

Poster Author Directory

For questions regarding the poster sessions, please contact the Poster Chair,
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Last Call to Post Your Achievements: Extraction 2018 Poster Session

M-1: Cyanide-free Treatment of Refractory Gold Ores - Process Simulation

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As the environmental legislations and the general attitude against cyanidation have become stricter, there is an increasing interest to develop environmentally friendly cyanide-free processes for gold production. To prevent future environmental disasters and to observe the consumption of chemicals, waste waters and carbon dioxide formations in gold leaching plants, process simulation and life cycle analysis should be conducted to evaluate the development stage processes. This study presents the simulation of pressure oxidation and cyanide-free gold leaching from highly refractory gold ore using halogens. The processes are simulated by HSC-Sim 9. In the current status of the study, the simulated pressure oxidation consisted of autoclave leaching, counter current decantation and neutralization. The simulated gold leaching consisted of halogen leaching, gold recovery on silica and neutralization. The mineralogy of ore was mainly pyrite and arsenopyrite, having also dolomite, muscovite and quartz. The simulation results predicted 97.9% gold recovery.

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M-2: Effect of Matrix Complexity on the Quantification of Platinum Group Metals using Inductively Coupled Plasma Optical Emission Spectroscopy

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Platinum group metals (PGMs) are widely used in various industrial fields, particularly in the manufacture of automobile catalytic converters to reduce the emission of harmful gases. Given the fact that PGMs are getting depleted because of resource limitation and increasing demand, considerable effort has been devoted to extracting PGMs from low-grade ores and recycling them from secondary sources. However, one of the major challenges of extracting PGMs from these sources is that they contain a high concentration of other elements that can potentially hamper the accurate

characterization of PGMs because of interferences. Here, we investigated the accuracy and precision of PGMs measurement in the presence of interfering elements using inductively coupled plasma optical emission spectrometry (ICP-OES), with an emphasis on the effect of analyte concentration, number and concentration of interferents, and interferent identity. A statistical approach was adopted to characterize how ICP-OES detection of PGMs is influenced by matrix parameters.

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M-3: Electrochemical Studies of Monoclinic and Hexagonal Pyrrhotite

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Pyrrhotite, $\text{Fe}_{(1-x)}\text{S}$, is the major iron sulphide typically associated with economic Ni and Cu sulphide. In some Ni-Cu bearing deposits within the Sudbury Basin, an increasing amount of more floatable hexagonal pyrrhotite ($\text{Fe}_{9}\text{S}_{10}$) has been observed. Due to more stringent environmental standards for SO_2 emissions from smelting operations, there is a need to develop a fundamental understanding for the rejection of hexagonal and monoclinic pyrrhotite in the flotation process. In order to fulfill this purpose, hexagonal and monoclinic pyrrhotite were studied via micro-flotation, cyclic voltammetry (CV), auger electron spectroscopy (AES) and x-ray photoelectron spectroscopy (XPS). In this study, the flotation recovery curves of hexagonal and monoclinic pyrrhotite as a function of electrochemical potential and pH were established. It was discovered by CV studies that monoclinic pyrrhotite presented a higher oxidation rate compared to hexagonal pyrrhotite. In addition, their oxidation mechanism at various potentials was studied by AES and XPS.

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M-4: Froth Flotation of Ilesha (South West Nigeria) Placer Gold Ore Using Conventional and Locally-sourced Frothers and Collectors

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The placer gold deposit in Ilesha gold field is finely disseminated and is amenable to amalgamation and cyanidation which are environmentally hazardous. There is a need for an alternative method of processing the ore and the favoured method is froth flotation which is environmentally friendly. However, the conventional flotation reagents are scarce and expensive. Hence, this work is aimed at enhanced and economic recovery of gold concentrate from Ilesha placer gold deposit using locally-sourced flotation reagents. Ilesha placer gold ore was panned and its chemical analysis, mineralogical assemblage and particle size analysis were carried out. MIBC and PAX were used as frother and collector respectively. For the locally-sourced flotation reagents, oils of groundnut and palm kernel, and potassium salts of groundnut and palm kernel oils were used as frothers and collectors respectively. The locally-sourced flotation reagents are potential substitutes for recovery of gold concentrate from Ilesha placer gold deposit.

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M-5: Fundamental Studies of the Surface Properties of Millerite under Different Pulp Potentials and Water Chemistry

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Millerite (NiS) is found in along the margins of Cu rich orebodies in the Sudbury region along with varying amounts of pentlandite, chalcopyrite, and bornite. Recently with the emergence of higher millerite bearing ores in the Sudbury region, an understanding of the surface properties and flotation chemistry of millerite is becoming important for the successful depression of millerite from chalcopyrite in copper-nickel separation. In this study, the wettability and electrochemical properties of millerite were investigated using cyclic voltammetry (CV) coupled with FTIR and contact angle measurements under different pulp potentials and pH. In addition, the xanthate adsorption mechanism on millerite surface was elucidated by CV, FTIR, XPS, and contact angle measurements. Our research provides more insights on the role of pulp potentials, pH, and collector on millerite flotation.

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M-6: Heat Recovery from Slag through Air Atomization

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The heat contained in metallurgical slags represents a significant source of lost energy in processing operations. In 2015, molten blast furnace slags alone contained ~ 5x10⁸ GJ of energy, most of which was lost. Additionally, metallurgical slags are underused in downstream applications such as concrete production. While many granulation technologies have been developed to take advantage of the inherent value of molten slags, none have shown definitive proof that heat recovery and idealized granulation can be performed simultaneously. This project's objective is to determine the feasibility of concurrent granulation and heat recovery by quantifying heat transfer during air atomization. A heat transfer model for a representative system is developed to quantify heat transfer from a granulated particle to the air within a heat recovery chamber, and to quantify the heat lost from the system during granulation.

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M-7: Rare Earths Extraction and Separation from Chloride Solutions Using Bis(2,4,4-Trimethylpentyl) Phosphinic Acid

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The importance of rare earth (RE) elements is growing due to their wide range of applications in clean energy, high-tech technologies and modern life. At the same time, sources of REs are very limited. The current study focuses on the aromatic diluents benzene, toluene and xylene to determine their suitability as well as their ability to improve the separation of light rare earth elements (LRE's). Bis(2,4,4-trimethylpentyl) phosphinic acid (tradename Cyanex[®] 272) is

used as an extractant and is dissolved the aforementioned diluents. Various experimental parameters, in this case the time effect, the influence of the pH, extractant concentration variations and the maximum loading capacity of the LRE under study associated with extraction with Cyanex® 272 were examined. Finally, the potential for separating LRE's are calculated and a suitable diluent system is proposed.

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M-8: The AMBS Flotation Process for Copper and Gold Ores

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The Air-Metabisulfite (AMBS) process has been developed to treat complex copper, molybdenum and precious metals (gold, silver) bearing ores using brackish and sea water. This process was able to produce significantly better copper concentrate grades and higher recovery than possible using conventional lime and/or cyanide based processes for certain complex ores with high sulfide gangue minerals. The AMBS technology is now used commercially. This poster presents a summary of the findings from testing the AMBS technology on various ores types.

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M-10: Thiosulphate Gold Leaching Process and the Role of Thiosulfate Counter Cations on the Leaching Process

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There are serious concerns associated with the conventional cyanidation process due to extreme toxicity of cyanide. Thiosulfate is a less-toxic alternative lixivants for effective gold leaching. This review elaborates on the chemistry of thiosulphate system which is rather complicated due to simultaneous presence of complexing ligands, Cu(I)- Cu(II) redox couple and thiosulphate decomposition reactions. Besides that, gold leaching is case-specific and depends on ore and solution chemistry. Leaching gold by thiosulphate is affected less by foreign counter cations in comparison with cyanidation. However, extraneous counter cation plays a major role on rate of the leaching process. In general, the gold dissolution rates decrease with increase in concentrations of the metallic ions. Decreased thiosulphate concentrations in the presence of the foreign ions also decreases gold dissolution. However, the effect of these cations is specific to the type of metal and solution conditions and can be elaborately understood by respective Eh-pH diagrams.

Peter Hayes Symposium on Pyrometallurgical Processing, sponsored by University of Queensland School of Chemical Engineering

M-12: Chemical Reactivity and Thermal Stability of the Phosphate Binder used in Ceramic Foam Filters (CFFs)

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Filtration of liquid aluminium is widely used in the industry for refining purposes prior to casting, and Ceramic Foam Filters (CFFs) are often the filtration media. Following an incident with generation of phosphine gas after cutting used alumina based CFFs, the need for improved understanding for the chemical reactivity and thermal stability of CFFs was realised. In the present work, three CFF substrates with varying $AlPO_4$ contents were investigated. The substrates, as produced and in contact with pure aluminium, were heat-treated in a vacuum induction furnace and in a Simultaneous Thermal Analyser at 850°C in an inert gas atmosphere. Mass changes of ~1m% were registered for the substrates, and ~3-9m% together with a clear colour change when in contact with aluminium. Chemical analyses of the aluminium after heat-treatment revealed that phosphorus from the binder had been reduced to aluminium phosphide, making further phosphine generation possible if in contact with water.

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M-15: The Cyclic Voltammetry Measurement of Redox Reactions for Gold in Acidic and Basic Media

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This poster presents the cyclic voltammetry measurement of redox reaction of gold in both acidic and alkaline solutions. The current and potential zones at which gold is reduced is investigated because of its importance in electrochemical evaluation of gold recovery. The solutions were prepared by reacting 0.1 and 0.5 M hydrochloric acid, sodium thiosulfate and sodium thiourea with 30 and 60 ppm gold concentration. These solutions with dissolved gold in 0.1 and 0.5 M of the three lixiviants were tested using potentiostat in cyclic voltammetry (CV) technique mode for possible measurement of reduction and oxidation reactions. Glassy carbon, saturated calomel (SC) and platinum wire mesh served as working, reference and counter electrodes, respectively. Comparative tests were carried out on 0, 30 and 60 ppm gold solution of the three lixiviants. The results show that no peak is observed in the case of the absence of gold in the solutions (0 ppm), 30 and 60 ppm gold in sodium thiourea and sodium thiosulfate, indicating no redox reaction or that CV is not a suitable technique to detect the peaks. However, appreciable cathodic and anodic peaks are observed for 30 and 60 ppm $AuCl_3$ concentration in the acid solution. The redox reaction in the gold(III) chloride acid solution is found to be reversible because the ratio of oxidation peak current and reduction peak current is 1. The concentration of $AuCl_4^-$ on the surface of the working electrode at the reduction site for the $AuCl_3$ concentrations using Nernst equation are 1.22×10^9 and 2.44×10^9 ppm. It is inferred from this experiment that the reduction potentials are independent of concentration, while current is concentration dependent.

Hydrometallurgy 2018

M-16: The Kinetics of Atmospheric Acid Leaching of Brazilian Lateritic Nickel

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Atmospheric processing of nickel lateritic ores with low costs has been encouraged. In this work the kinetic of atmospheric acid leaching of a northern-Brazilian ore with 1.63% Ni and large amount of fine particles ($d_{50} \sim 0.075$ mm and 40% below 0.038 mm) is presented. Chemical analysis showed a trend of Ni and Fe concentration in finer fraction

(-0.075 mm) and Si and Mg in the coarsest one (-0.500+0.150 mm) associated to distinct mineral phases. Nickel is widespread in the mineral matrix. Distinct behaviors were observed as a function of particle size associated to the distribution of silicates and iron oxides in the ore. The kinetic modeling indicated that leaching is controlled by porous layer diffusion at 65 °C, but at 95 °C exhibits a mixed control by porous layer diffusion in initial minutes (60 min) and by chemical reaction or diffusion through the pore layer in final minutes (60-240 min) depending on metal evaluated.

Hydrometallurgy 2018

M-17: Dy Permeation through an Alloy Diaphragm Using Molten Salt Electrolysis

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We have been developing a new process for the separation and recovery of rare earth metals using molten salt electrolysis and an alloy diaphragm. This new process was first applied to chloride melts, and the separation of Dy from Nd and Pr were investigated using Cu, Ni and Zn cathodic electrodes in molten LiCl-KCl-DyCl₃-NdCl₃ and LiCl-KCl-DyCl₃-NdCl₃-PrCl₃ systems. The highest mass ratio of Dy/(Nd+Pr) in Dy-Nd-Pr-Ni alloy sample was found to be 50 at 0.65 V (vs. Li⁺/Li) for 1 h by ICP-AES. In this study, the investigation of Dy permeation through Dy alloy diaphragm using molten salt electrolysis was investigated. The Dy permeation experiment was conducted with electrolytic cells in molten LiCl-KCl systems at 723 K in order to confirm the theoretical feasibility of the present process.

Hydrometallurgy 2018

M-18: Reuse Opportunity of Ferrous Grinding Swarf from Automobile Industry

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This research focused on the recovery of iron from ferrous grinding swarf. Grinding swarf comprised metal grindings, oil residue, and ceramic particles. Metalworking fluids provide better grinding properties by lubricating and cooling the interface between tool and material; however, it covers metal grindings after its use, and it is undesirable since the oil burns explosively during smelting operations for metal recovery. Based on the initial characterization, the sample contained about 78 % of metallic iron and 16 % of oil residue by weight (dry basis). Thus, aqueous washing with detergents was evaluated to obtain oil removed ferrous grinding swarf at different operating conditions. In addition to the aqueous washing, oxidation of ferrous grinding swarf at elevated temperatures was also conducted to find an alternative way to reuse the waste material as a pigment.

Gordon Ritcey Symposium: Advances in Hydrometallurgical Solution Purification Separations, sponsored by Purolite

M-19: Separation of Uranium and Molybdenum from Alkali Leaching Solution of U-Mo Ore

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Separation of uranium and molybdenum from alkali leaching solution of U-Mo ore was studied. The process of acidification-solvent extraction-precipitation uranium and molybdenum was determined. The influence of solution acidity and phase ratio of acidic washing on separation of uranium and molybdenum were examined. The molybdenum extraction equilibrium curve was drawn. The results show that the separation of molybdenum and uranium can be achieved by acidizing the alkali leaching solution to pH of 2.5, solvent extracting molybdenum using tri-fatty amine and washing the loaded organic phase using sulfuric acid solution. The strip solution can directly precipitate ammonium molybdate, and the raffinate neutralized can directly precipitate uranium which meets the correlation standards.

Gordon Ritcey Symposium: Advances in Hydrometallurgical Solution Purification Separations, sponsored by Purolite

M-20: Lithium Solvent Extraction with a Beta-diketone Reagent

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SGS Canada's Lakefield laboratories undertook an investigation of lithium solvent extraction from a chloride brine. The extract used was a commercially available beta-diketone reagent (Hallechem's Mextral 54-100) mixed with a liquid phosphine oxide (Solvay's Cyanex 923) in an aliphatic diluent. This work was carried out to expand on the successful results reported by workers from CSIRO in Australia using a beta-diketone reagent of similar chemical structure in a similar extractant mixture. The current report expands on some aspects of the data reported in the earlier study. Extraction with a more concentrated reagent mixture enabled higher lithium loading to be attained. The results of preliminary scrubbing and stripping tests are also reported.

Processing of Critical Metals

M-21: Challenges with the Use of Lime and Limestone for Impurity Removal in Rare Earth Elements Hydrometallurgical Treatment; A Fundamental Look

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Lime neutralization has a high efficiency in removal of dissolved heavy metals from the solution. After water leaching of the REE acid baked concentrate, different chemicals can be used to remove impurities from the solution, among which lime and limestone are the cheapest options. Although the application of lime and limestone to the impurity removal stage in hydrometallurgical treatment of REE ores could reduce the costs of operation, they are not widely in use; A proportion of REE is lost to gypsum while removing other impurities. An insight into the role of REE on the crystal morphology of gypsum is essential for a better fundamental understanding of the cation-assisted crystallization of calcium sulfate dihydrate. It is the scope of this poster to investigate the mechanism of the REE-loss in the said process and REE dopants effect on the crystallization of dihydrate in a $\text{Ca(OH)}_2\text{-H}_2\text{SO}_4$ system.

M-22: Impurities Analysis of a Magnetic Waste before Leaching and Extraction of Neodymium and Praseodymium: Elaboration of Fe-Nd Alloys

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The rare earths are becoming increasingly important in improving energy efficiency and developing clean technologies. This is due to their essential role in permanent magnets. Neodymium-iron-boron magnets are the most often used rare-earth permanent magnet. The objective of our work involves three steps: first we analyze the impurities from a magnetic waste. The second step includes extraction and determining the content of major elements. The third step involves producing an Nd-Fe alloy. The neutron activation (neutron flux of $3.4 \times 10^{12} \text{ n/cm}^2/\text{s}$), the SEM/EDX and DRX are used. We begin with an embrittlement of our material with hydrogen followed by acid leaching. The detected elements are: Ni, Al, Ti, Cu, Mn, In, Ta, Ce, Sm, Eu, Np, Yb, Gd, Lu. The analysis of the magnet by EDX shows that this sample contains Fe, Nd, Pr, and boron. The alloys are elaborated by ball milling.

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T-3: Towards the future of Top Submerged Lance Technology: Research in Freiberg

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One of the high temperature process investigations in Virtuhcon's project is on Top Submerged Lance (TSL) Technology at INEMET, TU Bergakademie Freiberg. The advantages of this technology are high reaction rates, less space-time footprint, multiple functionalities, low installation costs etc. These outstanding properties lead the TSL to play a vital role in the pyrometallurgy. The furnace exhibits a highly turbulent, aggressive and splashing environment during the pyrometallurgical extraction processes. These remarkable process conditions caused a demand on process simulations over a decade and are moderately established. The simulation results have not been validated with experiments until now because of the TSL conditions. Understanding and proving the complex phase transformations, thermodynamics, hydrodynamics and kinetics of the system is a challenging task. This poster presentation depicts the experimental complications and possible solutions in TSL which will help to validate the simulation results and a better understanding of the whole process.

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T-4: Potential of Ion Exchange Resins for Lithium Extraction from Brine

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There is great interest in lithium ion exchange technologies due to the advent of lithium ion batteries for mobile devices and electric vehicles. This study conducted batch tests of 27 ion exchange resins for lithium extraction from artificial brine, which is similar to brines in the South America. Some cation exchange resins, especially strongly cation exchange resins, showed good ability to adsorb lithium from lithium chloride solution. They recovered lithium at around 60–80% in terms of their capacity. For artificial brine, however, the selectivity for lithium was so low that the resins couldn't preconcentrate lithium. They used only about 1% of their capacity for lithium, and the rest of sites were used for other ions such as sodium, potassium, calcium and magnesium ions in brine. Therefore, in order to enhance the selectivity, this study additionally carried out tests with resins whose functional sites were modified.

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T-5: Promising New Depressant for Pyrite in Polymetallic Sulfide Flotation

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Compelling research has been performed with Silvateam reagents, specifically Benefloat, on a Peruvian polymetallic sulfide ore. The results from these on-site studies of the zinc rougher circuit show that Benefloat was an excellent depressant for both pyrite and silica. Subsequently, the zinc grade showed a dramatic increase. Surprisingly, the zinc recovery also increased with the addition of Benefloat, potentially indicating that the dispersive properties of the reagent may help to fully disperse the ore in solution. Benefloat shows great promise as a depressant and dispersant for polymetallic sulfide circuits.

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T-6: Separation of Uranium and Molybdenum in U-Mo Ore Alkaline Leach Liquor

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Separation of uranium and molybdenum in the alkaline leach solution of a U-Mo ore was studied. A process of acidification-solvent extraction-precipitation uranium and molybdenum was determined. The influences of solution acidity and phase ratio of acidic scrubbing on separation of uranium and molybdenum were examined. The molybdenum extraction equilibrium isotherm was drawn. The results show that the separation of molybdenum and uranium can be achieved by acidifying the alkaline leach solution, solvent extracting molybdenum using trialkylamine at equilibrium pH 2.5, and scrubbing the loaded organic phase using sulfuric acid solution. The strip solution can directly precipitate ammonium molybdate. Uranium can be directly precipitated from the raffinate.

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T-7: Silver Recovery from the Electronic Wastes Using Thiourea Leaching and Cyclone Type Electrowinning Cell

Jae-Woo Ahn



Sponsored by The Metallurgy and Materials Society (MetSoc) of the Canadian Institute of Mining, Metallurgy and Petroleum; The Society for Mining, Metallurgy & Exploration (SME); and The Minerals, Metals & Materials Society (TMS)

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The recovery of silver from electronic wastes was studied with acidic thiourea leaching and electrowinning process. The thiourea leaching of silver from the electronic waste was carried out with 60 g/L solid/liquid ratio, 0.6 M thiourea and 0.1 M hydrochloric acid at 600 rpm and 35°C. The results showed that more than 99% of silver could be leached out and the impurities such as aluminium, calcium, iron, strontium, zinc were dissolved less than 17% in the leachate. After leaching, in order to recover the silver from the solution, cyclone type electrolytic cell was used to obtain the metallic form. As a result, more than 99% of silver was achieved in the powdery form at the flow rate of 12 L/min., current density of 0.75 A/dm², and 35°C. The average particle size and the purity of the recovered silver powder was 20µm and 99.5% respectively.

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T-8: Simulation of the Solvent Extraction Process Applied to the Rare Earth Elements Separation

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Achieving the separation of rare earth elements (REE) is a hydrometallurgical challenge. Most Canadian REE companies consider producing a concentrate bulk of all the REE to sell to a refinery which separates individually the REE due to the lack of knowledge of both, operation conditions and the cost of the separation. To answer this problem, we are currently developing our own counter-current solvent extraction simulator at Université Laval that can assay different configurations of solvent extraction circuits and operation conditions to achieve the desired separation of REE. This simulator is also being used for the estimation of the capital and operation costs. Such simulators are not widely available. The benefit of a simulator is the reduced cost and time of testing separation circuits.

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T-9: Thermal Plasma Extractive Metallurgy for E-waste Recycling

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Recycling processes are now widely recognized as one of the solutions against the primary mineral resources supply risk. The most developed countries are aware of this issue and aim to find innovative processes to recycle strategical metallic elements. Within the framework of alternative new recycling processes, we use the thermal plasma media to perform extractive metallurgy. The selective extraction and recovery of desired metal in binary/ternary samples alloys (FeCu, CuSn, CuSnIn...) has been carried out by a 15kW enhanced plasma process with the further objective to recycle strategic metals from more diverse and complex matrices. The enhancement lies in the modification (additives) and the control of the hot plasma chemical reactivity and temperature. The extracted elements are transported by the plasma flow and recovered by condensation on a capture plate. Multiple diagnosis tools (OES, LIBS, DRX, ICP...) are employed in-situ and ex-situ so that an extraction mechanism can be proposed.

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T-10: Use of Non-cyanide Lixiviants for the In-situ-leaching of Gold

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To date, in-situ leaching (ISL) mining has been commercially applied for the recovery of copper and uranium only. In gold leaching, the most common leaching agent is cyanide. The application of ISL to gold mining has not been possible because of the threat that cyanide presents to the environment. Substitution of cyanide by other reagents could bridge the current gap that exists between ISL mining and the gold industry. Previous and current research has shown that gold dissolution is feasible using halides, aminoacids and calcium thiosulfate. In this work we compare different lixiviants for gold dissolution and assess the challenges and opportunities inherent to each technology from a thermodynamic and dissolution kinetics perspective.

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T-11: Selective Precipitation of Cerium from Acidic Rare Earth Solutions

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Separation of rare earth elements (REE) ores is usually achieved by acid leaching followed by solvent extraction (SX), to purify individual rare earth metals (REM). Cerium commonly accounts for 50 % of the REE in ores. Demand for less prevalent REE, such as neodymium have caused an overproduction and devaluing of cerium relative to processing costs. To improve the economics of REE separation, cerium should be precipitated from solution prior to SX, via the oxidation of cerium (III) to cerium (IV). This poster contains an overview of selective oxidation of cerium in acidic solutions using the oxidants hydrogen peroxide, sodium hypochlorite, potassium permanganate, and Caro's Acid. Test conditions ranged from pH 1 - 4, 25 to 65 °C, cerium concentrations of 2 to 16 g/L, stoichiometry of 100 to 150 %, and with REE present in solution. Cerium recovery ranged from 14.2 to 99.99 %, depending on test conditions.

Peter Hayes Symposium on Pyrometallurgical Processing, sponsored by University of Queensland School of Chemical Engineering

T-15: Assessing the Techno-economic Feasibility of High-pressure Oxy-fired Flash Metallization of Iron Ore

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CanmetENERGY-Ottawa is developing a transformative technology for the iron and steel industry, in which, iron ore concentrate is directly reduced to liquid iron in a pressurized entrained flow reactor (PEFR). The direct reduction of the ore concentrate allows for the elimination of pelletization/sintering as well as the use of natural gas as a reductant, in place of coke. Process conditions require temperatures in excess of 1500 °C and elevated operating pressures beyond

what would typically be seen in steel production processes. Various process arrangements were modelled using Aspen HYSYS to obtain material and energy balances. An economic analysis was then performed for the arrangements and compared to blast furnace and direct reduced iron (DRI) processes. The economic performance of the technologies was then compared under various market conditions to assess the feasibility of pressurized flash metallization as a next-generation technology.

Hydrometallurgy 2018

T-17: Insights into the Surface Chemistry of Activated Carbon-catalyzed Arsenic Oxidation

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Arsenic is a highly toxic element commonly associated with gold/copper-bearing ores. The arsenic immobilization is becoming increasingly crucial for mining and metallurgical operations. Activated carbon-catalysed arsenic oxidation is a promising process that employs oxygen as the sole oxidant. Surface chemistry is a significant and complex factor driving the catalyzed process which involves the oxidation and adsorption of arsenic species, occurring simultaneously. X-ray photoelectron spectroscopy was employed to examine the surface of activated carbon, treated with As(III) and/or As(V) solutions. Approximately 25% of the elements on the carbon surface was determined to correspond to O 1s spectra indicating large amounts of oxygen functional groups on the activated carbon surface which help the arsenic oxidation. Freundlich adsorption isotherm model was determined to best describe the characteristics of the activated carbon for As(III) and As(V) adsorption with an n parameter of 1.01 and a KF value of 0.01.

Hydrometallurgy 2018

T-18: Selective Recovery of Manganese from Anode Sludge by Reductive Leaching

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Manganese oxide containing anode sludge is a common side product in zinc electrowinning. Anode sludge mainly consists of oxidized manganese (>40 %) and lead (>15 %). Selective recovery of manganese can be achieved by reductive sulphuric acid leaching. In this work reducing agents, temperature and solid to liquid ratio were investigated. Concentrated manganese sulphate solution can be obtained while concentrations of unwanted calcium and lead are limited. Pure manganese sulphate solution can be manufactured by adjusting reaction conditions. After refining planned uses could include chemical, fertiliser or battery industry.

Hydrometallurgy 2018

T-20: Solvent Extraction of Rh(III), Pt(IV) and Pd(II) from HCl with Amide-containing Tertiary Amine Compounds

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We have found that amide-containing tertiary amine (ACTA) compounds exhibit high extraction efficiency for platinum group metal (PGM) complex anions in HCl solution. Among ACTA compounds, N-2-ethylhexyl-bis(N-di-2-ethylhexyl-ethylamide)amine (EHBAA) seems to be the most suitable for practical use, because EHBAA is superior in terms of solubility of extractants in practical diluents, formation of a third phase and so on. EHBAA extracted about 100% of Pd(II) and Pt(IV) in the studied HCl concentration range (0.5-10 M). The extraction efficiency of Rh(III) drastically decreased above 3 M HCl. In contrast, both Fe(III) and Cu(II) were quantitatively extracted above 3 M HCl. The extracted Fe(III) and Cu(II) were selectively scrubbed with distilled water over PGMs.

Processing of Critical Metals

T-21: Rare-Earth Elements Recovery from Nd-Fe-B Hard Magnets by Hydrometallurgical Processes

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In this study; the elements in the Nd-Fe-B hard magnetic structure have been recovered by hydrometallurgical processes. The rare-earth elements in the scrap (Nd, Dy and Pr) Nd-Fe-B hard magnet have been extracted by using hydrometallurgical process and then they have been recovered to compound form. Nowadays, the most used magnets are Nd-Fe-B hard magnets in electronic devices. This study also containing recovery or evaluate the other elements (Fe, B, coating materials) that in the magnet system. The chemicals that have been used during the study will be available again and avoid the poisonous gas emission. If the gas emission is cannot be avoided, these gases will be reused, stored or harmonized. The process will be designed for pilot scale industrialization. Nd-Fe-B hard magnets will be dissolve in solvent and the solution will be characterized. Precipitation agent and parameters will be determined and precipitation/extraction processes are proceed. The process efficiency will be calculated after the final characterization. The optimum experiment parameters will be determined.

Sulfide Flotation, sponsored by Newmont

T-22: Influence of Pulp Conditions on Oxidation, Grade and Recovery of Sulphide Minerals

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The semi-conducting properties of sulphide minerals have been exploited for their recovery in flotation since the discovery of xanthates collectors which are known to interact electrochemically with sulphide minerals. Interest in the effect of pulp potential on recovery is worth revisiting as mining depletes high grade ores leaving ores of increasingly complex mineralisation to be recovered. Whilst potential modifiers such as hydrogen peroxide have been applied in laboratory tests to control potential their possible application to operations still requires investigation. In this work, hydrogen peroxide is investigated as a potential modifier to two sulphide bearing ores from the Bushveld Complex in South Africa. It is found that low concentrations of hydrogen peroxide below 0.001 M can result in increased recovery and grade of sulphide minerals. Fundamental studies in the form of zeta potential measurements and voltammetry are used to provide further insight into the interaction of peroxide with sulphide minerals.

Sulfide Flotation, sponsored by Newmont

T-23: A Fundamental Study of Di-Sodium Carboxymethyl Trithiocarbonate (Orfom® D8) Depressant in Flotation Separation of Copper-Molybdenum Sulfides

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The Cu-Mo sulfide flotation industry is increasingly turning to organic depressants as suitable replacements for inorganic reagents, such as NaHS, due to environmental and safety concerns as well as high consumption rate of the inorganic reagents. This presents an opportunity for improvements or design and synthesis of alternative reagents. Di-sodium carboxymethyl trithiocarbonate (Orfom® D8) depressant is an organic depressant with a carboxylate group on one end and a trithiocarbonate group at the other end. Fundamental results are shown regarding the interaction of the Orfom® D8 depressant in the bulk flotation of a chalcopyrite-molybdenite concentrate from an operating North American mine. Cyclic Voltammetry on pure copper and Fourier Transform Infrared Spectroscopy (FT-IR) and X-ray Photoelectron Spectroscopy (XPS) measurements on pure chalcopyrite with Orfom® D8 depressant treatment are also reported. Through such characterization techniques, a potential adsorption mechanism of Orfom® D8 on the mineral surface was identified and its depressant characteristics in the Cu-Mo flotation systems explained.

Last Call to Post Your Achievements: Extraction 2018 Poster Session

W-1: A Fundamental Study of Hydrodynamic Cavitation Effect on Fine Particles Floc Generation and Flotation

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The hydrodynamic cavitation has been applied in the mineral flotation process to enhance the recovery, which was mainly explained by the generation of flocs in the cavitation process. This study aims to investigate the mechanism of flocs generation in hydrodynamic cavitation. The Venturi tube as a hydrodynamic cavitation device and fine molybdenite particles (<37µm) were investigated. The formations of flocs in different conditions were studied by measuring particle size distribution, microscopic imaging, turbidity, and zeta potential distribution. Experiment results demonstrated that fine particles are aggregated via the bubble bridge. The recovery of fine particles after cavitation has an increase of 10% in the micro-flotation test by using Hallimond tube, which could be explained by the formation of flocs through the cavitation enhanced the floatability of fine particles. The findings provide an important contribution to the fundamental understanding of the role of hydrodynamic cavitation on the enhancement of fine particles recovery.

Last Call to Post Your Achievements: Extraction 2018 Poster Session

W-2: An Investigation of the Impact of L-Cysteine on Elemental Sulphur Formation and Retention in the Application of Atmospheric Pyrite Oxidation

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Two carbon-based catalysts (AF 5 and activated carbon) enhanced atmospheric oxidation of pyrite, and improved elemental sulphur formation. AF 5 promoted amorphous sulphur formation with nearly 100% sulphur retention, while activated carbon promoted the formation of crystalline sulphur globules with 60% found in the solid residue. XPS indicated the presence of a sulphur group on AF 5, likely that of L-cysteine. L-cysteine could promote the sulphur formation found during testing with AF 5, thus enhancing elemental sulphur retention. This study intends to determine if L-Cysteine does promote the generation and/or retention of elemental sulphur on the catalyst surfaces during pyrite oxidation. PET and HDPE beads were doped with L-Cysteine and included in bench scale oxidative pyrite leaches in ferric sulphate media for 48h at 55°C. Carbon-sulphur determination, TGA and XPS analysis were used to analyze solid samples. The findings indicate that L-Cysteine does aid in elemental sulphur generation and retention.

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W-4: Extraction and Separation of Vanadium and Molybdenum from Estonian Phosphorite Using Ionic Liquids

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Rare-earth elements (REEs) as well as Vanadium and Molybdenum are becoming increasingly important in the transition from traditional economy to novel more efficient, green and low carbon economy as REEs are applied in innovative technologies, such as strong permanent magnets, Li-ion, and Na-ion batteries, fuel cells, solid oxide electrolyzers etc. In the report "Critical raw materials" (2014) made for the EU, REEs are associated with the highest long-term supply risks and the highest predicted demand growth. Separation of individual REE is challenging due to the similar physical and chemical properties of REEs. The most promising method is the homogeneous liquid-liquid extraction. Ionic nature of IL makes them thermodynamically favourable solvents for extractions of various ionic species from acidic or basic aqueous media. In current work we determine the content of Estonian phosphorite and separate V and Mo of it using ionic liquids such as OMImPF₆, HMImPF₆ and Aliquat 336.

Last Call to Post Your Achievements: Extraction 2018 Poster Session

W-5: Flash Furnace Burner Sensor for Monitoring Combustion

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A new, patented sensor for burner monitoring in copper flash smelting is being developed. The sensor uses fiber optics and optical emission spectroscopy to measure flame temperature and stability in real-time based on the black-body emission collected from flash combustion reactions. Proof of concept testing in the lab was done using a continuously fed, drop tube reactor with oxygen:sulfur ratios between 0-4. The testing was done on four different feeds to compare the emission spectra, flame temperatures and reaction mechanisms. Emission lines from Na (589.43 nm) and K (766.5 and 769.9 nm) were observed in the signal from all feeds, however the temperature of the flame in the lab was not high enough to produce copper or iron emissions which would be useful for diagnosing the flame quality. The temperature

attained by the flame was found to be dependent on the feed material and the oxygen:sulfur ratio.

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W-7: Recoveries of Elements from Coal Fly Ash Using Sulphuric Acid

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Coal fly ash (CFA) sample produced in coal fired power plants contains substantial amounts of oxides of iron, aluminium, and other strategic elements like silicon, magnesium, and calcium for the synthesis of wastewater treatment coagulant. In order to produce a coagulant, the dissolutions of these elements from CFA were investigated in sulphuric acid (H₂SO₄) media. The effects of contact time, H₂SO₄ concentration, temperature, and solid to liquid ratio were explored for the dissolution process. Leach residues were characterized using particle size distribution (PSD), X-ray diffraction (XRD), X-ray fluorescence (XRF), Fourier transform infrared (FTIR), and scanning electron microscope (SEM). Thermodynamic feasibility was explored using Hydra/Medusa software. The leaching efficiency of iron, aluminium, silicon, magnesium, and calcium were 57.90%, 33.86%, 11.12%, 73.21%, and 25.43% respectively, in 1.5 M H₂SO₄, pH ranges from 0.5 to 3.9, at 300 rpm, 150 °C, 0.20 solid to liquid ratio and leaching period of 6 h.

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W-8: Selective Flotation Separation of Copper-molybdenum Sulfides by a Nontoxic and Cost-effective Derivative of Chitosan

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The flotation separation of Cu-Mo sulfides generally relies on the toxic and hazardous depressants such as sodium sulfide. In this work, a nontoxic, biodegradable and cost-effective derivative of chitosan, O-Carboxymethyl chitosan (O-CMC), has been explored as a selective depressant for molybdenite during the Cu-Mo flotation separation. Single mineral flotation tests revealed that O-CMC strongly depresses molybdenite flotation from pH 3 to 11, while chalcopyrite flotation was not affected by O-CMC in most pH range. Mixed minerals flotation confirmed O-CMC depresses the molybdenite well without significantly affecting chalcopyrite recovery and selective separation was achieved from pH 3 to 11. The adsorption characteristics of O-CMC on both minerals and the interaction mechanisms were investigated by electrokinetic study, AFM imaging and ToF-SIMS analysis, which revealed that the interactions between chalcopyrite and O-CMC are relatively weak physical interactions such as electrostatic interaction, while the interactions between O-CMC and molybdenite are dominated by hydrophobic interaction.

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W-9: The Development of an Integrated Testing Methodology for In-situ Leaching

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In-Situ-Leaching (ISL) is becoming an area of focus due to the ever increasing difficulties in mining ores that are either too deep for open pit, or too low grade for conventional underground mining. AuTec and Naturafac have developed an integrated testing methodology that includes material properties testing, ore stimulation using Naturafac's patented Multi-Pulsed Dynamic High Pressure Combustion Technology and AuTec's pipe and large vessel leaching techniques on alternative leachants like glycine and iodine. This poster presents the various processes and techniques used to assess the potential for ISL of an ore.

Hydrometallurgy 2018

W-15: Adsorbent for Selective Recovery of Antimony

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We have synthesized an adsorbent for selective recovery of antimony from copper electrolyte, which contains antimony, arsenic, and bismuth as impurities. The adsorbent is made from tannin which is one of the biomass materials that are inexpensive and ubiquitous natural polymers extracted from leaves or barks of plants and has many hydroxyl groups. It was found that the tannin adsorbent adsorbed antimony from 200 g/L sulfuric acid solution. Arsenic and bismuth, on the other hand, were little adsorbed onto the adsorbent in the experimental conditions. As the result, the tannin adsorbent has the possibility for selective separation of antimony from copper electrolyte. We conducted the recovery test of antimony from simulated copper electrolyte using the tannin adsorbent-packed column. Antimony in the simulated solution was adsorbed, and the other elements were not adsorbed. The adsorbed antimony could be easily desorbed by hydrochloric acid and recovered with high concentration and purity.

Gordon Ritcey Symposium: Advances in Hydrometallurgical Solution Purification Separations, sponsored by Purolite

W-19: Crowding Effect on Dysprosium Extraction and Separation from Post-consumer Waste of Permanent Magnets

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Rare earths (REs) playing key role in new modern lives; REs were having numerous applications in the areas of electrical, electronic fields. Hydrometallurgy is the cheapest and convenient for REs recovery from primary resources/secondary resources. The present experimental approach towards recovery of rare earths such as dysprosium and terbium from post-consumer waste of permanent magnets (PCWPMs) was designed and developed by hydrometallurgical approaches. Numerous phosphorous based extractants such as Cyanex 272, D2EHPA, PC 88A and TBP tested for suitable for REs separation and recovery. Kinetics of the extraction equilibria was studied. And as well as various pH conditions were tested and optimum condition was fixed for possible separation of each other REs. Scrubbing studies (crowding effect) was tested with dysprosium rich solution as scrub solution at different feed pH conditions. Finally, proper flowsheet for dysprosium separation from other REs was developed.

W-21: Recovery of Rare Earth Elements from Coal Fly Ash and Recovery from PLS with IX

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Rare earth elements (REEs) may be produced from secondary waste sources such as: uranium tailings, red mud, coal by-products, wastes from phosphate fertilizer production, and mineral by-products. Total REE concentrations within these secondary sources range from 100s to 1000s of ppm. This study examines the technical feasibility of recovering REEs from several Canadian coal fly ash samples. During the screening phase a number of different lixivants were screened for their ability to selectively leach REEs from the coal ash samples. A number of ion exchange (IX) resins were screened for REE recovery from the pregnant leaching solutions; several of which were selective for recovering REEs. The results of the leaching and metal recovery experiments will be summarized.
