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Rearrangement of Aryl- and Benzylthiopyridinium Imides with Participation of a Methyl Substituent

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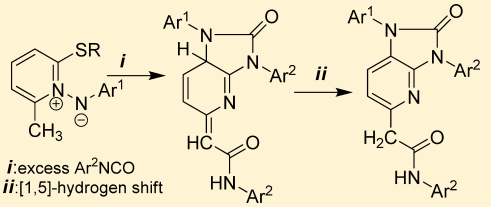
Supporting Information

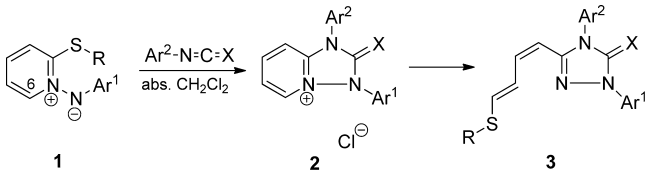
ABSTRACT: 6-Methyl substituted 2-aryl- and 2-benzylthiopyridinium *N*-imides reacted with an excess of isocyanates to give *N*,*N*-disubstituted exocyclic1*H*-imidazo[4,5-*b*]pyridin-2(3*H*)-ones. The products easily underwent spontaneous [1,5] hydrogen shift to provide the heteroaromatic imidazopyridinone isomers. The transformation implied the initial formation of [1,2,4]triazolo[2,3-*a*]pyridinium salt, followed by deprotonation and carbamoylation of the methylene moiety, and, finally, a rearrangement following a [1,3] sigmatropic pattern. Mechanistic considerations suggest and some experimental findings reveal the nonconcerted two-step mechanism of the ring transformation step.



INTRODUCTION

Recently, we have reported that some easily accessible 2-arylthio- and 2-benzylthiopyridinium *N*-imides easily undergo cycloadditions and rearrangement reactions to afford new heterocyclic skeletons.[1−4] Thus, we have described[3] that reaction of 2-arylsulfanyl- and benzylsulfanylpyridinium *N*-arylimides (**1**) with isocyanates and isothiocyanates affords oxo- and thioxo[1,2,4]triazolo[1,5-*a*]pyridinium salts (**2**) and thiodienyl[1,2,4]triazoles (**3**) in a tandem reaction series (Scheme 1). Appropriate adjustment of the reaction conditions

Scheme 1. Transformation of Substituted Mesomeric Betaine (1) with Isocyanates and Isothiocyanates



allowed, furthermore, elaboration of synthetic procedures to either **2** or **3** in acceptable to high yields.

As both in the case shown in Scheme 1 and in majority of other related transformations of **1**, position 6 (i.e., the unsubstituted pyridine carbon atom adjacent to the ring-nitrogen atom) played an important role, the question arose if substitution of this particular position could influence the reactivity of these compounds.

This consideration prompted us to prepare 6-methyl substituted 2-arylthio- and 2-benzylthiopyridinium imides (**8**) and to investigate their reactivity in cycloaddition reactions. The reaction pathway to the desired methyl-substituted mesomeric betaines, which is analogous to the earlier published protocol for unsubstituted derivatives,[2,5] is shown in Scheme 2.

Thus, the three-step synthesis starts from 6-methylpyridine-2-amine (**4**). Reaction of **4** with aryldiazonium salts affords triazenes (**5**), which can be subjected to oxidative cyclization to the stable 5-methyltetrazolo[1,5-*a*]pyridinium fluoroborates (**6**). Treatment of these salts (**6**) with aryl- or benzylthiolates results in formation of intermediate **7**, which rapidly undergoes nitrogen elimination to give the red crystalline *S*-substituted 2-thio-6-methylpyridinium imides (**8**). While the triazene **5b** and tetrazolium salt **6b** have already been prepared earlier, all other derivatives of **5**, **6**, and **8** have now been synthesized for the given purpose.

RESULTS AND DISCUSSION

When some of the new methyl substituted 2-thiopyridinium imides (**8**) were reacted with aryl isocyanates, the two expected products (**9** and **10**) were found in the reaction mixtures in accordance with the expectations based on the previous results[2,3] (Table 1, entries ii−v, vii, and viii). Most interestingly, however, instead of these products, new compounds (**11**) were isolated in two cases: when starting from **8a** and **8c** (Table 1, entries i and vi; Scheme 3).

Structure elucidation of compound **11b** (Ar^1 = 4-CH_3−C_6H_4, Ar^2 = 4-CH_3O−C_6H_4, entry vi in Table 1) was based on standard one- and two-dimensional NMR experiments. The assignments of the resonances followed the regular procedure: collection and analysis of selective 1D TOCSY, selective 1D NOESY, and heteronuclear through-bond correlations (^1H−^{13}C-gHSQC and ^1H−^{13}C-gHMBC). Inspection of the NMR data suggested that the methyl group also participated in the transformation. Accordingly, the CH_3 resonances in the ^1H

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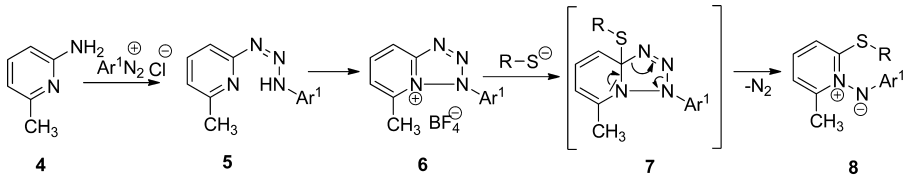
Scheme 2. Synthethic Route to Methyl Substituted Mesomeric Betaine (8)



	Ar^1	R
8a	4-CH_3-C_6H_4	4-CH_3-C_6H_4
8b	4-Cl-C_6H_4	Bn
8c	4-CH_3-C_6H_4	Bn
8d	4-CH_3O-C_6H_4	Bn

Table 1. Isolated Products in Reactions of Some Selected R-Substituted 2-Thiopyridinium Imides (8) with Phenyl and 4-Methoxyphenyl Isocyanates

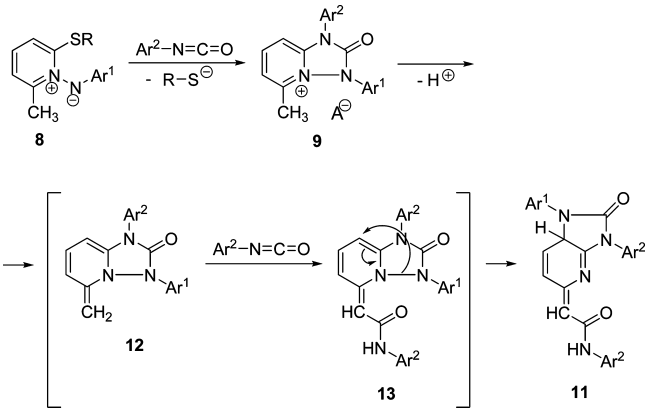
entry	Ar^1	R	Ar^2	**9** (%)	**10** (%)	**11** (%)
i	4-CH_3-C_6H_4–	4-CH_3-C_6H_4–	Ph			11
ii	4-CH_3-C_6H_4–	4-CH_3-C_6H_4–	4-CH_3O-C_6H_4–	39[a]		
iii	4-Cl-C_6H_4–	Bn	Ph		41	
iv	4-Cl-C_6H_4–	Bn	4-CH_3O-C_6H_4–		62	
v	4-CH_3-C_6H_4–	Bn	Ph		50	
vi	4-CH_3-C_6H_4–	Bn	4-CH_3O-C_6H_4–			22
vii	4-CH_3O-C_6H_4–	Bn	Ph		13	
viii	4-CH_3O-C_6H_4–	Bn	4-CH_3O-C_6H_4–	7[a]		

[a]These yields were improved to 61 and 57%, respectively, when applying the reaction conditions published in ref 3.

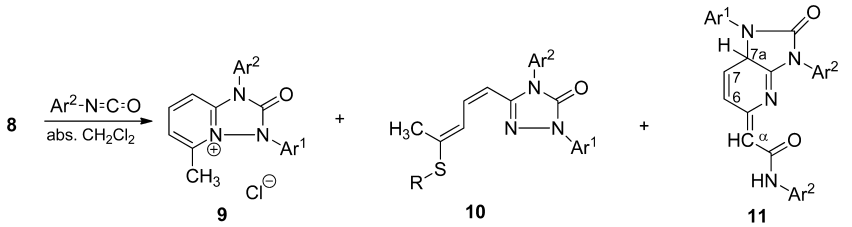
and ^{13}C spectra disappeared, while a new =CH moiety (denoted as $C_\alpha H$ and C_α in compounds **8**) has been detected and identified. The ^{13}C chemical shift of C3 carbon of compounds **8** has significantly shifted in compound **11b**, suggesting the existence of an sp3 carbon atom in the appropriate position (δ_C = 82.0 ppm). This observation could be rationalized by a basic structural change as compared to compound **8**, resulting in a dihydro-imidazo[4,5-*b*]pyridine derivative. The spatial proximity of Ar^1 (H2′ + H6′) protons to H7 and H7a and the long-range $^1H-^{13}C$ correlations of H_α and H7a to C6 also provided evidence for structure **11b**.

In the course of the conversion of **8** to **11**, obviously a ring transformation occurred (Scheme 4). The key to understand

Scheme 4. Suggested Mechanism of Transformation of 2-Arylthiopyridinium-imides (8) by Aryl Isocyanate to Give Imidazo[4,5-*b*]pyridine Derivative (11)



Scheme 3. Reaction of Mesomeric Betaine (8) with Aryl Isocyanate



a: Ar^1 = 4-CH_3-C_6H_4; Ar^2 = 4-CH_3O-C_6H_4
b: Ar^1 = 4-CH_3O-C_6H_4; Ar^2 = 4-CH_3O-C_6H_4

a: Ar^1 = 4-Cl-C_6H_4; R = Bn; Ar^2 = Ph
b: Ar^1 = 4-Cl-C_6H_4; R = Bn; Ar^2 = 4-CH_3O-C_6H_4
c: Ar^1 = 4-CH_3-C_6H_4; R = Bn; Ar^2 = Ph
d: Ar^1 = 4-CH_3O-C_6H_4; R = Bn; Ar^2 = Ph

a: Ar^1 = 4-CH_3-C_6H_4; Ar^2 = Ph
b: Ar^1 = 4-CH_3-C_6H_4; Ar^2 = 4-CH_3O-C_6H_4

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the mechanism of this reaction is most probably the fact that two strong bases are present in the reaction mixture: (1) ring closure of **8** to **9** results in formation of a free thiolate anion, which should temporarily be present[3] and (2) the starting mesomeric betaine **8** contains an anionic nitrogen atom. If these anions deprotonate the methyl group, an exomethylene substituted intermediate of enamine character (**12**) can be formed, in which the β-carbon atom of the enamine moiety (i.e., the terminal carbon atom of the methylene group) can react with another molecule of the isocyanate reagent to afford an amide intermediate (**13**).[6] Connectivity of the two different aryl groups in the product (**11**) suggests that the final step is a [1,3] sigmatropic rearrangement shown by the arrows involving an *N*–*N* fission followed by attachment of the nitrogen atom bearing Ar^1 to C3 of the pyridine ring.

Recognition of the fact that two molecules of the isocyanate are needed for the formation of **11** led us to repeat the reaction of **8** with a large (3-fold) excess of the reagent. By this experimental change, the isolated yields (Table 2) reasonably increased, and thus, the synthetic pathway from **8** to **11** can be regarded as a general approach to imidazopyridinone **11**. The used excess of the reagent therefore suppresses the previously observed ring-opening to a diene (**10**) and promotes the observed ring transformation to **11** in a fast reaction. The experimental fact that **11** became the main product and none of the compounds (**9** and **10**) were isolated under the modified experimental conditions seems to be in accordance with the reaction mechanism proposed.

Table 2. Isolated Yields of the Rearranged Product 11 by Using 3 equiv of Isocyanate

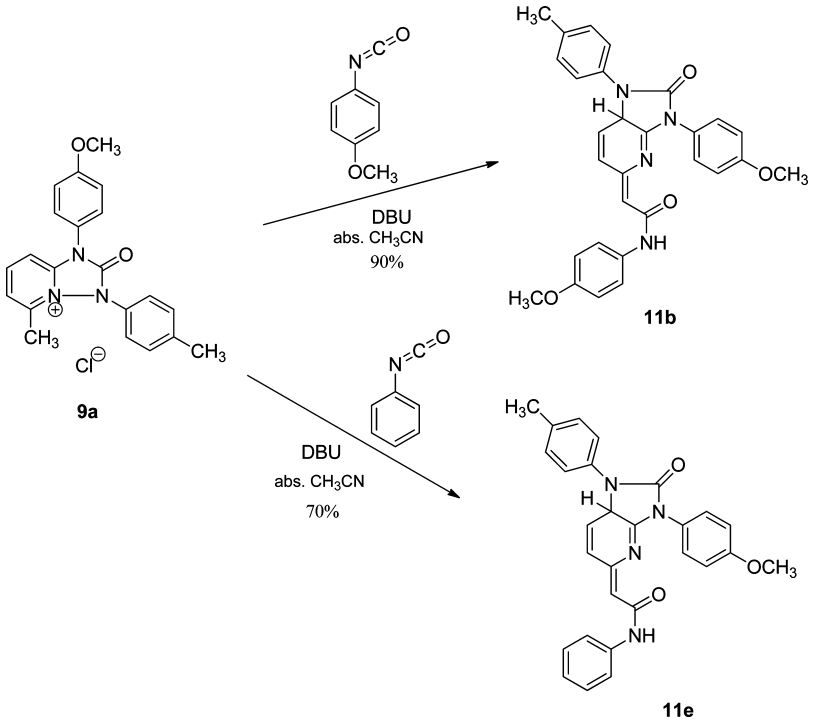
starting compound (**8**)	Ar^1	Ar^2	product (yield %)
8a or **8c**	4-CH_3-C_6H_4–	Ph	**11a** (59)
8a or **8c**	4-CH_3-C_6H_4–	4-CH_3O-C_6H_4–	**11b** (57–67)
8b	4-Cl-C_6H_4–	Ph	**11c** (57)
8b	4-Cl-C_6H_4–	4-CH_3O-C_6H_4–	**11d** (45)

Two additional experiments have been carried out that provided further support to the above suggested reaction mechanism.

(i) If deprotonation of the methyl moiety in **9** is the crucial step at the start of the forthcoming events, a much stronger base than aryl thiolate anion or the nitrogen anion of the mesomeric betaine **8** should accelerate the reaction. In line with this consideration, reaction of **9a** with 3 equiv of 4-methoxyphenyl isocyanate or phenyl isocyanate in the presence of DBU afforded the rearranged product **11b** and **11e** in high (90 and 70%) yield (Scheme 5). Thus, by this experimental change, a substantially improved route to **11** has been established.

(ii) The above-discussed reaction mechanism of the pathway from **8** to **11** suggests that the two isocyanate molecules participating in the formation of **11** have different roles during the reaction pathway: the first isocyanate is consumed for formation of the triazolium salt **9**, and the second molecule of reagent undertakes the carbamoylation of the methylene moiety. This is nicely supported by the experiment carried out with the thioxo substituted triazolopyridinium salt (**14**) and 4-methoxyphenyl isocyanate (Scheme 6). Structure of compound **14**, which is closely related to **9**, already involves one isothiocyanate structural unit, and this compound is ready to undergo deprotonation at the methyl group followed by carbamoylation and sigmatropic rearrangement to give **15**.

Scheme 5. Synthesis of the Imidazo[4,5-*b*]pyridine Derivative (11b and 11e) from Triazolopyridinium Salt (9a) by Using DBU as a Base



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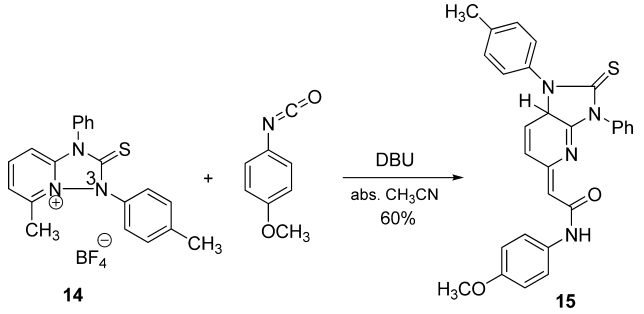
Scheme 6. Transformation of the Thioxo Substituted Triazolopyridinium Salt (14) with Aryl Isocyanate



The structure of the product (**15**) obtained in acceptable yield (60%) convincingly shows that the nitrogen atom bearing the tolyl group derives from the N3 atom of **14**, whereas the anisyl moiety provided by the isocyanate reagent is clearly located at the amide moiety attached to the methylene group.

As the experienced [1,3] sigmatropic rearrangement (**13** → **11**) would contradict the Woodward–Hoffmann rules if it proceeded as a pericyclic process in the sterically possible suprafacial manner, further consideration of the reaction mechanism seemed of interest. The radical nature of the rearrangement could be ruled out, as repetition of the reaction in the presence of 4-nitrosodimethylaniline as a radical trap did not cause any change in the outcome of the transformation. Thus, the *N*–*N* cleavage of the supposed intermediate **13** is of heterolytic character and can result in formation of intermediates **a** or **b** as shown in Figure 1. Although both **a**

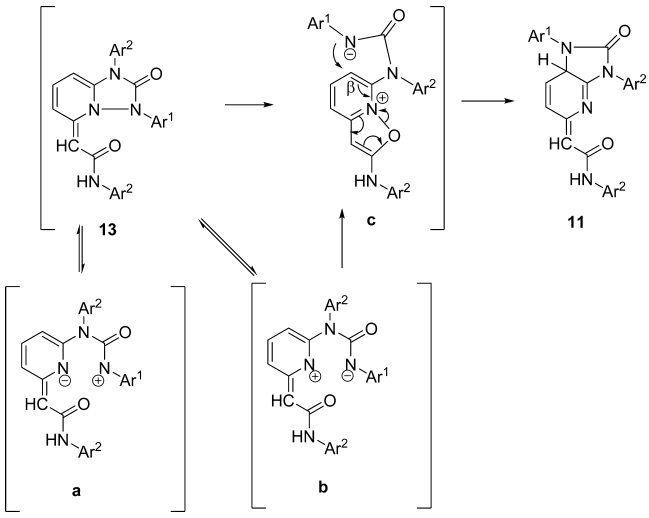


Figure 1. Probable intermediates along the pathway from **13** to **11** as a result of *N*–*N* cleavage.

and **b** should be of very high energy, in case of **b** a substantial stabilization can occur with participation of the Ar^2-containing amide oxygen atom to form a heteroaromatic isoxazolopyridinium cation (**c**), which can be regarded as a valence bond isomer of **13**. Direct formation of **c** from **13** can also be postulated. The subsequent events seem quite obvious: the side chain anion can conveniently attack the β carbon atom as shown by the arrows and can lead by valence bond isomerization to **11**.

When triazolopyridinium salt (**9**) was treated with a strong base (DBU) without the presence of aryl isocyanate, no rearrangement occurred and only decomposition was experienced. This observation reveals that the presence of the carbamoylmethylene moiety is a prerequisite of the rearrangement, and the most probable reason for this is the existing possibility for the delocalization.

The above suggested mechanism for ring transformation is not fully unprecedented, as similar nonconcerted sigmatropic rearrangements are known from the literature.[7] Also, there are some records on spontaneous thermal *N*–*N* fissions.[21,22]

During the measurement of the NMR spectra of **11** and **15**, we have observed that the yellow color of the chloroform solutions disappeared after a prolonged time of storage. The same change was achieved when refluxing these solutions for 8 h. Workup of the resulting colorless solution gave new crystalline products, which proved to be the heteroaromatic imidazo[4,5-*b*]pyridine-2(1*H*)one (**16**) and the related 2-(1*H*)-thione (**17**). This transformation is obviously a [1,5] H-shift, and the driving force of the reaction is formation of the heteroaromatic π-system (Scheme 7). We have found, furthermore, that the fused imidazolone **16a** can also be prepared directly from **8a** or **9a** also by one single manipulation.

Although several papers have been published on the synthesis of the imidazo[4,5-*b*]pyridine ring systems, all these reactions follow totally different pathways.[8–13] To the best of our knowledge, this is the first protocol yielding an *N*,*N*-diaryl substituted derivative of the imidazo[4,5-*b*]pyridine-2(1*H*)one system. Furthermore, no record can be found for formation of the isomeric exocyclic forms **11** and **15**. The new synthetic routes may be particularly useful, as imidazo[4,5-*b*]pyridines and imidazo[4,5-*b*]pyridine-2(1*H*)ones proved to exhibit valuable biological properties. Thus, analgetic,[14] FAAH inhibitory,[15] δ-opioid receptor antagonist,[16] angiotensine receptor antagonist,[17–19] and cytotoxic[20] behaviors were investigated.

■ CONCLUSION

The above findings reveal that a new preparative route to the imidazo[4,5-*b*]pyridine ring system has been found by utilization of a ring transformation starting from easily available sulfanylpyridinium *N*-arylimides. Recognition of the reaction mechanism of an unexpected ring transformation and proper adjustment of the reaction conditions allowed the elaboration of a well-executable reaction pathway to new imidazopyridines in high yields. Mechanistic considerations of the observed sigmatropic shift support a pathway involving a set of valence bond isomerizations.

■ EXPERIMENTAL SECTION

General Procedures. All reagents and solvents were purchased from commercial vendors. Concentration of reaction mixtures refers to rotary evaporation under reduced pressure carried out at 40 °C. Thin layer chromatography (TLC) was performed on aluminum oxide 60 F_{254}-precoated TLC plates (0.25 mm thickness) and visualized at 254 nm. Chromatographic separations were carried out on aluminum oxide (activated, neutral, Brockmann I, approximately 150 mesh). NMR spectral data were obtained at ambient temperature unless otherwise specified. ^{1}H NMR spectra were recorded at 200, 300, or 400 MHz in $CDCl_3$ or DMSO. ^{13}C NMR spectra were recorded at 50, 75, or 100 MHz in $CDCl_3$ or DMSO. Values of δ are reported and shown in parts per million (ppm) and referenced against $CDCl_3$ (7.26 ppm for ^{1}H and 77.16 ppm for ^{13}C) or DMSO (2.50 ppm for ^{1}H and 39.5 ppm for ^{13}C), and *J* coupling values are listed in Hz. Infrared spectral data were

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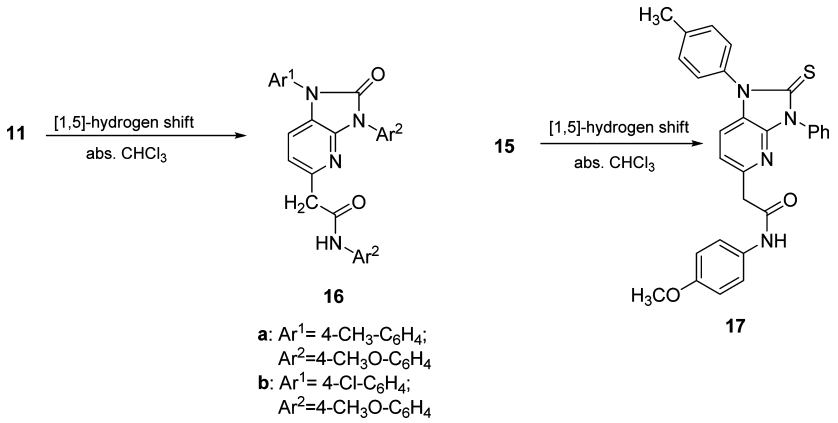
Scheme 7. [1,5]-Hydrogen Shift in (11) and (15) to Form Heteroaromatic Products (16) and (17), Respectively



obtained on an FT-IR spectrometer with major peaks listed. Melting points are uncorrected.

Syntheses of triazenylpyridines (**5**), tetrazolo[1,5-*b*]pyridinium salts (**6**),[5] and 6-methyl substituted 2-aryl- and 2-benzylthiopyridinium *N*-imides (**8**)[1] have been published earlier. Novel derivatives (i.e., **5a**, **5d**, **6a**, **6d**, **8a**–**d**) have been prepared according to these literature procedures.

2-Methyl-6-[(1*Z*)-3-(4-tolyl)triaz-1-en-1-yl]pyridine (5a). Reddish brown crystals (26.59 g, 43%): mp 123–124 °C; IR (KBr) ν_{max} 3088, 2919, 1582, 1461, 1302, 1197, 1153, 1106, 998, 825, 815, 781 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 2.40 (s, 3H, CH_3'), 2.52 (s, 3H, CH_3), 6.80 (d, J = 7.3 Hz, 1H, H-5), 7.20 (m, 2H, H3′ + H5′), 7.33 (d, J = 8.2 Hz, 1H, H-3), 7.50 (m, 2H, H2′ + H6′), 7.55 (dd, J = 8.2, 7.3 Hz, 1H, H-4), 10.32 (br. s, 1H, NH); ^{13}C NMR (50 MHz, $CDCl_3$) δ 21.2, 24.0, 105.5, 117.5, 121.3, 129.6, 137.8, 138.4, 147.0, 153.5, 157.3. Anal. Calcd. for $C_{13}H_{14}N_4$ (226.12): C, 69.00; H, 6.24; N, 24.76. Found: C, 68.84; H, 6.12; N, 24.47.

2-[(1*Z*)-3-(4-Methoxyphenyl)triaz-1-en-1-yl]-6-methylpyridine (5d). Brown crystals (22.66 g, 34%): mp 125–126 °C; IR (KBr) ν_{max} 3096, 2997, 2908, 2833, 1600, 1582, 1499, 1460, 1192, 1153, 1035, 832, 781 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 2.49 (s, 3H, CH_3), 3.84 (s, 3H, OCH_3'), 6.79 (d, J = 7.0 Hz, 1H, H-5), 6.93 (m, 2H, H3′ + H5′), 7.31 (d, J = 8.1 Hz, 1H, H-3), 7.55 (m, 3H, H-4 + H2′ + H6′), 10.16 (br. s, 1H, NH); ^{13}C NMR (50 MHz, $CDCl_3$) δ 24.0, 55.4, 105.4, 114.2, 117.3, 122.8, 138.4, 143.1, 153.9, 157.3, 159.6. Anal. Calcd. for $C_{13}H_{14}N_4O$ (242.12): C, 64.54; H, 5.82; N, 23.13. Found: C, 64.43; H, 5.64; N, 23.05.

5-Methyl-3-(4-tolyl)-3*H*-tetrazolo[1,5-*a*]pyridinium Tetrafluoroborate (6a). Colorless crystals (5.18 g, 81%): mp 252–254 °C; IR (KBr) ν_{max} 3096, 3038, 2996, 1639, 1507, 1449, 1070, 825 cm^{-1}; ^{1}H NMR (200 MHz, DMSO) δ 2.38 (s, 3H, CH_3'), 2.53 (s, 3H, CH_3), 7.63 (m, 2H, H3′ + H5′), 7.97 (m, 2H, H2′ + H6′), 8.07 (d, J = 8.0 Hz, 1H, H-5), 8.54 (t, J = 8.0 Hz, 1H, H-4), 8.95 (d, J = 8.0 Hz, 1H, H-3); ^{13}C NMR (50 MHz, DMSO) δ 18.3, 21.1, 116.6, 125.7, 129.2, 130.1, 130.6, 138.4, 139.4, 144.8, 150.0. Anal. Calcd. for $C_{13}H_{13}BF_4N_4$ (312.12): C, 50.03; H, 4.20; N, 17.95. Found: C, 49.95; H, 3.80; N, 17.91.

3-(4-Methoxyphenyl)-5-methyl-3*H*-tetrazolo[1,5-*a*]pyridinium Tetrafluoroborate (6d). Colorless crystals (4.08 g, 62%): mp 228–232 °C; IR (KBr) ν_{max} 3086, 3032, 2996, 1604, 1510, 1265, 1070, 807 cm^{-1}; ^{1}H NMR (200 MHz, DMSO) δ 2.38 (s, 3H, CH_3), 3.94 (s, 3H, OCH_3'), 7.33 (m, 2H, H3′ + H5′), 8.00 (m, 3H, H2′ + H6′ + H-5), 8.53 (t, J = 8.2 Hz, 1H, H-4), 8.93 (d, J = 8.2 Hz, 1H, H-3); ^{13}C NMR (50 MHz, DMSO) δ 18.2, 56.1, 114.8, 116.7, 125.2, 125.7, 131.2, 138.5, 139.4, 149.9, 163.1. Anal. Calcd. for $C_{13}H_{13}BF_4N_4O$ (328.11): C, 47.59; H, 3.99; N, 17.08. Found: C, 47.76; H, 3.62; N, 17.10.

{2-Methyl-6-[(4-tolyl)sulfanyl]pyridinium-1-yl}(4-tolyl)imide (8a). Red crystals (1.58 g, 98%): mp 98–110 °C; IR (KBr) ν_{max} 3007, 2921, 2855, 1607, 1495, 1465, 1287, 1249, 1174, 818 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 2.20 (s, 3H, CH_3''), 2.41 (s, 3H, CH_3'), 2.54 (s, 3H, CH_3), 6.15 (m, 2H, H2′ + H6′), 6.63 (d, J = 8.0 Hz, 1H, H3), 6.89 (m, 2H, H3′ + H5′), 7.08 (d, J = 7.1 Hz, 1H, H-5), 7.24–7.45 (m, 5H, H-4 + H2″ + H3″ + H5″ + H6″); ^{13}C NMR (50 MHz, $CDCl_3$) δ 19.7, 20.4, 21.3, 110.0, 121.0, 121.8, 122.3, 127.4, 129.7, 130.9, 132.7, 135.6, 140.5, 141.2, 153.0, 156.5.

[2-(Benzylsulfanyl)-6-methylpyridinium-1-yl](4-chlorophenyl)imide (8b). Red crystals (1.54 g, 90%): mp 123–128 °C; IR (KBr) ν_{max} 3063, 2950, 2922, 2849, 1579, 1476, 1301, 1254, 1172, 768 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 2.51 (s, 3H, CH_3), 4.02 (s, 2H, CH_2''), 6.00 (m, 2H, H2′ + H6′), 6.95 (m, 2H, H3′ + H5′), 7.00–7.65 (m, 8H, Ph″ + H-3 + H-4 + H-5); ^{13}C NMR (50 MHz, $CDCl_3$) δ 19.5, 37.2, 110.8, 117.0, 120.4, 121.8, 127.8, 1128.7, 128.8, 128.9, 134.0, 134.3, 154.1, 157.3, 162.1.

[2-(Benzylsulfanyl)-6-methylpyridinium-1-yl](4-tolyl)imide (8c). Red crystals (1.26 g, 79%): mp 102–107 °C; IR (KBr) ν_{max} 3048, 3009, 2942, 2918, 2847, 1605, 1497, 1468, 1254, 1175, 774 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 2.18 (s, 3H, CH_3'), 2.50 (s, 3H, CH_3), 4.00 (s, 2H, CH_2''), 6.10 (m, 2H, H2′ + H6′), 6.85 (m, 2H, H3′ + H5′), 7.12 (d, J = 8.1 Hz, 1H, H-3), 7.22–7.39 (m, 6H, H5 + Ph″), 7.52 (t, J = 8.1 Hz, 1H, H-4); ^{13}C NMR (50 MHz, $CDCl_3$) δ 19.9, 20.4, 37.3, 110.1, 120.3, 121.7, 122.7, 127.6, 128.7, 128.9, 129.7, 133.1, 134.6, 150.0, 152.6, 157.2.

2-[(Benzylsulfanyl)-6-methylpyridinium-1-yl](4-methoxyphenyl)imide (8d). Red crystals (1.50 g, 89%): mp 104–112 °C; IR (KBr) ν_{max} 3023, 2945, 2829, 1492, 1470, 1230, 1034, 773 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 2.47 (s, 3H, CH_3), 3.70 (s, 3H, OCH_3'), 4.00 (s, 2H, CH_2''), 6.13 (m, 2H, H2′ + H6′), 6.68 (m, 2H, H3′ + H5′), 7.09 (d, J = 8.0 Hz, 1H, H-3), 7.22 (d, J = 8.0 Hz, 1H, H-5), 7.26–7.42 (m, 5H, Ph″), 7.48 (t, J = 8.0 Hz, 1H, H-4); ^{13}C NMR (50 MHz, $CDCl_3$) δ 20.1, 37.4, 56.0, 110.9, 115.0, 120.0, 121.8, 127.6, 128.7, 128.9, 132.0, 134.7, 149.3, 150.1, 156.6, 160.8.

General Procedure for Reaction of 2-Arylthio-6-methylpyridinium Imides (8) with Aryl Isocyanates. A solution of the appropriate 2-arylthio-6-methylpyridinium imides (**8a**–**d**) (2 mmol) and aryl isocyanate (2.4 mmol) in dichloromethane (22 mL) was stirred at room temperature for a period specifically given in the description of the particular derivatives to give 5-methyl-1,3-diaryl-2-oxo-2,3-dihydro[1,2,4]triazolo[1,5-*a*]pyridinium chlorides (**9**) as precipitates. The colorless crystals were filtered off and washed with dichloromethane. The chloride salt was dissolved in acetonitrile, 50% tetrafluoroboric acid was added, and the obtained tetrafluoroborate salt was filtered off. The mother liquor was evaporated, and the residue was subjected to column chromatography on alumina by a mixture of hexane–ethyl acetate 4:1 as eluent. Separation of the main fraction around R_f = 0.6 gave the appropriate 5-[4-(arylthio)pentadienyl]-2,4-diaryl[1,2,4]triazol-3(3*H*)-one (**10**).

1-(4-Methoxyphenyl)-5-methyl-3-(4-tolyl)-2-oxo-2,3-dihydro-1*H*-[1,2,4]triazolo[1,5-*a*]pyridin-4-ium Tetrafluoroborate (9a). The reaction mixture was stirred for 5 days. Colorless crystals (0.11 g, 39%): mp 278–283 °C; IR (KBr) ν_{max} 3094, 1748, 1640, 1585, 1523, 1259, 1062, 833 cm^{-1}; ^{1}H NMR (200 MHz, DMSO) δ 2.19 (s, 3H, CH_3), 2.45 (s, 3H, CH_3'), 3.87 (s, 3H, OCH_3''), 7.26 (m, 2H, H3″ + H5″), 7.47–7.71 (m, 8H, H2″ + H6″ + H2′ + H3′ + H5′ +

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H6′ + H-3 + H-5), 8.22 (t, J = 8.0 Hz, 1H, H-4); ^{13}C NMR (50 MHz, DMSO) δ 19.1, 20.9, 55.6, 107.9, 115.5, 121.4, 121.9, 128.6, 129.0, 130.4, 131.0, 140.9, 141.6, 142.0, 142.7, 149.5, 160.6. Anal. Calcd. for $C_{21}H_{20}BF_4N_3O_2$ (433.16): C, 58.22; H, 4.65; N, 9.70. Found: C, 57.81; H, 4.59; N, 9.46.

1,3-Bis(4-methoxyphenyl)-5-methyl-2-oxo-2,3-dihydro-1*H*-[1,2,4]triazolo[1,5-*a*]pyridin-4-ium Tetrafluoroborate (9b). The reaction mixture was stirred for 7 days. Colorless crystals (0.062 g, 7%): mp 235−239 °C; IR (KBr) ν_{max} 3373, 3097, 3010, 2840, 1746, 1640, 1518, 1466, 1306, 1258, 1170, 1056, 840 cm^{-1}; ^{1}H NMR (200 MHz, DMSO) δ 2.19 (s, 3H, CH_3), 3.87 (s, 6H, OCH_3' + OCH_3''), 7.24 (m, 4H, H3′ + H5′ + H3″ + H5″), 7.51−7.80 (m, 6H, H-3 + H-5 + H2′ + H6′ + H2″ + H6″), 8.20 (t, J = 8.0 Hz, 1H, H-4); ^{13}C NMR (50 MHz, DMSO) δ 19.0, 55.7, 55.8, 107.9, 115.1, 115.5, 121.5, 122.0, 125.4, 128.7, 131.4, 140.7, 141.4, 142.4, 149.4, 160.6, 161.5. Anal. Calcd. for $C_{21}H_{20}BF_4N_3O_3$ (449.15): C, 56.15; H, 4.49; N, 9.35. Found: C, 55.96; H, 4.21; N, 9.48.

5-[(1*Z*,3*E*)-4-(Benzylthio)penta-1,3-dien-1-yl]-2-(4-chlorophenyl)-4-phenyl-2,4-dihydro-3*H*-1,2,4-triazol-3-one (10a). The reaction mixture was stirred for 2 days. Yellow crystals (0.38 g, 41%): mp 176−179 °C; IR (KBr) ν_{max} 3062, 2921, 1713, 1607, 1493, 1377, 1278, 1093, 1013, 829 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 2.12 (s, 3H, CH_3), 4.19 (s, 2H, CH_2''), 5.47 (d, J = 11.4 Hz, 1H), 6.68 (t, J = 11.4 Hz, 1H), 7.28−7.41 (m, 9H), 7.47−7.54 (m, 4H), 8.00 (m, 2H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 18.2, 36.5, 105.6, 118.0, 119.6, 127.5, 127.6, 128.7, 128.9, 129.1, 129.2, 129.7, 130.4, 131.7, 132.4, 135.6, 136.6, 144.1, 145.1, 145.9. HRMS calcd. for $C_{26}H_{22}ClN_3OS$ 459.1172, found 459.1195.

5-[(1*Z*,3*E*)-4-(Benzylthio)penta-1,3-dien-1-yl]-2-(4-chlorophenyl)-4-(4-methoxyphenyl)-2,4-dihydro-3*H*-1,2,4-triazol-3-one (10b). The reaction mixture was stirred for 16 h. Yellow crystals (0.60 g, 62%): mp 204−208 °C; IR (KBr) ν_{max} 3066, 3003, 2917, 2840, 1721, 1605, 1518, 1494, 1383, 1249, 1094, 1021, 1001, 812 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.12 (s, 3H, CH_3), 3.86 (s, 3H, OCH_3'''), 4.19 (s, 2H, CH_2''), 5.47 (d, J = 11.4 Hz, 1H), 6.68 (t, J = 11.4 Hz, 1H), 7.03 (m, 2H), 7.24−7.39 (m, 10H), 8.01 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 18.2, 36.5, 55.6, 105.8, 115.0, 117.8, 119.6, 124.8, 127.6, 128.7, 128.8, 128.9, 129.0, 130.4, 131.6, 135.6, 136.6, 144.5, 145.8, 151.1, 160.1. Anal. Calcd. for $C_{27}H_{24}ClN_3O_2S$ (489.13): C, 66.18; H, 4.94; N, 8.58; S, 6.54. Found: C, 65.88; H, 5.11; N, 8.55; S, 6.88.

5-[(1*Z*,3*E*)-4-(Benzylthio)penta-1,3-dien-1-yl]-2-(4-tolyl)-4-phenyl-2,4-dihydro-3*H*-1,2,4-triazol-3-one (10c). The reaction mixture was stirred for 6 days. Yellow crystals (0.46 g, 50%): mp 156−163 °C; IR (KBr) ν_{max} 3054, 2920, 1710, 1605, 1512, 1376, 1279, 1237, 1161, 1010, 816 cm^{-1}; ^{1}H NMR (300 MHz, DMSO) δ 2.12 (s, 3H, CH_3), 2.33 (s, 3H, CH_3'), 4.20 (s, 2H, CH_2''), 5.48 (d, J = 11.4 Hz, 1H), 6.80 (t, J = 11.4 Hz, 1H), 7.10−7.58 (m, 13H), 7.94 (m, 2H); ^{13}C NMR (75 MHz, DMSO) δ 18.4, 21.2, 36.8, 106.2, 118.2, 118.8, 127.7, 127.8, 127.9, 128.2, 128.9, 129.2, 129.7, 131.4, 135.3, 135.9, 144.5, 145.8, 151.1. Anal. Calcd. for $C_{27}H_{25}N_3OS$ (439.17): C, 73.77; H, 5.73; N, 9.56; S, 7.29. Found: C, 73.72; H, 5.99; N, 9.40; S, 7.29.

5-[(1*Z*,3*E*)-4-(Benzylthio)penta-1,3-dien-1-yl]-2-(4-methoxyphenyl)-4-phenyl-2,4-dihydro-3*H*-1,2,4-triazol-3-one (10d). The reaction mixture was stirred for 7 days. Yellow crystals (0.06 g, 13%): mp 140−154 °C; IR (KBr) ν_{max} 3054, 2913, 2836, 1710, 1604, 1513, 1380, 1252, 1161, 1031, 829 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 2.11 (s, 3H, CH_3), 3.78 (s, 3H, OCH_3'), 4.19 (s, 2H, CH_2''), 5.49 (d, J = 11.4 Hz, 1H), 6.65 (t, J = 11.4 Hz, 1H), 6.87 (m, 2H), 7.25−7.53 (m, 11H), 7.94 (m, 2H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 18.1, 36.6, 55.5, 106.1, 114.2, 118.2, 120.3, 127.5, 127.6, 128.7, 128.9, 129.6, 131.0, 131.5, 132.7, 135.8, 143.6, 144.5, 145.1, 150.8, 157.2. HRMS calcd. for $C_{27}H_{25}N_3O_2S$ 455.1667, found 455.1668.

General Procedure for the Synthesis of Imidazo[4,5-*b*]pyridinones (11a−d). A mixture of the appropriate 2-arylthio-6-methylpyridinium imides (**8a−d**) (1 mmol) and aryl isocyanate (3 mmol) in dichloromethane (22 mL) was stirred at room temperature for 15 min. The obtained precipitate was filtered off and washed with diethyl ether.

(2*Z*)-2-[1-(4-Tolyl)-2-oxo-3-phenyl-1,2,3,7a-tetrahydro-5*H*-imidazo[4,5-*b*]pyridin-5-ylidene]-*N*-phenylethanamide (11a). Starting from **8a** or **8c**, **11a** was isolated as yellow crystals (0.26 g, 59%): mp 149−151 °C; IR (KBr) ν_{max} 3249, 3056, 1755, 1650, 1592, 1553, 1497, 1437, 1301, 1249, 1167, 1141, 1017, 750 cm^{-1}; ^{1}H NMR (400 MHz, DMSO) δ 2.35 (s, 3H, CH_3'), 4.28 (s, 1H, C_αH), 5.40 (dd, J = 6.8, 1.1 Hz, 1H, H7a), 6.85 (m, 1H), 6.97 (dd, J = 9.6, 6.8 Hz, 1H, H7), 7.13−7.34 (m, 7H), 7.46−7.62 (m, 5H), 8.11 (dd, J = 9.6, 1.1 Hz, 1H, H6), 8.95 (s, 1H, CONH); ^{13}C NMR (100 MHz, DMSO) δ 20.6, 82.5, 83.0, 112.0, 118.4, 121.2, 122.6, 127.3, 128.3, 129.5, 129.6, 129.8, 131.0, 131.5, 133.7, 137.3, 140.8, 141.6, 144.2, 153.6, 165.2. HRMS Calcd. for $C_{27}H_{22}N_4O_2$ 434.1743, found 434.1756.

(2*Z*)-*N*-(4-Methoxyphenyl)-2-[3-(4-methoxyphenyl)-1-(4-tolyl)-2-oxo-1,2,3,7a-tetrahydro-5*H*-imidazo[4,5-*b*]pyridin-5-ylidene]ethanamide (11b). Starting from **8a** or **8c**, **11a** was isolated as yellow crystals (0.28 g, 57% or 0.33 g, 67%, respectively): mp 158−164 °C; IR (KBr) ν_{max} 3256, 3110, 3040, 2935, 2837, 1743, 1647, 1559, 1510, 1241, 1166, 1029, 826 cm^{-1}; ^{1}H NMR (400 MHz, DMSO) δ 2.32 (s, 3H, CH_3'), 3.65 (s, 3H, OCH_3'''), 3.80 (s, 3H, OCH_3''), 4.18 (s, 1H, C_αH), 5.27 (dd, J = 7.0, 1.1 Hz, 1H, H7a), 6.72 (m, 2H, H3‴ + H5‴), 6.90 (dd, J = 9.0, 7.0 Hz, 1H, H7), 7.10 (m, 2H, H3″ + H5″), 7.20 (m, 2H, H2′ + H6′), 7.29 (m, 2H, H3′ + H5′), 7.35 (m, 2H, H2‴ + H6‴), 7.51 (m, 2H, H2″ + H6″), 8.05 (dd, J = 9.0, 1.1 Hz, 1H, H6), 8.78 (s, 1H, CONH); ^{13}C NMR (100 MHz, DMSO) δ 20.6 (CH_3'), 55.0 (OCH_3'''), 55.5 (OCH_3''), 82.0 (C7a), 83.0 (C_α), 111.9 (C6), 113.5 (C3‴ + C5‴), 115.0 (C3″ + C5″), 120.0 (C2‴ + C6‴), 122.6 (C2′ + C6′), 123.3 (C1″), 128.89 (C2″ + C6″), 129.4 (C3′ + C5′), 131.1 (C7), 133.8 (C1′), 134.0 (C1‴), 137.2 (C4′), 142.0 (C3a), 145.0 (C5), 153.8 (C4‴), 153.9 (C2), 159.8 (C4″), 165.0 (HNCO). HRMS Calcd. for $C_{29}H_{26}N_4O_4$ 494.1954, found 494.1942.

(2*Z*)-2-[1-(4-Chlorophenyl)-2-oxo-3-phenyl-1,2,3,7a-tetrahydro-5*H*-imidazo[4,5-*b*]pyridin-5-ylidene]-*N*-phenylethanamide (11c). Yellow crystals (0.26 g, 57%): mp 164−168 °C; IR (KBr) ν_{max} 3293, 3126, 3095, 3064, 1754, 1647, 1560, 1497, 1437, 1253, 1184, 1092, 1015 cm^{-1}; ^{1}H NMR (400 MHz, DMSO) δ 4.16 (s, 1H, C_αH), 5.42 (dd, J = 6.9, 1.0 Hz, 1H, H7a), 6.85 (m, 1H), 6.98 (dd, J = 9.5, 6.9 Hz, 1H, H7), 7.18 (m, 2H), 7.30−7.70 (m, 11H), 8.15 (dd, J = 9.5, 1.0 Hz, 1H, H6), 9.00 (s, 1H, CONH); ^{13}C NMR (100 MHz, DMSO) δ 82.7, 83.5, 112.0, 118.4, 121.3, 124.1, 127.4, 128.3, 128.8, 129.7, 129.8, 131.0, 131.5, 131.7, 134.4, 140.7, 141.6, 144.1, 153.0, 165.1. HRMS Calcd. for $C_{26}H_{19}ClN_4O_2$ 454.1197, found 454.1210.

(2*Z*)-2-[1-(4-Chlorophenyl)-3-(4-methoxyphenyl)-2-oxo-1,2,3,7a-tetrahydro-5*H*-imidazo[4,5-*b*]pyridin-5-ylidene]-*N*-(4-methoxyphenyl)ethanamide (11d). Yellow crystals (0.23 g, 45%): mp 154−158 °C; IR (KBr) ν_{max} 3271, 3107, 2935, 2835, 1754, 1652, 1557, 1508, 1447, 1254, 1165, 1092, 1028, 830 cm^{-1}; ^{1}H NMR (400 MHz, DMSO) δ 3.68 (s, 3H, OCH_3''), 3.82 (s, 3H, OCH_3'''), 4.11 (s, 1H, C_αH), 5.32 (dd, J = 6.6, 1.0 Hz, 1H, H7a), 6.76 (m, 2H), 6.94 (dd, J = 9.7, 6.6 Hz, 1H, H7), 7.13−7.65 (m, 10H), 8.12 (dd, J = 9.7, 1.0 Hz, 1H, H6), 8.85 (s, 1H, CONH); ^{13}C NMR (100 MHz, DMSO) δ 55.0, 55.5, 82.3, 83.5, 111.9, 113.5, 115.0, 120.0, 123.3, 124.1, 128.8, 129.0, 131.2, 131.6, 133.9, 134.4, 142.0, 143.9, 153.2, 154.0, 159.9, 164.9. HRMS Calcd. for $C_{28}H_{23}ClN_4O_4$ 514.1408, found 514.1420.

Reaction of 1-(4-Methoxyphenyl)-5-methyl-3-(4-tolyl)-2-oxo-2,3-dihydro-1*H*-[1,2,4]triazolo[1,5-a]pyridin-4-ium chloride (9a) with 4-Methoxyphenyl Isocyanate and Phenyl Isocyanate in the Presence of DBU. A mixture of 1-(4-methoxyphenyl)-5-methyl-3-(4-tolyl)-2-oxo-2,3-dihydro-1*H*-[1,2,4]-triazolo[1,5-*a*]pyridin-4-ium chloride (**9a**, 100 mg, 0.26 mmol), DBU (31 mg, 0.26 mmol), 4-methoxyphenyl isocyanate (60 mg, 0.4 mmol), and absolute acetonitrile (8 mL) was stirred at room temperature for 10 min. The precipitated yellow crystals were filtered off and washed with diethyl ether to give (2*Z*)-*N*-(4-methoxyphenyl)-2-[3-(4-methoxyphenyl)-1-(4-tolyl)-2-oxo-1,2,3,7a-tetrahydro-5*H*-imidazo-[4,5-*b*]pyridin-5-ylidene]ethanamide (**11b**) (115 mg, 90%).

(2*Z*)-2-[1-(4-Tolyl)-3-(4-methoxyphenyl)-2-oxo-1,2,3,7a-tetrahydro-5*H*-imidazo[4,5-*b*]pyridin-5-ylidene]-*N*-phenylethanamide (11e). This compound was prepared from **9a** (100 mg, 0.26 mmol), DBU (31 mg, 0.26 mmol), phenyl isocyanate (48 mg, 0.4 mmol), and absolute acetonitrile (8 mL), which was stirred at room

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temperature for 10 min. The precipitated yellow crystals were filtered off and washed with diethyl ether.

Yellow crystals (83 mg, 70%): mp 151−153 °C; IR (KBr) ν_{max} 3273, 3035, 2934, 1758, 1651, 1552, 1514, 1497, 1254, 1164, 1027, 750 cm^{-1}; ^1H NMR (300 MHz, DMSO) δ 2.35 (s, 3H), 3.83 (s, 3H), 4.27 (s, 1H), 5.35 (d, 1H), 6.85 (t, 1H), 6.97 (t, 1H), 7.07−7.20 (m, 4H), 7.23 (m, 2H), 7.32 (m, 2H), 7.48 (m, 2H), 7.54 (m, 2H), 8.10 (d, 1H), 8.93 (s, 1H); APT (75 MHz, DMSO) δ 20.6, 55.5, 82.5, 82.8, 111.8, 115.0 (2C), 118.4 (2C), 121.2, 122.6 (2C), 123.3, 128.3 (2C), 128.9 (2C), 129.5 (2C), 131.5, 133.8, 137.3, 140.8, 142.1, 144.2, 153.9, 159.9, 165.2. HRMS [MH^+] Calcd. for $C_{28}H_{25}N_4O_3^+$ 465.1921, found 465.1927.

5-Methyl-1-phenyl-2-thioxo-3-(4-tolyl)-2,3-dyhidro-1*H*-[1,2,4]triazolo[1,5-*a*]pyridine-4-ium Tetrafluoroborate (14). Compound **8a** was reacted with phenyl isothiocyanate according to the procedure given for **9a** and **b**. The reaction mixture was stirred 4 days. Colorless crystals (192 mg, 23%): mp 264−266 °C; IR (KBr) ν_{max} 3086, 1635, 1578, 1520, 1509, 1396, 1332, 10345, 762 cm^{-1}; ^1H NMR (200 MHz, DMSO) δ 2.16 (s, 3H, CH_3), 2.48 (s, 3H, CH_3), 7.56 (t, 2H), 7.63−7.79 (m, 9H), 8.26 (t, 1H); ^{13}C NMR (50 MHz, DMSO) δ 19.0, 21.0, 108.7, 122.4, 127.9, 130.4, 130.5, 131.2, 131.6, 132.0, 140.8, 141.1, 142.7, 143.2, 170.6. Anal. Calcd. for $C_{20}H_{18}BF_4N_3S$ (419.13): C, 57.30; H, 4.33; N, 10.02; S, 7.65. Found: C, 56.96; H, 4.27; N, 9.84; S, 7.65.

(2*Z*)-*N*-(4-Methoxyphenyl)-2-[1-(4-tolyl)-3-phenyl-2-thioxo-1,2,3,7a-tetrahidro-5*H*-imidazo[4,5-*b*]pyridin-5-ylidene]-ethanamide (15) by Using DBU. This compound was prepared from 5-methyl-3-(4-tolyl)-1-phenyl-2-thioxo-2,3-dihydro-1*H*-[1,2,4]-triazolo[1,5-*a*]pyridin-4-ium tetrafluoroborate (**14**) by the same procedure as above.

Yellow crystals (50 mg, 60%): mp 145−148 °C; IR (KBr) ν_{max} 3292, 3043, 2924, 2828, 1650, 1553, 1508, 1348, 1271, 1160, 1037, 831 cm^{-1}; ^1H NMR (400 MHz, DMSO) δ 2.37 (s, 3H, CH_3'), 3.68 (s, 3H, OCH_3'''), 4.32 (s, 1H, CαH), 5.26 (dd, J = 7.0, 1.0 Hz, 1H, H7a), 6.77 (m, 2H), 6.94 (dd, J = 9.5, 7.0 Hz, 1H, H7), 7.33−7.70 (m, 11H), 8.10 (dd, J = 9.5, 1.0 Hz, 1H, H6), 8.74 (s, 1H, CONH); ^{13}C NMR (100 MHz, DMSO) δ 20.8, 55.1, 82.6, 83.0, 112.3, 113.8, 117.2, 120.6, 125.3, 128.8, 129.0, 129.4, 130.0, 131.2, 132.4, 134.7, 138.7, 144.9, 150.3, 155.2, 167.4, 171.1. HRMS calcd. for $C_{28}H_{24}N_4O_2S$ 480.1620, found 480.1607.

***N*-(4-Methoxyphenyl)-2-[3-(4-methoxyphenyl)-1-(4-tolyl)-2-oxo-2,3-dihydro-1*H*-imidazo[4,5-*b*]pyridin-5-yl]acetamide (16a).** A solution of (2*Z*)-*N*-(4-methoxyphenyl)-2-[3-(4-methyoxyphenyl)-1-(4-tolyl)-2-oxo-1,2,3,7a-tetrahidro-5*H*-imidazo[4,5-*b*]-pyridin-5-ylidene]ethanamide (**11b**) (494 mg, 1 mmol) in chloroform (21 mL) was refluxed for 8 h. The reaction mixture was evaporated, diethyl ether was added, and the obtained precipitate was filtered off and washed with diethyl ether.

Colorless crystals (480 mg, 97%): mp 211−215 °C; IR (KBr) ν_{max} 3281, 3130, 3060, 3016, 2937, 2837, 1728, 1661, 1513, 1457, 1408, 1299, 1256, 1171, 1030, 821 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 2.43 (s, 3H, CH_3'), 3.75 (s, 3H, OCH_3'''), 3.78 (s, 2H, $C_\alpha H_2$), 3.89 (s, 3H, OCH_3''), 6.73 (m, 2H, H3‴ + H5‴), 6.99 (d, J = 7.7 Hz, 1H, H6), 7.09 (m, 4H, H2‴ + H6‴ + H3″ + H5″), 7.29 (d, J = 7.7 Hz, 1H, H7), 7.35 (m, 2H, H3′ + H5′), 7.42 (m, 2H, H2′ + H6′), 7.60 (m, 2H, H2″+ H6″), 9.59 (s, 1H, CONH); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.2 (CH_3'), 44.8 (C_α), 55.4 (OCH_3'''), 55.6 (OCH_3''), 113.9 (C3‴ + C5‴), 114.7 (C3″ + C5″), 115.9 (C7), 117.7 (C6), 120.9 (C2‴ + C6‴), 123.0 (C7a), 125.4 (C2′ + C6′), 125.6 (C1″), 128.0 (C2″ + C6″), 130.3 (C3′ + C5′), 130.9 (C1′), 131.4 (C1‴), 138.2 (C4′), 143.0 (C3a), 146.8 (C5), 152.0 (C2), 155.9 (C4‴), 159.4 (C4″), 166.9 (CONH). HRMS calcd. for $C_{29}H_{26}N_4O_4$ 494.1954, found 494.1942.

2-[1-(4-Chlorophenyl)-3-(4-methoxyphenyl)-2-oxo-2,3-dihydro-1*H*-imidazo[4,5-*b*]pyridin-5-yl]-*N*-(4-methoxyphenyl)-acetamide (16b). This compound was obtained from (2*Z*)-2-[1-(4-Chlorophenyl)-3-(4-methyoxyphenyl)-2-oxo-1,2,3,7a-tetrahydro-5*H*-imidazo[4,5-*b*]pyridin-5-ylidene]-*N*-(4-methyoxyphenyl)ethanamide (**11d**) (515 mg, 1 mmol) by the procedure as described above for **16a**.

Colorless crystals (500 mg, 97%): mp 221−223 °C; IR (KBr) ν_{max} 3348, 1713, 1697, 1513, 1454, 1408, 1255, 1179, 832 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 3.75 (s, 3H, OCH_3), 3.79 (s, 2H, CH_2), 3.88 (s, 3H, OCH_3), 6.73 (m, 2H), 7.02 (d, J = 8.3 Hz, 1H, H6), 7.08 (m, 4H), 7.31 (d, J = 8.3 Hz, 1H, H7), 7.52 (m, 4H), 7.58 (m, 2H), 9.48 (s, 1H, CONH); ^{13}C NMR (100 MHz, $CDCl_3$) δ 44.9, 55.4, 55.6, 113.9, 114.8, 116.0, 117.9, 120.9, 122.4, 125.3, 126.7, 128.0, 129.9, 131.4, 132.2, 133.8, 143.1, 147.3, 151.8, 156.0, 159.5, 166.8. HRMS Calcd. for $C_{28}H_{23}ClN_4O_4$ 514.1408, found 514.1398.

Direct Formation of *N*-(4-Methoxyphenyl)-2-[3-(4-methoxyphenyl)-1-(4-tolyl)-2-oxo-2,3-dihydro-1*H*-imidazo[4,5-*b*]-pyridin-5-yl]acetamide (16a) from {2-Methyl-6-[(4-tolyl)-sulfanyl]pyridinium-1-yl}(4-tolyl)imide (8a). A solution of {2-methyl-6-[(4-tolyl)sulfanyl]pyridinium-1-yl}(4-tolyl)imide (**8a**) (100 mg, 0.31 mmol) and aryl 4-methoxyphenyl isocyanate (1 mmol) in dichloromethane (4 mL) was stirred at room temperature for 20 min and then refluxed for 16 h. The reaction mixture was evaporated, diethyl ether was added, and the obtained precipitate was filtered off and washed with diethyl ether. The mother liquor was evaporated, cold acetonitrile was added, and the obtained precipitate was filtered off and washed with cold acetonitrile to give *N*-(4-methoxyphenyl)-2-[3-(4-methoxyphenyl)-1-(4-tolyl)-2-oxo-2,3-dihydro-1*H*-imidazo[4,5-*b*]pyridin-5-yl]acetamide (**16a**) as white crystals (75 mg, 48%).

***N*-(4-Methoxyphenyl)-2-(3-phenyl-2-thioxo-1-(4-tolyl)-2,3-dihydro-1*H*-imidazo[4,5-*b*]pyridine-5-yl)acetamide (17).** A solution of (2*Z*)-*N*-(4-methoxyphenyl)-2-[1-(4-tolyl)-3-phenyl-2-thioxo-1,2,3,7a-tetrahydro-5*H*-imidazo[4,5-*b*]pyridin-5-ylidene]ethanamide (**15**) (0.48 g, 1 mmol) in chloroform (21 mL) was refluxed for 4 h. The reaction mixture was evaporated, diethyl ether was added, and the obtained precipate was filtered off and washed with diethyl ether.

Colorless crystals (0.43 g, 90%): mp 255−260 °C; IR (KBr) ν_{max} 3286, 2922, 2851, 1658, 1512, 1441, 1325, 1298, 1261, 1168, 1106, 1022, 822, 803 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 2.47 (s, 3H, CH_3'), 3.77 (s, 3H, OCH_3'''), 3.82 (s, 2H, $C_\alpha H_2$), 6.74 (m, 2H), 7.02 (m, 2H), 7.11 (d, J = 8.0 Hz, 1H, H-6), 7.20−7.70 (m, 10H), 9.42 (br. s, 1H, CONH); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.6, 45.1, 55.7, 114.2, 117.6, 119.5, 121.0, 126.5, 127.7, 128.8, 129.6, 129.9, 130.8, 131.5, 132.4, 134.8, 140.0, 145.6, 149.6, 156.3, 166.6, 172.8. HRMS calcd. for $C_{28}H_{24}N_4O_2S$ 480.1620, found 480.1641.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

^1H and ^{13}C NMR spectra of all new compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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(23) As shown by TLC analysis, both **9** and **10** were present in the reaction mixtures. The yields in Table 1 refer to those isolated and characterized.