Table of Figures

Figure 1. 1: Hydrogenation and isomerization of styrene oxide	.31
Figure 1.2: Hydrodeoxygenation of m-cresol	31

Figure 2. 1: Flowchart for (a) deposition-precipitation of zirconia-alumina supports (b) precipitation of a superior of the su	of
neat zirconia	.47
rigure 2. 2. Flowcharl of preparation of bicomponent zirconia-atumina supports by co-precipitation mathod	50
Figure 2 3: Specific surface area of support samples	56
Figure 2. 5. Specific surface area of support samples	. 50
Figure 2. 4. Trend of pore volume with pill of precipitation	. 50
Figure 2. 5: Average pore alameter of bicomponent zirconia-atumina supports	. 59
Figure 2. 0: EDAX analysis of (a) GA-7 (b) GA-8 (c) GA-9 (a) GA-10	.01
Figure 2. 7: EDAX analysis of (a) $GA(PHI)$ -7 (b) $GA(PHI)$ -10	.61
Figure 2. 8: DIG-DSC of alumina substrates used for deposition-precipitation (a) $AI(S)$ (b) $AM(S)$ (c) $CA(S)$	62
GA(S)	.03
Figure 2. 9: DIG-DSC comparison of (a) GA series and (b) ZrO_2 series samples	. 64
Figure 2. 10: DIG-DSC of supports prepared by deposition-precipitation using different diumind	C A
substrates (a) AI series (b) AM series (c) GA series	.64
Figure 2. 11: DIG-DSC of supports prepared by afferent methods (a) GA series – Deposition-	
method	۶F
Figure 2, 12: 9/waight logg by TCA for different supports	.05
Figure 2. 12. Noweight loss by IGA for upperent supports	.70 C
Figure 2. 15. Normalized willoss (70) at (a) <200 C (b) 200-400 C (c) 400-000 C and (a) 000-800 C	C 72
Figure 2. 14: Evolved gas analysis of GA series samples using TGA MS (a) evolution of $H_{2}O$ (m/z 18)	(h)
regure 2. 14. Evolved gas undysis of GA series samples using $1 \text{ GA-MS}(a)$ evolution of 11_{20} (m/z 16) (evolution of OH (m/z 17) (c) evolution of CO_2 (m/z 44) (d) evolution of NO (m/z 30)	(<i>U</i>) 75
Figure 2. 15: Evolved gas analysis of $ZrO2$ series samples using TGA-MS (a) evolution of H2O (m/z 18	.,, 8)
(h) evolution of ΩH (m/z 17) (c) evolution of $\Omega \Omega_2$ (m/z 44) (d) evolution of NO (m/z 30)	ッ 76
Figure 2. 16: various types of metal-carbonate species based on FTIR	.70
Figure 2. 17: Carbonate species in different co-ordination with metal ion	.70
Figure 2. 17. Curbonale species in algerent co-oraination with metal ion	.70 (S)
Figure 2. 16. AND of utuminu substrates used for deposition-precipitation (d) A1(5) (d) AM(5) (c) OA	() 02
Figure 2 10: YRD of 7rO. Sarias	.05 QA
Figure 2. 19. XRD of Supports propagad by deposition precipitation using different aluming substrates	.04
Figure 2. 20. AND of supports prepared by deposition-precipitation using afferent atamina substrates (a) AT series (b) AM series (c) GA series	85
Figure 2 21: YRD of supports prepared by different methods (a) GA series - Deposition-Precipitation	.05
method (b) G4-PHY series – Physical Mixing method (c) CP series – co-precipitation method	85
Figure 2 22: X-ray diffractogram of (a) GA_7 GA_{-10} (b) ZrO_{2-7} ZrO_{2-10} (c) $4M_{-7}$ $4M_{-10}$ and d) Cl	.05 P_7
and CP 10 supports calcined at 550° 8h	۰ - / ۵۸
Even 2^{-10} supports culculed at 550 C on	. 90
Figure 2. 25. SEM images of (a) $GA^{-7}(0) GA^{-0}(0) GA^{-9}$ and (a) GA^{-10}	.92
$Figure 2. 24. SEM images of (a) ZrO_2-7 (b) ZrO_2-10$.93

Even $2, 25 \cdot \text{SEM}$ images of (a) CP 7 (b) CP 10	02
Figure 2. 25 . SEM images of (a)CI -7 (b)CI -10	
Figure 2. 26: Comparison of conversion of MBOH of different supports at the first hour on st	<i>ream</i> 95
Figure 2. 27: Average of conversion over 8 hours on stream normalized for specific BET surf	face area96
Figure 2. 28: Trends of selectivity for formation of acetone	
Figure 2. 29: Trends of selectivity for formation of MByne	
Figure 2. 30: Trends of selectivity for formation of HMB	
Figure 2. 31: Trend of selectivity for formation of MiPk	
Figure 2. 32: Comparison of decay constants for reaction of MBOH	

Figure 3. 1 : Schematic of method of preparation of final supports	118
Figure 3. 2: XRD of support samples calcined at 550 $^{\circ}$ C 8h	122
<i>Figure 3. 3: Trend of inter planar distance of zirconia with varying zirconia: alumina molar ratio in</i>	
supports	124
Figure 3. 4: Trends of specific surface area, pore volume and average pore diameter of bicomponent	-
ZrO_2 - Al_2O_3 supports	127
Figure 3. 5: Adsorption-desorption isotherms of the zirconia-alumina bicomponent supports: a) ZA 1	00,
b) ZA 75, c) ZA 50, d) ZA 25 and e) ZA 0	129
Figure 3. 6: NH ₃ -TPD pattern of supports used in the study	130
Figure 3. 7: Trend of weak, strong and total acidity of support samples	131
Figure 3. 8: TEM of sample of (a) neat γ -alumina, ZA-0 (b) neat zirconia, ZA 100 (c) ZA-50 (d) ZA-7	'5 124
$E^{2} = 2 \circ DE^{2} = 1 \circ C \circ$	134
Figure 3. 9: BET specific surface area and pore volume of the catalysts determined by Nitrogen	1 1 1
physisorphion	141
rigure 5. 10 : Dijjraciograms of supported metal calalysis in their calcined form. a) Co calalysis b) I	142
Eisene 2. 11. Cruztallita zing of watel anidar of Co. Ni and Cu. datermined from non-day VBD by Sah	143
Figure 5. 11: Crystallie size of metal oxides of Co, NI and Cu determined from powder XRD by Sch	errer
Figure 3 12: NH ₂ -TPD pattern of a) supported Co catabasts b) supported Ni catabasts c) supported (144 7 ₁₁
catalysts	147
Figure 3 13: Weak strong and total acidity of a) carriers b) supported Co catalysts c) supported Ni	
catalysts d) supported Cu catalysts	148
Figure 3. 14: TPR profiles of a) Co-catalysts b) Ni-catalysts and c) Cu-catalysts supported on differe	ent
supports	150
Figure 3. 15: Ratio of experimental hydrogen consumption to theoretical consumption in TPR analys	is
	153
Figure 3. 16: XPS of a) Co-ZA 100, b) Ni-ZA 100 and c) Cu-ZA 100	154
Figure 3. 17: XPS of a) Co-ZA 0, b) Ni-ZA 0, c) Cu-ZA 0, d) Ni-ZA 50, e) Co-ZA 50 and f) Cu-ZA 50	155
Figure 3. 18: Trend of surface concentrations of active metals in the supported metal catalysts as	
determined by XPS	156
Figure 3. 19: Ratio of ZrO ₂ /Al ₂ O ₃ (molar) of the supported metal catalysts as determined by XPS	157
Figure 3. 20 : Raman Spectra of supported (a) Cobalt catalysts (b) Nickel catalysts and (c) Copper	
catalysts (d) Change in intensity of Raman band of Nickel catalysts with zirconia content (e) Change	in
intensity of Raman band of Copper catalysts with zirconia content	158

Figure 4. 1: Schematic of testing of catalysts for transformation of styrene oxide	174
Figure 4. 2: Retention time of various products/biproducts	174
Figure 4. 3: Reaction scheme for transformation of styrene oxide	177
Figure 4. 4: Conversion of styrene oxide on a) Co-catalysts b) Ni-catalysts c) Cu-catalysts supported	on
zirconia-alumina	177
Figure 4. 5: Space Time Yields of 2-PEA, PAA and (PAA+2-PEA) on Co, Ni and Cu catalysts support	∙ted
on zirconia-alumina	179
Figure 4. 6: Trends of STY of PAA and strong acidity by NH ₃ TPD	180
Figure 4. 7: Trend of surface concentration of active metals as a function of zirconia content of catal	yst.
	182
Figure 4. 8: XRD peak intensity ratio of Cu(200) and Cu(111) peaks of reduced Cu-ZA # series of	
catalysts	183
Figure 4. 9: Relative selectivity between formation of styrene and 2-PEA on a) Co-catalysts b) Ni-	
catalysts c) Cu-catalysts supported on zirconia-alumina	185
Figure 4. 10: Positional isomer selectivity of PEA on a) Co-catalysts b)Ni-catalysts c) Cu-catalysts	
supported on zirconia-alumina	188
Figure 4. 11: Trend of time on stream conversion of styrene oxide as a function of reaction temperatu	ıre.
	189
Figure 4. 12: Trends of steady state conversion of styrene oxide and selectivity to key products as a	
function of reaction temperature	190
Figure 4. 13: Effect of reaction pressure on conversion of styrene oxide and selectivity to key produce	ts191
Figure 4. 14: Effect of space velocity on conversion and product selectivity	192
Figure 4. 15: Conversion of styrene oxide on regenerated Ni-ZA 25	193
Figure 4. 16: Product selectivity on regenerated Ni-ZA 25	194

Figure 5. 1: Strong and total acidity of catalysts and supports by NH ₃ TPD	208
Figure 5. 2: Acid strength of catalysts and supports by NH ₃ TPD	210
Figure 5. 3: Crystallite size of the final catalysts	211
Figure 5. 4: Peak area of active metals by XPS	214
Figure 5. 5: Trend of conversion of m-cresol	215
Figure 5. 6: Trend of selectivity to xylenol and phenol.	217
Figure 5. 7: Weigh ratio of phenol/xylenol	218
Figure 5. 8: Selectivity to CH ₄	219
Figure 5. 9: Trend of selectivity to Benzene	220
Figure 5. 10: Selectivity trend of benzene and phenol	222
Figure 5. 11: Trends of cyclohexane and benzene	225
Figure 5. 12: Trend of selectivity to Toluene	226
Figure 5. 13: Selectivity for formation of aromatics (Benzene+Toluene+Xylene)catalysts	229
Figure 5. 14: Trends of product selectivity of Hydrogenation, hydrodeoxygenation and tautomeriz	ation of
the supported metal catalysts.	

Figure 5. 15: Trends of product yields of Hydrogenation (HYD), hydrodeoxygenation (HDO) and	
deoxygenation (TAU) of the supported metal catalysts	. 233
Figure 5. 16: Proposed scheme for HDO of m-cresol	. 235
Figure 5. 17: Carbon/coke content of used catalysts after HDO of m-cresol	236