



During the leaching process, movements of charges across the solid-solution phase boundary are indispensable for the dissolution process. The leaching mechanism can be described as the pathway by which the reaction happens or as the rate controlling step (kinetic mechanism) of the reaction. The slowest step is the rate-limiting step of the overall leaching process. During leaching, the rate-limiting step could change, from being a chemical reaction limited to fresh material for example to being limited by diffusion through the product layer at an advanced stage of the leaching process.

The shrinking core model (SCM) is frequently used to analyse kinetic data. This model assumes that the leaching process is controlled either by external diffusion, chemical reaction or diffusion through the ash layer. Using the SCM model, the leaching kinetics can be depicted by the following expressions:

If diffusion through the liquid film is the controlling mechanism, equation 7 is usually applicable assuming spherical geometry of the ore particle.

$$\alpha = k_1 \cdot t \quad (7)$$

Where k_1 is the rate constant and α the leaching fraction of the metal.

If the chemical reaction is the controlling mechanism for small particles in the stokes regime, the process can be modelled as:

$$1 - (1 - \alpha)^{1/3} = k_1 \cdot t \quad (8)$$

If diffusion through the ash layer is the controlling mechanism for small particles in the stokes regime, equation (9) is applied.

$$1 - \frac{2}{3}\alpha - (1 - \alpha)^{2/3} = k_2 \cdot t \quad (9)$$

Where k_2 is the rate constant and α the leaching fraction of the metal.

The distinction in the leaching rate at two stages suggest a different controlling step in each stage. The controlling mechanism's plot is linear with time (t).

In this paper, leaching of V from a V-slag was investigated using a mixture of gluconic, citric and oxalic acids. Low acid concentrations were used to simulate a bioleaching process. The impact of different parameters such as acid concentration, solid/liquid ratio, particles size and temperature on the rate of dissolution were investigated. This study is aimed at determining the kinetics of the dissolution reactions.

II. EXPERIMENTAL

A. Instruments and reagents

The slag was obtained from a vanadium steel making plant situated in North West province, South Africa. All reagents (organic acids and sodium carbonate) used were analytical grade (99% purity) and sourced from Merck, South Africa. The elemental composition of the raw and roasted slag was

determined using X-ray Fluorescence Spectrometer (XRF) Rigaku ZSX Primus II. The mineralogy of the slag was investigated using X-ray Diffraction (XRD) Rigaku Ultima IV and the study of the slag morphology was processed using SEM/EDX Vega 3 XMU.

B. Leaching experiments

The slag sample was ground to 100% passing 75 μm in a pulveriser to completely expose all metal surface to the leaching solution. It was then blended with sodium carbonate in a weight proportion of 80% Slag – 20% Na_2CO_3 and roasted at 900°C according to our recent work [2].

The leaching tests were executed in a water bath using 250ml conical flasks under different conditions. Once the experimental temperature (25, 35 or 45°C) was reached, the slag (mass depending on the solid/liquid ratio) was added and stirring was initiated at 150 rpm.

After leaching, the slurry was filtered and the filtrate was analysed using a Thermo scientific atomic absorption spectrometer (AAS). The % dissolution of V was calculated using equation 10.

$$\% \text{ dissolution} = [\text{Vs}] \cdot \text{Vol}[\text{s}] / (\text{m} \cdot \text{V}[\text{g}]) \cdot 100 \quad (10)$$

where [Vs]: Vanadium concentration in solution [mg/L]

Vol[s]: Volume of the solution [L]

m: Mass slag [mg]

V[g]: Vanadium grade in slag

C. Kinetic studies

The kinetic studies were done during the bioleaching simulation to determine the mechanism controlling the dissolution process. To achieve this, the shrinking core models were used to analyse the experimental data. A good data fit is a minimum requirement for validity of the model, however it does not guarantee that it is indeed valid. To check that the model applies to these results, the terms α , $1 - (1 - \alpha)^{1/3}$ and $1 - 2/3\alpha - (1 - \alpha)^{2/3}$ were calculated corresponding to the diffusion through the liquid layer, chemically and diffusion through the ash layer controlled reactions. The terms α , $1 - (1 - \alpha)^{1/3}$ and $1 - 2/3\alpha - (1 - \alpha)^{2/3}$ vs time were then plotted.

III. RESULTS AND DISCUSSION

D. Slag Characterisation

The chemical composition of the roasted slag according to the procedure detailed by [2] was analysed using XRF and the results are shown in Table 1.

TABLE I: CHEMICAL COMPOSITION OF THE ROASTED SLAG

Component	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	CaO	V ₂ O ₅	Fe ₂ O ₃
% Oxide	3.25	7.03	61.49	1.54	18.94	4.58	0.84

The slag contains a considerable amount of V which can be recovered. The Al oxide content in the slag was very high due to the preceding smelting process where Al was added as a reagent to react with V₂O₅ flasks to form ferrovanadium.

The XRD analysis was done to assess the phases in the roasted slag and the results are shown in Fig. 1. With an

