Oxidative dehydrogenation of ethane: Catalytic and mechanistic aspects and future trends

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Supporting Information

Table S1. Catalytic efficiency of metal oxide materials in the ethane ODH reaction.

Data point No. in Figure 47	Catalyst	Oxidant	Selectivity %	Conversion %	Temperature (°C)	Yield %	Ref.
	$LaSr_{0.02}O_x$	O_2	64	46	800	34-46	1
	$SmSr_{0.2}O_x$		66	52	855		
1	$SmNa_{0.028}P_{0.014}O_x$		68	67	867		
2	Sr-La_2O_3 (Sr/La=0.1)	O_2	83.4	59.1	850	-	2
	Sm_2O_3	O_2	60.6	8.2	700	-	3
3	90La-NaAl		77.5	17.2		-	
4	$YBa_2Cu_3O_{7-0.21}F_{0.16}$	O_2	81.8	84.1	680	68.8	4
	$YBa_2Cu_3O_{7-0.18}Cl_{0.13}$		72	92.5		66.6	
	$La_{0.8}Sr_{0.2}FeO_{3-0.103}F_{0.216}$	O_2	62.1	76.8	660	47.7	5
5	$La_{0.8}Sr_{0.2}FeO_{3-0.103}Cl_{0.164}$		68.4	84.4		57.6	
6	$La_{1.6}Sr_{0.4}CuO_{3.857}X_{0.143}$	O_2	76.7	83.2	660	63.8	6
	$La_{1.6}Sr_{0.4}CuO_{3.856}X_{0.126}$		74.6	79.6		59.4	
	$Sr_{0.63}Ca_{0.27}CuO_{1.901}X_{0.088}$	O_2	67.2	73.5	650	-	7
7	$Sr_{0.63}Ca_{0.27}CuO_{1.950}X_{0.036}$		74.4	87.4	680		
8	$Ba(Ce_{0.9}\ Ca_{0.1})O_{2.9}$	O_2	59	60	750	35	8
	$Ba(Ce_{0.9}Y_{0.1})O_{2.95}$		11	21		2.3	
	$Ba(Ce_{0.9}La_{0.1})O_{2.95}$		48	50		24	
	$Ba(Ce_{0.9}Nd_{0.1})O_{2.95}$		57	55		31	
9	α-Sb_2O_4+ Mo-V-O	O_2	28.1	11.7	500	3.3	9
	α-Sb_2O_4+ Ni-V-O		21.2	8.5		1.8	
10	Ga/Cr-ZrP	O_2	25	7.4	400	-	10
	Al/Cr-ZrP		23.9	5.4		-	
	$Mo_6V_2Al_1Ox$	O_2	70.4	3.9	340	-	11
	$Mo_6V_2Ga_1Ox$ $Mo_6V_2Bi_1Ox$		69	5.6			
	$Mo_6V_2Sb_1Ox$ $Mo_6V_2Te_1Ox$		69.2	3.5			
			74.7	16.8			
11			72.5	18.2			
	$Co_{1.5}Mg_{1.5}(PO_4)_2$	O_2	69.4	10	550	-	12
	Pt/γ-Al_2O_3	O_2	64.7	59.9	936	-	13

12	$BaMnAl_{11}O_{19}$		68	75.9	980		
13	$La_{1.85}Sr_{0.15}CuO_{3.930}Cl_{0.053}$	O_2	73.2	82.8	660	-	[14]
	$Nd_{1.85}Ce_{0.15}CuO_{3.981}F_{0.092}$		61.8	72.1			
	$La_{0.8}Ba_{0.2}Mn_{0.7}Cu_{0.3}O_{2.808}F_{0.124}$	O_2	66.8	49.2	680	32.9	[15]
	$La_{0.8}Ba_{0.2}Mn_{0.7}Cu_{0.3}O_{2.817}Cl_{0.114}$		69.5	73		50.8	
14	Fe^{3+}-$Cs_{2.5}H_{1.5}PVMo_{11}O_{40}$	O_2	39	10	425	3.9	[16]
15	$Sr_{0.1}La_{0.1}Nd_1O_x$	O_2	70.8	79.2	940	56.1	[17]
	$Bi_2Sr_2CaCU_2O_{7.811}F_{0.366}$	O_2	72.5	70.8	680	51.3	[18]
16	$Bi_2Sr_2CaCU_2O_{7.901}Cl_{0.394}$		76.6	77.2		59.1	
17	$LaMnO_3$/ γ-Al_2O_3	O_2	65	84	950	55	[19]
18	$Fe_xP_yO_z$	O_2	85.9	26.6	650	-	[20]
19	$Sr_{0.1}La_{0.1}Nd_1O_x$	O_2	71.2	65.2	700	46.4	[21]
20	Mo-V-Nb-O (1-0.6-0.12)	O_2	60.5	21.5	400	13	[22]
21	V-Mg-O (V/Mg=10.6)	O_2	78.29	43.6	600	34.1	[23]
22	LiCl-Dy-Mg-O	O_2	87.5	88	610	77	[24]
23	$Co_{0.280}Cr_{0.398}Sn_{0.158}W_{0.164}O_x$	O_2	63	33	500	21	[25]
	$Co_{0.086}Cr_{0.249}Ca_{0.196}$ $Mn_{0.208}P_{0.074}Sn_{0.093}W_{0.164}O_x$		46	30		14	
	$Cr_{0.501}Mo_{0.471}Sn_{0.028}O_x$		56	32		18	
	$Cr_{0.693}Mo_{0.284}Au_{0.023}O_x$		52	34		18	
	$Cr_{0.426}Mo_{0.161}Ga_{0.245}Sn_{0.043}Zr_{0.124}O_x$		53	32		17	
	$Cr_{0.601}Mo_{0.246}Au_{0.041}Mn_{0.0.112}O_x$		54	32		17	
	$Cr_{0.570}Mo_{0.233}Au_{0.038}Ga_{0.109}Zr_{0.049}O_x$		51	32		16	
	$Cr_{0.790}Mo_{0.290}O_x$		54	32		17	
	$Sn_{0.49}W_{0.51}O_x$		71	1		1	
24	$Mo_{0.71}V_{0.21}Nb_{0.08}O_x$	O_2	96	5	570	-	[26]
25	$Ni_{0.62}Ta_{0.10}Nb_{0.28}O_x$	O_2	86.2	20.5	300	-	[27]
26	4Zr-VPO	O_2	80	10	475	-	[28]
	3Bi-VPO		74.5	10		-	
27	$MoV_{0.39}Te_{0.16}Nb_{0.17}O_x$	O_2	93.9	39.8	380	-	[29]
	$MoV_{0.1}Nb_{0.21}Te_{0.01}O_x$	O_2	72.2	13.6	400	-	[30]
28	$MoV_{0.14}Nb_{0.17}Te_{0.19}O_x$		94.9	27.3	400	-	
29	$Ca_{10-x}Co_x(PO_4)_6(OH)_2$	O_2	63	35	550	22	[31]
	$Nb_{0.6}PMo_{12}Pyr$	O_2	29	16	380	-	[32]
	$Nb_{0.4}PMo_{12}Pyr$		28	17		-	
	$Nb_{0.68}PMo_{11}VPyr$		36	7.4		-	
	$Nb_{0.2}PMo_{11}VPyr$		41	5.5		-	
30	$Nb_{0.5}PMo_{11}GaPyr$		30	18		-	
31	V/TiP	O_2	56.5	31.8	700	-	[33]
32	$MoV_{0.31}Te_{0.2}Nb_{0.14}O_x$	O_2	87	90	400	-	[34]
33	$MoV_{0.18}Sb_{0.15}O$	O_2	81.5	64.6	400	52.5	[35]
34	$Ni_{0.85}Nb_{0.15}O$	O_2	70	66	400	46	[36, 37]
35	Cr/TS(30)	CO_2	90	52.7	650	47.4	[38]
36	Cr-O	O_2, CO_2	72	29	400	-	[39]
37	$Ni_{0.85}Nb_{0.15}O_x$	O_2	67.8	66.7	400	-	[40]
38	Li-Sr-MD	O_2	91	44	580	-	[41]
	Li-Ba-MD		88	40		-	
	Li-Na-MD		86	46		-	
	Li-K-MD		96	27		-	
39	Co-$BaCO_3$	CO_2	92.2	48	650	44.3	[42]
40	Pt, Sn/Mg(Al)O	CO_2	98.7	6.1	600	-	[43]
41	Ni-Nb-O	O_2	83	20.5	375	-	[44]
	$MoV_{0.1}Nb_{0.19}O_x$	O_2	44.8	24.3	380	-	[45]
42	$MoV_{0.18}Sb_{0.18}O_x$		75.5	45.6		-	
	$MoV_{0.51}Te_{0.16}O_x$		73.7	46.3		-	
	$MoV_{0.21}Te_{0.16}Nb_{0.18}O_x$		85.4	25.1		-	

43	$Mo_{11}VP$	O_2	67.7	14.3	550	8.8	[46]
	Nano-NiO	O_2	45.4	35	350	15.9	[47]
	Meso-NiO		51.5	43.3	450	22.5	
44	Meso-NiMgO		53.18	56.6	450	30.1	
45	$CoO_x/MgAl_2O_4$-HT (Hydrothermal)	CO_2	89.5	55.2	650	49.4	[48]
	$CoO_x/MgAl_2O_4$-CP (Co-precipitation)		85.5	50.5		43.18	
46	$BaCe_{0.85}Y_{0.15}O_{3-\delta}$		90	35	700	-	[49]
47	$BaCe_{0.85}Y_{0.15}O_{3-\delta}$		90.5	36.7	700	-	[50]
	Pt/ Mg(Al)O	O_2	99.9	0.66	600	-	[51]
48	Pt-Sn/Mg(Al)O		99.9	2.6		-	
	$Pt-Sn/Al_2O_3$	O_2 mixed with H_2	91.4	8.3	700	-	[52]
49	$LaMnO_3$		71.4	13.8		-	
	Ni-Nb-O	O_2	90	4.4	400	-	[53]
	Ni-Ta-O		90	0.36		-	
	Ni-Ti-O		84.9	3.1		-	
50	Ni-Al-O		63.5	8.91		-	
	Ni-Ga-O		54	9.17		-	
	Ni-Mg-O		28.6	7.5		-	
	Ni-Li-O		19	5.26		-	
51	$MoV_{0.4}Nb_{0.27}O_y$	O_2	76.9	10	400	-	[54]
52	$Ni_{0.85}Nb_{0.15}O$	O_2	78	33	350	25.7	[55]
53	5-$CoO_x/MgAl_2O_4$	CO_2	98.4	47.5	650	9.4	[56]
	$Mo_{0.16}Nb_{3.4}O_m$	O_2	70.17	0.82	380	-	[57]
54	$Mo_{2.3}Nb_{2.7}O_m$		67.87	3.49		-	
55	Ni2-Al-500	O_2	73.1	23.1	500	16.9	[58]
56	NiW0.36	O_2	60	5	400	-	[59]
57	NiO-CeO_2	O_2	59	10.4	275	6.14	[60]
58	$Nb_{0.03}Ni_{0.97}O$	O_2	62	41	350	25	[61]
	$Nb_{0.04}Ni_{0.96}O$		64	39		25	
59	$BaCl_2$-TiO_2-SnO_2	O_2	92.6	65.5	720	60.4	[62]
60	Orthorhombic MO_3VO_3	O_2	81.8	56	335	-	[63]
61	NiWO	O_2	59.5	11.8	450	-	[64]
62	NiSn	O_2	87	10	300	-	[65]
	NiLa		56	10		-	
	NiZr		78	10		-	
63	M1(Sb, Nb)- V- 6.6	O_2	97	10	385	-	[66]
	M1(Te)- V- 6.8		95	10		-	
	Ga-NiO	O_2	53	10	400	-	[67]
64	Nb-NiO		88.3	10		-	
	Li-NiO		17.9	10		-	
65	NiNb-E1	O_2	81.8	28.3	350	23.1	[68]
	NiNb-C1		77.3	17.8		13.8	
66	$Ni_{70}Al_{30}$-org	O_2	82	14	350	-	[69]
67	$MoVNbTeO_x$	O_2	85	73	460	-	[70]
68	$Ni_{85}Nb_{15}$(300)	O_2	70	40	330	-	[71]
69	Ni-Nb-Cr-O	O_2 and CO_2	65	26	450	32	[72]
70	VO_x/Al_2O_3-ZrO_2	Lattice oxygen	89	11	525-600	-	[73]
71	Cr/ZrO_2	CO_2	-	47.56	700	43.17	[74]
	Nb-NiO	O_2	83.4	8.6	450	-	[75]
72	Sn-NiO		83.7	8.8		-	
73	NiO/TiO_2	O_2	74.5	55	400	41	[76]
74	$Mo_1V_{0.3}Te_{0.23}Nb_{0.12}Bi_{0.025}$	O_2	95	37	400	-	[77]
75	$Ni_{0.85}Ce_{0.075}Zr_{0.075}O/Al_2O_3$	O_2	54.6	37.5	450	-	[78]
76	CeO_2-NiO-Al_2O_3/Ni-foam	O_2	55	37	450	-	[79]
77	NaW-Mg_6MnO_8	Lattice	87	64	850	55	[80]

		oxygen					
78	Nb_2O_5-NiO/Ni-foam	O_2	68	60	410	-	[81]
79	CeO_2-ZrO_2-NiO-Al_2O_3/Ni-foam	O_2	60.6	40.3	500	24.4	[82]
80	BaO-CeO_2-ZrO_2	O_2	48.5	55.7	700	27.01	[83]
	$BaCl_2$-TiO_2-SnO_2		97.6	13.7		13.4	
81	NiO/Ti-Si-O	O_2	83.3	9.5	400	-	[84]
82	0.5CeNiNb	O_2	65	15	400	-	[85]
83	NiO/P25TiO_2	O_2	89	10	450	-	[86]
	NiO/PCH-Ti		78	10		-	
84	CrO_x/Al_2O_3	CO_2	90	14	700	-	[87]
	CrO_x/ZrO_2		80	5		-	

Table S2. Catalytic performance of molecular sieves in the ethane ODH reaction

Data point No. in Figure 47	Catalyst support	Oxidant	Selectivity %	Conversion %	Temperature (°C)	Yield %	Ref.
85	CoH-BEA	O_2	60.5	5.2	450	-	[88]
	CoH-MFI		54.7	5.2		-	
	CoH-MOR		76.2	2.2		-	
	CoH-FER		78.3	0.8		-	
	Fe-H(Al)ZSM-5 H(Fe)ZSM-5	N_2O	75	44	350	-	[89]
86			58.4	62.7		-	
87	Cr/H-ZSM-5(1900)	CO_2	68.2	69.5	650	-	[90]
88	10%Ce/SBA-15/Al_2O_3/FeCrAl	CO_2	87.2	63.9	750	55.7	[91]
89	5Cr-10Ce/SBA-15	CO_2	96	55	700	52.8	[92]
90	5%Cr/SBA-15/Al_2O_3/FeCrAl	CO_2	95.5	66.5	750	63.5	[93]
91	Ni/HY	O_2	74.5	-	600	15.8	[94]
	Cu/HY		45.3	-		5.5	
92	Ga2O3/HZSM-5(97)	CO_2	93.7	14.5	500-650	13.6	[95]
	LiCl/HZSM-5	O_2	88	84.1	650	74.1	[96]
93	Ni/K-Y	O_2	77.9	18.8	600		[97]
	Co/K-Y		30.7	17.3		-	
	Cu/K-Y		23.6	17		-	
	Fe/K-Y		35.5	11.7		-	
94	V-SBA-16	O_2	63.3	40.7	600	-	[98]
95	CrAPSO	CO_2	94.8	40	700	-	[99]
	(NaMg)/NaY	O_2	100	2	500	2	[100]
	(NaMg)/NaY-La(Cl)			2		2	
	(KMg)/NaY-La(Cl)			27		27	
96	(RbMg)/NaY-La(Cl)			40		40	
	(CsMg)/NaY-La(Cl)			7		7	
	(NaKMg)/NaY			8		8	
	(NaKMg)/NaY-La(Cl)			20		20	
	(NaKMg)/NaY-La(N)			12		12	
	(NaKMg)/NaY-Tb(N)			18		18	

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