

Review

Phase Equilibrium Studies of Nonferrous Smelting Slags: A Review

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Abstract: Pyrometallurgy is the primary technique for the production of many nonferrous metals such as copper, lead, and zinc. The phase equilibrium information of smelting slags plays an important role in the efficient extraction of metals and energy consumption. The experimental technologies used in phase equilibrium studies are compared. The presentation and applications of the pseudo-ternary and pseudo-binary phase diagrams are demonstrated in the Fe-Si-Ca-Zn-Mg-Al-Cu-S-O system. Experimental results are also compared with the predictions of FactSage to evaluate the accuracy of the current thermodynamic database. This review paper provides comprehensive information for the operation of nonferrous metals and optimization of the thermodynamic database.

Keywords: phase equilibrium; nonferrous smelting slags; Fe-Cu-Si-Ca-Zn-Mg-Al-S-O system; liquidus temperature; FactSage

1. Introduction

Most of the copper, lead, and zinc exist in the Earth's crust as sulfide minerals. Pyrometallurgy is the primary technique used to produce primary copper, lead, and zinc from the sulfide concentrates [1,2]. Cathode copper can be obtained from copper concentrates through the smelting, converting, fire refining, and electrorefining of blister copper [3]. Major smelting technologies include flash smelting and bath smelting, depending on the difference in the reaction medium and spatial distribution within the furnace [4,5]. Flash smelting predominantly involves gas–solid reactions. By injecting dried and finely ground copper concentrates, along with oxygen and flux, into a flash furnace through a concentrate burner, rapid reactions occur to form molten matte and slag [6]. Flash smelting has a high production capacity due to the rapid oxidation of the fine sulfide concentrate [7]. The flash smelting technology is developing continuously through the optimization of burner operation and slag chemistry, resulting in reduced dust generation, increased oxygen concentration, and enhanced processing capacity [8–10]. Bath smelting primarily involves liquid–gas reactions. Within the furnace, copper concentrates are vigorously mixed and stirred by high-pressure gas to achieve fast oxidation. Depending on the location of the tuyeres, bath smelting technologies include side-blowing, top-blowing, and bottom-blowing processes [11]. Bottom-blowing smelting technology offers advantages such as feed adaptability, higher gas pressure, long lance life, autogenous smelting, and low-temperature smelting. Its technical superiority has become more prominent since Fangyuan Copper Co., Ltd. developed a two-step copper smelting process [11,12]. Crude lead is obtained from lead concentrates through an oxidation process to remove sulfur and a reduction process to remove oxygen [13]. Similar to the smelting technology used in copper production, flash smelting [14] and bath smelting [15] technologies are the main oxidation methods employed for lead concentrates. Bath technology has replaced the sinter plant–blast furnace process due to its high thermal efficiency, less feed preparation, and efficient SO₂ utilization [16]. Although oxygen pressure leaching has been developed for



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2007 Ed. 2007 Edition , *Phase Equilibria in Chemical Engineering* Stanley M. Walas, 2013-10-22 Phase Equilibria in Chemical Engineering is devoted to the thermodynamic basis and practical aspects of the calculation of equilibrium conditions of multiple phases that are pertinent to chemical engineering processes Efforts have been made throughout the book to provide guidance to adequate theory and practice The book begins with a long chapter on equations of state since it is intimately bound up with the development of thermodynamics Following material on basic thermodynamics and nonidealities in terms of fugacities and activities individual chapters are devoted to equilibria primarily between pairs of

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MRI applications are considered in the following five chapters Both the theoretical and practical aspects of MRI are emphasized The book ends with a discussion of instrumentation and the principles of signal detection in MRI Clear progression from fundamental physical principles of NMR to MRI and its applications Extensive discussion of image acquisition and reconstruction of MRI Discussion of different mechanisms of MR image contrast Mathematical derivation of the signal to noise dependence on basic MR imaging parameters as well as field strength In depth consideration of artifacts in MR images Comprehensive discussion of several techniques used for rapid MR imaging including rapid gradient echo imaging echo planar imaging fast spin echo imaging and spiral imaging Qualitative discussion combined with mathematical description of MR techniques for imaging flow *Physics, Uspekhi* ,1999 *A TEXTBOOK OF CHEMICAL ENGINEERING THERMODYNAMICS* K. V. NARAYANAN,2013-01-11 Designed as an undergraduate level textbook in Chemical Engineering this student friendly thoroughly class room tested book now in its second edition continues to provide an in depth analysis of chemical engineering thermodynamics The book has been so organized that it gives comprehensive coverage of basic concepts and applications of the laws of thermodynamics in the initial chapters while the later chapters focus at length on important areas of study falling under the realm of chemical thermodynamics The reader is thus introduced to a thorough analysis of the fundamental laws of thermodynamics as well as their applications to practical situations This is followed by a detailed discussion on relationships among thermodynamic properties and an exhaustive treatment on the thermodynamic properties of solutions The role of phase equilibrium thermodynamics in design analysis and operation of chemical separation methods is also deftly dealt with Finally the chemical reaction equilibria are skillfully explained Besides numerous illustrations the book contains over 200 worked examples over 400 exercise problems all with answers and several objective type questions which enable students to gain an in depth understanding of the concepts and theory discussed The book will also be a useful text for students pursuing courses in chemical engineering related branches such as polymer engineering petroleum engineering and safety and environmental engineering New to This Edition More Example Problems and Exercise Questions in each chapter Updated section on Vapour Liquid Equilibrium in Chapter 8 to highlight the significance of equations of state approach GATE Questions up to 2012 with answers *Revue roumaine de chimie* ,1978 *Equine Wound Management* Ted S. Stashak,Christine Theoret,2009-03-16 *Equine Wound Management* Second Edition is a comprehensive authoritative resource for both theoretical and practical information on the care of wounds in horses Now highly illustrated with full color photographs throughout this long awaited second edition is significantly expanded to include new developments and techniques in wound healing *Equine Wound Management* is an essential reference for veterinary students veterinary surgeons veterinary dermatologists and equine and large animal veterinarians PCAT Prep Plus 2018-2019 Kaplan Test Prep,2018-04-03 PCAT announced minor changes to the exam for the July 2018 test dates going forward but rest assured that the changes still align with the effective prep you ll get from Kaplan s PCAT Prep Plus Kaplan s

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