One-Pot Syntheses of 5-Amino-1-aryltetrazole Derivatives

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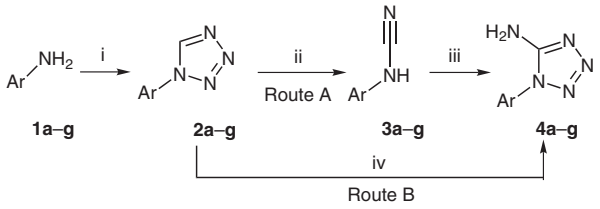
Received 25 September 2005; revised 1 December 2005

Abstract: A novel facile route for the introduction of 5-amino and 5-alkylamino substituents into 1-aryltetrazoles has been developed. A range of 5-amino-1-aryltetrazoles was obtained directly from the corresponding 1-aryltetrazoles in one pot by consecutive ring-opening, azidation and intramolecular cyclization. 5-Alkylamino-1-aryltetrazoles were formed by a similar mechanism from 1,4-disubstituted tetrazolium salts. An influence of the nature of aryl substituents and reaction conditions on the regioselectivity of the intramolecular cyclization of intermediate guanyl azides is revealed.

Key words: 5-aminotetrazoles, tetrazolium salts, heterocycles, tandem reactions, regioselectivity

The area of use of various tetrazole derivatives expands rapidly.[1] In particular, a range of 5-aminotetrazoles has been reported as biologically active compounds or intermediates for their production,[2] ingredients of gas-generating and explosive compositions, and anticorrosive additives.[3] However, the utility of these compounds is limited due to their insufficient synthetic availability. Substituted 5-aminotetrazoles are conventionally synthesized by diazotation of aminoguanidine derivatives[4] or azidation of cyanamides,[5a–5d] carbodiimides,[5e] thioureas,[5f,g,j] aminoiminomethanesulfonic acids,[5h] benzotriazol-1-ylcarboximidamides[5i] and other suitable substrates with subsequent intramolecular cyclization. 5-Amino groups can also be introduced into the tetrazole cycle by nucleophilic substitution of the tetrazoles containing leaving groups in 5-position with the appropriate amines.[6] Synthesis of 5-alkylaminotetrazoles by direct alkylation of the exocyclic nitrogen atom in the corresponding 5-aminotetrazoles is not applicable due to a concurrent formation of ring-alkylated products. Only the use of specific alkylating systems (e.g. alkyl iodide/hexamethyldisilazide) can be successful.[5b] It should be noted that most of the above methods are laborious and often require unstable, toxic and poorly available starting materials and reagents. Consequently, there is a need for a simple method for the synthesis of 5-aminotetrazole derivatives, which is free of the said drawbacks.

1-Aryltetrazoles are known to decompose under the action of strong bases yielding *N*-arylcyanamides.[7a] Congreve[5b] has proposed a two-step reaction sequence in which 1-aryltetrazoles were converted to 5-amino-1-aryltetrazoles via cyanamide intermediates. The use of large excess of sodium azide, low temperatures (–70 °C) and organolithium reagents are the drawbacks of this method making it fairly complicated and potentially dangerous. Recently, we have described a sufficiently simple and convenient three-step synthesis of 5-amino-1-aryltetrazoles from the corresponding arylamines (Scheme 1, route A).[5d] In the first stage, aromatic amines **1** undergo heterocyclization with triethyl orthoformate and sodium azide in acetic acid to give 1-aryltetrazoles **2**. The latter are smoothly decomposed by an inorganic alkali in dimethyl sulfoxide yielding the corresponding *N*-arylcyanamides **3**, which could be transformed to 5-amino-1-aryltetrazoles **4** by the cycloaddition of an azide ion. Despite rather versatile character of the described approach, some disadvantages restrict its application. Thus, in certain cases we encountered difficulties on the stage of cyanamide intermediates isolation and purification caused by their insufficient stability. Therefore, the overall yields of 5-amino-1-aryltetrazoles are frequently inadequate (see Table 1).



Scheme 1 *Reagents and conditions*: i) NaN_3 (1.1 equiv), triethyl orthoformate (3.0 equiv), AcOH (8.0 equiv), 80 °C, 3–4 h, 70–95%; ii) aq NaOH (1.5 equiv), DMSO; iii) NaN_3 (1.5 equiv), NH_4Cl (2.0 equiv), DMF, 80 °C, 3 h; iv) NaN_3 (1.5 equiv), NaOH (1.5 equiv), Et_3N (2.0 equiv), *i*-PrOH, DMSO, r.t., 0.5–2 h, then AcOH (3.0 equiv), 70–80 °C, 2 h.

Here, we report on an improved synthetic approach providing significantly higher yields of desired products in shorter time, including the cases when the intermediate cyanamides were not stable enough to be isolated. The proposed method is shown as route B in Scheme 1.

Both stages of the synthesis proceed successively in one pot, without isolation of intermediate cyanamides. The mechanism of the decomposition of 1-aryltetrazoles occurring under basic conditions on the first stage is similar to that of the same process induced by *n*-butyllithium.[8] The strong ionizing character of the NaOH/DMSO system

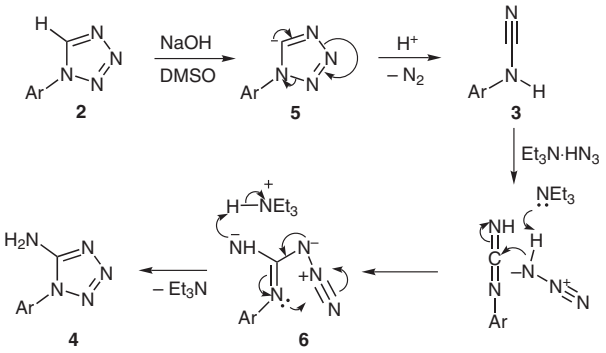
SYNTHESIS 2006, No. 8, pp 1307–1312
Advanced online publication: 27.03.2006
DOI: 10.1055/s-2006-926403; Art ID: T13505SS

Table 1 5-Aminotetrazoles **4** Prepared

Product	Aryl	Yield (%)[a]	
		Route A	Route B
4a	Ph	53	75
4b	4-$EtOC_6H_4$	–[b]	80
4c	4-$NO_2C_6H_4$	–[b]	60
4d	4-MeC_6H_4	66	87
4e	2-MeC_6H_4	–[b]	72
4f	2-$MeOC_6H_4$	21	71
4g	3-Cl,4-FC_6H_3	66	86

[a] Isolated overall yield of **4** from **2**.
[b] *N*-Arylureas and other by-products were mostly formed.

favors stabilization of the intermediate carbanion **5** and, therefore, results in dramatic acceleration of the reaction, compared to other solvents. Decomposition proceeds at room temperature and finishes within 0.5–2 hours, depending on the nature of an aryl substituent and reagents ratio. On the completion of the first stage, the second one is initiated by partial acidification of the reaction mixture. The resulting aminotetrazole derivatives were not obtained when no acid had been added. The importance of the acidification can be explained by the formation of triethylammonium azide, which is required for the completion of the heterocyclization process. Therefore, the amount of acid should be enough to neutralize an inorganic alkali and to form the amine salt, but should not exceed the total molar amount of bases in the reaction mixture to avoid the evolution of explosive and toxic hydrazoic acid. A possible reaction mechanism is shown in Scheme 2.



Scheme 2

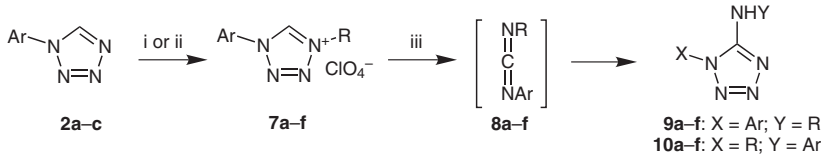
The stability of cyanamide intermediates did not affect the yields of aminotetrazoles **4**. We succeeded in performing the reaction even with the substrates which give no desired product by the route A. In other cases, yields were significantly improved (Table 1).

Next, we attempted to broaden the applicability of the above-described approach in order to expand it for the synthesis of tetrazoles containing a substituted amino function in 5-position of the heterocycle. Such compounds can be synthesized by azidation of *N*,*N*′-disubstituted carbodiimides.[5e] Unfortunately, this approach is not well developed due to poor availability and insufficient stability of functionalized carbodiimides. Moreover, the above mentioned synthesis requires the use of highly toxic and explosive hydrazoic acid. We have elaborated a safe and convenient one-pot procedure for the synthesis of 5-alkylamino-1-aryltetrazoles from the corresponding 1-alkyl-4-aryltetrazolium salts by treatment with triethylammonium azide in the presence of dimethyl sulfoxide. These tetrazolium salts are relatively stable and synthetically available compounds, which are known to decompose in basic media to form carbodiimides.[1d,7b]

The initial 1-alkyl-4-aryltetrazolium perchlorates **7** were synthesized by quaternization of 1-aryltetrazoles with either dimethyl sulfate or *tert*-butyl alcohol in perchloric acid. In both cases the process was not completely regioselective, therefore more or less significant amounts (up to 26%, as estimated by NMR) of 1,3-isomers were formed together with the desired 1,4-salts. Notably, the influence of electronic properties of aryl substituents on the regioselectivity of methylation was found to be negligible, while it was rather strong in the case of tert-butylation. The amount of 1,3-isomer was low for the compounds bearing electron-withdrawing groups in aryl substituents (e.g., **7f**, less than 1%) and high for the compounds containing electron-donating groups (e.g., **7e**, 26%). In the case of tert-butylation, the regioselectivity may be improved. Elongation of the reaction time resulted in rearrangement of initially formed 1,3-disubstituted tetrazolium salts into the corresponding 1,4-isomers that takes place in acidic media.[1d,9] We did not observe any influence of 1,3-isomers on the course of the further synthesis and used crude quaternization products without purification.

The synthesis of 5-alkylamino-1-aryltetrazoles from the corresponding 1-alkyl-4-aryltetrazolium salts includes two successive stages (Scheme 3). First, tetrazolium salts **7** undergo ring-opening under action of the bases contained in the reaction medium (dimethyl sulfoxide, sodium azide). Apparently, the strength of these bases is enough for the cleavage of the labile proton attached to the carbon atom of a heterocycle leading to unstable tetrazolidene intermediates. The latter decompose rapidly with the elimination of N_2 and formation of *N*-alkyl-*N*′-arylcarbodiimides **8**. In the second stage, carbodiimides **8** are attacked by an azide ion furnishing 5-alkylamino-1-aryltetrazoles **9** through the intermediate open-chain isomers **11**. The reaction normally completes within 1.5–2 hours being performed at 70–90 °C.

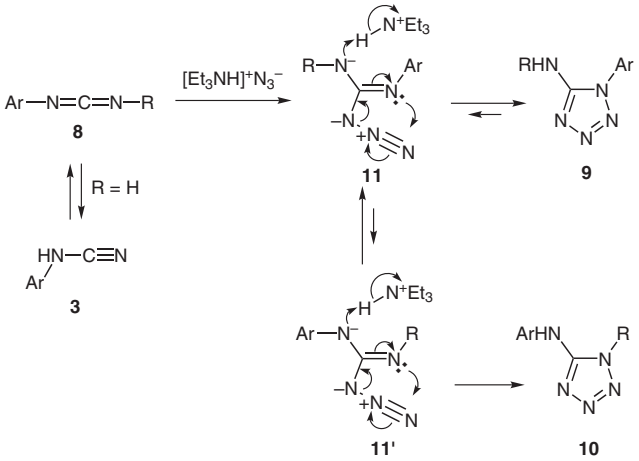
N-Arylcyanamides and *N*-alkyl-*N*′-arylcarbodiimides were previously reported to react with hydrazoic acid giving solely 5-alkylamino-1-aryltetrazoles.[5a–5e] In the course of our work, we have observed that the regioselectivity of cycloaddition of an azide ion to the heterocumulene moiety of carbodiimides is strongly affected by the nature of aryl substituents and reaction conditions. The



Scheme 3 *Reagents and conditions*: i) 1. $(MeO)_2SO_2$; 2. ClO_4^-; ii) *t*-BuOH, $HClO_4$; iii) NaN_3 (2.0 equiv), $Et_3N{\cdot}HCl$ (2.0 equiv), MeCN, DMSO, 70 °C, 2 h.

aforesaid tendency has been reproduced for the substrates with aryl substituents bearing electron-donating groups. In such cases only the corresponding 5-alkylamino-1-aryltetrazoles **9** were obtained. On the other hand, when the aryl substituent had contained electron-withdrawing groups, significant or even prevalent amounts of isomeric 1-alkyl-5-arylaminotetrazoles **10** were detected in the reaction products.

The reasons for the observed variations of regioselectivity are clarified by the following experimental facts. We found that the regioselectivity of the cyclization was restored and the principal products isolated from the reaction were 5-alkylamino-1-aryltetrazoles **9** when the reaction had been carried out at lower temperature (45–50 °C). Longer reaction periods were required in these cases to obtain satisfactory yields (Table 2). The pure *N*-methyl-1-(4-nitrophenyl)-1*H*-tetrazol-5-amine (**9c**) obtained this way gives a mixture of **9c** and **10c** at 1:7 ratio on heating at 80 °C for 1.5 hours in a mixture of DMSO and acetonitrile. Therefore, the most probable reason of accumulation of regioisomers **10** in the reaction mixture is a Dimroth-type rearrangement that occurs with the initially formed aminotetrazoles **9** (a possible mechanism is shown in Scheme 4). The nucleophilic attack of an azide ion onto the carbon atom of carbodiimide occurs in the first stage. The intermediate guanyl azide **11** undergoes intramolecular cyclization yielding almost exclusively the aminotetrazole derivative **9**. The cyclization process is practically irreversible for the compounds **9a**, **9b** and alike. The functional groups with strong electron-withdrawing effect in aryl substituents of compounds **9c** and **9f** at the reaction temperature (80 °C and higher) favor the increase of the azido form **11** in the equilibrium with tetrazole **9**. Consequently, isomeric 5-arylaminotetrazoles **10** are gradually accumulated in the reaction mixture due to practically irreversible character of their formation from azides **11′**.



Scheme 4

Table 2 5-Aminotetrazoles **4c** and **9a–f** Prepared

Product	Ar	R	Reaction conditions	Total yield (%)	Ratio of regioisomers **9**:**10**[a]
4c	4-$NO_2C_6H_4$	H	90–100 °C, 2.5 h	78	31:69[b]
			90–100 °C, 1.5 h	72	57:43
			60 °C, 2.5 h	37	100:0
9a	Ph	Me	70 °C, 2 h	60	100:0
9b	4-$EtOC_6H_4$	Me	70 °C, 2 h	92	100:0
9c	4-$NO_2C_6H_4$	Me	85 °C, 4 h	82	2:98
			45–50 °C, 4 h	52	87:13
9d	Ph	*t*-Bu	70 °C, 2 h	62	100:0
9e	4-$EtOC_6H_4$	*t*-Bu	70 °C, 2 h	65	100:0
9f	4-$NO_2C_6H_4$	*t*-Bu	85 °C, 4 h	76	9:91
			45–50 °C, 4 h	46	95:5

[a] Determined by NMR spectra of crude products.
[b] Ratio of **4c**:**10g**.

Such rearrangements of 5-aminotetrazole derivatives were previously reported and discussed.[1a,5c] Usually, they were performed under harsh conditions (very high temperatures, acid catalysis). In the present work, we have demonstrated that the rearrangement products can be selectively obtained in relatively mild conditions as a result of the conventional azidation–cyclization process.

In conclusion, we have developed a facile and efficient method of introduction of 5-amino and 5-alkylamino groups into 1-aryltetrazoles. The proposed scheme involves readily available and chemically stable starting materials and reagents. The reactions have temperature-dependent regioselectivity and proceed in high yields under mild conditions.

Melting points were determined in open capillary tubes using Electrothermal IA9200 apparatus and are uncorrected. Analytical TLC was performed using Merck 60 F_{254} silica gel plates. ^{1}H and ^{13}C NMR spectra were recorded on Bruker Avance 500 spectrometer at operating frequencies of 500 MHz and 125 MHz, respectively, using DMSO-d_6 or CD_3CN as a solvent. The data are reported in parts per million relative to TMS and referenced to the solvent in which they were run.

Commercially available reagents and solvents were used in syntheses. 1-Aryltetrazoles **2a–g** were synthesized by heterocyclization of substituted anilines with triethyl orthoformate and NaN_3 in AcOH according to the previously reported method.[5d]

Melting points and NMR spectra of previously reported compounds were in agreement with those of the authentic samples and/or available literature data.

5-Amino-1-aryltetrazoles 4a–g; General Procedure

A stirred mixture of 1-aryltetrazole **2** (5.0 mmol), NaN_3 (7.5 mmol, 488 mg), NaOH (7.5 mmol, 300 mg) and Et_3N (10.0 mmol, 1.01 g) in *i*-PrOH (1.5 mL) was treated dropwise with DMSO (3.5 mL). The mixture was stirred at r.t. until the gas evolution ceased (0.5–2 h) and then was treated with glacial AcOH (15 mmol, 900 mg). The resulting suspension was stirred at 70–80 °C for 2 h, cooled and diluted with brine (70 mL). The precipitate was separated by filtration, washed with H_2O and dried in vacuo at 50 °C to give 5-amino-1-aryltetrazoles **4a–g**. Analytical samples were obtained after recrystallization from *i*-PrOH.

1-Phenyl-1*H*-tetrazol-5-amine (4a)

Yield: 75%; mp 162–163 °C (Lit.[5a] mp 163–163.5 °C).

1-(4-Ethoxyphenyl)-1*H*-tetrazol-5-amine (4b)

Yield: 80%; mp 199–201 °C (Lit.[5g] mp 197 °C).

1-(4-Nitrophenyl)-1*H*-tetrazol-5-amine (4c)

Yield: 60%; mp 176, 222–224 °C (dec.) [Lit.[5a] mp 176, 221–223 °C (dec.)].

1-(4-Methylphenyl)-1*H*-tetrazol-5-amine (4d)

Yield: 87%; mp 174–175 °C (Lit.[5c] mp 175.5–177 °C).

1-(2-Methylphenyl)-1*H*-tetrazol-5-amine (4e)

Yield: 72%; mp 189–190 °C (Lit.[5c] mp 191–192 °C).

1-(2-Methoxyphenyl)-1*H*-tetrazol-5-amine (4f)

Yield: 71%; mp 164–166 °C (Lit.[5c] mp 172–174 °C).

^{1}H NMR (DMSO-d_6): δ = 3.80 (s, 3 H, CH_3), 6.62 (s, 2 H, NH_2), 7.12 (t, *J* = 7.6 Hz, 1 H, Ar), 7.28 (d, *J* = 8.4 Hz, 1 H, Ar), 7.40 (d, *J* = 7.7 Hz, 1 H, Ar), 7.57 (t, *J* = 7.3 Hz, 1 H, Ar).

^{13}C NMR (DMSO-d_6): δ = 55.6, 112.7, 120.5, 121.1, 128.1, 131.6, 153.9, 155.6.

Anal. Calcd for $C_8H_9N_5O$ (191.2): C, 50.26; H, 4.74; N, 36.63. Found: C, 50.14; H, 4.77; N, 36.51.

1-(3-Chloro-4-fluorophenyl)-1*H*-tetrazol-5-amine (4g)

Yield: 86%; mp 187–188 °C (Lit.[5d] mp 188–189 °C).

^{1}H NMR (DMSO-d_6): δ = 7.00 (s, 2 H, NH_2), 7.60–7.68 (m, 2 H, Ar), 7.89–7.91 (m, 1 H, Ar).

^{13}C NMR (DMSO-d_6): δ = 117.6 (d, *J* = 22.6 Hz), 120.2 (d, *J* = 19.2 Hz), 125.5 (d, *J* = 8.1 Hz), 126.9, 129.9 (d, *J* = 2.4 Hz), 154.7, 157.0 (d, *J* = 249.0 Hz).

Anal. Calcd for $C_7H_5ClFN_5$ (213.6): C, 39.36; H, 2.36; N, 32.79. Found: C, 39.30; H, 2.23; N, 32.90.

***N*-(4-Nitrophenyl)-1*H*-tetrazol-5-amine (10g)**

1-(4-Nitrophenyl)-1*H*-tetrazole was treated according to the above-described general procedure except that the temperature was kept at 100 °C for 2.5 h. The compound **4c** was filtered off. The filtrate was acidified with several drops of conc. HCl. The precipitate was separated by filtration, washed with H_2O and dried at reduced pressure at 50 °C to give the title compound which was chromatographically pure; yield: 53%; mp 221–223 °C (dec.) [Lit.[10] mp 221–223 °C (dec.)].

1-Aryl-4-methyltetrazolium Perchlorates 7a–c; General Procedure

A solution of 1-aryltetrazole **2** (2.0 mmol) in dimethyl sulfate (0.57 mL, 6.0 mmol) was kept at 80 °C for 3 h or at 45 °C for 16 h. The mixture was extracted several times with Et_2O to remove unreacted starting materials. The insoluble residue was mixed with 12.5% aq solution of $Mg(ClO_4)_2$ (4 mL). The precipitate was filtered, washed with H_2O and dried at reduced pressure to furnish the tetrazolium salts **7a–c** that were used in the next stage without further purification.

4-Methyl-1-phenyl-1*H*-tetrazolium Perchlorate (7a)

Yield: 68% (contains ca. 11% of 1,3-isomer).

^{1}H NMR (CD_3CN): δ = 4.43 (s, 3 H, CH_3), 7.71–7.89 (m, 5 H, C_6H_5), 10.61 (s, 1 H, CH).

^{13}C NMR (CD_3CN): δ = 39.0, 118.3, 123.4, 131.6, 133.5, 142.0.

Anal. Calcd for $C_8H_9ClN_4O_4$ (260.6): C, 36.87; H, 3.48; N, 21.50. Found: C, 36.99; H, 3.37; N, 21.38.

1-(4-Ethoxyphenyl)-4-methyl-1*H*-tetrazolium Perchlorate (7b)

Yield: 74% (contains ca. 8% of 1,3-isomer).

^{1}H NMR (CD_3CN): δ = 1.41 (t, *J* = 7.0 Hz, 3 H, CH_3), 4.16 (q, *J* = 7.0 Hz, 2 H, CH_2), 4.41 (s, 3 H, CH_3), 7.19 (d, *J* = 9.1 Hz, 2 H, Ar), 7.74 (d, *J* = 9.1 Hz, 2 H, Ar), 10.49 (s, 1 H, CH).

^{13}C NMR (CD_3CN): δ = 14.7, 38.8, 65.3, 116.8, 118.2, 125.0, 125.1, 141.4.

Anal. Calcd for $C_{10}H_{13}ClN_4O_5$ (304.7): C, 39.42; H, 4.30; N, 18.39. Found: C, 39.28; H, 4.21; N, 18.22.

4-Methyl-1-(4-nitrophenyl)-1*H*-tetrazolium Perchlorate (7c)

Yield: 70% (contains ca. 9% of 1,3-isomer).

^{1}H NMR (CD_3CN): δ = 4.47 (s, 3 H, CH_3), 8.11 (d, *J* = 9.2 Hz, 2 H, Ar), 8.54 (d, *J* = 9.2 Hz, 2 H, Ar), 10.74 (s, 1 H, CH).

^{13}C NMR (CD_3CN): δ = 39.1, 118.0, 124.7, 126.7, 142.4.

Anal. Calcd for $C_8H_8ClN_5O_6$ (305.6): C, 31.44; H, 2.64; N, 22.91. Found: C, 31.52; H, 2.69; N, 22.79.

1-Aryl-4-*tert*-butyltetrazolium Perchlorates 7d–f; General Procedure

A solution of 1-aryltetrazole **2** (2.0 mmol) and 1,1-dimethylethanol (450 mg, 6.1 mmol) in $HClO_4$ (70%, 2 mL) was kept at r.t. for 5 d. The mixture was diluted with H_2O (10 mL) and cooled to 10 °C. The precipitate was filtered, washed with H_2O and Et_2O and dried at reduced pressure to furnish the tetrazolium salts **7d–f** that were used in the next stage without further purification.

4-*tert*-Butyl-1-phenyl-1*H*-tetrazolium Perchlorate (7d)

Yield: 97% (contains ca. 16% of 1,3-isomer).

^{1}H NMR (CD_3CN): δ = 1.86 (s, 9 H, *t*-C_4H_9), 7.74–7.94 (m, 5 H, Ar), 10.61 (s, 1 H, CH).

^{13}C NMR (CD_3CN): δ = 29.1, 31.3, 118.4, 123.4, 131.7, 133.5, 140.2.

Anal. Calcd for $C_{11}H_{15}ClN_4O_4$ (302.7): C, 43.64; H, 4.99; N, 18.51. Found: C, 43.53; H, 5.08; N, 18.47.

4-*tert*-Butyl-1-(4-ethoxyphenyl)-1*H*-tetrazolium Perchlorate (7e)

Yield: 99% (contains ca. 26% of 1,3-isomer).

^{1}H NMR (CD_3CN): δ = 1.42 (t, *J* = 7.0 Hz, 3 H, CH_3), 1.84 (s, 9 H, *t*-C_4H_9), 4.17 (q, *J* = 7.0 Hz, 2 H, CH_2), 7.21 (d, *J* = 9.1 Hz, 2 H, Ar), 7.81 (d, *J* = 9.2 Hz, 2 H, Ar), 10.48 (s, 1 H, CH).

^{13}C NMR (CD_3CN): δ = 14.8, 28.9, 32.4, 65.3, 116.9, 118.2, 125.0, 125.1, 146.7.

Anal. Calcd for $C_{13}H_{19}ClN_4O_5$ (346.8): C, 45.03; H, 5.52; N, 16.16. Found: C, 45.17; H, 5.54; N, 16.11.

4-*tert*-Butyl-1-(4-nitrophenyl)-1*H*-tetrazolium Perchlorate (7f)

Yield: 95% (contains <1% of 1,3-isomer).

^{1}H NMR (CD_3CN): δ = 1.87 (s, 9 H, *t*-C_4H_9), 8.17 (d, *J* = 9.3 Hz, 2 H, Ar), 8.57 (d, *J* = 9.3 Hz, 2 H, Ar), 10.76 (s, 1 H, CH).

^{13}C NMR (CD_3CN): δ = 28.7, 68.3, 118.0, 124.3, 126.8, 140.5.

Anal. Calcd for $C_{11}H_{14}ClN_5O_6$ (347.7): C, 38.00; H, 4.06; N, 20.14. Found: C, 37.89; H, 4.10; N, 20.02.

5-Aminotetrazoles 9a–f, 10c, 10f; General Procedure

A stirred mixture of tetrazolium salt **7a–f** (1.5 mmol), NaN_3 (3.0 mmol, 195 mg) and triethylammonium chloride (3.0 mmol, 414 mg) in MeCN (2 mL) was treated dropwise with DMSO (2 mL). On the completion of vigorous gas evolution, the mixture was heated to 70 °C and stirred at this temperature for 2 h. In the syntheses of the compounds **10c** and **10f**, the temperature was kept at 85 °C for 4 h. The mixture was allowed to cool and diluted with brine (40 mL). The precipitate was filtered, washed with H_2O and dried at reduced pressure to give 5-aminotetrazole. Analytical samples were obtained after recrystallization from *i*-PrOH.

***N*-Methyl-1-phenyl-1*H*-tetrazol-5-amine (9a)**

Yield: 60%; mp 133–134 °C (Lit.[5e] mp 133–134 °C).

1-(4-Ethoxyphenyl)-*N*-methyl-1*H*-tetrazol-5-amine (9b)

Yield: 92%; mp 155–157 °C.

^{1}H NMR (DMSO-d_6): δ = 1.35 (t, *J* = 6.9 Hz, 3 H, CH_3), 2.85 (d, *J* = 4.6 Hz, 3 H, CH_3), 4.10 (q, *J* = 6.9 Hz, 2 H, CH_2), 6.70 (q, *J* = 4.4 Hz, 1 H, NH), 7.11 (d, *J* = 8.8 Hz, 2 H, Ar), 7.43 (d, *J* = 8.7 Hz, 2 H, Ar).

^{13}C NMR (DMSO-d_6): δ = 14.4, 30.1, 63.5, 115.3, 125.6, 126.3, 155.7, 159.1.

Anal. Calcd for $C_{10}H_{13}N_5O$ (219.2): C, 54.78; H, 5.98; N, 31.94. Found: C, 54.61; H, 5.95; N, 31.99.

***N*-Methyl-1-(4-nitrophenyl)-1*H*-tetrazol-5-amine (9c)**

Yield: 67%; mp 284–286 °C (dec.).

^{1}H NMR (DMSO-d_6): δ = 2.92 (d, *J* = 4.6 Hz, 3 H, CH_3), 7.21 (q, *J* = 4.5 Hz, 1 H, NH), 7.90 (d, *J* = 8.9 Hz, 2 H, Ar), 8.44 (d, *J* = 9.0 Hz, 2 H, Ar).

^{13}C NMR (DMSO-d_6): δ = 30.1, 124.6, 125.0, 138.1, 146.8, 155.2.

Anal. Calcd for $C_8H_8N_6O_2$ (220.2): C, 43.64; H, 3.66; N, 38.17. Found: C, 43.62; H, 3.70; N, 38.04.

***N*-*tert*-Butyl-1-phenyl-1*H*-tetrazol-5-amine (9d)**

Yield: 62%; mp 114–115 °C (Lit.[5e] mp 113–114 °C).

***N*-*tert*-Butyl-1-(4-ethoxyphenyl)-1*H*-tetrazol-5-amine (9e)**

Yield: 65%; mp 141–143 °C.

^{1}H NMR (DMSO-d_6): δ = 1.36 (t, *J* = 6.9 Hz, 3 H, CH_3), 1.37 (s, 9 H, *t*-C_4H_9), 4.10 (q, *J* = 6.8 Hz, 2 H, CH_2), 6.14 (s, 1 H, NH), 7.11 (d, *J* = 8.4 Hz, 2 H, Ar), 7.43 (d, *J* = 8.3 Hz, 2 H, Ar).

^{13}C NMR (DMSO-d_6): δ = 14.3, 28.1, 51.8, 63.3, 115.1, 125.8, 126.2, 153.6, 158.8.

Anal. Calcd for $C_{13}H_{19}N_5O$ (261.3): C, 59.75; H, 7.33; N, 26.80. Found: C, 59.62; H, 7.26; N, 26.67.

***N*-*tert*-Butyl-1-(4-nitrophenyl)-1*H*-tetrazol-5-amine (9f)**

Yield: 61%; mp 183–185 °C (darkens), 205–207 °C (melts with dec.).

^{1}H NMR (DMSO-d_6): δ = 1.40 (s, 9 H, *t*-C_4H_9), 6.75 (s, 1 H, NH), 7.90 (d, *J* = 8.8 Hz, 2 H, Ar), 8.44 (d, *J* = 8.8 Hz, 2 H, Ar).

^{13}C NMR (DMSO-d_6): δ =28.5, 52.7, 125.4, 125.5, 139.1, 147.3, 159.9.

Anal. Calcd for $C_{11}H_{14}N_6O_2$ (262.3): C, 50.38; H, 5.38; N, 32.04. Found: C, 50.34; H, 5.36; N, 31.91.

1-Methyl-*N*-(4-nitrophenyl)-1*H*-tetrazol-5-amine (10c)

Yield: 78%; mp 284–286 °C (dec.).

^{1}H NMR (DMSO-d_6): δ = 3.99 (s, 3 H, CH_3), 7.86 (d, *J* = 9.2 Hz, 2 H, Ar), 8.27 (d, *J* = 9.2 Hz, 2 H, Ar), 10.17 (s, 1 H, NH).

^{13}C NMR (DMSO-d_6): δ = 32.1, 116.0, 124.6, 140.2, 145.5, 151.1.

Anal. Calcd for $C_8H_8N_6O_2$ (220.2): C, 43.64; H, 3.66; N, 38.17. Found: C, 43.73; H, 3.62; N, 38.22.

1-*tert*-Butyl-*N*-(4-nitrophenyl)-1*H*-tetrazol-5-amine (10f)

Yield: 69%; mp 205–207 °C (dec.).

^{1}H NMR (DMSO-d_6): δ = 1.70 (s, 9 H, *t*-C_4H_9), 7.46 (d, *J* = 9.2 Hz, 2 H, Ar), 8.19 (d, *J* = 9.2 Hz, 2 H, Ar), 9.26 (s, 1 H, NH).

^{13}C NMR (DMSO-d_6): δ = 28.0, 60.3, 116.0, 125.0, 140.2, 147.7, 150.3.

Anal. Calcd for $C_{11}H_{14}N_6O_2$ (262.3): C, 50.38; H, 5.38; N, 32.04. Found: C, 50.44; H, 5.29; N, 32.00.

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