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Supporting Information for the Paper

Asymmetric Synthesis of Unusual Fused Tricyclic β-Lactam Structures via Aza-Cycloadditions/Ring Closing Metathesis

Benito Alcaide,*[a] Pedro Almendros,*[b] Jose M. Alonso,[a] and María C. Redondo[a]

[a]*Departamento de Química Orgánica I. Facultad de Química. Universidad Complutense 28040-Madrid. Spain*

[b]*Instituto de Química Orgánica General, CSIC, Juan de la Cierva 3, 28006-Madrid, Spain*

E-mail: alcaideb@quim.ucm.es; iqoa392@iqog.csic.es

Spectroscopic and analytical data for some representative forms of **2** follow.

C4,C4'-bis-2-azetidinone (+)-2b. From 97 mg (0.573 mmol) of aldehyde (+)-**1a** and 61 mg (0.86 mmol) of homoallylamine, after column chromatography eluting with ethyl acetate/hexanes (1:1), 157 mg (77%) of the compound (+)-**2b** was obtained. Colorless oil. $[\alpha]_D$ = +12.9 (*c* 0.7, $CHCl_3$). ^{1}H-NMR: δ 2.33 (m, 2H), 3.07 (m, 1H), 3.67 (m, 5H), 4.17 (m, 3H), 4.60 (d, 1H, *J* = 5.1 Hz), 5.15 (m, 4H), 5.26 (d, 1H, *J* = 5.1 Hz), 5.75 (m, 2H), 7.04 (m, 3H), 7.27 (m, 2H). ^{13}C-NMR: δ 167.4, 165.8, 157.0, 146.4, 135.0, 131.6, 129.9, 122.8, 118.2, 117.4, 115.8, 83.4, 80.3, 77.8, 59.3, 56.3, 56.2, 44.1, 41.0, 32.1. IR ($CHCl_3$, cm^{-1}): ν 1766, 1752. MS (CI), *m/z*: 357 (M^+ + 1, 100), 356 (M^+, 11). (Anal. Calcd. for $C_{20}H_{24}N_2O_4$: C, 67.40; H, 6.79; N, 7.86. Found: C, 67.47; H, 6.77; N, 7.88).

Spectroscopic and analytical data for some representative forms of **4** and **5** follow.

Preparation of Cycloadducts (+)-4a and (+)-5a. From 400 mg (2.35 mmol) of the aldehyde (+)-**1a** and 314 mg (3.53 mmol) of glycine methyl ester, after column chromatography eluting with ethyl acetate/hexanes (7:1 containing 10% of triethylamine), 261 mg (34%) of the less polar compound (+)-**4a** and 138 mg (18%) of the more polar compound (+)-**5a** were obtained.

Cycloadduct (+)-4a. Colorless oil. $[\alpha]_D$ = +15.3 (*c* 0.5, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 2.32 (m, 2H), 3.17 (m, 1H), 3.35 (dd, 1H, *J* = 10.2, 6.8 Hz), 3.59 (s, 3H), 3.68 (m, 4H), 3.78 (s, 3H), 3.86 (m, 2H), 4.17 (dd, 1H, *J* = 15.6, 4.9 Hz), 4.41 (d, 1H, *J* = 4.9 Hz), 5.26 (m, 2H), 5.76 (m, 1H).

^{13}C-NMR ($CDCl_3$): δ 174.0, 173.9, 167.6, 132.0, 118.8, 83.8, 63.6, 59.8, 59.6, 59.1, 52.4, 51.8, 45.5, 43.9, 34.3. IR ($CHCl_3$, cm^{-1}): ν 3336, 1735. MS (CI), *m/z* : 327 (M^+ + 1, 100), 326 (M^+, 21). (Anal. Calcd. for $C_{15}H_{22}N_2O_6$: C, 55.21; H, 6.79; N, 8.58. Found: C, 55.27; H, 6.78; N, 8.60).

Cycloadduct (+)-5a. Colorless oil. $[\alpha]_D$ = +60.6 (*c* 0.6, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 2.40 (m, 2H), 3.02 (m, 1H), 3.39 (dd, 1H, *J* = 8.5, 5.8 Hz), 3.59 (s, 3H), 3.65 (m, 4H), 3.89 (m, 3H), 4.49 (d, 1H, *J* = 5.0 Hz), 5.16 (m, 2H), 5.72 (m, 1H). ^{13}C-NMR ($CDCl_3$): δ 173.6, 173.1, 167.7, 132.3, 117.2, 83.9, 62.8, 59.1, 58.4, 57.6, 52.1, 51.8, 44.8, 43.2, 32.4. IR ($CHCl_3$, cm^{-1}): ν 3334, 1732. MS (CI), *m/z* : 327 (M^+ + 1, 100), 326 (M^+, 17). (Anal. Calcd. for $C_{15}H_{22}N_2O_6$: C, 55.21; H, 6.79; N, 8.58. Found: C, 55.15; H, 6.77; N, 8.59).

Preparation of Cycloadducts (+)-4e and (+)-5e. From 254 mg (1.38 mmol) of the aldehyde (+)-**1b** and 214 mg (2.07 mmol) of alanine methyl ester, after column chromatography eluting with ethyl acetate/hexanes (6:1 containing 10% of triethylamine), 206 mg (42%) of the less polar compound (+)-**4e** and 117 mg (24%) of the more polar compound (+)-**5e** were obtained.

Cycloadduct (+)-4e. Colorless oil. $[\alpha]_D$ = +47.5 (*c* 0.5, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 1.27 (s, 3H), 1.90 (dd, 1H, *J* = 13.7, 7.6 Hz), 2.31 (m, 2H), 2.50 (dd, 1H, *J* = 13.7, 4.1 Hz), 3.13 (m, 1H), 3.38 (m, 5H), 3.51 (s, 3H), 3.71 (s, 3H), 4.29 (d, 1H, *J* = 4.7 Hz), 5.07 (m, 2H), 5.67 (m, 1H). ^{13}C-NMR ($CDCl_3$): δ 176.7, 173.9, 168.1, 135.4, 117.1, 83.6, 65.7, 62.5, 59.6, 59.5, 52.6, 51.8, 46.7, 41.5, 40.8, 32.3, 27.5. IR ($CHCl_3$, cm^{-1}): ν 3340, 1735. MS (CI), *m/z* : 355 (M^+ + 1, 100), 354 (M^+, 21). (Anal. Calcd. for $C_{17}H_{26}N_2O_6$: C, 57.61; H, 7.39; N, 7.90. Found: C, 57.69; H, 7.37; N, 7.88).

Cycloadduct (+)-5e. Colorless oil. $[\alpha]_D$ = +60.3 (*c* 0.6, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 1.37 (s, 3H), 1.86 (dd, 1H, *J* = 13.8, 7.5 Hz), 2.24 (m, 2H), 2.57 (m, 1H), 2.75 (dd, 1H, *J* = 13.8, 1.6 Hz), 3.01 (m, 2H), 3.49 (m, 5H), 3.55 (s, 3H), 3.69 (s, 3H), 3.85 (dd, 1H, *J* = 8.3, 5.0 Hz), 4.41 (d, 1H, *J* = 5.0 Hz), 5.02 (m, 2H), 5.64 (m, 1H). ^{13}C-NMR ($CDCl_3$): δ 176.4, 173.2, 168.1, 134.6, 117.2, 83.7, 63.8, 61.4, 59.2, 57.9, 52.4, 51.8, 46.2, 40.5, 40.1, 32.2, 27.8. IR ($CHCl_3$, cm^{-1}): ν 3342, 1736. MS (CI), *m/z* : 355 (M^+ + 1, 100), 354 (M^+, 14). (Anal. Calcd. for $C_{17}H_{26}N_2O_6$: C, 57.61; H, 7.39; N, 7.90. Found: C, 57.53; H, 7.38; N, 7.92).

Preparation of Cycloadducts (+)-4f and (+)-5f. From 231 mg (1.09 mmol) of the aldehyde (+)-**1c** and 169 mg (1.64 mmol) of alanine methyl ester, after column chromatography eluting with

ethyl acetate/hexanes (5:1 containing 10% of triethylamine), 189 mg (47%) of the less polar compound (+)-**4f** and 132 mg (33%) of the more polar compound (+)-**5f** were obtained.

Cycloadduct (+)-4f. Colorless oil. $[\alpha]_D$ = +50.8 (*c* 0.7, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 1.38 (s, 3H), 1.70 (m, 2H), 1.92 (dd, 1H, *J* = 13.7, 7.3 Hz), 2.04 (m, 2H), 2.54 (dd, 1H, *J* = 13.9, 3.9 Hz), 3.22 (m, 2H), 3.37 (m, 2H), 3.57 (s, 3H), 3.65 (m, 4H), 3.76 (s, 3H), 4.35 (d, 1H, *J* = 4.6 Hz), 5.00 (m, 2H), 5.78 (m, 1H). ^{13}C-NMR ($CDCl_3$): δ 176.4, 172.9, 167.7, 137.4, 115.0, 83.4, 65.6, 62.3, 59.3, 52.4, 51.6, 46.4, 46.3, 41.2, 40.9, 30.9, 27.1, 26.8. IR ($CHCl_3$, cm^{-1}): ν 3341, 1736. MS (CI), *m/z* : 369 (M^+ + 1, 100), 368 (M^+, 15). (Anal. Calcd. for $C_{18}H_{28}N_2O_6$: C, 58.68; H, 7.66; N, 7.60. Found: C, 58.60; H, 7.68; N, 7.59).

Cycloadduct (+)-5f. Colorless oil. $[\alpha]_D$ = +79.9 (*c* 1.0, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 1.43 (s, 3H), 1.62 (m, 2H), 1.92 (dd, 1H, *J* = 13.9, 7.6 Hz), 2.04 (m, 2H), 2.82 (dd, 1H, *J* = 13.9, 1.7 Hz), 3.04 (m, 2H), 3.49 (m, 2H), 3.57 and 3.59 (s, each 3H), 3.75 (s, 3H), 3.89 (dd, 1H, *J* = 8.0, 4.9 Hz), 4.47 (d, 1H, *J* = 4.9 Hz), 5.01 (m, 2H), 5.71 (m, 1H). ^{13}C-NMR ($CDCl_3$): δ 176.4, 173.2, 167.9, 137.3, 115.4, 83.8, 63.9, 61.4, 59.3, 57.9, 52.5, 51.9, 46.3, 40.9, 40.5, 31.1, 27.8, 27.2. IR ($CHCl_3$, cm^{-1}): ν 3343, 1737. MS (CI), *m/z* : 369 (M^+ + 1, 100), 368 (M^+, 11). (Anal. Calcd. for $C_{18}H_{28}N_2O_6$: C, 58.68; H, 7.66; N, 7.60. Found: C, 58.75; H, 7.64; N, 7.58).

Preparation of Cycloadduct (+)-4g. From 250 mg (0.91 mmol) of the aldehyde (+)-**1d** and 141 mg (1.37 mmol) of alanine methyl ester, after column chromatography eluting with ethyl acetate/hexanes (1:2 containing 10% of triethylamine), 200 mg (51%) of the compound (+)-**4g** were obtained.

Cycloadduct (+)-4g. Pale yellow oil. $[\alpha]_D$ = +60.1 (*c* 0.5, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 1.26 (s, 3H), 1.87 (dd, 1H, *J* = 13.5, 8.1 Hz), 2.56 (dd, 1H, *J* = 13.5, 4.8 Hz), 3.29 (m, 1H), 3.62 and 3.67 (s, each 3H), 3.71 (m, 4H), 4.14 (dd, 1H, *J* = 12.6, 6.0 Hz), 4.35 (m, 2H), 4.57 (d, 1H, *J* = 5.4 Hz), 5.25 (m, 2H), 5.87 (m, 1H), 6.77 and 7.50 (m, each 2H). ^{13}C-NMR ($CDCl_3$): δ 176.1, 173.6, 165.7, 156.4, 133.6, 130.7, 120.3, 117.6, 113.9, 80.8, 72.5, 64.9, 61.6, 60.6, 55.3, 52.2, 45.5, 40.2, 26.7. IR ($CHCl_3$, cm^{-1}): ν 3337, 1736. MS (CI), *m/z* : 432 (M^+ + 1, 100), 431 (M^+, 21). (Anal. Calcd. for $C_{22}H_{27}N_2O_7$: C, 61.24; H, 6.31; N, 6.49. Found: C, 61.30; H, 6.32; N, 6.47).

Spectroscopic and analytical data for some representative forms of **6** follow.

Compound (–)-6c. Pale yellow oil (57%). $[\alpha]_D$ = –34.1 (*c* 0.4, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 1.75 (s, 3H), 3.22 (dd, 1H, *J* = 15.8, 6.1 Hz), 3.55 (m, 4H), 3.58 (m, 5H), 3.71 and 3.76 (s, each 3H), 4.29 (dd, 1H, *J* = 10.2, 5.4 Hz), 4.54 (d, 1H, *J* = 5.1 Hz), 5.12 (m, 2H), 5.70 (m, 2H), 6.52 (m, 2H). ^{13}C-NMR ($CDCl_3$): δ 173.8, 172.2, 171.5, 170.7, 170.4, 131.9, 130.9, 118.5, 117.7, 82.8, 61.9, 59.3, 58.9, 52.8, 52.6, 52.0, 50.6, 24.9. IR ($CHCl_3$, cm^{-1}): ν 1747, 1653. MS (CI), *m/z* : 453 (M^+ + 1, 100), 452 (M^+, 19). (Anal. Calcd. for $C_{21}H_{28}N_2O_9$: C, 55.75; H, 6.24; N, 6.19. Found: C, 55.82; H, 6.23; N, 6.21).

Compound (+)-6d. Pale yellow oil (90%).$[\alpha]_D$ = +26.5 (*c* 0.4, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 2.36 (m, 4H), 3.02 (m, 2H), 3.37 (m, 1H), 3.49 (s, 3H), 3.64 and 3.72 (s, each 3H), 4.09 (dd, 1H, *J* = 10.3, 5.2 Hz), 4.23 (d, 1H, *J* = 5.2 Hz), 4.53 (dd, 1H, *J* = 10.5, 8.3 Hz), 4.62 (dd, 1H, *J* = 10.3, 6.9 Hz), 5.01 (m, 2H), 5.69 (m, 2H), 6.45 (m, 2H). ^{13}C-NMR ($CDCl_3$): δ 172.1, 170.7, 169.5, 165.2, 135.2, 130.4, 126.8, 117.4, 82.7, 59.6, 58.9, 55.9, 52.5, 52.1, 45.9, 45.7, 41.1, 31.9, 30.9. IR ($CHCl_3$, cm^{-1}): ν 1736, 1652. MS (CI), *m/z* : 395 (M^+ + 1, 100), 394 (M^+, 23). (Anal. Calcd. for $C_{19}H_{26}N_2O_7$: C, 57.86; H, 6.64; N, 7.10. Found: C, 57.93; H, 6.63; N, 7.12).

Compound (+)-6e. Pale yellow oil (89%). $[\alpha]_D$ = +52.2 (*c* 0.7, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 1.52 (s, 3H), 2.06 (dd, 1H, *J* = 12.6, 6.0 Hz), 2.30 (m, 2H), 2.58 (t, 1H, *J* = 13.1 Hz), 2.83 (m, 1H), 3.32 (m, 2H), 3.48 (s, 3H), 3.65 and 3.72 (s, each 3H), 4.17 (m, 2H), 4.69 (dd, 1H, *J* = 9.5, 6.9 Hz), 5.01 (m, 2H), 5.63 (m, 2H), 6.37 (m, 2H). ^{13}C-NMR ($CDCl_3$): δ 173.6, 170.8, 169.9, 164.3, 135.2, 128.9, 127.9, 117.6, 82.8, 66.0, 59.5, 59.2, 56.5, 52.8, 52.2, 44.4, 41.4, 39.9, 31.9, 21.5. IR ($CHCl_3$, cm^{-1}): ν 1734, 1651. MS (CI), *m/z* : 409 (M^+ + 1, 100), 408 (M^+, 31). (Anal. Calcd. for $C_{20}H_{28}N_2O_7$: C, 58.81; H, 6.91; N, 6.86. Found: C, 58.72; H, 6.90; N, 6.88).

Compound (+)-6f. Pale yellow oil (97%). $[\alpha]_D$ = +8.7 (*c* 0.8, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 1.61 (s, 3H), 1.65 (m, 2H), 1.95 (m, 2H), 2.10 (dd, 1H, *J* = 12.9, 6.3 Hz), 2.62 (dd, 1H, *J* = 13.2, 12.9 Hz), 2.79 (m, 1H), 3.19 (m, 3H), 3.54 (s, 3H), 3.69 and 3.75 (s, each 3H), 4.26 (m, 1H), 4.76 (dd, 1H, *J* = 9.5, 6.8 Hz), 4.99 (m, 2H), 5.71 (m, 2H), 6.32 (m, 2H). ^{13}C-NMR ($CDCl_3$): δ 173.4, 170.7, 169.4, 164.1, 137.5, 128.9, 127.8, 114.9, 82.7, 65.8, 59.3, 59.0, 56.1, 52.6, 52.1, 44.2, 42.1, 39.7, 30.9, 26.5, 21.3. IR ($CHCl_3$, cm^{-1}): ν 1735, 1654. MS (CI), *m/z* : 423 (M^+ + 1, 100), 422 (M^+, 19). (Anal. Calcd. for $C_{21}H_{30}N_2O_7$: C, 59.70; H, 7.16; N, 6.63. Found: C, 59.77; H, 7.18; N, 6.62).

Spectroscopic and analytical data for some representative forms of **7** follow.

Cycloadduct 7b. From the allyl imine of aldehyde (+)-**1b** (540 mg, 2.43 mmol), 480 mg (72%) of cycloadduct **7b**, containing *ca.* 25% of its *syn*-epimer, was obtained as a colorless oil. ^{1}H-NMR ($CDCl_3$): δ 2.27 (m, 4H), 2.79 (m, 2H), 3.49 (s, 2.25H), 3.57 (s, 0.75H), 3.89 (m, 3.5H), 4.24 (dd, 0.5H, J = 9.5, 5.2 Hz), 4.39 (m, 1H), 5.01 (m, 3H), 5.28 (m, 2H), 5.62 (m, 2H), 6.97 (m, 1H). ^{13}C-NMR ($CDCl_3$): δ 190.9 (M), 190.2 (m), 168.9 (M+m), 152.5 (M+m), 134.9 (m), 134.3 (M), 133.4 (m), 132.9 (M), 119.1 (M), 118.9 (m), 118.0 (M), 117.6 (m), 98.7 (M+m), 82.9 (M), 82.4 (m), 59.6 (M), 58.7 (m), 58.5 (M), 56.8 (m), 56.3 (m), 54.9 (M), 54.5 (m), 53.4 (M), 41.6 (m), 40.6 (M), 37.8 (M), 37.5 (m), 31.7 (m), 31.5 (M). IR ($CHCl_3$, cm^{-1}): ν 1743, 1706. MS (CI), *m/z* : 291 (M^+ + 1, 100), 290 (M^+, 15).

Cycloadduct 7c. From the allyl imine of aldehyde (+)-**1c** (265 mg, 2.06 mmol), 172 mg (53%) of cycloadduct **7c**, containing *ca.* 15% of its *syn*-epimer, was obtained as a colorless oil. ^{1}H-NMR ($CDCl_3$): δ 1.57 (m, 2H), 1.98 (m, 2H), 2.38 and 2.80 (m, each 1H), 3.49 (s, 2.55H), 3.58 (s, 0.45H), 3.81 (m, 6.5H), 4.19 (dd, 0.5H, J = 9.6, 5.2 Hz), 4.41 (m, 1H), 4.97 (m, 2H), 5.25 (m, 2H), 5.73 (m, 2H), 6.92 (m, 1H). ^{13}C-NMR ($CDCl_3$): δ 190.4 (M), 189.7 (m), 168.4 (M+m), 151.9 (M), 151.7 (m), 136.9 (m), 136.5 (M), 133.4 (m), 132.9 (M), 118.8 (M), 118.7 (m), 115.8 (M), 115.3 (m), 98.5 (M+m), 82.7 (M), 82.3 (m), 59.3 (M), 58.5 (m), 58.3 (M), 56.6 (m), 56.1 (m), 54.9 (M), 54.4 (m), 52.9 (M), 42.2 (m), 40.8 (M), 37.7 (M), 37.4 (m), 30.8 (m), 30.7 (M), 26.3 (m), 25.9 (M). IR ($CHCl_3$, cm^{-1}): ν 1742, 1707. MS (CI), *m/z* : 305 (M^+ + 1, 100), 304 (M^+, 11).

Spectroscopic and analytical data for some representative forms of **8** and **9** follow.

Preparation of Compounds (+)-8b and (+)-9b. From 450 mg (1.54 mmol) of the cycloadduct **7b**, after column chromatography eluting with ethyl acetate/hexanes (1:1 containing 1% of triethylamine), 252 mg (56%) of the less polar compound (+)-**8b** and 84 mg (19%) of the more polar compound (+)-**9b** were obtained.

Compound (+)-8b. Colorless oil. $[\alpha]_D$ = +58.6 (*c* 1.0, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 2.17 (m, 4H), 2.49 (m, 2H), 3.27 (m, 6H), 3.48 (m, 4H), 3.68 (dd, 1H, J = 10.5, 4.9 Hz), 4.34 (d, 1H, J = 4.9 Hz), 5.05 (m, 4H), 5.68 (m, 2H). ^{13}C-NMR ($CDCl_3$): δ 208.7, 167.9, 135.3, 134.8, 118.1, 117.0, 82.7, 61.8, 59.8, 56.5, 55.8, 46.3, 40.6, 39.1, 37.2, 32.4. IR ($CHCl_3$, cm^{-1}): ν 1743, 1716. MS (CI),

m/z : 293 (M^+ + 1, 100), 292 (M^+, 15). (Anal. Calcd. for $C_{16}H_{24}N_2O_3$: C, 65.73; H, 8.27; N, 9.58. Found: C, 65.80; H, 8.28; N, 9.56).

Compound (+)-9b. Colorless oil. $[\alpha]_D$ = +42.0 (*c* 0.6, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 2.31 (m, 6H), 3.03 (m, 6H), 3.47 (s, 3H), 3.48 (m, 1H), 3.91 (dd, 1H, *J* = 5.3, 5.2 Hz), 4.38 (t, 1H, *J* = 5.2 Hz), 5.15 (m, 4H), 5.68 (m, 2H). ^{13}C-NMR ($CDCl_3$): δ 208.7, 168.4, 134.8, 134.6, 117.9, 117.2, 83.3, 59.7, 59.3, 58.1, 56.2, 48.5, 41.0, 40.9, 39.1, 31.6. IR ($CHCl_3$, cm^{-1}): ν 1742, 1714. MS (CI), *m/z* : 293 (M^+ + 1, 100), 292 (M^+, 11). (Anal. Calcd. for $C_{16}H_{24}N_2O_3$: C, 65.73; H, 8.27; N, 9.58. Found: C, 65.81; H, 8.30; N, 9.60).

Preparation of Compound (+)-8c. From 172 mg (0.593 mmol) of the cycloadduct **7c**, after column chromatography eluting with ethyl acetate/hexanes (1:2 containing 1% of triethylamine), 121 mg (70%) of the less polar compound (+)-**8c** and 36 mg of a complex mixture of more polar compounds were obtained.

Compound (+)-8c. Colorless oil. $[\alpha]_D$ = +116.9 (*c* 0.8, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 1.61 and 2.02 (m, each 2H), 2.42 and 2.57 (m, each 2H), 3.16 (m, 2H), 3.29 (m, 5H), 3.49 (s, 3H), 3.66 (dd, 1H, *J* = 10.5, 4.8 Hz), 4.35 (d, 1H, *J* = 4.8 Hz), 4.92 (m, 2H), 5.16 (m, 2H), 5.76 (m, 2H). ^{13}C-NMR ($CDCl_3$): δ 208.8, 167.9, 137.3, 135.4, 118.2, 115.3, 82.8, 61.9, 59.1, 56.4, 55.8, 46.4, 41.1, 39.2, 37.2, 31.0, 27.3. IR ($CHCl_3$, cm^{-1}): ν 1741, 1715. MS (CI), *m/z* : 307 (M^+ + 1, 100), 306 (M^+, 21). (Anal. Calcd. for $C_{17}H_{26}N_2O_3$: C, 66.64; H, 8.55; N, 9.14. Found: C, 6.72; H, 8.53; N, 9.15).

Spectroscopic and analytical data for some representative forms of tricyclic β-lactams **10–12** follow.

Tricyclic 2-Azetidinone (+)-10a. From 60 mg (0.175 mmol) of diene (+)-**2a**, 38 mg (69%) of compound (+)-**10a** was obtained as a pale yellow oil. $[\alpha]_D$ = +304.8 (*c* 1.0, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 3.36 (s, 3H), 3.99 (m, 6H), 4.46 (dd, 1H, *J* = 2.7, 1.7 Hz), 5.30 (dd, 1H, *J* = 2.7, 1.9 Hz), 6.06 (m, 2H), 6.94 (m, 2H), 7.04 (m, 3H), 7.20 (m, 2H). ^{13}C-NMR ($CDCl_3$): δ 166.2, 164.7, 157.5, 129.7, 129.6, 129.2, 122.6, 115.9, 83.2, 80.0, 59.7, 58.6, 58.3, 36.3, 36.1. IR ($CHCl_3$, cm^{-1}): ν 1763, 1752. MS (CI), *m/z* : 315 (M^+ + 1, 100), 314 (M^+, 11). (Anal. Calcd. for $C_{17}H_{18}N_2O_4$: C, 64.96; H, 5.77; N, 8.91. Found: C, 64.90; H, 5.73; N, 8.95).

Tricyclic 2-Azetidinone (+)-11a. From 43 mg (0.113 mmol) of diene (+)-**6a**, 24 mg (62%) of compound (+)-**11a** was obtained as a pale brown oil. $[\alpha]_D$ = +313.2 (*c* 0.3, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 2.39 (m, 1H), 2.59 (m, 1H), 3.12 (m, 1H), 3.49 and 3.69 (s, each 3H), 3.79 (s, 3H), 4.12 (m, 3H), 4.32 (d, 1H, *J* = 4.6 Hz), 4.51 (dd, 1H, *J* = 10.5, 7.1 Hz), 4.72 (dd, 1H, *J* = 10.5, 8.8 Hz), 6.14 (dt, 1H, *J* = 11.2, 0.9 Hz), 6.35 (m, 1H). ^{13}C-NMR ($CDCl_3$): δ 172.0, 170.6, 166.8, 166.4, 132.4, 128.2, 82.9, 60.5, 58.4, 57.4, 55.4, 52.6, 51.9, 45.7, 36.4, 31.2. IR ($CHCl_3$, cm^{-1}): ν 1742, 1660. MS (CI), *m/z* : 353 (M^+ + 1, 100), 352 (M^+, 12). (Anal. Calcd. for $C_{16}H_{20}N_2O_7$: C, 54.54; H, 5.72; N, 7.95. Found: C, 54.47; H, 5.71; N, 7.97).

Tricyclic 2-Azetidinone (+)-11b. From 71 mg (0.178 mmol) of diene (+)-**6b**, 44.5 mg (67%) of compound (+)-**11b** was obtained as a pale brown oil. $[\alpha]_D$ = +196.9 (*c* 1.0, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 1.72 (s, 3H), 2.13 (dd, 1H, *J* = 12.6, 5.7 Hz), 2.69 (t, 1H, *J* = 13.2 Hz), 3.35 (m, 1H), 3.49 (m, 4H), 3.78 (s, 3H), 3.81 (s, 3H), 4.11 (dd, 1H, *J* = 15.6, 8.1 Hz), 4.27 (dd, 1H, *J* = 10.5, 4.5 Hz), 4.33 (d, 1H, *J* = 4.5 Hz), 4.59 (dd, 1H, *J* = 10.8, 4.2 Hz), 6.11 (d, 1H, *J* = 9.6 Hz), 6.25 (m, 1H). ^{13}C-NMR ($CDCl_3$): δ 173.5, 170.8, 166.9, 166.2, 130.1, 129.1, 83.5, 65.8, 61.6, 59.3, 58.6, 56.5, 52.9, 52.1, 44.8, 40.8, 40.6, 36.7, 21.8. IR ($CHCl_3$, cm^{-1}): ν 1740, 1659. MS (CI), *m/z* : 367 (M^+ + 1, 100), 366 (M^+, 17). (Anal. Calcd. for $C_{17}H_{22}N_2O_7$: C, 55.73; H, 6.05; N, 7.65. Found: C, 55.80; H, 6.08; N, 7.61).

Tricyclic 2-Azetidinone (+)-11e. From 60 mg (0.147 mmol) of diene (+)-**6e**, 33 mg (58%) of compound (+)-**11e** was obtained as a pale brown oil. $[\alpha]_D$ = +137.5 (*c* 0.8, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 1.63 (s, 3H), 2.17 (dd, 1H, *J* = 12.6, 3.3 Hz), 2.43 (m, 1H), 2.68 (t, 1H, *J* = 13.2 Hz), 2.86 (m, 1H), 3.26 (m, 4H), 3.50 (s, 3H), 3.58 (m, 5H), 4.26 (m, 2H), 4.59 (m, 1H), 5.84 (m, 1H), 6.05 (dd, 1H, *J* = 12.3, 3.0 Hz). ^{13}C-NMR ($CDCl_3$): δ 174.9, 174.7, 171.3, 167.7, 131.5, 126.2, 82.7, 64.8, 61.5, 58.6, 56.8, 52.7, 51.9, 43.9, 40.4, 38.6, 26.7, 21.4. IR ($CHCl_3$, cm^{-1}): ν 1743, 1660. MS (CI), *m/z* : 381 (M^+ + 1, 100), 380 (M^+, 12). (Anal. Calcd. for $C_{18}H_{24}N_2O_7$: C, 56.83; H, 6.36; N, 7.36. Found: C, 56.75; H, 6.35; N, 7.38).

Tricyclic 2-Azetidinone (+)-12b. From 65 mg (0.223 mmol) of diene (+)-**8b**, 18 mg (31%) of the less polar compound (+)-**12b** and the corresponding more polar *N*-deallylation product were obtained. Colorless oil. $[\alpha]_D$ = +119.4 (*c* 0.5, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 2.05 (m, 1H), 2.21 (dd, 1H, *J* = 15.6, 4.8 Hz), 2.41 (m, 2H), 2.73 (dd, 1H, *J* = 15.6, 6.4 Hz), 2.99 (m, 7H), 3.51 (dd, 1H, *J* =

10.5, 4.9 Hz), 3.55 (s, 3H), 3.79 (ddd, 1H, *J* = 13.5, 11.6, 5.4 Hz), 4.27 (d, 1H, *J* = 4.9 Hz), 5.56 (m, 2H). ^{13}C-NMR ($CDCl_3$): δ 210.1, 169.6, 132.3, 127.8, 82.7, 65.2, 59.2, 56.9, 53.2, 48.3, 39.2, 39.1. IR ($CHCl_3$, cm^{-1}): ν 1744, 1715. MS (CI), *m/z* : 265 (M^+ + 1, 100), 264 (M^+, 11). (Anal. Calcd. for $C_{14}H_{20}N_2O_3$: C, 63.62; H, 7.63; N, 10.60. Found: C, 63.69; H, 7.62; N, 10.62).