A Waste-Minimized Approach to Cassar-Heck Reaction Based on POLITAG-Pd\textsuperscript{0} Heterogeneous Catalyst and Recoverable Acetonitrile Azeotrope

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1. General Remarks

Unless otherwise stated, all chemicals were purchased and used without any further purification. GLC analyses were performed by using Hewlett-Packard HP 5890 SERIES II equipped with a capillary column DB-5 MS (30 m, 0.32 mm), a FID detector, and helium as gas carrier. GC-EIMS analyses were carried out by using a Hewlett-Packard HP 6890N Network GC system/5975 mass selective detector equipped with an electron impact ionizer at 70 eV. Melting points were measured on a Büchi 510 apparatus. NMR spectra were recorded on a Bruker DRX-ADVANCE 400 MHz (\(^1\)H at 400 MHz, \(^{13}\)C at 100.6 MHz and \(^{19}\)F at 376.4 MHz) in CDCl\(_3\). Chemical shifts are reported in ppm (δ), coupling constant (J) in hertz and multiplicity are reported as follows: s = singlet, bs = broad singlet, d = doublet, dd = double doublet, td = double triplet, t = triplet, m = multiplet. Elemental Analysis (EA) were conducted on Elementar UNICUBE® elemental analyzer. Metal loading was measured using MP-AES 4210 instrument. Products purification was performed through filtration on silica plug using 230-400 mesh silica gel. TEM images were obtained using a PHILIPS CM 12 transmission electron microscopy operating in the range 20 to 120 kV with an image resolution of 0.34 nm.

Pyncker-type ligands 3,3-di(1H-imidazol-1-yl)propan-1-ol (L\(_1\)), \(^1\) 3,3-di(1H-1,2,4-triazol-1-yl)propan-1-ol (L\(_2\))\(^2\) and 3,3-di(1H-1,2,3-triazol-1-yl)propan-1-ol (L\(_3\))\(^3\) and SP-Cl\(^2\) support were prepared as described in literature.

Synthesis of POLITAGs-Pd(II) intermediates\(^1\)-\(^3\) and reduction step to afford the corresponding POLITAGs-Pd(0)\(^2\) have been performed as described in previously reported works.

Characterization data, \(^1\)H, \(^{13}\)C and \(^{19}\)F NMR spectra are reported below.
2. General procedures

General procedure

A 2 mL screw capped vial, equipped with a magnetic stirrer, was charged with the aryl iodide (1 mmol), the terminal alkyne (1.5 equiv), DABCO (1.2 equiv), catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.117 mg, 0.01 mmol%), and 1 mL of CH$_3$CN/H$_2$O azeotrope (1 M, 84/16 wt). The reaction mixture was then stirred at 90° for 7 h. The conversion was determined by GLC analyses. After reaction completion, the catalyst was separated through filtration and washed with 1 mL of CH$_3$CN/H$_2$O azeotrope, which was then recovered through distillation (95 % azeotrope recovered).

Work-up with heptane (method A):

The product was isolated through filtration and washing on silica plug (500 mg) using heptane (5 mL). The solvent was recovered at 94% through distillation.

Work-up with toluene (method B):

The product was isolated through filtration and washing on silica plug (150 mg) using toluene (5 mL). The solvent was recovered at 97% through distillation.

General procedure for leaching determination

After reaction completion, the catalyst was separated through filtration and washed with 1 mL of CH$_3$CN/H$_2$O azeotrope. The reaction mixture was dried under vacuum, dissolved in 2 mL of aqua regia, and stirred for 1h at room temperature. The reaction mixture was transferred in a 10 mL graduated flask and Milli-Q water was added to reach the final volume. If present, residual solid was filtered off and the sample was analysed by MP-AES 4210 instrument.
Figure S-1. TEM images of POLITAGs-Pd(0). [a-b] with L1 ligand, particle size distribution: 5.9 ± 2.0 nm; [c-d] with L2 ligand, particle size distribution: 5.7 ± 1.1 nm; [e-f] with L3 ligand, particle size distribution: 6.3 ± 1.8 nm.

Table S-1. Loading of ionic tags units on polymer surface and Pd nanoparticles for three different POLITAGs.

| POLITAG-L | Ionic-tag loading (mmol/g)\textsuperscript{a} | Pd loading (wt\%)\textsuperscript{b} |
|-----------|----------------|-----------------|
| L1        | 0.90           | 9.4             |
| L2        | 0.93           | 9.0             |
| L3        | 0.90           | 9.2             |

\textsuperscript{a}determined by elemental analysis. \textsuperscript{b}measured by MP-AES analysis.
Table S-2. Optimization of reaction conditions with POLITAG-L1-Pd(0) for Sonogashira reaction between 1a and 2a.

\[
\text{I} + \text{2a} \xrightleftharpoons[\text{T (°C), time}]{\text{DABCO, medium}} \text{POLITAG-L1-Pd(0) (0.01 mol%)} \rightarrow \text{3aa}
\]

| Entry | medium          | POLITAG-L1 (mol %) | T (°C) | t (h) | Conv (%) | Pd (ppm) |
|-------|-----------------|---------------------|--------|-------|----------|----------|
| 1     | GVL             | 0.05                | 60     | 4     | 71       | 6        |
| 2     | GVL             | 0.05                | 60     | 20    | 88       | 6        |
| 3     | GVL             | 0.05                | 80     | 4     | 78       | 6        |
| 4     | Propylene carbonate | 0.05          | 80     | 4     | 12       | --       |
| 5     | GVL             | 0.01                | 80     | 4     | 64       | 1        |
| 6     | GVL             | 0.01                | 80     | 7     | 65       | 1        |
| 7     | GVL             | 0.01                | 80     | 16    | 69       | 2        |
| 8     | GVL             | 0.01                | 80     | 24    | 80       | 2        |
| 9     | Propylene carbonate | 0.01          | 80     | 7     | 0        | --       |
| 10    | Az. CH₃CN/H₂O   | 0.01                | 80     | 4     | 89       | 2        |
| 11    | Az. CH₃CN/H₂O   | 0.01                | 80     | 7     | 97       | 3        |
| 12    | Az. CH₃CN/H₂O   | 0.01                | 90     | 7     | >99      | 1        |
| 13    | EtOH            | 0.01                | 80     | 4     | 58       | 2        |
| 14    | Az. CH₃CN/H₂O   | 0.01                | 90     | 7     | 89       | 1        |

aReaction conditions: POLITAG-L1-Pd(0), 1a (1 mmol), 2a (1.5 eq), DABCO (1.2 eq), solvent (1 mL).
bConversion was measured by GC analyses. cPd leaching was measured by MP-AES 4210 instrument.
dreaction performed with POLITAG-L1-Pd(0) with a low loading of Pd (3 wt%).

Table S-3. Optimization of reaction conditions for Sonogashira reaction between 1a and 2a with 0.01 mol% of POLITAG-L1-Pd(0) in CH₃CN/H₂O azeotrope.

\[
\text{I} + \text{2a} \xrightleftharpoons[\text{T (°C), time}]{\text{base, CH₃CN/H₂O az.}} \text{POLITAG-L1-Pd(0) (0.01 mol%)} \rightarrow \text{3aa}
\]

| Entry | Base         | Base (eq) | 2a (eq) | T (°C) | t (h) | Conv (%) |
|-------|--------------|-----------|---------|--------|-------|----------|
| 1     | K₂CO₃       | 1.2       | 1.5     | 80     | 16    | 11       |
| 2     | EtN         | 1.2       | 1.5     | 80     | 16    | 42       |
| 3     | DABCO       | 1.2       | 1.5     | 80     | 7     | 97       |
| 4     | DABCO       | 1.5       | 1.2     | 80     | 16    | 98       |
| 5     | DABCO       | 1.3       | 1.1     | 80     | 16    | 83       |
| 6     | DABCO       | 1.2       | 1.5     | 90     | 16    | >99      |
| 7     | DABCO       | 1.2       | 1.5     | 90     | 7     | >99      |
| 8     | DABCO       | 1.2       | 1.2     | 90     | 16    | 92       |
| 9     | DABCO       | 1.3       | 1.1     | 90     | 7     | 89       |
| 10    | DABCO       | 1.2       | 1.3     | 90     | 16    | 98       |

aConversion was measured by GC analyses.
References

[1] H. Mahmoudi, F. Valentini, F. Ferlin, L. A. Bivona, I. Anastasiou, L. Fusaro, C. Aprile, A. Marrocchi, L. Vaccaro, *Green Chem.* 2019, **21**, 355–360;

[2] F. Valentini, H. Mahmoudi, L. A. Bivona, O. Piermatti, M. Bagherzadeh, L. Fusaro, C. Aprile, A. Marrocchi, L. Vaccaro, *ACS Sustainable Chem. Eng.* 2019, **7**, 6939–6946;

[3] D. Sciosci, F. Valentini, F. Ferlin, S. Chen, Y. Gu, O. Piermatti, L. Vaccaro, *Green Chem.*, 2020, **22**, 6560–6566.
3. E-factor calculations

\[ E - factor = \frac{\text{Kg of waste}}{\text{Kg of product}} \]

General assumptions for the E-factor calculations:

E-factor calculated without purification process: SiO\textsubscript{2} and solvents for the purification have not been considered in this calculation.

E-factor calculated with purification process: SiO\textsubscript{2} and solvents not recovered after the purification have been considered in this calculation.

E-factor calculated without purification process (column chromatography): SiO\textsubscript{2} and solvents for the chromatography have not been considered in this calculation.

Note: the amount of azeotrope (64 mg) considered in the calculation is obtained by subtracting the amount of azeotrope recovered from the total amount of azeotrope used as reaction medium and in the catalyst washing.

Reaction of iodobenzene (1a) with phenylacetylene (2a):

Without purification process: E-factor = (0.117 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 208 mg (1a) + 156 mg (2a) + 64 mg (Azeotrope not recovered) – 173 mg (3aa))/ 173 mg (3aa) = 1.4

With purification process: E-factor = (0.117 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 208 mg (1a) + 156 mg (2a) + 64 mg (Azeotrope not recovered) + 410 mg (heptane not recovered) + 500 mg (SiO\textsubscript{2}) – 173 mg (3aa))/ 173 mg (3aa) = 8

Reaction of 1-iodo-4-nitrobenzene (1b) with phenylacetylene (2a):

Without purification process: E-factor= (0.117 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 254 mg (1b) + 156 mg (2a) + 64 mg (Azeotrope not recovered) – 221 mg (3ba))/ 221 mg (3ba) = 1.8

With purification process: E-factor= (0.117 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 254 mg (1b) + 156 mg (2a) + 64 mg (Azeotrope not recovered) + 130 mg (toluene not recovered) + 150 mg (SiO\textsubscript{2}) – 221 mg (3ba))/ 221 mg (3ba) = 3

Reaction of 1-iodo-3-nitrobenzene (1c) with phenylacetylene (2a):

Without purification process: E-factor= (0.117 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 252 mg (1c) + 156 mg (2a) + 64 mg (Azeotrope not recovered) – 208 mg (3ca))/ 208 mg (3ca) = 1.9

With purification process: E-factor= (0.117 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 252 mg (1c) + 156 mg (2a) + 64 mg (Azeotrope not recovered) + 130 mg (toluene not recovered) + 150 mg (SiO\textsubscript{2}) – 208 mg (3ca))/ 208 mg (3ca) = 3

Reaction of methyl 4-iodobenzoate (1d) with phenylacetylene (2a):

Without purification process: E-factor= (0.117 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 270 mg (1d) + 156 mg (2a) + 64 mg (Azeotrope not recovered) – 232 mg (3da))/ 232 mg (3da) = 1.7
With purification process: E-factor = (0.117 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 270 mg (1d) + 156 mg (2a) + 64 mg (Azeotrope not recovered) + 130 mg (toluene not recovered) + 150 mg (SiO₂) – 232 mg (3da))/ 232 mg (3da) = 3

Reaction of 4′-iodoacetophenone (1e) with phenylacetylene (2a):

Without purification process: E-factor = (0.117 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 254 mg (1e) + 156 mg (2a) + 64 mg (Azeotrope not recovered) – 209 mg (3ea))/ 209 mg (3ea) = 1.9

With purification process: E-factor = (0.117 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 254 mg (1e) + 156 mg (2a) + 64 mg (Azeotrope not recovered) + 150 mg (SiO₂) – 209 mg (3ea))/ 209 mg (3ea) = 3

Reaction of 4-iodoanisole (1f) with phenylacetylene (2a):

Without purification process: E-factor = (0.234 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 239 mg (1f) + 156 mg (2a) + 64 mg (Azeotrope not recovered) – 158 mg (3fa))/ 158 mg (3fa) = 2.8

With purification process: E-factor = (0.234 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 239 mg (1f) + 156 mg (2a) + 64 mg (Azeotrope not recovered) + 282 mg (heptane not recovered) + 500 mg (SiO₂) – 158 mg (3fa))/ 158 mg (3fa) = 7

Reaction of 3-iodoanisole (1g) with phenylacetylene (2a):

Without purification process: E-factor = (0.117 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 136 mg (1g) + 156 mg (2a) + 64 mg (Azeotrope not recovered) – 192 mg (3ga))/ 192 mg (3ga) = 1.6

With purification process: E-factor = (0.117 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 136 mg (1g) + 156 mg (2a) + 64 mg (Azeotrope not recovered) + 338 mg (heptane not recovered) + 500 mg (SiO₂) – 192 mg (3ga))/ 192 mg (3ga) = 6

Reaction of 4-iodotoluene (1h) with phenylacetylene (2a):

Without purification process: E-factor = (0.234 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 220 mg (1h) + 156 mg (2a) + 64 mg (Azeotrope not recovered) – 173 mg (3ha))/ 173 mg (3ha) = 2.3

With purification process: E-factor = (0.234 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 220 mg (1h) + 156 mg (2a) + 64 mg (Azeotrope not recovered) + 338 mg (heptane not recovered) + 500 mg (SiO₂) – 173 mg (3ha))/ 173 mg (3ha) = 7

Reaction of 2-iodotoluene (1i) with phenylacetylene (2a):

Without purification process: E-factor = (0.234 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 218 mg (1i) + 156 mg (2a) + 64 mg (Azeotrope not recovered) – 148 mg (3ia))/ 148 mg (3ia) = 2.9

With purification process: E-factor = (0.234 mg (POLITAG-Pd(0)) + 135 mg (DABCO) + 218 mg (1i) + 156 mg (2a) + 64 mg (Azeotrope not recovered) + 338 mg (heptane not recovered) + 500 mg (SiO₂) – 148 mg (3ia))/ 148 mg (3ia) = 9

Reaction of 4′-idoacetophenone (1e) with 2-ethynyl-α,α,α-trifluorotoluene (2b)
Without purification process: $E$-factor = \((0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 254 \text{ mg (1e)} + 263 \text{ mg (2b)} + 64 \text{ mg (Azeotrope not recovered)} - 270 \text{ mg (3eb)})/270 \text{ mg (3eb)} = 1.7

With purification process: $E$-factor = \((0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 254 \text{ mg (1e)} + 263 \text{ mg (2b)} + 64 \text{ mg (Azeotrope not recovered)} + 130 \text{ mg (toluene not recovered)} + 150 \text{ mg (SiO}_2) - 270 \text{ mg (3eb)})/270 \text{ mg (3eb)} = 3

Reaction of iodobenzene (1a) with 4-ethynyltoluene (2c):

Without purification process: $E$-factor = \((0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 208 \text{ mg (1a)} + 180 \text{ mg (2c)} + 64 \text{ mg (Azeotrope not recovered)} - 157 \text{ mg (3ac)})/157 \text{ mg (3ac)} = 2.7

With purification process: $E$-factor = \((0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 208 \text{ mg (1a)} + 180 \text{ mg (2c)} + 64 \text{ mg (Azeotrope not recovered)} + 338 \text{ mg (heptane not recovered)} + 500 \text{ mg (SiO}_2) - 157 \text{ mg (3ac)})/157 \text{ mg (3ac)} = 7

Reaction of 1-iodo-4-nitrobenzene (1b) with 4-ethynyltoluene (2c):

Without purification process: $E$-factor = \((0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 254 \text{ mg (1b)} + 180 \text{ mg (2c)} + 64 \text{ mg (Azeotrope not recovered)} - 235 \text{ mg (3bc)})/235 \text{ mg (3bc)} = 1.7

With purification process: $E$-factor = \((0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 254 \text{ mg (1b)} + 180 \text{ mg (2c)} + 64 \text{ mg (Azeotrope not recovered)} + 130 \text{ mg (toluene not recovered)} + 150 \text{ mg (SiO}_2) - 235 \text{ mg (3bc)})/235 \text{ mg (3bc)} = 3

Reaction of methyl 4-iodobenzoate (1d) with 4-ethynyltoluene (2c):

Without purification process: $E$-factor = \((0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 270 \text{ mg (1d)} + 180 \text{ mg (2c)} + 64 \text{ mg (Azeotrope not recovered)} - 248 \text{ mg (3dc)})/248 \text{ mg (3dc)} = 1.6

With purification process: $E$-factor = \((0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 270 \text{ mg (1d)} + 180 \text{ mg (2c)} + 64 \text{ mg (Azeotrope not recovered)} + 130 \text{ mg (toluene not recovered)} + 150 \text{ mg (SiO}_2) - 248 \text{ mg (3dc)})/248 \text{ mg (3dc)} = 3

Reaction of 4′-iodoacetophenone (1e) with 4-ethynyltoluene (2c):

Without purification process: $E$-factor = \((0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 254 \text{ mg (1e)} + 180 \text{ mg (2c)} + 64 \text{ mg (Azeotrope not recovered)} - 233 \text{ mg (3ec)})/2 \text{ mg (3ec)} = 1.7

With purification process: $E$-factor = \((0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 254 \text{ mg (1e)} + 180 \text{ mg (2c)} + 64 \text{ mg (Azeotrope not recovered)} + 130 \text{ mg (toluene not recovered)} + 150 \text{ mg (SiO}_2) - 233 \text{ mg (3ec)})/2 \text{ mg (3ec)} = 3

Reaction of 4-iodotoluene (1h) with 4-ethynyltoluene (2c):

Without purification process (column chromatography): $E$-factor = \((0.351 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 220 \text{ mg (1h)} + 180 \text{ mg (2c)} + 64 \text{ mg (Azeotrope not recovered)} - 185 \text{ mg (3hc)})/185 \text{ mg (3hc)} = 2

Reaction of 4′-iodoacetophenone (1e) with 1-octyne (2d):

Without purification process: $E$-factor = \((0.234 \text{ mg (POLITAG-Pd(0))} + 224 \text{ mg (DABCO)} + 254 \text{ mg (1e)} + 170 \text{ mg (2d)} + 64 \text{ mg (Azeotrope not recovered)} - 174 \text{ mg (3ed)})/174 \text{ mg (3ed)} = 3.1

With purification process: $E$-factor = \((0.234 \text{ mg (POLITAG-Pd(0))} + 224 \text{ mg (DABCO)} + 254 \text{ mg (1e)} + 170 \text{ mg (2d)} + 64 \text{ mg (Azeotrope not recovered)} + 164 \text{ mg (heptane not recovered)} + 300 \text{ mg (SiO}_2) - 174 \text{ mg (3ed)})/174 \text{ mg (3ed)} = 6
Reaction of 2-iodothiophene (4a) with phenylacetylene (2a):

Without purification process: E-factor = \( \frac{0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 214 \text{ mg (5a)} + 156 \text{ mg (2a)} + 64 \text{ mg (Azeotrope not recovered)} – 173 \text{ mg (5aa)}}{173 \text{ mg (5aa)}} \) = 2.3

With purification process: E-factor = \( \frac{0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 214 \text{ mg (5a)} + 156 \text{ mg (2a)} + 64 \text{ mg (Azeotrope not recovered)} + 500 \text{ mg (SiO}_2\text{)} – 173 \text{ mg (5aa)}}{173 \text{ mg (5aa)}} \) = 7

Reaction of 2-iodothiophene (4a) with 4-etiniltoluene (2b):

Without purification process: E-factor = \( \frac{0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 214 \text{ mg (5a)} + 180 \text{ mg (2b)} + 64 \text{ mg (Azeotrope not recovered)} – 118 \text{ mg (5ab)}}{118 \text{ mg (5ab)}} \) = 4.0

With purification process: E-factor = \( \frac{0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 214 \text{ mg (5a)} + 180 \text{ mg (2b)} + 64 \text{ mg (Azeotrope not recovered)} + 164 \text{ mg (heptane not recovered)} + 500 \text{ mg (SiO}_2\text{)} – 118 \text{ mg (5ab)}}{118 \text{ mg (5ab)}} \) = 10

Reaction of iodopyrazine (4b) with phenylacetylene (2a):

Without purification process (column chromatography): E-factor = \( \frac{0.234 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 212 \text{ mg (4b)} + 156 \text{ mg (2a)} + 64 \text{ mg (Azeotrope not recovered)} – 108 \text{ mg (5ba)}}{108 \text{ mg (5ba)}} \) = 4

Reaction of 2-amino-5-iodopyridine (4c) with phenylacetylene (2a):

Without purification process: E-factor = \( \frac{0.234 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 225 \text{ mg (4c)} + 156 \text{ mg (2a)} + 64 \text{ mg (Azeotrope not recovered)} – 113 \text{ mg (5ca)}}{113 \text{ mg (5ca)}} \) = 4.1

With purification process: E-factor = \( \frac{0.234 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 225 \text{ mg (4c)} + 156 \text{ mg (2a)} + 64 \text{ mg (Azeotrope not recovered)} + 2595 \text{ mg (toluene used for recrystallization)} – 113 \text{ mg (5ca)}}{113 \text{ mg (5ca)}} \) = 27

Reaction of N-methyl-4-iodo-pirazole (4d) with phenylacetylene (2a):

Without purification process (column chromatography): E-factor = \( \frac{0.351 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 210 \text{ mg (4d)} + 156 \text{ mg (2a)} + 64 \text{ mg (Azeotrope not recovered)} – 92 \text{ mg (5da)}}{92 \text{ mg (5da)}} \) = 5

Reaction of 5-iodouracil (6) with trimethylsilylacetylene (7):

With purification process: E-factor = \( \frac{0.117 \text{ mg (POLITAG-Pd(0))} + 135 \text{ mg (DABCO)} + 238 \text{ mg (6)} + 147 \text{ mg (7)} + 246 \text{ mg (azeotrope not recovered)} – 171 \text{ mg (8)}}{171 \text{ mg (8)}} \) = 3

E-factor calculation for reference 9a:

Procedure: To a suspension of 1-chloro-3-iodobenzene 1e (0.101 mg, 0.5 mmol) in 2.0 g of degassed Gly/ChCl (2:1 mol mol\(^{-1}\)), phenylacetylene 2a (0.102 mg, 1 mmol), Et\(_3\)N (0.2 mL, 1.5 mmol), and Pd/C (2 mol%, 10 mg), were sequentially added. The reaction mixture was stirred at 60 °C for 3 h until complete consumption of starting material (monitored by TLC), then cooled to room temperature, and finally extracted with 2.0 mL of CPME. The organic layer was filtered through a Celite pad and evaporated under reduced pressure to afford the crude product. This process leaves the catalyst in the eutectic mixture. The organic layer was filtered through a Celite pack and evaporated under reduced pressure to afford the crude product. The latter was then analyzed by 1 H NMR to determine the yield of 3ja (dimethyl sulfone was used as the internal standard). The eutectic mixture was dried in vacuo to remove organic volatiles until constant weight. Upon adding
new, fresh reagents, the catalyst and DES could be successfully re-used for over three cycles with only a negligible decrease in the final yield of 3ja (up to 9%).

\[
E\text{-factor} = \frac{2 \text{ g (Gly/ChCl)} + (4 \times 0.119 \text{ g (1-chloro-3-iodobenzene)}) + 0.010 \text{ g (Pd/C)} + (4 \times 0.152 \text{ (Et3N)}) + (4 \times 1.72 \text{ g (CPME)}) - 0.409 \text{ g (product))}}{0.409 \text{ g (product)}} = 24.4
\]

E-factor calculation for reference 9b:

Procedure: In reactions with conversions >99%, after 1 hour the mixture was quenched with H₂O (3 mL) and extracted with cyclohexane (3 x 5 mL). The collected organic phases were washed with brine, dried over anhydrous Na₂SO₄ and concentrated under reduced pressure to give a yellow oil, which was purified by flash chromatography (silica gel, 100% cyclohexane) to afford compound 3a as a white solid with quantitative yields if the reactions were performed in HEP or with 90-96% isolated yields with other N-alkylpyrrolidones.

The synthesis of 3a was optimized using the following conditions: Pd(PPh₃)₂Cl₂ (7.0 mg, 0.5 mmol, 2%), CuI (1.0 mg, 0.005 mmol, 1%), TMG (69 µL, 0.55 mmol, 1.1 eq), iodobenzene (56 µL, 0.5 mmol, 1.0 eq), phenylacetylene (58 µL, 0.525 mmol, 1.05 eq), HEP (1 mL), 30°C, 30 min (see Entry 17 Table 1). The same conditions were applied to a 10 mmol-scale reaction to verify the recovery of HEP. To this purpose the water/HEP phase was distilled under vacuum to afford 18.3 ml of HEP (91.5% recovery).

\[
E\text{-factor} = \frac{7 \text{ mg (Pd(PPh₃)₂Cl₂)} + 1 \text{ mg (CuI)} + 97 \text{ mg (HEP not recovered)} + 63 \text{ mg (TMG)} + 102 \text{ mg (iodobenzene)} + 54 \text{ mg (phenylacetylene)} + 3000 \text{ mg (H₂O)} + 11685 \text{ mg (cyclohexane)} - 86 \text{ mg (product))}}{86 \text{ mg (product)}} = 173
\]

E-factor calculation for reference 9g (heterogeneous base):

Procedure: The reaction was performed in a screw-capped vial with a magnetic stirrer. Catalyst (1) (10% wt. of Pd) (4 mg, 0.4 mmol%), CH₃CN/H₂O azeotrope (0.94 mL, 84/16 wt%), PS-piperazine (8) (335 mg, 1.13 mmol, 3.37 mmol/g), aryl iodide (0.94 mmol), alkyne (1.41 mmol,) were consequently added and the resulting mixture was purged with N₂ gas for 5 minutes under stirring. The resulting mixture was left under stirring at 90°C.

After reaction completion, 1 mL of acetonitrile/water azeotrope was added and the reaction mixture was stirred for 5 min, centrifuged for 2 min (5000 rpm) and the liquid was separated by decantation. Than 1 mL more of acetonitrile water azeotrope was added to the catalyst-base mixture and stirred for 2 min, centrifuged for 2 min (5000 rpm) and the liquid was separated by decantation. Resulting liquid phases were combined and the solvent was removed under vacuum to yield the product.

1-Methylpiperazine (143 mg, 1.41 mmol, 99% purity) in 1 mL of acetonitrile/water azeotrope was added to the catalyst-base mixture, stirred and after 1h centrifuged for 2 min (5000 rpm) and the liquid phase was separated by decantation. Then 1 mL more of acetonitrile water azeotrope was added to the catalyst-base mixture was stirred for 2 min, centrifuged for 2 min (5000 rpm) and the liquid was separated by decantation. The catalyst-base mixture was dried under vacuum at 50°C and reused for the next catalytic cycle where just reactants and reaction medium were added.

\[
E\text{-factor} = \frac{196 \text{ mg (iodobenzene)} + 245 \text{ mg (phenylacetylene)} + 143 \text{ mg (1-Methylpiperazine used for regeneration of 8)} + 120 \text{ mg (5% of azeotrope not recovered by distillation)} + 1636 \text{ mg (azeotrope for washing)} - 129 \text{ mg (product))}}{129 \text{ mg (product)}} = 17
\]
**E-factor calculation for reference 9g (homogeneous base):**

**Procedure:** The reaction was performed in a screw-capped vial with a magnetic stirrer. Catalyst (1) (10% wt. of Pd) (4 mg, 0.4 mmol%), CH₃CN/H₂O azeotrope (0.94 mL, 84/16 wt%), 1-methylpiperazine (2) (114 mg, 1.13 mmol, 99% purity), aryl iodide (0.94 mmol), alkyne (1.41 mmol) were consequently added and the resulting mixture was purged with N₂ gas for 5 minutes under stirring. The resulting mixture was left under stirring at 90°C.

After reaction completion, the reaction mixture was centrifuged for 10 min (5000 rpm) and the liquid was separated by decantation. 1 mL of acetonitrile/water azeotrope was added and the mixture was stirred for 5 min, centrifuged for 10 min (5000 rpm) and the liquid was separated by decantation. Ethyl acetate (5mL) was added and the organic layer was washed with water (3 x 1.5 mL), dried over anhydrous Na₂SO₄ and the solvent was removed under vacuum to yield the product.

The catalyst was dried under nitrogen at 50°C and reused for the next catalytic cycle where reactants, reaction medium and 1-methylpiperazine were added.

\[
\text{E-factor} = \frac{(769 \text{ mg (CH₃CN/H₂O))} + 114 \text{ mg (1-methylpiperazine))} + 196 \text{ mg (iodobenzene))} + 147 \text{ mg (phenylacetylene))} + 818 \text{ mg (azeotrope for washing))} + 4485 \text{ mg (EtOAc))} + 4500 \text{ mg (H₂O))} + 1500 \text{ mg (Na₂SO₄)) - 137 \text{ mg (product))}}{137 \text{ mg}} = 90
\]

**E-factor calculation for reference 9h:**

**Procedure:** In a screw capped vial equipped with a magnetic stirrer Pd/C 10% wt. (5.3 mg, 0.005 mmol), GVL (1 mL, 98% purity), DABCO (139 mg, 1.2 mmol, 99% purity), iodobenzene (1a) (139 mg, 0.114 mL, 1 mmol, 98% purity), and ethynylbenzene (2a) (156 mg, 0.168 mL, 1.5 mmol, 98% purity) were consecutively added, the resulting mixture was purged with nitrogen and left under stirring at 60 °C. After 4 hours, petroleum ether was added and the reaction mixture was filtered over a small pad of celite, washed with neutral water and, subsequently, with acidic water (1 M HCl). The organic layer was dried over sodium sulphate and the solvent was removed under vacuum. The crude oil was purified by column chromatography on silica gel (petroleum ether) to afford 3a as a white solid (124 mg, 70% yield).

**Assumption:** 5mL of petroleum ether and 3x1.5 mL of water for extraction were considered.

\[
\text{E-factor} = \frac{(5.3 \text{ mg (Pd/C))} + 1050 \text{ mg (GVL))} + 139 \text{ mg (DABCO))} + 204 \text{ mg (iodobenzene))} + 156 \text{ mg (ethynylbenzene))} + 4500 \text{ mg (H₂O))} + 3265 \text{ (petroleum ether))} - 124 \text{ mg (product))}}{124 \text{ mg}} = 74
\]
4. Characterization data

| Chem.Name      | 1,2-diphenylethyne (3aa) |
|----------------|--------------------------|
| Lit.Ref        | Kozell, V.; McLaughlin, M.; Strappaveccia, G.; Santoro, S.; Bivona, L. A.; Aprile, C.; Gruttadauria, M.; Vaccaro L. ACS Sustainable Chem. Eng. 2016, 4, 7209–7216 |

\[
\begin{array}{ccc}
  \text{1a} & \text{2a} & \text{3aa} \\
  \text{POLITAG-L1-Pd(0)} & \text{DABCO (1.2 eq)} & \text{MW: 178.23 g/mol} \\
  \text{Az. CH}_2\text{CN/H}_2\text{O (1 M)} & \text{90°, 7 h} & \\
\end{array}
\]

Method:

Prepared according to general procedure A: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.117 mg, 0.01 mmol%), DABCO (135 mg, 1.2 mmol), iodobenzene 1a (114 µL, 1 mmol, 97% purity), phenylacetylene 2a (170 µL, 1.5 mmol, 98% purity) and 1 mL of azeotrope CH₃CN/H₂O were consecutively added and the resulting mixture was left under stirring at 90 °C for 7 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH₃CN/H₂O (95% recovered). The product was isolated through filtration and washing on silica plug (500 mg) using heptane (10 mL) (94% recovered). The product 3aa was obtained as a white solid (173 mg, 97% yield).

Elemental Analysis: Calc: C: 94.34; H: 5.66; Found C: 94.33; H,: 5.67

| Mol Formula | C₁₄H₁₀ | m.p. | 61-63°C |
|-------------|--------|------|--------|

\( ^1\text{H NMR} \) (400 MHz, CDCl₃) δ value: No. H Mult J value/Hz

|        |        |      |        |
|--------|--------|------|--------|
| 7.55-7.53 | 6      | m    |        |
| 7.36-7.26 | 4      | m    |        |

\( ^{13}\text{C NMR} \) (100.6 Hz, CDCl₃) δ: 131.8, 128.5, 128.4, 123.4, 89.5.

GC-EIMS (m/z, %): 179 (M⁺+1, 15), 178 (M⁺, 100), 177 (11), 176 (20), 152 (13).
Chem.Name | 1-nitro-4-(phenylethynyl)benzene (3ba)
---|---
Lit.Ref | Kozell, V.; McLaughlin, M.; Strappaveccia, G.; Santoro, S.; Bivona, L. A.; Aprile, C.; Gruttadauria, M.; Vaccaro L. ACS Sustainable Chem. Eng. 2016, 4, 7209–7216

Method:
Prepared according to general procedure B: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.117 mg, 0.01 mmol%), DABCO (135 mg, 1.2 mmol), 1-iodo-4-nitrobenzene 1b (254 mg, 1 mmol, 98% purity), phenylacetylene 2a (170 µL, 1.5 mmol, 98% purity) and 1 mL of azeotrope CH3CN/H2O were consecutively added and the resulting mixture was left under stirring at 90 °C for 7 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH3CN/H2O (95% recovered). The product was isolated through filtration and washing on silica plug (150 mg) using toluene (5 mL) (97% recovered). The product 3ba was obtained as a yellow solid (221 mg, 99% yield).

Elemental Analysis: Calc: C: 75.33; H: 4.06; N: 6.27; Found C: 75.34; H: 4.07, N: 6.26

| Mol Formula | C14H9NO2 | m.p. | 116-118°C |
|---|---|---|---|

\( ^1H \) NMR (400 MHz, CDCl3) δ value:

| 8.22 | 2 | d | 8.0 |
| 7.67 | 2 | d | 8.0 |
| 7.57–7.55 | 2 | m |  |
| 7.39–7.40 | 3 | m |  |

\( ^{13}C \) NMR (100.6 Hz, CDCl3) δ: 147.1, 132.4, 132.0, 130.4, 129.4, 128.7, 123.8, 122.2, 94.9, 87.7.

GC-EIMS (m/z, %): 224 (16), 223 (100), 177 (20), 176 (67), 165 (49), 151 (24), 150 (23).
Chem. Name | 1-nitro-3-(phenylethynyl)benzene (3ca)  
--- | ---  
Lit. Ref | Kozell, V.; McLaughlin, M.; Strappaveccia, G.; Santoro, S.; Bivona, L. A.; Aprile, C.; Gruttadauria, M.; Vaccaro L. ACS Sustainable Chem. Eng. 2016, 4, 7209−7216  
Method:  
Prepared according to general procedure B: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.117 mg, 0.01 mmol%), DABCO (135 mg, 1.2 mmol), 1-iodo-3-nitrobenzene 1c (252 mg, 1 mmol, 99% purity), phenylacetylene 2a (170 µL, 1.5 mmol, 98% purity) and 1 mL of azeotrope CH₃CN/H₂O were consecutively added and the resulting mixture was left under stirring at 90 °C for 7 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH₃CN/H₂O (95% recovered). The product was isolated through filtration and washing on silica plug (150 mg) using toluene (5 mL) (97% recovered). The product 3ca was obtained as a yellow solid (208 mg, 93% yield).  
Elemental Analysis:  
Calc: C: 75.33; H: 4.06; N: 6.27; Found C: 75.34; H: 4.08; N: 6.28  
Mol Formula | C₁₄H₉NO₂  
--- | ---  
δ value: | No. H | Mult | J value/Hz  
--- | --- | --- | ---  
1H NMR (400 MHz, CDCl₃) |  
8.38 | 1 | s  
8.18 | 1 | d | 8.0  
7.83 | 1 | d | 8.0  
7.57-7.52 | 3 | m  
7.38-7.39 | 3 | m  
13C NMR (100.6 Hz, CDCl₃) δ: 148.3, 137.4, 131.9, 129.5, 129.2, 128.7, 126.5, 125.3, 123.0, 122.3, 92.1, 87.0.  
GC-EIMS (m/z, %): 224 (M⁺+1, 17), 223 (M⁺, 100), 177 (37), 165 (10), 151 (25), 150 (19).
Chem.Name: Methyl 4-(phenylethynyl)benzoate (3da)

Lit.Ref: Kozell, V.; McLaughlin, M.; Strappaveccia, G.; Santoro, S.; Bivona, L. A.; Aprile, C.; Gruttadauria, M.; Vaccaro L. ACS Sustainable Chem. Eng. 2016, 4, 7209–7216

Method:

Prepared according to general procedure B: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.117 mg, 0.01 mmol%), DABCO (135 mg, 1.2 mmol), methyl 4-iodobenzoate 1d (270 mg, 1 mmol, 97% purity), phenylacetylene 2a (170 µL, 1.5 mmol, 98% purity) and 1 mL of azeotrope CH₃CN/H₂O were consecutively added and the resulting mixture was left under stirring at 90 °C for 7 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH₃CN/H₂O (95% recovered). The product was isolated through filtration and washing on silica plug (150 mg) using toluene (5 mL) (97% recovered). The product 3da was obtained as a yellow solid (232 mg, 98% yield).

Elemental Analysis: Calc: C: 81.34; H: 5.12; Found C: 81.33; H: 5.14

| Mol Formula | C₁₆H₁₂O₂ | m.p. | 120-121°C |
|-------------|----------|------|-----------|

| δ value:    | No. H | Mult | J value/Hz |
|-------------|-------|------|------------|
| 8.02        | 2     | d    | 8.0        |
| 7.59        | 2     | d    | 8.0        |
| 7.56-7.54   | 2     | m    |            |
| 7.38-7.36   | 3     | m    |            |
| 3.93        | 3     | s    |            |

¹H NMR (400 MHz, CDCl₃)

| ¹³C NMR (100.6 Hz, CDCl₃) δ: 166.7, 131.9, 131.7, 129.7, 129.6, 128.9, 128.6, 128.2, 122.8, 92.5, 88.8, 52.4.

GC-EIMS (m/z, %): 237 (M⁺+1, 17), 236 (M⁺¹, 100), 206 (16), 205 (96), 177 (21), 176 (48), 151 (17), 150 (13).
Chem.Name 1-(4-(phenylethynyl)phenyl)ethan-1-one (3ea)

Lit.Ref Kozell, V.; McLaughlin, M.; Strappaveccia, G.; Santoro, S.; Bivona, L. A.; Aprile, C.; Gruttadauria, M.; Vaccaro L. ACS Sustainable Chem. Eng. 2016, 4, 7209–7216

\[
\begin{array}{ccc}
\text{POLITAG-L1-Pd(0)} (0.01 \text{ mol\%}) & \text{DABCO (1.2 eq)} & \text{Az. CH}_3\text{CN/H}_2\text{O (1 M)} \\
\text{MW: } 220.27 \text{ g/mol} & & \end{array}
\]

Method:

Prepared according to general procedure B: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.117 mg, 0.01 mmol%), DABCO (135 mg, 1.2 mmol), 4'-iodoacetophenone 1e (254 mg, 1 mmol, 97% purity), phenylacetylene 2a (170 µL, 1.5 mmol, 98% purity) and 1 mL of azeotrope CH\(_3\)CN/H\(_2\)O were consecutively added and the resulting mixture was left under stirring at 90 °C for 7 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH\(_3\)CN/H\(_2\)O (95% recovered). The product was isolated through filtration and washing on silica plug (150 mg) using toluene (5 mL) (97% recovered). The product 3ea was obtained as a yellow solid (209 mg, 95% yield).

Elemental Analysis: Calc: C: 87.25; H: 5.49; Found C: 87.26; H: 5.50

| Mol Formula | C\(_{16}\)H\(_{12}\)O | m.p. | 98-99 °C |
|-------------|----------------|------|----------|
| δ value:    | No. H | Mult | J value/Hz |
| 7.94        | 2    | d    | 8.0      |
| 7.61        | 2    | d    | 8.0      |
| 7.38-7.36   | 2    | m    |          |
| 7.57-7.54   | 3    | m    |          |
| 2.62        | 3    | s    |          |

\(^{13}\)C NMR (100.6 Hz, CDCl\(_3\)) δ: 197.5, 136.4, 131.9, 131.9, 129.0, 128.6, 128.4, 128.4, 122.8, 92.9, 88.8, 26.8.

GC-EIMS (m/z, %): 221 (M\(^+\)+1, 11), 220 (M\(^+\), 66), 206 (17), 205 (100), 177 (27), 176 (51), 151 (18), 150 (15).
Chem.Name  

1-methoxy-4-(phenylethynyl)benzene (3fa)

Lit.Ref  

Parka, S. B.; Alper, H. *Chem. Commun.*, 2004, 11, 1306-1307

\[
\begin{array}{c}
\text{POLITAG-L1-Pd(0)} (0.02 \text{ mol%}) \\
\text{DABCO (1.2 eq)} \\
\text{Az. CH}_3\text{CN/H}_2\text{O (1 M)} \\
90^\circ, 16 \text{ h}
\end{array}
\]

MW: 208.26 g/mol

Method:

Prepared according to general procedure A: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.234 mg, 0.02 mmol%), DABCO (135 mg, 1.2 mmol), 4-Iodoanisole 1f (239 mg, 1 mmol, 98% purity), phenylacetylene 2a (170 µL, 1.5 mmol, 98% purity) and 1 mL of azeotrope CH₃CN/H₂O were consecutively added and the resulting mixture was left under stirring at 90 °C for 16 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH₃CN/H₂O (95% recovered). The product was isolated through filtration and washing on silica plug (500 mg) using heptane (5 mL) (94% recovered). The product 3fa was obtained as a white solid (158 mg, 76% yield).

Elemental Analysis: Calc: C: 86.51; H: 5.81; Found C: 86.50; H: 5.82

| Mol.Formula | C₁₅H₁₂O | m.p. | 95-97 °C |
|-------------|---------|------|---------|

**¹H NMR (400 MHz, CDCl₃)**

| δ value: | No. H | Mult | J value/Hz |
|----------|-------|------|------------|
| 7.53-7.47| 4     | m    |            |
| 7.36-7.31| 3     | m    |            |
| 6.88     | 2     | d    | 8.0        |
| 3.83     | 3     | s    |            |

**¹³C NMR (100.6 Hz, CDCl₃)**

\(\delta\) 159.7, 133.2, 131.6, 128.5, 128.1, 123.7, 115.5, 114.1, 89.5, 88.2, 55.4.

**GC-EIMS (m/z, %):** 209 (M⁺+1, 16), 208 (M⁺, 100), 193 (53), 165 (52), 164 (20).
Chem.Name | 1-methoxy-3-(phenylethynyl)benzene (3ga)  
Lit.Ref | Kozell, V.; McLaughlin, M.; Strappaveccia, G.; Santoro, S.; Bivona, L. A.; Aprile, C.; Gruttadauria, M.; Vaccaro L. ACS Sustainable Chem. Eng. 2016, 4, 7209–7216  
Method:
Prepared according to general procedure A: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.117 mg, 0.01 mmol%), DABCO (135 mg, 1.2 mmol), 3-Iodoanisole 1g (236 mg, 1 mmol, 99% purity), phenylacetylene 2a (170 µL, 1.5 mmol, 98% purity) and 1 mL of azeotrope CH3CN/H2O were consecutively added and the resulting mixture was left under stirring at 90 °C for 7 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH3CN/H2O (95% recovered). The product was isolated through filtration and washing on silica plug (500 mg) using heptane (6 mL) (94% recovered). The product 3ga was obtained as a white solid (192 mg, 92% yield).

Elemental Analysis: Calc: C: 86.51; H: 5.81; Found C: 86.50; H: 5.83  
Mol Formula | C_{15}H_{12}O  
m.p. | 74-75°C  
\( ^1H \) NMR (400 MHz, CDCl₃) | δ value: | No. H | Mult | J value/Hz  
7.58-7.56 | 2 | m  
7.39-7.37 | 3 | m  
7.29 | 1 | t | 8.0  
7.17 | 1 | d | 8.0  
7.10 | 1 | s  
6.93 | 1 | d | 8.0  
3.86 | 3 | s  
\( ^13C \) NMR (100.6 Hz, CDCl₃) δ: 159.5, 131.7, 129.6, 128.5, 128.5, 124.4, 124.3, 123.3, 116.5, 115.1, 89.4, 89.3, 55.4.  
GC-EIMS (m/z, %): 209 (M⁺+1, 17), 208 (M⁺, 100), 178 (28), 165 (30), 164 (13), 163 (13).
Chem. Name: 1-methyl-4-(phenylethynyl)benzene (3ha)

Lit. Ref: Kozell, V.; McLaughlin, M.; Strappaveccia, G.; Santoro, S.; Bivona, L. A.; Aprile, C.; Gruttadauria, M.; Vaccaro L. ACS Sustainable Chem. Eng. 2016, 4, 7209−7216

Method:

Prepared according to general procedure A: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.234 mg, 0.02 mmol%), DABCO (135 mg, 1.2 mmol), 4-iodotoluene 1h (220 mg, 1 mmol, 99% purity), phenylacetylene 2a (170 µL, 1.5 mmol, 98% purity) and 1 mL of azeotrope CH₃CN/H₂O were consecutively added and the resulting mixture was left under stirring at 90 °C for 16 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH₃CN/H₂O (95% recovered). The product was isolated through filtration and washing on silica plug (500 mg) using heptane (6 mL) (94% recovered). The product 3ha was obtained as a yellow solid (173 mg, 90% yield).

Elemental Analysis: Calc: C: 93.71; H: 6.29; Found C: 93.70; H: 6.31

| Mol Formula | C₁₅H₁₂ | m.p. | 67-70°C |
|-------------|--------|------|---------|

| δ value: | No. H | Mult | J value/Hz |
|----------|-------|------|------------|
| 7.54-7.52 | 2     | m    |            |
| 7.43      | 2     | d    | 8.0        |
| 7.35-7.33 | 3     | m    |            |
| 7.16      | 2     | d    | 8.0        |
| 2.37      | 3     | s    |            |

¹H NMR (400 MHz, CDCl₃) δ: 7.54-7.52, 7.43, 7.35-7.33, 7.16, 2.37

¹³C NMR (100.6 Hz, CDCl₃) δ: 138.5, 131.7, 131.6, 129.3, 128.5, 128.2, 123.6, 120.3, 89.7, 88.9, 21.7.

GC-EIMS (m/z, %): 193 (M⁺+1, 16), 192 (M⁺1, 100), 191 (50), 189 (23), 165 (14).
Chem.Name | 1-methyl-2-(phenylethynyl)benzene (3ia)
---|---
Lit.Ref | Kozell, V.; McLaughlin, M.; Strappaveccia, G.; Santoro, S.; Bivona, L. A.; Aprile, C.; Gruttadauria, M.; Vaccaro L. ACS Sustainable Chem. Eng. 2016, 4, 7209–7216

Method:

Prepared according to general procedure A: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (0.02 mol%), DABCO (1.2 eq) in Az. CH3CN/H2O (1 M) 90°, 16 h. MW: 192.26 g/mol

Elemental Analysis: Calc: C: 93.71; H: 6.29; Found C: 93.73; H: 6.30

| Mol Formula | C15H12 | m.p. | oil |
|---|---|---|---|
| δ value: No. H Mult J value/Hz |
| 7.59-7.57 | 2 | m |
| 7.54 | 1 | d | 8.0 |
| 7.40-7.38 | 3 | m |
| 7.28-7.26 | 2 | m |
| 7.22-7.19 | 1 | m |
| 2.56 | 3 | s |

1H NMR (400 MHz, CDCl3) δ: 140.3, 132.0, 131.7, 129.6, 128.5, 128.4, 128.3, 125.7, 123.7, 123.2, 93.5, 88.5, 20.9.

13C NMR (100.6 Hz, CDCl3) δ: 193 (M+1, 15), 192 (M+, 100), 191 (95), 190 (19), 189 (35), 165 (28).
Chem.Name: 1-(4-((2-(trifluoromethyl)phenyl)ethyl(phenyl)phenyl)ethan-1-one (3eb)

Lit.Ref: Zhang, G. SYNLETT 2005, 4, 0619–0622

Method:
Prepared according to general procedure B: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.117 mg, 0.01 mmol%), DABCO (135 mg, 1.2 mmol), 4′-iodoacetophenone 1e (254 mg, 1 mmol, 97% purity), 2-ethynyl-α,α,α-trifluorotoluene 2b (215 µL, 1.5 mmol, 97% purity) and 1 mL of azeotrope CH₃CN/H₂O were consecutively added and the resulting mixture was left under stirring at 90 °C for 7 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH₃CN/H₂O (95 % recovered). The product was isolated through filtration and washing on silica plug (150 mg) using toluene (5 mL) (97% recovered). The product 3eb was obtained as a yellow solid (270 mg, 94% yield).

Elemental Analysis: Calc: C: 70.83; H: 3.85; Found C: 70.84; H: 3.87

| Mol Formula | C₁₆H₁₂O | p.f. | 83–85°C |
|-------------|---------|------|---------|

| δ value: No. H | Mult | J value/Hz |
|----------------|------|------------|
| 7.96          | 2    | d          | 8.0    |
| 7.70          | 2    | t          | 8.0    |
| 7.63          | 2    | d          | 8.0    |
| 7.55          | 1    | t          | 8.0    |
| 7.46          | 1    | t          | 8.0    |
| 2.62          | 3    | s          |

| 1³C NMR (100.6 Hz, CDCl₃) δ: | 197.5, 136.8, 134.0, 132.0, 131.7, 128.7, 128.4, 127.7, 126.2 (q, J_C-F = 5), 125.0, 122.3, 121.1, 94.0, 88.6, 26.8 |

| 1⁹F NMR (376 MHz, CDCl₃) δ: | -62.26 |

GC-EIMS (m/z, %): 288 (M⁺), 273 (base peak), 245, 225.
| Chem.Name         | 1-methyl-4-(phenylethynyl)benzene (3ac) |
|-------------------|----------------------------------------|
| Lit.Ref           | Kozell, V.; McLaughlin, M.; Strappaveccia, G.; Santoro, S.; Bivona, L. A.; Aprile, C.; Gruttadauria, M.; Vaccaro L. ACS Sustainable Chem. Eng. 2016, 4, 7209–7216 |

![Chemical Structure](image)

**Method:**

Prepared according to general procedure A: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (0.01 mol%), DABCO (1.2 eq), azobenzene 1a (114 µL, 1 mmol, 97% purity), 4-ethynyltoluene 2c (196 µL, 1.5 mmol, 97% purity) and 1 mL of azeotrope CH₃CN/H₂O were consecutively added and the resulting mixture was left under stirring at 90 °C for 7 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH₃CN/H₂O (95 % recovered). The product was isolated through filtration and washing on silica plug (500 mg) using heptane (6 mL) (94% recovered). The product 3ac was obtained as a yellow solid (157 mg, 82% yield).

**Elemental Analysis:**

| Mol Formula | C₁₅H₁₂ | m.p. | 67-70°C |
|-------------|--------|------|---------|
| δ value:    | No. H  | Mult | J value/Hz |
| 7.54-7.52   | 2      | m    |          |
| 7.43        | 2      | d    | 8.0      |
| 7.35-7.33   | 3      | m    |          |
| 7.16        | 2      | d    | 8.0      |
| 2.37        | 3      | s    |          |

| ¹³C NMR (100.6 Hz, CDCl₃) δ: | 138.5, 131.7, 131.6, 129.3, 128.5, 128.2, 123.6, 120.3, 89.7, 88.9, 21.7. |

| GC-EIMS (m/z, %): | 193 (M⁺1, 16), 192 (M⁺1, 100), 191 (50), 189 (23), 165 (14). |
Chem.Name | 1-methyl-4-((4-nitrophenyl)ethynyl)benzene (3bc)
---|---
Lit.Ref | Pan, D.; Zhang, C.; Ding, S. N. Jiao, *Eur. J. Org. Chem.* 2011, 25, 4751-4755

| Method: |
|---|
| Prepared according to general procedure B: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.117 mg, 0.01 mmol%), DABCO (135 mg, 1.2 mmol), 1-iodo-4-nitrobenzene 1b (254 mg, 1 mmol, 98% purity), 4-ethynyltoluene 2c (196 µL, 1.5 mmol, 97% purity) and 1 mL of azeotrope CH₃CN/H₂O were consecutively added and the resulting mixture was left under stirring at 90 °C for 7 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH₃CN/H₂O (95 % recovered). The product was isolated through filtration and washing on silica plug (150 mg) using toluene (5 mL) (97% recovered). The product 3bc was obtained as a yellow solid (235 mg, 99% yield). |

| Elemental Analysis: |
|---|
| Calc: C: 75.94; H: 4.67; N: 5.90; Found C: 75.96; H: 4.68; N: 5.89 |

| Mol Formula | C₁₅H₁₁NO₂ |
|---|---|
| m.p. | 155-157 °C |

| δ value: | No. H | Mult | J value/Hz |
|---|---|---|---|
| 8.21 | 2 | d | 8.0 |
| 7.65 | 2 | d | 8.0 |
| 7.45 | 2 | d | 8.0 |
| 7.20 | 2 | d | 8.0 |
| 2.39 | 3 | s | |

| ¹H NMR (400 MHz, CDCl₃) δ: 147.0, 139.8, 132.3, 131.9, 130.7, 129.5, 123.8, 119.2, 95.3, 87.2, 21.8. |

| ¹³C NMR (100.6 Hz, CDCl₃) δ: | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 237 (M⁺, 100), 207 (32), 190 (21), 189 (61). |
Chem.Name | Methyl-4-((p-tolylethynyl)benzoate (3dc)
---|---
Lit.Ref | Shi, Y.; Li, X.; Liu, J.; Jiang, W.; Sun, L. *Tetrahedron Letters*. 2010, 51, 28, 3626-3628

![Chemical structure](image)

**Method**

Prepared according to general procedure B: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.117 mg, 0.01 mmol%), DABCO (135 mg, 1.2 mmol), methyl 4-iodobenzoate 1d (270 mg, 1 mmol, 97% purity), 4-ethynyltoluene 2c (196 µL, 1.5 mmol, 97% purity) and 1 mL of azeotrope CH₃CN/H₂O were consecutively added and the resulting mixture was left under stirring at 90 °C for 7 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH₃CN/H₂O (95 % recovered). The product was isolated through filtration and washing on silica plug (150 mg) using toluene (5 mL) (97% recovered). The product 3dc was obtained as a yellow solid 248 mg, 99% yield).

**Elemental Analysis:** Calc: C: 81.58; H: 5.64; Found C: 81.59; H: 5.66

| Mol Formula | C₁₇H₁₄O₂ | m.p. | 134-136 °C |
|-------------|-----------|------|-----------|
| δ value: | No. H | Mult | J value/Hz |
| 8.01 | 2 | d | 8.0 |
| 7.57 | 2 | d | 8.0 |
| 7.44 | 2 | d | 8.0 |
| 7.17 | 2 | d | 8.0 |
| 3.93 | 3 | s |  |
| 2.38 | 3 | s |  |

**¹H NMR (400 MHz, CDCl₃)** δ: 166.8, 139.2, 131.8, 131.6, 129.7, 129.4, 129.4, 128.4, 128.4, 119.8, 92.8, 88.2, 52.4, 21.7.

**¹³C NMR (100.6 Hz, CDCl₃)** δ: 251 (M⁺+1, 19), 250 (M⁺, 100), 220 (13), 219 (75), 191 (14), 190 (13), 189 (33).

**GC-EIMS (m/z, %):** 251 (M⁺+1, 19), 250 (M⁺, 100), 220 (13), 219 (75), 191 (14), 190 (13), 189 (33).
Chem.Name: 1-(4-(p-tolyethynyl)phenyl)ethan-1-one (3ec)

Lit.Ref: Shi, Y.; Li, X.; Liu, J.; Jiang, W.; Sun, L. *Tetrahedron Letters*. 2010, 51, 28, 3626-3628

Method:

Prepared according to general procedure B: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.117 mg, 0.01 mmol%), DABCO (135 mg, 1.2 mmol), 4'-iodoacetophenone 1e (254 mg, 1 mmol, 97% purity), 4-ethynyltoluene 2c (196 µL, 1.5 mmol, 97% purity) and 1 mL of azetropes CH$_3$CN/H$_2$O were consecutively added and the resulting mixture was left under stirring at 90 °C for 7 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azetropes CH$_3$CN/H$_2$O (95% recovered). The product was isolated through filtration and washing on silica plug (150 mg) using toluene (5 mL) (97% recovered). The product 3ec was obtained as a yellow solid (233 mg, 99% yield).

Elemental Analysis: Calc: C: 87.15; H: 6.02; Found C: 87.17; H: 6.03

| Mol Formula | C$_{17}$H$_{14}$O$_2$ | m.p. | 130-132°C |
|-------------|----------------------|------|-----------|
| δ value:    | No. H | Mult | J value/Hz |
| 1H NMR (400 MHz, CDCl$_3$) | | | |
| 7.93 | 2 | d | 8.0 |
| 7.60 | 2 | d | 8.0 |
| 7.45 | 2 | d | 8.0 |
| 7.18 | 2 | d | 8.0 |
| 2.61 | 3 | s | |
| 2.38 | 3 | s | |

| δ: 197.5, 139.2, 136.2, 131.8, 131.8, 129.4, 128.6, 128.4, 119.7, 93.2, 88.2, 26.8, 21.7. |

GC-EIMS (m/z, %): 234 (M$^+$, 68%), 220 (18%), 219 (100%), 191 (18%), 189 (34%)
Chem.Name | 1,2-di-p-tolylythene (3hc)  
Lit.Ref | SYNTHESES, 2009, 16, 2785–2789  

\[
\begin{array}{ccccc}
\text{I} & \text{C} & \text{I} & \text{C} & \text{C} \\
1 \text{h} & + & \text{C} & = & 2 \text{c} \\
\text{POLITAG-L1-Pd(0)} (0.03 \text{ mol%}) & \text{DABCO (1.2 eq)} & \text{Az. CH}_3\text{CN/H}_2\text{O (1 M)} & 90^\circ, 16 \text{ h} & 3 \text{hc} \\
\text{MW: 206.29 g/mol} \\
\end{array}
\]

Method:
Prepared according to general procedure A: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.351 mg, 0.03 mmol%), DABCO (135 mg, 1.2 mmol), 4-iodotoluene 1h (220 mg, 1 mmol, 99% purity), 4-ethynyltoluene 2c (196 µL, 1.5 mmol, 97% purity) and 1 mL of azeotrope CH₃CN/H₂O were consecutively added and the resulting mixture was left under stirring at 90 °C for 16 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH₃CN/H₂O (95% recovered). The product was isolated through column chromatography using petroleum ether as eluent. The product 3hc was obtained as a white solid (185 mg, 90% yield).

Elemental Analysis: Calc: C: 93.16; H: 6.84; Found C: 93.17; H: 6.85

| Mol Formula | C₁₇H₁₄O₂ | m.p. | 130-132°C |
|-------------|----------|------|-----------|
| **¹H NMR (400 MHz, CDCl₃)** | δ value: | No. H | Mult | J value/Hz |
| 7.42 | 4 | d | 8.0 |
| 7.15 | 4 | d | 8.0 |
| 2.37 | 6 | s | |

| **¹³C NMR (100.6 Hz, CDCl₃)** δ: | 138.32, 131.58, 129.23, 120.53, 89.01, 21.65. |

| GC-EIMS (m/z, %): | 207 (M⁺+1,18); 206 (M⁺, 100); 205 (25); 191 (17), 189 (16) |
Chem.Name | 1-(4-(oct-1-yn-1-yl)phenyl)ethan-1-one (3ed)
---|---
Lit.Ref | Strappaveccia, G., Luciani, L., Bartollini, E., Marrocchi, A., Pizzo, F., Vaccaro, L. *Green Chem.*, 2015, 17, 1071-1076

![Chemical Structure](image)

**Method:**

Prepared according to general procedure A: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.234 mg, 0.02 mmol%), DABCO (224 mg, 2 mmol), 4′-iodoacetophenone 1e (254 mg, 1 mmol, 97% purity), 1-octyne 2 d (228 µL, 1.5 mmol, 97% purity) and 1 mL of azeotrope CH3CN/H2O were consecutively added and the resulting mixture was left under stirring at 90 °C for 24 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH3CN/H2O (95% recovered). The product was isolated through filtration and washing on silica plug (300 mg) using heptane (4 mL) (94% recovered). The product 3ed was obtained as an oil (174 mg, 76% yield).

**Elemental Analysis:** Calc: C: 84.16; H: 8.83; Found C: 84.17; H: 8.84

| Mol Formula | C_{16}H_{20}O | m.p. | oil |
|---|---|---|---|
| δ value: | No. H | Mult | J value/Hz |
| 7.87 | 2 | d | 8.0 |
| 7.46 | 2 | d | 8.0 |
| 2.58 | 3 | s | |
| 2.43 | 2 | t | 8.0 |
| 1.63-1.58 | 2 | m | |
| 1.45 | 2 | m | |
| 1.34-1.25 | 4 | m | |
| 0.91 | 3 | m | |

**1H NMR (400 MHz, CDCl3)** δ: 197.5, 135.8, 131.8, 129.3, 128.3, 94.6, 80.2, 31.6, 28.8, 28.7, 26.73, 22.7, 19.7, 14.2.

**13C NMR (100.6 Hz, CDCl3)** δ: 228 (M+, 26), 213 (48), 157 (25), 143 (25), 129 (51), 128 (28), 115 (28), 114 (33).
Chem.Name | 2-(phenylethynyl)thiophene (5aa)
---|---
Lit.Ref | Kozell, V.; McLaughlin, M.; Strappaveccia, G.; Santoro, S.; Bivona, L. A.; Aprile, C.; Gruttadauria, M.; Vaccaro L. ACS Sustainable Chem. Eng. 2016, 4, 7209–7216

| S | I
---|---

**Method:**

Prepared according to general procedure A: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (0.01 mol%), DABCO (1.2 eq), Az. CH$_3$CN/H$_2$O (1 M) at 90°, 7 h. The product was isolated through filtration and washing on silica plug (500 mg) using heptane (4 mL) (94% recovered). The product 5aa was obtained as a white solid (147 mg, 80% yield).

**Elemental Analysis:**

| Mol Formula | C$_{12}$H$_8$S | m.p. | 50-52°C |
---|---|---|---|
$^1$H NMR (400 MHz, CDCl$_3$) | δ value: No. H Mult J value/Hz |
7.52-7.51 | 2 | m |
7.35-7.34 | 3 | m |
7.30-7.29 | 2 | m |
7.03-7.00 | 1 | m |

$^{13}$C NMR (100.6 Hz, CDCl$_3$) δ: 132.0, 131.6, 128.6, 128.5, 127.4, 127.2, 123.5, 123.1, 93.2, 82.7.

GC-EIMS (m/z, %): 185 (M$^+$+1, 14), 184 (M$^+$, 100), 152 (16), 139 (19).
Chem.Name | 2-(p-tolylethynyl)thiophene (5ab)
---|---
Lit.Ref | Pan, C., Luo, F., Wang, W., Ye, Z., & Liu, M. *Journal of Chemical Research*, **2009**, 2009.8: 478-481

- **Method:**

Prepared according to general procedure A: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.117 mg, 0.01 mmol%), DABCO (135 mg, 1.2 mmol), 2-iodothiophene 4a (214 mg, 1 mmol, 98% purity), 4-ethynyltoluene 2b (196 µL, 1.5 mmol, 97% purity) and 1 mL of azeotrope CH3CN/H2O were consecutively added and the resulting mixture was left under stirring at 90 °C for 7 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH3CN/H2O (95 % recovered). The product was isolated through filtration and washing on silica plug (500 mg) using heptane (4 mL) (94% recovered). The product 5ab was obtained as a white solid (118 mg, 60% yield).

- **Elemental Analysis:**

  | Calc: | Found: |
  |---|---|
  | C: 78.75; H: 5.08; S: 16.17 | C: 78.74; H: 5.09; S: 16.18 |

| Mol Formula | C13H10S |
|---|---|
| m.p. | 68-70 °C |

- **1H NMR (400 MHz, CDCl3)**

| δ value | No. H | Mult | J value/Hz |
|---|---|---|---|
| 7.42 | 2 | d | 8.0 |
| 7.29-7.27 | 2 | m | |
| 7.16 | 2 | d | 8.0 |
| 7.01 | 1 | t | 4.0 |
| 2.38 | 3 | s | |

- **13C NMR (100.6 Hz, CDCl3)** δ: 138.8, 131.8, 131.5, 129.3, 127.2, 127.1, 123.7, 120.0, 93.4, 82.1, 21.7.

- **GC-EIMS (m/z, %):** 199 (M+1, 16), 198 (M+, 100), 197 (48)
**Chem.Name**
2-(phenylethynyl)pyrazine (5ba)

**Lit.Ref**
Zeidan, T. A., Kovalenko, S. V., Manoharan, M., Clark, R. J., Ghiviriga, I., Alabugin I. V. J. Am. Chem. Soc. 2005, 127, 12, 4270–4285

![Chemical Structure](image)

**Method:**
Prepared according to general procedure A: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.234 mg, 0.02 mmol%), DABCO (135 mg, 1.2 mmol), iodopyrazine 4b (102 µL, 1 mmol, 97% purity), phenylacetylene 2a (170 µL, 1.5 mmol, 98% purity) and 1 mL of azo trope CH$_3$CN/H$_2$O were consecutively added and the resulting mixture was left under stirring at 90 °C for 16 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azote trope CH$_3$CN/H$_2$O (95% recovered). The product was isolated through column chromatography using petroleum ether/ethyl acetate (9:1 ratio) as eluent mixture. The product 5ba was obtained as a yellow solid (108 mg, 60% yield).

**Elemental Analysis:**
Calc: C: 79.98; H: 4.47; N: 15.55; Found: C: 79.99; H: 4.48; N: 15.56

| Mol Formula | C$_{14}$H$_{10}$ | m.p. | 48-49°C |
|-------------|-----------------|------|---------|

| δ value:     | No. H | Mult | J value/Hz |
|--------------|-------|------|------------|
| 8.77         | 1     | s    |            |
| 8.59         | 1     | s    |            |
| 8.49         | 1     | s    |            |
| 7.63-7.61    | 3     | m    |            |
| 7.40-7.39    | 3     | m    |            |

| $^{13}$C NMR (100.6 Hz, CDCl$_3$) δ: 147.9, 144.6, 142.9, 140.6, 132.3, 129.7, 128.7, 121.6, 93.5, 85.9. |

**GC-EIMS (m/z, %):** 180 (M$^+$, 100), 127 (56)
Chem.Name: 5-(phenylethynyl)pyridin-2-amine (5ca)

Lit.Ref: Fleckenstein, C. A.; Plenio, H. Green Chem. 2008, 10, 563-570

Method:

Prepared according to general procedure A: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (0.02 mol%), DABCO (1.2 eq), 2- amino-5-iodopyridine 4b (225 mg, 1 mmol, 98% purity), phenylacetylene 2a (170 µL, 1.5 mmol, 98% purity) and 1 mL of azetotrope CH₃CN/H₂O were consecutively added and the resulting mixture was left under stirring at 90 °C for 16 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azetotrope CH₃CN/H₂O (95% recovered). The product was isolated through re crystallization in toluene (3 mL). The product 5ca was obtained as a white solid (113 mg, 58% yield).

Elemental Analysis: Calc: C: 80.39; H: 5.19; N: 14.42; Found C: 80.39; H: 5.20; N: 14.41

| Mol Formula | C₁₃H₁₀N₂ | m.p. |
|-------------|----------|------|
| δ value:    | No. H    | Mult | J value/Hz |
| 8.26        | 1        | s    |            |
| 7.58        | 1        | d    | 8.0        |
| 7.51-7.49   | 2        | m    |            |
| 7.34-7.33   | 3        | m    |            |
| 6.50        | 1        | d    | 8.0        |
| 4.74        | 2        | bs   |            |

¹H NMR (400 MHz, CDCl₃) δ: 157.3, 150.9, 140.8, 131.6, 128.5, 128.3, 123.4, 110.2, 108.4, 90.2, 86.8.

¹³C NMR (100.6 Hz, CDCl₃) δ: 157.3, 150.9, 140.8, 131.6, 128.5, 128.3, 123.4, 110.2, 108.4, 90.2, 86.8.

GC-EIMS (m/z, %): 195 (M⁺+1, 11), 194 (M⁺, 100), 193 (25), 166 (19), 139 (20).
Chem.Name | 1-methyl-4-(phenylethynyl)-1H-pyrazole (5da)  
| Lit.Ref |

![Reaction Scheme](image)

**Method:**

Prepared according to general procedure A: in an 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.351 mg, 0.03 mmol%), DABCO (135 mg, 1.2 mmol), N-methyl-4-iodo-pirazole 4d (210 mg, 1 mmol, 99% purity), phenylacetylene 2a (170 µL, 1.5 mmol, 98% purity) and 1 mL of azeotrope CH3CN/H2O were consecutively added and the resulting mixture was left under stirring at 90 °C for 16 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH3CN/H2O (95% recovered). The product was isolated through column chromatography using petroleum ether/ethyl acetate (9:1 ratio) as eluent mixture. The product 5da was obtained as a white solid (92 mg, 50% yield).

**Elemental Analysis:**

| Mol Formula | Elemental Analysis: Calc: C: 79.10; H: 5.53; N: 15.37; Found C: 79.11; H: 5.54; N: 15.36 |

### 1H NMR (400 MHz, CDCl3)

| δ value | No. H | Mult | J value/Hz |
|---------|-------|------|------------|
| 7.64 | 1 | s |
| 7.55 | 1 | s |
| 7.48-7.46 | 2 | m |
| 7.32-7.31 | 3 | m |
| 3.9111 | 3 | s |

### 13C NMR (100.6 Hz, CDCl3) δ: 142.1, 132.7, 131.4, 128.5, 128.1, 123.6, 103.5, 90.1, 80.8, 39.3.

**GC-EIMS (m/z, %):** 182 (M⁺, 100), 140 (16).
Chem.Name: 5-((trimethylsilyl)ethynyl)pyrimidine-2,4(1H,3H)-dione (8)

Lit.Ref: J. W. B. Cooke, R. Bright, M. J. Coleman, K. P. Jenkins, *Org. Proc. Res. Dev.* 2001, 5, 383–386

Method:

Prepared according to general procedure A: in a 4 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 0.117 mg, 0.01 mmol%), DABCO (135 mg, 1.2 mmol), 5-iodouracil 6 (238 mg, 1 mmol), trimethylsilyl acetylene 7 (208 µL, 1.5 mmol) and 3 mL of azeotrope CH$_3$CN/H$_2$O were consecutively added and the resulting mixture was left under stirring at 90 °C for 16 h. After reaction completion the catalyst was removed through filtration of the hot mixture and washed with 1 mL of hot azeotrope CH$_3$CN/H$_2$O. At room temperature the product precipitate from the reaction mixture and it was isolated by filtration and washing of the solid with 2 mL of cold azeotrope CH$_3$CN/H$_2$O (95% recovered). The product 8 was obtained as an off-white solid (171 mg, 82% yield).

Elemental Analysis: Calc: 51.90; H: 5.81; N: 13.45; Found C: 51.91; H: 5.82; N: 13.43

| Mol Formula | C$_9$H$_{12}$N$_2$O$_2$Si | m.p. | 275-276°C |
|-------------|--------------------------|------|----------|

$^1$H NMR (400 MHz, DMSO-$d_6$) δ value: No. H Mult J value/Hz

|            |            |       |          |
|------------|------------|-------|----------|
| 11.35-11.50| 2          | $m$   |          |
| 7.79       | 1          | $s$   |          |
| 0.18       | 9          | $s$   |          |

$^{13}$C NMR (100.6 Hz, DMSO-$d_6$) δ: 162.5, 150.4, 146.7, 98.3, 96.9, 96.5, 0.0

GC-EIMS (m/z, %):
Chem.Name 4-(phenylethynyl)benzaldehyde (10ca)

Lit.Ref A. D. Finke, E. C. Elleby, M. J. Boyd, H. Weissman, J. S. Moore, J. Org. Chem. 2009, 74, 8897–8900

Method:
Prepared according to general procedure A: in a 2 mL screw-capped vial equipped with a magnetic stirrer catalyst POLITAG-L1-Pd(0) (9.4 wt%, 5.66 mg, 0.5 mmol%), DABCO (135 mg, 1.2 mmol), 4-Bromo benzaldehyde 9c (185 mg, 1 mmol, 99% purity), phenylacetylene 2a (170 µL, 1.5 mmol, 98% purity) and 1 mL of azeotrope CH₃CN/H₂O were consecutively added and the resulting mixture was left under stirring at 120 °C for 8 h. After reaction completion the catalyst was removed through filtration and washed with 1 mL of azeotrope CH₃CN/H₂O (95% recovered). The product was isolated through column chromatography using petroleum ether/ethyl acetate as eluent mixture. The product 10ca was obtained as a yellow solid (189 mg, 92% yield).

Elemental Analysis: Calc: C: 87.36; H: 4.89; Found C: 87.35; H: 4.90

| Mol Formula | C₁₅H₁₀O | m.p. | 98-100 °C |
|-------------|---------|------|-----------|

| δ value:    | No. H | Mult | J value/Hz |
|-------------|-------|------|------------|
| 10.02       | 1     | s    |            |
| 7.87        | 2     | d    | 8.0        |
| 7.68        | 2     | d    | 8.0        |
| 7.57-7.55   | 2     | m    |            |
| 7.39-7.37   | 3     | m    |            |

¹H NMR (400 MHz, CDCl₃) δ: 191.6, 135.5, 132.2, 131.9, 129.8, 129.7, 129.1, 128.6, 122.6, 93.6, 88.7.

GC-EI/MS (m/z, %): 206 (M⁺, 100), 205 (70), 177 (21), 176 (39).
1,2-diphenylethyne (3aa)
1-nitro-4-(phenylethynyl)benzene (3ba) (10ba)
1-nitro-3-(phenylethynyl)benzene (3ca)

1-nitro-3-(phenylethynyl)benzene (3ca)
methyl 4-(phenylethynyl)benzoate (3da) (10da)

1H NMR (CDCl₃, 400 MHz)

1H NMR (CDCl₃, 400 MHz)

1H NMR (CDCl₃, 400 MHz)
1-(4-(phenylethynyl)phenyl)ethanone (3ea) (10ea)
1-methyl-4-(phenylethynyl)benzene (3ha) (10fa)
1-methyl-2-(phenylethynyl)benzene (3ia)
1-(4-((2-(trifluoromethyl)phenyl)ethynyl)phenyl)ethanone (3eb)
1-(4-((2-(trifluoromethyl)phenyl)ethynyl)phenyl)ethanone (3eb)

1-methyl-4-((4-nitrophenyl)ethynyl)benzene (3bc)
1-methyl-4-((4-nitrophenoxy)ethynyl)benzene (3bc)

methyl 4-(p-tolyethynyl)benzoate (3dc)
methyl 4-(p-tolylethynyl)benzoate (3dc)

1-(4-(p-tolylethynyl)phenyl)ethanone (3ec)
1-(4-((p-tolyethynyl)phenyl)ethanone (3ec)

1,2-di-p-tolyethyne (3hc)
1,2-di-\textit{p}-tolylethylene (3hc)

1-(4-(oct-1-yn-1-yl)phenyl)ethanone (3ed)
1-(4-(oct-1-yn-1-yl)phenyl)ethanone (3ed)

2-(phenylethynyl)thiophene (5aa)
2-(phenylethynyl)thiophene (5aa)

2-(p-tolylethynyl)thiophene (5ab)
2-(p-tolylethynyl)thiophene (5ab)

2-(phenylethynyl)pyrazine (5ba)
2-(phenylethynyl)pyrazine (5ba)

5-(phenylethynyl)pyridin-2-amine (5ca)
5-(phenylethynyl)pyridin-2-amine (5ca)

1-methyl-4-(phenylethynyl)-1H-pyrazole (5da)
1-methyl-4-(phenylethynyl)-1H-pyrazole (5da)

5-((trimethylsilyl)ethynyl)pyrimidine-2,4(1H,3H)-dione (8)
5-((trimethylsilyl)ethynyl)pyrimidine-2,4(1H,3H)-dione (8)

4-(phenylethynyl)benzaldehyde (10ca)
