Novel Synthesis of Azepine Derivatives via Copper Mediated Cyclization of 2-Aza-hepta-2,4-dien-6-ynyl Anions. Intramolecular Addition of Organocopper Centers to the CC-triple Bond

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Supporting Information 1

Materials and methods

Melting points: Büchi Melting Point B-540. ^{1}H NMR: Bruker WM 300 (300 MHz), Bruker AMX 400 (400 MHz), Varian 600 Unity plus (600 MHz) spectrometers. ^{13}C NMR: Bruker WM 300 (75 MHz), Bruker AMX 400 (100 MHz), Varian 600 Unity plus (150 MHz) spectrometers. TMS as internal standard. IR: Nicolet FT-IR 5DXC spectrometer. Gas Chromatography (GC): Hewlett Packard 6890 Series, column HP5 (30 m), temperature program: 40°C, 10°C/min, 280°C, 5 min. Electron ionization mass spectra (EI): Finnigan MAT C 312 spectrometer (70 eV). GC-MS: Varian MAT 8230 spectrometer with GC Varian 3400 plus datasystem Mass II using Quartz capillary column HP5. Exact mass determination (HRMS): Micromass MAT 8200 spectrometer. Elemental analysis: Elementar Vario EL III analyse automate. Flash chromatography: Silica gel Merck 60 (0.040-0.063 mm) with overpressure about 1.2 bar. TLC: Merck silica gel plates (silica gel 60 F_{254}). X-Ray Analysis: Nonius KappaCCD diffractometer, programs used: data collection COLLECT (Nonius B.V., 1998), data reduction Denzo-SMN,[1] absorption correction SORTAV,[2,3] structure solution SHELXS-97,[4] structure refinement SHELXL-97 (G.M. Sheldrick, Universität Göttingen, 1997), graphics SCHAKAL (E. Keller, Universität Freiburg, 1997).

Imines **1a-i** were prepared according to literature methods from the corresponding bromoarylcarbaldehydes by Sonogashira-coupling and imine condensation.[5,6]

General procedure: A solution of LDA was prepared by adding *n*-BuLi (0.625 mL, 1.00 mmol, 1.6 M solution in *n*-hexane) to diisopropylamine (0.10 g, 1.00 mmol) in dry THF (25 mL) at -78°C. The respective imine (1.00 mmol), dissolved in 10 mL THF, was added dropwise over a period of 30 minutes and stirred for additionally 1h, which leads to deep violet solution. In another flask a stirred suspension of 0.19 g of CuI (1.01 mmol, 99.999% purity, ALDRICH) in 30 mL of THF was treated with freshly prepared 1.01 mmol PhSLi (from 1.01 mmol PhSH and 1.01 mmol BuLi solution). A clear, yellow solution formed within 5 min but become colorless upon cooling to -78°C. To this solution of CuSPh through the Teflon tube at -78°C was fast added a violet solution of imine-anion. The obtained mixture was allowed to warm to rt during 16h. Then it was treated with 60 mL of diluted ammonium chloride solution (2.00 mmol) and 30 mL Et_2O. The precipitate was filtered off and the filtrate was extracted with diethyl ether (3 × 20 mL). The combined organic layers were washed with 2N solution sodium hydroxide, then with brine and dried over magnesium sulfate. The solvent was evaporated and the residue was purified by flash chromatography (20 cm length column).

3,4-Diphenyl-3*H*-2-benzazepine (11a) was obtained from imine **1a**[5] according to the general procedure. The subsequent purification (Et_2O/Et_3N/pentane, 0.5:0.2:10) gave 0.21 g (0.70 mmol, 70%) **11a** as yellowish solid, , mp: 113-115°C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.14 (s, 1H, N-C*H*-Ph), 6.98 (s, 1H), 7.06-7.22 (m, 8H), 7.33-7.40 (m, 3H), 7.47-7.50 (m, 2H), 7.66 (d, J = 7.6 Hz, 1H), 8.63 (1H, ^{4}J=1.4 Hz, C*H*=N). ^{13}C NMR (75 MHz, $CDCl_3$) δ 65.46 (N-*C*H-Ph), 126.57, 126.64, 127.18, 127.93, 127.95, 128.00, 128.55, 128.74, 129.69, 129.95, 130.06, 134.83, 137.38, 140.58, 140.87, 145.98, 161.06. IR (KBr): $\tilde{\nu}$ 3057 (s), 3020 (s), 2927 (s), 2810 (s), 1643 (s), 1614 (m), 1600 (m), 1573 (w), 1546 (w), 1492 (m), 1444 (m), 1365 (w), 1332 (w), 1296 (w), 1205 (w), 1184 (w), 1159 (w), 1072 (w), 1028 (w), 981 (m), 954 (w), 898 (w), 869 (w), 856 (w), 763 (s), 740 (m), 717 (m), 696 (s), 671 (m), 574 (m), 553 (m), 534 (w), 480 (w) cm^{-1}. MS *m/z* (GC-EI) 295 $[M]^+$, 294, 218, 216, 204, 192, 189, 178, 165, 152, 147, 139, 117, 90, 77. Anal. Calcd. for $C_{22}H_{17}N$: C 89.46, H 5.80, N 5.80. Found C 89.11, H 5.72, N 4.62.

4-Butyl-3-phenyl-3*H*-2-benzazepine (11b) was obtained from imine **1b**[5] according to the general procedure. The subsequent chromatographic purification (Et_2O/Et_3N/pentane, 0.5:0.2:10) gave **11b** 0.16 g (0.58 mmol, 58%) as yellowish oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 0.67 (t, J = 7.5 Hz, 3H, CH_2-CH_2-CH_2-C*H*$_3$), 0.99-1.10 (m, 2H, CH_2-CH_2-C*H*$_2$-CH_3), 1.16-1.28 (m, 2H, CH_2-C*H*$_2$-CH_2-CH_3), 1.87-1.94 (m, 2H, C*H*$_2$-CH_2-CH_2-CH_3), 4.19 (s, 1H, N-C*H*-Ph), 6.51 (s, 1H), 7.17-7.52 (m, 9H), 8.42 (d, J = 2.0 Hz, 1H, C*H*=N) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 13.89 (CH_2-CH_2-CH_2-*C*H$_3$), 22.39 (CH_2-CH_2-*C*H$_2$-CH_3), 31.57 (CH_2-*C*H$_2$-CH_2-CH_3), 34.23 (*C*H$_2$-CH_2-CH_2-CH_3), 65.94 (N-*C*H-Ph), 125.03, 125.88, 127.07, 128.28, 128.45, 129.43, 129.47, 129.90, 134.56, 138.12, 141.32, 147.44, 160.01 ppm. IR (Film) $\tilde{\nu}$ 3084 (w), 3060 (m), 3026 (m), 2956 (s), 2929 (s), 2869 (m), 2858 (m), 1631 (m), 1620 (m), 1602 (m), 1583 (m), 1552 (w), 1492 (m), 1479 (m), 1452 (w), 1379 (w), 1342 (w), 1303 (w), 1288 (w), 1255 (w), 1213 (w), 1193 (w), 1159 (w), 1076 (w), 1029 (w), 1002 (w), 987 (w), 956 (w), 939 (w), 920 (w), 906 (w), 896 (w), 869 (w), 842 (w), 756 (s), 730 (m), 702 (s), 667 (w), 651 (w), 586 (m), 449 (s), 428 (s) cm^{-1}. HRMS calcd. for $C_{20}H_{21}NH$: 276.1752. Found 276.1747. Purity (GC): 94%.

4-Phenyl-3-vinyl-3*H*-2-benzazepine (**11c**) was obtained from imine **1c**[6] according to the general procedure. The subsequent chromatographic purification (Et_2O/pentane/Et_3N, 0.5:10:0.2) gave 0.10 g (0.41 mmol, 41%) **11c** as yellowish oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ

4.76 (dm, *J* = 6.6 Hz, 1H, =N-C*H*), 5.03 (dt, *J* = 10.3, 1.5 Hz, CH=CH_2^{cis}), 5.78 (dt, *J* = 17.0, 1.5 Hz, CH=CH_2^{trans}), 5.92-6.00 (m, C*H*=CH_2), 6.85 (s, 1H, C*H*=C), 7.28-7.32 (m, 1H), 7.34-7.39 (m, 3H), 7.42-7.49 (m, 4H), 7.56 (d, *J* = 7.9 Hz), 8.50 (d, *J* = 1.1 Hz, N=C*H*) ppm. ^{13}C NMR (100 MHz, $CDCl_3$) δ 65.12 (=N-C*H*), 116.06, 126.44, 127.48, 128.10, 128.18, 128.24, 129.68, 129.98, 130.18, 134.73, 136.27, 137.20, 140.87, 144.85, 160.88 ppm. IR (Film): $\tilde{\nu}$ 3078 (m), 3057 (m), 3020 (m), 2976 (w), 2968 (w), 2925 (m), 2869 (w), 2854 (w), 1641 (s), 1624 (s), 1598 (m), 1573 (w), 1552 (w), 1490 (s), 1444 (s), 1402 (w), 1365 (w), 1336 (w), 1313 (w), 1253 (w), 1215 (w), 1188 (w), 1161 (w), 1120 (w), 1074 (w), 1028 (w), 985 (m), 921 (s), 898 (w), 879 (w), 858 (w), 796 (w), 763 (s), 734 (m), 700 (s), 671 (m), 609 (s) cm^{-1}. MS *m/z* (%) (EI) 244 $[M-H]^+$ (100.00), 217 (8.23), 215 (86.89), 189 (12.96), 168 (10.71), 141 (3.90), 115 (10.24), 102 (2.71), 89 (4.97), 63 (2.36). HRMS calcd. for $C_{18}H_{15}NH$: 246.1283. Found 246.1277. Anal. Calcd. for $C_{18}H_{15}N$: C 88.13, H 6.16, N 5.71. Found: C 87.99, H 6.01 N 5.66

3,4-Diphenyl-3*H*-benzo[4,5]thieno[3,2-*c*]azepine (11d) was obtained from imine **1d**[6] according to the general procedure. The subsequent chromatographic purification (EtOAc/pentane/Et_3N, 0.4:10:0.2) gave 0.10 g (0.65 mmol, 65%) **11d** as yellowish solid, mp: 173-175°C. ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.94 (br s, 1H, N-C*H*), 7.12-7.23 (m, 9H), 7.41-7.51 (m, 4H), 7.84-7.88 (m, 1H), 7.95-7.98 (m, 1H), 8.86 (d, *J* = 1.7 Hz, 1H, C*H*=N) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 67.53 (N-*C*H), 121.71, 122.53, 122.72, 125.33, 125.96, 126.74, 127.31, 127.80, 127.94, 127.99, 129.13, 132.78, 137.93, 138.35, 139.13, 140.84, 143.19, 145.70, 153.20 ppm. IR (KBr): $\tilde{\nu}$ 3060 (m), 3022 (m), 2814 (m), 1643 (m), 1598 (s), 1577 (s), 1571 (m), 1552 (m), 1490 (s), 1444 (s), 1431 (s), 1365 (w), 1342 (m), 1313 (m), 1305 (m), 1259 (m), 1211 (s), 1182 (m), 1157 (w), 1132 (w), 1072 (m), 1031 (w), 1008 (s), 977 (m), 939 (w), 910 (w), 898 (w), 858 (s), 829 (w), 765 (s), 740 (s), 696 (s) cm^{-1}. MS *m/z* (GC-EI) 350 $[M-H]^+$, 336, 321, 273, 247, 215, 202, 175, 165, 137, 102, 91, 89, 77. Anal. Calcd. for $C_{24}H_{17}NS$: C 82.02, H 4.88, N 3.99. Found C 81.80, H 4.82, N 3.85.

3,4-Diphenyl-3*H*-benzo[4,5]thieno[2,3-*c*]azepine (11e) was obtained from imine **1e**[6] according to the general procedure. The subsequent chromatographic purification (Et_2O/Et_3N/pentane, 0.5:0.2:10) gave 0.22 g (0.63 mmol, 63%) **11e** as yellowish solid, mp: 150-152°C. ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.92 (br s, 1H, N-C*H*-Ph), 7.13-7.23 (m, 8H), 7.34 (s, 1H), 7.45-7.53 (m, 4H), 7.89-7.92 (m, 1H), 8.03-8.07 (m, 1H), 8.72 (d, *J* = 1.6 Hz, 1H, C*H*=N). ^{13}C NMR (75 MHz, $CDCl_3$) δ 67.62 (N-*C*H-Ph), 121.98, 123.05, 123.17, 125.17,

126.82, 127.22, 127.25, 127.87, 127.98, 128.03, 129.32, 137.64, 137.69, 138.01, 139.68, 139.88, 140.95, 141.93, 153.49. IR (KBr): $\tilde{\nu}$ = 3072 (w), 3051 (w), 3018 (w), 2802 (w), 1668 (w), 1651 (w), 1598 (m), 1573 (s), 1554 (m), 1539 (w), 1519 (w), 1483 (s), 1460 (m), 1442 (s), 1425 (m), 1394 (w), 1386 (w), 1369 (m), 1352 (m), 1321 (w), 1307 (w), 1265 (w), 1249 (w), 1232 (w), 1180 (m), 1161 (w), 1128 (w), 1072 (m), 1049 (w), 1033 (m), 1020 (m), 1001 (w), 983 (m), 956 (m), 937 (m), 929 (m), 912 (w), 896 (w), 869 (s), 846 (m), 775 (s), 752 (s), 727 (s), 696 (s), 675 (s) cm^{-1}. MS *m/z* (%) (EI) 350 $[M-H]^+$ (80.85), 231 (6.07), 213 (17.28), 169 (13.45), 127 (72.13), 83 (21.68), 69 (100.00). HRMS calcd. for $C_{24}H_{17}NSH$: 352.1160. Found 352.1154. Anal. Calcd. for $C_{24}H_{18}NS$: C 82.02, H 4.88, N 3.99. Found C 81.80, H 4.71, N 3.87.

3-Methyl-2,6,7-triphenyl-3,6-dihydroimidazo[4,5-*c*]azepine (11f) was obtained from imine **1f**[6] according to the general procedure. The subsequent chromatographic purification (EtOAc/Et_3N/pentane, 2.5:0.2:10) gave 0.27 g (0.73 mmol, 73%) **11f** as yellowish solid, mp: 168-170.5°C. ^{1}H NMR (300 MHz, $CDCl_3$) δ 3.86 (s, 3H, N-C*H*$_3$), 4.75 (br s, 1H, N-C*H*-Ph), 7.08-7.22 (m, 9H), 7.50-7.54 (m, 5H), 7.07-7.73 (m, 2H), 8.56 (d, *J* = 1.8 Hz, 1H, C*H*=N). ^{13}C NMR (75 MHz, $CDCl_3$) δ 32.63, 67.97, 123.37, 126.59, 126.66, 127.83, 127.98, 128.95, 129.24, 129.49, 129.58, 130.00, 131.74, 138.13, 140.13, 141.66, 145.26, 147.04, 150.87. IR (KBr) $\tilde{\nu}$ 3080 (w), 3058 (w), 3041 (w), 3022 (w), 2923 (w), 1598 (m), 1573 (m), 1510 (m), 1492 (m), 1467 (m), 1446 (m), 1404 (s), 1365 (m), 1074 (s), 1043 (s), 1022 (s), 1001 (w), 985 (w), 950 (w), 939 (w), 920 (w), 898 (w), 852 (w), 823 (w), 775 (m), 759 (m), 730 (m), 694 (s), 675 (w), 646 (w), 617 (w), 599 (w), 561 (w), 545 (m), 495 (w), 486 (w) cm^{-1}. MS *m/z* (%) (EI) 374 $[M-H]^+$ (100.00), 359 (2.25), 348 (0.91), 331 (0.53), 310 (0.18), 303 (0.42), 298 (8.87), 271 230 (1.55), 187 (3.64), 127 (4.96), 118 (3.16), 57 (2.69). Anal. Calcd. for $C_{26}H_{21}N_3$: C 83.17, H 5.64, N 11.19. Found C 83.17, H 5.54, N 11.15.

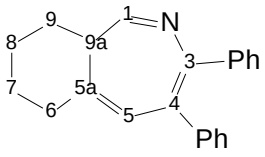
8-Butyl-7-phenyl-7*H*-pyrido[3,2-*c*]azepine (11g) was obtained from imine **1g**[6] according to the general procedure. The subsequent chromatographic purification (Et_2OAc/pentane/Et_3N, 0.5:10:0.3) gave 0.12 g (0.45 mmol, 58%) **11g** as yellowish oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.76 (t, *J* = 7.4 Hz, 1H, CH_2-CH_2-CH_2-C*H*$_3$), 1.09-1.23 (m, 2H, CH_2-CH_2-C*H*$_2$-CH_3), 1.29-1,39 (m, 2H, CH_2-C*H*$_2$-CH_2-CH_3), 2.02-2.06 (m, 2H, C*H*$_2$-CH_2-CH_2-CH_3), 4.35 (s, 1H, N-C*H*), 6.82 (d, *J* = 0.9 Hz, 1H), 7.25-7.31 (m, 2H), 7.36-7.40 (m, 2H), 7.56-7.58 (m, 2H), 7.86 (dd, *J* = 7.9, 1.6 Hz, 1H), 8.49 (d, *J* = 1.9 Hz, 1H), 8.76 (dd, *J* = 4.6, 1.8 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.85 (CH_2-CH_2-CH_2-*C*H_3), 22.34 (CH_2-CH_2-*C*H_2-CH_3), 31.10 (CH_2-

CH_2-CH_2-CH_3), 34.53 (CH_2-*C*H_2-CH_2-CH_3), 66.33 (N-*C*H), 120.46, 127.77, 127.30, 128.35, 128.37, 130.30, 137.63, 140.57, 150.93, 151.41, 155.48, 158.35. IR (Film) $\tilde{\nu}$ 3085 (m), 3060 (m), 3030 (m), 2956 (s), 2869 (s), 2860 (s), 1631 (s), 1604 (s), 1585 (s), 1546 (s), 1494 (s), 1463 (s), 1454 (s), 1433 (s), 1379 (m), 1359 (w), 1305 (w), 1282 (w), 1207 (w), 1110 (w), 983 (m), 956 (m), 937 (m), 900 (m), 858 (m), 794 (m), 765 (m), 736 (m), 702 (m), 669 (s), 657 (s), 586 (s), 472 (s), 459 (s), 447 (s), 432 (s), 412 (s) cm^{-1}. MS *m/z* (GC-EI) 276 $[M]^+$, 261, 247, 234, 233, 231, 220, 219, 218, 204, 185, 169, 143, 130, 91, 89, 77, 63. Anal. Calcd. for $C_{19}H_{20}N_2$: C 82.57, H 7.29, N 10.14. Found C 82.68, H 7.54, N 9.59.

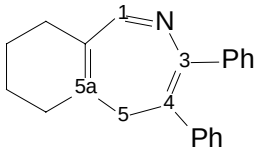
2,3-Diphenyl-6,7-dihydro-5a*H*-naphtho[2,1-*c*]azepine (11h) was obtained from imine **1h**[5] according to the general procedure. The subsequent chromatographic purification (Et_2O/pentane/Et_3N, 0.5:10:0.2) gave 0.14 g (0.41 mmol, 41%) **11h** as yellowish solid, mp 165-168°C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.96-2.00 (m,1H), 2.13-2.19 (m, 1H), 2.47-2.52 (m, 1H), 2.86-2.91 (m, 1H), 2.96-2.30 (m, 1H), 6.53 (d, *J* = 4.2 Hz, 1H), 6.82 (d, *J* = 1.5 Hz, 1H), 7.13-7.24 (m, 11H), 7.42-7.43 (m, 2H), 7.49 (d, *J* = 7.5 Hz, 1H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$) δ 24.17, 27.61, 42.87, 122.73, 124.92, 125.55, 125.61, 126.15, 126.20, 126.27, 126.89, 126.94, 127.01, 127.20, 128.58, 130.72, 133.06, 138.56, 139.05, 139.10, 141.71, 148.99 ppm. IR (KBr): $\tilde{\nu}$ 3055 (w), 3014 (w), 2960 (w), 2943 (w), 2912 (w), 2854 (w), 2846 (w), 1606 (w), 1595 (w), 1577 (w), 1556 (w), 1473 (m), 1456 (w), 1440 (s), 1369 (w), 1348 (w), 1309 (w), 1296 (w), 1251 (w), 1176 (m), 1157 (m), 1120 (w), 1080 (w), 1068 (s), 1022 (m), 1006 (m), 979 (w), 943 (m), 910 (s), 889 (m), 858 (w), 804 (w), 777 (s), 763 (s), 746 (s) cm^{-1}. MS *m/z* (%) (EI) 347 $[M]^+$ (93.34), 346 $[M-H]^+$ (100.00), 330 (3.40), 270 (3.48), 244 (21.77), 228 (7.07), 174 (4.34), 173 (4.34), 165 (8.64), 115 (6.15), 91 (6.95). HRMS calcd. for $C_{26}H_{21}NH$: 348.1752. Found 348.1747. Anal. Calcd. for $C_{26}H_{21}N$: C 89.88, H 6.09, N 4.03; Found C 89.80, H, 5.94 N 3.88.

3,4-Diphenyl-7,8,9,9a-tetrahydro-6*H*-2-benzazepine (11i)

The treatment of imine **1i**[5] according to the general procedure (column chromatography purification, using Et_2O/pentane/Et_3N, 0.5:10:0.2 as eluent) led to a mixture of two compounds (100:52 ratio) in overall yield 58% as yellowish oil (the most characteristic signals of major isomer are marked as "o" in the ^{1}H NMR spectra (see supporting information) and of the minor one – as "x"). After stirring of this mixture at 40°C for 52h a ratio of 100:16 of the two compounds was observed, further heating slowly led to some decomposition.



11i



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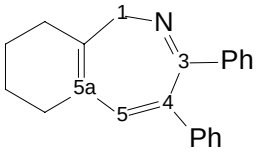
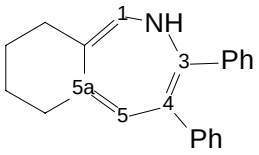


11ib



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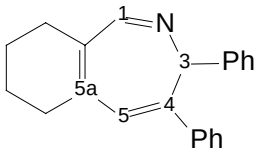
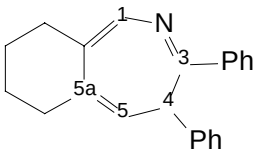
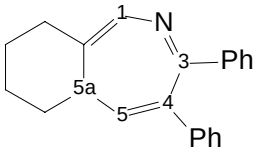


11id



11ie



11if

All possible isomers (**11i**, **11ia-11if**) were considered as candidates for the major compound. The structures **11ia** and **11ib** can be rejected because of a CH_2-group in the seven-membered cycle, which was not observed in the spectrum according to the signal intensities. Compound **11ic** has only four aliphatic carbon atoms, whereas in the ^{13}C NMR spectrum five sp^3-hybridised carbons (21.66, 23.72, 24.43, 29.84 and 44.16 ppm) were observed. Structure **11id** doesn't show a H-3-proton with a typical chemical shift at 4-5 ppm (this was observed for all other azepines **11a-g**).

The ghmbc-experiment is not in accord with structure **11ie,** since there is a long range correlation (through three or two bonds, see gHMQC-spectrum in supporting materials, the corresponding signals are marked) between protons at 6.12 and 6.37 ppm (H-1 and H-5 of compound **11ie**) and carbon atom at 44.16 ppm (C-4 for **11ie**). Moreover, a NOE between the doublet at 6.37 ppm and the aromatic protons should be observed for compounds **11ie** and **11if**, which was not the case. In case of structure **11if** a $^1H\{^{15}N\}$-gHMQC-experiment (^1H-^{15}N correlation between two or three bonds) should show a long range correlation between N and singlet at 6.12 ppm (H-1), whereas in case of isomer **11i** such a correlation should be seen for the doublet at 6.37 ppm (H-1), which is indeed observed. All other spectroscopic properties also in accord with structure **11i**.

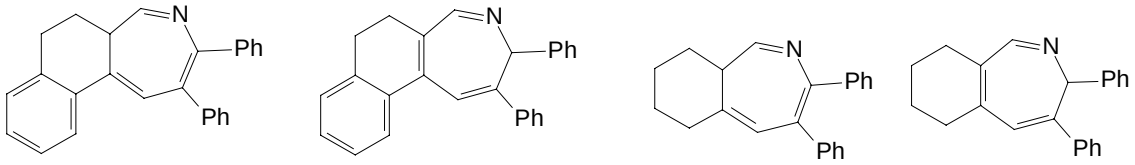
It was impossible to determine the structure of minor product because of overlapping signals. However, its slow isomerization into compound **11i** confirms that this minor compound is another isomer of azepine **11i**.

^1H NMR (500 MHz, $CDCl_3$, one drop Et_3N was added for the stabilization) δ 1.53 (s, 1H, H-9a), 1.69 (m, 1H, H-8), 1.70 (m, 1H, H-7), 1.80 (m, 1H, H-7), 1.87 (m, 1H, H-8), 2.05 (m, 1H, H-9), 2.30 (m, 1H, H-9), 2.38 (m, 1H, H-6), 2.63 (m, 1H, H-6), 6.12 (s, 1H, H-5), 6.37 (d, J = 5.0 Hz, 1H, H-1), 7.12-7.39 (m, 10H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$) δ 21.66 (C-8), 23.72 (C-7), 24.43 (C-9), 29.84 (C-6), 44.16 (C-9a), 126.00 (C-5), 126.12, 126.71, 126.93, 127.53,

127.68, 127.71, 129.36, 131.47, 137.55 (C-1), 140.18, 142.41, 147.89 ppm. IR (Film): $\tilde{\nu}$ 3084 (w), 3060 (w), 3026 (w), 2929 (m), 2858 (m), 2835 (m), 1620 (s), 1494 (m), 1452 (s), 1379 (m), 1205 (m), 1074 (w), 995 (w), 947 (w), 935 (w), 908 (w), 854 (w), 815 (w), 765 (m), 734 (s), 702 (s) cm^{-1}. HRMS calcd. for $C_{22}H_{21}NH$: 300.1752. Found 300.1747.

5-Methyl-3,4-diphenyl-3*H*-2-benzazepine (11j) was synthesised according to the general procedure from imine **1a**,[5] but after the mixing of the CuSPh solution with the imine lithium compound the mixture was warmed to 0°C for 30 min and stirred for additionally 1h at this temperature. Then methyl iodide (0.43 g, 3 mmol) was added dropwise. Aqueous workup and subsequent purification (EtOAc/Et_3N/pentane, 0.5:0.2:10) gave 0.09 g (0.30 mmol, 30%) **11j** as yellowish oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.00 (d, J = 0.8 Hz, 3H, C*H*$_3$), 4.45 (br s, 1H, N-C*H*-Ph), 6.88-7.12 (m, 8H), 7.27-7.45 (m, 4H), 7.53-7.62 (m, 2H), 7.77 (d, J = 7.8 Hz, 1H), 8.61 (d, J = 2.0 Hz, C*H*=N). ^{13}C NMR (75 MHz, $CDCl_3$) δ 20.17 (*C*H$_3$), 67.09 (N-*C*H-Ph), 126.61, 126.64, 126.78, 127.74, 127.96, 128.00, 128.06, 128.86, 129.51, 129.79, 130.39, 131.06, 134.75, 141.92, 142.06, 144.61, 160.48. IR (KBr) $\tilde{\nu}$ 3057 (s), 3020 (s), 2927 (s), 2810 (s), 1643 (s), 1614 (m), 1600 (m), 1573 (w), 1546 (w), 1492 (m), 1444 (m), 1365 (w), 1332 (w), 1296 (w), 1205 (w), 1184 (w), 1159 (w), 1072 (w), 1028 (w), 981 (m), 954 (w), 898 (w), 869 (w), 856 (w), 763 (s), 740 (m), 717 (m), 696 (s), 671 (m), 574 (m), 553 (m), 534 (w), 480 (w) cm^{-1}. MS *m/z* (GC-EI) 308 $[M-H]^+$, 231, 178, 83, 57. Anal. Calcd. for $C_{23}H_{19}N$: C 89.28, H 6.19, N 4.53. Found C 89.17, H 5.69, N 4.56.

Quantum chemical details[7]



11h **11ha** **11i** **11id**

Scheme 1. Species studied by computation in this work

Table 1. Total and relative energies of **11h, 11ha, 11i** and **11id** (B3LYP/6-311G(d,p)//B3LYP/6-311G(d,p), also including zero point correction, NImag = 0)

	E_{tot} [au]	E_{rel} [kcal/mol]	E_{0K} [au]	$E_{rel(0K)}$ [kcal/mol]
11h	-1058.40106	0.00	-1058.00735	0.00
11ha	-1058.39008	6.89	-1058.99651	6.80

	E_{tot} [au]	E_{rel} [kcal/mol]	E_{0K} [au]	$E_{rel(0K)}$ [kcal/mol]
11i	-905.93332	0.00	-905.563212	0.00
11id	-905.92635	4.37	-905.556283	4.35

Table 2. Cartesian coordinates of the optimized geometries (B3LYP/6-311G(d,p))

11h			
C	4.737358	-1.298131	-1.854357
C	5.651984	-1.887879	-0.982903
C	5.206565	-2.435536	0.217399
C	3.858842	-2.389504	0.571790
C	2.930031	-1.782277	-0.301538
C	3.389833	-1.255255	-1.519662
C	3.353542	-2.982075	1.865224
C	2.022928	-3.704901	1.620381
C	0.969726	-2.740432	1.059580
C	1.518153	-1.700557	0.109236
C	-0.088972	-3.424974	0.221180
N	-1.222667	-2.909775	-0.045256
C	-1.572819	-1.607753	0.238676
C	-0.715639	-0.539646	-0.016290
C	0.688669	-0.693144	-0.298844
C	-1.234249	0.853071	-0.192120
C	-2.304894	1.138483	-1.051129
C	-2.737387	2.446602	-1.242113
C	-2.108685	3.500108	-0.579796
C	-1.037282	3.233762	0.269207
C	-0.601911	1.923874	0.455850
C	-2.994918	-1.462735	0.652936
C	-3.378280	-0.529894	1.627105
C	-4.702709	-0.439457	2.041942

C	-5.670851	-1.278321	1.492728
C	-5.299333	-2.218732	0.533412
C	-3.973785	-2.317746	0.123959
H	5.072232	-0.886676	-2.799885
H	6.703581	-1.932712	-1.242927
H	5.915357	-2.905283	0.892134
H	2.677693	-0.827921	-2.215854
H	3.205711	-2.188334	2.609543
H	4.096064	-3.667893	2.281439
H	2.196794	-4.519069	0.907587
H	1.649760	-4.162547	2.540637
H	0.449384	-2.220653	1.875833
H	0.144483	-4.401311	-0.206547
H	1.134682	0.119375	-0.863316
H	-2.795790	0.327339	-1.575212
H	-3.565164	2.644765	-1.914099
H	-2.448091	4.519068	-0.728424
H	-0.538959	4.045301	0.788190
H	0.231312	1.722209	1.120312
H	-2.632930	0.121285	2.066215
H	-4.978105	0.285471	2.799885
H	-6.703582	-1.204542	1.814780
H	-6.044284	-2.879476	0.103622
H	-3.677916	-3.056672	-0.609426

11ha

C	4.393232	-0.056128	-2.140473
C	5.126382	-1.209880	-1.879689
C	4.454946	-2.396461	-1.598531
C	3.062827	-2.449355	-1.579366
C	2.309422	-1.284545	-1.846139
C	3.003492	-0.094881	-2.118506
C	2.333021	-3.726458	-1.245195
C	1.052456	-3.835104	-2.068348
C	0.210291	-2.585786	-1.902719
C	0.821136	-1.354436	-1.808100
C	-1.226615	-2.753539	-2.078933
N	-2.191665	-2.086220	-1.564009
C	-1.813562	-1.083866	-0.568445
C	-1.187786	0.072679	-1.339640
C	0.057076	-0.116328	-1.836385
C	-1.919196	1.337897	-1.594471
C	-3.242813	1.319522	-2.058155
C	-3.913907	2.506050	-2.333188
C	-3.283067	3.734360	-2.142076
C	-1.971961	3.766470	-1.674026
C	-1.296405	2.579531	-1.402936
C	-2.961891	-0.738862	0.367471
C	-2.740397	0.154058	1.421449
C	-3.756295	0.460327	2.320922

C	-5.012656	-0.129071	2.183706
C	-5.237827	-1.026323	1.143838
C	-4.218802	-1.331505	0.241790
H	4.900600	0.876118	-2.361076
H	6.210133	-1.187301	-1.895403
H	5.019064	-3.300152	-1.390780
H	2.462161	0.819525	-2.320518
H	2.072547	-3.726318	-0.177700
H	2.980520	-4.590324	-1.415027
H	1.307133	-3.969496	-3.129844
H	0.479320	-4.716531	-1.768273
H	-1.514751	-3.562248	-2.757280
H	-1.005053	-1.496452	0.055904
H	0.508460	0.717915	-2.360039
H	-3.735741	0.369246	-2.220472
H	-4.934053	2.470721	-2.698957
H	-3.810968	4.657874	-2.351534
H	-1.475083	4.716531	-1.510884
H	-0.283915	2.612568	-1.016170
H	-1.765147	0.616722	1.536615
H	-3.567873	1.157687	3.129843
H	-5.805929	0.107726	2.884084
H	-6.210133	-1.494164	1.032135
H	-4.385015	-2.032350	-0.565909

11i

C	4.535101	-0.900713	0.046711
C	4.465924	0.620156	-0.123771
C	3.224803	1.011226	-0.935319
C	1.940277	0.389668	-0.429236
C	1.965039	-0.954270	0.256484
C	3.319484	-1.402179	0.834717
C	1.390778	-1.844894	-0.822858
N	0.143726	-1.882683	-1.090001
C	-0.789416	-1.010942	-0.569028
C	-0.568377	0.361681	-0.484591
C	0.731080	0.960198	-0.678953
C	-1.697170	1.338120	-0.391556
C	-1.633175	2.389212	0.534513
C	-2.647166	3.340880	0.612286
C	-3.742162	3.267289	-0.245078
C	-3.810979	2.237488	-1.182401
C	-2.800224	1.284599	-1.255564
C	-2.098990	-1.663830	-0.288175
C	-2.560880	-2.703090	-1.109428
C	-3.762876	-3.346224	-0.833107
C	-4.518435	-2.978011	0.278852
C	-4.057543	-1.962781	1.114857
C	-2.860172	-1.312142	0.835161
H	5.453217	-1.190239	0.566777

H	4.575473	-1.375977	-0.942162
H	4.432122	1.094284	0.864900
H	5.364189	0.995208	-0.623321
H	3.384183	0.691570	-1.974837
H	3.104496	2.098390	-0.974689
H	1.214262	-0.939306	1.056866
H	3.394241	-1.018140	1.858071
H	3.331968	-2.494187	0.917145
H	2.063910	-2.464358	-1.418270
H	0.726540	1.966351	-1.091746
H	-0.783284	2.450281	1.205683
H	-2.580986	4.139319	1.343387
H	-4.531972	4.007957	-0.188247
H	-4.653272	2.178412	-1.862961
H	-2.860042	0.491937	-1.991473
H	-1.962784	-2.997364	-1.962261
H	-4.109549	-4.139319	-1.486712
H	-5.453217	-3.482598	0.496412
H	-4.629207	-1.678676	1.991473
H	-2.507391	-0.530294	1.496300

11id

C	-4.602828	-0.770076	0.053126
C	-4.326837	0.425487	-0.860043
C	-3.012755	1.106398	-0.467805
C	-1.864422	0.145193	-0.196526
C	-2.085832	-1.193689	-0.011527
C	-3.477164	-1.799205	-0.078737
C	-1.026265	-2.086187	0.456328
N	0.224605	-2.080780	0.182379
C	0.660189	-1.157373	-0.870195
C	0.646600	0.229762	-0.223533
C	-0.573670	0.775744	0.004069
C	1.870071	0.950483	0.213879
C	2.925679	1.248520	-0.661548
C	4.028971	1.974509	-0.223847
C	4.110006	2.408230	1.097944
C	3.074028	2.114436	1.981094
C	1.966271	1.394859	1.542228
C	1.964570	-1.629869	-1.481103
C	2.954231	-2.238577	-0.705492
C	4.148958	-2.655180	-1.286138
C	4.369913	-2.474748	-2.650854
C	3.382717	-1.882301	-3.434919
C	2.187006	-1.467687	-2.851117
H	-5.564640	-1.232188	-0.188007
H	-4.665972	-0.426648	1.092676
H	-4.265987	0.078627	-1.898559
H	-5.146058	1.149269	-0.818086
H	-3.166135	1.714454	0.434546
H	-2.704830	1.811047	-1.247682

H	-3.568280	-2.566610	0.697808
H	-3.582075	-2.334494	-1.032393
H	-1.347462	-2.843636	1.177415
H	-0.096213	-1.135166	-1.668336
H	-0.607780	1.802739	0.360682
H	2.877751	0.924588	-1.692379
H	4.828786	2.201770	-0.919865
H	4.974620	2.968040	1.436748
H	3.129360	2.439695	3.014150
H	1.169450	1.151089	2.235223
H	2.767620	-2.396499	0.348997
H	4.909318	-3.125681	-0.672290
H	5.300203	-2.802828	-3.101332
H	3.538028	-1.751813	-4.500365
H	1.415996	-1.014704	-3.467631

References

[1] Otwinowski, Z.; Minor, W. *Methods in Enzymology*, **1997**, *276*, 307.

[2] Blessing, R. H. *Acta Cryst.* **1995**, *A51*, 33.

[3] Blessing, R. H. *J. Appl. Cryst.* **1997**, *30*, 421.

[4] Sheldrick, G. M. *Acta Cryst.* **1990**, *A46*, 467.

[5] Sagar, P.; Fröhlich, R.; Würthwein, E.-U. *Angew. Chem.* **2004**, *116*, 5812; *Angew. Chem. Int. Ed.* **2004**, *42*, 5694.

[6] Lyaskovskyy, V.; Fröhlich, R.; Würthwein, E.-U. in preparation.

[7] Gaussian 03, Revision C.02, Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G. E.; Robb, M. A.; Cheeseman, J. R.; Montgomery, Jr., J. A.; Vreven, T.; Kudin, K. N.; Burant, J. C.; Millam, J. M.; Iyengar, S. S.; Tomasi, J.; Barone, V.; Mennucci, B.; Cossi, M.; Scalmani, G.; Rega, N.; Petersson, G. A.; Nakatsuji, H.; Hada, M.; Ehara, M.; Toyota, K.; Fukuda, R.; Hasegawa, J.; Ishida, M.; Nakajima, T.; Honda, Y.; Kitao, O.; Nakai, H.; Klene, M.; Li, X.; Knox, J. E.; Hratchian, H. P.; Cross, J. B.; Bakken, V.; Adamo, C.; Jaramillo, J.; Gomperts, R.; Stratmann, R. E.; Yazyev, O.; Austin, A. J.; Cammi, R.; Pomelli, C.; Ochterski, J. W.; Ayala, P. Y.; Morokuma, K.; Voth, G. A.; Salvador, P.; Dannenberg, J. J.; Zakrzewski, V. G.; Dapprich, S.; Daniels, A. D.; Strain, M. C.; Farkas, O.; Malick, D. K.; Rabuck, A. D.; Raghavachari, K.; Foresman, J. B.; Ortiz, J. V.; Cui, Q.; Baboul, A. G.; Clifford, S.; Cioslowski, J.; Stefanov, B. B.; Liu, G.; Liashenko, A.; Piskorz, P.; Komaromi, I.; Martin, R. L.; Fox, D. J.; Keith, T.; Al-Laham, M. A.; Peng, C. Y.; Nanayakkara, A.; Challacombe, M.; Gill, P. M. W.; Johnson, B.; Chen, W.; Wong, M. W.; Gonzalez, C.; and Pople, J. A.; Gaussian, Inc., Wallingford CT, **2004**.