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Supporting Information

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Supported Gold (III) Catalysts for Highly Efficient Three-Component Coupling Reactions

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Catalyst Preparation and Characterization

Preparation of Au/ZrO_2: ZrO_2 was prepared by the method as described earlier.[1s] The BET surface area of ZrO_2 powders is 120 m^2/g after being calcined in air at 400 ^oC for 5 h. Au/ZrO_2 catalysts were prepared by deposition-precipitation method by mixing ZrO_2 powders (2 g) with appropriate amounts of aqueous solutions of chloroauric acid ($HAuCl_4$) at a fixed pH = 7.60 adjusting with appropriate urea at 80 ^oC. The aqueous dispersion was stirred for 6 h and aged for 2 h, and then suction filtered. Extensive washing with deionized water was then followed until it was free of chloride ions. The sample was dried in flowing air at 120 ^oC for 12 h.

Preparation of Au/C: A colloidal solution of gold nanoparticles stabilized by polyvinyl alcohol were deposited on activated carbon (KB-B-100, provided by Aldrich), using $NaBH_4$ to reduce the gold precursor $HAuCl_4$ following the procedure reported earlier.[2s]

Preparation of Au/SiO_2: Au/SiO_2 was prepared by impregnation method using $HAuCl_4$ as a precursor. The sample was dried in flowing air at 120 ^oC for 12 h.

Catalyst Characterization:

Surface areas of the samples were measured with nitrogen adsorption at 77 K on a Micrometrics ASAP 2000 apparatus. The gold content of Au/CeO_2 and Au/ZrO_2 was determined by X-ray Fluoroscopy (XRF); and the gold content of Au/SiO_2 and Au/C was determined by atomic absorption spectroscopy (AAS). TEM analyses (Figure 1s) were performed on a Jeol 2200 HRTEM (200 kV) in the case of 3.0% Au/C and 2.5% Au/CeO_2, and JEM-2010F (200 kV) in the case of 2.8% Au/ZrO_2. FT-IR using CO as probe molecule to measure different gold species of Au/CeO_2 has been reported

earlier.[3s] The XPS and TPR measurements to quantitatively determine the cationic gold species of Au/ZrO_2 were described elsewhere.[4s]

Three-Component Coupling Reactions

Typical procedure for the three-component coupling reaction of benzaldehyde, piperidine, and phenylacetylene (entry 1, Table 2)

A mixture of 2.5% Au/CeO_2 (10 mg, 0.00127 mmol Au), benzaldehyde (1.0 mmol, 106.1mg), piperidine (1.2 mmol, 102.2 mg), phenylacetylene (1.3 mmol, 132.8 mg), and water (MiliQ, 1.0 mL) was put into a closed glass reactor (2.0 mL, SUPELCO) and was extensively stirred (ca. 1000 rpm) at 100 ^oC oil bath for 6 h. After the reaction mixture was cooled to room temperature, it was removed into a glass vial (2.0 mL) and centrifuged at 6000 rpm for 2 minutes. The product oil was suspended in water; while 2.5% Au/CeO_2 was deposited in the bottom of the vial. The oil was separated from water and directly isolated by flash chromatograph with silica give propargylamine in quantitative yield.

Typical procedure for the three-component coupling and cyclization of benzaldehyde, piperidine, and N-protected ethynylaniline (entry 1, Table 3)

A mixture of 2.8% Au/ZrO_2 (5 mg, 0.0007 mmol Au), paraformaldehyde (0.20 mmol, 6.0 mg), piperidine (0.24 mmol, 20.4 mg), N-protected ethynylaniline (0.26 mmol, 70.5 mg), and dioxane (1.0 mL) was put into a closed glass reactor (2.0 mL, SUPELCO) and was extensively stirred (ca. 1000 rpm) at 100 ^oC oil bath for 6 h. After the reaction mixture was cooled to room temperature, it was removed into a glass vial (2.0 mL) and centrifuged at 6000 rpm for 2 minutes. The 2.8% Au/ZrO_2 was deposited in the bottom of vial and was separated from the liquid. The liquid was concentrated under reduced pressure and then isolated by flash chromatograph with silica give 2-(amino-methyl)indole derivative in quantitative yield.

Table S1. Physicochemical properties of supported gold catalysts.

Catalyst	BET surface area[l] (m^2/g)	Au-loading (wt%)	D_{Au} (nm)
Au/SiO_2	524	0.2	n.m.
Au/C	n.m.	3.0	2 – 5
Au/TiO_2[a]	n.m.	1.5	2 – 5
Au/Fe_2O_3[a]	n.m.	4.5	2 – 5
Au/ZrO_2	110	2.8	2 – 5
Au/CeO_2	160	2.5	2 – 5

[a] Supplied by the World Gold Council, the representative TEM images and size distribution of Au particles was reported by reference [5s].

Table S2. Effect of gold oxidation states on catalytic activity of 2.5% Au/CeO_2 and 2.8% Au/ZrO_2 catalysts for the A^3 coupling reaction.[a]

Catalyst	Au^{III}/Au^T	Au^I/Au^T	Conv. (%)[e]	TON[f]	TON[g]	TON[h]
Au/CeO_2[b]	0.29	0.37	100	788	2717	2130
Au/CeO_2[c]	0.22	0.32	59	465	2113	1453
Au/CeO_2[d]	0	0.37	13	102	-	277
Au/ZrO_2[b]	0.25	0	95	668	2674	-
Au/ZrO_2[d]	0	0	16	113	-	-

[a] Reaction conditions: Benzaldehyde (1.0 mmol), piperidine (1.2 mmol), and phenylacetylene (1.3 mmol), 2.5% Au/CeO_2 (10 mg, gold: 0.00127 mmol), 2.8% Au/ZrO_2 (10 mg, gold: 0.00142 mmol), H_2O (MiliQ, 1.0 mL), 6 h. The frequency and intensity of the IR band of CO adsorption on 2.5% Au/CeO_2 were used to identify Au^{III} (band at 2148 cm^{-1} representing Au^{III}-bound CO), Au^I (band at 2130 cm^{-1} representing Au^I-bound CO) and Au^0 (band at 2104 cm^{-1} representing Au^0-bound CO).[3s] The XPS and TPR were combined to quantitatively determine the cationic gold species of 2.8% Au/ZrO_2.[4s] Au^T: total amount of gold. [b] As prepared. [c] H_2 treatment at 100 ^oC for 3 h. [d] H_2 treatment at 300 ^oC for 3 h. [e] Benzaldehyde conversion. [f] Calculated on the basis of gold weight. [g] Calculated on the basis of Au^{III}. [h] Calculated on the basis of Au^I.

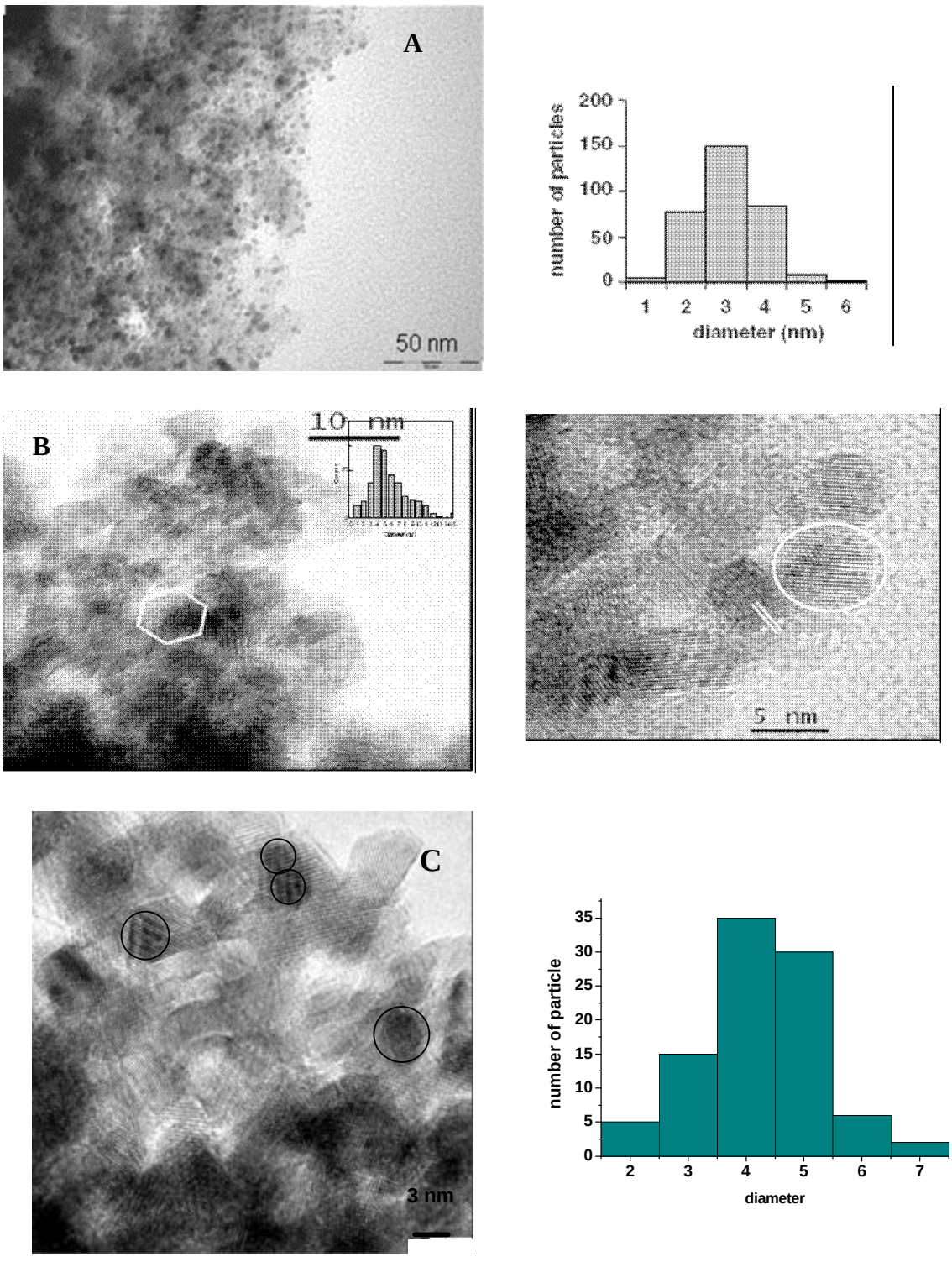


Figure S1 TEM images of (A) 3.0% Au/C (Right: Au particle size distribution), (B) 2.5% Au/CeO_2 (The inset shows the Au particle size distribution; right: high resolution TEM image), and (C) 2.8% Au/ZrO_2 (Right: Au particle size distribution).

Comparison the catalytic performance between Au/CeO_2 and $AuCl_3$ under the same reaction conditions

Taking 5.4 mg $AuCl_3$ (99.99%, Sigma-Aldrich) dissolve in 3.0 mL H_2O (MiliQ), the solution was divided into three parts and added into three glass reactors (2.0 mL, SUPELCO). After addition of benzaldehyde (2.0 mmol), piperidine (2.4 mmol), phenylacetylene (2.6 mmol), and 30 mg n-octane (internal standard) into each reactor, the reactors were purged with N_2 for several times to remove the air and closed. For another three reactors, use 5.0 mg Au/CeO_2 in each reactor, the other procedures are the same with $AuCl_3$.The reaction was assumed to start after the 6 reactors were put into the oil bath at 100 ^oC and stirred extensively. At 0.17, 0.50, and 1.0 h, stopped two reactions containing $AuCl_3$ and Au/CeO_2 catalysts and analyzed with GC, respectively. Repeat the above process, but stop reactions at 2.0, 6.0, and 12.0 h. The results are shown in Figure 1b and Table S3.

Table S3. Comparison catalytic performance of Au/CeO_2 and $AuCl_3$ for the A^3 coupling reaction of benzaldehyde, phenylacetylene and piperidine under the identical conditions.[a]

Reaction Time (h)	Au/CeO_2					$AuCl_3$		
	Conv. (%)	TON[b]	TON[c]	TOF[b] (h^{-1})	TOF[c] (h^{-1})	Conv. (%)	TON[b]	TOF[c] (h^{-1})
0.17	9	274	946	1645	5674	31	106	635
0.50	19	593	2043	1185	4087	52	177	353
1.0	31	977	3369	977	3369	77	258	258
2.0	59	1860	6413	930	3206	80	270	135
6.0	84	2648	9130	441	1522	80	270	45
12.0	99	3120	10760	260	897	81	273	23

[a] Reaction Conditions: benzaldehyde (2.0 mmol), piperidine (2.4 mmol), and phenylacetylene (2.6 mmol), H_2O (MiliQ, 1.0 mL), 100 ^oC. $AuCl_3$: 1.8 mg (Au: 5.93×10^{-3} mmol), 5.0 mg 2.5% Au/CeO_2 (Au: 6.34×10^{-4} mmol). [b] Calculated on the basis of total gold weight (Au^T). [c] Calculated on the basis of Au^{III} (for 2.5% Au/CeO_2, $Au^{III}/Au^T = 0.29$).

The recycling of Au/CeO_2 catalysts

The reused catalyst was recovered by separation of solid 2.5wt% Au/CeO_2 from liquid after extensively centrifuging. Washing the recovered catalyst with acetone for three times and then wash with distilled water for several times (at least 3 times). The catalyst was drying at 100 ^oC for 12 h and reused. In the four successive cycles, the conversion of benzaldehyde was 100, 87, 78, and 75%. ICP analysis for the three successive cycling catalyst has shown that the gold loading was 2.1 wt%.

Reference

[1s] X. Zhang, H. Wang, B.-Q. Xu, *J. Phys. Chem. B* **2005**, 109, 9678.

[2s] A. Corma, A. Abad, H. Garcia, Topics in Catal. **2007**, 44, 237.

[3s] a) S. Carrettin, M. C. Blanco, A. Corma, A.S.K. Hashmi, *Adv. Synth. Catal.* **2006**, 348, 1283; b) S. Carrettin, J. Guzman, A. Corma, *Angew.Chem. Int. Ed*. **2005**, 44, 2242

[4s] a) X. Zhang, H. Shi, B.-Q. Xu, *Angew. Chem. Int. Ed*. **2005**, 44, 7132; b) X. Zhang, H. Shi and B.-Q. Xu, *Catal. Today*, **2007**, 122, 330

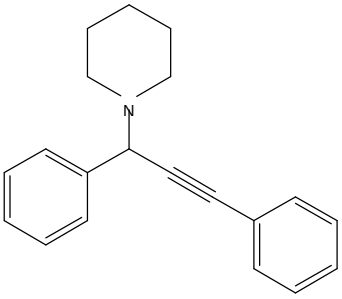
[5s] a) Gold Bulletin, 2003, 36(1), 24; b) S. Tsubota, A. Yamaguchi, M. Daté, M. Haruta, "Characterization of Reference Gold Catalysts" in Gold 2003: New Industrial Applications for Gold, Vancouver, Canada, 2003.

GC/MS and ^{1}H-NMR Analysis

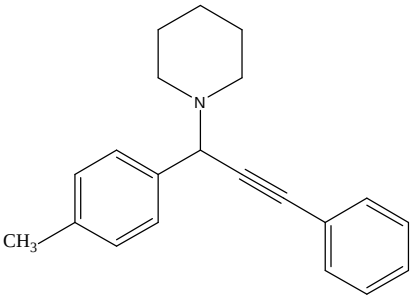
GC/MS analyses were performed on a Agilent 5973N spectrometer equipped with the same column and in the same conditions as GC.

Flash column chromatograph was performed over silica gel (0.04 - 0.06 mm, Scharlau) using the mixtures of hexane and ethyl acetate (ethyl acetate = 10 - 20 vol%) as effluent.

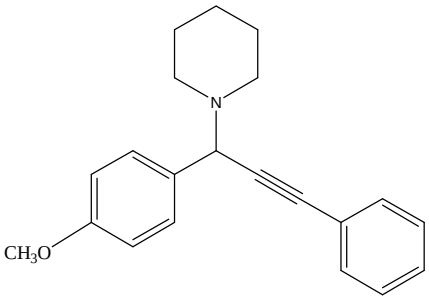
^{1}H-NMR spectra were recorded in $CDCl_3$ with TMS as an internal standard at ambient temperature on a Bruker Avance 300 operating at 300 MHz.



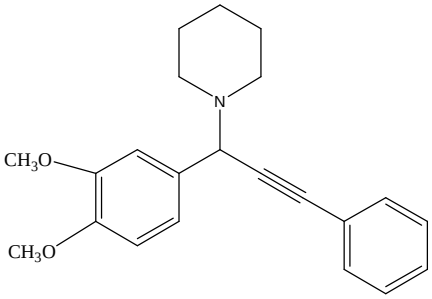
N-(1,3-diphenyl-2-propynyl)piperidine, $C_{20}H_{21}N$ (Product of entry 1 of Table 2).
MS m/z (%) 275 (M^+, 20), 191 (100), 198 (79), 192 (24), 189 (24), 115 (11), 165 (8), 232 (8).
^{1}H-NMR d: 7.57 – 7.51 (m, 2H), 7.46 – 7.37 (m, 2H), 7.30 – 7.11 (m, 6H), 4.71 (s, 1H), 2.60 – 2.40 (m, 4H), 1.60 – 1.45 (m, 4H), 1.40 – 1.30 (m, 2H).



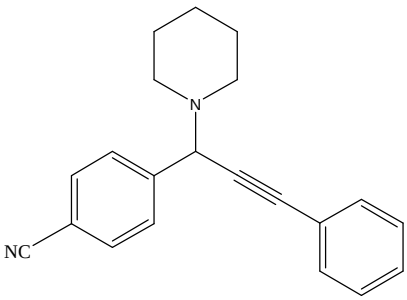
N-[1-(4-Methylphenyl)-3-phenyl-2-propynyl]piperidine, $C_{21}H_{23}N$ (Product of entry 2 of Table 2).
MS m/z (%) 289 (M^+, 20), 205 (100), 198 (35), 288(9), 189 (8), 84 (7), 115 (6), 165 (4).
^{1}H-NMR d: 7.57 – 7.51 (m, 2H), 7.30 – 7.20 (m, 3H), 7.05 – 6.90 (m, 4H), 4.70 (s, 1H), 2.60 – 2.46 (m, 4H), 2.40 (s, 3H), 1.60 – 1.45 (m, 4H), 1.40 – 1.30 (m, 2H).



N-[1-(4-Methoxyphenyl)-3-phenyl-2-propynyl]piperidine, $C_{21}H_{23}NO$ (Product of entry 3 of Table 2).
MS m/z (%) 305 (M^+, 15), 221 (100), 222 (24), 178 (13), 198 (5), 206 (5), 152 (4), 153 (3).
^{1}H-NMR d: 7.57 – 7.51 (m, 2H), 7.30 – 7.20 (m, 3H), 7.15 – 6.90 (m, 2H), 6.80 – 6.70 (m, 2H), 4.70 (s, 1H), 3.78 (s, 3H), 2.60 – 2.46 (m, 4H), 1.60 – 1.45 (m, 4H) 1.40 – 1.30 (m, 2H).

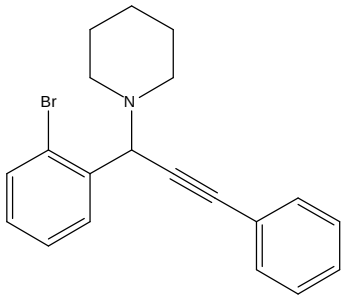


N-[1-(3,4-Dimethoxy-phenyl)-3-phenyl-2-propynyl]piperidine, $C_{22}H_{25}NO_2$ (Product of entry 4 of Table 2).
MS m/z (%) 335 (M^+, 12), 251 (100), 252 (25), 198 (6), 165 (6), 115 (4), 320 (2), 84 (2).
^{1}H-NMR d: 7.57 – 7.51 (m, 2H), 7.30 – 7.20 (m, 3H), 6.70 – 6.60 (m, 3H), 3.77 (s, 6H), 4.70 (s, 1H), 2.60 – 2.46 (m, 4H), 1.65 – 1.45 (m, 4H) 1.40 – 1.30 (m, 2H).

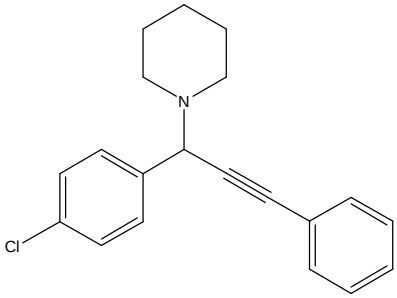


4-(3-Phenyl-1-piperidin-1-yl-2-propynyl)benzonitrile, $C_{21}H_{20}N_2$ (Product of entry 5 of Table 2).
MS m/z (%) 300 (M^+, Tr), 191 (100), 198 (74), 275 (26), 192 (26), 189 (24), 274 (18), 232 (8).

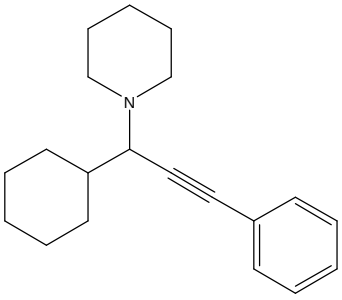
^{1}H-NMR d: 7.57 – 7.51 (m, 4H), 7.30 – 7.20 (m, 5H), 4.71 (s, 1H), 2.60 – 2.46 (m, 4H), 1.65 – 1.45 (m, 4H) 1.40 – 1.30 (m, 2H).



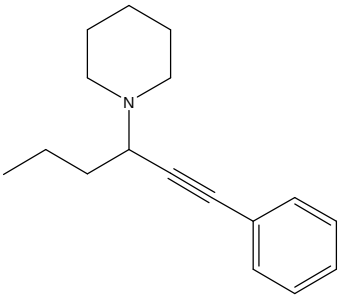
N-[1-(2-Bromophenyl)-3-phenyl-2-propynyl]piperidine, $C_{20}H_{20}NBr$ (Product of entry 6 of Table 2).
MS m/z (%) 355 (M^+, 20), 353 (M^+, 21), 198 (100), 271 (59), 269 (58), 189 (56), 191 (27), 115 (8).
^{1}H-NMR d: 7.57 – 7.51 (m, 2H), 7.30 – 7.20 (m, 4H), 7.10 – 7.00 (m, 3H), 4.71 (s, 1H), 2.60 – 2.46 (m, 4H), 1.65 – 1.45 (m, 4H) 1.40 – 1.30 (m, 2H).



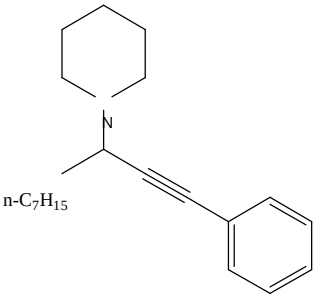
N-[1-(4-Chlorophenyl)-3-phenyl-2-propynyl]piperidine, $C_{20}H_{20}NCl$ (Product of entry 7 of Table 2).
MS m/z (%) 309 (M^+, 22), 311 (M^+, 8), 225 (100), 198 (59), 227 (33), 188 (30), 115 (8), 84 (7).
^{1}H-NMR d: 7.57 – 7.51 (m, 2H), 7.30 – 7.20 (m, 4H), 7.10 – 7.00 (m, 3H), 4.72 (s, 1H), 2.60 – 2.46 (m, 4H), 1.65 – 1.45 (m, 4H) 1.40 – 1.30 (m, 2H).



N-(1-Cyclohexyl-3-phenyl-2-propynyl)-piperidine, $C_{20}H_{27}N$ (Product of entry 9 of Table 2).
MS m/z (%) 281 (M^+, Tr), 280 (M^+, 2), 198 (100), 115 (91), 199 (79), 128 (12), 55 (13), 141 (8).
^{1}H-NMR d: d: 7.57 – 7.51 (m, 2H), 7.30 – 7.20 (m, 3H), 3.08 (d, 1H), 1.75 – 1.39 (m, 11H), 2.60 – 2.40 (m, 4H), 1.60 – 1.45 (m, 4H), 1.40 – 1.30 (m, 2H).

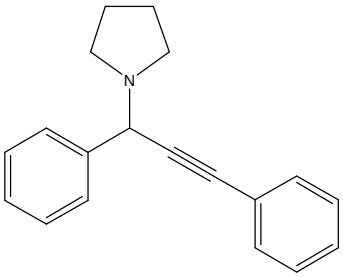


N-(1-Phenylethynyl-butyl)piperidine, $C_{17}H_{23}N$ (Product of entry 10 of Table 2).
MS m/z (%) 241 (M^+, Tr), 198 (100), 115 (47), 199 (17), 128 (9), 55 (6), 77 (5), 91 (4).
^{1}H-NMR d: 7.40 – 7.15 (m, 5H), 3.40 – 3.50 (t, 1H), 2.50 – 2.35 (m, 4H), 1.70 – 1.50 (m, 6H), 1.48 – 1.15 (m, 4H), 0.90 – 0.75 (t, 3H),

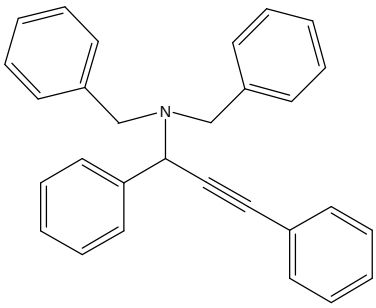


N-(1-Phenylethynyl-octyl)piperidine, $C_{21}H_{31}N$ (Product of entry 11 of Table 2).
MS m/z (%) 297 (M^+, Tr), 296 (M^+, 2), 198 (100), 115 (70), 199 (67), 128 (16), 55 (8), 91 (7).

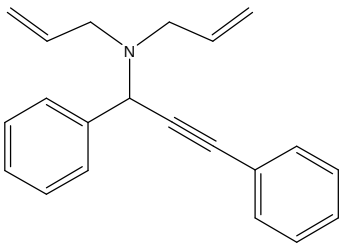
^{1}H-NMR d: 7.50 – 7.20 (m, 5H), 3.55– 3.45 (t, 1H), 2.55 – 2.45 (m, 4H), 1.78 – 1.58 (m, 2H), 1.50 – 1.47 (m, 6H) 1.31 – 1.29 (m, 10H), 0.96 – 0.85 (t, 3H).



N-(1,3-Diphenyl-2-propynyl)pyrrolidine, $C_{19}H_{19}N$ (Product of entry 12 of Table 2).
MS m/z (%) 261 (M^+, 25), 260 (M^+, 18), 191 (100), 184 (55), 192 (26), 115 (9), 232 (8), 165 (7).
^{1}H-NMR d: d: 7.57 – 7.51 (m, 2H), 7.30 – 7.20 (m, 3H), 7.20 – 7.05 (m, 5H), 4.83 (s, 1H), 2.43 – 2.30 (m, 4H), 1.67 – 1.57 (m, 4H).

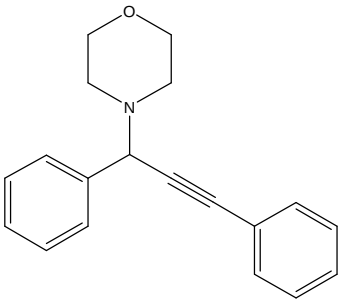


Dibenzyl-(1,3-diphenyl-2-propynyl)amine, $C_{29}H_{25}N$ (Product of entry 13 of Table 2).
MS m/z (%) 387 (M^+, 14), 191 (100), 91 (88), 192 (44), 310 (20), 296 (15), 165 (13), 65 (13).
^{1}H-NMR d: 7.90 – 7.80 (m, 2H), 7.79 – 7.68 (m, 2H), 7.58 – 7.28 (m, 16H), 5.05 (s, 1H), 3.95 – 3.85 (d, 2H), 3.70 – 3.59 (d, 2H).

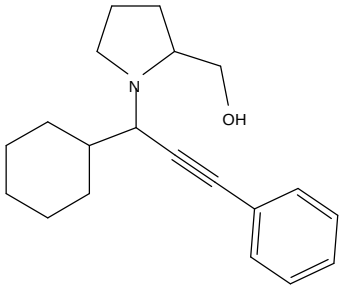


Diallyl-(1,3-diphenyl-2-propynyl)amine, $C_{21}H_{21}N$ (Product of entry 14 of Table 2).
MS m/z (%) 287 (M^+, 13), 286 (M^+, 32), 191 (100), 210 (35), 189 (22), 246 (13), 165 (6), 218 (6).

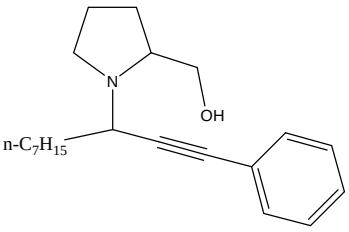
^{1}H-NMR d: 7.57 – 7.51 (m, 2H), 7.30 – 7.20 (m, 3H), 7.20 – 7.05 (m, 5H), 5.90 – 5.81 (m, 2H), 5.20 – 5.15 (m, 4H), 5.06 (s, 1H), 3.10 – 3.01 (m, 4H).



4-(1,3-Diphenyl-2-propynyl)-morpholine, $C_{19}H_{19}NO$ (Product of entry 15 of Table 2).
MS m/z (%) 277 (M^+, 52), 191 (100), 200 (64), 189 (55), 86 (26), 246 (21), 56 (25), 165 (19).
^{1}H-NMR d: 7.57 – 7.51 (m, 2H), 7.30 – 7.20 (m, 3H), 7.20 – 7.05 (m, 5H), 4.71 (s, 1H), 3.70 – 3.60 (t, 4H), 2.40 – 2.20 (t, 4H).

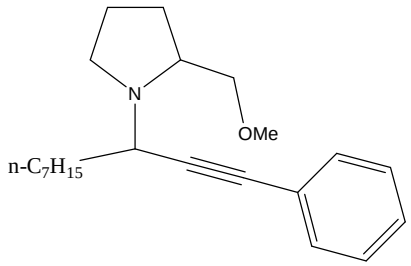


[1-(1-Cyclohexyl-3-phenyl-2-propynyl)-2-pyrrolidinyl]methanol, $C_{20}H_{27}NO$ (Mixtures of diastereomeric isomers, entry 16 of Table 2).
MS m/z (%) of the major diastereomeric isomer: 297 (M^+, Tr), 214 (100), 115 (21), 266 (13), 215 (16), 70 (8), 128 (6), 91 (4).
^{1}H-NMR(mixtures of diastereomeric isomers) d: 7.50 – 7.40 (m, 2H), 7.35 – 7.20 (m, 3H), 3.72 – 3.62 (dd, 1H), 3.48 – 3.35 (dd, 2H), 3.17 – 3.08 (m, 1H), 2.97 – 2.81 (m, 2H), 2.22 – 2.05 (m, 2H), 1.95 – 1.51 (m, 8H), 1.87 – 1.36 (m, 4H), 1.08 – 0.86 (m, 2H).

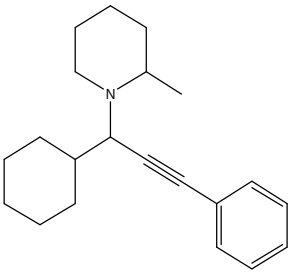


[1-(1-Phenylethynyl-octyl)-2-pyrrolidinyl]-methanol, $C_{21}H_{31}NO$ (Mixtures of diastereomeric isomers, entry 17 of Table 2). The diastereomeric isomers can be separated by GC with HP-5 column using a suitable temperature program.

MS m/z (%) of the major diastereomeric isomer: MS m/z (%) 313 (M^+, Tr), 214 (100), 282 (64), 70 (35), 115 (31), 130 (29), 91 (19), 143 (10).
MS m/z (%) of the minor diastereomeric isomer: MS m/z (%) 313 (M^+, Tr), 214 (100), 282 (21), 70 (15), 115 (30), 130 (43), 91 (14), 145 (20).
^{1}H-NMR(mixtures of diastereomeric isomers): d: 7.40 – 7.29 (m, 2H), 7.30 – 7.15 (m, 3H), 3.68 – 3.55 (m, 1H), 3.40 – 3.30 (d, 2H), 3.08 – 2.98 (m, 1H), 2.93 – 2.83 (m, 1H), 2.82 – 2.70 (m, 2H), 1.89 – 1.62 (m, 6H), 1.48 – 1.14 (m, 10H), 0.86 – 0.78 (t, 3H).

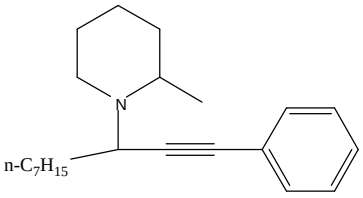


2-Methoxymethyl-1-(1-phenylethynyl-octyl)-pyrrolidine, $C_{22}H_{33}NO$ (Mixtures of diastereomeric isomers, entry 18 of Table 2). The diastereomeric isomers can be separated by GC with HP-5 column using a suitable temperature program.
MS m/z (%) of the major diastereomeric isomer: MS m/z (%) 327 (M^+, Tr), 282 (100), 228 (60), 70 (56), 115 (34), 91 (26), 128 (23), 143 (16).
MS m/z (%) of the minor diastereomeric isomer: MS m/z (%) 327 (M^+, Tr), 282 (100), 228 (84), 70 (39), 115 (28), 91 (19), 128 (19), 143 (12).
^{1}H-NMR(mixtures of diastereomeric isomers): d: 7.40 – 7.29 (m, 2H), 7.25 – 7.18 (m, 3H), 3.83 – 3.76 (dd, 1H), 3.35 – 3.23 (dd, 1H), 3.10 – 3.02 (dd, 1H), 2.93 – 2.83 (m, 1H), 3.28 (s, 3H), 2.86 – 2.75 (m, 1H), 2.70 – 2.62 (q, 1H), 1.89 – 1.62 (m, 6H), 1.48 – 1.14 (m, 10H), 0.80 (t, 3H).

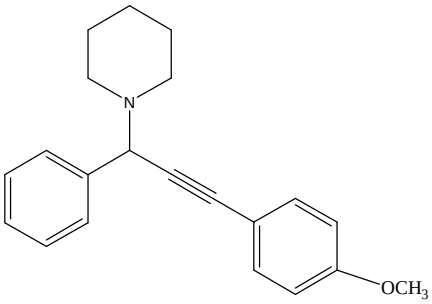


N-(1-Cyclohexyl-3-phenyl-2-propynyl)-2-methyl-piperidine, $C_{21}H_{29}N$ (Mixtures of diastereomeric isomers, entry 19 of Table 2). The diastereomeric isomers can be separated by GC with HP-5 column using a suitable temperature program.

MS m/z (%) of the major diastereomeric isomer: 295 (M^+, Tr), 212 (100), 213 (17), 115 (10), 55 (6), 130 (3), 91 (2), 141 (2).
MS m/z (%) of the minor diastereomeric isomer: 295 (M^+, Tr), 212 (100), 213 (25), 115 (16), 55 (9), 130 (5), 91 (3), 141 (2).
^{1}H-NMR (mixtures of diastereomeric isomers) d: 7.40 – 7.30 (m, 2H), 7.25 – 7.15 (m, 3H), 3.48 – 3.45 (d, 1H)*, 3.12 – 3.09 (d, 1H)*, 2.49 – 2.29 (m, 1H), 2.18 – 1.88 (m, 2H), 1.74 – 1.45 (m, 1H), 1.45 – 1.08 (m, 16H), 0.98 – 0.92 (d, 3H). *represents diastereomeric pairs

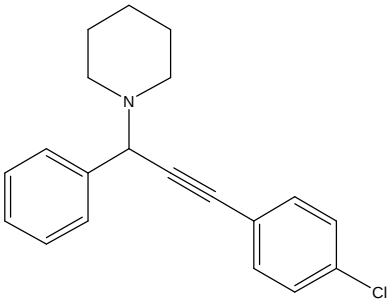


2-Methyl-1-(1-phenylethynyl-octyl)-piperidine, $C_{22}H_{33}N$ (Mixtures of diastereomeric isomers, entry 20 of Table 2). The diastereomeric isomers can be separated by GC with HP-5 column using a suitable temperature program.
MS m/z (%) of the major diastereomeric isomer: MS m/z (%) 311 (M^+, Tr), 212 (100), 213 (20), 115 (5), 130 (3), 296 (3), 128 (3), 55 (2).
MS m/z (%) of the minor diastereomeric isomer: MS m/z (%) 311 (M^+, Tr), 212 (100), 213 (7), 115 (2), 130 (1), 128 (1), 55 (1), 296 (0.6), 55 (1).
^{1}H-NMR(mixtures of diastereomeric isomers) d: 7.40 – 7.29 (m, 2H), 7.24 – 7.15 (m, 3H), 3.88 – 3.78 (dd, 1H)*, 3.17 – 3.08 (dd, 1H)*, 2.62 – 2.34 (m, 1H), 2.34 – 2.08 (m, 2H), 1.63 – 1.40 (m, 8H), 1.30 – 1.10 (m, 10H), 1.10 – 1.00 (d, 3H), 0.90 – 0.75 (t, 3H). *represents diastereomeric pairs

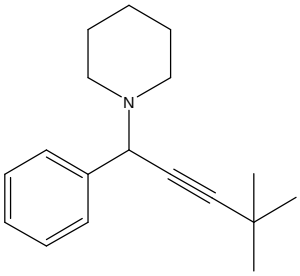


N-[3-(4-Methoxyphenyl)-1-phenyl-2-propynyl]piperidine, $C_{21}H_{23}NO$ (Product of entry 21 of Table 2).
MS m/z (%) 305 (M^+, 25), 304 (M^+, 12), 221 (100), 228 (40), 222 (26), 178 (17), 206 (8), 152 (5).

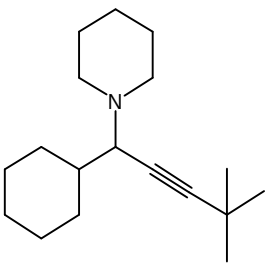
^{1}H-NMR d: 7.40 – 7.30 (m, 2H), 7.20 – 7.10 (m, 5H), 6.78 – 6.61 (m, 2H), 4.71 (s, 1H), 3.71 (s, 3H), 2.60 – 2.40 (m, 4H), 1.60 – 1.45 (m, 4H), 1.40 – 1.30 (m, 2H).



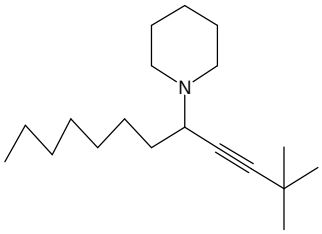
N-[3-(4-Chlorophenyl)-1-phenyl-2-propynyl]piperidine, $C_{20}H_{20}NCl$ (Product of entry 22 of Table 2).
MS m/z (%) 310 (M^+, 9), 309 (M^+, 20), 225 (100), 232 (74), 189 (33), 227 (33), 149 (8), 266 (5).
^{1}H-NMR d: 7.46 – 7.35 (m, 2H), 7.33 – 7.23 (m, 2H), 7.20 – 7.10 (m, 5H), 4.71 (s, 1H), 2.60 – 2.40 (m, 4H), 1.60 – 1.45 (m, 4H), 1.40 – 1.30 (m, 2H).



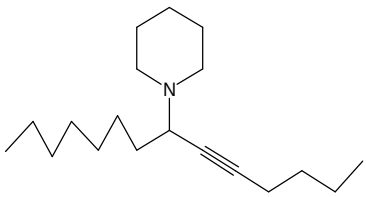
N-(4,4-Dimethyl-1-phenyl-2-pentynyl)piperidine, $C_{18}H_{25}N$ (Product of entry 23 of Table 2).
MS m/z (%) 255 (M^+, 10), 178 (100), 91 (15), 143 (13), 129 (11), 115 (10), 84 (9), 198 (6).
^{1}H-NMR d: 7.20 – 7.10 (m, 5H), 4.63 (s, 1H), 2.40 – 2.20 (m, 4H), 1.60 – 1.45 (m, 4H), 1.40 – 1.30 (m, 2H), 1.15 (s, 9H).



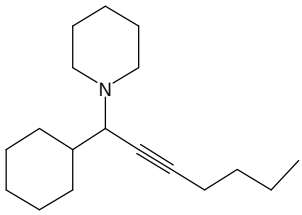
N-(1-Cyclohexyl-4,4-dimethyl-2-pentynyl)piperidine, $C_{18}H_{31}N$ (Product of entry 24 of Table 2).
MS m/z (%) 261 (M^+, Tr), 178 (100), 55 (30), 148 (22), 84 (16), 162 (12), 77 (12), 67 (12).
^{1}H-NMR d: 2.79 – 2.75 (d, 1H), 2.48 – 2.41 (m, 2H), 2.24 – 2.16 (m, 2H), 1.94 – 1.86 (m, 2H), 1.70 – 1.30 (m, 15H), 1.15 (s, 9H).



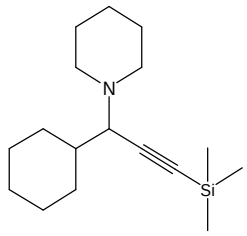
N-[1-(3,3-Dimethyl-1-butynyl)-octyl]-piperidine, $C_{19}H_{35}N$ (Product of entry 25 of Table 2).
MS m/z (%) 277 (M^+, Tr), 178 (100), 148 (13), 84 (12), 55 (12), 162 (8), 67 (8), 95 (7).
^{1}H-NMR d: 2.78 – 2.74 (t, 1H), 2.48 – 2.41 (m, 2H), 2.24 – 2.16 (m, 2H), 1.61 – 1.48 (m, 8H), 1.35 – 1.20 (m, 10H), 1.15 (s, 9H), 0.90 – 0.83 (t, 3H).



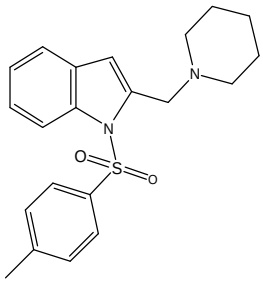
N-(1-Hex-1-ynyl-octyl)-piperidine, $C_{19}H_{35}N$ (Product of entry 26 of Table 2).
MS m/z (%) 277 (M^+, Tr), 178 (100), 134 (6), 84 (3), 55 (3), 148 (2), 67 (2), 77 (2).
^{1}H-NMR d: 2.79 – 2.75 (t, 1H), 2.48 – 2.41 (m, 2H), 2.24 – 2.11 (m, 2H), 1.94 – 1.86 (t, 2H), 1.61 – 1.48 (m, 10H), 1.29 – 1.05 (m, 12H), 0.90 – 0.83 (t, 6H).



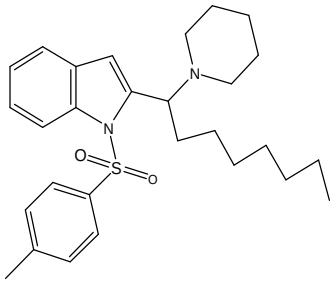
N-(1-Cyclohexyl-2-heptynyl)-piperidine, $C_{18}H_{31}N$ (Product of entry 27 of Table 2).
MS m/z (%) 261 (M^+, Tr), 178 (100), 134 (32), 55 (31), 79 (14), 67 (13), 91 (10), 106 (8).
^{1}H-NMR d: 2.79 – 2.75 (d, 1H), 2.48 – 2.41 (m, 2H), 2.24 – 2.11 (m, 2H), 1.94 – 1.86 (t, 2H), 1.70 – 1.33 (m, 21H), 1.19 – 1.05 (m, 2H), 0.88 – 0.82 (t, 3H).



N-(1-Cyclohexyl-3-trimethylsilanyl-2-propynyl)-piperidine, $C_{17}H_{31}NSi$ (Product of entry 28 of Table 2)
MS m/z (%) 277 (M^+, Tr), 194 (100), 55 (5), 83 (4), 73 (3), 120 (1), 179 (2), 96 (1).
^{1}H-NMR d: 2.79 – 2.75 (d, 1H), 2.48 – 2.41 (m, 2H), 2.24 – 2.11 (m, 2H), 1.70 – 1.33 (m, 17H), 0.10 (s, 9H).

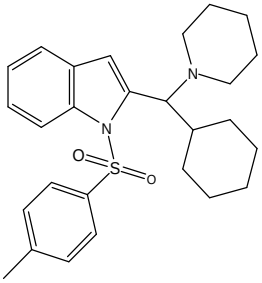


2-Piperidin-1-ylmethyl-1-(toluene-4-sulfonyl)-1H-indole, $C_{21}H_{24}N_2SO_2$ (Product of entry 1 of Table 3)
MS m/z (%) 368 (M^+, 12), 130 (100), 213 (80), 91 (41), 220 (22), 103 (15), 84 (14), 65 (12).
^{1}H-NMR d: d: 8.04 – 8.02 (d, 1H), 7.83 – 7.80 (d, 2H), 7.38 – 7.36 (d, 2H), 7.16 – 7.03 (m, 3H), 6.42 (s, 1H), 3.87 (s, 2H), 2.54 – 2.46 (m, 4H), 2.26 (s, 3H), 1.58 – 1.50 (m, 6H).

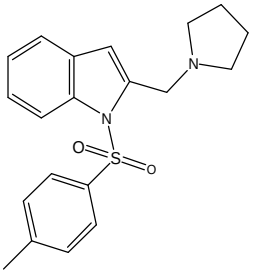


2-(1-Piperidin-1-yl-octyl)-1-(toluene-4-sulfonyl)-1H-indole, $C_{28}H_{38}N_2SO_2$ (Product of entry 2 of Table 3).
MS m/z (%) 466 (M^+, Tr), 367 (100), 212 (37), 130 (23), 91 (22), 143 (21), 311 (11), 156 (9).

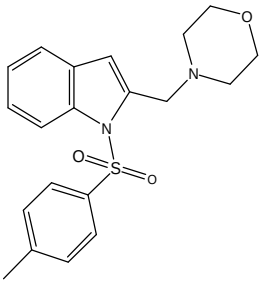
^{1}H-NMR d: 8.04 – 8.02 (d, 1H), 7.83 – 7.80 (d, 2H), 7.38 – 7.36 (d, 2H), 7.16 – 7.03 (m, 3H), 6.42 (s, 1H), 4.59 – 4.55 (q, 1H), 2.55 – 2.45 (m, 4H), 2.20 (s, 3H), 1.80 – 1.70 (m, 2H), 1.56 (m, 6H), 1.37 – 1.12 (m, 10H), 0.76 (t, 3H).



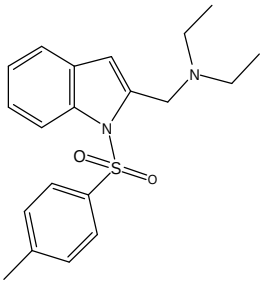
2-(Cyclohexyl-piperidin-1-yl-methyl)-1-(toluene-4-sulfonyl)-1H-indole, $C_{27}H_{34}N_2SO_2$ (Product of entry 3 of Table 3).
MS m/z (%) 450 (M^+, Tr), 367 (100), 212 (52), 130 (21), 91 (17), 183 (10), 156 (9), 168 (8).
^{1}H-NMR d: 8.04 – 8.02 (d, 1H), 7.83 – 7.80 (d, 2H), 7.38 – 7.36 (d, 2H), 7.16 – 7.03 (m, 3H), 6.42 (s, 1H), 4.54 – 4.50 (t, 1H), 2.55 – 2.45 (m, 4H), 2.25 (m, 1H), 2.20 (s, 3H), 1.58 – 1.50 (m, 6H), 1.48 – 1.39 (m, 10H).



2-Pyrrolidin-1-ylmethyl-1-(toluene-4-sulfonyl)-1H-indole, $C_{20}H_{22}N_2SO_2$ (Product of entry 4 of Table 3).
MS m/z (%) 354 (M^+, 11), 130 (100), 199 (83), 91 (46), 220 (36), 103 (34), 70 (14), 77 (13).
^{1}H-NMR d: 8.04 – 8.02 (d, 1H), 7.79 – 7.77 (d, 2H), 7.38 – 7.35 (d, 2H), 7.18 – 7.06 (m, 3H), 6.52 (s, 1H), 3.87 (s, 2H), 2.54 – 2.46 (m, 4H), 2.26 (s, 3H), 1.58 – 1.50 (m, 4H).



2-Morpholin-4-ylmethyl-1-(toluene-4-sulfonyl)-1H-indole, $C_{20}H_{22}N_2SO_3$ (Product of entry 5 of Table 3).
MS m/z (%) 370 (M^+, 25), 130 (100), 215 (63), 91 (47), 185 (18), 65 (18), 102 (16), 157 (14).
^{1}H-NMR d: 8.04 – 8.02 (d, 1H), 7.79 – 7.77 (d, 2H), 7.38 – 7.35 (d, 2H), 7.18 – 7.06 (m, 3H), 6.52 (s, 1H), 3.87 (s, 2H), 2.54 – 2.46 (m, 4H), 2.26 (s, 3H), 3.78 – 3.76 (m, 4H).



Diethyl-[1-(toluene-4-sulfonyl)-1H-indol-2-ylmethyl]-amine, $C_{20}H_{24}N_2SO_2$ (Product of entry 6 of Table 3).
MS m/z (%) 356 (M^+, 12), 130 (100), 284 (88), 220 (76), 91 (53), 65 (16), 103 (16), 201 (16).
^{1}H-NMR d: 8.04 – 8.02 (d, 1H), 7.79 – 7.77 (d, 2H), 7.38 – 7.35 (d, 2H), 7.18 – 7.06 (m, 3H), 6.52 (s, 1H), 3.87 (s, 2H), 2.56 – 2.48 (q, 4H), 2.25 (s, 3H), 0.94 – 0.88 (t, 6H).