Supporting Information: Self-complementary purines by quadruple hydrogen bonding

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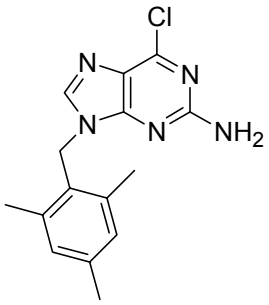
I. Experimental Protocol

A. General. Reagents were purchased from Acros or Aldrich, and were used without further purification unless stated otherwise. Dry solvents were degassed and purified under an atmosphere of argon using the GlassContour solvent system (GlassContour, Inc.). Pyridine was distilled onto 3 Å activated molecular sieves. Column chromatography was carried out using Whatman 230–400 mesh silica gel. Thin layer chromatography (TLC) was performed on Duracil TLC aluminum sheets with visualization by UV light. Melting points (Mp) were determined on a MEL-TEMP melting apparatus and are uncorrected. ^{1}H (300, 500 MHz) and ^{13}C (75, 125 MHz) nuclear magnetic resonance (NMR) spectra were recorded on Varian Gemini 300, Mercury 300BB, and Inova 500 spectrometer at room temperature unless otherwise specified. Chemical shifts (δ) are given in parts per million (ppm) relative to TMS and referenced to residual protonated solvent ($CHCl_3$: δ_H 7.24 ppm, δ_C 77.0 ppm; DMSO: δ_H 2.49 ppm, δ_C 39.5 ppm). Abbreviations used are singlet (s), doublet (d), triplet (t), multiplet (m), and broad (b). High resolution mass spectrometry (HRMS) spectra were recorded on a Finnigan LCQ-Ion Trap Spectrometer.

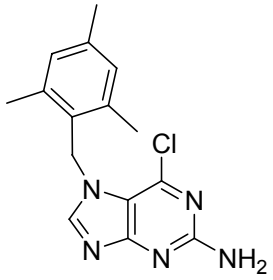
B. Synthetic Details for Compounds 1 and 3–5.



2-Amino-6-chloro-*N*-9-(2,4,6-trimethylbenzyl)purine (3a).

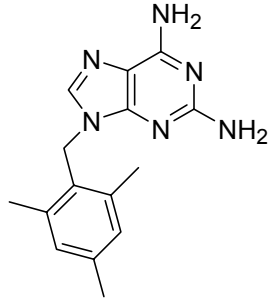
6-Chloro-2-aminopurine[1] **2** (2.08 g, 11.1 mmol), 2-bromomethyl-1,3,5-trimethyl-benzene[2] (3.52 g, 16.5 mmol), and K_2CO_3 (2.30 g, 16.6 mmol) were placed in an oven-dried round-bottomed flask and dried under argon. Dry DMF (180 mL) was added and the mixture was stirred overnight at room temperature. The solvent was removed under vacuum and the residue was purified by column chromatography on silica gel (5% MeOH/CH_2Cl_2) to yield a yellow/white powder (1.42 g, 40%). Mp 205–208 °C; ^{1}H NMR ($CDCl_3$) δ 2.25 (s, 6H), 2.31 (s, 4H), 5.17 (s, 4H), 6.94 (s, 2H), 7.25 (s, 1H); ^{1}H NMR

(DMSO-d_6) δ 2.23 (s, 3H), 2.25 (s, 6H), 5.16 (s, 2H), 6.92 (s, 2H), 6.95 (s, 2H), 7.55 (s, 1H); ^{13}C NMR (DMSO-d_6) δ 19.4, 20.5, 123.1, 128.2, 128.3, 129.1, 129.2, 137.5, 141.7, 149.3, 153.9, 159.7; HRMS (ESI-FT-ICR) calculated for $C_{15}H_{16}N_5Cl$ $(M + H)^+$ 302.1167, found 302.1166.



2-Amino-6-chloro-*N*-7-(2,4,6-trimethylbenzyl)purine (3a′).

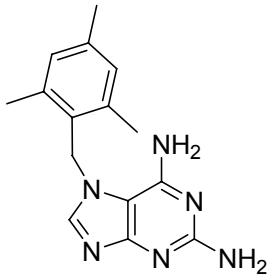
Using conditions identical to those designed for **3a**, the *N*(7) regioisomer was isolated as a yellow/white solid from 5.30 g (28.1 mmol) of starting material **2** to give 1.04 g (12%) of **3a′**. Mp 223–225 °C; ^{1}H NMR ($CDCl_3$) δ 2.25 (s, 6H), 2.30 (s, 3H), 5.16 (s, 2H), 5.26 (bs, 2H), 6.94 (s, 2H), 7.25 (s, 1H); ^{1}H NMR (DMSO-d_6) δ 2.22 (s, 3H), 2.24 (s, 6H), 5.14 (s, 2H), 6.90 (s, 2H), 6.95 (bs, 2H), 7.54 (s, 1H); ^{13}C NMR (DMSO-d_6; 100 °C) δ 19.4, 20.5, 41.1, 123.2, 128.3, 129.2, 137.5, 137.6, 141.8, 149.4, 154.0, 159.8.



2,6-Diamino-*N*-9-(2,4,6-trimethylbenzyl)purine (4a).

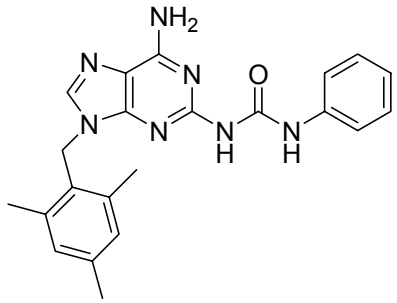
Vacuum dried starting material **3a** (1.05 g, 3.30 mmol) was placed in a 330 mL pressure tube. Methanolic ammonia (95 mL, 7 N) was added to the solid followed by heating under pressure to 90 °C for 16 h. The solvent was removed under vacuum and the residue was purified by chromatography on silica gel (5% MeOH/CH_2Cl_2) to yield **4a** (0.640 g, 50%) as a white powder. Mp 275–278 °C; ^{1}H NMR ($CDCl_3$) δ 2.24 (s, 6H), 2.29 (s, 3H), 4.72 (bs, 2H), 5.11 (s, 2H), 5.30 (bs, 2H), 6.92 (s, 2H), 6.97 (s, 1H); ^{1}H NMR (DMSO-d_6) δ 2.24 (s, 9H), 5.04 (s, 2H), 5.80 (bs, 2H), 6.65 (bs, 2H), 6.91 (s, 2H), 7.04 (s, 1H); ^{13}C NMR (DMSO-d_6; 100 °C) δ 18.9, 20.1, 40.2, 112.9, 128.7, 128.7, 135.6, 136.9, 137.1,

151.7, 155.8, 159.9; HRMS (ESI-FT-ICR) calculated for $C_{15}H_{18}N_6$ $(M + H)^+$ 283.1666, found 283.1668.



2,6-Diamino-*N*-7-(2,4,6-trimethylbenzyl)purine (4a′).

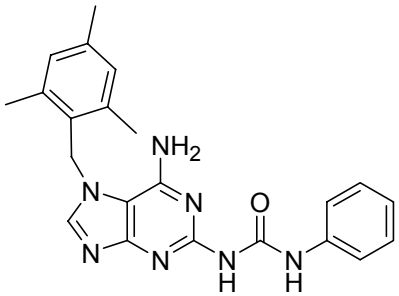
This compound was prepared by the same procedure as **4a** from 1.00 g (3.11 mmol) of **3a** to yield **4a′** as a white solid (0.530 g, 42%). Mp 282–285 °C; ^{1}H NMR ($CDCl_3$) δ 2.24 (s, 6H), 2.29 (s, 3H), 4.72 (bs, 2H), 5.11 (s, 2H), 5.29 (bs, 2H), 6.92 (s, 2H), 6.97 (s, 1H); ^{1}H NMR (DMSO-d_6) δ 2.24 (s, 6H), 2.26 (s, 6H) 5.08 (s, 2H), 5.46 (bs, 2H), 6.27 (bs, 2H), 6.91 (s, 2H), 7.05 (s, 1H); ^{13}C NMR (DMSO-d_6; 100 °C) δ 18.7, 19.9, 113.0, 128.5, 128.6, 135.5, 136.8, 136.9, 151.6, 155.7, 159.8.



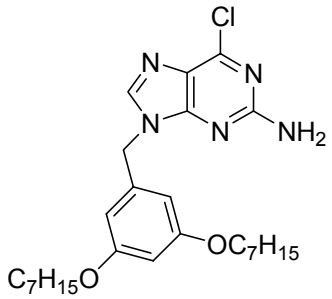
6-Amino-*N*-9-(2,4,6-trimethylbenzyl)-2-*N*-(4-phenylamino)ureidopurine (1a).

Compound **4a** (0.050 g, 0.21 mmol) was placed in an oven-dried two-necked round-bottomed flask and dried under vacuum. Under argon atmosphere CH_2Cl_2 (29 mL) was added to the solid and the mixture was heated to 50–55 °C to dissolve **4a**. When the starting material was completely dissolved, the temperature was lowered to 40 °C. Pyridine (0.034 mL, 0.43 mmol) and phenyl isocyanate (0.051 mL, 0.47 mmol) were added. The mixture was stirred at 40 °C for 20.5 h followed by evaporation. Purification by column chromatography on silica gel (1% MeOH/CH_2Cl_2) afforded **1a** (0.058 g, 70%). Mp 263–265 °C; ^{1}H NMR ($CDCl_3$) δ 2.29 (s, 6H) 2.32 (s, 3H), 5.26 (s, 2H), 6.96 (s, 2H), 7.09 (t, J = 7.1 Hz, 3H), 7.16 (bs, 1H), 7.34 (t, J = 7.3 Hz, 2H), 7.59 (d, J = 7.6 Hz, 2H), 9.34 (bs, 1H), 12.04 (s, 1H); ^{1}H NMR (DMSO-d_6) δ 2.24 (s, 3H), 2.26 (s, 6H),

5.20 (s, 2H), 6.92 (s, 2H), 7.02 (t, J = 7.0 Hz, 1H), 7.30 (t, J = 7.3 Hz, 2H), 7.37 (s, 1H), 7.61 (s, 2H), 7.73 (d, J = 7.7 Hz, 2H), 9.31 (s, 1H), 11.82 (s, 1H); ^{13}C NMR (DMSO-d_6; 100 °C) δ 18.8, 19.9, 40.7, 114.6, 119.3, 122.2, 128.1, 128.7, 137.0, 137.1, 137.9, 138.6, 149.8, 151.4, 153.1, 155.2; HRMS (ESI-FT-ICR) calculated for $C_{19}H_{17}N_7O$ $(M + H)^+$ 402.2037, found 402.2027; calculated for $2(C_{19}H_{17}N_7O)$ $(2M + H)^+$ 803.4001, found 803.4088.

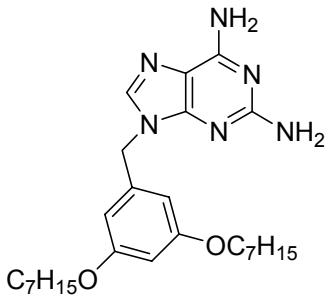


6-Amino-*N*-7-(2,4,6-trimethylbenzyl)-2-*N*-(4-phenylamino)ureidopurine (1a′). Starting material **4a′** (0.052g, 0.22 mmol) was dried under vacuum in a 50 mL two-necked round-bottomed flask fitted with a reflux condenser. CH_2Cl_2 (45 mL) was added and the mixture was heated to reflux until **4a′** was dissolved. The temperature was reduced to 40 °C. Without equilibration of the temperature, pyridine (0.035 mL, 0.44 mmol) was added followed by phenyl isocyanate (0.024 mL, 0.22 mmol). The mixture was stirred 24 h. The solvent was removed under vacuum and the residue was purified by column chromatography on silica gel (2% MeOH/CH_2Cl_2) to yield **1a′** (0.064 g, 72%). Mp 243–246 °C; ^{1}H NMR ($CDCl_3$) δ 2.27 (s, 3H), 2.32 (s, 3H), 4.94 (s, 2H), 5.17 (s, 2H), 6.95 (s, 2H), 7.13 (t, J = 7.1 Hz, 1H), 7.35 (m, 2H), 7.36 (s, 1H), 7.59 (d, J = 7.5, 2H), 7.81 (s, 1H), 11.52 (s, 1H); ^{1}H NMR (DMSO-d_6) δ 2.23 (s, 3H), 2.26 (s, 6H), 5.13 (s, 2H), 6.83 (s, 2H), 6.92 (s, 1H), 7.05 (t, J = 7.0 Hz, 1H), 7.32 (t, J = 7.3 Hz, 2H), 7.38 (s, 1H), 7.75 (d, J = 7.7 Hz, 2H), 9.35 (s, 1H), 11.81 (s, 1H); ^{13}C NMR (DMSO-d_6) δ 19.4, 20.6, 113.1, 119.9, 123.0, 128.6, 128.7, 129.1, 137.4, 137.5, 138.5, 138.9, 150.0, 151.2, 153.1, 158.6.



2-Amino-6-chloro-*N*-9-(3,5-bis-heptyloxybenzyl)purine (3b).

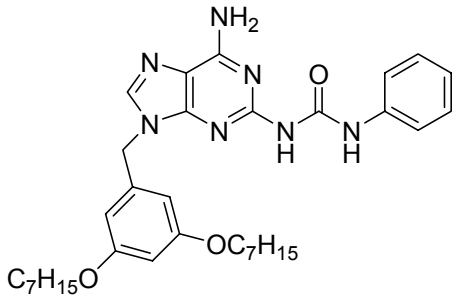
6-Chloro-2-aminopurine[1] **2** (0.175 g, 0.931 mmol), 2-bromomethyl-3,5-bis-heptyloxybenzene[3] (0.464 g, 1.16 mmol), and K_2CO_3 (0.322 g, 2.33 mmol) were placed in an oven-dried round-bottomed flask and dried under argon. Dry DMF (50 mL) was added to the solid mixture and the mixture was stirred overnight at room temperature. The solvent was removed under vacuum and the residue was purified by column chromatography on silica gel (5% MeOH/CH_2Cl_2) to yield a yellow/white powder (0.386 g, 85%). Mp 110–111 °C; ^{1}H NMR ($CDCl_3$) δ 0.86 (t, J = 6.6 Hz, 6H), 1.35 (m, 16H), 1.72 (m, 4H), 3.87 (t, J = 3.9 Hz, 4H), 5.14 (s, 2H), 5.20 (s, 2H), 6.34 (m, 3H), 7.74 (s, 1H); ^{1}H NMR (DMSO-d_6) δ 0.85 (t, J = 6.6 Hz, 6H), 1.32 (m, 16H), 1.64 (m, 4H), 3.88 (t, J = 3.9 Hz, 4H), 5.17 (s, 2H), 6.38 (s, 3H), 6.96 (s, 2H), 8.21 (s, 1H); ^{13}C NMR (DMSO-d_6) δ 13.9, 22.0, 25.4, 28.4, 28.6, 31.2, 38.7, 46.1, 67.4, 99.8, 105.7, 123.2, 138.7, 143.15, 149.43, 154.0, 159.9, 160.0; HRMS (ESI-FT-ICR) calculated for $C_{26}H_{40}N_6O_2$ $(M + H)^+$ 488.2787, found 488.2790.



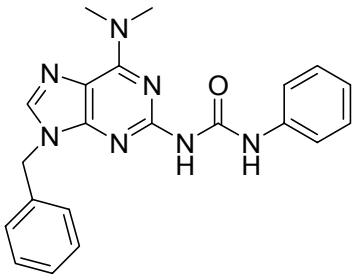
2,6-Diamino-*N*-9-(3,5-bis-heptyloxybenzyl)purine (4b).

Vacuum dried starting material **3b** (0.323 g, 0.717 mmol) was placed in a 100 mL pressure tube. Methanolic ammonia (60 mL, 7 N) was added to the solid followed by heating under pressure to 90 °C for 19 h. The solvent was removed under vacuum and the residue was purified by column chromatography on silica gel (5% MeOH/CH_2Cl_2) to yield **4b** (0.231 g, 69%) as a white powder. Mp 151–152 °C; ^{1}H NMR ($CDCl_3$) δ 0.85 (t,

J = 6.6 Hz, 6H), 1.34 (m, 16H), 1.70 (m, 4H), 3.84 (t, *J* = 3.9 Hz, 4H), 4.88 (bs, 2H), 5.067 (s, 2H), 5.68 (bs, 2H), 6.33 (m, 3H), 7.44 (s, 1H); ^{1}H NMR (DMSO-d_6) δ 0.85 (t, *J* = 6.6 Hz, 6H), 1.30 (m, 16H), 1.64 (m, 4H), 3.87 (t, *J* = 3.9 Hz, 4H), 5.06 (s, 2H), 6.34 (s, 2H), 6.66 (s, 2H), 7.75 (s, 1H); ^{13}C NMR ($CDCl_3$) δ 14.3, 22.8, 26.2, 29.2, 29.4, 32.0, 46.9, 68.3, 100.8, 106.3, 114.4, 138.2, 152.4, 156.1, 160.2, 160.9; HRMS (ESI-FT-ICR) calculated for $C_{26}H_{40}N_6O_2$ $(M + H)^+$ 469.3286, found 469.3285.



6-Amino-*N*-9-(3,5-bis-heptyloxybenzyl)-2-*N*-(4-phenylamino)ureidopurine (1b). Compound **4b** (0.055 g, 0.12 mmol) was placed in an oven-dried round-bottomed flask and dried under vacuum. Methylene chloride (6 mL), pyridine (0.012 mL, 0.015 mmol), and phenyl isocyanate (0.017 mL, 0.015 mmol) were added sequentially. The mixture was stirred at room temperature for 19 h. Solvent was removed under vacuum. Purification of the residue was performed by column chromatography on silica gel (1% MeOH/CH_2Cl_2) to afford **1b** (0.050 g, 73%). Mp 217–220 °C; ^{1}H NMR ($CDCl_3$) 0.86 (t, *J* = 6.6 Hz, 6H), 1.26 (m, 16H), 1.69 (m, 4H), 3.80 (t, *J* = 3.9 Hz, 4H), 5.23 (s, 2H), 6.33 (m, 1H), 6.37 (m, 2H), 7.05 (t, *J* = 7.0 Hz, 1H), 7.27 (t, *J* = 7.3, 3H), 7.37 (d, *J* = 7.4 Hz 3H), 7.65 (s, 1H), 9.41 (s, 1H), 11.84 (s, 1H); ^{1}H NMR (DMSO-d_6) δ 0.83 (t, *J* = 6.6 Hz, 6H), 1.22 (m, 16H), 1.59 (m, 4H), 3.82 (t, *J* = 3.8 Hz, 4H), 5.25 (s, 2H), 6.35 (s, 1H), 6.41 (s, 2H), 7.00 (t, *J* = 7.0 Hz, 1H), 7.26 (t, *J* = 7.2 Hz, 2H), 7.58 (d, *J* = 7.6 Hz, 2H), 7.61 (s, 1H), 8.11 (s, 1H), 9.30 (s, 1H), 11.75 (s, 1H); ^{13}C NMR (DMSO-d_6; 100 °C) δ 13.3, 21.5, 25.0, 27.9, 28.2, 28.5, 30.7, 46.0, 67.4, 100.4, 105.7, 114.8, 119.2, 122.2, 128.2, 138.7, 139.7, 149.5, 151.4, 153.4, 155.5, 159.9; HRMS (ESI-FT-ICR) calculated for $C_{33}H_{45}N_7O_3$ $(M + H)^+$ 588.3657, found 588.3678; calculated for $2(C_{33}H_{45}N_7O_3)$ $(2M + H)^+$ 1175.7241, found 1175.7484.

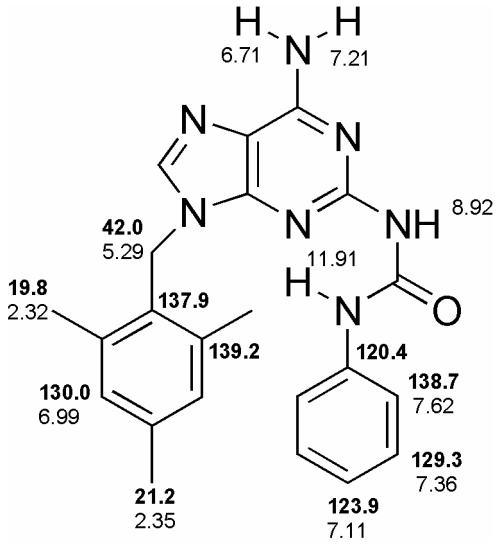


***N*-9-benzyl-6-dimethylamino-2-*N*-(4-phenylamino)ureidopurine (5).**
Phenyl isocyanate (0.65 mL, 6.0 mmol) was added dropwise to 2-amino-6-dimethylamino-9-benzyl purine[4] (0.10 g, 0.37 mmol) dissolved in dry pyridine (7.5 mL). After stirring at room temperature for 1 h the crude reaction mixture was concentrated under reduced pressure and the crude solid was recrystallized with ethanol to give a white solid (0.137 g, 94%). Mp 234–236 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 3.56 (bs, 6H), 5.31 (s, 2H), 7.16 (s, 1H), 7.33 (m, 10H), 7.61 (s, 1H) 11.39 (s, 1H); ^{1}H NMR (300 MHz, DMSO-d_6) δ 3.62 (bs, 6H), 5.40 (s, 2H), 7.28 (m, 10H), 8.13 (s, 1H), 9.41 (1.37, 1H), 11.45 (s, 1H); ^{13}C NMR (75 MHz, DMSO-d_6) δ 46.1, 60.0, 115.46, 119.17, 122.7, 126.8, 126.9, 127.6, 128.7, 128.8, 136.8, 138.7, 138.9, 151.8, 153.0, 154.1. HRMS (ESI-FT-ICR) calculated for $C_{21}H_{22}N_7O$ $(M + H)^+$ 388.1886, found 388.1921.

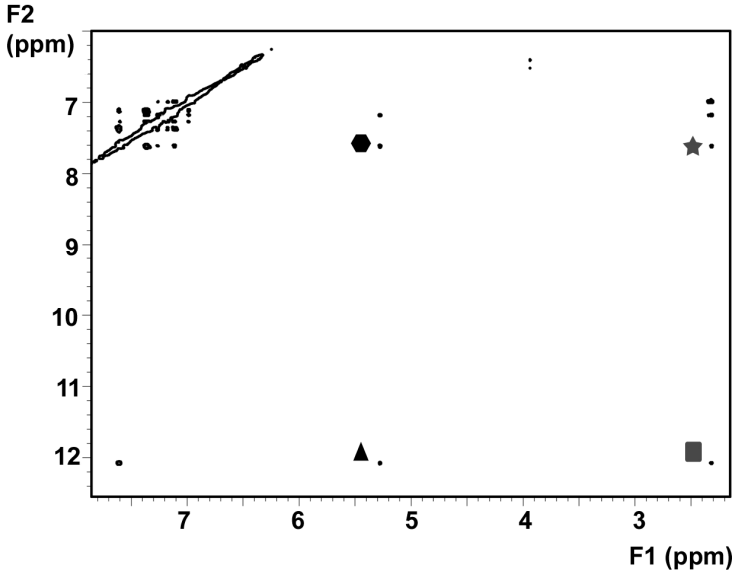
II. Structural Details by NMR, Computation, and X-ray Analysis.

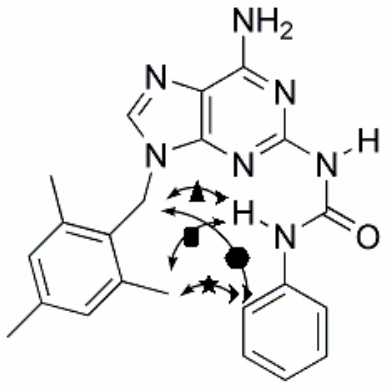
A. Analysis of Dimers 1a and 1b by NMR. NMR spectra were recorded at 25 °C on a Varian Inova spectrometer equipped with a 5 mm indirect detection probe, operating at 500 MHz for ^{1}H and at 125 MHz for ^{13}C. Chemical shifts are reported in ppm relative to TMS.

1. gHMBC Results. The gHMBC spectrum was recorded with the standard pulse sequence in vnmr, in 512 increments, each acquired in 16 transients. The number of points in the FIDs was 4k, and the same number was used for the spectrum in f2. The number of points for the spectrum in f1 was 2k. The preacquisition delay was 0.5 s. The 8 Hz. Spectrum was taken in $CDCl_3$ at an approximate concentration of 2 mM. All shifts are reported in ppm downfield of TMS, and ^{13}C shifts are listed in bold.



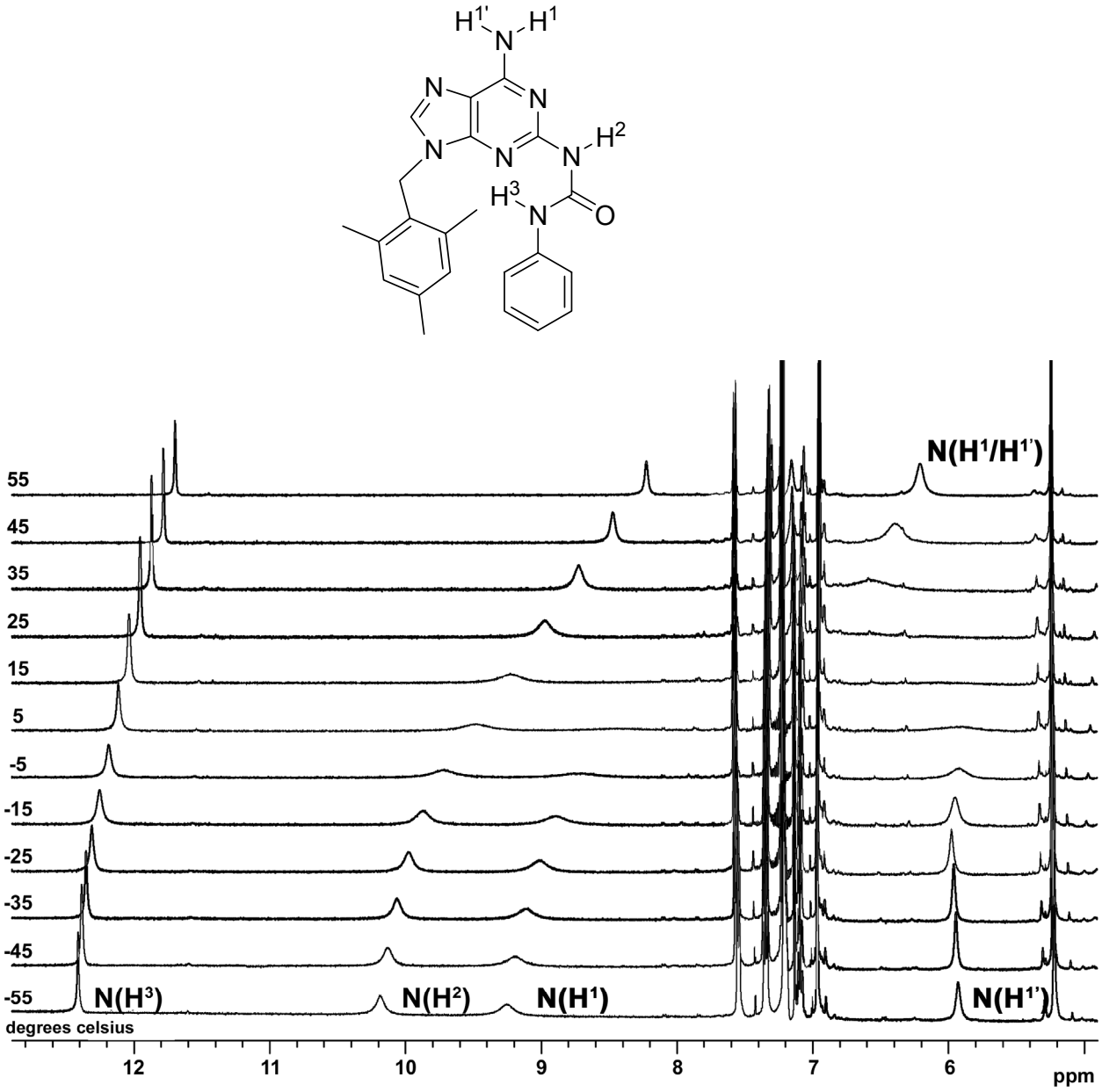
2. NOESY Spectrum. The NOESY spectrum was recorded at 25 °C with the standard pulse sequence in vnmr, in 2k increments, each acquired in 32 transients. The number of points in the FIDs was 4k, and the same number was used for the spectrum, in both f1 and f2. The preacquisition delay was 1 s and the mixing time 0.5 s. Spectrum was obtained in $CDCl_3$ at an approximate concentration of 2 mM.





3. Variable Temperature ^{1}H NMR Spectra. The variable temperature spectrum was recorded on a sample in $CDCl_3$ (~ 4 mM), on automation, arraying the temperature from -55 ºC to 55 ºC in steps of 10 ºC. For each change in temperature, a delay of 300 s allowed

for the temperature equilibration, followed by shimming z1-z2 on the lock level, then acquisition in 128 transients with an acquisition time of 5 s.

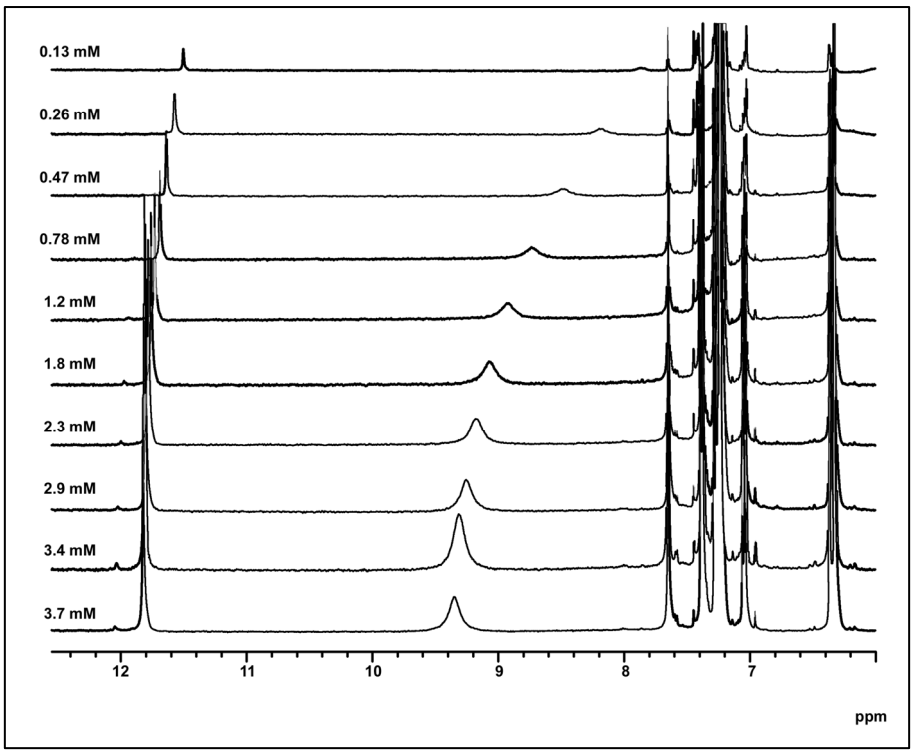


4. Dilution Studies

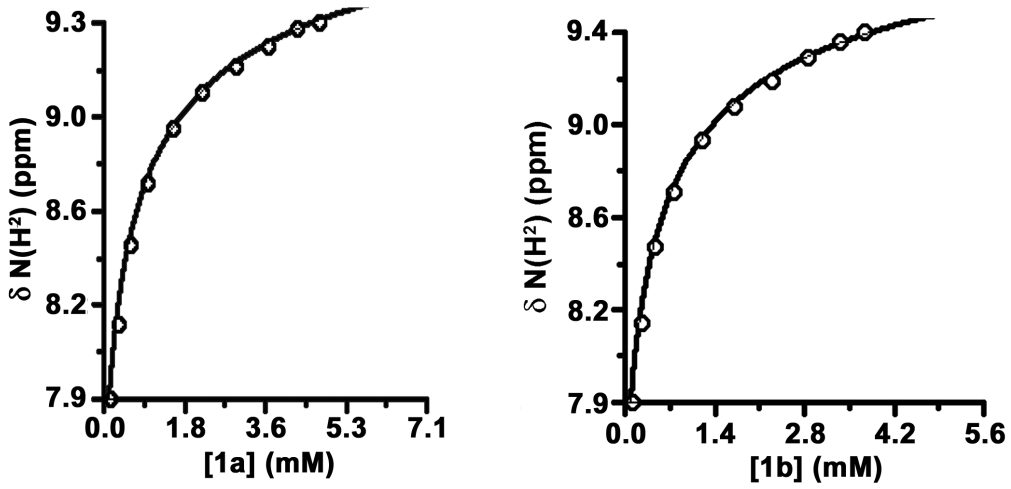
a. Experimental Protocol. Stock solutions were made by transferring the purified urea compound, dissolved in methylene chloride, to 10 mL screw-capped volumetric flasks. The solvent was removed under vacuum. The residue was dried overnight, and placed in a dessicator until addition of $CDCl_3$. Deuterated chloroform was placed over activated

molecular sieves to sit overnight. Before use it was then decanted onto fresh activated molecular sieves and stored under argon. Dilutions of the stock solution were made at 1 mL volumes sequentially. The dilutions were monitored by ^{1}H NMR (Inova 500).

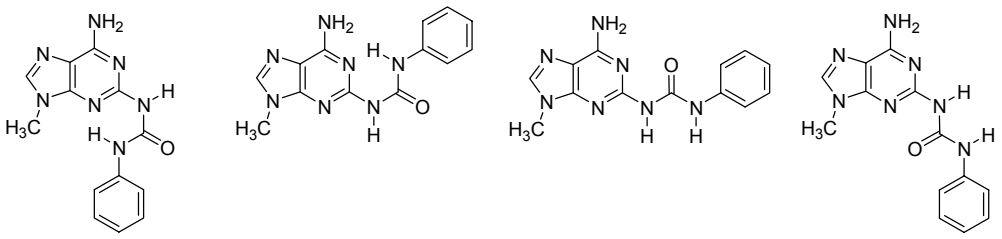
b. Representative Stacked Dilution Spectra for 1b.



c. Representative Curve Fitting for 1a and 1b. Plots of the chemical shift of N(H^2) versus concentration were fit to a non-linear binding equation using *Associate 1.6*.[5] Two representative curve fits, one from **1a** and the other from **1b**, are shown below. The fit for **1a** corresponds to the following calculated parameters: K_{dim} = 1180 ± 170 M^{-1}; δ_{dimer} = 10.1 ± 0.05 ppm; $\delta_{monomer}$ = 7.2 ± 0.1 ppm. The fit for **1b** corresponds to the following calculated parameters: K_{dim} = 1520 ± 270 M^{-1}; δ_{dimer} = 10.1 ± 0.05 ppm; $\delta_{monomer}$ = 7.2 ± 0.1 ppm. All data points for all runs fall within the 20–80% saturation range.



B. Computational Details.



1^{N3} **1^{N1}** **syn_1** **syn_2**

	relative energies (kcal mol^{-1})			
Amber*	0	–0.19	5.0	4.5
MM3*	0	0.06	5.7	5.5
HF/3-21G*	0	0.75	–	–
HF/6-31G*	0	0.50	–	–
MP2/6-31G*// HF/6-31G*	0	0.55	–	–

Monte Carlo conformational searching was done on a Dell PC (2.4 GHz) running the Fedora Core using MacroModel *v*. 9.0 (Schrodinger, LLC)[6] and the MCMM method (relevant parameters include: steps = 100, iterations = 2000, solvent (GB/SA) = $CHCl_3$, force field = Amber*). The two low-energy *anti* conformers (**1^{N3}** and **1^{N1}**) were identified as well as the two lowest energy *syn* conformers (with respect to the urea) for the N(9) methyl derivative shown above. The energies of the conformers are given at various levels of theory. Only **1^{N3}** and **1^{N1}** were further refined using ab initio methods (using Gaussian 03 (revision D.01)[7]) as implemented through the National Center for

Supercomputing Applications, SGI Altix cluster "Cobalt" (http://www.ncsa.uiuc.edu/UserInfo/Resources/Hardware/SGIAltix/).

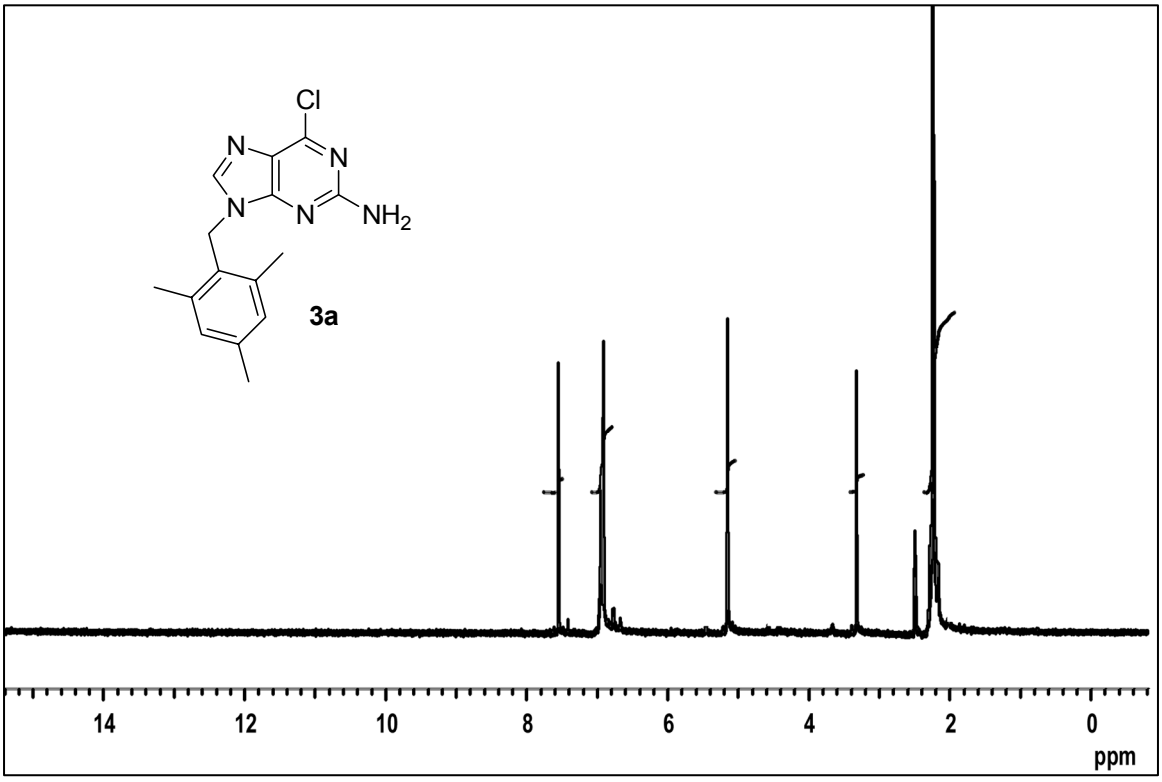
C. X-ray Crystallographic Analysis of 5.

Data were collected at 173 K on a Siemens SMART PLATFORM equipped with A CCD area detector and a graphite monochromator utilizing MoK_α radiation (λ = 0.71073 Å). Cell parameters were refined using up to 8192 reflections. A full sphere of data (1850 frames) was collected using the ω-scan method (0.3° frame width). The first 50 frames were re-measured at the end of data collection to monitor instrument and crystal stability (maximum correction on I was < 1 %). Absorption corrections by integration were applied based on measured indexed crystal faces.

The structure was solved by the Direct Methods in *SHELXTL6,* and refined using full-matrix least squares. The non-H atoms were treated anisotropically, whereas the hydrogen atoms were calculated in ideal positions and were riding on their respective carbon atoms. A total of 272 parameters were refined in the final cycle of refinement using 3194 reflections with $I > 2\sigma(I)$ to yield R_1 and wR_2 of 3.74% and 9.66%, respectively. Refinement was done using F^2. The structure has been deposited with the Cambridge Crystallographic Data Centre as CCDC 615504.

III. ^{1}H NMR Spectra for 1 and 3–5.

All proton spectra for precursors to the ureidopurines are shown in DMSO unless otherwise specified. For the urea compounds, $CDCl_3$ spectra are also included.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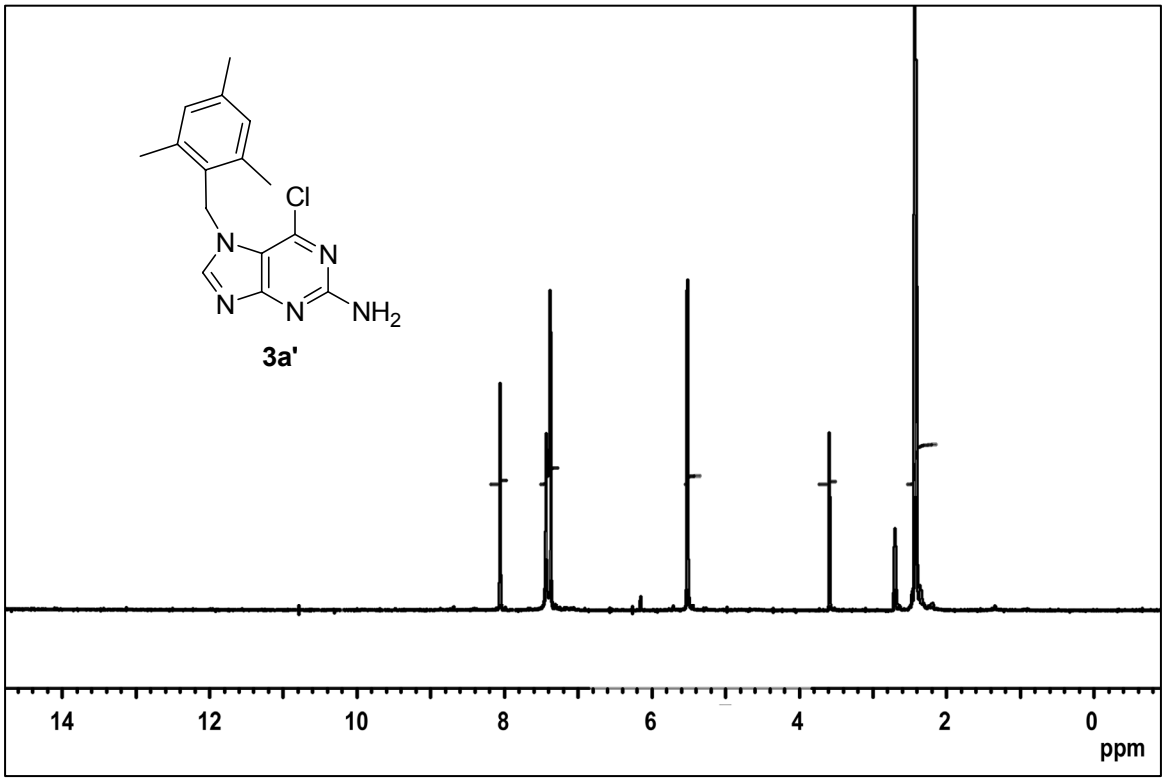
N
N
N
N
NH2
3a
14
12
10
8
6
4
2
0
ppm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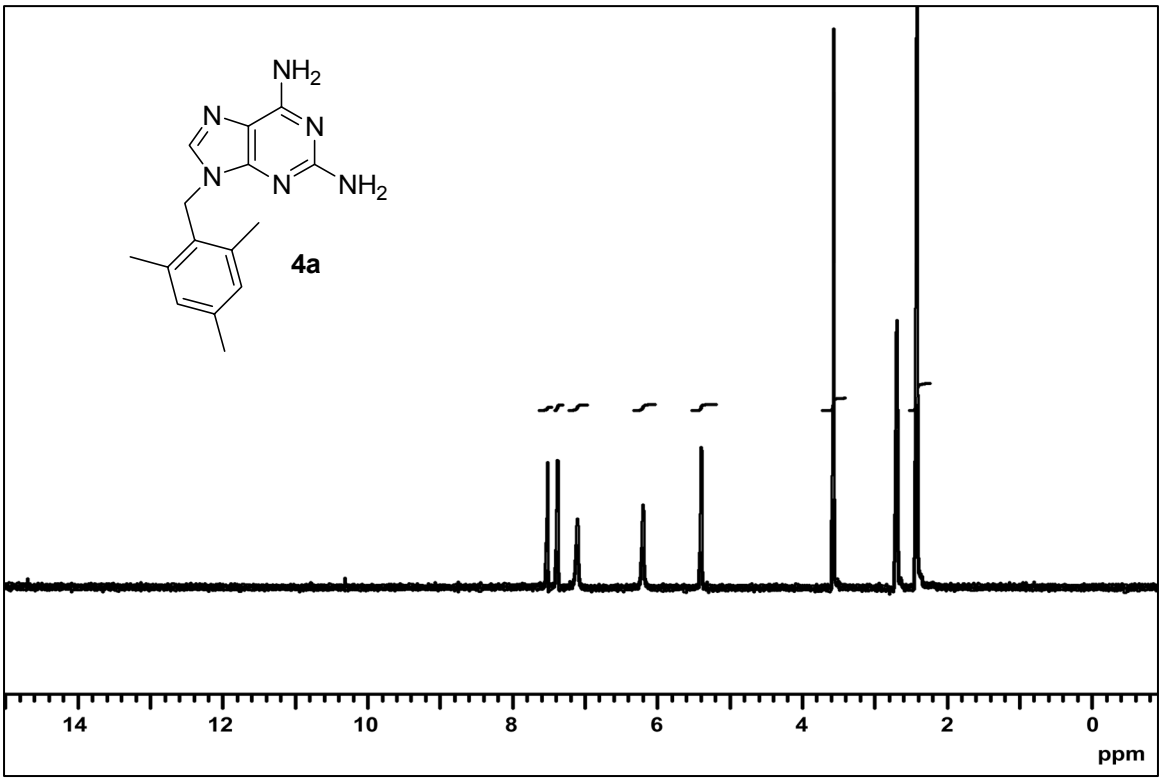
N
N
N
N
NH2
3a'
14
12
10
8
6
4
2
0
ppm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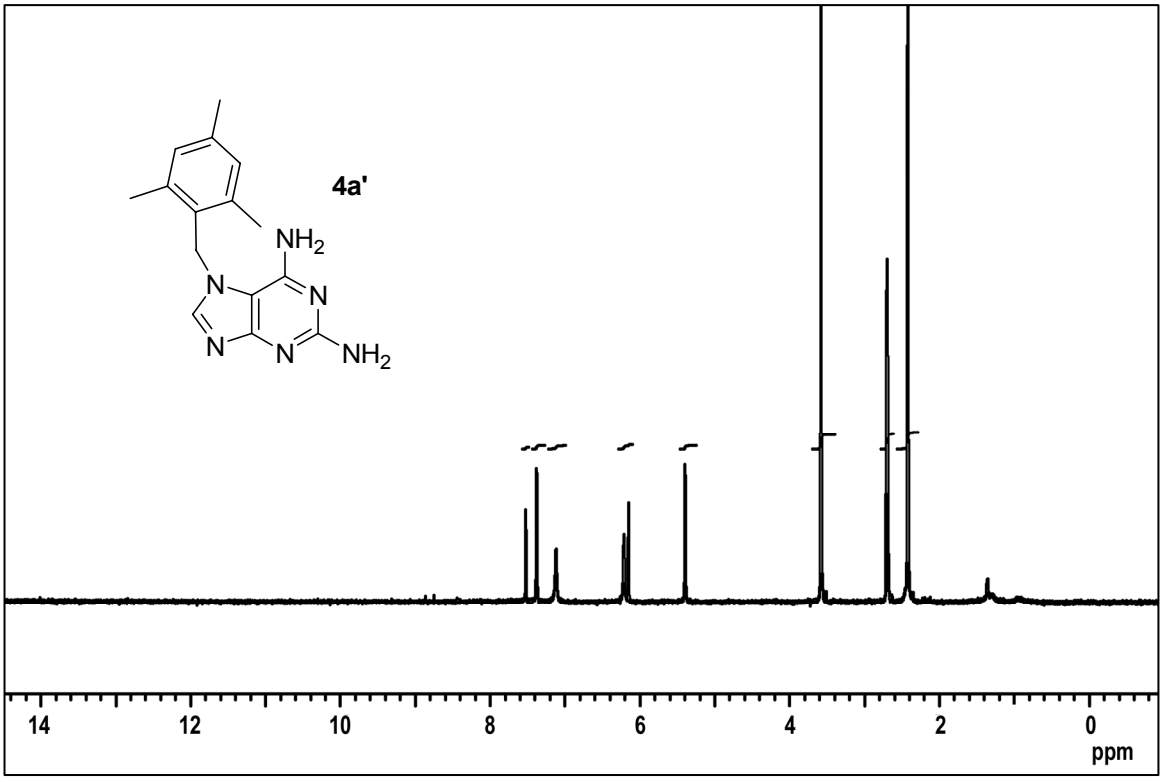
N
N
N
N
NH2
4a
14
12
10
8
6
4
2
0
ppm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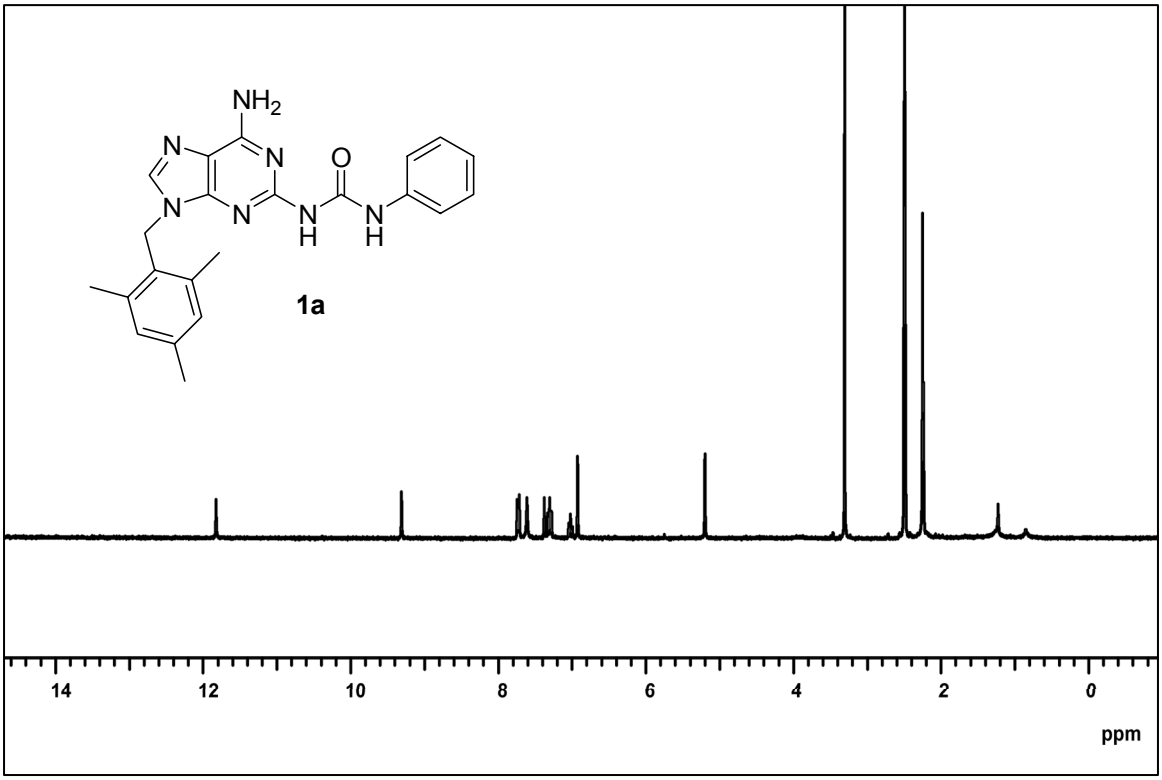
N
N
N
NH2
14
12
10
8
6
4
2
0
ppm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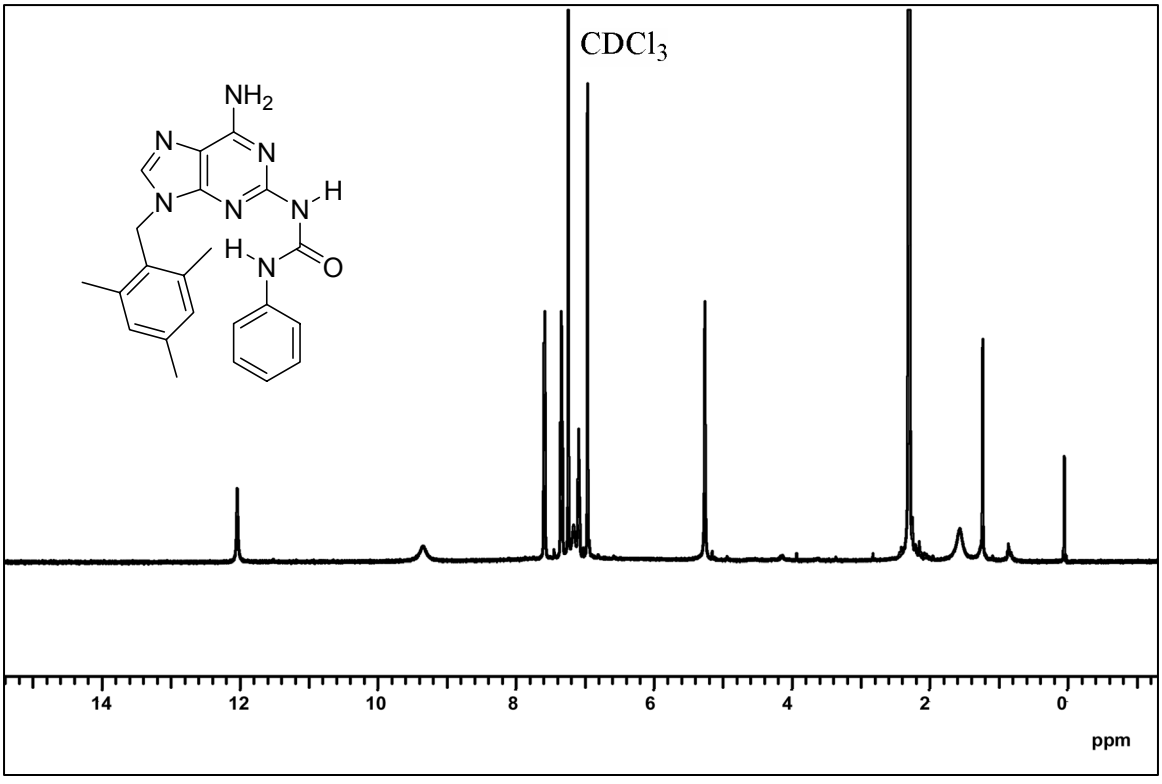
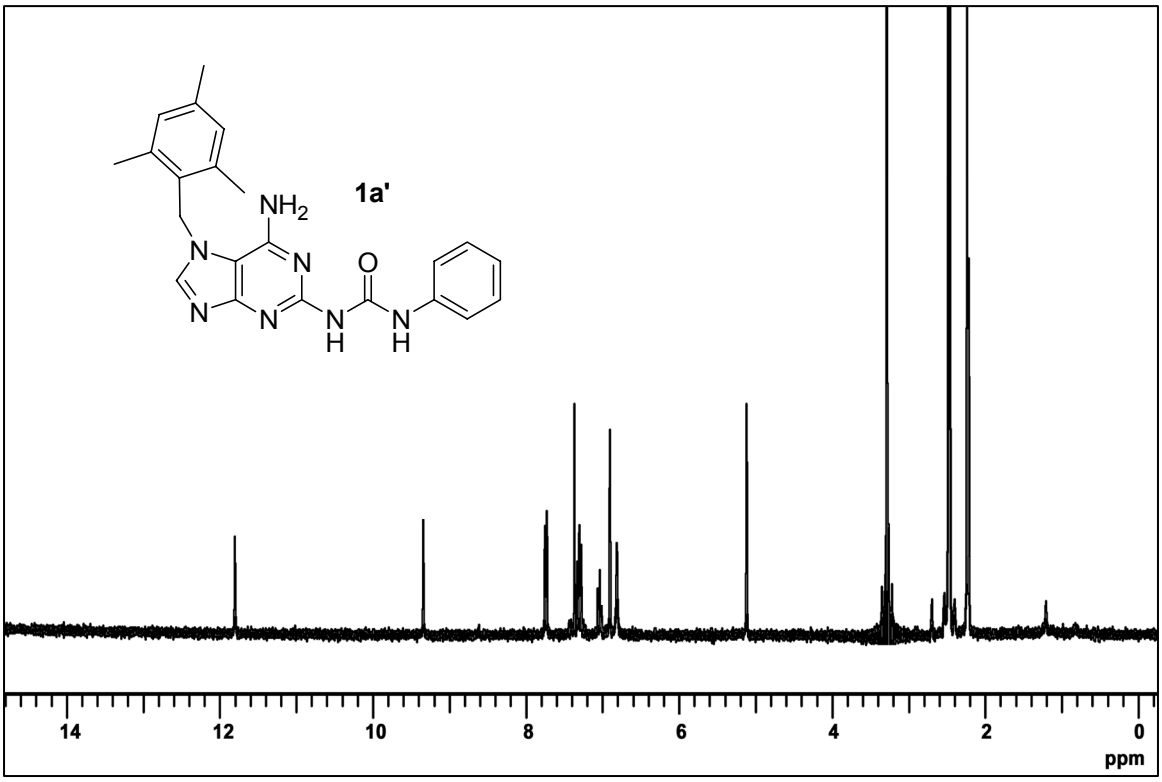
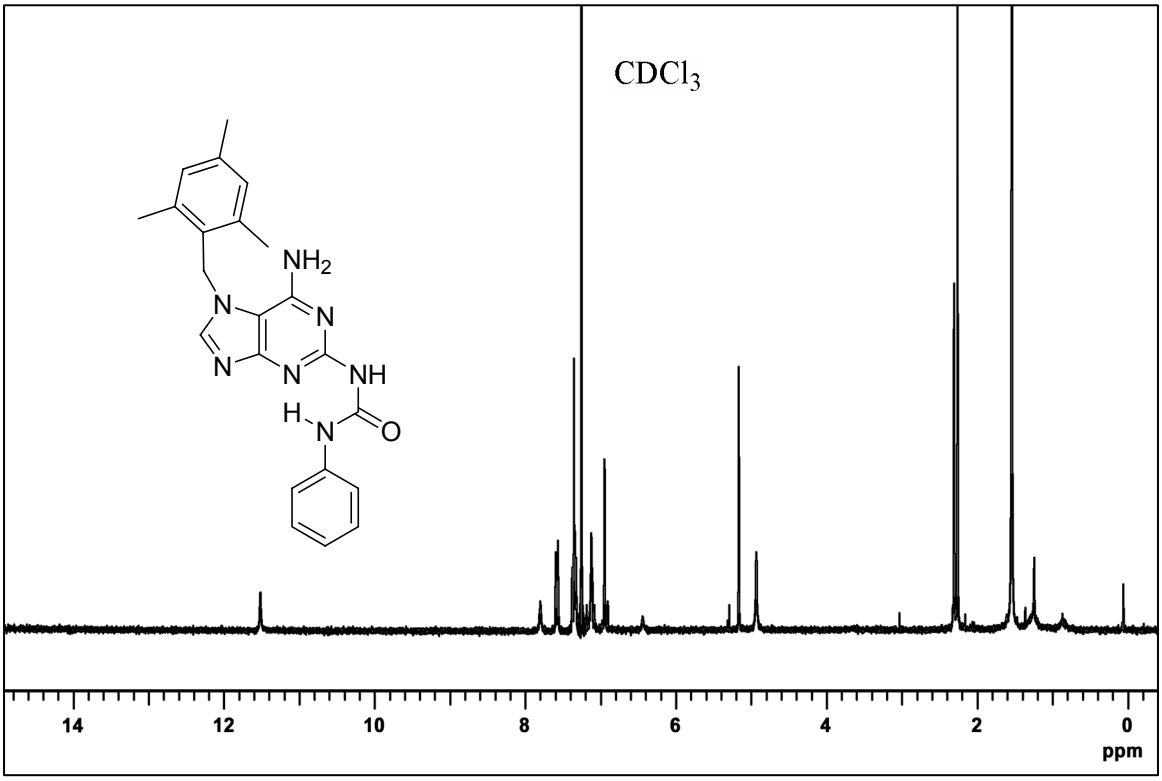
N
O
N
N
N
N
H
H
1a
14
12
10
8
6
4
2
0
ppm


CDCl3
NH2
N
N
N
N
N
H
H
N
O
14
12
10
8
6
4
2
0
ppm


1a'
NH2
N
N
N
N
N
O
N
H
N
H
14
12
10
8
6
4
2
0
ppm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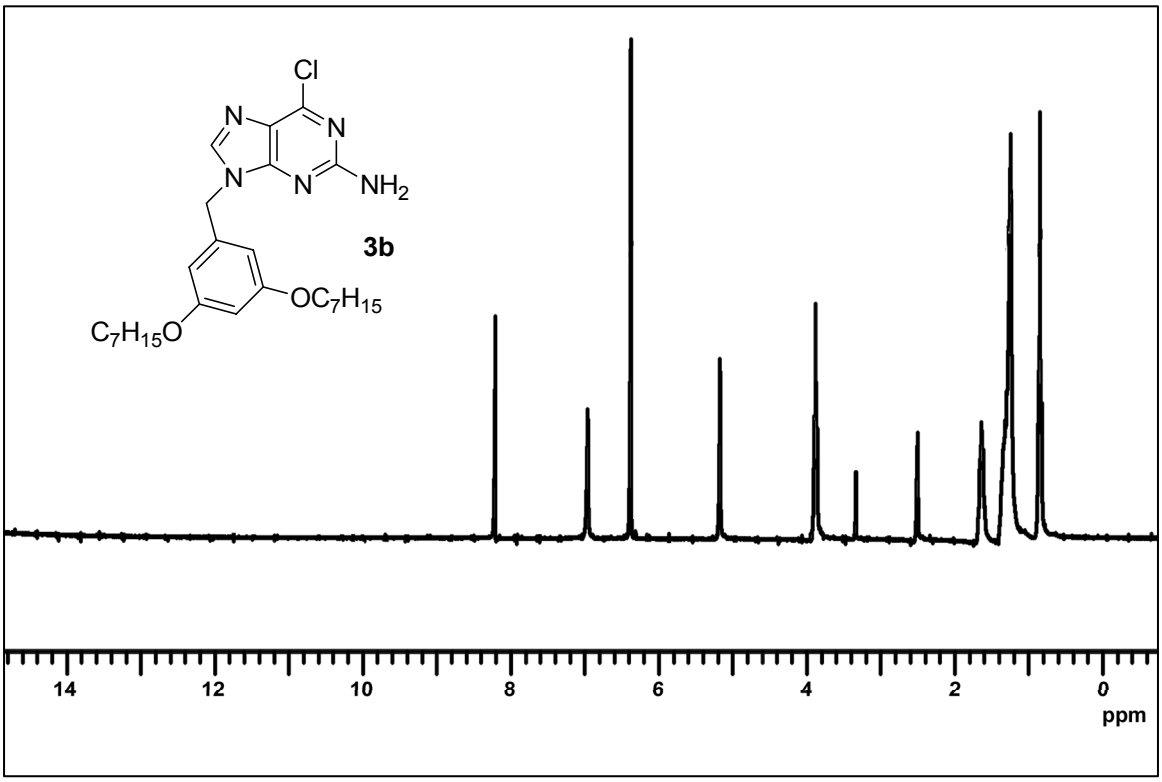
N
N
N
NH
H
N
O
14
12
10
8
6
4
2
0
ppm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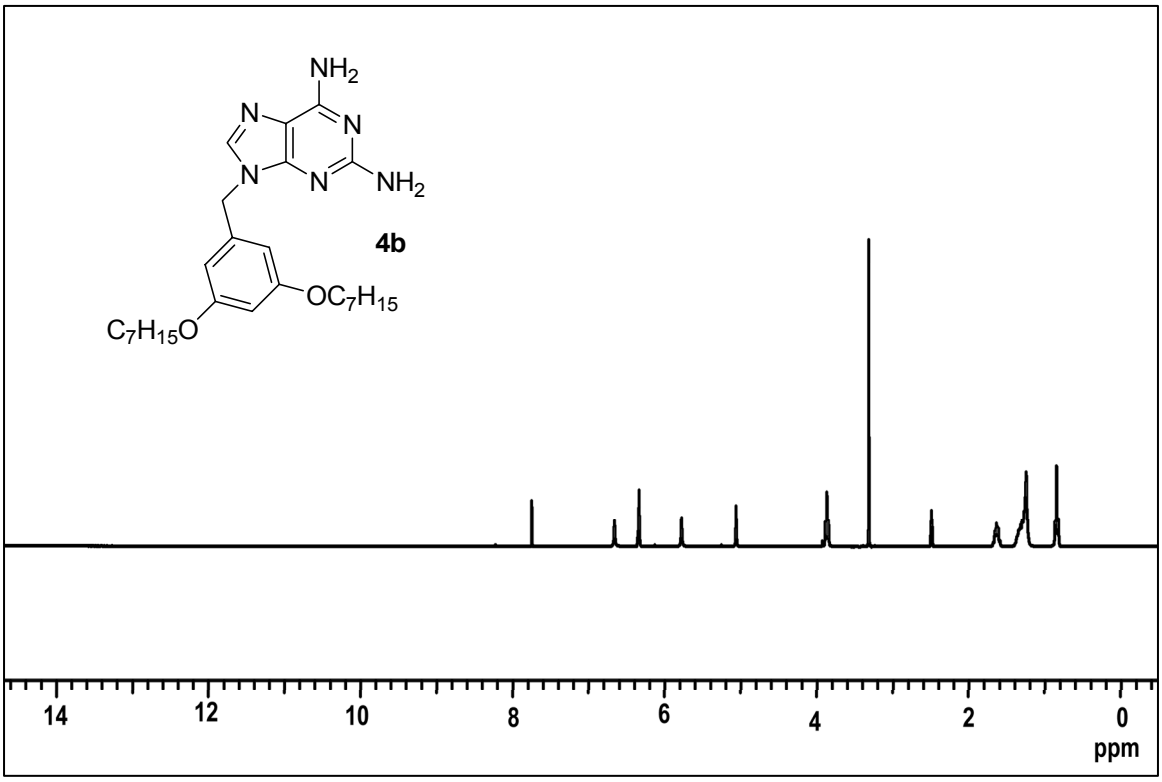
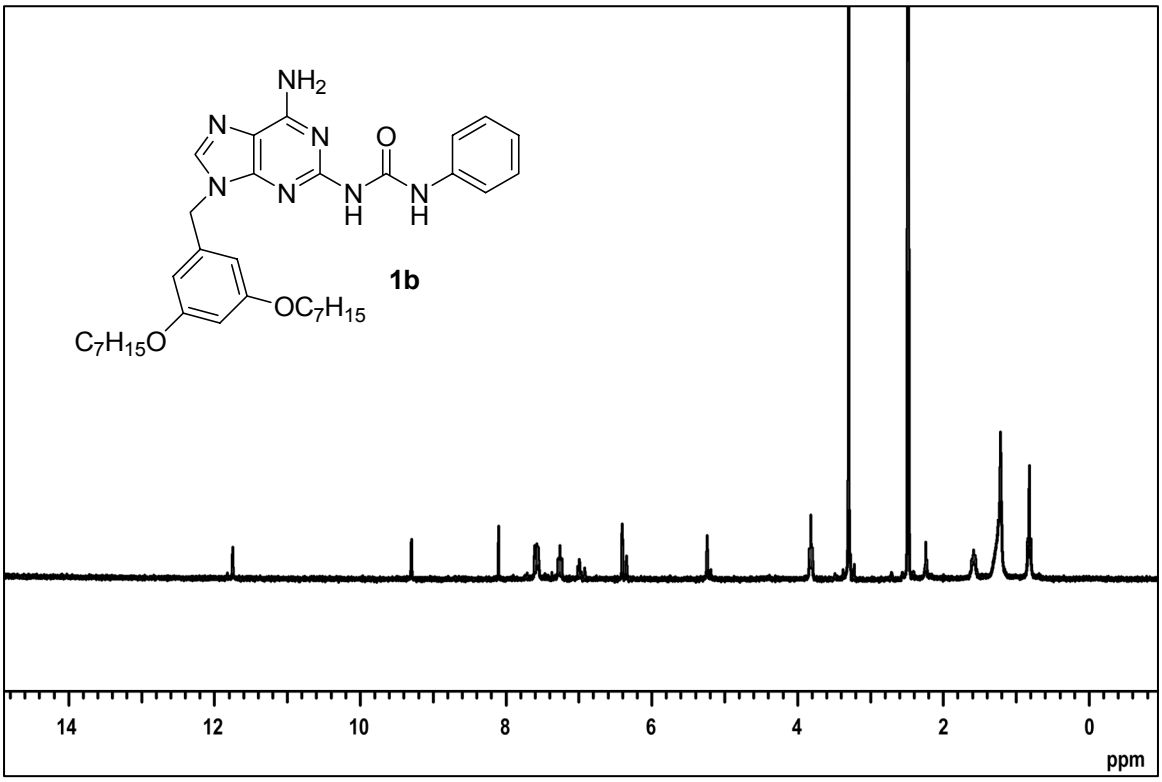
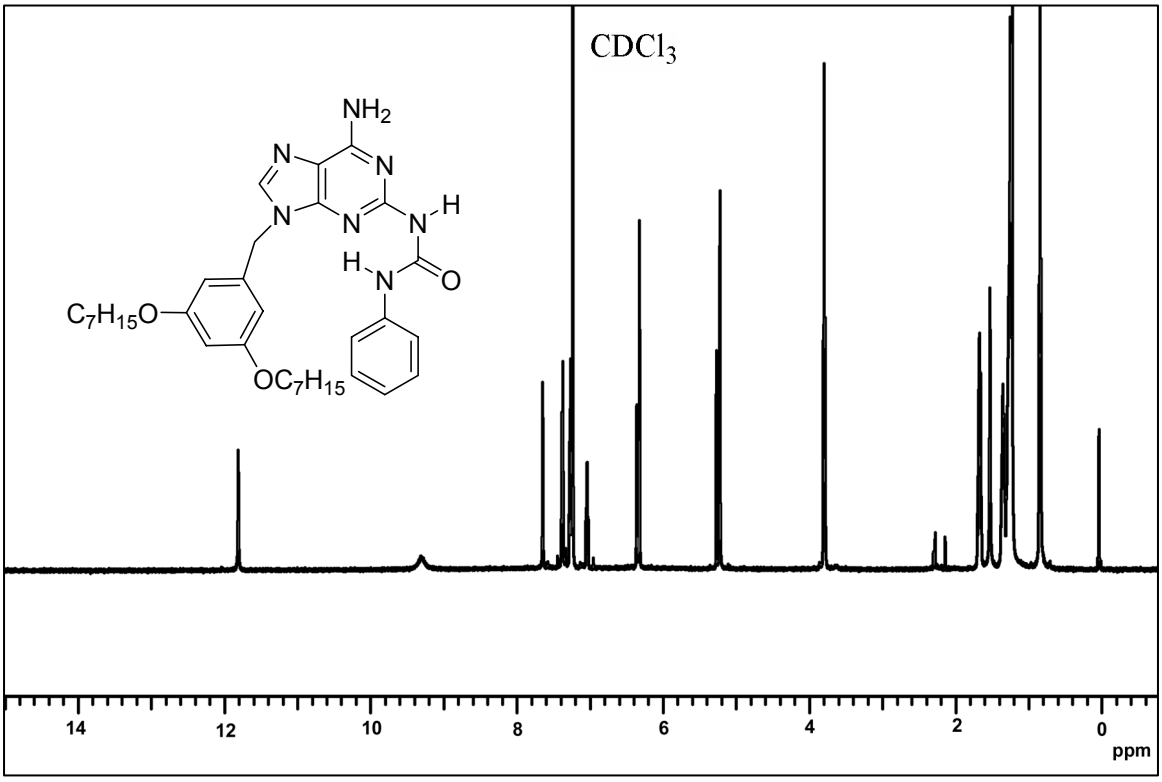
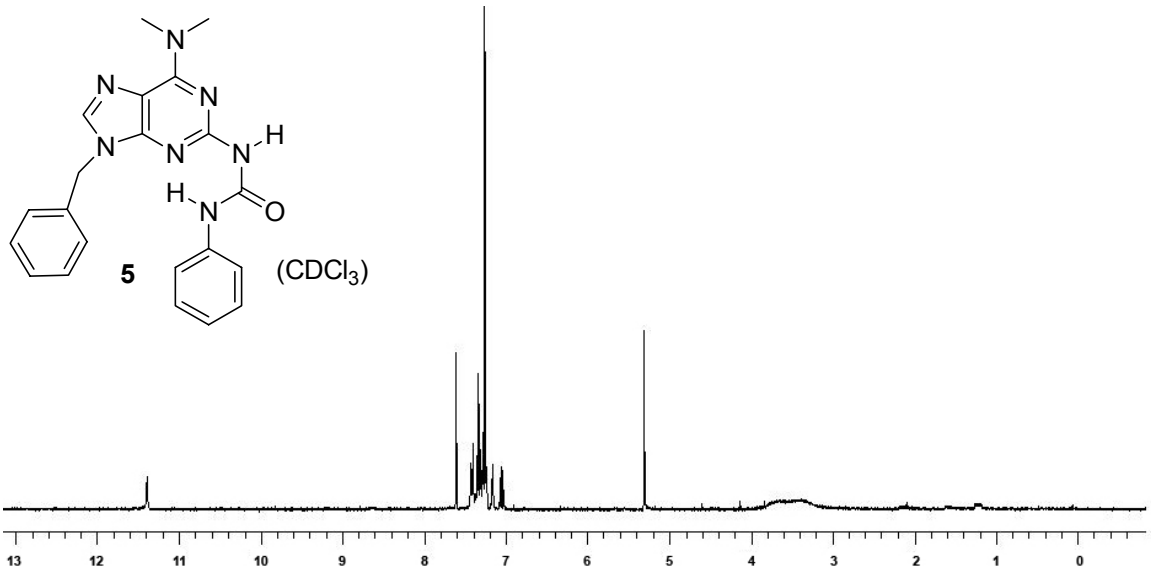
N
N
N
NH2
3b
OC7H15
C7H15O
14
12
10
8
6
4
2
0
ppm


NH2
N
N
N
N
NH2
4b
OC7H15
C7H15O
14
12
10
8
6
4
2
0
ppm


NH2
N
N
N
N
O
N
H
N
H
1b
OC7H15
C7H15O
14
12
10
8
6
4
2
0
ppm


CDCl3
NH2
N
N
N
N
H
N
H
N
O
C7H15O
OC7H15
14
12
10
8
6
4
2
0
ppm



[1] Eur. Pat., EP 543095, 1993.
[2] C. D. Shacklett and H. A. Smith, *J. Am. Chem. Soc.*, 1953, **75**, 2654.
[3] S. V. Aathimanikandan, B. S. Sandanaraj, C. G. Arges, C. J. Bardeen, and S. Thayumanavan, *Org. Lett.* 2005, **7**, 2809.
[4] Synthetic details will be published elsewhere.
[5] B. R. Peterson, *Associate 1.6*, Ph.D. thesis, University of California, Los Angeles, 1994.
[6] F. Mohamadi, N. G. Richards, W. C. Guida, R. Liskamp, M. Lipton, C. Caufield, G. Chang, T. Hendrickson, and W. C. Still, *J. Comput. Chem.* 1990, **11**, 440.
[7] M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, J. A. Montgomery, Jr., T. Vreven, K. N. Kudin, J. C. Burant, J. M. Millam, S. S. Iyengar, J. Tomasi, V. Barone, B. Mennucci, M. Cossi, G. Scalmani, N. Rega, G. A. Petersson, H. Nakatsuji, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, M. Klene, X. Li, J. E. Knox, H. P. Hratchian, J. B. Cross, V. Bakken, C. Adamo, J. Jaramillo, R. Gomperts, R. E. Stratmann, O. Yazyev, A. J. Austin, R. Cammi, C. Pomelli, J. W. Ochterski, P. Y. Ayala, K. Morokuma, G. A. Voth, P. Salvador, J. J. Dannenberg, V. G. Zakrzewski, S. Dapprich, A. D. Daniels, M. C. Strain, O. Farkas, D. K. Malick, A. D. Rabuck, K. Raghavachari, J. B. Foresman, J. V. Ortiz, Q. Cui, A. G. Baboul, S. Clifford, J. Cioslowski, B. B. Stefanov, G. Liu, A. Liashenko, P. Piskorz, I. Komaromi, R. L. Martin, D. J. Fox, T. Keith, M. A. Al-Laham, C. Y. Peng, A. Nanayakkara, M. Challacombe, P. M. W. Gill, B. Johnson, W. Chen, M. W. Wong, C. Gonzalez, and J. A. Pople, Gaussian, Inc., Wallingford CT, 2004