ELUCIDATION OF THE CONFORMATIONAL PROPERTIES OF 3-PYRIDINOYL INDOLES AS INTERMEDIATES OF CANNABIMIMETICS

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Abstract — The conformations of 3-pyridinoyl indoles, which are intermediates of 5-fluoropentyl-3-pyridinoyl indole, were investigated using their X-ray crystal structures. All derivatives existed as s-trans conformers. A pseudo-planar conformation was observed in the 2'-yl isomer of 3-pyridinoyl indoles. On the other hand, twisted conformations were observed in 3-pyridinoyl 2-methylindoles. The conformations of these compounds in solution were also investigated using VT-NMR.

INTRODUCTION

Synthetic cannabinoids, which constitute a majority of the illegal drug market, have N-alkyl-3-aroylindole as one of the core structures. The ease of the synthetic strategy enabled dramatically increased modifications at the N-1 and C-3 positions. Therefore, hundreds of species of synthetic cannabinoids with frequent displacement of functional groups or substituents were synthesized by clandestine laboratories and distributed illegally. In order to identify a single compound in a series of closely related structural isomers of synthetic cannabinoids, we decided to prepare a compound library of synthetic cannabinoids as authentic preparations, which should be furnished exclusively to official research institutions. In the course of our preparation of the compound library, we planned to synthesize analogues of 1-(5-fluoropentyl)-3-pyridinoyl indole, which were controlled as designated substances under the
Japanese Pharmaceutical Affairs Law in 2013. Hence, the isomers of 3-pyridinoyl indoles (1–3) with different substitutional sites (at the 2'-, 3'-, and 4'-positions) (Figure 1) were prepared as intermediates of the synthesis. In order to elucidate the conformation of these compounds, we performed X-ray crystallographic analysis and VT-NMR. Here we report the conformational properties of the differentially substituted isomers of 3-pyridinoyl indoles. The weak interaction between the N atom of pyridine and C2-H of the indole/H of 2-Me of 2-methylindole was suggested in the crystal states of 1a4 and 1b, respectively.

Figure 1. 1-(5-Fluoropentyl)-3-pyridinoyl indole and the isomers of 3-pyridinoyl indoles (1–3)

RESULTS AND DISCUSSION

1. Preparation

As shown in Scheme 1, the isomers of 3-pyridinoyl indoles (1–3) were synthesized according to the method reported previously.5 Friedel-Crafts-type aroylation of indole/5-bromoindole/2-methylindole using 2'/3'/4'-substituted pyridinoyl chloride in the presence of Et2AlCl provided 3-pyridinoyl indoles 1–3. Because the basic nature of pyridine reduced the reactivity of Lewis acid, the reaction was hampered and gave rather low yields.

Scheme 1. Preparation of 3-pyridinoyl indoles 1–3
2. Conformational study of 3-pyridinoyl indoles

In the course of the characterization of the synthesized 3-pyridinoyl indoles 1a, 2a, and 3a, we found that the \(^1\)H NMR spectrum (in CD\(_2\)Cl\(_2\), +23 °C) of 2'-yl isomer 1a had a characteristic downfield shift of 2-H of indole (at 8.95 ppm). In contrast, the corresponding peak in 3'-yl isomer 2a\(^6\) and 4'-yl isomer 3a\(^7\) was observed at 7.72 ppm and 7.71 ppm, respectively. Such a discriminating downfield shift prompted us to conduct a conformational study using X-ray structural analysis. Because of the difficulties in obtaining single crystals of compounds 1a, 2a, and 3a, the more easily crystallized 5-bromo-substituted indole derivatives 1c, 2c, and 3c were subjected to X-ray structural analysis (Figure 2). We believed that the substitution at the outside 5-position of the indole would have little effect on the conformation of the compounds.\(^8\)

![Diagram showing conformational study results](image)

**Figure 2.** X-Ray crystal structures of 1c, 2c, and 3c

Although two conformers (s-trans and s-cis) caused by the rotations of the C3–(C=O) axis (ax1) of the ketone moiety were expected,\(^5\) X-ray analysis of 1c, 2c, and 3c confirmed that these compounds exist as s-trans conformers (Figure 2). Additionally, 2'-yl isomer 1c revealed interesting structural features. The twist angle\(^9\) (dihedral angle between the C3–C2 and C2'–N planes) was 15.5°, which was smaller than those of 2c (36.1°) and 3c (43.0°), indicating that the pyridine ring and indole ring were arranged in a pseudo-planar conformation. It was also revealed that the distance between 2-H of the indole and
pyridine-nitrogen (C2–H•N) was 0.23 nm and the bond angle (C2–H•N) was 117.1°. According to the criteria for hydrogen bonds,10 these properties suggest weak bonding.

Since such a pseudo-planar conformation caused by a weak hydrogen bond was observed in the crystal state, we directed our focus to the conformation in the solution state. Thus, the conformations of 1a, 2a, and 3a were examined using VT-NMR (+23 °C ~ +120 °C in DMSO-d6, −90 °C ~ +23 °C in CD2Cl2).11

In the spectra of 3'-yl isomer 2a and 4'-yl isomer 3a, one set of signals remained virtually unchanged (−90 °C ~ +120 °C)11 (see the Supporting Information). On the other hand, that of 1a changed characteristically as the temperature was lowered (Figure 3).
In the VT-NMR spectra of 1a, one set of sharp signals remained virtually unchanged\(^\text{12}\) (\(-40 \, ^\circ\text{C} \sim +100 \, ^\circ\text{C}\)), which suggested that the stable \textit{s-trans} conformation observed in the crystal state was maintained. However, the peaks became broad at +120 °C, which might be a sign of the beginning of the conformational change from \textit{s-trans} to \textit{s-cis} caused by the rotation of the C3–(C=O) axis (ax1). In contrast, as the temperature decreased (\(-40 \, ^\circ\text{C} \sim -90 \, ^\circ\text{C}\)), each peak gradually became broad, and the peaks corresponding to 2-H of the indole and 3'-H, 4'-H, and 6'-H of pyridine upshifted. These results indicate that the conformational change around the pyridine moiety caused by the rotation of the (C=O)–C2' axis (ax2) always occurs in solution (\(-90 \, ^\circ\text{C} \sim +120 \, ^\circ\text{C}\)). However, below –40 °C, the rotation of ax2 was partly reduced so that the surrounding hydrogens of pyridine become broad and shifted. Considering that such changes were observed only in 2'-yl isomer 1a, the electronic interaction between 2-H of the indole and N of pyridine (C2–H–N) somewhat affected the conformation in solution, although the existence of the hydrogen bond was not confirmed.

\textbf{Figure 3.} VT-NMR of 1a (a): +23 °C ~ +120 °C in DMSO-\textit{d}_6; (b): −90 °C ~ +23 °C in CD\textsubscript{2}Cl\textsubscript{2}
3. Conformational study of 3-pyridinoyl 2-methylindoles

We conducted further X-ray analysis of 2-methyl-substituted indole derivatives 1b, 2b, and 3b (Figure 4).

![Diagram showing the structures of 1b, 2b, and 3b]

The s-trans conformer was similarly observed in each crystal state (Figure 4), although steric hindrance of the 2-methyl substitution caused a more twisted conformation of the indole ring and pyridinoyl moiety. The twist angle (dihedral angle between the C3–C2 and C2′–N planes) in 1b, 2b, and 3b was 65.0°, 69.2°, and 57.2°, respectively. Interestingly, the distance between H of 2-Me of the indole and pyridine-nitrogen (C–H...N) was 0.26 nm and the bond angle (C–H...N) was 116.6° in 1b, which implied a weak interaction, as shown in Figure 4.

Next, the conformations of 1b, 2b, and 3b in solution were examined using VT-NMR (+23 °C ~ +120 °C in DMSO-d6; −90 °C ~ +23 °C in CD2Cl2).11
Figure 5. VT-NMR of 1b (a): +23 °C ~ +120 °C in DMSO-\textsubscript{d6}; (b): −90 °C ~ +23 °C in CD\textsubscript{2}Cl\textsubscript{2}
One set of signals remained virtually unchanged$^{12}$ (−90 °C ~ +120 °C) in 2b and 3b$^{11}$ (see the Supporting Information). However, the spectrum of 1b (Figure 5) at lower temperature was different. As the temperature decreased (−40 °C to −90 °C), peaks corresponding to the indole ring (4-H, 5-H, 6-H, and 7-H) gradually became broader and shifted upfield.$^{13}$ At −90 °C, these four peaks were totally fused together at around 6.6–7.0 ppm. In contrast, peaks belonging to pyridine hydrogens (3'-H, 4'-H, 5'-H, and 6'-H) shifted less. Considering these results, the conformational change from s-trans to s-cis caused by the rotation of the C3–(C=O) axis (ax1) always occur in solution and the averaged spectrum was observed (−40 °C to +120 °C). We assumed that the steric hindrance caused by 2-Me of the indole destabilized the s-trans conformation observed in the crystal state, and hence the averaged spectrum of s-trans and s-cis conformers was observed. As the temperature decreased below −40 °C, the rotation of ax1 may have been reduced so that the surrounding hydrogens of the indole became broad and shifted. Therefore, it appears that the weak interaction between H of 2-Me of the indole and pyridine-nitrogen (C–H–N) observed in the crystal state was not maintained in solution.

4. CONCLUSION

Conformations of 3-pyridinoyl indoles/2-methylindoles 1–3 were examined using X-ray crystal structure analysis and VT-NMR. Theoretically, two conformers (s-trans and s-cis) caused by the rotations of the C3–(C=O) axis (ax1) of the ketone moiety are deduced, although only s-trans conformers were observed in all crystal states. In the crystal state of 1c, the pyridine ring and indole ring were arranged in a pseudo-planar conformation supported by the hydrogen bond between 2-H of the indole and pyridine-nitrogen. In contrast, a twisted conformation in the crystal state was revealed in 1b, 2b, and 3b. In 2'-yl isomer 1b, a weak interaction between H of 2-Me of the indole and pyridine-nitrogen (C–H–N) was suggested. VT-NMR spectra revealed that the weak interaction existing in the crystal states of 1b and 1c were not observed in the solution state. The understanding of weak interaction related to N of pyridine described in this paper may give information on the structure–activity relationships of synthetic cannabinoids.

EXPERIMENTAL

General remarks: All reagents were purchased from commercial suppliers and used as received. Reaction mixtures were stirred magnetically, and the reactions were monitored by thin-layer chromatography (TLC) with precoated silica gel plates. Column chromatography was performed using silica gel (45–60 μm). Extracted solutions were dried over anhydrous MgSO₄ or Na₂SO₄. Solvents were
evaporated under reduced pressure. NMR spectra were recorded on a spectrometer at 600 MHz for $^1$H NMR and 150 MHz for $^{13}$C NMR at 296 K unless otherwise stated. Chemical shifts are given in parts per million (ppm) downfield from tetramethylsilane as an internal standard, and coupling constants ($J$) are reported in Hertz (Hz). Splitting patterns are abbreviated as follows: singlet (s), doublet (d), triplet (t), quartet (q), multiplet (m), and broad (br). The high-resolution mass spectra (HRMS) were obtained with an ionization mode of ESI. IR spectra were recorded on an FT-IR spectrometer equipped with ATR (Diamond). Melting points were recorded on a melting point apparatus and are uncorrected.

(2-Methyl-1H-indol-3-yl)-2-pyridinylmethanone (1b).

Pale pink solid (yield 57%), mp 196–198 °C: $^1$H NMR (600 MHz, DMSO-$d_6$) $\delta$ 11.98 (br, 1H), 8.64 (ddd, $J = 1.2, 1.2, 4.8$ Hz, 1H), 8.01 (ddd, $J = 1.2, 7.2, 7.2$ Hz, 1H), 7.67 (dd, $J = 1.2, 7.2$ Hz, 1H), 7.58 (ddd, $J = 1.2, 4.8, 7.2$ Hz, 1H), 7.43 (d, $J = 8.4$ Hz, 1H), 7.38 (d, $J = 8.4$ Hz, 1H), 7.13 (t, $J = 8.4$ Hz, 1H), 7.04 (t, $J = 8.4$ Hz, 1H), 2.24 (s, 3H); $^{13}$C NMR (150 MHz, DMSO-$d_6$) $\delta$ 190.3, 158.5, 148.7, 145.7, 137.4, 135.0, 127.5, 125.2, 122.1, 122.0, 121.3, 120.3, 111.2, 14.4; IR (ATR) 1535 cm$^{-1}$; HRMS (ESI-TOF) $m/z$: [M+H]$^+$. Calcd for C$_{15}$H$_{13}$N$_2$O 237.1022; found 237.1023.

(5-Bromo-1H-indol-3-yl)-2-pyridinylmethanone (1c).

Pale orange solid (yield 16%), mp 256–257 °C: $^1$H NMR (600 MHz, DMSO-$d_6$) $\delta$ 12.27 (br, 1H), 8.91 (s, 1H), 8.77 (ddd, $J = 1.8, 4.8$ Hz, 1H), 8.53 (d, $J = 2.4$ Hz, 1H), 8.06–8.02 (m, 2H), 7.65 (ddd, $J = 1.2, 4.8, 7.8$ Hz, 1H), 7.52 (d, $J = 9.0$ Hz, 1H), 7.40 (ddd, $J = 2.4, 9.0$ Hz, 1H); $^{13}$C NMR (150 MHz, DMSO-$d_6$) $\delta$ 186.0, 155.7, 148.6, 139.0, 137.5, 134.9, 128.7, 126.4, 125.6, 123.8, 122.9, 114.9, 114.4, 113.2; IR (ATR) 1566 cm$^{-1}$; HRMS (ESI-TOF) $m/z$: [M+H]$^+$. Calcd for C$_{14}$H$_{10}$N$_2$OBr 300.9971; found 300.9988.

$^1$H-Indol-3-yl-3-pyridinylmethanone (2a).

Pale orange solid (yield 35%).

(2-Methyl-1H-indol-3-yl)-3-pyridinylmethanone (2b).

Pale pink solid (yield 17%), mp 199–200 °C: $^1$H NMR (600 MHz, DMSO-$d_6$) $\delta$ 12.08 (br, 1H), 8.77 (ddd, $J = 1.8, 4.8$ Hz, 1H), 8.75 (d, $J = 1.8$ Hz, 1H), 7.98 (ddd, $J = 1.8, 1.8, 7.8$ Hz, 1H), 7.55 (dd, $J = 4.8, 7.8$ Hz, 1H), 7.41 (d, $J = 7.8$ Hz, 1H), 7.35 (d, $J = 7.8$ Hz, 1H), 7.15 (t, $J = 7.8$ Hz, 1H), 7.05 (t, $J = 7.8$ Hz, 1H), 2.39 (s, 3H); $^{13}$C NMR (150 MHz, DMSO-$d_6$) $\delta$ 189.5, 151.6, 148.6, 145.3, 137.1, 135.6, 135.0, 127.1, 123.6, 122.1, 121.3, 119.9, 112.4, 111.4, 14.4; IR (ATR) 1564 cm$^{-1}$; HRMS (ESI-TOF) $m/z$: [M+H]$^+$. Calcd for C$_{15}$H$_{13}$N$_2$O 237.1022; found 237.1029.
(5-Bromo-1H-indol-3-yl)-3-pyridinylmethanone (2c).
Pale orange solid (yield 27%), mp 276–277 °C: ¹H NMR (600 MHz, DMSO-d₆) δ 12.38 (br, 1H), 8.95 (s, 1H), 8.79 (d, J = 4.8 Hz, 1H), 8.40 (s, 1H), 8.17 (d, J = 7.8 Hz, 1H), 8.12 (s, 1H), 7.58 (dd, J = 4.8, 7.8 Hz, 1H), 7.51 (d, J = 9.0 Hz, 1H), 7.42 (d, J = 9.0 Hz, 1H); ¹³C NMR (150 MHz, DMSO-d₆) δ 187.9, 151.8, 148.9, 137.6, 135.6, 135.5, 127.9, 126.0, 123.7, 123.5, 115.0, 114.5; IR (ATR) 1615 cm⁻¹; HRMS (ESI-TOF) m/z: [M+H]⁺. Calcd for C₁₄H₁₀N₂OBr 300.9971; found 300.9976.

1H-Indol-3-yl-4-pyridinylmethanone (3a).
Pale brown solid (yield 25%).

(2-Methyl-1H-indol-3-yl)-4-pyridinylmethanone (3b).
Pale orange solid (yield 25%), mp 231–233 °C: ¹H NMR (600 MHz, DMSO-d₆) δ 12.13 (br, 1H), 8.75 (d, J = 4.8 Hz, 2H), 7.50 (d, J = 4.8 Hz, 2H), 7.40 (d, J = 7.8 Hz, 1H), 7.38 (d, J = 7.8 Hz, 1H), 7.15 (d, J = 7.8 Hz, 1H), 7.06 (d, J = 7.8 Hz, 1H), 2.36 (s, 3H); ¹³C NMR (150 MHz, DMSO-d₆) δ 189.8, 150.3, 150.3, 148.8, 146.0, 135.1, 127.0, 122.3, 121.6, 121.5, 120.0, 111.7, 111.5, 14.5; IR (ATR) 1566 cm⁻¹; HRMS (ESI-TOF) m/z: [M+H]⁺. Calcd for C₁₅H₁₃N₂O 237.1022; found 237.1037.

(5-Bromo-1H-indol-3-yl)-4-pyridinylmethanone (3c).
Pale orange solid (yield 14%), mp 276–278 °C: ¹H NMR (600 MHz, DMSO-d₆) δ 12.41 (br, 1H), 8.78 (d, J = 4.2 Hz, 2H), 8.40 (s, 1H), 8.09 (d, J = 1.2 Hz, 1H), 7.69 (d, J = 4.2 Hz, 2H), 7.52 (d, J = 9.6 Hz, 1H), 7.43 (d, J = 9.6 Hz, 1H); ¹³C NMR (150 MHz, DMSO-d₆) δ 188.4, 150.2, 150.2, 146.5, 138.1, 135.7, 127.7, 126.1, 123.5, 122.1, 115.1, 114.6, 114.0; IR (ATR) 1617 cm⁻¹; HRMS (ESI-TOF) m/z: [M+H]⁺. Calcd for C₁₄H₁₀N₂OBr 300.9971; found 301.0001.

Crystal data of 1b, 1c, 2b, 2c, 3b, and 3c: All measurements were made on a Rigaku Raxis Rapid imaging plate area detector with graphite monochromated Cu-Kα radiation. The data were collected at a temperature of –100 °C. The structure was solved by direct method SIR92 and expanded using Fourier techniques. The non-hydrogen atoms were refined anisotropically. All calculations were performed using the Crystal Structure (Crystal Structure 4.0) crystallographic software package or SHELXL97.

Crystal data of 1b (CCDC: 1954418). C₁₅H₁₂N₂O, mp 196–198 °C, Mr = 236.27, Cu Kα (λ = 1.54187 Å), triclinic, P-1, colorless, block 0.200 × 0.100 × 0.050 mm, crystal dimensions a = 7.393 (3) Å, b = 8.5137 (3) Å, c = 9.7129 (3) Å, α = 80.807°, β = 82.352°, γ = 78.712°, T = 173 K, Z = 2, V =
587.45 (4) Å³, $D_{\text{calc}} = 1.336 \text{ gcm}^{-3}$, $\mu \text{Cu K} \alpha = 6.838 \text{ cm}^{-1}$, $F_{000} = 248.00$, GOF = 1.109, $R_{\text{int}} = 0.0432$, $R_1 = 0.0502$, $wR_2 = 0.1215$.

**Crystal data of 2b** (CCDC: 1954419). $C_{15}H_{12}N_2O$, mp 199–200 °C, $M_r = 236.27$, Cu Kα ($\lambda = 1.54187$ Å), triclinic, $P\overline{1}$, colorless, block $0.100 \times 0.100 \times 0.040$ mm, crystal dimensions $a = 7.3314$ (4) Å, $b = 9.0093$ (5) Å, $c = 9.3743$ (4) Å, $\alpha = 78.142^\circ$, $\beta = 84.247^\circ$, $\gamma = 77.151^\circ$, $T = 173$ K, $Z = 2$, $V = 589.83$ (11) Å³, $D_{\text{calc}} = 1.330 \text{ gcm}^{-3}$, $\mu \text{Cu K} \alpha = 6.811 \text{ cm}^{-1}$, $F_{000} = 248.00$, GOF = 1.132, $R_{\text{int}} = 0.1061$, $R_1 = 0.0869$, $wR_2 = 0.1744$.

**Crystal data of 3b** (CCDC: 1954420). $C_{15}H_{12}N_2O$, mp 231–233 °C, $M_r = 236.27$, Cu Kα ($\lambda = 1.54187$ Å), monoclinic, $P2_1/n$, colorless, block $0.200 \times 0.150 \times 0.100$ mm, crystal dimensions $a = 12.6657$ (2) Å, $b = 7.65408$ (14) Å, $c = 13.2910$ (2) Å, $\alpha = 90^\circ$, $\beta = 111.0288^\circ$, $\gamma = 90^\circ$, $T = 173$ K, $Z = 4$, $V = 1202.67$ (4) Å³, $D_{\text{calc}} = 1.305 \text{ gcm}^{-3}$, $\mu \text{Cu K} \alpha = 6.680 \text{ cm}^{-1}$, $F_{000} = 496.00$, GOF = 1.000, $R_{\text{int}} = 0.0721$, $R_1 = 0.0488$, $wR_2 = 0.0874$.

**Crystal data of 1c** (CCDC: 1954421). $C_{14}H_9OBrN_2O$, mp 256–257 °C, $M_r = 301.14$, Cu Kα ($\lambda = 1.54187$ Å), monoclinic, $C_2/c$, colorless block $0.150 \times 0.100 \times 0.050$ mm, crystal dimensions $a = 25.2774$ (18) Å, $b = 7.3174$ (4) Å, $c = 13.5233$ (9) Å, $\alpha = 90^\circ$, $\beta = 108.094^\circ$, $\gamma = 90^\circ$, $T = 173$ K, $Z = 8$, $V = 2377.6$ (3) Å³, $D_{\text{calc}} = 1.682 \text{ gcm}^{-3}$, $\mu \text{Cu K} \alpha = 46.179 \text{ cm}^{-1}$, $F_{000} = 1200.00$, GOF = 1.345, $R_{\text{int}} = 0.1194$, $R_1 = 0.0886$, $wR_2 = 0.1647$.

**Crystal data of 2c** (CCDC: 1954422). $C_{14}H_9OBrN_2O$, mp 275–277 °C, $M_r = 301.14$, Cu Kα ($\lambda = 1.54187$ Å), orthorhombic, $Pbc_a$, colorless block $0.200 \times 0.050 \times 0.050$ mm, crystal dimensions $a = 12.4555$ (2) Å, $b = 13.2581$ (2) Å, $c = 14.8054$ (3) Å, $\alpha = 90^\circ$, $\beta = 90^\circ$, $\gamma = 90^\circ$, $T = 173$ K, $Z = 8$, $V = 2444.91$ (8) Å³, $D_{\text{calc}} = 1.636 \text{ gcm}^{-3}$, $\mu \text{Cu K} \alpha = 44.908 \text{ cm}^{-1}$, $F_{000} = 1200.00$, GOF = 1.222, $R_{\text{int}} = 0.0508$, $R_1 = 0.0397$, $wR_2 = 0.1195$.

**Crystal data of 3c** (CCDC: 1954423). $C_{14}H_9OBrN_2O$, mp 276–278 °C, $M_r = 301.14$, Cu Kα ($\lambda = 1.54187$ Å), monoclinic, $P2_1/c$, colorless block $0.150 \times 0.100 \times 0.050$ mm, crystal dimensions $a = 16.3977$ (4) Å, $b = 8.6968$ (3) Å, $\alpha = 90^\circ$, $\beta = 107.3810^\circ$, $\gamma = 90^\circ$, $T = 173$ K, $Z = 4$, $V = 1198.13$ (6) Å³, $D_{\text{calc}} = 1.669 \text{ gcm}^{-3}$, $\mu \text{Cu K} \alpha = 45.820 \text{ cm}^{-1}$, $F_{000} = 600.00$, GOF = 1.314, $R_{\text{int}} = 0.0658$, $R_1 = 0.0582$, $wR_2 = 0.1681$. 
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REFERENCES AND NOTES
8. The downfield shift of 2-H of the indole (δ = 8.91 ppm) in the 1H NMR spectrum (in DMSO-d6) was also observed in 1c, which indicates a similar weak hydrogen bond.
11. See the Supporting Information for VT-NMR. In 3'-yl isomers 2a and 2b and 4'-yl isomers 3a and 3b, both ax1 and ax2 always rotated so that the averaged NMR spectra remained the same (–90 °C ~
+120 °C).

12. Exceptionally, NH of the indole was shifted to a lower field as the temperature decreased.
13. Exceptionally, 2-methyl of the indole remained virtually unchanged (−90 °C ~ +120 °C).
14. CCDC 1954418 (1b), CCDC 1954419 (2b), CCDC 1954420 (3b), CCDC 1954421 (1c), CCDC 1954422 (2c), and CCDC 1954423 (3c) contain the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.