Detailed Studies of the Alkylation Sides of Pyridin-2-yl and 4,6-Dimethylpyrimidin-2-yl-cyanamides

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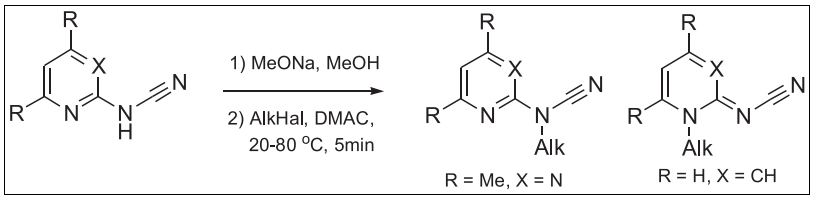

Pyridin-2-yl- and 4,6-dimethylpyrimidin-2-yl-cyanamides entered into an alkylation reaction in the form of sodium salts. Pyridin-2-yl cyanamide **2** was alkylated at endo-nitrogen atom of pyridine ring, while 4,6-dimethylpyrimidin-2-yl cyanamide **1** was effectively alkylated at exo-nitrogen atom of amino cyanamide group. The alkylation of cyanamides **1** and **2** with phenacylbromide gave the corresponding acetophenone derivatives. As a result of their intramolecular cyclization reactions 3-(4,6-dimethylpyrimidin-2-yl)-5-phenyloxazol-2(3*H*)-imine in the case of cyanamide **1** and 2-amino-3-benzoylimidazo[1,2-*a*]pyridine in the case of cyanamide **2** were formed. The alkylated derivatives of pyridin-2-ylcyanamide **2** possess visible blue fluorescence with the main peak at 421 – 427 nm.

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INTRODUCTION

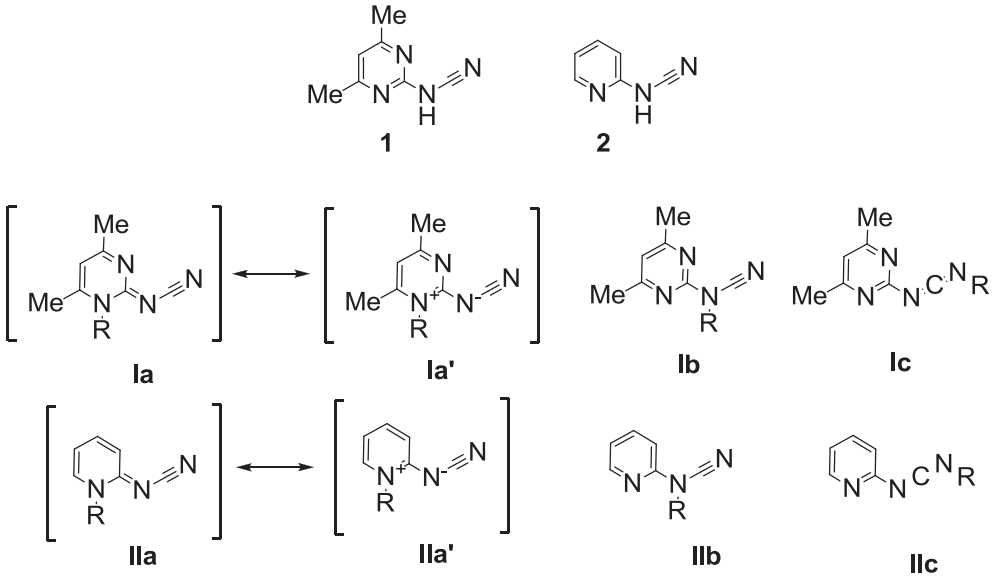
Cyanamide and its derivatives have been applied as building blocks for the synthesis of amidines, guanidines, and nitrogen-containing heterocycles [1]. Compounds of this class have been studied extensively because of their biological activity [2]. Moreover, some of these compounds have been used in the preparation of organometallic compounds [3].

Despite the fact that the reactions of cyanamides have been well previously studied [1], their alkylation was not studied independently, only as intermediate compounds in cyclization reactions. For example, alkylation products of aryl- and hetarylcyanamides with methyl bromoacetate [4], ethyl iodoacetate [5], propargyl bromide [6], or (chloromethyl)thiirane [7] acted as intermediates in the heterocyclization reactions. Triazinylcyanamides were reported to react with a wide range of haloalkanes and halocarboxylic acid derivatives [8]. Also, a series of *N*-alkyl 2-cyanoaminobenzimidazole derivatives were obtained [9]. Stanovnik and co-workers pioneered the methylation of cyanoamino-pyridazines and -pyrazines by using dimethylformamide-dimethylacetal (DMFDMA) [10] and diazomethane [11], respectively. As we were well aware, the alkylation of triazinylcyanamides and cyanoaminopyridazines was carried out at cyanoamino group, but in other cases the reaction proceeded with participation of the heterocyclic moiety. For example, 2-cyanoaminobenzimidazole was alkylated at the two nitrogen atoms of benzimidazole ring [9]. In the case of cyanoaminopyrazines, the alkylation proceeded with the formation of approximately equal amount of *N*-alkyl-*N*-(pyrazin-2-yl)cyanamides and N-1 alkylated pyrazines [11]. Thus, the products of *N*-alkyl hetarylcyanamides depend on the nature of the reaction centers; their reaction preferences require a further study. Herein, we report a facile approach to provide N-alkylation of 4,6-dimethylpyrimidin-2-yl-cyanamide **1** at exo-nitrogen atom cyanoamino group and pyridin-2-yl-cyanamide **2** at endo-nitrogen atom pyridine ring.

RESULTS AND DISCUSSION

Initially, 4,6-dimethylpyrimidin-2-yl-cyanamide **1** and pyridin-2-yl-cyanamide **2** were selected in our work for studying their alkylation (Scheme 1). In a one-pot procedure, the alkylated cyanamide derivatives were obtained in a two-stage process. In the first step, when cyanamides reacted with sodium methoxide (MeONa) in the presence of methanol, their sodium salt was formed. In fact, the acidity of the amino group in cyanamides (cyanamide NH_2CN has an acid pK_a of 7 [12] and cyanamide **1** has an acid pK_a of 6.95 [13]) is significantly higher than pK_a

Scheme 1. The structure of cyanamides **1** and **2,** and possible products of their alkylation.



of 15.5 for methanol. When methanol was evaporated, the resulting sodium salt of cyanamides was dissolved in dimethylacetamide (DMAC) to interact with alkyl halides.

Hetarylcyanamides are known to exist as amino-imine tautomers [14]. The direction of the alkylation of 2-aminopyridine is highly dependent on the position of the tautomeric equilibrium [15]. However, this is true for neutral conditions. In the anions of 2-amino-pyridine and -pyrimidine, both exo-cyclic nitrogen atom of amino cyanamide group and endo-cyclic nitrogen atom of heterocycle are considered potential ambident nucleophiles. Indeed, in our case the cyanamide anion from the sodium salt participated in the reaction, so the formation of *N*-alkyl derivatives of both exo- and endo-cyclic nitrogen atoms could be expected. Consequently, the formation of regioisomers **Ia–c** and **IIa–c** can be expected for alkylation of cyanamides **1** and **2** (Scheme 1). The structures **IIa** and **IIa′**, as well as **Ia** and **Ia′**, correspond to different canonical forms of the same compound; the question of the best representation of such compounds has not yet been resolved.

We have performed quantum chemical calculations of the geometry and electron structure of cyanamide anions (*see* Experimental). The calculations showed that HOMO orbitals in all cyanamides were located in all nitrogen atoms of hetarylcyanamides. In addition, the alkylation of substrate cyanamides has been investigated by means of the calculated molecular electrostatic potentials, which indicate that the negative charges are roughly equally distributed over all nitrogen atoms. Therefore, from these data we cannot give preference to any reaction center. Under thermodynamic control of the reaction, the energy difference between the alkylated products should determine the reaction outcome.

Table 1 shows the calculations for *N*-benzyl of cyanamide derivatives **I** and **II**. In all cases $\Delta E = E_i - E_{min}$, when E_{min} is an energy for the most stable isomer. For cyanamide **1**, isomer **Ib** is more energetically preferable, but the difference in the energies of isomers **Ia** and **Ib** is small. For cyanamide **2**, the isomers **IIa** and **IIc** are energetically favorable, and the formation of alkylated carbodiimide derivatives **Ic** and **IIc** has not been reported for the studied reaction [4–11]. Thus, we can predict that the reaction with **1** in thermodynamic conditions can produce both **Ia** and **Ib**, with **Ib** being slightly more favorable, while the only product of reaction with **2** will be **IIa**. It should be noted that the calculations were carried out without considering the solvent effects, and the substituent effects can affect the outcome.

As it turned out, the 4,6-dimethylpyrimidin-2-ylcyanamide **1** was entirely alkylated at nitrogen atom of amino cyanamide group (Scheme 2), resulting in products of **Ib** type.

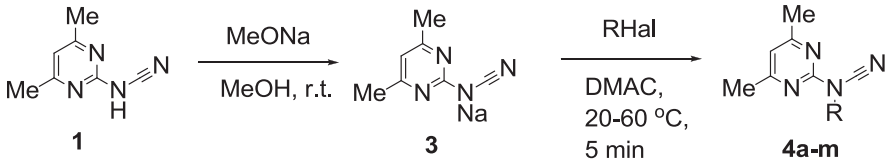
Structure of compound **4** has been confirmed unambiguously by the following data. First, in ^{1}H NMR spectra methyl groups at positions 4 and 6 are represented by one singlet; in ^{13}C NMR carbons at positions 4 and 6 as well as carbons of methyl groups are represented by one signal

Table 1

The difference in the energies of possible alkylated products **I** and **II**, ΔE, kcal/mol (R = benzyl).

	A	B	C
I	2.20	0	3.48
II	0.50	4.73	0

Scheme 2



4a R=Me (41%)
4b R=Et (63%)
4c R=$CH_2C(O)OEt$ (54%)
4d R=Bn (59%)
4e R=4-Me-Bn (69%)
4f R=2-Me-Bn (87%)
4g R=4-Cl-Bn (70%)
4h R=3-Cl-Bn (76%)
4i R=2-Cl-Bn (63%)
4j R=4-Br-Bn (92%)
4k R=3-NO_2-Bn (82%)
4l R=naphthalen-1-ylmethyl (68%)
4m R=CH_2Bz (78%)

and showed magnetic equivalence, unlike those of N-1 or N-3 alkylated cyanamide **Ia**.

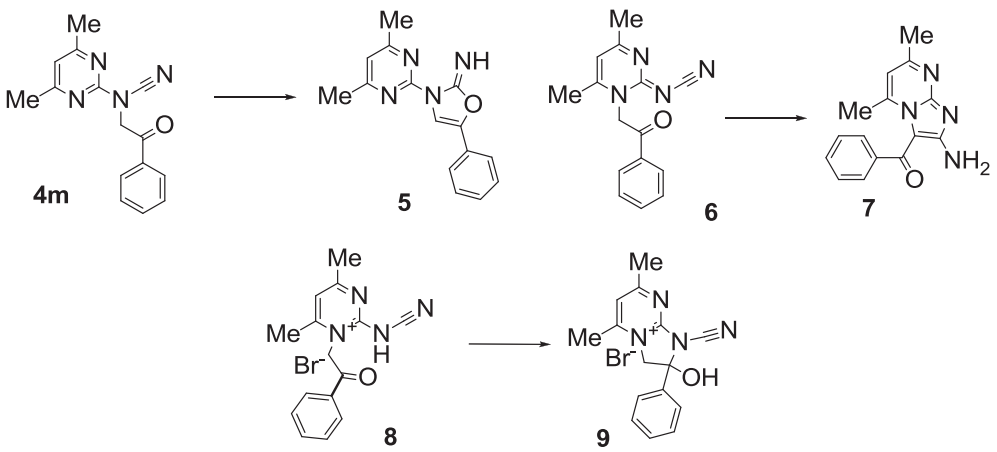
Second, the IR spectra showed that cyano group is represented by an absorption band at 2225–2240 cm^{-1}, which is in excellent agreement with the structure —N(R)—C≡N. The alkylation of endo-cyclic nitrogen atom should lead to the formation of cyanoimino =N—C≡N group, in which an absorption band of cyano group is given at 2150–2190 cm^{-1} [9,16].

Third, melting points of compound **4** do not exceed 150° C, whereas the introduction of alkyl substituents to cyanamide at positions 1 or 3 leads to the formation of the compounds with much higher melting points. Thus, minor 2 (1*H*)cyanoimino-1,4,6-trimethylpyrimidine (**Ia**, R=CH_3) with a melting point 259°C has been isolated along with 2(*N*-methylcyanoamino)-4,6-dimethylpyrimidine **4a** (melting point 107–108°C), when *N*-(4,6-dimethylpyrimidin-2-yl)formamide oxime was treated with DMFDMA [10].

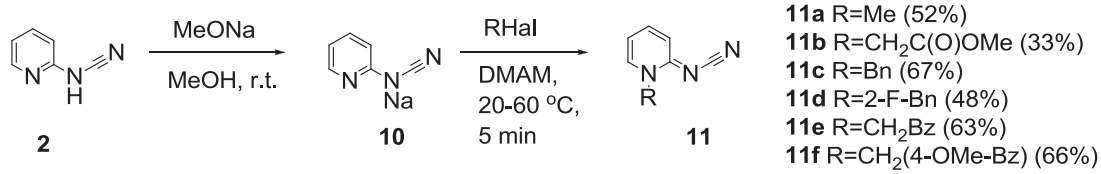
The results of the interaction of cyanamide **1** with phenacylbromide and subsequent intramolecular cyclization of the resulting alkylated cyanamides are the fourth argument which confirms the alkylation of exo-cyclic nitrogen atom. Compounds **5**, **7** (in a basic medium), or **9** (in a neutral medium) [17] may be considered as the results of cyclization for different alkylated cyanamide derivatives **4m**, **6**, and **8**, respectively (Scheme 3). As it turned out, the formation of compound **5** is precisely defined. The presence of magnetically equivalent protons and carbons in ^1H and ^{13}C NMR spectra shows no changes in the pyrimidine cycle structure during its alkylation and cyclization. This would be impossible in the case of compound **7** or **9**. Also, in ^1H NMR spectrum the structure of compound **5** is confirmed by the presence of signals at 8.16 and 8.40 ppm, corresponding to protons of oxazole cycle and imino group, respectively. In IR spectrum an imino group shows the absorption bands at 3290 and 1686 cm^{-1}, corresponding to NH and C=N stretching vibrations. Earlier, compounds **4m** and **5** were prepared by converting the reaction product of 5,7-dimethyl[1,2,4]triazolo[1,5-*a*]pyrimidine with phenacylbromide [18].

A different picture is observed for alkylation of pyridin-2-ylcyanamide **2**. In IR spectra an absorption band for nitrile group is observed at 2150–2170 cm^{-1}, which

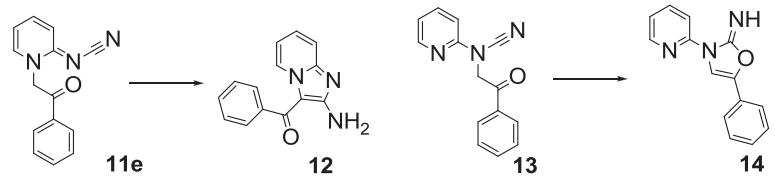
Scheme 3



Scheme 4



Scheme 5



indicates that the triple bond C≡N is conjugated with the double bond C=N to form compound **11** (Scheme 4).

The alkylation of cyanamide **2** with phenacylbromide and treatment of the resulting alkylated derivative with triethylamine led to the formation of fused 2-aminoimidazo[1,2-*a*]pyridine system **12** (Scheme 5) [19]. The results of ^{1}H, ^{13}C NMR, and IR spectroscopy speak in favor of the formation of compounds **11e** and **12**, but not **13** and **14**. Indeed, the ^{1}H NMR spectrum shows a characteristic singlet for NH_2 group at 5.61 ppm; in the ^{13}C NMR spectrum a characteristic signal is observed at 181.9 ppm because of a carbon atom of carbonyl group. In IR spectrum the absorption bands occur at 3300 and 3481 cm^{-1} (symmetric and asymmetric stretching vibrations within —NH_2 group) and 1699 cm^{-1} because of carbonyl group.

X-ray crystallography. View of **4d–f**, **11b,** and **11c** are shown at Figures 1–5, respectively. For other details of structure determination see Experimental. All structures have been deposited with CCDC, refcodes 927772–927774 for **4d,e,f** and 927770, 927771 for **11b,c**. Atoms are represented by thermal displacement ellipsoids (ρ = 50%).

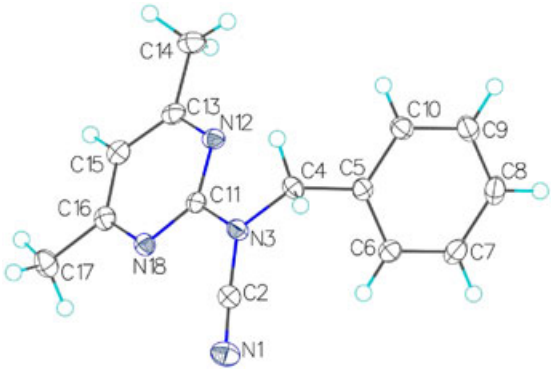


Figure 1. X-ray crystal structure of **4d**. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

The **4e** unit cell contains four independent molecules of **4e**. The geometry of these molecules in the independent part is very similar, differing only slightly in the rotation

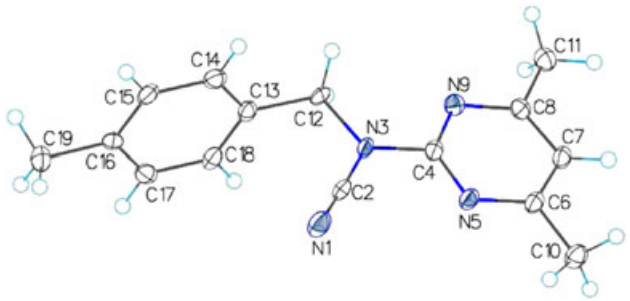


Figure 2. X-ray crystal structure of **4e**. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

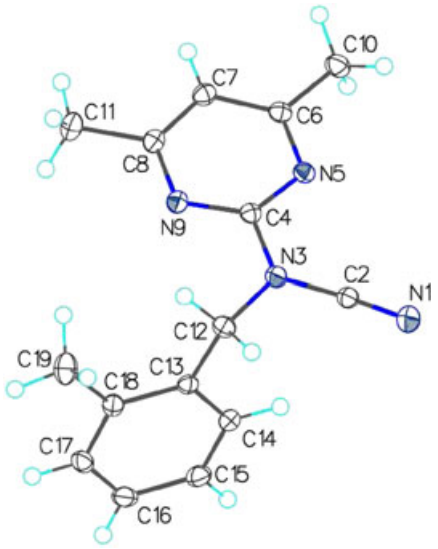


Figure 3. X-ray crystal structure of **4f**. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

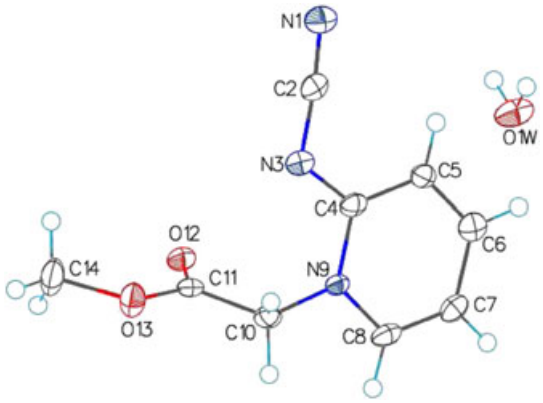


Figure 4. X-ray crystal structure of **11b**. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

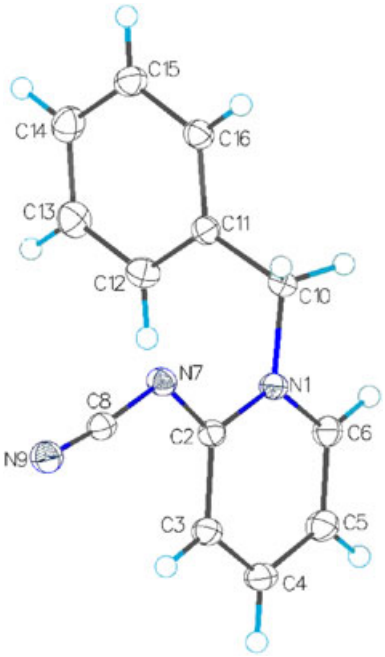


Figure 5. X-ray crystal structure of **11c**. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

of the *p*-tolyl group; an example molecule is shown in Figure 2.

The crystal of **11b** contains one **11b** molecule and one water molecule in independent part (Fig. 4). The water formed a hydrogen bond with N1 atom of the NCN group (N…O 2.865(6) Å, N—H…O 176(3)°), which did not significantly affect the bond length distribution in comparison with **11c** (Fig. 5).

This is the first manuscript to report the crystal structures of pyridines with linear N—C—N substituent (according to Cambridge Structural Database), so we decided to perform a deeper analysis of bond length distribution in these compounds. One can assume two possible canonical structures **IIa** and **IIa′** for the studied fragment (Scheme 1), with the charge separation required for retaining the aromaticity. The comparison of pyridine- and amino-substituted fragments should reveal which representation is more relevant: one can expect little bond redistribution if the pyridinium fragment retains aromaticity (canonical structure **IIa′**).

The bond lengths in heterocyclic and NCN fragments of **4d–f** and **11b, c** are summarized in Table 2. The N1—C2 and C2—N3 bond lengths, corresponding to the N≡C—N fragments, remain remarkably similar between N3- and N9-substituted compounds, indicating that the conjugation with the CN-group is not significantly affected by N-alkylation. Indeed, the most pronounced changes upon moving the substituent from amino group to heterocycle are observed for bonds with C4 atom: N3—C4 bond is shortened, on average, by 0.066 Å, and N9—C4 and C4—N5(C5) are elongated significantly more than one can expect upon change from pyridinium to pyrimidine fragment. The bond redistribution pattern thus is consistent with canonical structure **IIa**. The bond length within the aromatic ring, with equal C8—N9 and N9—C4 bond lengths, also supports the representation **IIa**. This result is in agreement with UV spectroscopy studies, which indicate that the studied system is different from both pyridine and 2-aminopyridine.

The resulting alkylated cyanamides **4** and **11** have characteristic ultraviolet absorption spectra, which consist of low-intensity long-wavelength band and high-intensity short-wavelength band. The positions of the absorption bands-maxima for compounds **4** and **11** are different: in the case of compound **11** they are longer waves shifted (Table 3). We can suppose that the substituted heterocyclic moiety of these compounds is responsible for observed long-wavelength absorption band [20], and acetophenone fragment—for the shoulder maximum in the spectrum of compounds **4m, 11e,** and **11f** [21].

Unlike pyrimidine-containing compound **4**, the alkylated derivatives of pyridin-2-ylcyanamide **2** possess visible blue fluorescence in solution. The fluorescence spectra of all studied compounds contain a broad band at 380 – 550 nm with the main peak at 421–427 nm and shoulder maxima at about 400 and 460 nm. The shape of the solution fluorescence spectra does not depend on the excitation wavelength (270nm, 330 nm, and 370 nm). Fluorescence excitation spectra of these compounds have almost the same shape as their absorption spectra. Fluorescence quantum yield values of compounds **11a**, **11c,** and **11d** in solution are slightly different (ϕ_{fl} ~ 0.28 – 0.32), for compounds **11b** and **11f** it is somewhat lower (ϕ_{fl} ~ 0.22 and ϕ_{fl} ~ 0.16, respectively), and for compound **11e** it is almost equal to zero (ϕ_{fl} ~ 0.03, Table 3). The fluorescence lifetimes for compounds **11a**, **11c,** and **11d** are approximately 5 ns, but for compounds **11b, 11e,** and **11f** they are slightly lower—3.7, 0.4, and 2.7 ns, respectively (Table 3).

Table 2

The bond lengths (Å) of heterocyclic and NCN fragments in **4d–f** and **11b–c**.

	4d	4e[b]	4f	11b	11c
N1—C2	1.1505(14)	1.151(3)	1.1558(12)	1.166(3)	1.1628(13)
C2—N3	1.3421(13)	1.346(4)	1.3430(11)	1.319(3)	1.3212(12)
N3—C4	1.4094(13)	1.409(4)	1.4083(11)	1.347(3)	1.3398(12)
C4—N5(C5)[a]	1.3343(13)	1.335(4)	1.3370(11)	1.417(4)	1.4187(13)
N5(C5)[a]—C6	1.3479(14)	1.347(4)	1.3446(11)	1.370(4)	1.3657(14)
C6—C7	1.3917(15)	1.388(4)	1.3969(12)	1.417(4)	1.4089(14)
C7—C8	1.3905(15)	1.384(4)	1.3914(13)	1.356(4)	1.3633(14)
C8—N9	1.3478(14)	1.358(4)	1.3506(12)	1.378(3)	1.3705(12)
N9—C4	1.3305(13)	1.326(4)	1.3316(11)	1.378(3)	1.3713(12)
N3—C12	1.4786(13)	1.497(4)	1.4799(11)	—	—
N9-C10	—	—	—	1.471(4)	1.4738(11)

[a]N5 in **4d,e,f** and C5 in **11b,c**.
[b]For **4e**, average bond lengths are provided.

Table 3

Absorption and fluorescent properties of compound **11** in methylene chloride.

Compound	λ_{max}^{abs}, nm (ε)	λ_{max}^{fl}, nm	ϕ	τ, nc
11a	265 (13 610), 340 (5500)	423	0.29	5.2
11b	263 (14 030), 342 (6500)	391[a], 421	0.22	3.7
11c	265 (14 570), 343 (5800)	427	0.32	5.4
11d	264 (17 010), 342 (7320)	425	0.28	4.8
11e	252 (20 460), 268[a] (13 930), 344 (6270)	426	0.03	0.4
11f	269 (26 400), 285[a] (19 000), 343 (6940)	424	0.16	2.7

[a]Shoulder maximum.

CONCLUSIONS

In summary, we have studied the sides of the alkylation reaction for sodium salts of cyanamides, and we found that, the exo-cyclic nitrogen atom of amino cyanamide group was alkylated in the case of *N*-(4,6-dimethylpyrimidin-2-yl)cyanamide, while the endo-cyclic nitrogen atom was found to be the reaction center in the case of pyridin-2-yl cyanamide. The crystal structures of such compounds have been reported for the first time. Alkylated cyanamides can be regarded as potential building blocks for the construction of heterocyclic compounds. The ability of alkylated derivatives of pyridin-2-yl cyanamide to fluoresce in a visible region can be employed in creation of fluorescent labels containing such groups. Presently, 4- and 4,5-substituted pyrimidin-2-yl cyanamides and their alkylated derivatives are considered the aim of further study.

EXPERIMENTAL

All commercially available reagents were purchased from Merck, Aldrich, and Fluka and were used without further purification. The progress of the reactions was monitored by TLC using aluminum silica gel plates 60 F_{254} using UV light (254 nm/365 nm) for visualization. Melting points were detected with a Büchi B-540 melting point apparatus and were uncorrected. Infrared spectra were recorded with a FTIR Bruker Vertex 70 and are given as cm^{-1} using the attenuated total reflection (ATR) method. NMR spectra were recorded in DMSO-d_6 on a Bruker AC-300 or Bruker DRX-500 spectrometers with a 300, 500-MHz NMR spectrometer for ^1H NMR and 75 MHz for ^{13}C NMR. Chemical shifts (δ) were given in parts per million (ppm) with reference to tetramethylsilane (TMS) as an internal standard and the coupling constants (*J*) were given in hertz (Hz). Elemental analyses were obtained on a Carlo Erba NA-1500 CHNS Elemental Analyzer.

Density functional theory (DFT) calculations were performed using Gaussian 03 program [22] with the B3LYP exchange-correlation functional. The basis (6-311++G**) was used for all atoms. Geometry optimizations were performed with full relaxation of all atoms. Calculations were performed in gas phase without solvent effects. Vibrational frequency calculations were performed to check that the stable structures had no imaginary frequency.

Single crystals of **4d–f**, **11b,** and **11c** were grown from 2-propanol, 2-propanol-water, and acetonitrile. Suitable crystals were selected and studied on a Bruker Apex II Duo diffractometer. The crystals were kept at 100 K during data collection. Using Olex2 [23], the structures was solved with the XS structure solution program [24] using Direct Methods and refined with the XL refinement package using Least Squares

minimization. The crystal of **4e** has systematic twinning. The twinning matrix is (0.0, 0.0, 1.0, 0.0, −1.0, 0.0, 1.0, 0.0, 0.0), and BASF parameter is 0.44338.

UV absorption spectra were taken on a Varian Cary 100 spectrophotometer. Samples were dissolved in methylene chloride and scanned in a layer L = 0.1 cm. Fluorescence spectra were measured on a Horiba Jobin Yvon Fluorolog 3–221 spectrofluorometer an angle 7–10° and 1 × 1 cm quartz cells. All measurements were carried out at room temperature (298 K). The relative fluorescence quantum yield (ϕ_{fl}) was measured in a weakly concentrated solution of methylene chloride (C~10^{-6} mol/L). The solution of diphenylanthracene in ethanol was used as standard solution ($\phi_{fl} = 0.9$) [25].

General procedure for the synthesis of *N*-alkyl-*N*-(4,6-dimethylpyrimidin-2-yl)cyanamide derivatives (4a–m). Cyanamide **1** (1.48 g, 10 mmol) was dissolved in a solution of 1*M* sodium methoxide (10 mL). The solvent was removed under vacuum, and the remaining sodium salt was dissolved in DMAC (5 mL). To this reaction mixture, alkyl halide (10 mmol) and/or (15 mmol for methyl iodide and ethyl bromide) was added and stirred at 20–60°C for 5 min. After cooling, it was poured onto ice-cold distilled water (50–100 mL); the obtained solid was filtered, washed by distilled water, and recrystallized from 2-propanol to afford **4c–m**. The reaction mixture of compound **4a** and/or **4b** was extracted three times with methylene chloride (3 × 30 mL) from distilled water. The combined extract was dried over Na_2SO_4, concentrated, and recrystallized from the same solvent.

***N*-(4,6-Dimethylpyrimidin-2-yl)-*N*-methylcyanamide (4a).** Colorless prisms, (0.66 g, 41% yield), mp 110–112°C (Lit. [10]: 107–108°C). IR (ATR), ν_{max}: 2945, 2925, 2228, 1597, 1550, 1437 cm^{-1}; UV: λ max 232 nm (ε 16 530), 273 nm (ε 4310); ^{1}H NMR (300 MHz, DMSO-d_6 + CCl_4): δ 2.38 (s, 6H, $2CH_3$), 3.39 (s, 3H, CH_3), 6.98 (s, 1H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 23.3, 35.2, 112.3, 114.8, 157.7, 186.4. *Anal.* Calcd for $C_8H_{10}N_4$: C, 59.24; H, 6.21; N, 34.54. Found: C, 59.32; H, 6.28; N, 34.40.

***N*-(4,6-Dimethylpyrimidin-2-yl)-*N*-ethylcyanamide (4b).** Colorless prisms, (1.11 g, 63% yield), mp 68–69°C. IR (ATR), ν_{max}: 2970, 2224, 1593, 1547, 1460 cm^{-1}; UV: λ max 233 nm (ε 19 170), 274 nm (ε 4860); ^{1}H NMR (300 MHz, DMSO-d_6 + CCl_4): δ 1.29 (t, J = 7.1 Hz, 3H, CH_3CH_2), 2.37 (s, 6H, $2CH_3$), 3.86 (q, J = 7.1 Hz, 2H, CH_2CH_3), 6.98 (s, 1H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 12.6, 23.4, 42.4, 111.3, 115.0, 157.3, 168.5. *Anal.* Calcd for $C_9H_{12}N_4$: C, 61.34; H, 6.86; N, 31.79. Found: C, 61.30; H, 6.86; N, 31.84.

***Ethyl 2-(N-(4,6-dimethylpyrimidin-2-yl)cyanamide)acetate (4c).** Colorless prisms, (1.26 g, 54% yield), mp 125–127°C (Lit. [5]: 107–108°C). IR (ATR), ν_{max}: 2973, 2239, 1741, 1597, 1546, 1432 cm^{-1}; UV: λ max 228 nm (ε 13 690), 270 nm (ε 4290); ^{1}H NMR (500 MHz, DMSO-d_6): δ 1.19 (t, J = 7.1 Hz, 3H, CH_3CH_2), 2.39 (s, 6H, $2CH_3$), 4.19 (q, J = 7.1 Hz, 2H, CH_2CH_3), 4.68 (s, 2H, CH_2N), 7.12 (s, 1H, ArH). ^{13}C NMR (75 MHz, DMSO-d_6): δ 13.9, 23.3, 48.5, 61.2, 111.2, 115.5, 156.8, 167.6, 168.6. *Anal.* Calcd for $C_{11}H_{14}N_4O_2$: C, 56.40; H, 6.02; N, 23.92. Found: C, 56.34; H, 5.95; N, 24.02.

***N*-Benzyl-*N*-(4,6-dimethylpyrimidin-2-yl)cyanamide (4d).** Colorless prisms, (1.41 g, 59% yield), mp 76–77°C. IR (ATR), ν_{max}: 3010, 2227, 1597, 1550, 1500, 1446 cm^{-1}; UV: λ max 232 nm (ε 16 170), 273 nm (ε 4030); ^{1}H NMR (500 MHz, DMSO-d_6): δ 2.39 (s, 6H, $2CH_3$), 5.07 (s, 2H, CH_2), 7.00 (s, 1H, ArH), 7.33–7.42 (m, 5H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 23.4, 50.2, 111.5, 115.3, 128.1, 128.2, 128.7, 135.4, 157.3, 168.7. *Anal.* Calcd for $C_{14}H_{14}N_4$: C, 70.57; H, 5.92; N, 23.51. Found: C, 70.55; H, 5.87; N, 23.58.

X-ray crystallographic data for 4d. Formula $C_{14}H_{14}N_4$, M = 238.29, monoclinic, space group $P2_1/c$ (no. 14), a = 9.6261 (19) Å, b = 6.9517(14) Å, c = 19.192(4) Å, β = 92.29(3)°, V = 1283.3(4) $Å^3$, Z = 4, T = 100 K, μ(MoKα) = 0.077 mm^{-1}, *Dcalc* = 1.233 g/mm^3, 16 787 reflections measured (4.24 ≤ 2θ ≤ 61), 3905 unique (R_{int} = 0.0313) which were used in all calculations. The final R_1 was 0.0424 (>2sigma(I)) and wR_2 was 0.1245 (all data).

***N*-(4,6-Dimethylpyrimidin-2-yl)-*N*-(4-methylbenzyl)-cyanamide (4e).** Colorless needles (1.74 g, 69% yield), mp 79–80°C. IR (ATR), ν_{max}: 3018, 2230, 1591, 1545, 1515, 1452 cm^{-1}; UV: λ max 231 nm (ε 17 850), 273 nm (4180); ^{1}H NMR (300 MHz, DMSO-d_6 + CCl_4): δ 2.35 (s, 3H, CH_3), 2.41 (s, 6H, $2CH_3$), 4.99 (s, 2H, CH_2), 6.87 (s, 1H, ArH), 7.15 (d, J = 7.2 Hz, 2H, ArH), 7.29 (d, J = 7.2 Hz, 2H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 20.6, 23.3, 49.9, 111.5, 115.2, 128.1, 129.2, 132.3, 137.5, 157.3, 168.6. *Anal.* Calcd for $C_{15}H_{16}N_4$: C, 71.40; H, 6.39; N, 22.20. Found: C, 71.34; H, 6.45; N, 22.21.

X-ray crystallographic data for 4e. Formula $C_{15}H_{16}N_4$, M = 252.32, monoclinic, space group $P2_1/n$ (no. 14), a = 28.550(3) Å, b = 6.6861(7) Å, c = 28.535(2) Å, β = 99.264 (2)°, V = 5376.0(9) $Å^3$, Z = 16, T = 100 K, μ(MoKα) = 0.078 mm^{-1}, *Dcalc* = 1.247 g/mm^3, 29 691 reflections measured (1.44 ≤ 2θ ≤ 56.56), 13 044 unique (R_{int} = 0.0897) which were used in all calculations. The final R_1 was 0.0506 (>2sigma(I)) and wR_2 was 0.1061 (all data).

***N*-(4,6-Dimethylpyrimidin-2-yl)-*N*-(2-methylbenzyl)-cyanamide (4f).** Colorless prisms, (2.19 g, 87% yield), mp 120–122°C. IR (ATR), ν_{max}: 2995, 2226, 1595, 1547, 1495, 1449 cm^{-1}; UV: λ max 232 nm (ε 16 900), 273 nm (ε 4210); ^{1}H NMR (300 MHz, DMSO-d_6 + CCl_4): δ 2.38 (s, 3H, CH_3), 2.42 (s, 6H, $2CH_3$), 5.02 (s, 2H, CH_2), 6.89 (s, 1H, ArH), 7.13–7.25 (m, 3H, ArH), 7.31 (d, J = 7.2 Hz, 1H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 18.7, 23.3, 48.2, 111.3, 115.3, 126.0, 128.2, 128.7, 130.4, 133.0, 136.6, 157.4, 168.6. *Anal.* Calcd for $C_{15}H_{16}N_4$: C, 71.40; H, 6.39; N, 22.20. Found: C, 71.45; H, 6.40; N, 22.15.

X-ray crystallographic data for 4f. Formula $C_{15}H_{16}N_4$, M = 252.32, monoclinic, space group $P2_1/c$ (no. 14), a = 9.4605 (5) Å, b = 7.2101(3) Å, c = 19.3871(9) Å, β = 94.025(1)°, V = 1319.15(11) $Å^3$, Z = 4, T = 100 K, μ(MoKα) = 0.079 mm^{-1}, *Dcalc* = 1.2704 g/mm^3, 20 953 reflections measured (4.22 ≤ 2θ ≤ 67.34), 5233 unique (R_{int} = 0.0269) which were used in all calculations. The final R_1 was 0.044956 (I ≥ 2u(I)) and wR_2 was 0.131241 (all data).

***N*-(4-Chlorobenzyl)-*N*-(4,6-dimethylpyrimidin-2-yl)-cyanamide (4g).** Colorless needles, (1.91 g, 70% yield), mp 88–89°C. IR (ATR), ν_{max}: 2998, 2233, 1593, 1549, 1489, 1445 cm^{-1}; UV: λ max 231 nm (ε 20 830), 273 nm (ε 4180); ^{1}H NMR (300 MHz, DMSO-d_6 + CCl_4): δ 2.41 (s, 6H, $2CH_3$), 5.03 (s, 2H, CH_2), 6.89 (s, 1H, ArH), 7.36 (d, J = 7.1 Hz, 2H, ArH), 7.41 (d, J = 7.1 Hz, 2H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 23.3, 49.5, 111.3,

115.3, 128.6, 130.0, 132.9, 134.4, 157.1, 168.6. *Anal.* Calcd for $C_{14}H_{13}ClN_4$: C, 61.65; H, 4.80; N, 20.54. Found: C, 61.72; H, 4.74; N, 20.63.

N-(3-Chlorobenzyl)-N-(4,6-dimethylpyrimidin-2-yl)-cyanamide (4h). Colorless prisms, (2.07 g, 76% yield), mp 77–78°C. IR (ATR), ν_{max}: 3006, 2226, 1595, 1543, 1475, 1443 cm^{-1}; UV: λ max 233 nm (ε 14 910), 274 nm (ε 3970); ^{1}H NMR (300 MHz, DMSO-d_6 + CCl_4): δ 2.44 (s, 6H, $2CH_3$), 5.06 (s, 2H, CH_2), 6.90 (s, 1H, ArH), 7.29–7.40 (m, 3H, ArH), 7.43 (s, 1H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 23.3, 49.5, 111.3, 115.4, 126.7, 127.9, 128.1, 130.6, 133.2, 137.8, 157.1, 168.6. *Anal.* Calcd for $C_{14}H_{13}ClN_4$: C, 61.65; H, 4.80; N, 20.54. Found: C, 61.64; H, 4.79; N, 20.47.

N-(2-Chlorobenzyl)-N-(4,6-dimethylpyrimidin-2-yl)-cyanamide (4i). Colorless prisms, (1.72 g, 63% yield), mp 141–143°C. IR (ATR), ν_{max}: 3007, 2232, 1600, 1543, 1474, 1448 cm^{-1}; UV: λ max 230 nm (ε 15 830), 272 nm (ε 4120); ^{1}H NMR (300 MHz, DMSO-d_6 + CCl_4): δ 2.43 (s, 6H, $2CH_3$), 5.12 (s, 2H, CH_2), 6.90 (s, 1H, ArH), 7.30–7.37 (m, 2H, ArH), 7.42–7.50 (m, 2H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 23.4, 48.3, 111.0, 115.5, 127.5, 129.6, 130.2, 130.7, 132.3, 133.1, 157.2, 168.7. *Anal.* Calcd for $C_{14}H_{13}ClN_4$: C, 61.65; H, 4.80; N, 20.54. Found: C, 61.58; H, 4.82; N, 20.54.

N-(4-Bromobenzyl)-N-(4,6-dimethylpyrimidin-2-yl)-cyanamide (4j). Colorless needles, (2.92 g, 92% yield), mp 105–106°C. IR (ATR), ν_{max}: 2995, 2236, 1593, 1545, 1487, 1422 cm^{-1}; UV: λ max 231 nm (ε 22 900), 272 nm (ε 4320); ^{1}H NMR (300 MHz, DMSO-d_6 + CCl_4): δ 2.41 (s, 6H, $2CH_3$), 5.03 (s, 2H, CH_2), 6.89 (s, 1H, ArH), 7.35 (d, J = 7.3 Hz, 2H, ArH), 7.51 (d, J = 7.3 Hz, 2H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 23.3, 49.5, 111.4, 115.4, 121.4, 130.3, 131.6, 134.8, 157.1, 168.7. *Anal.* Calcd for $C_{14}H_{13}BrN_4$: C, 53.01; H, 4.13; N, 17.66. Found: C, 52.93; H, 4.14; N, 17.71.

N-(4,6-Dimethylpyrimidin-2-yl)-N-(3-nitrobenzyl)-cyanamide (4k). Pale yellow prisms, (2.32 g, 82% yield), mp 102–103°C. IR (ATR), ν_{max}: 3042, 2231, 1593, 1553, 1524, 1452 cm^{-1}; UV: λ max 230 nm (ε 18 500), 266 nm (ε 11 240), 302 nm (ε 1610, shoulder maximum); ^{1}H NMR (300 MHz, DMSO-d_6 + CCl_4): δ 2.43 (s, 6H, $2CH_3$), 5.20 (s, 2H, CH_2), 6.91 (s, 1H, ArH), 7.67 (t, J = 7.2 Hz, 1H, ArH), 7.85 (d, J = 7.2 Hz, 1H, ArH), 8.20 (d, J = 7.2 Hz, 1H, ArH), 8.35 (s, 1H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 23.3, 49.5, 111.3, 115.5, 123.0, 123.1, 130.3, 134.8, 137.7, 147.8, 157.0, 168.8. *Anal.* Calcd for $C_{14}H_{13}N_5O_2$: C, 59.36; H, 4.63; N, 24.72. Found: C, 59.33; H, 4.68; N, 24.66.

N-(4,6-Dimethylpyrimidin-2-yl)-N-(naphthalene-1-ylmethyl) cyanamide (4l). Colorless prisms, (1.96 g, 68% yield), mp 121–123°C. IR (ATR), ν_{max}: 3015, 2230, 1597, 1543, 1512, 1434 cm^{-1}; UV: λ max 230 nm (ε 26 840), 264 nm (ε 7030, shoulder maximum), 272 nm (ε 10 130), 282 nm (ε 10 390), 293 nm (ε 5570), 313 nm (ε 390, shoulder maximum); ^{1}H NMR (300 MHz, DMSO-d_6 + CCl_4): δ 2.41 (s, 6H, $2CH_3$), 5.53 (s, 2H, CH_2), 7.04 (s, 1H, ArH), 7.50–7.62 (m, 4H, ArH), 7.93–8.04 (m, 2H, ArH), 8.10 (m, 1H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 23.4, 47.9, 111.0, 115.3, 123.1, 125.3, 126.0, 126.7, 127.3, 128.7, 129.0, 130.4, 130.9, 133.3, 157.3, 168.7. *Anal.* Calcd for $C_{18}H_{16}N_4$: C, 74.98; H, 5.59; N, 19.43. Found: C, 75.06; H, 5.54; N, 19.40.

N-(4,6-Dimethylpyrimidin-2-yl)-N-(2-oxo-2-phenylethyl)-cyanamide (4m). Colorless prisms, (2.08 g, 78% yield), mp 146–148°C. IR (ATR), ν_{max}: 2998, 2236, 1704, 1689, 1595, 1541, 1408 cm^{-1}; UV: λ max 234 nm (ε 20 560), 271 nm (ε 5680), 323 nm (ε 340 shoulder maximum); ^{1}H NMR (300 MHz, DMSO-d_6): δ 2.33 (s, 6H, $2CH_3$), 5.50 (s, 2H, CH_2), 6.98 (s, 1H, ArH), 7.59 (t, J = 7.2 Hz, 2H, ArH), 7.72 (t, J = 7.2 Hz, 1H, ArH), 8.04 (d, J = 7.2 Hz, 2H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 23.3, 53.4, 111.6, 115.3, 128.0, 129.0, 134.1, 134.3, 157.2, 168.6, 192.6. *Anal.* Calcd for $C_{15}H_{14}N_4O$: C, 67.65; H, 5.30; N, 21.04. Found: C, 67.72; H, 5.22; N, 21.12.

3-(4,6-Dimethylpyrimidin-2-yl)-5-phenyl-oxazol-2(3*H*)-imine (5). To a solution of cyanamide **4m** (1.6 g, 6 mmol) in DMAC (15 mL), triethylamine (0.92 mL, 6.6 mmol) was added. The reaction mixture was heated at 70°C for 10 h, and then poured onto distilled water. The crude product was filtered, dried, and purified by recrystallization from dimethylformamide to give compound **5** as pale yellow prisms, (1.07 g, 67% yield), mp 160–161°C. IR (ATR), ν_{max}: 3290, 3165, 1686, 1650, 1596, 1531, 1423 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ 2.48 (s, 6H, $2CH_3$), 7.11 (s, 1H, ArH), 7.35 (t, J = 7.5 Hz, 1H, ArH), 7.45 (t, J = 7.6 Hz, 2H, ArH), 7.70 (d, J = 7.7 Hz, 2H, ArH), 8.16 (s, 1H, ArH), 8.40 (s, 1H, NH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 23.5, 107.1, 115.8, 123.2, 126.9, 128.3, 128.8, 138.2, 152.8, 154.4, 168.1. *Anal.* Calcd for $C_{15}H_{14}N_4O$: C, 67.65; H, 5.30; N, 21.04. Found: C, 67.60; H, 5.31; N, 20.97.

General procedure for the synthesis of (E)-*N*-(1-alkylpyridin-2(1*H*)-ylidene)cyanamide derivatives (11a–f). Cyanamide **2** (0.60 g, 5 mmol) was dissolved in a solution of 1*M* sodium methoxide (5 mL). The solvent was removed under vacuum, and the remaining sodium salt was dissolved in DMAC (2 mL). To this reaction mixture, alkyl halide (5 mmol) and/or (0.47 mL, 7.5 mmol for methyl iodide) was added and stirred at 20–60°C for 5 min. After cooling, it was poured onto ice-cold distilled water (20–30 mL); the solid obtained was filtered, washed by distilled water, and recrystallized from 2-propanol to afford **11c–m**. The reaction mixture of compound **11a** and/or **11b** was extracted three times with CH_2Cl_2 (3 × 30 mL) from distilled water. The combined extract was dried over Na_2SO_4, concentrated, and recrystallized from the same solvent.

(E)-N-(1-Methylpyridin-2(1H)-ylidene)cyanamide (11a). Colorless prisms, (0.35 g, 52% yield), mp 99–101°C. IR (ATR), ν_{max}: 3421, 2171, 1638, 1553, 1517, 1465 cm^{-1}; UV: λ max 265 nm (ε 13 610), 340 nm (ε 5500); ^{1}H NMR (300 MHz, DMSO-d_6): δ 3.63 (s, 3H, CH_3), 6.58 (ddd, J = 1.3, 6.6, 7.0 Hz, 1H, ArH), 7.15 (d, J = 8.9 Hz, 1H, ArH), 7.66 (ddd, J = 1.5, 6.6, 8.9 Hz, 1H, ArH), 7.96 (dd, J = 1.4, 6.6 Hz, 1H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 40.3, 110.5, 116.7, 118.0, 141.0, 141.1, 160.9. *Anal.* Calcd for $C_7H_7N_3$: C, 63.14; H, 5.30; N, 31.56. Found: C, 63.21; H, 5.22; N, 31.57.

(E)-Methyl 2-(2-(cyanoimino)pyridin-1(2H)-yl)acetate (11b). Colorless prisms, (0.32 g, 33% yield), mp 119–120°C. IR (ATR), ν_{max}: 3392, 2154, 1735, 1638, 1552, 1516 cm^{-1}; UV: λ max 263 nm (ε 14 030), 342 nm (ε 6500); ^{1}H NMR (300 MHz, DMSO-d_6): δ 3.76 (s, 3H, CH_3), 4.90 (s, 2H, CH_2), 6.62 (ddd,

J = 1.4, 6.6, 7.2 Hz, 1H, ArH), 7.18 (d, J = 9.0 Hz, 1H, ArH), 7.71 (ddd, J = 1.8, 6.6, 8.8 Hz, 1H, ArH), 7.92 (dd, J = 1.8, 6.6 Hz, 1H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 52.5, 52.9, 110.7, 116.9, 117.2, 140.8, 141.9, 160.8, 167.4. *Anal.* Calcd for $C_9H_9N_3O_2$: C, 56.54; H, 4.74; N, 21.98. Found: C, 56.46; H, 4.77; N, 22.06.

X-ray crystallographic data for 11b. Formula $C_9H_{11}N_3O_3$, M = 209.21, monoclinic, space group $P2_1/c$ (no. 14), a = 11.95(3) Å, b = 17.15(3) Å, c = 5.007(10) Å, β = 97.617 (6)°, V = 1017(4) Å^3, Z = 4, T = 100 K, μ(MoKα) = 0.105 mm^{-1}, $Dcalc$ = 1.366 g/mm^3, 8234 reflections measured (3.44 ≤ 2θ ≤ 61.02), 3060 unique (R_{int} = 0.1726) which were used in all calculations. The final R_1 was 0.0555 (>2sigma(I)) and wR_2 was 0.1245 (all data).

(E)-N-(1-Benzylpyridin-2(1H)-ylidene)cyanamide (11c). Colorless prisms, (0.71 g, 67% yield), mp 143–144°C. IR (ATR), ν_{max}: 3080, 3041, 2976, 2139, 1634, 1556, 1510 cm^{-1}; UV: λ max 265 nm (ε 14 570), 343 nm (ε 5800); ^{1}H NMR (300 MHz, DMSO-d_6): δ 5.33 (s, 2H, CH_2), 6.75 (t, J = 6.5 Hz, 1H, ArH), 7.18 (d, J = 8.8 Hz, 1H, ArH), 7.26–7.38 (m, 5H, ArH), 7.76 (ddd, J = 1.1, 6.4, 7.6 Hz, 1H, ArH), 8.16 (dd, J = 1.1, 6.4 Hz, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 54.3, 111.0, 117.4, 117.7, 127.6, 127.8, 128.6, 135.6, 140.5, 141.3, 160.6. *Anal.* Calcd for $C_{13}H_{11}N_3$: C, 74.62; H, 5.30; N, 20.08. Found: C, 74.62; H, 5.35; N, 20.03.

X-ray crystallographic data for 11c. Formula $C_{13}H_{11}N_3$, M = 209.25, monoclinic, space group $P2_1/c$ (no. 14), a = 9.6282 (7) Å, b = 7.3585(5) Å, c = 15.3953(11) Å, β = 95.5830(10)°, V = 1085.57(13) Å^3, Z = 4, T = 100 K, μ(MoKα) = 0.079 mm^{-1}, $Dcalc$ = 1.280 g/mm^3, 11 505 reflections measured (4.26 ≤ 2θ ≤ 58), 2882 unique (R_{int} = 0.0178) which were used in all calculations. The final R_1 was 0.0460 (>2sigma(I)) and wR_2 was 0.1303 (all data).

(E)-N-(1-(2-Fluorobenzyl)pyridin-2(1H)-ylidene)-cyanamide (11d). Colorless prisms, (0.55 g, 48% yield), mp 162–163°C. IR (ATR), ν_{max}: 2146, 1632, 1553, 1512 cm^{-1}; UV: λ max 264 nm (ε 17 010), 342 nm (ε 7320); ^{1}H NMR (300 MHz, DMSO-d_6): δ 5.34 (s, 2H, CH_2), 6.64 (ddd, J = 1.3, 6.6, 7.3 Hz, 1H, ArH), 7.10–7.25 (m, 4H, ArH), 7.35 (dd, J = 6.5, 12.8 Hz, 1H, ArH), 7.69 (ddd, J = 1.7, 6.6, 8.9 Hz, 1H, ArH), 7.98 (dd, J = 1.4, 6.6 Hz, 1H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 49.3, 110.9, 115.3, 117.4, 117.5, 122.3, 124.6, 129.7, 130.1, 140.7, 141.5, 160.7, 161.7. *Anal.* Calcd for $C_{13}H_{10}FN_3$: C, 68.71; H, 4.44; N, 18.49. Found: C, 68.59; H, 4.36; N, 18.37.

(E)-N-(1-(2-Oxo-2-phenylethyl)pyridin-2(1H)-ylidene)-cyanamide (11e). Colorless prisms, (0.75 g, 63% yield), mp 210–212°C (Lit. [19b]: mp 180°C (dec.)). IR (ATR), ν_{max}: 3423, 3234, 2150, 1693, 1638, 1554, 1515 cm^{-1}; UV: λ max 252 nm (ε 20 460), 268 nm (ε 13 930 shoulder maximum), 344 nm (ε 6270); ^{1}H NMR (500 MHz, DMSO-d_6): δ 5.77 (s, 2H, CH_2), 6.79 (t, J = 6.6 Hz, 1H, ArH), 7.19 (d, J = 8.9 Hz, 1H, ArH), 7.62 (t, J = 7.5 Hz, 2H, ArH), 7.75 (t, J = 7.3 Hz, 1H, ArH), 7.83 (ddd, J = 1.7, 6.6, 8.9 Hz, 1H, ArH), 7.97 (dd, J = 1.4, 6.6 Hz, 1H, ArH), 8.07 (d, J = 7.5 Hz, 2H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 58.0, 110.7, 117.0, 117.5, 128.1, 129.1, 134.1, 134.3, 141.2, 141.8, 160.7, 191.6. *Anal.* Calcd for $C_{14}H_{11}N_3O$: C, 70.87; H, 4.67; N, 17.71. Found: C, 70.76; H, 4.74; N, 17.83.

(E)-N-(1-(2-(4-Methoxyphenyl)-oxoethyl)pyridin-2(1H)-ylidene) cyanamide (11f). Colorless prisms, (0.89 g, 66% yield), mp 187–188°C. IR (ATR), ν_{max}: 3423, 2154, 1686, 1638, 1601, 1552, 1513 cm^{-1}; UV: λ max 269 nm (ε 26 400), 285 nm (ε 19 000 shoulder maximum), 343 nm (ε 6940); ^{1}H NMR (300 MHz, DMSO-d_6): δ 3.89 (s, 3H, CH_3), 5.64 (s, 2H, CH_2), 6.63 (ddd, J = 1.6, 6.6, 8.1 Hz, 1H, ArH), 7.04 (d, J = 8.8 Hz, 2H, ArH), 7.21 (d, J = 9.0 Hz, 1H, ArH), 7.71 (ddd, J = 1.8, 6.6, 8.8 Hz, 1H, ArH), 7.86 (dd, J = 1.8, 6.6 Hz, 1H, ArH), 8.02 (d, J = 8.8 Hz, 2H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 55.7, 57.6, 110.7, 114.3, 117.0, 117.5, 127.1, 130.5, 141.3, 141.7, 160.7, 163.9, 189.8. *Anal.* Calcd for $C_{15}H_{13}N_3O_2$: C, 67.41; H, 4.90; N, 15.72. Found: C, 67.49; H, 4.82; N, 15.81.

2-Amino-3-benzoylimidazo[1,2-a]pyridine (12). To a solution of cyanamide **11e** (0.48 g, 2 mmol) in DMAC (5 mL), triethylamine (0.42 mL, 3 mmol) was added. The reaction mixture was heated at 90°C for 10 h, and then poured onto distilled water. The crude product was filtered, dried, and purified by recrystallization from dimethylformamide to give compound **12** as pale yellow solid, (0.428 g, 89% yield), mp 202–204°C (Lit. [19b]: mp 196–200°C). IR (ATR) ν_{max} 3481, 3300, 3110, 1699, 1644, 1619, 1553, 1516, 1491 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ 5.62 (s, 2H, NH_2), 6.98 (t, J = 6.8 Hz, 1H, ArH), 7.38 (d, J = 8.8 Hz, 1H, ArH), 7.52 (t, J = 7.9 Hz, 1H, ArH), 7.56–7.60 (m, 5H, ArH), 9.14 (d, J = 5.6 Hz, 1H, ArH); ^{13}C NMR (75 MHz, DMSO-d_6): δ 112.6, 113.8, 117.0, 126.8, 128.2, 129.2, 130.6, 130.7, 140.3, 147.3, 158.4, 181.9. *Anal.* Calcd for $C_{14}H_{11}N_3O$: C, 70.87; H, 4.67; N, 17.71. Found: C, 71.03; H, 4.76; N, 17.72.

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