The Reaction of Cyanamidium Salts with Ylidenecyanamide Derivatives

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Cyanamidium salts **1** undergo ene reactions with ylidenecyanamide derivatives **5** to afford conjugated iminium salts **12**. The *N*,*N*,*N*′-trialkylcyanamidium salts **1** react as the ene, and the ylidenecyanamide derivatives **5** react as the enophile components to form the 2-azoniaallene salts **11** followed by the formation of conjugated iminium salts **12** as cationic polynitrogen compounds with guanidine and amidine subgroups. The constitution of the new conjugated iminium salts **12** was secured by elemental analyses and spectroscopic data (IR and NMR).

Key words: Ene Reactions, Ylidenecyanamide, Cyanamidium Salts, 2-Azoniallenes, Iminium Salts

Introduction

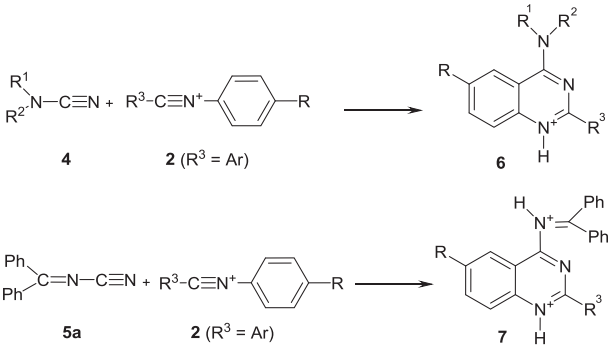
Cyanamidium and nitrilium salts are used as building blocks in organic synthesis, and they were proposed as reactive intermediates in named reactions. Several stable cyanamidium and nitrilium salts **1** could be generated and isolated, and they were found to be highly reactive electrophiles [1 – 8]. The iminium functional group is used in synthetic building blocks such as iminium salts **3** in organic synthesis. The iminium salts usually react easily with a wide range of nucleophiles. Several well known named reactions include iminium salts as intermediates, for example the Vilsmaier-Haack and the Mannich reactions [9].

Furthermore, it has been reported that *N*′-alkyl cyanamidium (**1**) and *N*-alkyl nitrilium (**2**) salts react readily with various electron-rich nucleophiles, such as alkynes [10], alkenes [11, 12], carbonyl compounds [13 – 17], amides [18, 19], 1,3-dipoles [20 – 24], nitrile oxides [25], amidoximes [26, 27], imines [4, 28], carbodiimides [6, 29], and cyanamides [5, 6] furnishing 2-azoniaallene salts *via* ene reactions and/or *via* $[2^+ + 2]$ and/or $[2^+ + 2 + 2]$ cycloadditions.

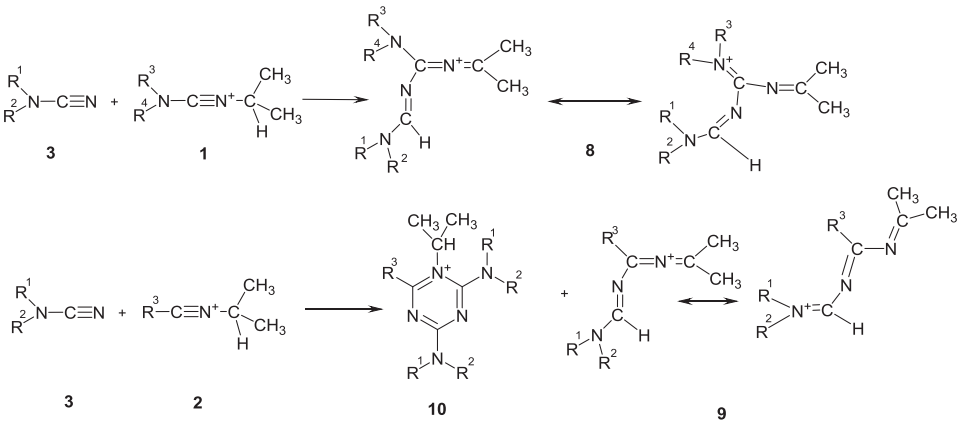
Interestingly, arenes react with *N*-aryl or *N*-alkyl nitrilium salts to give iminium ions [30, 31]. In these reactions the incoming nucleophiles are placed in *cis*-position with respect to the *N*-substituent [32]. An ene reaction was also proposed for the reaction of nitrilium ions with arenes in the sense of inverse electron demand, where the nitrilium ion acts as the ene and the arene as the enophile [33].

It has also been reported that *N*-aryl nitrilium salts **2** (R^2 = aryl) react with *N*,*N*-dialkylcyanamides **4** and diphenylmethylenecyanamide (**5a**) to furnish 4-dialkylaminoquinazolinium salts (**6**) and quinazoline-4-(diphenylmethylenammonium) salts (**7**) [34]. The compounds **7** are pyrimidinium-iminium salts (Scheme 1).

Recently, we found that *N*,*N*,*N*′-trialkyl cyanamidium (**1**) and *N*-alkylnitrilium salts (**2**) undergo ene reactions with *N*,*N*-dialkylcyanamides **4** to afford 2-azoniaallene salts **8** and **9** which have resonance contributions from an iminium structure. In these reac-



Scheme 1.



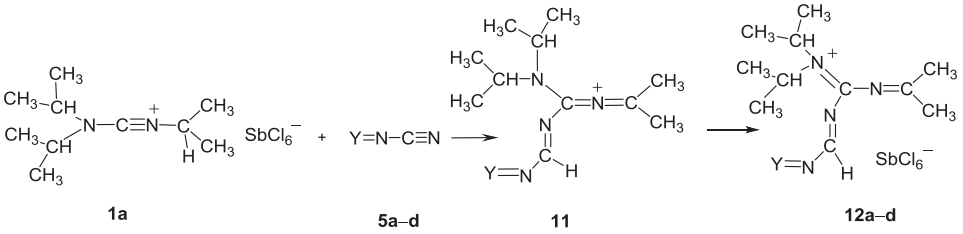
Scheme 2.

tions, the *N*-alkylnitrilium salts **2** react as ene, and the *N*,*N*-dialkylcyanamides **4** react as enophile components [6]. In competition with the ene reaction, *N*-alkyl nitrilium salts **2** undergo $[2^+ + 2 + 2]$ cycloadditions to furnish triazinium salts **10** (Scheme 2). In other studies [5, 29], dealing with the reaction of nitrilium salts **2** and cyanamidium salts **1** with carbodiimides, 2,3,4,5-tetrahydro-2,4-diimino-1,3,5-triazin-1-ium salts were formed by the addition of carbodiimides to *N*-alkylnitrilium salts **2** [29], salts **1** to produce **8**, while salts **2** furnished mixtures of **9** and **10** [5].

In previous work we have disclosed the preparation of compounds **1** and reactions of these reactive intermediates [2–6, 10, 12, 14, 15, 18, 25, 28, 29, 35]. In continuation of our studies we report here on substitutions with cyanamidium salts **1** as outlined in Scheme 3. The iminium salts **13a–d** are interesting cationic polynitrogen compounds with guanidine and amidine subgroups and will deserve attention not only from organic chemists, but also from material scientists, in case a manyfold insertion reaction will be possible in the future.

Results and Discussion

N,*N*,*N*′-Triisopropylcyanamidium salt **1a** [2] was employed as a representative of *N*,*N*,*N*′-trialkylcyanamidium salts. In the course of the reaction of **1a** with ylidenecyanamides **5a–d** in dichloromethane the strong and broad IR absorption around $\nu_{max} = 2220\,cm^{-1}$ stemming from the cyanamidium salt disappeared, and the conjugated imimium salts **12a–d** were isolated in good yields (80–97 %). These compounds display a strong broad IR absorption around $\nu_{max} = 1670\,cm^{-1}$, characteristic for iminium salts [4, 41, 42] (Scheme 3).



Compounds **5a**–**d** and **12a**–**d**

Entry	a	b	c	d
Y	Ph_2C	Ph_3P	$(MeS)_2C$	$(Me_2N)_2C$

Scheme 3.

Non aza-substituted 2-azoniaallene salts are identified by the broad IR absorption around ν_{max} = 1900 cm^{-1}, which can be assigned to the skeletal stretching vibration of an almost linear C=N^+=C unit [43–47]. It was reported that the corresponding IR absorptions of hetero-substituted 2-azoniaallene salts are shifted to longer wavelengths [4, 22], which is consistent with our results due to the presence of amino and conjugated imino-imino substituents on the C=N^+=C unit and to iminium salts.

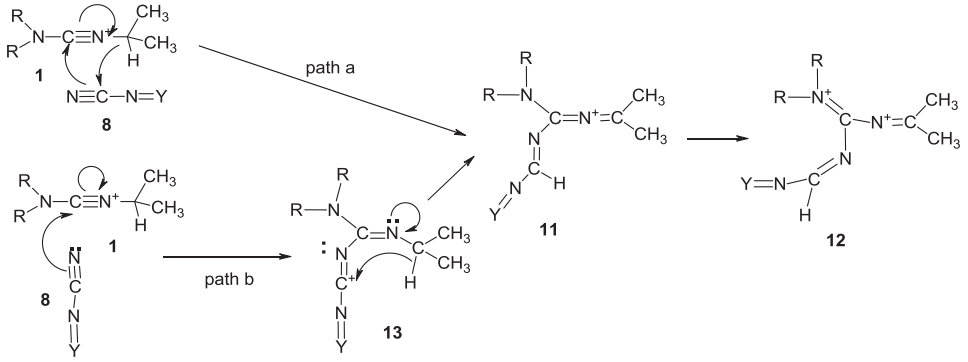
The structure of the conjugated imimium salts **12** were unambiguously supported by their IR and NMR spectra and elemental analyses. The IR spectra of most iminium salts **12** show strong IR absorption bands in the range of 1500 to 1670 cm^{-1}, which can be assigned to C=N and C=N^+ stretching vibrations.

A simple shift of an electron pair in the cumulene unit of the non-planar 2-azoniaallene salts **11** leads to the formation of conjugated iminium salts **12** which have a planar 1-azonia-3-aza-1,3-diene system. Therefore we do not place resonance arrows between these two structures (**11** and **12**, Scheme 4); the one on the left is non-planar, and should show allene-type IR bands, the one on the right is planar, and should not. The 2-aza-allenium structure contains an *sp*-hybridized N atom, while the iminum salts **12** have sp^2 N hybridization. Conjugated iminium salts **12** take advantage of the many possibilities for mesomeric stabilization of the positive charge, which is only possible for bent structures, not for a linear one.

The room-temperature ^{1}H NMR spectrum of **12a** shows signals for two non-equivalent isopropyl methyl groups, which are observed at δ = 1.29 and 1.32 ppm, two equivalent methyl groups at 2.23 ppm assigned to N=C(CH_3)$_2$, and an aldimino proton (N-C*H*=N) at 8.64 ppm. The ^{13}C NMR spectrum shows signals for two non-equivalent isopropyl methyl carbon nuclei (CH_3)$_2$CH) at δ = 19.9 and 20.6 ppm, a methyl carbon resonance at 27.4 ppm ((CH_3)$_2$=C), a methane resonance at 51.7 (CH_3)$_2$*C*H), and quaternary nuclei at 64.8, 165.8, 174.2 (assigned to two C=N and C=N^+) and 181.4 ppm (assigned to aldimino carbon nucleus N-*C*H=N).

Compounds **12** and **13** are formed in a completely stereoselective manner with respect to the configuration of the aldimino imine double bond. This can be deduced from the presence of only a single type of aldimino proton (C*H*=N) at −20 °C. At room temperature in the proton spectra of **12b** and **12d** two aldimino resonances are detected, which arise from the hindered geometrical isomerization at room temperature on the time scale of ^{1}H and ^{13}C NMR.

The reaction of **1** with **8** proceeds either *via* a concerted ene reaction (path a) or *via* a stepwise mechanism with the formation of intermediates **13** followed by a concluding [1, 5]-H shift (path b) followed by the formation of conjugated iminium salts **12** as outlined in Scheme 4. The concerted mechanism is more likely to occur (path a), since Hegarty and co-workers reported that the nucleophilic addition to nitrilium ions is stereo-electronically controlled. The nitrogen lone-pair always develops *anti* with respect to the incoming nucleophile giving rise to the *Z*-isomer. For the resulting imines, the nucleophile and the nitrilium *N*-substituent are mutually *syn* oriented, followed by a rapid [1, 5]-H transfer to give **13**. The formation of only **12** and the absence of tri-



Scheme 4.

azinium salts through [$2^+ + 2 + 2$] cycloadditions [5] support a concerted mechanism (path a) as shown in Scheme 4.

It was found that the reaction of nitrilium salts **2** with ylidenecyanamide **5** gave only tarry materials as a mixture of products as indicated by NMR spectroscopy. Expectedly, nitrilium salts are more reactive towards nucleophiles as we have already reported [5, 29].

Experimental Section

All experiments were carried out with the exclusion of moisture, in solvents dried by standard methods. Melting points were determined with an Electrothermal 9100 apparatus and are uncorrected. The ^{1}H and ^{13}C NMR spectra were recorded on Bruker AC-250 and Bruker DPX-300 instruments, using TMS as an internal standard, and with deuterated chloroform, dichloromethane or acetonitrile as solvents; chemical shifts (δ) are given in ppm and coupling constants (J) in Hz. IR spectra were recorded on a Perkin-Elmer 1600 FT-IR instrument in CH_2Cl_2 solution; the frequencies are expressed in cm^{-1}. Elemental microanalyses were obtained on an Elemental Analyzer (Carlo Erba 1106) from vacuum-dried samples.

The *N*-(diphenylmethylene)cyanamide **5a** [36], *N*-(triphenylphosphoranylidene)cyanamide **5b** [37, 38], dimethyl cyanocarbonimidodithioate **5c** [39], and 2-cyano-1,1,3,3-tetramethylguanidine **5d** [40] were prepared according to literature procedures. The *N*,*N*,*N*′-triisopropylcyanamidium salt **1a** was prepared by the reaction of *N*-chloro-*N*,*N*-diisopropylamines with isopropyl isocyanides in the presence of zinc chloride or mercurous chloride, followed by the addition of antimony pentachloride as a Lewis acid according to our previously reported procedure [2].

General procedure

An ylidenecyanamide derivative **5a–d** (5.1 mmol) dissolved in 10 mL of dichloromethane was added dropwise to a solution of *N*,*N*,*N*′-triisopropylcyanamidium hexachloroantimonate (**1a**) (5.1 mmol) dissolved in 10 mL of dichloromethane cooled to −78 °C with good stirring. The reaction solution was stirred for 20 min at this temperature followed by stirring for 30 min at 10 – 15 °C until the IR absorption band (2220 cm^{-1}, br) of cyanamidium salts had disappeared. The reaction solution was cooled to −20 °C followed by the addition of 100 mL of diethyl ether until turbidity was observed. The solvent mixture was evaporated under reduced pressure at 10 °C until a colorless or yellow precipitate with some oily gum was formed. The precipitate was separated and washed with 15 mL of diethyl ether, then dissolved in 10 mL of dichloromethane and precipitated with 100 mL of diethyl ether at −20 °C. The product was collected and dried under reduced pressure (80 – 97 % yield).

*N-(((((Diphenylmethylene)amino)methylene)amino)-(propan-2-ylideneamino)methylene)-N-isopropylpropan-2-aminium hexachloroantimonate(V) (**12a**)*

Yellow solid (82 %); m. p.: 155 – 157 °C. – IR (CH_2Cl_2) ν_{max} (cm^{-1}) = 1100, 1200, 1360, 1670. – ^{1}H NMR (300 MHz, CD_2Cl_2, 263 K): δ = 1.29 (d, J = 6.5 Hz, 6H, $(CH_3)_2CH$), 1.32 (d, J = 6.5 Hz, 6H, $(CH_3)_2CH$), 2.23 (s, 6H, $(CH_3)_2$=C), 4.06 (sept., J = 6.5 Hz, 2H, $2(CH_3)_2CH$), 7.59 (m, 10H, $2\times(C_6H_5)$), 8.64 (s, 1H, N-CH=N). – ^{13}C NMR (75 MHz, CD_2Cl_2): δ = 19.9 ($CH_3)_2CH$), 20.6 ($CH_3)_2CH$), 27.4 (($CH_3)_2$=C), 51.7 ($CH_3)_2CH$), 128.5, 129.2, 130.1, 130.5, 133.2, 164.8, 165.8, 174.2, 181.4 (N-CH=N). – Anal. for $C_{22}H_{31}N_4 \cdot SbCl_6$ (710.1): calcd. C 40.60, H 4.40, N 7.89; found C 40.34, H 4.33, N 7.82.

N-Isopropyl-N-((propan-2-ylideneamino)((((triphenylphosphoranylidene)amino)methylene)amino)methylene)propan-2-aminium hexachloroantimonate(V) (***12b***)

Colorless solid (84 %); m. p.: 157 – 160 °C. – IR (CH_2Cl_2): ν_{max} (cm^{-1}) = 1100, 1200, 1340, 1400, 1490, 1570, 1670. – ^{1}H NMR (300 MHz, CD_3CN, 303 K): δ = 0.98 (d, J = 6.7 Hz, 6H, $(CH_3)_2CH$), 1.15 (d, J = 6.7 Hz, 6H, $(CH_3)_2CH$), 1.92 (s, 6H, $(CH_3)_2$=C), 3.82, 4.01 (sept., J = 6.7 Hz, 2H, $2(CH_3)_2CH$), 7.69 (m, 15H, 3 × (C_6H_5)), 8.11 and 8.29 (s, 1H, N-CH=N). – ^{13}C NMR (75 MHz, CD_3CN): δ = 20.1 $(CH_3)_2CH$), 20.4 $(CH_3)_2CH$), 26.5 $((CH_3)_2$=C), 49.7, 124.8, 126.4, 130.2, 130.4, 133.6, 133.8, 134.5, 134.6, 166.3, 168.6, 168.7, 180.1 (N-CH=N). – Anal. for $C_{29}H_{36}N_4P{\cdot}SbCl_6$ (806.1): calcd. C 43.21, H 4.50, N 6.95; found C 43.13, H 4.26, N 6.94.

N-Isopropyl-N-(9-methyl-3-(methylthio)-2-thia-4,6,8-triazadeca-3,5,8-trien-7-ylidene)propan-2-aminium hexachloroantimonate(V) (***12c***)

Colorless solid (80 %); m. p.: 99 – 102 °C. – IR (CH_2Cl_2): ν_{max} (cm^{-1}) = 1230, 1400 (br), 1570, 1670. – ^{1}H NMR (300 MHz, CD_3CN, 303 K): δ = 1.32 (d, J = 7.0 Hz, 6H, $(CH_3)_2CH$), 1.42 (d, J = 7.0 Hz, 6H, $(CH_3)_2CH$), 2.19 (s, 6H, $(CH_3)_2$=C), 2.67 (s, 6H, $(CH_3S)_2$=C), 4.36 (sept., J = 7.0 Hz, 2H, $2(CH_3)_2CH$), 8.34 (s, 1H, N-CH=N). – ^{13}C NMR (75 MHz, CD_3CN): δ = 17.1 $(CH_3)_2CH$), 19.9 $(CH_3)_2CH$), 20.7 $(CH_3S)_2$=C), 27.3 $((CH_3)_2$=C), 52.4 $(CH_3)_2CH$), 159.6, 167.3, 182.3 (N-CH=N), 191.5 $(CH_3S)_2$=C). – Anal. for $C_{14}H_{27}N_4S_2{\cdot}SbCl_6$ (640.0): calcd. C 25.87, H 4.19, N 8.62; found C 26.03, H 4.26, N 8.58.

N-(3-(Dimethylamino)-2,9-dimethyl-2,4,6,8-tetraazadeca-3,5,8-trien-7-ylidene)-N-isopropylpropan-2-aminium hexachloroantimonate(V) (***12d***)

Corlorless solid (97 %); m. p.: 115 °C (dec.). – IR (CH_2Cl_2): ν_{max} (cm^{-1}) = 1020, 1345, 1500, 1520, 1600, 1670. – ^{1}H NMR (300 MHz, CD_3CN, 263 K): δ = 1.17 (d, J = 6.8 Hz, 6H, $(CH_3)_2CH$), 1.42(d, J = 6.8 Hz, 6H, $(CH_3)_2CH$), 2.10 (s, 6H, $(CH_3)_2$=C), 3.01 (s, 12H, $(((CH_3)_2N)_2)$=C), 3.96 (sept., J = 6.8 Hz, 2H, $2(CH_3)_2CH$), 7.63 (s, 1H, N-CH=N). – ^{13}C NMR (75 MHz, CD_3CN): δ = 20.3 $(CH_3)_2CH$), 21.1 $(CH_3)_2CH$), 26.1 $((CH_3)_2$=C), 41.4 $(((CH_3)_2N)_2)$=C), 48.7 $(CH_3)_2CH$), 50.8 $(CH_3)_2CH$), 159.4, 165.5, 170.5, 178.7 (N-CH=N). – Anal. for $C_{16}H_{33}N_6{\cdot}SbCl_6$ (644.0): calcd. C 29.84, H 5.17, N 13.05; found C 29.93, H 5.07, N 12.86.

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