Solvent extraction of copper from high-tenor pressure leach solutions using new modified aldoximes

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ABSTRACT

Modern chalcopyrite pressure-leaching processes produce leach solutions of substantially higher copper and acid concentrations than traditional heap leach operations. The purification of such liquors presents interesting challenges for the chemistry of the solvent-extraction process, and for the integration of this unit operation into the overall process flowsheet. LIX 612N-LV and LIX 6422N, two new copper extractants recently commercialised by Cognis Corporation, feature an aldoxime functionality that is well suited to the processing of high tenor, low pH liquors, while the incorporation of novel modifiers (patent pending) gives these extractants lower viscosity and density than currently available modified aldoximes. LIX 612N-LV and LIX 6422N nevertheless exhibit similar Cu-Fe selectivity to the highly modified Acorga M5774.

A significant advantage offered by the low-viscosity extractants is that they can be used at concentrations as high as 50 vol.%, in contrast to conventional extractants that become impractical much above 30 vol.%. Copper can be loaded from leach solutions containing 35 to 50 g/l Cu using advance O:A ratios of ~ 2:1, rather than the values of 3:1 to 5:1 that have previously been necessary to attain acceptable copper recoveries from such liquors. Utilisation of the low-viscosity extractants in typical pressure leaching flowsheets could potentially reduce the required mixer-settler size, with associated reductions in capital and operating costs.

The performances of LIX 612N-LV and LIX 6422N are compared with those of their competitors, Acorga M5774 and LIX 984N, in laboratory tests on both synthetic and pilot-plant autoclave discharge liquors. The comparative continuous operating characteristics are evaluated under mini-plant conditions for the recovery of copper from a synthetic leach solution of composition simulating that derived from the leaching of a chalcopyrite concentrate using the AAC/UBC pressure leaching process.
INTRODUCTION

Two newly commercialised solvent extractants, LIX 612N-LV and LIX 6422N, specially designed for treating concentrated liquors from chalcopyrite pressure leach processes, have recently become available from Cognis. They are aldoxime-based systems, but incorporate new equilibrium modifiers (patent pending) that give the extractants a much lower viscosity (the “LV”) than conventionally modified extractants. Although Cu-Fe selectivity is not often critical in pressure leach flowsheets, these extractants exhibit similar Cu-Fe selectivity to the highly modified Acorga M5774 (currently the most selective extractant available). The low-viscosity extractants also offer some benefit over ester-modified reagents with respect to entrainment losses in plant raffinate solutions.

There is considerable focus of late on the development of pressure-leaching processes for the dissolution of copper from chalcopyrite (1,2). Since pressure leaching typically generates liquors containing 20 to 60 g/l Cu and up to 30 g/l H₂SO₄, there is a need for solvent-extraction (SX) plants to treat pregnant leach solutions (PLS) of higher copper and acid concentrations than those generated by traditional heap leach operations (3-6). For this application, it is desirable that an extractant exhibit high copper-transfer capacity, and that the extractant concentration in the organic phase be as high as practically possible to reduce the advance organic-to-aqueous (O:A) volumetric flowrate ratio in the extraction circuit. By operating at an extractant concentration of 50 vol.%, instead of the current practical limit of 30 vol.%, the extraction O:A could be reduced by half, significantly reducing the size of the mixer settlers by up to 50%.

Of the commercial operations that use high extractant concentrations, in Chile, Chuquicamata currently operates at 29 vol.% LIX Chuqui TB (a custom blend of components), although they have run as high as 35 vol.% for a brief six-month period; Lomas Bayas operated for three years at 29 vol.% LIX 84-I before dropping to the current 27 vol.% as the PLS tenor dropped; Tesoro operates at 22 vol.% LIX 84-I; Collahuasi and Radomiro Tomic use 26 to 27 vol.% Acorga M5640. In Arizona, Morenci’s Stargo plant has been up to 25 vol.% LIX 984N, while the Mt. Gordon pressure-leach circuit (Australia) currently uses 23 vol.% Acorga M5640.

LIX 612N-LV has recently been introduced to two Arizona SX plants. The Metcalfe plant at Morenci now uses this extractant. The Bagdad SX plant, which treats high copper PLS from their pressure leach process combined with dump-leach solution, has recently changed from LIX 984N to LIX 612N-LV (7).

Since these two new extractants offer significant advantages for the SX processing of pressure leach liquors, the aim of this study was to compare the performances of LIX 612N-LV and LIX 6422N with other common extractants for potential application to pressure leach liquors of interest to Anglo American plc. In particular, solution compositions typical of the autoclave discharge liquors arising from...
the AAC/UBC pressure leaching process (8) were tested. Initial laboratory testwork was
carried out using synthetic liquors, however PLS generated during the Hudson Bay
(HBMS) 777 integrated pilot-plant campaign (AAC/UBC pressure leaching of a
chalcopyrite concentrate containing ~ 24% Cu) (9) was also evaluated. A mini-plant trial
enabled further comparison of chemical and physical performance of the extractants to be
undertaken under continuous operating conditions.

EXPERIMENTAL

Aqueous and Organic Phases

Synthetic solutions of varying copper and acid concentrations, made up using
chemically pure reagents and representing typical ranges of pressure leach liquors, were
employed for most testwork. Selected laboratory experiments and the final day of the
mini-plant campaign employed actual liquor generated during the HBMS 777 piloting
campaign (9), the composition of which is shown in Table I. The strip liquor simulated a
typical copper electrowinning spent electrolyte (SE) (37 g/l Cu, 180 g/l H₂SO₄).

Table I – Composition of Autoclave Discharge Liquor from the
AAC/UBC Pressure Leaching of the HBMS 777 Chalcopyrite Concentrate

<table>
<thead>
<tr>
<th>Element</th>
<th>Concentration (g/l)</th>
<th>Element</th>
<th>Concentration (g/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>0.32</td>
<td>Mn</td>
<td>0.03</td>
</tr>
<tr>
<td>Ca</td>
<td>0.39</td>
<td>Ni</td>
<td>0.01</td>
</tr>
<tr>
<td>Co</td>
<td>0.08</td>
<td>Si</td>
<td>0.30</td>
</tr>
<tr>
<td>Cu</td>
<td>27.1</td>
<td>Zn</td>
<td>13.7</td>
</tr>
<tr>
<td>Fe</td>
<td>4.43</td>
<td>H₂SO₄</td>
<td>20.0</td>
</tr>
<tr>
<td>Mg</td>
<td>0.39</td>
<td>pH</td>
<td>0.9</td>
</tr>
</tbody>
</table>

The extractants tested were LIX 984N (1:1 mixture of C₉ ketoxime and C₉
aldoxime), and LIX 612N-LV and LIX 6422N (C₉ aldoximes with proprietary low-
viscosity modifiers) supplied by Cognis, and Acorga M5774 (ester-modified C₉
aldoxime) supplied by Avecia. The extractants were made up to the required
concentrations in Escaid 100, a partially aromatic (~ 25 vol.%) diluent supplied by
ExxonMobil Chemical. Prior to use, each organic phase was contacted at a phase ratio of
unity for 15 min with a standard solution comprising 160 g/l H₂SO₄ and 35 g/l Cu.

Extraction and Stripping Isotherms

Isotherms were generated by contacting the appropriate aqueous and organic
phases at various volumetric phase ratios by magnetic stirring for 10 min. The phases
were then allowed to separate, filtered to remove entrainment, and analysed for copper
content.
Kinetics and Settling Tests

The two phases were contacted in a standard reaction vessel under aqueous- and organic-continuous mixing conditions using standard procedures (10). Samples of the agitated mixture were taken after 30 and 300 s of mixing, and the organic phase analysed for copper content. Following 300 s mixing, the time required for complete phase disengagement was measured.

Mini-Plant Equipment and Procedures

A continuous mini-plant trial was run for seven days, operating for 8 hours per day. The four extractants were tested simultaneously, and every attempt was made to maintain identical operating conditions for all four circuits. Each circuit comprised two extraction stages and a single strip stage (Figure 1).

Extractant concentration was 50 vol.%. Synthetic PLS was initially used, having copper and acid concentrations similar to those of a typical autoclave discharge liquor from the AAC/UBC process (30 g/l Cu, 20 g/l H₂SO₄). The final shift of the campaign employed pressure leach liquor produced during the HBMS piloting campaign (Table 1).

The mini-plant was constructed of polypropylene. Each mixer had a volume of 100 cm³ and an initial settling area of 74 cm². After three days of operation, the settling area was reduced by 50% by inserting plastic blocks into the settlers, which occupied about one half of the settler volume. A photograph of the equipment is given in Figure 2.

The PLS, stripped organic phase (SO), and SE were pumped into the plant via Watson Marlow peristaltic pumps. The PLS and SE were fed from common bulk storage tanks, while stripped organic phase reservoirs were used. Inter-stage solution transfer was achieved by means of flat-vane pumping impellers. No recycles were included because of the small size of the plant, and all stages exhibited organic-continuous mixing.

The advance O:A in each extraction circuit was maintained at 2:1, while that of the strip circuits was 1.5:1. Flowrates of the PLS, SE, and SO were monitored hourly.
The impeller rotation speeds, set at 1260 rpm, were also regularly monitored. The circuits were operated at ambient temperature to highlight any effect of poor phase separation.

Daily samples of the PLS and SE were analysed for Cu and H₂SO₄. Raffinate (E2aq), advance electrolyte (AE) (S1aq), loaded organic (E1org), and stripped organic (S1org) samples were taken at the end of each day and assayed for copper to allow mass balances and plant performance to be determined. Outgoing aqueous streams (E2aq and S1aq) were analysed twice per day for entrained organic content.

Analyses

Aqueous-phase copper analyses were carried out by inductively coupled plasma-optical emission spectroscopy. The organic phases were back-stripped into 500 g/l H₂SO₄ at an O:A of 2:5, and the resulting aqueous phase assayed for copper.

Aqueous-phase organic entrainments were measured using an Aquadoc total organic carbon (TOC) analyser. The method involves the photocatalytic degradation of the organic components, and the resulting CO₂ analysed by infrared spectroscopy. Densities of the various phases were measured using a Paar DMA 35 N density meter, while dynamic viscosities were measured using a Mettler RM180 Rheomat instrument.
RESULTS OF LABORATORY TESTWORK

Extraction Characteristics

Effect of Copper Concentration

The influence of the extractant on the extraction isotherms measured at 30 vol.% extractant concentration and a PLS acid concentration of 10 g/l $H_2SO_4$ are shown in Figures 3 to 5 for copper concentrations ranging from 20 to 60 g/l. At 30 vol.% extractant concentration, and relatively low copper and acid tenors in the PLS, the low viscosity LIX 612N-LV and LIX 6422N appear to have marginally more favourable extraction characteristics than the other two extractants. However, as copper tenor increases with no increase in acid concentration and maximum loading on the organic phase is reached, any advantage is nullified.

Figure 3 – Extraction of Copper from 20 g/l Cu, 10 g/l $H_2SO_4$ by 30 vol.% Extractant

Figure 4 – Extraction of Copper from 40 g/l Cu, 10 g/l $H_2SO_4$ by 30 vol.% Extractant
Effect of Acid Concentration

Comparison of Figures 4, 6, and 7 shows the effect of increasing the acid content of the PLS from 10 to 30 g/l H₂SO₄ for a fixed copper concentration (40 g/l). The two low-viscosity extractants show some advantage as the acidity of the PLS increases. For circuits using the AAC/UBC leaching process (and certain other processes), this feature could have a significant effect on copper-transfer capacity in the SX plant.
Effect of Extractant Concentration

The effect of increasing the extractant concentration from 30 to 50 vol.% for the extraction of 60 g/l Cu in 10 g/l H₂SO₄ is shown in Figure 8 for LIX 612N-LV. Similar results were obtained for LIX 6422N. The copper extraction characteristics of the four extractants at 50 vol.% concentration (Figure 9) shows that their chemical behaviour is very similar for the processing of a low-acid PLS (10 g/l H₂SO₄). As shown above, this performance is expected to deteriorate with increasing PLS acid strength.
Processing of HBMS Autoclave Discharge Liquor

Pressure leach liquor originating from a continuous pilot-plant campaign using the AAC/UBC process for the leaching of Hudson Bay 777 chalcopyrite concentrate (9) was treated for copper extraction using the two new extractants. The results for LIX 6422N are compared with two of the synthetic solutions in Figure 10. As expected, at a given acid strength, the loading increases with copper concentration, while for a given copper concentration, the loading decreases with increasing acid strength. The influence of acid strength is more important than copper concentration in determining loading behaviour – as would be expected from the equilibrium of the extraction reaction. No adverse physical effects, crud formation, or phase-separation problems were observed.
**Stripping Characteristics**

All extractants demonstrated satisfactory stripping performance, as shown in Figure 11 for an extractant concentration of 30 vol.%, and Figure 12 for the low-viscosity extractants at 50 vol.% concentration.

![Figure 11 – Stripping of Copper from 30 vol.% Extractant by 37 g/l Cu, 180 g/l H₂SO₄](image1)

![Figure 12 – Stripping of Copper from 50 vol.% Extractant by 37 g/l Cu, 180 g/l H₂SO₄](image2)

**Extraction Kinetics and Phase Separation**

As shown, the chemical behaviour of the four extractants was very similar. It was also essential to evaluate their physical behaviour under the high-tenor PLS conditions. The effect of the different modifiers in the circuits was likely to be significant in influencing entrainment losses, settling rates, and other physical characteristics of the SX systems, as well as affecting reaction kinetics.
The kinetics of copper extraction and the rate of phase disengagement were measured as a function of extractant, extractant concentration, and phase continuity of mixing under standard test conditions (10). The extraction kinetics (defined as the Cu loaded after 30 s mixing as a percentage of the loading after 300 s mixing) and relative settling times are presented in Table II.

Table II – Kinetics and Settling Rate for Copper Extraction from 60 g/l, 10 g/l H₂SO₄

<table>
<thead>
<tr>
<th>Extractant</th>
<th>Extractant Concentration (vol.%)</th>
<th>Extraction Kinetics (%)</th>
<th>Settling Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aqueous-Continuous</td>
<td>Organic-Continuous</td>
<td>Aqueous-Continuous</td>
</tr>
<tr>
<td>LIX 984N</td>
<td>30</td>
<td>92</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>88</td>
<td>95</td>
</tr>
<tr>
<td>Acorga M5774</td>
<td>30</td>
<td>97</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>90</td>
<td>99</td>
</tr>
<tr>
<td>LIX 612N-LV</td>
<td>30</td>
<td>97</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>96</td>
<td>98</td>
</tr>
<tr>
<td>LIX 6422N</td>
<td>30</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>93</td>
<td>90</td>
</tr>
</tbody>
</table>

The approach to equilibrium was very similar for all extractants at a given concentration, although the rate of extraction slowed with increasing extractant concentration (although less so for the two low-viscosity extractants). Under organic-continuous mixing conditions, the kinetics were slightly enhanced.

Phase separation for all extractants at 50 vol.% was comparable. The extremely fast phase separation for the Acorga M5774 at 30 vol.% concentration is somewhat surprising: too fast a phase break may cause “aqueous locking” in secondary mix stages. It may also reduce coalescence opportunities for very fine entrained droplets in the settler of a conventional mixer settler, resulting in increased entrainment losses. Entrained loss will, however, also depend on the characteristics of the contactor used.

RESULTS OF CONTINUOUS MINI-PLANT TRIAL

The comparative chemical and physical characteristics of the four extractants were examined under continuous operating conditions in a simple mini-plant trial. The main objectives of this campaign were to compare the extraction and stripping behaviour of copper, and the relative organic losses to the raffinate and advance electrolyte. A synthetic PLS of similar copper and acid concentrations to that produced in the AAC/UBC process was employed, with actual HBMS pilot-plant autoclave discharge liquor being run through the circuit on the final day.
Extraction Performance

Figure 13 shows that the best copper extraction for this PLS composition (30 g/l Cu, 20 g/l H2SO4) was achieved using LIX 6422N, followed by Acorga M5774. This is supported by the measured maximum loading capacities and extraction efficiencies achieved by each organic phase used in the mini-plant campaign (Table III). Acorga M5774 exhibited slightly higher copper loading than the LIX extractants. The extraction efficiencies of LIX 984N and Acorga M5774 dropped when processing the HBMS liquor, while those of the two low-viscosity extractants improved.

Table III – Extraction Performance under Continuous Operating Conditions

<table>
<thead>
<tr>
<th>Extractant</th>
<th>Maximum Loading (g/l Cu)</th>
<th>Extraction Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Synthetic PLS</td>
<td>HBMS PLS</td>
</tr>
<tr>
<td>LIX 984N</td>
<td>22.8</td>
<td>54</td>
</tr>
<tr>
<td>Acorga M5774</td>
<td>24.0</td>
<td>63</td>
</tr>
<tr>
<td>LIX 612N-LV</td>
<td>23.8</td>
<td>60</td>
</tr>
<tr>
<td>LIX 6422N</td>
<td>22.4</td>
<td>65</td>
</tr>
</tbody>
</table>

Table IV provides an analysis of the main impurities present on the loaded organic phase when the HBMS pressure leach liquor was processed. Since these samples were filtered prior to analysis, these data can be considered to represent impurity transfer by chemical means, rather than by physical transfer. The two low-viscosity extractants show marginally improved selectivity over iron and zinc, which are present in fairly high concentrations in this PLS (Table I). The chemical transfer of all other impurity elements was at the analytical detection limit (2.5 mg/l) and was comparable for all extractants.
Table IV – Co-Extraction of Impurities from HBMS 777 Autoclave Discharge Liquor

<table>
<thead>
<tr>
<th>Element</th>
<th>Concentration on Loaded Organic Phase (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LIX 984N</td>
</tr>
<tr>
<td>Fe</td>
<td>8</td>
</tr>
<tr>
<td>Zn</td>
<td>15</td>
</tr>
</tbody>
</table>

Physical Characteristics and Phase Separation

The densities of the various phases are presented in Table V, as measured under steady-state operating conditions. Also shown is the density difference for a given stage, as this has important implications for the settling rate (and hence on the settler design). The viscosities of the mini-plant organic phases are shown in Table VII.

For application to high copper tenor solutions, the LIX extractants all show lower viscosities and greater inter-phase density differences than Acorga M5774. In the absence of agitation, the latter extractant could not be maintained in homogeneous organic solution at 50 vol.% concentration, and a differential concentration gradient through the organic reservoir was experienced during the mini-plant campaign.

Table V – Densities of the Mini-Plant Aqueous and Organic Phases

<table>
<thead>
<tr>
<th>Extractant</th>
<th>Density (g/cm³)</th>
<th>E1aq</th>
<th>E1org</th>
<th>ΔE1</th>
<th>E2aq</th>
<th>E2org</th>
<th>ΔE2</th>
<th>S1aq</th>
<th>S1org</th>
<th>ΔS1</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIX 984N</td>
<td>1.070</td>
<td>0.881</td>
<td>0.189</td>
<td></td>
<td>1.060</td>
<td>0.872</td>
<td>0.240</td>
<td>1.223</td>
<td>0.871</td>
<td>0.352</td>
</tr>
<tr>
<td>Acorga M5774</td>
<td>1.068</td>
<td>0.917</td>
<td>0.151</td>
<td></td>
<td>1.058</td>
<td>0.906</td>
<td>0.152</td>
<td>1.221</td>
<td>0.902</td>
<td>0.319</td>
</tr>
<tr>
<td>LIX 612N-LV</td>
<td>1.072</td>
<td>0.889</td>
<td>0.192</td>
<td></td>
<td>1.061</td>
<td>0.885</td>
<td>0.176</td>
<td>1.223</td>
<td>0.876</td>
<td>0.347</td>
</tr>
<tr>
<td>LIX 6422N</td>
<td>1.070</td>
<td>0.886</td>
<td>0.184</td>
<td></td>
<td>1.069</td>
<td>0.880</td>
<td>0.189</td>
<td>1.223</td>
<td>0.873</td>
<td>0.350</td>
</tr>
</tbody>
</table>

Table VII – Organic-Phase Viscosities under Mini-Plant Conditions

<table>
<thead>
<tr>
<th>Extractant</th>
<th>Viscosity (cP)</th>
<th>Stripped Organic</th>
<th>Loaded Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIX 984N</td>
<td>7.2</td>
<td>6.9</td>
<td></td>
</tr>
<tr>
<td>Acorga M5774</td>
<td>9.6</td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>LIX 612N-LV</td>
<td>7.7</td>
<td>7.2</td>
<td></td>
</tr>
<tr>
<td>LIX 6422N</td>
<td>8.4</td>
<td>7.4</td>
<td></td>
</tr>
</tbody>
</table>

Reagent Losses

Average organic-phase entrainments in the raffinate and AE are shown in Table VIII. Although it is not readily possible to convert the measured values of mg/l C to an
actual volume of organic phase entrained in the aqueous phase or similar quantitative representation, consideration of the relative values of the measurements is considered valid, since the same diluent was used throughout and the extractants all have similar average molecular masses and C₉ alkyl chain lengths on the oxime molecules.

Table VIII – Organic-in-Aqueous Entrainment for Mini-Plant Processing of Synthetic PLS and HBMS Pilot-Plant Autoclave Discharge Liquor

<table>
<thead>
<tr>
<th>Extractant</th>
<th>Synthetic PLS</th>
<th></th>
<th>HBMS PLS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raffinate AE</td>
<td>Raffinate AE</td>
<td>Raffinate</td>
<td>AE</td>
</tr>
<tr>
<td>LIX 984N</td>
<td>50</td>
<td>20</td>
<td>357</td>
<td>61</td>
</tr>
<tr>
<td>Acorga M5774</td>
<td>34</td>
<td>16</td>
<td>435</td>
<td>157</td>
</tr>
<tr>
<td>LIX 612N-LV</td>
<td>40</td>
<td>17</td>
<td>151</td>
<td>17</td>
</tr>
<tr>
<td>LIX 6422N</td>
<td>82</td>
<td>24</td>
<td>144</td>
<td>49</td>
</tr>
</tbody>
</table>

As is typically observed in these systems, the aqueous-phase acidity has a strong influence on the extent of organic entrainment. In all cases, the organic content of the AE (~150 g/l H₂SO₄) was substantially lower than that of the raffinate (~ 35 g/l H₂SO₄).

A more striking feature of interest to this project, however, was the notable difference in the behaviour of the synthetic PLS compared to the HBMS pilot-plant liquor. The effect of the modifier characteristics on typical measurements of the TOC in the exiting aqueous phases throughout the campaign is shown by a comparison of the data for Acorga M5774 and LIX 612N-LV in Figure 14.

Figure 14 – Organic-in-Aqueous Entrainment during the Mini-Plant Campaign

A critical feature of the AAC/UBC process is the use of surfactants in the pressure leach to act as a dispersant for the product sulphur and thereby prevent the
formation of sulphur balls (8). These surface-active agents or their decomposition products may have adverse effects on the physical properties of the SX system. Table VIII and Figure 14 indicate that the ester-modified aldoxime (Acorga M5774) has significantly worse entrainment losses in the presence of the HBMS liquor than the other extractants. Specifically, the two low-viscosity extractants show much better coalescence characteristics than either of the conventional extractants. This has important implications for the operating cost of extractant replacement, as well as the frequency at which organic-recovery systems or electrolyte filters need to be cycled or serviced.

CONCLUSIONS

Based on the laboratory and mini-plant testwork presented, the low-viscosity modified aldoxime extractants from Cognis exhibit some distinct advantages for processing liquors originating from the pressure leaching of chalcopyrite concentrates. LIX 612N-LV and LIX 6422N appear to offer benefit in terms of good copper extraction from acidic solutions due to their aldoxime functionality, coupled with low organic entrainment losses and good settling characteristics due to their low-viscosity modifiers. These extractants are able to be used at much higher organic-phase concentrations (up to 50 vol.%) than their main competitors, Acorga M5774 and LIX 984N, while no compromise in selectivity was measured. No disadvantages of the low-viscosity extractants relative to the conventional extractants tested were apparent during this testwork.

ACKNOWLEDGEMENTS

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REFERENCES


