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Efficient Synthesis of 4,4′-Bi-1*H*-imidazol-2-ones from 5-Amino-α-imino-1*H*-imidazole-4-acetonitriles and Isocyanates

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Reactions of 5-amino-α-imino-1*H*-imidazole-4-acetonitriles **1** with alkyl and aryl isocyanates led to efficient syntheses of 5′-amino-5-imino-4,4′-bi-1*H*-imidazol-2-ones **3** formed by intramolecular cyclization of the corresponding 5-amino-α-(*N*-alkyl/arylcarbamoyl)imino-1*H*-imidazole-4-acetonitriles **2**. The cyclization occurs only slowly in solution but is considerably accelerated by the addition of a catalytic amount of DBU (1,8-diazabicyclo[5.4.0]undec-7-ene). The reaction of the *N*-arylamidine **6b**, the synthetic precursor of the imidazole **1b**, with benzyl isocyanate also led to the formation of 4,4′-bi-1*H*-imidazol-2-one **3b** in quantitative yield. The imidazole intermediate **2b** has been isolated and found to be identical with the compound obtained by reaction of the imidazole **1b** and benzyl isocyanate. The *N*-arylamidine **6c** (R = 4-NC$_6$H$_4$) reacted with benzyl isocyanate in a similar way, but the electrophilicity of the amidine carbon atom resulted in rapid hydrolysis of the intermediate **7c** leading ultimately to the isolation of the urea **9**. The *N*-alkylamidines **6a** and **6d** behaved differently in their reaction with benzyl isocyanate, and the major product isolated in these reactions is again the urea **9**.

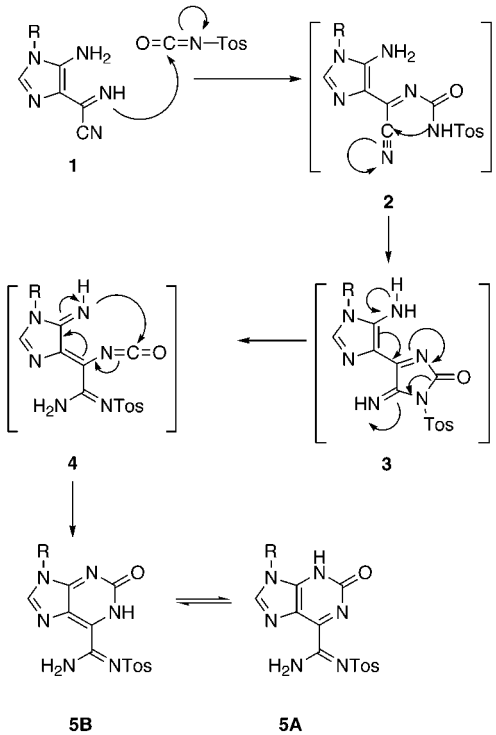
Introduction

Our previous work on the reaction of 5-amino-α-imino-1*H*-imidazole-4-acetonitriles **1** with tosyl isocyanate resulted in efficient syntheses of 6-amidino-2-oxopurines.[1] Mechanistic studies suggested that this process starts with reaction of the imino nitrogen of **1** with the isocyanate leading to structures **2** that cyclize to give **3** (Scheme 1). Rearrangement of the imidazolones **3** via the isocyanates **4** finally affords the 2-oxopurines **5**. However, none of the intermediates could be isolated or detected in solution, and thus, the mechanism could not be unambiguously established. In the present work, the imidazoles **1a**,**b** were reacted with alkyl and aryl isocyanates to understand the chemical behavior of less electrophilic isocyanates. These reactions proved to be an efficient method for syntheses of hitherto unreported 4,4′-bi-1*H*-imidazol-2-ones **3**. To our knowledge, there is only one reference in the literature reporting the synthesis of 4,4′-biimidazoles,[2] which were prepared by palladium-catalyzed coupling of 4-iodo-1-triphenylmethylimidazoles.

Results and Discussion

All reactions of imidazoles **1** were carried out under a nitrogen atmosphere, in dry acetonitrile with 2−5 equiv of the isocyanate. The reaction mixtures were stirred at 23 °C or below (Table 1).

SCHEME 1



The reactive aryl isocyanates [phenyl and 4-(trifluoromethyl)phenyl] gave good yields with both *N*-aryl- and *N*-alkylimidazoles. With the less reactive alkyl isocyanates (R^2 = benzyl, ethyl, *n*-butyl, and allyl), longer reaction times were required. Good yields were still obtained with the more stable *N*-arylimidazoles, but in some cases, e.g., reaction between **1a** and ethyl isocyan-

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(1) Booth, B. L.; Cabral, I. M.; Dias, A. M.; Freitas, A. P.; Matos Beja, A. M.; Proença M. F.; Ramos Silva, M. *J. Chem. Soc., Perkin Trans. 1* **2001**, 1241−1251.

(2) Cliff, M. D.; Pyne, S. G. *Synthesis* **1994**, 681.

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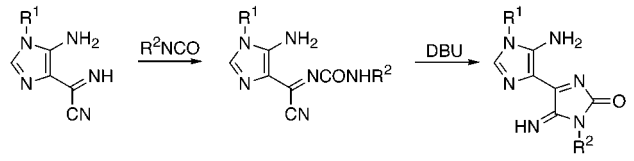
TABLE 1



1a, b **2a-h** **3a,b,d-k**

Compound	R^1	R^2	Ratio 1:R^2NCO	Reaction Conditions	Yield (%)
1a	CH_2CH_2OH	-	-	-	ref (3a)
1b	4-$MeOC_6H_4$	-	-	-	ref (4)
2a	CH_2CH_2OH	CH_2Ph	1:2.0	10 min (0 °C); 3 days (-18 °C); 7 h (4 °C)	93
2b	4-$MeOC_6H_4$	CH_2Ph	1:3.5	4 days (4 °C)	71
2c	$(CH_2)_2OCONHEt$	Et	1:5.0	10 min (-4 °C); 7 days (23 °C)	6
2d	4-$MeOC_6H_4$	Et	1:5.0	10 min (-4 °C); 4 days (rt)	76
2e	4-$MeOC_6H_4$	Bu	1:4.5	10 min (-4 °C); 4 days (23 °C)	81
2f	CH_2CH_2OH	Ph	1:2.0	4 h (0 °C)	66
2g	4-$MeOC_6H_4$	Ph	-	-	a)
2h	CH_2CH_2OH	4-$CF_3C_6H_4$	1:2.2	45 min (-15 °C); 18 h (-18 °C)	100
2i	4-$MeOC_6H_4$	4-$CF_3C_6H_4$	1:1.5	45 min (-15 °C)	100
2j	CH_2CH_2OH	allyl	1:4.0	10 min (-4 °C); 3 h (23 °C)	24
2k	4-$MeOC_6H_4$	allyl	1:3.0	10 min (-4 °C); 18 h (23 °C)	61
3a	CH_2CH_2OH	CH_2Ph	-	2 h (23 °C) 8 h (reflux)	60 91[b]
3b	4-$MeOC_6H_4$	CH_2Ph	-	5 min (23 °C)	88
3d	4-$MeOC_6H_4$	Et	-	15 min (23 °C)	81
3e	4-$MeOC_6H_4$	Bu	-	90 min (23 °C)	85
3f	CH_2CH_2OH	Ph	-	15 min (23 °C)	90
3g	4-$MeOC_6H_4$	Ph	1:2.0	4 h (-4 °C); 2 h (4 °C)	95[c]
3h	CH_2CH_2OH	4-$CF_3C_6H_4$	-	15 min (23 °C)	76
3i	4-$MeOC_6H_4$	4-$CF_3C_6H_4$	-	15 min (23 °C)	83
3j	CH_2CH_2OH	allyl	-	15 min (23 °C)	27
3k	4-$MeOC_6H_4$	allyl	-	15 min (23 °C)	92

[a] Not isolated. [b] From **1a** in ethanol in the absence of DBU. [c] From **1b** in the absence of DBU.

ate, the long reaction time required (7 days at 23 °C) resulted in extensive degradation of the imidazole **1a** resulting in a poor product yield even when 5 equiv of the isocyanate was used.

The structures of imidazoles **2** were confirmed spectroscopically. In the IR spectra, weak bands at 2200−2250 cm^{-1} indicated the presence of the cyano group. A strong band at 1645−1660 cm^{-1} was assigned to the carbonyl stretching vibration. The presence of both carbonyl and cyano groups was confirmed by ^{13}C NMR spectroscopy with signals around δ 159−161 and 112−113. The peak for C-2 at δ 135−138 is characteristic for the imidazole ring as is the signal for C-2(H) in the ^1H NMR spectrum (δ 7.3−7.5). In the ^1H NMR spectra, the amino group gave rise to broad singlets at δ 7.6−8.2 while the singlets for the amide protons were found at δ 7.9−8.4 if R^2 = alkyl, respectively at δ 10.0−10.4 for R^2 = aryl.

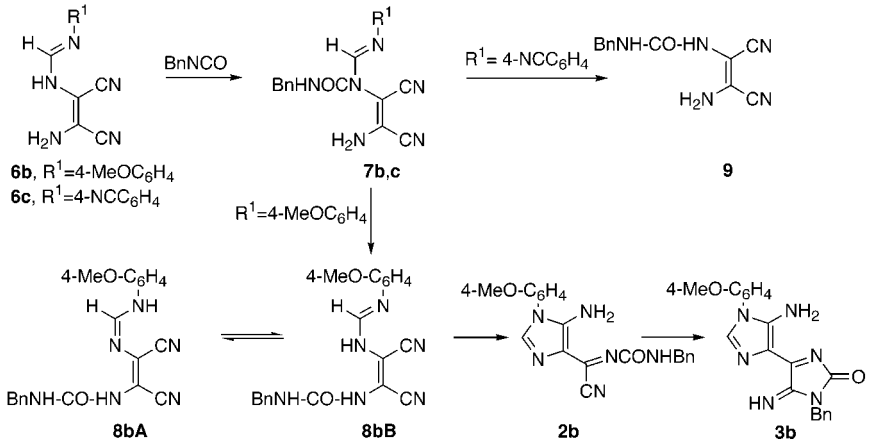
The addition of DBU (0.03−1 equivalent) to the suspension of a imidazole **2** in acetonitrile immediately lead to the formation of yellow/orange solids isolated in excellent yields after 15 min at 23 °C. These products were identified as 4,4′-bi-1*H*-imidazol-2-ones **3**. This intramolecular cyclization does not necessarily require the addition of base but it is considerably accelerated by it. Thus, when compound **2a** was refluxed in ethanol for 8 h in the absence of a base, the biimidazol-2-one **3a** was isolated in 88% yield.

The bicyclic structure **3** is characterized by the absence of a cyano stretching vibration in the IR spectrum. A very strong band at 1708−1717 cm^{-1} indicates that the carbonyl group is now part of the heterocyclic ring. In the ^{13}C NMR spectrum the carbonyl signal is shifted to δ 165−167, while the signals for the imidazole ring are almost unchanged with C-2 at δ 139−140, C-4 at δ 113−114 and C-5 at δ 152−153. In the ^1H NMR spectrum the imine N−H appears at δ 9.6−10.2. The $^1H/^{13}C$ NMR signals were assigned on the basis of a correlation study by HMBC (heteronuclear multiple bond correlation) for compound **3b**.

The *N*-aryl- and *N*-alkylamidines **6a**−**d** were also treated with benzyl isocyanate in an attempt to generate imidazoles **2** and/or **3** by intramolecular cyclization of the acylated amidines (Table 2).

The reaction of the formamidine **6b** with benzyl isocyanate in acetonitrile led to a quantitative yield of a colorless solid identified as the *N*-(benzylcarbamoyl)-amidine **7b**. When this reaction was carried out at room temperature, extensive decomposition occurred and the product **7b** was isolated in only 47% yield. Application of the HMBC technique indicated the presence of the amino function (δ 8.0) of **7b** in the vicinity of the cyano group (δ 114.7). The amidine C−H (δ 8.46) turned out to be linked to the carbon atom at δ 146.9 and to be three bonds separated from the ipso carbon atom of the aryl group (δ 143.7) and from C-1 of the vinylidene substituent (δ 86.7). The IR spectrum showed an intense carbonyl stretching vibration at 1676 cm^{-1} and absorptions at 2243 cm^{-1} (weak) and 2195 cm^{-1} (medium) for two cyano groups. Stirring a solution of compound **7b** in acetonitrile at room temperature for 18 h afforded the amidine **8b** (60%) as a yellow solid. This product arose by migration of the benzylcarbamoyl group from the amidine nitrogen atom to the amino group, possibly via a five-membered ring intermediate. The IR spectrum of compound **8b** showed a strong carbonyl stretching vibration at 1650 cm^{-1} and a single band of medium intensity at 2219 cm^{-1} for the two cyano groups. The ^1H and ^{13}C NMR spectra could be interpreted assuming the presence of tautomers **8bA** and **8bB** in a 1.5:1 ratio. The major isomer showed three N−H signals as broad singlets at δ 10.3 and 8.3 and under the aromatic multiplet at δ 7.2−7.4. The C−H signal at δ 7.9 turned out to be associated with the carbon signal at δ 150.9. In the minor isomer, the C−H signal occurred at δ 8.3 (underneath of one of the N−H peaks of **8bA**). The N−H bands appeared as broad signals at δ 10.5, 8.5 and 7.5. The presence of the two tautomers and the fact that compound **8b** rapidly cyclized in solution to give the imidazole **2b** led to a complex mixture that was difficult to analyze with NMR techniques. When a solution of **8b** in acetonitrile was stirred at room temperature for 30 min in the presence of a catalytic amount of DBU compound **3b** was formed quantitatively via **2b**. These results suggest that imidazole **1b** reacts with benzyl isocyanate either directly at the imino nitrogen to give **2b** or at the 5-amino substituent followed by acyl migration affording **2e**.

TABLE 2



Compound	R^1	Ratio **6**:BnNCO	Reaction Conditions	Yield (%)
7b	4-$MeOC_6H_4$	1:1.3	2 h (-15 °C); 2 days (-18 °C);	100
		1:2.2	5 min (0 °C) 1 h (23 °C)	47[a]
8b	4-$MeOC_6H_4$	-	18 h (23 °C)	60
3b	4-$MeOC_6H_4$	-	30 min (23 °C);	100[b]
9	-	1:1.5	3 days (-4 °C) 18 h (-18 °C)	59[c]

[a] **8b** was also isolated (6%). [b] From **8b**, with DBU. [c] From **6c** and benzyl isocyanate.

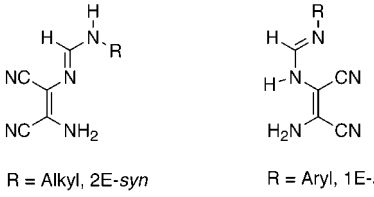


FIGURE 1. Tautomeric and configurational equilibrium of compounds **6** in solution.

The reaction of the amidine **6c** with benzyl isocyanate under conditions used for **6b** afforded the urea **9** (59%) as an off-white solid probably resulting from hydrolysis of **7c** during the workup procedure. The electron-withdrawing effect of the aryl substituent enhances the electrophilicity of the amidine carbon atom. When the reaction of the amidine **6c** with 1 equiv of benzyl isocyanate was followed by ^{1}H NMR, the formation of compound **7c** was almost complete after 2 h at 20 °C. As the DMSO-d_6 was not completely anhydrous, some hydrolysis product **9** was observed after 1 day.

Previous work indicated that in solution *N*-alkylformamidines **6a** and **6d** adopt a constitution other than N^2-arylformamidines (Figure 1).[3,4] This could be the reason for the different reactions of these two types of formamidines with isocyanates. Reactions of **6a** and **6d** with excess of benzyl isocyanate (Table 3) furnished a creamy solid product identified as the amidine **10a**, in low yields. The structure of the amidine **10a** was confirmed by HMBC and COSY techniques. In the IR spectrum a single band at 2220 cm^{-1} of medium intensity was observed for the cyano groups.

When the amidine **6a** and benzylisocyanate (1:2.6 molar ratio) in dry acetonitrile were kept at −18 °C for 1 week, compound **11** was isolated in low yield (13%). This product was formed from **10** by intramolecular nucleophilic attack of the hydroxyl group on the amidine carbon atom. The constitution of compound **11** was secured using HMBC and COSY techniques.

As the NMR spectra were determined in wet DMSO-d_6, compound **11** was slowly hydrolyzed to the urea **9** and 2-(3-benzylureido)ethyl formate. The urea **9** was also isolated in 29% yield from the reaction mixture where compound **11** was generated. All reactions involving the amidine **6a** and benzyl isocyanate led to **9** as a major product.

From the reaction of benzyl isocyanate with the amidine **6d** the urea **9** was isolated as the major product (30%). The acylated amidine **10d** could only be isolated in one of the experiments (3% yield) after dry flash chromatography. Its structure was confirmed by spectroscopic analysis.

Conclusions

It has been demonstrated that 4,4′-bi-1*H*-imidazol-2-ones **3** are formed in excellent yields from reactions of 1-alkyl- or 1-arylimidazoles **1** with either alkyl or aryl

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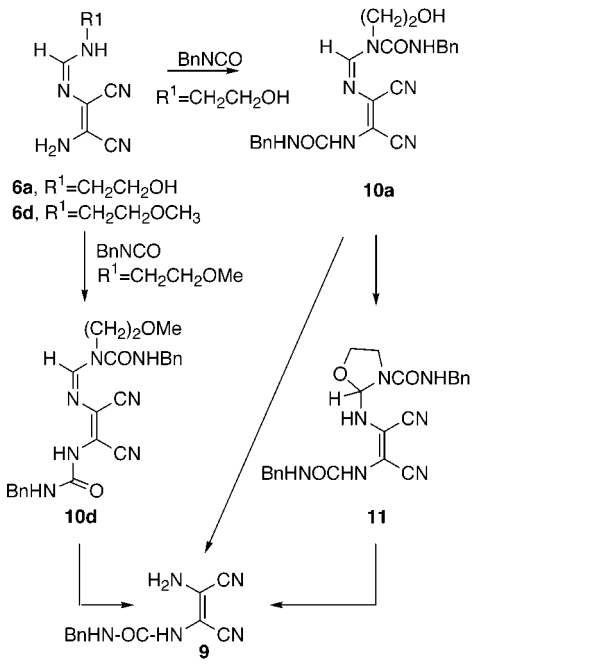
TABLE 3



Compound	R^1	Ratio **6**:BnNCO	Reaction Conditions	Yield (%)
10a	CH_2CH_2OH	1:2.3	10 min (-4 °C); 5 h (4 °C); 18 h (-18 °C)	17 (**9**, 5%)
		1:1.3	2 h (0 °C); 18 h (-18 °C)	15
		1:1.2	40 min (-4 °C); 18 h (4 °C)	11 (**9**, 2%)
		1:2.3	2 days (-4 °C)	16 (**9**, 23%)
		1:1.4	2 h (-15 °C) 4 h (0 °C)	5 (**9**, 9%)
10d	$CH_2CH_2OCH_3$	1:1.2	2 h (0 °C); 2 days (-18 °C)	3 (**9**, 26%)
11	-	1:2.7	1 h (-4 °C); 8 days (-18 °C)	13 (**9**, 29%)

isocyanates. Synthesis of compounds **3** can also be achieved from isocyanates and *N*-arylamidines with electron-donating groups (**6b**, R = 4-$CH_3OC_6H_4$). *N*-Aryl- and *N*-alkylamidines adopt different constitutions in solution. As a consequence, *N*-alkylamidines **6** incorporate two isocyanate molecules to give diacyl products **10**, which are easily hydrolyzed leading to the formation of urea **9**. A similar behavior was registered for *N*-arylamidines with electron-withdrawing groups (**6c**, R = 4-NCC_6H_4).

Experimental Section

General Procedure for the Preparation of 5-Amino-α-(*N*-alkyl/arylcarbamoyl)imino-1*H*-imidazole-4-acetonitriles (2). A suspension of **1** in dry MeCN was stirred at 0 °C under an N_2 atmosphere. After 10 min, the isocyanate (1.5−5.0 equiv) was added. The mixture was stirred under the conditions described in Table 1. The reaction was followed by TLC. When the starting material was consumed, the yellow/orange product was isolated by filtration and washed with MeCN and cold Et_2O.

5-Amino-α-(*N*-benzylcarbamoyl)imino-1-(2′-hydroxyethyl)-1*H*-imidazole-4-acetonitrile (2a): 93% yield (2.66 mmol); dec above 167 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 8.33 (t, 1H, J = 6.0 Hz), 7.75 (brs, 2H), 7.34 (s, 1H), 7.27−7.33 (m, 5H), 5.05 (brs, 1H), 4.35 (d, 2H, J = 6.0 Hz), 3.93 (t, 2H, J = 5.0 Hz), 3.61−3.65 (m, 2H); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 160.7, 149.0, 139.6, 136.4, 136.1, 128.4, 127.4, 126.9, 119.5, 112.3, 58.9, 45.6, 43.5; IR (Nujol mull) 2240 (w, CN), 1630 (s, C═O); MS (FAB) m/z (rel int) 313 (M + 1, 30); HRMS (FAB) m/z calcd for $C_{15}H_{16}N_6O_2$ 313.1413, found 313.1414.

5-Amino-α-(*N*-benzylcarbamoyl)imino-1*H*-imidazole-1-(4′-methoxyphenyl)-4-acetonitrile (2b): 71% yield (1.47 mmol); mp 223−225 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 8.51 (t, 1H, J = 6.0 Hz), 7.68 (brs, 2H), 7.49 (s, 1H), 7.43 (d, 2H, J = 9.0 Hz), 7.27−7,33 (m, 5H), 7.13 (d, 2H, J = 9.0 Hz), 4.35 (d, 2H, J = 6.0 Hz), 3.82 (s, 3H); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 160.6, 159.6, 148.5, 139.5, 136.5, 135.6, 128.3, 127.4, 127.0, 126.8, 125.9, 119.0, 115.1, 112.3, 55.6, 43.4; IR (Nujol mull) 2223 (w, CN), 1653 (s, C═O); MS (FAB) m/z (rel int) 375 (M + 1, 100); HRMS (FAB) m/z calcd for $C_{20}H_{18}N_6O_2$ 375.1569, found 375.1553.

5-Amino-α-(*N*-ethylcarbamoyl)imino-1-(2′-ethylcarbamoyloxyethyl)-1*H*-imidazole-4-acetonitrile (2c): 6% yield (0.16 mmol); mp 209−210 °C dec; ^{1}H NMR (DMSO-d_6, 300 MHz)) δ 7.88 (t, 1H, J = 5.0 Hz), 7.73 (brs, 2H), 7.29 (s, 1H), 7.21 (t, 1H, J = 5.0 Hz), 4.16 (t, 2H, J = 5.0 Hz), 4.11 (t, 2H, J = 5.0 Hz), 3.11 (qui, 2H, J = 7.0 Hz), 2.95 (qui, 2H, J = 7.0 Hz), 1.08 (t, 3H, J = 7.0 Hz), 0.97 (t, 3H, J = 7.0 Hz); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 160.3, 155.5, 148.3, 136.0, 135.7, 118.9, 112.3, 58.6, 45.6, 35.1, 34.5, 15.0, 14.9; IR (Nujol mull) 2200 (w, CN), 1736 (s, C═O), 1633 (s, C═O). Anal. Calcd for $C_{13}H_{19}N_7O_3 \cdot H_2O$: C, 46.02; H, 5.61; N, 28.91. Found: C, 45.67; H, 5.88; N, 29.11.

5-Amino-α-(*N*-ethylcarbamoyl)imino)-1*H*-imidazole-1-(4′-methoxyphenyl)-4-acetonitrile (2d): 76% yield (1.57 mmol); mp 209−210 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 7.99 (t, 1H, J = 5.0 Hz), 7.56 (brs, 2H), 7.47 (s, 1H), 7.46 (d, 2H, J = 9.0 Hz), 7.13 (d, 2H, J = 9.0 Hz), 3.82 (s, 3H), 3.17 (q, 2H, J = 7.0 Hz), 1.08 (t, 3H, J = 7.0 Hz); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 160.2, 159.6, 148.2, 136.3, 135.3, 127.2, 125.9, 118.6, 115.1, 112.3, 55.6, 34.5, 14.8; IR (Nujol mull) 2200 (w, CN), 1652 (s, C═O); MS (EI) m/z (rel int) 312 (M^+, 18). Anal. Calcd for $C_{15}H_{16}N_6O_2$: C, 57.69; H, 5.13; N, 26.92. Found: C, 57.69; H, 5.40; N, 26.73.

5-Amino-α-(*N*-butylcarbamoyl)imino-1*H*-imidazole-1-(4′-methoxyphenyl)-4-acetonitrile (2e): 81% yield (1.44 mmol); mp 205−206 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 7.98 (t, 1H, J = 5.0 Hz), 7.56 (brs, 2H), 7.47 (s, 1H), 7.43 (d, 2H, J = 9.0 Hz), 7.14 (d, 2H, J = 9.0 Hz), 3.82 (s, 3H), 3.12 (q, 2H, J = 7.0 Hz), 1.45 (qui, 2H, J = 7.0 Hz), 1.28 (sex, 2H, J = 7.0 Hz), 0.88 (t, 3H, J = 7.0 Hz); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 160.4, 159.6, 148.1, 136.3, 135.3, 127.2, 125.9, 118.6, 115.1, 112.3, 55.6, 39.4, 31.4, 19.7, 13.7; IR (Nujol mull) 2227 (w, CN), 1645 (s, C═O); MS (FAB) m/z (rel int) 341 (M + 1, 93). Calcd for $C_{17}H_{20}N_6O_2$: C, 60.00; H, 5.88; N, 24.71. Found: C, 60.03; H, 5.94; N, 24.64.

5-Amino-1-(2′-hydroxyethyl)-α-(*N*-phenylcarbamoyl)-imino-1*H*-imidazole-4-acetonitrile (2f): 66% yield (1.84 mmol); mp 187−191 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 9.98 (s, 1H), 8.05 (brs, 2H), 7.63 (d, 2H, J = 8.0 Hz), 7.40 (s, 1H), 7.31 (t, 2H, J = 8.0 Hz), 7.01 (t, 1H, J = 8.0 Hz), 5.10 (brs, 1H), 3.97 (t, 2H, J = 5.0 Hz), 3.66 (brs, 2H); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 158.5, 150.0, 139.7, 137.4, 135.9, 128.9, 122.6, 120.7, 118.3, 112.7, 58.8, 45.6; IR (Nujol mull) 2222 (w, CN), 1660 (s, C═O); MS (FAB) m/z (rel int) 299 (M + 1, 100); HRMS (FAB) m/z calcd for $C_{14}H_{14}N_6O_2$ 299.1256, found 299.1254.

5-Amino-α-[*N*-(4′-trifluoromethylphenyl)carbamoyl]-imino-1-(2′-hydroxyethyl)-1*H*-imidazole-4-acetonitrile (2h): 100% yield (3.90 mmol); mp 243−246 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 10.27 (s, 1H), 8.19 (brs, 2H), 7.83 (d, 2H, J = 9.0 Hz), 7.66 (d, 2H, J = 9.0 Hz), 7.44 (s, 1H), 5.10 (brs, 1H), 3.95−4.00 (m, 2H), 3.67 (brs, 2H); ^{13}C NMR (DMSO-d_6, 75 MHz) δ

158.8, 150.7, 143.4, 138.1, 136.1, 126.3 (q, J = 3.6 Hz), 124.5 (q, J = 270.0 Hz), 122.4, (q, J = 32.0 Hz), 121.5, 118.1, 112.6, 58.8, 45.7; IR (Nujol mull) 2254 (w, CN), 1647 (s, C═O); MS (FAB) *m*/*z* (rel int) 367 (M + 1, 93); HRMS (FAB) *m*/*z* calcd for $C_{15}H_{13}N_6O_2F_3$ 367.1130, found 367.1116.

5-Amino-α-[*N*-(4′-trifluoromethylphenyl)carbamoyl]-imino-1*H*-imidazole1-(4′-methoxyphenyl)-4-acetonitrile (2i): 100% yield (2.57 mmol); mp 270−274 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 10.43 (s, 1H), 8.20 (brs, 2H), 7.83 (d, 2H, J = 9.0 Hz), 7.67 (d, 2H, J = 9.0 Hz), 7.47 (d, 2H, J = 9.0 Hz), 7.44 (s, 1H), 7.16 (d, 2H, J = 9.0 Hz), 3.82 (s, 3H); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 159.8, 158.6, 150.1, 143.3, 137.2, 136.6, 127.4, 126.1 (q, J = 3.7 Hz), 125.6, 124.5 (q, J = 270.0 Hz), 122.3 (q, J = 32.0 Hz), 120.8, 118.3, 115.2, 112.5, 55.6; IR (Nujol mull) 2234 (w, CN), 1667 (s, C═O); MS (EI, 70 eV) *m*/*z* (rel int) 428 (M^+, 40). Anal. Calcd for $C_{20}H_{15}N_6O_2F_3$: C, 56.06; H, 3.74; N, 19.62. Found: C, 56.08; H, 3.70; N, 19.44.

α-(*N*-Allylcarbamoyl)imino-5-amino-1-(2′-hydroxyethyl)-1*H*-imidazole-4-acetonitrile (2j): 24% yield (0.61 mmol); mp 148−150 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 8.01 (t, 1H, J = 6.0 Hz), 7.74 (brs, 2H), 7.32 (s, 1H), 5.87 (ddt, 1H, J = 17.4, 10.2, 5.1 Hz), 5.18 (dd, 1H, J = 17.4, 1.8 Hz), 5.09 (dd, 1H, J = 10.2, 1.8 Hz), 5.05 (brs, 1H) 3.93 (t, 2H, J = 5.0 Hz), 3.77 (t, 2H, J = 6.0 Hz), 3.63 (brs, 2H); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 160.5, 148.9, 136.3, 135.5, 132.9, 119.8, 115.4, 112.4, 58.8, 45.5, 42.2; IR (Nujol mull) 2219 (w, CN), 1640 (s, C═O); MS (FAB) *m*/*z* (rel int) 263 (M+1, 100); HRMS (FAB) *m*/*z* calcd for $C_{11}H_{14}N_6O_2$ 263.1256, found 263.1262. Anal. Calcd for $C_{11}H_{14}N_6O_2 \cdot 0.25\ H_2O$: C, 49.53; H, 5.44; N, 31.52. Found: C, 49.38; H, 5.28; N, 31.33.

α-(*N*-Allylcarbamoyl)imino-5-amino-1*H*-imidazole-1-(4′-methoxyphenyl)-4-acetonitrile (2k): 61% yield (1.11 mmol); mp 202−204 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 8.17 (t, 1H, J = 6.0 Hz), 7.63 (brs, 2H), 7.48 (s, 1H), 7.44 (d, 2H, J = 9.0 Hz), 7.14 (d, 2H, J = 9.0 Hz), 5.87 (ddt, 1H, J = 17.1, 10.5, 5.4 Hz), 5.19 (dd, 1H, J = 17.1, 1.8 Hz), 5.10 (dd, 1H, J = 10.5, 1.8 Hz), 3.83 (s, 3H), 3.78 (t, 2H, J = 6.0 Hz); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 160.3, 159.6, 148.4, 136.4, 135.4, 132.8, 127.2, 125.9, 118.8, 115.4, 115.3, 112.3, 55.6, 42.1; IR (Nujol mull) 2234 (w, CN), 1660 (s, C═O); MS (FAB) *m*/*z* (rel int) 325 (M + 1, 100). Anal. Calcd for $C_{16}H_{16}N_6O_2$: C, 59.26; H, 4.94; N, 25.93. Found: C, 59.46; H, 5.07; N, 25.75.

General Procedure for the Preparation of 5′-Amino-5-imino-4,4′-bi-1*H*-imidazol-2-ones (3). At 23 °C, a suspension of the imidazole **2** in MeCN was stirred. Addition of DBU (0.03−1.0 molar equiv) caused an immediate color change, and a yellow solid gradually precipitated. Stirring was continued according to the conditions given in Table 1. Filtration and washing of the residue with MeCN/Et_2O afforded the pure products.

5′-Amino-1-benzyl-1′-(2-hydroxyethyl)-5-imino-4,4′-bi-1*H*-imidazol-2-one (3a): 60% yield (0.06 mmol); dec 182−201 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 9.77 (s, 1H), 7.57 (s, 1H), 6.60−7.40 (brs, 2H), 7.20−7.30 (m, 5H), 4.70 (s, 2H), 3.97 (t, 2H, J = 5.0 Hz), 3.64 (t, 2H, J = 5.0 Hz); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 166.8, 159.7, 156.8, 152.4, 139.8, 137.7, 128.4, 127.2, 127.0, 113.9, 58.8, 45.8, 41.6; IR (Nujol mull) 1708 (s, C═O), 1650 (s); MS (EI, 70 eV) *m*/*z* (rel int) 312 (M^+, 16). Anal. Calcd for $C_{15}H_{16}N_6O_2$: C, 57.66; H, 5.13; N, 26.38. Found: C, 57.73; H, 5.34; N, 26.91.

5′-Amino-1-benzyl-5-imino-1′-(4-methoxyphenyl)-4,4′-bi-1*H*-imidazol-2-one (3b): 88% yield (0.83 mmol); mp 236−237 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 9.80 (brs, 1H), 7.60−7.80 (brs, 2H), 7.80 (s,1H) 7.47 (d, 2H, J = 9.0 Hz), 7.20−7.30 (m, 5H), 7.14 (d, 2H, J = 9.0 Hz), 4.73 (s, 2H), 3.82 (s, 3H); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 166.6, 159.8, 159.5, 157.4, 151.9, 139.0, 137.6, 128.4, 127.3, 127.2, 127.1, 125.6, 115.2, 113.5, 55.7, 41.7; IR (Nujol mull) 1714 (s, C═O), 1651 (s); MS (EI, 70 eV) *m*/*z* (rel int) 374 (M^+, 25). Anal. Calcd for $C_{20}H_{18}N_6O_2$: C, 64.17; H, 4.81; N, 22.46. Found: C, 64.07; H, 5.01; N, 22.13.

5′-Amino-1-ethyl-5-imino-1′-(4-methoxyphenyl)-4,4′-bi-1*H*-imidazol-2-ones (3d): 81% yield (0.26 mmol); mp 239−242 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 9.60 (brs, 1H), 7.83 (s, 1H), 7.47 (d, 2H, J = 9.0 Hz), 7.40 (brs, 2H), 7.17 (d, 2H J = 9.0 Hz), 3.83 (s, 3H), 3.60 (brs, 2H), 1.13 (brs, 3H); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 166.1, 160.4, 159.4, 157.3, 151.9, 139.4, 127.3, 125.5, 115.2, 113.2, 55.7, 33.7, 13.1; IR (Nujol mull) 1708 (s, C═O), 1651 (s); MS (EI, 70 eV) *m*/*z* (rel int) 312 (M^+, 29). Anal. Calcd for $C_{15}H_{16}N_6O_2$: C, 57.69; H, 5.13; N, 26.92. Found: C, 57.99; H, 5.33; N, 26.83.

5′-Amino-1-butyl-5-imino-1′-(4-methoxyphenyl)-4,4′-bi-1*H*-imidazol-2-one (3e): 85% yield (1.03 mmol); mp 211−213 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 9.76 (brs, 1H), 7.76 (s, 1H), 7.65 (brs, 2H), 7.47 (d, 2H, J = 9.0 Hz), 7.14 (d, 2H, J = 9.0 Hz), 3.82 (s, 3H), 3.53 (t, 2H, J = 7.0 Hz), 1.56 (qui, 2H, J = 7.0 Hz), 1.26 (sex, 2H, J = 7.0 Hz), 0.88 (t, 3H, J = 7.0 Hz); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 166.7, 159.8, 159.7, 157.5, 151.5, 138.6, 127.2, 125.6, 115.1, 113.7, 55.6, 38.0, 29.5, 19.4, 13.6; IR (Nujol mull) 1708 (s, C═O), 1652 (s). Anal. Calcd for $C_{17}H_{20}N_6O_2$: C, 60.00; H, 5.88; N, 24.70. Found: C, 60.14; H, 6.00; N, 24.67.

5′-Amino-1′-(2-hydroxyethyl)-5-imino-1-phenyl-4,4′-bi-1*H*-imidazol-2-one (3f): 90% yield (0.27 mmol); mp 180−181 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 10.06 (s, 1H), 7.95 (brs, 2H), 7.61 (s, 1H), 7.46 (m, 4H), 7.32 (m, 1H), 5.10 (brs, 1H), 3.99 (t, 2H, J = 5.0 Hz), 3.65 (t, 2H, J = 5.0 Hz); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 165.6, 159.7, 156.5, 152.3, 140.1, 134.0, 128.5, 126.6, 113.9, 58.8, 45.8; IR (Nujol mull) 1708 (s, C═O), 1644 (s); MS (FAB) *m*/*z* (rel int) 299 (M + 1, 100). Anal. Calcd for $C_{14}H_{14}N_6O_2$: C, 56.34; H, 4.70; N, 28.19. Found: C, 56.55; H, 4.88; N, 27.97.

5′-Amino-5-imino-1′-(4-methoxyphenyl)-1-phenyl-4,4′-bi-1*H*-imidazol-2-one (3g): 95% yield (1.97 mmol); mp 219−221 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 10.08 (s, 1H), 7.90 (brs, 2H), 7.82 (s, 1H), 7.47 (m, 4H), 7.43 (d, 2H, J = 9.0 Hz), 7.32 (m, 1H), 7.13 (d, 2H, J = 9.0 Hz), 3.82 (s, 3H); the sample was not soluble enough in DMSO-d_6 for ^{13}C NMR; IR (Nujol mull) 1717 (s, C═O), 1655 (s); MS (FAB) *m*/*z* (rel int) 361 (M + 1, 9). Anal. Calcd for $C_{19}H_{16}N_6O_2$: C, 63.33; H, 4.44; N, 23.33. Found: C, 63.49; H, 4.61; N, 23.34.

5′-Amino-1′-(2-hydroxyethyl)-1-(4-trifluoromethylphenyl)-5-imino-4,4′-bi-1*H*-imidazol-2-one (3h): 76% yield (2.13 mmol); mp 247−250 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 10.21 (s, 1H), 8.00 (brs, 2H), 7.82 (s, 4H), 7.64 (s, 1H), 5.10 (brs, 1H), 4.00 (t, 2H J = 5.0 Hz), 3.65 (t, 2H, J = 5.0 Hz); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 165.0, 159.1, 156.2, 152.9, 140.4, 137.8, 126.27, 126.30 (q, J = 32.0 Hz), 125.5 (q, J = 3.7 Hz), 124.2 (q, J = 272.0 Hz), 114.2, 58.8, 45.9; IR (Nujol mull) 1709 (s, C═O), 1650 (s). Anal. Calcd for $C_{15}H_{13}N_6O_2F_3 \cdot 0.5H_2O$: C, 48.00; H, 3.73; N, 22.40. Found: C, 47.81; H, 3.66; N, 22.18.

5′-Amino-1-(4-trifluoromethylphenyl)-5-imino-1′-(4-methoxyphenyl)-4,4′-bi-1*H*-imidazol-2-one (3i): 83% yield (0.19 mmol); mp 292−294 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 10.23 (s, 1H), 7.90 (brs, 2H), 7.86 (s, 1H), 7.84 (s, 4H), 7.50 (d, 2H, J = 9.0 Hz), 7.16 (d, 2H, J = 9.0 Hz), 3.83 (s, 3H); the sample was not soluble enough in DMSO-d_6 for ^{13}C NMR; IR (Nujol mull) 1714 (s, C═O), 1652 (s); MS (EI, 70 eV) *m*/*z* (rel int) 428 (M^+, 5). Anal. Calcd for $C_{20}H_{15}N_6O_2F_3$: C, 56.06; H, 3.74; N, 19.62. Found: C, 56.10; H, 3.73; N, 19.59.

1-Allyl-5′-amino-1′-(2-hydroxyethyl)-5-imino-4,4′-bi-1*H*-imidazol-2-ones (3j): 27% yield (0.04 mmol); mp 187−190 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 9.65 (s, 1H), 7.54 (s, 1H), 7.20−6.80 (brs, 2H), 5.82 (ddt, 1H, J = 17.5, 10.5, 5.0 Hz), 5.06 (dd, 1H, J = 10.5, 1.5 Hz), 5.00 (dd, 1H, J = 17.5, 1.5 Hz), 3.93 (t, 2H, J = 5.0 Hz), 3.77 (t, 2H, J = 6.0 Hz), 3.62 (t, 2H, J = 5.0 Hz); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 166.6, 159.4, 157.0, 152.2, 139.7, 132.9, 115.4, 113.7, 58.9, 45.8, 40.3; IR (Nujol mull) 1711 (s, C═O), 1638 (s).

1-Allyl-5′-amino-5-imino-1′-(4-methoxyphenyl)-4,4′-bi-1*H*-imidazol-2-one (3k): 92% yield (0.43 mmol); mp 235−238

°C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 9.78 (s, 1H), 7.77 (s, 1H), 7.70 (brs, 2H), 7.47 (d, 2H, J = 9.0 Hz), 7.14 (d, 2H, J = 9.0 Hz), 5.85 (ddt, 1H, J = 17.1, 10.8, 5.1 Hz), 5.08 (dd, 1H, J = 10.8, 1.2 Hz), 5.03 (dd, 1H, J = 17.1, 1.2 Hz), 4.14 (d, 2H, J = 5.1 Hz), 3.83 (s, 3H); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 166.3, 159.8, 159.2, 157.4, 151.7, 138.8, 132.8, 127.2, 125.6, 115.8, 115.2, 113.3, 55.6, 40.4; IR (Nujol mull) 1711 (s, C═O), 1651 (s). Anal. Calcd for $C_{16}H_{16}N_6O_2$: C, 59.26; H, 4.94; N, 25.93. Found: C, 59.39; H, 5.06; N, 25.73.

Reaction of (*Z*)-*N*-(2-Amino-1,2-dicyanovinyl)-*N*′-(4′-methoxyphenyl)formamidine 6b with Benzyl Isocyanate. Method A. A suspension of **6b** (0.50 g, 2.07 mmol) in MeCN (5 mL) was stirred at 0 °C, under N_2. Benzyl isocyanate (0.59 g, 0.55 mL, 4.45 mmol) was added, and the mixture was stirred at 0 °C for 5 min and then allowed to reach room temperature. The green solution turned brown and then black, and after 5 min a white solid started to develop. The mixture was stirred at room temperature for a further 1 h, when the solid was filtered and washed with MeCN and Et_2O. The product was identified as formamidine **7b** (0.36 g, 0.96 mmol, 47%): mp 130−133 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 8.46 (s, 1H), 8.31 (t, 1H, J = 6.0 Hz), 8.00 (brs, 2H), 7.20−7.40 (m, 5H), 7.01 (d, 2H, J = 9.0 Hz), 6.88 (d, 2H, J = 9.0 Hz), 4.36 (d, 2H, J = 6.0 Hz), 3.73 (s, 3H); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 157.3, 153.4, 146.9, 143.7, 140.4, 133.5, 129.2, 129.1, 127.9, 127.8, 118.4, 115.2, 114.7, 86.7, 56.3, 44.4; IR (Nujol mull) 2195 (m, CN), 1676 (s, C═O); MS (EI, 70 eV) *m*/*z* (rel int) 374 (M^+, 20). Anal. Calcd for $C_{20}H_{18}N_6O_2$: C, 64.17; H, 4.81; N, 22.46. Found: C, 64.50; H, 5.03; N, 22.29. The mother liquor was stirred at 23 °C for another 18 h leading to a yellow solid that was filtered, washed with MeCN and Et_2O and identified as formamidine **8b** (0.04 g, 0.12 mmol, 6%): mp 211−213 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) for **8bA** δ 10.50 (brs, 1H), 8.50 (m, 1H), 8.30 (brs, 1H), 7.23−7.37 (m, 5H), 7.22 (d, 2H, J = 8.0 Hz), 7.20−7.40 (brs, 1H), 6.93 (d, 2H, J = 8.0 Hz), 4.31 (brs, 2H), 3.72 (s, 3H); for **8bB** δ 10.30 (brs, 1H), 8.30 (m, 1H), 7.90 (brs, 1H), 7.71 (d, 2H, J = 8.0 Hz), 7.50 (brs, 1H), 7.23−7.37 (m, 5H), 6.92 (d, 2H, J = 8.0 Hz), 4.31 (brs, 2H), 3.72 (s, 3H); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 157.3 (**8bA**), 156.8 (**8bB**), 153.4, 150.9 (**8bB**), 149.0 (**8bA**), 140.6, 136.0 (**8bA**), 132.6 (**8bB**), 129.5, 129.4, 128.4, 128.1, 122.5 (**8bB**), 120.1 (**8bA**), 118.0, 115.8 (**8bA**), 115.7, 115.2 (**8bB**), 109.0, 56.3, 44.0; IR (Nujol mull) 2217 (m, CN), 1650 (s, C═O); MS (EI, 70 eV) *m*/*z* (rel int) 374 (M^+, 20). Anal. Calcd for $C_{20}H_{18}N_6O_2$: C, 64.17; H, 4.81; N, 22.46. Found: C, 64.45; H, 5.00; N, 22.14.

Method B. A suspension of formamidine **6b** (0.55 g, 2.28 mmol) in MeCN (5 mL) was stirred at −15 °C (Cardice/ethyleneglycol bath), under N_2, and after 5 min, benzyl isocyanate (0.40 g, 0.37 mL, 3.00 mmol) was added. The reaction mixture was stirred at −15 °C for 2 h, when TLC indicated that the starting material was still present. The reaction mixture was allowed to stand at −18 °C for a further 2 days. MeCN (3 mL) was than added to the thick suspension, which was filtered and washed with MeCN and Et_2O. The white solid was identified as formamidine **7b** (0.85 g, 2.27 mmol, 100%).

Preparation of (*Z*)-*N*-(2-Benzylureido-1,2-dicyanovinyl)-*N*′-(4′-methoxyphenyl)formamidine (8b). A solution of formamidine **7b** (0.20 g, 0.53 mmol) in MeCN (10 mL) was stirred at 23 °C under N_2. After 18 h, the yellow solid was filtered and washed with MeCN and Et_2O. The product was identified as the title compound (0.12 g, 0.32 mmol, 60%).

Cyclization of (*Z*)-*N*-(2-Benzylureido-1,2-dicyanovinyl)-*N*′-(4′-methoxyphenyl)formamidine (8b). A solution of formamidine **8b** (0.02 g, 0.05 mmol) in MeCN (1 mL) was stirred at 23 °C. DBU (0.04 g, 0.03 mmol) was added, and the mixture was stirred for 30 min. The orange solid was filtered and washed with MeCN and Et_2O. The product was identified as imidazole **3b** (0.02 g, 0.05 mmol, 100%).

Reaction of (*Z*)-*N*-(2-Amino-1,2-dicyanovinyl)-*N*′-(4′-cyanophenyl)formamidine 6c with Benzyl Isocyanate. A suspension of formamidine **6c** (0.22 g, 0.93 mmol) in MeCN (6 mL) was kept stirring at 0 °C, under N_2, before the addition of benzyl isocyanate (0.18 g, 0.17 mL, 1.35 mmol). The mixture was stirred at −4 °C for 3 days and then at −18 °C for 18 h. The solid was filtered and washed with MeCN, $MeCO_2Et$ and Et_2O. Dry flash chromatography on the mother liquor led to the isolation of the same product. The various crops were combined and identified as urea **9** (0.13 g, 0.55 mmol, 59%); dec above 173 °C (lit.[5] dec above 173 °C); IR (Nujol mull) 2249 (w, CN), 2205 (s, CN) 1644 (s, C═O).

Representative Procedure for the Reaction of (*Z*)-*N*-(2-Amino-1,2-dicyanovinyl)-*N*′-(2′-hydroxyethyl)formamidine 6a with Benzyl Isocyanate. Method A. A suspension of formamidine **6a** (0.42 g, 2.35 mmol) in MeCN (5 mL) was stirred at 0 °C under N_2, and after 5 min, benzyl isocyanate (0.73 g, 0.68 mL, 5.48 mmol) was added. The mixture was stirred at 4 °C for 5 h and was then allowed to stand at −18 °C for 18 h. The off-white solid was filtered and washed with MeCN and Et_2O. The product was identified as formamidine **10a** (0.18 g, 0.40 mmol, 17%): mp 164−165 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 8.76 (s, 1H), 8.53 (brs, 1H), 8.31 (t, 1H, J = 6.0 Hz), 7.71 (t, 1H, J = 5.7 Hz), 7.20−7.40 (m, 10H), 5.15 (t, 1H, J = 4.8 Hz), 4.38 (d, 2H, J = 5.4 Hz), 4.31 (d, 2H, J = 5.7 Hz), 4.04 (t, 2H, J = 5.0 Hz), 3.58 (dt, 2H, J = 5.1 Hz, J = 4.5 Hz); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 154.6, 152.2, 151.8, 139.0, 138.9, 128.5, 128.3, 127.6, 127.2, 127.0, 126.9, 114.4, 113.8, 113.1, 112.7, 58.5, 45.2, 43.9, 43.1; IR (Nujol mull) 2220 (m, CN), 1681 (s, C═O), 1649 (s, C═O). Anal. Calcd for $C_{23}H_{23}N_7O_3$: C, 62.02; H, 5.17; N, 22.02. Found: C, 61.78; H, 5.44; N, 21.87. The mother liquor was concentrated in the rotary evaporator, and the solid isolated was identified as the urea **9** (0.03 g, 0.12 mmol, 5%).

Note: Several reactions were carried out where the ratio of amidine **6a**:benzylisocyanate was varied from 1:1.3 to 1:2.6, and the reaction conditions (temperature and reaction time) were also varied according to Table 3.

Method B. A suspension of amidine **6a** (0.35 g, 1.95 mmol) in MeCN (4 mL) was stirred at −4 °C under N_2 before the addition of benzyl isocyanate (0.69 g, 0.64 mL, 5.18 mmol) and stirring the mixture at −4 °C for 1 h. The dark solution was than allowed to stand at −18 °C for 8 days. Acetic acid (0.01 g, 0.01 mL, 0.17 mmol) was added to the reaction medium, and the suspension was filtered and washed with Et_2O. The product was identified as 2-[2-(3-benzylureido)-1,2-dicyanovinylamino]-oxazolidine-3-carboxylic acid benzylamide **11** (0.11 g, 0.25 mmol, 13%): mp 132−133 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 8.04 (s, 1H), 7.70 (d, 1H, J = 6.9 Hz), 7.20−7.30 (m, 10H), 7.00 (t, 1H, J = 6.0 Hz), 6.17 (d, 1H, J = 6.6 Hz), 4.24 (d, 2 × 2H, J = 5.1 Hz), 3.54 (m, 1H), 3.44 (m, 1H); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 154.9, 153.8, 140.3, 139.7, 128.3, 128.2, 127.2, 127.1, 126.8, 126.6, 119.4, 115.7, 113.2, 98.2, 92.3, 64.6, 44.3, 43.1; IR (Nujol mull) 2225 (m, CN), 1706 (s, C═O), 1640 (s, C═O). Anal. Calcd for $C_{23}H_{23}N_7O_3 \cdot 0.5H_2O$: C, 60.79; H, 5.29; N, 21.59. Found: C, 61.05; H, 5.11; N, 22.02. The solid isolated from the mother liquor after concentration on the rotary evaporator was identified as the urea **9** (0.13 g, 0.56 mmol, 29%).

Reaction of (*Z*)-*N*-(2-Amino-1,2-dicyanovinyl)-*N*′-(2′-methoxyethyl)formamidine 6d with Benzyl Isocyanate. A suspension of formamidine **6d** (0.35 g, 1.82 mmol) in MeCN (4 mL) was stirred at 0 °C under N_2. Benzyl isocyanate (0.73 g, 0.68 mL, 5.50 mmol) was added, and the mixture was stirred at 0 °C for 2 h, followed by 4 days at −18 °C. After this time, extensive darkening of the reaction mixture had occurred. Dry flash chromatography on the reaction mixture using Et_2O as

(5) Booth, B. L.; Dias, A. M.; Proença M. F.; Zaki, M. *J. Org. Chem.* **2001**, *66*, 8436.

eluant led to the isolation of compound **10d** (0.03 g, 0.06 mmol, 3%): mp 151−152 °C; ^{1}H NMR (DMSO-d_6, 300 MHz) δ 8.73 (s, 1H), 8.55 (brs, 1H), 8.32 (t, 1H, J = 6.0 Hz), 7.70 (t, 1H, J = 5.5 Hz), 7.20−7.40 (m, 10H), 4.37 (d, 2H, J = 5.4 Hz), 4.31 (d, 2H, J = 5.4 Hz), 4.12 (t, 2H, J = 5.4 Hz), 3.48 (t, 2H, J = 5.5 Hz), 3.20 (s, 3H); ^{13}C NMR (DMSO-d_6, 75 MHz) δ 154.2, 152.0, 151.7, 139.0, 138.9, 128.5, 128.3, 128.2, 127.2, 127.1, 127.0, 114.3, 113.7, 113.0, 112.8, 69.2, 58.2, 43.8, 43.0; IR (Nujol mull) 2217 (m, CN), 1683 (s, C═O), 1656 (s, C═O). Anal. Calcd for $C_{24}H_{25}N_7O_3$: C, 62.75; H, 5.45; N, 21.35. Found: C, 63.10; H, 5.53; N, 21.11. The urea **9** (0.12 g, 0.48 mmol, 26%) was also obtained upon elution with CH_2Cl_2 and $MeCO_2Et$.

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Supporting Information Available: NMR spectra. This material is available free of charge via the Internet at http://pubs.acs.org.

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