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Abstract

It is accepted worldwide that the dissolution of minerals in some cases, is an electrochemical process where anodic and cathodic reactions take place. There are many parameters, such as agent concentration, that directly affect the dissolution process. The rate of leaching of minerals may differ depending on the oxygen concentration.

In this paper, the existence of anodic and cathodic zones on the mineral surface during the dissolution/leaching of minerals and metals has been presented with some different works. It is worth mentioning that a good number of published papers have experimentally demonstrated the existence of anodic and cathodic areas on the mineral surface.

We read with interest the recent paper entitled “The Dissolution and Leaching of Minerals. Mechanisms, Myths, and Misunderstandings”, by F.K. Crundwell, published in Hydrometallurgy Volume 139, July 2013, pages 132–148. We agree with the author that the rate of leaching of minerals may have an order 1 or ½ with respect to oxygen as seen in Figs. 1 and 2 but we reject his argument and his conclusions regarding the non-existence of anodic and cathodic zones on the mineral surface.

We believe that the existence of anodic and cathodic zones during the dissolution of conducting and semiconducting minerals is real. It has been experimentally demonstrated in a number of cases.

The educational film Corrosion in Action (LaQue et al., 1955), produced by the International Nickel Company some years ago, shows many experiments with an iron nail embedded in a gel containing phenolphthalein and potassium ferricyanide. After some time, a region of the nail becomes coloured pink (the cathodic zone) due to the reduction of oxygen to OH⁻ ions, while another region of the nail becomes coloured blue due to the liberation of ferrous ion which forms Prussian blue (the anodic zone) (Fig. 3):

\[
\frac{1}{2}O_2 + H_2O + e^- \rightarrow 2OH^- \\
Fe \rightarrow Fe^{2+} + e^-
\]

Thompson (1947) embedded gold particle in a gel of cyanide solution to which air was completely excluded. When oxygen was allowed to flow in one direction he observed the dissolution of the particle by means of a microscope. He found that gold dissolved through only one region (Fig. 4).

The experiment of Thornber (1975) on the dissolution of pyrite: pyrite embedded in an agar gel to which phenolphthalein was added; after some days a red colour appeared on the surface of the gel due to the liberation of OH⁻ ions at the cathodic zone (Fig. 5).

The model for the formation of anodic and cathodic zones during dissolution of minerals (Fig. 6) permitted the establishment of a kinetic equation:

\[
\text{Rate of dissolution} = \frac{k_1 k_2 A [D] [C]}{k_1 [D] + k_2 [C]}
\]

where [D] is the concentration of depolarizer, [C] the concentration of complexing agent, \( A \) = area of mineral exposed in the leaching agent,
and \( k_1 \) and \( k_2 \) are constants. This theoretical equation coincided with experiment (Fig. 7):

- At low concentrations of \( C \), the second term in the denominator may be neglected in comparison with the first, and the rate equation simplifies to:

\[
\text{Rate} = k_3 [D]
\]

i.e., the rate of dissolution in this case is only a function of the complexing agent concentration.
At high concentrations of C, the first term in the denominator may be neglected in comparison with the second, and the velocity equation simplifies to:

\[ \text{Rate} = k_2 A[C] \]

i.e., the rate of dissolution under these conditions depends only on the concentration of the depolarizer.

This has been discussed in a number of publications (Habashi, 1969, 1970, 2007, 2012).

References