

Contents

Certificate.....	i
Declaration by the Candidate.....	ii
Certificate by the Supervisors.....	ii
Copyright Transfer Certificate.....	iii
Acknowledgement	iv
Contents.....	vii
List of Figure.....	xi
List of Table.....	xx
Preface.....	xxii
Chapter 1 Introduction.....	27-74
1.1 Magnetism : Introduction.....	29
1.1.1 Diamagnetism.....	29
1.1.2 Paramagnetism.....	30
1.1.3 Ferromagnetism.....	31
1.1.4 Antiferromagnetism.....	31
1.1.5 Ferrimagnetism.....	32
1.2 Rules define the different types of magnetic ordering.....	32
1.2.1 Curie-Weiss Law.....	32
1.2.2 Mean field theory	33
1.2.3 Heisenberg Model.....	34
1.2.4 Ising Model	35
1.2.5 Landau theory of phase transition	35
1.3 Spin Frustration.....	36
1.3.1 Geometrical Spin Frustration.....	36
1.3.1.1 Pyrochlore oxide materials.....	40
1.3.1.1.1 Long range ordered.....	44
1.3.1.1.2 Spin Liquid	44
1.3.1.1.3 Spin Ice.....	44
1.3.1.1.4 Spin Glass.....	46

1.3.2 Disorder driven Spin Frustration	46
1.3.2.1 Single Perovskite Material.....	46
1.3.2.2 Double Perovskite Material	47
1.4 Literature survey on $A_2Ti_2O_7$ type Pyrochlore materials	49
1.5 Literature survey on A_2CoFeO_6 type Double Perovskite.....	55
1.6 Different Physical Phenomena related to our research.....	60
1.6.1 Spin relaxation or Spin freezing Process.....	60
1.6.2 Dzyaloshinsky-Moriya (DM) interaction.....	63
1.6.3 Spin-glass/ Cluster glass phenomenology	64
1.6.4 Exchange Bias (EB) effect.....	67
1.6.5 Magneto-dielectric coupling.....	70
1.6.6 Transport Property.....	71
1.6.6.1 Variable Range Hopping (VRH) Model.....	71
1.6.6.2 Arrhenius law.....	71
1.7 Motivation of the thesis.....	72
Chapter 2 Experimental Procedure.....	75-97
2.1 Sample Synthesis.....	77
2.1.1 Solid State Reaction Route.....	77
2.2 Experimental characterization techniques and their working principles	78
2.2.1 Characterization tools for structural property study	79
2.2.1.1 X-Ray Diffraction (XRD) technique	79
2.2.1.2 Raman Spectroscopy.....	81
2.2.1.3 Neutron Powder Diffraction (NPD) technique	84
2.2.1.4 X-ray Photoemission Spectroscopy (XPS) technique.....	87
2.2.1.5 X-ray Absorption Spectroscopy (XAS) technique	90
2.2.2 Characterization tools for magnetic property study.....	92
2.2.2.1 Magnetic Property Measurement System (MPMS): SQUID-VSM	92
2.2.3 Characterization tools for Dielectric study.....	95
2.2.3.1 Dielectric analysis.....	95

2.2.3.2 Magneto-Dielectric Analysis.....	96
Chapter 3 Spin freezing and Field induced transition in $(\text{Tb}_{1-x}\text{Eu}_x)_2\text{Ti}_2\text{O}_7$: A Magnetic Property study.....	99-120
3.1 Introduction	101
3.2 Experiment	103
3.3 RESULTS AND DISCUSSION	104
3.3.1 Stability Study.....	104
3.3.2 Structural Study	105
3.3.3 Raman Study.....	106
3.3.4 DC Magnetic Study.....	108
3.3.5 AC Magnetic Study.....	112
3.4 Conclusion.....	120
Chapter 4 Wasp - Waisted loop and Spin frustration in $\text{Dy}_{2-x}\text{Eu}_x\text{Ti}_2\text{O}_7$ Pyrochlore....	121-143
4.1 Introduction.....	123
4.2 Experimental detail	125
4.3 RESULTS AND DISCUSSION	126
4.3.1 Stability and Structural Analysis.....	126
4.3.2 Raman Spectroscopy Analysis.....	128
4.3.3 Magnetization Analysis	130
4.3.3.1 DC magnetic Study.....	130
4.3.3.2 AC magnetic Study.....	137
4.4 Conclusion.....	143
Chapter 5 Roles of Re-entrant Cluster glass state and Spin lattice coupling in magneto-dielectric behavior of giant dielectric double perovskite $\text{La}_{1.8}\text{Pr}_{0.2}\text{CoFeO}_6$	145-163
5.1 Introduction	147
5.2 Experiment	148
5.3 Results	149
5.3.1 Stability and Structure Study	149
5.3.2 XAS Study	150
5.3.3 Magnetic Study	151
5.3.4 Dielectric Study	156

5.3.5	Resistivity Study	157
5.3.6	Magneto-dielectric Study	158
5.4	Conclusion.....	162
Chapter 6	Double glassy states and large spontaneous and conventional exchange bias effect in $\text{La}_{1.5}\text{Ca}_{0.5}\text{CoFeO}_6$ double perovskite.....	165-191
6.1	Introduction	167
6.2	Experimental details.....	169
6.3	Results and discussion.....	170
6.3.1	Stability and Structure Analysis.....	170
6.3.2	X-ray photoelectron spectroscopy (XPS) Analysis	172
6.3.3	Theoretical Analysis	175
6.3.4	Temperature dependent Neutron diffraction Analysis.....	177
6.3.5	Magnetic Analysis	180
6.4	Conclusion.....	190
Chapter 7	Conclusions and Future scopes.....	193-197
7.1	Conclusion of the thesis	195
7.2	Future Plans.....	196
References	198-241
List of publications.....		242-245

List of Figure

Figure 1.1 Schematic representation of spin alignment in diamagnetic and paramagnetic materials microscopic structures at rest and in the presence of a magnetic field H.....	31
Figure 1.2 Schematic representation of spin alignment in ferromagnetic, antiferromagnetic and ferrimagnetic materials.	32
Figure 1.3 Temperature variation of inverse magnetic susceptibility for paramagnetic, ferromagnetic and antiferromagnetic material.....	33
Figure 1.4 (a) Variation of free energy with magnetization. (b) Variation of Magnetization as a function of temperature. [Courtsey: Stephen Blundell, Magnetism in condensed matter; Oxford master series in condensed matter physics]	34
Figure 1.5 Direction of Ising spins on the vertices of 2 d triangular lattice illustrates geometrical spin frustration in which two spins are align antiferromagnetically where as the direction of third spin is not definite.....	37
Figure 1.6 Direction of Ising spins on the vertices of 2 d triangular lattice illustrates geometrical spin frustration in which two spins are align antiferromagnetically where as the direction of third spin is not definite.....	38
Figure 1.7 Examples of some possible geometrically frustrated magnetic lattices along with their space groups. The top two examples are of two dimensional frustrating lattice geometries, the bottom two examples are of two dimensional frustrating lattice geometries.....	39
Figure 1.8 Shows the Conventional unit cell of the corner-sharing tetrahedral $A_2B_2O_7$ pyrochlore structure with A^{3+} and B^{4+} sublattices.)	40

Figure 1.9 Shows the Conventional unit cell of $A_2B_2O_7$ pyrochlore structure with the arrangement of O and O' ion.....	41
Figure 1.10 Shows the pyrochlore lattice posses alternating kagome and triangular planar layers stacked along [111] direction [4]......	42
Figure 1.11 Shows the structural stability map for $A_2B_2O_7$ Pyrochlore.[4]	43
Figure 1.12 Showing the ‘two-in, two-out’ arrangement as A) In water ice between oxygen (large circle) and Hydrogen atom (black sphere). B) Ice rule follow in a single tetrahedral C) The cubic unit cell of spin ice pyrochlore lattice in which white sphere directs to spins into a ‘downward’ towards tetrahedra, while black sphere directs to spins ‘upwards’ towards tetrahedral [12]......	45
Figure 1.13 Show the crystal structure of ABX_3 perovskite.....	47
Figure 1.14 Describe the Double Perovskite unit cell structure formed by two perovskite unit cell. In this figure, blue sphere denotes A-site ion, violet sphere denotes B-site ion and yellow sphere presents B'-site ion.....	48
Figure 1.15 Shows the ground state spin configuration achieved for $Er_2Ti_2O_7$ [32].....	49
Figure 1.16 Showing the all in-all out spin arrangement in $Sm_2Ti_2O_7$	54
Figure 1.17 The frequency varying real and imaginary part of χ . χ_T and χ_S occur at lowest and highest frequencies respectively. Inset of fig.1.17 demonstrate the phasor diagram of χ . Here, ψ is the phase difference.....	62
Figure 1.18 Shows the DM interaction between two neighboring spins.....	63
Figure 1.19 Depicts the spin arrangement in ferromagnetic, antiferromagnetic and spin glass state.....	65
Figure 1.20 Depicts the arrangement of spins in spin glass state and cluster glass state.....	66
Figure 1.21 Represents the symmetric and asymmetric hysteresis loop in M-H curve.....	67

Figure 1.22 Shows the schematic explanation of exchange Bias effect.....	69
Figure 1.23 Shows the $\ln\rho$ versus $(1/T)^{0.25}$ curve with VRH fit (blue colour).....	71
Figure 1.24 (a) Shows the $\ln\rho$ versus $(1/T)$ curve with Arrhenius fit (green colour). (b) Shows the activation energy and the band gap between valence and conduction bands.....	72
Figure 2.1 Flow chart showing the steps of solid state reaction method.....	78
Figure 2.2 Schematic diagram of Bragg's law.....	80
Figure 2.3 Picture of Rigaku-MiniFlex-II DESKTOP powder X-ray diffractometer.	81
Figure 2.4 Energy level diagram of Rayleigh scattering and Raman Scattering.....	83
Figure 2.5 Renishaw Micro Raman Spectrometer.....	84
Figure 2.6 Setup of PD-2 (Powder Diffractometer-2) located at Bhabha Atomic Research, Mumbai, India.....	87
Figure 2.7 (a) Shows the photoelectric effect. (b) Depicts the schematic representation of XPS set up.....	89
Figure 2.8 Transition between the core levels which rise to XAS edges	91
Figure 2.9 Block diagram of XAS beam line consists of various components	92
Figure 2.10 Quantum Design MPMS 3 magnetometer	95
Figure 2.11 Magneto-dielectric measurement set up.....	97
Figure 3.1 Powder x-ray diffraction pattern for the $(\text{Tb}_{1-x}\text{Eu}_x)_2\text{Ti}_2\text{O}_7$ samples. Inset (i) Diffraction peak (222) of $(\text{Tb}_{1-x}\text{Eu}_x)_2\text{Ti}_2\text{O}_7$ samples. Inset (ii) Rietveld refinement for the $\text{Tb}_{1.0}\text{Eu}_{1.0}\text{Ti}_2\text{O}_7$ sample.	106
Figure 3.2 (a) Raman Spectra of the $(\text{Tb}_{1-x}\text{Eu}_x)_2\text{Ti}_2\text{O}_7$ samples at 300 K. (b) Variation of all four active phonon modes as a function of x in $(\text{Tb}_{1-x}\text{Eu}_x)_2\text{Ti}_2\text{O}_7$ samples ..	108

Figure 3.3 (a) The temperature dependent magnetization (ZFC) of the $(\text{Tb}_{1-x}\text{Eu}_x)_2\text{Ti}_2\text{O}_7$ samples. (b) $M(H)$ at 2 K for all TETO samples. Inset: Variation of effective magnetic moments with Eu content (x) derived from Curie–Weiss Law at high temperature for TETO sample. (c) The inverse DC susceptibility of $(\text{Tb}_{1-x}\text{Eu}_x)_2\text{Ti}_2\text{O}_7$ samples. (d) High Temperature Series Expansion fit for $(\text{Tb}_{1-x}\text{Eu}_x)_2\text{Ti}_2\text{O}_7$ ($x = 0.90, 0.95, 1.0$) samples. Inset: Curie–Weiss fit for $(\text{Tb}_{1-x}\text{Eu}_x)_2\text{Ti}_2\text{O}_7$ ($x = 0, 0.25, 0.50$) samples..... 112

Figure 3.4 (a): $\chi'(T)$ of $\text{Tb}_2\text{Ti}_2\text{O}_7$ ($f = 300, 500, 700$ Hz) and YTTO ($f = 500$ Hz) at zero applied DC field. Inset (i) $\chi''(T)$ of $\text{Tb}_2\text{Ti}_2\text{O}_7$. Inset (ii) $\chi''(T)$ of TTO and YTTO compounds at $H = 0$ Oe (500 Hz). (b) $\chi''(f)$ at different temperatures for $\text{Tb}_2\text{Ti}_2\text{O}_7$. Inset: Normalized χ'' as a function of f/f_{peak} and fitted theoretically (red) by Casimir du pre relations at and near the transition temperature for $\text{Tb}_2\text{Ti}_2\text{O}_7$ 113

Figure 3.5. (a) $\chi'(T)$ of all TETO compounds measured at $H = 0$ Oe ($f = 500$ Hz). Inset: $\chi'(T)$ of ETO at $H = 0$ Oe. (b) $\chi''(T)$ of all TETO compounds measured at $H = 0$ Oe ($f = 500$ Hz). Inset: $\chi''(T)$ of ETO at $H = 0$ Oe..... 115

Figure 3.6 $\chi'(T)$ (upper panel) and $\chi''(T)$ (lower panel) of TETO compounds at applied field of 10 kOe. (a) $x = 0.0$, (b) $x = 0.5$, (c) $x = 0.95$, (d) $x = 1.0$. The inset in every upper panel: $d\chi'(T)/dT$ with T . Marked by arrow are: Single ion spin freezing peak (T_f) and Single moment saturation peak (T^*)..... 117

Figure 3.7(a) The Arrhenius Fit of (T_f) peak for compounds $(\text{Tb}_{1-x}\text{Eu}_x)_2\text{Ti}_2\text{O}_7$ ($x = 0.25, 0.50, 0.90, 0.95$). Inset: Arrhenius Fit of $\text{Tb}_2\text{Ti}_2\text{O}_7$. (b) Variation of field induced transition temperature T^* with Eu content (x) for TETO samples..... 119

Figure 4.1 The lattice constant (Cubic Structure) of $Dy_{2-x}Eu_xTi_2O_7$ as a function of x value. Inset (i): X-ray powder diffraction pattern for the $Dy_{2-x}Eu_xTi_2O_7$ samples. Inset (ii): Rietveld refinement for the $Dy_{1.0}Eu_{1.0}Ti_2O_7$ sample..... 128

Figure 4.2. Raman spectra of the $Dy_{2-x}Eu_xTi_2O_7$ samples at 300 K. Inset: Variation of four active phonon modes as a function of x in $Dy_{2-x}Eu_xTi_2O_7$ samples along with the straight horizontal dashed lines for reference. 129

Figure 4.3. The temperature dependent DC magnetic susceptibility (ZFC) with standard Curie-Weiss fit of the x = 0.0, 0.5, 1.0 samples. Inset (i): The temperature dependent DC magnetic susceptibility (ZFC) with standard Curie-Weiss fit of the x = 1.5, 1.8, 1.9 samples. Inset (ii): χ vs. T curve of x = 2.0 sample with standard CW fit. (b): Inverse DC susceptibility vs. T curve of $Dy_{2-x}Eu_xTi_2O_7$ compounds with inverse CW fit at (100-300 K). (c): High temperature series expansion fit for $Dy_{2-x}Eu_xTi_2O_7$ (x = 1.5, 1.8, 1.9, 2.0) samples. (d): Variation of derived CW temperature with x value of $Dy_{2-x}Eu_xTi_2O_7$ series from (2-20 K) CW fit. Inset: Variation of calculated effective magnetic moments with Eu content (x) derived from inverse CW fit at high temperature (100-300 K) for DETO samples.. 131

Figure 4.4 Zoom part of M-H curve for x = 1.5, 1.8, 1.9 samples at 2 K. Inset: M-H curves at 2 K for all DETO samples. (b): Variation of $d^2\delta M/dH^2$ curve with applied H at 2 K for x = 1.5 sample. {Zoom part of 4.4(b)} - $d^2\delta M/dH^2$ curve with applied H (0.4-1.0 T) at 2 K for x = 1.5 sample. Inset: δM between ascending and descending portions of M-H curve for x = 1.5 sample. {Zoom part of inset 4.4(b)}- δM of M-H curve for x = 1.5 sample from 0.25-0.75 T. (c): Variation of $d^2\delta M/dH^2$ curve with applied H at 2 K for x = 1.8, 1.9 samples. Inset: δM between ascending and descending portions of M-H curves for x = 1.8, 1.9 samples. (d): Descending first

quadrant M-H curve for $x = 1.5, 1.8, 1.9$ samples with LA fit above 1 T.....	134
Figure 4.5 $\chi'(T)$ of $x = 0.0, 0.5, 1.0$ for $f = 500$ Hz at zero applied DC field. Inset (i): $\chi'(T)$ of $x = 1.5, 1.8, 1.9$ for $f = 500$ Hz at zero applied DC field. Inset (ii): $\chi'(T)$ of $x = 2.0$ for $f = 500$ Hz at zero applied DC field. (b): $\chi''(T)$ of $x = 0.0, 0.5, 1.0$ for $f = 500$ Hz at zero applied DC field. Inset (i): $\chi''(T)$ of $x = 1.5, 1.8, 1.9$ for $f = 500$ Hz at zero applied DC field. Inset (ii): $\chi''(T)$ of $x = 2.0$ for $f = 500$ Hz at zero applied DC field.....	138
Figure 4.6 $\chi'(T)$ (upper panel) and $\chi''(T)$ (lower panel) of $Dy_{2-x}Eu_xTi_2O_7$ compounds at applied field of 2 T. (a): $Dy_{1.5}Eu_{0.5}Ti_2O_7$, (b): $Dy_{1.0}Eu_{1.0}Ti_2O_7$, (c): $Dy_{0.5}Eu_{1.5}Ti_2O_7$, (d): $Dy_{0.2}Eu_{1.8}Ti_2O_7$, (e): $Dy_{0.1}Eu_{1.9}Ti_2O_7$. Marked by arrow are: Single ion spin freezing peak of Dy^{3+} ions (T_f) and Single ion spin freezing peak of Eu^{3+} ions (T_s).....	140
Figure 4.7 The Arrhenius Fit of (T_f) peak for ($x = 0.5, 1.0, 1.5, 1.8, 1.9$) compounds and Arrhenius Fit of (T_s) peak for ($x = 1.5, 1.8, 1.9$) compounds.(b): Variation of derived E_a values of T_f and T_s peaks with x value of $Dy_{2-x}Eu_xTi_2O_7$.(c): Variation of T_f and T_s peaks with x value of $Dy_{2-x}Eu_xTi_2O_7$	141
Figure 5.1. The XRD pattern along with the Rietveld refinement of LPCFO at 300 K.....	150
Figure 5.2. XAS spectra of (a) Co edge (b) Fe edge recorded at 300K.....	151
Figure 5.3. (a) The temperature dependent ZFC and FC Curve of LPCFO at different magnetic fields. (b) The isothermal (M-H) curves of LPCFO at different temperatures. Inset: dM/dT as a function of temperature.....	152
Figure 5.4. The temperature dependent real $\chi'(T)$ (a) and imaginary $\chi''(T)$ (b) part of AC susceptibility of LPCFO at zero field. (c) Dynamic Scaling fit of $\log f$ Vs $\log (T_f/T_{SG} - 1)$. Inset :	

Vogel-Fulcher fit of $\ln f$ Vs $1/(T_f-T_0)$ curve. (d): TRM data at 25 K fitted with KWW equation.
..... 154

Figure 5.5 (a) Temperature dependent dielectric constant (ϵ') of LPCFO. Inset: Arrhenius fit of dielectric relaxation of LPCFO. (b) Temperature dependent dielectric tangent loss ($\tan\delta$) of LPCFO. Inset: a comparative plot of $\tan\delta(T)$ and imaginary part of dielectric function $\epsilon''(T)$ at 10 kHz frequency..... 156

Figure 5.6 (a) Temperature dependent resistivity $\rho(T)$ curve of LPCFO at zero magnetic field. (b) 3-d VRH fit of $\rho(T)$ at 120 – 190 K temperature range. (c) SPH fit of $\rho(T)$ at 240 – 300 K temperature range..... 158

Figure 5.7 (a): Magneto dielectric (%) as a function of magnetic field for LPCFO at different temperatures. Inset: Raw pictorial diagram of Magneto dielectric (%) Vs. temperature at 1.3 T magnetic field. (b) Raman scattering intensity of LPCFO at different temperatures (80-330 K) as a function of Raman shift. (c) Temperature dependence of the phonon positions of two typical modes (A_g and B_g) observed for LPCFO. Brown vertical dotted lines represent anomalies. (d) Temperature dependence of the Raman line widths (FWHM) of A_g and B_g modes. Blue dotted line shows the different slopes. Brown vertical dotted lines represent anomalies.....160

Figure 6.1 (a) The XRD pattern along with the Rietveld refinement of LCCFO at 300 K. (b) The Crystal structure of LCCFO sample using VESTA.....172

Figure 6.2 (a): The full XPS surface scan survey of LCCFO sample. Deconvoluted XPS Spectra of LCCFO (b) La 3d level, (c) Ca 2p level, (d) Co 2p level, (e) Fe 2p level and (f) O1s level.
.....175

Figure 6.3. (a) : TDOS of LCCFO system. (b): Spin resolved PDOS for La-f, Ca-d, Co-d, Fe-d, and O-p orbitals inset (i) PDOS of Co-d state. (ii) PDOS of Fe-d state.....176

Figure 6.4. (a): Rietveld refined neutron diffraction patterns at various temperatures of LCCFO system. The oval marked area indicates the purely magnetic (011) Bragg peak. (b): Magnetic structure of LCCFO from 6 K NPD data.....178

Figure 6.5 (a) : ZFC and FC curve of LCCFO sample at 100 Oe magnetic field. Inset : Temperature dependence of dM/dT for FC data at 100 Oe magnetic field. (b) Temperature dependence of the magnetization under ZFC protocol at $H = 100$ Oe, 1000 Oe and 10000 Oe. (c): Power-law fitting to the log-log plot of " $1/\chi$ Vs $((T-T_C^R)/T_C^R)$ " at 100 Oe ZFC data. Inset : Inverse susceptibility Vs temperature curve at 1000 Oe magnetic field with Curie-Weiss law fit. (d): $M(H)$ curves of LCCFO at different temperature. 183

Figure 6.6 Temperature dependence of the AC susceptibility of LCCFO at zero magnetic field. (a)Upper panel : The real part χ' and lower panel : The imaginary part χ'' from $T = 140-180$ K. (b)Upper panel : The real part χ' and lower panel : The imaginary part χ'' from $T = 2-50$ K. T_1 and T_s are the cluster glass temperature. (c) Dynamic Scaling fit of $\log f$ Vs $\log (T_f/T_{SG} - 1)$ curve. Inset : Vogel-fulcher fit $\ln f$ Vs $1/(T_f-T_0)$ data in the T_1 RCG region. (d) Dynamic Scaling fit of $\log f$ Vs $\log (T_f/T_{SG} - 1)$ curve. Inset : Vogel-fulcher fit of $\ln f$ Vs $1/(T_f-T_0)$ data in the T_s RCG region.....186

Figure 6.7 (a) ZFC $M(H)$ isotherms in the range ± 70 kOe at 5 K. (b) The $M(H)$ isotherms measured at 5 K after cooling the sample under +50 kOe (green curve) and -50 kOe (orange curve). (c): ZFC $M(H)$ isotherms in the range ± 20 kOe at 10 K, 20 K, 30 K and 40 K. Inset : ZFC $M(H)$ isotherms in the range ± 20 kOe at 50 K (d): ZFC $M(H)$ isotherms in the range ± 20 kOe at 60 K, 70 K, 80 K, 90 K and 100 K. (e): Variation of H_{EB} (left Y -axis) and H_C (right Y-

axis) with the temperature (10 – 90 K). (f): Variation of M_{SEB} (left Y –axis) and M_C (right Y-axis) with the temperature (10 – 90 K). 189

List of Table

Table 1.1 Shows the crystallographic positions of cubic $A_2B_2O_6O'$ Pyrochlore oxide having $Fd\bar{3}m$ space group symmetry.....	41
Table 1.2 Shows the characteristics of different $A_2Co/Mn/NiO_6$ type double perovskite materials.....	58
Table 3.1 The ionic radius ratio of TETO series compounds.....	105
Table 3.2 Lattice parameters obtained from rietveld refinement of all TETO compositions with Space Group $Fd\bar{3}m$	105
Table 3.3 Curie–Weiss temperature, theoretical and calculated magnetic moment of ($x = 0.00, 0.25, 0.50$) samples obtained from Curie–Weiss fit (25-300 K).....	109
Table 3.4 Theoretical and calculated magnetic moment of ($x = 0.90, 0.95$) samples obtained from Curie–Weiss (150-300 K) fit.....	110
Table 3.5 Curie–Weiss temperature, classical exchange energy, dipolar interaction energy and calculated magnetic moment of ($x = 0.90, 0.95, 1.0$) samples obtained from the fitting of the High Temperature Series Expansion [2-5 K].....	111
Table 4.1 The ionic radius ratio of DETO series compounds.....	127
Table 4.2 Extracted Curie–Weiss temperature, classical exchange energy, dipolar interaction energy and calculated magnetic moment of ($x = 1.5, 1.8, 1.9, 2.0$) samples by high temperature series expansion fit [2-5 K].....	132
Table 4.3 Extracted anisotropy constant (K_I) values of $x = 1.5, 1.8, 1.9$ samples.....	137
Table 6.1 Structural parameters obtained by Rietveld profile refinement of the powder XRD pattern for $La_{1.5}Ca_{0.5}CoFeO_6$ at 300K. (Monoclinic – $P2_1/n$).....	171

Table 6.2 The magnetic moment values of Co and Fe sublattices evaluated by NPD data at different temperatures180

Table 6.3 Fitted parameters obtained by dynamic scaling law and Vogel fulcher fit at T_1 and T_S temperatures.....185