

Synthesis of 3-substituted pyridinium salts

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Abstract

A novel class of 3-substituted pyridinium salts have been synthesised in high yield by a convenient two-step procedure. A new synthetic pathway to 1-substituted benzimidazolium salts has been developed and the effects of the anionic component of the salts have been studied.

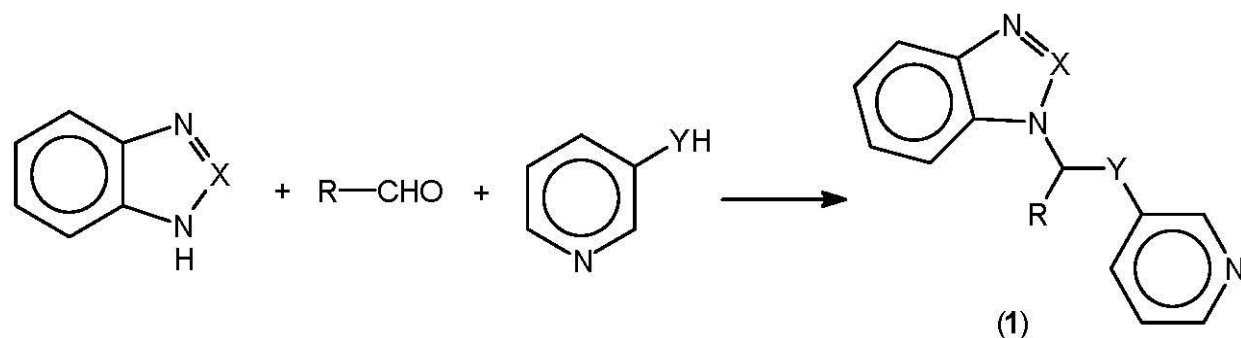
Keywords: Alkylations, Mannich bases, condensations, pyridinium salts, benzimidazolium salts

Introduction

Compounds containing a pyridinium moiety attached to a heterocyclic system are important in natural product chemistry¹ and in organic synthesis^{2, 3}. Pyridinium salts have found use as acylating agents⁴, phase transfer catalysts⁵, biocides with a wide range of antimicrobial activity⁶, dyes⁷ and cationic surfactants. The 1-alkylpyridinium salts, which are liquid at rt., so-called ionic liquids, are potential new solvents for synthesis and catalysis⁸. Several synthetic routes to pyridinium salts are known, but the most commonly used method is the Menshutkin reaction, the SN2 reaction of a pyridine derivative with an organic halide. Chloromethylalkyl ethers or sulphides are also reagents for the quaternization of the pyridine nitrogen. In these cases the reactions proceed via the SN1 mechanism⁹⁻¹¹.

The present paper reports on a general and convenient route for the preparation of 3-substituted pyridinium salts such as shown in Figure 1 by utilization of N-Mannich bases as starting materials.

The *N*-(1*H*-benzimidazolalkyl)-3-pyridinecarboxamides (**1a** and **1b**) are new compounds which were obtained in a one-pot condensation reaction of benzimidazole-aldehyde-nicotinamide (Scheme 1).



Scheme 1

The chemotypes which have been prepared along with reaction times, yields and melting points are tabulated in Table 1.

The limitation of this procedure is that only two aldehydes, formaldehyde and benzaldehyde undergo reaction with benzimidazole and nicotinamide.

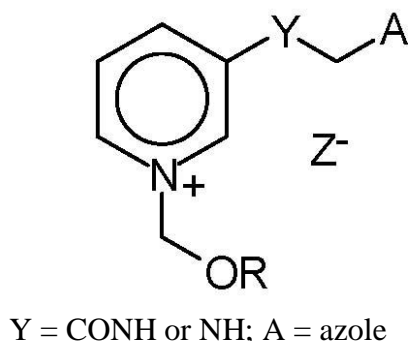


Figure 1

The compounds were characterised by their ¹H and ¹³C NMR spectra and by elemental analyses. The NH proton for **1a** resonated at $\delta = 9.93 - 9.89$ as a triplet with a coupling constant in the range 5.6 Hz. The methine protons appeared in the spectrum as a doublet at $\delta = 5.83 - 5.81$ ($J = 6$ Hz). The chemical shift of the carbonyl carbon appeared at $\delta = 165.3$. As expected, the absorption peak for the characteristic α carbon between the benzimidazole ring and the amide fall in the region of $\delta = 53 - 48$. Analogue **1c** was prepared by treatment of 3-aminopyridine with formaldehyde and benzimidazole.

Table 1. Condensation Products 1

| Product | R | X | Y | Time(h) | Yield(%) | m.p. ^a (°C) |
|---------|---|---|---|---------|----------|------------------------|
|---------|---|---|---|---------|----------|------------------------|

| | | | | | | |
|----|-------------------------------|----|------|----|-----------------|----------------------|
| 1a | H | CH | CONH | 48 | 90 | 218-220 |
| 1b | C ₆ H ₅ | CH | CONH | 48 | 45 | 230-232 |
| 1c | H | CH | NH | 5 | 80 ^b | 160-162 ^c |
| 1d | H | N | CONH | 48 | 86 | 177-178 ^d |
| 1e | C ₆ H ₅ | N | CONH | 48 | 75 | 184-186 ^e |
| 1f | H | N | NH | 5 | 80 ^b | 153-154 ^f |

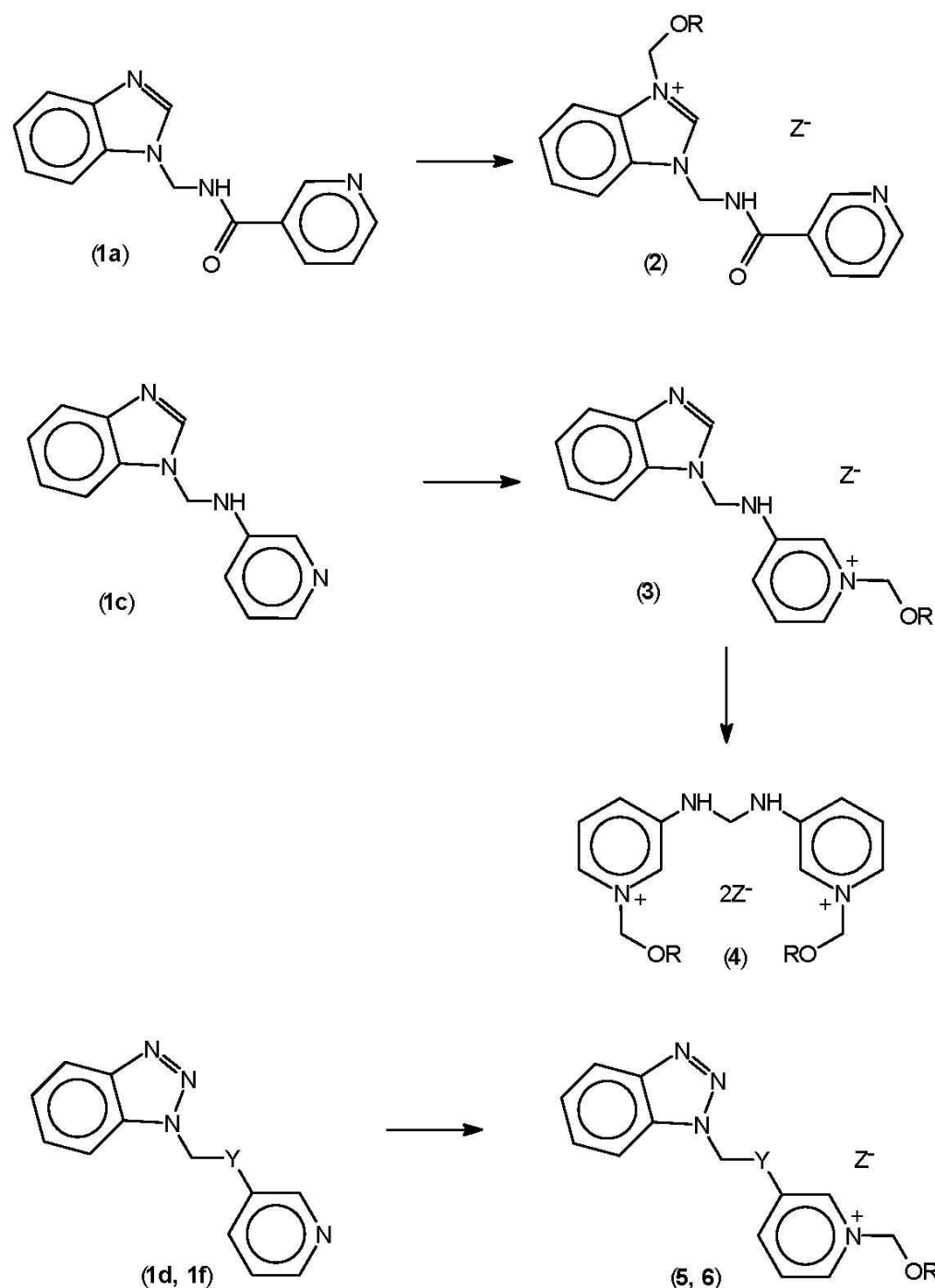
^a Solvent for recrystallization: MeOH (**1a**, **b**), EtOH/H₂O (**1c-f**), ^b The same yield in microwave reactor (time 10 min., 200°C, 850W), ^c Lit.¹² m.p. 163-164°C, ^d Lit.¹³ m.p. 177-178°C, ^e Now is available in Aldrich, ^f Lit.¹² m.p. 150-151°C

The N-Mannich reagents, N-(1 *H*-benzotriazol-1-ylmethyl)-3-pyridinecarboxamide (**1d**) and 3-(benzotriazol-1-ylmethylamino)pyridine (**1f**), were easily prepared by the condensation of benzotriazole-formaldehyde with the appropriate amide or amine^{14,15}. The 3-aminopyridine reacts with formaldehyde and benzotriazole at rt to give monosubstituted product **1f**, previously prepared by the condensation of 3-aminopyridine with 1-(hydroxymethyl)benzotriazole¹⁴.

When the condensed product **1d** was prepared directly from nicotinamide, formaldehyde and benzotriazole, the reaction conditions required were more vigorous due to the lower nucleophilicity of nicotinamide compared to 3-aminopyridine.

Analogue **1e** was prepared from pyridine-3-carboxamide-benzaldehyde-benzotriazole. The reactions of benzotriazole was carried out in high yield with the regioselective formation of the N-1 isomer. In this condensation, azoles other than benzotriazole have been utilized (imidazole¹⁶, triazole¹³).

The quaternization of a N-Mannich bases such as benzimidazoles **1a** and **1c** by chloromethylalkyl ether afforded two products **2** and **3** (Scheme 2).



Scheme 2

The structure of the quaternization product depends on the Y group in compounds 1a and 1c. The strong electron-withdrawing group (CONH) in the 3-position of the pyridine ring deactivates the nitrogen atom in pyridine. Chloromethylalkyl ether quaternarizes the N-3 of 1-substituted benzimidazole giving benzimidazolium chlorides 2 (Table 2). This study has shown that N-3 is

nucleophilic enough to react with electrophiles.

Table 2. 1-Alkoxyethyl-3-[N-methyl-(3-pyridinecarbonyl)] benzimidazolium Salts 2

| Salt | R | Z | Yield (%) | m.p. ^a (°C) |
|-----------|--------------------------------------|------------------|-----------|------------------------|
| 2a | C ₄ H ₉ | Cl | 85 | 133-137 ^b |
| 2b | C ₁₂ H ₂₅ | Cl | 70 | 119-123 ^b |
| 2c | CycloC ₁₂ H ₂₅ | Cl | 70 | 163-165 ^b |
| 2d | C ₃ H ₇ | BF ₄ | 78 | 128-130 |
| 2e | C ₈ H ₁₇ | BF ₄ | 75 | 125-128 |
| 2f | C ₁₂ H ₂₅ | I | 80 | 111-112 |
| 2g | C ₁₂ H ₂₅ | BF ₄ | 83 | 127-128 |
| 2h | C ₁₂ H ₂₅ | ClO ₄ | 81 | 133-134 |
| 2i | CycloC ₁₂ H ₂₅ | ClO ₄ | 80 | 175-176 |
| 2j | CycloC ₁₂ H ₂₅ | Br | 80 | 164-166 |
| 2k | CycloC ₁₂ H ₂₅ | I | 78 | 154-156 |
| 2l | CycloC ₁₂ H ₂₅ | NO ₃ | 70 | 138-143 |
| 2m | CycloC ₁₂ H ₂₅ | BF ₄ | 70 | 138-140 |

^a Solvent for recrystallization: CHCl₃:CH₃CO₂C₂H₅ - **2a-2c**; CH₃CO₂C₂H₅ - **2d-2m**;
^bHygroscopic

The pyridinium salts 3-6 were prepared by the reaction of N-Mannich bases 1c, 1d and 1f with chloromethylalkyl ethers. The reactions and the results are shown in Scheme 2 and Tables 3 and 4.

Table 3. 1-Alkoxyethyl-3-(1-benzimidazolmethylamino)- pyridinium Salts 3 And Bis(1-Alkoxyethyl- pyridinium) Salts 4

| Salt | R | Z | Yield (%) | m.p. ^a (°C) |
|-----------|---------------------------------|------------------|-----------|------------------------|
| 3a | C ₃ H ₇ | Cl | 82 | 143-145 |
| 3b | C ₈ H ₁₇ | Cl | 70 | 141-143 |
| 3c | C ₁₁ H ₂₃ | Cl | 70 | 146-147 |
| 3d | C ₃ H ₇ | Br | 70 | 143-144 |
| 3e | C ₈ H ₁₇ | NO ₃ | 70 | 118-120 |
| 3f | C ₈ H ₁₇ | I | 70 | 121-122 |
| 3g | C ₈ H ₁₇ | BF ₄ | 70 | 115-117 |
| 3h | C ₈ H ₁₇ | PF ₆ | 75 | 109-112 |
| 3i | C ₈ H ₁₇ | ClO ₄ | 73 | 108-110 |
| 3j | C ₁₂ H ₂₅ | I | 70 | 107-109 |
| 3k | C ₁₂ H ₂₅ | PF ₆ | 70 | 111-114 |
| 3l | C ₁₂ H ₂₅ | ClO ₄ | 80 | 114-116 |
| 4a | C ₉ H ₁₉ | Cl | 85 | 68-71 |
| 4b | C ₁₁ H ₂₃ | Cl | 84 | 72-73 |
| 4c | C ₈ H ₁₇ | ClO ₄ | 87 | 125-127 |
| 4d | C ₈ H ₁₇ | BrO ₃ | 85 | 129-130 |
| 4e | C ₈ H ₁₇ | I | 85 | 130-132 |
| 4f | C ₈ H ₁₇ | Br | 80 | 126-128 |
| 4g | C ₁₂ H ₂₅ | PF ₆ | 76 | 129-132 |
| 4h | C ₁₂ H ₂₅ | SbF ₆ | 73 | 92-94 |
| 4i | C ₁₂ H ₂₅ | I | 70 | 144-146 |

^a Solvent for recrystallization: MeOH/Me₂CO (1:10) for 3a, 3b, H₂O for 3c, MeOH/H₂O (1:1) for 3c, 3d, H₂O-4a, 4b, MeOH 4c-4i

Symmetrically substituted bis(1-alkoxyethyl)pyridinium chlorides **4** were synthesised by treating 1-alkoxyethyl-3-(1-benzimidazolmethylamino)pyridinium chloride **3** with chloromethyl-alkyl ether (Scheme 2). The formation of bispyridinium chloride is probably the result of the attack of chloromethylalkyl ether on the N-3 of benzimidazole ring to give an intermediate shown in Figure 2 which is unstable and quickly converted to bispyridinium chloride to replace the benzimidazole moiety.

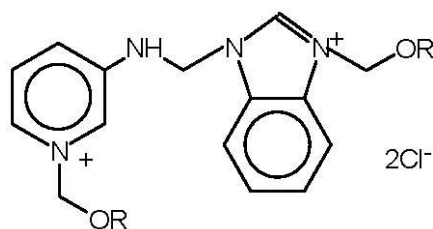


Figure 2

The substrate **3** was converted into the same derivative **4** by heating with hydrochloric acid.

Benzimidazole is a good leaving group in N-(1 *H*-benzimidazolmethyl)-3-pyridinecarboxamide **1a** in basic and acidic solutions (Scheme 3). Hydrolysis is generally effected by heating with dilute hydrochloric acid. Treatment of compound **1a** with alkoxides at rt, displaces the benzimidazole anion giving a symmetrical diamide.

All of the salts 2-6 were prepared via metathesis of pyridinium or benzimidazolium chlorides with the appropriate inorganic salt in water solution (Tables 2, 3 and 4). In general, the chlorides were very hygroscopic.

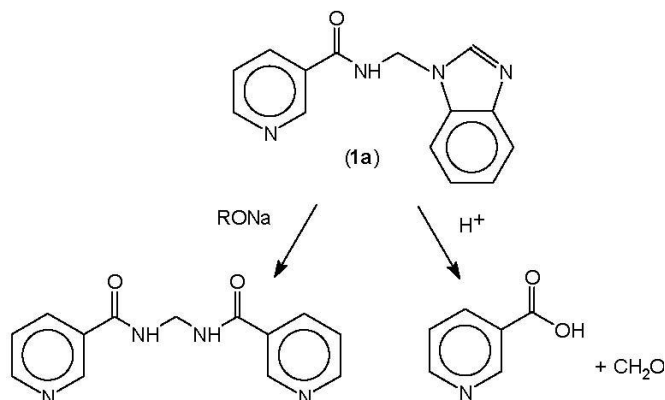
Table 4. Pyridinium Salts 5,6

| Salt | R | Y | Z | Yield(%) | m.p. ^a (°C) |
|-----------|---------------------------------|------|------------------|----------|------------------------|
| 5a | C ₆ H ₁₃ | CONH | I | 80 | 138-140 |
| 5b | C ₈ H ₁₇ | CONH | Br | 80 | 159-161 |
| 6a | C ₃ H ₇ | NH | Cl | 80 | 132-134 |
| 6b | C ₄ H ₉ | NH | Cl | 80 | 139-140 |
| 6c | C ₅ H ₁₁ | NH | Cl | 82 | 139-141 |
| 6d | C ₆ H ₁₃ | NH | Cl | 81 | 146-148 |
| 6e | C ₇ H ₁₅ | NH | Cl | 78 | 133-135 |
| 6f | C ₈ H ₁₇ | NH | Cl | 80 | 132-134 |
| 6g | C ₉ H ₁₉ | NH | Cl | 80 | 134-136 |
| 6h | C ₁₀ H ₂₁ | NH | Cl | 78 | 138-140 |
| 6i | C ₁₁ H ₂₃ | NH | Cl | 77 | 135-136 |
| 6j | C ₁₂ H ₂₅ | NH | Cl | 78 | 134-136 |
| 6k | C ₃ H ₇ | NH | I | 70 | 140-141 |
| 6l | C ₃ H ₇ | NH | SbF ₆ | 70 | 136-138 |
| 6m | C ₄ H ₉ | NH | ClO ₄ | 73 | 138-140 |
| 6n | C ₄ H ₉ | NH | NO ₃ | 70 | 134-136 |
| 6o | C ₄ H ₉ | NH | PF ₆ | 70 | 141-143 |
| 6p | C ₄ H ₉ | NH | BF ₄ | 72 | 144-145 |
| 6q | C ₄ H ₉ | NH | I | 73 | 145-147 |

^a Solvent for recrystallization: H₂O (**5a**, **5b** and **6a-j**), MeOH-H₂O -(**6k-6q**).

The conversions of the chlorides to the Br, I, NO₃, BrO₃, ClO₄, BF₄, PF₆ and SbF₆ salts led to some which were hydrophobic. The larger -size anions changed the character of the salt.

In conclusion, a procedure has been developed for the preparation of 3-substituted pyridinium and 1-substituted benzimidazolium salts. The work-up procedures are very simple, the products are easily purified and the yields are high.



Scheme 3

Experimental Section

General Procedures. Melting points were determined on a Kofler hot stage apparatus and are uncorrected. The ¹H NMR spectra were recorded with a Varian Model XL 300 Spectrometer at 300 MHz with TMS as the standard. The ¹³C NMR spectra were recorded on the same instrument at 75 MHz. Elemental analyses was performed at the A. Mickiewicz University, Poznań. For all compounds **1-6** satisfactory microanalyses were obtained C ± 0.31, H ± 0.30 and N ± 0.28. Chloromethylalkyl ethers were prepared via the procedures, which were reported earlier¹⁷.

The salts obtained were characterised by their ¹H and ¹³C NMR spectra and by elemental analyses. The ¹H and ¹³C NMR chemical shifts are summarised in Tables 5-10. The chemical shifts of the protons are anion-dependent in equivalent concentrations. This effect is strong for protons in the Y group (H-N) and weaker for the benzimidazole or benzotriazole ring protons. The H-N chemical shift decreases in the following order Cl > NO₃ > I, ClO₄, PF₆ > BF₄. This phenomenon has been noticed previously in the imidazole ring protons in 1,3 dialkylimidazolium salts¹⁸.

General Procedure for the condensation of nicotinamide

Nicotinamide (12.2 g, 0.1 mol), formaldehyde (3 g, 0.1 mol, paraformaldehyde - powder) and benzimidazole or benzotriazole (0.1 mol) were refluxed in toluene (200 mL) to which two drops of concd. sulphuric acid had been added. The water formed during the reaction was removed azeotropically by a Dean-Stark apparatus. The toluene was then removed under reduced pressure

(60 °C/30 Torr) and the resulting solids were recrystallized.

3-(Benzimidazolmethylamino)pyridine (1c): A mixture of 3-aminopyridine (9.4 g, 0.1 mol), formaldehyde (3 g, 0.1 mol, paraformaldehyde - powder) and benzimidazole (11.8 g, 0.1 mol) was refluxed in EtOH (100 mL). After cooling to r.t. H₂O (50 mL) was added, the product was collected by filtration and recrystallized.

Pyridinium salts 3, 5 and 6. General procedure

The 3-(Benzimidazolmethylamino)pyridine (**1c**) or 3-(benzotriazol-1-yl-methylamino)pyridine (**1f**) or N-(1 *H*-benzotriazol-1-ylmethyl)-3-pyridinecarboxamide (**1d**) (0.01 mol) was dissolved in anhydrous acetone and the corresponding chloromethylalkyl ether (0.01 mol) was added. The mixture was stirred at rt for 5-10 min. The precipitated solid was collected by filtration and recrystallized. A solution of the 1-alkoxymethylpyridinium chloride (0.005 mol) in 40 mL of H₂O and the appropriate inorganic salt (0.02 mol, MZ) in 20 mL of H₂O were mixed at rt by stirring. The solid was collected by filtration and recrystallized.

Benzimidazolium salts 2; General procedure

The corresponding chloromethylalkyl ether (0.01 mol) was added to N-(1 *H*-benzimidazolmethyl)-3-pyridinecarboxamide (2.52 g, 0.01 mol, **1a**) in dry DMF (30 mL) by stirring for 1h at r.t. The solvent was removed under reduced pressure. The crude product was washed with hexane and acetone and recrystallized. A sample of the benzimidazolium chloride (0.01 mol) in 40 mL of H₂O and the appropriate inorganic salt (0.01 mol, MZ) in 20 mL was mixed at r.t. The solution was extracted by 50 mL of ethyl acetate, the extract was dried over Na₂SO₄ and concentrated *in vacuum*. The resultant residue was recrystallized.

Bispyridinium Salts 4; General procedure

To 1-alkoxymethylpyridinium chloride (0.01 mol, **3**) in dry CHCl₃ (40 mL), chloromethylalkyl ether (0.01 mol) was added with stirring for 10 min at r.t. The solvent was removed under reduced pressure. The crude product was washed with hexane and recrystallized. A solution of prepared bispyridinium chloride (0.01 mol) in 80 mL of H₂O and a solution of inorganic salt (0.02 mol, MZ) in 20 mL was mixed with stirring. The resulting product was collected by filtration and recrystallized.

Table 5. ¹H NMR Spectral Data (δ, J in Hz)^a Benzimidazolium Salts **2**

| Salt | NH | Pyridine | NCH ₂ N | Benzimidazole | NCH ₂ O | R | |
|-----------|--------------------------|---|--|--|---|---------|---|
| 2b | 11.25 (t, <i>J</i> =6.0) | 9.22(s, 1H), <i>J</i> =4.2, 1H), 7.60(t, <i>J</i> =6.7, 1H), <i>J</i> =7.7, 1H) | 8.80(d, 1H), 8.52(d, 1H), 7.60(t, <i>J</i> =7.4) | 6.08 (d, <i>J</i> =6.2, 1H), 8.08(d, <i>J</i> =5.8, 1H), 7.74(m, 2H) | 10.38(s, 1H), 8.58(d, 1H), 8.23(m, 1H), 8.09(d, <i>J</i> =7.0, 1H), 7.77(m, 2H) | 6.06(s) | 3.57(t, <i>J</i> =6.3, 2H), 1.45(m, 2H), 1.13(m, 18H), 0.85(t, <i>J</i> =6.6, 3H) |
| 2d | 10.10 (t, <i>J</i> =6.0) | 9.07(s, 1H), <i>J</i> =4.8, 1H), 7.58(t, 1H), <i>J</i> =8.0, 1H) | 8.78(d, 1H), 8.23(m, 1H), <i>J</i> =8.0, 1H) | 6.08 (d, <i>J</i> =6.0) | 10.10(s, 1H), 8.23(m, 1H), 8.09(d, <i>J</i> =7.0, 1H), 7.77(m, 2H) | 6.01(s) | 3.55(t, <i>J</i> =6.3, 2H), 1.53(m, 2H), 0.81(t, <i>J</i> =6.7, 3H) |
| 2e | 10.08 (t, <i>J</i> =6.0) | 9.05(s, 1H), <i>J</i> =4.8, 1H), 7.56(t, 1H), <i>J</i> =7.8, 1H) | 8.77(d, 1H), 8.23(m, 1H), <i>J</i> =7.8, 1H) | 6.05 (d, <i>J</i> =6.3) | 10.08(s, 1H), 8.23(m, 1H), 8.10(d, <i>J</i> =7.4, 1H), 7.75(m, 2H) | 6.00(s) | 3.56(t, <i>J</i> =6.3, 2H), 1.47(m, 2H), 1.14(m, 10H), 0.81(t, <i>J</i> =6.7, 3H) |
| 2f | 10.16 (t, <i>J</i> =6.0) | 9.07(s, 1H), <i>J</i> =5.0, 1H), 7.58(t, 1H), <i>J</i> =7.8, 1H) | 8.78(d, 1H), 8.25(m, 1H), <i>J</i> =7.8, 1H) | 6.08 (d, <i>J</i> =6.0) | 10.16(s, 1H), 8.25(m, 1H), 8.08(d, <i>J</i> =6.0, 1H), 7.77(m, 2H) | 6.01(s) | 3.56(t, <i>J</i> =6.3, 2H), 1.47(m, 2H), 1.14(m, 18H), 0.86(t, <i>J</i> =6.7, 3H) |
| 2g | 10.21 (t, <i>J</i> =6.0) | 9.07(s, 1H), <i>J</i> =3.6, 1H), 7.58(t, 1H), <i>J</i> =7.8, 1H) | 8.78(d, 1H), 8.25(m, 1H), <i>J</i> =7.8, 1H) | 6.08 (d, <i>J</i> =6.0) | 10.16(s, 1H), 8.25(m, 1H), 8.08(d, <i>J</i> =7.1, 1H), 7.77(m, 2H) | 6.01(s) | 3.56(t, <i>J</i> =6.3, 2H), 1.47(m, 2H), 1.14(m, 18H), 0.86(t, <i>J</i> =6.7, 3H) |
| 2h | 10.21 (t, <i>J</i> =6.0) | 9.07(s, 1H), <i>J</i> =3.6, 1H), 7.58(t, 1H), <i>J</i> =7.7, 1H) | 8.78(d, 1H), 8.25(m, 1H), <i>J</i> =7.7, 1H) | 6.08 (d, <i>J</i> =6.0) | 10.16(s, 1H), 8.25(m, 1H), 8.08(d, <i>J</i> =7.1, 1H), 7.77(m, 2H) | 6.01(s) | 3.56(t, <i>J</i> =6.3, 2H), 1.47(m, 2H), 1.14(m, 18H), 0.86(t, <i>J</i> =6.7, 3H) |
| 2m | 10.23 (t, <i>J</i> =6.0) | 9.06(s, 1H), <i>J</i> =4.8, 1H), 7.58(t, 1H), <i>J</i> =8.0, 1H) | 8.78(d, 1H), 8.25(m, 1H), <i>J</i> =8.0, 1H) | 6.08 (d, <i>J</i> =6.0) | 10.21(s, 1H), 8.25(m, 1H), 8.07(d, <i>J</i> =7.8, 1H), 7.78(m, 2H) | 6.03(s) | 3.63(m, 1H), 1.54(m, 2H), 1.40(m, 2H), 1.14(m, 18H) |

^a Solvent DMSO-*d*₆

Table 6. ^{13}C NMR Spectral Data Benzimidazolium Salts **2**^a

| Salt | C=O | Pyridine | NCH ₂ N | Benzimidazole | NCH ₂ O | R |
|-----------|-------|-----------------------------------|--------------------|---|--------------------|---|
| 2b | 165.8 | 152.2, 148.3, 136.2, 128.2, 123.9 | 51.81 | 143.9, 130.6, 130.5, 127.0, 114.6, 114.2 | 76.76 | 69.0, 31.3, 29.0, 28.98, 28.92, 28.89, 28.7, 28.5, 28.0, 25.2, 22.1, 14.0 |
| 2d | 166.2 | 152.7, 148.4, 135.2, 128.1, 123.5 | 51.76 | 143.3, 130.5, 130.4, 127.0, 126.9, 114.0, 113.9 | 76.78 | 70.79, 21.83, 9.99 |
| 2e | 166.2 | 152.7, 148.4, 135.1, 128.1, 123.5 | 51.76 | 143.3, 130.5, 130.4, 126.9, 114.1, 113.9 | 76.76 | 69.1, 30.9, 28.4, 28.3, 28.2, 25.1, 21.8, 13.7 |
| 2f | 166.2 | 152.9, 148.6, 135.3, 128.0, 123.6 | 51.84 | 143.6, 130.5, 130.4, 127.0, 114.2, 114.1 | 76.82 | 69.0, 31.3, 29.0, 28.9, 28.86, 28.85, 28.7, 28.6, 28.5, 25.2, 22.1, 13.9 |
| 2g | 166.3 | 152.8, 148.6, 135.3, 128.1, 123.7 | 51.86 | 143.6, 130.6, 130.5, 127.1, 114.2, 114.1 | 76.85 | 69.1, 31.3, 29.0, 28.98, 28.93, 28.91, 28.7, 28.6, 28.5, 25.3, 22.1, 13.9 |
| 2h | 166.3 | 152.9, 148.6, 135.3, 128.1, 123.7 | 51.86 | 143.6, 130.6, 130.5, 127.1, 114.2, 114.1 | 76.84 | 69.1, 31.3, 29.0, 28.98, 28.92, 28.89, 28.7, 28.6, 28.5, 25.3, 22.1, 13.9 |
| 2m | 166.3 | 152.9, 148.6, 135.2, 128.1, 123.7 | 51.73 | 143.2, 130.6, 130.4, 127.1, 114.3, 114.1 | 76.49 | 75.2, 28.5, 23.6, 23.4, 22.6, 20.3 |

^a Solvent DMSO-*d*₆**Table 7.** ^1H NMR Spectral Data (δ , J in Hz)^a of Pyridinium Salts **3** and Bispyridinium Salts **4**

| Salt | NH | Pyridine | NCH ₂ N | Benzimidazole | NCH ₂ O | R |
|-----------|--------------------|--|-------------------------------|---|--------------------|--|
| 3a | - | 8.53(s, 1H), J=6.0, 1H), 8.05(d, J=8.8, 1H), 7.84(m, 1H) | 8.30(d, 5.95(s) | 8.51(s, 1H), 7.65(d, J=7.7, 1H), 7.84(m, 1H), 7.32(m, 2H) | 5.81(s) | 3.46(t, J=6.6, 2H), 1.55(m, 2H), 0.85(t, J=7.4, 3H) |
| 3b | 8.98 (t, J=6.9) | 8.75(s, 1H), J=5.8, 1H), 8.08(d, J=8.7, 1H), 7.87(t, J=8.5, 1H) | 8.36(d, 5.91 (d, J=6.9) | 8.69(s, 1H), 7.94(d, J=7.4, 1H), 7.64(d, J=7.7, 1H), 7.25(m, 2H) | 5.82(s) | 3.45(t, J=6.4, 2H), 1.45(m, 2H), 1.22(m, 10H), 0.84(t, J=6.8, 3H) |
| 3c | 9.09 (t, J=6.9) | 8.81(s, 1H), J=5.5, 1H), 8.10(d, J=8.6, 1H), 7.86(t, J=8.6, 1H) | 8.36(d, 5.91 (d, J=6.9) | 8.71(s, 1H), 7.96(d, J=7.4, 1H), 7.62(d, J=7.4, 1H), 7.23(m, 2H) | 5.83(s) | 3.48(t, J=6.5, 2H), 1.46(m, 2H), 1.21(m, 16H), 0.85(t, J=6.7, 3H) |

Table 7. Continued

| | | | | | | | | |
|-----------|------------------------|--|---|------------------------|--|---------------------------------------|--------------|---|
| 3f | 8.52 (t, $J=6.7$) | 8.60(s, 1H), $J=5.8$, 1H), 7.93(t, $J=8.5$, 1H) | 8.41(d, 1H), 8.09(d, 1H), 7.93(t, 1H) | 5.94 (d, $J=6.7$) | 8.62(s, 1H), $J=7.9$, 1H), 7.67(d, $J=7.6$, 1H), 7.28(m, 2H) | 7.87(d, 1H), 7.67(d, 1H), 7.28(m, 2H) | 5.84(s) | 3.50(t, $J=6.4$, 2H), 1.46(m, 2H), 1.23(m, 10H), 0.85(t, $J=6.7$, 3H) |
| 3g | 8.49 (t, $J=6.6$) | 8.56(s, 1H), $J=5.8$, 1H), 7.90(t, $J=8.8$, 1H) | 8.36(d, 1H), 8.05(d, 1H), 7.90(t, $J=8.8$, 1H) | 5.91 (d, $J=6.9$) | 8.52(s, 1H), $J=7.7$, 1H), 7.67(d, $J=7.4$, 1H), 7.27(m, 2H) | 7.84(d, 1H), 7.67(d, 1H), 7.27(m, 2H) | 5.79(s) | 3.49(t, $J=6.3$, 2H), 1.48(m, 2H), 1.22(m, 10H), 0.85(t, $J=6.4$, 3H) |
| 3h | 8.49 (t, $J=6.9$) | 8.55(s, 1H), $J=5.8$, 1H), 7.89(t, $J=8.7$, 1H) | 8.35(d, 1H), 8.03(d, 1H), 7.89(t, 1H) | 5.90 (d, $J=6.6$) | 8.52(s, 1H), $J=8.0$, 1H), 7.66(d, $J=7.7$, 1H), 7.23(m, 2H) | 7.83(d, 1H), 7.66(d, 1H), 7.23(m, 2H) | 5.78(s) | 3.48(t, $J=6.6$, 2H), 1.48(m, 2H), 1.22(m, 10H), 0.85(t, $J=6.7$, 3H) |
| 4b | 9.51 (t, $J=6.0$, 2H) | 9.38(s, 2H), $J=8.5$, 2H), 7.65(t, $J=8.5$, 2H) | 8.16(d, 2H), 7.97(d, 2H), 7.65(t, 2H) | 4.87 (t, $J=5.5$, 2H) | – | – | 6.07 (s, 4H) | 3.68(t, $J=6.4$, 4H), 1.61(m, 4H), 1.32(m, 32H), 0.88(t, $J=6.6$, 6H) |
| 4c | 8.01 (t, $J=5.5$, 2H) | 8.35(m, 4H), 4H) | 7.89(m, 4H) | 4.84 (t, $J=5.4$, 2H) | – | – | 5.79 (s, 4H) | 3.56(t, $J=6.6$, 4H), 1.52(m, 4H), 1.25(m, 20H), 0.85(t, $J=6.7$, 6H) |
| 4e | 8.58 (t, $J=6.0$, 2H) | 9.17(s, 2H), $J=8.6$, 2H), 7.69(t, $J=5.8$, 2H), $J=8.8$, 2H) | 8.33(d, 2H), 8.12(d, 2H), 7.69(t, 2H) | 4.87 (t, $J=5.9$, 2H) | – | – | 6.18 (s, 4H) | 3.74(t, $J=6.5$, 4H), 1.64(m, 4H), 1.31(m, 20H), 0.87(t, $J=6.7$, 6H) |
| 4i | 8.02 (t, $J=5.5$, 2H) | 8.35(m, 4H), 4H) | 7.89(m, 4H) | 4.83 (t, $J=5.5$, 2H) | – | – | 5.78 (s, 4H) | 3.54(t, $J=6.5$, 4H), 1.51(m, 4H), 1.24(m, 36H), 0.86(t, $J=6.7$, 6H) |

^a Solvent: CD₃OD – **3a**; CDCl₃ – **4b**, **4e**; DMSO-*d*₆ – **3b**, **3c**, **3f**, **3g**, **3h**, **4c**, **4i**

Table 8. ^{13}C NMR Spectral Data^a of Pyridinium Salts **3** and Bispyridinium Salts **4**

| Salt | Pyridine | NCH ₂ N | Benzimidazole | NCH ₂ O | R |
|-----------|---------------------------------------|--------------------|---|--------------------|---|
| 3a | 147.8, 133.0, 130.1, 129.3, 127.5 | 53.94 | 144.5, 144.3, 134.2, 124.2, 120.4, 112.1 | 124.9, 90.73 | 73.9, 23.5, 10.6 |
| 3b | 146.0, 131.8, 128.5, 128.0, 126.6 | 51.89 | 144.0, 143.5, 133.0, 122.1, 119.4, 111.4 | 122.6, 88.62 | 70.1, 31.2, 28.6, 25.2, 22.1, 14.0 |
| 3c | 146.0, 131.8, 128.4, 128.0, 126.6 | 51.88 | 143.9, 122.6, 122.0, 111.3 | 119.5, 88.62 | 70.1, 31.3, 28.9, 28.6, 28.6, 25.1, 22.1, 13.9 |
| 3f | 146.0, 132.0, 128.6, 128.2, 126.5 | 52.00 | 144.0, 143.7, 133.2, 122.1, 119.6, 111.2 | 122.7, 88.68 | 70.2, 31.1, 28.5, 28.45, 25.1, 22.0, 13.8 |
| 3g | 145.9, 131.9, 128.4, 128.1, 126.5 | 51.96 | 122.7, 122.1, 119.6, 111.1 | 88.01 | 70.2, 31.2, 28.6, 25.2, 22.1, 14.0 |
| 3h | 145.9, 131.9, 128.4, 128.1, 126.5 | 51.95 | 122.7, 122.1, 119.6, 111.1 | 88.78 | 70.2, 31.2, 28.6, 25.2, 22.1, 14.0 |
| 4b | 146.7, 130.7, 127.5, 127.0, 125.8 | 50.00 | – | 88.83 | 71.7, 31.7, 29.4, 29.3, 29.1, 29.0, 25.6, 22.5, 13.9 |
| 4c | 146.1, 130.8, 128.3, 127.5, 126.0 | 50.70 | – | 88.61 | 70.1, 31.1, 28.6, 28.5, 25.2, 22.0, 13.9 |
| 4e | 145.8, 130.4, 128.4, 127.0, 124.6, | 49.01 | – | 88.31 | 71.6, 31.4, 29.0, 28.9, 28.8, 25.5, 22.3, 13.8 |
| 4i | 146.3, 131.4, 128.5, 127.8, 126.3 | 50.66 | – | 88.74 | 70.2, 31.3, 29.1, 29.0, 29.0, 28.8, 28.7, 28.65, 25.3, 22.1, 14.0 |

^a Solvent: CD₃OD – **3a**; CDCl₃ – **4b, 4e**; DMSO-*d*₆ – **3b, 3c, 3f, 3g, 3h, 4c, 4i**

Table 9. ^1H NMR Spectral Data (δ , J in Hz)^a of Pyridinium Salts **5,6**

| Salt | NH | Pyridine | NCH ₂ N | Benzotriazole | NCH ₂ O | R |
|-----------|---------------------------|---|--------------------------|--|--------------------|---|
| 5a | 10.61 (t, <i>J</i> =6) | 9.53(s, 1H), <i>J</i> =6, 1H), 9.07(d, <i>J</i> =7, 1H), 8.37(t, <i>J</i> =7, 1H) | 6.34 (d, <i>J</i> =6) | 8.09(d, <i>J</i> =9, 2H), <i>J</i> =8, 1H), 7.47(t, <i>J</i> =8, 1H) | 7.65(t, 5.97(s) | 3.60(t, <i>J</i> =7, 2H), 1.54(m, 2H), 1.24(m, 6H), 0.84(t, <i>J</i> =7, 3H) |
| 5b | 10.78 (t, <i>J</i> =6) | 9.59(s, 1H), <i>J</i> =6, 1H), 9.15(d, <i>J</i> =7, 1H), 8.37(t, <i>J</i> =7, 1H) | 6.33 (d, <i>J</i> =6) | 8.15(d, <i>J</i> =8, 1H), <i>J</i> =8, 1H), 7.64(t, <i>J</i> =8, 1H), 7.46(t, <i>J</i> =8, 1H) | 8.08(d, 5.98(s) | 3.60(t, <i>J</i> =7, 2H), 1.54(m, 2H), 1.24(m, 8H), 0.86(t, <i>J</i> =7, 3H) |

Table 9. Continued

| | | | | | | | |
|-----------|---------------------|--|--|--------------------|--|---------|---|
| 6b | 9.55 (t, $J=7.0$) | 8.70(s, 1H), $J=5.8$, 1H), $J=8.7$, 1H), $J=8.5$, 1H) | 8.44(d, 1H), 8.17(d, $J=6.9$), 7.92(t, $J=8.5$, 1H) | 6.38 (d, $J=6.9$) | 8.27(d, $J=8.2$, 1H), 8.04(d, $J=8.5$, 1H), 7.58(t, $J=7.7$, 1H), 7.41(t, $J=7.6$, 1H) | 5.84(s) | 3.47(t, $J=6.5$, 2H), 1.45(m, 2H), 1.20(m, 2H), 0.75(m, $J=7.3$, 3H) |
| 6h | 9.47 (t, $J=6.6$) | 8.70(s, 1H), $J=5.8$, 1H), $J=8.7$, 1H), $J=8.5$, 1H) | 8.43(d, 1H), 8.14(d, $J=6.9$), 7.92(t, $J=8.5$, 1H) | 6.37 (d, $J=6.9$) | 8.26(d, $J=8.2$, 1H), 8.02(d, $J=8.5$, 1H), 7.58(t, $J=7.6$, 1H), 7.41(t, $J=7.7$, 1H) | 5.84(s) | 3.48(t, $J=6.6$, 2H), 1.46(m, 2H), 1.16(m, 14H), 0.83(t, $J=6.7$, 3H) |
| 6i | 10.31 (t, $J=6.6$) | 8.97(s, 1H), $J=5.8$, 1H), $J=8.7$, 1H), $J=8.5$, 1H) | 8.36(d, 1H), 8.23(d, $J=6.6$), 7.7(t, $J=8.5$, 1H) | 6.24 (d, $J=6.6$) | 8.32(d, $J=8.5$, 1H), 7.95(d, $J=8.2$, 1H), 7.47(t, $J=7.3$, 1H), 7.33(t, $J=8.0$, 1H) | 5.92(s) | 3.56(t, $J=6.6$, 2H), 1.58(m, 2H), 1.23(m, 16H), 0.87(t, $J=6.7$, 3H) |
| 6m | 8.67 (t, $J=7.0$) | 8.59(s, 1H), $J=5.8$, 1H), $J=8.7$, 1H), $J=8.6$, 1H) | 8.41(d, 1H), 8.15(d, $J=7.0$), 7.97(t, $J=8.6$, 1H) | 6.43 (d, $J=7.0$) | 8.10(d, 2H), 7.68(t, $J=7.9$, 1H), 7.47(t, $J=8.1$, 1H) | 5.84(s) | 3.53(t, $J=6.6$, 2H), 1.51(m, 2H), 1.26(m, 2H), 0.81(t, $J=7.3$, 3H) |
| 6n | 8.78 (t, $J=6.9$) | 8.62(s, 1H), $J=6.1$, 1H), $J=8.5$, 1H), $J=8.5$, 1H) | 8.44(d, 1H), 8.15(d, $J=7.0$), 7.98(t, $J=8.5$, 1H) | 6.44 (d, $J=7.0$) | 8.10(d, 2H), 7.66(t, $J=8.2$, 1H), 7.47(t, $J=8.1$, 1H) | 5.85(s) | 3.52(t, $J=6.6$, 2H), 1.50(m, 2H), 1.25(m, 2H), 0.80(t, $J=7.3$, 3H) |
| 6o | 8.67 (t, $J=7.0$) | 8.59(s, 1H), $J=5.5$, 1H), $J=8.9$, 1H), $J=8.9$, 1H) | 8.41(d, 1H), 8.14(d, $J=7.0$), 7.96(t, $J=8.9$, 1H) | 6.42 (d, $J=7.0$) | 8.09(d, 2H), 7.67(t, $J=7.9$, 1H), 7.47(t, $J=7.8$, 1H) | 5.82(s) | 3.52(t, $J=6.6$, 2H), 1.50(m, 2H), 1.25(m, 2H), 0.81(t, $J=7.3$, 3H) |
| 6p | 8.66 (t, $J=7.0$) | 8.59(s, 1H), $J=5.8$, 1H), $J=8.7$, 1H), $J=8.9$, 1H) | 8.41(d, 1H), 8.14(d, $J=7.0$), 7.97(t, $J=8.9$, 1H) | 6.42 (d, $J=7.0$) | 8.10(d, 2H), 7.67(t, $J=8.2$, 1H), 7.47(t, $J=8.1$, 1H) | 5.83(s) | 3.53(t, $J=6.6$, 2H), 1.50(m, 2H), 1.25(m, 2H), 0.81(t, $J=7.3$, 3H) |
| 6q | 8.67 (t, $J=7.0$) | 8.61(s, 1H), $J=5.8$, 1H), 1H), 7.98(t, $J=8.6$, 1H) | 8.44(d, 1H), 8.12(m, $J=7.0$), 1H), 7.98(t, $J=8.6$, 1H) | 6.44 (d, $J=7.0$) | 8.12(m, 1H), 8.07(d, $J=8.4$, 1H), 7.65(t, $J=7.5$, 1H), 7.45(t, $J=7.7$, 1H) | 5.86(s) | 3.52(t, $J=6.6$, 2H), 1.49(m, 2H), 1.24(m, 2H), 0.79(t, $J=7.5$, 3H) |

^a Solvent: DMSO-*d*₆ for **5a**, **5b**, **6b**, **6m-6q** and in CDCl₃ for **6i**, **6h**

Table 10. ^{13}C NMR Spectral Data^a of Pyridinium Salts **5,6**

| Salt | C=O | Pyridine | NCH ₂ N | Benzotriazole | NCH ₂ O | R |
|-----------|-------|-----------------------------------|--------------------|--|--------------------|--|
| 5a | 162.0 | 144.9, 143.3, 127.9, 127.4, 124.1 | 51.4 | 145.1, 145.0, 132.2, 132.0, 118.9, 111.2 | 88.8 | 70.4, 30.8, 28.6, 24.8, 21.6, 13.9 |
| 5b | 162.0 | 145.2, 143.6, 128.0, 127.7, 124.3 | 51.4 | 145.3, 145.1, 132.4, 132.3, 119.1, 111.2 | 88.9 | 70.4, 31.2, 28.6, 25.2, 22.1, 14.0 |
| 6b | - | 145.5, 132.1, 128.6, 128.0, 126.7 | 54.8 | 146.2, 132.3, 127.7, 124.5, 119.3, 111.5 | 88.6 | 69.9, 30.6, 18.3, 13.4 |
| 6h | - | 145.2, 131.8, 128.4, 127.7, 126.4 | 54.7 | 145.8, 132.0, 127.4, 124.2, 119.0, 111.2 | 88.5 | 70.2, 31.3, 28.9, 28.7, 28.6, 25.2, 22.2, 14.0 |
| 6i | - | 146.1, 129.7, 128.5, 128.1, 126.7 | 55.1 | 147.1, 132.2, 127.7, 124.4, 119.3, 111.1 | 89.3 | 71.8, 31.6, 29.3, 29.2, 29.2, 29.0, 28.9, 28.8, 25.4, 22.3, 13.8 |
| 6m | - | 145.5, 132.3, 128.9, 128.1, 126.8 | 54.8 | 146.1, 132.3, 127.9, 124.6, 119.4, 111.0 | 88.8 | 70.0, 30.6, 18.3, 13.4 |
| 6n | - | 145.5, 132.3, 128.9, 128.1, 126.8 | 54.8 | 146.1, 132.3, 127.9, 124.5, 119.4, 111.0 | 88.8 | 69.8, 30.6, 18.3, 13.4 |
| 6o | - | 145.5, 132.3, 128.9, 128.1, 126.8 | 54.8 | 146.1, 132.2, 127.9, 124.6, 119.4, 111.0 | 88.8 | 70.0, 30.6, 18.4, 13.4 |
| 6p | - | 145.5, 132.3, 128.9, 128.1, 126.8 | 54.8 | 146.1, 132.3, 127.9, 124.6, 119.4, 111.0 | 88.8 | 70.0, 30.6, 18.4, 13.4 |
| 6q | - | 145.2, 132.0, 128.7, 127.8, 126.5 | 54.8 | 145.7, 132.0, 127.6, 124.3, 119.1, 110.9 | 88.5 | 69.9, 30.5, 18.3, 13.4 |

^a Solvent: DMSO-*d*₆ for **5a**, **5b**, **6b**, **6m-6q** and CDCl₃ for **6i**, **6h**

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