Supporting Information for

Improved Catalytic Performance by Changing Surface and Textural Properties of Ru Supported Bifunctional Periodic Mesoporous Organosilicas in the Aerobic Oxidation of Alcohols

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Mterials and Methods

General Information

The transmission electron microscopy (TEM) images were taken on FEI Tecnai Spirit microscope operated at an accelerating voltage of 150 kV. Textural properties were obtained using a Belsorp analyser (BELMAX, Japan) at 77 K. The samples were degassed at 373 K for 5 h, prior to the N_2 adsorption-desorption analysis. Specific surface areas were evaluated from the relative pressure range of 0.05-0.15 by Brunauer–Emmett–Teller (BET) method. Pore size distribution (PSD) of the samples was calculated from the adsorption branch using the Barrett–Joyner–Halenda (BJH) method. Total pore volumes were determined using the adsorbed volume at $P/P_0 \approx 0.995$. Solid-state magic-angle spinning (MAS) nuclear magnetic resonance (NMR) spectra were collected on a Bruker 400 MHz Avance FT-NMR spectrometer with the MAS speed of 13 kHz. Cross-polarization (CP) technique was used for both ^{13}C and ^{29}Si spectra, which were referenced to tetramethylsilane. XPS spectra of the samples were recorded on the Kratos Analytical X-ray photoelectron spectrometer. Thermogravimetric analysis was performed using a NETZSCH STA 409 PC/PG instrument (Germany) at scan rates of 10 $K.min^{-1}$ from 25 to 800 ˚C under both N_2 and O_2 atmospheres. The nitrogen content of the materials was determined using elemental analysis (C, H, N) by the Vario-EL CHNS instrument. The fourier transform infrared (FTIR) spectra of the prepared BFPMOs were recorded on a Bruker-Vector 22 FTIR spectrometer in the range of 400 and 4000 cm^{-1}, and the samples were prepared by the KBr pellet method. The oxidation products were analyzed using a Varian CP-3800 gas chromatograph (GC) equipped with a capillary column [Teknokroma Meta. BLOOD 2 (30 m × 0.53 mm × 2.0 μm)] and a flame-ionization detector (FID).

Materials

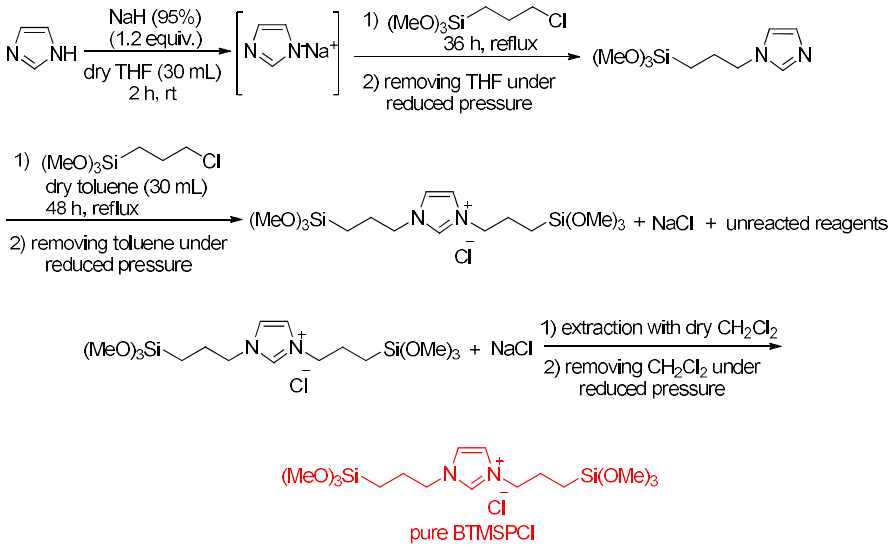
Sodium hydride (NaH 95%), Pluronic P123 ($EO_{20}PO_{70}EO_{20}$ (EO = ethylene oxide, PO = propylene oxide), average M_n = 5800) 1,4-bis(triethoxysilyl)benzene (BTEB), 1,4-bis(trimethoxysilyl)ethane (BTME), and tetramethoxyorthosilicate (TMOS) were purchased from Sigma-Aldrich Company. Potassium perruthenate ($KRuO_4$), imidazole and (3-chloropropyl)trimethoxysilane (CPTMS) were purchased from Acros Company. Potassium chloride (KCl) and conc. HCl (37%) were obtained from Merck Company. Imidazole was re-crystallized in distilled CH_2Cl_2 and dried under vacuum for 3 days at room temperature. All the reagents were used without further purification.

Synthesis of 1,3-bis(trimethoxysilylpropyl)imidazolium chloride (BTMSPCl)

The ionic liquid precursor (BTMSPCl) was prepared according to the procedure used in our previous reports.[1, 2] Typically, a suspension of sodium imidazolide in dry THF was prepared through the direct reaction of freshly dried imidazole (2 g) and NaH 95% (0.77 g) in a flame-dried two-neck flask containing dry THF (60 mL) under an argon atmosphere. CPTMS (5.4 mL) was added to the above suspension and the resulting mixture was refluxed for 30 h. The reaction mixture was allowed to cool at room temperature and then the solvent was removed under a reduced pressure condition until an oily mixture containing NaCl was obtained. In the second part, (3-chloropropyl)trimethoxysilane (5.4 mL) and dry toluene (60 mL) were added to the oily mixture, and then the reaction flask was placed under the reflux condition for 48 h. The toluene phase was separated from the resulting two-phasic mixture, and then dry CH_2Cl_2 (60 mL) was added into the flask to take out the precipitated NaCl. In the next step, the CH_2Cl_2 phase was transferred to the well-dried two-neck flask, and volatiles were removed under reduced pressure. Finally, the ionic liquid (BTMSPCl) was

washed with dry toluene (5×50 mL) to remove the unreacted starting materials and obtain pure BTMSPCl.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 0.47 (br, 4H) 1.84 (m, 4H) 3.37 (s, 18H), 4.21 (br, 4H), 7.41 (s, 2H), 10.46 (s, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 5.8, 24.0, 50.5, 51.5, 122.0, 137.1. Hz).



Scheme S1. Synthesis of 1,3-bis(trimethoxysilylpropyl) imidazolium chloride (BTMSPCl)

Synthesis of BFPMO Materials

The plugged BFPMO materials (comprising 15% phenylene or ethylene bridge and 10% ionic liquid) were synthesized according to the procedure previously reported in our research group.[1] In a typical method, the Pluronic P123 (2.0 g) template was dissolved in a solution of H_2O (12.20 g) and HCl (2 M, 49.53 g). After three hours, KCl (10.23 g) was added to the reaction flask, and the mixture was kept under stirring until a homogenous solution was obtained. A pre-mixture of TMOS (15.00 mmol, 2.65 g), BTMSPCl (2.00 mmol, 1.0 g) and the organic bridge (BTEB (3.00 mmol, 1.40 g) or BTME (3.00 mmol, 0.943 g)) in dry methanol was added to the obtained solution, and then the reaction was stirred at 40 ˚C for 24 h. The resulting mixture was heated under static condition at 100 ˚C for 72 h. The obtained white solid was collected by vacuum filtration and then washed with a solution of ethanol and

conc. HCl (100:3 volume ratios) using a Soxhlet apparatus for 48 h to remove the surfactant. Finally, the BFPMO product was dried at 60 ˚C overnight.

For the synthesis of unplugged BFPMO materials, the organosilica and silica precursors were added to the reaction flask in two steps; so that in the first step, BTMSPCl and BTEB (or BTME) were added to the reaction flask, and the resulting mixture was stirred for at least 15 minutes. In the second step, TMOS was added to the mixture, and stirring was continued at 40 ˚C for 24 h. The structure of these materials was thoroughly characterized using various analyses.

Preparation of Ru@U-Ph15 Catalyst

For the preparation of the Ru@U-Ph15 catalyst, the unplugged BFPMO material containing phenyl and imidazolium bridges (0.5 g, 0.464 mmol.g^{-1} ILs) was dispersed in deionized water (10 mL) and sonicated for at least 30 min. Then, $KRuO_4$ (0.016 g, 0.08 mmol), dissolved in deionized water (20 mL), was slowly added to the above suspension and vigorously stirred at room temperature for 24 h. Finally, the suspension was filtered and washed with deionized water (3×10 mL) and acetone (2×10 mL). The resulting gray powder was dried in an oven at 70 ˚C overnight. The exact loading amount of Ru species was calculated by ICP-AES analysis (0.192 mmol.g^{-1}).

General Procedure for the Oxidation of Alcohols

In a 5 mL two-necked round-bottom flask equipped with a magnetic stir bar and condenser alcohol substrate (0.25 mmol), **Ru@U-Ph-15 (19.5 mg, 1.5 mol% of Ru**) and toluene (1 mL) were added. The top of condenser was sealed tightly with a rubber septum. The reaction vessel was evacuated and re-filled three times with oxygen and finally a balloon filled with

pure oxygen (622 torr) was attached to the top of condenser. The reaction mixture was stirred at 90 ˚C for the indicated reaction time (see Table 5 of the manuscript). After completion of the reaction, **the catalyst was separated by centrifugation** and the catalyst was washed several times with toluene and ethyl acetate to ensure the extraction of any substrate and corresponding product that may be trapped into the channels of the catalyst. The reaction solution was then filtered using a 0.45 μm syringe filter (Sartorius Minisart RC,) and analyzed by GC without any further purification.

General Procedure for the Recyclability of Ru@U-Ph15 in the Aerobic Oxidation of Benzyl alcohol

To a test tube equipped with a condenser, **benzyl alcohol (108 mg, 1mmol), Ru@U-Ph-15** (**78 mg, 1.5 mol% of Ru)** and toluene (4 mL) were added. Top of the condenser was sealed tightly with a rubber septum. The reaction vessel was evacuated three times and refilled with oxygen and finally a balloon filled with pure oxygen (622 torr) was attached to the top of the condenser. The reaction mixture was stirred at 90 ˚C for 3 hours. The yield of the reaction was evaluated by GC analysis. The Ru@U-Ph15 catalyst was then **separated by centrifugation,** washed several times with toluene and ethyl acetate, and dried in an oven at 70 ˚C. For the next runs, the recovered catalyst was weighed and appropriate amounts of benzyl alcohol and toluene (proportionate to the above amounts) were added to the test tube. The oxidation reactions for the next cycles were repeated following the same procedure as described above. The reaction time for all cycles was **3 hours, which was the optimal time for complete oxidation of benzyl alcohol to benzaldehyde according to the data in Table 4** in the manuscript.

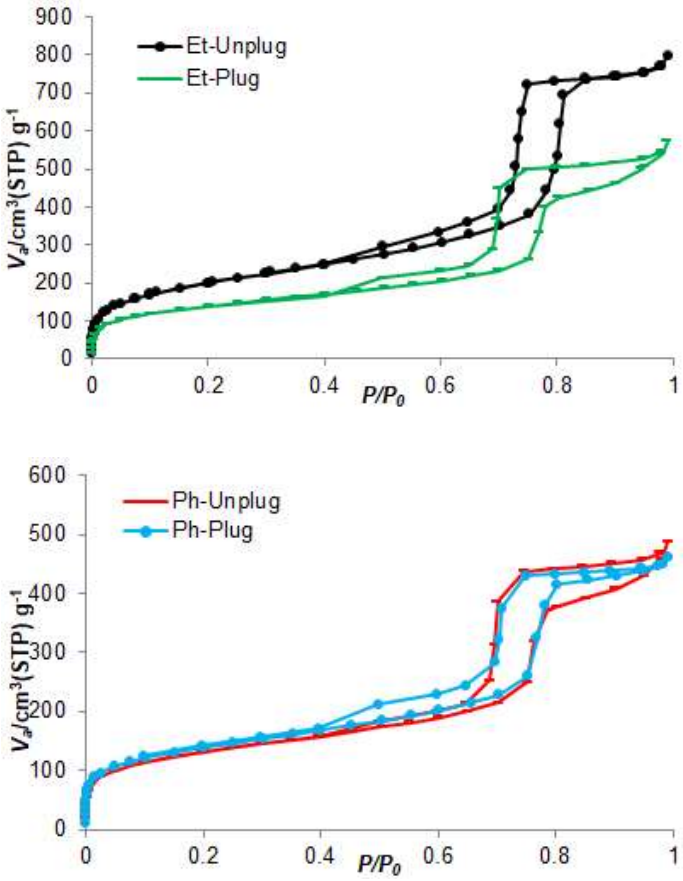


Figure S1. Nitrogen adsorption-desorption isotherms of the BFPMO materials

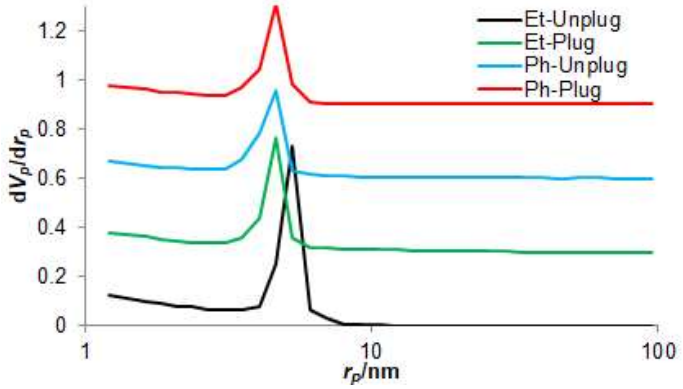


Figure S2. BJH-Plots of the BFPMO materials

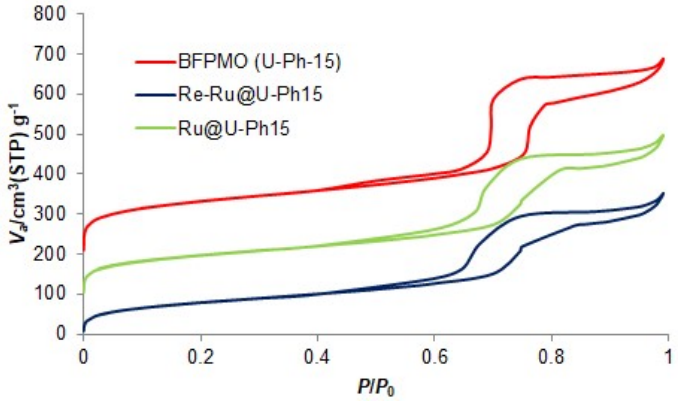


Figure S3. Nitrogen adsorption-desorption isotherms of the BFPMO (U-Ph15), Ru@U-Ph15 and Re-Ru@U-Ph15 materials

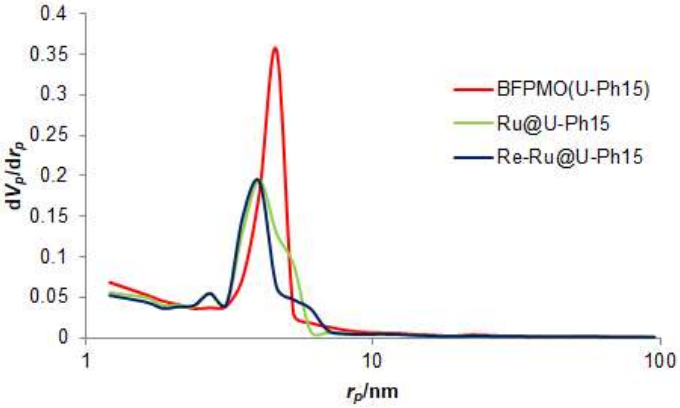


Figure S4. BJH-Plots of the BFPMO (U-Ph15), Ru@U-Ph15 and Re-Ru@U-Ph15 materials

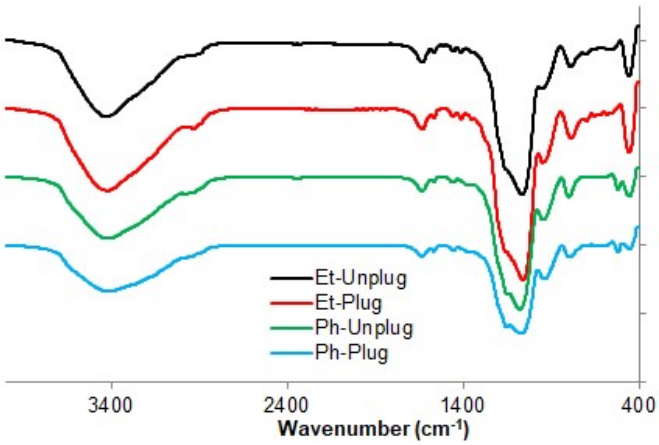


Figure S5. FTIR spectra of the BFPMO materials

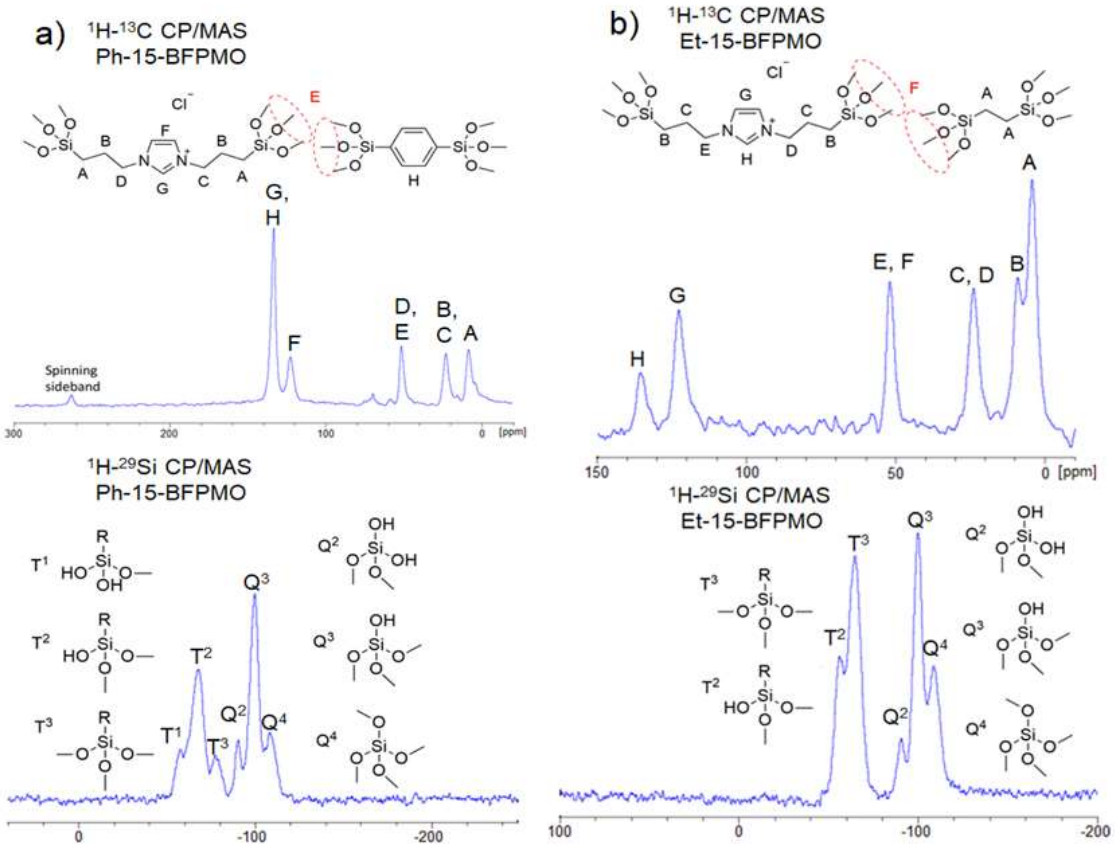


Figure S6. ^{13}C and ^{29}Si CP/MAS NMR spectra of a) Ph-15- and b) Et-15-BFPMO

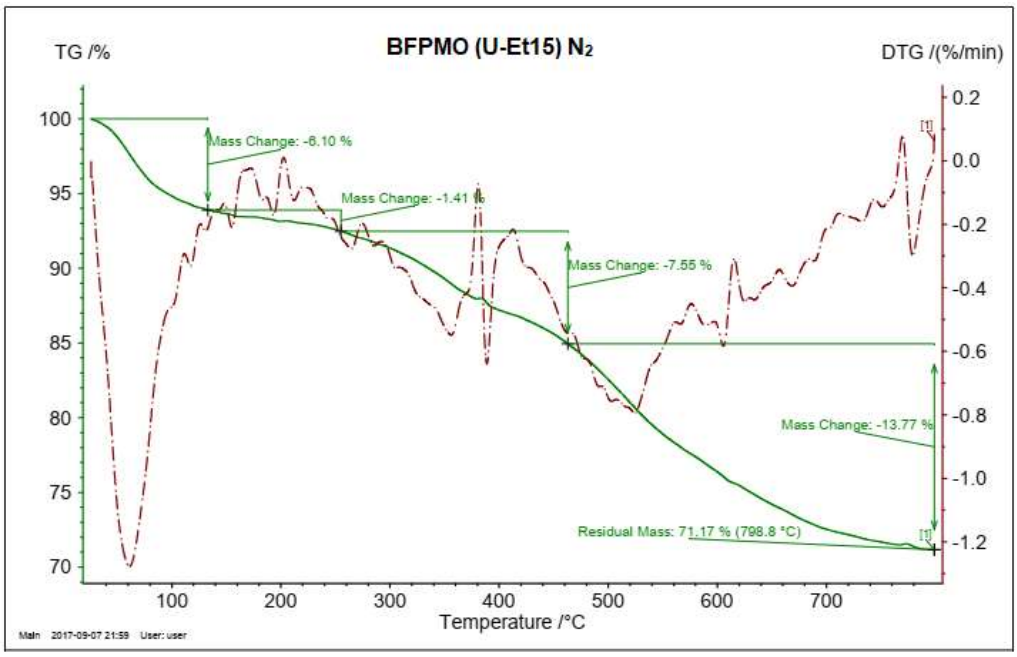


Figure S7. Thermogravimetric analysis curve of the BFPMO (U-Et15) material under the nitrogen atmosphere

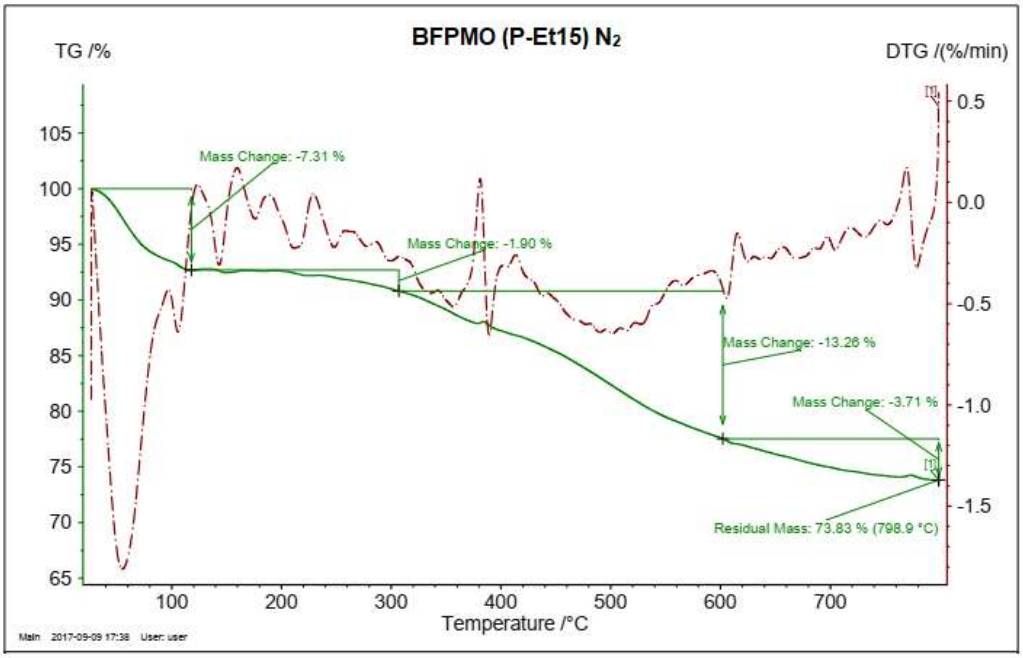


Figure S8. Thermogravimetric analysis curve of the BFPMO (P-Et15) material under the nitrogen atmosphere

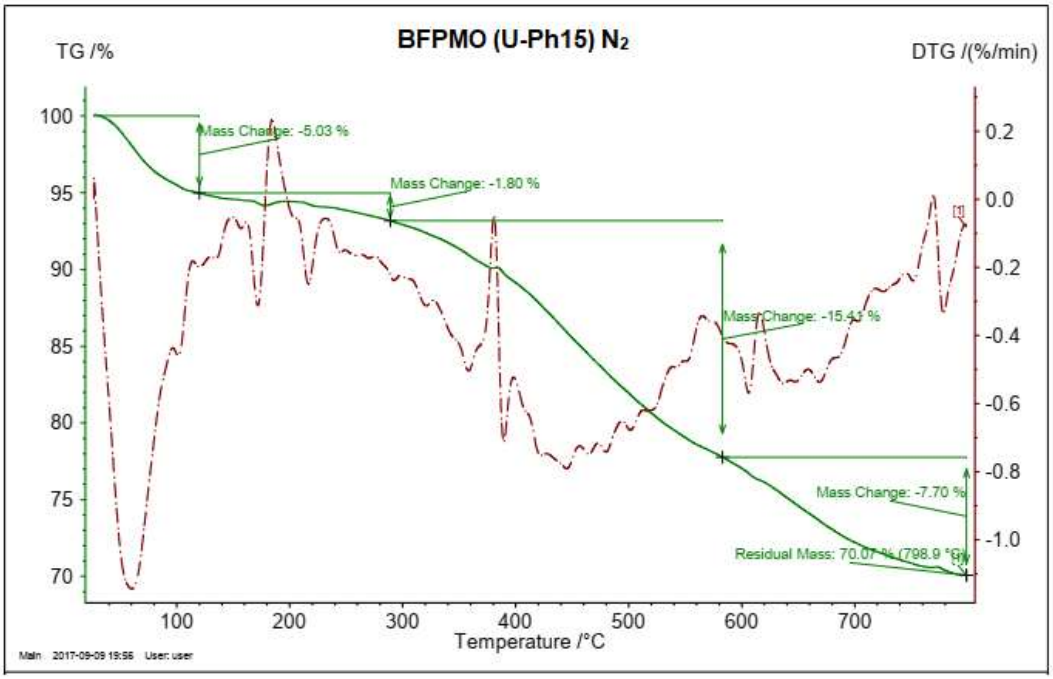


Figure S9. Thermogravimetric analysis curve of the BFPMO (U-Ph15) material under the nitrogen atmosphere

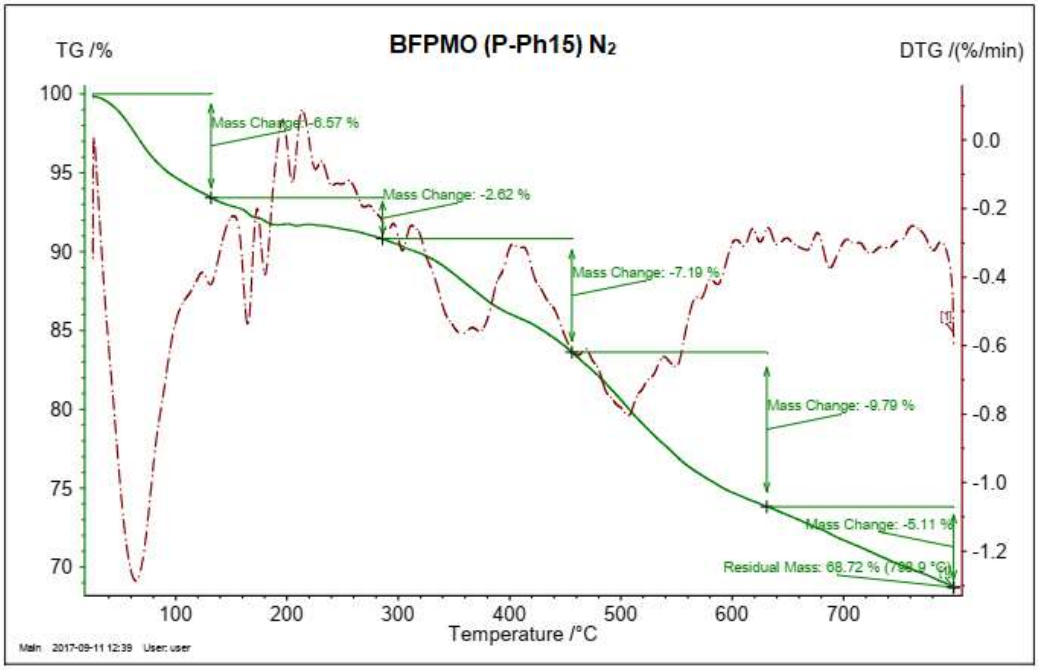


Figure S10. Thermogravimetric analysis curve of the BFPMO (P-Ph15) material under the nitrogen atmosphere

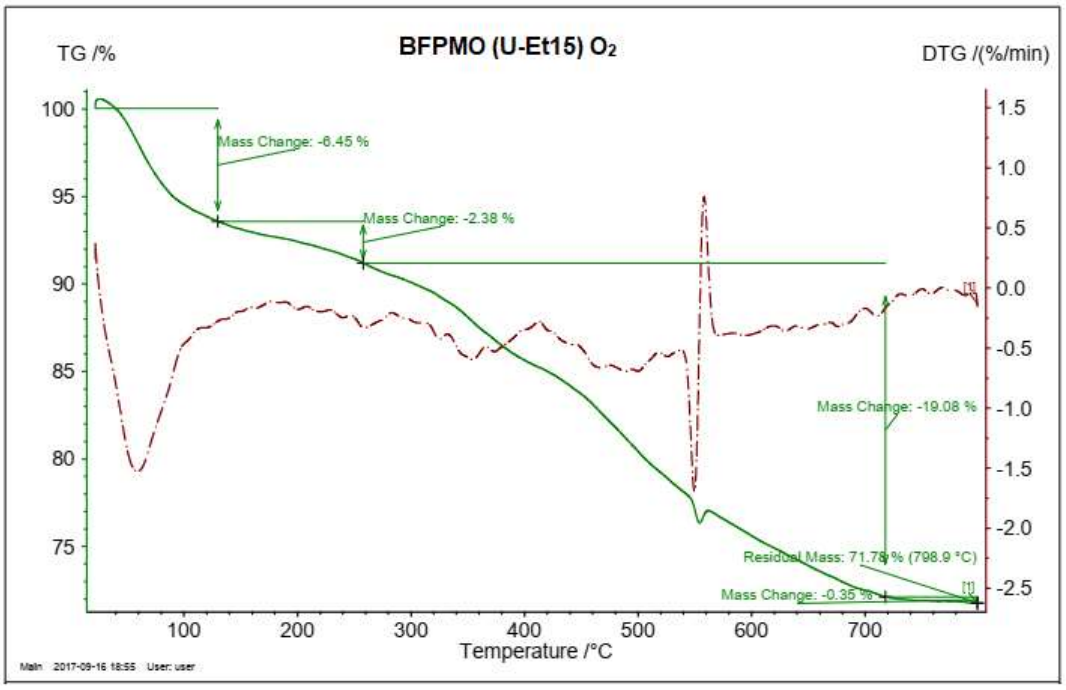


Figure S 11. Thermogravimetric analysis curve of the BFPMO (U-Et15) material under the oxygen atmosphere

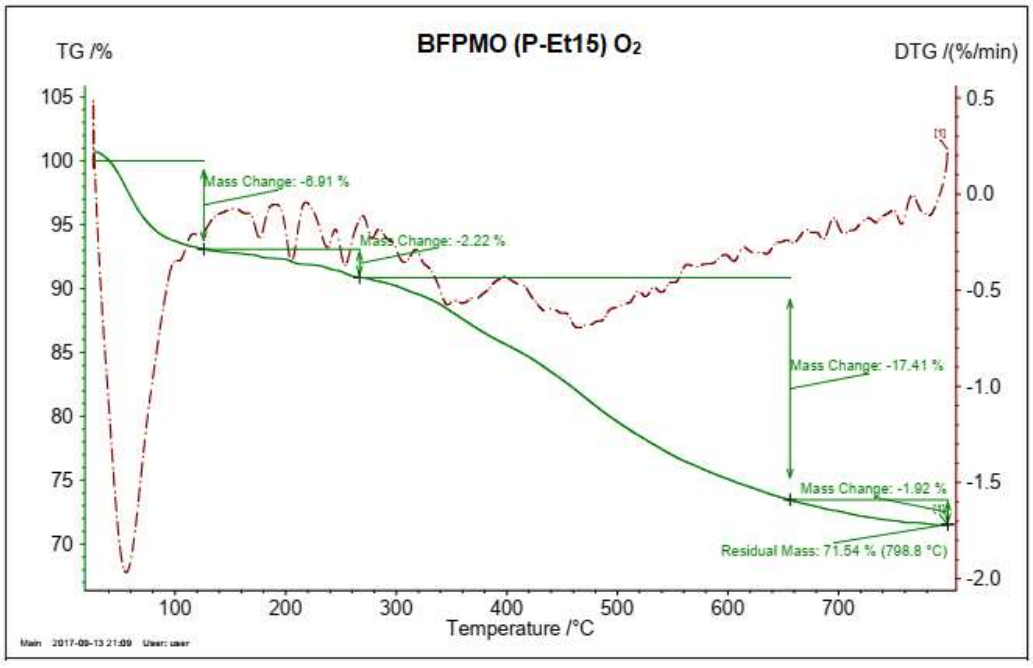


Figure S12. Thermogravimetric analysis curve of the BFPMO (P-Et15) material under the oxygen atmosphere

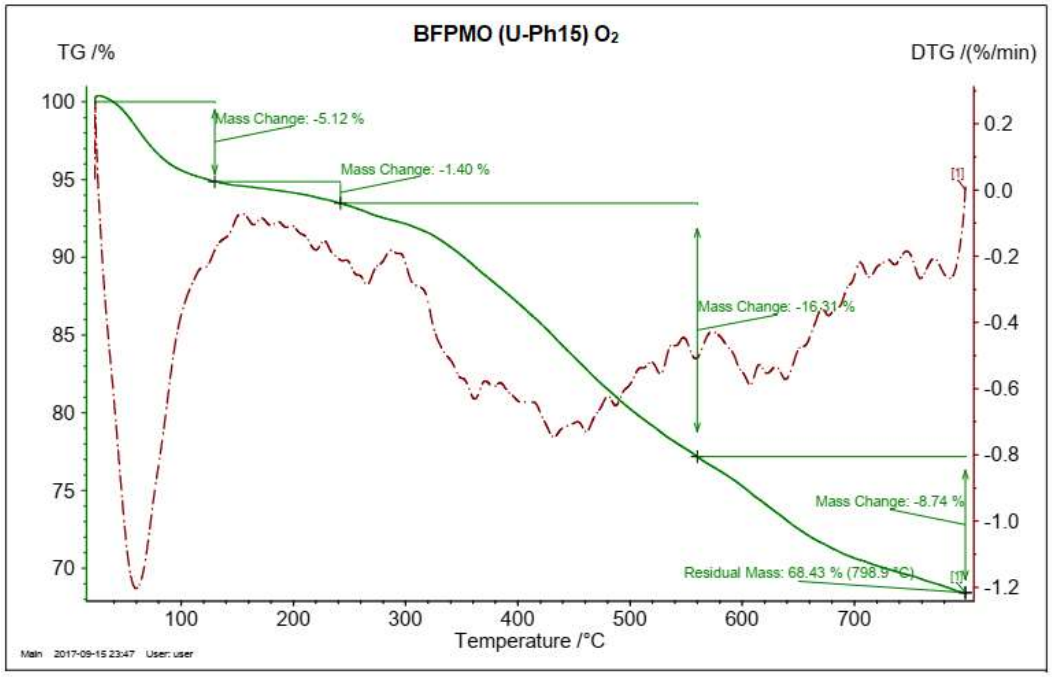


Figure S13. Thermogravimetric analysis curve of the BFPMO (U-Ph15) material under the oxygen atmosphere

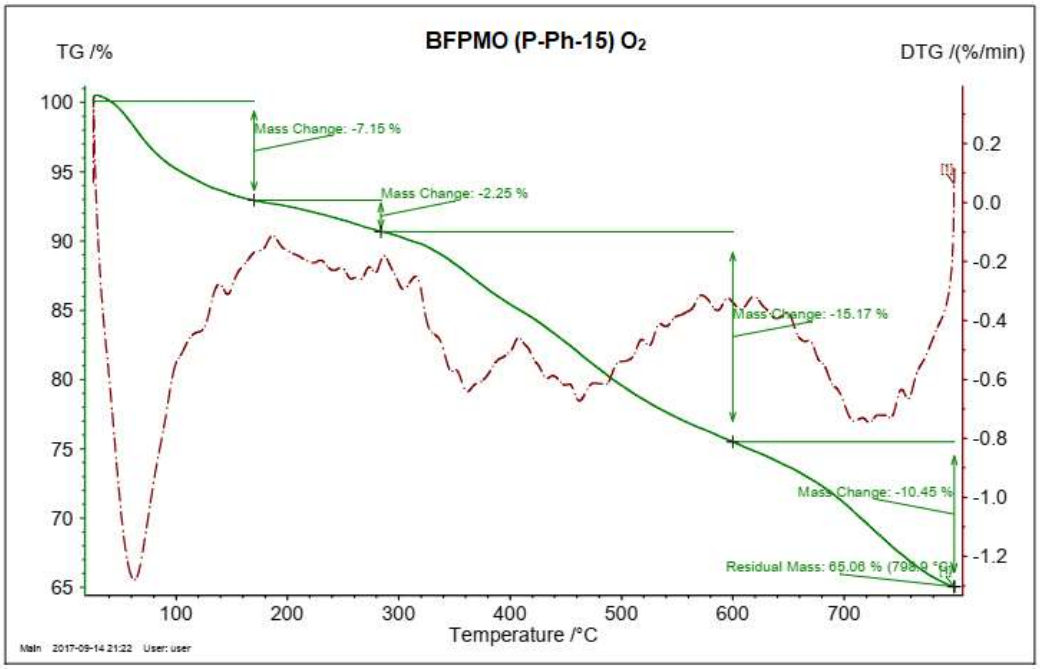


Figure S14. Thermogravimetric analysis curve of the BFPMO (P-Ph15) material under the oxygen atmosphere

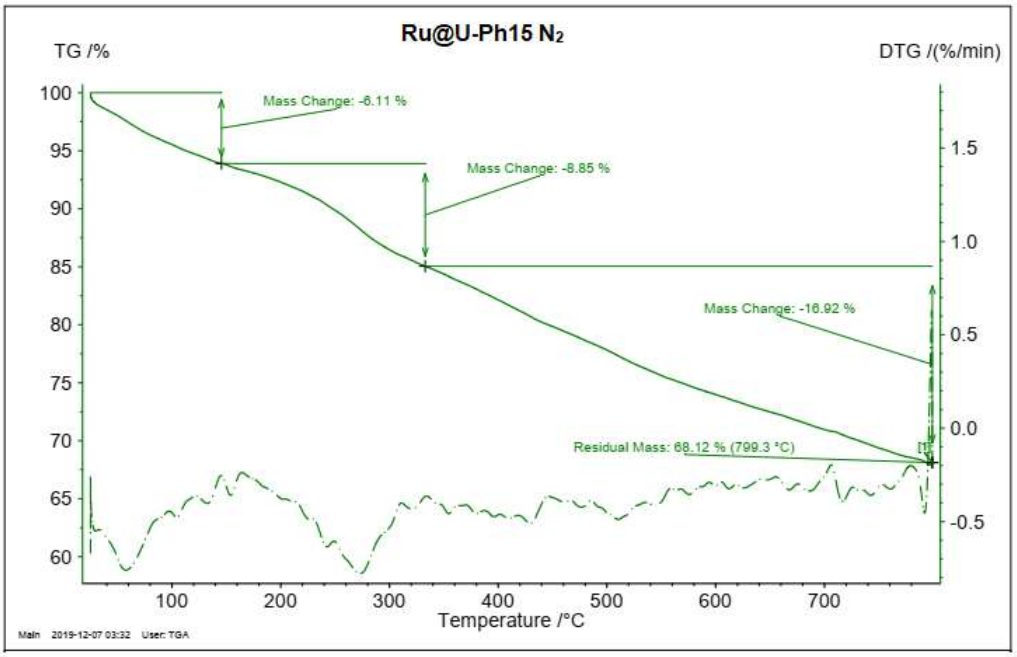


Figure S15. Thermogravimetric analysis curve of the Ru@U-Ph15 material under the nitrogen atmosphere

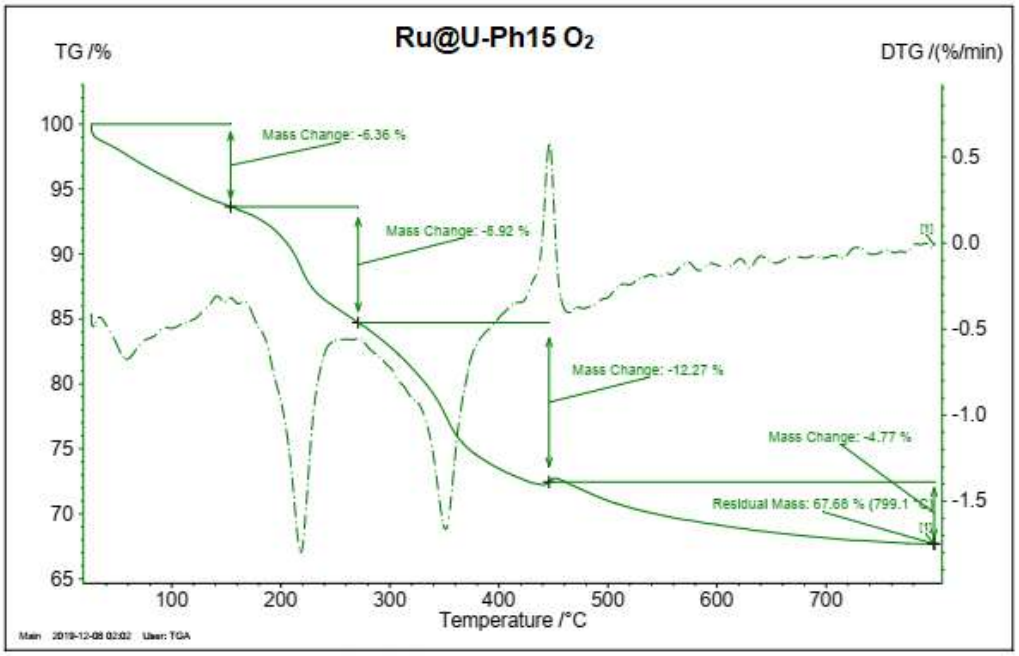


Figure S16. Thermogravimetric analysis curve of the Ru@U-Ph15 material under the oxygen atmosphere

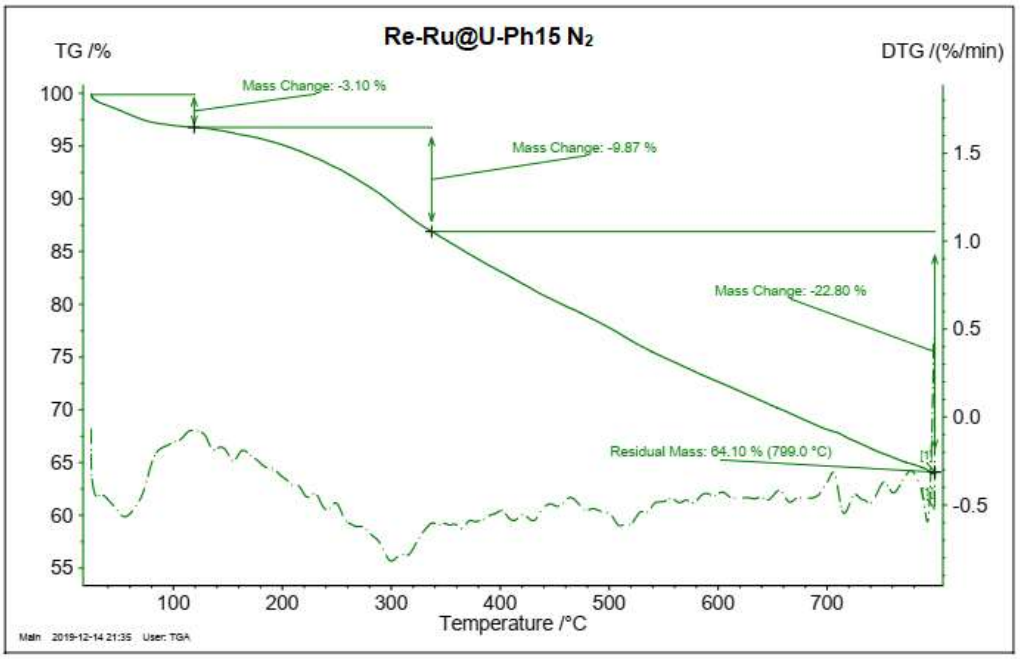


Figure S17. Thermogravimetric analysis curve of the recovered Ru@U-Ph15 material under the nitrogen atmosphere

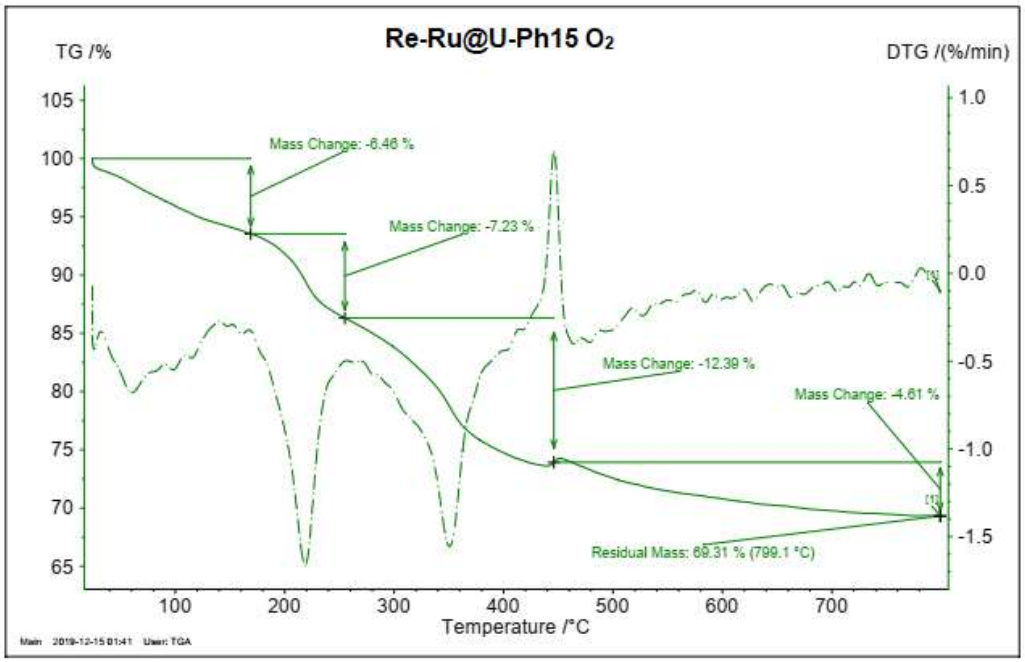


Figure S18. Thermogravimetric analysis curve of the recovered Ru@U-Ph15 material under the oxygen atmosphere

Table S1. Ru loading of Ru@BFPMOs obtained by ICP-AES

Materials	Concentration of Ru (ppm)	mmol.g^{-1} (Ru)
Ru@U-Et15	9.26	0.2292
Ru@P-Et15	7.01	0.1735
Ru@U-Ph15	7.77	0.1923
Ru@P-Ph15	6.96	0.1722

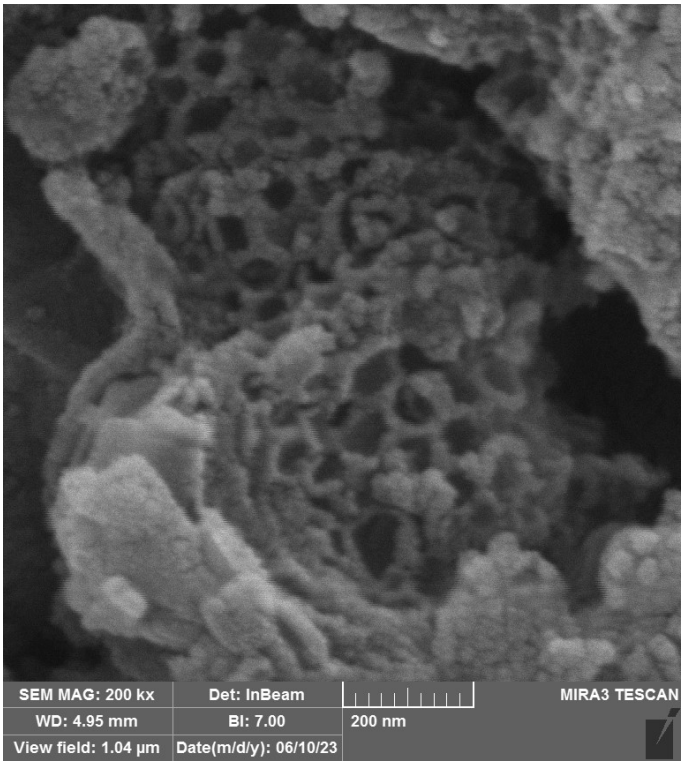


Figure S19. SEM image of the Ru@U-Ph15 (scale bar: 200 nm).

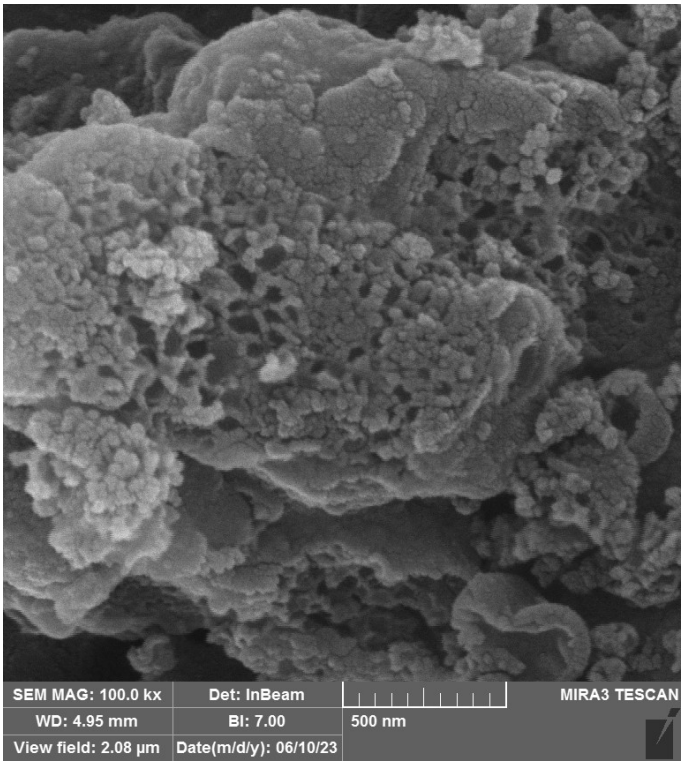


Figure S20. SEM image of the Ru@U-Ph15 (scale bar: 500 nm).

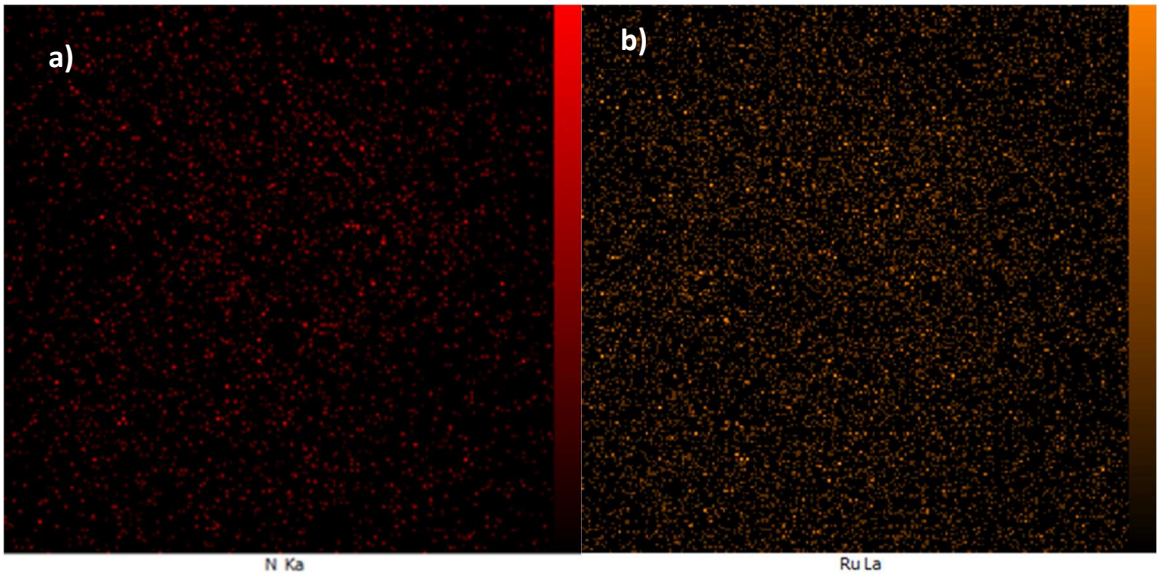


Figure S21. EDX Elemental mapping of (a) Nitrogen and (b) Ruthenium of the Ru@U-Ph15 Catalyst.

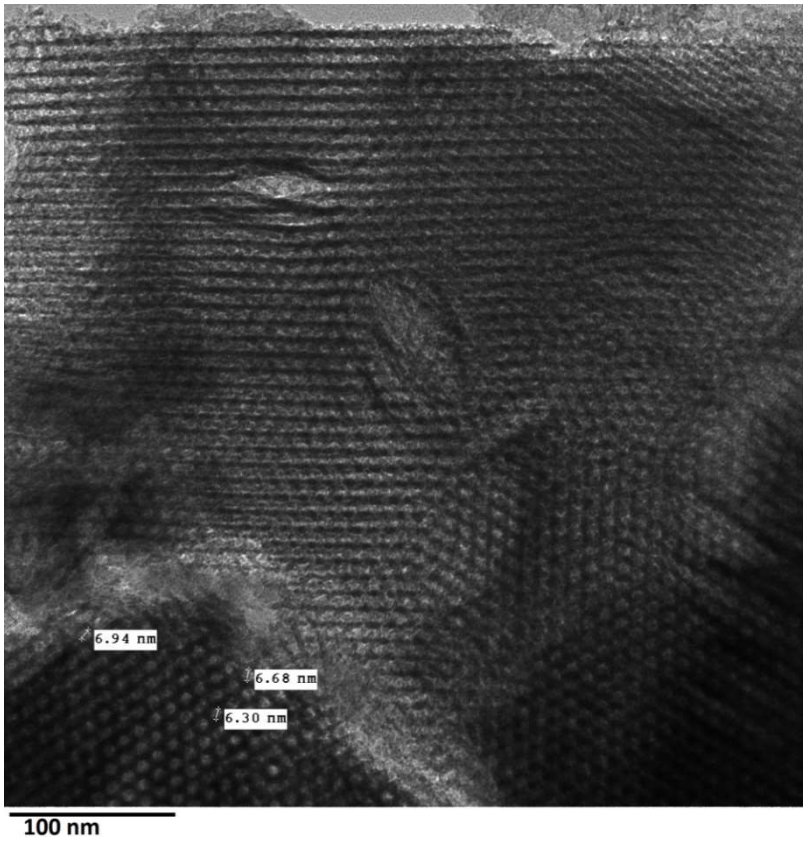


Figure S22. HRTEM image of the Unplugged Ph-BFPMO (scale bar: 100 nm).

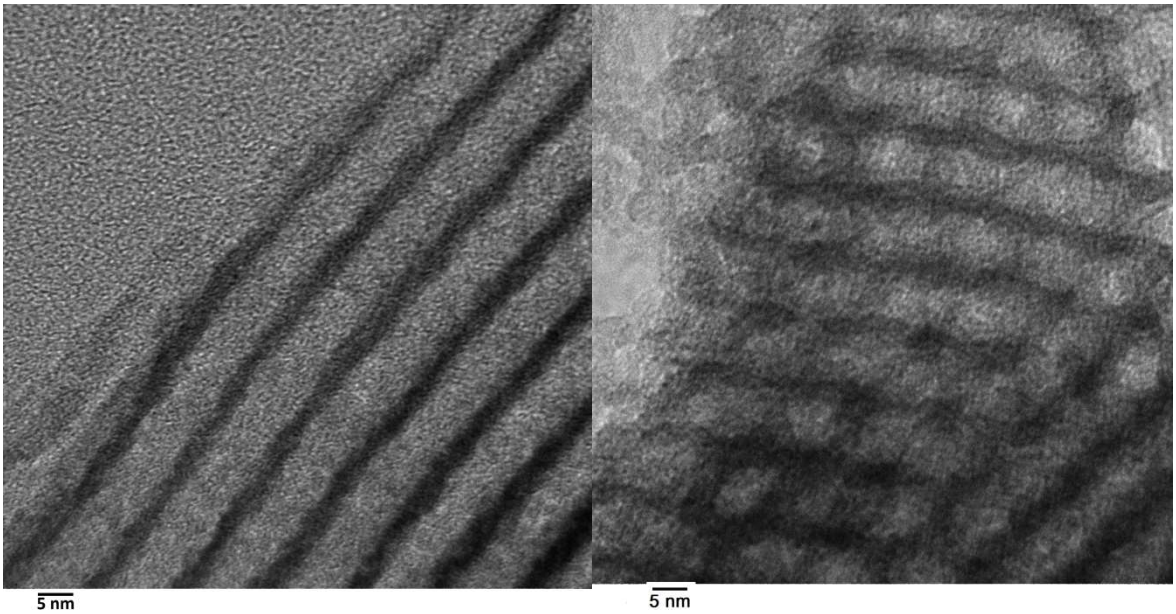


Figure S23. HRTEM image of the Unplugged Ph-BFPMO with 2D hexagonal structure and uniform cylindrical mesochannels (scale bar: 5 nm).

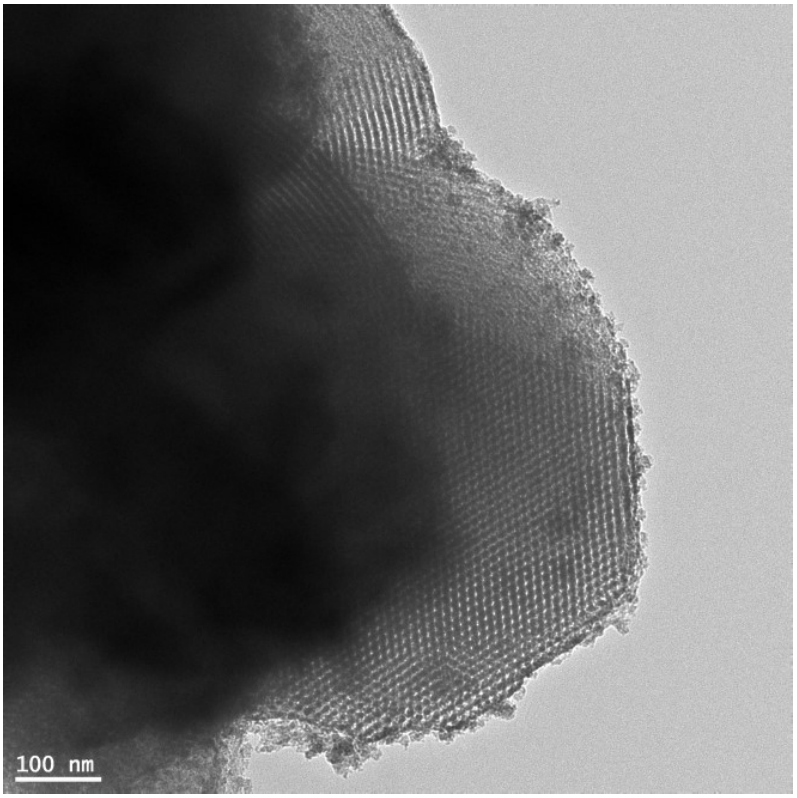


Figure S24. HRTEM image of the Ru@U-Ph15 (scale bar: 100 nm).

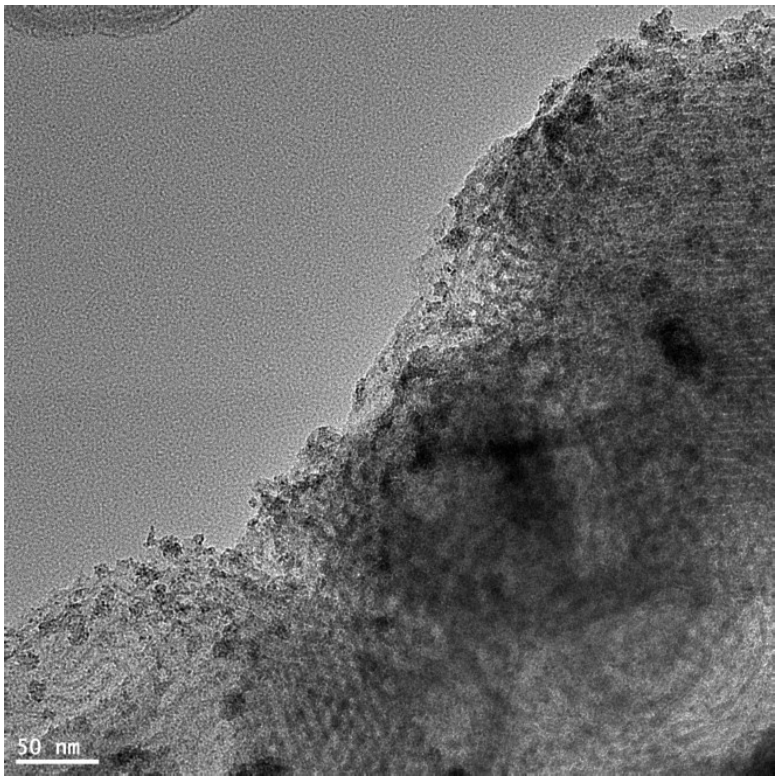


Figure S25. HRTEM image of the Ru@U-Ph15 (scale bar: 50 nm).

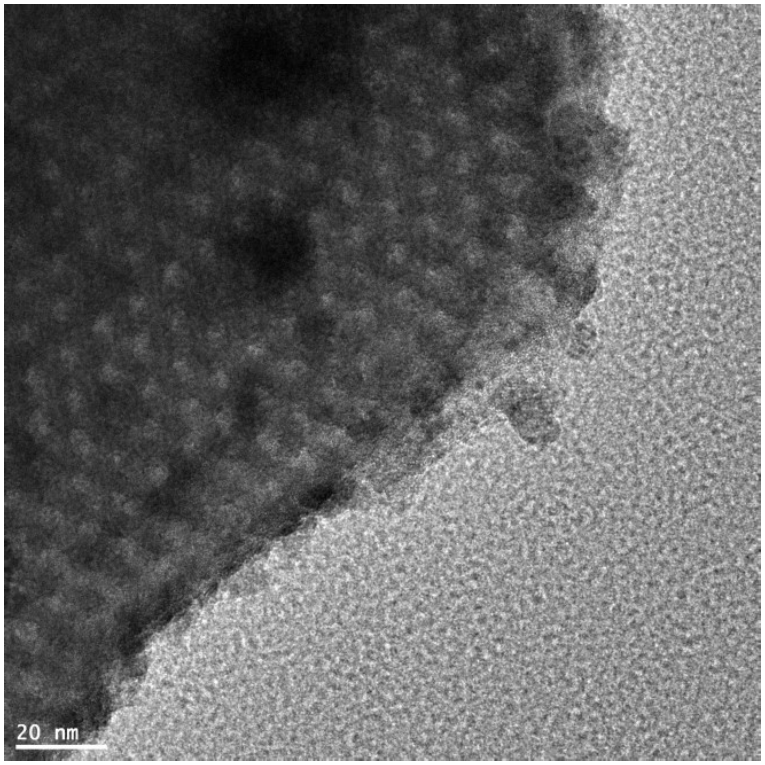


Figure S26. HRTEM image of the Ru@U-Ph15 (scale bar: 20 nm).

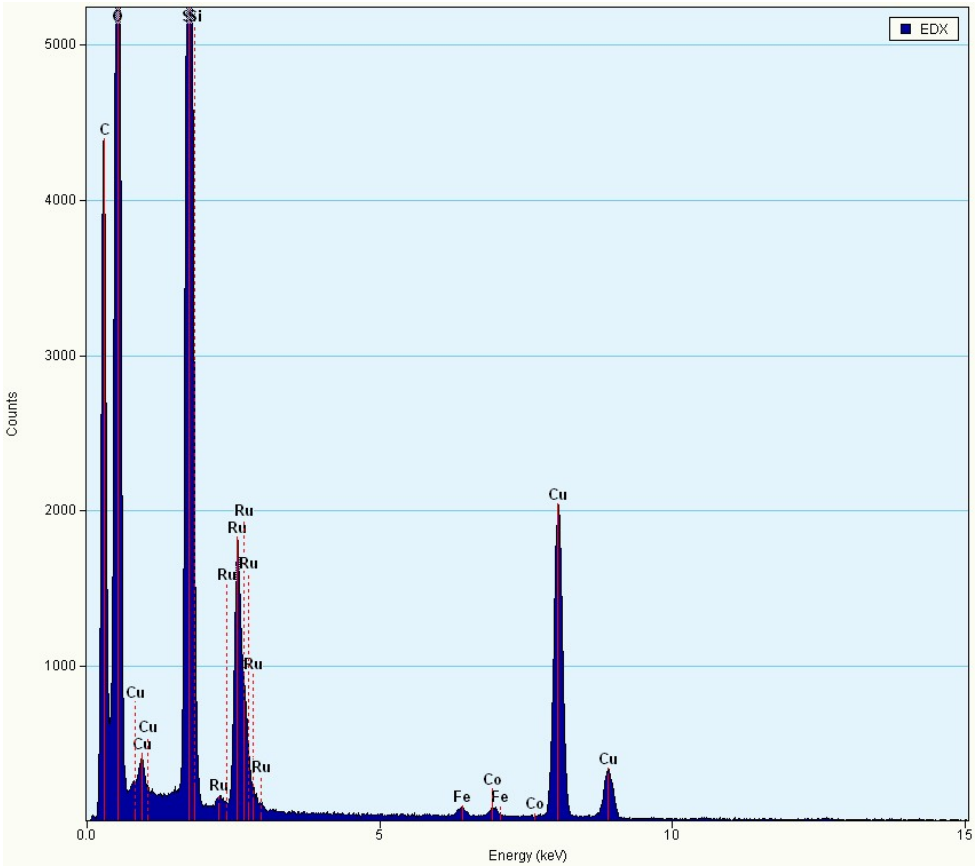


Figure S27. Energy-dispersive X-ray spectroscopy (EDS) of Ru@U-Ph15

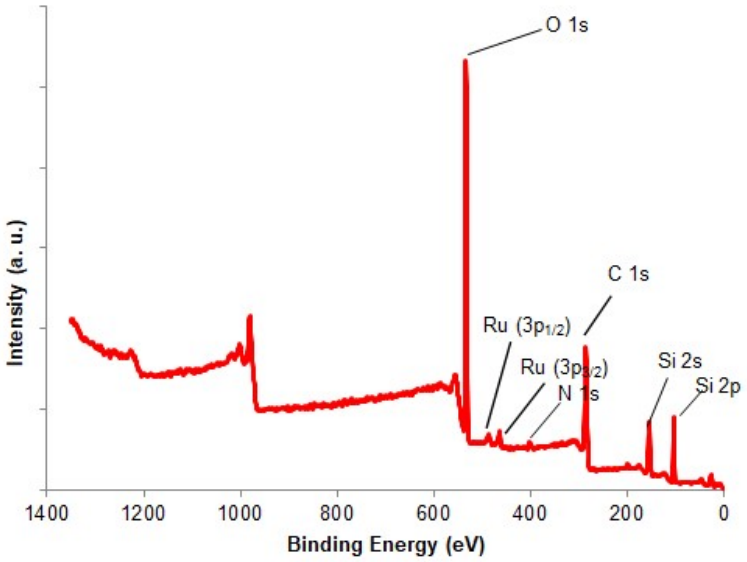


Figure S28. XPS survey spectrum of Ru@U-Ph15

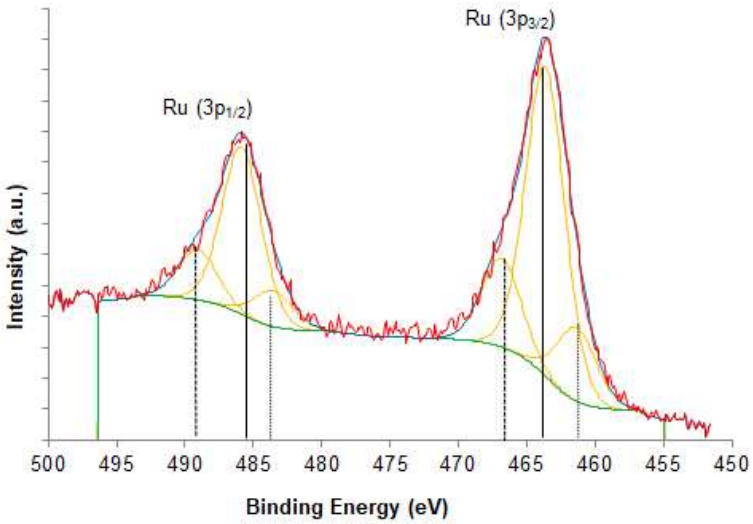


Figure S29. High-resolution XPS spectrum of Ru3p of Ru@U-Ph15

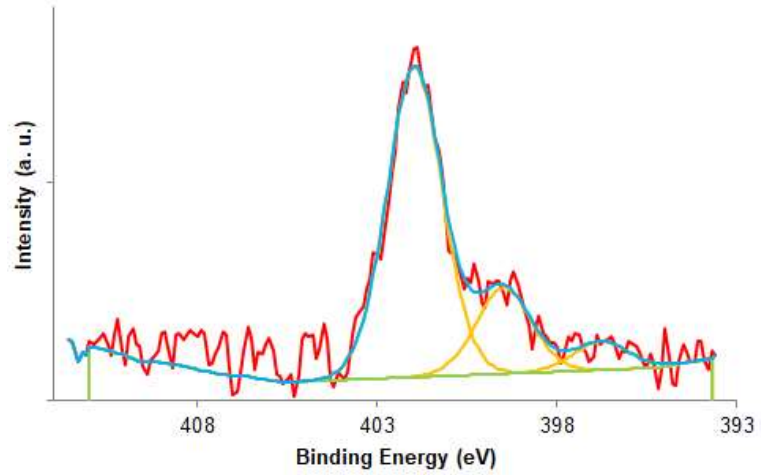


Figure S30. High-resolution XPS spectrum of N1s of Ru@U-Ph15

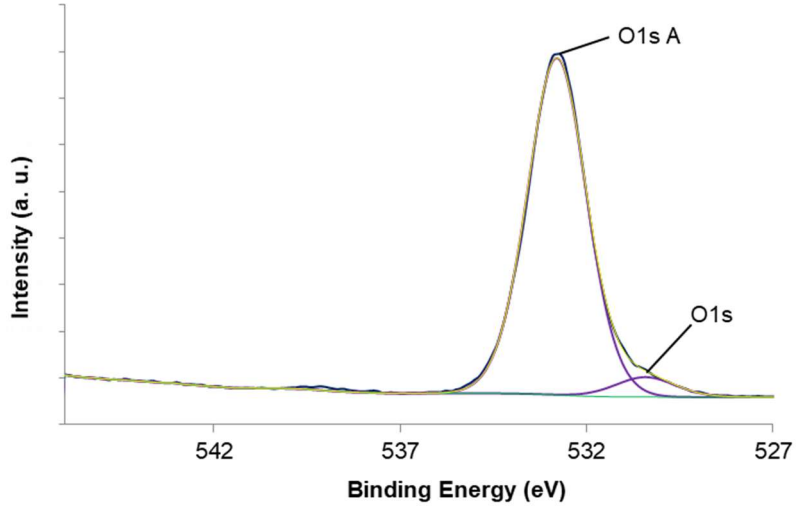


Figure S31. High-resolution XPS spectrum of O1s of Ru@U-Ph15

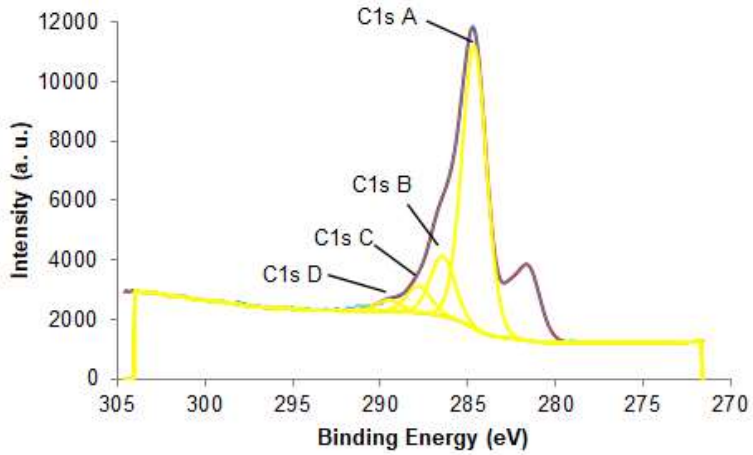


Figure S32. High-resolution XPS spectrum of C1s of Ru@U-Ph15

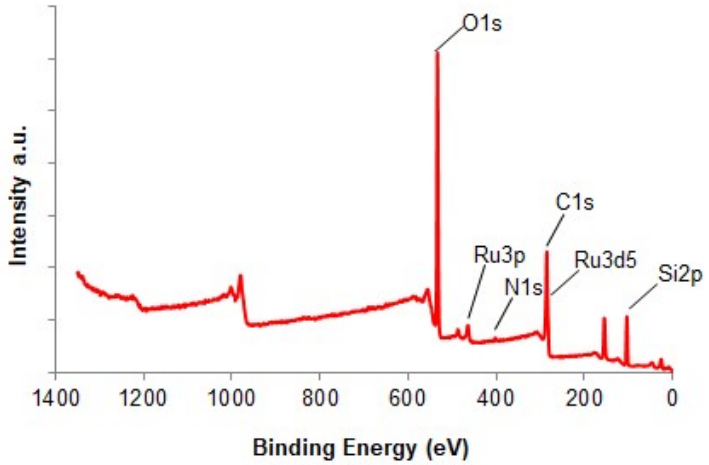


Figure S33. XPS survey spectrum of Re-Ru@U-Ph15

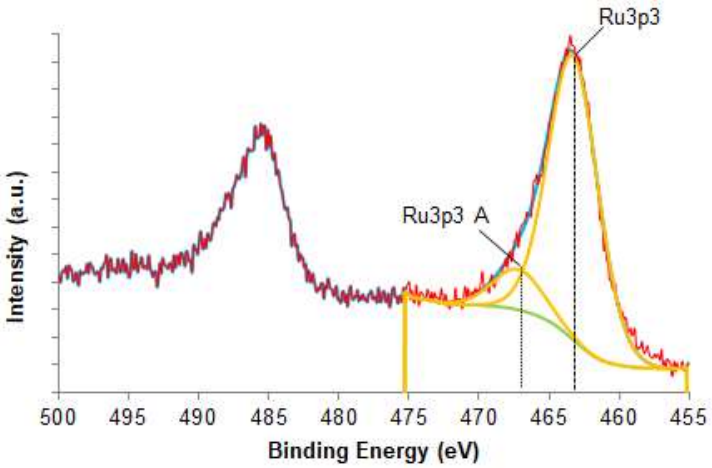


Figure S34. High-resolution XPS spectrum of Ru3p of Re-Ru@U-Ph15

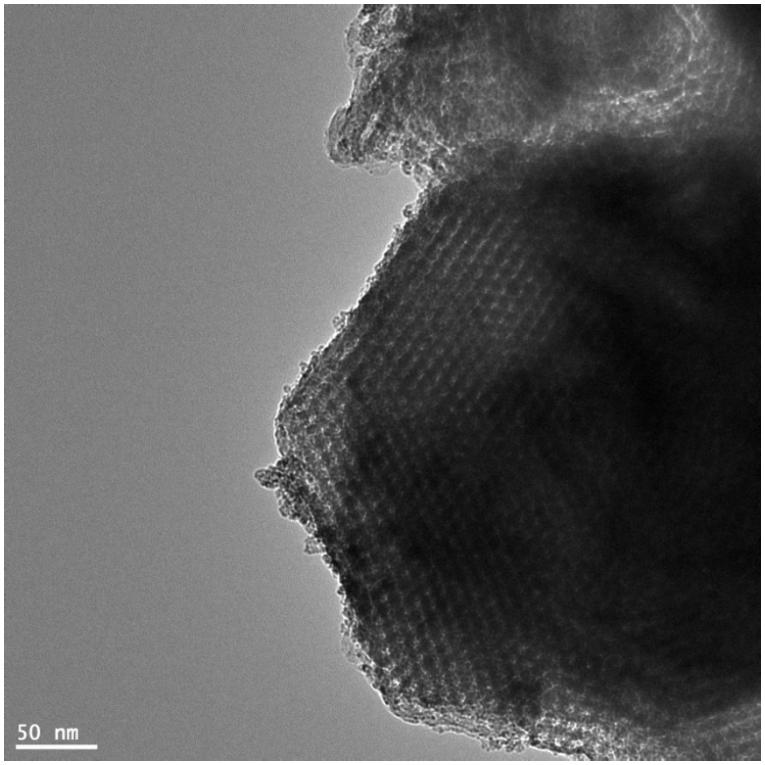


Figure S35. HRTEM image of the Re-Ru@U-Ph15 (scale bar: 50 nm).

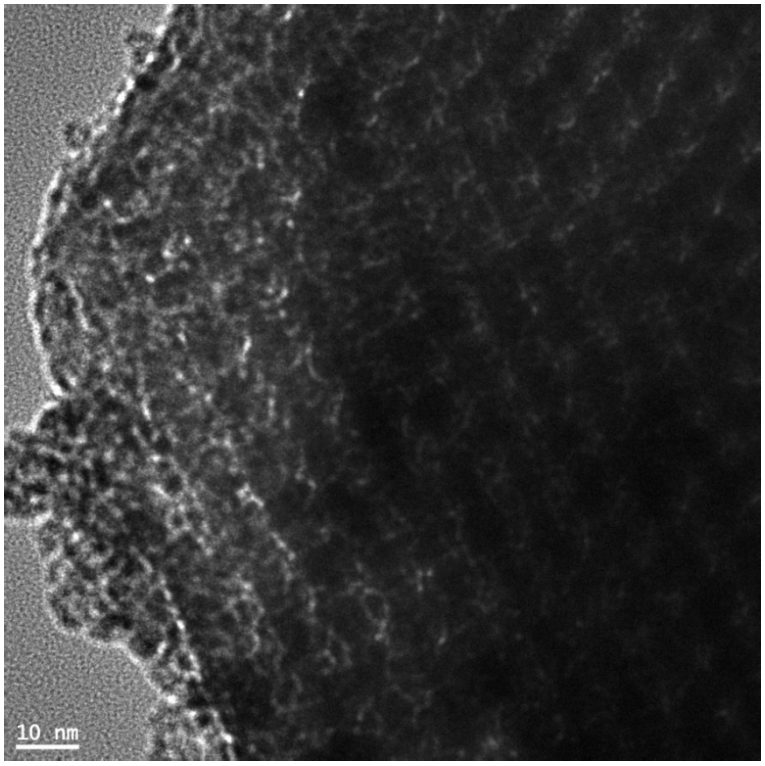
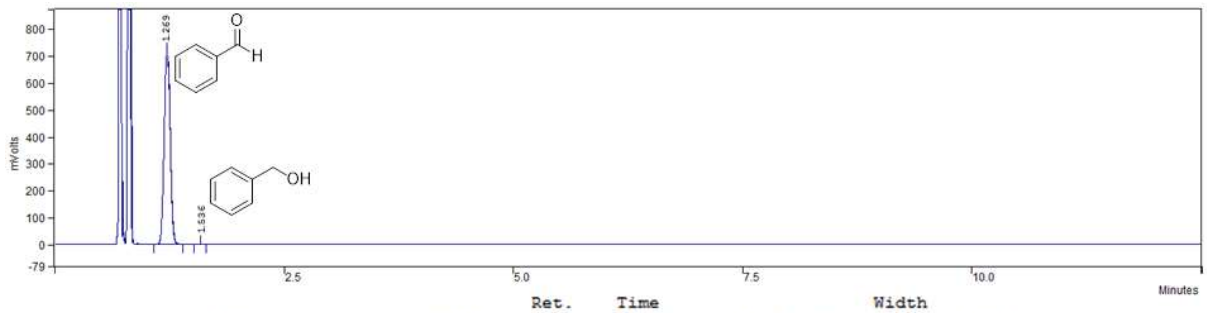


Figure S36. HRTEM image of the Re-Ru@U-Ph15 (scale bar: 10 nm).

Table S2. Comparison of several Ru-based catalytic systems in the oxidation of alcohols into the corresponding carbonyl compounds

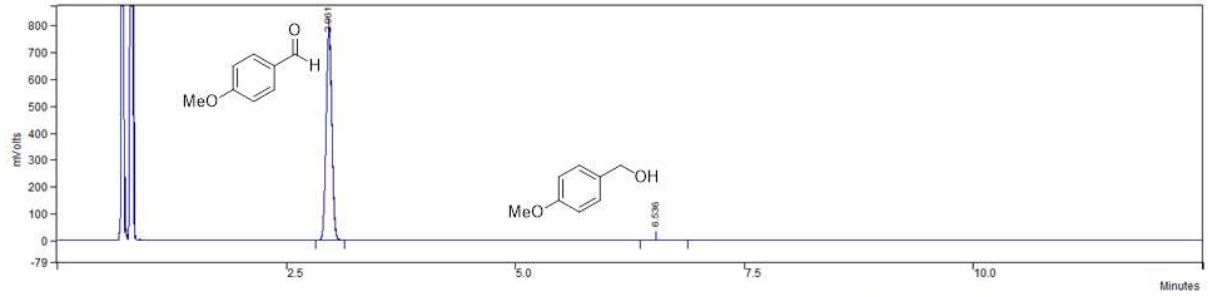
Entry	Catalyst (mg, mol %)	Reaction conditions	Type of alcohols	Reusability	Ref.
1	Ru/Al_2O_3 (2.5 mol%)	Trifluorotoluene, O_2 (1 atm), 83 ˚C	18 substrates (including primary and secondary benzylic and aliphatic alcohols, allylic and heterocyclic alcohols)	7 cycles without drop in reaction yield and selectivity	[3]
2	rGO@Ru-RMβ-CD (80 mg, 2 mol% Ru)	K_2CO_3, water, O_2 balloon, 85 ˚C	22 substrates (including primary and secondary benzylic alcohols, and propargylic alcohols)	5 cycle with a drop in reaction yield after the third cycle	[4]
3	Ru@PMO-IL (80 mg, 2.5 mol %)	Trifluorotoluen, O_2, 70 ˚C	24 substrates (including primary and secondary benzylic and aliphatic alcohols, allylic and heterocyclic alcohols)	5 cycle with a drop in reaction yield after the third cycle	[2]
4	ZC-Ru[a] (300 mg, (2.4 wt % Ru)	Toluene, O_2 (1 atm), 80 ˚C	10 substrates (including primary and secondary benzylic and aliphatic alcohols, allylic and heterocyclic alcohols)	5 cycles without drop in reaction yield and selectivity	[5]
5	Ru@ Anodic Aluminum Oxide (20 mg, 2.3 wt % Ru)	Toluene, air flow (1 atm), 50 ˚C	18 substrates (including primary and secondary benzylic alcohols, secondary aliphatic alcohols, allylic and heterocyclic alcohols)	5 cycles without drop in reaction yield and selectivity	[6]
6	**Ru@U-Ph15 (19.5 mg, 1.5 mol %)**	**Toluene, O_2, 90 ˚C**	**32 substrates (including primary and secondary benzylic and aliphatic alcohols, allylic and heterocyclic alcohols)**	**5 cycles with a steadily drop in reaction yield**	**This work**

[a]Zeolite confined nanostructured dinuclear ruthenium clusters



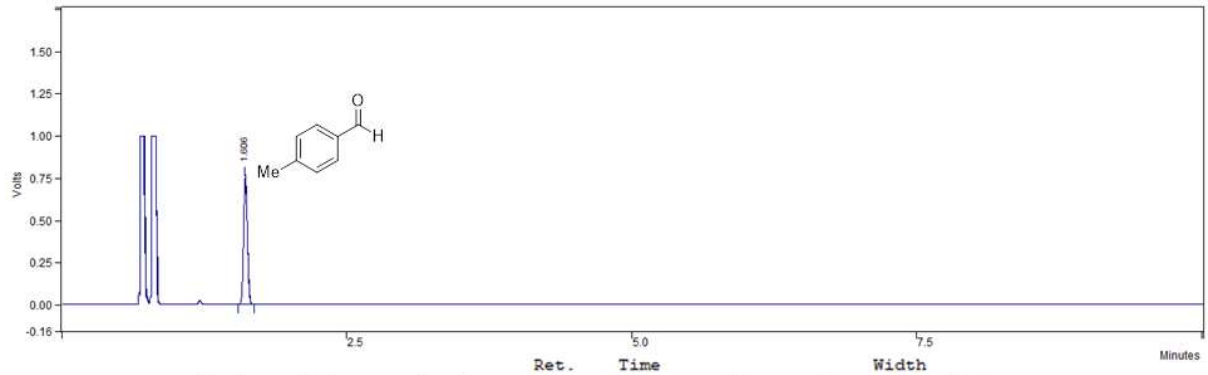
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		99.8130	1.269	0.000	3419554	BB	4.0	
2		0.1870	1.536	0.000	6408	BB	12.8	
Totals:		100.0000		0.000	3425962			

Figure S37. Gas chromatogram of benzyl alcohol reaction (Table 4, Entry 1)



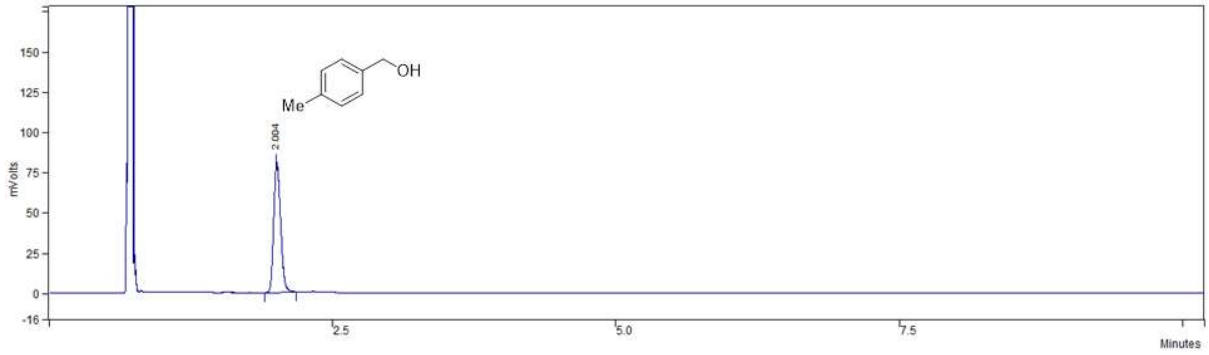
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		99.8130	2.961	0.000	3419554	BB	4.0	
2		0.1870	6.536	0.000	6408	BB	12.8	
Totals:		100.0000		0.000	3425962			

Figure S38. Gas chromatogram of 4-methoxybenzyl alcohol reaction (Table 4, Entry 2)



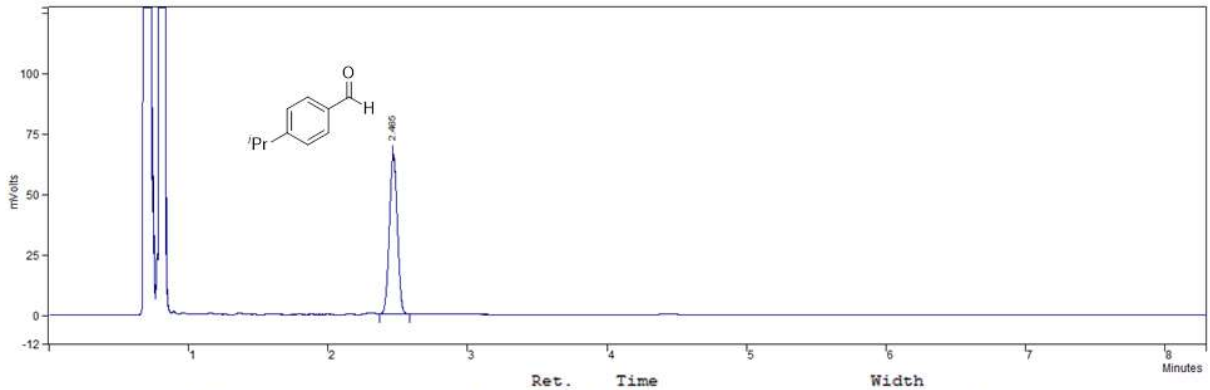
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	1.606	0.000	1750619	BB	2.2	
Totals:		100.0000		0.000	1750619			

Figure S39. Gas chromatogram of 4-methylbenzyl alcohol reaction (Table 4, Entry 3)



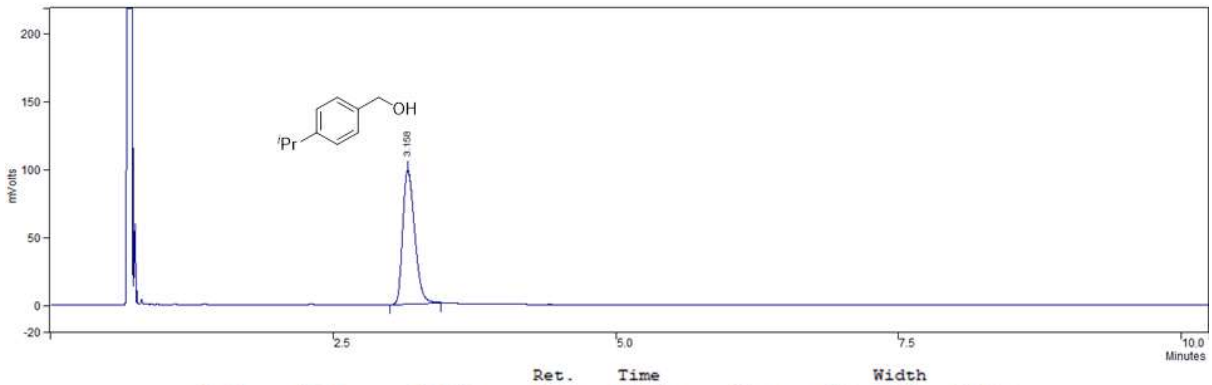
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	2.004	0.000	340458	BB	3.9	
	Totals:	100.0000		0.000	340458			

Figure S40. Gas chromatogram of 4-methylbenzyl alcohol (blank)



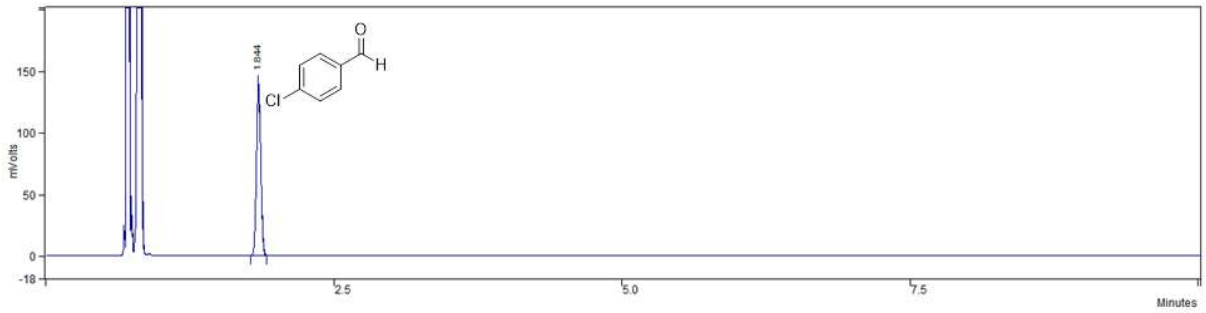
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	2.465	0.000	259294	BB	3.7	
	Totals:	100.0000		0.000	259294			

Figure S41. Gas chromatogram of 4-*iso*propylbenzyl alcohol reaction (Table 4, Entry 4)



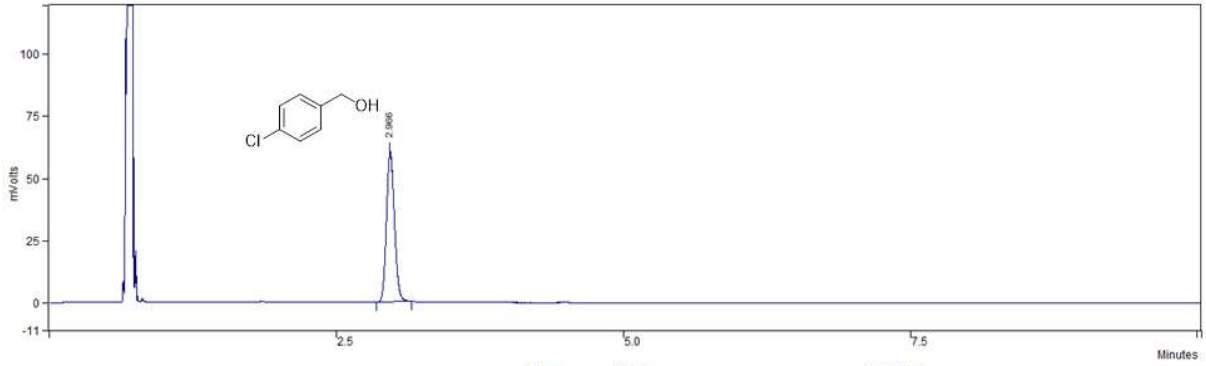
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	3.158	0.000	722600	BB	6.8	
	Totals:	100.0000		0.000	722600			

Figure S42. Gas chromatogram of 4-*iso*propylbenzyl alcohol (blank)



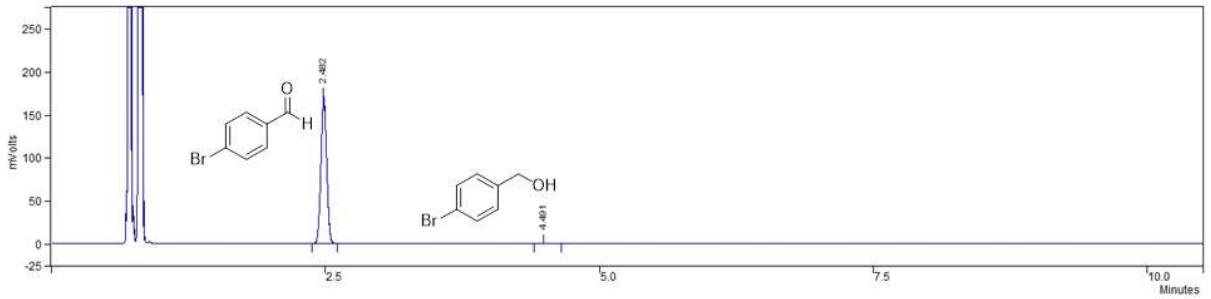
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	1.844	0.000	360989	BB	2.4	
Totals:		100.0000		0.000	360989			

Figure S43. Gas chromatogram of 4-chlorobenzyl alcohol reaction (Table 4, Entry 5)



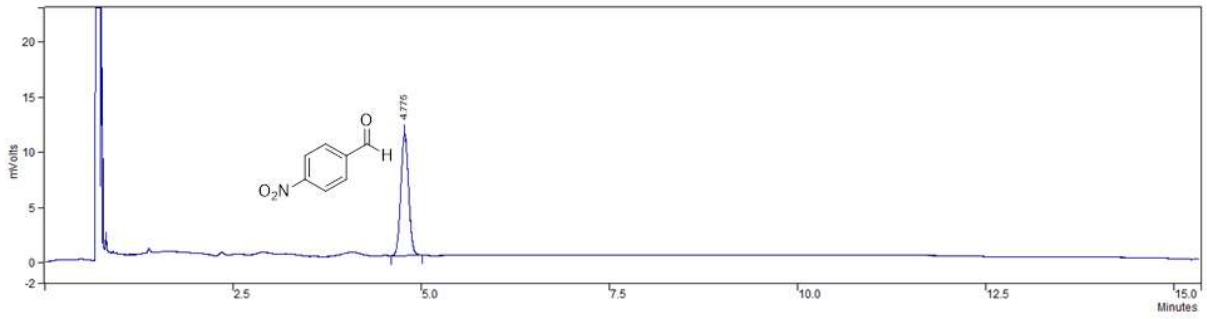
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	2.966	0.000	294534	BB	4.5	
Totals:		100.0000		0.000	294534			

Figure S44. Gas chromatogram of 4-chlorobenzyl alcohol (blank)



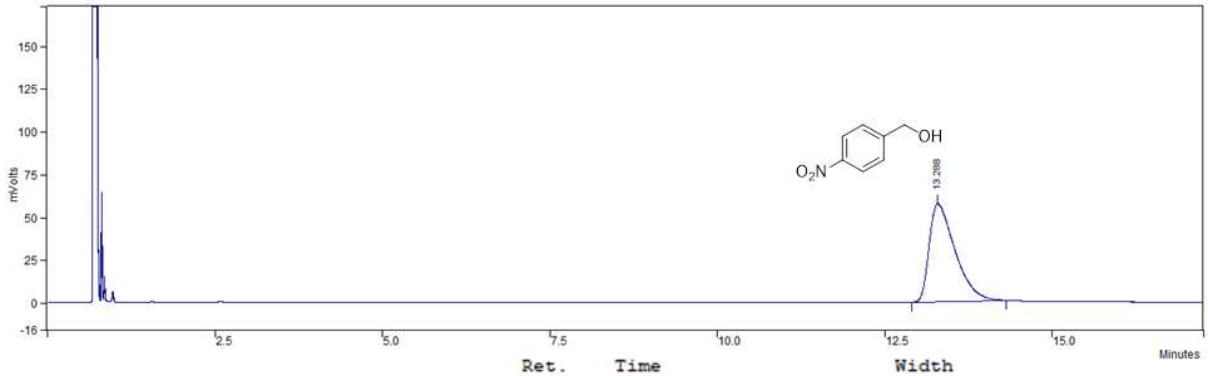
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		99.8260	2.482	0.000	620404	BB	3.4	
2		0.1740	4.491	0.000	1081	BB	7.1	
Totals:		100.0000		0.000	621485			

Figure S45. Gas chromatogram of 4-bromobenzyl alcohol reaction (Table 4, Entry 6)



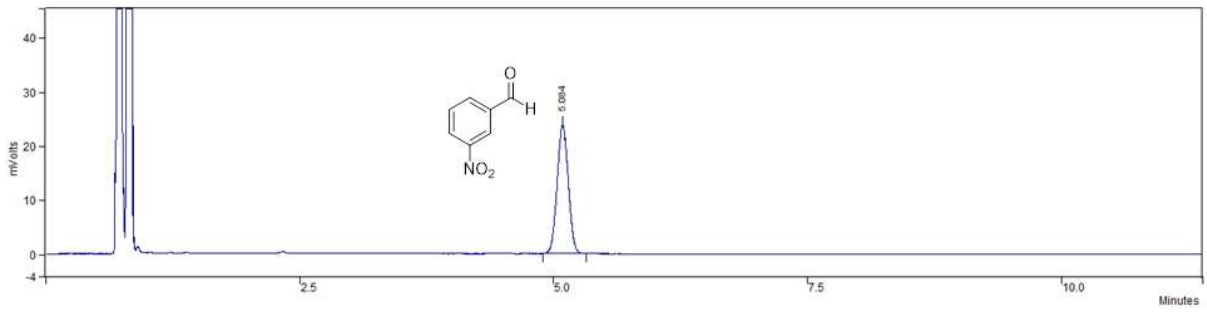
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	4.775	0.000	79360	BB	6.7	
Totals:		100.0000		0.000	79360			

Figure S46. Gas chromatogram of 4-nitrobenzyl alcohol reaction (Table 4, Entry 7)



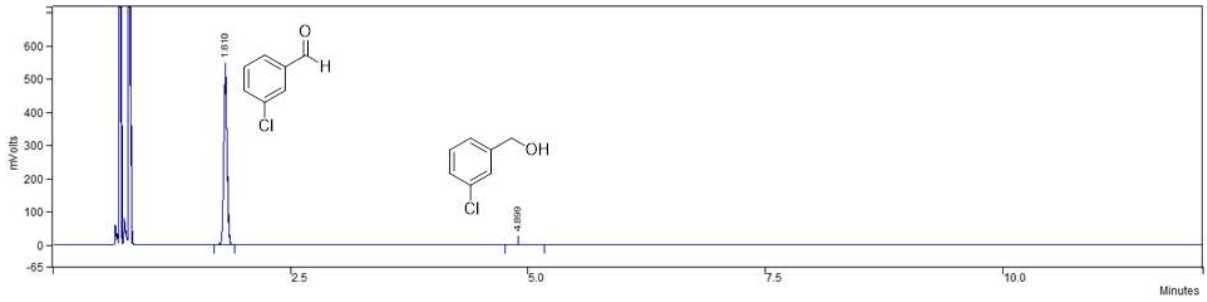
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	13.288	0.000	1544709	BB	24.8	
Totals:		100.0000		0.000	1544709			

Figure S47. Gas chromatogram of 4-nitrobenzyl alcohol (blank)



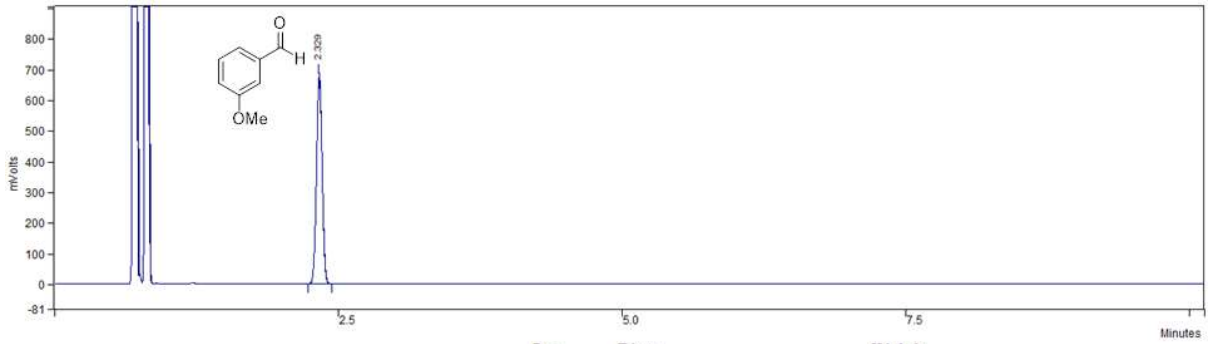
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	5.084	0.000	181847	BB	7.1	
Totals:		100.0000		0.000	181847			

Figure S48. Gas chromatogram of 3-nitrobenzyl alcohol reaction (Table 4, Entry 8)



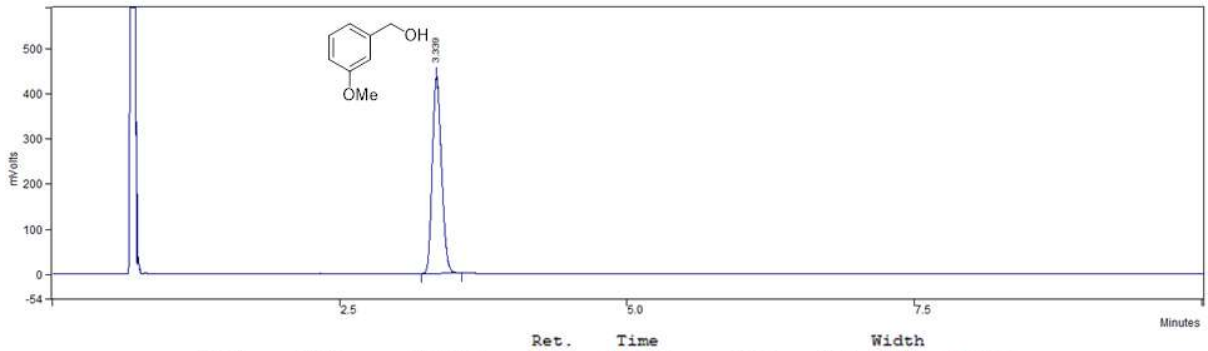
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		99.6705	1.810	0.000	1272115	BB	2.3	
2		0.3295	4.899	0.000	4205	BB	12.1	
	Totals:	100.0000		0.000	1276320			

Figure S49. Gas chromatogram of 3-chlorobenzyl alcohol reaction (Table 4, Entry 9)



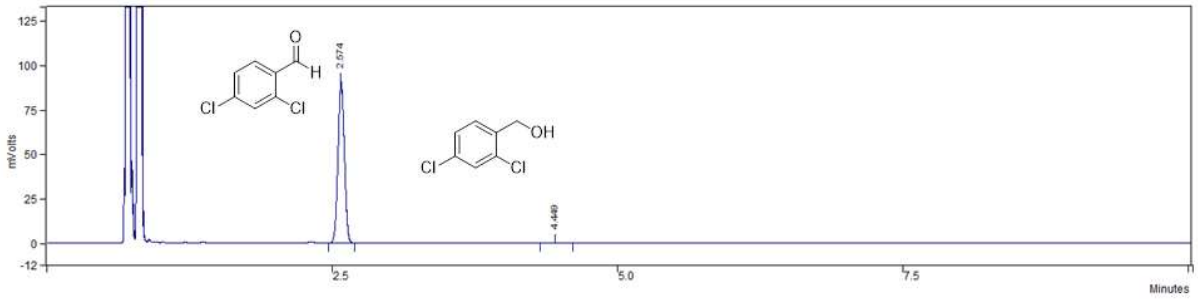
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	2.329	0.000	2353214	BB	3.2	
	Totals:	100.0000		0.000	2353214			

Figure S50. Gas chromatogram of 3-methoxybenzyl alcohol reaction (Table 4, Entry 10)



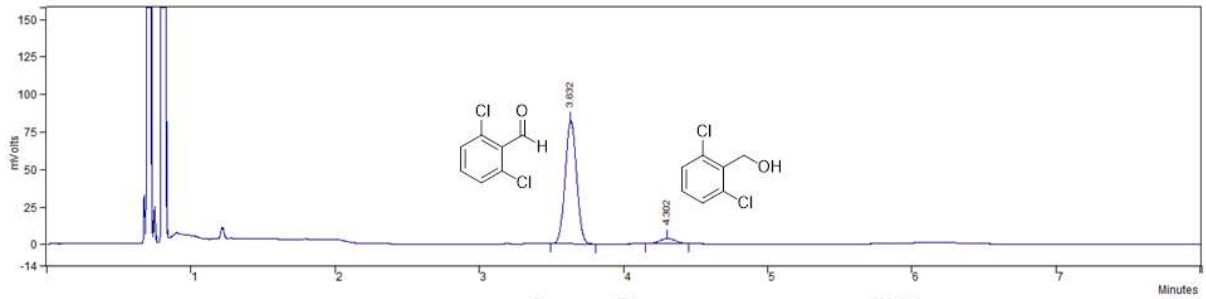
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	3.339	0.000	2430900	BB	5.2	
	Totals:	100.0000		0.000	2430900			

Figure S51. Gas chromatogram of 3-methoxybenzyl alcohol (blank)



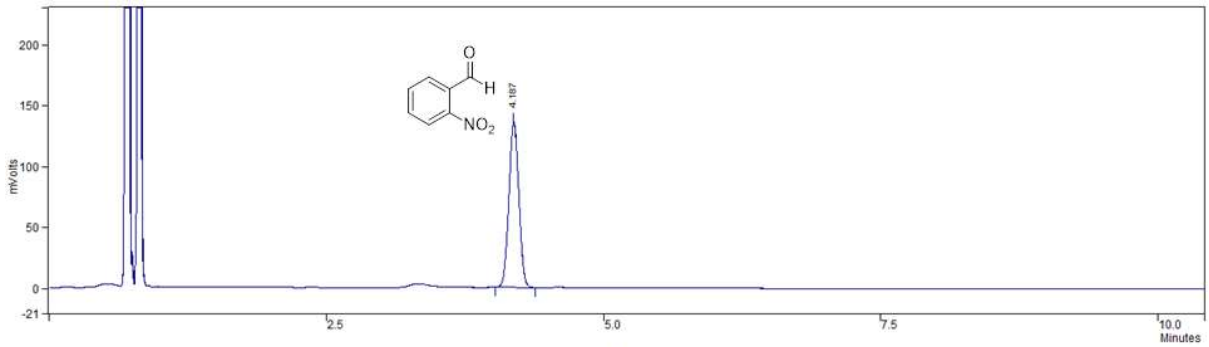
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		99.7081	2.574	0.000	352413	BB	3.7	
2		0.2919	4.449	0.000	1032	BB	7.7	
Totals:		100.0000		0.000	353445			

Figure S52. Gas chromatogram of 2,4-dichlorobenzyl alcohol reaction (Table 4, Entry 11)



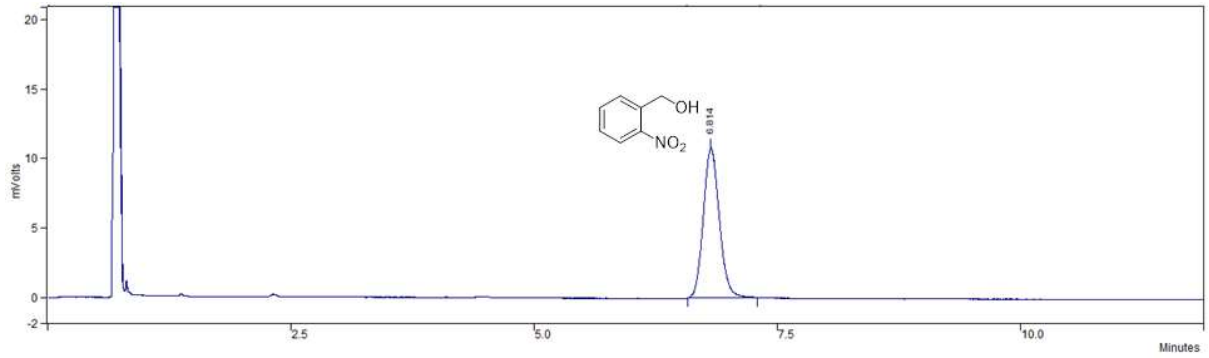
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		94.3705	3.632	0.000	451081	BB	5.1	
2		5.6295	4.302	0.000	26909	BB	7.3	
Totals:		100.0000		0.000	477990			

Figure S53. Gas chromatogram of 2,6-dichlorobenzyl alcohol reaction (Table 4, Entry 12)



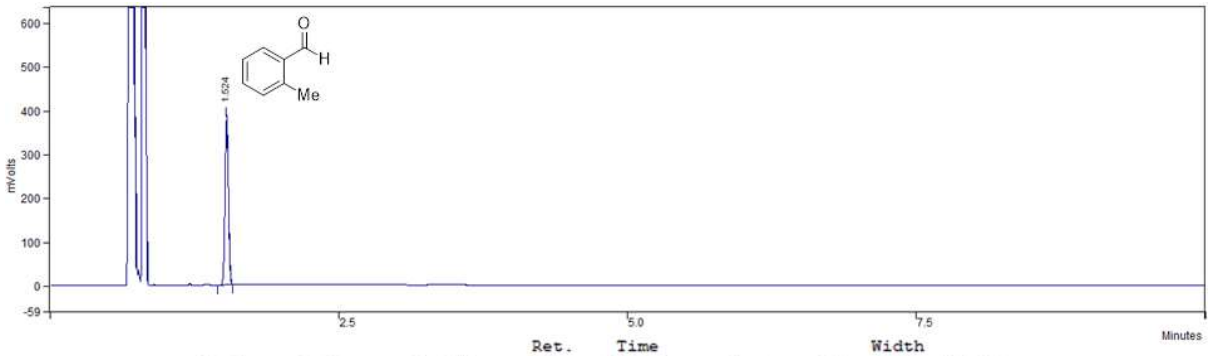
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	4.187	0.000	849696	BB	5.8	
Totals:		100.0000		0.000	849696			

Figure S54. Gas chromatogram of 2-nitrobenzyl alcohol reaction (Table 4, Entry 13)



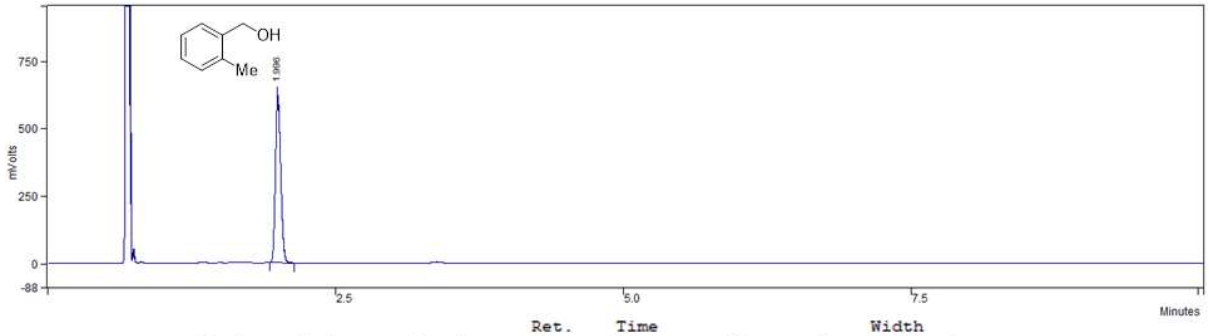
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	6.814	0.000	123448	BB	10.5	
	Totals:	100.0000		0.000	123448			

Figure S55. Gas chromatogram of 2-nitrobenzyl alcohol (blank)



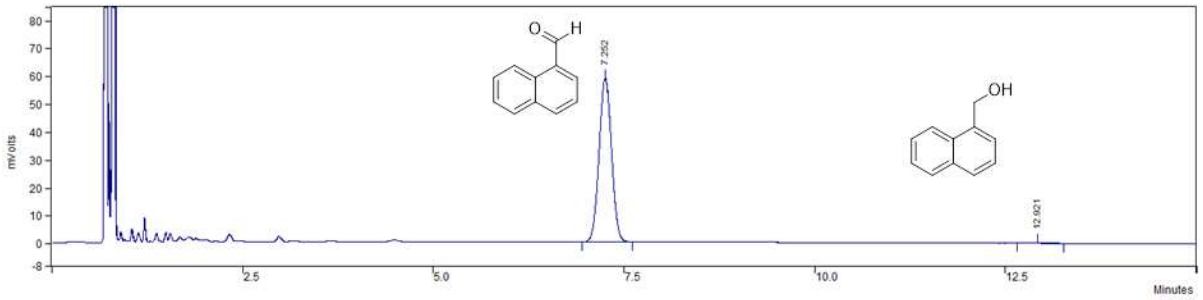
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	1.524	0.000	770012	BP	1.9	
	Totals:	100.0000		0.000	770012			

Figure S56. Gas chromatogram of 2-methylbenzyl alcohol reaction (Table 4, Entry 14)



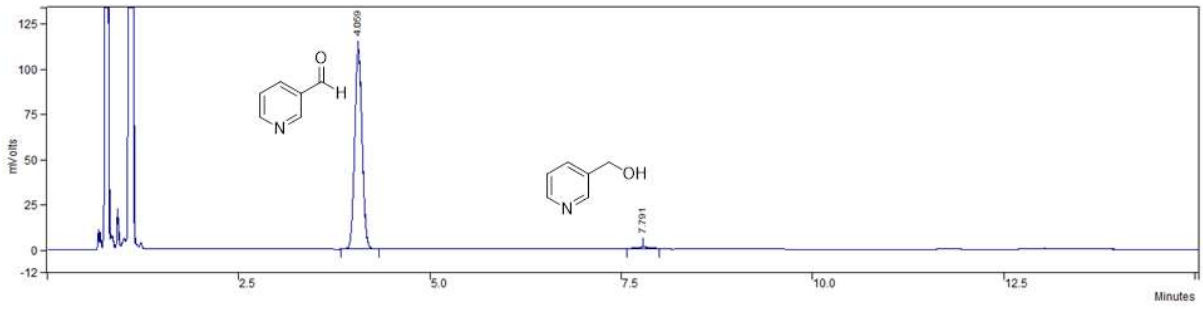
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	1.996	0.000	1968297	BB	3.0	
	Totals:	100.0000		0.000	1968297			

Figure S57. Gas chromatogram of 2-methylbenzyl alcohol (blank)



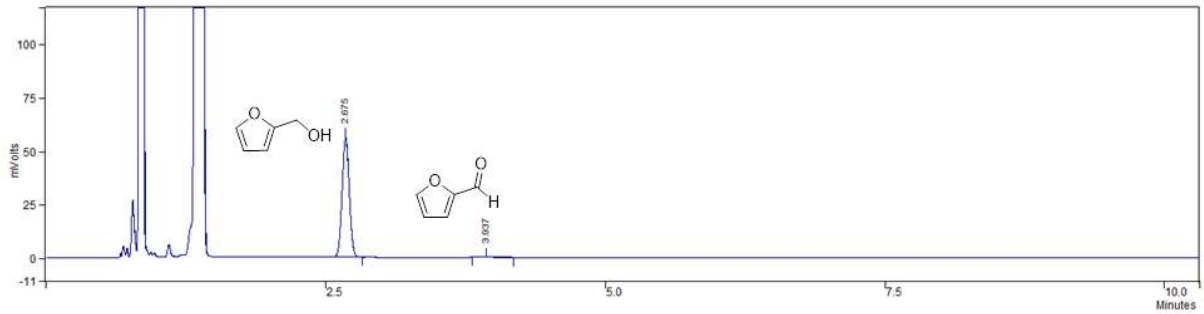
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		99.2844	7.252	0.000	667239	BB	10.6	
2		0.7156	12.921	0.000	4809	BB	17.5	
Totals:		100.0000		0.000	672048			

Figure S58. Gas chromatogram of 1-naphthyl methanol reaction (Table 4, Entry 15)



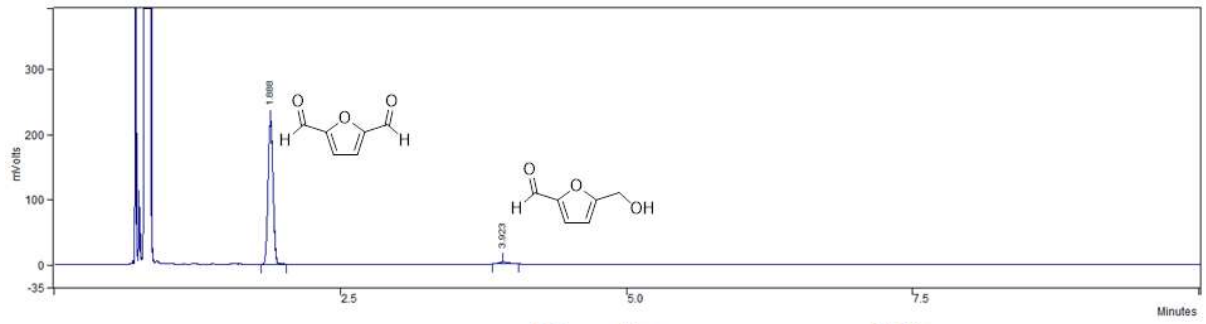
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		98.4774	4.059	0.000	749378	BB	6.3	
2		1.5226	7.791	0.000	11587	BB	16.1	
Totals:		100.0000		0.000	760965			

Figure S59. Gas chromatogram of 3-pyridine methanol reaction (Table 4, Entry 16)



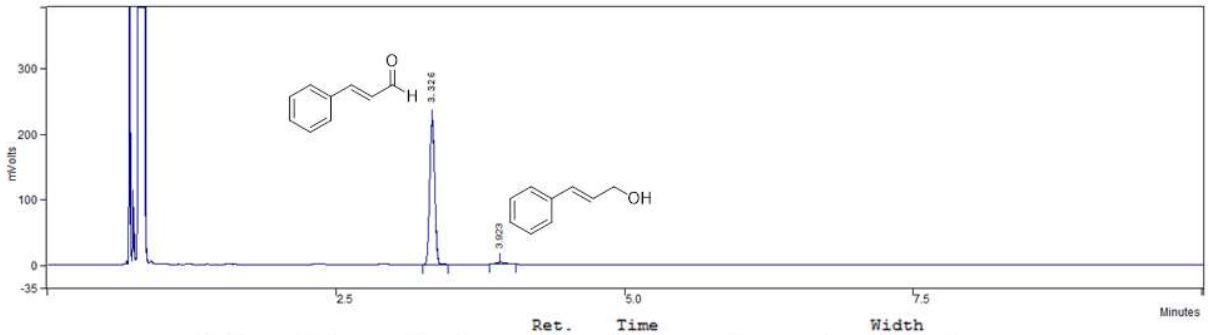
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		98.5524	2.675	0.000	253396	BB	4.2	
2		1.4476	3.937	0.000	3722	BB	9.9	
Totals:		100.0000		0.000	257118			

Figure S60. Gas chromatogram of 2-furyl alcohol reaction (Table 4, Entry 17)



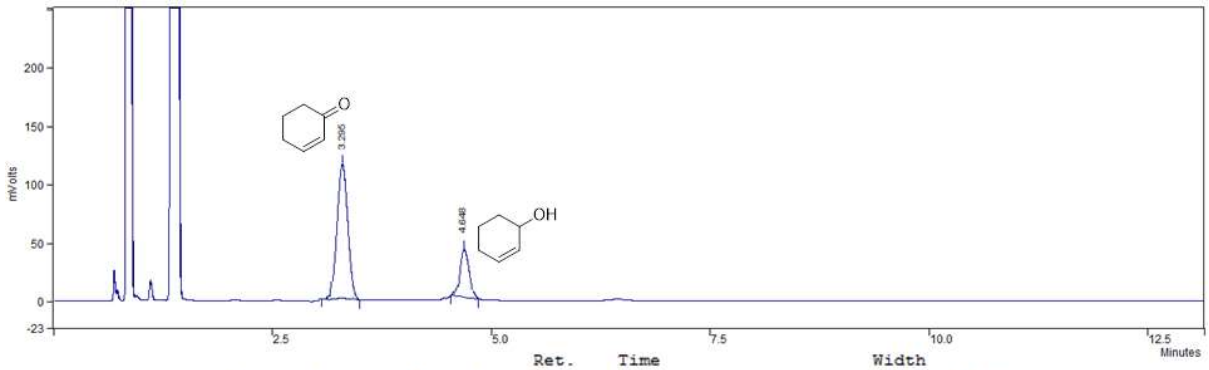
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		97.1474	1.888	0.000	665742	BB	2.8	
2		2.8526	3.923	0.000	19549	BB	6.4	
	Totals:	100.0000		0.000	685291			

Figure S61. Gas chromatogram of 5-hydroxymethylfurfural (HMF) reaction (Table 4, Entry 18)



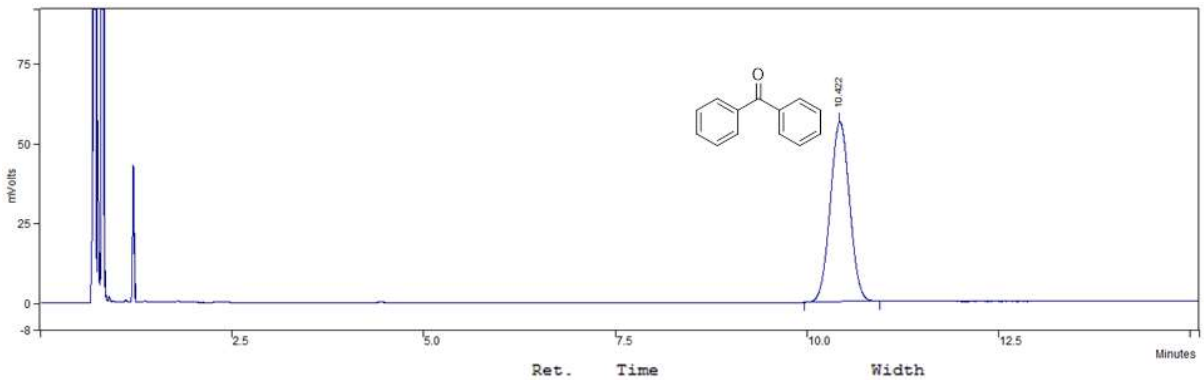
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		97.1474	3.326	0.000	665742	BB	2.8	
2		2.8526	3.923	0.000	19549	BB	6.4	
	Totals:	100.0000		0.000	685291			

Figure S62. Gas chromatogram of cinnamyl alcohol reaction (Table 4, Entry 19)



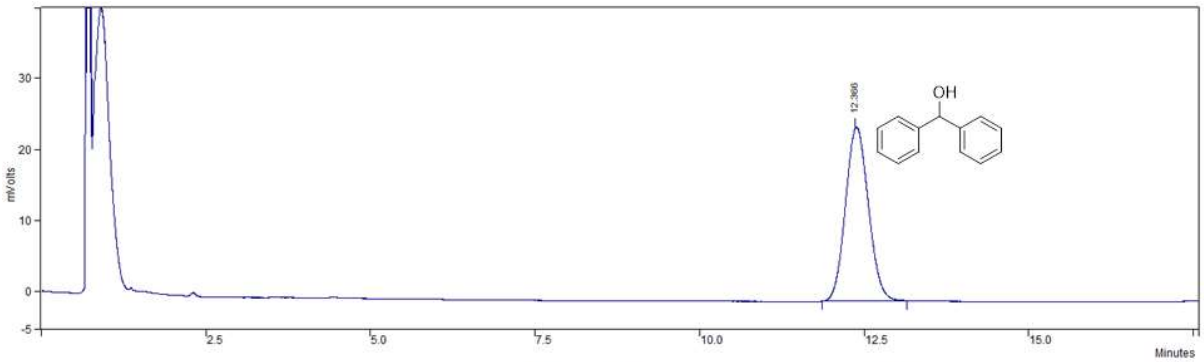
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		73.3099	3.295	0.000	959007	BB	9.0	
2		26.6901	4.648	0.000	647638	BB	7.9	
	Totals:	100.0000		0.000	1606645			

Figure S63. Gas chromatogram of 2-cyclohexene-1-ol reaction (Table 4, Entry 20)



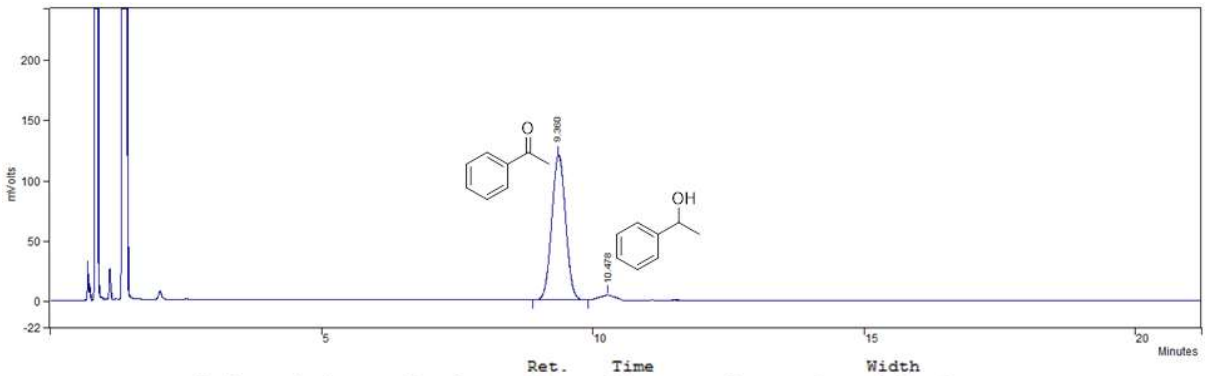
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	10.422	0.000	989033	BB	16.4	
Totals:		100.0000		0.000	989033			

Figure S64. Gas chromatogram of diphenylmethanol reaction (Table 4, Entry 21)



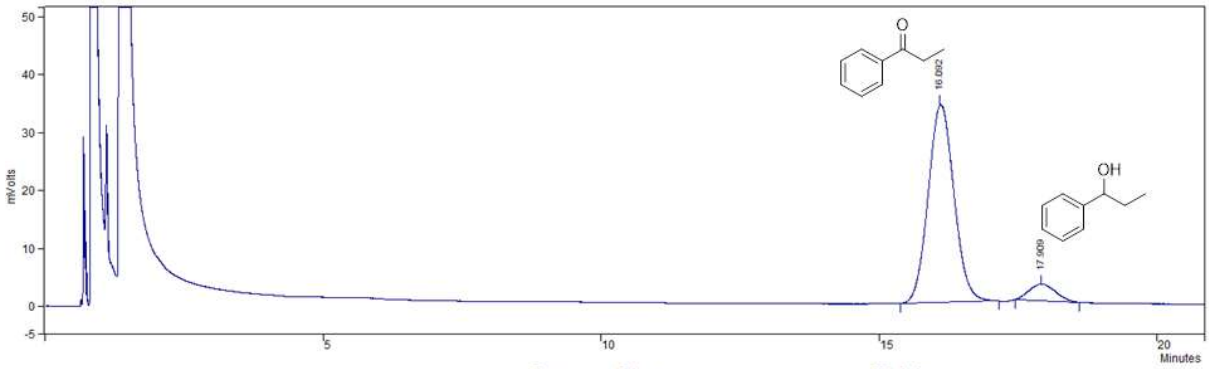
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	12.366	0.000	593273	BB	22.7	
Totals:		100.0000		0.000	593273			

Figure S65. Gas chromatogram of diphenylmethanol (blank)



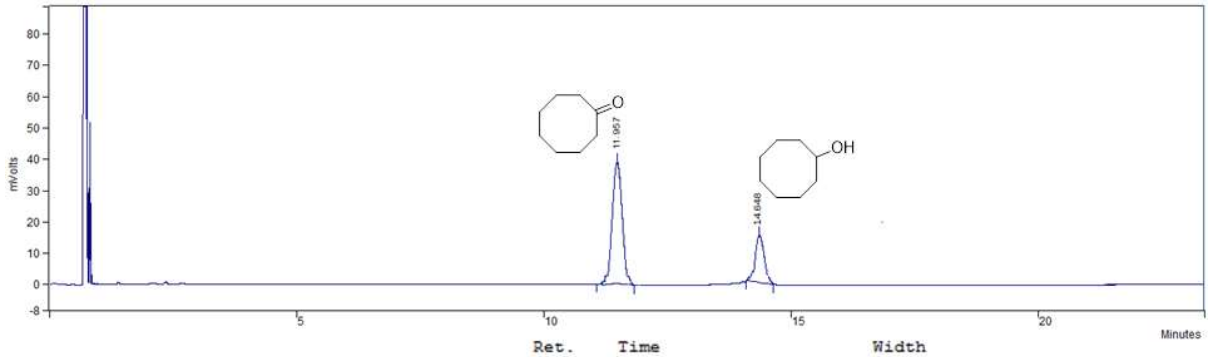
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		93.0614	9.360	0.000	2135964	BB	16.6	
2		6.9396	10.478	0.000	482002	BB	26.5	
Totals:		100.0000		0.000	2617966			

Figure S66. Gas chromatogram of 1-phenyl-1-ethanol reaction (Table 4 Entry 22)



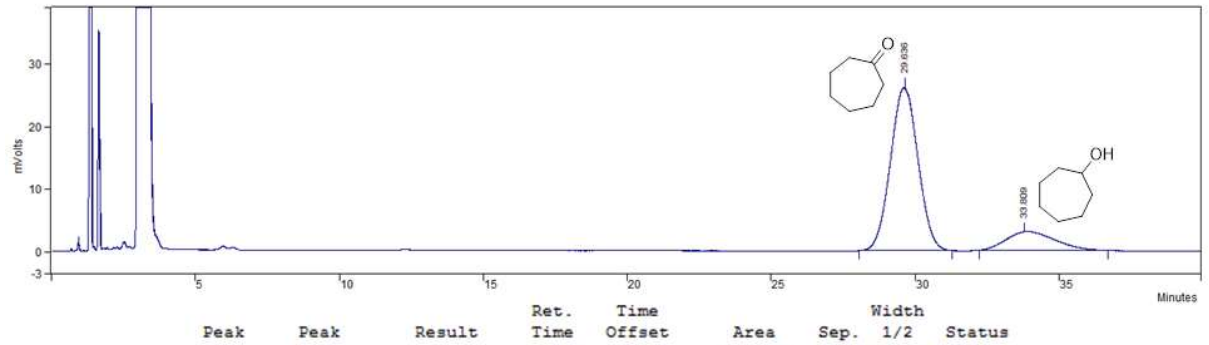
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		92.2570	16.092	0.000	1108057	BB	30.0	
2		7.7430	17.909	0.000	92998	BB	29.9	
	Totals:	100.0000		0.000	1201055			

Figure S67. Gas chromatogram of 1-phenyl-1-propanol reaction (Table 4, Entry 23)



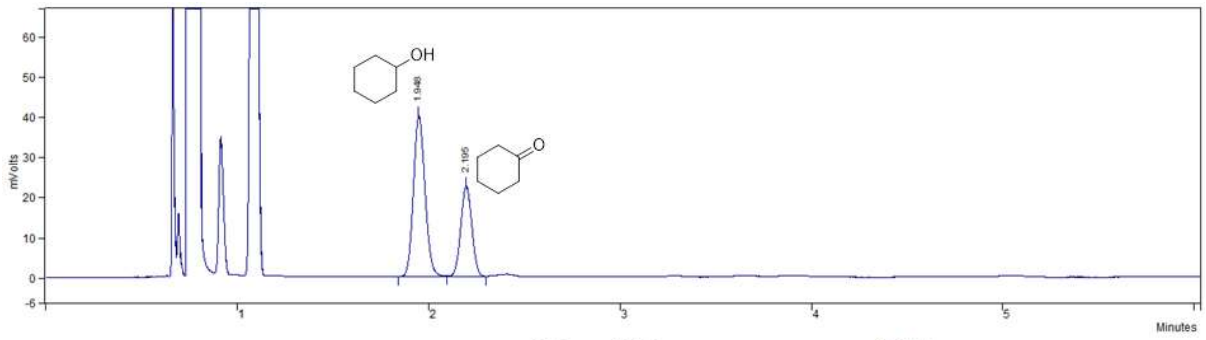
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		63.6342	11.957	0.000	647638	BB	9.0	
2		36.3658	14.648	0.000	342025	BB	6.6	
	Totals:	100.0000		0.000	989663			

Figure S68. Gas chromatogram of cyclooctanol reaction (Table 4, Entry 24)



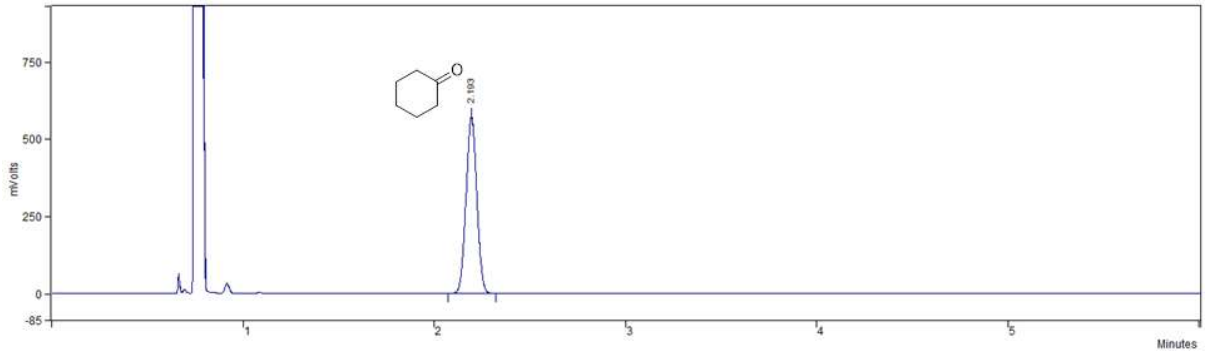
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		83.3079	29.636	0.000	1730845	BB	62.4	
2		16.6921	33.809	0.000	346804	BB	110.1	
	Totals:	100.0000		0.000	2077649			

Figure S69. Gas chromatogram of cycloheptanol reaction (Table 4, Entry 25)



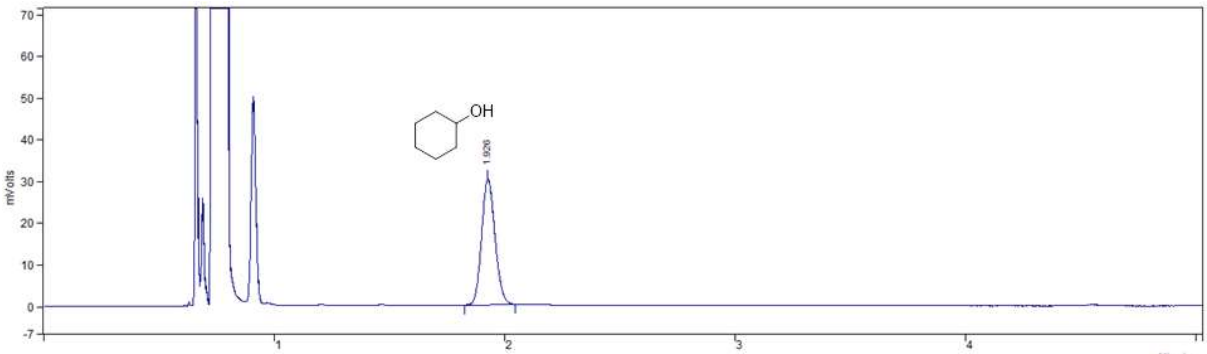
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		65.0536	1.948	0.000	168706	BV	3.9	
2		34.9464	2.195	0.000	90628	VB	3.8	
	Totals:	100.0000		0.000	259334			

Figure S70. Gas chromatogram of cyclohexanol reaction (Table 4, Entry 26)



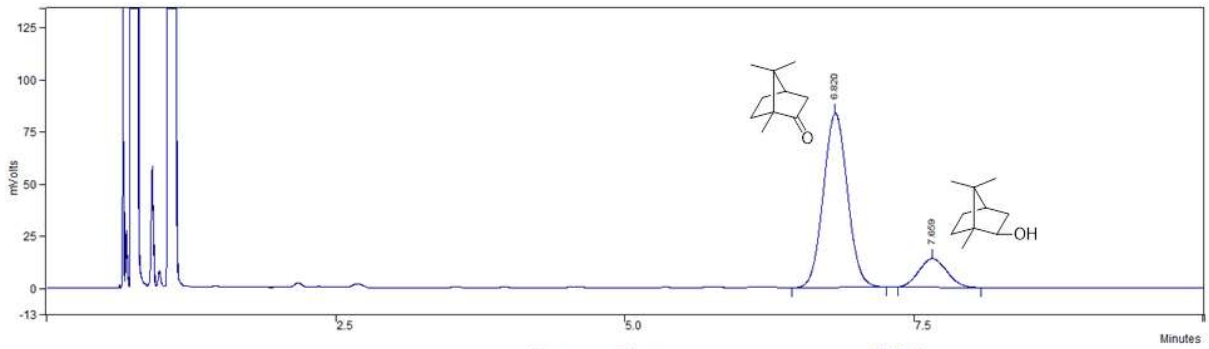
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	2.193	0.000	2242425	BB	3.7	
	Totals:	100.0000		0.000	2242425			

Figure S71. Gas chromatogram of cyclohexanone (blank)



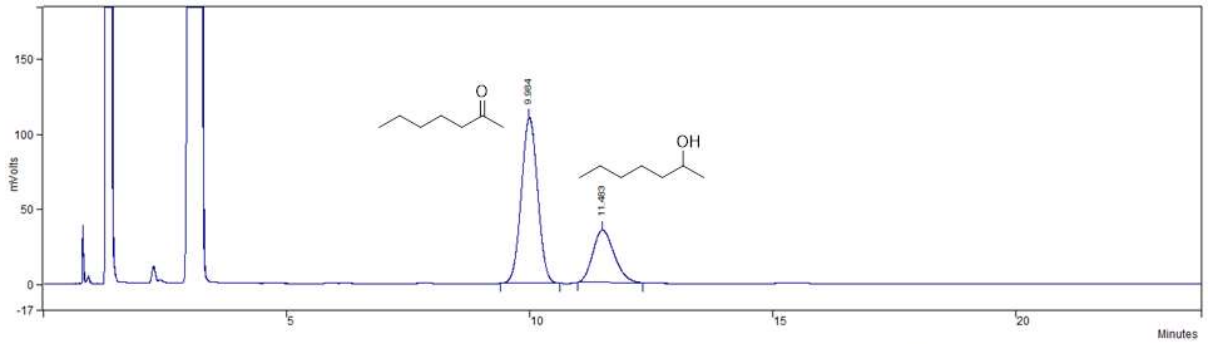
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		100.0000	1.926	0.000	122484	BB	3.8	
	Totals:	100.0000		0.000	122484			

Figure S72. Gas chromatogram of cyclohexanol (blank)



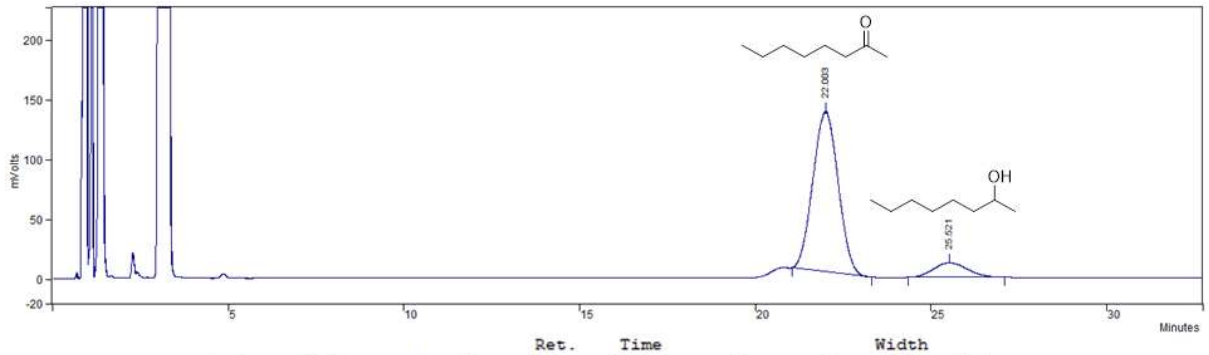
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		84.0557	6.820	0.000	1212470	BB	13.5	
2		15.9443	7.659	0.000	229990	BB	15.8	
	Totals:	100.0000		0.000	1442460			

Figure S73. Gas chromatogram of borneol reaction (Table 4, Entry 27)



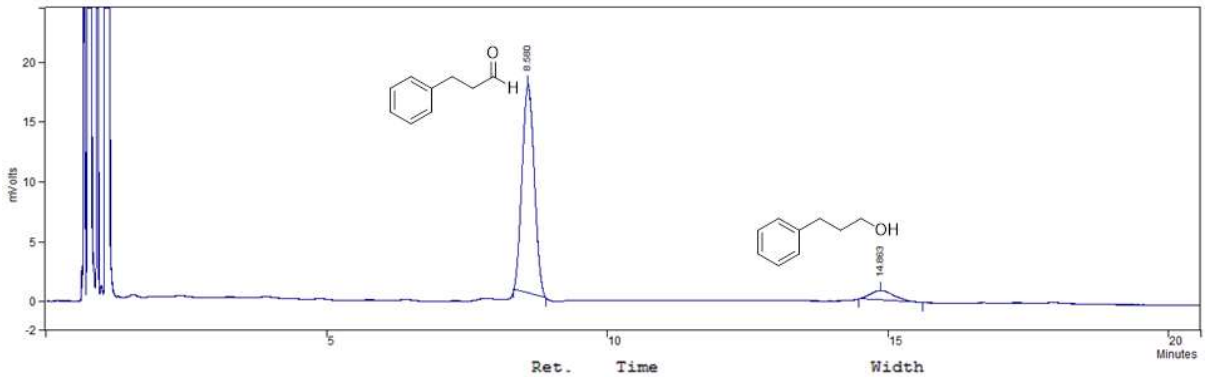
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		70.7906	9.984	0.000	2576345	BB	21.8	
2		29.2094	11.483	0.000	1063041	BB	28.3	
	Totals:	100.0000		0.000	3639386			

Figure S74. Gas chromatogram of 2-heptanol reaction (Table 4, Entry 28)



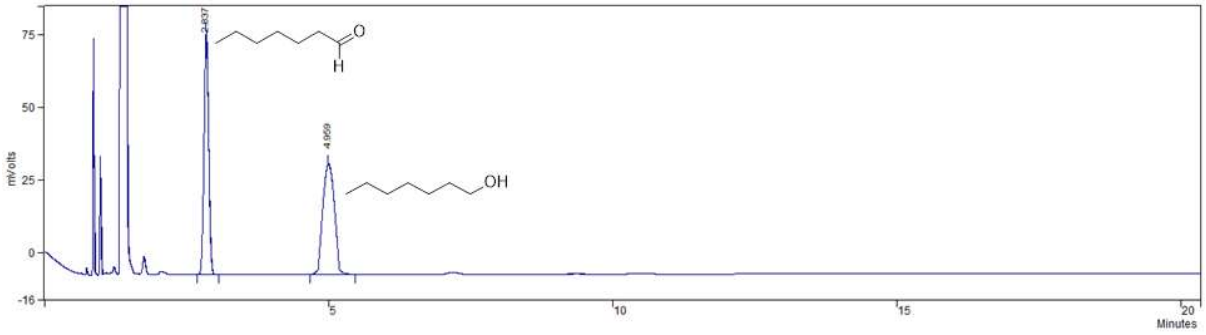
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		89.2349	22.003	0.000	6723395	BB	46.8	
2		10.7651	25.521	0.000	811096	BB	62.7	
	Totals:	100.0000		0.000	7534491			

Figure S75. Gas chromatogram of 2-octanol reaction (Table 4, Entry 29)



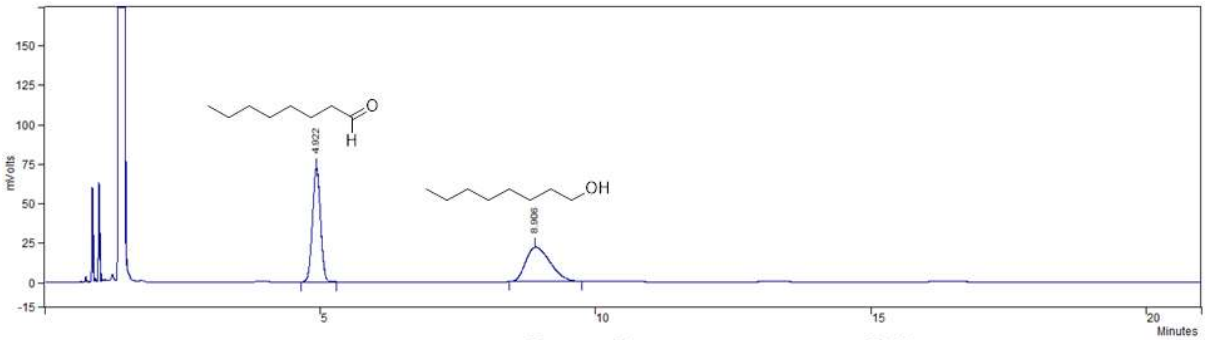
Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		91.7168	8.580	0.000	263828	BB	14.4	
2		8.2832	14.863	0.000	23827	BB	25.1	
Totals:		100.0000		0.000	287655			

Figure S76. Gas chromatogram of 3-phenyl-1-propanol reaction (Table 4, Entry 30)



Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		58.1115	2.837	0.000	475124	BB	5.3	
2		41.8885	4.959	0.000	342483	BB	10.1	
Totals:		100.0000		0.000	817607			

Figure S77. Gas chromatogram of 1-heptanol reaction (Table 4, Entry 31)



Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		52.1349	4.922	0.000	733646	BB	9.5	
2		47.8651	8.906	0.000	673562	BB	29.4	
Totals:		100.0000		0.000	1407208			

Figure S78. Gas chromatogram of 1-octanol reaction (Table 4, Entry 32)

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