

INFLUENCE OF SLAG MINERALOGY ON POSSIBILITIES FOR USE IN ALTERNATIVE APPLICATIONS

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Introduction

Large amounts of by-products are produced by the Swedish steelmaking industry each year. In 2010, the total amount of slag produced reached approximately 1.3 million tonnes, corresponding to almost 0.4% of the total steel slag production worldwide the same year.^{1,2} The main purpose of slags in pyrometallurgical processes, such as the basic oxygen furnace (BOF) and the electric arc furnace (EAF), is to extract unwanted elements/compounds from the steel bath, prevent metal oxidation and limit heat loss from the steel. Accumulation of minor elements in the slag often limits the possibility to reuse the slag within the process. In order to avoid landfilling, the steelmakers usually try to process the slag into useful materials. During the last 35 years, extensive work has been conducted in order to develop new slag products. Research has, for example, shown that due to its high strength and durability, steel slag is often a suitable material in various construction applications and can replace gravel and rock³, thereby saving natural resources. However, leaching of metals, such as chromium, and volume instability (volumetric expansion and disintegration) are technical and environmental properties of the slag that must be avoided.⁴⁻⁷

Solidified slag can have many different appearances; some slags look like gravel, some like fine sand and some are glossy. Some slags may be amorphous, lacking a long-range ordering, depending on cooling rate and chemistry, but most slags are crystalline, Figure 1. The properties of the crystalline slags are all connected to the mineralogical composition. Properties like volume expansion, disintegration and leaching are all results of the behaviour of individual slag mineral.

This paper deals with some of the important properties of slag minerals found in ordinary steel slags. In this paper, dissolution and water purification (phosphor) of some synthetic slag minerals will be discussed and shown.

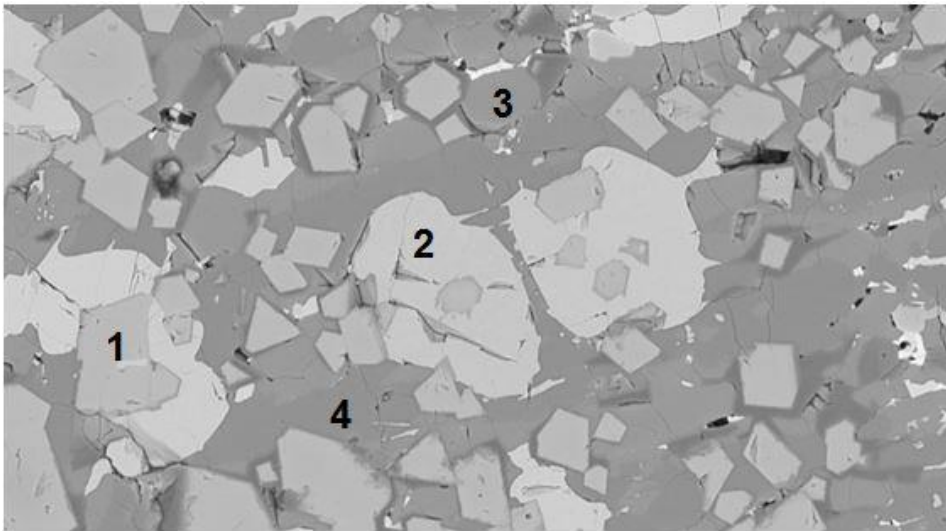


Figure 1: SEM picture of a slag with 4 different minerals 1: spinel, 2: magnesiowüstite, 3: β -dicalcium silicate, 4: merwinite

Dissolution of slag minerals

The aim of this study was to take the understanding of leaching that occurs from ordinary steel slags one step further, and actually investigate how individual slag minerals behave during dissolution. Since steel slags are mixtures of numerous types of minerals, the dissolution of each mineral will affect the leachability. Five common silica-based slag minerals, γ -dicalcium silicate (DKS, Ca_2SiO_4), akermanite ($\text{Ca}_2\text{MgSi}_2\text{O}_7$), merwinite ($\text{Ca}_3\text{MgSi}_2\text{O}_8$), monticellite (CaMgSiO_4) and pseudowollastonite (CaSiO_3) were synthesised and evaluated through titration using HNO_3 at constant pH and particle size (20-38 μm). Neutral to alkaline pH (7 and 10) were selected to investigate the dissolution of the minerals under conditions comparable to those prevailing in newly produced slags, Figure 2.

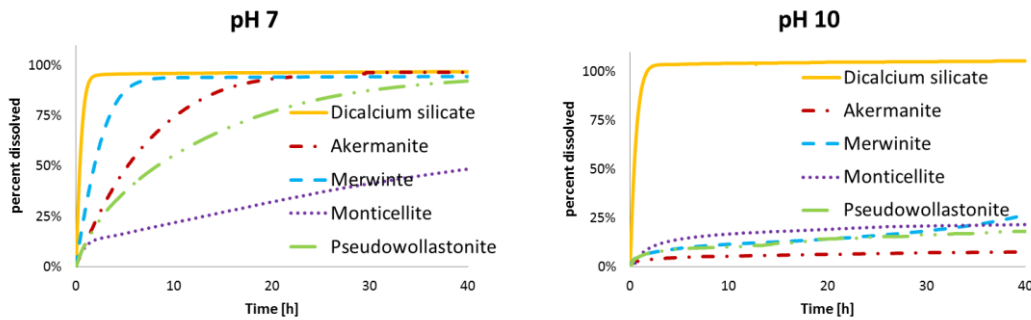


Figure 2: Dissolution of silica-based minerals at pH 7 and pH 10

As can be seen in Figure 2, the rate of dissolution differs between the minerals. At pH 10, the typical pH of a leachate from newly produced steel slag, the dissolution is slower compared to at pH 7. At pH 10, excluding the γ -dicalcium silicate, none of the silica based minerals dissolve completely. Akermanite is the slowest dissolving

mineral; the other silica-based minerals have dissolved to approximately 20% after 40 hours. Table 1 is constructed with the dissolution rate of the minerals at pH 7 in decreasing order. The silicon content in the minerals seems to inhibit the dissolution. The calcium content, on the other hand, increases the dissolution rate. Magnesium seems to decrease the dissolution rate compared to calcium.

Table 1: The silica-based minerals ordered in decreasing dissolution rate at pH 7. The atomic ratios are calculated from the stoichiometric composition

Mineral	Ca/Si	Mg/Si	(Ca+Mg)/Si	Ca/Mg	Ca/(Si+Mg)	Structure
Dicalcium silicate	2	-	2	-	2	β is monoclinic, γ is orthorhombic
Merwinite	1.5	0.5	2	3	1	monoclinic
Akermanite	1	0.5	1.5	2	0.7	tetragonal
Pseudowollastonite	1	-	1	-	1	monoclinic
Monticellite	1	1	2	1	0.5	orthorhombic

Water purification (phosphor) of slag minerals

The aim of this study was to investigate to what extent different slag minerals contribute in water purification aiming on phosphor removal. Five common silica-based slag minerals, γ -dicalcium silicate (DKS, Ca_2SiO_4), akermanite ($\text{Ca}_2\text{MgSi}_2\text{O}_7$), merwinite ($\text{Ca}_3\text{MgSi}_2\text{O}_8$), monticellite (CaMgSiO_4) and pseudowollastonite (CaSiO_3) were synthesised and evaluated. 0.1 g of each mineral (20-38 μm) was mixed in 10 ml of synthetic manufactured phosphor solution with a concentration of 10 mg/L phosphorus. The experiments were run for 4 and 24 hours respectively. After filtration the samples were analysed using ICP-MS.

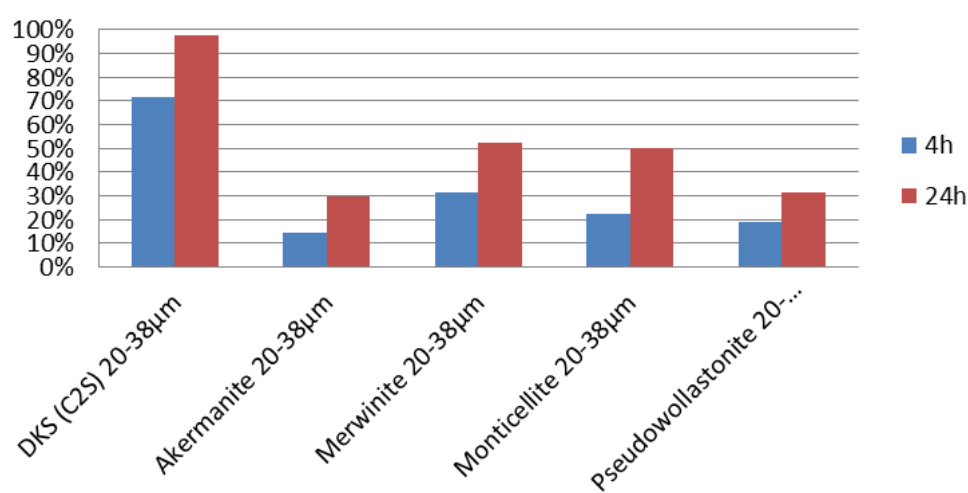


Figure 3: Phosphor capacity

As can be seen in Figure 3, the phosphor removal capacity differs between the minerals. γ -dicalcium silicate has the highest removal of phosphor while akermanite and pseudowollastonite have the lowest after 24 hours. Comparing the results with the dissolution study being presented earlier it can be concluded that a fast reacting calcium containing mineral is preferable when it comes to phosphor removal.

Based on the results shown it can be concluded that it is important to consider the mineralogical composition of the slags when application is chosen, as also is the case for leaching and hydraulic properties.⁸⁻¹¹

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