Supporting Information

for

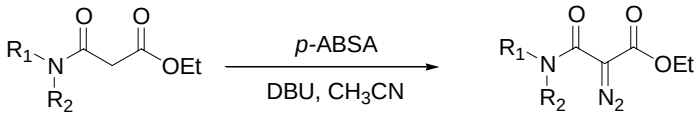
"Ruthenium Catalyzed Stereoselective Intramolecular Carbenoid C–H Insertion for β- and γ-Lactam Formations by Decomposition of α-Diazoacetamides"

Matthew Kwok-Wai Choi, Wing-Yiu Yu* and Chi-Ming Che

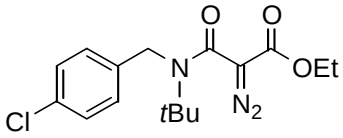
Department of Chemistry and Open Laboratory of Chemical Biology of the Institute of Molecular Technology for Drug Discovery and Synthesis, The University of Hong Kong, Pokfulam Road, Hong Kong

General Experimental Section: All reactions were performed using the standard Schlenk technique under a nitrogen atmosphere. Pyridine bis(oxazoline) ligand (L^*) was obtained commercially and used without further purification unless indicated otherwise. $[RuCl_2(p\text{-cymene})]_2$ and $[RuCl_2(L^*)(C_2H_4)]$ were synthesized by the literature method.[1] Toluene was freshly distilled from sodium/benzophenone under a nitrogen atmosphere. Dichloromethane was freshly distilled from calcium hydride under a nitrogen atmosphere. Flash chromatography was performed on a silica gel (Merck Kiesegel 60 F_{254} 230-400 mesh) column. ^1H and ^{13}C-NMR spectra were recorded on Bruker DPX-300, 400 or 500 spectrometer. Chemical shifts (δ, ppm) were determined with TMS as internal reference, carbon multiplicities were determined by DEPT-135 experiments. Mass spectra were obtained on a Finnigan MAT 95 mass spectrometer. IR spectra (ν, cm^{-1}) were recorded on a Bio-RAD PTS-165 spectrometer.

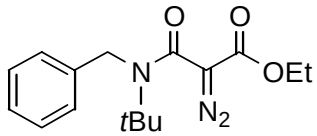
General Procedure for the Synthesis of the *α*-Diazo compounds



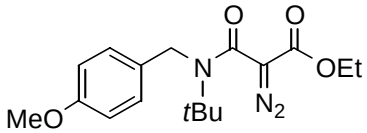
To a mixture of malonic acid ethyl esters (10 mmol) and *p*-ABSA (15 mmol) in anhydrous acetonitrile (20 mL), DBU (15 mmol) was added dropwise. The resulting mixture was stirred at room temperature, and the reaction was monitored by TLC (20% EtOAc-hexanes mixture). Upon complete consumption of the starting materials, the reaction mixture was diluted with 20 mL distilled water, followed by extraction with diethyl ether. After washing with 10% $NaHCO_3$ solution and brine, the combined organic extracts were dried over $MgSO_4$ and concentrated to ca. 2 mL by rotory evaporation. The residue was purified by flash chromatography (10 – 15% EtOAc-hexanes) to afford the α-diazoacetamides.



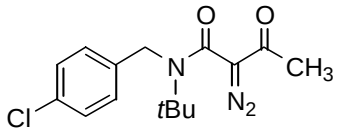
***N*-*p*-Chlorobenzyl-*N*-*tert*-butyl-*α*-ethoxycarbonyl-*α*-diazoacetamide (1a).** Yellow solid, 89% yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ_H7.30 (d, *J* = 6.7 Hz, 2H), 7.14 (d, *J* = 6.7 Hz, 2H), 4.58 (s, 2H), 4.23 (q, *J* = 7.1 Hz, 2H), 1.38 (s, 9H) 1.29 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 163.6, 138.4, 133.3, 129.0, 128.4, 61.5, 59.2, 51.1, 29.0, 14.6. IR (neat): 2978, 2126, 1764, 1708, 1629, 1492, 1384, 1288, 1196, 1092, 1014, 722, 696, 542. MS (EI): 280(3), 236(4), 165(5), 210(8), 125(18). HRMS (EI): Found 309.1130, $C_{16}H_{20}NClO_3$ requires 309.1132.



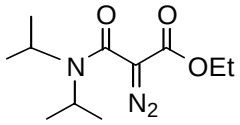
***N*-Benzyl-*N*-*tert*-butyl-*α*-ethoxycarbonyl-*α*-diazoacetamide (1b).** Yellow solid, 90% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.36-7.19 (m, 5H), 4.62 (s, 2H), 4.23 (q, *J* = 7.1 Hz, 2H), 1.39 (s, 9H), 1.32 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C 163.4, 162.7, 139.7, 128.7, 127.4, 126.9, 61.3, 59.0, 51.7, 28.9, 14.5. IR (neat): 2983, 2119, 1692, 1622, 1393, 1292, 1199, 1093, 1018, 966, 715, 464. MS (EI): 288(M^+-N_2, 3), 246(62), 202(65), 191(11), 190(100), 176(91), 147(49), 131(69). HRMS (EI): Found 288.1347, $C_{17}H_{20}NO_4$ requires 288.1362.



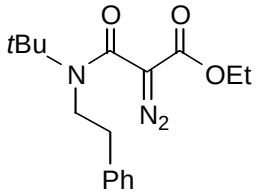
***N*-*p*-Methoxybenzyl-*N*-*tert*-butyl-*α*-ethoxycarbonyl-*α*-diazoacetamide (1c).** Yellow solid, 92% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.11 (d, *J* = 8.6 Hz, 2H), 6.86(d, *J* = 8.6 Hz, 2H), 4.55 (s, 2H), 4.24 (q, *J* = 7.1 Hz, 2H), 3.81 (s, 3H), 1.37 (s, 9H), 1.29 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C 163.4, 162.8, 159.0, 131.6, 128.2, 114.2, 61.4, 59.0, 55.5, 51.2, 28.9, 14.6. IR (neat): 2965, 2121, 1703, 1607, 1511, 1396, 1289, 1241, 1107, 817, 756, 554, 421. MS (EI): 305(M^+-N_2, 1), 232(11), 206(8), 176(8), 161(6), 121(15). HRMS (EI): Found 305.1627, $C_{17}H_{20}NO_4$ requires 305.1627.



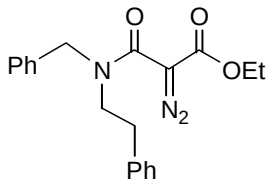
***N*-*p*-Chlorobenzyl-*N*-*tert*-butyl-*α*-carbonyl-*α*-diazoacetamide (1d).** Yellow solid, 90% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.32 (d, *J* = 6.6 Hz, 2H), 7.13(d, *J* = 6.6 Hz, 2H), 4.56 (s, 2H), 2.26 (s, 3H), 1.42 (s, 9H). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C 163.3, 162.5, 137.8, 133.5, 129.1, 127.7, 59.3, 50.7, 28.8, 27.3. IR (neat): 2978, 2126, 1764, 1708, 1629, 1492, 1384, 1288, 1196, 1092, 1014, 722, 696, 542. MS (EI): 281(M^+, 15), 131(100), 111(97). HRMS (EI): Found 280.9824, $C_{15}H_{20}ClNO_2$ requires 281.1183.



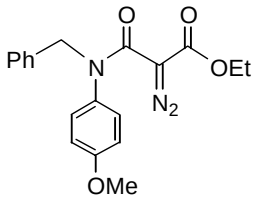
***N,N*-Diisopropyl-*α*-ethoxycarbonyl-*α*-diazoacetamide (1e).** Yellow oil, 95% yield**.** ^{1}H NMR (400 MHz, $CDCl_3$): δ_H 4.24 (q, *J* = 7.1 Hz, 2H), 3.71 (m, 2H), 1.34 (d, *J* = 6.7 Hz, 12H), 1.29 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 163.2, 159.5, 61.2, 20.9, 14.4. IR (neat): 2972, 2121, 1712, 1625, 1438, 1334, 1282, 1135, 1089, 1036, 918, 836, 756, 619, 531. MS (EI): 226(M^+-CH_3, 12), 128(100), 124(32), 110(97). HRMS (EI): Found 226.1189, $C_{10}H_{16}N_3O_3$ requires 226.1192.



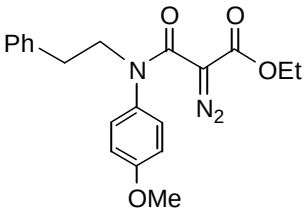
***N*-Phenylethyl-*N*-*tert*-butyl-*α*-ethoxycarbonyl-*α*-diazoacetamide (1f).** Yellow oil, 86% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.33-7.15 (m, 5H), 4.20 (q, *J* = 7.1 Hz, 2H), 3.66 (t, *J* = 7.4 Hz, 2H), 2.85 (t, *J* = 7.4 Hz, 2H), 1.54 (s, 9H), 1.26 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 162.6, 162.4, 138.4, 128.8, 128.7, 126.7, 61.2, 58.0, 53.9, 38.3, 29.2, 14.4. IR (neat): 2980, 2126, 1706, 1632, 1390, 1290, 1196, 1095, 1020, 761, 701. MS (EI): Found 317(M^+), 226(54), 170(100), 105(13). HRMS (EI): Found 317.1757, $C_{17}H_{23}N_3O_3$ requires 317.1739.



***N*-Phenylethyl-*N*-benzyl-*α*-ethoxycarbonyl-*α*-diazoacetamide (1g).** Pale yellow oil, 81%. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.35-7.10 (m, 10H), 4.60 (s, 2H), 4.23 (q, *J* = 7.1 Hz, 2H), 3.51 (t, *J* = 7.4 Hz, 2H), 2.84 (t, *J* = 7.4 Hz, 2H), 1.26 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C 162.4, 161.8, 138.5, 136.5, 128.8, 128.6, 128.5, 127.7, 127.6, 126.5, 61.3, 51.0, 49.1, 34.0, 14.4. IR (neat): 2127, 1711, 1627, 1496, 1454, 1421, 1292, 1104, 753, 700. MS (EI): 323([M-N_2]$^+$ 24), 260(57), 250(81), 232(19), 131(29), 118(100). HRMS (EI): Found 323.1518, $C_{20}H_{21}NO_3$ requires 323.1521.



***N*-Benzyl-*N*-*p*-methoxybenzyl-*α*-ethoxycarbonyl-*α*-diazoacetamide (1h).** Yellow solids, 72% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.26-7.21 (m, 5H), 6.98 (d, *J* = 6.7 Hz, 2H), 6.80(d, *J* = 6.7 Hz, 2H), 4.94 (s, 2H), 4.07 (q, *J* = 7.1 Hz, 2H), 3.76 (s, 3H), 1.16 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C 162.4, 162.1, 160.9, 158.5, 137.0, 134.9, 128.6, 128.4, 128.1, 127.5, 118.2, 114.4, 61.4, 55.4, 54.4, 14.3. IR (neat): 2981, 2119, 1722, 1634, 1512, 1388, 1297, 1249, 1107, 1027, 837, 730, 700, 626, 565. MS (EI): 325(10), 279(19), 91(17). HRMS (EI): Found 353.1372, $C_{19}H_{19}N_3O_4$ requires 353.1376.

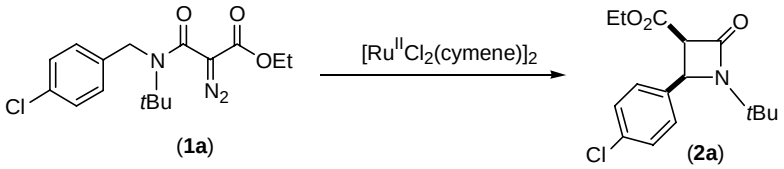


***N*-Phenylethyl-*N*-*p*-methoxybenzyl-*α*-ethoxycarbonyl-*α*-diazoacetamide (1i).** Yellow oil, 84% yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ_H 7.27-7.17 (m, 5H), 7.00 (d, *J* = 6.7 Hz, 2H), 6.87 (d, *J* = 6.7 Hz, 2H), 4.09 (q, *J* = 7.1 Hz, 2H), 3.93 (t, *J* = 7.9 Hz, 2H), 3.80 (s, 3H), 2.90 (t, *J* = 7.9 Hz, 2H), 1.18 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (400 MHz, $CDCl_3$): δ_C 162.3, 160.7, 158.7, 138.9, 135.2, 129.0, 128.6, 128.1, 126.5, 114.7, 61.4, 55.6, 53.2, 33.9, 14.4. IR (neat): 2932, 2117, 1724, 1635, 1511, 1298, 1249, 1107, 1028, 750, 701**.** MS (EI): 367(M^+, 14), 339(19), 293(21), 267(100), 248(31), 222(30), 202(60), 176(96), 163(16), 148(69), 136(18), 134(16), 133(19), 105(20). HRMS (EI): Found 367.1522, $C_{20}H_{21}N_3O_4$ requires 367.1532.

General Procedure for the [$RuCl_2$(*p*-cymene)]$_2$Catalyzed Intramolecular Carbenoid C–H Insertion Reaction

A mixture of **1a** (0.1 mmol) and [$RuCl_2$(*p*-cymene)]$_2$ (0.5 mol%) were stirred in a solvent (10 mL) at 70^{o}C. After 0.5 – 1.5h, the mixture was concentrated to ca. 2 mL by vacuum evaporation and the yield of **2a** was determined by ^{1}H NMR using the internal standard method. Results are summarized in Table S1.

Table S1. Ru-Catalyzed Cyclization of α-Diazoacetamide **1a** to *cis*-β-Lactam **2a**

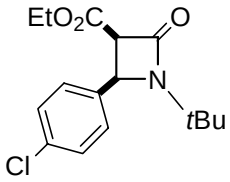


(**1a**) (**2a**)

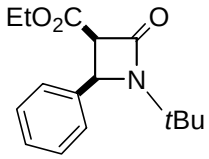
entry	solvent	temp / ^{o}C	time / h	%conv	%yield
1	toluene	70	0.5	100	>99 [b]
2	EtOAc	70	1	100	>99
3	acetone	70	1	100	>99
4	$CHCl_3$	70	1.5	78	>99 [c]
5	CH_2Cl_2	40	1.5	62	61 [c]
6	THF	70	1.5	60	>99 [c]
7	DMF	70	1.5	5	trace
8	CH_3OH	70	1.5	0	0
9	CH_3CN	70	1.5	0	0

[a]: Reaction conditions: A mixture of **1a** (0.1 mmol) and [$RuCl_2$(*p*-cymene)]$_2$ (0.5 mol%) were stirred in a solvent at 70 ^{o}C (oil bath temperature) in an open atmosphere. Yield of **2a** was determined by ^{1}H NMR using the internal standard method. [b]: Identical yield was obtained when the reaction was carried out under N_2 atmosphere. [c]: Yield was determined based on % substrate conversion

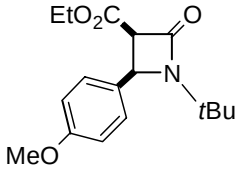
A mixture of diazo compound (0.1 mmol) and $[RuCl_2(p\text{-cymene})]_2$ (0.5 – 2.5 mol%) were stirred in toluene (10 mL) at 70°C. By means of TLC analysis (20% EtOAc – hexanes), the reaction was monitored for complete consumption of the diazo starting materials. To work-up, the mixture was concentrated to ca. 2 mL by vacuum evaporation, and the residue was purified by flash chromatography (5 – 20% EtOAc-hexanes) to afford the lactams.



***N*-*tert*-Butyl-*cis*-1-ethoxycarbonyl-2-*p*-chlorophenyl-*β*-lactam (2a).**[2] White oil, >99% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.33-7.27 (m, 4H), 4.89 (d, J = 6.3 Hz, 1H), 4.21 (d, J = 6.3 Hz, 1H), 3.81 (q, J = 7.1 Hz, 2H), 1.26 (s, 9H), 0.91 (t, J = 7.1 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C 166.9, 163.9, 136.4, 135.7, 129.7, 62.2, 60.1, 57.0, 56.2, 30.8, 29.2, 14.8. IR (neat): 2978, 1764, 1723, 1492, 1371, 1093, 1014, 842, 588, 511. MS (EI): 210(100), 182(38), 165(82). HRMS (EI): Found M^+ 309.1124, $C_{16}H_{20}NClO_3$ requires 309.1132.

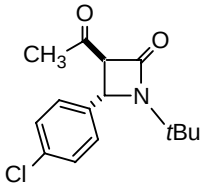


***N*-*tert*-Butyl-*cis*-1-ethoxycarbonylphenyl-*β*-lactam (2b).** Yellow solid, >99% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.34-7.27 (m, 5H), 4.91 (d, J = 6.3 Hz, 1H), 4.21 (d, J = 6.3 Hz, 1H), 3.76 (q, J = 7.1 Hz, 2H), 1.31 (s, 9H), 0.84 (t, J = 7.1 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C 166.0, 163.1, 136.8, 128.8, 128.4, 127.3, 118.3, 61.0, 59.1, 56.7, 28.2, 13.7. IR (neat): 2978, 1762, 1730, 1634, 1457, 1369, 1325, 1229, 1186, 1186, 1022, 753, 701. MS (EI): 275(M^+, 3), 177(42), 176(100), 148(26), 131(183). HRMS (EI): Found M^+ 275.1521, $C_{16}H_{21}ClNO_3$ requires 275.1522.

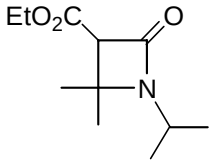


***N*-*tert*-Butyl-*cis*-1-ethoxycarbonyl-2-*p*-methoxyphenyl-*β*-lactam (2c).** White solid, >99% yield. ^{1}H NMR (300MHz, $CDCl_3$): δ_H 7.31 (d, J = 8.5 Hz, 2H), 6.86 (d, J = 8.5 Hz, 2H), 4.87 (d, J = 6.2 Hz, 1H), 4.18 (d, J = 6.2 Hz, 1H), 3.83 (q, J = 7.1 Hz, 2H), 3.82 (s, 3H), 1.30 (s, 9H), 0.91 (t, J = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ_C 166.2, 163.0, 159.9, 128.51, 128.46, 113.7, 61.0, 59.1, 56.2, 55.3, 29.7,

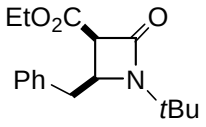
28.1, 13.8. IR (neat): 2976, 1761, 1723, 1614, 1514, 1369, 1249, 1176, 1031, 841, 771, 526. MS (EI): 305(M^+, 25), 248(11), 232(22), 206(100), 176(86), 161(78). HRMS (EI): Found M^+ 305.1625, $C_{17}H_{23}NO_4$ requires 305.1627.



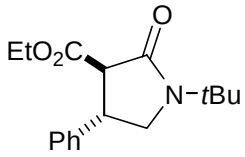
***N*-*tert*-Butyl-*trans*-1-carbonyl-2-*p*-chlorophenyl-*β*-lactam (2d).** Yellow oil, >99% yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ_H 7.35 (s, 4H), 5.00 (d, J = 2.2 Hz, 1H), 3.87 (d, J = 2.2 Hz, 1H), 2.29 (s, 3H), 1.25 (s, 9H). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C 199.6, 163.0, 138.1, 129.3, 128.1, 71.0, 55.3, 53.8, 30.1, 28.2. IR (neat): 2975, 1749, 1713, 1493, 1369, 1224, 1171, 1091, 1012, 841, 567, 527, 421. MS (EI): 279(M^+, 3), 222(3), 180(52), 165(100), 145(52), 136(20). HRMS (EI): Found M^+ 279.1028, $C_{15}H_{18}NClO_2$ requires 279.1026.



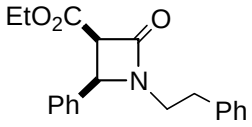
***N*-Isopropyl-1-ethoxycarbonyl-2,2-dimethyl-*β*-lactam (2e).** Yellow oil, 89% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 4.27-4.16 (m, 2H), 3.64 (s, 1H), 3.62-3.55 (m, 1H), 1.63-1.29 (m, 12H), 1.26 (t, J = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ_C 167.4, 161.0, 63.8, 61.2, 59.2, 44.6, 27.4, 22.2, 21.8, 21.7, 14.3. IR (neat): 2977, 1759, 1729, 1373, 1253, 1182, 1030, 798, 669, 596. MS (EI): 213(M^+, 5), 198(5), 128(95), 113(9), 100(71), 84(16), 83(100). HRMS (EI): Found M^+ 213.1362, $C_{11}H_{19}NO_3$ requires 213.1365.



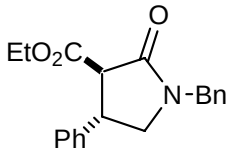
***N*-*tert*-Butyl-*cis*-1-ethoxycarbonyl-2-benzyl-*β*-lactam (2f).**[3] Yellow oil, 12% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.31-7.11 (m, 5H), 4.28-4.21 (m, 1H), 4.12-4.01 (m, 1H), 3.95-3.87 (m, 1H), 3.85 (d, J = 5.7 Hz, 1H), 3.32 (dd, J = 14.5 Hz, 4.2 Hz, 1H), 3.20 (dd, J = 14.5 Hz, 10.6 Hz, 1H), 1.44 (s, 9H), 1.08 (t, J = 7.2 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ_C 168.2, 161.8, 137.3, 128.6, 128.5, 126.8, 70.0, 55.3, 54.6, 52.7, 36.0, 29.1, 28.2, 13.9. IR (neat): 2976, 1730, 1691, 1456, 1367, 1158, 1030, 760, 700, 504. MS (EI): 289(M^+, 68), 243(17), 216(36), 198(100), 188(18), 160(47), 153(40), 142(40), 136(26). HRMS (EI): Found M^+ 289.1676, $C_{17}H_{23}NO_3$ requires 289.1678.



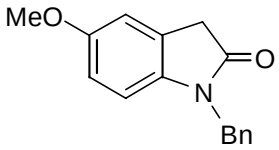
***N*-*tert*-Butyl-*trans*-1-ethoxycarbonyl-2-phenyl-γ-lactam (3).**[3] White solid. 51% yield. ^{1}H NMR (400 MHz, $CDCl_3$:C_6D_6 = 2:1): δ_H 7.24-7.13 (m, 5H), 4.22-4.05(m, 2H), 3.82 (q, *J* = 8.6 Hz, 1H), 3.69 (t, *J* = 8.8 Hz, 1H), 3.53 (d, *J* = 9.5 Hz, 1H), 3.22 (t, *J* = 8.8 Hz, 1H), 1.35 (s, 9H), 1.17 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ_C 170.0, 169.1, 128.9, 128.1, 127.4, 127.0, 61.4, 57.3, 54.7, 50.8, 41.1, 27.5, 13.9. IR (neat): 2976, 1737, 1690, 1456, 1366, 1156, 1030, 761, 700, 669, 421. MS (EI): 289(M+, 93), 274(100), 246(29), 234(24), 228(28), 216(23), 200(16), 188(32), 160(34), 145(11), 131(17), 117(12). HRMS (EI): Found M^+ 289.1688, $C_{17}H_{23}NO_3$ requires 289.1678.



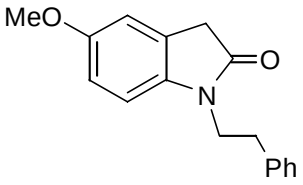
***N*-Phenylethyl-*cis*-1-ethoxycarbonyl-2-phenyl-*β*-lactam (2g).** Colorless oil, 28% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.33-7.14 (m, 10H), 4.58 (d, *J* = 6.0 Hz, 1H), 4.25 (d, *J* = 6.0 Hz, 1H), 3.83-3.90 (m, 1H), 3.73(q, *J* = 7.1 Hz, 2H), 3.20-3.13 (m, 1H), 3.29-2.87 (m, 2H), 0.83 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C 165.8 ,163.0, 138.3, 134.0, 129.0, 128.8, 128.7, 128.6, 127.3, 126.8, 61.1, 60.5, 58.1, 42.4, 34.0, 29.8, 13.7 IR (neat): 1771, 1507, 1457, 750, 669. MS (EI): 323(M^+, 14), 250(10), 232(15), 131(57), 118(100), 104(56), 103(11). HRMS (EI): Found M^+ 323.1509, $C_{20}H_{21}NO_3$ requires 323.1521.



***N*-Benzyl-*trans*-1-ethoxycarbonyl-2-phenyl-γ-lactam (4).** Colorless oil, 53% yield. ^{1}H NMR (500 MHz, $CDCl_3$): δ_H 7.40-7.28 (m, 10H), 4.56 (dd, *J* = 50.7 Hz, 14.8 Hz, 2H), 4.27-4.15 (m, 2H), 4.03-3.98 (m, 1H), 3.76 (d, *J* = 9.8 Hz, 1H), 3.65 (dd, *J* = 8.4 Hz, 9.6 Hz, 1H), 3.31 (dd, *J* = 8.7 Hz, 9.4 Hz, 1H), 1.24 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ_C 169.6, 168.7, 140.3, 136.8, 128.9, 128.7, 128.1, 127.6, 127.3, 127.2, 61.1, 56.0, 51.6, 46.4, 42.3, 13.8. IR (neat): 1700, 1698, 1507, 1456, 1255, 1028, 759, 700, 419. MS (EI): 323(M^+, 100), 250(70), 209(21), 131(40), 119(50). HRMS (EI): Found M^+ 323.1520, $C_{20}H_{21}NO_3$ requires 323.1521.



***N*-Benzyl-5-methoxy-1,3-dihydro-indol-2-one (5).** Yellow oil, 97% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.32-7.23 (m, 5H), 6.87 (s, 1H), 6.68 (d, *J* = 8.5 Hz, 1H), 6.59 (d, *J* = 8.5 Hz, 1H), 4.88 (s, 2H), 3.74 (s, 3H), 3.59 (s, 2H). ^{13}C NMR (125 MHz, $CDCl_3$): δ_C 174.8, 155.9, 137.9, 136.0, 128.8, 127.6, 127.4, 125.9, 112.2, 112.0, 109.4, 55.8, 43.9, 36.2. IR (neat): 2915, 1716, 1558, 1490, 1385, 1179, 1035, 772, 670, 420. MS (EI): 253(M^+, 100), 162(17). HRMS (EI): Found M^+ 253.1099, $C_{16}H_{15}NO_2$ requires 253.1103.

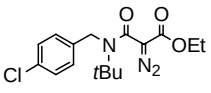
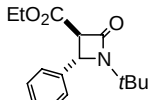
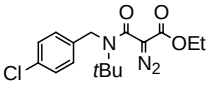
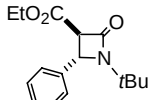
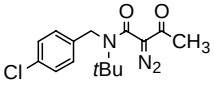
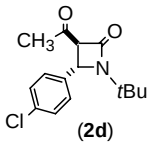
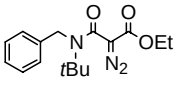
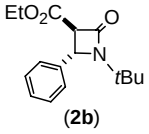
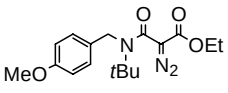
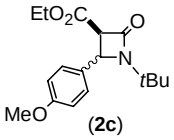


***N*-Phenethyl-5-methoxy-1,3-dihydro-indol-2-one (6**). Yellow oil, 92% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H 7.31-7.22 (m, 5H), 6.88 (s, 1H), 6.77 (d, *J* = 8.5 Hz, 1H), 6.67 (d, *J* = 8.5 Hz, 1H), 3.90 (t, *J* = 7.8 Hz, 2H), 3.79 (s, 3H), 3.48 (s, 2H), 2.95 (t, *J* = 7.8 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C 174.5, 155.7, 138.4, 138.0, 128.8, 128.7, 126.7, 126.0, 112.2, 112.0, 108.5, 55.9, 41.7, 36.2, 33.8. IR (neat): 2927, 1705, 1600, 1494, 1351, 1287, 1172, 1024, 802, 702, 547, 426. MS (EI): 268(M^+, 18), 267(93), 176(100), 148(69), 133(13). HRMS (EI): Found M^+ 267.1261, $C_{17}H_{17}NO_2$ requires 267.1259.

General Procedure for the [$RuCl_2(L^*)(C_2H_4)$] Catalyzed Asymmetric Intramolecular Carbenoid C–H Insertion Reaction

A mixture of diazo compound (0.1 mmol), $[RuCl_2(p\text{-cymene})]_2$ (5 mol%) and L^* (10 mol% were stirred in toluene (10 mL) at 70°C under N_2 atmosphere. By means of TLC analysis (20% EtOAc – hexanes), the reaction was monitored for complete consumption of the diazo starting materials. To work-up, the mixture was concentrated to ca. 2 mL by vacuum evaporation, and the residue was purified by flash chromatography (5 – 20% EtOAc-hexanes) to afford the product β-lactams. Results are summarized in Table S2.

Table S2. Asymmetric Intramolecular Carbenoid C-H Insertion of α-Diazoacetamides

entry	diazo compound	product	% yield[b]		% ee[c]	
			trans	cis	trans	cis
1	 (**1a**)	 (**2a**)	80	-	50	-
2 [d]	 (**1a**)	 (**2a**)	72	-	53	-
3	 (**1d**)	 (**2d**)	70	-	30	-
4	 (**1b**)	 (**2b**)	70	-	41	-
5	 (**1c**)	 (**2c**)	56	8	53	55

[a] : Reaction conditions: A mixture of diazo **1** (0.1 mmol), $[RuCl_2(p\text{-cymene})]_2$ (5 mol%) and L^* (10 mol%) was stirred in toluene at 70 °C under N_2 atmosphere. [b] : Isolated yield. [c] : Determined by ^1H NMR analysis using $Eu(hfc)_3$ as chiral shift reagent. [d] : Using $[RuCl_2(L^*)(C_2H_4)]$ (10 mol%) as catalyst

Figure S1. ^{1}H NMR Spectrum of
N-*p*-Chlorobenzyl-*N*-*tert*-butyl–α-ethoxycarbonyl-α-diazoacetamide (**1a**)

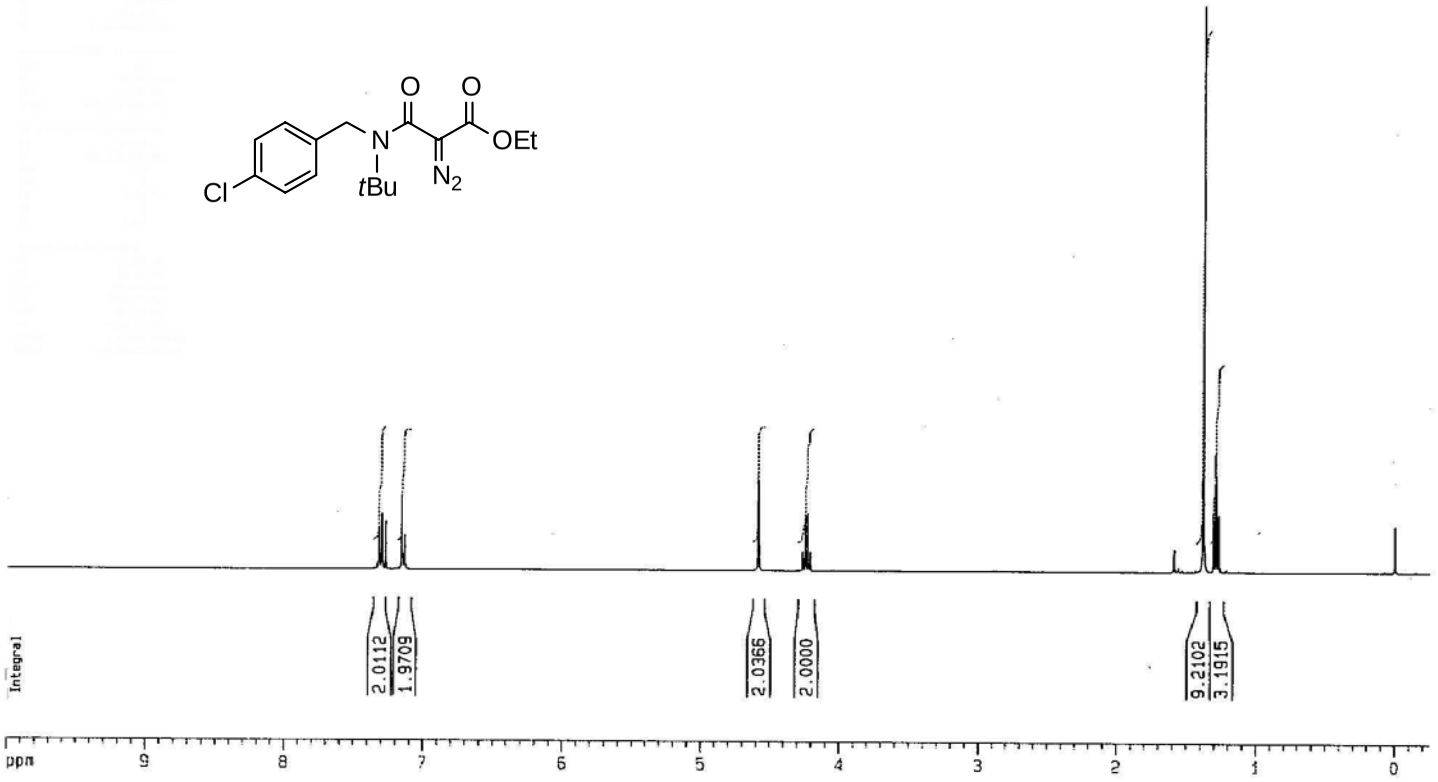


Figure S2. ^{1}H NMR Spectrum of *N*-Benzyl-*N*-*tert*-butyl-*α*-ethoxycarbonyl-*α*-diazoacetamide (**1b**)

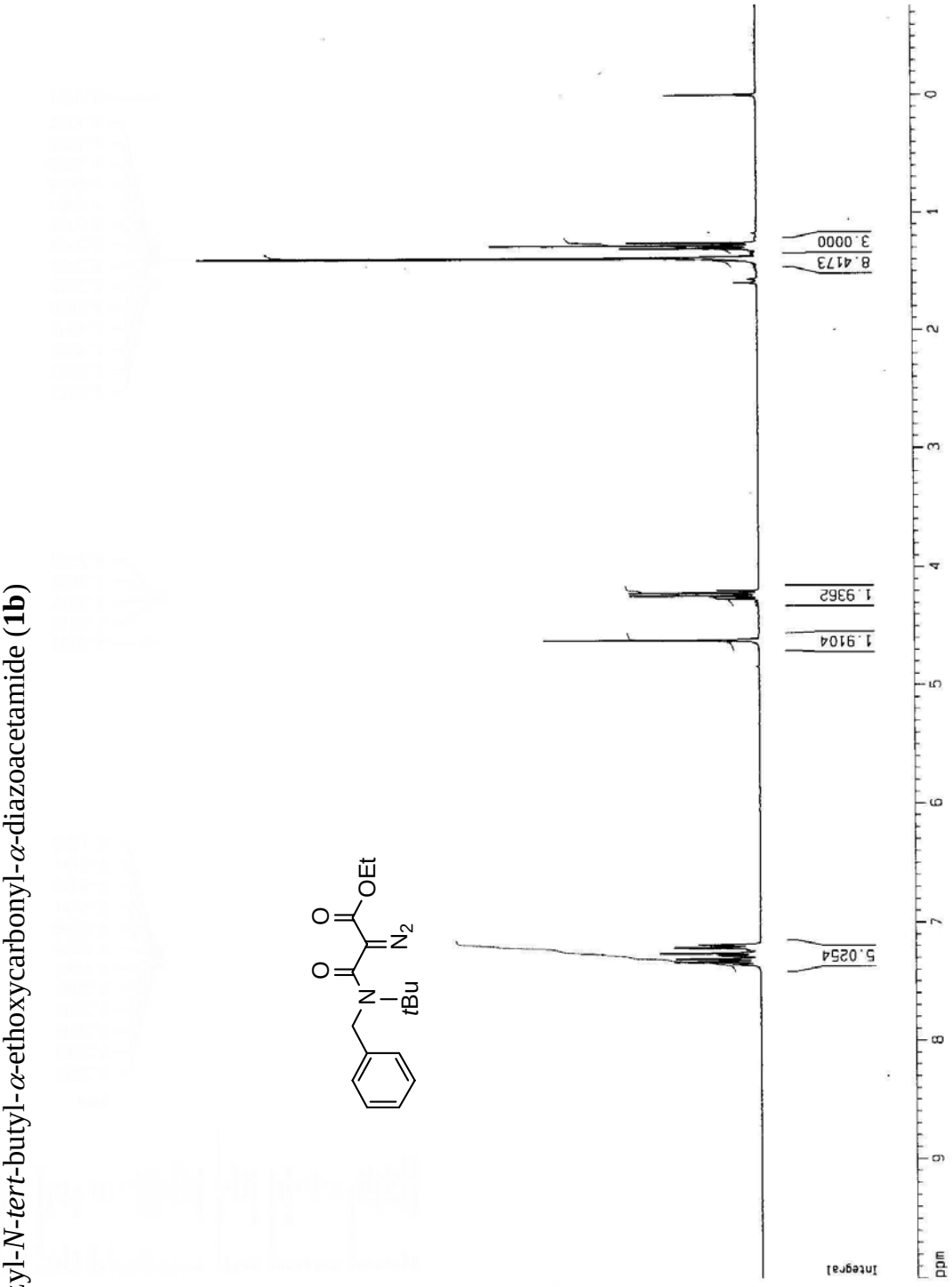


Figure S3. ^{1}H NMR Spectrum of
N-*p*-Methoxybenzyl-*N*-*tert*-butyl-α-ethoxycarbonyl-α-diazoacetamide (**1c**)

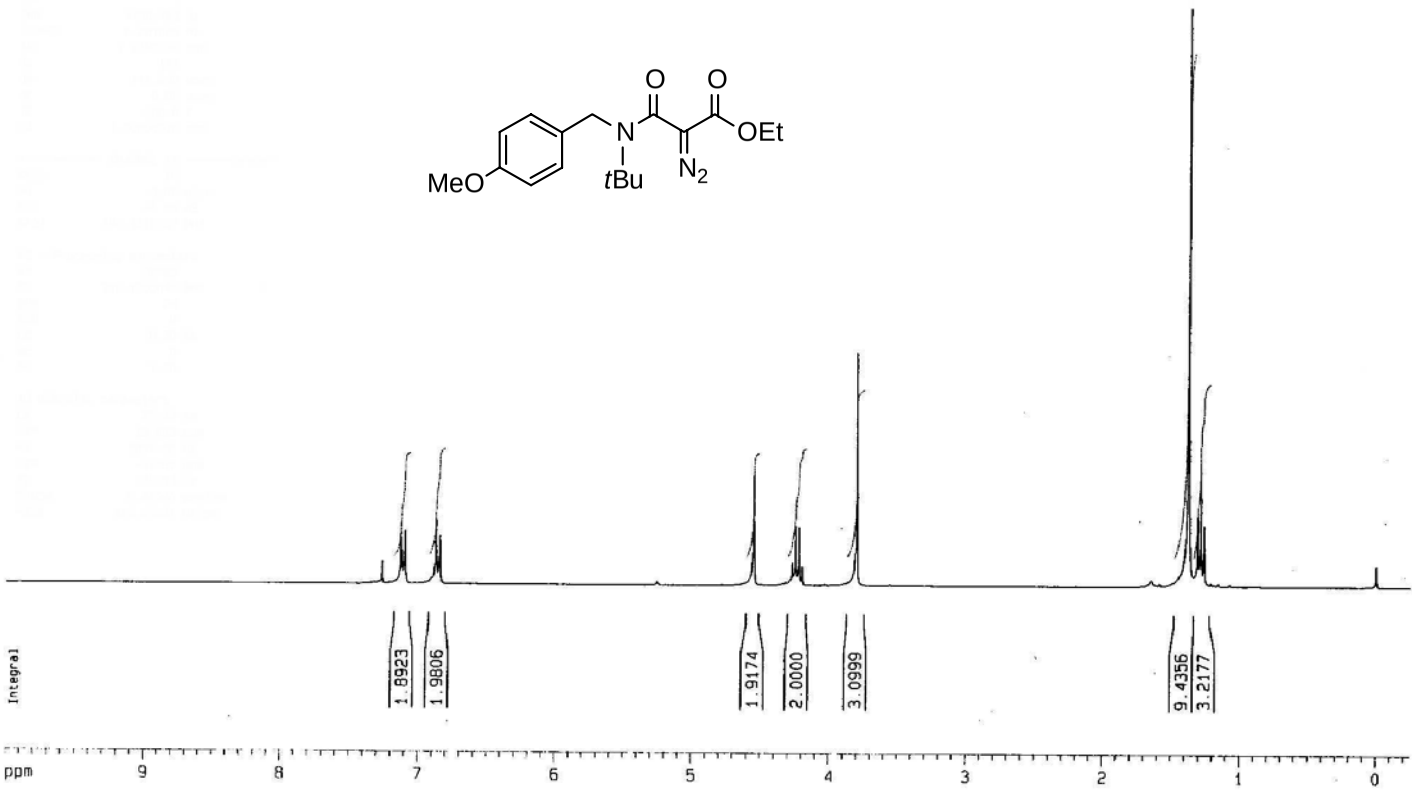


Figure S4. ^{1}H NMR Spectrum of
N-*p*-Chlorobenzyl-*N*-*tert*-butyl-α-carbonyl-α-diazoacetamide (**1d**)

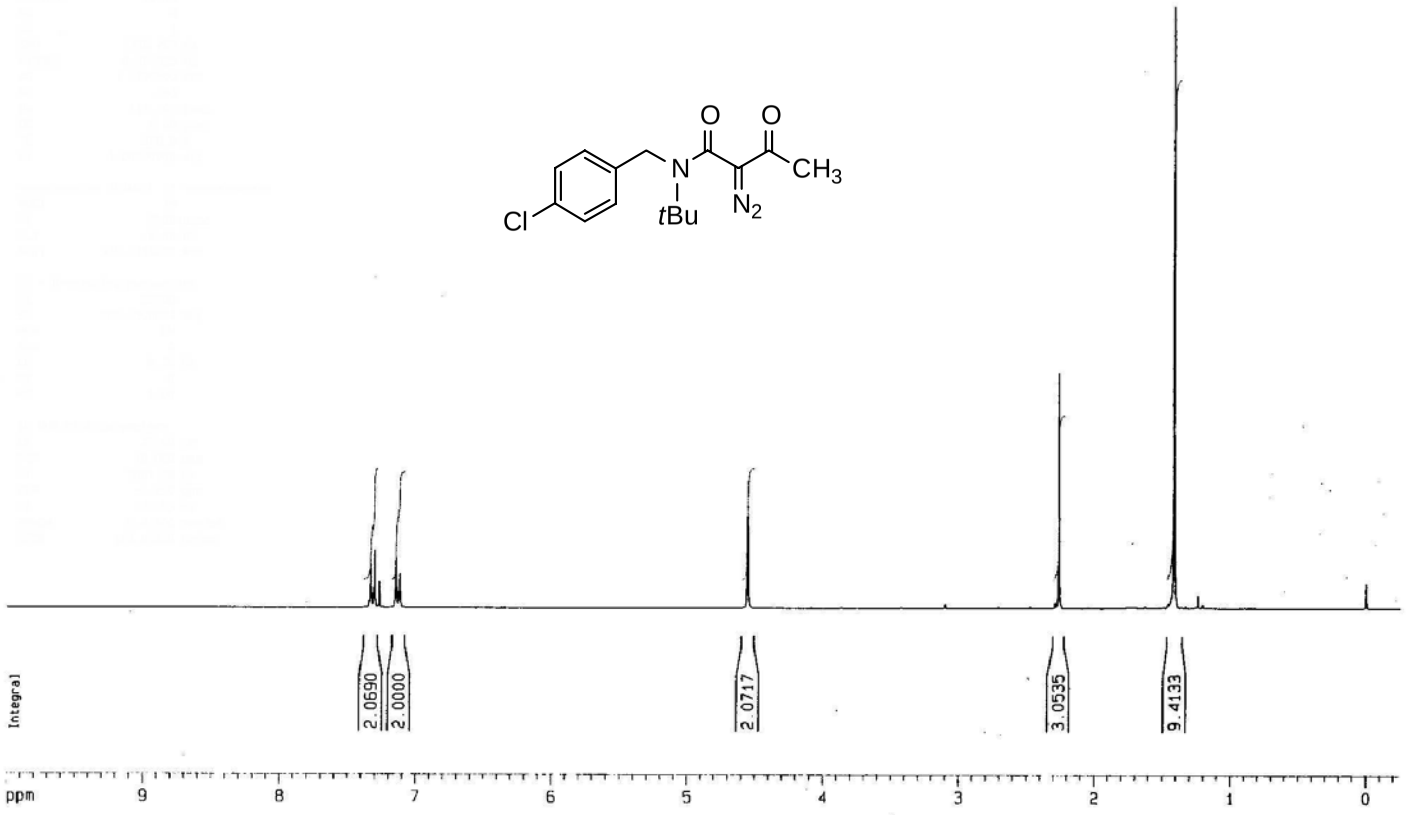


Figure S5. ^{1}H NMR Spectrum of
N,*N*-Diisopropyl-α-ethoxycarbonyl-α-diazoacetamide (**1e**)

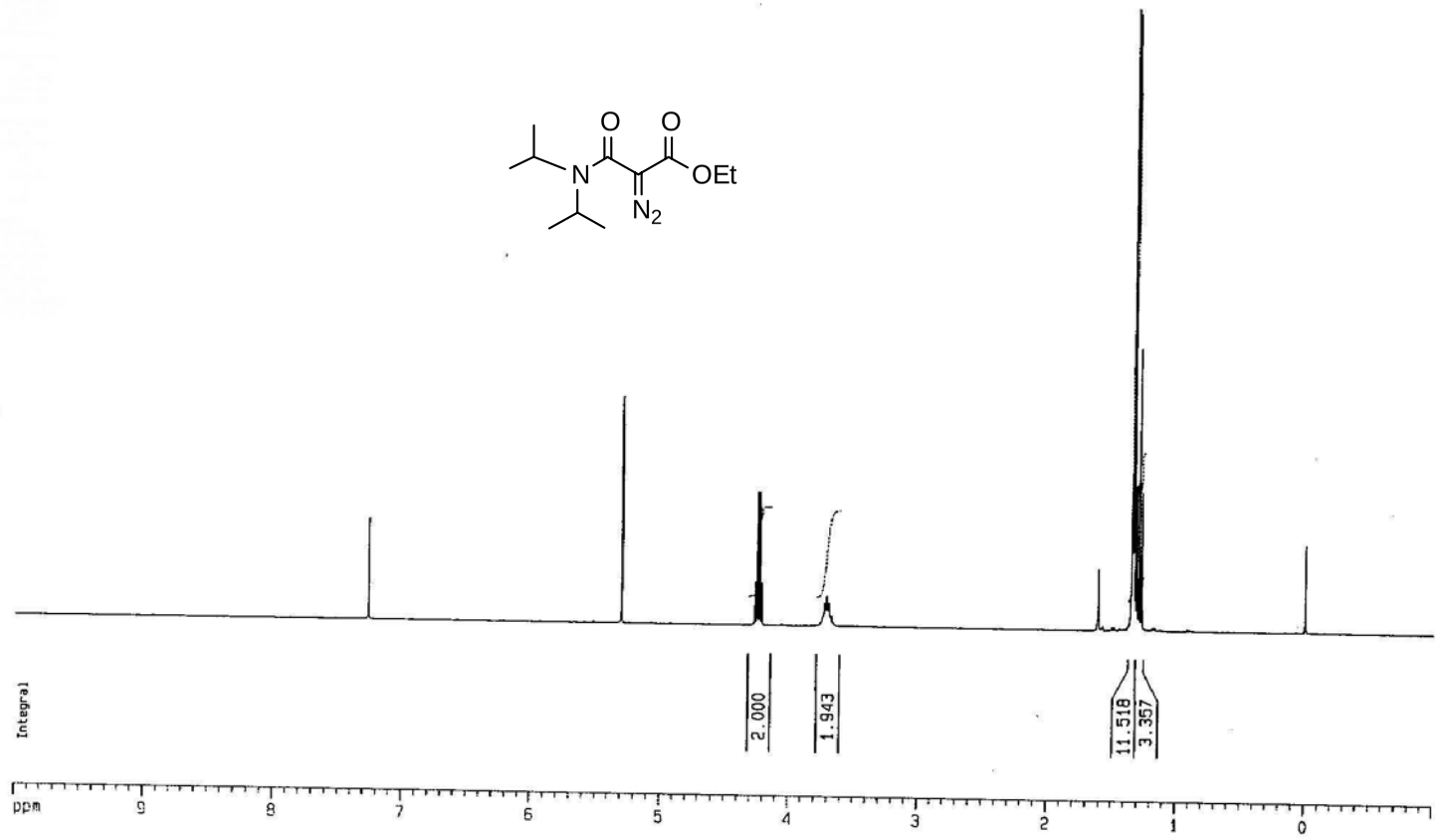


Figure S6. 1^{H} NMR Spectrum of
N-Phenylethyl-*N*-*tert*-butyl-α-ethoxycarbonyl-α-diazoacetamide (**1f**)

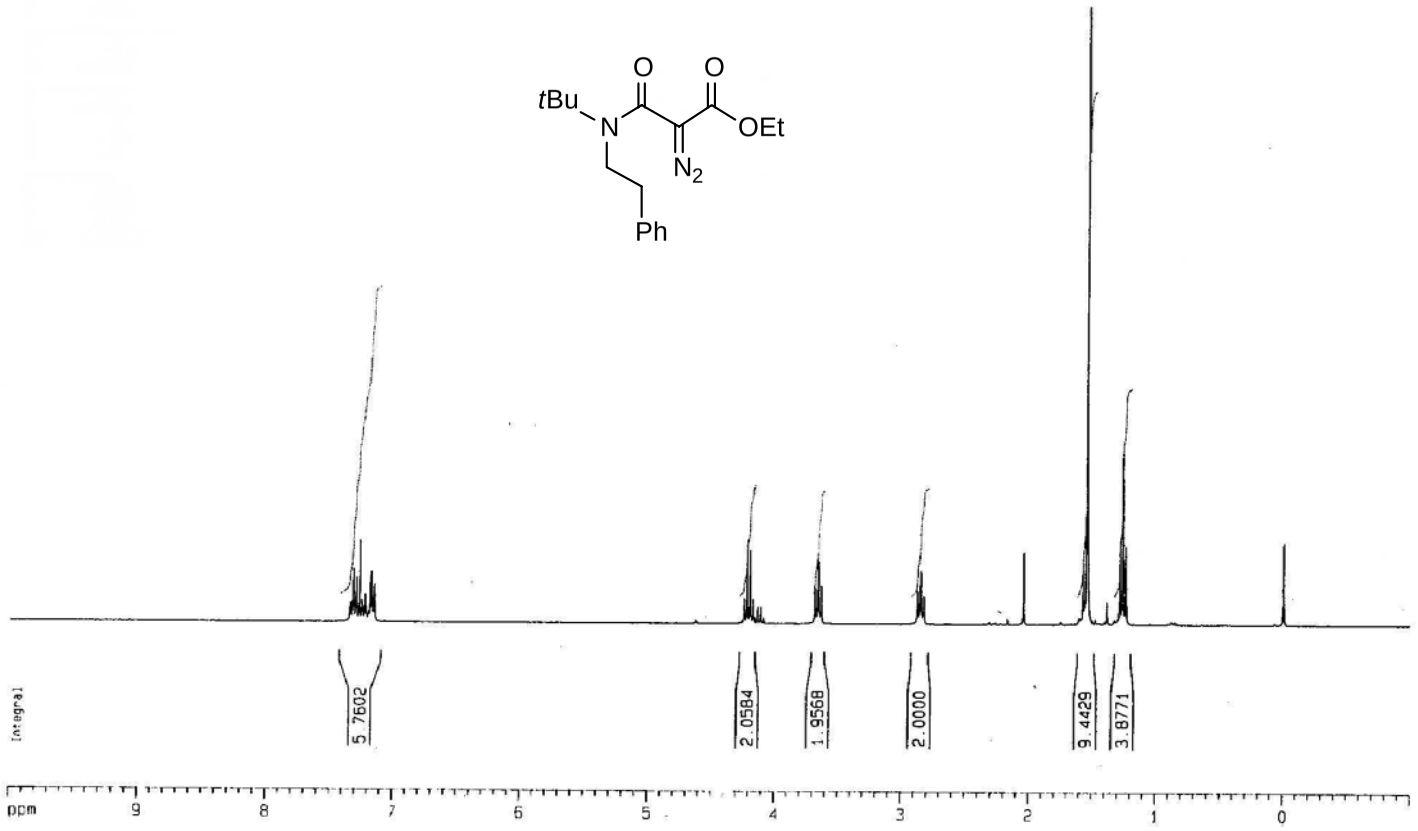


Figure S7. ^{1}H NMR Spectrum of
N-Phenylethyl-*N*-benzyl-α-ethoxycarbonyl-α-diazoacetamide (**1g**)

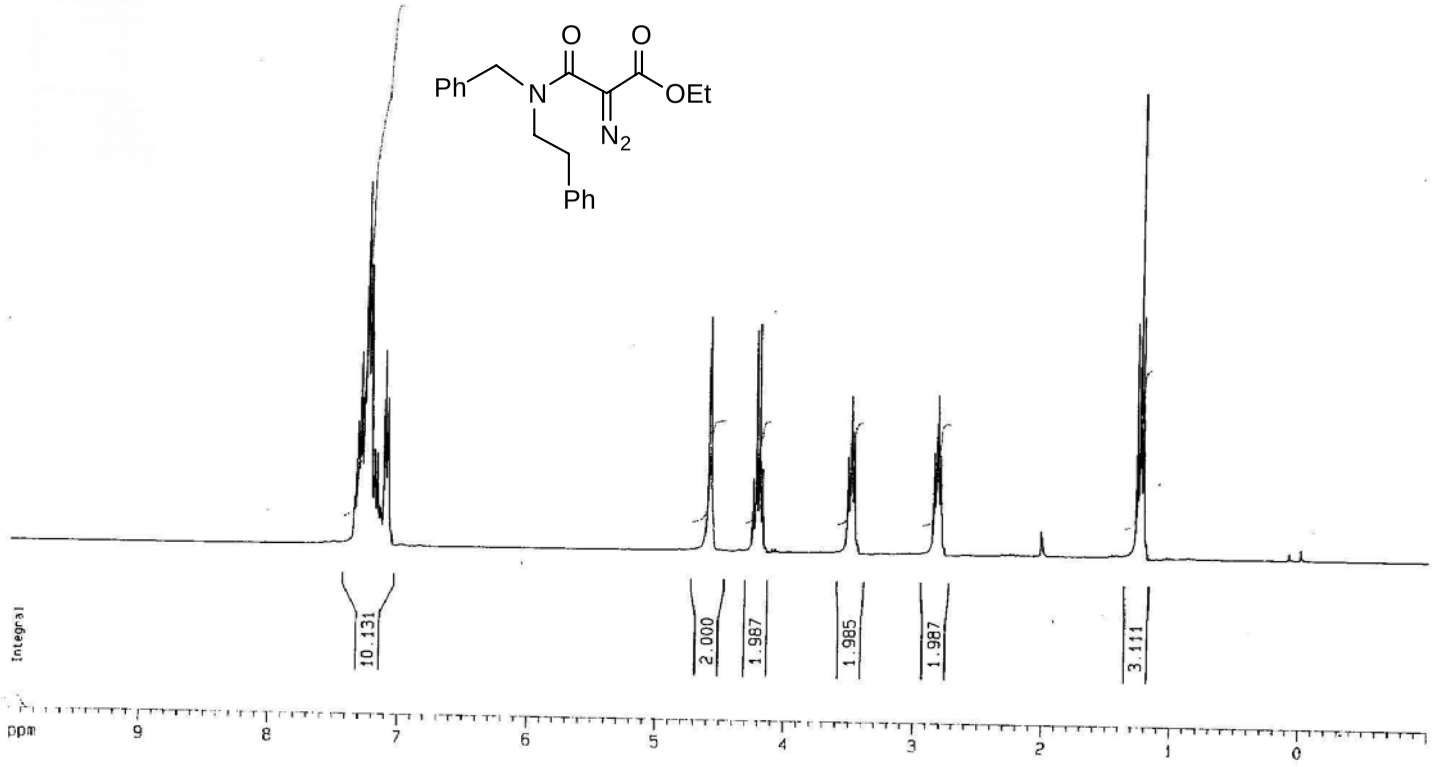


Figure S8. ^{1}H NMR Spectrum of
N-Benzyl-*N*-*p*-methoxybenzyl-α-ethoxycarbonyl-α-diazoacetamide (**1h**)

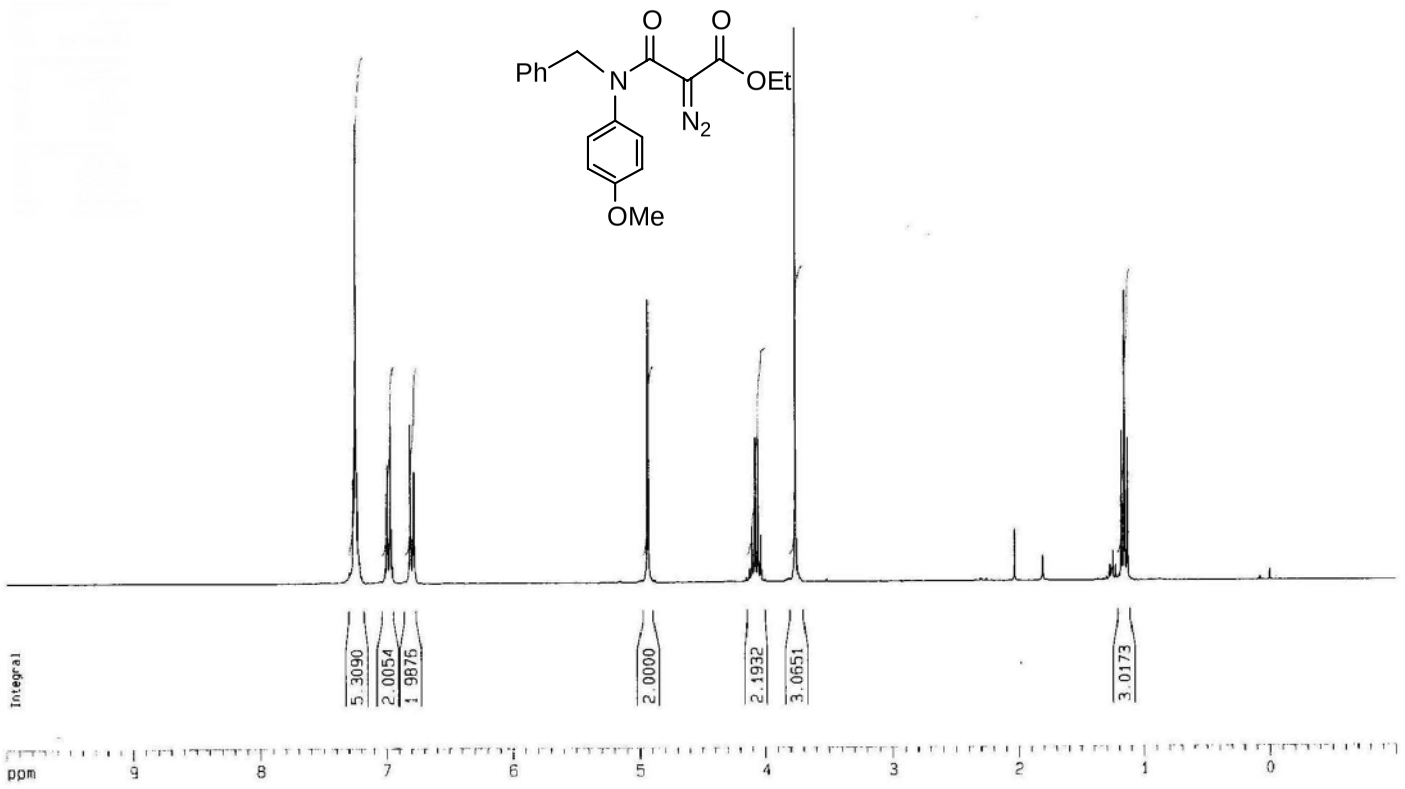


Figure S9. ^{1}H NMR Spectrum of *N*-Phenylethyl-*N*-*p*-methoxybenzyl-α-ethoxycarbonyl-α-diazoacetamide (**1i**)

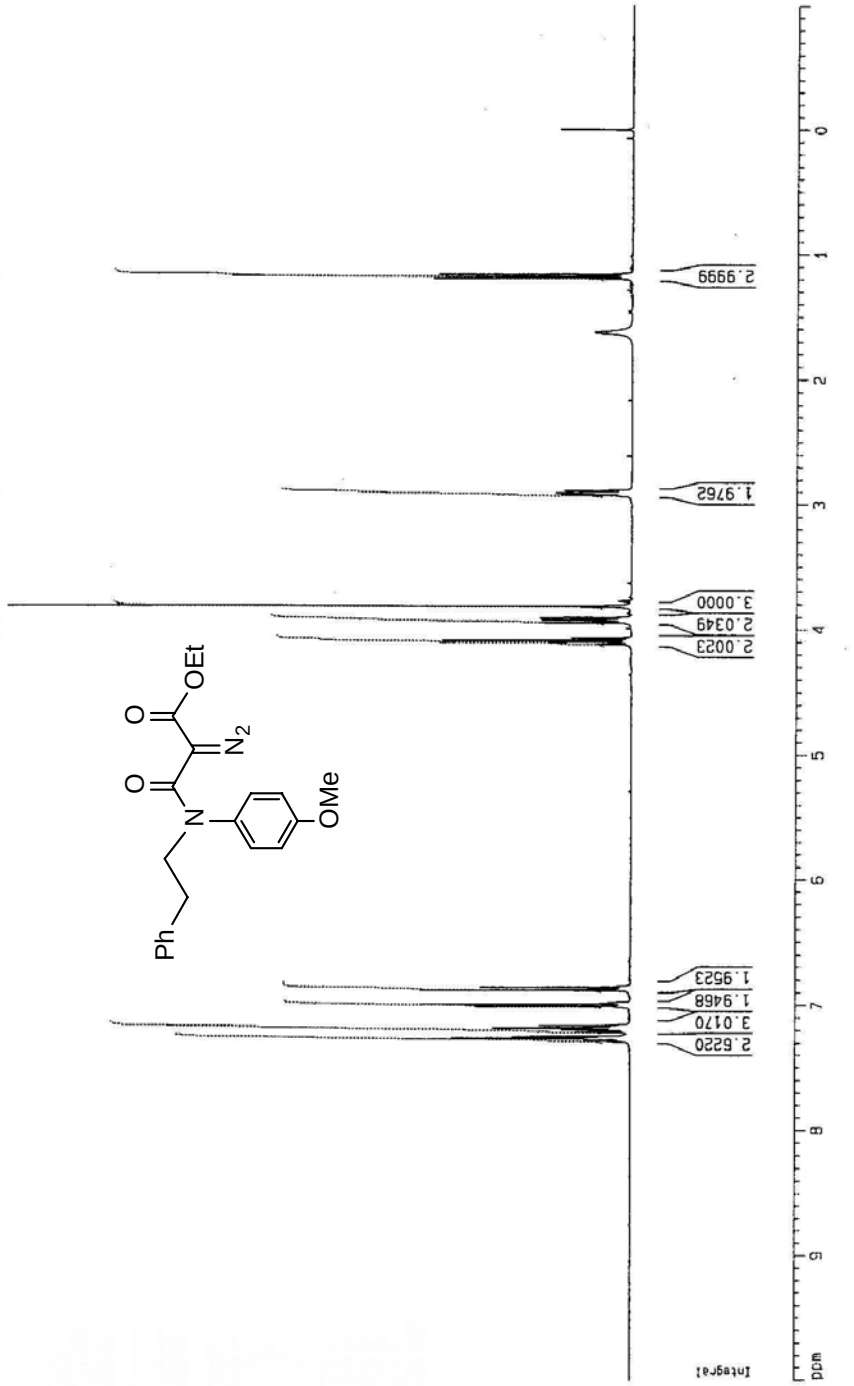


Figure S10. ^{1}H NMR Spectrum of
N-tert-Butyl-*cis*-1-ethoxycarbonyl-2-*p*-chlorophenyl-*β*-lactam (**2a**)

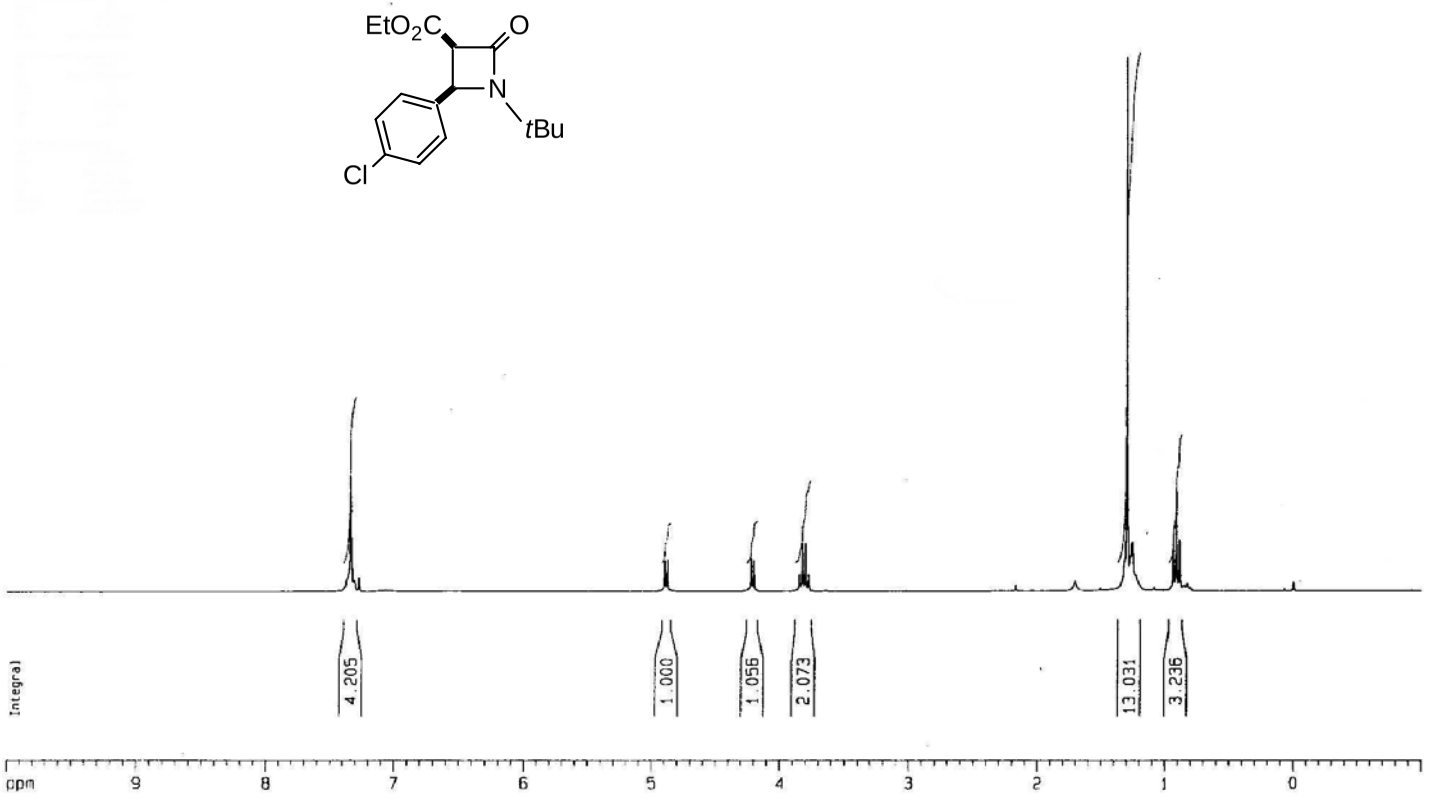


Figure S11. ^{1}H NMR Spectrum of
N-tert-Butyl-*cis*-1-ethoxycarbonylphenyl-*β*-lactam (**2b**)

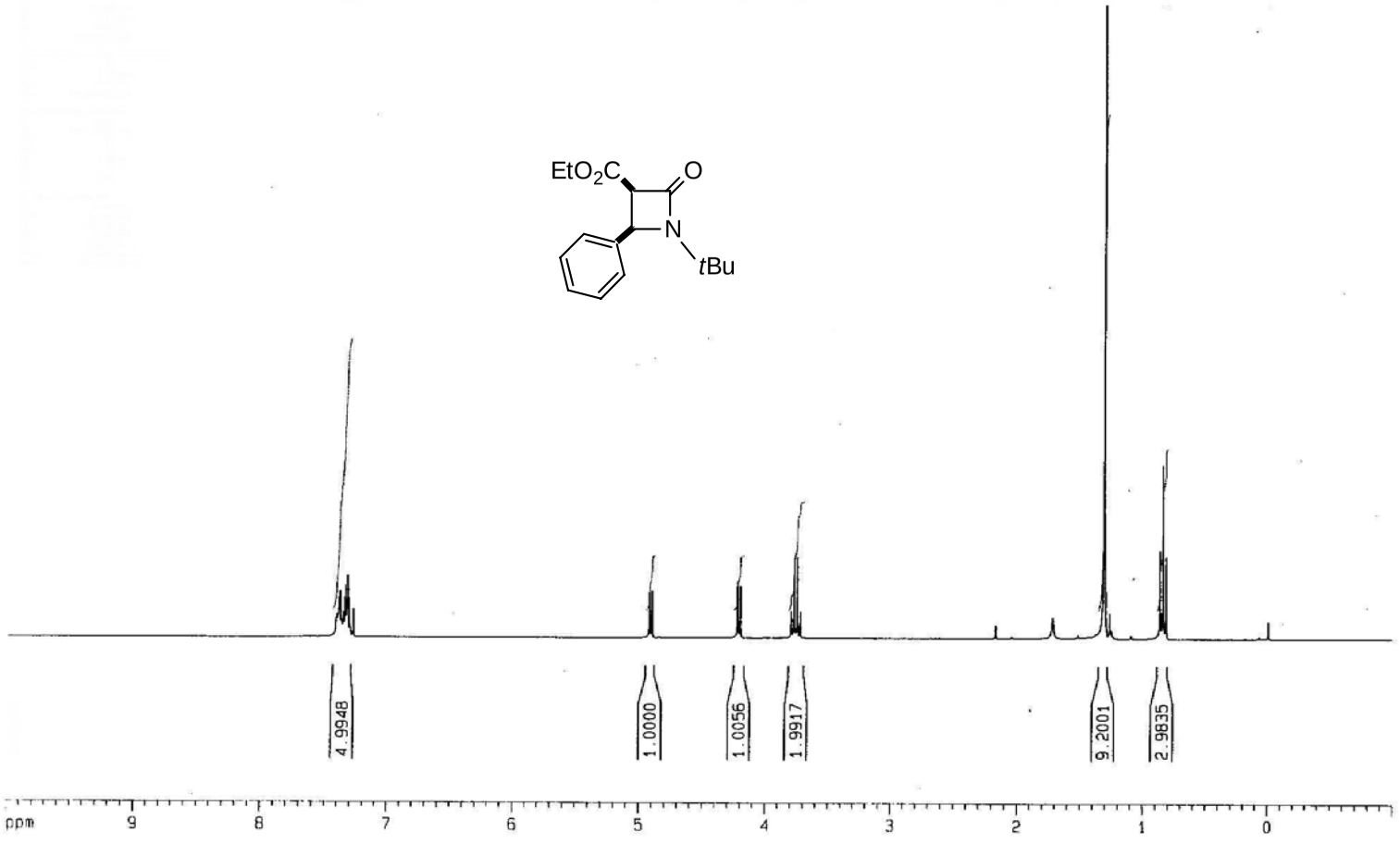


Figure S12. ^{1}H NMR Spectrum of
N-tert-Butyl-*cis*-1-ethoxycarbonyl-2-*p*-methoxyphenyl-*β*-lactam (**2c**)

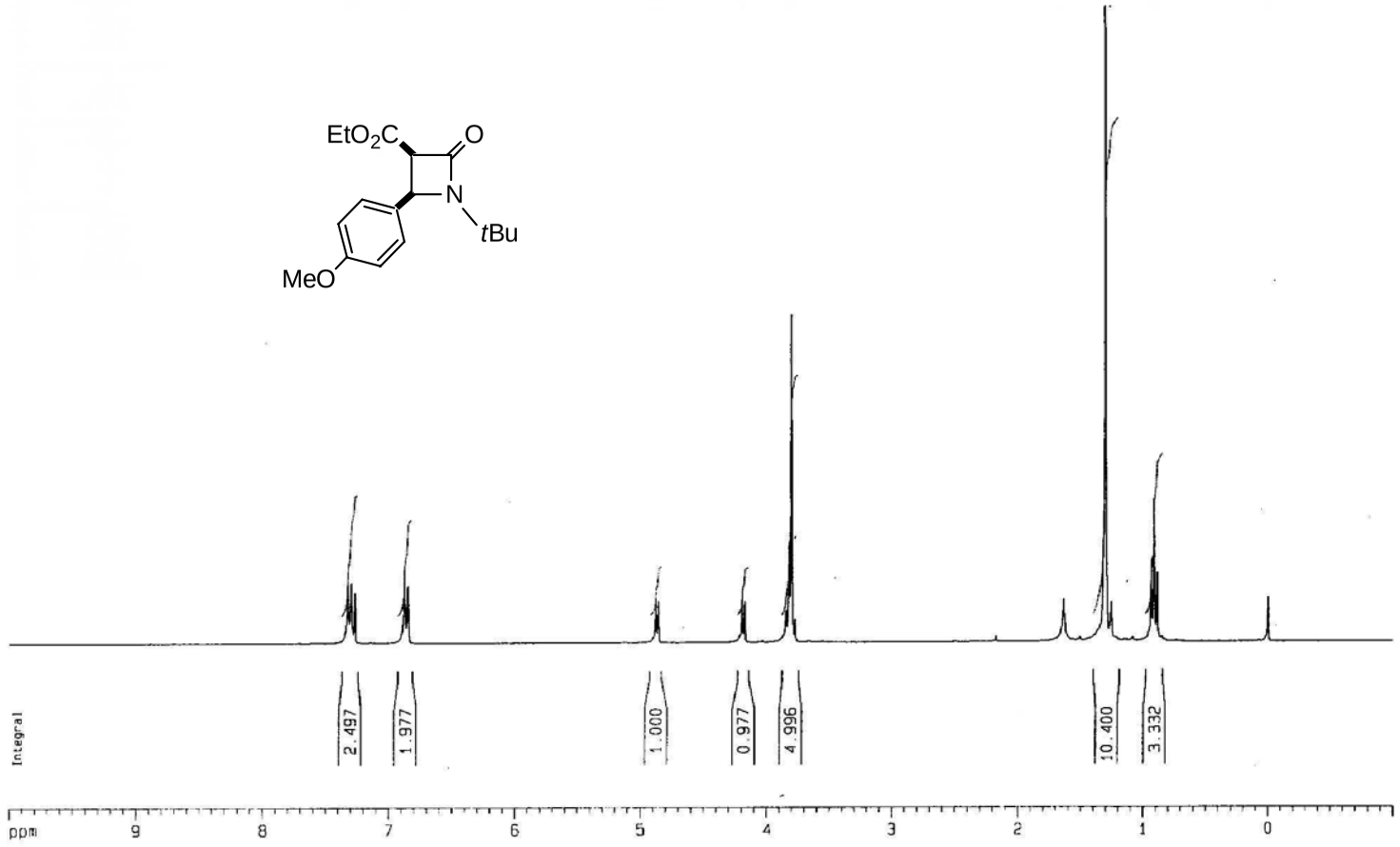


Figure S13. ^{1}H NMR Spectrum of
N-tert-Butyl-*trans*-1-carbonyl-2-*p*-chlorophenyl-*β*-lactam (**2d**)

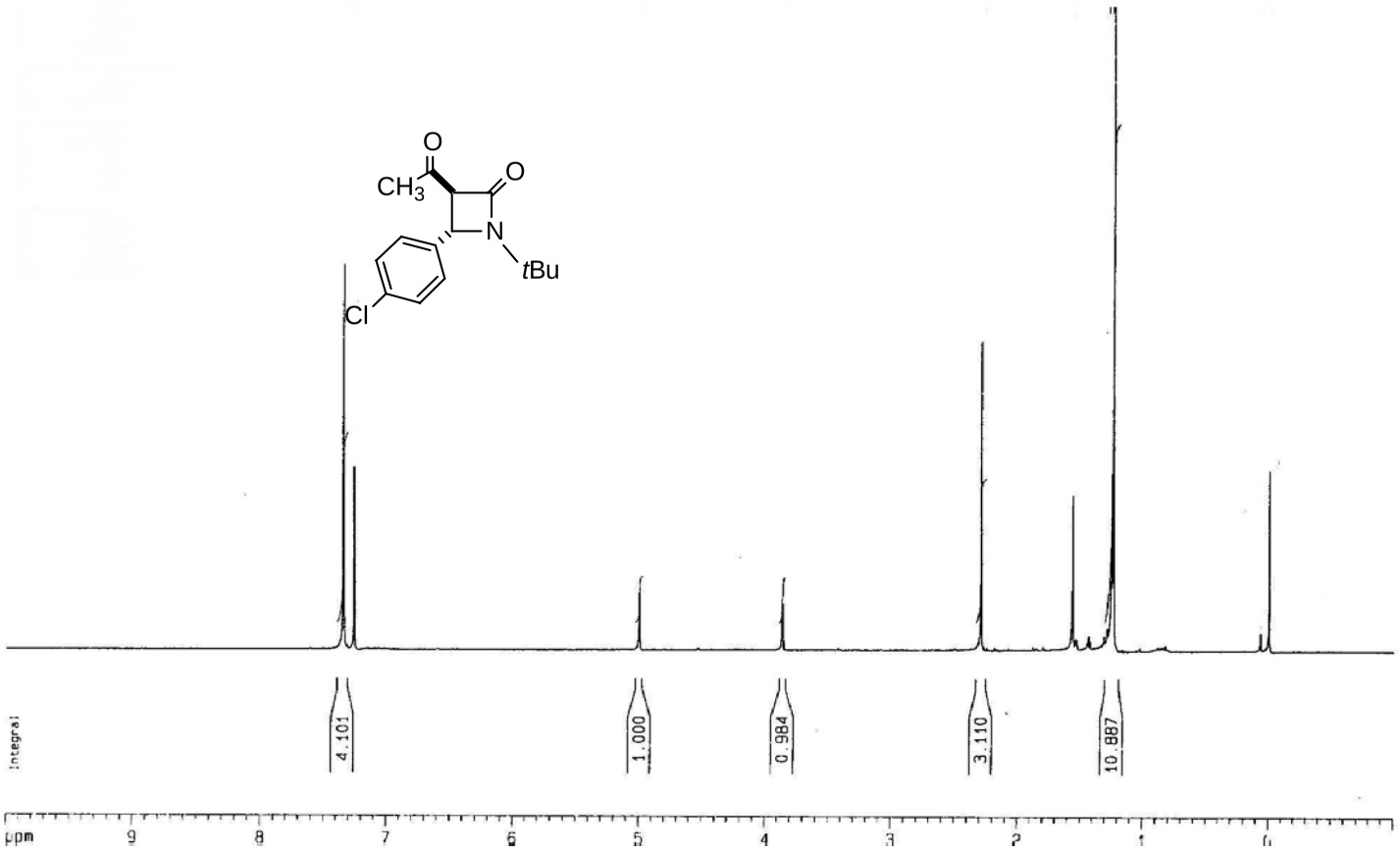


Figure S14. ^{1}H NMR Spectrum of *N*-Isopropyl-1-ethoxycarbonyl-2,2-dimethyl-*β*-lactam (**2e**)

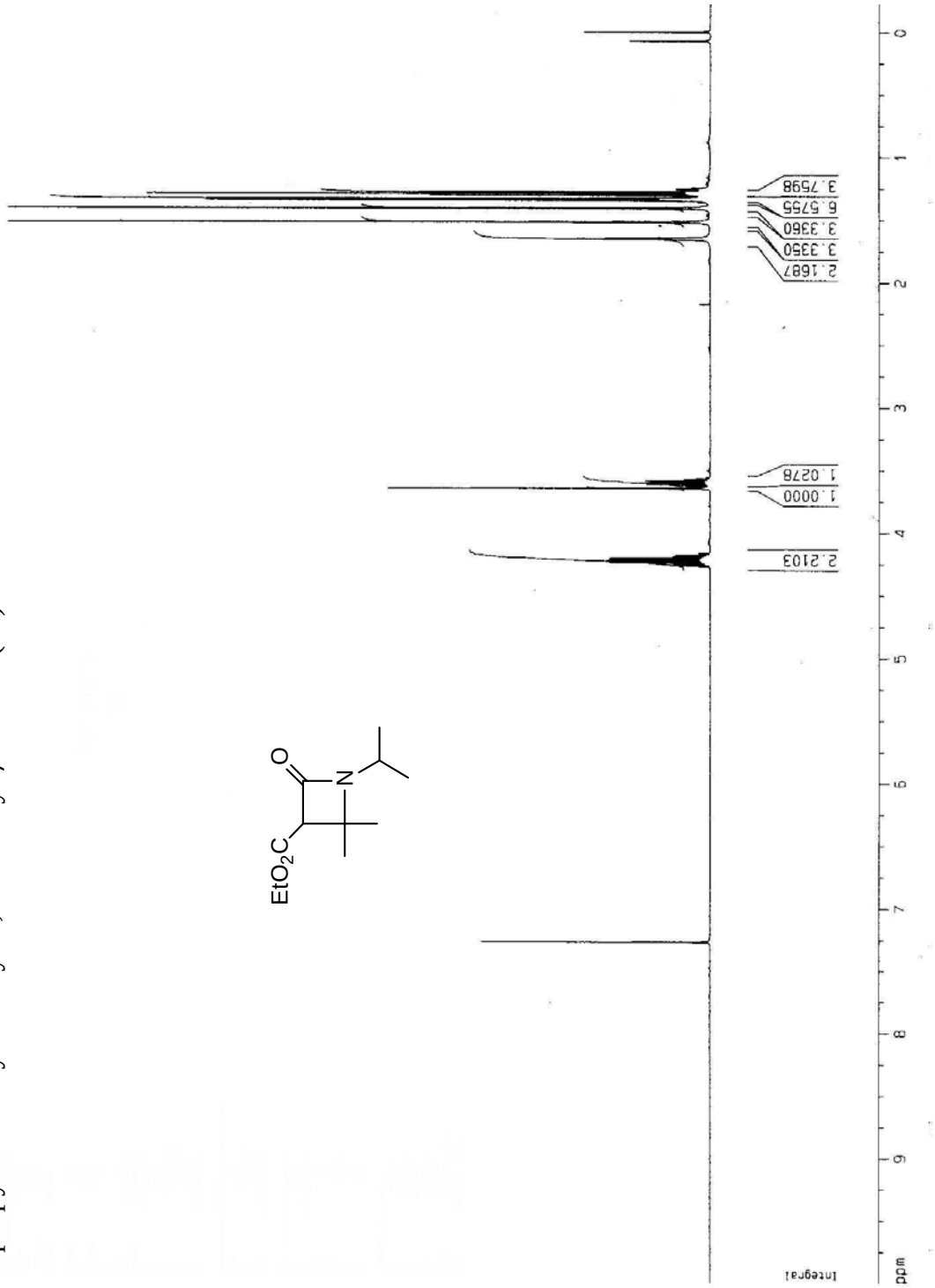


Figure S15. ^{1}H NMR Spectrum of
N-tert-Butyl-*cis*-1-ethoxycarbonyl-2-benzyl-β-lactam (**2f**)

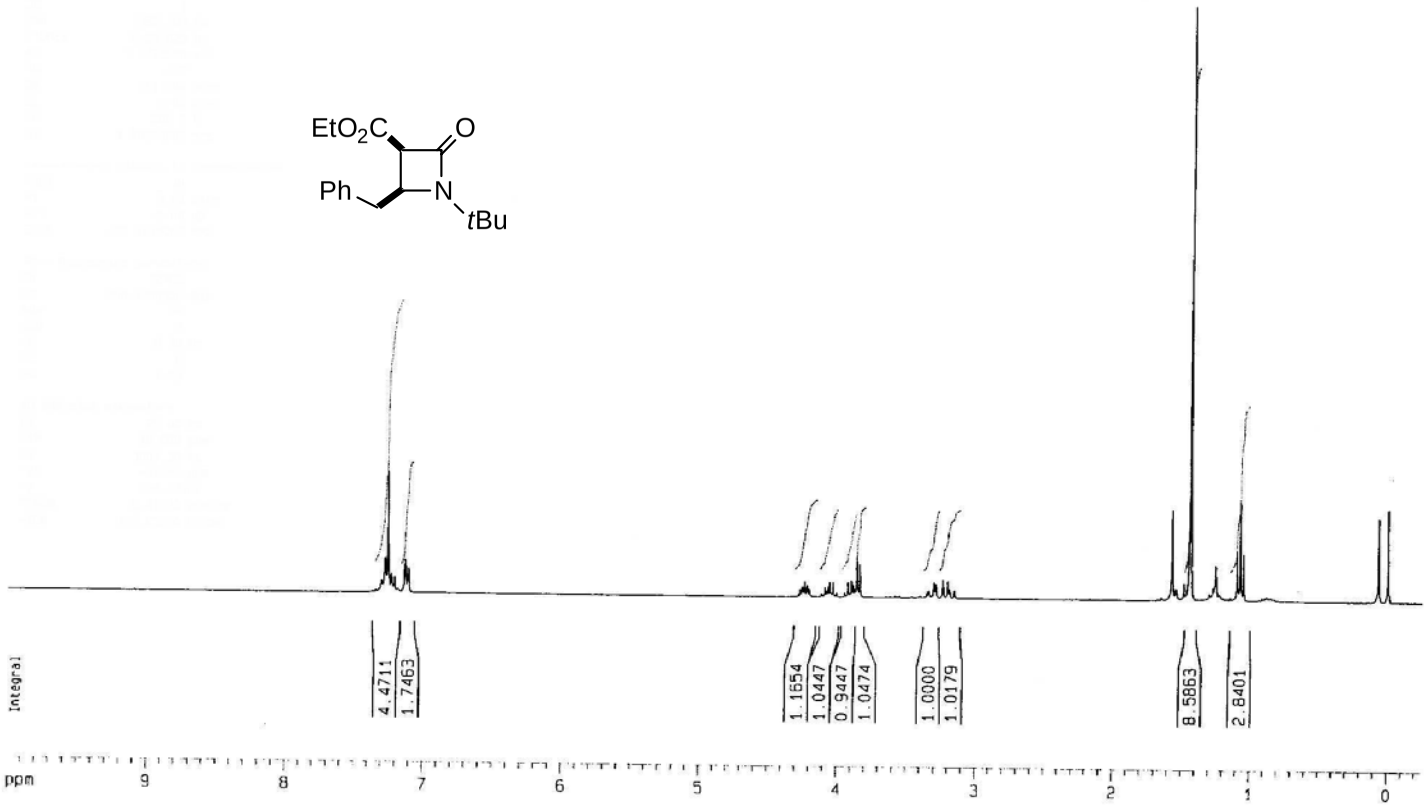


Figure S16. ^{1}H NMR Spectrum of
N-tert-Butyl-*trans*-1-ethoxycarbonyl-2-phenyl-γ-lactam (**3**)

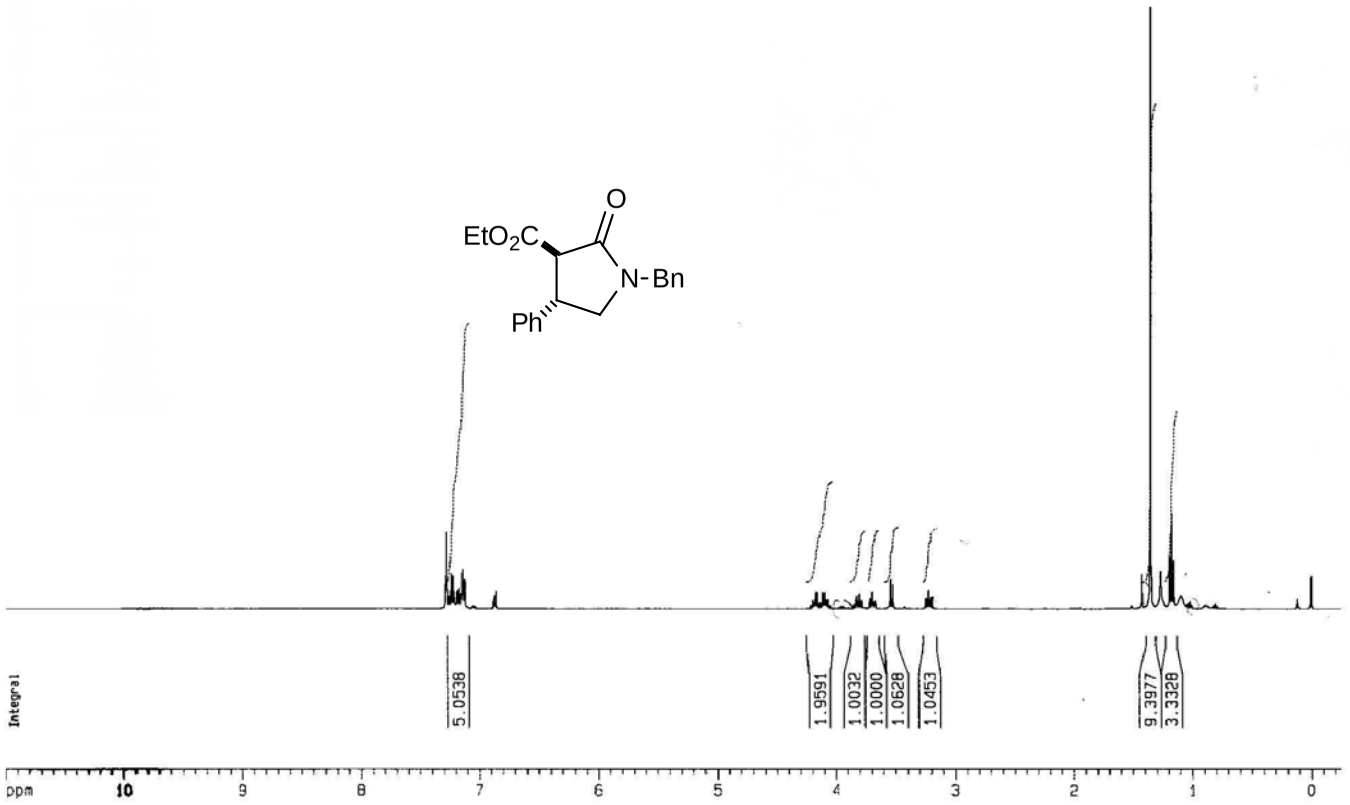


Figure S17. ^{1}H NMR Spectrum of
N-Phenylethyl-*cis*-1-ethoxycarbonyl-2-phenyl-*β*-lactam (**2g**)

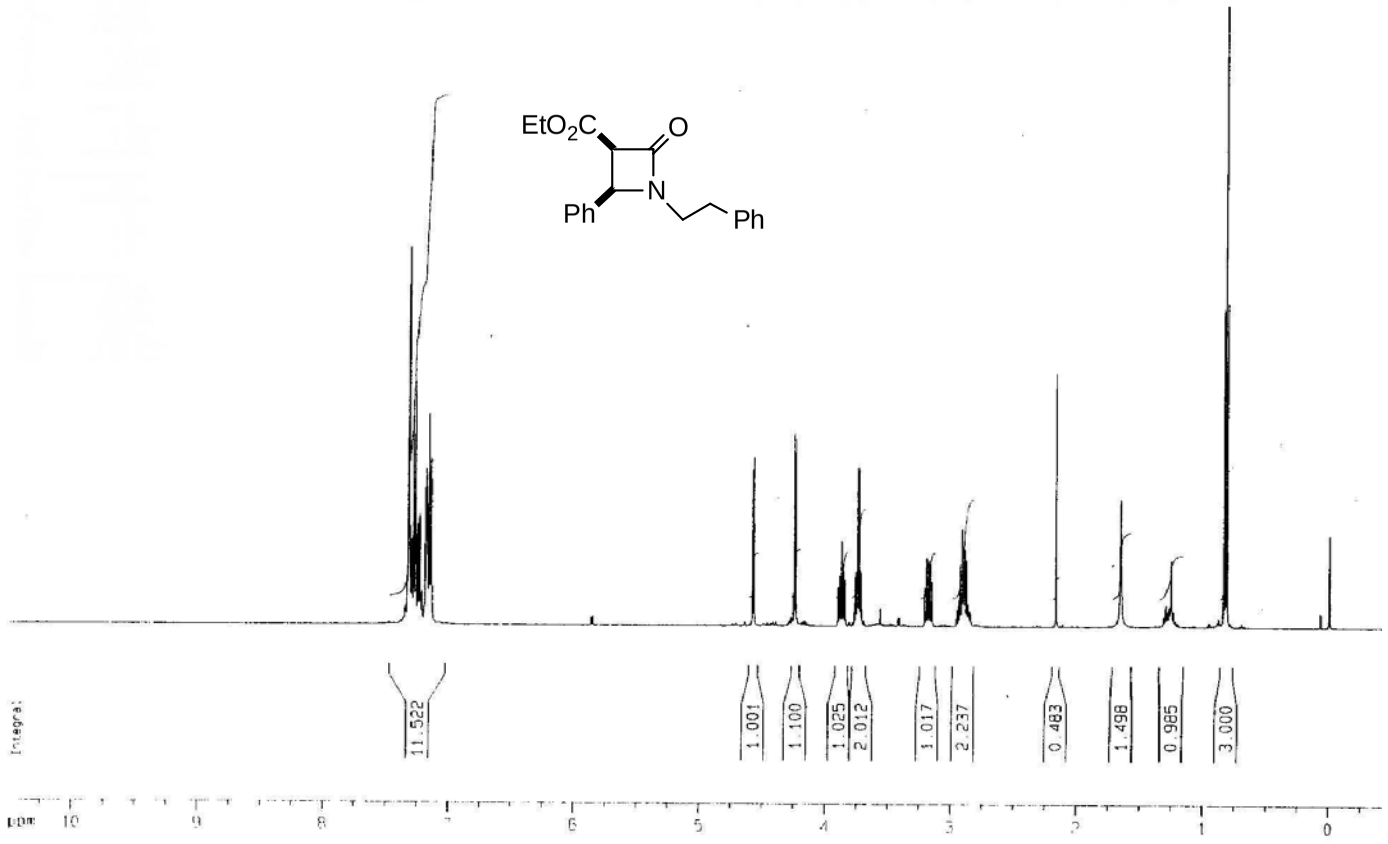


Figure S18. ^{1}H NMR Spectrum of
N-Benzyl-*trans*-1-ethoxycarbonyl-2-phenyl-γ-lactam (**4**)

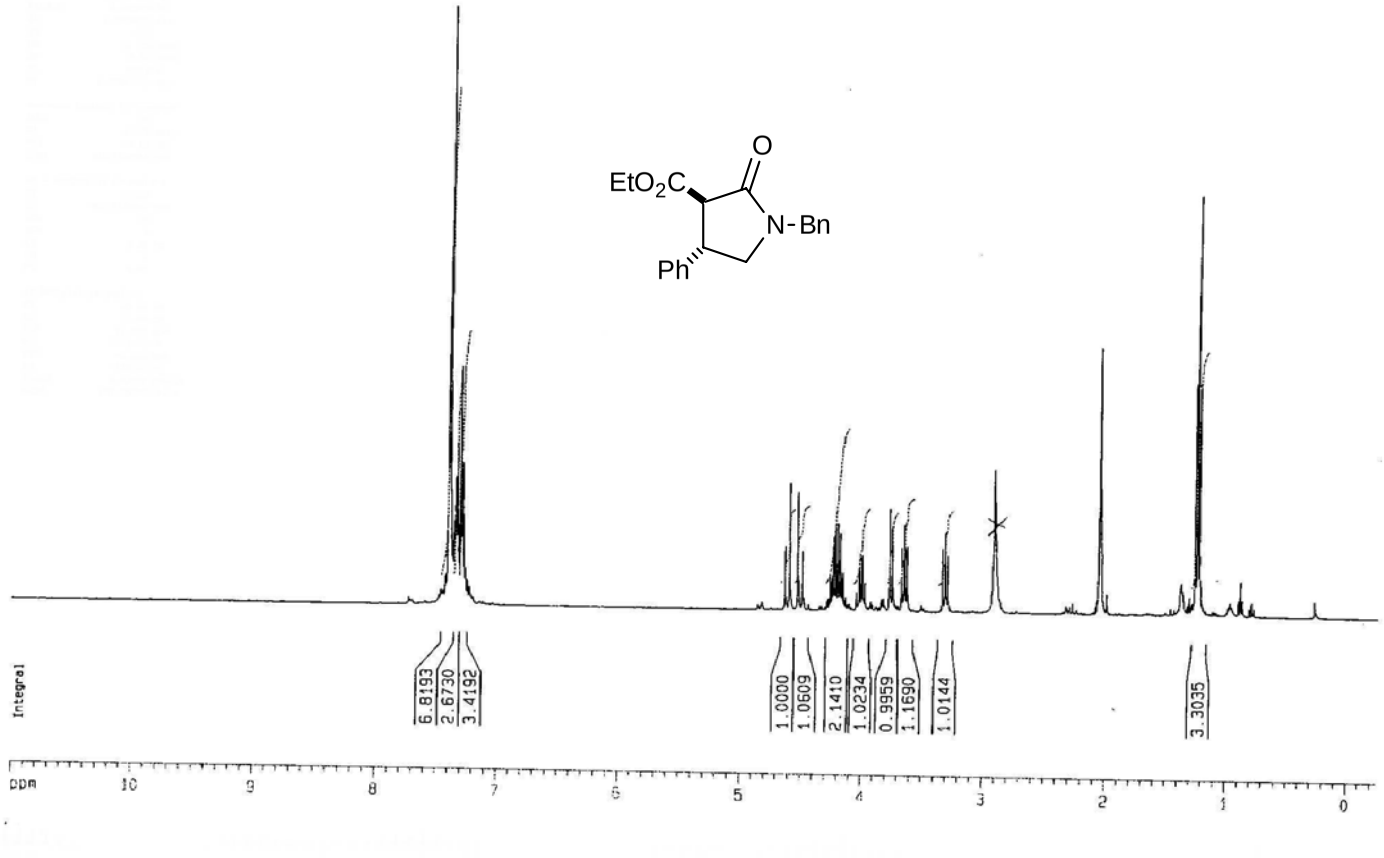


Figure S19. ^{1}H NMR Spectrum of *N*-Benzyl-5-methoxy-1,3-dihydro-indol-2-one (**5**)

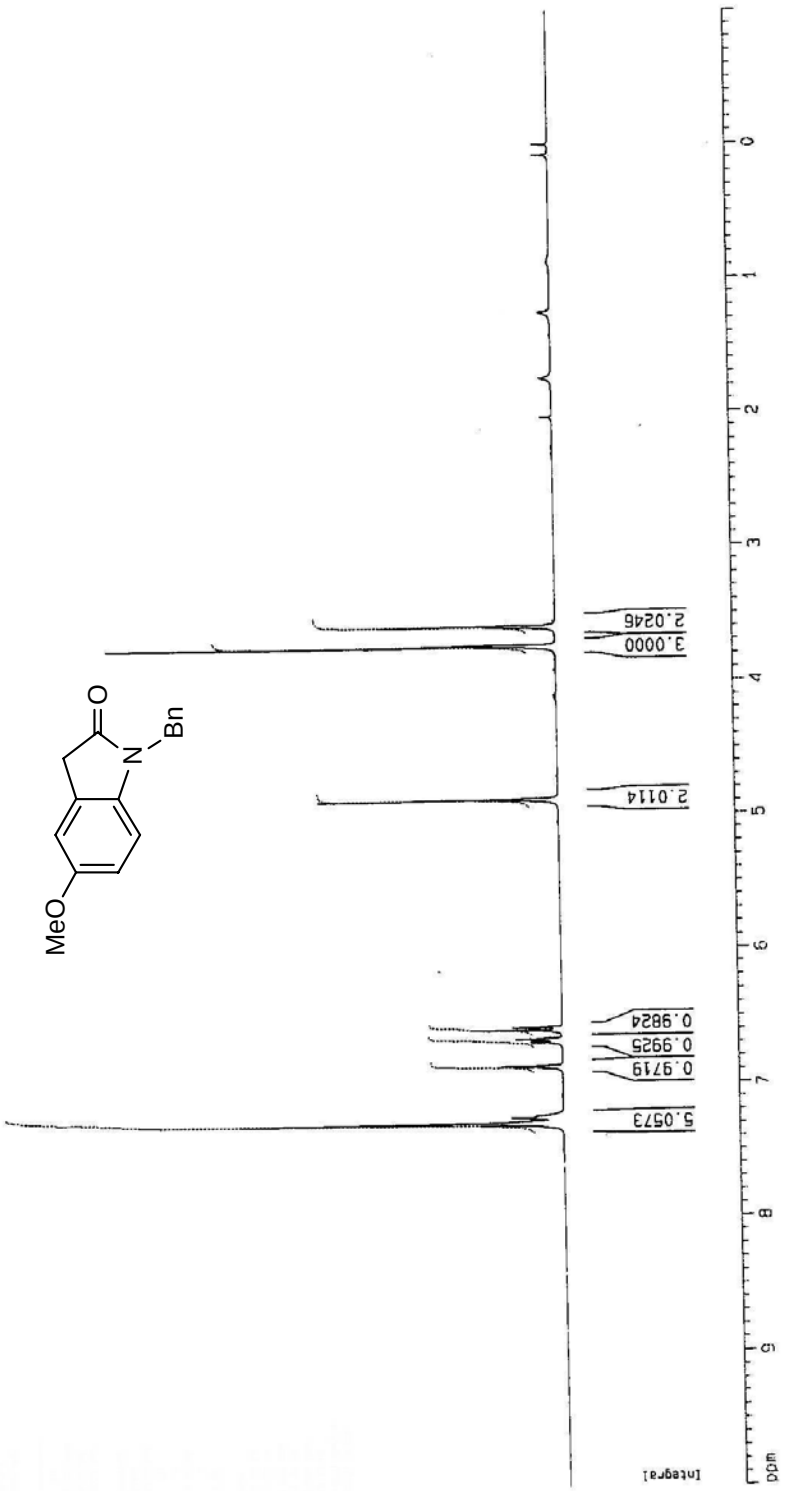


Figure S20. ^{1}H NMR Spectrum of
N-Phenethyl-5-methoxy-1,3-dihydro-indol-2-one (**6**)

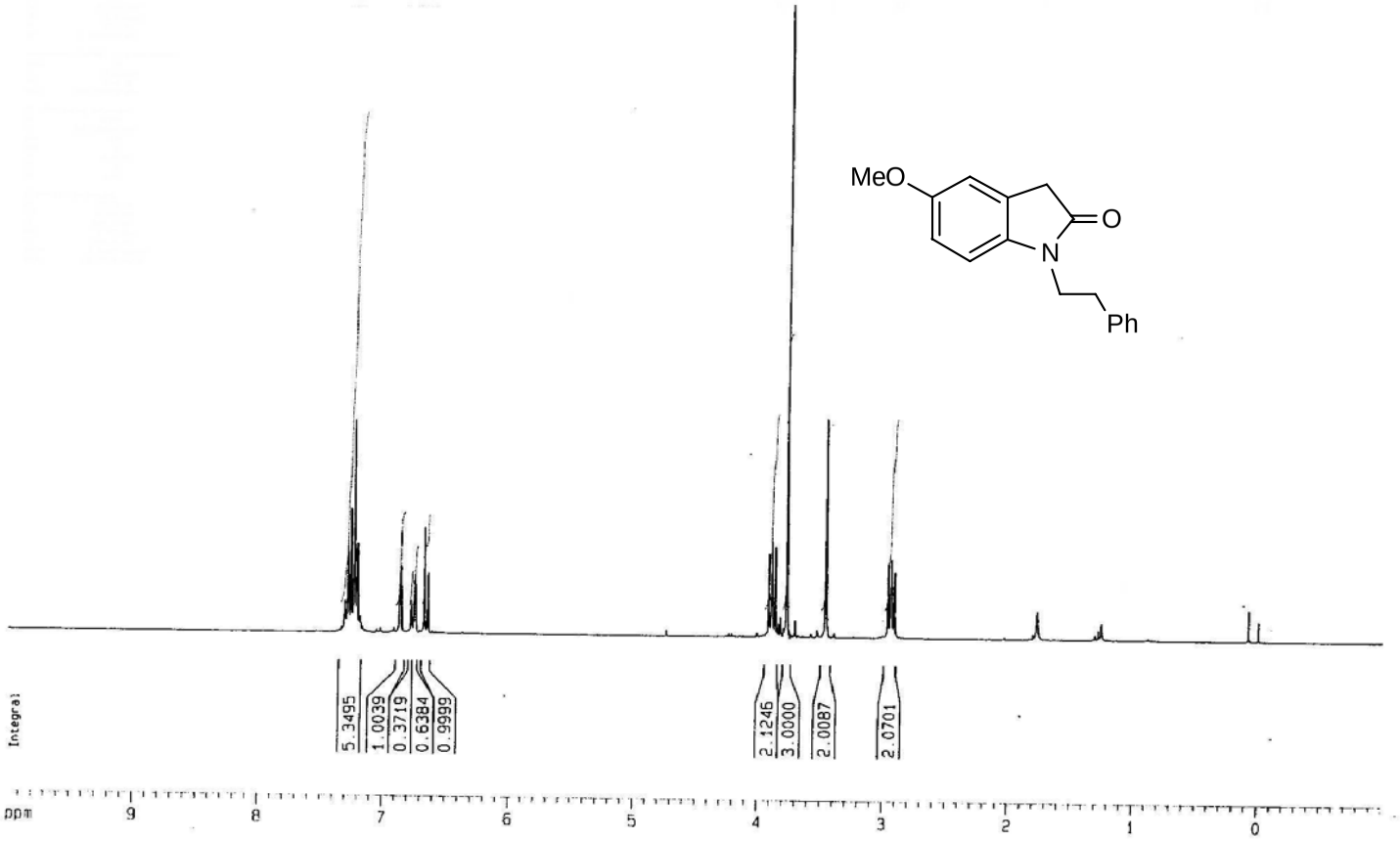


Figure S21. NOESY of *trans*-(**3**)

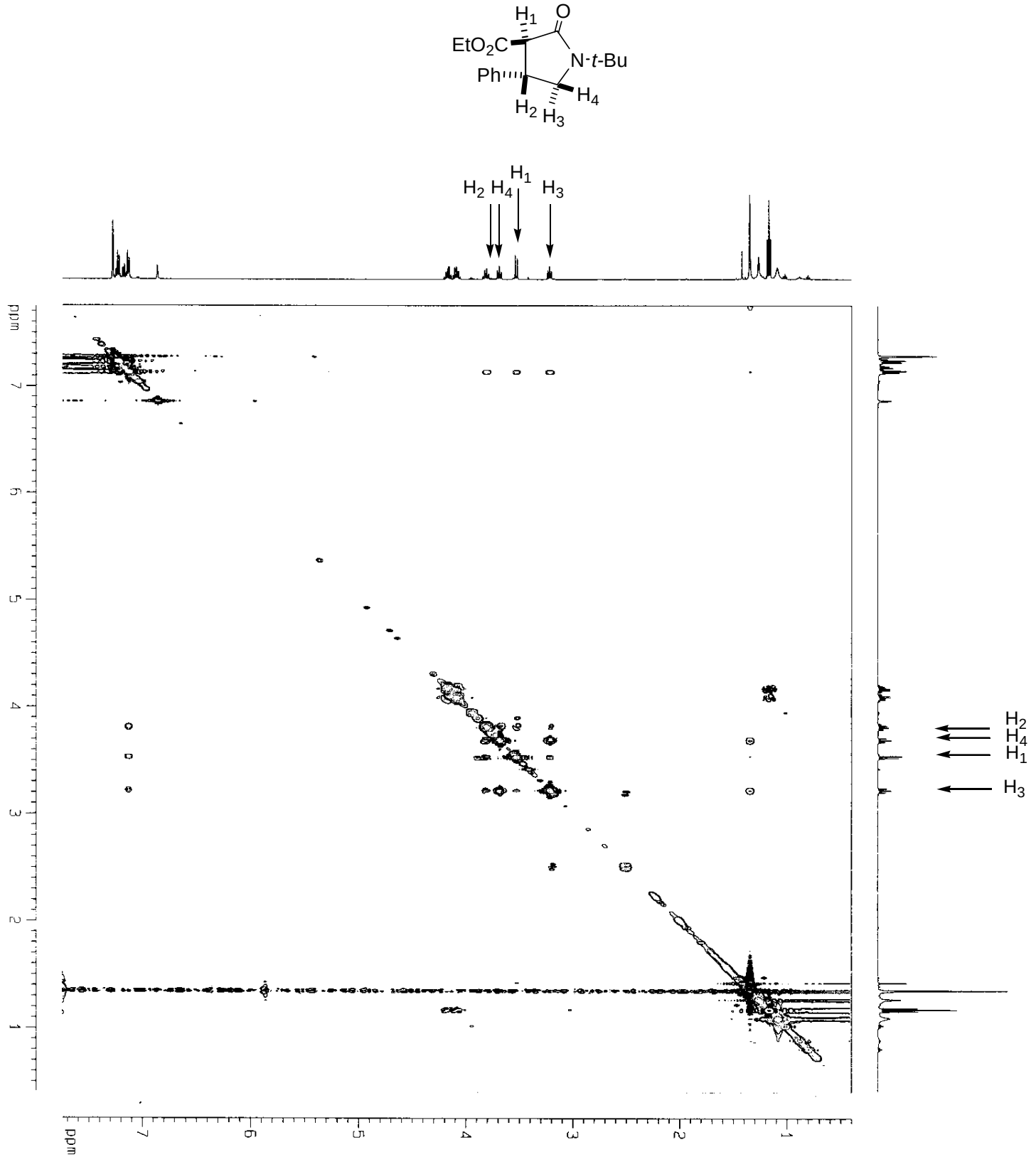
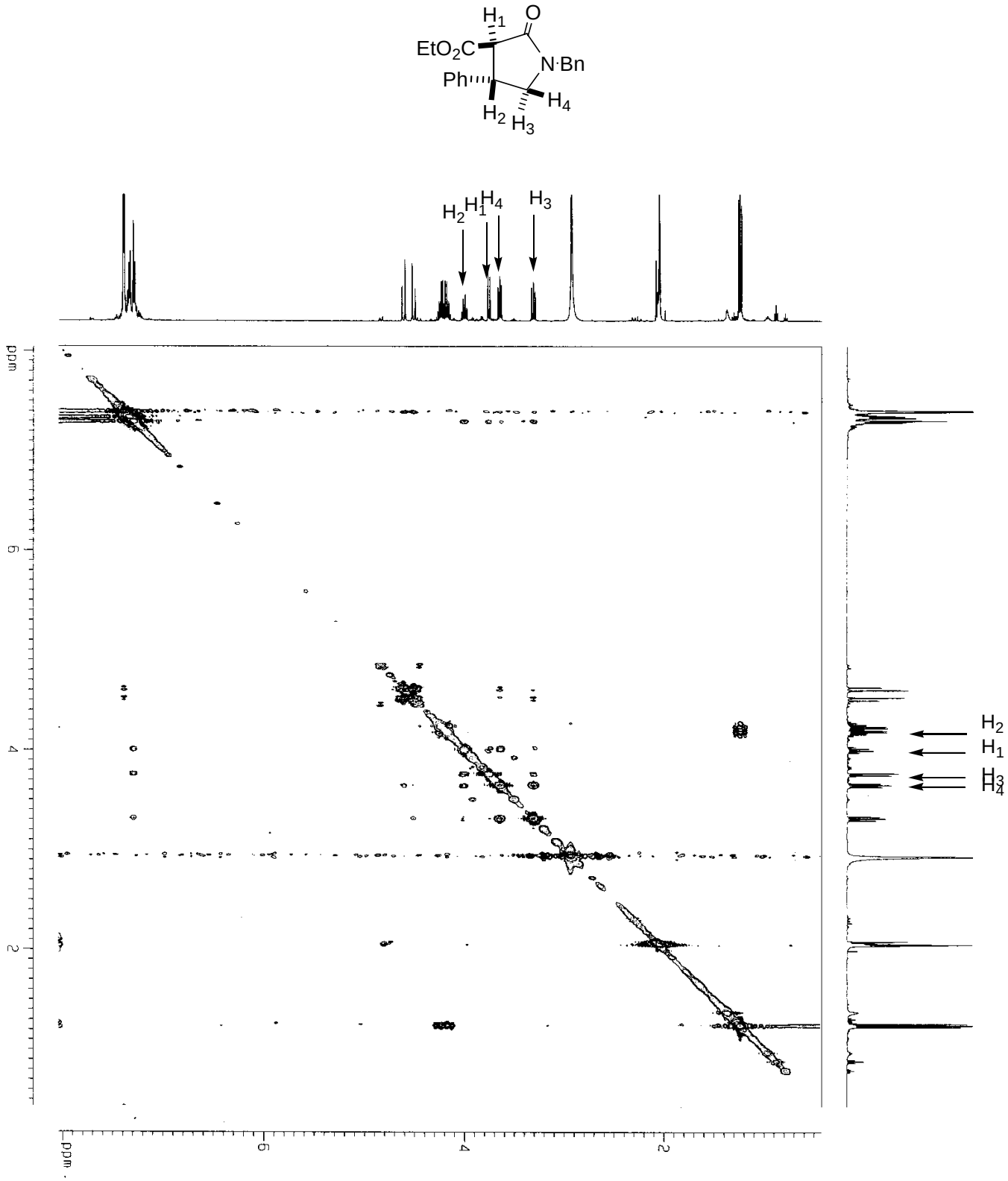


Figure S22. NOESY of *trans*-(**4**)



References

1. (a) Bennett, M. A.; Smith, A. K. *J. Chem. Soc., Dalton Trans.* **1974**, 223. (b) Bennett, M. A.; Huang, T. N.; Matheson, T. W.; Smith, A. K. *Inorg. Synth.* **1982**, *21*, 74. (c) Nishiyama, H.; Itoh, Y.; Sugawara, Y.; Matsumoto, H.; Aoki, K.; Itoh, K. *Bull. Chem. Soc. Jpn.* **1995**, *68*, 1247.

2. (a) Doyle, M. P.; Shanklin, M. S.; Oon, S.-M.; Pho, H. Q.; van der Heide, F. R.; Veal, W. R. *J. Org. Chem*. **1988**, *53*, 3384. (b) Wee, A. G. H.; Liu, B.; Zhang, L. *J. Org. Chem*. **1992**, *57*, 4404. (c) Watanabe, N.; Anada, M.; Hashimoto, S.; Ikegami, S. *Synlett* **1994**, 1031.

3. Padwa, A.; Austin, D. J.; Price, A. T.; Semones, M. A.; Doyle, M. P.; Protopopova, M. N.; Winchester, W. R.; Tran, A. *J. Am. Chem. Soc*. **1993**, *115*, 8669.