catalysts

Supplementary Materials: Fine-Tuning Synthesis and Characterization of Mono-Sized H-Beta Zeolite-Supported Palladium-Iridium Nanoparticles and Application in the Selective Hydrogenation of Acetylene

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Table S1. Total amount of Si/(Al+SDA) ratio for synthesis of Beta-based catalysts.

Supports	$NaAlO_2$ (mM)	NaOH (mM)	TEOS (mM)	i (mM)	ii (mM)	iii (mM)	iv (mM)	$\frac{Si}{(Al+SDA)}$	BET (m^2/g)
Beta(0)	70	95	2	---	---	---	---	28.57	1474.78
Beta(i)	50	95	1.45	20	---	---	---	20.71	---
Beta(i)	50	95	2	20	---	---	---	28.57	500
Beta(i)	50	95	3	20	---	---	---	42.86	---
Beta(i)	60	95	2	20	---	---	---	25.00	---
Beta(i)	70	95	2	20	---	---	---	22.22	950
Beta(i)	80	95	2	20	---	---	---	20.00	---
Beta(i)	70	95	2	35	---	---	---	19.05	1358.3
Beta(i)	70	95	2	40	---	---	---	18.18	---
Beta(i)	70	95	2	50	---	---	---	16.67	---
Beta(ii)	50	95	1.45	---	15.27	---	---	22.21	---
Beta(ii)	50	95	2	---	15.27	---	---	30.64	375
Beta(ii)	50	95	3	---	15.27	---	---	45.96	---
Beta(ii)	60	95	2	---	15.27	---	---	26.57	---
Beta(ii)	70	95	2	---	15.27	---	---	23.45	546
Beta(ii)	80	95	2	---	15.27	---	---	20.99	---
Beta(ii)	70	95	2	---	26.73	---	---	20.68	1054.2
Beta(ii)	70	95	2	---	30.55	---	---	19.89	---
Beta(ii)	70	95	2	---	38.19	---	---	18.49	---
Beta(iii)	50	95	1.45	---	---	46.68	---	15.00	---
Beta(iii)	50	95	2	---	---	46.68	---	20.69	257
Beta(iii)	50	95	3	---	---	46.68	---	31.03	---
Beta(iii)	60	95	2	---	---	46.68	---	18.75	---
Beta(iii)	70	95	2	---	---	46.68	---	17.14	348
Beta(iii)	80	95	2	---	---	46.68	---	15.79	---
Beta(iii)	70	95	2	---	---	81.70	---	13.18	745.9
Beta(iii)	70	95	2	---	---	93.37	---	12.24	---
Beta(iii)	70	95	2	---	---	116.71		10.71	---
Beta(iv)	50	95	1.45	---	---	---	55.61	13.73	---
Beta(iv)	50	95	2	---	---	---	55.61	18.94	110
Beta(iv)	50	95	3	---	---	---	55.61	28.41	---
Beta(iv)	60	95	2	---	---	---	55.61	17.30	---
Beta(iv)	70	95	2	---	---	---	55.61	15.92	250.3
Beta(iv)	80	95	2	---	---	---	55.61	14.75	---

Beta(iv)	70	95	2	---	---	---	97.31	11.95	587.4
Beta(iv)	70	95	2	---	---	---	111.22	11.04	---
Beta(iv)	70	95	2	---	---	---	139.02	9.57	---

i:TPAOH ii:TPABr iii: morpholine iv:n-butylamine

Table S2. The amount value of metals loading on H-Beta(i)-based catalysts.

Catalysts	H_2PdCl_4(%mol)	$AgNO_3$(%mol)	$Ir.Cl_3.H_2O$(%mol)	$Ce(NO_3)_3.6H_2O$(%mol)	BET(m^2/gr)
1	0.009	---	---	---	
2	0.117	---	---	---	
3	0.235	---	---	---	
4	0.376	---	---	---	1248.1
5	0.399	---	---	---	
6	0.470	---	---	---	
7	0.376	0.927	---	---	
8	0.376	1.391	---	---	
9	0.376	1.669	---	---	
10	0.376	1.761	---	---	850.3
11	0.376	1.854	---	---	
12	0.376	2.781	---	---	
13	0.376	---	0.052	---	
14	0.376	---	0.104	---	
15	0.376	---	0.130	---	
16	0.376	---	0.151	---	1108.9
17	0.376	---	0.156	---	
18	0.376	---	0.208	---	
19	0.376	---	---	0.714	
20	0.376	---	---	1.427	
21	0.376	---	---	1.784	
22	0.376	---	---	1.998	
23	0.376	---	---	2.070	973.7
24	0.376	---	---	2.141	

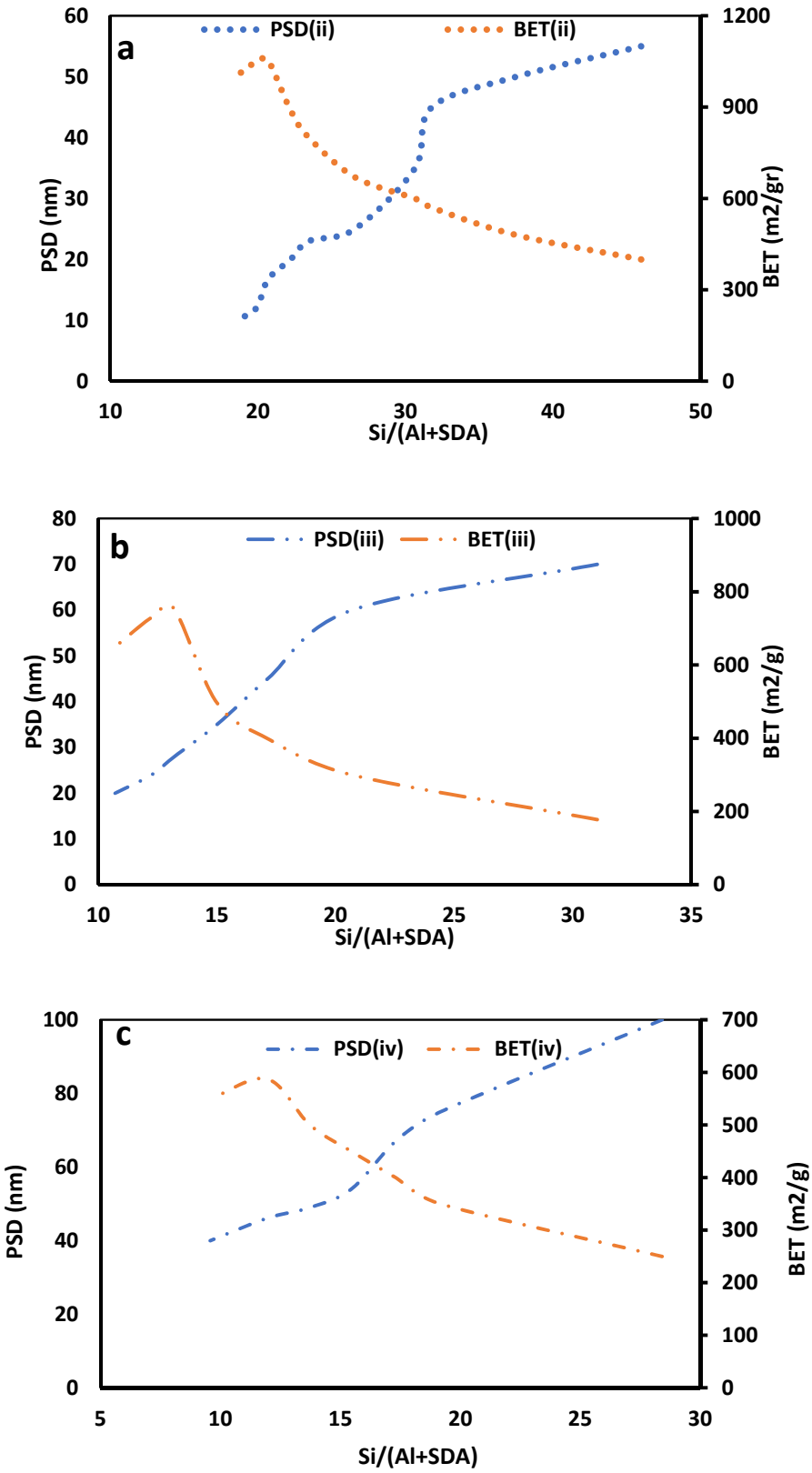

a
PSD(ii)
BET(ii)
PSD (nm)
BET (m2/gr)
Si/(Al+SDA)
b
PSD(iii)
BET(iii)
PSD (nm)
BET (m2/g)
Si/(Al+SDA)
c
PSD(iv)
BET(iv)
PSD (nm)
BET (m2/g)
Si/(Al+SDA)

Figure S1. Effect of Si/(Al+SDA) ratio over PSD and BET of Beta-based catalyst for (**a**) TPABr, (**b**) morpholine and (**c**) n-butylamine as SDA.

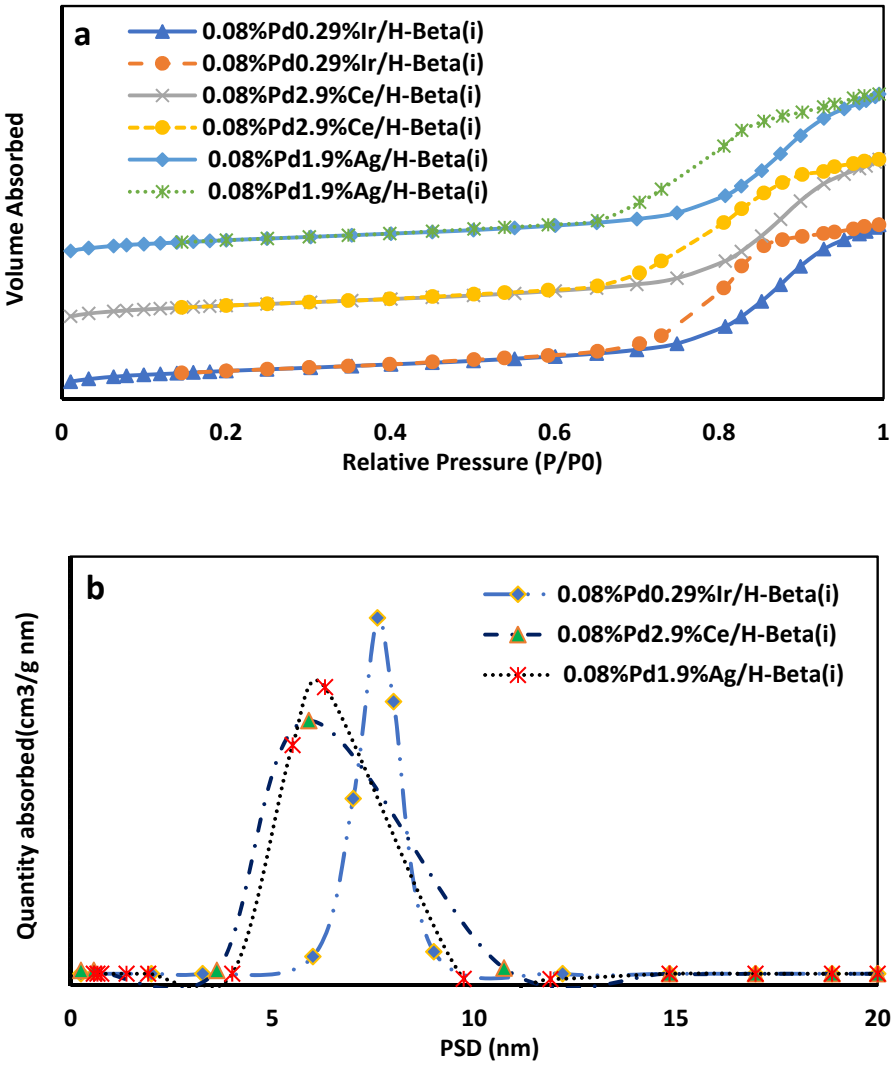


Figure S2. N_2 adsorption-desorption isotherms (**a**) and BJH pore diameter distributions patterns (**b**) of the optimum catalysts.

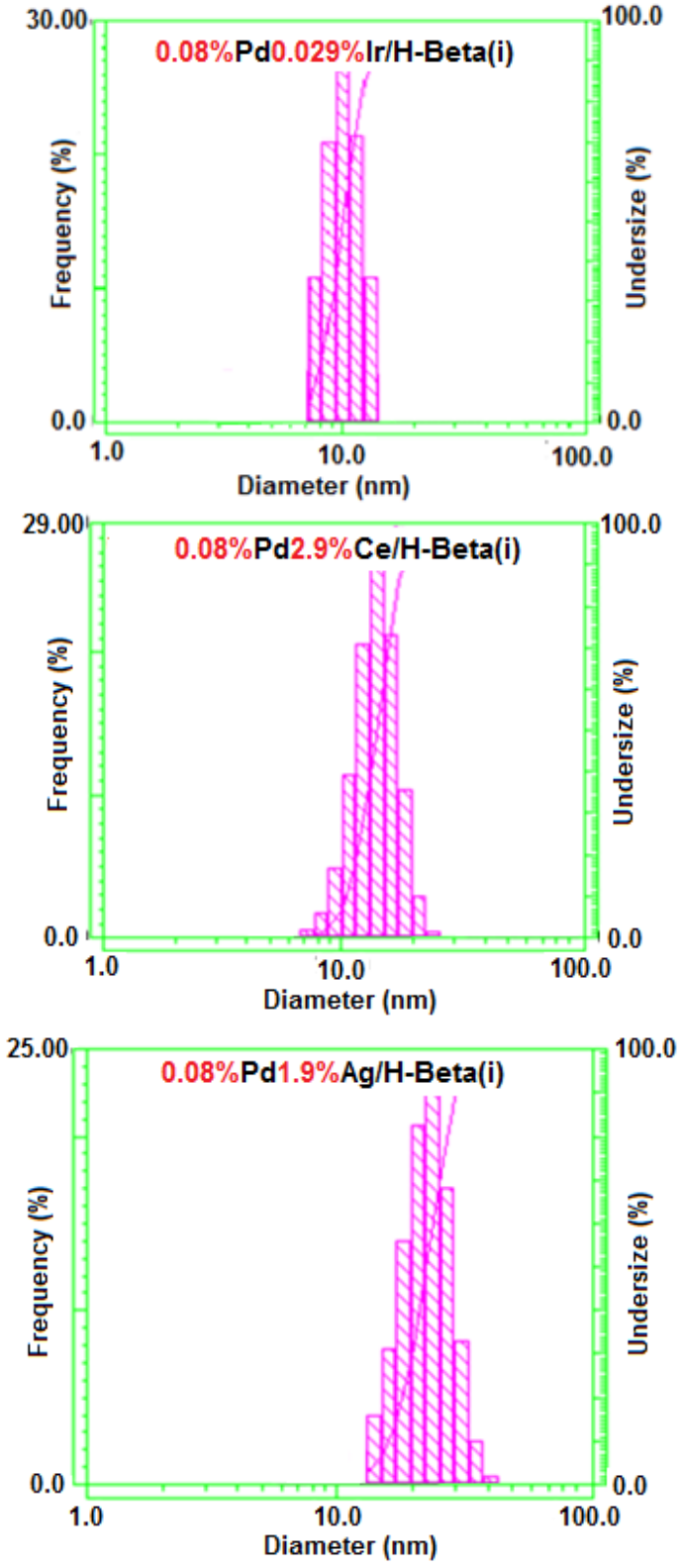
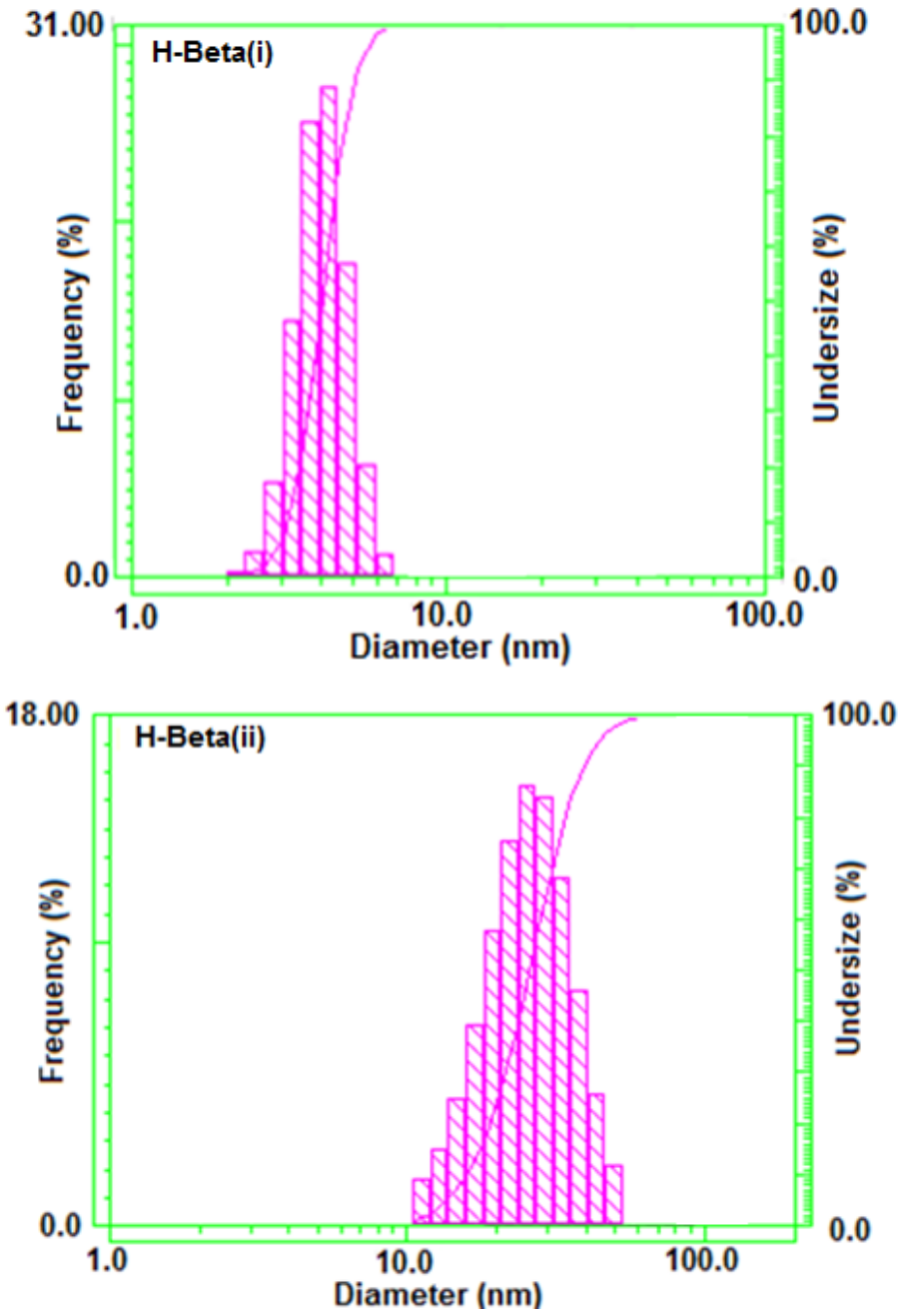


Figure S3. DLS pictures of the catalysts of optimum via TPAOH.


31.00
H-Beta(i)
100.0
Frequency (%)
Undersize (%)
0.0
0.0
1.0
10.0
100.0
Diameter (nm)
18.00
H-Beta(ii)
100.0
Frequency (%)
Undersize (%)
0.0
0.0
1.0
10.0
100.0
Diameter (nm)

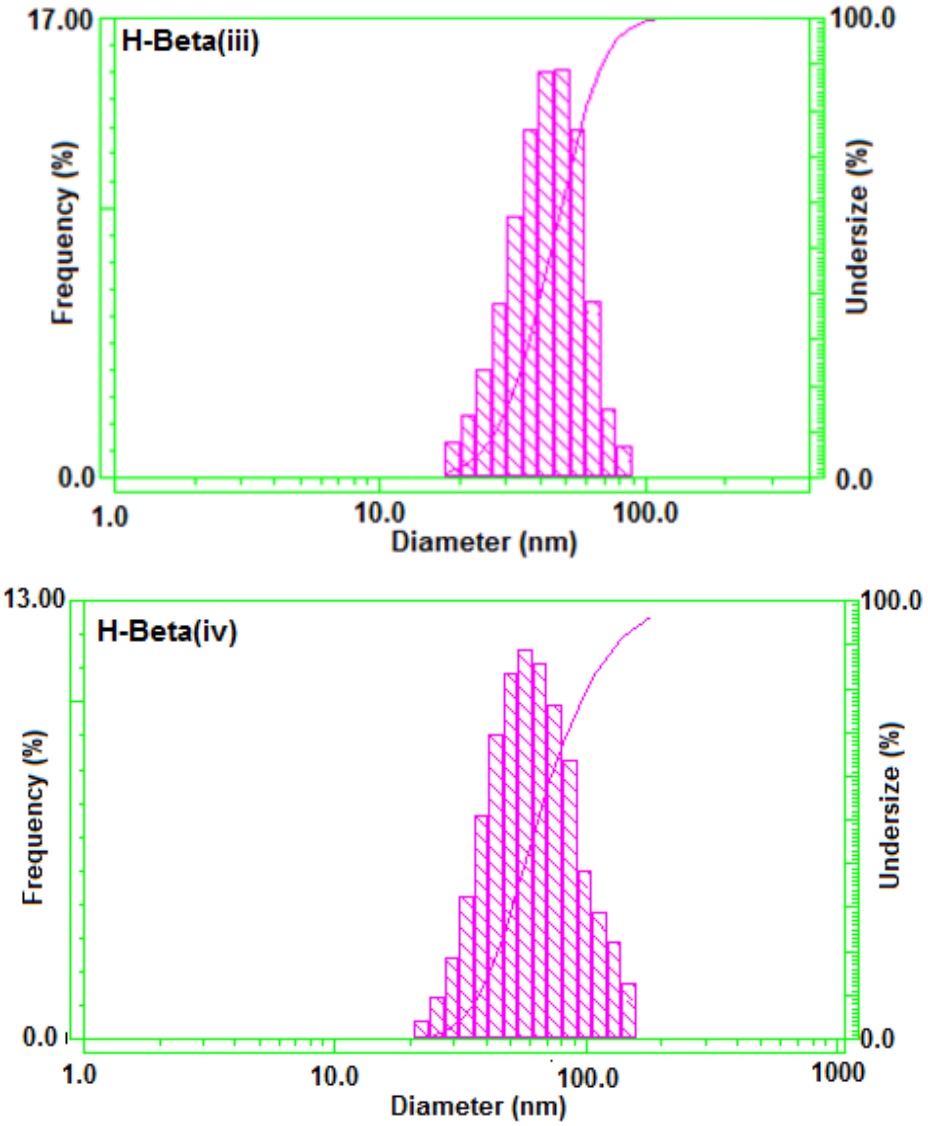
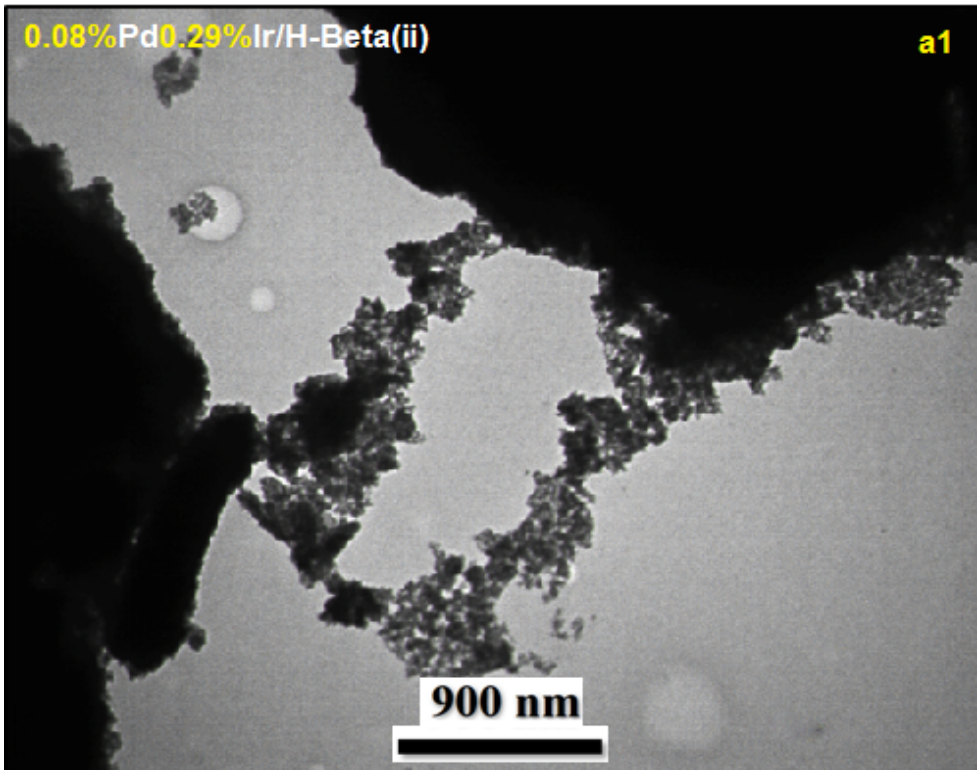
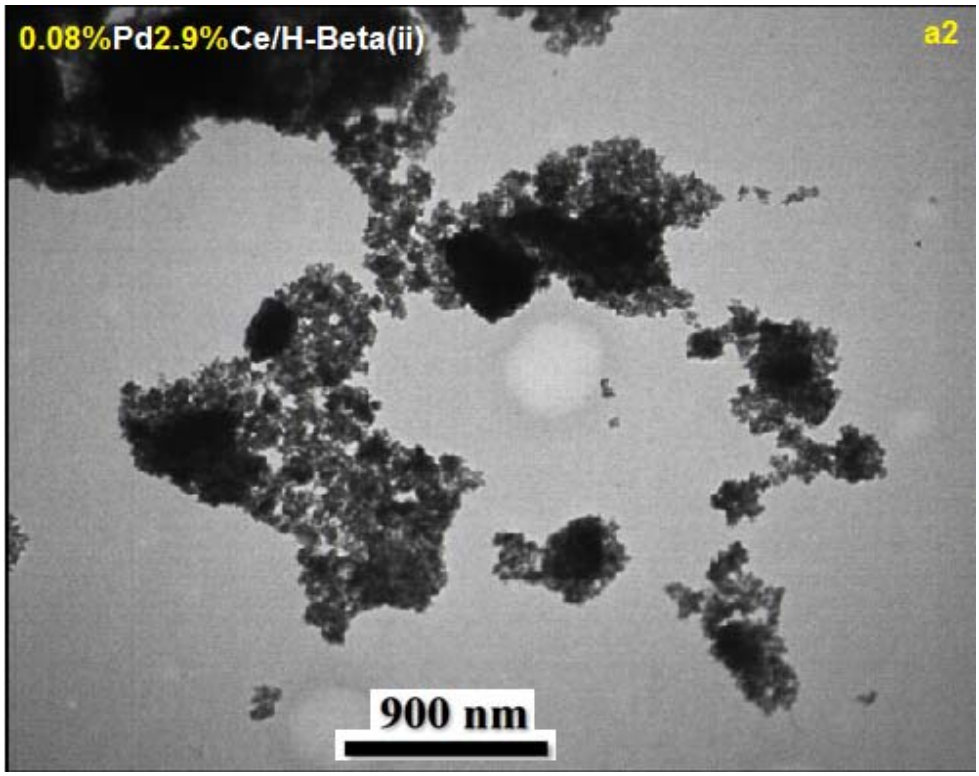
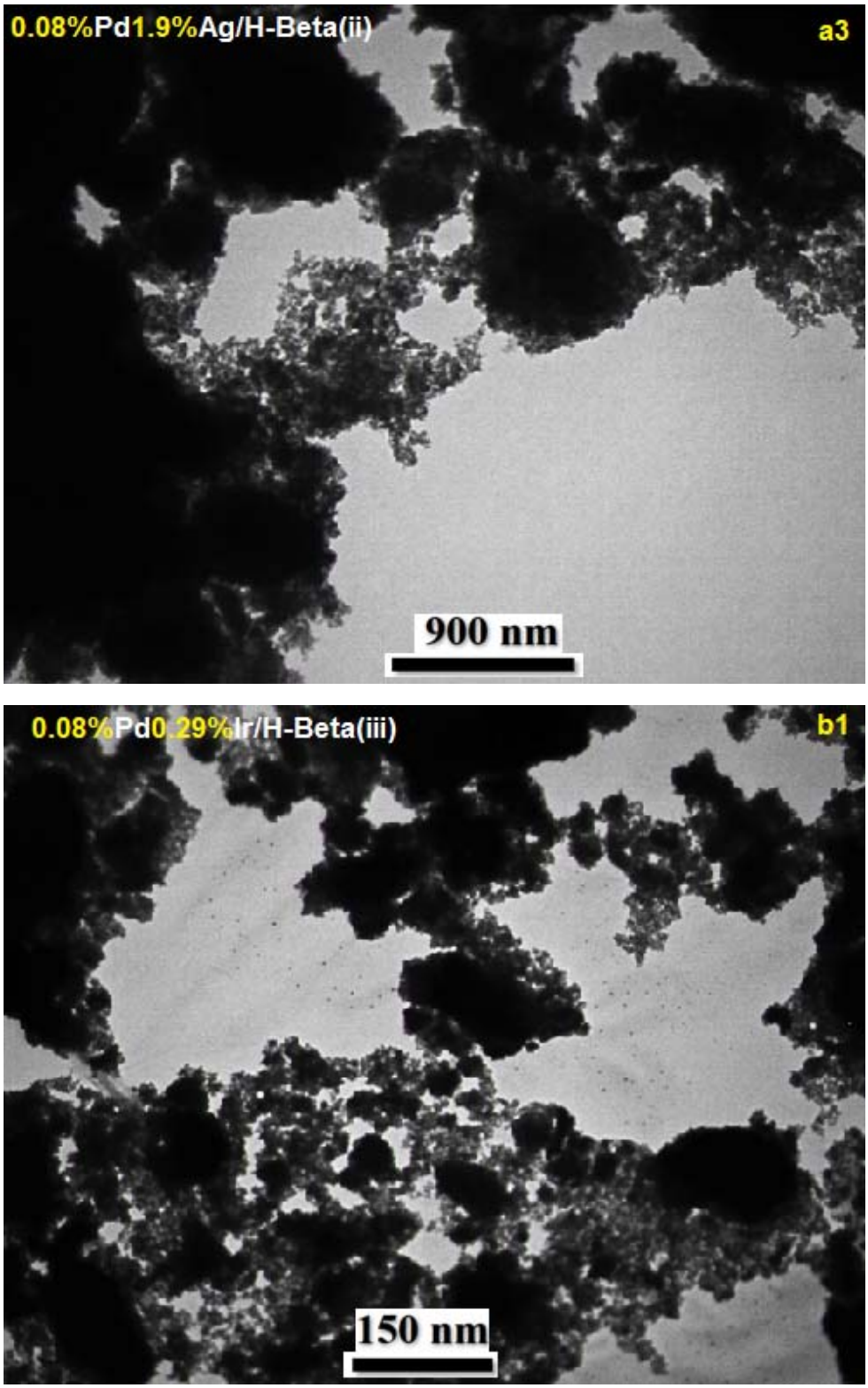
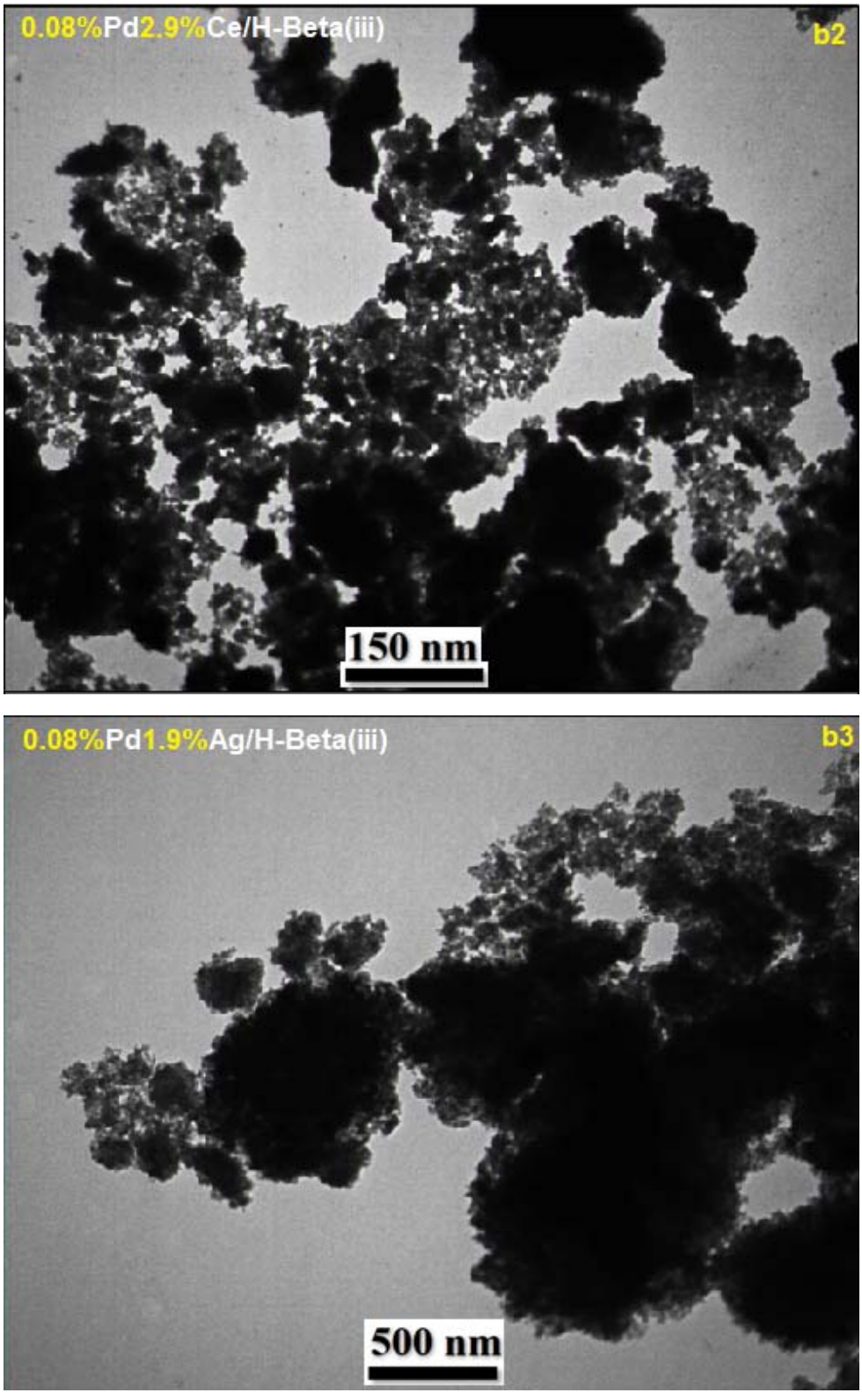


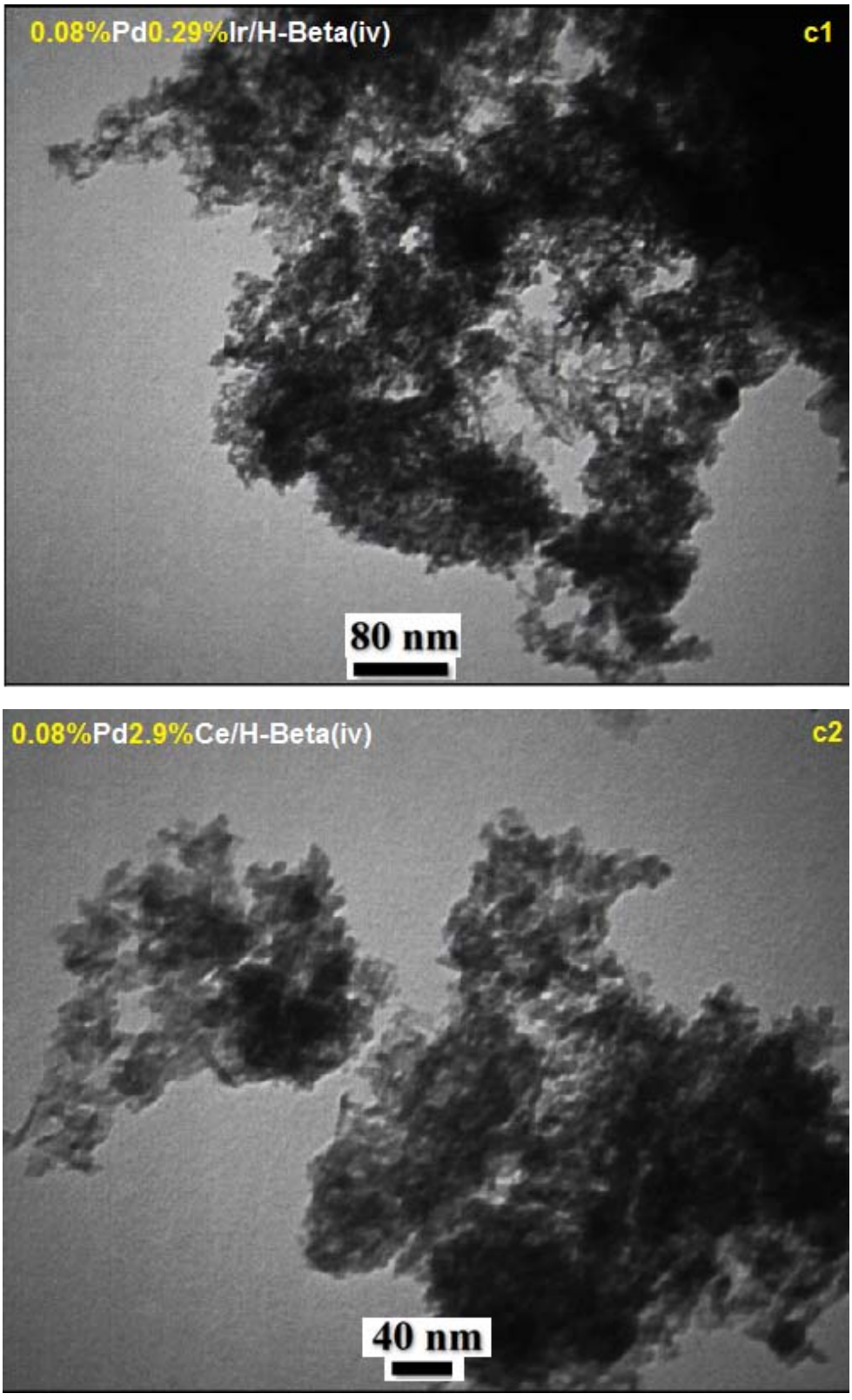
Figure S4. DLS patterns of H-Beta-based catalyst with SDA.


0.08%Pd0.29%Ir/H-Beta(ii)
a1
900 nm


0.08%Pd2.9%Ce/H-Beta(ii)
a2
900 nm


0.08%Pd1.9%Ag/H-Beta(ii)
a3
900 nm
0.08%Pd0.29%Ir/H-Beta(iii)
b1
150 nm


0.08%Pd2.9%Ce/H-Beta(iii)
b2
150 nm
0.08%Pd1.9%Ag/H-Beta(iii)
b3
500 nm


0.08%Pd0.29%Ir/H-Beta(iv)
c1
80 nm
0.08%Pd2.9%Ce/H-Beta(iv)
c2
40 nm

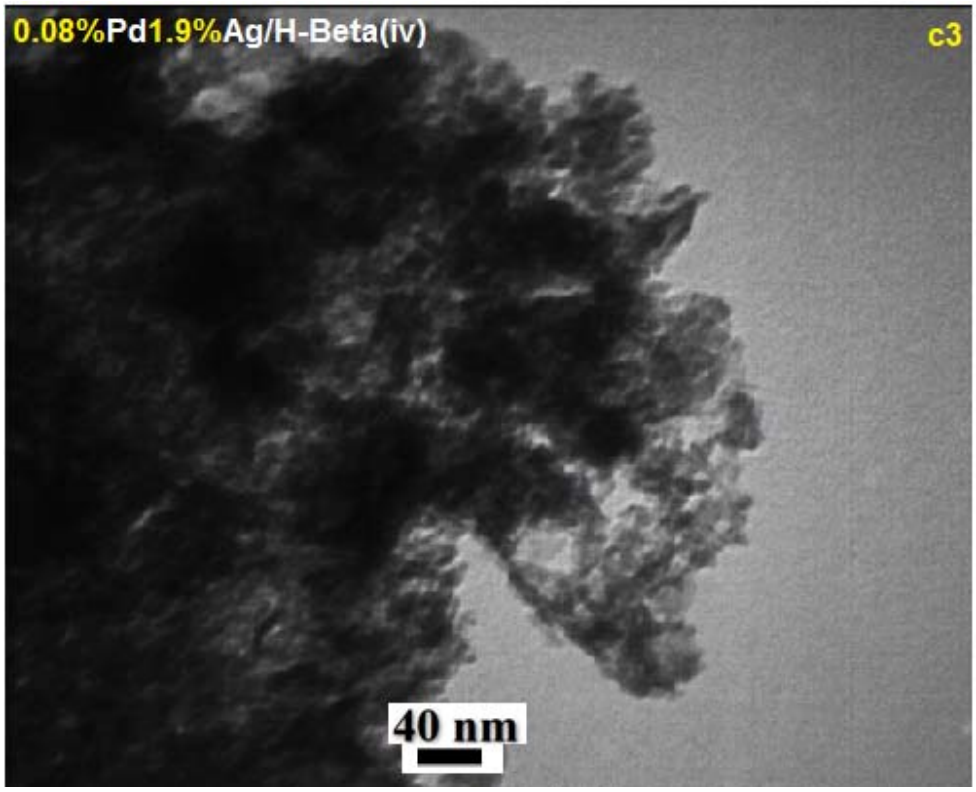
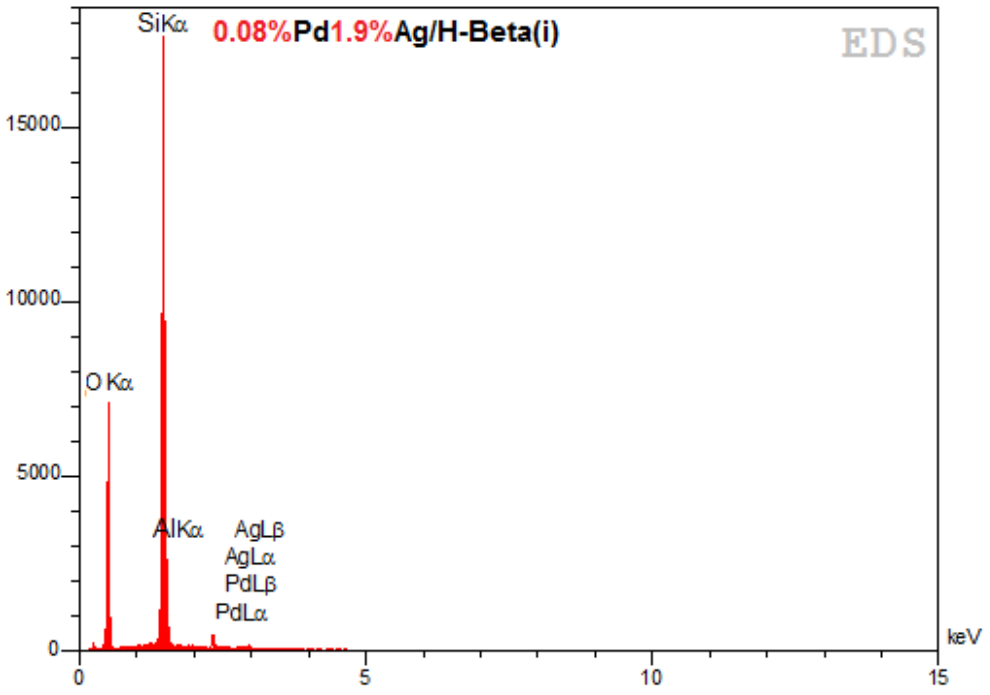


Figure S5. TEM patterns of different Beta-based catalysts, (**a**1) 0.08%Pd0.29%Ir/H-Beta(ii), (**a**2) 0.08%Pd2.9%Ce/H-Beta(ii), (**a**3) 0.08%Pd1.9%Ag/H-Beta(ii), (**b**1) 0.08%Pd0.29%Ir/H-Beta(iii), (**b**2) 0.08%Pd2.9%Ce/H-Beta(iii), (**b**3) 0.08%Pd1.9%Ag/H-Beta(iii), (**c**1) 0.08%Pd0.29%Ir/H-Beta(iv), (**c**2) 0.08%Pd2.9%Ce/H-Beta(iv), (**c**3) 0.08%Pd1.9%Ag/H-Beta(iv).



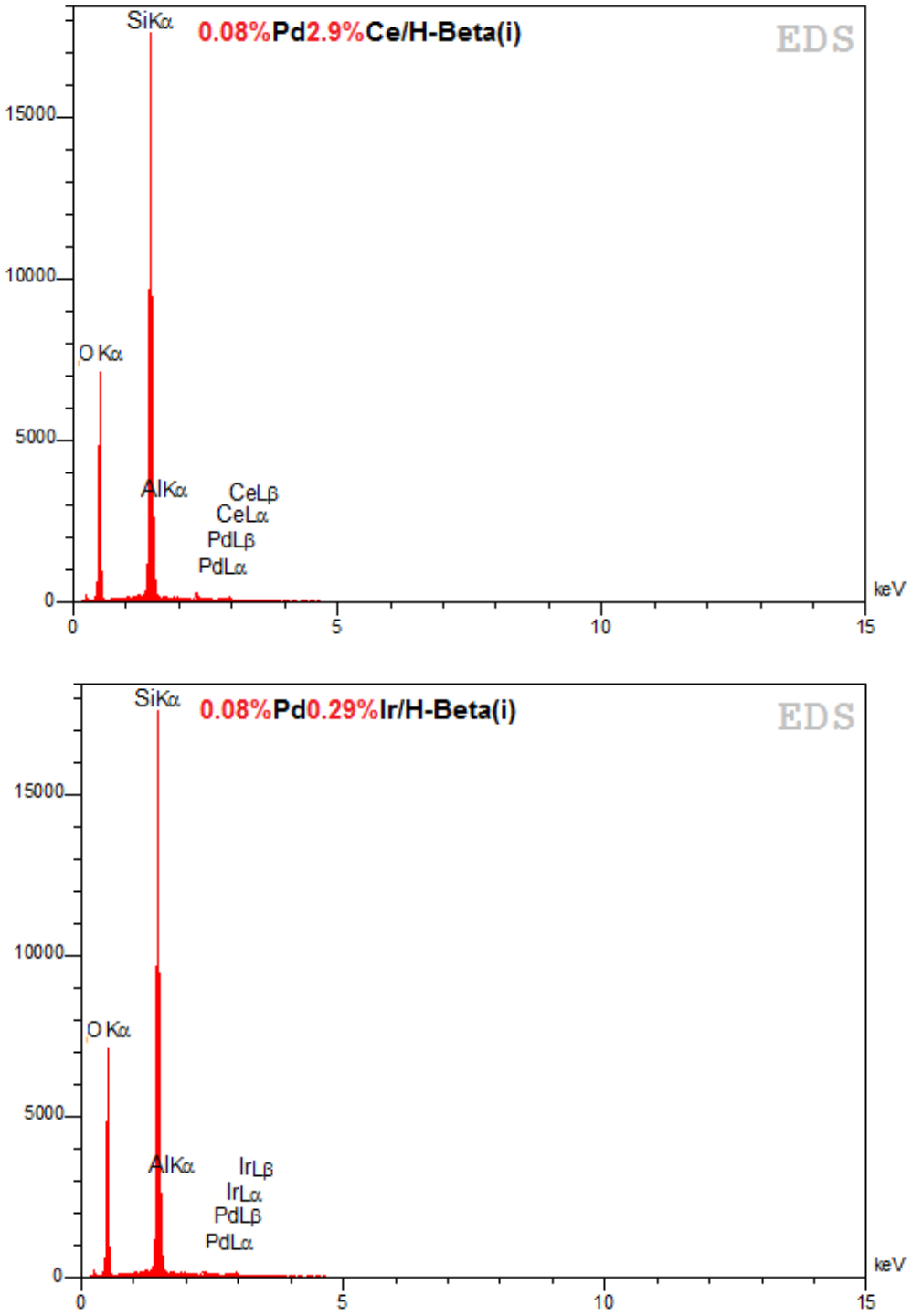
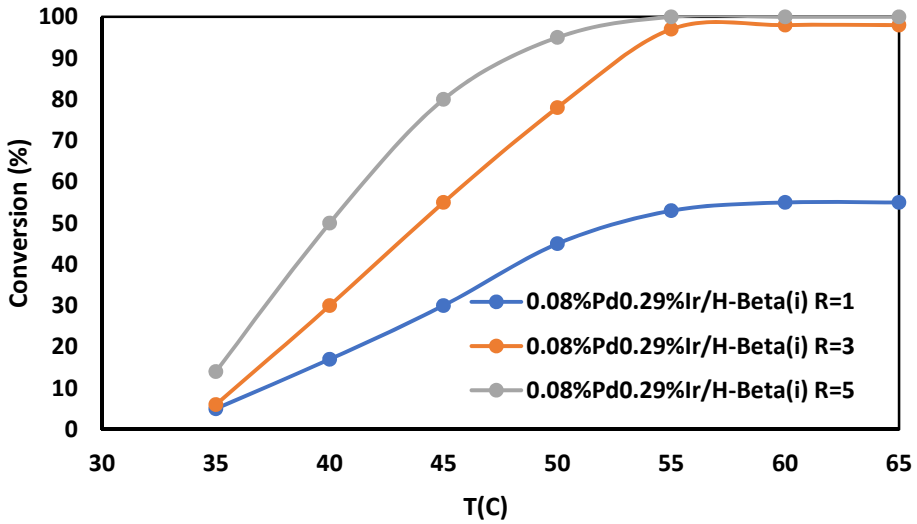
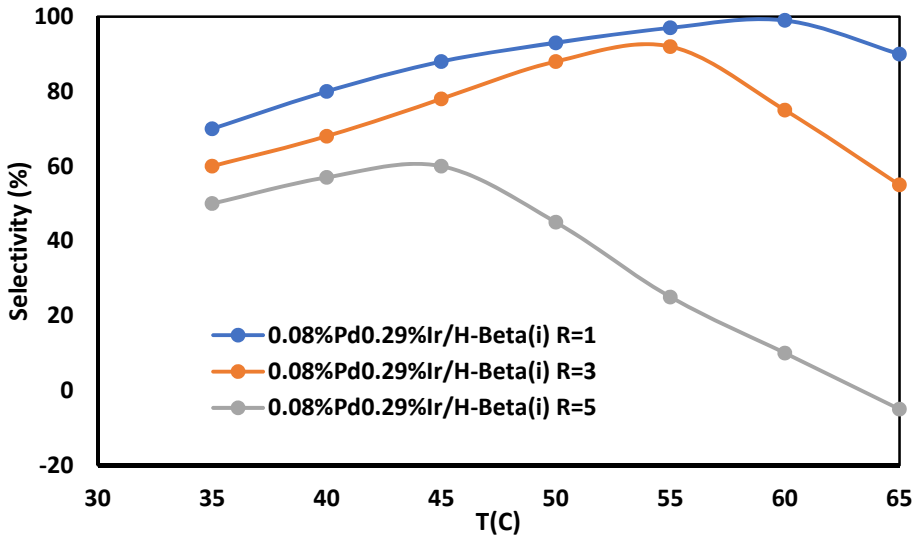


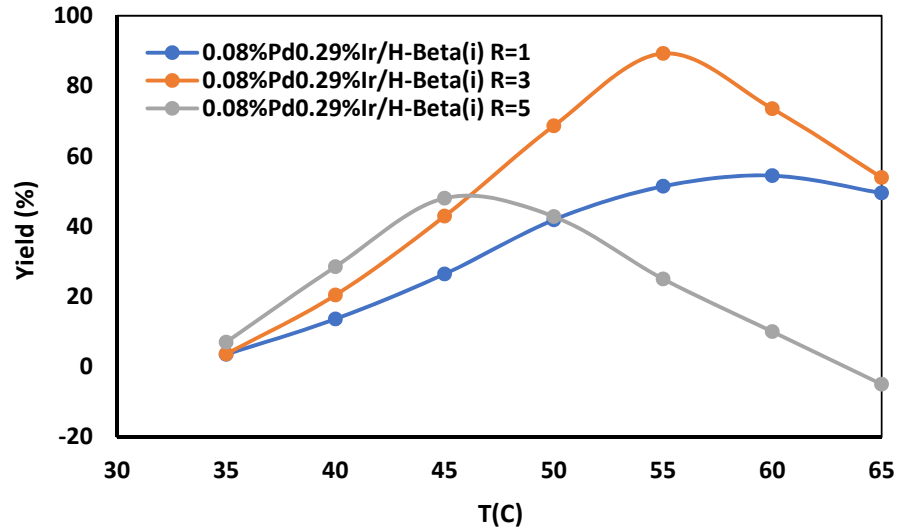
Figure S6. EDX analyses of the optimum catalysts.


Conversion (%)
T(C)
0.08%Pd0.29%Ir/H-Beta(i) R=1
0.08%Pd0.29%Ir/H-Beta(i) R=3
0.08%Pd0.29%Ir/H-Beta(i) R=5

(a)

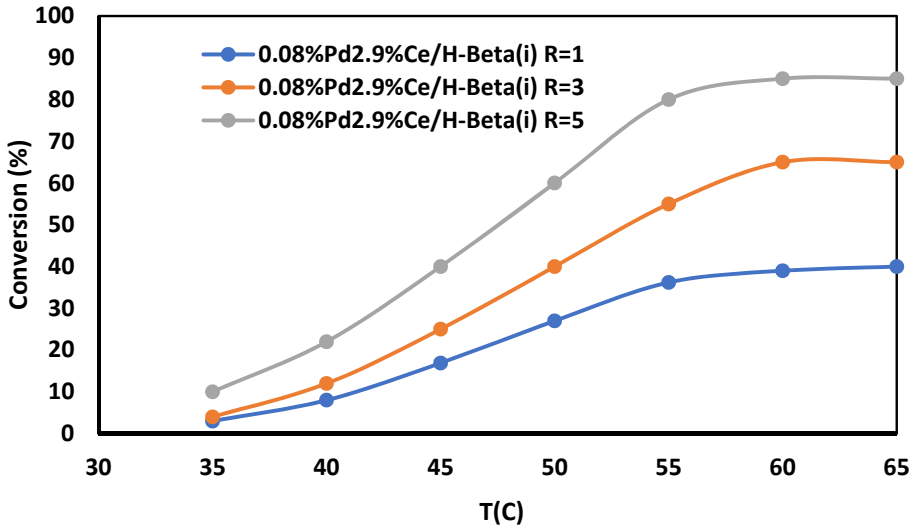

Selectivity (%)
T(C)
0.08%Pd0.29%Ir/H-Beta(i) R=1
0.08%Pd0.29%Ir/H-Beta(i) R=3
0.08%Pd0.29%Ir/H-Beta(i) R=5

(b)

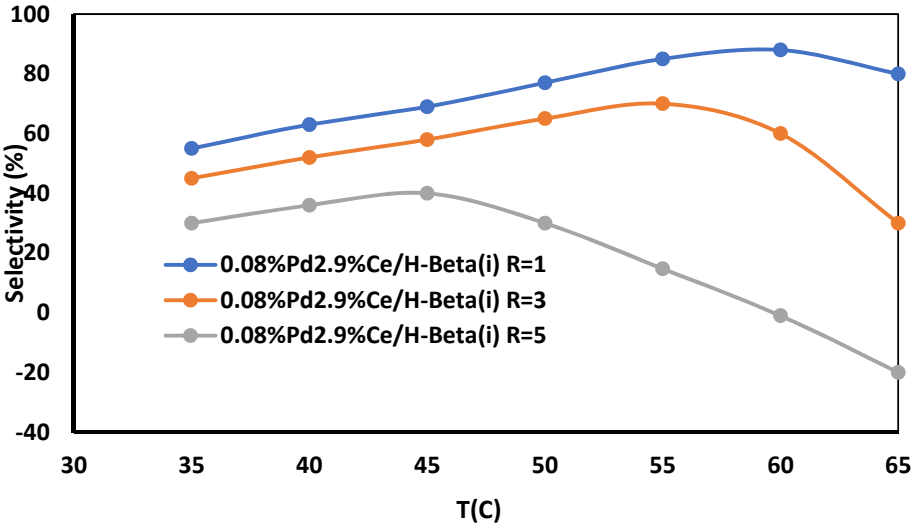


(**c**)

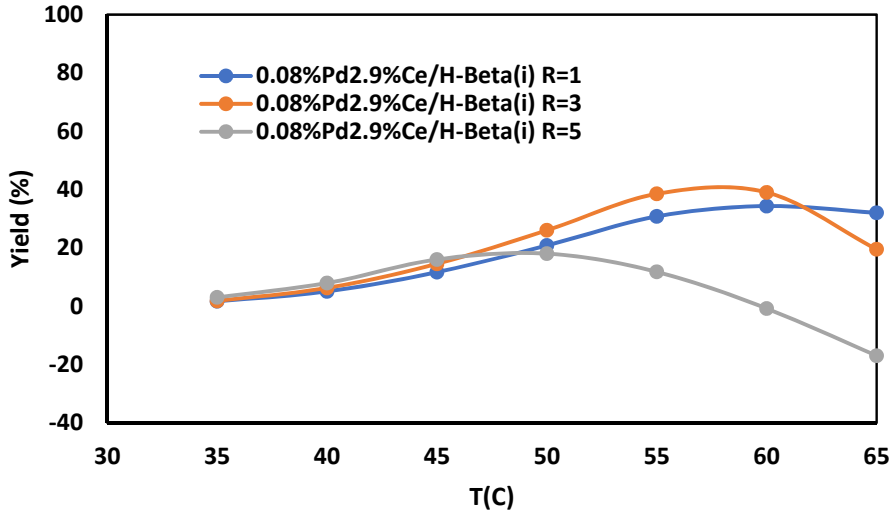
Figure S7. (**a**) Acetylene conversion, (**b**) Ethylene selectivity and (**c**) Yield percentage over 0.08%Pd 0.29%Ir/H-Beta(i) catalysts under different H_2/C_2H_2 ratios, GHSV=4030 h^{-1}, and P=20 bar.



(**a**)

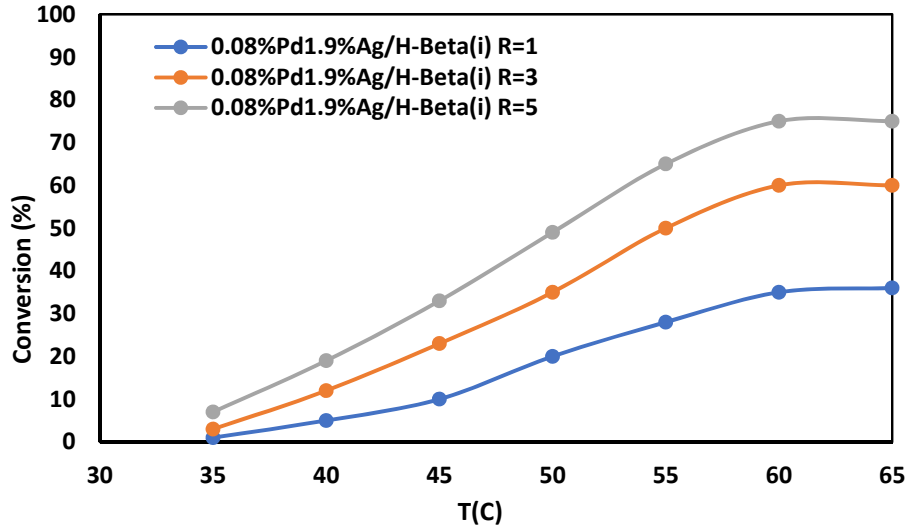


(**b**)

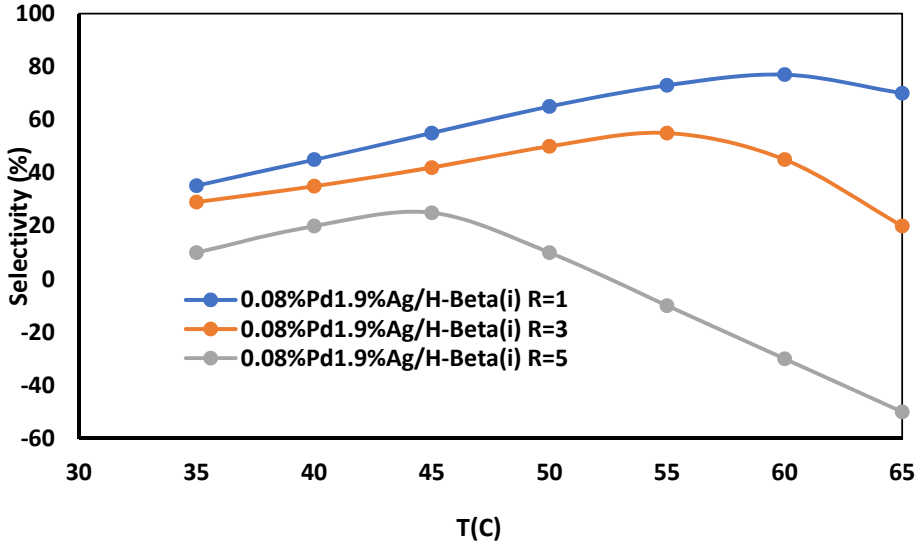


(**c**)

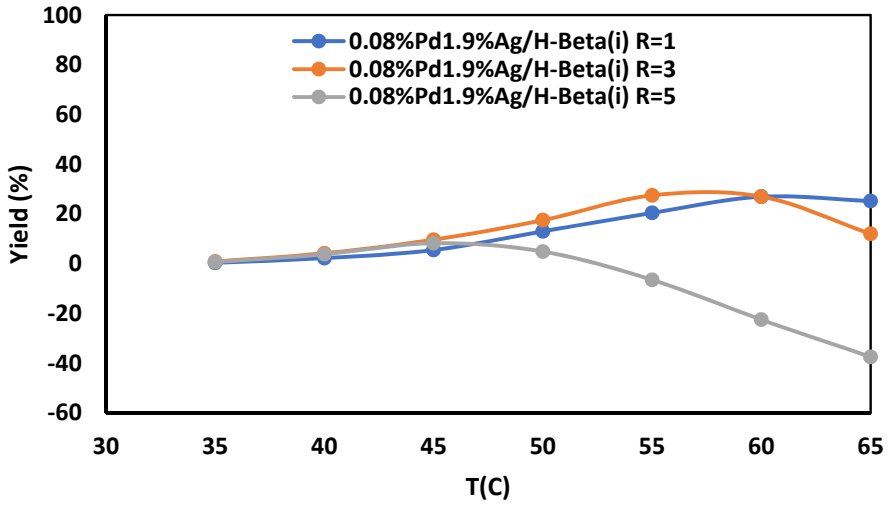
Figure S8. (a) Acetylene conversion, (b) Ethylene selectivity and (c) Yield percentage over 0.08%Pd 2.9%Ce/H-Beta(i) catalysts under different H_2/C_2H_2 ratios GHSV=4030 h^{-1}, and P=20 bar.


100
90
80
70
60
50
40
30
20
10
0
Conversion (%)
0.08%Pd1.9%Ag/H-Beta(i) R=1
0.08%Pd1.9%Ag/H-Beta(i) R=3
0.08%Pd1.9%Ag/H-Beta(i) R=5
30
35
40
45
50
55
60
65
T(C)

(a)

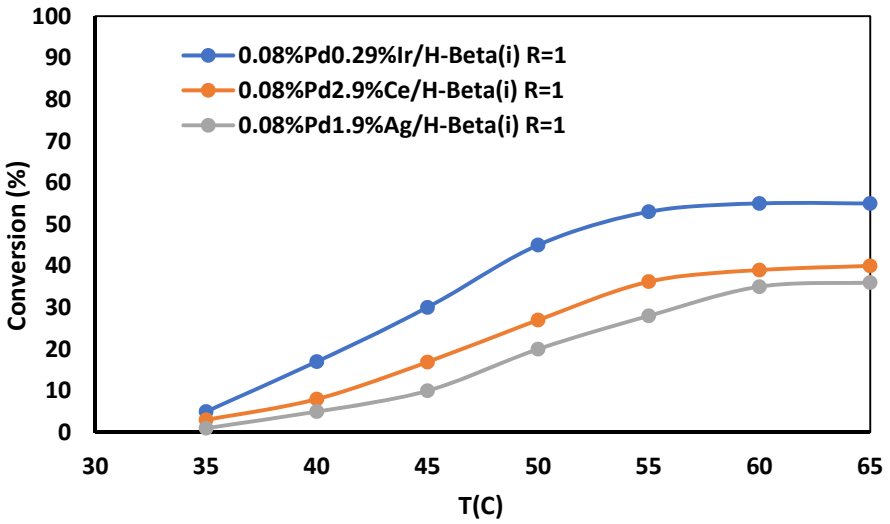

100
80
60
40
20
0
-20
-40
-60
Selectivity (%)
0.08%Pd1.9%Ag/H-Beta(i) R=1
0.08%Pd1.9%Ag/H-Beta(i) R=3
0.08%Pd1.9%Ag/H-Beta(i) R=5
30
35
40
45
50
55
60
65
T(C)

(b)

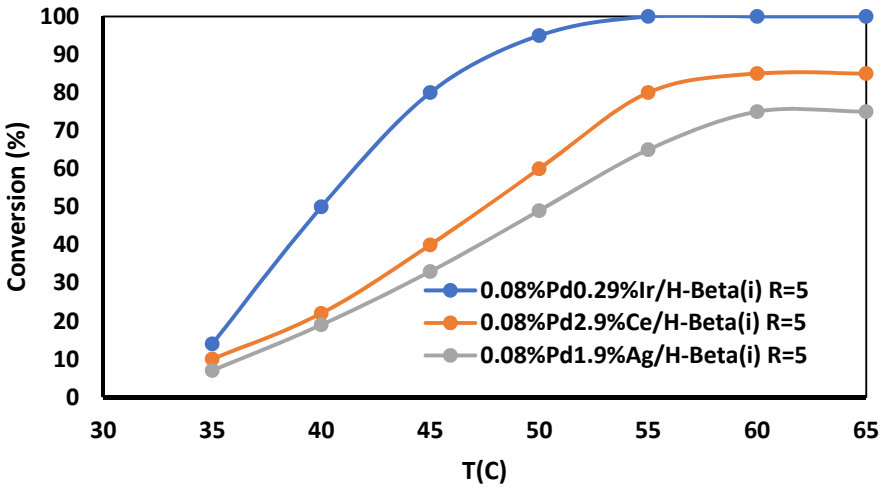


(**c**)

Figure S9. (a) Acetylene conversion, (b) Ethylene selectivity and (c) Yield percentage over 0.08%Pd 1.9%Ag/H-Beta(i) catalysts under different H_2/C_2H_2 ratios GHSV=4030 h^{-1}, and P=20 bar.

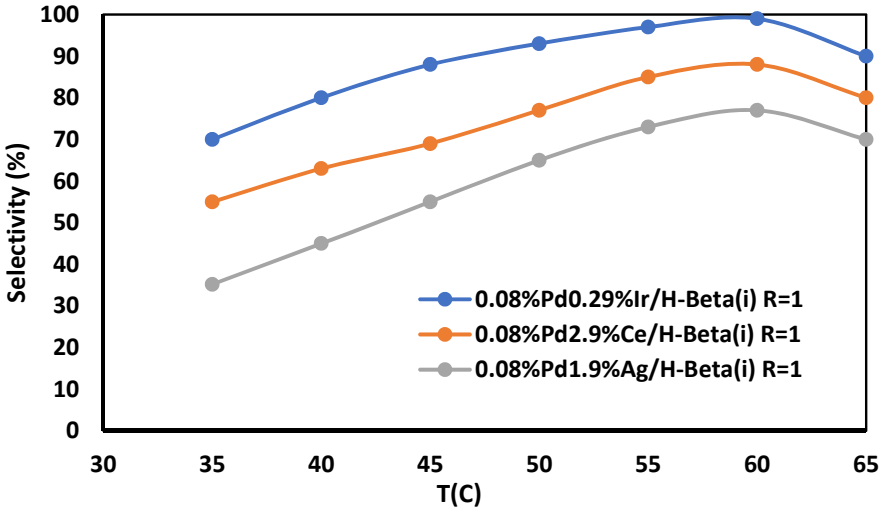


(**a**)

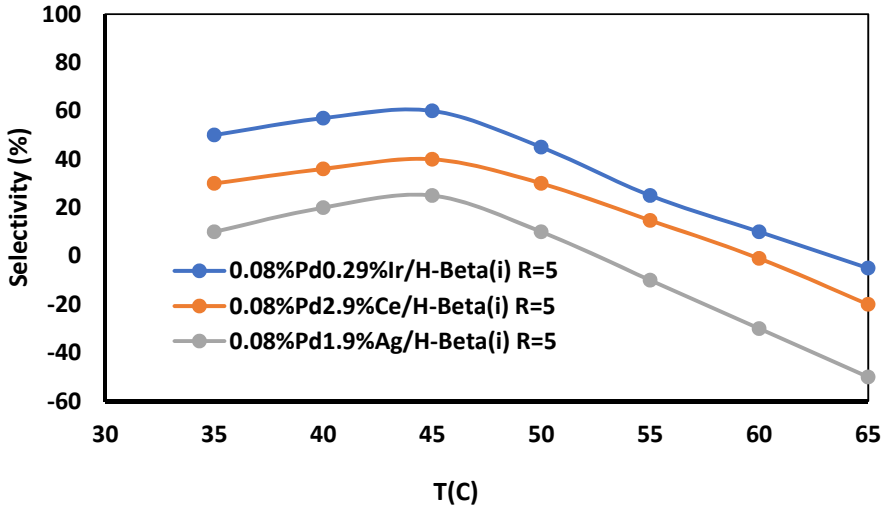


(**b**)

Figure S10. Acetylene conversion over optimum catalysts under P=20 bar and GHSV= 4030 h^{-1} (a) R=1 and (**b**) R=5.

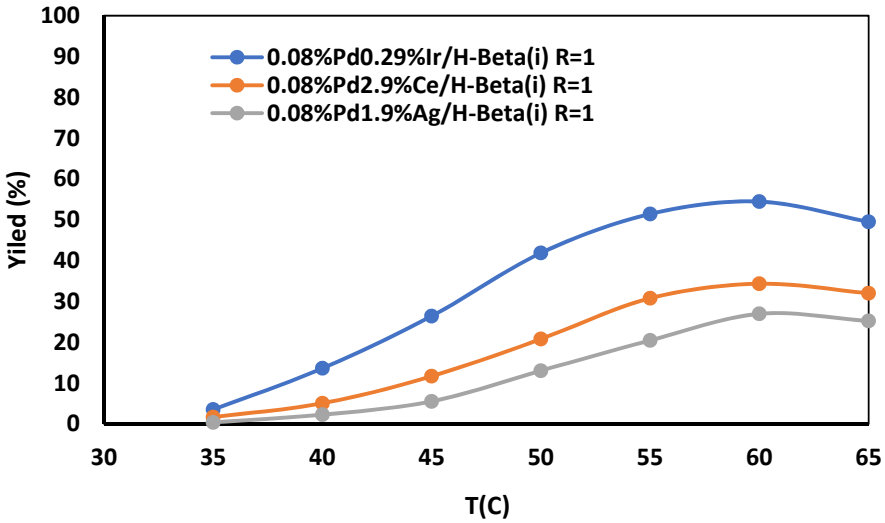


(**a**)

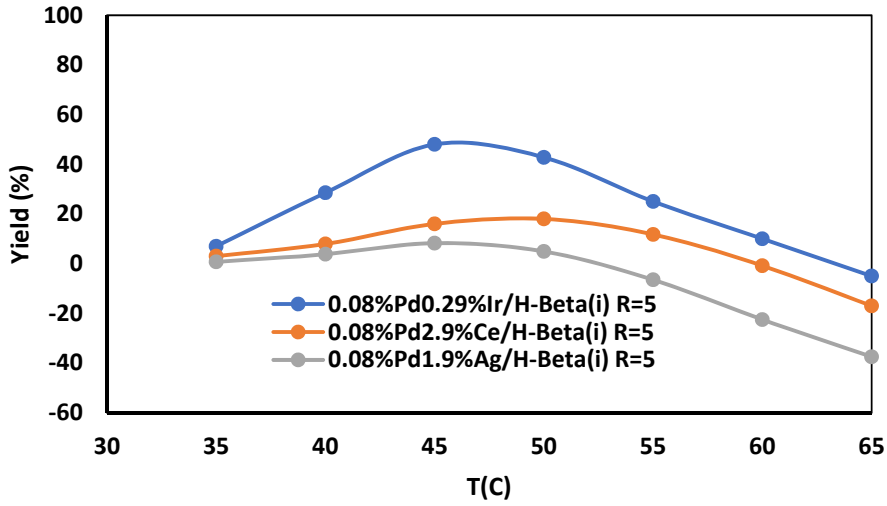


(**b**)

Figure S11. Ethylene selectivity optimum catalysts under P=20 bar and GHSV= 4030 h^{-1} (**a**) R=1 and (**b**) R=5.

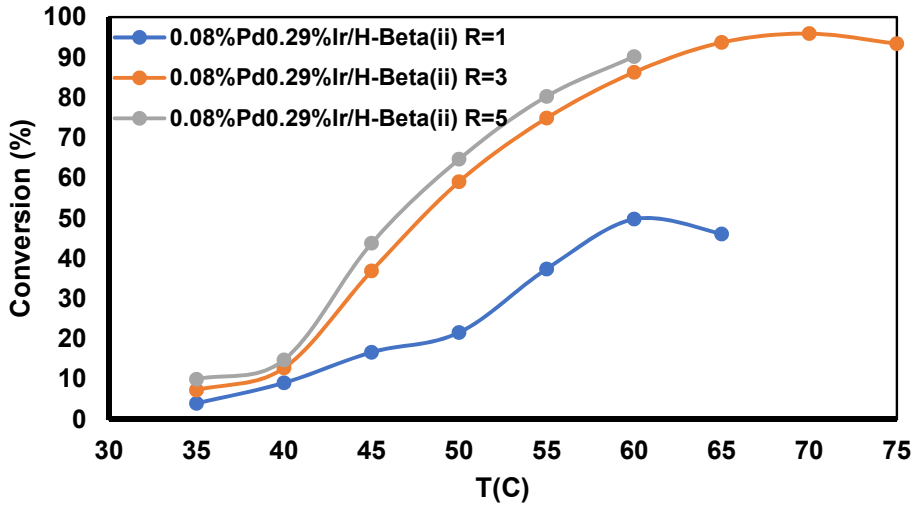


(**a**)

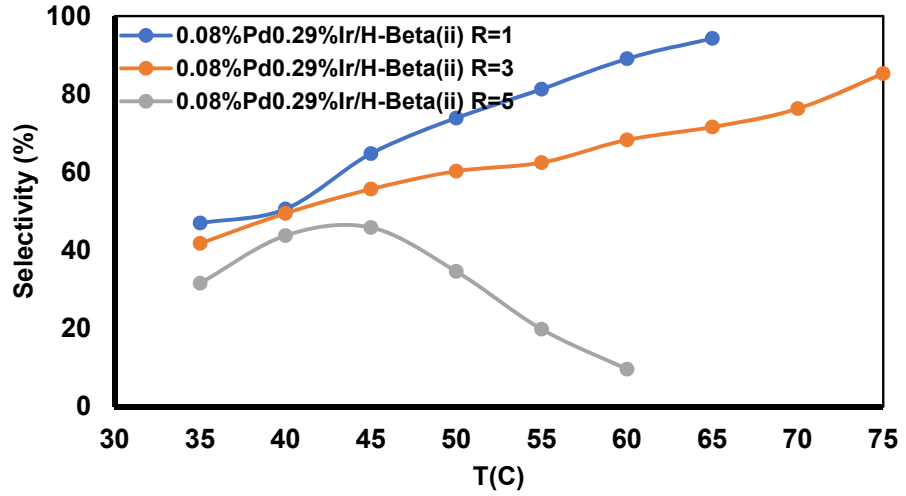


(**b**)

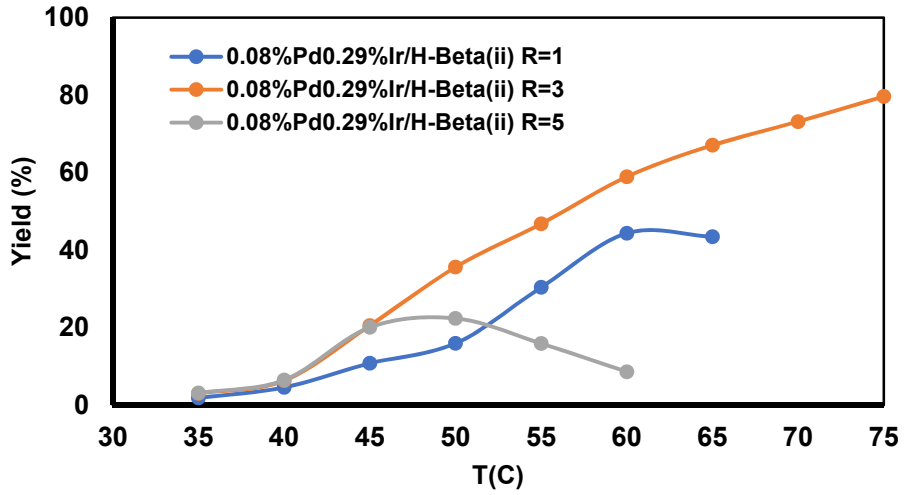
Figure S12. Yield over optimum catalysts under P=20 bar and GHSV= 4030 h^{-1} (**a**) R=1 and (**b**) R=5.



(**a**)

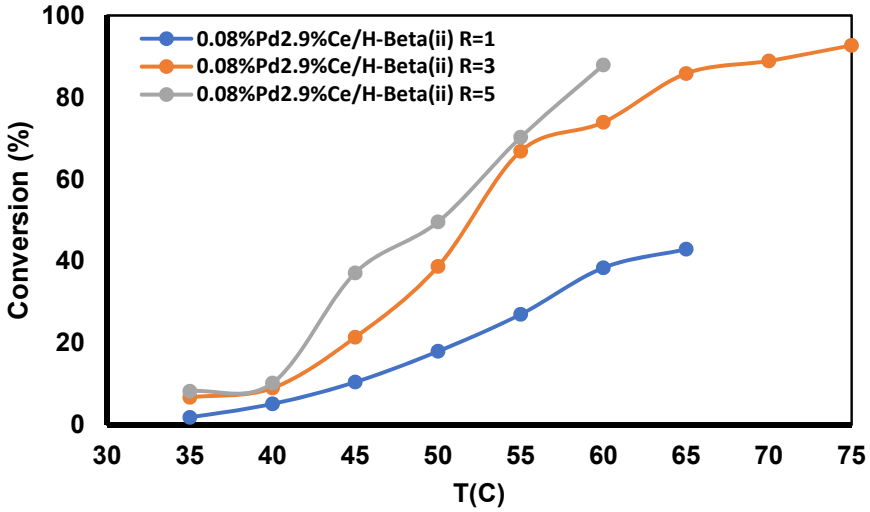


(**b**)

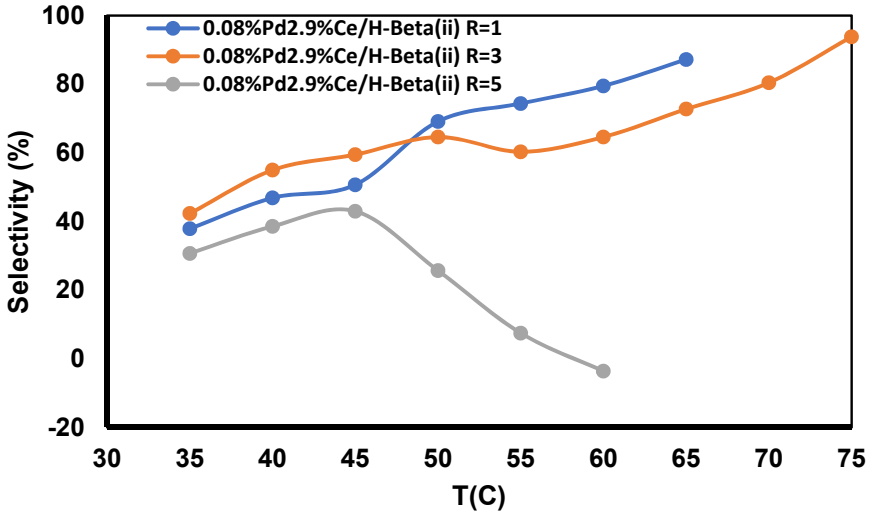


(**c**)

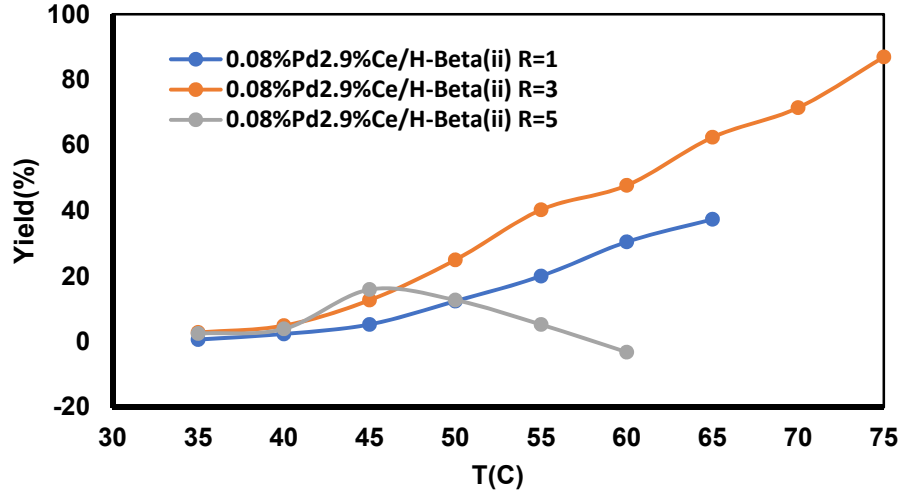
Figure S13. (**a**) Acetylene conversion, (**b**) Ethylene selectivity and (**c**) Yield percentage over 0.08%Pd 0.29%Ir/H-Beta(ii) catalysts under different H_2/C_2H_2 ratios, GHSV=4030 h^{-1}, and P=20 bar.


0.08%Pd2.9%Ce/H-Beta(ii) R=1
0.08%Pd2.9%Ce/H-Beta(ii) R=3
0.08%Pd2.9%Ce/H-Beta(ii) R=5
Conversion (%)
T(C)
100
80
60
40
20
0
30
35
40
45
50
55
60
65
70
75

(**a**)

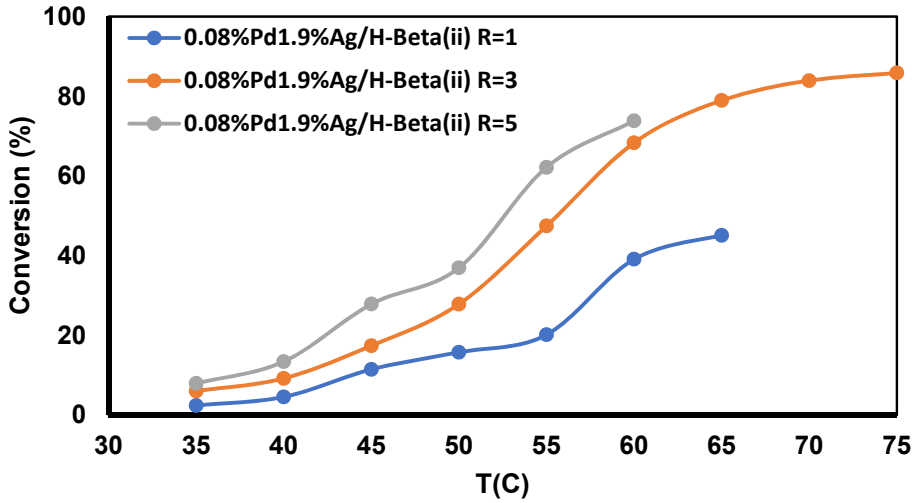

0.08%Pd2.9%Ce/H-Beta(ii) R=1
0.08%Pd2.9%Ce/H-Beta(ii) R=3
0.08%Pd2.9%Ce/H-Beta(ii) R=5
Selectivity (%)
T(C)
100
80
60
40
20
0
-20
30
35
40
45
50
55
60
65
70
75

(**b**)

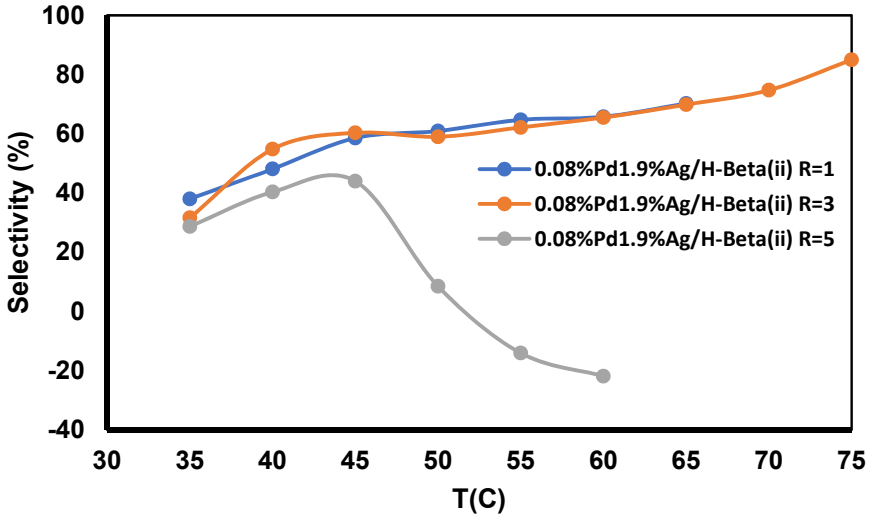


(**c**)

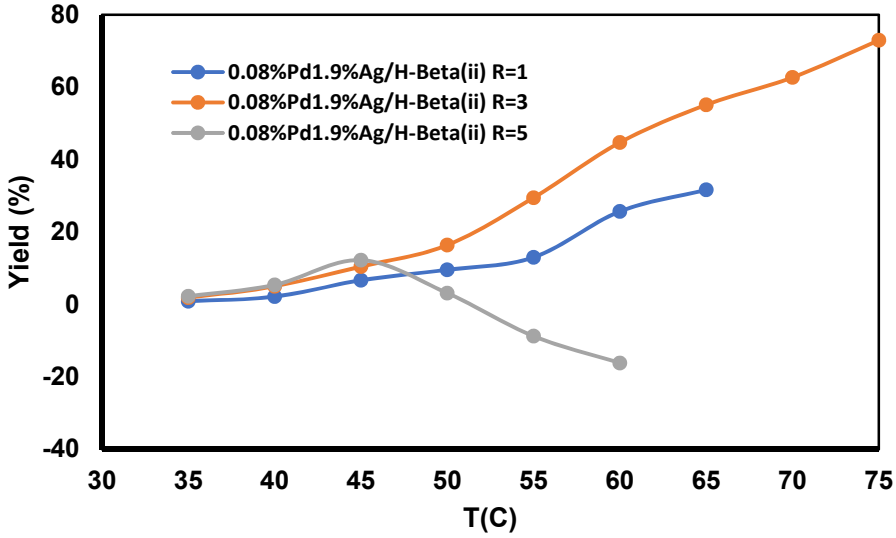
Figure S14. (**a**) Acetylene conversion, (**b**) Ethylene selectivity and (**c**) Yield percentage over 0.08%Pd 2.9%Ce/H-Beta(ii) catalysts under different H_2/C_2H_2 ratios GHSV=4030 h^{-1}, and P=20 bar.



(**a**)

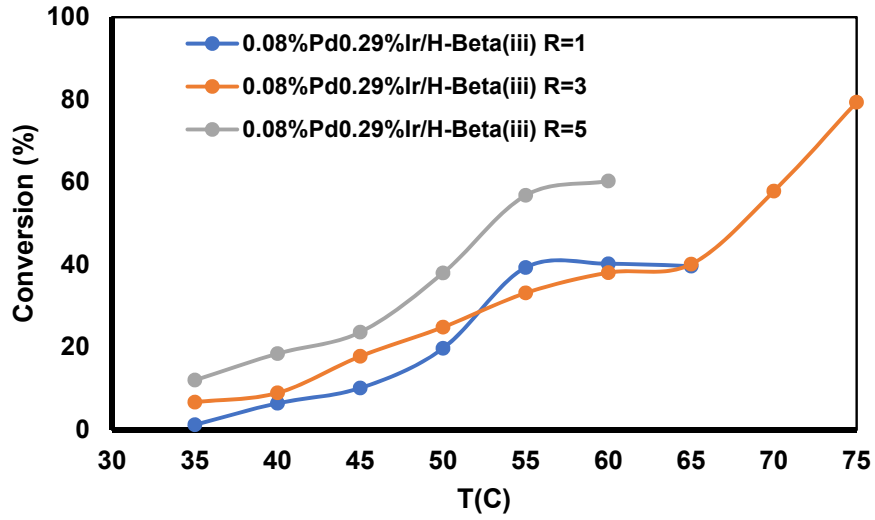


(**b**)

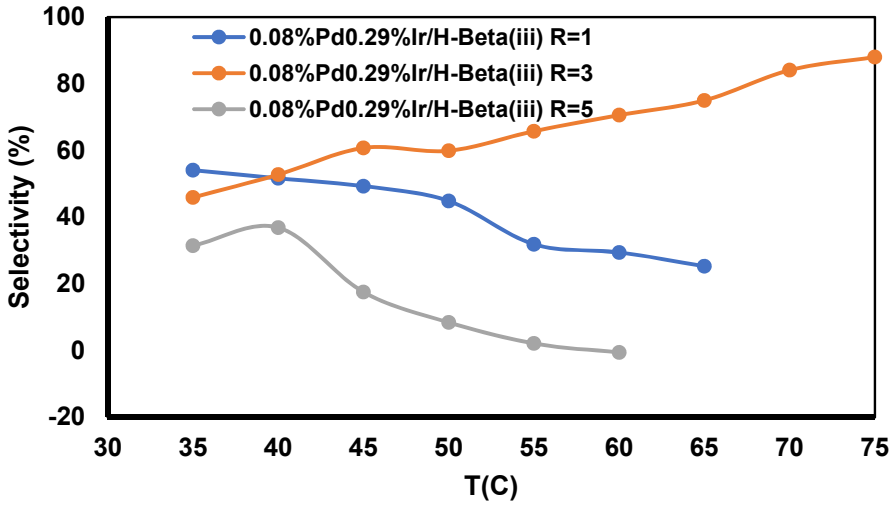


(**c**)

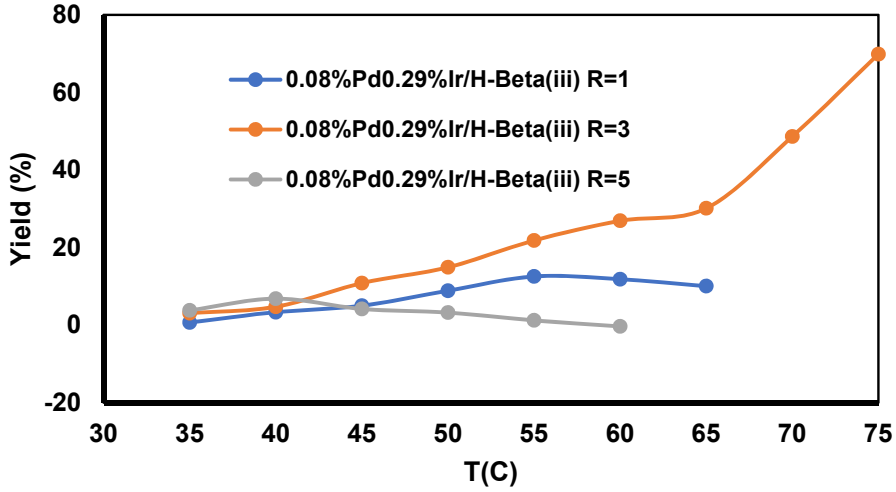
Figure S15. (**a**) Acetylene conversion, (**b**) Ethylene selectivity and (**c**) Yield percentage over 0.08%Pd 1.9%Ag/H-Beta(ii) catalysts under different H_2/C_2H_2 ratios GHSV=4030 h^{-1}, and P=20 bar.


0.08%Pd0.29%Ir/H-Beta(iii) R=1
0.08%Pd0.29%Ir/H-Beta(iii) R=3
0.08%Pd0.29%Ir/H-Beta(iii) R=5
Conversion (%)
T(C)
100
80
60
40
20
0
30
35
40
45
50
55
60
65
70
75

(**a**)

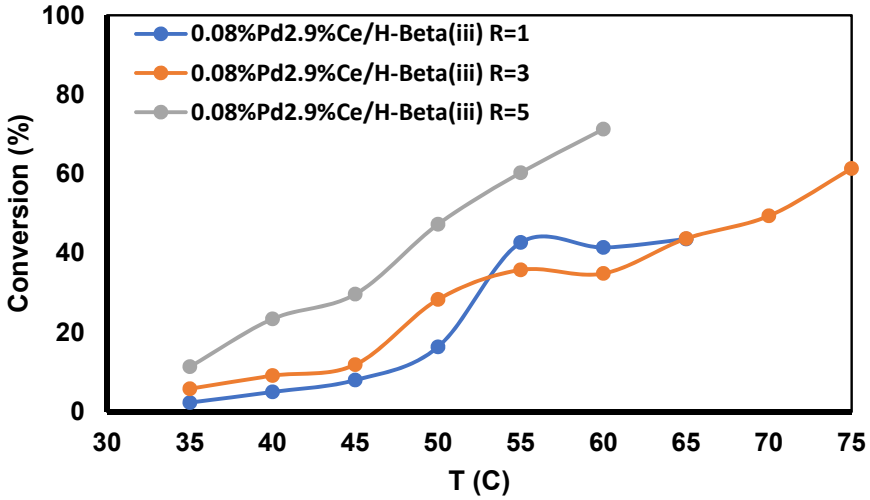

0.08%Pd0.29%Ir/H-Beta(iii) R=1
0.08%Pd0.29%Ir/H-Beta(iii) R=3
0.08%Pd0.29%Ir/H-Beta(iii) R=5
Selectivity (%)
T(C)
100
80
60
40
20
0
-20
30
35
40
45
50
55
60
65
70
75

(**b**)

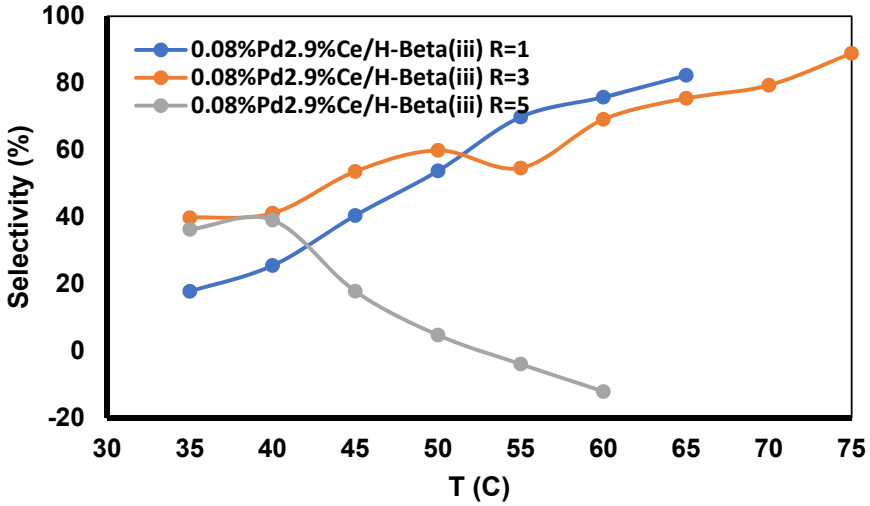


(**c**)

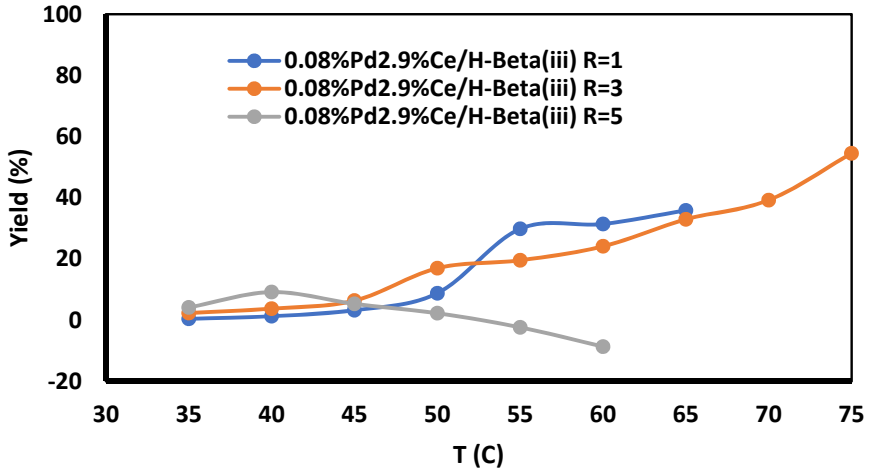
Figure S16. (**a**) Acetylene conversion, (**b**) Ethylene selectivity and (**c**) Yield percentage over 0.08%Pd 0.29%Ir/H-Beta(iii) catalysts under different H_2/C_2H_2 ratios, GHSV=4030 h^{-1}, and P=20 bar.



(**a**)

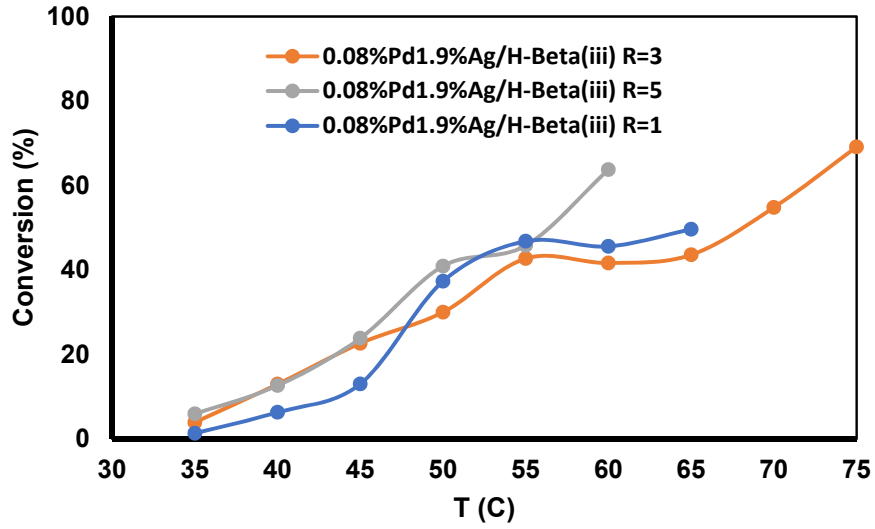


(**b**)

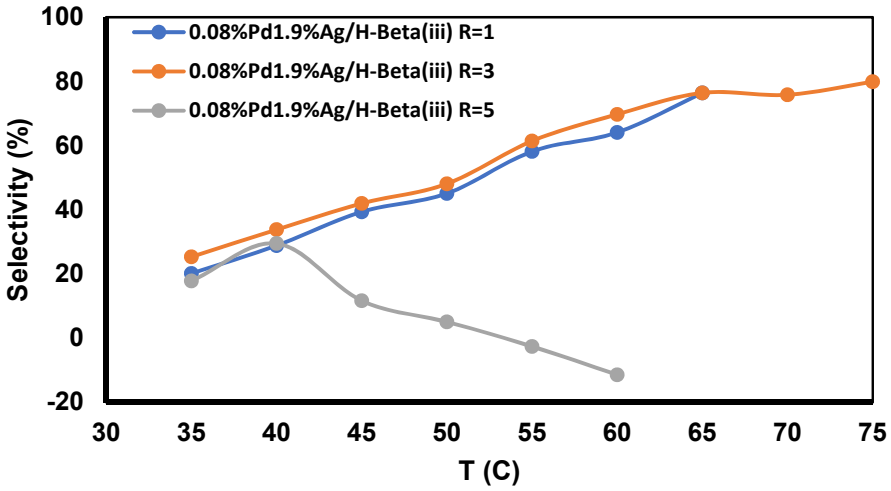


(**c**)

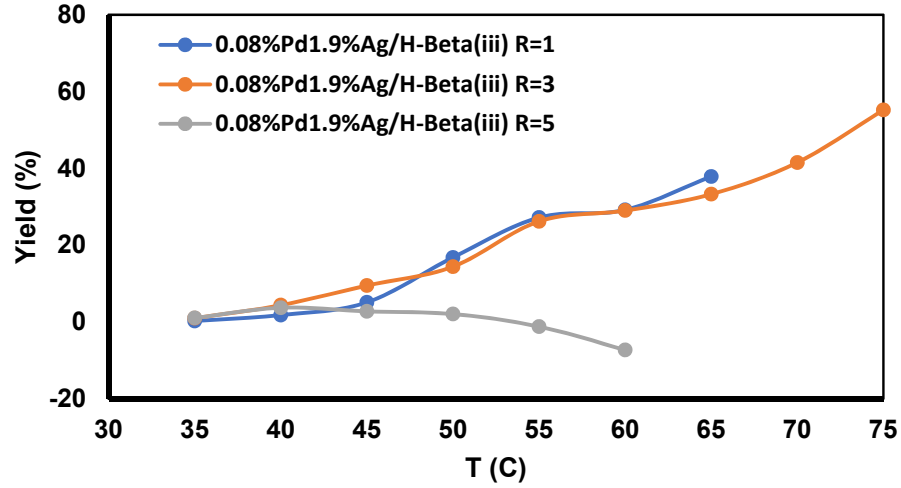
Figure S17. (**a**) Acetylene conversion, (**b**) Ethylene selectivity and (**c**) Yield percentage over 0.08%Pd 2.9%Ce/H-Beta(iii) catalysts under different H_2/C_2H_2 ratios GHSV=4030 h^{-1}, and P=20 bar.


0.08%Pd1.9%Ag/H-Beta(iii) R=3
0.08%Pd1.9%Ag/H-Beta(iii) R=5
0.08%Pd1.9%Ag/H-Beta(iii) R=1
Conversion (%)
T (C)
100
80
60
40
20
0
30
35
40
45
50
55
60
65
70
75

(**a**)

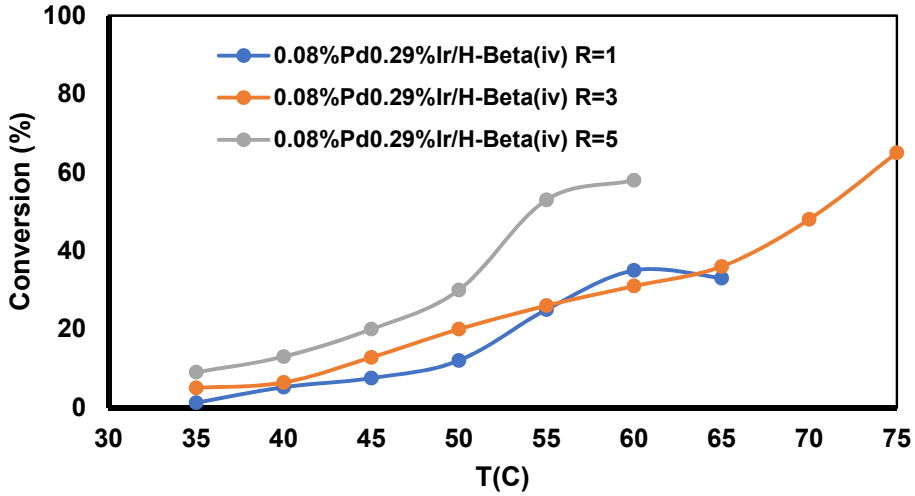

0.08%Pd1.9%Ag/H-Beta(iii) R=1
0.08%Pd1.9%Ag/H-Beta(iii) R=3
0.08%Pd1.9%Ag/H-Beta(iii) R=5
Selectivity (%)
T (C)
100
80
60
40
20
0
-20
30
35
40
45
50
55
60
65
70
75

(**b**)

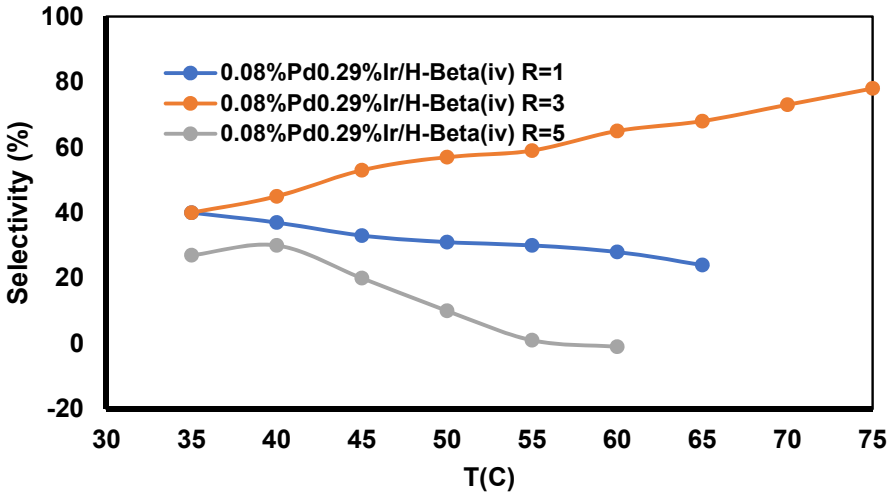


(**c**)

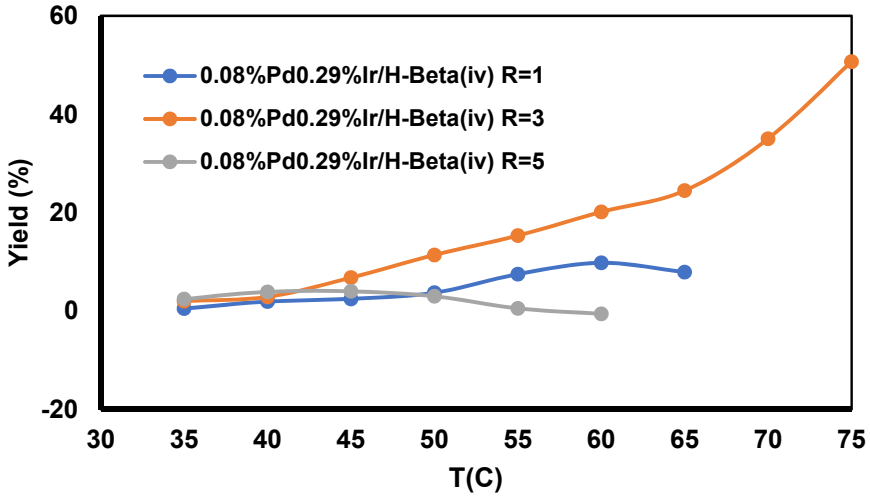
Figure S18. (**a**) Acetylene conversion, (**b**) Ethylene selectivity and (**c**) Yield percentage over 0.08%Pd 1.9%Ag/H-Beta(iii) catalysts under different H_2/C_2H_2 ratios GHSV=4030 h^{-1}, and P=20 bar.



(**a**)

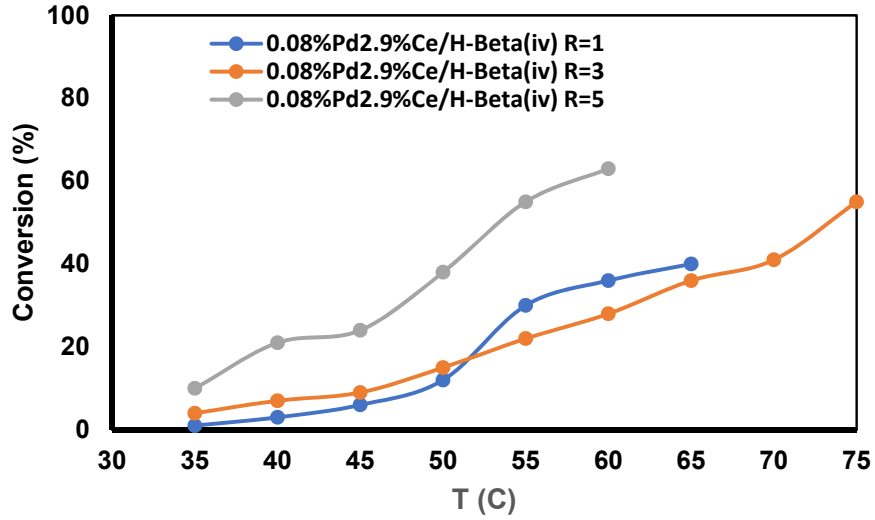


(**b**)

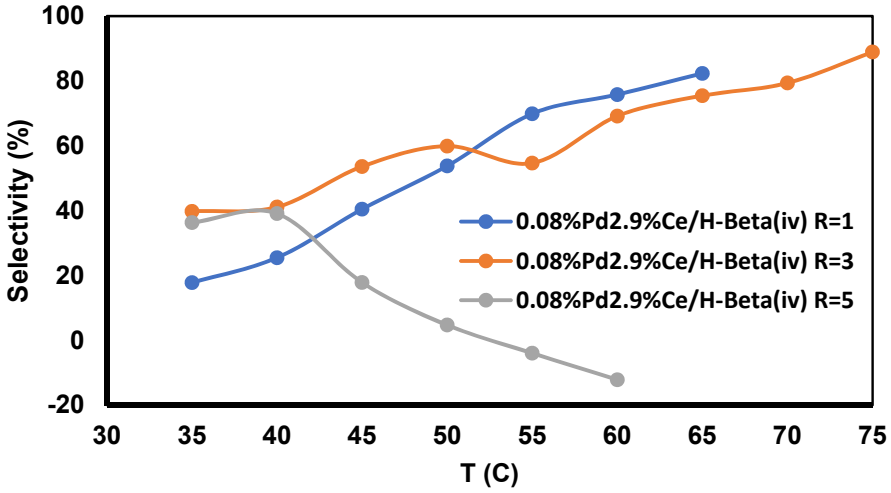


(**c**)

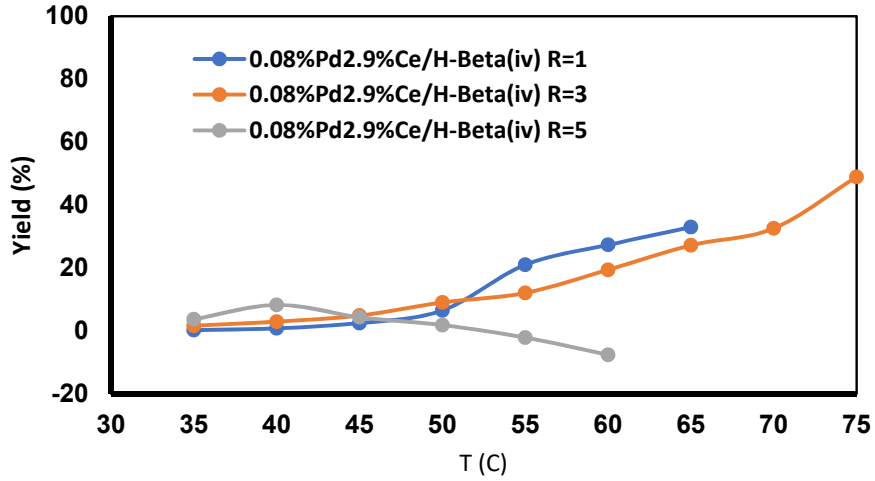
Figure S19. (**a**) Acetylene conversion, (**b**) Ethylene selectivity and (**c**) Yield percentage over 0.08%Pd0.29%Ir/H-Beta(iv) catalysts under different H_2/C_2H_2 ratios GHSV=4030 h^{-1}, and P=20 bar.


100
80
60
40
20
0
Conversion (%)
30
35
40
45
50
55
60
65
70
75
T (C)
0.08%Pd2.9%Ce/H-Beta(iv) R=1
0.08%Pd2.9%Ce/H-Beta(iv) R=3
0.08%Pd2.9%Ce/H-Beta(iv) R=5

(**a**)

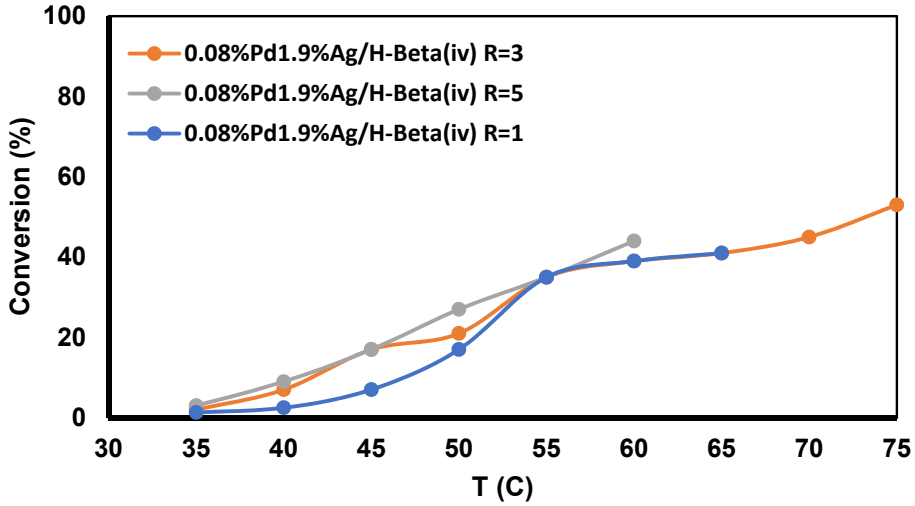

100
80
60
40
20
0
-20
Selectivity (%)
30
35
40
45
50
55
60
65
70
75
T (C)
0.08%Pd2.9%Ce/H-Beta(iv) R=1
0.08%Pd2.9%Ce/H-Beta(iv) R=3
0.08%Pd2.9%Ce/H-Beta(iv) R=5

(**b**)

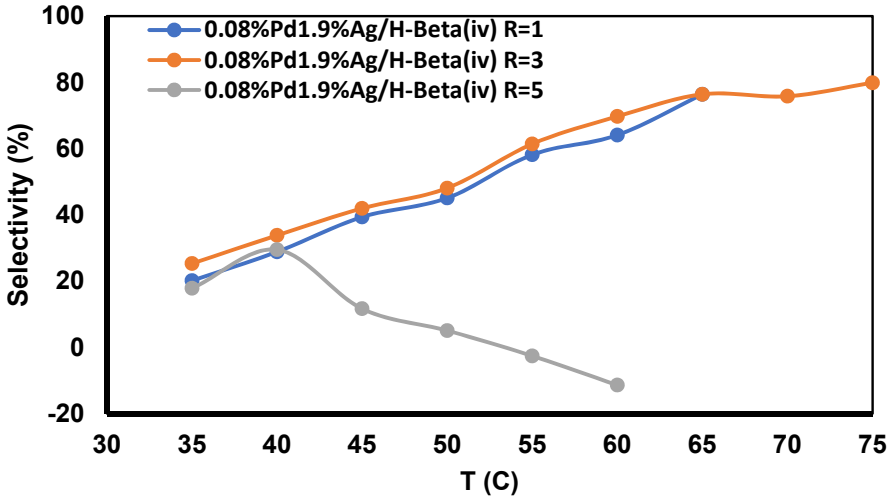


(**c**)

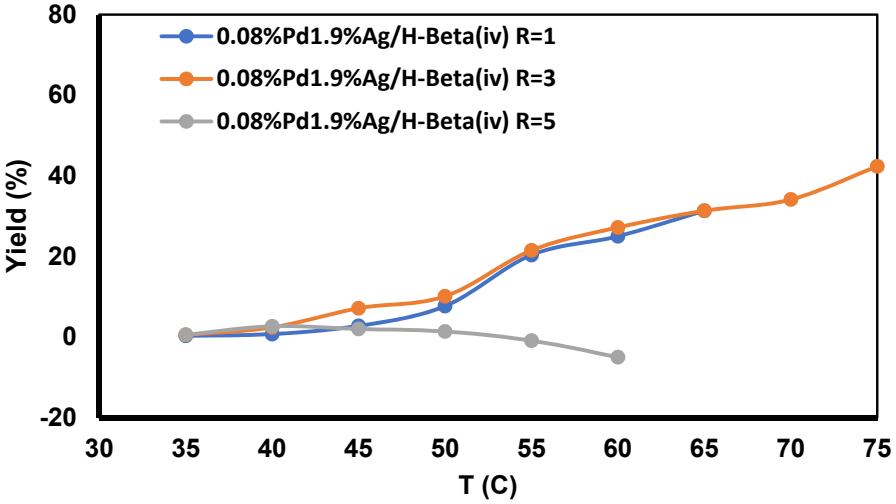
Figure S20. (**a**) Acetylene conversion, (**b**) Ethylene selectivity and (**c**) Yield percentage over 0.08%Pd2.9%Ce/H-Beta(iv) catalysts under different H_2/C_2H_2 ratios GHSV=4030 h^{-1}, and P=20 bar.



(**a**)



(**b**)



(**c**)

Figure S21. (**a**) Acetylene conversion, (**b**) Ethylene selectivity and (**c**) Yield percentage over 0.08%Pd1.9%Ag/H-Beta(iv) catalysts under different H_2/C_2H_2 ratios GHSV=4030 h^{-1}, and P=20 bar.