

Synthesis of furo[3,2-*c*]- and pyrano[3,2-*c*]quinolines by lanthanide triflate catalyzed imino-Diels-Alder reaction

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Imino Diels-Alder reaction of imines with 2,3-dihydrofuran or 3,4-dihydro-2*H*-pyran proceeded smoothly in the presence of a catalytic amount (0.5 mol %) of ytterbium triflate to afford furo[3,2-*c*]- and pyrano[3,2-*c*]quinolines conveniently in high yield.

Keywords Imino Diels-Alder, furo[3,2-*c*]- and pyrano[3,2-*c*]quinolines, lanthanide triflate

Introduction

Tetrahydroquinoline derivatives are an important class of natural products and exhibit biological activities in various fields,¹ such as psychotropic activity,² antiallergic activity,³ anti-inflammatory activity⁴ and estrogenic activity.⁵ In addition, pyrano quinoline derivatives are used as a potential pharmaceuticals.⁶ Therefore, many synthetic methods for their synthesis have been developed.⁷ Of the methods, aza-Diels-Alder reaction between *N*-arylimines and nucleophilic olefins is one of the most powerful synthetic tools for constructing *N*-containing six-membered heterocyclic compounds. $\text{BF}_3 \cdot \text{OEt}_2$ has been mainly used for this purpose since the pioneering work of Povarov⁸ and transition metal catalysts such as $\text{Co}_2(\text{CO})_8$, $\text{Ni}(\text{CO})_4$ ⁹ as well as InCl_3 ¹⁰ have also been found to be effective. The rare earth metal triflates are excellent water tolerant and reusable catalysts and have unique properties compared to traditional Lewis acids in several important carbon-carbon bond forming reactions, such as aldol condensations,¹¹ Friedel-Crafts acylations¹² and ring-opening reactions of epox-

ides.¹³ We had reported that glyoxylates react smoothly with alkenes in the presence of ytterbium triflate¹⁴ and one-pot synthesis of amino phosphonates from aldehydes using ytterbium triflate as catalyst.¹⁵ Takaki⁷ had ever reported the catalytic reaction of *N*-aryldimines with vinyl ethers, but the amount of catalyst was not screened in detail and afforded products was in low yield together with by-product. We improved this reaction and found that the amount of lanthanide triflate catalyst affects strongly the yield of products and chemical selectivity. In the presence of $\text{Yb}(\text{OTf})_3$ (0.5 mol%), the reaction of imines with 2,3-dihydrofuran or 3,4-dihydro-2*H*-pyran afforded pyrano[3,2-*c*]- and furo[3,2-*c*]quinolines in high yield.

Results and discussion

Benzylideneaniline (**1a**) was treated with 2,3-dihydrofuran (**2**) in the presence of a catalytic amount $\text{Yb}(\text{OTf})_3$ (0.5 mol%) in acetonitrile at room temperature. The reaction proceeded smoothly to afford two isomers furo[3,2-*c*]quinolines **3a** and **4a** in a ratio of 35:65 with an overall yield of 92% (Scheme 1). The reaction is instantaneous and produce the furo[3,2-*c*]quinolines stereoisomers **3a** and **4a** as mixture of *cis* and *trans* isomers as expected. Among the lanthanide triflate screened, $\text{Yb}(\text{OTf})_3$ exhibited the superior catalytic activity, while the yield of the adduct was lower for other lanthanide triflates (Table 1, Entries 9—10). Various amounts were used in the model reaction in the acetonitrile.

Received June 29, 1999; accepted November 12, 1999.

Project supported by the National Natural Science Foundation of China and Postdoctoral Foundation of China.

trile, and 0.5 mol% $\text{Yb}(\text{OTf})_3$ was the best yield up to 92%.

Table 1 Effect of metal salts on the reaction of benzylideneaniline and 2,3-dihydrofuran

Entry	Catalyst	Amount of catalyst (mol%)	Yield (%) ^a
1	$\text{Yb}(\text{OTf})_3$	none	no reaction
2	$\text{Yb}(\text{OTf})_3$	10	52
3	$\text{Yb}(\text{OTf})_3$	5	80
4	$\text{Yb}(\text{OTf})_3$	1.25	83
5	$\text{Yb}(\text{OTf})_3$	0.8	90
6	$\text{Yb}(\text{OTf})_3$	0.5	92
7	$\text{Yb}(\text{OTf})_3$	0.3	85
8	$\text{Yb}(\text{OTf})_3$	0.1	81
9	$\text{Sc}(\text{OTf})_3$	0.5	62
10	$\text{La}(\text{OTf})_3$	0.5	39
11	$\text{Ce}(\text{OTf})_3$	0.5	27

^a isolated yield.

Several imines were examined and the results are listed in Table 2. In all cases, the reaction proceeded smoothly to give the corresponding furo[3,2-*c*]quinolines. The two stereo isomers **3** and **4** could be separated by column chromatography.

Furthermore, benzylideneaniline derivatives were treated with 3,4-dihydro-2*H*-pyran in the presence of a catalytic amount $\text{Yb}(\text{OTf})_3$ (0.5 mol%) in acetonitrile at room temperature. The reaction proceeded smoothly to afford the corresponding pyrano[3,2-*c*]quinolines in high yield, too. It shows that $\text{Yb}(\text{OTf})_3$ does effectively catalyze imino Diels-Alder reaction (Table 3). Recently we have reported¹⁸ that in the presence of 20 mol% of GdCl_3 the imine reacted with dihydropyran or dihydrofuran to afford the corresponding imino Diels-Alder

adduct, a pyrano [3,2-*c*]- or furo [3,2-*c*] quinolines in high yields. In comparison with GdCl_3 , we found the catalytic activity of $\text{Yb}(\text{OTf})_3$ is higher and it is 40 times active as GdCl_3 . Among lanthanide compounds, lanthanide triflates were expected to be some of the strongest Lewis acids because of the electrowithdrawing of the trifluoromethane sulfonyl group. Moreover, the $\text{Yb}(\text{OTf})_3$ could be easily recovered almost quantitatively from the aqueous layer after the reaction was completed by simple evaporation and it could be reused. On the contrary, the recovering process of GdCl_3 is complicate.

The structures of compounds **3**, **4**, **7** and **8** were characterized by IR, ¹H NMR, ¹³C NMR, MS and elemental analyses. There are strong NH stretching bands at 3200–3450 cm^{-1} in the IR spectra. The most diagnostic parameter for structural assignment is the scalar coupling constant between protons H-4a and H-5 (Fig. 1). In the isomer **7a** the coupling constant $J(4a,5) = 5.6$ Hz is significantly smaller and typical for *gauche*. This orientation is present in both conformers of the configuration having *cis* orientation of the pyranoid ring and phenyl group. As expected for this configuration, reciprocal interactions between protons H-4a, H-5 and H-10b were observed in NOSEY (Fig. 1). In the isomer **8a** the $J(4a,5) = 10.8$ Hz is relevant and indicative of *anti* reciprocal orientation of protons H-5 and H-4a. This orientation is only possible when the pyranoid ring and phenyl group are on opposite sides of the quinoline ring of **8a**. The NOE analysis confirms this structural assignment for **8a**: a strong reciprocal interaction is found between H-4a and H-10b, a weak one between protons H-4a and H-5, but none between protons H-10b and H-5 and the reciprocal orientation is *trans*.

Scheme 1

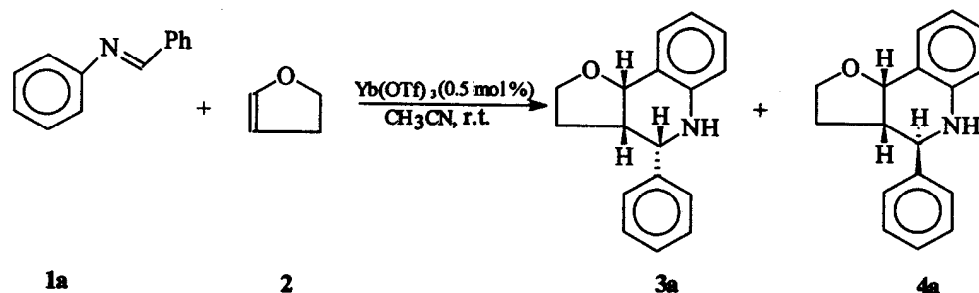
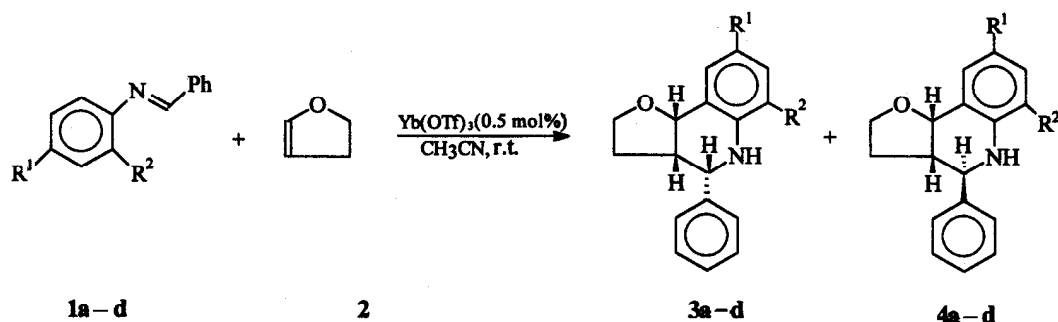
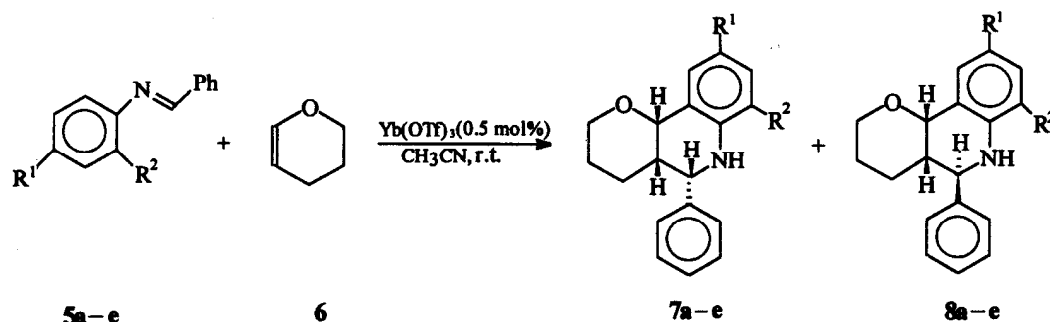


Table 2 Synthesis of furo[3,2-*c*]quinolines by lanthanide triflate catalyzed imino-Diels-Alder reaction

Entry	Schiff's base	Substituent		Time (min)	Product ratio of 3:4	Overall Yield (%) ^a
		R ¹	R ²			
1	1a	H	H	10	35:65	92
2	1b	H	OCH ₃	25	43:57	84
3	1c	CH ₃	H	30	30:70	92
4	1d	H	Cl	30	38:65	94

^a isolated yield**Table 3** Synthesis of pyrano[3,2-*c*]quinolines by lanthanide triflate catalyzed imino-Diels-Alder reaction

Entry	Schiff's base	Substituent		Time (min)	Product ratio of 7:8	Overall Yield (%) ^a
		R ¹	R ²			
1	5a	H	H	30	52:48	88
2	5b	H	Cl	45	51:49	87
3	5c	Cl	H	60	45:55	75
4	5d	H	CH ₃	40	41:59	82
5	5e	OCH ₃	H	30	30:66	74

^a isolated yield

The X-ray analysis of compound **7b** was achieved in order to confirm their molecular structure as shown in Fig. 2. The results clearly illustrate that compound **7b** is the *cis*,¹⁶ which is in agreement with the ¹H NMR analysis.

It can be concluded that ytterbium triflate (0.5

mol%) is an efficient catalyst both in the reaction of imines with 2,3-dihydrofuran and 3,4-dihydro-2*H*-pyran to afford furo[3,2-*c*]- and pyrano[3,2-*c*]quinolines in high yield under the mild conditions. Further synthetic application of these reactions is in progress.

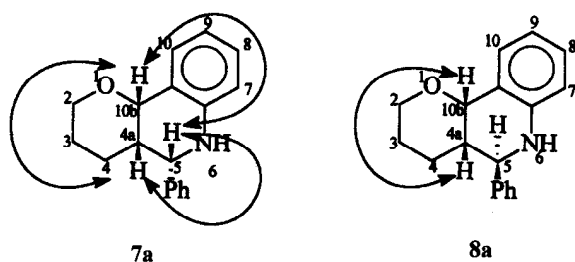


Fig. 1 Significant NOESY correlation (CDCl_3) of compounds 7a and 8a.

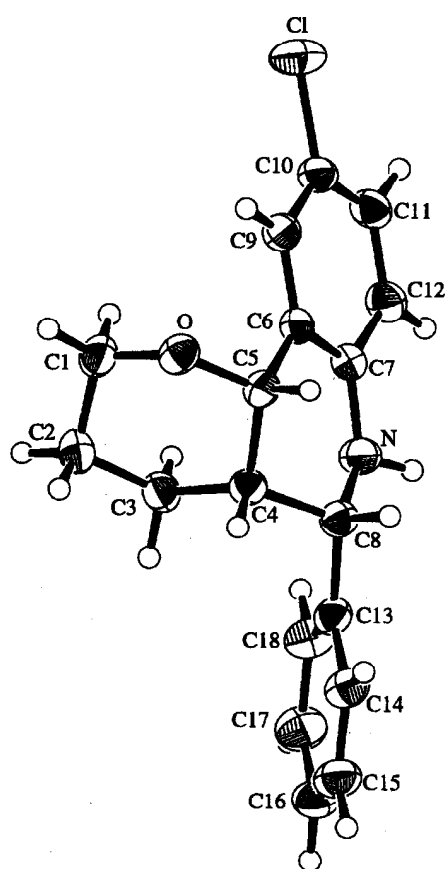


Fig. 2 X-ray molecular structure of 7b with the atom numbering scheme.

Experimental

Melting points were determined on a Kofler hot stage and are uncorrected. CH_3CN was distilled from CaH_2 under Ar. ^1H NMR and ^{13}C NMR spectra were

recorded at 300 MHz or 400 MHz in CDCl_3 using TMS as internal standard. ^{13}C NMR spectral measurements were performed at 75.4 MHz using CDCl_3 as an internal standard. IR spectra were obtained on FTS-185 as neat films. Mass spectra were determined on Finigan 8230 mass spectrometer. Benzylideneaniline was prepared from aniline and benzaldehyde.¹⁷

A typical procedure for the reaction of benzylideneaniline with 2,3-dihydrofuran

$\text{Yb}(\text{OTf})_3$ (3 mg, 0.005 mmol, 0.5 mol%), benzylideneaniline (181 mg, 1.0 mmol) and 2,3-dihydrofuran (1.1 mL, 1.4 mmol) were mixed in 5 mL of acetonitrile, the mixture was stirred at room temperature for 30 min, water was then added and the product was extracted with EtOAc. The organic layer was dried over anhydrous Na_2SO_4 and evaporated to give the crude product. Analytically pure products 3a and 4a were then obtained (231 mg, overall yield 92%) by column chromatography.

3a mp 117–118°C (Lit.⁷ 95°C). ν_{max} : 3348 cm^{-1} . $\delta_{\text{H}}(\text{CDCl}_3)$: 7.47–7.26(m, 6H), 7.08(td, $J = 7.8, 1.5$ Hz, 1H), 6.80(td, $J = 7.8, 1.1$ Hz, 1H), 6.59(dd, $J = 7.8, 1.0$ Hz, 1H), 5.26(d, $J = 8.0$ Hz, 1H), 4.69(d, $J = 3.0$ Hz, 1H), 3.77(m, 3H), 2.75(m, 1H), 2.19(m, 1H), 1.50(m, 1H). $\delta_{\text{C}}(\text{CDCl}_3)$: 144.9, 142.2, 130.1, 128.6, 128.3, 127.6, 126.5, 122.7, 119.2, 114.9, 75.9, 66.8, 57.5, 45.8, 24.7. m/z (%): 251 (M^+ , 85), 206(100). Anal. $\text{C}_{17}\text{H}_{17}\text{NO}$. Calcd: C, 81.28; H, 6.77; N, 5.58. Found: C, 80.88; H, 6.65; N, 5.29.

4a Viscous oil. ν_{max} : 3327 cm^{-1} . $\delta_{\text{H}}(\text{CDCl}_3)$: 7.46–7.24(m, 6H), 7.12(td, $J = 7.7, 1.1$ Hz, 1H), 6.79(td, $J = 7.8, 0.9$ Hz, 1H), 6.62(d, $J = 8.0$ Hz, 1H), 4.59(d, $J = 5.1$ Hz, 1H), 4.08(m, 1H), 3.85(m, 3H), 2.45(m, 1H), 2.01(m, 1H), 1.72(m, 1H). $\delta_{\text{C}}(\text{CDCl}_3)$: 145.3, 141.7, 131.1, 128.8, 128.6, 128.2, 128.0, 120.0, 118.2, 114.6, 76.1, 65.0, 57.6, 43.3, 28.7. m/z (%): 251 (M^+ , 68), 206(100). HRMS Calcd for $\text{C}_{17}\text{H}_{17}\text{NO}$: 251.1299; Found: 251.1409.

The following compounds were prepared similarly; the reaction time and yields were listed in Table 2 and Table 3.

3b mp 132–133°C. ν_{max} : 3300 cm^{-1} . δ_{H}

(CDCl₃): 7.46—7.25(m, 5H), 6.96(d, $J = 2.8$ Hz, 1H), 6.73(dd, $J = 8.6, 2.8$ Hz, 1H), 6.52(d, $J = 8.7$ Hz, 1H), 5.23(d, $J = 8.0$ Hz, 1H), 4.64(d, $J = 2.9$ Hz, 1H), 3.77(s, 3H), 3.52—3.80(m, 3H), 2.75(m, 1H), 2.20(m, 1H), 1.52(m, 1H). δ_{C} (CDCl₃): 153.1, 142.4, 139.0, 128.6, 127.6, 126.5, 123.5, 116.2, 115.8, 113.8, 76.3, 66.9, 57.9, 55.7, 45.9, 24.5. m/z (%): 282(M⁺ + 1, 29), 281(100). Anal. C₁₈H₁₉NO₂. Calcd: C, 76.87; H, 6.76; N, 4.98. Found: C, 76.80; H, 6.77; N, 5.06.

4b mp 94—96°C. ν_{max} : 3298 cm⁻¹. δ_{H} (CDCl₃): 7.46—7.39(m, 5H), 6.99(d, $J = 2.8$ Hz, 1H), 6.80(dd, $J = 8.1, 2.8$ Hz, 1H), 6.61(d, $J = 8.1$ Hz, 1H), 4.63(d, $J = 5.3$ Hz, 1H), 4.06(m, 1H), 3.78(s, 3H), 3.87—3.73(m, 2H), 2.49(br, 1H), 2.01(m, 1H), 1.70(m, 1H), 1.20(m, 1H). m/z (%): 282(M⁺ + 1, 3), 220(100). Anal. C₁₈H₁₉NO₂. Calcd: C, 76.87; H, 6.76; N, 4.98. Found: C, 77.02; H, 6.85; N, 5.17.

3c mp 102—103°C. ν_{max} : 3322 cm⁻¹. δ_{H} (CDCl₃): 7.51—7.33(m, 5H), 7.25(d, $J = 6.6$ Hz, 1H), 6.99(d, $J = 6.6$ Hz, 1H), 6.77(t, $J = 7.5$ Hz, 1H), 5.32(d, $J = 8.0$ Hz, 1H), 4.70(d, $J = 3.0$ Hz, 1H), 3.80—3.66(m, 3H), 2.79(m, 1H), 2.20(m, 1H), 2.14(s, 3H), 1.46(m, 1H). δ_{C} (CDCl₃): 143.1, 142.5, 129.4, 128.7, 127.9, 127.7, 126.6, 122.2, 121.8, 118.4, 76.2, 66.7, 57.3, 45.6, 24.6, 17.2. m/z (%): 265(M⁺, 100). HRMS. Calcd for C₁₈H₁₉NO: 265.1457; Found: 265.1467.

4c mp 92—94°C. ν_{max} : 3401 cm⁻¹. δ_{H} (CDCl₃): 7.46—7.26(m, 6H), 6.99(d, $J = 7.4$ Hz, 1H), 6.72(t, $J = 7.5$ Hz, 1H), 4.55(d, $J = 4.9$ Hz, 1H), 4.02(m, 2H), 3.82(m, 2H), 2.43(m, 1H), 2.08(s, 3H), 1.92(m, 1H), 1.65(m, 1H). δ_{C} (CDCl₃): 143.4, 142.0, 130.0, 129.1, 128.7, 128.4, 128.2, 121.7, 119.4, 117.8, 76.5, 65.1, 57.8, 43.2, 28.9, 17.2. m/z (%): 265(M⁺, 73), 220(100). Anal. C₁₈H₁₉NO. Calcd: C, 81.48; H, 7.16; N, 5.28. Found: C, 81.63; H, 7.28; N, 5.43.

3d mp 153—155°C. ν_{max} : 3342 cm⁻¹. δ_{H} (CDCl₃): 7.42—7.21(m, 6H), 6.98(dd, $J = 8.50, 3.4$ Hz, 1H), 6.48(d, $J = 8.5$ Hz, 1H), 5.16(d, $J = 7.8$ Hz, 1H), 4.63(d, $J = 2.9$ Hz, 1H), 3.80—

3.64(m, 3H), 2.72(m, 1H), 2.14(m, 1H), 1.50(m, 1H). δ_{C} (CDCl₃): 143.4, 141.9, 129.8, 128.8, 128.4, 127.9, 126.6, 124.2, 123.8, 116.2, 75.7, 67.0, 57.4, 45.5, 24.6. m/z (%): 285(M⁺, 100). Anal. C₁₇H₁₆ClNO. Calcd: C, 71.48; H, 5.60; N, 4.90. Found: C, 71.34; H, 5.58; N, 5.13.

4d mp 99—101°C. ν_{max} : 3343 cm⁻¹. δ_{H} (CDCl₃): 7.39—7.28(m, 6H), 7.05(dd, $J = 8.5, 2.4$ Hz, 1H), 6.51(d, $J = 8.5$ Hz, 1H), 4.50(d, $J = 5.1$ Hz, 1H), 3.89—4.25(m, 2H), 3.78(m, 2H), 2.43(m, 1H), 1.98(m, 1H), 1.68(m, 1H). δ_{C} (CDCl₃): 144.0, 141.3, 130.8, 128.9, 128.8, 128.3, 128.2, 122.9, 121.6, 115.9, 75.7, 65.3, 57.8, 43.3, 28.8. m/z (%): 285(M⁺, 100). Anal. C₁₇H₁₆ClNO. Calcd: C, 71.48; H, 5.60; N, 4.90. Found: C, 71.39; H, 5.63; N, 5.07.

7a mp 130—132°C, (Lit.⁷ 128.8—131°C). ν_{max} : 3313 cm⁻¹. δ_{H} (CDCl₃): 7.43—7.25(m, 6H), 7.03(tt, $J = 7.6, 0.7$ Hz, 1H), 6.77(td, $J = 7.6, 1.0$ Hz, 1H), 6.58(dd, $J = 7.8, 0.9$ Hz, 1H), 5.31(d, $J = 5.6$ Hz, 1H), 4.68(d, $J = 2.6$ Hz, 1H), 3.58—3.85(m, 3H), 2.15(m, 1H), 1.50—1.25(m, 4H). δ_{C} (CDCl₃): 145.2, 141.2, 128.4, 128.1, 127.7, 127.6, 126.9, 120.0, 118.4, 114.5, 72.8, 60.7, 59.4, 39.0, 25.5, 18.1. m/z (%): 265(M⁺, 41), 206(100). Anal. C₁₈H₁₉NO. Calcd: C, 81.52; H, 7.16; N, 5.28. Found: C, 81.28; H, 7.23; N, 5.32.

8a Viscous oil. ν_{max} : 3373 cm⁻¹. δ_{H} (CDCl₃): 7.42—7.36(m, 5H), 7.25(dd, $J = 7.1, 0.5$ Hz, 1H), 7.07(td, $J = 7.0, 1.3$ Hz, 1H), 6.70(td, $J = 7.0, 1.1$ Hz, 1H), 6.51(dd, $J = 7.1, 1.0$ Hz, 1H), 4.72(d, $J = 10.8$ Hz, 1H), 4.39(d, $J = 2.7$ Hz, 1H), 4.08(m, 2H), 3.71(td, $J = 11.6, 2.5$ Hz, 1H), 2.11(m, 1H), 1.83(m, 1H), 1.66(m, 1H), 1.48(m, 1H), 1.25(m, 1H). δ_{C} (CDCl₃): 144.7, 142.3, 130.9, 129.3, 128.6, 127.9, 127.8, 120.7, 117.4, 114.2, 74.5, 68.5, 54.9, 38.9, 24.1, 22.1. m/z (%): 265(M⁺, 42), 206(100). HRMS Calcd for C₁₈H₁₉NO: 265.1471; Found: 265.1431.

7b mp 154—156°C. ν_{max} : 3306 cm⁻¹. δ_{H} (CDCl₃): 7.39—7.29(m, 6H), 7.12(d, $J = 7.6$ Hz, 1H), 6.65(t, $J = 7.6$ Hz, 1H), 5.29(d, $J = 5.4$ Hz, 1H), 4.68(d, $J = 2.3$ Hz, 1H), 4.41(br, s, 1H), 3.55(m, 1H), 3.33(m, 1H), 2.12(m,

1H), 1.50—1.41(m, 2H), 1.20(m, 2H). m/z (%): 299(M^+ , 46), 240(100). Anal. $C_{18}H_{18}ClNO$. Calcd: C, 72.15; H, 6.01; N, 4.67. Found: C, 72.35; H, 6.00; N, 4.85.

8b mp 109—101°C. ν_{max} : 3384 cm^{-1} . δ_H ($CDCl_3$): 7.39—7.27(m, 5H), 7.15(m, 2H), 6.64(t, $J = 7.7$ Hz, 1H), 4.66(d, $J = 10.7$ Hz, 1H), 4.58(br, s, 1H), 4.34(d, $J = 2.7$ Hz, 1H), 4.04(dt, $J = 10.0, 2.1$ Hz, 1H), 3.66(td, $J = 10.8, 2.6$ Hz, 1H), 2.01(m, 1H), 1.85(m, 1H), 1.63(m, 1H), 1.48(m, 1H), 1.30(m, 1H). δ_C ($CDCl_3$): 141.9, 141.0, 129.7, 129.3, 129.2, 128.8, 128.1, 127.8, 121.9, 118.1, 117.0, 74.4, 68.6, 54.9, 38.8, 24.0, 22.1. m/z (%): 301($M^+ + 2$, 14), 299(M^+ , 38), 240(100). Anal. $C_{18}H_{18}ClNO$. Calcd: C, 72.15; H, 6.01; N, 4.67. Found: C, 72.10; H, 5.99; N, 4.85.

7c mp 170—172°C. ν_{max} : 3370 cm^{-1} . δ_H ($CDCl_3$): 7.39—7.32(m, 6H), 7.01(dd, $J = 8.2, 0.7$ Hz, 1H), 6.50(d, $J = 8.0$ Hz, 1H), 5.25(d, $J = 5.5$ Hz, 1H), 4.60(d, $J = 2.5$ Hz, 1H), 3.85(br, 1H), 3.60(m, 1H), 3.41(m, 1H), 2.13(m, 1H), 1.51(m, 3H), 1.25(m, 1H). δ_C ($CDCl_3$): 143.7, 140.7, 128.5, 128.1, 127.7, 127.3, 126.8, 123.1, 121.7, 115.6, 72.5, 60.8, 59.3, 38.6, 25.3, 18.1. m/z (%): 301($M^+ + 2$, 33), 299(M^+ , 99), 240(100). Anal. $C_{18}H_{18}ClNO$. Calcd: C, 72.15; H, 6.01; N, 4.67. Found: C, 72.02; H, 6.01; N, 4.78.

8c mp 125—126°C. ν_{max} : 3298 cm^{-1} . δ_H ($CDCl_3$): 7.39—7.30(m, 5H), 7.19(d, $J = 2.3$ Hz, 1H), 7.01(dd, $J = 8.0, 1.9$ Hz, 1H), 6.41(d, $J = 8.1$ Hz, 1H), 4.63(d, $J = 10.6$ Hz, 1H), 4.30(d, $J = 2.8$ Hz, 1H), 4.02(m, 2H), 3.66(td, $J = 15.0, 3.0$ Hz, 1H), 2.01(m, 1H), 1.75(m, 1H), 1.62(m, 1H), 1.45(m, 1H), 1.27(m, 1H). δ_C ($CDCl_3$): 143.3, 142.0, 130.4, 129.2, 128.7, 128.0, 127.7, 121.9, 121.8, 115.3, 74.0, 68.5, 55.0, 38.7, 24.0, 22.1. m/z (%): 301($M^+ + 2$, 19), 299(M^+ , 58), 240(100). Anal. $C_{18}H_{18}ClNO$. Calcd: C, 72.15; H, 6.01; N, 4.67. Found: C, 72.12; H, 6.02; N, 4.81.

7d mp 143—144°C. ν_{max} : 3338 cm^{-1} . δ_H ($CDCl_3$): 7.48—7.32(m, 6H), 7.03(dd, $J = 7.5, 0.6$ Hz, 1H), 6.75(t, $J = 7.5$ Hz, 1H), 5.37(d, $J = 5.5$ Hz, 1H), 4.71(d, $J = 2.4$ Hz, 1H), 3.85—3.34(m, 3H), 2.15(s, 4H), 1.32—1.29(m, 4H). δ_C ($CDCl_3$): 143.3, 141.5, 129.2, 128.5, 127.6,

126.9, 125.5, 121.6, 119.5, 117.8, 73.0, 60.7, 59.3, 38.8, 25.5, 18.1, 17.5. m/z (%): 279(M^+ , 62), 220(100). Anal. $C_{19}H_{21}NO$. Calcd: C, 81.73; H, 7.52; N, 5.01. Found: C, 81.33; H, 7.63; N 5.02.

8d mp 130—132°C. ν_{max} : 3389 cm^{-1} . δ_H ($CDCl_3$): 7.48—7.44(m, 2H), 7.42—7.39(m, 2H), 7.33—7.31(m, 1H), 7.12(dd, $J = 7.5, 1.2$ Hz, 1H), 7.03(dd, $J = 7.5, 0.6$ Hz, 1H), 6.66(t, $J = 7.5$ Hz, 1H), 4.77(d, $J = 9.9$ Hz, 1H), 4.40(d, $J = 2.7$ Hz, 1H), 4.11(dt, $J = 12.3, 2.3$ Hz, 1H), 3.90(br, 1H), 3.73(td, $J = 11.7, 2.5$ Hz, 1H), 2.11(m, 1H), 2.07(s, 3H), 1.87(m, 1H), 1.69(m, 1H), 1.49(m, 1H), 1.32(m, 1H). δ_C ($CDCl_3$): 142.8, 142.7, 130.3, 128.9, 128.7, 128.0, 127.9, 121.2, 120.2, 117.0, 74.9, 68.7, 55.0, 38.9, 24.2, 22.1, 17.3. m/z (%): 279(M^+ , 40), 220(100). Anal. $C_{19}H_{21}NO$. Calcd: C, 81.73; H, 7.52; N, 5.01. Found: C, 81.70; H, 7.65; N, 5.13.

7e mp 144—146°C (Lit.⁷ 144—146°C). ν_{max} : 3401 cm^{-1} . δ_H ($CDCl_3$): 7.44—7.26(m, 5H), 7.02(d, $J = 2.8$ Hz, 1H), 6.75(dd, $J = 8.7, 2.8$ Hz, 1H), 6.60(d, $J = 8.7$ Hz, 1H), 5.30(d, $J = 5.3$ Hz, 1H), 4.60(d, $J = 1.9$ Hz, 1H), 3.75(s, 3H), 3.55(m, 1H), 3.33(m, 1H), 3.85—3.12(br, 1H), 2.08(m, 1H), 1.48—1.24(m, 4H). m/z (%): 295(M^+ , 100). Anal. $C_{19}H_{21}NO_2$. Calcd: C, 77.30; H, 7.11; N, 4.74. Found: C, 77.12; H, 7.25; N 4.95.

8e mp 98—100°C. ν_{max} : 3373 cm^{-1} . δ_H ($CDCl_3$): 7.37—7.27(m, 5H), 6.79(d, $J = 2.8$ Hz, 1H), 6.65(dd, $J = 8.4, 2.8$ Hz, 1H), 6.45(d, $J = 8.4$ Hz, 1H), 4.60(d, $J = 10.4$ Hz, 1H), 4.31(d, $J = 2.8$ Hz, 1H), 4.04(m, 1H), 3.70(s, 3H), 3.64(m, 1H), 2.05(m, 1H), 1.75(m, 1H), 1.61(m, 1H), 1.43(m, 1H), 1.25(m, 1H). δ_C ($CDCl_3$): 152.0, 142.4, 139.0, 128.6, 127.8, 121.4, 116.9, 115.5, 114.9, 74.6, 68.5, 55.9, 55.3, 39.0, 24.2, 22.1. m/z (%): 295(M^+ , 100). Anal. $C_{19}H_{21}NO_2$. Calcd: C, 77.30; H, 7.11; N, 4.74. Found: C, 77.48; H, 7.23; N, 4.92.

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 16. Colorless prismatic crystal of **7b** with dimensions 0.2 × 0.2 × 0.3 mm was mounted on a Rigaku AFC7R diffractometer. 2787 reflections measured, maximum 2θ value 49.9°, 2097 unique reflections measured ($R_{int} = 0.037$), 1645 of these with $I > 3.00\sigma(I)$ used in refinement. The data were corrected for horizon and polarization effects. The structure was solved by direct methods using SHELXS-86 of expanded using Fourier technique. The non-hydrogen atoms were refined anisotropically, hydrogen atoms were included but not refined. The final cycle of full-matrix least squares refinement was based on 1464 observed reflections of 199 variable parameters. All calculations were performed using the TEXSAN crystallographic software package of Molecular Structure Corporation. Crystal data $C_{18}H_{18}ClNO$, $M_r = 299.80$, mp 154—156°C, triclinic, space group $P1$ (# 2), $a = 0.9992(2)$, $b = 1.1009(2)$, $c = 0.9486(2)$ nm. $\alpha = 99.01(2)^\circ$, $\beta = 112.29(1)^\circ$, $\gamma = 114.27(1)^\circ$, $V = 0.7492(3)$ nm³. $Z = 2$, $D_c = 1.329$ g·cm⁻³, μ (MoK α) = 2.53 cm⁻¹, $F(000) = 316.00$, $R = 0.034$, $R_w = 0.043$.
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