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SYNTHESIS OF POLYSUBSTITUTED 5,6-DIHYDROPYRROLO[3,4-*b*]PYRROL-4(1*H*)-ONES FROM 2-[ARYL(AZIDO)METHYL]-1*H*-PYRROLE-3-CARBOXYLATES VIA A CONCISE THREE-STEP SEQUENCE

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Abstract – A concise approach to pyrrolopyrrolone skeletons via a three-step synthesis was developed. The substrates for the transformation could be readily prepared by the reaction of α,γ-diazido-α,β-unsaturated esters with 1,3-dicarbonyl compounds. A total of 14 examples were examined to show the broad substrate scope.

Heterocycles containing a pyrrolopyrrolone ring are important building blocks because these ring systems are the core skeletons of a pharmaceutically important class of heterocyclic compounds with biological activity.[1-3] For example, the anti-cancer therapeutic efficacy of pyrrolopyrrolone-containing bromodomain

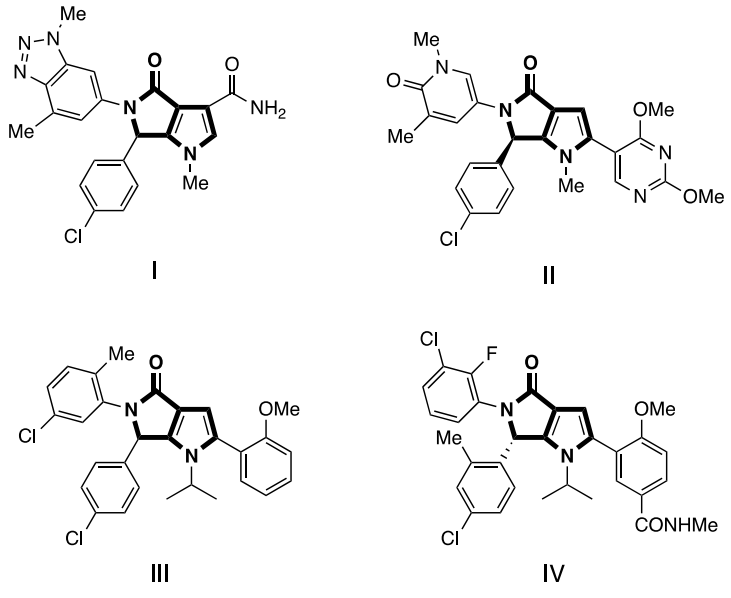
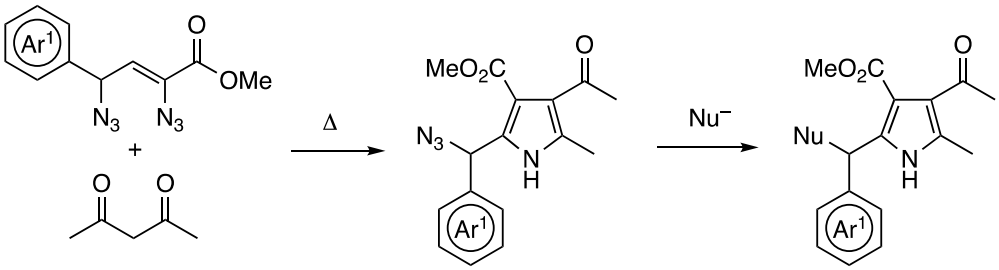


Figure 1. Biologically important synthetic pyrrolopyrrolones

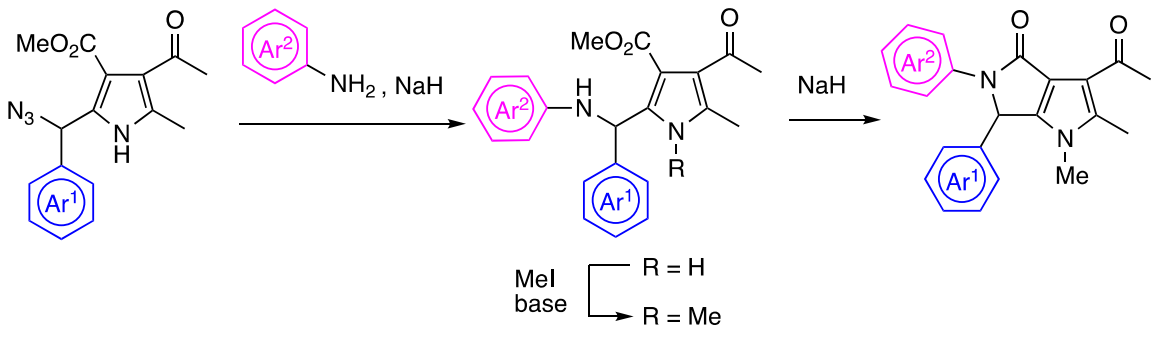
inhibitors has been explored and compounds patented by Novartis.[4,5] Compound I showed potential selectivity toward BRD2 and BRD3 inhibitory activity. CREBBP inhibition was displayed by compound II. Another class of pyrrolopyrrolone compounds, including compounds III and IV, showed potent inhibition of the MDM2/p53 interaction. Blocking the MDM2/p53 protein–protein interaction is an attractive therapeutic strategy for the treatment of cancers.[6]

Recently, the use of combinatorial chemistry for the design and synthesis of polysubstituted complex biological molecules has considerably changed the synthetic strategies available for such complex molecules. In our laboratory, we have developed several novel reactions that provide easy access to useful functionalized N-containing heterocycles of chemical and biological interest.[7-9] As a continuation of our research investigating multicomponent reaction using α,γ-diazido-α,β-unsaturated esters, we herein report a novel for the construction of 5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-ones.

In our previous paper,[7] we reported that the reaction of α,γ-diazido-α,β-unsaturated esters with 1,3-dicarbonyl compounds afforded pyrrole derivatives with an α-azido side chain at the C2 position. Furthermore, substitution of the azido group with various nucleophiles at the α-position occurred smoothly with good yields (**Scheme 1**). Herein, we report a route for the formation of a pyrrolopyrrolone core by a three-step sequence: substitution using arylamine as a nucleophile; followed by methylation of the pyrrole N1 position; and lactam ring formation (**Scheme 2**).

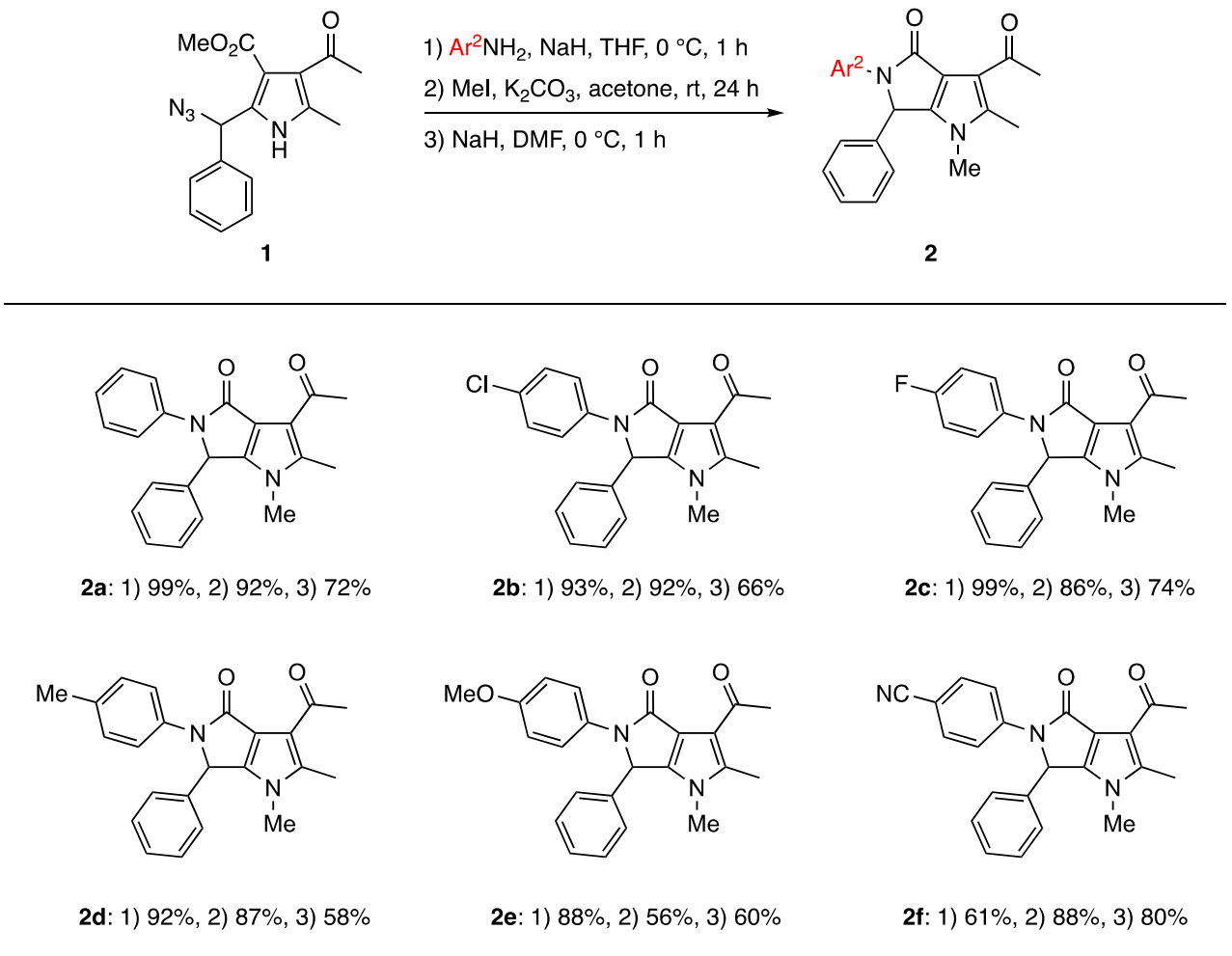


Scheme 1. Previous study for synthesis of polysubstituted pyrroles



Scheme 2. Construction of pyrrolopyrrolone by a three-step sequence

We began the substitution reaction by investigating the reaction of a model substrate, pyrrole derivative **1**, with aniline under the previously reported conditions[7] (**Scheme 3**). When aniline was used as the nucleophile in the presence of NaH in THF, the substitution product was obtained in 99% isolated yield. N1-Methylation of the obtained pyrrole was performed using MeI in the presence of K_2CO_3 in acetone,[10] affording the N1-methylated pyrrole in 92% yield. Finally, treatment of the N1-methylated pyrrole with NaH in DMF gave the pyrrolopyrrolone compound **2a** in 72% yield. The reaction conditions in this sequence were set as the standard conditions, and reactions using various arylamines as the nucleophiles were investigated (**Scheme 3**).

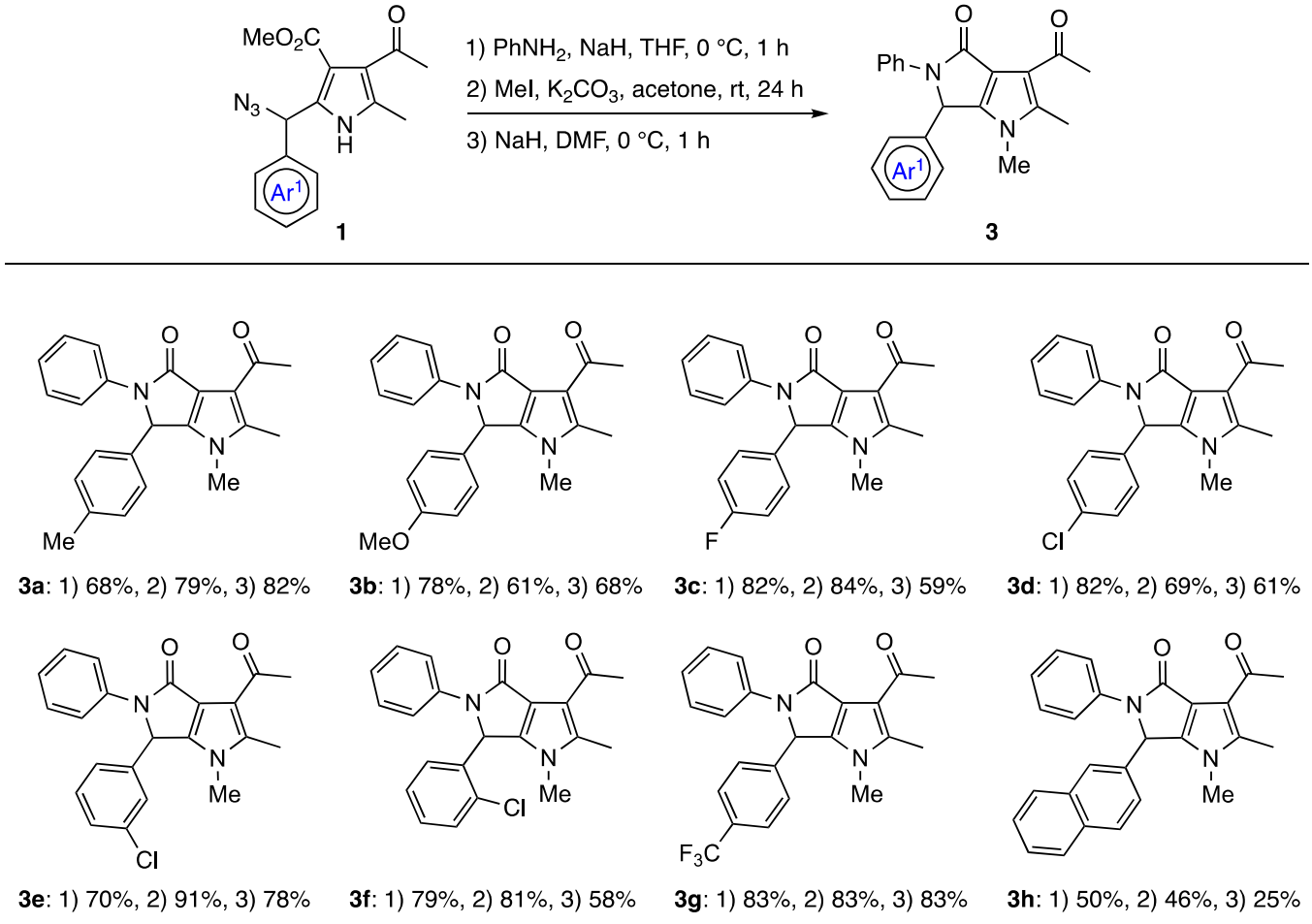


Scheme 3. Scope of nucleophiles

Generally, these reactions proceeded smoothly to generate the series of products **2b**–**f**, with various substituents, in good yields for every steps. For example, Ar^2 could have various groups (4-Cl, 4-F, 4-Me, 4-MeO, and 4-CN) substituted on the phenyl ring to afford the polysubstituted pyrrolopyrrolone **2** in good yields. However, when Ar^2 was a 4-nitrophenyl or 3-pyridyl group, the methylation step failed to give the N1-methylated products (0% and 13%, respectively) although the substitution reaction proceeded to give

the corresponding products in 42% and 96% yields, respectively. The low yields may be due to over alkylation of the secondary amine moiety.

To expand the scope of the three-step sequence, different substrates were used in the reaction with aniline (**Scheme 4**). The reaction of compounds with electron-donating group, such as Me and MeO, and electron-withdrawing groups, such as F, Cl, and CF_3, on the phenyl ring of substrate **1** all proceeded efficiently to give the desired polysubstituted pyrrolopyrrolone **3a**–**g** in good yields. The position of the substituents on the phenyl ring had no effect on the product yields (**3d** vs **3e** vs **3f**). However, the use of 2-naphthyl for Ar^1 in the substrate resulted in lower yields at each step (**3h**), probably due to the steric hinderance.



Scheme 4. Scope of substrates

In summary, we have developed a facile route to synthesize polysubstituted 5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-ones by a three-step sequence. This simple process can incorporate multiple functional groups into a desired pyrrolopyrrolone system, providing an attractive strategy for the synthesis of pharmaceutical building blocks for medicinal chemistry applications. Further studies on the synthetic applications of this procedure are in progress in our laboratory.

EXPERIMENTAL

All experiments were performed in well-dried glassware fitted with rubber septa under an argon atmosphere. Solvents and commercially available chemicals were purified by standard methods or used as purchased. Heated reactions were allowed to run using an oil bath on a hot plate equipped with a temperature probe. Analytical TLC was performed on silica gel plates 60 F_{254} (Merck Co.). Flash column chromatography was performed on silica gel 60A (Kanto Co.). Melting points (Mp) were determined in open capillaries and are uncorrected. IR spectra were recorded on a JASCO FTIR-4100A spectrometer as thin films. NMR spectra were recorded on a JEOL JNM-ECX-500II spectrometer in $CDCl_3$ with TMS as the internal standard. High-resolution ESI mass spectra were recorded with an Orbitrap analyzer in positive or negative ion mode by using an Exactive mass spectrometer at the Global Facility Center, Creative Research Institution (Hokkaido University). Pyrroles **1** used in this study were prepared following our previous work.[7]

General procedure for synthesis of 5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-ones.

[Substitution step] To a solution of pyrrole **1** (1.0 mmol) in 10 mL of THF was added arylamine (2.5 mmol) and sodium hydride (60%, 1.8 mmol) at 0 °C. After the mixture was stirred at 0 °C for 1 h, the reaction was quenched with saturated aqueous NH_4Cl. The organic layer was separated, and the aqueous layer was extracted with CH_2Cl_2. The combined organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was purified by silica gel column chromatography (hexane/AcOEt) to afford the corresponding substitution products.

[Methylation step] To a solution of pyrrole derivative (1.0 mmol), obtained by the above procedure, in 5 mL of acetone was added K_2CO_3 (5.0 mmol) at 0 °C, and the mixture was stirred for 15 min. After addition of iodomethane (2.0 mmol), stirring continued at rt for 24 h. The reaction was quenched with saturated aqueous NH_4Cl. The organic layer was separated, and the aqueous layer was extracted with CH_2Cl_2. The combined organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was purified by silica gel column chromatography (hexane/AcOEt) to afford the N1-methylated pyrrole products.

[Lactam formation step] To a solution of N1-methylated pyrrole derivative (1.0 mmol) in 10 mL of DMF was added sodium hydride (60%, 2.0 mmol) at 0 °C, and the mixture was stirred for 1 h. The reaction was quenched with acetic acid (2.0 mmol) and diluted with water (10 mL) and AcOEt (10 mL). The organic layer was separated, and the aqueous layer was extracted with AcOEt. The combined organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was purified by silica gel column chromatography (hexane/AcOEt) to afford 5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one products.

3-Acetyl-1,2-dimethyl-5,6-diphenyl-5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one (2a): Yellow solids; Mp 201.0–202.0 °C; IR (KBr) : 2923, 1687, 1657, 1597, 1527, 1495, 1374, 1342, 1130 cm^{-1}; ^1H NMR (500

MHz, $CDCl_3$) : δ 7.38 (d, *J* = 7.5 Hz, 2H), 7.24–7.31 (m, 5H), 7.22 (d, *J* = 8.0 Hz, 2H), 7.03 (t, *J* = 7.5 Hz, 1H), 5.85 (s, 1H), 3.22 (s, 3H), 2.87 (s, 3H), 2.55 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) : δ 196.4, 164.8, 147.0, 142.0, 137.8, 135.0, 129.3, 129.1, 128.8, 127.8, 124.9, 123.6, 116.5, 116.4, 60.9, 32.0, 31.2, 11.7; HRMS (ESI) *m/z* $[M + Na]^+$ calcd for $C_{22}H_{20}N_2O_2Na$ 367.1417; found 367.1417.

3-Acetyl-5-(4-chlorophenyl)-1,2-dimethyl-6-phenyl-5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one (2b): White solids; Mp 215.0–216.0 °C; IR (KBr) : 2925, 1694, 1661, 1593, 1534, 1491, 1440, 1378, 1333, 1117 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) : δ 7.25–7.35 (m, 5H), 7.18-7.20 (m, 4H), 5.80 (s, 1H), 3.19 (s, 3H), 2.85 (s, 3H), 2.52 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) : δ 196.1, 164.6, 146.8, 142.1, 136.4, 134.5, 129.9, 129.3, 129.2, 128.7, 127.6, 124.3, 116.4, 116.0, 60.6, 31.9, 31.1, 11.6; HRMS (ESI) *m/z* $[M + Na]^+$ calcd for $C_{22}H_{19}ClN_2O_2Na$ 401.1032; found 401.1027.

3-Acetyl-5-(4-fluorophenyl)-1,2-dimethyl-6-phenyl-5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one (2c): White solids; Mp 167.0–168.0 °C; IR (KBr) : 2969, 1689, 1651, 1509, 1452, 1356, 1291, 1219, 1157, 1111 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) : δ 7.24–7.31 (m, 5 H), 7.18 (d, *J* = 7.5 Hz, 2H), 6.95 (t, *J* = 8.6 Hz, 2H), 5.76 (s, 1H), 2.85 (s, 3H) , 2.55 (s, 3H), 3.21 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) : δ 196.3, 164.8, 160.0 (*J* = 245 Hz), 146.8, 141.9, 134.6, 133.6, 129.3, 129.2, 128.7, 127.7, 126.1, 125.8 (*J* = 8.4 Hz), 116.4, 116.2, 115.5 (*J* = 22.8 Hz), 61.3, 31.9, 31.1, 11.6; HRMS (ESI) *m/z* $[M + Na]^+$ calcd for $C_{22}H_{19}FN_2O_2Na$ 385.1323; found 385.1325.

3-Acetyl-1,2-dimethyl-6-phenyl-5-(*p*-tolyl)-5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one (2d): White solids; Mp 194.0–195.0 °C; IR (KBr) : 3285, 1679, 165, 1640, 1600, 1514, 1414, 1315, 1253, 1161, 1072 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) : δ 7.17–7.28 (m, 7H, Ph), 7.03 (d, *J* = 8.6 Hz, 2H), 5.77 (s, 1H), 3.18 (s, 3H), 2.85 (s, 3H), 2.52 (s, 3H), 2.23 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) : δ 196.4, 164.8, 146.8, 141.7, 135.1, 135.0, 134.7, 129.3, 129.1, 129.0, 127.7, 123.9, 116.4, 61.0, 31.9, 31.1, 20.8, 11.6; HRMS (ESI) *m/z* $[M + Na]^+$ calcd for $C_{23}H_{22}N_2O_2Na$ 381.1574; found 381.1573.

3-Acetyl-5-(4-methoxyphenyl)-1,2-dimethyl-6-phenyl-5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one (2e): White solids; Mp 223.0–224.0 °C; IR (KBr) : 1685, 1649, 1511, 1424, 1353, 1288, 1257, 1178, 1135, 1036 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) : δ 7.17–7.30 (m, 7H), 6.79 (d, *J* = 8.6 Hz, 2H), 5.71 (s, 1H), 3.74 (s, 3H), 3.20 (s, 3H), 2.86 (s, 3H), 2.55 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) : δ 196.5, 165.0, 157.2, 146.7, 141.6, 135.0, 130.5, 129.1, 129.0, 127.8, 126.2, 116.5, 114.0, 61.6, 55.3, 31.9, 31.1, 11.6; HRMS (ESI) *m/z* $[M + Na]^+$ calcd for $C_{23}H_{22}N_2O_3Na$ 397.1523; found 397.1527.

3-Acetyl-5-(4-cyanophenyl)-1,2-dimethyl-6-phenyl-5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one (2f): White solids; Mp 254.0–255.0 °C; IR (KBr) : 2229, 1694, 1657, 1604, 1510, 1441, 1334, 1185, 1111 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) : δ 7.68, (d, *J* = 9.2 Hz, 2H), 7.53 (d, *J* = 9.2 Hz, 2H), 7.17–7.30 (m, 5H), 5.91 (s, 1H), 3.24 (s, 3H), 2.85 (s, 3H), 2.54 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) : δ 195.8, 164.5, 147.1, 142.7, 142.2, 134.1, 132.9, 132.8, 129.6, 129.4, 129.0, 127.4, 121.1, 119.9, 118.8, 116.5, 115.5,

106.5, 60.0, 31.9, 31.1, 11.6; HRMS (ESI) *m/z* [M + Na]$^+$ calcd for $C_{23}H_{19}N_3O_2Na$ 392.1370; found 392.1371.

3-Acetyl-1,2-dimethyl-5-phenyl-6-(*p*-tolyl)-5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one (3a): White solids; Mp 204.0–204.5 °C; IR (KBr) : 3014, 2920, 2370, 2351, 1686, 1597, 1532, 1501, 1378, 1346 cm^{-1}; H NMR (500 MHz, $CDCl_3$) : δ 7.38 (d, *J* = 7.4 Hz, 2H), 7.26–7.22 (m, 2H), 7.08–7.04 (m, 5H), 5.81 (s, 1H), 3.19 (s, 3H), 2.87 (s, 3H), 2.52 (s, 3H), 2.27 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) : δ 196.5, 164.9, 147.2, 141.9, 139.0, 137.9, 131.8, 130.0, 128.8, 127.7, 124.8, 123.6, 116.5, 116.4, 60.6, 32.0, 31.2, 21.3, 11.7; HRMS (ESI) *m/z* [M + Na]$^+$ calcd for $C_{23}H_{22}N_2O_2Na$ 381.1574; found 381.1572.

3-Acetyl-6-(4-methoxyphenyl)-1,2-dimethyl-5-phenyl-5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one (3b): White solids; Mp 222.5–223.0 °C; IR (KBr) : 3001, 2966, 2934, 2839, 2362, 2351, 1685, 1651, 1533, 1514, 1350, 1254, 1177, 1026 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) : δ 7.36 (d, *J* = 7.4 Hz, 2H), 7.23 (t, *J* = 8.0 Hz, 2H), 7.11 (d, *J* = 9.2 Hz, 2H), 7.03 (t, *J* = 7.4 Hz, 1H), 6.79 (d, *J* = 8.6 Hz, 2H), 5.80 (s, 1H), 3.73 (s, 3H), 3.18 (s, 3H), 2.87 (s, 3H), 2.51 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) : δ 196.4, 164.8, 160.0, 147.2, 141.9, 137.8, 129.0, 128.7, 126.6, 124.8, 123.7, 116.4, 116.3, 114.6, 114.0, 60.2, 55.3, 32.0, 31.1, 11.7; HRMS (ESI) *m/z* [M + Na]$^+$ calcd for $C_{23}H_{22}N_2O_3Na$ 397.1523; found 397.1526.

3-Acetyl-6-(4-fluorophenyl)-1,2-dimethyl-5-phenyl-5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one (3c): White solids; Mp 191.0–192.0 °C; IR (KBr) : 3007, 2921, 2367, 2354, 1906, 1689, 1646, 1508, 1378, 1345, 1226 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) : δ 7.35–7.34 (m, 2H), 7.27–7.24 (m, 2H), 7.19 (q, *J* = 4.6 Hz, 2H), 7.08 (d, *J* = 7.4 Hz, 1H), 6.98 (t, *J* = 8.6 Hz, 2H), 5.85 (s, 1H), 3.21 (s, 3H), 2.86 (s, 3H), 2.54 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) : δ 196.2, 164.5, 162.8 (*J* = 248 Hz), 146.5, 141.9, 137.4, 130.7, 129.5 (*J* = 8.4 Hz), 128.8, 125.0, 123.7, 116.3 (*J* = 22.8 Hz), 60.0, 31.9, 31.1, 11.6; HRMS (ESI) *m/z* [M + Na]$^+$ calcd for $C_{22}H_{19}FN_2O_2Na$ 385.1323; found 385.1324.

3-Acetyl-6-(4-chlorophenyl)-1,2-dimethyl-5-phenyl-5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one (3d): White solids; Mp 219.0–220.0 °C; IR (KBr) : 3065, 2361, 1685, 1647, 1532, 1490, 1378, 1348, 1128, 1013 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) : δ 7.35 (d, *J* = 8.6 Hz, 2H), 7.27–7.23 (m, 4H), 7.15 (d, *J* = 8.6 Hz, 2H), 7.06 (t, *J* = 7.4 Hz, 1H), 5.84 (s, 1H), 3.20 (s, 3H), 2.86 (s, 3H), 2.52 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) : δ 196.3, 164.6, 146.5, 142.1, 137.5, 135.0, 133.6, 130.4, 129.6, 129.1, 128.9, 128.8, 125.1, 123.7, 120.0, 116.5, 116.5, 60.0, 32.0, 31.3, 11.7; HRMS (ESI) *m/z* [M + Na]$^+$ calcd for $C_{22}H_{19}ClN_2O_2Na$ 401.1027; found 401.1029.

3-Acetyl-6-(3-chlorophenyl)-1,2-dimethyl-5-phenyl-5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one (3e): White solids; Mp 170.0–171.0 °C; IR (KBr) : 3007, 2926, 2352, 2245, 1666, 1651, 1534, 1493, 1378, 1353 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) : δ 7.36 (dd, *J* = 8.6, 1.1 Hz, 2H), 7.30–7.24 (m, 5H), 7.20 (m, 1H), 7.09 (m, 1H), 5.82 (s, 1H), 3.24 (s, 3H), 2.86 (s, 3H), 2.55 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) : δ 196.3, 164.6,

146.3, 142.2, 137.5, 137.3, 135.3, 130.6, 129.5, 129.0, 127.8, 126.0, 125.2, 123.7, 116.6, 116.6, 60.2, 32.0, 31.3, 11.7; HRMS (ESI) *m/z* $[M + Na]^+$ calcd for $C_{22}H_{19}ClN_2O_2Na$ 401.1027; found 401.1028.

3-Acetyl-6-(2-chlorophenyl)-1,2-dimethyl-5-phenyl-5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one (3f): White solids; Mp 185.5–186.5 °C; IR (KBr) : 3022, 2999, 2366, 2350, 1686, 1645, 1534, 1377, 1348 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) : δ 7.48 (d, *J* = 7.4 Hz, 2H), 7.38 (dd, *J* = 8.0, 1.1 Hz, 1H), 7.28–7.15 (m, 4H), 7.03–7.01 (m, 2H), 6.58 (s, 1H), 3.29 (s, 3H), 2.87 (s, 3H), 2.53 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) : δ 196.3, 164.8, 147.0, 142.2, 137.8, 133.8, 132.3, 130.2, 129.9, 128.9, 128.4, 128.3, 124.5, 122.2, 116.7, 116.6, 55.7, 32.0, 31.2, 11.7; HRMS (ESI) *m/z* $[M + Na]^+$ calcd for $C_{22}H_{19}ClN_2O_2Na$ 401.1027; found 401.1028.

3-Acetyl-1,2-dimethyl-5-phenyl-6-(4-(trifluoromethyl)phenyl)-5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one (3g): White solids; Mp 105.0–106.0 °C; IR (KBr) : 3360, 3005, 2921, 2368, 2351, 2243, 1946, 1684, 1652, 1379, 1356, 1325, 1167, 1128 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) : δ 7.56 (d, *J* = 8.0 Hz, 2H), 7.36 (d, *J* = 8.0 Hz, 4H), 7.28–7.25 (m, 2H), 7.07 (t, *J* = 7.4 Hz, 1H), 5.93 (s, 1H), 3.21 (s, 3H), 2.86 (s, 3H), 2.53 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) : δ 196.1, 164.5, 146.1, 142.2, 139.2, 137.3, 128.9, 128.1, 126.3, 126.2, 125.1, 123.5, 116.5, 60.0, 31.9, 31.2, 11.6; HRMS (ESI) *m/z* $[M + Na]^+$ calcd for $C_{22}H_{19}F_3N_2O_2Na$ 435.1291; found 435.1289.

3-Acetyl-1,2-dimethyl-6-(naphthalen-2-yl)-5-phenyl-5,6-dihydropyrrolo[3,4-*b*]pyrrol-4(1*H*)-one (3h): White solids; Mp 75.5–76.5 °C; IR (KBr) : 3676, 3567, 3061, 2960, 2925, 2854, 2348, 1697, 1655, 1531, 1377, 1340 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) : δ 7.81–7.75 (m, 4H), 7.50–7.48 (m, 2H), 7.42–7.40 (m, 2H), 7.26–7.16 (m, 3H), 7.03 (d, *J* = 7.4 Hz, 1H), 6.01 (s, 1H), 3.18 (s, 3H), 2.90 (s, 3H), 2.53 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) : δ 196.5, 164.9, 142.1, 137.8, 133.6, 133.2, 132.5, 129.6, 128.8, 128.0, 127.9, 127.9, 126.9, 126.8, 125.0, 124.0, 123.8, 116.6, 61.1, 32.1, 31.2, 11.7; HRMS (ESI) *m/z* $[M + Na]^+$ calcd for $C_{26}H_{22}N_2O_2Na$ 417.1574; found 417.1572.

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REFERENCES AND NOTES

1. A. Ghoshal, D. Yugandhar, and A. K. Srivastava, *Expert Opin. Ther. Pat.*, 2016, **26**, 505.
2. Z. Liu, P. Wang, H. Chen, E. A. Wold, B. Tian, A. R. Brasier, and J. Zhou, *J. Med. Chem.*, 2017, **60**, 4533.
3. Y. Duan, Y. Guan, W. Qin, X. Zhai, B. Yu, and H. Liu, *Med. Chem. Commun.*, 2018, **9**, 1779.
4. S. Cotesta, P. Furet, V. Guagnano, P. Holzer, J. Kallen, R. Mah, K. Masuya, A. Schlapbach, S. Stutz, and A. Vaupel, *WO2013175417*.

5. J. Blank, G. Bold, V. Bordas, S. Cotesta, V. Guagnano, H. Rüeger, and A. Vaupel, *WO2015075665*.
6. Y. Fang, G. Liao, and B. Yu, *Acta Pharm. Sin. B*, 2020, **10**, 1253.
7. N. Kishii, M. Shimadu, S. Maruyama, S. Tou, I. Sasaki, and H. Sugimura, *Tetrahedron Lett.*, 2018, **59**, 776.
8. H. Sugimura, R. Takeuchi, S. Ichikawa, E. Nagayama, and I. Sasaki, *Org. Lett.*, 2018, **20**, 3434.
9. T. Kodama, I. Sasaki, and H. Sugimura, *J. Org. Chem.*, 2021, **86**, 8926.
10. Examples for *N*1-alkylation of pyrrole derivatives; (a) A. Fürstner, H. Weintritt, and A. Hupperts, *J. Org. Chem.*, 1995, **60**, 6637; (b) J.-H. Liu, Q.-C. Yang, T. C. W. Mak, and H. N. C. Wong, *J. Org. Chem.*, 2000, **65**, 3587.