# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER 1. - INTRODUCTION TO THE SOLID STATE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Changes of State</td>
<td>1</td>
</tr>
<tr>
<td>2. Energetics of Changes of State</td>
<td>3</td>
</tr>
<tr>
<td>3. Propagation Models and the Close-Packed Solid</td>
<td>4</td>
</tr>
<tr>
<td>4. The Structure of Solids</td>
<td>7</td>
</tr>
<tr>
<td>5. Determination of Structure of Compounds and Materials</td>
<td>15</td>
</tr>
<tr>
<td>6. The Defect Solid</td>
<td>18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHAPTER 2. - THE POINT DEFECT</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Types of Point Defects</td>
<td>25</td>
</tr>
<tr>
<td>2. The Plane Net</td>
<td>27</td>
</tr>
<tr>
<td>3. Non-Stoichiometric Crystals</td>
<td>30</td>
</tr>
<tr>
<td>4. Defect Equation Symbolism</td>
<td>32</td>
</tr>
<tr>
<td>5. Some Applications for Defect Chemistry</td>
<td>33</td>
</tr>
<tr>
<td>I. Phosphors</td>
<td></td>
</tr>
<tr>
<td>II. Bubble Memories</td>
<td></td>
</tr>
<tr>
<td>6. Thermodynamics of the Point Defect</td>
<td>35</td>
</tr>
<tr>
<td>I. Statistical Mechanics Approach</td>
<td></td>
</tr>
<tr>
<td>II. Defect Thermodynamics</td>
<td></td>
</tr>
<tr>
<td>III. Defect Equilibria</td>
<td></td>
</tr>
<tr>
<td>7. Defect Equilibria in Various Types of Compounds</td>
<td>40</td>
</tr>
<tr>
<td>I. Stoichiometric Binary Compounds of $MX$</td>
<td></td>
</tr>
<tr>
<td>II. Defect Concentrations in $MX$ Compounds</td>
<td></td>
</tr>
<tr>
<td>III. Non-Stoichiometric Binary Compounds</td>
<td></td>
</tr>
<tr>
<td>IV. Defect Concentrations in $MX$</td>
<td></td>
</tr>
<tr>
<td>V. Ionization of Defects</td>
<td></td>
</tr>
<tr>
<td>8. Brouwer's Approximation Method</td>
<td>51</td>
</tr>
<tr>
<td>9. Analysis of A Real Crystal using Brouwer's Method - Comparison to the Thermodynamic Method</td>
<td>57</td>
</tr>
<tr>
<td>I. The AgBr Crystal with a Divalent Impurity, Cd $^{2+}$</td>
<td></td>
</tr>
<tr>
<td>II. Defect Disorder in AgBr - A Thermodynamic Approach</td>
<td></td>
</tr>
<tr>
<td>10. The Effects of Purity (and Impurities)</td>
<td>66</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHAPTER 3 - THERMAL ANALYSIS IN SOLID STATE CHEMISTRY</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Scanning Methods</td>
<td>69</td>
</tr>
<tr>
<td>2. Differential Thermal Analysis</td>
<td>70</td>
</tr>
<tr>
<td>3. Differential Scanning Calorimetry</td>
<td>81</td>
</tr>
<tr>
<td>4. Uses of DTA and DSC</td>
<td>83</td>
</tr>
<tr>
<td>5. Thermogravimetry</td>
<td>85</td>
</tr>
</tbody>
</table>
CHAPTER 4. SOLID STATE REACTION MECHANISMS

1. Types of Solid State Reactions
2. Defining Reaction Conditions
3. Heterogeneous Nucleation Rate Processes and Models
4. The Tarnishing Reaction
5. Fick's Laws of Diffusion
6. Diffusion Mechanisms
7. Analysis of Diffusion Reactions
8. Diffusion in Silicates
9. Diffusion Mechanisms Where the Cation Changes Valence State
10. Homogeneous Nucleation Processes

CHAPTER 5. GROWTH OF PARTICLES AND PARTICLE PROPERTIES

1. Sequences in Particle Growth
2. Sintering and Sintering Processes
3. Particle Size
4. Particle Distributions
5. Particle Distributions and the Binomial Theorem
6. Measuring Particle Distributions
7. Analysis of Particle Distribution Parameters
   I. The Histogram
   II. Frequency Plots
   III. Cumulative Frequency
   IV. Log- Normal Probability Method
8. Types of Log Normal Particle Distributions
   I. Unlimited Particle Distributions
   II. Limited Particle Distributions
   III. Particle Distributions with Discontinuous Limits
   IV. Multiple Particle Distributions
9. A Typical PSD Calculation
10. Methods of Measuring PSD
    I. The Microscope- Visual Counting of Particles
    II. Sedimentation Methods
    III. Electrical Resistivity
    IV. Other Methods of Measuring Particle Size

CHAPTER 6. GROWTH OF SINGLE CRYSTALS

1. Types of Crystals
2. Furnace Construction 170
3. Steps in Growing a Single Crystal 173
4. Czochralski Growth of Single Crystals 175
5. The Bridgeman-Stockbarger Method for Crystal Growth 187
6. Zone Melting as a Means for Forming Single Crystals 190
7. Zone Refining 191
8. The Impurity Leveling Factor 193
9. The Verneuil Method of Crystal Growth 197
10. Molten Flux Growth of Crystals 200
11. Hydrothermal Growth 202
12. Vapor Methods Used for Single Crystal Growth 205
13. Edge Defined Crystal Growth 208
14. Melting and Stoichiometry 209
15. Actual Imperfections in Crystals 211
16. Electronic Properties of Crystals 214
17. The Calculation of Energy Bands In Crystals 222
18. Point Defects and the Energy Band Model 225

Appendix to Chapter 6: Mathematics of the Reciprocal Lattice 228

CHAPTER 7 - OPTICAL PROPERTIES AND LUMINESCENCE

1. Absorbance, Reflectivity and Transmittance 235
2. Electronic Aspects of Phosphors 241
   I. Energy Processes in a Phosphor
   II. Properties Associated with Phosphors
      A. Notation
      B. Quantum efficiency
      C. Decay times
      D. Band shapes
3. Factors Associated with Energy Conversion by Phosphors 250
   I. Energy Dissipation
   II. Phonons as Quantized Lattice Vibrations
   III. Phonon Dispersion Equations
   IV. The Case of the Impurity Activator Center
   V. Spectroscopic Terminology
4. Prediction of Electronic Transition Intensities 261
   I. Einstein Absorption and Emission Coefficients
   II. Electronic Transition Moments
   III. Dipole and Multipole Oscillator Strengths
5. Mechanisms of Energy Transfer in Solids 267
   I. Radiative Transfer (Radiation Trapping)
   II. Energy Transfer by Resonance Exchange
   III. Energy Transfer by a Spatial Process
   IV. Energy Exchange by Spin Coupling
   V. Energy Transfer by Non-Resonant Processes
6. Summary of Phonon Processes as Related to Phosphors 277
CHAPTER 8 - DESIGN OF PHOSPHORS

1. The Luminescent Center in Inorganic Phosphors
2. The Ground State Perturbation Factor
3. Design of a Phosphor
   I. Choice of the Host Components
   II. Choice of the Activator
   III. Quenchers or "Killers" of Luminescence
4. Factors Affecting Phosphor Efficiencies (Brightness)
5. Preparation of Phosphors
   I. Phosphor Parameters
      A. Independent Variables
      B. Dependent Variables
      C. The Firing Cycle as a Dependent Variable
      D. Size and Mass Fired
      E. Firing Atmosphere
      F. Effect of Host Structure
      G. Effect of Preparation Method Employed
      H. Ratios of Components and Use of a Flux
6. Commercial Phosphors
   I. Cathode-ray Phosphors
   II. Fluorescent Lamp Phosphors
7. Measurement of Optical Properties of Phosphors
   I. Brightness Measurements
   II. Emission Band Measurements
   III. Measurement of Quantum Efficiencies
   IV. Specification and Measurement of Color
      A. The Human Eye
      B. The Nature of Chroma
      C. The Standard Observer
8. Color Spaces
   I. The Munsell Color Tree
   II. Color Matching and MacAdam Space

CHAPTER 9 - LANTHANIDES AND LASERS

1. History of the Lanthanides
2. Chemistry and Separation Techniques
3. Rare Earth Energy Levels and Electronic States
4. Methods of Calculation of Rare Earth Energy Levels
5. Mixed States in Intermediate Coupling
6. Experimental Stark States
7. Charge Transfer States and 5d Multiplets
8. Phonon Assisted Relaxation and Anti-Stokes
CHAPTER 10 - SOLID STATE CHEMISTRY APPLIED TO PHOSPHORS

THE APATITE PHOSPHOR SYSTEM
1. Apatite as a Structure 413
2. Defect Chemistry of Apatite 419
3. Preparation and Defect Properties of the
   $\text{Sr}_5\text{(F,Cl)}\text{(PO}_4\text{)}_9$: Sb Phosphor System 421

RARE EARTH ACTIVATED PHOSPHOR SYSTEMS
4. Preparation of the Rare Earth Phosphors 432
5. Optical Properties of the Hosts 432
6. Spectroscopic Properties of the Rare Earth Activated
   Phosphors 435

SUBJECT INDEX 449