

dissolution barrier could be a combination of Fe precipitates, covellite, and gypsum. Further investigation focusing on the control of redox potential should be considered to improve the Cu dissolution rate.

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REFERENCES

- [1] M. C. Ruiz, K. S. Montes, and R. Padilla, "Hydrometallurgy Chalcopyrite leaching in sulfate – chloride media at ambient pressure," *Hydrometallurgy*, vol. 109, no. 1–2, pp. 37–42, 2011. <https://doi.org/10.1016/j.hydromet.2011.05.007>
- [2] S. Zhong and Y. Li, "An improved understanding of chalcopyrite leaching kinetics and mechanisms in the presence of NaCl," *Integr. Med. Res.*, vol. 8, no. 4, pp. 3487–3494, 2019. <https://doi.org/10.1016/j.jmrt.2019.06.020>
- [3] H. R. Watling, "Chalcopyrite hydrometallurgy at atmospheric pressure : 1 . Review of acidic sulfate , sulfate – chloride and sulfate – nitrate process options," *Hydrometallurgy*, vol. 140, pp. 163–180, 2013. <https://doi.org/10.1016/j.hydromet.2013.09.013>
- [4] X. Xiong *et al.*, "Oxidation mechanism of chalcopyrite revealed by X-ray photoelectron spectroscopy and first principles studies," *Appl. Surf. Sci.*, vol. 427, pp. 233–241, 2018. <https://doi.org/10.1016/j.apsusc.2017.08.047>
- [5] Kolela J Nyembwe, Elvis Fosso-Kankeu, Frans Waanders, Kasongo D Nyembwe. 2019. Structural, compositional and mineralogical characterisation of carbonatitic copper sulfide concentrator plant streams: Run of mine, concentrate and tailings. *International Journal of Minerals, Metallurgy and Materials*. 26(2): 143-151. <https://doi.org/10.1007/s12613-019-1718-8>
- [6] Kolela J Nyembwe, Elvis Fosso-Kankeu, Frans Wanders and Edward Ntumba Malenga. 2018. Mineralogical Observation Made During the Kinetic Dissolution Study of Chalcopyrite Mineral in Sulphate Media under Free pH at Room Temperature. Editors: Elvis Fosso-Kankeu, Frans Waanders, Michel Plaisent. 10th Int'l Conference on Advances in Science, Engineering, Technology & Healthcare (ASETH-18) Nov. 19-20, 2018 Cape Town (South Africa). ISBN: 978-81-938365-2-1. Vol II. Pp 144-148.
- [7] Brad Barlow, Elvis Fosso-Kankeu, Kolela J Nyembwe, Frans Waanders and Edward Ntumba Malenga. 2018. Prediction of Dissolution of Copper from a Chalcopyrite Carbonatite Ore of South Africa. Editors: Elvis Fosso-Kankeu, Frans Waanders, Michel Plaisent. 10th Int'l Conference on Advances in Science, Engineering, Technology & Healthcare (ASETH-18) Nov. 19-20, 2018 Cape Town (South Africa). ISBN: 978-81-938365-2-1. Vol I. Pp 96-100.
- [8] A. F. Tshilombo, "Mechanism and kinetics of chalcopyrite passivation and depassivation during ferric and microbial leaching," British Columbia, 2004.
- [9] H. Naderi, M. Abdollahy, N. Mostoufi, M. J. Koleini, S. A. Shojaosadati, and Z. Manafi, "Kinetics of chemical leaching of chalcopyrite from low grade copper ore: Behavior of different size fractions," *Int. J. Miner. Metall. Mater.*, vol. 18, no. 6, pp. 638–645, 2011. <https://doi.org/10.1007/s12613-011-0489-7>
- [10] O. G. Olvera, M. Rebolledo, and E. Asselin, "Atmospheric ferric sulfate leaching of chalcopyrite: Thermodynamics , kinetics and electrochemistry," *Hydrometallurgy*, vol. 165, pp. 148–158, 2016. <https://doi.org/10.1016/j.hydromet.2015.09.017>
- [11] C. Klauber, "A critical review of the surface chemistry of acidic ferric sulphate dissolution of chalcopyrite with regards to hindered dissolution," *Int. J. Miner. Process.*, vol. 86, pp. 1–17, 2008. <https://doi.org/10.1016/j.minpro.2007.09.003>
- [12] S. M. J. Koleini, V. Aghazadeh, and Å. Sandström, "Acidic sulphate leaching of chalcopyrite concentrates in presence of pyrite," *Miner. Eng.*, vol. 24, no. 5, pp. 381–386, 2011. <https://doi.org/10.1016/j.mineng.2010.11.008>
- [13] P. B. Munoz, J. D. Miller, and M. E. Wadsworth, "Reaction mechanism for the acid ferric sulfate leaching of chalcopyrite," *Metall. Trans. B*, vol. 10, no. 2, pp. 149–158, 1979. <https://doi.org/10.1007/BF02652458>
- [14] J. E. Dutrizac, "The dissolution of chalcopyrite in ferric sulfate and ferric chloride media," *Metall. Trans. B*, vol. 12, no. 2, pp. 371–378, 1981. <https://doi.org/10.1007/BF02654471>
- [15] T. Havlik and M. Skrobjan, "Acid leaching of chalcopyrite in the presence of ozone," *Can. Metall. Q.*, vol. 29, no. 2, pp. 133–139, 1990. <https://doi.org/10.1179/cm.1990.29.2.133>
- [16] C. Gómez, M. Figueroa, J. Muñoz, M. L. Blázquez, and A. Ballester, "Electrochemistry of chalcopyrite," *Hydrometallurgy*, vol. 43, no. 1–3, pp. 331–344, 1996. [https://doi.org/10.1016/0304-386X\(96\)00010-2](https://doi.org/10.1016/0304-386X(96)00010-2)
- [17] E. M. Córdoba, J. A. Muñoz, M. L. Blázquez, F. González, and A. Ballester, "Passivation of chalcopyrite during its chemical leaching with ferric ion at 68 ° C," *Miner. Eng.*, vol. 22, no. 3, pp. 229–235, 2009. <https://doi.org/10.1016/j.mineng.2008.07.004>
- [18] E. M. Córdoba, J. A. Muñoz, M. L. Blázquez, F. González, and A. Ballester, "Leaching of chalcopyrite with ferric ion . Part IV : The role of redox potential in the presence of mesophilic and thermophilic bacteria," *Hydrometallurgy*, vol. 93, pp. 106–115, 2008. <https://doi.org/10.1016/j.hydromet.2007.11.005>
- [19] G. Viramontes-gamboa, M. M. Peña-gomar, and D. G. Dixon, "Hydrometallurgy Electrochemical hysteresis and bistability in chalcopyrite passivation," *Hydrometallurgy*, vol. 105, no. 1–2, pp. 140–147, 2010. <https://doi.org/10.1016/j.hydromet.2010.08.012>
- [20] A. Sandstrom, A. Shchukarev, and J. Paul, "XPS characterisation of chalcopyrite chemically and bio-leached at high and low redox potential," *Miner. Eng.*, vol. 18, pp. 505–515, 2005. <https://doi.org/10.1016/j.mineng.2004.08.004>
- [21] A. L. A. Santos, F. A. Arena, A. V. Benedetti, and D. Bevilacqua, "Effect of redox potential on chalcopyrite dissolution imposed by addition of ferrous ions," *Eclat. Quim.*, vol. 42, no. 1, pp. 40–50, 2017. <https://doi.org/10.26850/1678-4618eqj.v42.1.2017.p40-50>
- [22] K. Simons, "Soil Sampling," Geogia, 2014.
- [23] P. Acero, P. Cama, J Ayora, C Asta, M, "Chalcopyrite dissolution rate law from pH 1 to 3," *Geol. Acta*, vol. 7, no. 3, pp. 389–397, 2009.
- [24] J. E. Dutrizac, T. T. Chen, and J. L. Jambor, "Mineralogical changes occurring during the ferric ion leaching of bornite," *Metall. Trans. B*, vol. 16, no. 4, pp. 679–693, 1985. <https://doi.org/10.1007/BF02667505>
- [25] H. Zhao, J. Wang, W. Qin, M. Hu, and G. Qiu, "Electrochemical dissolution of chalcopyrite concentrates in stirred reactor in the presence of Acidithiobacillus ferrooxidans," *Int. J. Electrochem. Sci.*, vol. 10, no. 1, pp. 848–858, 2015.