Electronic Supplementary Material (ESI) for RSC Advances.

Study of the Pauson-Khand reaction in flow over alkynylphenyl vinyl ethers: Towards the synthesis of tricyclic multisubstituted benzofurans.

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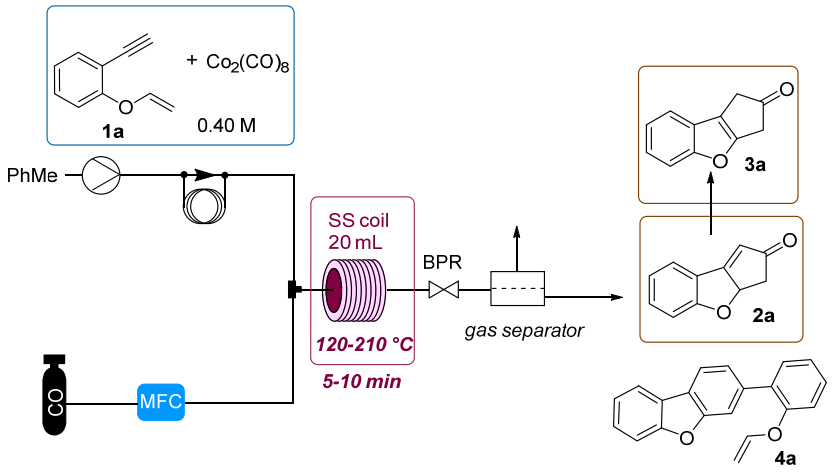
General information

All chemicals were obtained from Aldrich/Merck (St. Louis, MO, USA), VWR (Radnor, PA, USA) and Fluorochem (Derbyshire, UK). TLC analyses were performed on Merck silica gel 60 F254 plates using phosphomolybdic acid or anisaldehyde and heat for detection. Silica gel NORMASIL 60 40–63 μm was used for flash chromatography. NMR spectra were recorded on a Bruker spectrometer (400 MHz for ^{1}H and 100 MHz for ^{13}C). Chemical shifts are reported in δ ppm referenced to $CDCl_3$ (δ = 7.26 for ^{1}H and 77.00 for ^{13}C). Infrared spectra were performed in a Perkin-Elmer spectrum 100 (Agilent, Santa Clara, CA, USA). Melting points of solid compounds were determined using a Stuart Scientific Melting Point Apparatus SMP3 (Stuart, Staffordshire, UK). Microanalyses were done on a LECO CHNS-932 (LECO, St. Joseph, MI, USA). $Co_2(CO)_8$ was purchased from Acros Organics. It is a solid that decomposes partially after some days even when kept in the fridge, which diminishes or precludes its reactivity. This can be observed by a change in the color. We kept the reagent in the fridge and opened the bottle under Ar every time. Thus, we performed the reactions during the first week after opening every new bottle !

Flow set-up information

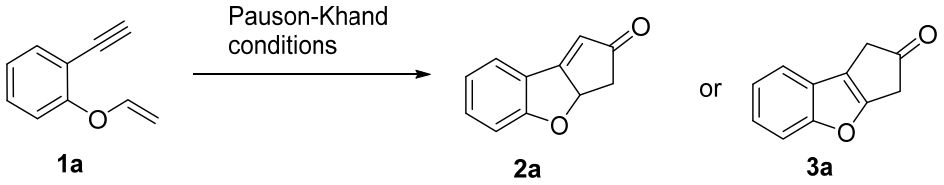
The flow system is a PFR (Plug flow reactor, coil reactor, composed by a 316 stainless steel tube with internal diameter of 17 mm and 25 mm of external diameter, volume = 20 mL or 60 mL) in a forced air oven, with one feeding line with a semi-preparative HPLC pump ASI Model 501. The system pressure is automated, controlled by a high precision needle backpressure valve and WIKA pressure sensor. CO is introduced by a Bronkhorst mass flow controller calibrated for this gas, and it is mixed with the solution in a T-shape stainless steel piece. The system has a gas liquid separator after the reactor. Samples were introduced in the system through a Rheodyne 6 ways valve.



General protocol for sample preparation: 0.5 or 0.8 mmol (for 0.25 M or 0.40 M) were added in a 2 mL volumetric flask with 1 mL of toluene, then 5/10 mol% of $Co_2(CO)_8$ was added and toluene was added until a final volume of 2 mL. Then, the solution is degassed with Ar in an ultrasound bath for 1 minute. Two consecutive injections (0.8 mL each) were introduced in the system. After the residence time, all the sample was collected, and the solvent evaporated in vacuo. Conversion/NMR yield was calculated in the ^1H spectrum a crude sample previously filtered through celite. In table 1, an internal standard (4,5-dibromo-*o*-xylene, 15 mol%) was introduced in order to calculate the decomposition ratio. A small aliquot (100 uL) was analyzed from the starting volumetric flask and compared to the collected solution at the end of the reactor in the steady state.

Batch sample preparation: 0.5 or 0.8 mmol (for 0.25 M or 0.40 M) were added in a 2 mL volumetric flask with 1 mL of toluene, then 5/10 mol% of $Co_2(CO)_8$ was added and toluene was added until a final volume of 2 mL. The mixture is transferred to a stainless steal pressure tube, where it's degassed with Ar in an ultrasound bath for 1 minute. The tube is closed and 3 cycles of CO/opening the tube were made. Finally, the required pressure of CO is introduced and the tube is placed in a heating plate at the corresponding temperature. In table 1, an internal standard (4,5-dibromo-*o*-xylene, 15 mol%) was introduced in order to calculate the decomposition ratio. A small aliquot (100 μL) was analyzed from the starting volumetric flask and compared to the collected solution when the pressure tube is cooled down and opened.

Preliminary PK reactions of **1a**



Conditions A: Flow protocol described by our group:[1] 120 ºC, 3 equiv of CO, 5 mol% of $Co_2(CO)_8$, 10 minutes of residence time.

Conditions B: Stochiometric PK, promoted by NMO and ethylene glycol[2] (Protocol used with vinyl ethers in intermolecular PK without incorporation of the ether moiety) 1.0 equiv of $Co_2(CO)_8$, 6 equiv of NMO, ethylene glycol (1.7 mL/mmol) and 4 Å molecular sieves.

Conditions C: Preformation of the complex alkyne with cobalt octacarbonyl (purified) and then reaction at refluxing toluene overnight.

Conditions D: 10 mol% of $Co_2(CO)_8$, 10 mol% TMTU, 1 atm. CO, in toluene, 16h stirring at 80 ºC.

Conditions E: 10 mol% $(Rh(CO)_2Cl)_2$, 1 atm of CO, in THF, 16h stirring at 40 ºC.

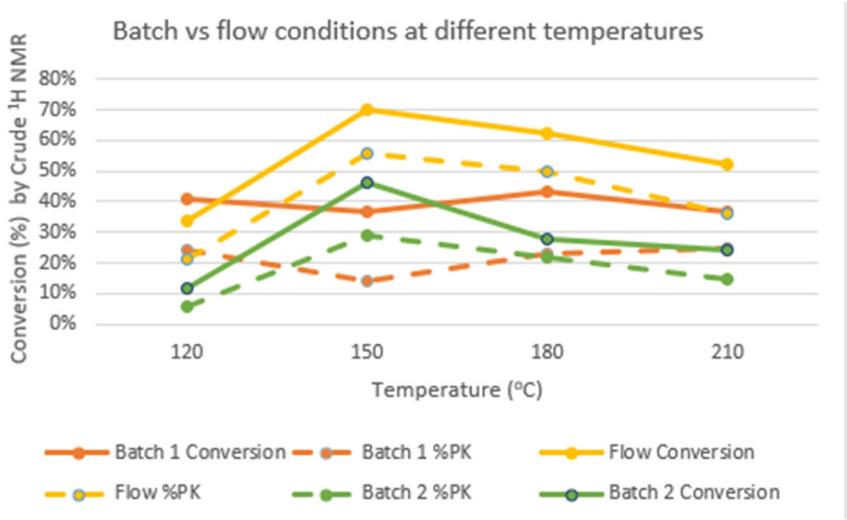
	A	**B**	**C**	**D**	**E**
% PK product (**2a**+**3a**)	16%	-	-	-	-
% **1a** recovered	35%	-	64%	-	85%

Flow tables

Table 1 Optimization of the PKr conditions for the synthesis of **3a**

Entry[a)]	Pump flow mL/min	Gas flow (mLN/min)	Temp (ºC)	Res. time (min)	Conc (M)	CO equiv	P (bar)	cat. (mol %)	% of conversion[b]	% of **3a**
1	0.92	26	150	11	0.25	5	28	5	70	56
2	0.92	26	180	8	0.25	5	28	5	62	50
3	0.92	26	180	8	0.25[c]	5	28	5	60	52
4[d]	0.96	27	180	13	0.25	5	35	5	72	64
5	0.70	31	180	10	0.40	5	28	5	35	5
6	1.40	24	180	15	0.15	5	28	5	53	46
7	0.92	26	180	8	0.25	5	28	2.5	49	42
8	1.10	19	180	16	0.25	3	28	5	50	35

[a] All reactions in PFR (20 mL). See ESI for system pump and MFC flows. [b] % of conversion is measured in the 1H NMR spectrum of the crude mixture using 4,5-dibromo-o-xylene as Internal standard. [c] 0.12 equiv of DME were added as additive. [d] A long run with 720 mg (20 mL of volume) was performed to check the reliability of the IS, reaching an isolated yield of 55%. In this experiment **4a** was isolated in 6% yield.



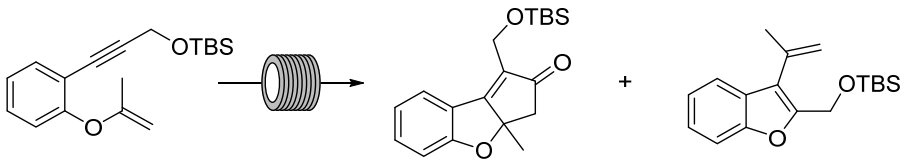
Batch Conditions 1: 5 bar of CO, 45 min of reaction time, 5 mol% of $Co_2(CO)_8$, 0.25 M

Batch Conditions 2: 20 bar of CO, 45 min of reaction time, 5 mol% of $Co_2(CO)_8$. 0.25 M

Flow conditions 1: Pump flow: 0.92 mL/min; Gas flow: 26 mL/min (5 equiv of CO), 7-15 min of residence time depending on the temperature, 28 bar of system pressure, 0,25M.

	120 ºC	150 ºC	180 ºC	210 ºC
Batch 1	41% (24%)	37% (14%)	43% (23%)	37% (25%)
Batch 2	12% (6%)	46% (29%) [13%]	28% (22%)	24% (15%)
Flow 1	34% (21%)	70% (56%) [44%]	62% (50%) [38%]	52% (36%)

% of detectable products (% of PK products) by ^{1}H NMR and [isolated yield]



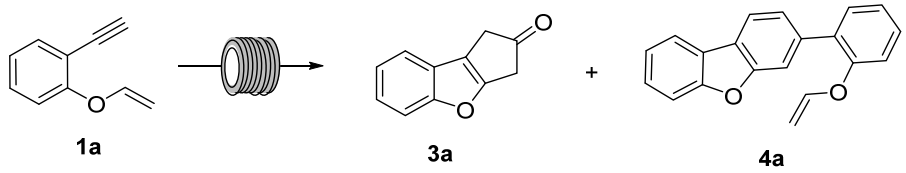
1m **2m** **5**

Table 2 Optimization of the PKr conditions for the synthesis of **2m**

Entry[a)]	Pump flow mL/min	Gas flow mLN/min	Temp (ºC)	Res. time (min)	Conc (M)	CO equiv	P (bar)	cat. (mol %)	% of Conv.	% of **2m/5**
1	0.58	16	150	11	0.25	5	20	5	7	99
2	0.56	25	150	26	0.40	5	35	5	14	99
3	1.10	25	180	14	0.40	3	28	5	66	79
4	0.56	25	180	19	0.40	5	35	5	48	81
5	0.57	16	180	16	0.25	5	28	5	64	80
6	0.92	26	210	7	0.25	5	28	5	86	67
7	0.56	25	150	26	0.40	5	35	10	62	>99
8[b]	0.56	25	150	91	0.40	5	35	10	82	73
9[b]	0.56	25	170	67	0.40	5	35	10	97	88[c]

a) All reactions in PFR (20 mL), % of products were measured by crude ^{1}H NMR. See ESI for system pump and MFC flows. b) A 60 mL reactor was used in these entries. c) A long run with 1.21 g was performed, an isolated yield of 79% was achieved. Total time: 102 minutes.

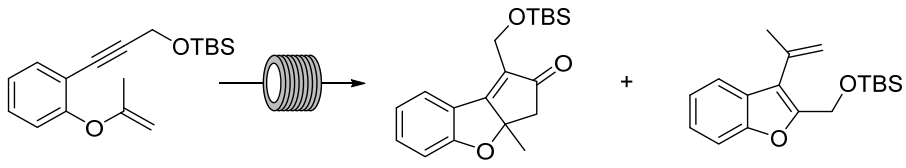
Control experiments



1a **3a** **4a**

Entry 4, table 1 conditions

- Without Catalyst: 0% of conversion with starting material fully recovered
- Without CO: (The pump flow was adjusted to 0.65 mL/min). 100% of conversion, but only product **4a** was detected in 16% yield.



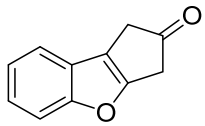
1m **2m** **5**

Entry 9 table 2 conditions:

- Without Catalyst: 0% of conversion with starting material fully recovered
- Without CO: (The pump flow was adjusted to 0.9 mL/min). 100% of conversion, but only product **5** was detected in 56% yield.

Experimental data of PK-products

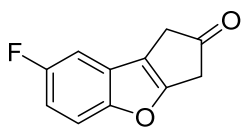
3a: 1,3-dihydro-2*H*-cyclopenta[*b*]benzofuran-2-one:



Entry 4 of table 1 (long run with 720 mg): 720 mg of **1a** were dissolved in 10 mL of anhydrous toluene. Then, 85 mg (5 mol%) of $Co_2(CO)_8$ were slowly added. The solution was filled with anhydrous toluene until a final volume of 20 mL. Next, the solution was degassed with Ar in an ultrasound bath for 1 minute. The solution was then placed in the inlet of the HPLC pump. The flow set up was previously stabilized at 180 ºC, 35 bar, pump flow: 0.96 mL/min, gas flow: 27 mLN/min, 13 minutes of residence time, total time: 42 minutes. Silica gel column chromatography in a hexane:ethyl acetate gradient gave **3a** as a light orange solid (408 mg, 50% yield). M.p.: 121–123 ºC. ^{1}H RMN (400 MHz, $CDCl_3$): δ 7.54 – 7.52 (m, 1H, Ar), 7.49 – 7.46 (m, 1H, Ar), 7.33 – 7.27 (m, 2H, Ar), 3.55 (s, 2H, CH_2), 3.49 (s, 2H, CH_2) ppm. ^{13}C RMN (101 MHz, $CDCl_3$) δ 210.7 (C), 157.5 (C), 155.6 (C), 125.2 (C), 124.1 (CH), 123.3 (CH), 119.4 (CH), 116.5 (C), 111.9 (CH), 39.3 (CH_2), 39.0 (CH_2) ppm. Elemental analysis calcd for $C_{11}H_8O_2$: C, 76.73; H, 4.68; found: C, 76.79; H, 4.64.

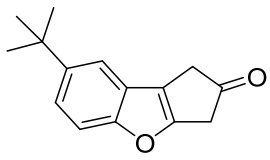
The rest of the products (except **2m**, long run) were injected in the system through two consecutive injections of 0.8 mL, the crude NMR yield is calculated with the internal standard and then purified by a hexane:ethyl acetate gradient in silica gel column chromatography. In order to avoid some decomposition, product purification must be done the same day of the experiment, and otherwise, the crude solution must be kept in the fridge.

3b: 7-fluoro-1,3-dihydro-2*H*-cyclopenta[*b*]benzofuran-2-one



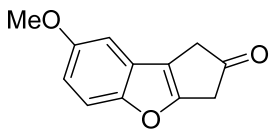
After purification, 65 mg of **1b** afforded 23 mg (31% yield) as an orangish solid. M.p: 130–133 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 (dd, *J* = 9.0, 4.1 Hz, 1H, Ar), 7.13 (dd, *J* = 8.4, 2.7 Hz, 1H, Ar), 7.01 (td, *J* = 9.0, 2.7 Hz, 1H, Ar), 3.54 (s, 2H, CH_2), 3.47 (s, 2H, CH_2) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 209.9 (C), 159.5 (d, *J* = 239.2 Hz, C), 157.6 (C), 153.7 (d, *J* = 0.9 Hz, C), 126.0 (d, *J* = 10.7 Hz, C), 116.7 (d, *J* = 4.0 Hz, C), 112.5 (d, *J* = 9.7 Hz, CH), 111.5 (d, *J* = 26.3 Hz, CH), 105.4 (d, *J* = 25.3 Hz, CH), 39.2 (CH_2), 39.1 (CH_2) ppm. Elemental analysis calcd for $C_{11}H_7FO_2$: C, 69.47; H, 3.71; F, 9.99; found: C, 69.51; H, 3.76.

3c: 7-(*tert*-butyl)-1,3-dihydro-2*H*-cyclopenta[*b*]benzofuran-2-one



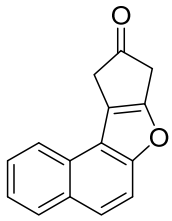
After purification, 80 mg of **1c** afforded 27 mg (30% yield) as a white solid. M. p.: 152–153 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, *J* = 2.0 Hz, 1H, Ar), 7.44 (d, *J* = 8.7 Hz, 1H, Ar), 7.36 (dd, *J* = 8.7, 2.0 Hz, 1H, Ar), 3.53 (s, 2H, CH_2), 3.48 (s, 2H, CH_2), 1.39 (s, 9H, 3xCH_3) ppm.^{13}C NMR (101 MHz, $CDCl_3$) δ 211.0 (C), 155.7 (C), 155.6 (C), 146.5 (C), 124.9 (C), 121.9 (CH), 116.6 (C), 115.8 (CH), 111.2 (CH), 39.4 (CH_2), 39.1 (CH_2), 34.8 (C), 31.8 (3xCH_3) ppm. Elemental analysis calcd for $C_{15}H_{16}O_2$: C, 78.92; H, 7.06; found: C, 78.94; H, 7.02.

3d: 7-methoxy-1,3-dihydro-2*H*-cyclopenta[*b*]benzofuran-2-one



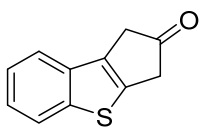
After purification, 70 mg of **1d** afforded 19 mg (24% yield) as a pale orange solid. M. p.: 169–172 ºC. ^{1}H RMN (400 MHz, $CDCl_3$) δ 7.41 (d, *J* = 8.9 Hz, 1H, Ar), 6.93 (d, *J* = 2.6 Hz, 1H, Ar), 6.89 (dd, *J* = 8.9, 2.7 Hz, 1H, Ar), 3.86 (s, 3H, OMe), 3.53 (s, 2H, CH_2), 3.46 (s, 2H, CH_2) ppm. ^{13}C RMN (101 MHz, $CDCl_3$): δ 210.7 (C), 156.4 (C), 156.3 (C), 152.4 (C), 125.8 (C) 116.6 (C), 112.3 (CH), 112.2 (CH), 102.5 (CH), 55.9 (CH_3), 39.3 (CH_2), 39.1 (CH_2) ppm. Elemental analysis calcd for $C_{12}H_{10}O_3$: C, 71.28; H, 4.98; found: C, 71.33; H, 4.93.

3e: 8,10-dihydro-9*H*-cyclopenta[*b*]naphtho[1,2-*d*]furan-9-one



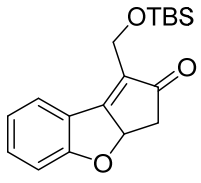
After purification, 78 mg of **1e** afforded 35 mg (40% yield) as a yellowish solid. M. p.: 132–134 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (d, *J* = 8.7 Hz, 1H, Ar), 7.97 (d, *J* = 7.5 Hz, 1H, Ar), 7.75 – 7.68 (m, 2H, Ar), 7.61 – 7.57 (m, 1H, Ar), 7.53 – 7.49 (m, 1H, Ar), 3.79 (s, 2H, CH_2), 3.62 (s, 2H, CH_2) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 210.8 (C), 154.8 (C), 154.6 (C), 130.6 (C), 128.7 (CH), 127.2 (C), 126.4 (CH), 124.84 (CH), 124.79 (CH), 123.7 (CH), 120.6 (C), 117.1 (C), 112.8 (CH), 40.2 (CH_2), 38.9 (CH_2) ppm. Elemental analysis calcd for $C_{15}H_{10}O_2$: C, 81.07; H, 4.54 found: C, 81.00; H, 4.49.

3f: 1,3-dihydro-2*H*-benzo[*b*]cyclopenta[*d*]thiophen-2-one



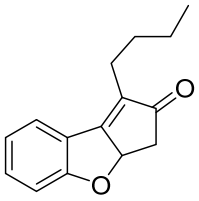
After purification, 65 mg of **1f** afforded 27 mg (36% yield) as a yellowish solid. M.p.: 143–146 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (d, *J* = 7.8 Hz, 1H, Ar), 7.62 (d, *J* = 7.7 Hz, 1H, Ar), 7.42 – 7.33 (m, 2H, Ar), 3.66 (s, 2H, CH_2), 3.55 (s, 2H, CH_2) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 213.1 (C), 142.0 (C), 136.9 (C), 135.2 (C), 134.7 (C), 124.7 (CH), 124.4 (CH), 123.2 (CH), 121.8 (CH), 42.4 (CH_2), 40.8 (CH_2) ppm. Elemental analysis calcd for $C_{11}H_8OS$: C, C, 70.19; H, 4.28; S, 17.03 found: C, 70.13; H, 4.31, S, 17.13.

2k: 1-(((*tert*-butyldimethylsilyl)oxy)methyl)-3,3a-dihydro-2*H*-cyclopenta[*b*] benzofuran-2-one



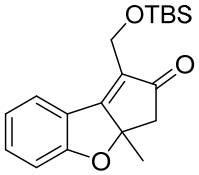
After purification, 115 mg of **1k** afforded 39 mg (31% yield) as a light yellow oil. ^{1}H RMN (400 MHz, $CDCl_3$): δ 7.87 (dd, *J* = 7.7, 1.5 Hz, 1H, Ar), 7.44 – 7.39 (m, 1H, Ar), 7.04 (td, *J* = 7.5, 0.8 Hz, 1H, Ar), 6.98 (d, *J* = 8.3 Hz, 1H, Ar), 5.56 – 5.52 (m, 1H, CH), 4.67 (dd, *J* = 14.9, 2.7 Hz, 1H, CH_2O), 4.51 (dd, *J* = 14.9, 2.9 Hz, 1H, CH_2O), 3.05 (dd, *J* = 16.2 , 6.0 Hz, 1H, CH_2CO), 2.81 (dd, *J* = 16.2, 4.3 Hz, 1H, CH_2CO), 0.93 (s, 9H, $(CH_3)_3C$), 0.13 (s, 6H, $(CH_3)_2Si$) ppm. ^{13}C RMN (101 MHz, $CDCl_3$): δ 201.9 (C), 172.0 (C), 165.7 (C), 134.1 (CH), 133.6 (C), 127.6 (CH), 122.1 (CH), 121.8 (C), 111.9 (CH), 85.9 (CH), 57.4 (CH_2), 44.3 (CH_2), 26.0 (3xCH_3), 18.5 (C), -5.2 (CH_3), -5.3 (CH_3) ppm. Elemental analysis calcd for $C_{18}H_{24}O_3Si$, C, 68.32; H, 7.64; Si, 8.87 found: C, 68.28; H, 7.71.

2l: 1-butyl-3,3a-dihydro-2*H*-cyclopenta[*b*]benzofuran-2-one.



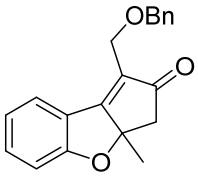
After purification, 75 mg of **1l** afforded 26 mg (29% yield) as a yellowish oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (dd, *J* = 7.6, 1.4 Hz, 1H, Ar), 7.43 – 7.38 (m, 1H, Ar), 7.05 (td, *J* = 7.5, 1.0 Hz, 1H, Ar), 6.99 (dt, *J* = 8.2, 0.8 Hz, 1H, Ar), 5.55 – 5.51 (m, 1H, CH), 3.04 (dd, *J* = 16.3, 5.9 Hz, 1H, CH_2CO), 2.79 (dd, *J* = 16.2, 4.1 Hz, 1H, CH_2CO), 2.56 – 2.48 (m, 1H, CH_2), 2.38 – 2.30 (m, 1H, CH_2), 1.60 – 1.49 (m, 2H, CH_2), 1.42 – 1.33 (m, 2H, CH_2), 0.93 (t, *J* = 7.3 Hz, 3H, CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 203.7 (C), 169.7 (C), 165.2 (C), 135.2 (C), 133.6 (CH), 124.6 (CH), 122.2 (C), 122.1 (CH), 112.2 (CH), 85.7 (CH), 44.4 (CH_2), 30.6 (CH_2), 23.5 (CH_2), 22.7 (CH_2), 13.9 (CH_3) ppm. Elemental analysis calcd for $C_{15}H_{16}O_2$: C, 78.92; H, 7.06 found: C, 78.99; H, 7.00.

2m: 1-(((*tert*-butyldimethylsilyl)oxy)methyl)-3a-methyl-3,3a-dihydro-2*H*-cyclopenta[*b*]benzofuran-2-one.



Long run (Entry 9 of table 2): 1.21 g of **1m** were dissolved in 5 mL of anhydrous toluene. Then, 136 mg (10 mol%) of $Co_2(CO)_8$ were slowly added. The solution was filled with anhydrous toluene until a final volume of 10 mL. Next, the solution was degassed with Ar in an ultrasound bath for 1 minute. The solution was then placed in the inlet of the HPLC pump. The flow set up was previously stabilized at 170 ºC, 35 bar, pump flow:0.56 mL/min, gas flow: 25 mLN/min, 67 min of residence time, total time: 102 minutes. After purification, 1.05 g were obtained as a pale orange oil (79% yield). ^{1}H RMN (400 MHz, $CDCl_3$): δ 7.88 (dd, *J* = 7.7, 1.4 Hz, 1H, Ar), 7.44 – 7.39 (m, 1H, Ar), 7.03 (td, *J* = 7.5, 1.0 Hz, 1H, Ar), 6.96 (dt, *J* = 8.3, 0.8 Hz, 1H, Ar), 4.66 (d, *J* = 14.9 Hz, 1H, OCH_2), 4.49 (d, *J* = 14.9 Hz, 1H, OCH_2), 2.94 (dq, *J* = 15.5, 1.1 Hz, 1H, CH_2), 2.80 (d, *J* = 15.6 Hz, 1H, CH_2), 1.55 (d, *J* = 1.1 Hz, 3H, CH_3), 0.92 (s, 9H, $(CH_3)_3C$), 0.13 (s, 3H, CH_3Si), 0.12 (s, 3H, CH_3Si) ppm.^{13}C RMN (101 MHz, $CDCl_3$): δ 202.4 (C), 175.4 (C), 164.0 (C), 134.0 (CH), 132.5 (C), 128.3 (CH), 121.9 (CH), 120.9 (C), 112.2 (CH), 92.2 (C), 57.2 (CH_2), 51.0 (CH_2), 27.3 (CH_3), 26.0 (3xCH_3), 18.5 (C), -5.19 (CH_3), -5.23 (CH_3) ppm. Elemental analysis calcd for $C_{19}H_{26}O_3Si$: C, 69.05; H, 7.93; Si, 8.50 found: C, 68.99; H, 7.98.

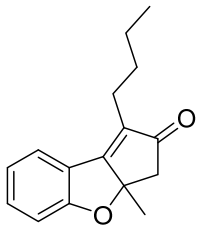
2n: 1-((benzyloxy)methyl)-3a-methyl-3,3a-dihydro-2*H*-cyclopenta[*b*]benzofuran-2-one.



After purification, 178 mg of **1n** afforded 133 mg (68% yield) as a pale-yellow oil. ^{1}H RMN (400 MHz, $CDCl_3$): δ 7.73 (dd, *J* = 7.6, 1.5 Hz, 1H, Ar), 7.44 – 7.39 (m, 1H, Ar), 7.35 – 7.30 (m, 5H, Ph), 6.99 – 6.95 (m, 2H, Ar), 4.64 – 4.57 (m, 2H, OCH_2Ph), 4.49 (d, *J* = 13.8 Hz, 1H, OCH_2C=), 4.36 (d, *J* = 13.8 Hz, 1H, OCH_2C=), 2.93 (dd, *J* = 15.7, 1.1 Hz, 1H, CH_2CO), 2.80 (d, *J* = 15.6 Hz, 1H, CH_2CO), 1.54 (d, *J* = 1.1 Hz, 3H, CH_3) ppm.^{13}C RMN (101 MHz, $CDCl_3$): δ 202.6 (C), 176.2 (C), 164.1 (C), 137.7 (C), 134.3 (CH), 129.5 (C), 128.5 (2xCH), 128.1 (2xCH), 127.89 (CH), 127.85 (CH), 122.0 (CH),

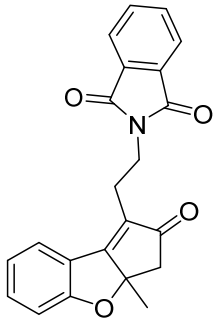
120.7 (C), 112.3 (CH), 92.2 (C), 73.3 (CH_2), 63.3 (CH_2), 50.9 (CH_2), 27.4 (CH_3) ppm. Elemental analysis calcd for $C_{20}H_{18}O_3$: C, 78.41; H, 5.92 found: C, 78.52; H, 5.97.

2o: 1-butyl-3a-methyl-3,3a-dihydro-2*H*-cyclopenta[*b*]benzofuran-2-one



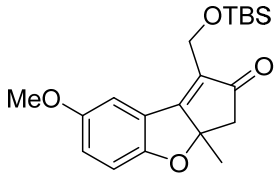
After purification, 137 mg of **1o** afforded 107 mg (69% yield) as a colorless oil. ^{1}H RMN (400 MHz, $CDCl_3$) δ 7.58 (dd, *J* = 7.6, 1.4 Hz, 1H, Ar), 7.42 – 7.38 (m, 1H, Ar), 7.04 (td, *J* = 7.5, 0.9 Hz, 1H, Ar), 6.96 (d, *J* = 8.2 Hz, 1H, Ar), 2.93 (dd, *J* = 15.7, 1.1 Hz, 1H, CH_2CO), 2.78 (d, *J* = 15.6 Hz, 1H, CH_2CO), 2.54 – 2.46 (m, 1H, CH_2C=), 2.36 – 2.29 (m, 1H, CH_2C=), 1.57 – 1.50 (m, 2H, CH_2), 1.52 (d, *J* = 1.1 Hz, 3H, CH_3C), 1.41 – 1.32 (m, 2H, CH_2), 0.93 (t, *J* = 7.3 Hz, 3H, CH_3) ppm. ^{13}C RMN (101 MHz, $CDCl_3$) δ 204.1 (C), 172.9 (C), 163.5 (C), 133.9 (C), 133.5 (CH), 125.2 (CH), 121.8 (CH), 121.2 (C), 112.4 (CH), 91.9 (C), 51.0 (CH_2), 30.6 (CH_2), 27.2 (CH_3), 23.4 (CH_2), 22.6 (CH_2), 13.9 (CH_3) ppm. Elemental analysis calcd for $C_{16}H_{18}O_2$: C 79.31; H, 7.49 found: C, 79.27; H, 7.54.

2p: 2-(2-(3a-methyl-2-oxo-3,3a-dihydro-2*H*-cyclopenta[*b*]benzofuran-1-yl)ethyl)isoindoline-1,3-dione.



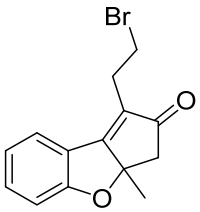
After purification, 212 mg of **1p** afforded 163 mg (71% yield) as a white solid. M. p.: 166–168 ºC. ^{1}H RMN (400 MHz, $CDCl_3$) δ 7.67 – 7.63 (m, 2H, Ar), 7.61 – 7.58 (m, 2H, Ar), 7.42 (dd, *J* = 7.5, 1.4 Hz, 1H, Ar), 7.13 – 7.08 (m, 1H, Ar), 6.75 – 6.69 (m, 2H, Ar), 3.91 – 3.88 (m, 2H, CH_2N), 3.00 (dd, *J* = 15.7, 1.1 Hz, 1H, CH_2CO), 2.94 – 2.87 (m, 1H, CH_2C=), 2.78 (d, *J* = 15.8 Hz, 1H, CH_2CO), 2.78 – 2.72 (m, 1H, CH_2C=), 1.42 (d, *J* = 1.0 Hz, 3H, CH_3). ^{13}C RMN (101 MHz, $CDCl_3$) δ 203.7 (C), 174.4 (C), 168.2 (2xC), 163.3 (C), 133.7 (2xCH), 133.4 (CH), 131.8 (2xC), 129.8 (C), 124.6 (CH), 123.0 (2xCH), 121.8 (CH), 120.3 (C), 112.2 (CH), 92.0 (C), 50.9 (CH_2), 36.1 (CH_2), 26.4 (CH_3), 23.4 (CH_2). Elemental analysis calcd for $C_{22}H_{17}NO_4$ 73.53; H, 4.77; N, 3.90 found: C, 73.49; H, 4.83, N, 3.81.

2q:1-(((*tert*-butyldimethylsilyl)oxy)methyl)-7-methoxy-3a-methyl-3,3a-dihydro-2*H*-cyclopenta[*b*]benzofuran-2-one.



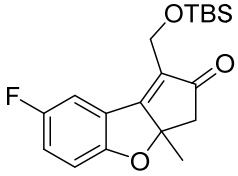
After purification, 213 mg of **1q** afforded 152 mg (66% yield) as a intense yellow oil. ^{1}H RMN (400 MHz, $CDCl_3$) δ 7.39 (d, *J* = 2.8 Hz, 1H, Ar), 7.02 (dd, *J* = 8.9, 2.8 Hz, 1H, Ar), 6.87 (d, *J* = 8.9 Hz, 1H, Ar), 4.65 (d, *J* = 15.0 Hz, 1H, CH_2O), 4.48 (d, *J* = 14.9 Hz, 1H, CH_2O), 3.81 (s, 3H, CH_3O), 2.93 (d, *J* = 15.6 Hz, 1H, CH_2CO), 2.78 (d, *J* = 15.6 Hz, 1H, CH_2CO), 1.54 (s, 3H, CH_3C), 0.92 (s, 9H, $(CH_3)_3C$), 0.14 (s, 3H, CH_3Si), 0.12 (s, 3H, CH_3Si) ppm. ^{13}C RMN (101 MHz, $CDCl_3$) δ 202.2 (C), 176.1 (C), 158.5 (C), 155.0 (C), 132.3 (C), 122.0 (CH), 121.1 (C), 112.7 (CH), 111.0 (CH), 92.5 (C), 57.1 (CH_2), 56.1 (CH_3), 51.1 (CH_2), 27.4 (CH_3), 26.0 (3xCH_3), 18.5 (C), -5.1 (CH_3), -5.2 (CH_3) ppm. Elemental analysis calcd for $C_{20}H_{28}O_4Si$: C, 66.63; H, 7.83; Si, 7.79 found: C, 66.71; H, 7.84.

2r: 1-(2-bromoethyl)-3a-methyl-3,3a-dihydro-2*H*-cyclopenta[*b*]benzofuran-2-one



After purification, 170 mg of **1r** afforded 143 mg (76% yield) as a light brown oil. ^{1}H RMN (400 MHz, $CDCl_3$) δ 7.69 (dd, *J* = 7.7, 1.4 Hz, 1H, Ar), 7.46 – 7.42 (m, 1H, Ar), 7.06 (td, *J* = 7.5, 1.0 Hz, 1H, Ar), 6.99 (d, *J* = 8.3 Hz, 1H, Ar), 3.69 – 3.63 (m, 1H, CH_2Br), 3.58 – 3.52 (m, 1H, CH_2Br), 3.12 (dt, *J* = 14.2, 6.0 Hz,1H, CH_2C=), 2.96 (dd, *J* = 15.8, 1.1 Hz, 1H, CH_2CO), 2.91 – 2.85 (m, 1H, CH_2C=), 2.81 (d, *J* = 15.7 Hz, 1H, CH_2CO), 1.57 (d, *J* = 1.1 Hz CH_3) ppm. ^{13}C RMN (101 MHz, $CDCl_3$) δ 203.4 (C), 176.0 (C), 163.9 (C), 134.2 (CH), 129.3 (C), 125.4 (CH), 122.0 (CH), 120.7 (C), 112.6 (CH), 92.1 (C), 50.7 (CH_2), 30.8 (CH_2), 27.4 (CH_2), 27.2 (CH_3) ppm. Elemental analysis calcd for $C_{14}H_{13}BrO_2$: C, 57.36; H, 4.47; Br, 27.26 found: C, 57.32; H, 4.53.

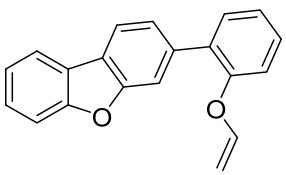
2s: 1-(((*tert*-butyldimethylsilyl)oxy)methyl)-7-fluoro-3a-methyl-3,3a-dihydro-2*H*-cyclopenta[*b*]benzofuran-2-one.



After purification, 205 mg of **1s** afforded 165 mg (74% yield) as a yellow viscous oil. ^{1}H RMN (400 MHz, $CDCl_3$) δ 7.60 (dd, *J* = 8.0, 2.8 Hz, 1H, Ar), 7.11 (td, *J* = 8.8, 2.9 Hz, 1H, Ar), 6.88 (dd, *J* = 8.9, 4.0 Hz, 1H, Ar), 4.65 (d, *J* = 15.6 Hz, 1H, CH_2O), 4.51 (d, *J* = 15.6 Hz, 1H, CH_2O), 2.95 (dd, *J* = 15.7, 1.1 Hz, 1H, CH_2CO), 2.79 (d, *J* = 15.7 Hz, 1H, CH_2CO), 1.54 (d, *J* = 1.1 Hz, 3H, CH_3), 0.92 (s, 9H, $(CH_3)_3C$), 0.14 (s, 3H, CH_3Si), 0.14 (s, 3H, CH_3Si) ppm. ^{13}C RMN (101 MHz, $CDCl_3$) δ 202.1 (C), 174.0 (d, *J* = 3.0 Hz, C), 159.9 (d, *J* = 1.4 Hz, C), 157.8 (d, *J* = 239.6 Hz, C), 133.5 (C), 121.5 (d, *J* = 10.1 Hz, C), 120.8 (d, *J* = 25.0 Hz, CH), 114.4 (d, *J* = 25.3 Hz, CH), 112.7 (d, *J* = 8.3 Hz, CH), 93.0 (C), 57.8 (CH_2), 51.1 (CH_2), 27.2 (CH_3), 26.0 (3xCH_3), 18.6 (C), -5.2 (CH_3), -5.3 (CH_3) ppm. Elemental analysis calcd for $C_{19}H_{25}FO_3Si$: C, 65.49; H, 7.23; F, 5.45; Si, 8.06 found: C, 65.57; H, 7.19.

Side products isolated from the PKr:

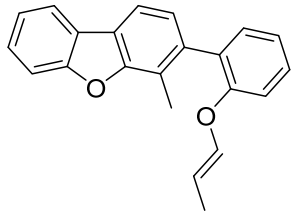
4a: 3-(2-(vinyloxy)phenyl)dibenzo[*b*,*d*]furan



Yellowish oil. [2+2+2] aromatized cycloadduct. Detected as side product in the Pauson-Khand optimization study with **1a**. In the long run experiment (Entry 4 of table 1) 720 mg of **1a** afforded of 42 mg of **4a** (6% yield). ^{1}H RMN (400 MHz, $CDCl_3$): δ 7.99 (dd, *J* = 8.0, 0.6 Hz, 1H, Ar), 7.98 (ddd, *J* = 7.7, 1.4, 0.7 Hz, 1H, Ar), 7.76 (d, *J* = 0.9 Hz, 1H, Ar), 7.59 (dt, *J* = 8.3, 0.8 Hz, 1H, Ar), 7.53 – 7.45 (m, 3H, Ar), 7.39 – 7.34 (m, 2H, Ar), 7.23 (td, *J* = 7.5, 1.2 Hz, 1H, Ar), 7.15 (dd, *J* = 8.1, 1.2 Hz, 1H, Ar), 6.60 (dd, *J* = 13.8, 6.1 Hz, 1H, HC=), 4.63 (dd, *J* = 13.8, 1.8 Hz, 1H,=CH_2), 4.36 (dd, *J* = 6.1, 1.8 Hz, 1H,=CH_2) ppm. ^{13}C RMN (101 MHz, $CDCl_3$) δ 156.6 (C), 156.2 (C), 153.4 (C), 149.0 (CH), 137.0 (C), 132.3 (C), 131.3 (CH), 128.8 (CH), 127.1 (CH), 124.3 (CH), 124.1 (C), 124.0 (CH), 123.2 (C), 122.7 (CH), 120.6 (CH),

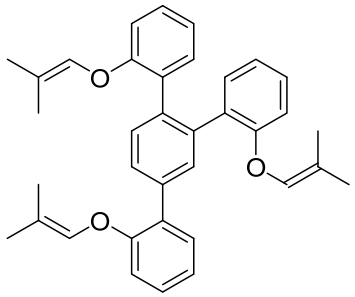
120.1 (CH), 118.3 (CH), 112.6 (CH), 111.6 (CH), 94.6 (CH_2) ppm. Elemental analysis calcd for $C_{20}H_{14}O_2$: C, 83.90; H, 4.93 found: C, 83.93; H, 4.99.

4i: (*E*)-4-methyl-3-(2-(prop-1-en-1-yloxy)phenyl)dibenzo[b,d]furan



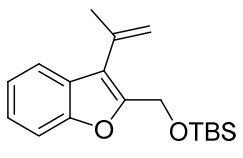
After purification 63 mg of **1i** afforded 13 mg (21% yield) as a yellowish oil. Purity was ca 95 % (NMR) as traces of the non-aromatized [2+2+2] cycloadduct could not be separated. ^{1}H RMN (400 MHz, $CDCl_3$) δ 7.97 – 7.95 (m, 1H, Ar), 7.81 (d, *J* = 7.9 Hz, 1H, Ar), 7.60 (d, *J* = 8.2 Hz, 1H, Ar), 7.45 (ddd, *J* = 8.4, 7.3, 1.4 Hz, 1H, Ar), 7.39 – 7.32 (m, 2H, Ar), 7.29 (dd, *J* = 7.5, 1.8 Hz, 1H, Ar), 7.24 (d, *J* = 7.9 Hz, 1H, Ar), 7.14 (td, *J* = 7.5, 1.2 Hz, 1H, Ar), 7.08 (dd, *J* = 8.3, 1.1 Hz, 1H, Ar), 6.31 (dq, *J* = 6.1, 1.8 Hz, 1H, OHC=), 4.75 (p, *J* = 6.8 Hz, 1H, =C*H*CH_3), 2.44 (s, 3H, CH_3C), 1.50 (dd, *J* = 6.9, 1.7 Hz, 3H, C*H*$_3$CH=) ppm. ^{13}C RMN (101 MHz, $CDCl_3$) δ 156.4 (C), 155.3 (C), 154.8 (C), 141.1 (CH), 137.2 (C), 131.7 (CH), 130.9 (C), 128.8 (CH), 126.7 (CH), 125.1 (CH), 124.8 (C), 122.6 (C), 122.5 (CH), 122.3 (CH), 121.1 (C), 120.6 (CH), 117.1 (CH), 115.2 (CH), 111.6 (CH), 107.4 (CH), 13.0 (CH_3), 9.4 (CH_3) ppm.

4j: 2,2''-bis((2-methylprop-1-en-1-yl)oxy)-4'-(2-((2-methylprop-1-en-1-yl)oxy)phenyl)-1,1':2',1''-terphenyl



White solid. [2+2+2] cyclotrimerization product. Isolated in the Pauson-Khand attempts of **1j** as only detectable product. After purification 69 mg of **1l** afforded 12 mg (18% yield). M. p.: >280 ºC. ^{1}H RMN (400 MHz, $CDCl_3$) δ 7.65 – 7.61 (m, 2H, Ar), 7.50 – 7.47 (m, 2H, Ar), 7.28 (td, *J* = 7.5, 1.8 Hz, 2H, Ar), 7.14 – 7.02 (m, 5H, Ar), 6.86 (td, *J* = 7.4, 1.2 Hz, 1H, Ar), 6.84 – 6.80 (m, 2H, Ar), 6.77 (d, *J* = 8.1 Hz, 1H, Ar), 6.22 – 6.20 (m, 1H, HC=), 5.69 – 5.68 (m, 1H, CH=), 5.54 (bs, 1H, CH=), 1.68 (d, *J* = 1.4 Hz, 3H, CH_3), 1.66 (d, *J* = 1.5 Hz, 3H, CH_3), 1.59 (d, *J* = 1.4 Hz, 3H, CH_3), 1.56 (s, 6H, 2xCH_3), 1.49 (d, *J* = 1.4 Hz, 3H, CH_3) ppm. ^{13}C RMN (101 MHz, $CDCl_3$) δ 154.79 (C), δ 154.78 (C), 154.7 (C), 137.3 (C), 136.4 (C), 136.3 (C), 135.8 (CH), 135.74 (CH), 135.71 (CH), 131.9 (CH), 131.85 (CH), 131.82 (CH), 131.4 (C), 131.1 (CH), 131.0 (C), 130.9 (C), 130.4 (CH), 128.3 (CH), 128.0 (CH), 127.9 (CH), 127.8 (CH), 122.2 (CH), 121.3 (CH), 121.1 (CH), 117.1 (C), 116.82 (C), 116.76 (C), 115.2 (CH), 114.8 (CH), 114.7 (CH), 19.5 (CH_3), 19.41 (CH_3), 19.38 (CH_3), 15.4 (CH_3), 15.2 (CH_3), 15.1 (CH_3) ppm. Elemental analysis calcd for $C_{36}H_{36}O_3$: C, 83.69; H, 7.02 found: C, 83.60 H, 7.11.

5: *tert*-butyldimethyl((3-(prop-1-en-2-yl)benzofuran-2-yl)methoxy)silane

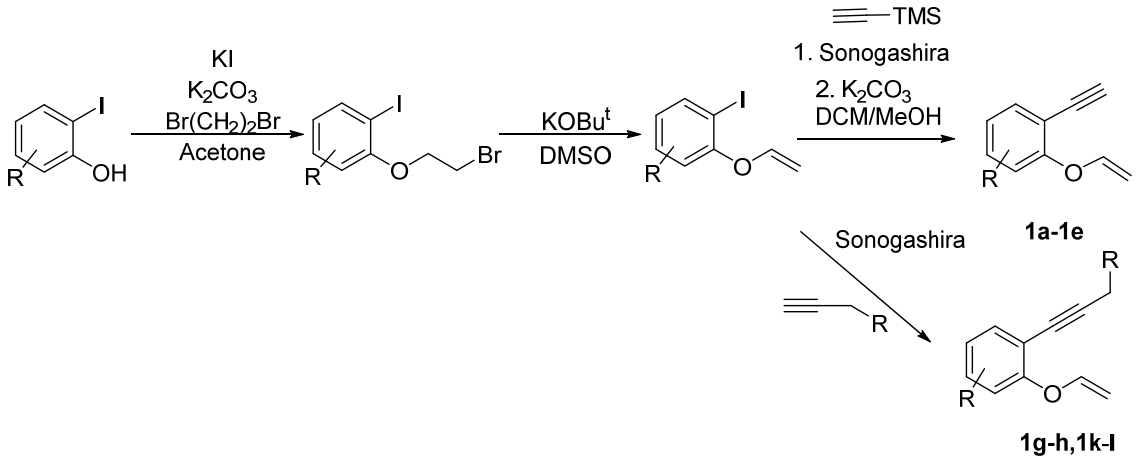


Yellow oil obtained as side product of Pauson-Khand attempts of **1m**. In the long run experiment (Entry 9 of table 2): 1.21 g of **1m** afforded 80 mg (7% yield) of **5**. ^{1}H RMN (400 MHz, $CDCl_3$) δ 7.59 (dd, *J* = 8.1, 1.4 Hz, 1H, Ar), 7.46 (d, *J* = 7.9 Hz, 1H, Ar), 7.28 (td, *J* = 7.2, 1.4 Hz, 1H, Ar), 7.22 (td,

J = 7.4, 1.1 Hz, 1H, Ar), 5.30 (p, *J* = 1.6 Hz, 1H, =CH_2), 5.17 (d, *J* = 1.0 Hz, 1H, =CH_2), 4.80 (s, 2H, CH_2), 2.21 (t, *J* = 1.2 Hz, 3H, CH_3), 0.91 (s, 9H, $(CH_3)_3C$), 0.11 (s, 6H, $(CH_3)_2Si$) ppm. ^{13}C RMN (101 MHz, $CDCl_3$) δ 154.1 (C), 151.8 (C), 136.1 (C), 128.0 (C), 124.3 (CH), 122.5 (CH), 120.8 (CH), 120.7 (C), 116.5 (CH_2), 111.3 (CH), 56.9 (CH_2), 25.9 (3xCH_3), 23.3 (CH_3), 18.4 (C), -5.2 (2xCH_3) ppm. Elemental analysis calcd for $C_{18}H_{26}O_2Si$: C, 71.47; H, 8.66; Si, 9.28 found: C, 71.55; H, 8.57.

Synthesis of substrates for the PKr: alkynylaryl vinyl ethers

- Synthesis of vinyl ethers **1a-1e, 1g-1j and 1f** See procedure described by Y-C Lin. *et al.*[3]



Commercial starting materials used: 1,2-iodophenol (for **1a, 1g-h, 1k-l**), 4-fluoro-2-iodophenol (**1b**). 4-(*tert*-butyl)-2-iodophenol (**1c**), 2-bromo-4-methoxyphenol (**1d**), 1-bromonaphthalen-2-ol (**1e**) and 2-bromothiophenol (**1f).**

General procedure for Sonogashira coupling A:

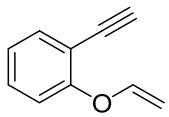
Once the iodo-arene (1 equiv) was dissolved in Et_3N (10 mL/g), the alkyne (1.1 equiv) was added, and the solution was degassed with Ar during 10 min. Then, $PdCl_2(PPh_3)_2$ (4 mol%) and CuI (8 mol%) were added, and the resulting suspension was degassed again for 10 min. The reaction mixture is stirred at room temperature for 12 hours and afterwards was filtered over celite and washed 3 times with MTBE. The solvent was evaporated *in vacuo* and the product is purified by column chromatography in silica gel.

General procedure for Sonogashira coupling B: (used with bromo-arene starting materials)

The bromo-arene (1 equiv), CuI (2 mol%), and $Pd(PhCN)_2Cl_2$ were added to a dry, sparged with Ar flask and dioxane was added (1 mL/mmol). Then, the alkyne (1.2 equiv), $P(t\text{-}Bu)_3$ (1M in toluene, 6 mol%) and diisopropylamine (1.2 equiv) were added. The suspension was degassed for 10 min with Ar. The reaction was stirred at room temperature for 16 hours. The crude reaction mixture was filtered over celite and was washed 3 times with MTBE. The solvent was evaporated *in vacuo* and the product was purified by column chromatography in silica gel.

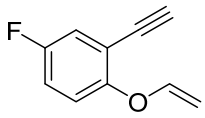
For products **1a-1f** (using TMS-alkyne as alkyne): After purification of the product, it was dissolved in a mixture of MeOH/DCM (1/3, 12 mL/g) and K_2CO_3 (3 equiv) was added in an ice bath. After 3h of stirring at room temperature, H_2O was added, and the mixture was extracted with DCM twice. Combined organic extracts were washed with brine and dried over Na_2SO_4. The solvent was evaporated *in vacuo* (20 ^oC bath temperature). These products no need further purification.

1a: 1-ethynyl-2-(vinyloxy)benzene



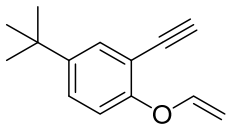
Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 (dd, *J* = 7.7, 1.7 Hz, 1H, Ar), 7.33 (td, *J* = 7.9, 1.7 Hz, 1H, Ar), 7.05 (t, *J* = 7.6 Hz, 1H, Ar), 7.00 (d, *J* = 8.3 Hz, 1H, Ar), 6.64 (dd, *J* = 13.7, 6.1 Hz, 1H, HC=), 4.81 (dd, *J* = 13.7, 1.9 Hz, 1H, $=CH_2$), 4.51 (dd, *J* = 6.1, 1.9 Hz, 1H, $=CH_2$), 3.30 (s, 1H, ≡CH) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 157.6 (C), 148.0 (CH), 134.2 (CH), 130.2 (CH), 123.1 (CH), 116.7 (CH), 113.1 (C), 95.9 (CH_2), 81.8 (CH), 79.2 (C) ppm. Elemental analysis calcd for $C_{10}H_8O$: C, 83.31; H, 5.59 found: C, 83.39; H, 5.52. Data consistent with those reported in the literature.[3]

1b: 2-ethynyl-4-fluoro-1-(vinyloxy)benzene



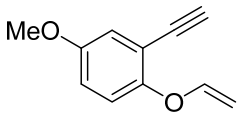
Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.19 (dd, *J* = 8.5, 3.0 Hz, 1H, Ar), 7.03 (td, *J* = 8.6, 3.0 Hz, 1H, Ar), 6.96 (dd, *J* = 9.0, 4.7 Hz, 1H, Ar), 6.58 (dd, *J* = 13.7, 6.1 Hz, 1H, HC=), 4.71 (dd, *J* = 13.8, 1.7 Hz, 1H, $=CH_2$), 4.46 (dd, *J* = 6.2, 1.7 Hz, 1H, $=CH_2$), 3.31 (s, 1H, ≡CH) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.0 (d, *J* = 242.8 Hz, C), 153.8 (d, *J* = 2.6 Hz, C), 148.6 (CH), 120.4 (d, *J* = 24.6 Hz, CH), 118.7 (d, *J* = 8.8 Hz, CH), 117.1 (d, *J* = 23.4 Hz, CH), 114.8 (d, *J* = 9.8 Hz, C), 95.3 (CH_2), 82.7 (CH), 78.1 (d, *J* = 2.8 Hz, C) ppm. Elemental analysis calcd for $C_{10}H_7FO$: C, 74.07; H, 4.35; F, 11.72 found: C, 74.11; H, 4.28.

1c: (*tert*-butyl)-2-ethynyl-1-(vinyloxy)benzene



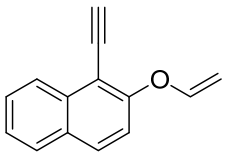
Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.51 (d, *J* = 2.5 Hz, 1H, Ar), 7.34 (dd, *J* = 8.7, 2.5 Hz, 1H, Ar), 6.93 (d, *J* = 8.7 Hz, 1H, Ar), 6.62 (dd, *J* = 13.7, 6.1 Hz, 1H, HC=), 4.76 (dd, *J* = 13.8, 1.8 Hz, 1H, $=CH_2$), 4.45 (dd, *J* = 6.1, 1.8 Hz, 1H, $=CH_2$), 3.27 (s, 1H, ≡CH), 1.30 (s, 9H, $3xCH_3$) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 155.4 (C), 148.4 (CH), 146.1 (C), 131.1 (CH), 127.3 (CH), 116.5 (CH), 112.4 (C), 95.3 (CH_2), 81.1 (CH), 79.8 (C) 34.2 (C), 31.3 ($3xCH_3$) ppm. Elemental analysis calcd for $C_{14}H_{16}O$: C, 83.96; H, 8.05 found: C, 83.89; H, 8.11.

1d: 2-ethynyl-4-methoxy-1-(vinyloxy)benzene



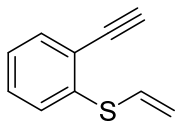
Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.01 (d, *J* = 3.1 Hz, 1H, Ar), 6.94 (d, *J* = 8.9 Hz, 1H, Ar), 6.87 (dd, *J* = 9.0, 3.1 Hz, 1H, Ar), 6.59 (dd, *J* = 13.8, 6.1 Hz, 1H, HC=), 4.63 (dd, *J* = 13.8, 2.0 Hz, 1H, $=CH_2$), 4.38 (dd, *J* = 6.2, 1.9 Hz, 1H, $=CH_2$), 3.78 (s, 3H, CH_3), 3.27 (s, 1H, ≡CH) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 155.3 (C), 151.5 (C), 149.5 (CH), 119.2 (CH), 118.2 (CH), 116.5 (CH), 114.3 (C), 93.9 (CH_2), 81.6 (CH), 79.1 (C), 55.7 (CH_3) ppm. Elemental analysis calcd for $C_{11}H_{10}O_2$: C, 75.84; H, 5.79 found: C, 75.75; H, 5.72,

1e: 1-ethynyl-2-(vinyloxy)naphthalene



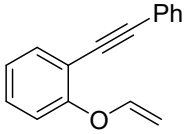
Off-white solid. M.p.: 97–100 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.32 (dq, *J* = 8.4, 0.9 Hz, 1H, Ar), 7.85 – 7.81 (m, 2H, Ar), 7.59 (ddd, *J* = 8.4, 6.9, 1.3 Hz, 1H, Ar), 7.47 (ddd, *J* = 8.1, 6.8, 1.2 Hz, 1H, Ar), 7.26 (d, *J* = 9.0 Hz, 1H, Ar), 6.76 (dd, *J* = 13.8, 6.1 Hz, 1H, HC=), 4.79 (dd, *J* = 13.7, 2.0 Hz, 1H, $=CH_2$), 4.51 (dd, *J* = 6.1, 2.0 Hz, 1H, $=CH_2$), 3.72 (s, 1H, ≡CH) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 156.5 (C), 148.7 (CH), 134.5 (C), 130.5 (CH), 129.8 (C), 128.1 (CH), 127.6 (CH), 125.6 (CH), 125.4 (CH), 117.7 (CH), 108.4 (C), 95.3 (CH_2), 87.1 (CH), 77.2 (C) ppm. Elemental analysis calcd for $C_{14}H_{10}O$, C, 86.57; H, 5.19 found: C, 86.51; H, 5.33.

1f: (2-ethynylphenyl)(vinyl)sulfane



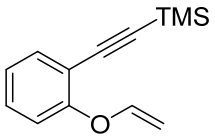
Intense yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.51 (dd, *J* = 7.6, 1.3 Hz, 1H, Ar), 7.36 – 7.30 (m, 2H, Ar), 7.19 (ddd, *J* = 7.6, 6.8, 1.8 Hz, 1H, Ar), 6.56 (dd, *J* = 16.6, 9.5 Hz, 1H, HC=), 5.51 (d, *J* = 16.7 Hz, 1H $=CH_2$), 5.50 (d, *J* = 9.4 Hz, 1H $=CH_2$), 3.43 (s, 1H, ≡CH) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.2 (C), 133.5 (CH), 130.0 (CH), 129.4 (CH), 128.8 (CH), 126.3 (CH), 122.2 (C), 118.3 (CH_2), 83.2 (CH), 81.0 (C) ppm. Elemental analysis calcd for $C_{10}H_8S$: C, 74.96; H, 5.03; S, 20.01 found: C, 75.04; H, 5.00.

1g: 1-(phenylethynyl)-2-(vinyloxy)benzene



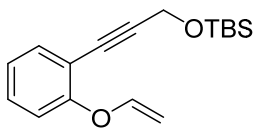
Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 – 7.53 (m, 3H, Ar), 7.38 – 7.29 (m, 4H, Ar), 7.09 (td, *J* = 7.6, 1.1 Hz, 1H, Ar), 7.04 (dd, *J* = 8.3, 1.1 Hz, 1H, Ar), 6.70 (dd, *J* = 13.7, 6.1 Hz, 1H, HC=), 4.80 (dd, *J* = 13.7, 1.8 Hz, 1H, $=CH_2$), 4.48 (dd, *J* = 6.1, 1.8 Hz, 1H, $=CH_2$) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 157.0 (C), 148.7 (CH), 133.6 (CH), 131.6 (2xCH), 129.6 (CH), 128.29 (CH), 128.27 (2xCH), 123.4 (C), 123.3 (CH), 117.3 (CH), 114.7 (C), 95.0 (CH_2), 94.1 (C), 85.0 (C) ppm. Elemental analysis calcd for $C_{16}H_{12}O$ C, 87.25; H, 5.49 found: C, 87.16; H, 5.54.

1h: trimethyl((2-(vinyloxy)phenyl)ethynyl)silane



Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 (dd, *J* = 7.6, 1.7 Hz, 1H, Ar), 7.30 – 7.26 (m, 1H, Ar), 7.03 (td, *J* = 7.6, 1.1 Hz, 1H, Ar), 6.98 (d, *J* = 8.3 Hz, 1H, Ar), 6.64 (dd, *J* = 13.7, 6.1 Hz, 1H, HC=), 4.75 (dd, *J* = 13.7, 1.7 Hz, 1H, $=CH_2$), 4.44 (dd, *J* = 6.1, 1.8 Hz, 1H, $=CH_2$), 0.26 (s, 9H, $3xCH_3$) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) 157.5 (C), 148.6 (CH), 134.1 (CH), 129.9 (CH), 123.2 (CH), 117.2 (CH), 114.5 (C), 100.4 (C), 99.6 (C), 95.0 (CH_2), 0.0 ($3xCH_3$) ppm. Elemental analysis calcd for $C_{13}H_{16}OSi$: C, 72.17; H, 7.45; Si, 12.98 found: C, 72.17; H, 7.39.

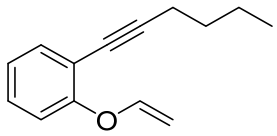
1k: *tert*-butyldimethyl((3-(2-(vinyloxy)phenyl)prop-2-yn-1-yl)oxy)silane



Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.43 (dd, *J* = 7.6, 1,7 Hz, 1H, Ar), 7.28 (td, *J* = 7.8, 1.7 Hz, 1H, Ar), 7.03 (t, *J* = 7.5 Hz, 1H, Ar), 6.98 (d, *J* = 8.3 Hz, 1H, Ar), 6.62 (dd, *J* = 13.7, 6.1 Hz, 1H, HC=), 4.76 (dd, *J*

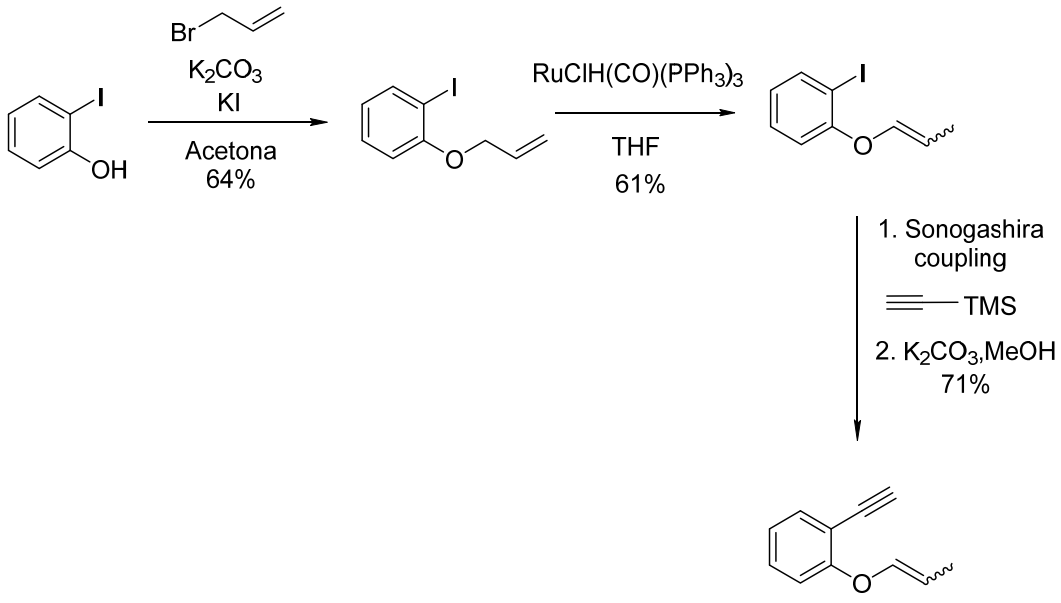
= 13.8, 1.7 Hz, 1H, =CH_2), 4.58 (s, 2H, CH_2O), 4.46 (dd, *J* = 6.1, 1.8 Hz, 1H, =CH_2), 0.94 (s, 9H, $(CH_3)_3C$), 0.18 (s, 6H, $(CH_3)_2Si$) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 157.1 (C), 148.2 (CH), 133.7 (CH), 129.5 (CH), 123.1 (CH), 116.7 (CH), 114.1 (C), 95.4 (CH_2), 92.6 (C), 80.3 (C), 52.4 (CH_2), 25.8 (3xCH_3), 18.3 (C), -5.0 (2xCH_3) ppm. Elemental analysis calcd for $C_{17}H_{24}O_2Si$, C, 70.78; H, 8.39; Si, 9.74 found: C, 70.69; H, 8.30.

1l: 1-(hex-1-yn-1-yl)-2-(vinyloxy)benzene

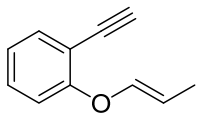


Yellow oil.^1H NMR (400 MHz, $CDCl_3$) δ 7.40 (d, *J* = 7.6 Hz, 1H, Ar), 7.22 (t, *J* = 7.7 Hz, 1H, Ar), 7.02 (t, *J* = 7.5 Hz, 1H, Ar), 6.97 (d, *J* = 8.2 Hz, 1H, Ar), 6.63 (dd, *J* = 13.7, 6.1 Hz, 1H, HC=), 4.73 (d, *J* = 13.7 Hz, 1H, =CH_2), 4.42 (d, *J* = 6.0 Hz, 1H, =CH_2), 2.45 (t, *J* = 7.0 Hz, 2H, ≡C-CH_2), 1.64 – 1.57 (m, 2H, CH_2), 1.53 – 1.46 (m, 2H, CH_2), 0.95 (t, *J* = 7.3 Hz, 3H, CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 156.9 (C), 148.7 (CH), 133.6 (CH), 128.7 (CH), 123.2 (CH), 117.1 (CH), 115.4 (C), 95.5 (C), 94.6 (CH_2), 75.9 (C), 30.7 (CH_2), 21.9 (CH_2), 19.4 (CH_2), 13.6 (CH_3) ppm. Elemental analysis calcd for $C_{14}H_{16}O$: C, 83.96; H, 8.05 found C, 84.01; H, 8.65

Substrate **1i** was synthesized following the protocol described by Y-C Lin *et al.*[3]: starting with 1,2-iodophenol.

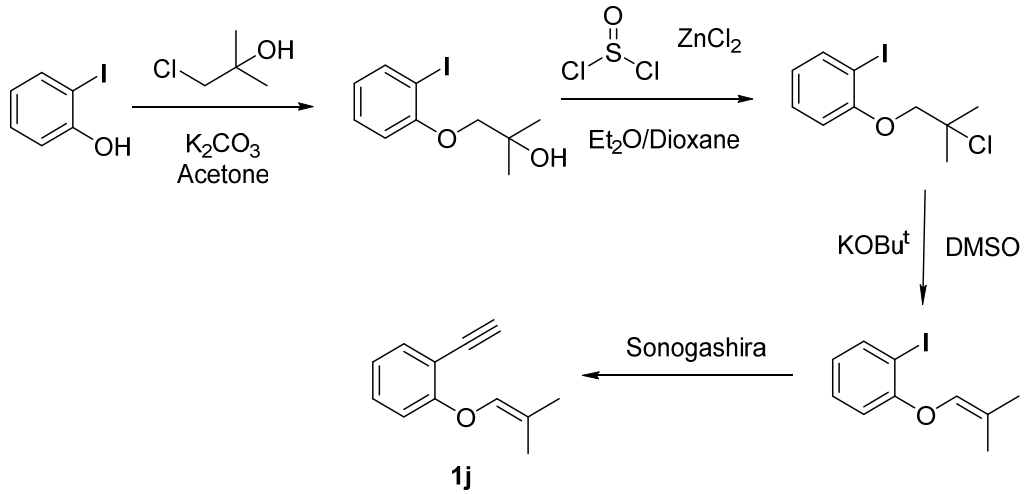


1i: (*E*)-1-ethynyl-2-(prop-1-en-1-yloxy)benzene

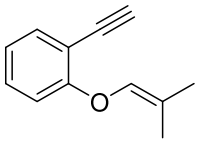


Colorless oil. ^1H RMN (400 MHz, $CDCl_3$) δ 7.48 (dd, *J* = 7.6, 1.7 Hz, 1H, Ar), 7.32 – 7.27 (m, 1H, Ar), 7.01 – 6.95 (m, 2H, Ar), 6.39 (dq, *J* = 5.9, 1.8 Hz, 1H, OHC=), 4.98 (qd, *J* = 6.9, 6.0 Hz, 1H, =C*H*CH_3), 3.29 (s, 1H, ≡CH), 1.75 (dd, *J* = 6.9, 1.8 Hz, 3H, CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.5 (C), 140.4 (CH), 134.1 (CH), 130.1 (CH), 122.0 (CH), 114.6 (CH), 112.2 (C), 109.0 (CH), 81.5 (CH), 79.4 (C), 9.4 (CH_3) ppm. With traces of the *Z* isomer. Data consistent with those reported in the literature.[3]

Substrate **1j** was synthesized following the protocol described by Y-C Lin *et al.*[1] starting with 1,2-iodophenol.

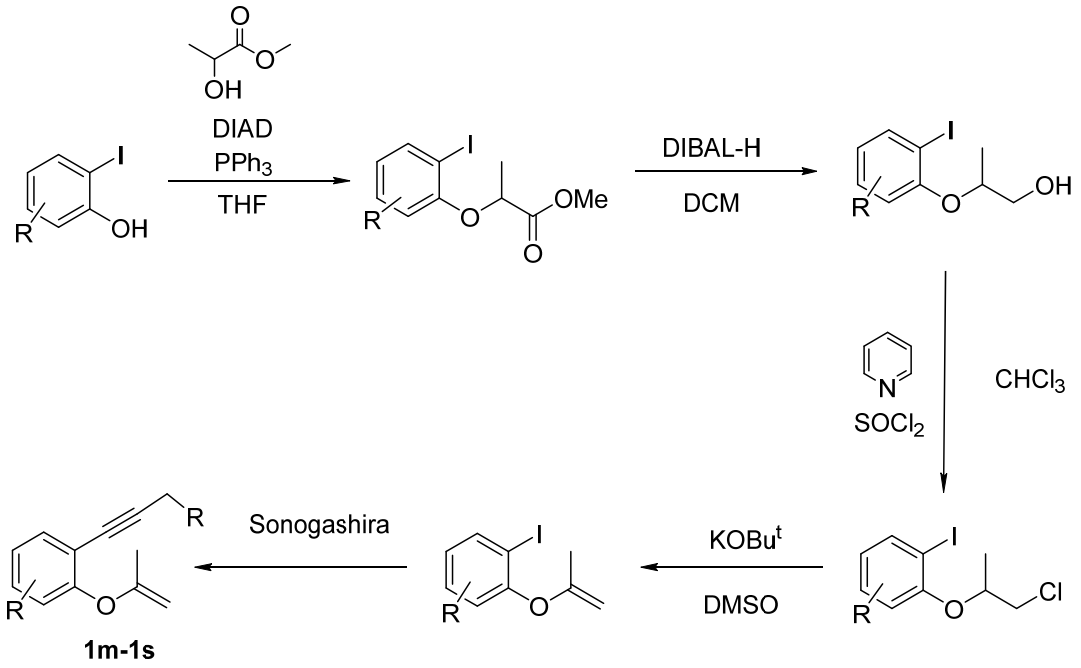


1j: 1-ethynyl-2-((2-methylprop-1-en-1-yl)oxy)benzene

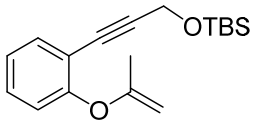


Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, *J* = 7.6 Hz, 1H, Ar), 7.32 – 7.24 (t, *J* = 8.1 Hz, 1H, Ar), 6.97 – 6.93 (m, 2H, Ar), 6.23 (s, 1H, HC=), 3.28 (s, 1H, ≡CH), 1.76 (s, 3H, CH_3), 1.71 (s, 3H, CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.8 (C), 134.6 (CH), 134.1 (CH), 130.0 (CH), 121.5 (CH), 119.5 (C), 114.0 (CH), 111.7 (C), 81.3 (CH), 79.6 (C), 19.4 (CH_3), 15.3 (CH_3) ppm. Elemental analysis calcd for $C_{12}H_{12}O$: C, 83.69; H, 7.02 found: C, 83.75; H, 6.98. Data consistent with those reported in the literature.[3]

Substrates **1m-1s** were synthesized following the protocol described by Y-C Lin *et al.*[3]

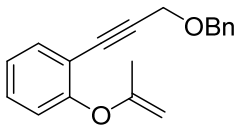


1m: *tert*-butyldimethyl((3-(2-(prop-1-en-2-yloxy)phenyl)prop-2-yn-1-yl)oxy)silane



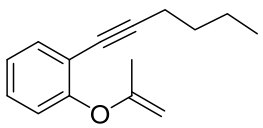
Light yellow oil. ^{1}H RMN (400 MHz, $CDCl_3$) δ 7.45 (d, *J* = 7.5 Hz, 1H, Ar), 7.27 (t, *J* = 7.8 Hz, 1H, Ar), 7.09 – 7.03 (m, 2H, Ar), 4.55 (s, 2H, CH_2O), 4.15 (s, 1H, $=CH_2$), 3.85 (s, 1H, $=CH_2$), 2.02 (s, 3H, CH_3), 0.93 (s, 9H, $(CH_3)_3C$), 0.16 (s, 6H, $(CH_3)_2Si$) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.3 (C), 156.1 (C), 133.6 (CH), 129.4 (CH), 123.9 (CH), 121.2 (CH), 116.5 (C), 92.0 (C), 89.5 (CH_2), 80.4 (C), 52.3 (CH_2), 25.8 (3xCH_3), 20.0 (CH_3), 18.3 (C), -5.1 (2xCH_3) ppm. Elemental analysis calcd for $C_{18}H_{26}O_2Si$: C, 71.47; H, 8.66; Si, 9.28 found: C, 71.40; H, 8.71.

1n: 1-(3-(benzyloxy)prop-1-yn-1-yl)-2-(prop-1-en-2-yloxy)benzene



Colorless oil. ^{1}H RMN (400 MHz, $CDCl_3$) δ 7.48 (dd, *J* = 7.7, 1.6 Hz, 1H, Ar), 7.41 – 7.29 (m, 6H, Ar), 7.12 – 7.05 (m, 2H, Ar), 4.69 (s, 2H, OCH_2Ph), 4.42 (s, 2H, $OCH_2C\equiv$), 4.16 (bs, 1H, $=CH_2$), 3.87 (d, *J* = 1.7 Hz, 1H, $=CH_2$), 2.02 (s, 3H, CH_3) ppm. ^{13}C RMN (101 MHz, $CDCl_3$) δ 159.3 (C), 156.2 (C), 137.6 (C), 133.6 (CH), 129.7 (CH), 128.4 (2xCH), 128.2 (2xCH), 127.8 (CH), 124.1 (CH), 121.3 (CH), 116.3 (C), 89.3 (CH_2), 89.2 (C), 82.3 (C), 71.3 (CH_2), 57.8 (CH_2), 20.0 (CH_3) ppm. Elemental analysis calcd for $C_{19}H_{18}O_2$: C, 81.99; H, 6.52 found: C, 81.92; H, 6.60.

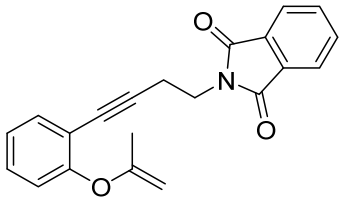
1o: 1-(hex-1-yn-1-yl)-2-(prop-1-en-2-yloxy)benzene



Yellowish oil. ^{1}H RMN (400 MHz, $CDCl_3$) δ 7.41 (dd, *J* = 7.7, 1.7 Hz, 1H, Ar), 7.24 (td, *J* = 7.9, 1.7 Hz 1H, Ar), 7.08 – 7.02 (m, 2H, Ar), 4.10 (bs, 1H, $=CH_2$), 3.78 (d, *J* = 1.7 Hz, 1H, $=CH_2$), 2.43 (t, *J* = 6.9 Hz, 2H, $\equiv CCH_2$), 2.02 (s, 3H, $CH_3C=$), 1.62 – 1.46 (m, 4H, 2xCH_2), 0.94 (t, *J* = 7.2 Hz, 3H,

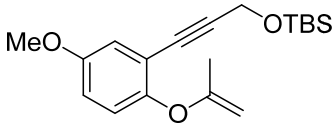
CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.5 (C), 155.8 (C), 133.4 (CH), 128.6 (CH), 124.1 (CH), 121.6 (CH), 117.8 (C), 94.8 (C), 88.2 (CH_2), 76.0 (C), 30.8 (CH_2), 21.9 (CH_2), 20.0 (CH_3), 19.3 (CH_2), 13.6 (CH_3) ppm. Elemental analysis calcd for $C_{15}H_{18}O$: C 84.07; H, 8.47 found: C, 83.99; H, 8.52.

1p: 2-(4-(2-(prop-1-en-2-yloxy)phenyl)but-3-yn-1-yl)isoindoline-1,3-dione



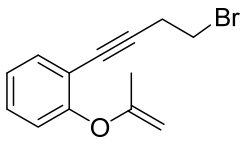
Yellowish solid (quicky decomposes at rt). M. p.: 142-144 °C. ^1H RMN (400 MHz, $CDCl_3$) δ 7.88 – 7.83 (m, 2H, Ar), 7.74 – 7.69 (m, 2H, Ar), 7.37 (dd, *J* = 7.7, 1.7 Hz, 1H, Ar), 7.23 (td, *J* = 7.7, 1.7 Hz, 1H, Ar), 7.04 (td, *J* = 7.6, 1.2 Hz, 1H, Ar), 6.99 (dd, *J* = 8.1, 1.2 Hz, 1H, Ar), 4.02 (bs, 1H, =CH_2), 3.96 (t, *J* = 7.2 Hz, 2H, CH_2N), 3.76 (d, *J* = 1.7 Hz, 1H, =CH_2), 2.85 (t, *J* = 7.2 Hz, 2H, ≡CCH_2), 1.94 (s, 3H, CH_3) ppm. ^{13}C RMN (101 MHz, $CDCl_3$) δ 168.0 (2xC), 159.2 (C), 155.9 (C), 134.0 (2xCH), 133.6 (CH), 132.1 (2xC), 129.0 (CH), 124.0 (CH), 123.3 (2xCH), 121.1 (CH), 116.8 (C), 89.9 (C), 89.1 (CH_2), 77.9 (C), 36.8 (CH_2), 19.9 (CH_2), 19.6 (CH_3) ppm. Elemental analysis calcd for $C_{21}H_{17}NO_3$: C, 76.12; H, 5.17; N, 4.23 found: C, 76.07; H, 5.21; N, 4.17.

1q*: tert*-butyl((3-(5-methoxy-2-(prop-1-en-2-yloxy)phenyl)prop-2-yn-1-yl)oxy)dimethylsilane



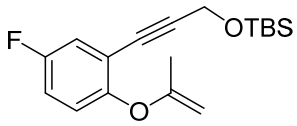
Yellow oil. ^1H NMR (400 MHz, $CDCl_3$) δ 6.96 (d, *J* = 3.4 Hz, 1H, Ar), 6.95 (d, *J* = 8.8 Hz, 1H, Ar), 6.84 (dd, *J* = 8.9, 3.1 Hz, 1H, Ar), 4.54 (s, 2H, CH_2O), 4.04 (bs, 1H, =CH_2), 3.78 (s, 3H, CH_3O), 3.72 (d, *J* = 1.8 Hz, 1H, =CH_2), 2.00 (s, 3H, CH_3), 0.93 (s, 9H, $(CH_3)_3C$), 0.16 (s, 6H, 2xCH_3Si) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.1 (C), 155.8 (C), 149.7 (C), 122.8 (CH), 117.5 (CH), 117.3 (C), 115.8 (CH), 91.8 (C), 87.5 (CH_2), 80.3 (C), 55.6 (CH_3), 52.3 (CH_2), 25.8 (3xCH_3), 20.1 (CH_3), 18.3 (C), -5.1 (2xCH_3) ppm. Elemental analysis calcd for $C_{19}H_{28}O_3Si$: C, 68.63; H, 8.49; Si, 8.45 found: C, 68.59; H, 8.52.

1r: 1-(4-bromobut-1-yn-1-yl)-2-(prop-1-en-2-yloxy)benzene



Colorless oil. ^1H RMN (400 MHz, $CDCl_3$) δ 7.43 (dd, *J* = 7.7, 1.7 Hz, 1H, Ar), 7.28 (dt, *J* = 7.7, 1.7 Hz, 1H, Ar), 7.08 (td, *J* = 7.5, 1.2 Hz, 1H, Ar), 7.04 (dd, *J* = 8.2, 1.2 Hz, 1H, Ar), 4.13 (bs, 1H, =CH_2), 3.82 (d, *J* = 1.7 Hz, 1H, =CH_2), 3.52 (t, *J* = 7.4 Hz, 2H, CH_2Br), 3.00 (t, *J* = 7.4 Hz, 2H, ≡CCH_2), 2.03 (s, 3H, CH_3) ppm. ^{13}C RMN (101 MHz, $CDCl_3$) δ 159.3 (C), 156.0 (C), 133.6 (CH), 129.3 (CH), 124.1 (CH), 121.4 (CH), 116.7 (C), 90.7 (C), 88.9 (CH_2), 78.0 (C), 29.4 (CH_3), 24.1 (CH_2), 20.0 (CH_2) ppm. Elemental analysis calcd for $C_{13}H_{13}BrO$: C, 58.89; H, 4.94; Br, 30.14 found: C, 58.93; H, 4.88.

1s: *tert*-butyl((3-(5-fluoro-2-(prop-1-en-2-yloxy)phenyl)prop-2-yn-1-yl)oxy)dimethylsilane



Yellowish oil. ^{1}H RMN (400 MHz, $CDCl_3$) δ 7.14 – 7.11 (m, 1H, Ar), 7.00 – 6.98 (m, 2H, 2xAr), 4.54 (s, 2H, CH_2O), 4.11 (bs, 1H, $=CH_2$), 3.77 (d, *J* = 1.9 Hz, 1H, $=CH_2$), 2.01 (s, 3H, CH_3), 0.93 (s, 9H, $(CH_3)_3C$), 0.15 (s, 6H, $(CH_3)_2Si$) ppm.^{13}C NMR (101 MHz, $CDCl_3$) δ 159.7 (C), 158.6 (d, *J* = 243.2 Hz, C), 152.1 (d, *J* = 2.8 Hz, C), 122.9 (d, *J* = 8.9 Hz, CH), 119.7 (d, *J* = 24.3 Hz, CH), 118.1 (d, *J* = 10.1 Hz, C), 116.4 (d, *J* = 23.2 Hz, CH), 93.0 (C), 88.6 (CH_2), 79.3 (d, *J* = 2.9 Hz, C), 52.2 (CH_2), 25.8 ($3xCH_3$), 20.0 (CH_3), 18.3 (C), -5.1 ($2xCH_3$) ppm. Elemental analysis calcd for $C_{18}H_{25}FO_2Si$: C, 67.46; H, 7.86; F, 5.93; Si, 8.76 found: C, 67.50; H, 7.92.

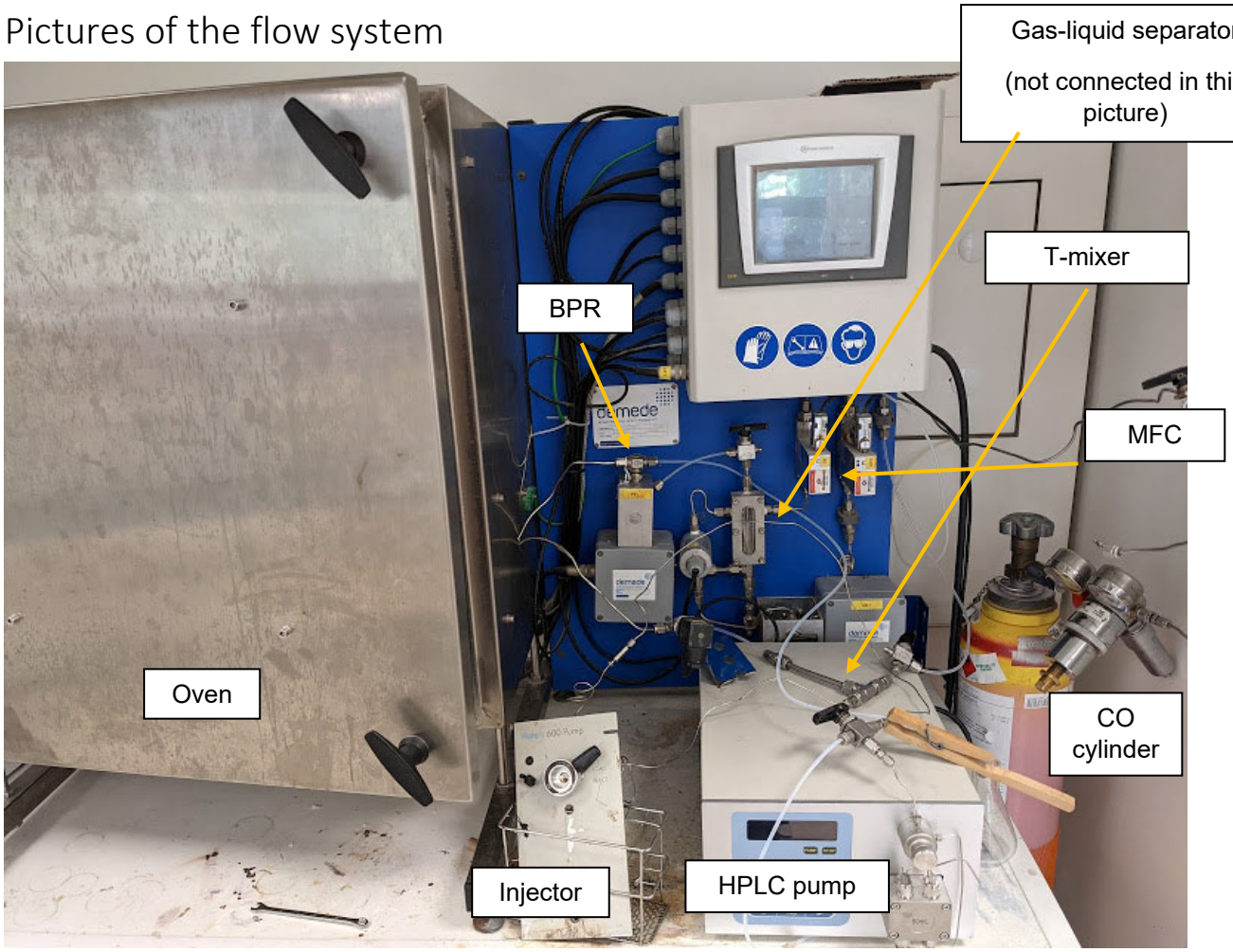
References

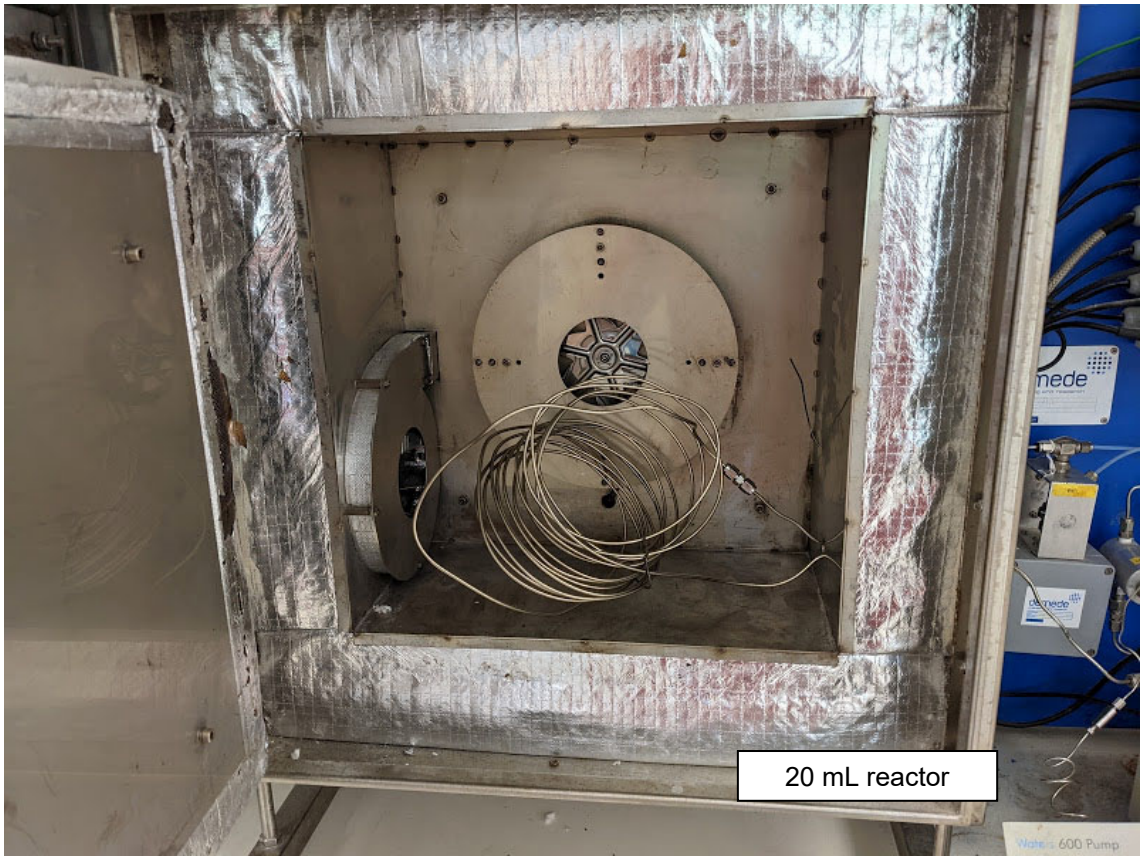
1 J. Garcia-Lacuna, G. Dominguez, J. Blanco-Urgoiti and J. Perez-Castells, *Chem. Commun.,* 2017, **53**, 4014.

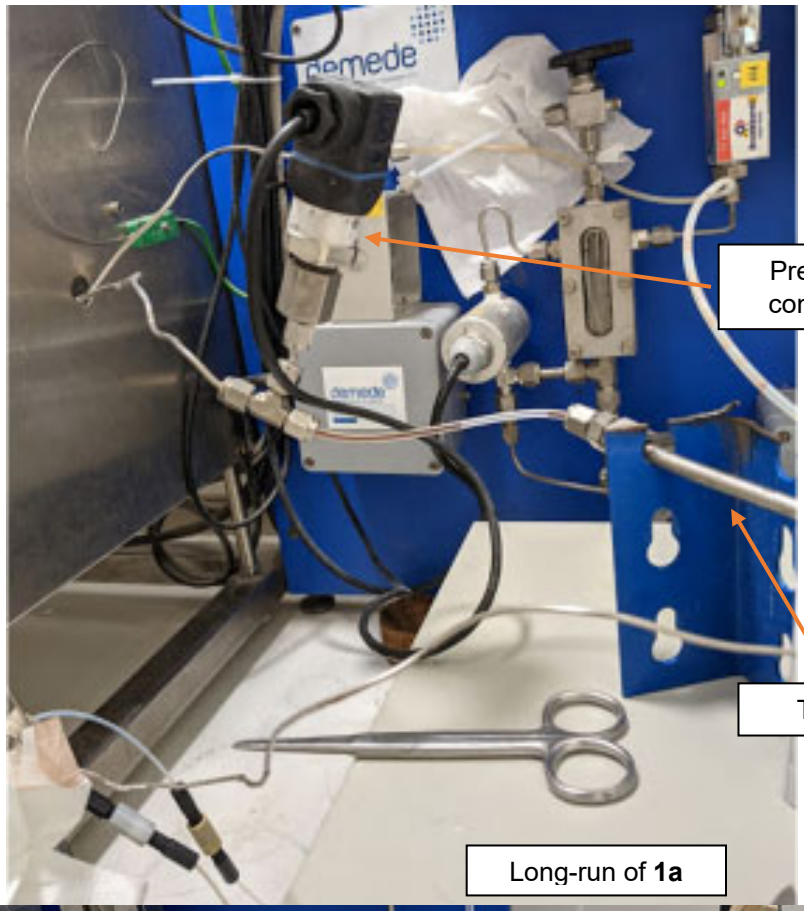
2 A. Cabré, X. Verdaguer and A. Riera, *Synthesis,* 2017, **49**, 3945

3 C. Chen, Y. Lai, R. Wu, Y. Liu and Y. Lin, *ChemCatChem,* 2016, **8**, 2193.

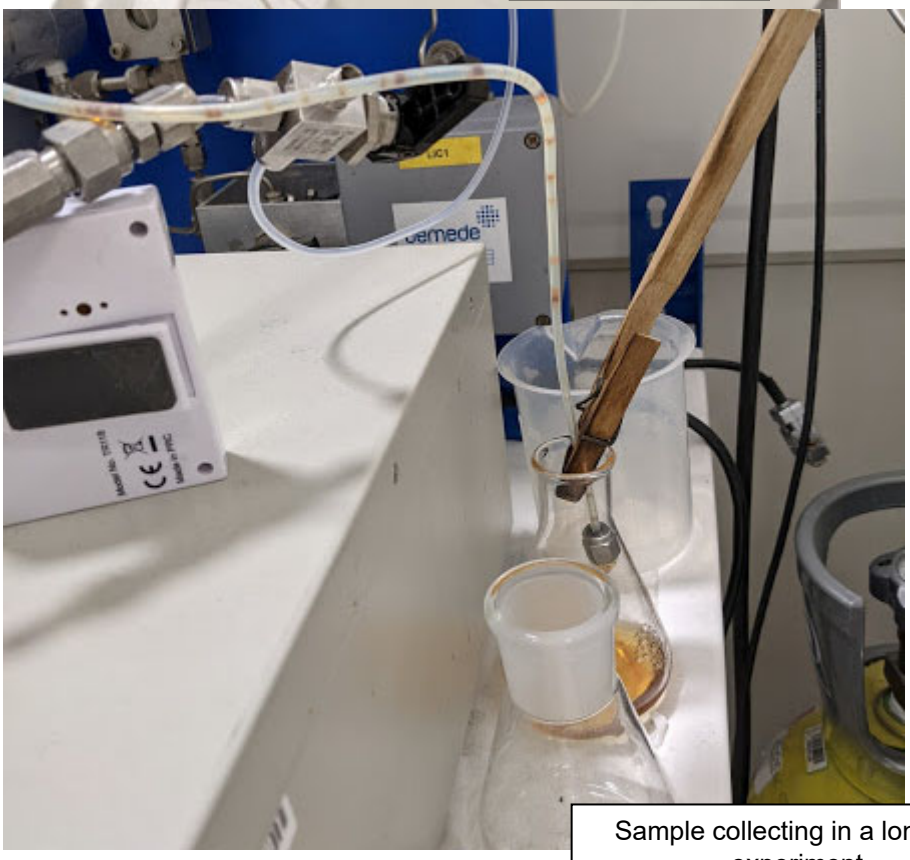
Pictures of the flow system



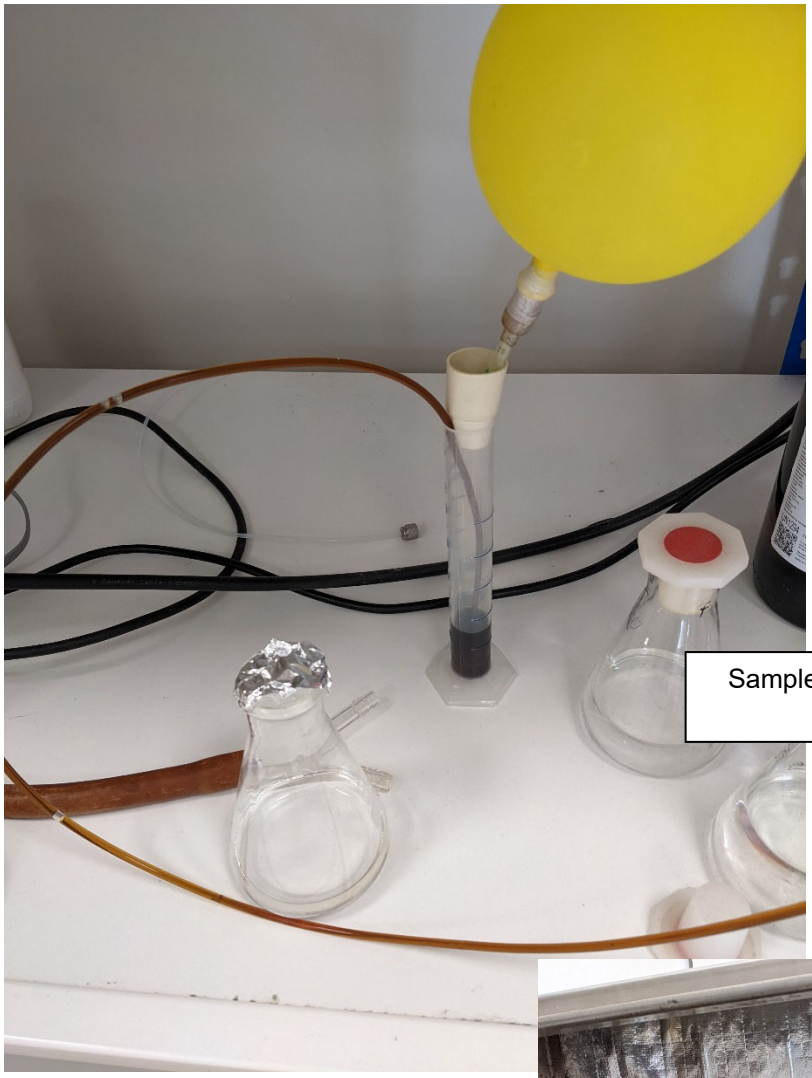




Long-run of **1a**



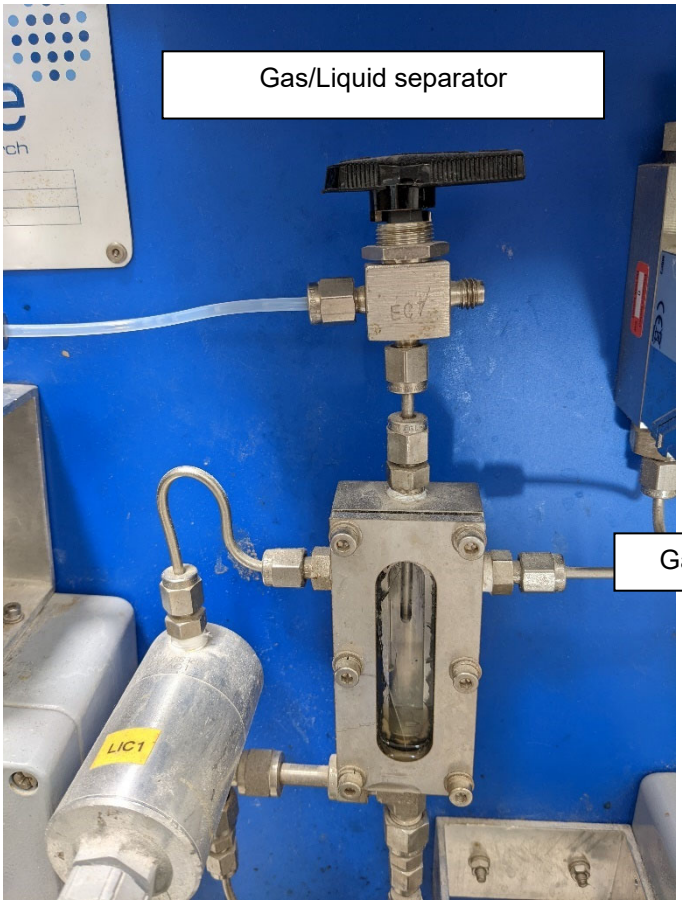
Sample collecting in a long-run experiment



Sample in the pump inlet in the long run of **1a**

60 mL reactor

Injector with a 0.8 mL loop



Gas/Liquid separator

Gas outlet

Liquid outlet