

DECLARATION.....	iv
ACKNOWLEDGEMENTS.....	v
TABLE OF CONTENTS.....	vi
LIST OF TABLES.....	viii
LIST OF FIGURES.....	ix
LIST OF SYMBOLS.....	xi
INTISARI.....	xii
ABSTRACT.....	xiii
CHAPTER I.....	1
INTRODUCTION.....	1
1.1 Background.....	1
1.2 Problem Statement.....	7
1.3 Novelty.....	9
1.4 Aims of Research.....	12
1.5 Research Benefits.....	13
CHAPTER II.....	14
LITERATURE REVIEW.....	14
2.1 Literature Review.....	14
2.1.1 Lithium Metal.....	14
2.1.2 Lithium Ion Batteries.....	16
2.1.2.1 Lithium Iron Phosphate (LiFePO ₄) Batteries.....	20
2.1.3 Recovery of Lithium Metal in Spent LiFePO ₄ Batteries.....	23
2.1.4 Hydrometallurgy.....	28
2.1.4.1 Leaching.....	29
2.1.5 Sulfuric Acid.....	32
2.1.6 Justification of Sulfuric Acid as the Leaching Reagent.....	33
2.2 Theoretical Background.....	37
2.2.1 Kinetics of Fluid-Particles Reaction.....	37
2.2.2 Shrinking-Core Model.....	38
2.2.2.1 First Model: Diffusion through Product Layer Control.....	39
2.2.2.2 Second Model: Chemical Reaction Control.....	42
2.2.3 Third Model: Reversible Reaction.....	44
2.2.4 Model Parameters.....	45
2.2.4.1 Arrhenius Equation.....	46

2.2.4.2	Reaction Thermodynamics Parameters.....	47
2.2.5	Yield of Lithium from Leaching Solution.....	49
2.3	Hypothesis.....	50
CHAPTER III.....		51
RESEARCH METHODOLOGY.....		51
3.1	Research Location.....	51
3.2	Materials.....	51
3.3	Apparatus.....	51
3.4	Research Procedures.....	52
3.4.1	Pre-treatment Process of Spent LiFePO ₄ Battery.....	52
3.4.2	Leaching Process by Using Sulfuric Acid.....	53
3.4.3	Analysis Methods.....	53
3.5	Data Analysis.....	54
3.5.1	Yield Calculation.....	54
3.5.2	Fitting Experimental Data into Kinetics Models.....	54
3.5.3	Equilibrium Constant and Thermodynamics Parameters Calculation.....	55
3.6	Data Interpretation.....	55
CHAPTER IV.....		57
RESULTS AND DISCUSSION.....		57
4.1	Characterization of Metals in Spent LFP Battery.....	57
4.2	Effects of Various Parameters on the Yield of Li and Fe.....	58
4.2.1	Effect of H ₂ SO ₄ Concentration.....	58
4.2.2	Effect of Solid-Liquid Ratio.....	62
4.2.3	Effect of H ₂ O ₂ Concentration.....	64
4.2.4	Effect of Reaction Temperature.....	66
4.2.5	Effect of Leaching Duration.....	68
4.3	Kinetics and Thermodynamics Study of Leaching.....	69
4.3.1	Thermodynamics Parameters.....	69
4.3.2	Leaching Kinetic Models.....	72
CHAPTER V.....		77
CONCLUSION.....		77
5.1	Conclusion.....	77
5.2	Recommendation.....	77
BIBLIOGRAPHY.....		78
APENDICES.....		83
	MATLAB Program.....	83