# CONTENTS

## Abstract

## Chapter I

1. **INTRODUCTION**

1.1 Nanoparticles

1.2 Nanotechnology

1.3 Properties of Nanoparticles

1.4 Advantages of Nanoparticles

1.5 Application of Nanoparticles

1.6 Limitations of Nanoparticles

1.7 Green Chemistry

1.7.1 Origin of Green Chemistry

1.7.2 Principles of Green Chemistry

1.7.3 Application of Green Chemistry in Various Industries

1.8 Green Chemicals

1.8.1 Ionic Liquids (ILs)

1.8.2 Classification of Ionic Liquids

References

## Chapter II

2. **REVIEW OF LITERATURE**

References
Chapter III

3. AIM AND SCOPE

Chapter IV

4. EXPERIMENTAL SECTION

4.1 Chemicals

4.2 Instruments

4.3 Synthesis of ionic liquids

4.3.1 Synthesis of 1-Butyl-3-methylimidazolium bromide [BMIM] Br

4.3.2 Synthesis of 1-Ethyl-3-methylimidazolium bromide [EMIM] Br

4.3.3 Synthesis of 1-Butyl-2-ethyl-3-methylimidazolium bromide [BEMIM] Br

4.3.4 Synthesis of 1, 2 - dibutyl - 3- methylimidazolium bromide [BBMIM] Br

4.3.5 Synthesis of 2-butyl-1-ethyl-3-methylimidazolium bromide [EBMIM] Br

4.3.6 Synthesis of 1, 2-diethyl-3-methylimidazolium bromide [EEMIM] Br

4.3.7 Synthesis of 1-butyl-3-methylimidazolium tetrafluoroborate [BMIM] BF$_4$

4.3.8 Synthesis of 1-butyl-3-methylimidazolium hexafluorophosphate [BMIM] PF$_6$

4.3.9 Synthesis of 1-butyl-2-ethyl-3-methylimidazolium tetrafluoroborate [BEMIM] BF$_4$
4.3.10 Synthesis of 1-butyl-2-ethyl-3-methylimidazolium hexafluorophosphate [BEMIM] PF$_6$

4.3.11 Synthesis of 1-ethyl-3-methylimidazolium tetrafluoroborate [EMIM] BF$_4$

4.3.12 Synthesis of 1-ethyl-3-methylimidazolium hexafluorophosphate [EMIM] PF$_6$

4.4. Synthesis of Silver Nanoparticles

4.4.1 Synthesis of Ag Nanoparticles in [BMIM] BF$_4$

4.4.2 Synthesis of Ag Nanoparticles in [BMIM] PF$_6$

4.4.3 Synthesis of Ag Nanoparticles in [BEMIM] BF$_4$

4.4.4 Synthesis of Ag Nanoparticles in [BEMIM] PF$_6$

4.4.5 Synthesis of Ag Nanoparticles in [EMIM] BF$_4$

4.4.6 Synthesis of Ag Nanoparticles in [EMIM] PF$_6$

4.5 Synthesis of Cadmium sulphide Nanoparticles

4.5.1 Synthesis of Cadmium sulphide Nanoparticles in [BMIM] BF$_4$

4.5.2 Synthesis of Cadmium sulphide Nanoparticles in [BMIM] PF$_6$

4.5.3 Synthesis of Cadmium sulphide Nanoparticles in [BEMIM] BF$_4$

4.5.4 Synthesis of Cadmium sulphide Nanoparticles in [BEMIM] PF$_6$

4.5.5 Synthesis of Cadmium sulphide Nanoparticles in [EMIM] BF$_4$

4.5.6 Synthesis of Cadmium sulphide Nanoparticles in [EMIM] PF$_6$

4.6 Synthesis of Zinc oxide Nanoparticles

iii
4.6.1 Synthesis of Zinc oxide Nanoparticles in [BMIM] BF$_4$  
4.6.2 Synthesis of Zinc oxide Nanoparticles in [BMIM] PF$_6$  
4.6.3 Synthesis of Zinc oxide Nanoparticles in [BEMIM] BF$_4$  
4.6.4 Synthesis of zinc oxide Nanoparticles in [BEMIM] PF$_6$  
4.6.5 Synthesis of Zinc oxide Nanoparticles in [EMIM] BF$_4$  
4.6.6 Synthesis of Zinc oxide Nanoparticles in [EMIM] PF$_6$  
4.7 Antimicrobial activity  

References  

Chapter V  

5. RESULTS AND DISCUSSION

5.1 Spectral Data of ILs  
5.2 Antimicrobial activity of ILs  
5.3 Synthesis of IL assisted nanoparticles  
5.4 Characterization of Ag (0) nanoparticles  
5.4.1 FT-IR Spectral interpretation of Ag (0) nanoparticles  
5.4.2 XRD analysis of Ag (0) nanoparticles  
5.4.3 SEM analysis of Ag (0) nanoparticles  
5.4.4 Antimicrobial activity of Ag (0) nanoparticles  
5.5 Characterization of CdS nanoparticles  
5.5.1 FT-IR Spectral interpretation of CdS nanoparticles  
5.5.2 XRD analysis of CdS nanoparticles  
5.5.3 SEM analysis of CdS nanoparticles  
5.5.4 Antimicrobial activity of CdS nanoparticles  
5.6 Characterization of ZnO nanoparticles  
5.6.1 FT-IR Spectral interpretation of ZnO nanoparticles
5.6.2 XRD analysis of ZnO nanoparticles 99

5.6.3 SEM analysis of ZnO nanoparticles 103

5.6.4 Antimicrobial activity of ZnO nanoparticles 108

References 109

Chapter VI

6. CONCLUSION 114

RESEARCH PUBLICATIONS
LIST OF TABLES

1. Interpretation of FT-IR spectra of [BMIM] Br
2. Interpretation of $^1$H-NMR spectra of [BMIM] Br
3. Interpretation of $^{13}$C-NMR spectra of [BMIM] Br
4. Interpretation of FT-IR spectra of [EMIM] Br
5. Interpretation of $^1$H-NMR spectra of [EMIM] Br
6. Interpretation of $^{13}$C-NMR spectra of [EMIM] Br
7. Interpretation of FT-IR spectra of [BEMIM] Br
8. Interpretation of $^1$H-NMR spectra of [BEMIM] Br
9. Interpretation of $^{13}$C-NMR spectra of [BEMIM] Br
10. Interpretation of FT-IR spectra of [BBMIM] Br
11. Interpretation of $^1$H-NMR spectra of [BBMIM] Br
12. Interpretation of $^{13}$C-NMR spectra of [BBMIM] Br
13. Interpretation of FT-IR spectra of [EBMIM] Br
14. Interpretation of $^1$H-NMR spectra of [EBMIM] Br
15. Interpretation of $^{13}$C-NMR spectra of [EBMIM] Br
16. Interpretation of FT-IR spectra of [EEMIM] Br
17. Interpretation of $^1$H-NMR spectra of [EEMIM] Br
18. Interpretation of $^{13}$C-NMR spectra of [EEMIM] Br
19. Interpretation of FT-IR spectra of [BMIM] BF$_4$
20. Interpretation of $^1$H-NMR spectra of [BMIM] BF$_4$
21. Interpretation of $^{13}$C-NMR spectra of [BMIM] BF$_4$
22. Interpretation of FT-IR spectra of [BMIM] PF$_6$
23. Interpretation of $^1$H-NMR spectra of [BMIM] PF$_6$
24. Interpretation of $^{13}$C-NMR spectra of [BMIM] PF$_6$
25. Interpretation of FT-IR spectra of [BEMIM] BF$_4$
26. Interpretation of $^1$H-NMR spectra of [BEMIM] BF$_4$
27. Interpretation of $^{13}$C-NMR spectra of [BEMIM] BF$_4$
28. Interpretation of FT-IR spectra of [BEMIM] PF$_6$
29. Interpretation of $^1$H-NMR spectra of [BEMIM] PF$_6$
30. Interpretation of $^{13}$C-NMR spectra of [BEMIM] PF$_6$
31. Interpretation of FT-IR spectra of [EMIM] BF$_4$
32. Interpretation of $^1$H-NMR spectra of [EMIM] BF$_4$
33. Interpretation of $^{13}$C-NMR spectra of [EMIM] BF$_4$
34. Interpretation of FT-IR spectra of [EMIM] PF$_6$
35. Interpretation of $^1$H-NMR spectra of [EMIM] PF$_6$
36. Interpretation of $^{13}$C-NMR spectra of [EMIM] PF$_6$
37. The MIC values of ionic liquids (1 – 6)
38. The MIC values of ionic liquids (7 – 12)
39. Interpretation of FT-IR spectrum of Ag (0) nanoparticles synthesized in [BMIM] BF$_4$
40. Interpretation of FT-IR spectrum of Ag (0) nanoparticles synthesized in [BMIM] PF$_6$
41. Interpretation of FT-IR spectrum of Ag (0) nanoparticles synthesized in [BEMIM] BF₄
42. Interpretation of FT-IR spectrum of Ag (0) nanoparticles synthesized in [BEMIM] PF₆
43. Interpretation of FT-IR spectrum of Ag (0) nanoparticles synthesized in [EMIM] BF₄
44. Interpretation of FT-IR spectrum of Ag (0) nanoparticles synthesized in [EMIM] PF₆
45. Interpretation of XRD pattern of Ag (0) nanoparticle in [BMIM] BF₄
46. Interpretation of XRD pattern of Ag (0) nanoparticle in [BMIM] PF₆
47. Interpretation of XRD pattern of Ag (0) nanoparticle in [BEMIM] BF₄
48. Interpretation of XRD pattern of Ag (0) nanoparticle in [BEMIM] PF₆
49. Interpretation of XRD pattern of Ag (0) nanoparticle in [EMIM] BF₄
50. Interpretation of XRD pattern of Ag (0) nanoparticle in [EMIM] PF₆
51. The MIC Values of of Ag(0) nanoparticles in RTILs [7-12]
52. Interpretation of FT-IR spectrum of CdS nanoparticle in ionic liquid [BMIM] BF₄
53. Interpretation of FT-IR spectrum of CdS nanoparticle in ionic liquid [BMIM] PF₆
54. Interpretation of FT-IR spectrum of CdS nanoparticle in ionic liquid [BEMIM] BF₄
55. Interpretation of FT-IR spectrum of CdS nanoparticle in ionic liquid [BEMIM] PF₆
56. Interpretation of FT-IR spectra of CdS nanoparticle in ionic liquid [EMIM] BF₄
57. Interpretation of FT-IR spectrum of CdS nanoparticle in ionic liquid [EMIM] PF₆
58. XRD data of CdS nanoparticle in [BMIM] BF₄
59. XRD data of CdS nanoparticle in [BMIM] PF₆
60. XRD data of CdS nanoparticle in [BEMIM] BF₄
61. XRD data of CdS nanoparticle in [BEMIM] PF₆
62. XRD data of CdS nanoparticle in [EMIM] BF₄
63. XRD data of CdS nanoparticle in [EMIM] PF₆
64. The MIC Values of CdS nanoparticles in RTILs [7-12]
65. FT-IR data of ZnO nanoparticle in ionic liquid [BMIM] BF₄
66. FT-IR data of ZnO nanoparticle in ionic liquid [BMIM] PF₆
67. FT-IR data of ZnO nanoparticle in ionic liquid [BEMIM] BF₄
68. FT-IR data of ZnO nanoparticle in ionic liquid [BEMIM] PF₆
69. FT-IR data of ZnO nanoparticle in ionic liquid [EMIM] BF₄
70. FT-IR data of ZnO nanoparticle in ionic liquid [EMIM] PF₆
71. XRD data of ZnO nanoparticle in [BMIM] BF₄
72. XRD data of ZnO nanoparticle in [BMIM] PF₆
73. XRD data of ZnO nanoparticle in [BEMIM] BF₄
74. XRD data of ZnO nanoparticle in [BEMIM] PF₆
75. XRD data of ZnO nanoparticle in [EMIM] BF₄
76. XRD data of ZnO nanoparticle in [EMIM] PF₆
77. The MIC Values of ZnO nanoparticles in RTILs [7-12]
# LIST OF FIGURES

1. A solidified Ionic liquid
2. FT-IR instrument
3. NMR instrument
4. XRD instrument
5. Structure of [BMIM] BF₄
6. Synthesized Ionic liquids (1-6)
7. Synthesized Ionic liquids (7-12)
8. FT-IR spectrum of pure ionic liquid [BMIM] Br
9. $^1$H-NMR spectrum of pure ionic liquid [BMIM] Br
10. $^{13}$C-NMR spectrum of pure ionic liquid [BMIM] Br
11. FT-IR spectrum of pure ionic liquid [EMIM] Br
12. $^1$H-NMR spectrum of pure ionic liquid [EMIM] Br
13. $^{13}$C-NMR spectrum of pure ionic liquid [EMIM] Br
14. FT-IR spectrum of pure ionic liquid [BEMIM] Br
15. $^1$H-NMR spectrum of pure ionic liquid [BEMIM] Br
16. $^{13}$C-NMR spectrum of pure ionic liquid [BEMIM] Br
17. FT-IR spectrum of pure ionic liquid [BBMIM] Br
18. $^1$H-NMR spectrum of pure ionic liquid [BBMIM] Br
19. $^{13}$C-NMR spectrum of pure ionic liquid [BBMIM] Br
20. FT-IR spectrum of pure ionic liquid [EBMIM] Br
21. $^1$H-NMR spectrum of pure ionic liquid [EBMIM] Br
22. $^{13}$C-NMR spectrum of pure ionic liquid [EBMIM] Br
23. FT-IR spectrum of pure ionic liquid [EEMIM] Br
24. $^1$H-NMR spectrum of pure ionic liquid [EEMIM] Br
25. $^{13}$C-NMR spectrum of pure ionic liquid [EEMIM] Br
26. FT-IR spectrum of pure ionic liquid [BMIM] BF$_4$
27. $^1$H-NMR spectrum of pure ionic liquid [BMIM] BF$_4$
28. $^{13}$C-NMR spectrum of pure ionic liquid [BMIM] BF$_4$
29. FT-IR spectrum of pure ionic liquid [BMIM] PF$_6$
30. $^1$H-NMR spectrum of pure ionic liquid [BMIM] PF$_6$
31. $^{13}$C-NMR spectrum of pure ionic liquid [BMIM] PF$_6$
32. FT-IR spectrum of pure ionic liquid [BEMIM] BF$_4$
33. $^1$H-NMR spectrum of pure ionic liquid [BEMIM] BF$_4$
34. $^{13}$C-NMR spectrum of pure ionic liquid [BEMIM] BF$_4$
35. FT-IR spectrum of pure ionic liquid [BEMIM] PF$_6$
36. $^1$H-NMR spectrum of pure ionic liquid [BEMIM] PF$_6$
37. $^{13}$C-NMR spectrum of pure ionic liquid [BEMIM] PF$_6$
38. FT-IR spectrum of pure ionic liquid [EMIM] BF$_4$
39. $^1$H-NMR spectrum of pure ionic liquid [EMIM] BF$_4$
40. $^{13}$C-NMR spectrum of pure ionic liquid [EMIM] BF$_4$
41. FT-IR spectrum of pure ionic liquid [EMIM] PF$_6$
42. $^1$H-NMR spectrum of pure ionic liquid [EMIM] PF$_6$
43. $^{13}$C-NMR spectrum of pure ionic liquid [EMIM] PF$_6$
44. Structure of representative ILs
45. The comparisons of MIC values of synthesized ionic liquids (1-6)
46. The comparisons of MIC values of synthesized ionic liquids (7-12)
47. Synthesized Ag(0) nanoparticles in Ionic Liquids
48. FT-IR spectrum of Ag nanoparticle in ionic liquid [BMIM] BF$_4$
49. FT-IR spectrum of Ag nanoparticle in ionic liquid [BMIM] PF$_6$
50. FT-IR spectrum of Ag nanoparticle in ionic liquid [BEMIM] BF$_4$
51. FT-IR spectrum of Ag nanoparticle in ionic liquid [BEMIM] PF$_6$
52. FT-IR spectrum of Ag nanoparticle in ionic liquid [EMIM] BF$_4$
53. FT-IR spectrum of Ag nanoparticle in ionic liquid [EMIM] PF$_6$
54. XRD pattern of Ag (0) nanoparticle in [BMIM] BF$_4$
55. XRD pattern of Ag (0) nanoparticle in [BMIM] PF$_6$
56. XRD pattern of Ag (0) nanoparticle in [BEMIM] BF$_4$
57. XRD pattern of Ag (0) nanoparticle in [BEMIM] PF$_6$
58. XRD pattern of Ag (0) nanoparticle in [EMIM] BF$_4$
59. XRD pattern of Ag (0) nanoparticle in [EMIM] PF$_6$
60. SEM image of Ag (0) nanoparticle in [BMIM] BF$_4$
61. SEM image of Ag (0) nanoparticle in [BMIM] PF$_6$
62. SEM image of Ag (0) nanoparticle in [BEMIM] BF$_4$
63. SEM image of Ag (0) nanoparticle in [BEMIM] PF$_6$
64. SEM image of Ag (0) nanoparticle in [EMIM] BF$_4$
65. SEM image of Ag (0) nanoparticle in [EMIM] PF$_6$
66. Antimicrobial activity of Ag (0) nanoparticles in ILs (7-12)
67. Synthesized CdS nanoparticles in Ionic Liquids
68. FT-IR spectrum of CdS nanoparticle in ionic liquid [BMIM] BF$_4$
69. FT-IR spectrum of CdS nanoparticle in ionic liquid [BMIM] PF$_6$
70. FT-IR spectrum of CdS nanoparticle in ionic liquid [BEMIM] BF$_4$
71. FT-IR spectrum of CdS nanoparticle in ionic liquid [BEMIM] PF$_6$
72. FT-IR spectrum of CdS nanoparticle in ionic liquid [EMIM] BF$_4$
73. FT-IR spectrum of CdS nanoparticle in ionic liquid [EMIM] PF$_6$
74. The powder XRD pattern of CdS nanoparticle in [BMIM] BF₄
75. The powder XRD pattern of CdS nanoparticle in [BMIM] PF₆
76. The powder XRD pattern of CdS nanoparticle in [BEMIM] BF₄
77. The powder XRD pattern of CdS nanoparticle in [BEMIM] PF₆
78. The powder XRD pattern of CdS nanoparticle in [EMIM] BF₄
79. The powder XRD pattern of CdS nanoparticle in [EMIM] PF₆
80. SEM image of CdS nanoparticle in [BMIM] BF₄
81. SEM image of CdS nanoparticle in [BMIM] PF₆
82. SEM image of CdS nanoparticle in [BEMIM] BF₄
83. SEM image of CdS nanoparticle in [BEMIM] PF₆
84. SEM image of CdS nanoparticle in [EMIM] BF₄
85. SEM image of CdS nanoparticle in [EMIM] PF₆
86. Anti-bacterial activity of CdS nanoparticles synthesized in ILs (7-12)
87. Synthesized ZnO nanoparticles in Ionic Liquids
88. FT-IR spectrum of ZnO nanoparticle in ionic liquid [BMIM] BF₄
89. FT-IR spectrum of ZnO nanoparticle in ionic liquid [BMIM] PF₆
90. FT-IR spectrum of ZnO nanoparticle in ionic liquid [BEMIM] BF₄
91. FT-IR spectrum of ZnO nanoparticle in ionic liquid [BEMIM] PF₆
92. FT-IR spectrum of ZnO nanoparticle in ionic liquid [EMIM] BF₄
93. FT-IR spectrum of ZnO nanoparticle in ionic liquid [EMIM] PF₆
94. The powder XRD pattern of ZnO nanoparticle in [BMIM] BF₄
95. The powder XRD pattern of ZnO nanoparticle in [BMIM] PF₆
96. The powder XRD pattern of ZnO nanoparticle in [BEMIM] BF₄
97. The powder XRD pattern of ZnO nanoparticle in [BEMIM] PF₆
98. The powder XRD pattern of ZnO nanoparticle in [EMIM] BF₄
99. The powder XRD pattern of ZnO nanoparticle in [EMIM] PF$_6$
100. SEM image of ZnO nanoparticle in [BMIM] BF$_4$
101. SEM image of ZnO nanoparticle in [BMIM] PF$_6$
102. SEM image of ZnO nanoparticle in [BEMIM] BF$_4$
103. SEM image of ZnO nanoparticle in [BEMIM] PF$_6$
104. SEM image of ZnO nanoparticle in [EMIM] BF$_4$
105. SEM image of ZnO nanoparticle in [EMIM] PF$_6$
106. Comparative account of ZnO nanoparticle in ILs (7-12)
LIST OF SCHEMES

1. Synthesis of 1-Butyl-3-methylimidazolium bromide [BMIM] Br
2. Synthesis of 1-Ethyl-3-methylimidazolium bromide [EMIM] Br
4. Synthesis of 1, 2 - dibutyl - 3- methylimidazolium bromide [BBMIM] Br
5. Synthesis of 2-butyl-1-ethyl-3-methylimidazolium bromide [EBMIM] Br
6. Synthesis of 1, 2-diethyl-3-methylimidazolium bromide [EEMIM] Br
7. Synthesis of 1-butyl-3-methylimidazolium tetrafluoroborate [BMIM] BF$_4$
8. Synthesis of 1-butyl-3-methylimidazolium hexafluoro phosphate [BMIM] PF$_6$
10. Synthesis of 1-butyl-2-ethyl-3-methylimidazolium hexafluoro phosphate [BEMIM] PF$_6$
11. Synthesis of 1-ethyl-3-methylimidazolium tetrafluoroborate [EMIM] BF$_4$
13. Plausible interaction of ZnO with ILs
LIST OF ABBREVIATION

1. ILs- Ionic liquids
2. RTIL- Room Temperature Ionic liquids
3. [BMIM] Br - 1-Butyl-3-methylimidazolium bromide
4. [EMIM] Br - 1-ethyl-3-methylimidazolium bromide
5. [BEMIM] Br - 1-butyl-2-ethyl-3-methylimidazolium bromide
6. [BBMIM] Br - 1, 2 - dibutyl - 3- methylimidazolium bromide
7. [EBMIM] Br - 1-ethyl-2-butyl-3-methylimidazolium bromide
8. [EEMIM] Br - 1, 2-diethyl-3-methylimidazolium bromide
9. [BMIM] BF$_4$ - 1-butyl-3-methylimidazolium tetrafluoroborate
10. [BMIM] PF$_6$ - 1-butyl-3-methylimidazolium hexafluoro phosphate
11. [BEMIM] BF$_4$ - 1-butyl-2-ethyl-3-methylimidazolium tetrafluoroborate
12. [BEMIM] PF$_6$ - 1-butyl-2-ethyl-3-methylimidazolium hexafluoro phosphate
13. [EMIM] BF$_4$ - 1-ethyl-3-methylimidazolium tetrafluoroborate
14. [EMIM] PF$_6$ - 1-ethyl-3-methylimidazolium hexafluoro phosphate
15. NPs - Nanoparticles
16. ZnO - Zinc Oxide
17. CdS - Cadmium Sulphide
18. TAA – Thioacetaamide
19. VOCS-Volatile organic compound solvents
20. 1H-NMR – Hydrogen-Nuclear Magnetic Resonance Spectra
21. 13C-NMR – Carbon-Nuclear Magnetic Resonance Spectra
22. FTIR - Fourier Transform Infrared Spectroscopy
23. XRD - X-ray Diffraction Studies
24. SEM - Scanning Electron Microscope