(dd, 1 H); mass spectrum, m/z (rel intensity) 250 (26, M^+), 235 (100), 207 (29). Anal. Calcd for $C_{13}H_{14}OS_2$: C, 62.36; H, 5.63; S, 25.61. Found: C, 62.64; H, 5.88; S, 25.90.

2,3-Dihydro-5,5-dimethyl-8-methoxy-5*H*-benzo[*b*]thiopyrano[3,4-*b*][1,4]dithiin (4g): yield 73%, yellow oil; ^1H NMR δ 1.48 (s, 6 H), 3.20 (s, 4 H), 3.79 (s, 3 H), 6.70 (dd, 1 H), 6.83 (d, 1 H), 7.62 (d, 1 H); mass spectrum, m/z (rel intensity) 296 (55, M^+), 281 (93), 255 (36), 235 (100). Anal. Calcd for $C_{14}H_{16}OS_3$: C, 56.71; H, 5.44; S, 32.44. Found: C, 56.52; H, 5.40; S, 32.61.

2,3,5,6-Tetrahydro-9-methoxynaphtho[1,2-*b*][1,4]dithiin (4h): yield 87%; mp 82–84 °C; ^1H NMR δ 2.40 (m, 2 H), 2.75 (m, 2 H), 3.20–3.38 (m, 4 H), 3.83 (s, 3 H), 6.68 (dd, 1 H), 7.03 (d, 1 H), 7.07 (d, 1 H); mass spectrum, m/z (rel intensity) 250 (100, M^+), 222 (13), 191 (16), 190 (14). Anal. Calcd for $C_{13}H_{14}OS_2$: C, 62.36; H, 5.63; S, 25.61. Found: C, 62.50; H, 5.76; S, 25.47.

2,3-Dihydro-5,5-dimethyl-8-methoxy-9-bromo-5*H*-benzo[*b*]pyrano[3,4-*b*][1,4]dithiin (4i): yield 83%; mp 132–134 °C; ^1H NMR δ 1.48 (s, 6 H), 3.23 (s, 4 H), 3.85 (s, 3 H), 6.43 (s, 1 H), 7.45 (s, 1 H); mass spectrum, m/z (rel intensity) 360 (25, M^+), 358 (22), 345 (100), 343 (92), 317 (14), 315 (14). Anal. Calcd for $C_{14}H_{15}BrO_2S_2$: C, 46.80; H, 4.21; Br, 22.24; S, 17.85. Found: C, 46.75; H, 4.34; Br, 22.30; S, 17.85.

2,3-Dihydro-5,5-dimethyl-8-ethoxy-9-bromo-5*H*-benzo[*b*]pyrano[3,4-*b*][1,4]dithiin (4j): yield 79%; mp 129–132 °C; ^1H NMR δ 1.42 (t, 3 H), 1.48 (s, 6 H), 3.24 (s, 4 H), 4.05 (q, 2 H), 6.41 (s, 1 H), 7.46 (s, 1 H); mass spectrum, m/z (rel intensity) 374 (35, M^+), 372 (33), 359 (100), 357 (97), 331 (29), 329 (29), 279 (48). Anal. Calcd for $C_{15}H_{17}BrO_2S_2$: C, 48.25; H, 4.59; Br, 21.40; S, 17.17. Found: C, 48.42; H, 4.79; Br, 21.61; S, 17.38.

2,3-Dihydro-5-phenyl-1,4-dithiin (14):[6] yield 79%; mp 54–55 °C; ^1H NMR δ 3.20–3.36 (m, 4 H), 6.39 (s, 1 H), 7.24–7.49 (m, 5 H); mass spectrum, m/z (rel intensity) 194 (68, M^+), 166 (38), 134 (24), 121 (100). Anal. Calcd for $C_{10}H_{10}S_2$: C, 61.81; H, 5.19; S, 33.00. Found: C, 61.72; H, 5.50, S, 32.68.

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Registry No. **1a**, 20321-73-7; **1b**, 76348-94-2; **1c**, 65383-61-1; **1d**, 65383-62-2; **1e**, 491-37-2; **1f**, 3780-33-4; **1g**, 64793-90-4; **1h**, 6836-19-7; **2a**, 136545-72-7; **2b**, 136545-73-8; **2c**, 136545-74-9; **2d**, 136545-75-0; **2e**, 7156-48-1; **2f**, 136545-76-1; **2g**, 136545-77-2; **2h**, 136545-78-3; **4a**, 136545-79-4; **4b**, 136545-80-7; **4c**, 136545-81-8; **4d**, 136545-82-9; **4e**, 104169-49-5; **4f**, 136545-83-0; **4g**, 136545-84-1; **4h**, 136545-85-2; **4i**, 131356-27-9; **4j**, 136545-86-3; **5a**, 5769-02-8; **5b**, 6317-10-8; **5c**, 16775-67-0; **14**, 35756-26-4; HF/Py, 32001-55-1; $SH(CH_2)_2SH$, 540-63-6; CH_3COPh, 98-86-2; PhCOPh, 119-61-9; cyclododecanone, 830-13-7.

2-Aza 1,3-Dienes: A New and Simple Method for the Synthesis of Functionalized Pyridine Derivatives

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The synthesis of 4(1*H*)-pyridones and 4-chloropyridines from 2-aza 1,3-dienes is described, using carbonic acid derivatives. The process involves a [5 + 1] heterocyclization reaction, with formation of two new carbon–carbon bonds.

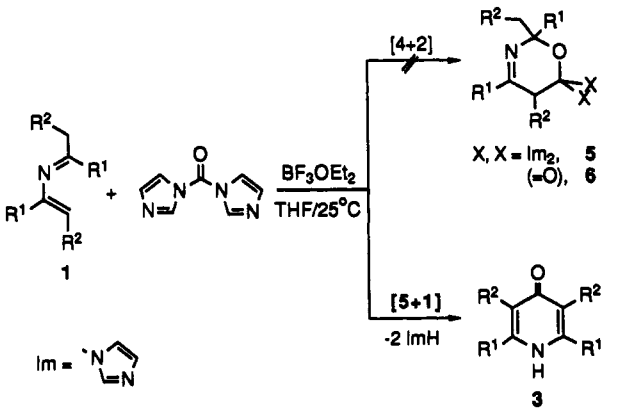
Introduction

Heterodienes have been extensively used in organic synthesis for the preparation of both open-chain functionalized compounds and heterocyclic systems. They have found important use in heterocyclic synthesis mainly due to their ability to take part in [4 + 2] cycloaddition reactions; other utilities are also known.[1] In this context, the synthetic possibilities of C-substituted 2-aza 1,3-dienes 1 have been well established in previous reports from these laboratories.[2] Thus, we have studied the behavior of compounds 1 in [4 + 2] cycloaddition reactions,[3] as well as their reactivity through either the nitrogen[4] or the C-α carbon atoms,[5] as outlined in Figure 1.

More recently, a new type of process which involves the participation of both the dienic system and the C_α-H hydrogen atom, i.e., a [5 + 1] formal cyclocondensation reaction (Figure 1), has also been described. For instance, the reaction of 1 with phosphorus(III) halide derivatives led, in a simple way, to λ^3- and λ^5-azaphosphinine derivatives 2 (Z = PR, OPR, Figure 2).[6]

This methodology was investigated as a simple route to several types of heterocycles 2 by replacing the halo-

Scheme I



(1) Boger, D. L.; Weinreb, S. M. *Hetero Diels-Alder Methodology in Organic Synthesis*; Academic Press, Inc.: New York, 1987.

(2) (a) Barluenga, J.; Joglar, J.; González, F. J.; Fustero, S. *Synlett* **1990**, 129. (b) Barluenga, J.; Aznar, F.; Fustero, S.; Tomás, M. *Pure Appl. Chem.* **1990**, *62*, 1957.

(3) See ref 2 and the following: Barluenga, J.; González, F. J.; Fustero, S. *Tetrahedron Lett.* **1990**, *31*, 397.

(4) Barluenga, J.; Joglar, J.; Fustero, S.; Gotor, V. *J. Chem. Soc., Chem. Commun.* **1986**, 361.

(5) Barluenga, J.; Joglar, J.; González, F. J.; Gotor, V.; Fustero, S. *J. Org. Chem.* **1988**, *53*, 5960 and references cited therein.

(6) Barluenga, J.; Palacios, F.; González, F. J.; Fustero, S. *J. Chem. Soc., Chem. Commun.* **1988**, 1596.

0022-3263/91/1956-6751$02.50/0

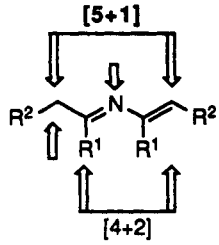
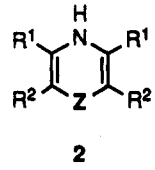


Figure 1.



2

Figure 2.

Table I. 4(1*H*)-Pyridones 3 Obtained from 1 and CDI

entry	compd	R^1	R^2	yield, %
1	3a	Ph	Me	80
2	3b	Ph	Et	90
3	3c	*p*-MeC_6H_4	Me	83
4	3d	Ph	CH_2=$CHCH_2CH_2$	87
5	3e	Ph	Pr	85
6	3f	*c*-C_6H_{11}	Me	75

phosphines by a suitable reagent. We focused our attention on the preparation of pyridine derivatives by the reaction of 2-aza dienes 1 with carbonic and monothiocarbonic derivatives, e.g., 1,1′-carbonyldiimidazole (CDI)[7] and thiophosgene.

The pyridine nucleus is a structural unit in many natural products having simple or very complex structures, like coenzymes, alkaloids, etc.[8] Because of the importance of this ring system and the pharmacological properties of functionalized pyridines, a number of methods of synthesis of pyridines have been developed.[1,5,9] However, the 4-hydroxy and particularly 4-chloro derivatives are not easily obtainable[10] from these routes. Therefore, these types of derivatives are mostly synthesized from heterocyclic precursors.[11]

We report in this paper a new and easy synthetic entry to 4(1*H*)-pyridones 3 and 4-chloropyridines 4 by reaction of aza dienes 1 and CDI or thiophosgene.[12]

Scheme II

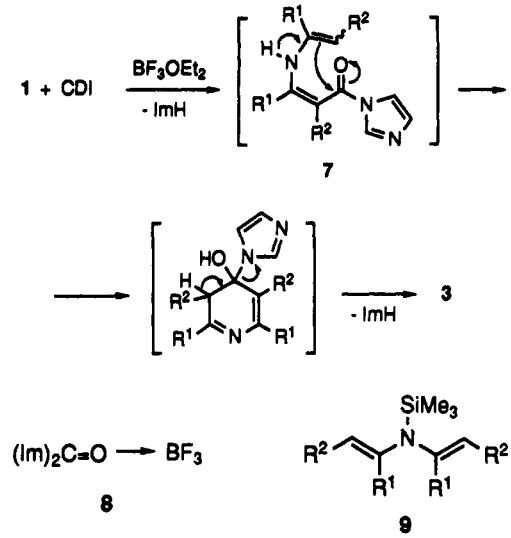


Figure 3.

Results and Discussion

Synthesis of 4(1*H*)-Pyridones 3. The reaction of 2-aza 1,3-dienes 1 with 1,1′-carbonyldiimidazole, which is depicted in Scheme I, was carried out in THF (25 °C, 2–8 h) and required the presence of 1 equiv of BF_3·OEt_2. The reaction worked well, and 4(1*H*)-pyridones 3 were obtained and isolated as white crystalline solids in good to excellent yields (Table I). Compounds 5, which would be formed during a [4 + 2] cycloaddition of 1 and CDI,[13] and their derivatives 6 were never detected (Scheme I).

Compounds 3 were fully characterized by their spectroscopic and mass spectrometric data. For instance, the ^1H NMR (300 MHz) spectrum of **3b** (Table I) shows characteristic signals at δ 1.1 (t, 6 H) and δ 2.4 (q, 4 H) due to the CH_3 and CH_2 groups, respectively; these methyl and methylene carbon atoms appear at δ 13.7 (CH_3) and 19.8 (CH_2) in the ^{13}C NMR (75 MHz) spectrum, while the carbonyl group is observed at 178.2 (*C*). The MS spectrum shows the molecular peak at m/z 303 (M^+).

The formation of 4(1*H*)-pyridones 3 may be rationalized in terms of a [5 + 1] heterocyclization reaction involving the formation of two carbon–carbon bonds.[14] This process might occur via a two-step mechanism, involving the initial formation of a β-enamino imidazolide derivative 7 followed by intramolecular cyclization and subsequent aromatization with loss of a second equivalent of imidazole (Scheme II).

The course of the reaction is strongly influenced by the Lewis acid; thus, when the reaction was carried out without BF_3·OEt_2, the starting materials were recovered.[15] The

(7) Simpkins, N. S. *100 Modern Reagents*; The Royal Society of Chemistry: Nottingham, 1989; p 4.

(8) Yates, F. S. In *Comprehensive Heterocyclic Chemistry*; Boulton, A. J., Mc Killop, A., Eds.; Pergamon Press: Oxford, 1984; Vol. 2, pp 511–524.

(9) (a) Jones, G. In *Comprehensive Heterocyclic Chemistry*; Boulton, A. J., Mc Killop, A., Eds.; Pergamon Press: Oxford, 1984; Vol. 2, pp 359–510. (b) Barluenga, J.; Gotor, V. *Synthesis* **1975**, 191. (c) Guzman, A.; Romero, M.; Maddox, M.; Muchowski, J. *J. Org. Chem.* **1990**, *55*, 5793.

(10) Some of the methods developed for the synthesis of these systems involved (a) pyrolytic reactions with enamines, (b) [3 + 3] additions of ketimines to deficient acetylenes, (c) [4 + 2] nucleophilic additions of dianions to nitriles, or (d) thermolysis of 2,2-dichlorocyclopropanecarboxaldimines. See, for example: (a) Chuche, J.; Arya, F.; Bouquant, J. *Synthesis* **1983**, 947. (b) Barluenga, J.; López Ortiz, F.; Palacios, F.; Gotor, V. *Synth. Commun.* **1983**, *13*, 411. (c) Jiang, J. B.; Urbansky, M. J. *Tetrahedron Lett.* **1985**, *26*, 259. (d) Kagabu, S.; Naruse, S.; Tagami, Y.; Watanabe, Y. *J. Org. Chem.* **1989**, *54*, 4274.

(11) (a) Domagala, J. H.; DeJohn, D.; Kaltenbronn, J. S.; Krolls, U. *J. Heterocycl. Chem.* **1983**, *20*, 1295. (b) Domagala, J. M. *J. Org. Chem.* **1984**, *49*, 127. (c) Comins, D. L.; LaMunyon, D. H. *Tetrahedron Lett.* **1989**, *30*, 5053. (d) Knorr, H.; Gildemeister, H.; Mildenberger, H.; Sabeck, G. *Justus Liebigs Ann. Chem.* **1982**, 1656. (e) Neier, R.; Guerry, P. *Synthesis* **1984**, 485. (f) Mittelbach, M. *Synthesis* **1988**, 479.

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(13) 1,1′-Carbonyldiimidazole can behave as a carbon dioxide equivalent. For a related reaction with *N,N″*-carbonyltriazole, see: (a) Larsen, C.; Harpp, D. N. *J. Org. Chem.* **1980**, *45*, 3713. (b) Harpp, D. N.; Mc Donnald, J. G.; Larsen, C. *Can. J. Chem.* **1985**, *63*, 951. For reactions which involve the use of other carbon dioxide equivalents and 2-aza 1,3-dienes, see: Barluenga, J.; González, F. J.; Fustero, S. *Tetrahedron Lett.* **1989**, *30*, 2685.

(14) Very few examples of [5 + 1] heterocyclization reactions have been reported for the synthesis of these systems, and most proceed through the formation of two C–N bonds (usually by nucleophilic addition of amines or ammonia to several substrates). See, for example: (a) Smith, D. M. In *Comprehensive Organic Chemistry*; Sammes, P. G., Ed.; Pergamon Press: Oxford, 1979; Vol. 4, pp 64–65. (b) Jones, G. In *Comprehensive Heterocyclic Chemistry*; Boulton, A. J., Mc Killop, A., Eds.; Pergamon Press: Oxford, 1984; Vol. 2, pp 436–437. (c) Meht-Cohn, O.; Westwood, K. T. *J. Chem. Soc., Perkin Trans. 1* **1983**, 2089.

(15) Surprisingly, other Lewis acids like $AlCl_3$, $TiCl_4$, or $ZnCl_2$ were inefficient.

Scheme III

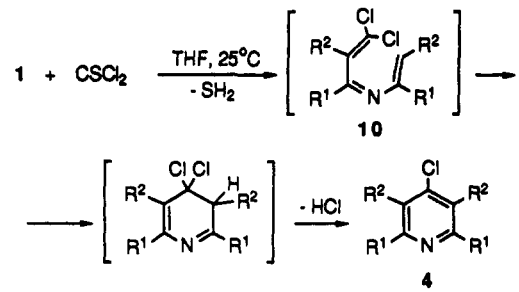


Table II. 4-Chloropyridines 4 Obtained from 1 and 3

entry	compd	R^1	R^2	method[a]	yield, %
1	**4a**	Ph	Me	A	62
2	**4b**	Ph	Et	A (B)	60 (90)[b]
3	**4c**	*p*-MeC_6H_4	Me	A	57
4	**4d**	Ph	CH_2=$CHCH_2CH_2$	A	55
5	**4e**	Ph	Pr	A (B)	60 (85)[b]

[a] Method A: reaction of 1 with thiophosgene (Scheme III). Method B: reaction of 3 with $POCl_3$ and PCl_5 (Scheme IV). [b] In parentheses, yield obtained from 3.

influence of the boron trifluoride in the course of the reaction can be understood by assuming the formation of CDI–BF_3 complexes 8 in preference to 1–BF_3 complexes, so allowing the CDI to become much more reactive toward the 2-aza 1,3-diene 1 (Figure 3). Indeed, the reaction failed when (trimethylsilyl)divinylamines 9[4] were used instead of 2-aza 1,3-dienes 1 under the same reaction conditions, because of the lower reactivity of compounds 9.[6]

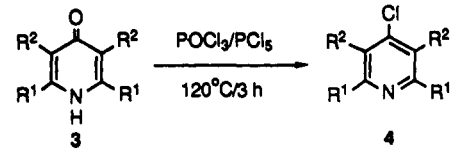
Finally, it is worth noting that, to the best of our knowledge, the 1,1′-carbonyldiimidazole behaves for the first time as a "carbonyl transfer reagent"[7,16] allowing the formation of two carbonyl–carbon bonds. Moreover, a critical step in the total synthesis of the antibiotic (+)-actinobolin[17] is the only example reported in which CDI is able to form a unique carbonyl–carbon bond.

The above results prompted us to extend this process to the synthesis of the corresponding 4(1*H*)-thiopyridones starting from 1,1′-thiocarbonyldiimidazole (TCDI)[18] instead of CDI. When the reaction of TCDI with 1 was carried out as above, the starting materials were recovered in all instances. This could be explained by taking into account the lower reactivity of the carbon–sulfur double bond compared with the oxygen analogue. This problem might be circumvented with the more reactive reagent thiophosgene, which shows remarkable applications both as dienophile in [4 + 2] cycloaddition reactions[19] and as a "thiocarbonyl transfer reagent".[20]

Synthesis of 4-Chloropyridines 4. The reaction between 2-aza 1,3-dienes 1 and thiophosgene led neither to the desired 4(1*H*)-thiopyridones nor to compounds resulting from the Diels–Alder cycloaddition. On the contrary, the unexpected 4-chloropyridines 4 were isolated in high yields (Scheme III).

The treatment of 1 with stoichiometric amounts of thiophosgene in THF (25 °C, 48 h), followed by basic hydrolysis, afforded substituted 4-chloropyridines 4 (Table II). The reaction takes place in the absence of Lewis acids. In fact, the presence of BF_3·OEt_2 completely inhibits the process in sharp contrast to the results obtained with CDI. These results can be explained by assuming that thiophosgene and 1 first condense, followed by loss of 1 equiv of H_2S. The dihalogenated aza triene 10 then undergoes an electrocyclic ring closure followed by loss of hydrogen chloride to give 4 (Scheme III).[21]

Scheme IV



Compounds 4 were fully characterized on the basis of their ^1H and ^{13}C NMR spectra and mass spectrometry (see the Experimental Section). Finally, compounds 4 can be alternatively obtained by heating the corresponding 4-(1*H*)-pyridones 3 with a mixture of PCl_5 and $POCl_3$.[11d] The process works well, giving rise after 3 h to excellent yields of pyridines 4 (see Table II, entries 2 and 5; Scheme IV).

In most instances, variable amounts of the iminium salt $R^2CH_2(R^1)C{=}NH_2{}^+Cl^-$ (11), resulting from cleavage of the 2-aza 1,3-diene by the HCl formed during the reaction, were formed. This byproduct was easily separated by filtration. It could also be synthesized unambiguously by reaction of the 2-aza 1,3-diene with an equimolecular amount of hydrogen chloride in ether.

Conclusions

An efficient [5 + 1] heterocyclization route to 4(1*H*)-pyridones 3 and 4-chloropyridines 4 from 2-aza 1,3-dienes has been developed. It was also demonstrated that the course of the process to 4(1*H*)-pyridones strongly depends on the Lewis acid. Thus, the reaction of 1 with CDI that leads to 3 must be carried out in the presence of BF_3·OEt_2, but compounds 4 can be obtained only in the absence of the catalyst. Finally, this is the first example in which 1,1′-carbonyldiimidazole and thiophosgene act as "carbonyl and chloroalkylidene transfer reagents", respectively, with formation of two carbon–carbon bonds in both cases.

Experimental Section

General Methods. Melting points are uncorrected. 2-Aza 1,3-dienes 1 were prepared according to the previously described method.[22] THF, hexane, Et_2O, and BF_3·OEt_2 were dried, distilled, and stored under nitrogen prior to use.[23] All other reagents were commercially available and used as received. All reactions were run under nitrogen.

General Preparative Procedure for 4(1*H*)-Pyridones 4 from 1. To a stirred solution of the 2-aza 1,3-diene 1 (10 mmol) in 5 mL of THF were added 2.9 mL (12 mmol) of BF_3·OEt_2 and 1.95 g (12 mmol) of carbonyldiimidazole (CDI), and the mixture was allowed to react for 2–8 h at room temperature. Most of the solvent was removed at reduced pressure, and 30 mL of Et_2O and 30 mL of 3 N NaOH were added to the residue. After extraction with Et_2O, the organic layer was washed with brine (3×) and dried (Na_2SO_4). The solvent was removed at reduced pressure, and the resulting solid was washed with Et_2O (5 mL) and collected. The material could be purified further by recrystallization (hexane–$CHCl_3$, 3:1). All 4(1*H*)-pyridones were isolated as white solids.

3,5-Dimethyl-2,6-diphenyl-4(1*H*)-pyridone (3a): mp 260–262 °C dec; ^1H NMR ($CDCl_3$, 300 MHz) δ 2.0 (s, 6 H), 7.5

(16) Ogata, M.; Matsumoto, H.; Kida, S.; Shimizu, S. *Tetrahedron Lett.* **1979**, 5011.
(17) Weinreb, S. M.; Garigipati, R. S.; Tschaen, D. M. *J. Am. Chem. Soc.* **1985**, *107*, 7790.
(18) Staab, H. A. *Angew. Chem., Int. Ed. Engl.* **1962**, *1*, 351.
(19) See ref 1, pp 132–134.
(20) Jones, N. In *Comprehensive Organic Chemistry*; Pergamon Press: Oxford, 1979; Vol. 3, p 434.
(21) For a related mechanism, see ref 5.
(22) Barluenga, J.; Joglar, J.; Fustero, S.; Gotor, V.; Krüger, C.; Romao, M. J. *Chem. Ber.* **1985**, *118*, 3652.
(23) Perrin, D. D.; Armarego, W. L. F.; Perrin, D. R. *Purification of Laboratory Chemicals*, 2nd ed.; Pergamon: New York, 1980.

(m, 10 H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 178.8 (C=O), 144.6 (CN), 134.8 (C), 129.0 (CH), 128.6 (CH), 128.4 (CH), 120.7 (O=CC=CN), 12.4 (CH_3); MS, m/z 275 (M^+), 274 (100). Anal. Calcd for $C_{19}H_{17}NO$: C, 82.91; H, 6.18; N, 5.09. Found: C, 82.90; H, 6.20; N, 5.11.

3,5-Diethyl-2,6-diphenyl-4(1*H*)-pyridone (3b): mp 260–262 °C dec; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.1 (t, 6 H, J = 6.7 Hz), 2.4 (q, 4 H, J = 6.7 Hz), 7.4 (m, 11 H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 178.2 (C=O), 144.1 (CN), 135.0 (C), 129.4 (CH), 128.8 (CH), 128.3 (CH), 127.4 (O=CC=CN), 19.8 (CH_2), 13.7 (CH_3); MS, m/z 303 (M^+), 302 (100). Anal. Calcd for $C_{21}H_{23}NO$: C, 83.17; H, 6.93; N, 4.62. Found: C, 83.19; H, 6.90; N, 4.63.

3,5-Dimethyl-2,6-di-*p*-tolyl-4(1*H*)-pyridone (3c): mp 260–262 °C dec; ^1H NMR ($CDCl_3$, 300 MHz) δ 2.0 (s, 6 H), 2.4 (s, 6 H), 7.3 (m, 8 H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 178.4 (C=O), 144.0 (CN), 139.4 (C), 132.3 (C), 129.4 (CH), 128.4 (CH), 120.7 (O=CC=CN), 21.2 (CH_3), 12.4 (CH_3); MS, m/z 303 (M^+), 302 (100). Anal. Calcd for $C_{21}H_{23}NO$: C, 82.91; H, 6.18; N, 5.09. Found: C, 82.93; H, 6.15; N, 5.12.

3,5-Di-3′-butenyl-2,6-diphenyl-4(1*H*)-pyridone (3d): mp 220–224 °C dec; ^1H NMR ($CDCl_3$, 300 MHz) δ 2.3 (dt, 2 H, J = 6.7 Hz, J = 6.5 Hz), 2.6 (t, 2 H, J = 6.7 Hz), 4.9 (dd, 1 H, J = 10.2 Hz, J = 2.1 Hz), 5.0 (dd, 1 H, J = 17.0 Hz, J = 2.1 Hz), 5.8 (ddt, 1 H, J = 17.0 Hz, J = 10.2 Hz, J = 6.5 Hz), 7.5 (m, 10 H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 178.0 (C=O), 144.8 (CN), 138.7 (CH), 134.7 (C), 129.1 (CH), 128.5 (CH), 128.4 (CH), 124.9 (O=CC=CN), 114.0 (CH_2), 32.7 (CH_2), 26.0 (CH_2); MS, m/z 355 (M^+), 326 (100). Anal. Calcd for $C_{25}H_{35}NO$: C, 84.51; H, 7.04; N, 3.94. Found: C, 84.48; H, 7.07; N, 3.96.

2,6-Diphenyl-3,5-dipropyl-4(1*H*)-pyridone (3e): mp 234–236 °C dec; ^1H NMR ($CDCl_3$, 300 MHz) δ 0.8 (t, 6 H, J = 6.7 Hz), 1.5 (m, 4 H), 2.4 (m, 4 H), 7.4 (m, 10 H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 178.2 (C=O), 144.5 (CN), 135.0 (C), 129.4 (CH), 128.8 (CH), 128.4 (CH), 126.1 (O=CC=CN), 28.6 (CH_2), 22.3 (CH_2), 14.4 (CH_3); MS, m/z 331 (M^+), 330 (100). Anal. Calcd for $C_{23}H_{29}NO$: C, 83.88; H, 7.55; N, 4.23. Found: C, 83.91; H, 7.56; N, 4.21.

2,6-Dicyclohexyl-3,5-dimethyl-4(1*H*)-pyridone (3f): mp 270–272 °C dec; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.1–1.5 (m, 9 H), 1.8–2.1 (m, 11 H), 2.0 (s, 6 H), 2.8 (m, 2 H), 7.8 (br s, 1 H, NH); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 179.0 (C=O), 147.0 (CN), 118.7 (O=CC=CN), 39.3 (CH), 31.0 (CH_2), 26.2 (CH_2), 25.6 (CH_2), 10.1 (CH_3); MS, m/z 287 (M^+), 232 (100). Anal. Calcd for $C_{19}H_{29}NO$: C, 79.44; H, 10.10; N, 4.88. Found: C, 79.41; H, 10.11; N, 4.86.

General Preparative Procedure for 4-Chloropyridines 4 from 1. Method A. 2-Aza 1,3-diene 1 (10 mmol) and an equimolecular amount of thiophosgene in 5 mL of THF were allowed to react for 6 h. A white solid was separated from the reaction mixture by filtration, which was the salt 11. The filtrate was diluted with 30 mL of 3 N NaOH and 30 mL of Et_2O. The organic layer was washed with H_2O (3×) and dried (Na_2SO_4). The solvents were removed at reduced pressure. The resulting dark oil was purified by chromatography on silica gel (230–400 mesh, hexane–Et_2O, 9:1). All products were obtained as white solids.

General Procedure for the Synthesis of 4 from 3. Method B. A mixture of 10 mmol of 4(1*H*)-pyridone 3, 5 mL (54 mmol) of $POCl_3$, and 1.0 g (5 mmol) of PCl_5 was warmed at 120 °C for 3 h. Ice was added, and the solution was extracted with Et_2O. The organic layer was washed with H_2O (3×) and dried (Na_2SO_4). The solvents were removed at reduced pressure, affording compounds 4 as white solids in excellent yields (see Table II, entries 2 and 5).

4-Chloro-3,5-dimethyl-2,6-diphenylpyridine (4a): mp 127–130 °C; ^1H NMR ($CDCl_3$, 300 MHz) δ 2.4 (s, 6 H), 7.3–7.5 (m, 10 H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 156.6 (CN), 146.5 (CCl), 140.3 (CEt and C_{ipso}), 129.1 (CH), 128.0 (CH), 127.8 (CH), 17.7 (CH_3); MS, m/z 295 (M^+), 292 (100); R_f 0.35. Anal. Calcd for $C_{19}H_{16}ClN$: C, 77.68; H, 5.45; N, 4.77. Found: C, 77.65; H, 5.45; N, 4.76.

4-Chloro-3,5-diethyl-2,6-diphenylpyridine (4b): mp 127–130 °C; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.2 (t, 6 H, J = 6.8 Hz), 2.8 (q, 2 H, J = 6.8 Hz), 7.2–7.5 (m, 10 H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 156.9 (CN), 145.5 (CCl), 140.4 (CEt), 134.4 (C), 128.8 (CH), 128.1 (CH), 127.9 (CH), 24.0 (CH_2), 13.7 (CH_3); MS, m/z 322 (M^+), 320 (100); R_f 0.35. Anal. Calcd for $C_{21}H_{20}ClN$: C, 78.38; H, 6.22; N, 4.35. Found: C, 78.41; H, 6.20; N, 4.34.

4-Chloro-3,5-dimethyl-2,6-di-*p*-tolylpyridine (4c): mp 63–65 °C; ^1H NMR ($CDCl_3$, 300 MHz) δ 2.4 (s, 6 H), 2.4 (s, 6 H), 7.2–7.3 (m, 8 H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 156.6 (CN), 146.4 (CCl), 137.7 (CMe), 137.6 (C), 129.2 (C), 128.6 (CH), 127.6 (C), 21.2 (CH_3), 17.9 (CH_3); MS, m/z 321 (M^+), 320 (100); R_f 0.20. Anal. Calcd for $C_{21}H_{20}ClN$: C, 78.38; H, 6.22; N, 4.35. Found: C, 78.39; H, 6.20; N, 4.35.

4-Chloro-3,5-di-3′-butenyl-2,6-diphenylpyridine (4d): mp 81–83 °C; ^1H NMR ($CDCl_3$, 300 MHz) δ 2.1 (dt, 4 H, J = 6.8 Hz, J = 6.5 Hz), 2.8 (m, 4 H), 4.9 (dd, 2 H, J = 10.0 Hz, J = 2.1 Hz), 5.0 (dd, 2 H, J = 17.0 Hz, J = 2.1 Hz), 5.7 (ddt, 2 H, J = 17.0 Hz, J = 10.0 Hz, J = 6.5 Hz), 7.4 (m, 10 H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 157.5 (CN), 145.5 (CCl), 140.4 (C-3-butenyl), 137.3 (CH), 132.2 (C), 128.8 (CH), 128.1 (CH), 127.9 (CH), 115.0 (CH_2), 33.1 (CH_2), 30.1 (CH_2); MS, m/z 373 (M^+), 290 (100); R_f 0.19. Anal. Calcd for $C_{25}H_{24}ClN$: C, 80.32; H, 6.43; N, 3.75. Found: C, 80.35; H, 6.40; N, 3.75.

4-Chloro-2,6-diphenyl-3,5-dipropylpyridine (4e): mp 94–96 °C; ^1H NMR ($CDCl_3$, 300 MHz) δ 0.9 (t, 6 H, J = 6.7 Hz), 1.6 (m, 4 H), 2.7 (m, 4 H), 7.2–7.5 (m, 10 H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 157.1 (CN), 145.9 (CCl), 140.6 (CEt), 133.1 (C), 128.8 (CH), 128.0 (CH), 127.8 (CH), 32.7 (CH_2), 22.7 (CH_2), 14.2 (CH_3); MS, m/z 351 (M^+), 348 (100); R_f 0.30. Anal. Calcd for $C_{23}H_{24}ClN$: C, 78.97; H, 6.87; N, 4.01. Found: C, 78.41; H, 6.25; N, 4.37.

[Et(Ph)C=$NH_2^+Cl^-$] (11). 2-Aza 1,3-diene 1 (R^1 = Ph, R^2 = Me) (0.5 g, 2 mmol) was dissolved in 25 mL of dry Et_2O and treated with 10.6 mL of a solution of 0.19 M HCl (2 mmol) in dry ether. A white solid appeared in the reaction mixture, which was purified by removal of the solvents and washing with a small amount of ether (40%, 0.14 g): mp 139–144 °C; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.5 (t, 3 H, J = 7 Hz), 3.4 (q, 2 H, J = 7 Hz), 7.5–8.4 (m, 5 H), 13.3 (br d, 2 H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 188.0 (CNH_2^+), 135.8 (CH), 129.5 (CH), 129.4 (CH), 128.2 (C), 27.6 (CH_2), 12.6 (CH_3); MS, m/z 134 (M^+), 104 (100). Anal. Calcd for $C_9H_{12}ClN$: C, 63.72; H, 7.08; N, 8.26. Found: C, 63.74; H, 7.11; N, 8.23.

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Supplementary Material Available: NMR and mass spectra of compounds 3, 4, and 11 (24 pages). Ordering information is given on any current masthead page.