

# Kinetics of Hydrochloric Acid Leaching of Copper from its Ore

Yousef Mubarak

Department of Chemical Engineering, American University of Beirut, Lebanon, ym26@aub.edu.lb

## ABSTRACT

The effects of some experimental parameters on the copper leaching process were investigated and presented in a previous article, while in the current article kinetic models to represent the effects of leaching temperature, acid concentration, and ore particle size on the leaching rate will be examined and analyzed. The obtained results showed that none of the surface chemical reaction or the pore diffusion on its own can control the whole copper dissolution process. The mixed kinetics model which includes two different leaching processes including the surface chemical reaction and diffusion through a porous product layer was found to be suitable for describing and fitting the experimental data up to 65 % copper dissolution ( $X$ ) at a high stirring speed of 1000 rpm. The apparent activation energies for pore diffusion and surface reaction were estimated to be 12.26 and 9.61 kcal/mol, respectively. Values of surface reaction rate constant in the range from  $6.35 \times 10^{-4}$  to  $5.49 \times 10^{-3}$  cm/sec and pore diffusion coefficient in the range from  $3.58 \times 10^{-5}$  to  $2.36 \times 10^{-7}$  cm<sup>2</sup>/sec have been obtained.

**Key words:** Leaching, Copper Ore, Shrinking Core, Surface Reaction, Pore Diffusion, Mixed Kinetics

## 1. INTRODUCTION

One of the most widely used metals in various industries is copper which is found in nature as oxide and sulfide ores [1, 2]. Due to the global increase in demand, low-grade oxides as well as high-grade ores are considered as main sources of copper. To eliminate some of the negative environmental and economical impacts of pyrometallurgical methods such as high initial investment costs, high energy requirements, and the generation of environmentally hazardous SO gases, and the incentive to development metal extraction processes with reduced environmental impact, researchers have focused on the development of hydrometallurgical processes that may be alternatives to conventional pyrometallurgical methods [3]. On the other hand, pyrometallurgical methods are not suitable for the processing of low-grade ores and this can be considered as another reason to recover copper from low-grade ores by hydrometallurgical methods [4].

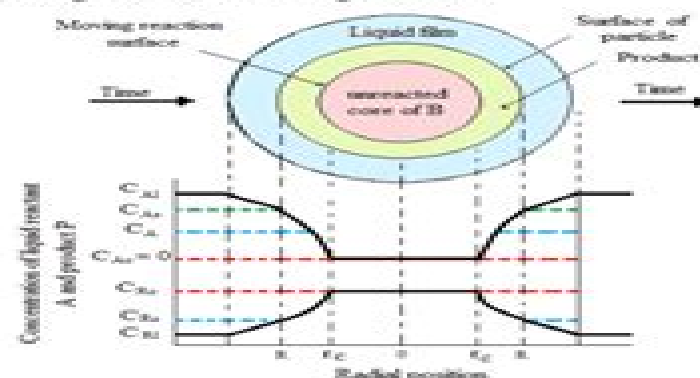
In previous studies [5, 6], the effects of leaching temperature, acid concentration, particle size, stirring speed, and solid/liquid ratio on the leaching process of copper ore using

hydrochloric acid as the main lixiviant were studied and presented. The present work quantitatively investigates the kinetic mechanism of the leaching process of copper in hydrochloric acid solution, hence a theoretical background for the available heterogeneous reaction models will be presented here for heterogeneous reactions between fluid A and solid B, which may be represented by  $A_{(l)/v_{A(l)}} + v_B B_{(solid)} \rightarrow \text{Products}$ , where  $v_B$  is the stoichiometric factor (number of moles of metal reacted per mole of lixiviant).

A single model can't incorporate all the features of liquid/solid reactions. In fact, different classes of models have been postulated and used to describe these systems.

## 1.1 Shrinking Core Model

The shrinking core model (SCM), is one of the earliest models used and is well described in standard textbooks on chemical reaction engineering [7, 8]. The model is mainly applicable to nonporous or relatively less porous solids and assume that the reaction occurs at a sharp interface that separates the reacted outer shell (product or "ash" layer) and the unreacted inner core of the solid. This model was first developed in 1955 by Yagi and Kunii [9]. Figure 1, who presented five steps occurring in succession during a reaction:



**Figure 1:** Representation of concentrations of reactants and products for the reaction  $A_l + v_B B_s \rightarrow P$  for a particle of unchanging size

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