## LIST OF FIGURE

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>Title</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Structure of CeO$_2$: (a) cfc array of cerium atoms; (b) and (c) row of cubic cells of oxygen.</td>
<td>65</td>
</tr>
<tr>
<td>2.2</td>
<td>Schematic representation of L-H mechanism (a) and the E-R mechanism (b) for the catalytic oxidation of CO.</td>
<td>86</td>
</tr>
<tr>
<td>2.3</td>
<td>Schematic representations of the Mars Van Krevelen mechanism</td>
<td>87</td>
</tr>
<tr>
<td>3.1</td>
<td>(a-e) Photographs and Schematic diagram of Experimental set-up and other accessories</td>
<td>102</td>
</tr>
<tr>
<td>3.2</td>
<td>(a) Glass Reactor</td>
<td>106</td>
</tr>
<tr>
<td></td>
<td>(b) Schematic diagram of the reactor</td>
<td>107</td>
</tr>
<tr>
<td>3.3</td>
<td>Micro graduated pipette attachment</td>
<td>109</td>
</tr>
<tr>
<td>3.4</td>
<td>Orsat Analysis Setup</td>
<td>110</td>
</tr>
<tr>
<td>3.5</td>
<td>(a) Schematic diagram of gas chromatography</td>
<td>111</td>
</tr>
<tr>
<td></td>
<td>(b) Photograph of gas chromatograph</td>
<td>112</td>
</tr>
<tr>
<td>3.6</td>
<td>Photograph of TGA/DSC - Perkin Elmer (model STA-6000).</td>
<td>115</td>
</tr>
<tr>
<td>3.7</td>
<td>Photograph of XRD - X'Pert Pro Model, Panalytical Co. (Philips) Netherlands.</td>
<td>116</td>
</tr>
<tr>
<td>3.8</td>
<td>Photograph of Surface area analyser (model: Quantachrome Nova 2200e).</td>
<td>118</td>
</tr>
<tr>
<td>3.9</td>
<td>Photograph of HITACHI-3700 N model.</td>
<td>119</td>
</tr>
<tr>
<td>4.1</td>
<td>Catalytic activity of oxides of copper prepared from various precursors.</td>
<td>121</td>
</tr>
<tr>
<td>4.2</td>
<td>TGA analysis of (a) Cu(NO$_3$)$_3$·3H$_2$O (b) CuSO$_4$·5H$_2$O and (c) CuC$_2$O$_4$·½H$_2$O.</td>
<td>124</td>
</tr>
<tr>
<td>4.3</td>
<td>XRD analysis of (a) CuO obtained from copper nitrate (b) CuO obtained from copper sulphate and (c) CuO obtained from Copper Oxalate.</td>
<td>125</td>
</tr>
<tr>
<td>4.4</td>
<td>(a) SEM images (a1), (a2), (a3) for CuO obtained from copper nitrate at 5k, 10k, 15k</td>
<td>126</td>
</tr>
<tr>
<td></td>
<td>(b) SEM images (b1), (b2), for CuO obtained from copper sulphate at 5k, 10k.</td>
<td>127</td>
</tr>
<tr>
<td></td>
<td>(c) SEM images: (c1),(c2),(c3) for CuO obtained from copper oxalate at 5k,10k, 15k</td>
<td>128</td>
</tr>
<tr>
<td>4.5</td>
<td>N$_2$ adsorption-desorption isotherm of: (a) cat-A1, (b) cat-A2, and (c) cat-A3</td>
<td>130</td>
</tr>
</tbody>
</table>
4.6 Pore size distribution of catalyst cat-A1, cat-A2, cat-A3
4.7 Optimisation of γ-Al₂O₃ loading on copper.
4.8 Optimisation of calcination temperature
4.9 Conversion of CO over cat-B4 at 290°C as a function of calcination temperature
4.10 CO conversion vs. temperature for individual components of catalysts CuO, CeO₂, and ZrO₂.
4.11 XRD patterns combined for Catalysts a) cat-A1 b) cat-A5, c) cat-A6
4.12 TGA analysis curves for (a) CeO₂ (b) ZrO₂
4.13 (a) Images of SEM for CeO₂ at 5k, 10k and 15k
(b) Images of SEM for ZrO₂ at 5k, 10k and 15k
(c) Images of SEM for γ-Al₂O₃ at 5k, 10k and 15k
(d) SEM micrographs of CuO (cat-A1), CeO₂ (cat-A4) and ZrO₂ (cat-A5)
4.14 N₂ adsorption-desorption isotherm of (a) cat-A5 (b) cat-A6 (c) cat-A7
4.15 Pore size distribution of a) CeO₂ (cat-A5), b) ZrO₂ (cat-A6), c) γ-Al₂O₃ (cat-A7)
4.16 Catalytic activity of catalysts cat-D1, cat-D2, cat-D3, cat-D4, cat-D5, cat-D6 and cat-D7 having 0-30% Alumina
4.17 (a) Thermogram for precursor of catalyst cat-D1 prepared using Co Impregnation method.
(b) Thermogram for precursor of catalyst cat-D4 prepared using Co Impregnation method.
(c) Thermogram for precursor of catalyst cat-D5 prepared using Co Impregnation method.
(d) Thermogram for precursor of catalyst cat-D6 prepared using Co Impregnation method.
4.18 XRD patterns of Catalysts prepared by Cl Method a) cat-D1 b) cat-D4 c) cat-D5, d) cat-D6
4.19 (a) SEM images of catalyst cat-D1 at 3.2 k, 4k, 400SE
(b) SEM images of catalysts cat-D4 at 5k, 10k, 15k
(c) SEM images of catalyst cat-D5 at 5k, 10k, 15k
(d) SEM images of catalyst cat-D6 at 5k, 10k, 15k

4.20 N$_2$ adsorption-desorption isotherm of: (a) cat-D1, (b) cat-D4, (c) cat-D5, and (d) cat-D6

4.21 Pore size distribution of catalyst-Cu-Ce$_{5.17}$Zr$_{3.83}$O$_x$/γ-Al$_2$O$_3$(15, 20, 25 wt%) prepared by Co impregnation method

4.22 Catalytic activity of Cu-Ce$_{5.17}$Zr$_{3.83}$O$_x$/γ-Al$_2$O$_3$ catalysts, prepared by Citric acid Sol Gel Method.

4.23 (a) TGA/DSC patterns of the catalyst cat-E1 catalysts prepared by citric acid sol-gel method.
(b) TGA/DSC patterns of the catalyst cat-E4 prepared by citric acid sol-gel method.
(c) TGA/DSC patterns of the catalyst cat-E5 catalysts prepared by citric acid sol-gel method.
(d) TGA/DSC patterns of the catalyst cat-E6 catalysts prepared by citric acid sol-gel method.

4.24 (a) SEM images of cat-E1 at 5k, 10k, 15k
(b) SEM images of cat-E4 at 3k, 5k and 10k
(c) SEM images of cat-E5 at 3k, 5k, 10k
(d) SEM images of cat-E6 at 3k, 5k, 10k

4.25 XRD patterns of Catalysts prepared by citric acid sol. gel. Method a) cat-E1, b) cat-E4, c) cat-E5, d) cat-E6

4.26 N$_2$ adsorption-desorption isotherm of: (a) cat-E1, (b) cat-E4, (c) cat-E5, and (d) cat-E6

4.27 Pore size distribution of catalyst cat-E1, cat-E4, cat-E5, cat-E6 prepared by citric acid sol gel method

4.28 Catalytic activity of cat-F1, cat-F2, cat-F3, cat-F4, cat-F5, cat-F6 and cat-F7.

4.29 XRD patterns of Catalysts prepared by UC Method a) Cu-Ce$_{5.17}$Zr$_{3.83}$O$_x$/γ-Al$_2$O$_3$ 0%, b) Cu-Ce$_{5.17}$Zr$_{3.83}$O$_x$/γ-Al$_2$O$_3$ 15%, c) Cu-Ce$_{5.17}$Zr$_{3.83}$O$_x$/γ-Al$_2$O$_3$ 20%, d) Cu-Ce$_{5.17}$Zr$_{3.83}$O$_x$/γ-Al$_2$O$_3$ 25%

4.30 (a) SEM images of catalyst cat-F1 at 5k, 10k, 15k
(b) SEM images of catalyst cat-F4 at 3k, 5k, 10k
4.31 N\textsubscript{2} adsorption-desorption isotherm of: (a) cat-F1, (b) cat-F4, (c) cat-F5, and (d) cat-F6

4.32 Pore size distribution of catalyst-Cu-Ce\textsubscript{5.17}-Zr\textsubscript{3.83}O\textsubscript{3}/\(\gamma\)-Al\textsubscript{2}O\textsubscript{3} (15, 20, 25 wt\%) prepared by UC method


4.34 XRD patterns of Catalysts prepared by UG Method a) Cu-Ce\textsubscript{5.17}-Zr\textsubscript{3.83}O\textsubscript{3}/\(\gamma\)-Al\textsubscript{2}O\textsubscript{3} 0\%, b) Cu-Ce\textsubscript{5.17}-Zr\textsubscript{3.83}O\textsubscript{3}/\(\gamma\)-Al\textsubscript{2}O\textsubscript{3} 15\%, c) Cu-Ce\textsubscript{5.17}-Zr\textsubscript{3.83}O\textsubscript{3}/\(\gamma\)-Al\textsubscript{2}O\textsubscript{3} 10\%, d) Cu-Ce\textsubscript{5.17}-Zr\textsubscript{3.83}O\textsubscript{3}/\(\gamma\)-Al\textsubscript{2}O\textsubscript{3} 30\%

4.35 (a) SEM images of catalyst cat-G1 at 5k, 10k, 15k
(b) SEM images of catalyst cat-G3 at 3k, 5k, 10k
(c) SEM images of catalyst cat-G4 at 3k, 5k, 10k
(d) SEM images of catalyst cat-G7 at 5k, 10k, 15k

4.36 N\textsubscript{2} adsorption-desorption isotherm of cat-G1, cat-G3, cat-G4, and cat-G7

4.37 Pore size distribution of catalyst- cat-G3, cat-G4, and cat- G7

4.38 Catalytic activity of catalysts Cu-Ce\textsubscript{5.17}-Zr\textsubscript{3.83}O\textsubscript{3}/\(\gamma\)-Al\textsubscript{2}O\textsubscript{3} (0\%), cat-D1, cat-E1, cat-F1 and cat-G1 prepared by four methods.

4.39 Optimization of \(\gamma\)-Al\textsubscript{2}O\textsubscript{3} loading on Cu-Ce\textsubscript{5.17}-Zr\textsubscript{3.83}O\textsubscript{3}/\(\gamma\)-Al\textsubscript{2}O\textsubscript{3} catalysts prepared by (a) CI (at 210\(^\circ\)C) (b) SG (at 190\(^\circ\)C) (c) UC (at 250\(^\circ\)C) (d) UG (at 190\(^\circ\)C) methods.

4.40 Effect of preparation methods on CO oxidation activity of the catalysts, (1) cat-E4, (2) cat-D4, (3) cat-G4 and (4) cat-F4

4.41 N\textsubscript{2} adsorption-desorption isotherm of (1) \(\gamma\)-Al\textsubscript{2}O\textsubscript{3}, (2) cat-D4, (3) cat-G4, (4) cat-F4, (5) cat-E4

4.42 Pore size distribution of (1) cat-A6, (2) cat-D4, (3) cat-G4, (4) cat-F4, (5) cat-E4

4.43 SEM micrographs of CuO, CeO\textsubscript{2} and ZrO\textsubscript{2} obtained by decomposition of respective nitrates at 500\(^\circ\)C, and \(\gamma\)-Al\textsubscript{2}O\textsubscript{3} support.

4.45 XRD patterns of (1) γ-Al₂O₃, (2) cat-D4, (3) cat-E4, (4) cat-F4, (5) cat-G4.

4.46 TGA/DSC thermograms of the precursors of CuCe₅₋₁₇Zr₃₋₈₃Oₓ/γ-Al₂O₃ (15wt%) catalysts prepared by (1) co-impregnation and (2) sol-gel methods.

4.47 Comparison of catalysts cat-E1, cat-E4 and cat-B4


4.49 Optimization of promoter composition.

4.50 Comparison of catalysts prepared by Method-I (cat-H3), and method-II (cat-H6), using cat-E4 and adding 6% K₂O.

4.51 XRD patterns of Catalysts a) cat-E4, b) cat-H3 c) cat-H6

4.52 (a) SEM images of catalyst cat-H3 at 5k, 10k, 15k

4.53 N₂ adsorption-desorption isotherm of: (a) cat-H3, (b) cat-H6

4.54 Pore size distribution of catalyst cat-H3 and cat-H6

4.55 Deactivation studies of catalysts cat-H3, cat-H6, cat-E4

5.1 Effect of particle size of catalysts cat-E4, cat-H3, cat-H6 on conversion of CO at 350K, feed composition 2.5% CO by volume, W/F_{CO} = 21.20 gm cat-hr/gm-mole.

5.2 Effect of catalyst weight (cat-H3) on conversion of CO at 400 K, feed composition 2.5% CO by volume.

5.3 Plot of conversion of CO (%) vs. W/F_{CO} Temperatures

5.4 Plot of ln r_{obs} vs. ln C_{CO}

5.5 Arrhenius Plot

5.6 Parity plot of predicted vs. experimental reaction rates