Synthesis of 1-amino-1,2,4-triazolium 4-nitroimides and their reactions with electrophiles

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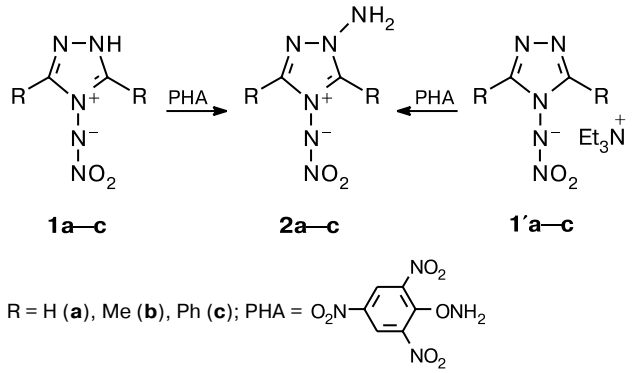
A procedure was developed for the preparation of 1-amino-1,2,4-triazolium 4 nitroimides by amination of triethylammonium salts of 4-nitramino-1,2,4-triazoles with *O*-picrylhydroxylamine. The resulting nitroimides reacted with electrophilic reagents (acyl chlorides, aldehydes, phenyl isocyanate, NO_2BF_4, *etc.*) at the amino group.

Key words: triethylammonium salts of 3,5-disubstituted 4-nitramino-1,2,4-triazoles, amination, *O*-picrylhydroxylamine, 3,5-disubstituted 1-amino-1,2,4-triazolium 4-nitroimides.

As part of our continuing studies on the synthesis and properties of 1,2,4-triazolium 4-nitroimides,[1] it was of interest to examine amination of this class of compounds. The introduction of the amino group into the triazole ring substantially extends the potentialities of derivatives of this heterocyclic system in the synthesis, primarily, as intermediates for the construction of biologically active compounds[2,3] as well as for the preparation of energetic polynitrogen materials.[4] *N*-Aminoazoles are generally synthesized by electrophilic amination of azoles or their salts with hydroxylamine derivatives.[5] However, *N*-aminoazoles containing electron-withdrawing groups are difficultly accessible.[6] Moreover, such compounds bearing the nitroimide group remain unknown.

We studied amination of 1*H*-1,2,4-triazolium 4-nitroimides **1a**—**c** and their salts **1´a**—**c** with *O*-picrylhydroxylamine (PHA) (Scheme 1). The use of the latter reagent in reactions with weakly basic azoles has given good results.[7]

Scheme 1



1a—c **2a—c** **1´a—c**

R = H (**a**), Me (**b**), Ph (**c**); PHA = O_2N–C$_6$H$_2$(NO$_2$)(ONH$_2$)–NO$_2$

Attempts to subject compounds **1a**—**c** to amination failed due, apparently, to their low nucleophilicty. Even the presence of the electron-releasing methyl groups in compound **1b** does not enhance its reactivity. In all reactions, only the starting compounds **1a**—**c** were isolated. However, amination of more nucleophilic triethylammonium salts **1´a**—**c** gave rise to 1-amino-1,2,4-triazolium 4-nitroimides **2a**—**c** in 67—75% yields. The latter compounds appeared to be stable crystalline substances, which decompose at temperatures higher than 165 °C. It should be noted that nitroimides containing substituents at positions 3 and 5 are thermodynamically more stable.

The structures of compounds **2a**—**c** were confirmed by the IR spectra, which have absorption bands in the regions of 1260—1300 and 1380—1415 cm^{-1} characteristic of the aromatic *N*-nitroimide group.[8] The structures of compounds **2a**—**c** were also supported by the ^1H NMR spectra. These spectra show signals for the protons of the NH_2 group at δ 6.9—7.4, whose chemical shifts depend on the nature of the substituents at positions 3 and 5. The signals for the protons of the substituents at the C(3) and C(5) atoms are nonequivalent, which confirmed that the amino group is inserted into the triazole ring giving rise to an unsymmetrical structure.

A series of chemical reactions of compounds **2a**—**c** proceeded at the amino group. The reactions of these compounds with aromatic aldehydes in ethanol in the presence of catalytic amounts of H_2SO_4 at 60—65 °C afforded 3,5-disubstituted 1-benzylideneamino-1,2,4-triazolium 4-nitroimides **3a**—**g** in good yields (Scheme 2).

Heating of compounds **2a**—**c** with acyl chlorides in acetonitrile in the presence of 4-dimethylaminopyridine afforded 1-acylamino-1,2,4-triazolium 4-nitroimides **4a**—**e**. However, the reactions performed in DMF re-

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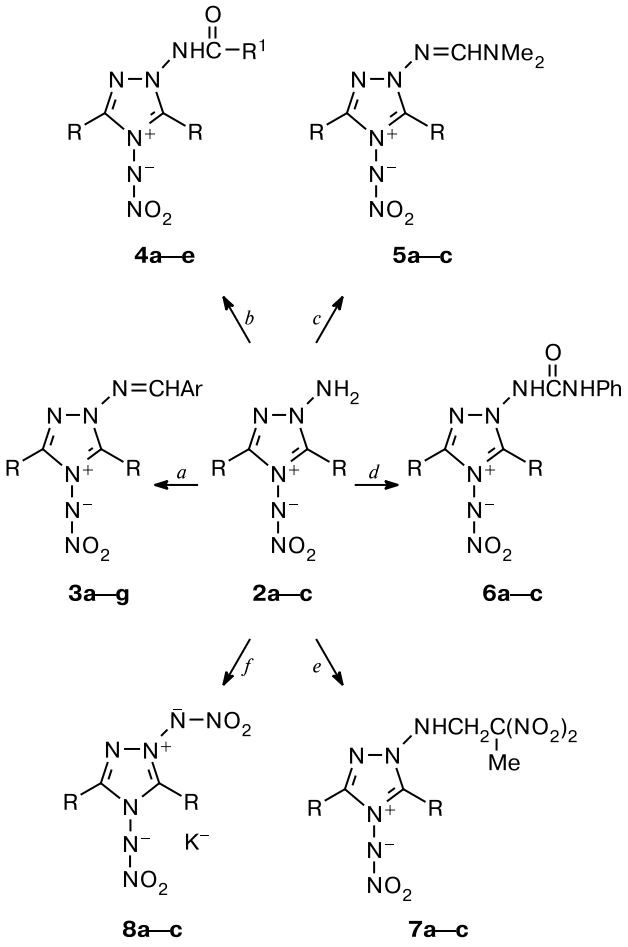
Scheme 2



Compound	R	Ar
3a, **5a**	H	Ph
3b	H	2-HOC$_6$H$_4$
3c	H	4-HO-3-MeOC$_6$H$_3$
3d, **5b**	Me	Ph
3e	Me	2-HO-4-O$_2$NC$_6$H$_3$
3f, **5c**	Ph	Ph
3g	Ph	2-HO-4-O$_2$NC$_6$H$_3$

Compound	R	R^1
2a, **4a**, **6a**—**8a**	H	Me
2b, **6b**—**8b**	Me	3,5-(O$_2$N)$_2$C$_6$H$_3$
2c, **6c**—**8c**	Ph	Me
4b	H	Ph
4c	H	3,5-(O$_2$N)$_2$C$_6$H$_3$
4d	Me	3,5-(O$_2$N)$_2$C$_6$H$_3$
4e	Ph	Me

Reagents and conditions: *a*. ArCHO; *b*. R^{1}COCl, DMAP, MeCN; *c*. RCOCl, DMF; *d*. PhNCO; *e*. CH_2O, $MeCH(NO_2)_2$; *f*. NO_2BF_4—KOAc, MeCN.

sulted not in acylation but in condensation of DMF at the amino group to give 1-(*N*,*N*-dimethylaminomethyleneamino)-1,2,4-triazolium 4-nitroimides **5a**—**c**. Analogous reactions of aminopyrroles with sulfonyl chlorides in DMF have been carried out earlier.[9] The reactions of amines with phenyl isocyanate in DMF at 40 °C afforded substituted ureas **6a**—**c**.

The Mannich reactions of compounds **2a**—**c** were performed with formaldehyde and *gem*-dinitroethane. It was found that the amines were condensed at 60—65 °C in the absence of catalysts to produce 1-(2,2-dinitropropyl)ami-

Table 1. Physicochemical characteristics of the resulting compounds

Compound	Yield (%)	M.p./°C	Found / Calculated (%) C	H	N	Molecular formula
2a	70	165—167 (decomp.)	16.73 / 16.67	2.86 / 2.80	58.11 / 58.32	$C_2H_4N_6O_2$
2b	75	233—235 (decomp.)	28.13 / 27.91	4.77 / 4.68	48.54 / 48.82	$C_4H_8N_6O_2$
2c	67	226—230 (decomp.)	57.07 / 56.75	4.17 / 4.08	28.13 / 28.36	$C_{14}H_{12}N_6O_2$
3a	73	200—203 (decomp.)	46.72 / 46.55	3.40 / 3.47	36.22 / 36.19	$C_9H_8N_6O_2$
3b	81	221—224 (decomp.)	43.64 / 43.55	3.28 / 3.25	33.72 / 33.86	$C_9H_8N_6O_3$
3c	86	202—204 (decomp.)	43.36 / 43.17	3.67 / 3.62	30.34 / 30.21	$C_{10}H_{10}N_6O_4$
3d	77	238—241 (decomp.)	51.06 / 50.77	4.58 / 4.65	32.04 / 32.29	$C_{11}H_{12}N_6O_2$
3e	86	240—243 (decomp.)	41.42 / 41.13	4.41 / 3.45	30.28 / 30.52	$C_{11}H_{11}N_7O_5$
3f	75	244—247 (decomp.)	65.83 / 65.62	4.22 / 4.20	21.65 / 21.86	$C_{21}H_{16}N_6O_2$
3g	82	256—258 (decomp.)	56.54 / 56.63	3.46 / 3.39	21.88 / 22.01	$C_{21}H_{15}N_7O_5$
4a	63	206—207 (decomp.)	26.05 / 25.81	3.41 / 3.25	44.75 / 45.15	$C_4H_6N_6O_3$
4b	73	227—228 (decomp.)	43.78 / 43.55	3.28 / 3.25	33.72 / 33.86	$C_9H_8N_6O_3$
4c	81	219—220 (decomp.)	32.17 / 31.96	1.76 / 1.79	33.00 / 33.13	$C_9H_6N_8O_7$
4d	67	237—238 (decomp.)	36.25 / 36.07	2.78 / 2.75	30.64 / 30.59	$C_{11}H_{10}N_8O_7$
4e	78	245—248 (decomp.)	57.02 / 56.80	4.23 / 4.17	24.72 / 24.84	$C_{16}H_{14}N_6O_3$
5a	58	170—172	30.38 / 30.15	4.63 / 4.55	49.05 / 49.23	$C_5H_9N_7O_2$
5b	67	242—245 (decomp.)	36.87 / 37.00	5.72 / 5.77	43.27 / 43.15	$C_7H_{13}N_7O_2$
5c	74	254—256 (decomp.)	58.18 / 58.11	4.96 / 4.88	27.75 / 27.90	$C_{17}H_{17}N_7O_2$
6a	87	168—170	41.22 / 41.07	3.34 / 3.45	37.03 / 37.25	$C_9H_9N_7O_3$
6b	85	232—234 (decomp.)	45.23 / 45.36	4.41 / 4.50	33.72 / 33.66	$C_{11}H_{13}N_7O_3$
6c	79	243—245 (decomp.)	60.82 / 60.72	4.05 / 4.12	23.43 / 23.60	$C_{21}H_{17}N_7O_3$
7a	73	165—167 (decomp.)	21.94 / 21.75	2.88 / 2.92	40.64 / 40.57	$C_5H_8N_8O_6$
7b	54	191—192 (decomp.)	27.52 / 27.64	4.13 / 3.98	36.75 / 36.83	$C_7H_{12}N_8O_6$
7c	78	205—207 (decomp.)	47.85 / 47.67	3.84 / 3.76	25.93 / 26.16	$C_{17}H_{16}N_8O_6$
8a	68	151—153 [13] (decomp.)	—	—	—	—
8b	59	227—229 (decomp.)	19.01 / 18.82	2.41 / 2.37	38.27 / 38.41	$C_4H_6KN_7O_4$
8c	69	234—236 (decomp.)	44.16 / 44.32	2.75 / 2.66	25.93 / 25.84	$C_{14}H_{10}KN_7O_4$

no-1,2,4-triazolium 4-nitroimides **7a—c**. The reactions with the use of a small excess of amine **2** with respect to *gem*-dinitroethane and a 1.5—2-fold excess of formaldehyde gave the best results.

One of the aims of the present study was to examine the possibility of the synthesis of *N*-azo compounds (tetrazenes) by oxidation of the amino group in compounds **2a—c**. A number of tetrazenes have been prepared according to this procedure. For example, oxidation of 4-amino-3,5-dimethyl-1,2,4-triazole and 4-amino-3,5-diphenyl-1,2,4-triazole with potassium bromate in acidic medium[10] or oxidation of 1-aminobenzimidazoles with NBS[11] afforded the corresponding tetrazenes. By contrast, oxidation of 4-amino-1,2,4-triazole with lead tetraacetate[12] and oxidation of 1-aminobenzotriazole with different oxidizing agents[10] led to the fragmentation of the heterocycle accompanied by elimination of nitrogen.

We used NBS, DBI (dibromoisocyanurate), Bu^tOCl, $KBrO_3$—HCl, and NaBrO as oxidizing agents. The reactions were carried out in both nonaqueous media (CH_2Cl_2 or MeCN) and water. In all cases, only deamination products **1a—c** were isolated.

Treatment of compounds **2a—c** with nitronium tetrafluoroborate NO_2BF_4 in acetonitrile in the presence of potassium acetate as a base led to nitration at the amino group giving rise to potassium salts of 4-nitramino-1,2,4-triazolium 1-nitroimides **8a—c**. The presence of substituents at positions 3 and 5 enhances thermal stability of these salts. Earlier, salt **8a** has been prepared[13] by nitration of 1,4-diamino-1,2,4-triazolium nitrate.

Table 2. IR and ^{1}H NMR spectroscopic data for the resulting compounds

Compound	IR (KBr), ν/cm^{-1}		^{1}H NMR, δ, *J*/Hz
	$-NNO_2$	Other groups	
2a	1404, 1290	3340, 3120 (NH_2)	7.33 (s, 2 H, NH_2); 9.08 (s, 1 H); 10.21 (s, 1 H)
2b	1412, 1264	3385, 3180 (NH_2)	2.27, 2.43 (both s, 6 H, 2 Me); 6.98 (s, 2 H, NH_2)
2c	1400, 1272	3360, 3125 (NH_2)	7.38 (s, 2 H, NH_2); 7.64—7.94 (m, 10 H)
3a	1428, 1292	—	7.64—8.04 (m, 5 H, Ph); 9.41 (s, 2 H, =C<u>H</u>—Ph); 9.47 (s, 1 H); 10.83 (s, 1 H)
3b	1420, 1276	3330 (OH)	6.99—7.89 (4 H, Ph); 9.43 (s, 1H, =C<u>H</u>—Ph); 9.53 (s, 1 H); 10.74 (s, 1 H, OH); 10.78 (s, 1 H)
3c	1416, 1288	3428 (OH)	3.85 (s, 3 H, OMe); 6.96—7.55 (3 H, Ph); 9.23 (s, 1 H, =C<u>H</u>—Ph); 9.43 (s, 1 H); 9.56 (s, 1 H, OH); 10.73 (s, 1 H)
3d	1416, 1288	—	2.37, 2.63 (both s, 6 H, 2 Me); 7.56—7.92 (m, 5 H, Ph); 9.38 (s, 2 H, =C<u>H</u>—Ph)
3e	1400, 1292	3400 (OH)	2.43, 2.70 (both s, 6 H, 2 Me); 7.17—8.55 (m, 3 H, Ph); 9.42 (s, 2 H, =C<u>H</u>—Ph); 10.51 (s, 1 H, OH)
3f	1420, 1316	—	7.63—8.07 (m, 15 H, 3 Ph); 9.45 (s, 2 H, =C<u>H</u>—Ph)
3g	1408, 1316	3350 (OH)	7.21—8.58 (m, 13 H, 3 Ph); 9.69 (s, 2 H, =C<u>H</u>—Ph); 10.67 (s, 1 H, OH)
4a	1412, 1284	1728 (C=O)	2.10 (s, 3 H, Me); 9.30 (s, 1 H); 10.59 (s, 1 H)
4b	1424, 1296	1704 (C=O)	7.62—7.99 (m, 5 H, Ph); 9.46 (s, 1 H); 10.83 (s, 1 H)
4c	1416, 1280	1716 (C=O); 1540, 1348 (C—NO_2)	9.04—9.15 (m, 3 H, Ph); 9.42 (s, 1 H); 10.74 (s, 1 H)
4d	1384, 1268	1712 (C=O); 1540, 1348 (C—NO_2)	2.39, 2.54 (both s, 6 H, 2 Me); 9.09—9.14 (m, 3 H, Ph)
4e	1416, 1272	1728 (C=O)	2.07 (s, 3 H, Me); 7.64—7.98 (m, 10 H, 2 Ph)
5a	1400, 1292	—	2.95, 3.12 (both s, 6 H, Me_2N); 8.59 (s, 1 H, CH=N); 9.12 (s, 1 H); 10.14 (s, 1 H)
5b	1420, 1316	—	2.32, 2.47 (both s, 6 H, Me); 2.90, 3.15 (both s, 6 H, Me_2N); 8.52 (s, 1 H, CH=N)
5c	1424, 1296	—	2.92, 3.20 (s, 6 H, Me_2N); 7.65—8.02 (m, 10 H, 2 Ph); 8.83 (s, 1 H, CH=N)
6a	1416, 1292	1720 (C=O)	7.05—7.48 (m, 5 H, Ph); 9.37 (s, 1 H); 10.75 (s, 1 H); 9.71 (s, 1 H, N<u>H</u>Ph); 11.04 (br.s, 1 H, N<u>H</u>CONHPh)
6b	1412, 1284	1712 (C=O)	2.36, 2.62 (both s, 6 H, 2 Me); 7.07—7.53 (m, 5 H, Ph); 9.78 (s, 1 H, N<u>H</u>Ph); 10.72 (br.s, 1 H, N<u>H</u>CONHPh)
6c	1408, 1296	1708 (C=O)	7.19—8.17 (m, 15 H, 3 Ph); 9.9 (s, 1 H, N<u>H</u>Ph); 11.15 (br.s, 1 H, N<u>H</u>CONHPh)
7a	1404, 1290	1568, 1328 ($C(NO_2)_2$)	2.25 (s, 1 H, Me); 4.42 (d, 2 H, NHC<u>H</u>$_2$, *J* = 7.4); 8.51 (t, 1 H, N<u>H</u>CH_2, *J* = 7.4); 9.30 (s, 1 H); 10.47 (s, 1 H)
7b	1408, 1268	1568, 1328 ($C(NO_2)_2$)	2.33, 2.42 (both s, 6 H, 2 Me); 2.25 (s, 1 H, Me); 4.41 (d, 2 H, NHC<u>H</u>$_2$, *J* = 7.3); 8.12 (t, 1 H, N<u>H</u>CH_2, *J* = 7.3)
7c	1404, 1272	1568, 1328 ($C(NO_2)_2$)	2.25 (s, 1 H, Me); 4.45 (d, 2 H, NHC<u>H</u>$_2$, *J* = 7.5); 7.60—8.00 (m, 10 H, 2 Ph); 8.44 (t, 1 H, N<u>H</u>CH_2, *J* = 7.5)
8a [13]	1432, 1272	—	9.09 (s, 1 H); 10.17 (s, 1 H)
8b	1444, 1304	—	2.25, 2.37 (both s, 6 H, 2 Me)
8c	1436, 1268	—	7.59—7.96 (m, 10 H, 2 Ph)

Experimental

The melting points were measured on a Boetius stage. The ^{1}H NMR spectra were recorded on a Bruker WM-250 instrument (250 MHz) in DMSO-d_6. The IR spectra were measured on a UR-20 instrument in KBr pellets.

The physicochemical and spectroscopic characteristics of the resulting compounds are given in Tables 1 and 2, respectively.

Triethylammonium salts of 4-nitramino-1,2,4-triazoles 1´a—c (general procedure). Triethylamine (1.3 mL, 1.0 g, 10.0 mmol) was added to a suspension of compound **1a—c** (9.0 mmol) in EtOH (10—15 mL). The reaction mixture was heated until the precipitate was completely dissolved and then concentrated on a rotary evaporator to dryness. The oily products thus obtained were used in subsequent reactions without additional purification.

1-Amino-1,2,4-triazolium 4-nitroimides 2a—c (general procedure). *O*-Picrylhydroxylamine (6.0 mmol) was gradually added to a solution of the corresponding triethylammonium salt of 4-nitramino-1,2,4-triazole **1a—c** (5.0 mmol) in anhydrous $CHCl_3$ (30 mL). The reaction mixture was stirred at ~20 °C for 3 h. The precipitate that formed was filtered off, washed with $CHCl_3$ and cold EtOH, and recrystallized from aqueous EtOH.

1-Arylideneamino-1,2,4-triazolium 4-nitroimides 3a—g (general procedure). The corresponding aromatic aldehyde (3.5 mmol) and one drop of H_2SO_4 were added to a suspension of compound **2a—c** (3.0 mmol) in EtOH (15 mL). The reaction mixture was stirred at 50—55 °C for 1 h, concentrated on a rotary evaporator to 1/2 of the initial volume, and cooled. The precipitate that formed was filtered off and recrystallized from MeOH.

1-Acylamino-1,2,4-triazolium 4-nitroimides 4a—e (general procedure). The corresponding acyl chloride (1.7 mmol) and 4-dimethylaminopyridine (1.7 mmol) were added to a suspension of compound **2a—c** (1.5 mmol) in MeCN (4 mL). The reaction mixture was stirred at ~20 °C for 1 h and then at 45—50 °C for 3—5 h, after which the mixture was concentrated on a rotary evaporator and water (5 mL) was added to the residue. The mixture was acidified with HCl to pH 1 and cooled to 0 °C. The precipitate that formed was filtered off and recrystallized from aqueous EtOH.

1-(*N*,*N*-Dimethylaminomethyleneamino)-1,2,4-triazolium 4-nitroimides 5a—c (general procedure). Acyl chloride (3.2 mmol) was added to a solution of compound **2a—c** (3.0 mmol) in DMF (4 mL) at 0 °C. The reaction mixture was stirred at 0—5 °C for 15 min and then at 45—50 °C for 2 h, after which the mixture was concentrated on a rotary evaporator and the residue was recrystallized from aqueous Pr^{i}OH.

1-(3-Phenylureido)-1,2,4-triazolium 4-nitroimides 6a—c (general procedure). Phenyl isocyanate (1.6 mmol) was added to a solution of compound **2a—c** (1.5 mmol) in DMF (2 mL) at 5—10 °C. The reaction mixture was stirred at this temperature for 15 min and then at 40 °C for 1 h, after which the mixture was concentrated on a rotary evaporator and the residue was recrystallized from aqueous EtOH.

1-[(2,2-Dinitropropyl)amino]-1,2,4-triazolium 4-nitroimides 7a—c (general procedure). A 32% formaldehyde solution (0.47 mL, 5.0 mmol) was added to a suspension of compound **2a—c** (3.5 mmol) in 50% aqueous MeOH (8 mL) at 0—5 °C. The reaction mixture was stirred at this temperature for 10 min and then *gem*-dinitroethane (0.36 g, 3 mmol) was added. The reaction mixture was stirred at ~20 °C for 15 min and then at 50—55 °C for 1 h, after which the mixture was cooled to −5 °C. The precipitate that formed was filtered off and recrystallized from EtOH.

Potassium salts of 4-nitramino-1,2,4-triazolium 1-nitroimides 8a—c (general procedure). Compound **2a—c** (3 mmol) and AcOK (0.64 g, 6.5 mmol) were added to a suspension of NO_2BF_4 (0.43 g, 3.2 mmol) in MeCN (15 mL) at −25 °C. The reaction mixture was stirred at the temperature from −25 to −20 °C for 40 min, was warmed to ~20 °C during 30 min, and then stirred for 2 h. The precipitate that formed was filtered off and extracted with hot MeOH (5×15 mL). The extract was concentrated on a rotary evaporator. The filtrate was concentrated to 1/4 of the initial volume. The precipitate was filtered off, combined with the residue obtained after concentration of the filtrate (see above), and recrystallized from aqueous EtOH.

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