HETEROCYCLES, Vol. 85, No. 5, 2012, pp. 1187 - 1195. © 2012 The Japan Institute of Heterocyclic Chemistry
Received, 27th February, 2012, Accepted, 26th March, 2012, Published online, 3rd April, 2011
DOI: 10.3987/COM-12-12457

FACILE SYNTHESIS OF 2,3-DISUBSTITUTED PYRROLES FROM 2-SUBSTITUTED 1-PYRROLINES

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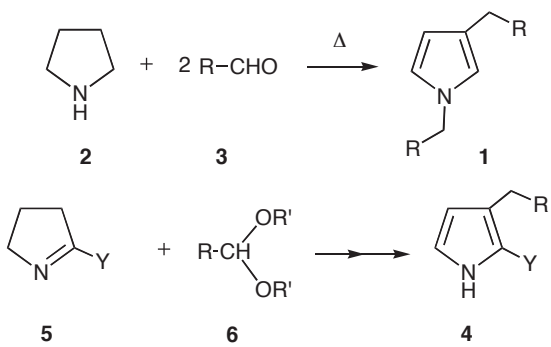
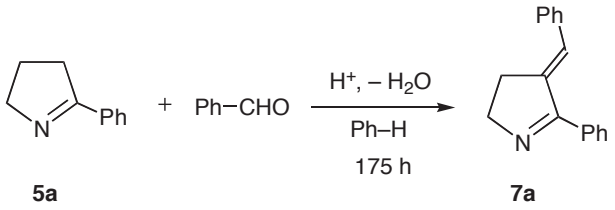
Abstract – 2-Substituted-1-pyrrolines react with various arylaldehyde acetals in the presence of a Lewis acid and base to give 2-substituted 3-arylmethylidene-1-pyrrolines, which are transformed to 2,3-disubstituted pyrroles by base-catalyzed double-bond isomerization.

Pyrrole derivatives are an important family of compounds especially because of their significance in the synthesis of natural products and pharmaceuticals.[1] In addition to reliable classical methods such as the Knorr,[2] Paal–Knorr,[3] and Hantzsch syntheses,[4] synthetic methodologies for pyrroles have been continuously developed.[5] Although the development of nitrogen-containing five-membered rings is a recent topic of interest, synthetic routes for pyrroles by inexpensive or easily available hydrogenated materials such as pyrrolines and pyrrolidines are also still important.[6] Previously, we reported the synthesis of 1,3-disubstituted pyrroles **1** simply by heating pyrrolidine (**2**) and aldehydes **3** without any catalyst in a pressure vessel, as shown in Scheme 1.[7] In this paper, we describe a new facile synthesis of 2,3-disubstituted pyrroles **4** from 2-substituted 1-pyrrolines **5** with acetals **6** by a two-step sequence, which involves an aldol-type condensation followed by base-catalyzed double-bond isomerization.



Scheme 1

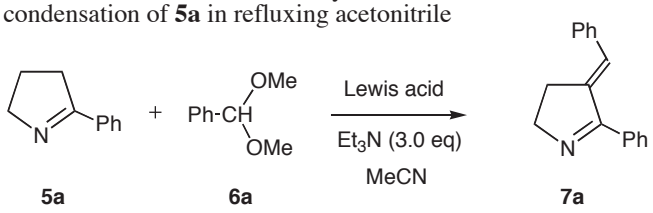
For the first step, we found that a conventional aldol-type condensation[8] of 2-phenyl-1-pyrroline (**5a**)[9] with benz-aldehyde under continuous azeotropic distillation of water provided 3-benzylidene-2-phenyl-1-pyrroline (**7a**) in 73% yield.[10,11] However, it took a very long time (175 h) to complete the reaction (Scheme 2).



5a **7a**

Scheme 2

Table 1. Lewis acid- and triethyamine-assisted aldol condensation of **5a** in refluxing acetonitrile

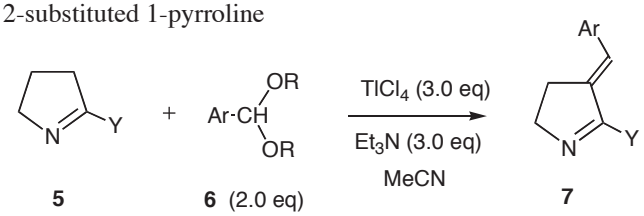


5a **6a** **7a**

entry	reaction conditions	yield of **7a** (%)[a]
1	BF_3·Et_2O (3.0 eq), **6a** (1.5 eq), 22 h	30 [b]
2	$TiCl_4$ (3.0 eq), **6a** (1.5 eq), 22 h	75 [b]
3	$TiCl_4$ (3.0 eq), **6a** (2.0 eq), 18 h	81
4	TMSOTf (4.0 eq), **6a** (1.5 eq), 23 h	65
5	$SnCl_4$ (3.0 eq), **6a** (2.0 eq), 23 h	48

[a] Isolated yield. [b] Some recovery of **5a** was observed.

Table 2. $TiCl_4$- and triethyamine-assisted aldol condensation of 2-substituted 1-pyrroline



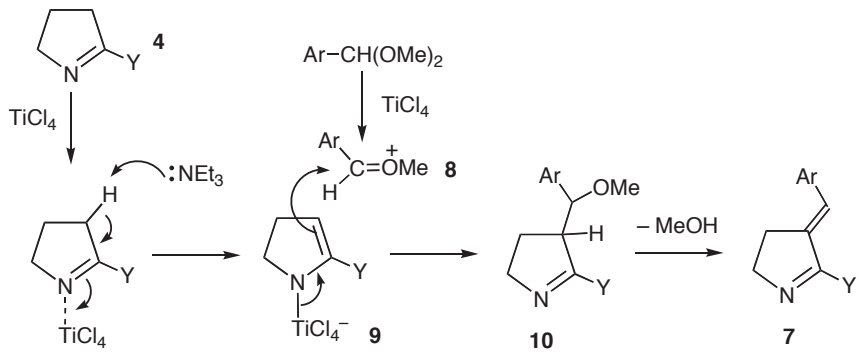
5 **6** (2.0 eq) **7**

entry	Y	Ar	R	reaction time	product (yield:%)
1	Ph	Ph	Et	25 h	**7a** (74)
2	Ph	*p*-Br-C_6H_4	Me	22 h	**7b** (70)
3	Ph	*o*-Me-C_6H_4	Me	29 h	**7c** (41)
4	Ph	1-naphthyl	Me	27 h	**7d** (36)
5	Ph	2-thienyl	Me	26 h	**7e** (39)
6	*p*-MeO-C_6H_4	Ph	Me	24 h	**7f** (79)
7	*p*-Me_2N-C_6H_4	Ph	Me	24 h	**7g** (57)
8	*t*-Bu	Ph	Me	26 h	**7h** (12)
9	MeO_2C	Ph	Me	26 h	**7i** (0)

Then, we examined reactions with benzaldehyde dimethyl acetal assisted by a Lewis acid and triethyamine[12] (Table 1). The results indicate that the yield depends on the Lewis acid used. Among the Lewis acids used, $TiCl_4$ was the most effective, giving the most satisfactory yield of **7a** (Table 1, entry 3). This reaction proceeded much faster than the conventional method.

Several 2-substituted 1-pyrrolines were subjected to condensation with some acetals under these conditions. The results are summarized in Table 2. Benzaldehyde diethyl acetal reacted similarly, but the reaction proceeded slightly slower, giving **7a** in a similar yield (Table 2, entry 1). Various dimethyl acetals such as *p*-bromobenzaldehyde, *o*-methylbenzaldehyde, 1-naphthylcarbaldehyde, and 2-thienylcarbaldehyde dimethyl acetals react with **5a** to give **7b**–**7e** (Table 2, entry 2–5), respectively, and the yield mainly depends on the structure of the aryl group. Using alkanal dimethyl acetals, such as acetaldehyde and propanal dimethyl acetals, did not form the expected condensation products. None of the dimethyl ketals – acetone, benzophenone, acetophenone, and cyclohexane dimethyl ketals – react with **5a** under these conditions. Reactions of other 2-(substituted phenyl)-1-pyrrolines with **6a** provide satisfactory yields of **7f**–**g** (Table 2, entries 6 and 7, respectively). However, **7h** was obtained in low yield

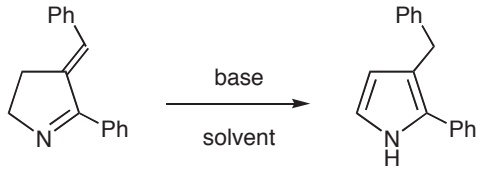
(Table 2, entry 8) probably because of the sterically bulky *t*-Bu group. Moreover, 2-(methoxycarbonyl)-1-pyrroline was found to be inactive under these conditions (Table 2, entry 9). We propose the following reaction mechanism, shown in Scheme 3, to explain the change of product yields. A reaction of $TiCl_4$ and triethylamine with **4** produces the enamine **9**, which then reacts with the methyloxonium ion **8** generated *in situ* to yield the adduct **10**.[13] The elimination of methanol subsequently forms the final product **7**. The reason why alkanal dimethyl acetals does not give the expected product may be ascribed to that the methyloxonium ion derived from alkanal dimethyl acetals undergoes elimination of proton to give the corresponding methylvinyl ether, which is observed in the crude reaction mixture accompanied with the starting material **4**.



Scheme 3. Proposed mechanism for condensation

Then, the second step, which is the base-catalyzed double-bond isomerization of pyrroline **7** to the corresponding pyrrole **4**, was examined. The results under various conditions with several bases are shown in Table 3. *t*-BuOK in DMSO worked efficiently as a catalyst for double-bond isomerization to give **4a** in high yield (Table 3, entry 5), though the reactions at elevated temperatures and with a larger amount of the *t*-BuOK resulted in lower yields (Table 3, entries 4 and 6, respectively). Under optimal

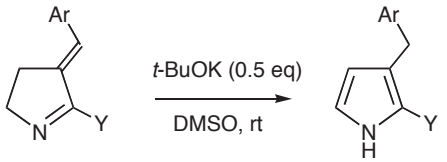
Table 3. Base-catalyzed double-bond isomerization of **7a**



7a **4a**

entry	reaction conditions	yield of **4a** (%)
1	(*i*-Pr)$_2$NEt (3.0 eq), toluene, 110˚C, 12 h	trace
2	DBN (1.0 eq), MeCN, 85˚C, 10 h	4
3	*t*-BuOK (1.0 eq), *t*-BuOH, 100˚C, 8 h	67
4	*t*-BuOK (0.8 eq), DMSO, rt, 4 h	37
5	*t*-BuOK (0.5 eq), DMSO, rt, 8 h	94
6	*t*-BuOK (0.1 eq), DMSO, 60˚C, 4 h	17

Table 4. *t*-BuOK-catalyzed double-bond isomerization of **7**



7 **4**

entry	Y	Ar	reaction time	product (yield:%)
1	Ph	*p*-Br-C$_6$H$_4$	3 h	**4b** (89)
2	Ph	*o*-MeC$_6$H$_4$	5 h	**4c** (73)
3	Ph	1-naphthyl	7 h	**4d** (76)
4	Ph	2-thienyl	6 h	**4e** (96)
5	*p*-MeO-C$_6$H$_4$	Ph	6 h	**4f** (84)
6	*p*-Me$_2$N-C$_6$H$_4$	Ph	5 h	**4g** (46)
7	*t*-Bu	Ph	6 h	**4h** (31)

conditions with *t*-BuOK/DMSO, other pyrrolines **7** were also converted to the corresponding pyrroles in good-to-high yields (Table 4, entry 1–5). However, compounds with the strong electron-donating groups at the 2 position in **7** gave **4** in low yields (Table 4, entries 6 and 7). Therefore, the isomerization must proceed through repeated deprotonation and protonation steps. The electron-donating groups may reduce the acidity of the C–H bonds of the tetrahedral carbons of **7**, and consequently decrease the yield of these reactions.

We have demonstrated transformation of 2-substituted 1-pyrrolines to 2,3-disubstituted pyrroles in two steps, which involve condensation with acetals assisted by a combination of $TiCl_4$ and triethylamine, followed by the double-bond isomerization catalyzed by *t*-BuOK in DMSO. Although limited acetals can be employed in the condensation step, the reactions were completed in a reasonably short time. The results suggest a new facile synthetic method for 2,3-disubstituted pyrroles, which can be applied to the synthesis of bioactive compounds such as pharmaceuticals.

EXPERIMENTAL

Melting points were measured on a Yanaco MP-3. IR spectra were recorded on JEOL Diamond-20 and JASCO FT/IR-4100 spectrometers. UV spectra were measured on a Shimadzu UV-2550 spectrometer. ^{1}H and ^{13}C-NMR spectra were recorded with tetramethylsilane as internal standard on JEOL λ400 and ECA500 NMR instruments. Mass spectra were measured on a JMS-700 mass spectrometer. Column chromatography was done with Silica gel 60N from Kanto Chem., Inc. Trimethylsilyl triflate, titanium tetrachloride, stannic tetrachloride, benzaldehyde acetals, *t*-BuOK, and borontrifluoride-ether complex were purchased from Tokyo Kasei Industrial Co. 2-Phenyl- and 2-(4-methoxyphenyl)-1-pyrrolines were synthesized from *N*-vinylpyrrolidin-2-one by the method of Sorgi *et al*.[9f] 2-(4-Dimethylaminophenyl)-, and 4-*t*-butyl-1-pyrrolines were prepared from 2-methoxy-1-pyrroline according to a literature procedure.[9d]

3-Benzylidene-2-phenyl-1-pyrroline (7a) from 5a and benzaldehyde

A mixture of **5a** (1.06 g, 7.27 mM), benzaldehyde (0.763 g, 7.19 mM), *p*-toluenesulfonic acid (72 mg, 0.42 mM) in 50 mL of benzene was charged in a 100-mL flask, which was connected with a Dean-Stark trap to remove water continuously. The mixture was refluxed on an oil bath for 175 h to completion of the reaction. The resulted mixture was washed with a saturated aqueous $NaHCO_3$ solution (100 mL) and brine, and then, was dried over $MgSO_4$. After evaporation of the solvent, the residue was purified by silica gel column chromatography to give 1.31 g (73% yield) of **7a** as colorless needles. Mp 110–112 ˚C (lit., 110–111˚C[10a] and 108–109˚C[10b]). ^{1}H NMR ($CDCl_3$) δ = 3.09 (dt, J = 5.6, 3.2 Hz, 2H), 4.22 (t, J = 5.6

Hz, 2H), 6.84 (t, *J* = 3.2 Hz, 1H), 7.30 (t, *J* = 7.2 Hz, 1H), 7.39 (t, *J* = 7.6 Hz, 2H), 7.44 (t, *J* = 7.2 Hz, 2H), 7.44–7.49 (m, 3H), 7.65 (m, 2H) ppm; ^{13}C NMR ($CDCl_3$) δ = 30.9, 59.6, 127.89, 127.93, 128.47, 128.58, 128.8, 128.9, 129.6, 134.5, 134.0, 142.1, 175.0 ppm.

A typical procedure of Lewis acid ad triethylamine-assisted condensation of 2-substituted 1-pyrrolines with dialkoxymethylarenes

To a solution of **5** (1.00 mM), triethylamine (417 μL, 3.00 mM), dimethyl acetal (2.00 mM) in solvent (10 mL) at 0 ˚C was added dropwise Lewis acid (3.00 mM). Then, the mixture was heated in an oil bath under nitrogen atmosphere using a balloon. The reaction was monitored by TLC analysis and the resulted reaction mixture was poured into a saturated aqueous $NaHCO_3$ solution (50 mL). The solids formed were removed by filtration and the filtrate was extracted three times with 20 mL of chloroform. The combined organic layer was washed with brine and was dried over $MgSO_4$. The solvent was removed and the residue was purified by silica gel chromatography to give the product.

3-(4-Bromobenzylidene)-2-phenyl-1-pyrroline (**7b**); Brown needles, mp 83–86 ˚C. ^{1}H NMR ($CDCl_3$) δ = 3.03 (dt, *J* = 5.8, 2.8 Hz, 2H), 4.23 (t, *J* = 5.8 Hz, 2H), 6.76 (t, *J* = 2.8 Hz, 1H), 7.28 (d, *J* = 8.8 Hz, 2H), 7.46–7.52 (m, 5H), 7.62–7.64 (m, 2H) ppm; ^{13}C NMR ($CDCl_3$) δ = 30.9, 59.7, 121.8, 126.5, 128.5, 128.7, 129.7, 130.3, 131.7, 134.3, 136.0, 142.8, 174.8 ppm; UV (EtOH) λ_{max} = 227 (logε = 4.03), 235 (4.01), 252sh (4.02), 287sh (4.40), 295 (4.19), 300 (4.48), 312 (4.35) nm; MS (70 eV): *m/z* (rel int) 313 (M^+, 98), 312(58), 311 (M^+, 100), 310 (40), 285 (11), 283 (12), 232 (18), 231 (14), 230 (13), 204 (18), 203 (21), 202 (14), 156 (25), 129 (47), 128 (32), 127 (14), 117 (47), 101 (11), 91 (16), 77 (21). *Anal*. Calcd for $C_{17}H_{14}BrN$: C, 65.40; H, 4.52; N, 4.49%. Found C, 65.24; H, 4.62; N, 4.33%.

3-(2-Methybenzylidene)-2-phenyl-1-pyrroline (**7c**); Brown solids, mp 80–84 ˚C. ^{1}H NMR ($CDCl_3$) δ = 2.21 (s, 3H), 2.98 (dt, *J* = 6.3, 2.8 Hz, 2H), 4.15 (t, *J* = 6.3 Hz, 2H), 6.98 (t, *J* = 2.8 Hz, 1H), 7.17–7.24 (m, 3H), 7.44–7.48 (m, 4H), 7.66–7.70 (m, 2H) ppm; ^{13}C NMR ($CDCl_3$) δ = 20.0, 30.6, 59.1, 125.5, 125.8, 127.3, 127.8, 128.4, 128.7, 129.6, 130.2, 134.4, 135.9, 136.9, 142.5, 174.6 ppm; UV (EtOH) λ_{max} = 229 (logε = 4.03), 236 (4.03), 248 (4.01), 287sh (4.18), 295 (4.19), 318sh (3.83) nm; MS (70 eV): *m/z* (rel int) 247 (M^+, 100), 246 (41), 232 (20), 219 (11), 156 (18), 129 (33), 128 (22), 117 (26), 116(10), 115 (18), 91 (11), 77 (14). HRMS *m/z* Calcd for $C_{18}H_{17}N$ (M^+) 247.1361, found: 247.1356.

3-(1-Naphthylmethylidene)-2-phenyl-1-pyrroline (**7d**); Brown microcrystals, mp 119–120 ˚C. ^{1}H NMR ($CDCl_3$) δ = 3.00 (dt, *J* = 6.3, 2.5 Hz, 2H), 4.16 (t, *J* = 6.3 Hz, 2H), 7.46 (t, *J* = 2.5 Hz, 1H), 7.43–7.52 (m, 6H), 7.63 (d, *J* = 7.5 Hz, 1H), 7.76–7.81 (m, 3H), 7.85 (dt, *J* = 8.0, 2.0 Hz, 2H) ppm; ^{13}C NMR ($CDCl_3$) δ = 31.0, 59.0, 123.9, 124.5, 125.2, 125.5, 125.9, 126.2, 128.3, 128.5, 128.6, 128.8, 129.8, 131.5, 133.6, 134.0, 134.3, 144.1, 174.2 ppm; UV (EtOH) λ_{max} = 225 (logε = 4.52), 267sh (3.98), 319sh (4.13), 326 (4.13), 346sh (3.91), 393sh (2.56) nm; MS (70 eV): *m/z* (rel int) 283 (M^+, 100), 282 (50), 180 (13), 179

(22), 178 (14), 118 (11), 117 (22). HRMS *m/z* Calcd for $C_{21}H_{17}N$ (M^+) 283.1361, found: 283.1360.

2-Phenyl-3-(2-thienylmethylidene)-1-pyrroline (**7e**); Brown microcrystals, mp 95–96 °C. ^{1}H NMR ($CDCl_3$) δ = 3.02 (dt, *J* = 6.0, 2.8 Hz, 2H), 4.26 (t, *J* = 6.0 Hz, 2H), 7.05 (t, *J* = 2.8 Hz, 1H), 7.08 (dd, *J* = 5.0, 3.5 Hz, 1H), 7.12 (d, *J* = 3.5 Hz, 1H), 7.39 (d, *J* = 5.0 Hz, 1H), 7.45–7.48 (m, 3H), 7.59–7.62 (m, 2H) ppm; ^{13}C NMR ($CDCl_3$) δ = 31.1, 59.7, 120.3, 126.8, 127.5, 128.4, 128.5, 128.9, 129.5, 134.4, 140.0, 141.6, 174.2 ppm; UV (EtOH) λ_{max} = 254 (logε = 3.91), 316 (4.39), 329sh (4.33), 377 (2.29) nm. MS (70 eV): *m/z* (rel int) 239 (M^+, 100), 238 (53), 211 (21), 135 (12), 117 (18), 77 (11). HRMS *m/z* Calcd for $C_{15}H_{13}NS$ (M^+) 239.0769, found: 239.0772.

3-Benzylidene-2-(4-methoxyphenyl)-1-pyrroline (**7f**); Brown prisms, mp 142–144 °C. ^{1}H NMR ($CDCl_3$) δ = 3.06 (dt, *J* = 5.6, 2.8 Hz, 2H), 3.86 (s, 3H), 4.18 (t, *J* = 5.6 Hz, 2H), 6.86 (t, *J* = 2.8 Hz, 1H), 6.99 (dt, *J* = 8.8, 2.8 Hz, 2H), 7.29 (t, *J* = 7.2 Hz, 1H), 7.41 (m, 4H), 7.63 (dt, *J* = 8.8, 2.8 Hz, 2H) ppm; ^{13}C NMR ($CDCl_3$) δ = 31.1, 55.4, 59.3, 113.9, 126.9, 127.5, 127.8, 128.6, 128.9, 130.2, 137.1, 142.2, 160.8, 174.3 ppm; UV (EtOH) λ_{max} = 222 (logε = 4.16), 224sh (4.15), 230sh (4.06), 282sh (4.36), 290sh (4.37), 304sh (4.22) nm; MS (70 eV): *m/z* (rel int) 263 (M^+, 100), 262 (42), 232 (37), 186 (12), 147 (19), 129 (12). *Anal*. Calcd for $C_{18}H_{17}NO$: C, 82.10; H, 6.51; N, 5.32%. Found C, 82.14; H, 6.45; N, 5.22%.

3-Benzylidene-2-(4-dimethylaminophenyl)-1-pyrroline (**7g**); Brown microcrystals, mp 125–126 °C. ^{1}H NMR ($CDCl_3$) δ = 3.03 (s, 6H), 3.04 (dt, *J* = 5.8, 3.0 Hz, 2H), 4.14 (t, *J* = 5.8 Hz, 2H), 6.77 (d, *J* = 8.7 Hz, 2H), 6.94 (t, *J* = 3.0 Hz, 1H), 7.27 (t, *J* = 7.3 Hz, 1H), 7.37 (t, *J* = 7.3 Hz, 2H), 7.43 (d, *J* = 7.3 Hz, 2H), 7.60 (d, *J* = 8.7 Hz, 2H) ppm; ^{13}C NMR ($CDCl_3$) δ = 31.4, 40.5, 59.1, 111.8, 122.0, 127.5, 127.7, 128.6, 129.0, 130.1, 137.5, 142.5, 151.5, 174.4 ppm; UV (EtOH) λ_{max} = 223 (logε = 4.08), 232sh (4.01), 270sh (4.39), 293 (4.45), 306 (4.35), 328 (3.96) nm; MS (70 eV): *m/z* (rel int) 276 (M^+, 100), 275 (46), 248 (22), 199 (14), 138 (12), 129 (11), 128 (11), 114 (12). *Anal*. Calcd for $C_{19}H_{20}N_2 \cdot 0.2H_2O$: C, 81.51; H, 7.34; N, 10.01%. Found C, 81.60; H, 7.44; N, 10.22%.

3-Benzylidene-2-*t*-butyl-1-pyrroline (**7h**); A brown oil. ^{1}H NMR ($CDCl_3$) δ = 1.41 (s, 9H), 2.90 (dt, *J* = 5.8, 3.0 Hz, 2H), 3.95 (t, *J* = 5.8 Hz, 2H), 7.04 (t, *J* = 3.0 Hz, 1H), 7.27 (t, *J* = 7.5 Hz, 1H), 7.38 (t, *J* = 7.5 Hz, 2H), 7.43 (d, *J* = 7.5 Hz, 2H) ppm; ^{13}C NMR ($CDCl_3$) δ = 29.5, 31.8, 36.2, 58.0, 126.7, 127.6, 128.6, 129.0, 137.6, 141.0, 181.0 ppm; UV (EtOH) λ_{max} = 277 (logε = 4.28), 286 (4.31), 303 (4.09), 330 (2.91) nm; MS (70 eV): *m/z* (rel int) 213 (M^+, 62), 212 (55), 198 (100), 188 (14), 172 (10), 171 (38), 170 (47), 155 (17), 136 (22), 116 (16), 115 (33), 105 (21), 91 (19). HRMS *m/z* Calcd for $C_{15}H_{19}N$ (M^+) 213.1518, found: 213.1507.

A typical procedure of *t*-BuOK-catalyzed double-bond isomerization of 7 to 4

A mixture of **7** (0.500 mmol), *t*-BuOK (33 mg, 0.50 mmol) in DMSO (2 mL) was stirred at room temperature under argon atmosphere for 3–7 h. The reaction mixture was poured into cold water and was

neutralized by 0.1 N HCl, and then extracted with Et_2O (15 mL x 3). The combined organic layer was washed with brine and was dried over $MgSO_4$. After removal of the solvent, the residue was purified by silica gel chromatography to give the product. Analytical samples were obtained by recrystallization from EtOAc-hexane. These pyrroles were colorless or creamy white just after chromatographic purification. However, the samples were colorized during the recrystallization, as often seen in other pyrroles.

3-Benzyl-2-phenylpyrrole (**4a**); Purple prisms, mp 107–108 ˚C. ^{1}H NMR ($CDCl_3$) δ = 4.01 (s, 2H), 6.09 (t, J = 2.8 Hz, 1H), 6.80 (t, J = 2.8 Hz, 1H), 7. 12 (tt, J = 7.2, 1.2 Hz, 1H), 7.22-7.30 (m, 5H), 7.34-7.39 (m, 4H), 8.16 (s, 1H) ppm; ^{13}C NMR ($CDCl_3$) δ = 32.6, 111.6, 117.8, 119.3, 125.7, 126.5, 126.8, 128.4, 128.6, 128.8, 129.0, 133.4, 142.3 ppm; IR (KBr) ν_{max} = 3404vs, 3396vs, 761s, 710s, 694s cm^{-1}; UV (EtOH) λ_{max} = 206 (logε = 4.57), 287 (4.17) nm; MS (70 eV): *m/z* (rel int) 233 (M^+, 100), 232 (44), 156 (96), 154 (12), 128 (11). *Anal*. Calcd for $C_{17}H_{15}N$: C, 87.52; H, 6.48; N, 6.00%. Found C, 87.33; H, 6.49; N, 5.92%.

3-(4-Bromobenzyl)-2-phenylpyrrole (**4b**); Red needles, mp 55–58 ˚C. ^{1}H NMR ($CDCl_3$) δ = 3.95 (s, 2H), 6.07 (t, J = 2.4 Hz, 1H), 6.82 (t, J = 2.4 Hz, 1H), 7. 09 (d, J = 8.4 Hz, 2H), 7.34-7.40 (m, 7H), 8.19 (s, 1H) ppm; ^{13}C NMR ($CDCl_3$) δ = 32.0, 111.5, 117.9, 118.6, 119.5, 126.6, 126.8, 128.9, 129.1, 130.3, 131.4, 133.3, 141.3 ppm; IR (KBr) ν_{max} = 3388vs, 1485s, 1011s, 772s, 734s cm^{-1}; UV (EtOH) λ_{max} = 202 (logε = 4.52), 221sh (4.27), 284 (4.15) nm; MS (70 eV): *m/z* (rel int) 313 (M^+, 98), 311 (M^+, 100), 232 (19), 230 (13), 156 (100), 154 (17), 128 (13). *Anal*. Calcd for $C_{17}H_{14}BrN$: C, 65.40; H, 4.52; N, 4.49%. Found C, 65.42; H, 4.62; N, 4.41%.

3-(2-Methylbenzyl)-2-phenylpyrrole (**4c**); Brown microcrystals, mp 132–133 ˚C. ^{1}H NMR ($CDCl_3$) δ = 2.24 (s, 3H), 3.94 (s, 2H), 5.98 (t, J = 3.0 Hz, 1H), 6.79 (t, J = 3.0 Hz, 1H), 7.10–7.16 (m, 4H), 7.24 (m, 1H), 7.34–7.38 (m, 4H), 8.18 (s, 1H) ppm; ^{13}C NMR ($CDCl_3$) δ = 19.7, 30.5, 111.7, 117.8, 118.9, 125.98, 126.03, 126.5, 126.7, 128.9, 129.0, 130.0, 133.6, 136.4, 140.4, 144.0 ppm; IR (ATR) ν_{max} = 3380s, 763s, 731vs, 694s cm^{-1}; UV (EtOH) λ_{max} = 286 (logε = 4.15) nm; MS (70 eV): *m/z* (rel int) 247 (M^+, 100), 246 (21), 232 (11), 156 (40), 143 (68). HRMS *m/z* Calcd for $C_{18}H_{17}N$ (M^+) 247.1361, found: 247.1356.

3-(1-Naphthylmethy)-2-phenylpyrrole (**4d**); Brown microcrystals, mp 124–126 ˚C. ^{1}H NMR ($CDCl_3$) δ = 4.44 (s, 2H), 6.01 (t, J = 2.9 Hz, 1H), 6.80 (t, J = 2.9 Hz, 1H), 7.24 (tt, J = 7.2, 1.2 Hz, 1H), 7.31 (dd, J = 6.8, 1.2 Hz, 1H), 7.33–7.37 (m, 2H), 7.39–7.41 (m, 2H), 7.44–7.47 (m, 3H), 7.73 (d, J = 8.0 Hz, 1H), 7.86 (dd, J = 7.5, 2.0 Hz, 1H), 8.01 (dd, J = 7.5, 2.0 Hz, 1H), 8.23 (s, 1H) ppm; ^{13}C NMR ($CDCl_3$) δ = 30.0, 111.8, 117.8, 118.7, 124.0, 125.4, 125.7, 125.8, 126.0, 126.4, 126.6 (2C), 128.6, 128.85, 128.90, 132.1, 133.4, 133.7, 137.9 ppm; IR (ATR) ν_{max} = 3437vs, 803s, 783vs, 767vs, 696s cm^{-1}; UV (EtOH) λ_{max} = 273sh (logε = 4.23), 283 (4.32), 295sh (4.24) nm; MS (70 eV): *m/z* (rel int) 283 (M^+, 100), 282 (51), 155 (48). HRMS *m/z* Calcd for $C_{21}H_{17}N$ (M^+) 283.1361, found: 283.1357.

2-Phenyl-3-(2-thienylmethy)pyrrole (**4e**); Brown microcrystals, mp 75–76 ˚C. ^{1}H NMR ($CDCl_3$) δ = 4.15 (d, J = 1.0 Hz, 2H), 6.22 (t, J = 3.0 Hz, 1H), 6.81-6.83 (m, 2H), 6.92 (dd, J = 5.0, 3.5 Hz, 1H), 7.12 (dd, J

= 5.0, 1.0 Hz, 1H), 7.27 (tt, *J* = 7.2, 1.2 Hz, 1H), 7.37–7.41 (m, 4H), 8.16 (s, 1H) ppm; ^{13}C NMR ($CDCl_3$) δ = 27.1, 111.3, 117.7, 118.9, 123.2, 124.3, 126.6, 126.7, 126.9, 128.8, 128.9, 133.1, 146.1 ppm; IR (ATR) ν_{max} = 3406s, 3397s, 763s, 690vs cm^{-1}; UV (EtOH) λ_{max} = 227 (logε = 4.13), 284 (4.14) nm; MS (70 eV): *m/z* (rel int) 239 (M^+, 100), 238 (75), 162 (12), 154 (14). HRMS *m/z* Calcd for $C_{15}H_{13}NS$ (M^+) 239.0769, found: 239.0773.

3-Benzyl-2-(4-methoxyphenyl)pyrrole (**4f**); Blue needles, mp 78–79 ˚C. ^{1}H NMR ($CDCl_3$) δ = 3.81 (s, 2H), 3.96 (s, 3H), 6.08 (t, *J* = 2.8 Hz, 1H), 6.77 (t, *J* = 2.8 Hz, 1H), 6.92 (d, *J* = 8.4 Hz, 2H), 7.16–7.31 (m, 7H), 8.08 (s, 1H) ppm; ^{13}C NMR ($CDCl_3$) δ = 32.0, 55.3, 111.3, 114.2, 117.1, 118.4, 125.7, 126.2, 128.3, 128.3, 128.5, 128.9, 142.5, 158.4 ppm; IR (KBr) ν_{max} = 3359s, 3345s, 1509vs, 1254s, 1030s, 708s cm^{-1}; UV (EtOH) λ_{max} = 268sh (logε = 4.19), 276 (4.23) nm; MS (70 eV): *m/z* (rel int) 263 (M^+, 100), 262 (32), 248 (8), 218 (5), 186 (57). *Anal*. Calcd for $C_{18}H_{17}NO{\cdot}0.05H_2O$: C, 81.82; H, 6.52; N, 5.30%. Found C, 81.74; H, 6.39; N, 5.30%.

3-Benzyl-2-(4-dimethylaminophenyl)pyrrole (**4g**); Blue microcrystals, mp 108–111 ˚C. ^{1}H NMR ($CDCl_3$) δ = 2.95 (s, 6H), 3.96 (s, 2H), 6.05 (t, *J* = 2.5 Hz, 1H), 6.73–6.75 (m, 3H), 7.16 (t, *J* = 7.0 Hz, 1H), 7.22–7.28 (m, 6H), 8.04 (s, 1H) ppm; ^{13}C NMR ($CDCl_3$) δ = 41.6, 48.0, 104.4, 105.7, 108.8, 109.7, 113.0, 116.0, 117.9, 118.1, 118.4, 119.2, 129.7, 135.0 ppm; UV (EtOH) λ_{max} = 291 (logε = 4.33) nm; IR (ATR) ν_{max} = 3390s, 3348s, 1617s, 1520vs, 820s, 707s cm^{-1}; MS (70 eV): *m/z* (rel int) 276 (M^+, 100), 199 (48), 185 (34), 155 (10), 138 (16), 137 (17), 84 (11). *Anal*. Calcd for $C_{19}H_{20}N_2{\cdot}0.1H_2O$: C, 82.04; H, 7.32; N, 10.07%. Found C, 82.07; H, 7.33; N, 9.93%.

3-Benzyl-2-*t*-butylpyrrole (**4h**); A brown oil. ^{1}H NMR ($CDCl_3$) δ = 1.34 (s, 9H), 3.99 (s, 2H), 5.88 (t, *J* = 3.0 Hz, 1H), 6.56 (t, *J* = 3.0 Hz, 1H), 7.13-7.19 (m, 3H), 7.23-7.27 (m, 2H), 7.91 (s, 1H) ppm; ^{13}C NMR ($CDCl_3$) δ = 30.6, 32.4, 33.6, 112.0, 113.9, 116.3, 125.6, 128.2, 128.7, 135.3, 142.9 ppm; IR (ATR) ν_{max} = 3455s, 3423s, 2959vs, 2906s, 1494s, 1453s, 726vs, 709vs cm^{-1}; UV (EtOH) λ_{max} = 262 (logε = 2.97), 270 (2.86) nm; MS (70 eV): *m/z* (rel int) 213 (M^+, 89), 248 (22), 198 (100), 188 (18), 173 (11), 131 (12), 120 (43), 115 (14), 91 (62). HRMS *m/z* Calcd for $C_{15}H_{19}N$ (M^+) 213.1518, found : 213.1511.

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