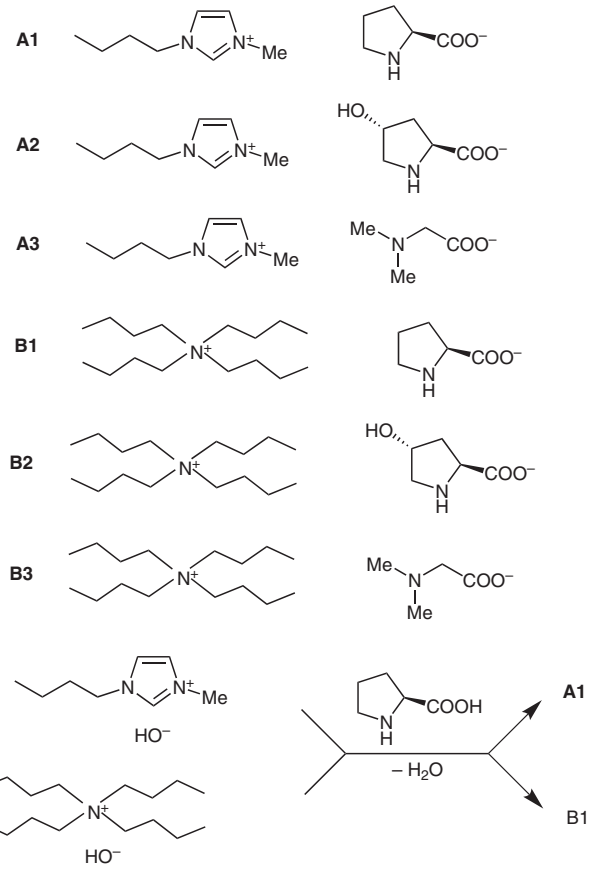
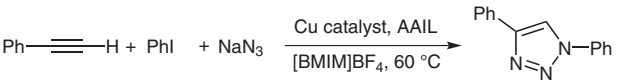
The amino acid ionic liquids (AAILs) shown in Scheme 2 can be easily prepared by the following synthetic procedure, also indicated in Scheme 2. The prepared [BMIM]OH according to the literature[24] or tetrabutylammonium hydroxide was reacted with appropriate amino acid such as L-proline, *trans*-4-hydroxy-L-proline, and *N*,*N*-dimethylglycine at room temperature, and the solution was then evaporated and dried in vacuo to generate the desired amino acid ionic liquids (AAILs), **A1**, **A2**, **A3**, **B1**, **B2**, and **B3**, respectively.



Scheme 2 Amino acid ionic liquids (AAILs) and their synthesis

After preparing the amino acid ionic liquids, a variety of copper salts and prepared AAILs were screened. The 1,3-dipolar cycloaddition reactions between phenylacetylene, iodobenzene, and sodium azide was chosen as the model reaction (Table 1). When the reaction of phenylacetylene, iodobenzene, and sodium azide in a 1:1:2 molar ratio, was catalyzed by CuI (10 mol%) and prepared AAIL (20 mol%) in [BMIM]BF_4 at 60 °C for 10 hours, the corresponding 1,4-disubstituted 1,2,3-triazole was obtained in the range of 49–88% isolated yields (Table 1, entries 1–6). Among prepared AAILs, tetrabutylammonium hydroxide with L-proline (**B1**) was found to be the most effective one (Table 1, entry 4). When CuI was changed into CuBr or CuCl, a significant decrease in the product yield was observed (Table 1, entries 7–10), and when Cu(II) was used as catalyst instead of Cu(I), less than 10% yield of the desired product was isolated (Table 1, entry 11). When the reaction was carried out in the presence of CuI without AAIL, less than 10% yield of the product was observed (Table 1, entry 12). Meanwhile, when the solvent was changed from [BMIM]BF_4 into Bu_4NOAc or [BMIM]OH, only 61% and 37% yield of product was obtained, respectively (Table 1, entries 13 and 14).

Table 1 Screening of the Copper Salt and AAIL[a]

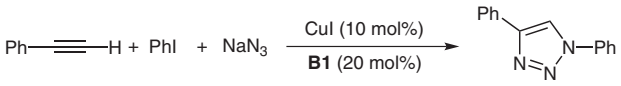


Entry	Copper salt	AAIL	Yield (%)[b]
1	CuI	**A1**	85
2	CuI	**A2**	49
3	CuI	**A3**	57
4	CuI	**B1**	88
5	CuI	**B2**	71
6	CuI	**B3**	56
7	CuBr	**A1**	61
8	CuBr	**B1**	56
9	CuCl	**A1**	23
10	CuCl	**B1**	42
11	$Cu(OAc)_2$	**B1**	<10
12	CuI	–	<10
13	CuI	**B1**	61[c]
14	CuI	**B1**	37[d]

[a] Reaction conditions: phenylacetylene (102 mg, 1.00 mmol), PhI (204 mg, 1.00 mmol), NaN_3 (130 mg, 2.00 mmol), Cu salt (0.10 mmol) and AAIL (0.20 mmol) in [BMIM]BF_4 (3.0 mL) at 60 °C for 10 h.
[b] Isolated yield.
[c] Using Bu_4NOAc (3.0 mL) instead of [BMIM]BF_4 (3.0 mL).
[d] Using [BMIM]OH (3.0 mL) instead of [BMIM]BF_4 (3.0 mL).

Effects of other reaction conditions, such as solvent, time and temperature on the reaction were investigated and the results are shown in Table 2. Among the solvents tested, [BMIM]BF_4 was found to be the best one (Table 2, entry 3). Reaction time and temperature also affected the reaction, and in our work, its yield remains 88% even if the reaction time was prolonged to 24 hours (Table 2, entry 6). When the reaction was performed in 6 hours, the yield of product was decreased (Table 2, entry 5). Lowering the temperature to 40 °C caused drastic decrease of the yield (Table 2, entry 7) and raising the temperature to 80 °C could not improve the product yield (Table 2, entry 8). With respect to CuI and **B1** loading, 10 mol% of CuI and 20 mol% of **B1** were found to be optimal. When 5 mol% of CuI and 10 mol% of **B1** were used, the desired product was isolated in 62% yield (Table 2, entry 9).

Table 2 Effect of Solvent, Time, and Temperature on the Click Reaction[a]



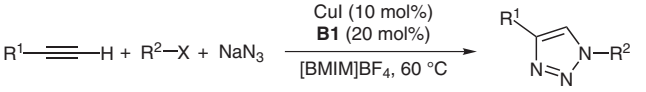
Entry	Solvent	Time (h)	Temp (°C)	Yield (%)[b]
1	EtOH	10	60	86
2	MeOH	10	60	71
3	[BMIM]BF_4	10	60	88
4	[BMIM]PF_6	10	60	81
5	[BMIM]BF_4	6	60	81
6	[BMIM]BF_4	24	60	88
7	[BMIM]BF_4	10	40	21
8	[BMIM]BF_4	10	80	85
9	[BMIM]BF_4	10	60	62[c]

[a] Reaction conditions: phenylacetylene (102 mg, 1.00 mmol), PhI (204 mg, 1.00 mmol), NaN_3 (130 mg, 2.00 mmol), CuI (19 mg, 0.10 mmol), and **B1** (69 mg, 0.20 mmol) in [BMIM]BF_4 (3.0 mL).
[b] Isolated yield.
[c] CuI (0.05 mmol) and **B1** (0.10 mmol) were used in the reaction.

To examine the generality of the reaction, we extended our studies to a variety of alkynes and organic halides. When the reaction of phenylacetylene, alkyl chloride, and sodium azide in a 1:1:2 molar ratio was catalyzed by CuI (10 mol%) and **B1** (20 mol%) in [BMIM]BF_4 at 60 °C for 10 hours, the corresponding 1,4-disubstituted 1,2,3-triazoles were obtained in almost quantitative yields (Table 3, entries 1 and 2). When the alkyl chloride was changed to aryl iodide, both aromatic and aliphatic alkynes gave moderate to high yields of the corresponding products (Table 3, entries 3–12). It is noteworthy that the position of the substituted groups on the benzene rings affects the reaction slightly (Table 3, entries 7–12). When other acetylenes, such as oct-1-yne and 4-ethynyltoluene, were used as alkyne partner, the reactions also underwent smoothly and the corresponding products were obtained in good yields (Table 3, entries 13–15). However, when aryl bromides were used as one of the substrate, a drastic decrease of the yields was observed (Table 3, entries 16–20).

To screen the recyclability of copper, amino acid ionic liquid as the reaction medium, they were reused several times under the standard reaction conditions. When the reaction of phenylacetylene, iodobenzene, and sodium azide in a 1:1:2 molar ratio, was catalyzed by CuI (10 mol%) and **B1** (20 mol%) in [BMIM]BF_4 at 60 °C for 10 hours, the corresponding 1,4-disubstituted 1,2,3-triazole was obtained in 88% yield (Table 4, entry 1). After carrying out the reaction and workup, recovered CuI, **B1**, [BMIM]BF_4, and fresh starting materials were charged into the reaction system. The reactions still proceeded well. CuI, **B1**, and [BMIM]BF_4 could be recycled in six repetitive cycles without significant loss of activity (Table 4).

Table 3 The Click Reaction Catalyzed by CuI and **B1**[a]



Entry	R^1	R^2	X	Yield (%)[b]
1	Ph	Bn	Cl	99[c]
2	*n*-C_8H_{17}	Bn	Cl	97[c]
3	Ph	Ph	I	88
4	*n*-C_8H_{17}	Ph	I	91
5	Ph	4-$MeOC_6H_4$	I	85
6	*n*-C_8H_{17}	4-$MeOC_6H_4$	I	87
7	Ph	4-MeC_6H_4	I	91
8	*n*-C_8H_{17}	4-MeC_6H_4	I	52
9	Ph	3-MeC_6H_4	I	81
10	*n*-C_8H_{17}	3-MeC_6H_4	I	67
11	Ph	2-MeC_6H_4	I	79
12	*n*-C_8H_{17}	2-MeC_6H_4	I	63
13	*n*-C_6H_{13}	4-$MeOC_6H_4$	I	67
14	4-MeC_6H_4	4-$MeOC_6H_4$	I	83
15	4-MeC_6H_4	4-$MeOC_6H_4$	I	68
16	Ph	Ph	Br	71[d]
17	Ph	4-NCC_6H_4	Br	61[d]
18	Ph	4-AcC_6H_4	Br	59[d]
19	*n*-C_8H_{17}	4-AcC_6H_4	Br	23[d]
20	Ph	4-MeC_6H_4	Br	trace[d]

[a] Reaction conditions: alkyne (1.00 mmol), organic halide (1.00 mmol), NaN_3 (130 mg, 2.00 mmol), CuI (19 mg, 0.10 mmol), and **B1** (69 mg, 0.20 mmol) in [BMIM]BF_4 (3.0 mL) at 60 °C for 10 h.
[b] Isolated yield.
[c] The reactions were performed at 50 °C for 6 h.
[d] The reactions were performed at 100 °C for 24 h.

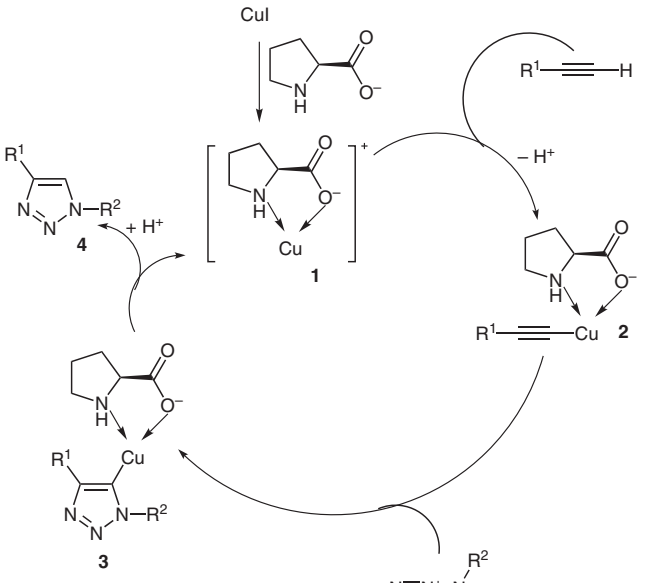
A possible mechanism of CuI- and AAIL-catalyzed click reaction is shown in Scheme 3. The amino acid ionic liquid (AAIL) played the role of ligand in the reaction. The reaction is thought to proceed in a stepwise manner starting with the coordination of Cu(I) with proline, and then the generation of copper(I) acetylide **2**. The concerted cycloaddition was performed to generate **3**, in which the 1,4-isomer was favored because of the steric hindrance. Protonation of **3** gave the final 1,4-disubstituted 1,2,3-triazoles **4**.[4a] Further investigation is under way in our laboratory.

In summary, an efficient and green one-pot synthesis of 1,4-disubstituted 1,2,3-triazoles from alkyl chlorides and

Table 4 Recyclability of the Catalytic System and Reaction Medium[a]

Run	Yield (%)[b]	Run	Yield (%)[b]
1	88	5	82
2	88	6	79
3	87	7	70
4	85	8	86[c]

[a] Reaction conditions: phenylacetylene (102 mg, 1.00 mmol), PhI (204 mg, 1.00 mmol), NaN_3 (130 mg, 2.00 mmol), CuI (19 mg, 0.10 mmol), and **B1** (69 mg, 0.20 mmol) were performed in $[BMIM]BF_4$ (3.0 mL) at 60 °C for 10 h.
[b] Isolated yield.
[c] Additional CuI (0.10 mmol) was added.



Scheme 3 Proposed mechanism of the reaction

aryl iodides, sodium azide, and alkynes catalyzed by copper(I) and amino acid ionic liquid **B1** in $[BMIM]BF_4$ has been developed. The reactions proceeded smoothly to generate the corresponding products in high yields. In addition, CuI, **B1**, and $[BMIM]BF_4$ could be recovered for six consecutive trials without significant loss of activity.

All ^1H NMR and ^{13}C NMR spectra were recorded on a 400 MHz Bruker FT-NMR spectrometers. All chemical shifts are given in δ (ppm) with reference to TMS as an internal standard. The CHN analysis was performed on a Vario El III elementary analyzer. Products were purified by flash chromatography on 230–400 mesh silica gel. Chemicals and solvents were purchased from commercial suppliers either from Aldrich, Fluka, USA, or Shanghai Chemical Company, China and were used without purification prior to use.

Amino Acid Ionic Liquids (AAILs)

A1–**A3**: To a 50 mL of round-bottomed flask was added 1-butyl-3-methylimidazolium hydroxide ([BMIM]OH, 2.57 g, 16.5 mmol) in H_2O (10 mL) and L-proline (1.89 g, 16.5 mmol). After extracting the mixture with MeOH (3 × 50 mL), the combined MeOH layers were evaporated, and the residue was dried in vacuo to afford **A1** (3.79 g, 91%). **A2** and **A3** were obtained following the above procedure.

B1–**B3**: To a 50 mL of round-bottomed flask was added Bu_4NOH (10% in H_2O, 2.45 g, 1.0 mmol) and L-proline (0.12 g, 1.0 mmol). After the solid had dissolved, the pale yellow solution was extracted with MeOH (3 × 10 mL), the combined MeOH layers were evaporated, and the residue was dried in vacuo to give **B1** (0.331 g, 93%). **B2** and **B3** were prepared following the same procedure.

Click Reaction; General Procedure

A two-necked round-bottomed flask containing a stirrer bar was charged with terminal alkyne (1.00 mmol), NaN_3 (130 mg, 2.00 mmol), organic halide (1.00 mmol), CuI (19 mg, 0.10 mmol), amino acid ionic liquid **B1** (69 mg, 0.20 mmol), and $[BMIM]BF_4$ (3.0 mL) under N_2. The mixture was heated and stirred at 60 °C for 10 h. After cooling to r.t., the mixture was extracted with Et_2O (3 × 5 mL). The combined organic layers were dried ($MgSO_4$) and evaporated under reduced pressure. The residue was purified by flash chromatography (silica gel) to give the desired 1,4-disubstituted 1,2,3-triazole (Table 3).

Recyclability of the Catalyst System and Reaction Medium

After the reaction was carried out, the mixture (containing CuI, **B1**, and $[BMIM]BF_4$) was washed with Et_2O (3 × 5 mL) and hexane (3 × 5 mL). After drying the mixture in vacuo for 24 h, it could be reused directly without further purification.

1-Benzyl-4-phenyl-1*H*-1,2,3-triazole[25]

^1H NMR (400 MHz, $CDCl_3$): δ = 5.50 (s, 2 H), 7.47–7.79 (m, 8 H), 7.62 (s, 1 H), 7.82 (d, *J* = 7.2 Hz, 2 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 55.89, 120.11, 125.78, 127.49, 127.10, 130.07, 135.15, 146.60.

1-Benzyl-4-octyl-1*H*-1,2,3-triazole[26]

^1H NMR (400 MHz, $CDCl_3$): δ = 0.88 (t, *J* = 6.0 Hz, 3 H), 1.25–1.29 (m, 10 H), 1.62–1.68 (m, 2 H), 2.69 (t, *J* = 8.0 Hz, 2 H), 5.45 (s, 2 H), 7.12–7.42 (m, 6 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 15.02, 23.59, 26.68, 30.04, 32.66, 54.89, 121.60, 128.85, 129.12, 135.11, 149.23.

1,4-Diphenyl-1*H*-1,2,3-triazole[27]

^1H NMR (400 MHz, $CDCl_3$): δ = 7.36–7.39 (m, 1 H), 7.40–7.48 (m, 3 H), 7.47–7.58 (m, 2 H), 7.80 (d, *J* = 6.0 Hz, 2 H), 7.91 (d, *J* = 8.0 Hz, 2 H), 8.20 (s, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 119.53, 120.02, 124.22, 127.50, 127.96, 128.06, 130.01, 131.09, 137.50, 148.96.

4-Octyl-1-phenyl-1*H*-1,2,3-triazole[27]

^1H NMR (400 MHz, $CDCl_3$): δ = 0.88 (t, *J* = 6.0 Hz, 3 H), 1.25–1.32 (m, 10 H), 1.37–1.40 (m, 2 H), 2.78–2.82 (t, *J* = 8.0 Hz, 2 H), 7.39–7.43 (m, 1 H), 7.49–7.53 (m, 2 H), 7.71–7.74 (m, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.09, 22.65, 29.34, 31.85, 120.40, 128.39, 129.65, 149.21.

1-(4-Methoxyphenyl)-4-phenyl-1*H*-1,2,3-triazole[28]

^1H NMR (400 MHz, $CDCl_3$): δ = 3.88 (s, 3 H), 7.04 (d, *J* = 8.0 Hz, 2 H), 7.34–7.39 (m, 1 H), 7.44–7.48 (m, 2 H), 7.69 (d, *J* = 8.0 Hz, 2 H), 7.91 (d, *J* = 8.0 Hz, 2 H), 8.12 (s, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 55.63, 114.74, 122.16, 125.77, 128.31, 128.88, 130.30, 148.17, 159.79.

1-(4-Methoxyphenyl)-4-octyl-1*H*-1,2,3-triazole[28]

^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.82 (t, *J* = 6.0 Hz, 3 H), 1.25–1.32 (m, 10 H), 1.65–1.75 (m, 2 H), 2.77–2.81 (t, *J* = 8.0 Hz, 2 H), 3.87 (s, 3 H), 6.70–7.02 (m, 2 H), 7.60–7.63 (m, 3 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.10, 22.68, 29.30, 29.60, 30.92, 31.85, 33.20, 55.62, 114.32, 119.22, 120.80, 130.88, 145.66.

4-Phenyl-1-*p*-tolyl-1*H*-1,2,3-triazole[28]

^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.44 (s, 3 H), 7.32–7.38 (m, 4 H), 7.44–7.48 (m, 3 H), 7.66–7.68 (m, 2 H), 8.16 (s, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 24.33, 117.61, 120.44, 125.82, 128.34, 128.89, 130.25, 138.89.

4-Octyl-1-*p*-tolyl-1*H*-1,2,3-triazole[13]

^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.89 (t, *J* = 6.0 Hz, 3 H), 1.25–1.32 (m, 10 H), 1.36–1.39 (m, 2 H), 2.41 (s, 3 H), 2.77–2.80 (m, 2 H), 7.29–7.31 (m, 2 H), 7.58–7.60 (m, 2 H), 7.67 (s, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.08, 22.64, 25.67, 29.20, 29.30, 31.84, 118.77, 120.31, 130.13, 138.44, 149.03.

4-Phenyl-1-*m*-tolyl-1*H*-1,2,3-triazole[28]

^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.46 (s, 3 H), 7.25–7.26 (m, 1 H), 7.42–7.48 (m, 4 H), 7.55–7.62 (m, 2 H), 7.90–7.92 (m, 2 H), 8.18 (s, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 21.40, 117.57, 117.64, 121.18, 125.82, 128.36, 128.88, 129.52, 130.28, 136.99, 140.00, 148.27.

4-Octyl-1-*m*-tolyl-1*H*-1,2,3-triazole[13]

^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.88 (t, *J* = 6.0 Hz, 3 H), 1.28–1.30 (m, 10 H), 1.69–1.77 (m, 2 H), 2.44 (s, 3 H), 2.77–2.81 (m, 2 H), 7.21–7.40 (m, 2 H), 7.48–7.50 (m, 2 H), 7.57 (s, 1 H), 7.70 (s, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.08, 22.64, 25.67, 29.20, 29.33, 31.84, 117.44, 121.09, 129.14, 129.41, 139.85, 149.08.

4-Phenyl-1-*o*-tolyl-1*H*-1,2,3-triazole[29]

^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.40 (s, 3 H), 7.31–7.33 (m, 4 H), 7.48–7.52 (m, 3 H), 7.57–7.60 (m, 2 H), 8.10 (s, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 21.52, 120.12, 125.89, 129.36, 130.88, 133.98, 148.56.

4-Octyl-1-*o*-tolyl-1*H*-1,2,3-triazole

^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.88 (t, *J* = 6.0 Hz, 3 H), 1.27–1.34 (m, 10 H), 1.33–1.36 (m, 2 H), 2.36 (s, 3 H), 2.75–2.79 (m, 2 H), 7.31–7.35 (m, 2 H), 7.52–7.57 (m, 2 H), 7.70 (s, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.12, 20.20, 22.36, 29.23, 29.33, 31.84, 33.56, 119.01, 120.36, 130.69, 138.55, 147.30.

Anal. Calcd for $C_{17}H_{25}N_3$: C, 75.23; H, 9.28; N, 15.48. Found: C, 75.35; H, 9.31; N, 15.29.

4-Hexyl-1-(4-methoxyphenyl)-1*H*-1,2,3-triazole[29]

^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.86 (t, *J* = 6.0 Hz, 3 H), 1.27–1.38 (m, 6 H), 1.62–1.71 (m, 2 H), 2.78–2.82 (t, *J* = 8.0 Hz, 2 H), 3.82 (s, 3 H), 6.68–7.00 (m, 2 H), 7.57–7.60 (m, 2 H), 7.69 (s, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.01, 22.56, 29.30, 30.00, 31.12, 55.67, 114.35, 119.28, 120.65, 130.72, 145.86.

1-(4-Methoxyphenyl)-4-*p*-tolyl-1*H*-1,2,3-triazole

^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.35 (s, 3 H), 3.80 (s, 3 H), 7.06 (d, *J* = 8.0 Hz, 2 H), 7.41–7.47 (m, 2 H), 7.65 (d, *J* = 8.0 Hz, 2 H), 7.90 (d, *J* = 8.0 Hz, 2 H), 8.10 (s, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 22.96, 55.72, 114.50, 121.73, 125.77, 128.31, 128.88, 130.30, 138.47, 148.17, 159.79.

Anal. Calcd for $C_{16}H_{15}N_3O$: C, 72.43; H, 5.70; N, 15.84. Found: C, 72.51; H, 5.84; N, 15.68.

1-(4-Methoxyphenyl)-4-phenyl-1*H*-1,2,3-triazole

^{1}H NMR (400 MHz, $CDCl_3$): δ = 3.85 (s, 3 H), 7.00 (d, *J* = 8.0 Hz, 2 H), 7.39–7.43 (m, 2 H), 7.59 (d, *J* = 8.0 Hz, 2 H), 7.70 (d, *J* = 8.0 Hz, 2 H), 8.11 (s, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 55.61, 114.12, 123.24, 131.55, 132.56, 148.12, 159.70.

Anal. Calcd for $C_{15}H_{12}BrN_3O$: C, 54.56; H, 3.66; N, 12.73. Found: C, 54.63; H, 3.79; N, 12.56.

4-(4-Phenyl-1*H*-1,2,3-triazol-1-yl)benzonitrile[30]

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.36 (d, *J* = 8.0 Hz, 2 H), 7.40–7.45 (m, 3 H), 7.59–7.65 (m, 2 H), 7.70 (d, *J* = 8.0 Hz, 2 H), 8.10 (s, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 113.12, 116.20, 127.20, 129.56, 132.30, 133.30, 148.25.

1-[4-(4-Phenyl-1*H*-1,2,3-triazol-1-yl)phenyl]ethanone[27]

^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.78 (s, 3 H), 7.36 (d, *J* = 8.0 Hz, 2 H), 7.45–7.48 (m, 3 H), 7.52–7.55 (m, 2 H), 7.82–7.86 (m, 2 H), 8.15 (s, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 29.65, 127.50, 129.83, 132.56, 133.80, 135.69, 148.20, 192.68.

1-[4-(4-Octyl-1H-1,2,3-triazol-1-yl)phenyl]ethanone

^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.86 (t, *J* = 6.0 Hz, 3 H), 1.29–1.35 (m, 10 H), 1.64–1.69 (m, 2 H), 2.72–2.80 (t, *J* = 8.0 Hz, 2 H), 2.87 (s, 3 H), 7.10–7.12 (m, 2 H), 7.60–7.63 (m, 2 H), 7.95 (s, 1 H).

^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.15, 22.78, 29.33, 29.65, 30.92, 31.85, 33.00, 118.57, 128.50, 146.81, 192.66.

Anal. Calcd for $C_{24}H_{29}N_3O$: C, 76.76; H, 7.78; N, 11.19. Found: C, 76.89; H, 7.90; N, 11.02.

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