A Facile Preparation of Imidazolinium Chlorides

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Supporting Information

General Information
NMR spectra were recorded on an Oxford 300 MHz NMR spectrometer running Varian VNMR Software. Chemical Shifts are reported in parts per million (ppm) downfield from tetramethylsilane (TMS) with reference to internal solvent for ^{1}H NMR and ^{13}C NMR spectra. Spectra are reported as follows: chemical shift (δ ppm), integration, multiplicity and coupling constant (Hz). (Multiplicities are abbreviated as follows: singlet (s), doublet (d), triplet (t), quartet (q), quintet (quint), septet (sept), multiplet (m), and broad (br). All new compounds were also characterized by high-resolution mass spectrometry(FAB) at the California Institute of Technology Mass Spectrometry Facility. Compounds are numbered according to their entry number in Table 1; (a) denotes the formamidine and (b) denotes the imidazolinium chloride. All commercial chemicals were used as obtained.

A Note on Formamidine Isomerization and NMR Spectra
Although many diarylformamidines are well known and highly utilized compounds, their NMR spectra are rarely found in the literature. While this is presumed to be a result of their age in the literature, it could also be a result of their surprisingly complex NMR spectra. Formamidines have two rotational isomers that interconvert at rates dependent on both substituents and solvent. This often leads to spectra that are considerably more complex than expected for these small molecules. Because the NMR spectra of a single formamidine can vary significantly depending on the solvent, we have tried to provide spectral data for the known formamidines in solvents that supply the most information about each compound.

General Procedure For the Preparation of Symmetric Formamidines
Acetic acid (86 µL, 1.5 mmol) was added to a round bottom flask charged with the corresponding aniline (60 mmol, 2 equiv) and triethyl orthoformate (5 mL, 30 mmol, 1 equiv). The flask was fitted with a distillation head and was heated with stirring overnight. Upon cooling to room temperature, the solution solidified. The crude product was triturated with cold hexanes (30 mL), collected by vacuum filtration and dried *in vacuo*, providing pure product as a colorless powder (80-92%). The following formamidines were prepared by this procedure:

***N,N'*-Bis(2,4,6-trimethylphenyl)formamidine (1a).** Prepared according to the above general procedure (140 °C) in 92% yield as a white semi-crystalline solid. In C_6D_6 (25 °C) the formamidine exists in two isomeric forms in a 1:1 ratio. ^{1}H NMR chemical shifts for the two isomers will be listed separately. Isomer 1: ^{1}H NMR (C_6D_6): δ 1.86 [s, 6H], 2.03 [s, 3H], 2.23 [s, 3H], 2.31 [s, 3H], 4.99 [d, 1H, J_{HH} = 7.2 Hz], 6.55 [s, 2H], 6.90 [s, 2 H], 6.94 [d, 1H, J_{HH} = 7.2 Hz]. Isomer 2: ^{1}H NMR (C_6D_6): δ 2.12 [s, 6H], 2.16 [s, 12H], 6.74 [s, 4H], 6.83 [s, 1H]. $^{13}C\{^{1}H\}$ NMR (C_6D_6): δ 18.62, 18.86, 19.14, 21.18, 21.27, 21.29, 129.50, 129.74, 129.83, 134.52, 134.93, 135.97, 144.44, 146.77.

***N,N'*-Bis(2-methylphenyl)formamidine (2a)**. Prepared according to the above general procedure (140 °C) in 90% yield as a white semi-crystalline solid. ^{1}H NMR (C_6D_6): δ 2.03 [s, 6H], 6.87-7.04 [m, 8H], 7.68 [s, 1H]. $^{13}C\{^{1}H\}$ NMR (C_6D_6): δ 18.20, 118.50, 123.95, 127.59, 131.24, 147.92.

***N,N'*-Bis(2,6-diisopropylphenyl)formamidine (3a).** Prepared according to the above general procedure (160 °C) in 85% yield as a white semi-crystalline solid. Major isomer(>95%): ^{1}H NMR (C_6D_6): δ 1.12 [d, 24H, J_{HH} = 6.7 Hz], 3.42 [sept, 4H, J_{HH} = 6.7 Hz], 6.99-7.1 [m, 6H]. $^{13}C\{^{1}H\}$ NMR (C_6D_6): δ 24.11, 28.71, 123.84, 126.23 (br), 144.17 (br), 155.92 (br).

***N,N'*-Bis(2-tert-butylphenyl)formamidine (4a).** Prepared according to the above general procedure (160 °C) and was obtained in 85% yield as a white solid. ^{1}H NMR (CD_2Cl_2): δ 1.50 [s, 18H], 7-7.5 [m, 8H], 7.86 [s, 1H]. $^{13}C\{^{1}H\}$ NMR (CD_2Cl_2): δ 30.81, 35.55, 121.99, 124.27, 127.01, 127.52, 148.22. HRMS (FAB^{+}) calculated for $C_{21}H_{29}N_2$ [M^{+}] 309.2331, observed 309.2325.

General Procedure For the Preparation of Unsymmetric Formamidines

Acetic acid (86 µL, 1.5 mmol) was added to a round bottom flask charged with the first aniline (30 mmol, 1 equiv) and triethyl orthoformate (5 mL, 30 mmol, 1 equiv). The flask was fitted with a distillation head and was heated with stirring to 140 °C until ethanol (3.5 ml, 60 mmol, 2 equiv) was collected by distillation. The second substituted aniline (30 mmol, 1 equiv) was then added to the reaction mixture. Heating at 140 °C continued until ethanol (1.75 mL, 30 mmol, 1 equiv) was collected by distillation. Upon cooling to room temperature, the solution solidified. The crude product was triturated with cold hexanes and collected by vacuum filtration. Solids were then dissolved in minimal hot acetone and recrystallized at -15 °C to remove traces of symmetric formamidine byproducts. The crystals were collected by vacuum filtration and dried *in vacuo*, providing pure product (82-86%). The following formamidines were prepared by this procedure:

***N*-(2,6-difluorophenyl)-*N'*-(2,4,6-trimethylphenyl)formamidine (5a).** Prepared according to the above general procedure in 86% yield as colorless needles. ^{1}H NMR (DMSO-d_6): δ 2.21 [s, 6H], 2.23 [s, 3H], 6.89-7.1 [m, 5H], 7.83 [s, 1H], 8.70 [s, 1H]. ^{13}C{^{1}H} NMR (DMSO-d_6): δ 18.20, 20.51, 111.34, 111.54, 111.65, 121.41, 128.35, 128.81, 133.10, 134.74, 135.30, 152.34. ^{19}F{^{1}H} NMR (DMSO-d_6): δ -126.87 [s]. HRMS (FAB^{+}) calculated for $C_{16}H_{17}N_2F_2$ [M^{+}] 275.1357, observed 275.1360.

***N*-(2,6-diisopropylphenyl)-*N'*-(2-methylphenyl)formamidine (6a).** Prepared according to the above general procedure in 82% yield as faintly pink plates. In $CDCl_3$ (25 °C) this formamidine exists in two isomeric forms in a 2:1 ratio (unassigned). ^{1}H NMR chemical shifts that differ between isomers will be denoted by (maj) and (min). ^{1}H NMR ($CDCl_3$): δ 1.22 [d, 12H, J_{HH} = 6.9 Hz], 1.975(min) [s, 1H], 2.31(maj) [s, 2H], 3.13(min) [sept, 0.68H, J_{HH} = 6.9 Hz], 3.24(maj) [sept, 1.32H, J_{HH} = 6.9 Hz], 6.95-7.26 [m, 7H], 7.79(maj) [s, 0.66H], 7.91(min) [d, 0.34H, J_{HH} = 11 Hz]. ^{13}C{^{1}H} NMR (CD_2Cl_2): δ 18.15, 18.24, 23.83, 24.01, 28.55, 116.90, 118.30, 123.31, 123.58, 123.74, 123.85, 123.97, 124.35, 126.80, 126.85, 126.89, 127.38, 127.76, 131.04, 131.52, 139.18, 143.98. HRMS (FAB^{+}) calculated for $C_{20}H_{27}N_2$ [M^{+}] 295.2174, observed 295.2175.

Preparation of imidazolinium chlorides

Three procedures were used to prepare the imidazolinium chlorides.

From the corresponding formamidine

Method A: Diisopropylethylamine (0.96 mL, 5.5 mmol, 1.1 equiv) was added to a stirred solution of formamidine (5 mmol, 1 equiv) and dichloroethane (3.8 mL, 50 mmol, 10 equiv) in a Schlenk tube. The tube was evacuated until the solvent began to bubble, then sealed under static vacuum and heated to 120 °C for 24-168 hours. The reaction mixture was then cooled to room temperature, and excess dichlorooethane was removed *in vacuo*. The residue was triturated with acetone or hot toluene, and the product was collected by vacuum filtration, washed with excess solvent and dried *in vacuo,* providing pure product as a colorless powder (85-95%). Upon sitting overnight, the diisopropylethylamine hydrochloride precipitated from the filtrate.

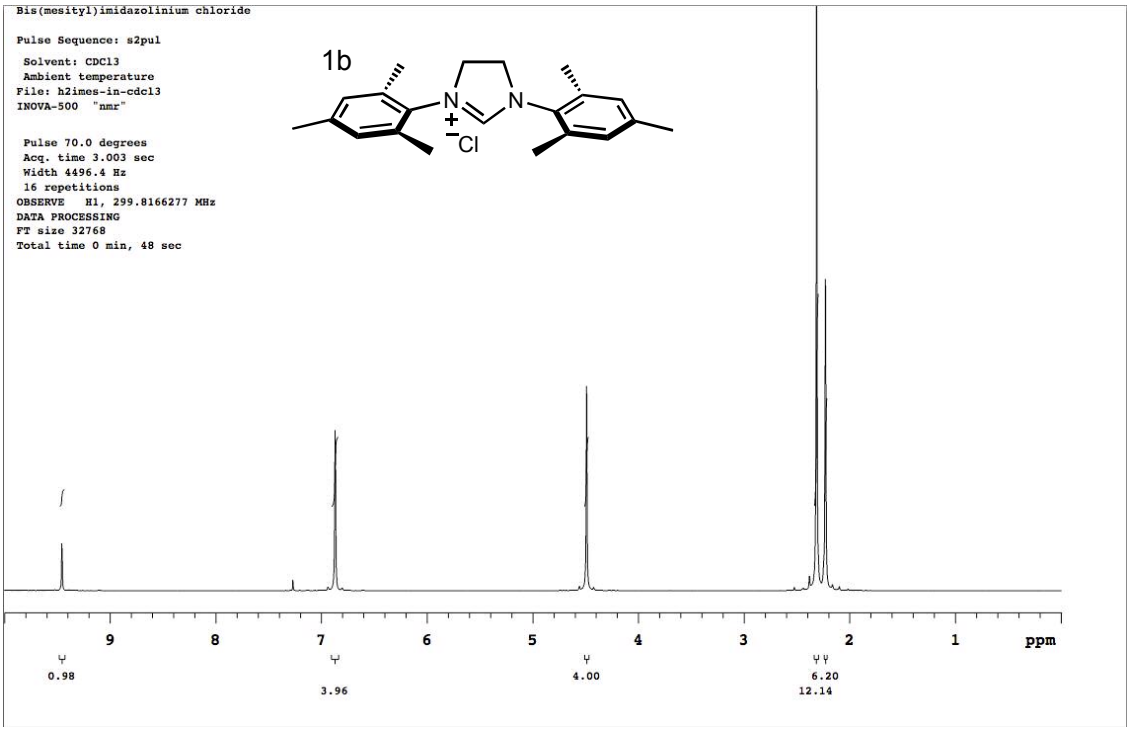
Method B: Dichloroethane (7.6 mL, 100 mmol, 10 equiv) was added to a Schlenk flask charged with formamidine (10 mmol, 1 equiv). The tube was evacuated until the solvent began to bubble, then sealed under static vacuum and heated to 120 °C for 24-168 hours. The reaction mixture was then cooled to room temperature, and excess dichlorooethane was removed *in vacuo*. The residue was triturated with acetone or hot toluene, and the product was collected by vacuum filtration, washed with excess solvent and dried *in vacuo,* providing pure product as a colorless powder (85-95%). Upon sitting overnight, the formamidine hydrochloride precipitated from the filtrate.

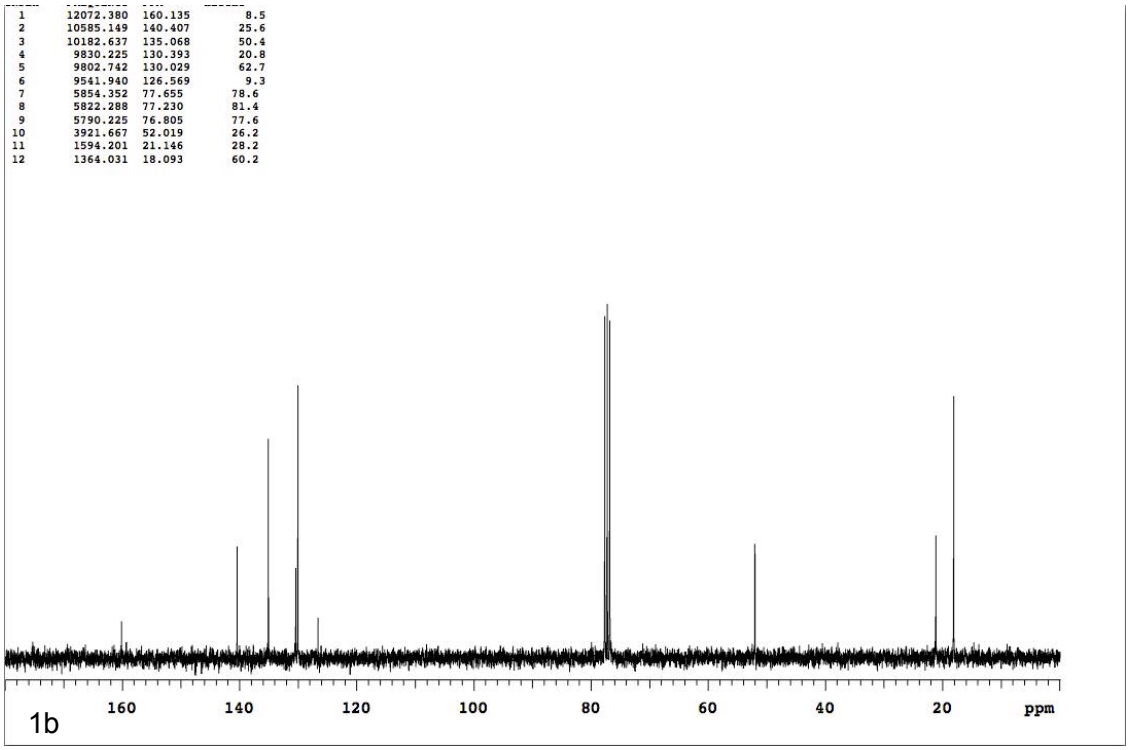
From the corresponding aniline

Dichloroethane (1.9 mL, 25 mmol, 5 equiv) was added to a Schlenk flask charged with the aniline (10 mmol, 2 equiv) and triethyl orthoformate (0.83 mL, 5 mmol, 1 equiv). The tube was evacuated until solvent began to bubble, then sealed under static vacuum and heated to 120 °C for 24-36 hours. The reaction mixture was then cooled to room temperature. Unreacted substrates were then removed *in vacuo*. The residue was triturated with acetone or hot toluene, and the product was collected by vacuum filtration, washed with excess solvent and dried *in vacuo,* providing pure product as a colorless powder (85-95%). Upon sitting overnight, the formamidine hydrochloride precipitated from the filtrate.

1,3-Bis(2,4,6-trimethylphenyl)-imidazolinium chloride (1b). Prepared according to methods **A** (92%), **B** (49%), and **C** (45%). in 24 hours. The product was collected as a white solid after trituration with boiling toluene. The

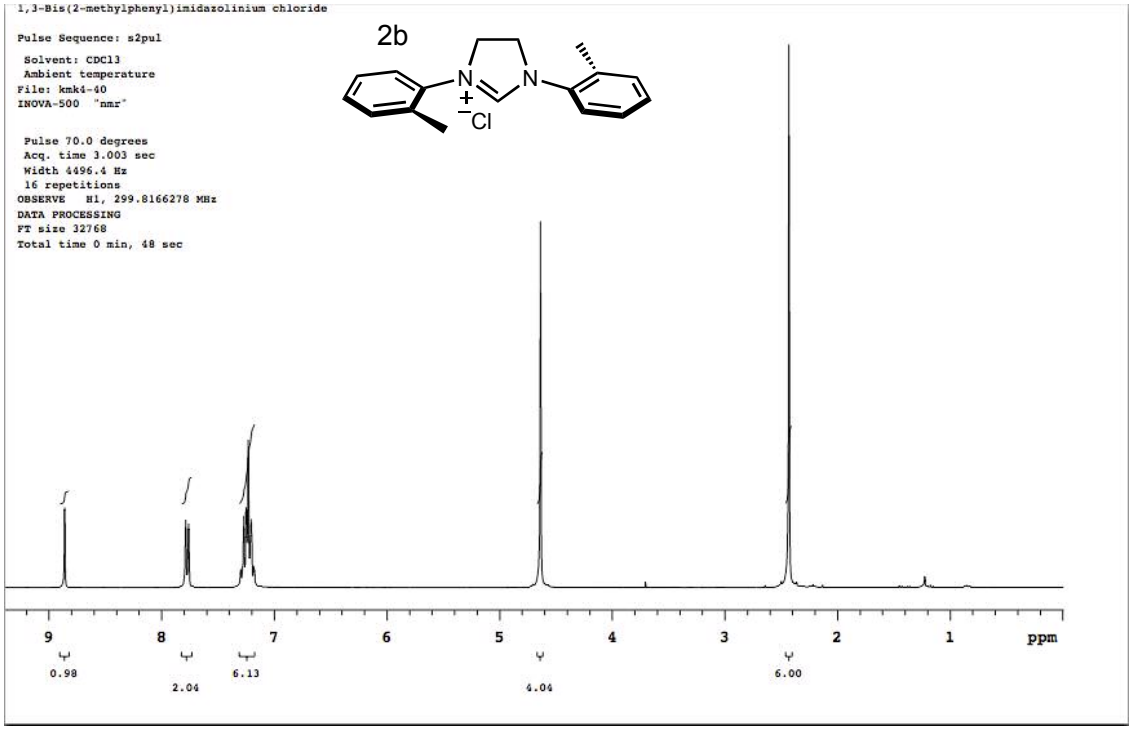
NMR data are in accordance with those reported.[1] ^{1}H NMR ($CDCl_3$): δ 2.29 [s, 6H], 2.31 [s, 12H], 4.49 [s, 4H], 6.87 [s, 4H], 9.46 [s, 1H]. $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 18.09, 21.15, 52.02, 130.03, 130.39, 135.07, 140.41, 160.14.

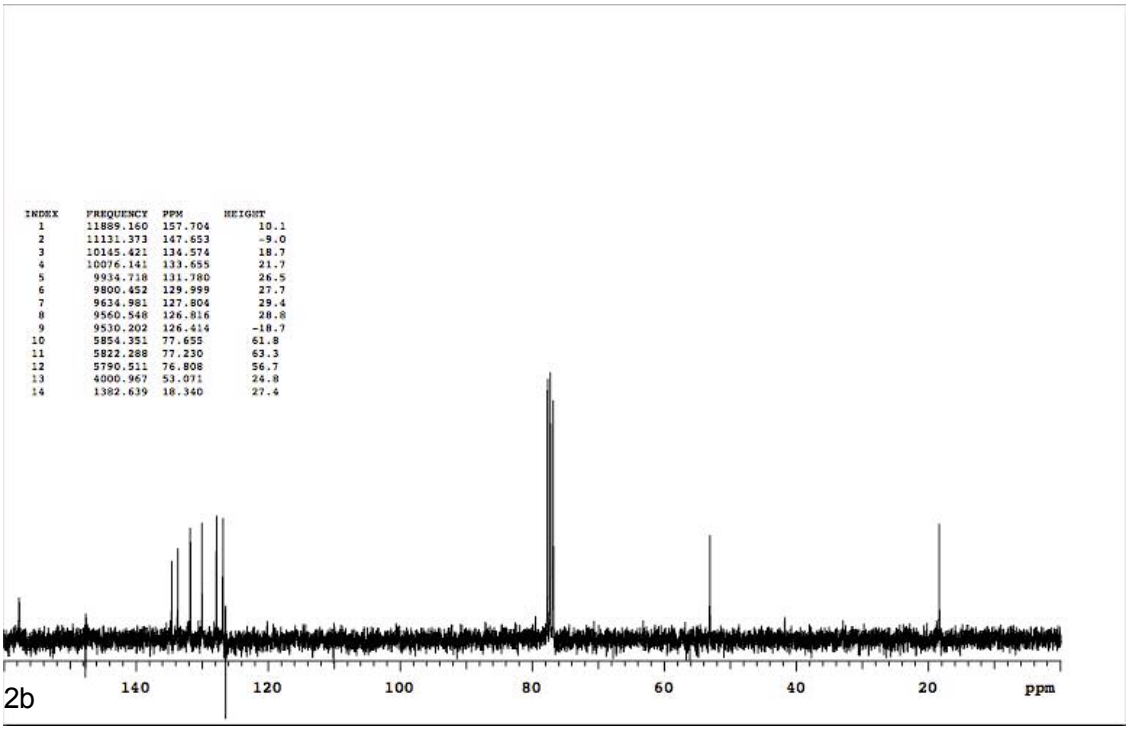




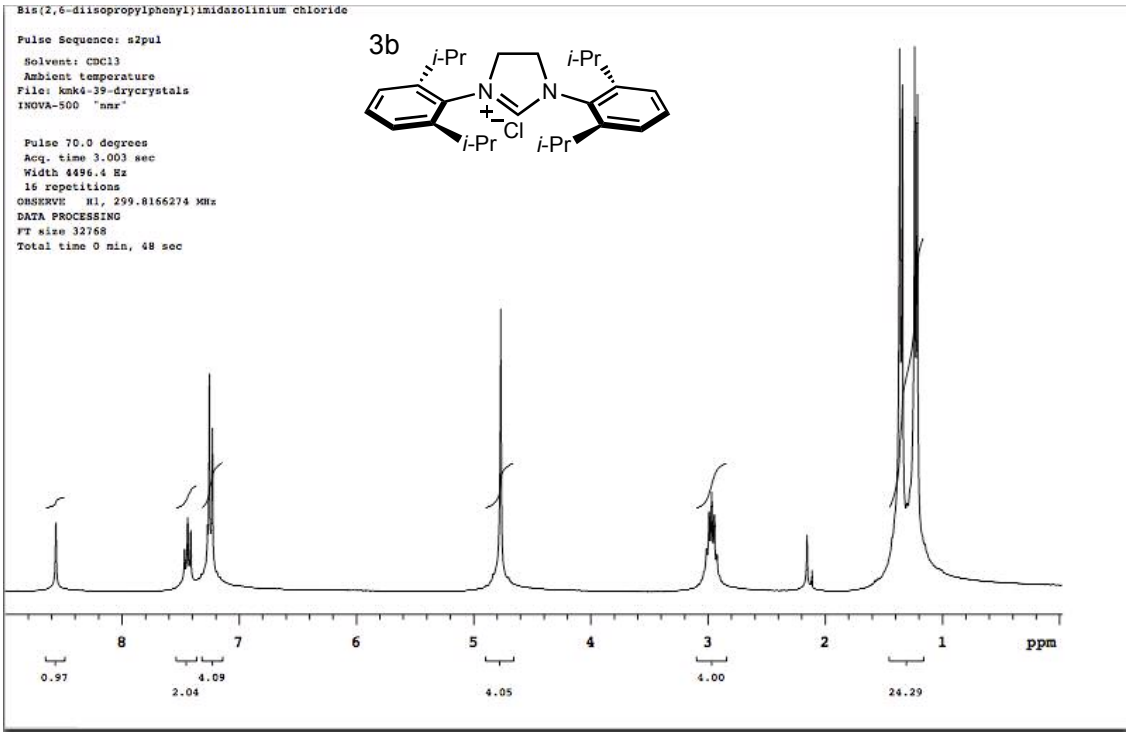
1,3-Bis(2-methylphenyl)-imidazolinium chloride (2b). Prepared according to methods **A** (43%), **B** (48%), and **C** (26%). in 24 hours. The product was collected as a white solid after trituration with acetone. The NMR data are in accordance with those reported.[2] ^{1}H NMR ($CDCl_3$): δ 2.43 [s, 6H], 4.64 [s, 4H], 7.21-7.79 [m, 8H], 8.86 [s, 1H]. $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 18.34, 53.07, 126.82, 127.80, 130.0, 131.78, 133.66, 134.57, 157.68.

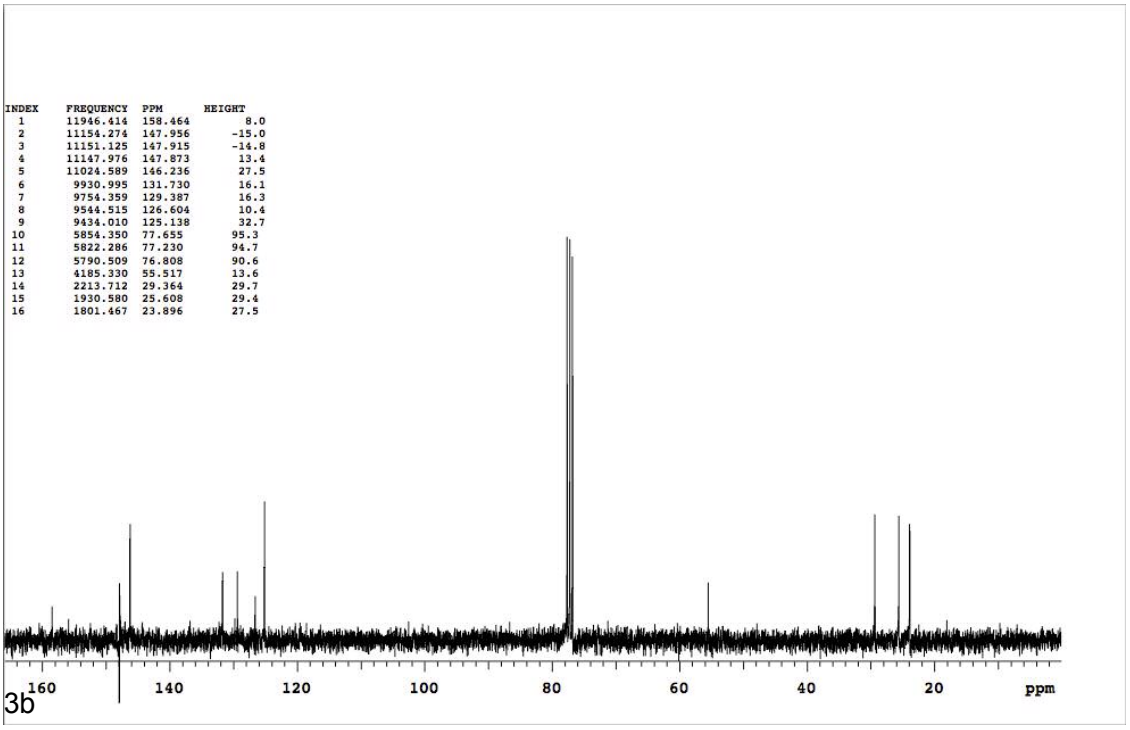
[1] A. J. Arduengo III et al. *Tetrahedron* **1999**, *55*, 14523-14534.
[2] Stewart, I. C.; Ung, T.; Pletnev, A. A.; Berlin, J. M.; Grubbs, R. H.; Schrodi, Y. *Org. Lett.* **2007**, *9*, 1589-1592.



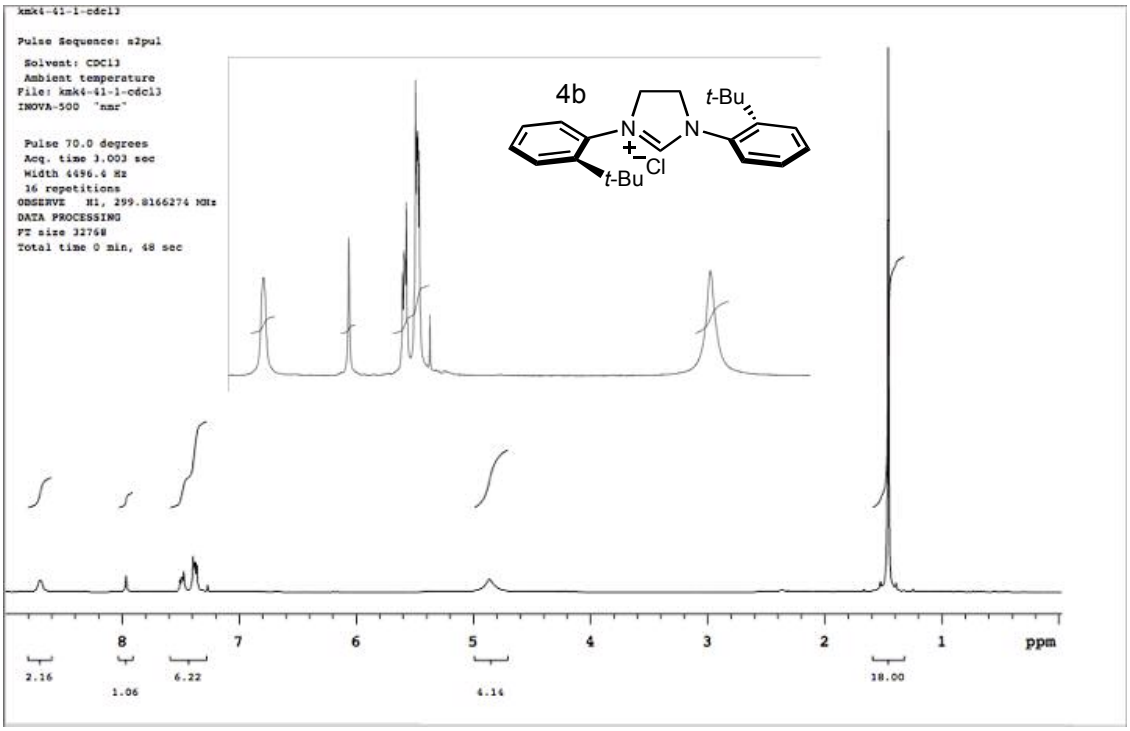


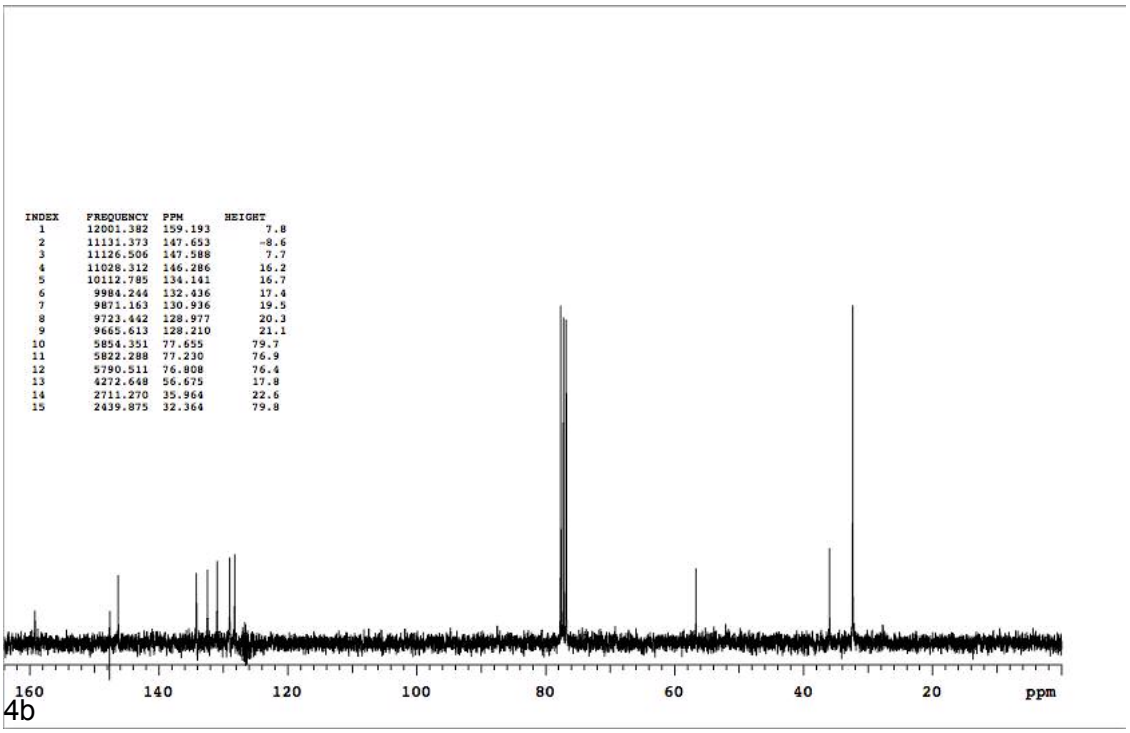
1,3-Bis(2,6-diisopropylphenyl)-imidazolinium chloride (3b). Prepared according to methods **A** (91%), **B** (46%), and **C** (42%). in 36 hours. The product was collected as a white solid after trituration with minimal acetone. The NMR data are in accordance with those reported.[1] ^{1}H NMR ($CDCl_3$): δ 1.22 [d, 12H, J_{HH} = 6.9 Hz], 1.35 [d, 12H, J_{HH} = 6.9 Hz], 2.97 [sept, 4H, J_{HH} = 6.9 Hz], 4.77 [s, 4H], 7.2-7.5 [m, 6H], 8.56 [s, 1H]. ^{13}C{^{1}H} NMR ($CDCl_3$): δ 23.90, 25.61, 29.36, 55.52, 125.14, 129.39, 131.73, 146.24, 158.46.





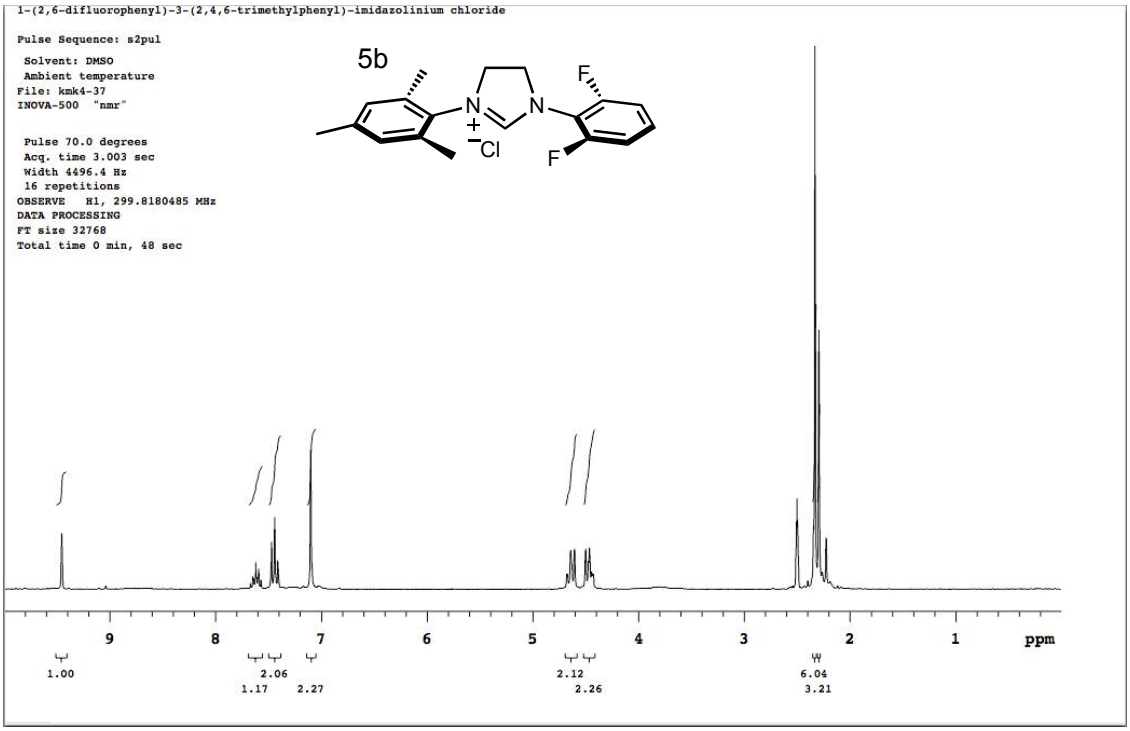
1,3-Bis(2-tert-butylphenyl)-imidazolinium chloride (4b). Prepared according to methods **A** (91%) and **B** (46%), in 168 hours (7 days). The product was collected as a white solid after trituration in acetone. ^{1}H NMR ($CDCl_3$): δ 1.46 [s, 18H], 4.86 [s, 4H], 7.35-7.50 [m, 6H], 7.97 [s, 1H], 8.70 [br, 2H]. $^{13}C\{^{1}H\}$ NMR ($CDCl_3$): δ 32.36, 35.96, 56.68, 128.21, 128.98, 130.93, 132.43, 134.14, 146.28, 159.19. HRMS (FAB^+) calculated for $C_{23}H_{31}N_2$ [M^+] 335.2487, observed 335.2479.

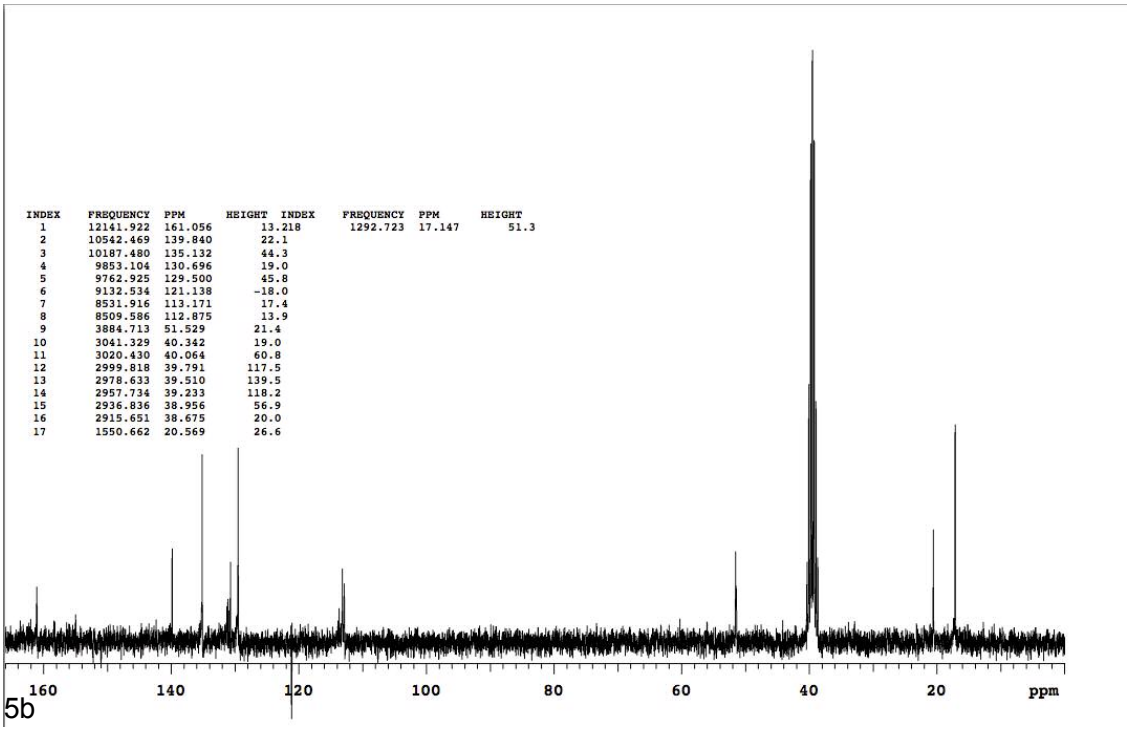




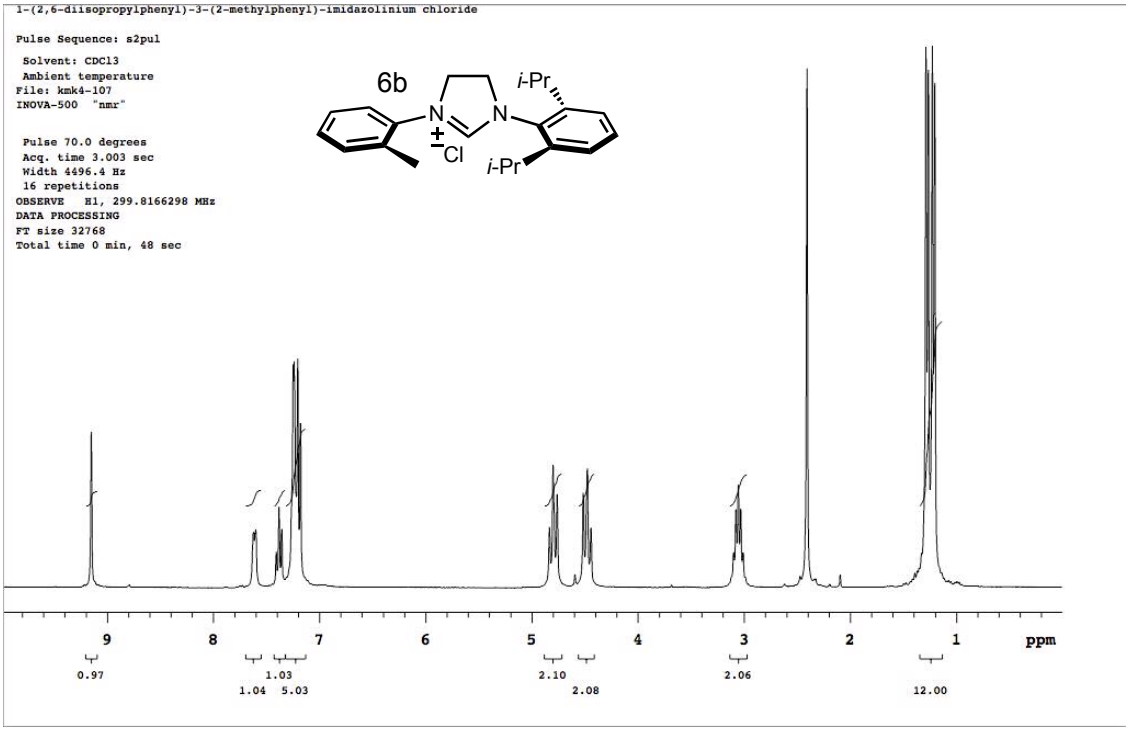
1-(2,6-difluorophenyl)-3-(2,4,6-trimethylphenyl)-imidazolinium chloride (5b). Prepared according to methods **A** (75%) and **B** (41%), in 36 hours. The product was collected as a white solid after trituration with acetone. The NMR data are in accordance with those reported.[3] ^{1}H NMR (DMSO-d_6): δ 2.29 [s, 3H], 2.31 [s, 6H], 4.42-4.5 [m, 2H], 4.6-4.7 [m, 2H], 7.1 [s, 2H], 7.41-7.47 [m, 2H], 7.57-7.67 [m, 2H], 9.45 [s, 1H]. ^{13}C{^{1}H} NMR (DMSO-d_6): δ 17.15, 20.57, 51.53, 112.88, 113.17, 129.5, 130.7, 135.13, 139.84, 161.06. ^{19}F{^{1}H} NMR (DMSO-d_6): δ -119.84 [s].

[3] Vougioukalakis, G. C.; Grubbs, R. H.; *Organometallics* **2007**, *26*, 2469-2472.





1-(2,6-diisopropylphenyl)-3-(2-methylphenyl)-imidazolinium chloride (6b). Prepared according to methods **A** (80%) and **B** (43%), in 24 hours. The product was collected as a white solid after trituration with acetone. ^{1}H NMR ($CDCl_3$): δ δ 1.22 [d, 6H, J_{HH} = 6.6 Hz], 1.28 [d, 6H, J_{HH} = 6.6 Hz], 2.41 [s, 3H], 3.05 [sept, 2H, J_{HH} = 6.6 Hz], 4.44-4.52 [m, 2H], 4.76-4.83 [m, 2H], 7.18-7.28 [m, 5H], 7.36-7.41 [m, 1H], 7.6-7.63 [m, 1H], 9.15 [s, 1H]. ^{13}C{^{1}H} NMR ($CDCl_3$): δ 18.16, 24.07, 25.18, 28.83, 53.25, 54.43, 124.83, 126.05, 127.72, 129.83, 131.13, 131.87, 133.15, 134.18, 146.31, 158.58. HRMS (FAB$^+$) calculated for $C_{2s}H_{29}N_2$ [M$^+$] 321.2331, observed 321.2342.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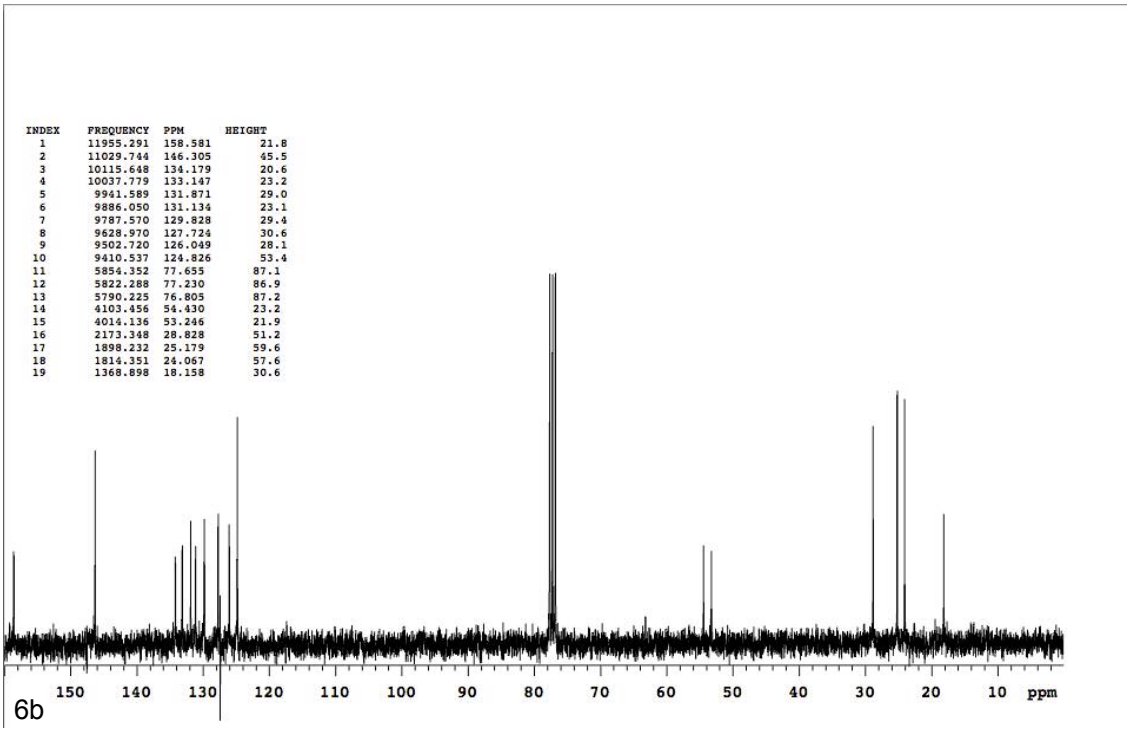
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