

International Solvent Extraction Conference – ISEC 2008

REFINING AND PROCESSING OF PGMs AND GOLD AT THE 18th ISEC

Reviewed by David J. Robinson

The Parker CRC for Integrated Hydrometallurgy Solutions and The Minerals Division, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Waterford, Perth, WA 6152, Australia; E-mail: david.robinson@csiro.au

Following the successful 2005 conference in Beijing (Solvent Extraction for Sustainable Development (1)), the 18th International Solvent Extraction Conference (ISEC 2008), Solvent Extraction: Fundamentals to Industrial Applications, was held in Tucson, Arizona, U.S.A., between 15th and 19th September 2008 (2). The programme emphasised the development from fundamentals to industrial applications of solvent extraction. Session topics were:

- Hydrometallurgy and Metals Extraction
- Process Chemistry and Engineering
- Nuclear Applications
- Analytical and Preparative Chemistry
- Biotechnology, Pharmaceuticals, Life-Science Products and Organic Products
- Fundamentals
- Novel Reagents, Materials and Techniques

The conference followed a traditional format with five excellent plenary lectures from experts in the various fields, five parallel oral programmes, two poster sessions and two panel discussion sessions specifically considering ‘Uranium Processing’ and ‘New Reagents and Their Design’. Full conference proceedings have been published (3).

The interesting and potentially exploitable aspects of the chemistry of the platinum group metals (pgms) in solvent extraction-based refining circuits continue to be of significant interest (4–10). Comments on selected oral and poster presentations most relevant to the furthering of fundamental chemistry, refining and processing of both the pgms and gold are given here under the titles of the sessions in which they appeared (with the relevant page numbers of the aforementioned proceedings given in brackets).

Hydrometallurgy and Metals Extraction

Several systems have been proposed for the replacement of cyanide as a lixiviant for gold and silver, and a thermodynamic model has been developed by G. T. Lapidus *et al.* (Universidad Autónoma Metropolitana-Iztapalapa, Mexico) (pp. 299–304) for the precious metal complexes extracted from an ammonium copper thiosulfate solution. Similarly, the use of thiourea as an alternative to cyanide for the recovery of gold and silver has several advantages, including improved kinetics and lower toxicity of the reagents. Z. Gamino-Arroyo *et al.* (École Centrale Paris, France) (pp. 293–298) presented a mechanistic study of the extraction of precious metals from a di(2-ethylhexyl)dithiophosphoric acid solution system. A study of the influence of residual gold on the solvent extraction-based recovery of cyanide from more traditional industrial cyanidation liquors was presented by M. B. Mansur *et al.* (Universidade Federal de Minas Gerais, Brazil) (pp. 311–316).

As part of the capacity expansion project within the Anglo Platinum Precious Metals Refinery in South Africa, S. F. Woollam (Anglo Research, South Africa) and R. A. Grant (Johnson Matthey Technology Centre (JMTC), U.K.) (pp. 281–286) observed a significant increase in the rate of acid-catalysed degradation of the hydroxyoxime LIX 84I in the palladium solvent extraction circuit when the reagent concentration was increased. However, a reduction in strip acid concentration was found to alleviate this problem sufficiently, while leaving phase disengagement and overall strip circuit efficiency at acceptable levels. A number of reagents have been reported previously as

useful extractants for gold(III) from hydrochloric acid solutions, and more recently the use of liquid membranes for such a process has been described. An interesting poster by C. Vargas *et al.* (Instituto Politécnico Nacional, Mexico) (pp. 287–292), considering gold(III) extraction with 2-ethylhexanol, introduced ‘emulsion petraction’ in a hollow-fibre contactor, an arrangement which enjoys the benefits of the liquid membrane approach without the often-associated problems.

Process Chemistry and Engineering

Improved recovery of the entrained organic phase from the raffinate at the Morenci Mine operations of Freeport-McMoRan Copper and Gold, Inc (FMCG), U.S.A., was achieved using a Krebs hydrocyclone unit. The results were reported by M. A. Thumberg and E. P. Kramer (FMCG, U.S.A.) (pp. 491–496). R. A. Grant *et al.* (JMTC, U.K.) (pp. 415–420) presented the development of a computer simulation of the solvent extraction of platinum from a chloride matrix using an Amberlite LA-2 (a secondary amine) based system. This approach enabled several flow sheet options to be simulated and the results of the selected configuration were validated in a subsequent mini-pilot plant trial.

Nuclear Applications

A range of polycyclic molecules has been developed and tested for the separation of actinides from lanthanides. The method is potentially useful in a spent nuclear fuel treatment flow sheet, where the resistance of reagents to ionising radiation is clearly an issue. A presentation by A. Fermvik *et al.* (Chalmers University of Technology,

Sweden) (pp. 551–556) reported the accelerated degradation after irradiation of C5-BTBP in cyclohexanone and the detrimental effect this has on such a separation. The presentation also addressed the associated department of fission products, including palladium and silver.

The less than ideal department of ruthenium in otherwise very promising simulated and ‘hot’ trials of the diglycolamide derivative TODGA/TBP process for the recovery of trivalent actinides from a PUREX (11) raffinate was reported by G. Modolo *et al.* (Institute for Energy Research, Germany) (pp. 521–526). Another PUREX raffinate treatment strategy involves the DIAMEX process developed by the French Atomic Energy Commission (Commissariat à l’énergie atomique, CEA), which employs a malondiamide as the extractant. Results from the successful recent tests on the DMDOHEMA malonamide based step of this process, including palladium department, were presented by C. Sorel *et al.* (pp. 715–720) from the CEA, France.

Fundamentals

Recovery and separation of the chloro complexes of the pgms continue to attract considerable research due to their fundamental interest and relevance to the pgm refining industry. For example, the rapid and highly selective recovery of palladium(II) from hydrochloric acid solutions in the presence of platinum(IV) using sulfur-containing monoamide and diamide compounds was presented by H. Narita *et al.* (National Institute of Advanced Industrial Science and Technology, Japan) (pp. 1445–1450). The results compared well to the slower separation achieved using more

Glossary

BDPDA: bis(2,2'-dipyridyl-6-yl)diazene

C5-BTBP: 6,6'-bis-(5,6-dipentyl-[1,2,4]triazin-3-yl)-[2,2']bipyridinyl

DIAMEX process: **D**iamide **E**xtraction process

DMDOHEMA: *N,N'*-dimethyl-*N,N'*-dioctylhexylethoxymalonamide

LIX 84I: (2'-hydroxy-5'-nonylacetophenone oxime)

PUREX process: **P**lутonium-**U**ranium **E**xtraction process (for spent nuclear fuel)

TBP: tributylphosphate

TODGA: *N,N,N',N'*-tetraoctyldiglycolamide

conventional dialkylsulfide extractants. The effect of hydrochloric acid concentration on the kinetics and equilibrium data for the extraction of palladium(II) with novel pyridine carboxamide and phosphonium ionic liquid systems was reported by M. Wisniewski *et al.* (Institute of Chemical Technology and Engineering, Poznan, Poland) (pp. 1295–1300), although reported issues with phase separation and solids formation will be the next hurdles to overcome with these systems.

M. G. Sánchez-Loredo *et al.* (Universidad Autónoma de San Luis Potosi, Mexico) (pp. 1049–1055) presented a series of polyamines based on the tris(2-aminoethyl)amine (tren) platform, together with results from testing these as extractants for the chloro complexes of palladium(II), platinum(II), rhodium(III) and ruthenium(III). The isolation and crystal structure characterisation of the complex $[2(\text{trenH}_4)^{4+} \cdot 2(\text{PdCl}_4)^{2-} \cdot 4\text{Cl}^- \cdot \text{H}_2\text{O}]$ during this study helped to confirm the importance of water in some of these structures. Similarly, P. A. Tasker *et al.* (University of Edinburgh, U.K.) (pp. 1457–1462) presented a series of new tripodal amido and urea group-based anion-binding ligands as potential extractants for $[\text{PtCl}_6]^{2-}$ from acidic chloride solutions, Figure 1. Much greater selectivity for the complex anion over chloride was reported compared to model reagents such as trioctylamine.

The radiation-induced interconversion of isomers of BDPDA from their *trans* to *cis* configurations was demonstrated by observing an

increase in the resulting distribution ratio for gold(III), although K. Takeshita *et al.* (Tokyo Institute of Technology, Japan) (pp. 1505–1511) currently consider the process impractical for use. The introduction of a synergist, octanoic acid, into this system was effective for improving the extraction performance significantly and may offer further development opportunities.

The efficient extraction of soft metal ions, including silver(I) and palladium(II), onto various copolymers of *N*-isopropylacrylamide and thioethers was reported by K. Chayama *et al.* (Konan University, Japan) (pp. 1585–1590). Some potential for enhanced selectivity may encourage further development of these systems.

Conclusions

The International Solvent Extraction Conference series (1, 2, 12), with its traditionally associated short course and technical tours (see Figure 2), continues to be the preeminent forum for sharing both incremental changes and breakthrough developments in operational practice and fundamental science and engineering in this area of technology. As long as solvent extraction technology continues to be an attractive option to pgm producers, this conference should remain on the calendars of anyone with an interest in this area. The organisers are to be congratulated on a fine conference and we look forward to the nineteenth such conference, ISEC 2011, which will be held in Santiago, Chile, between 16th and 20th October 2011 (12).

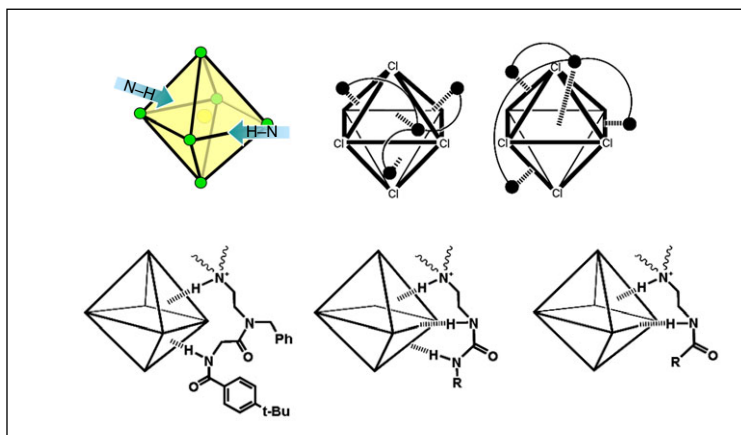


Fig. 1 Possible binding modes for the amide and urea arms of the tripodal reagents used as potential extractants for $[\text{PtCl}_6]^{2-}$ from acidic chloride solutions, as presented by P. A. Tasker *et al.*, University of Edinburgh, U.K. (pp. 1457–1462) (3)



Fig. 2 Typical copper mixer settler as seen on the ISEC post-conference technical tour

References

- 1 ISEC 2005: <http://www.meeting.edu.cn/webmedia/jingpin/meet4/index.htm> (Accessed on 16th March 2009)
- 2 ISEC 2008: <http://www.isec2008.org/> (Accessed on 5th March 2009)
- 3 “Solvent Extraction: Fundamentals to Industrial Applications, Proceedings of ISEC 2008 International Solvent Extraction Conference”, ed. B. A. Moyer, The Canadian Institute of Mining, Metallurgy and Petroleum, Montreal, Canada, 2008, in 2 vols., 1661 PP
- 4 M. J. Cleare, P. Charlesworth and D. J. Bryson, *J. Chem. Technol. Biotechnol.*, 1979, 29, (4), 210
- 5 P. Charlesworth, *Platinum Metals Rev.*, 1981, 25, (3), 106
- 6 I. E. Cottington, *Platinum Metals Rev.*, 1983, 27, (3), 110
- 7 L. R. P. Reavill, *Platinum Metals Rev.*, 1984, 28, (1), 2
- 8 J. Yu, *Platinum Metals Rev.*, 2005, 49, (4), 189
- 9 D. J. Robinson and M. Arendse, *Platinum Metals Rev.*, 2007, 51, (1), 36
- 10 P. Malik and A. P. Paiva, *Solvent Extr. Ion Exch.*, 2009, 27, (1), 36
- 11 G. R. Choppin, J.-O. Liljenzin and J. Rydberg, “Radiochemistry and Nuclear Chemistry”, 3rd Edn., Butterworth-Heinemann, Woburn, Massachusetts, U.S.A., 2002, p. 627
- 12 ISEC 2011: http://www.isec2011.com/evento_2011/ (Accessed on 16th March 2009)

The Reviewer



David John Robinson was active in both fundamental and applied pgm chemistry research, and in particular, the development of improved separation technologies, over a fifteen-year career with Anglo Platinum. He was involved directly in their production process at the modern precious metals refinery near Rustenburg, South Africa. He is now Research Programme Leader for Base Metals Hydrometallurgy within CSIRO Minerals and Market Leader for Base Metals within the Parker Cooperative Research Centre for Integrated Hydrometallurgy Solutions, Karawara, Western Australia. His interests include developing improved industry-academia research collaborations and applying improved fundamental knowledge to the solution of real metal refining problems. He is active in the areas of fundamental and applied base metal hydrometallurgy and developing advantages for industry through better scientific research, optimising hydrometallurgical processing and efficient technology transfer.