

Hydrometallurgy

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The science and technology of hydrometallurgy and chemical processing continues to advance both at the laboratory level and in plant practice. In past decades, hydrometallurgy was rather limited in scope and received relatively little attention, being largely a laboratory curiosity. But curiosity is the mother of invention and with the dawn of the seventies this technology has come into its own; prompted to a large extent by the interest of society in protecting the environment.

Highlights of the year included the annual AIME meeting in New York City, the conference, "In Place Leaching and Extraction Technology," sponsored by the New Mexico Tech. Research Foundation, and the SME Fall meeting at Seattle. A new technical periodical, *Intermet Bulletin*, published by the College of Mines, University of Utah, provides accurate, timely reports on recent developments in hydrometallurgy and chemical processing in foreign countries, especially the Communist Block and South America. Also, a review of pressure hydrometallurgy technology, which includes design and engineering of autoclave types, has been given.¹

Of particular interest this past year has been the developments and research in the hydrometallurgy of copper and nickel. A classic example, in the case of copper, is Bagdad's new \$5 million plant in Arizona, capable of producing 7200 tpy of cathode copper.^{2,3,4} The plant interfaces a solvent extraction system with an electrolytic circuit and is the second of its kind. Reports have been circulated that an even bigger plant (60,000 tpy copper) of this type will be completed by Nchanga Consolidated Mines Ltd. of Chingola, Zambia.⁵ Thus, it appears that solvent extraction techniques for the recovery of a base metal, such as copper, are metallurgically and economically feasible. Plants such as these represent the future technology of hydrometallurgy, just as flotation was to mineral processing in the 1920's and the BOF was to steelmaking in the late 1950's. In this regard, it would be interesting to speculate on the use of the solvent extraction process in copper metallurgy by a simple model for technological forecasting.⁶

Nickel Hydrometallurgy Active

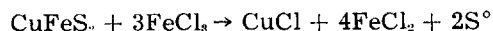
There seems to be considerable activity in nickel hydrometallurgy and chemical processing, but little has been published. Many companies and contract research firms have been studying, both in the laboratory and in pilot plant facilities, various schemes for the recovery of nickel from lateritic deposits and, also, sulfide deposits. Typical of this activity is the Falconbridge Matte Leach Process, which involves hydrochloric acid dissolution of nickel from

matte, followed by solution purification via solvent extraction, hydrolysis of the chloride, and hydrogen reduction of the oxide.⁷ The plant described is capable of producing 15 million lb of nickel per year.

Developments on in-situ and dump leaching techniques were reported during a conference at Socorro, N.M.⁸ Chemical mining of a typical copper porphyry ore under an oxygen atmosphere at high temperature and pressure was discussed.⁹ A nuclear explosion was proposed to fracture the ore and provide the necessary porosity. The resulting model, which predicted rate of copper recovery, considered particle size distribution of the broken rock and dispersion of gas in the circulating lixiviant, as well as more conventional parameters. Practical aspects of in-place leaching were discussed with regard to coverage of broken ore by leach solutions, cycle time and rate of recovery.¹⁰ At Miami, 28 million tons of ore have been blocked caved and are presently being leached in place. Also included in this conference was a report on the application of the hydro-fracturing techniques, common in the petroleum industry, to base metal deposits.

With regard to dump leaching, a recent laboratory investigation of simulated dump leaching indicates that sodium chloride accelerates the dissolution of chalcopyrite only at temperatures exceeding 50°C.¹¹ The authors concluded from this study that additions of sodium chloride would not appreciably increase the rate of copper recovery. A review article on dump leaching by A. W. Fletcher¹² gives examples of dump leaching practice over the past 100 years with operational data from Bingham, Utah; Rio Tinto, Spain; Miami, Arizona; and Butte, Montana.

Leaching of concentrates has received considerable attention, especially chalcopyrite, in an effort to find an economical, non-polluting technique for dissolution. In this regard, the pilot plant study of Anaconda's Treadwell Process represents a significant effort.¹³ Research on ferric chloride leach of chalcopyrite by the Bureau of Mines has resulted in a hydrometallurgical procedure for treating copper sulfide concentrates.¹⁴ The process is represented by the following overall reaction in which elemental sulfur is produced:



Under optimum conditions the reaction essentially goes to completion, while any pyrite in the concentrate remains unoxidized. Another laboratory technique, which was worthy of extension to the pilot plant stage is sulfation of copper-iron sulfide concentrates with concentrated sulfuric acid.¹⁵ In the case of chalcopyrite, over 99% sulfation was attained after one hour at 190°C with an excess of H₂SO₄. The industrial practice of Outokumpu Oy, Finland in treating a cobaltiferous pyrite concentrate has been reported.¹⁶ The process involves roasting, leaching, and solution purification prior to cobalt metal recovery. A laboratory study on the rate of dissolution of copper from sintered discs of bornite with minor sulfide impurities indicated that the rate of copper dissolution is independent of the presence of pyrite and chalcocite at 70°C.¹⁷ At 15°C the presence of pyrite increases the rate. A novel technique for the dissolu-

tion of PbS via oxidation by PbO₂ has been demonstrated.¹⁹ The leach, followed by electrolysis, results in metallic lead and PbO₂ which is recycled. Hydrometallurgical conversion of stibnite to antimony oxide was accomplished by alkaline leaching in an ammonium polysulfide solution.¹⁹

Other developments in leaching carbonaceous gold ores has been reported by USBM investigators.²⁰ A study on the dissolution of oxide copper minerals from carbonate ores in basic solution with chelating agents is rather interesting to consider.²¹ The economics of this technique depend on how efficiently the chelating agent can be re-cycled. The dissolution of manganese from concentrates has been accomplished both by forming soluble bicarbonates²² and by reaction with ammonium carbamate.²³ Hydrometallurgical treatments for manganese nodules continue to be studied.²⁴

In the area of ion exchange and solvent extraction, a report on a symposium dealing with processes and equipment was recently given.²⁵ A relatively inexpensive, high capacity resin has been developed which is very selective for extraction of precious metals from acid solutions.²⁶ Also, a continuous ion exchange system for the recovery of uranium from dilute sulfate solutions is described in the literature.²⁷ Much engineering data and technology that led to the development of Rancher's and Bagdad's copper solvent extraction plants has been reported.^{3,4,5,28} In this regard, considerations in the design of mixer-settler extractors were given in two papers presented in New York.^{29,30} Furthermore, as a result of the new solvent extraction technology, many researchers have begun to examine the LIX-type reagents in order to determine the reaction mechanisms involved. The USBM Metallurgical Research Laboratory developed a process for treating super alloy scrap, one step of which involves selective solvent extraction separations.³¹ Nearly 90% recovery of Ni, Co, and Mo are reported.

Electrolytic processing technology has advanced during the past year. A report on the first electrolytic refinery in the Republic of South Africa, located in Palabora, is given in the literature.³² On the theoretical side, a study of the electrochemical dissolution of copper sulfide was presented in New York.³³ A unique study on cementation of copper by divalent chromium ions, which are recycled electrolytically, shows that a high purity cement copper powder can be produced because both reactants and the other products are soluble.³⁴ This process does not lend itself to solutions of high iron concentration because of the proximity of the iron and chromium half cell potentials.

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Environment

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Federal legislation during the period 1963-70 sparked much of the governmental action taken in 1971. Late in 1970 the newly created Environmental Protection Agency (EPA) was assigned the task of establishing anti-air pollution standards (the primary standard), and guidelines for protecting the public welfare (the secondary standard). These standards had been set as of April 1971, establishing the criteria to be met by state and local regulations. State plans for meeting the primary standards must have been formulated and submitted to the EPA for