Draslovka

Update on Cyanide-Free Leaching of Gold Using Glycine Leaching Technology

Elsayed Oraby,
Glen O'Malley,
Jacques Eksteen

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Curtin University

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- Continuous Piloting and Demonstration
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Draslovka: Leader in CN-Based Chemistry

- ❑ Global leader in CN-based chemicals
- ❑ World's largest producer of sodium cyanide
- ❑ Private holding company based in the Czech Republic, owned by a leading family with office based in Prague
- ❑ Operations in Czech Republic, United States, Australia, South Africa & India
- ❑ Over 100 years of experience in hydrogen cyanide (HCN) production and chemistry
- ❑ Owners of Mining and Process Solutions (MPS) and the Glycine Leaching Technology developed by Curtin University

Introduction

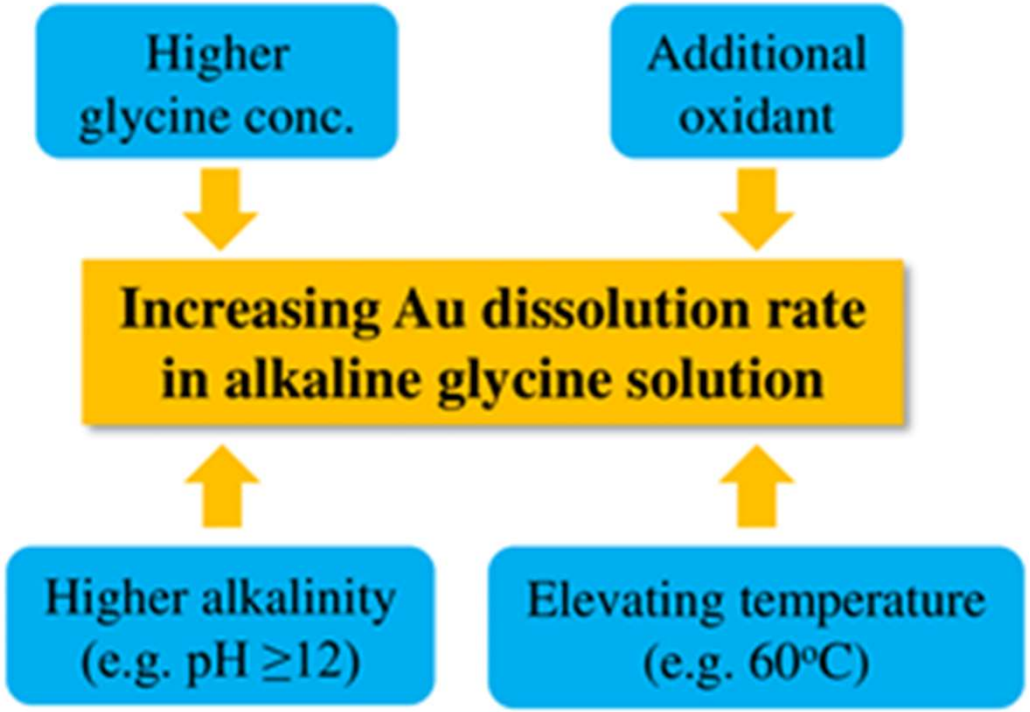
- Cyanidation still remains the best process for the gold extraction because of its efficiency and simplicity.
- However, there are a number of drawbacks associated with the cyanide use
  - Environmental concerns are due to cyanide toxicity
  - High cyanide consumption and low gold recovery in the treatment of complex or refractory gold resources.
- In order to overcome these drawbacks, intensive research has been made to find non-cyanide alternatives to cyanidation.
- These alternatives include thiourea, glycine, thiosulfate, thiocyanate and halides.
- Of all these alternatives, recently glycine has been shown as a promising alternative for gold extraction.

Introduction

- Glycine (NH_2-CH_2-COOH) is a stable amino acid that has various aqueous ionic forms.
- Glycine has a high solubility in water of around 250 g/litre at 25°C, a density of 1.607 kg/ton, molar mass of 75.07 g/mole and a melting point of 233°C.
- Initial research indicated that using only alkaline glycine and air, in the absence of catalyst, leaching times would be too long for conventional agitated tank leaching of ores.
- The leach rate of gold with glycine is significantly slower than with cyanide

Introduction

- Some improvement has been reported with a combination of high temperature and high pH, but the rate is still less than cyanide.
- More development of the glycine leaching technology has been shown comparable extraction to cyanide.



Options of Glycine Leaching Technology

GlyCat™
Glycine + NaCN

Leaching of Gold, Silver and PGMs

GlyLeach™
Glycine + Additive

Leaching of **Copper, Nickel, Zinc, Gold, Silver, PGMs and Cobalt**

GlyAmm™
Glycine + Ammonia

Leaching of **Copper, Nickel, Zinc, and Cobalt** Sulphide

GT™
Glycine + Thiourea

Leaching of **Gold, Silver, Copper** and **Rare Earths**

Introduction

Options of cyanide-free glycine based leaching systems

- Glycine leaching-High Temperature
- Glycine leaching-High pH
- Glycine-Strong Oxidant
  - Glycine-Permanganate
  - Glycine-Ferricyanide
- Glycine-Thiourea for acidic leaching

GlyLeach™ Chemistry

❑ Gold

$$Au^{+} + 2\,NH_3CH_2COO^{-} \rightarrow Au(NH_2CH_2COO)_2 \quad logK \sim 18.0$$

$$Au + 2\,NH_2CH_2COO^{-} + 0.25\,O_2 + 0.5\,H_2O \rightarrow Au(NH_2CH_2COO)_2^{-} + OH^{-}$$

❑ Copper

$$Cu + 2\,NH_2CH_2COO^{-} + 0.5\,O_2 + H_2O \rightarrow Cu(NH_2CH_2COO)_2 + 2\,OH^{-}$$

GT™ Chemistry

❑ Gold

$$Au^{+} + 2\,SC(NH)_2 \rightarrow Au(\mathrm{SC(NH)_2})_2^{+} \quad logK = 22.1$$

$$Au + 2\,SC(\mathrm{NH})_2 + Fe^{3+} \rightarrow Au(SC(NH)_2)_2^{+} + Fe^{2+}$$

$$Au^{+} + NH_2CH_2COOH + SC(\mathrm{NH})_2 \rightarrow Au(NH_2CH_2COOH)(SC(NH)_2)_2^{+} \quad logK > 22$$

$$Au + NH_2CH_2COOH + SC(\mathrm{NH})_2 + Fe^{3+} \rightarrow Au(NH_2CH_2COOH)(SC(NH)_2)_2^{+} + Fe^{2+}$$

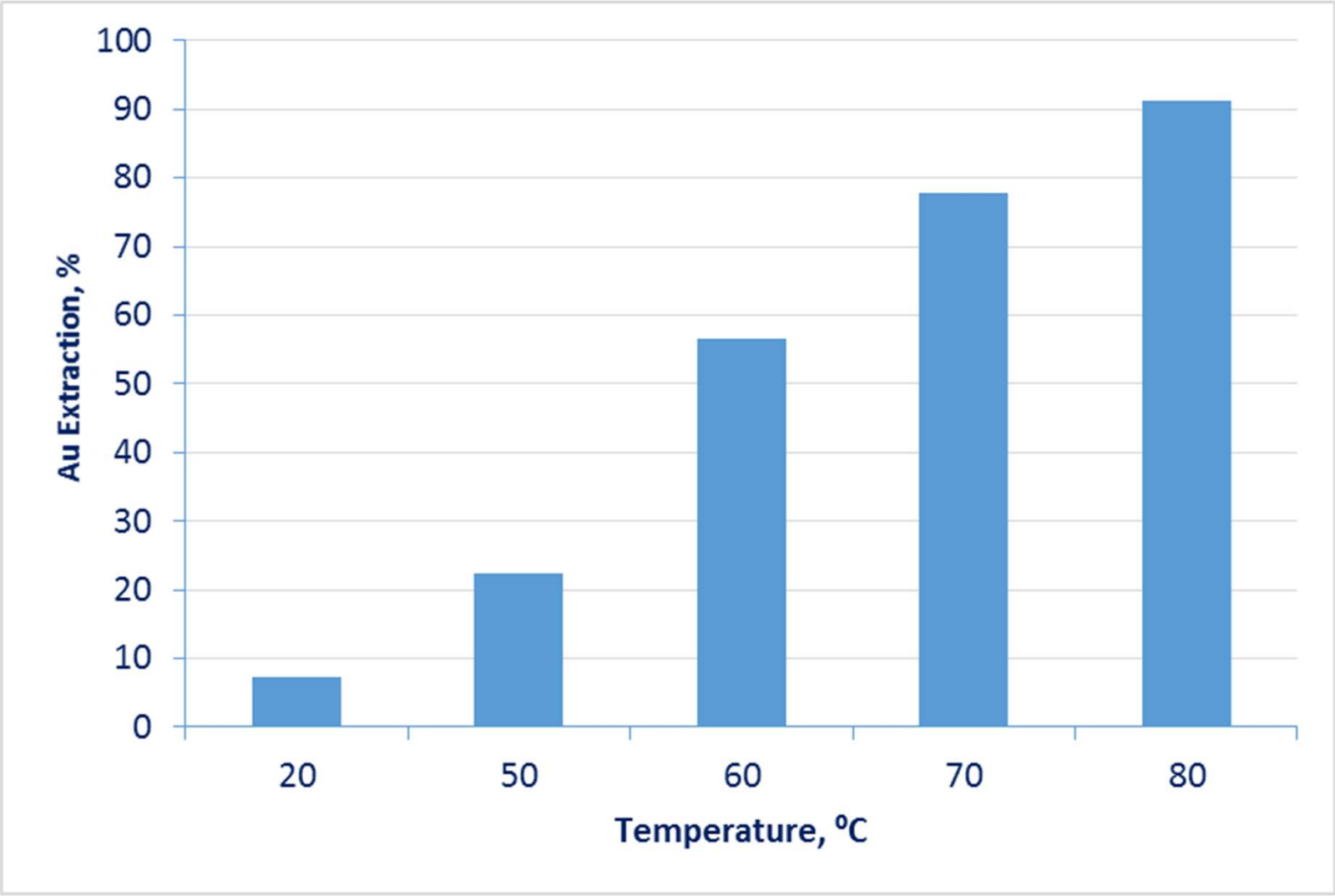
❑ Copper

$$2\,Cu + 2\,\mathrm{SC(NH)_2} + 2\,\mathrm{Fe^{3+}} \rightarrow Cu_2(\mathrm{SC(NH)_2})_2^{2+} + 2\,Fe^{2+}$$

$$Cu + NH_2CH_2COOH + SC(\mathrm{NH})_2 + Fe^{3+} \rightarrow Cu(NH_2CH_2COOH)(SC(NH)_2)_2^{+} + Fe^{2+}$$

GlyLeach™ and Temperature

Gold extraction from oxides ore (1.8 g/t)- **Effect of temperature**



0.2 M Glycine, 20 ppm Cu^{2+}, O_2, pH 10.5-11, 48 hrs

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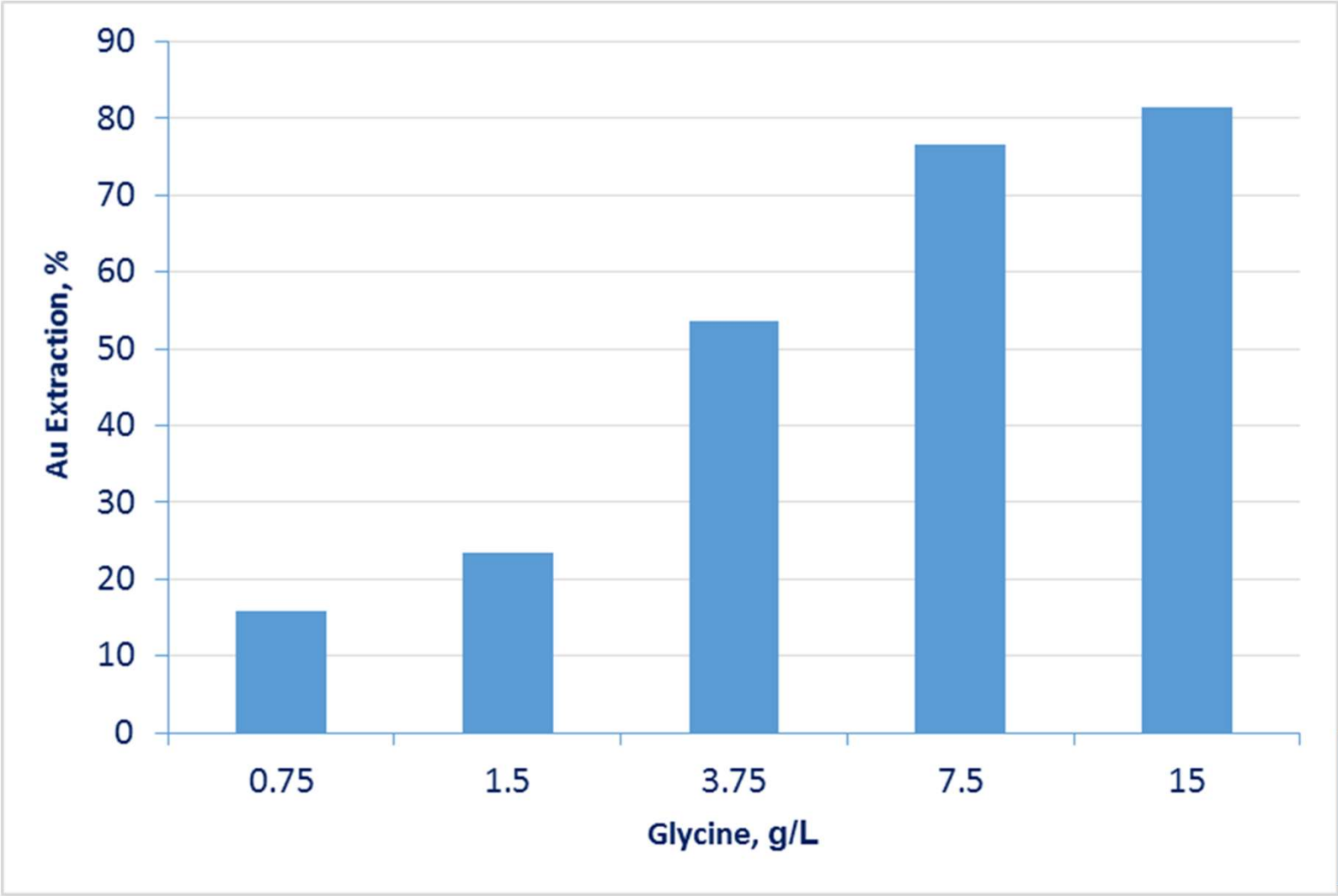
GlyLeach™ and Glycine Concentration

Gold extraction from oxides ore (1.8 g/t)- **Effect of Glycine**



Glycine. 20 ppm Cu^{2+}, O_2, pH 10.5-11, 70 C, 48 hrs

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GlyLeach™ Heated Glycine

Contents lists available at ScienceDirect
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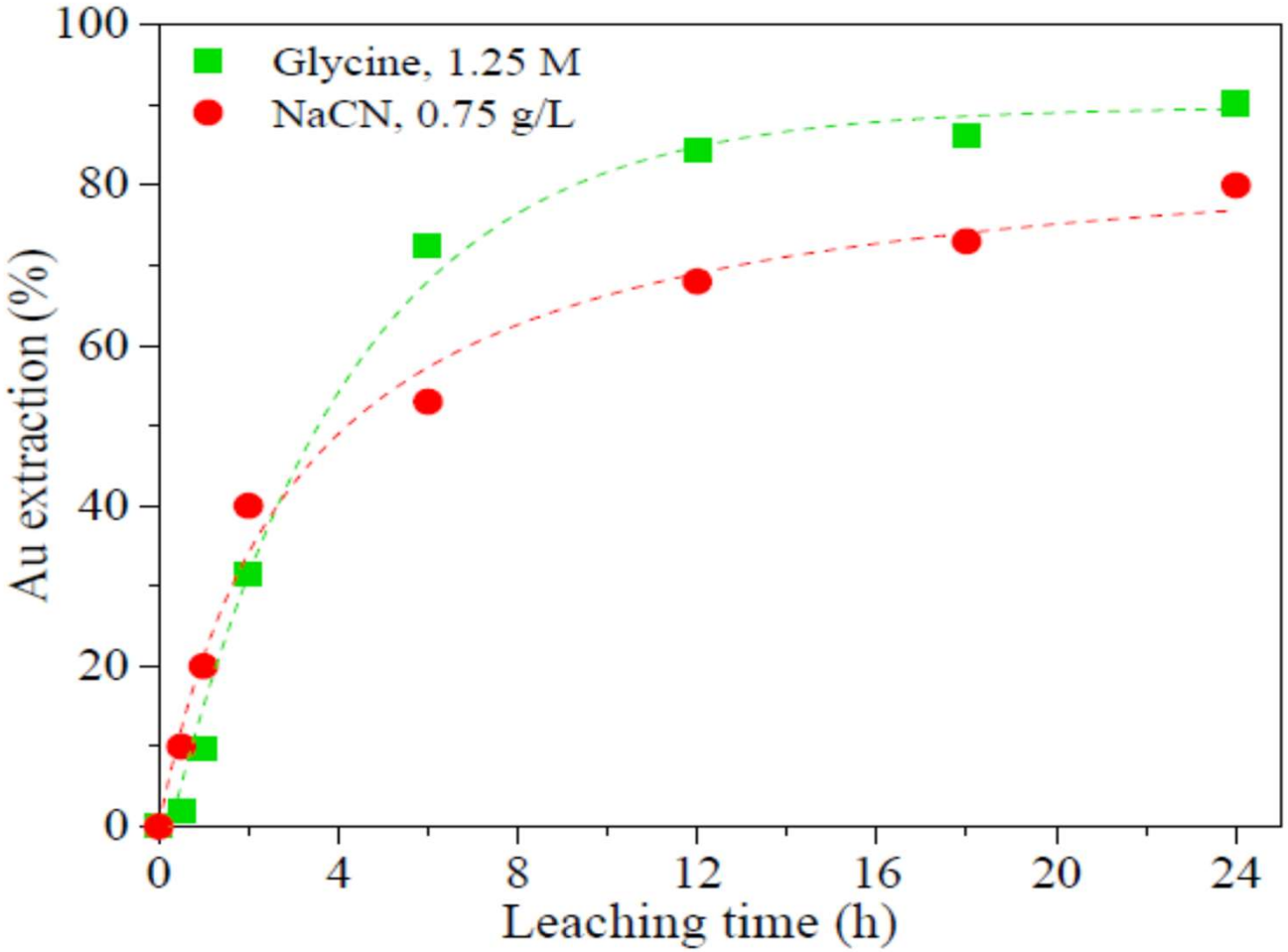
Leaching and recovery of gold from ore in cyanide-free glycine media

Pelin Altinkaya[a,b], Zulin Wang[b], Ivan Korolev[a,b], Joseph Hamuyuni[a], Mika Haapalainen[a], Eero Kolehmainen[a], Kirsi Yliniemi[c], Mari Lundström[b,*]

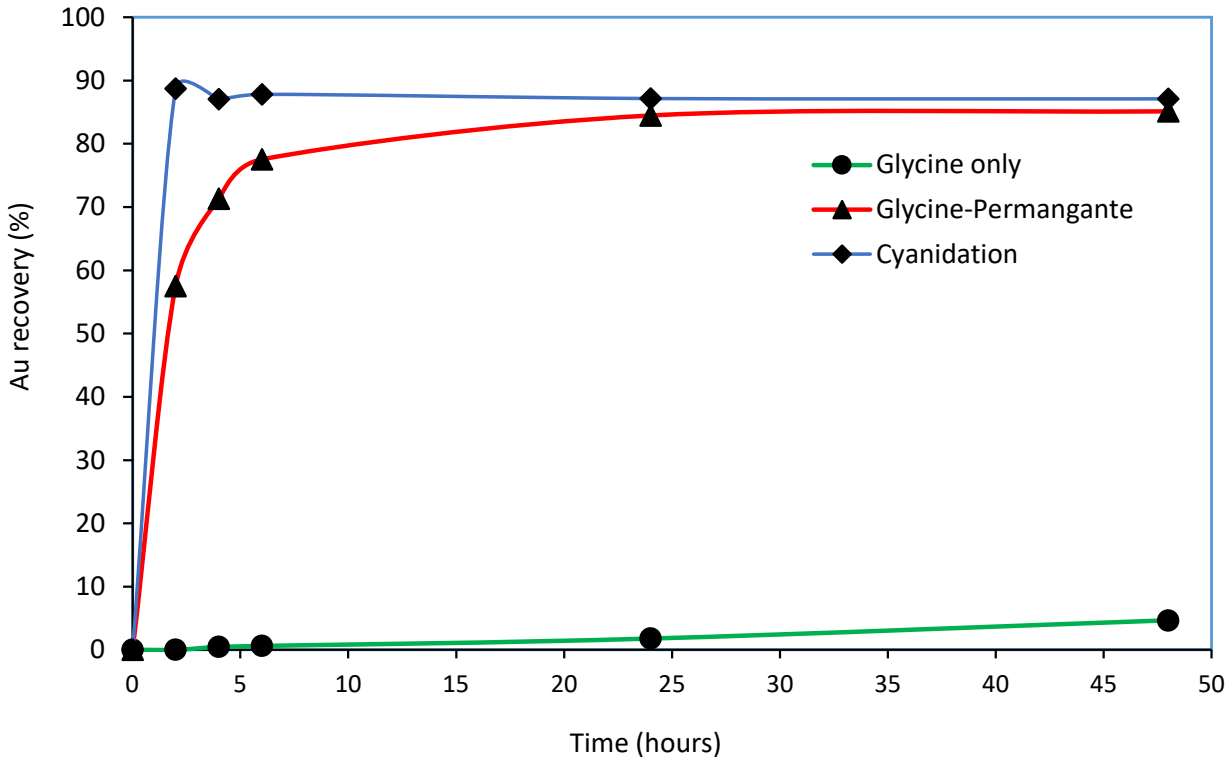
[a] Pori Research Center, Metso Outotec, Kuparitie 10, PO Box 69, 28101 Pori, Finland
[b] Hydrometallurgy and Corrosion, Department of Chemical and Metallurgical Engineering, Aalto University, P.O. Box 16200, Vuorimiehentie 2, 02150 Espoo, Finland
[c] Department of Chemistry and Materials Science, Aalto University, P.O. Box 16100, Kemistintie 1, 02150 Espoo, Finland



Gold extraction from gold oxide ore by glycine at 1.25M glycine, pH 12 and 60C

Glycine-Permanganate

Gold leaching in Glycine-permanganate system

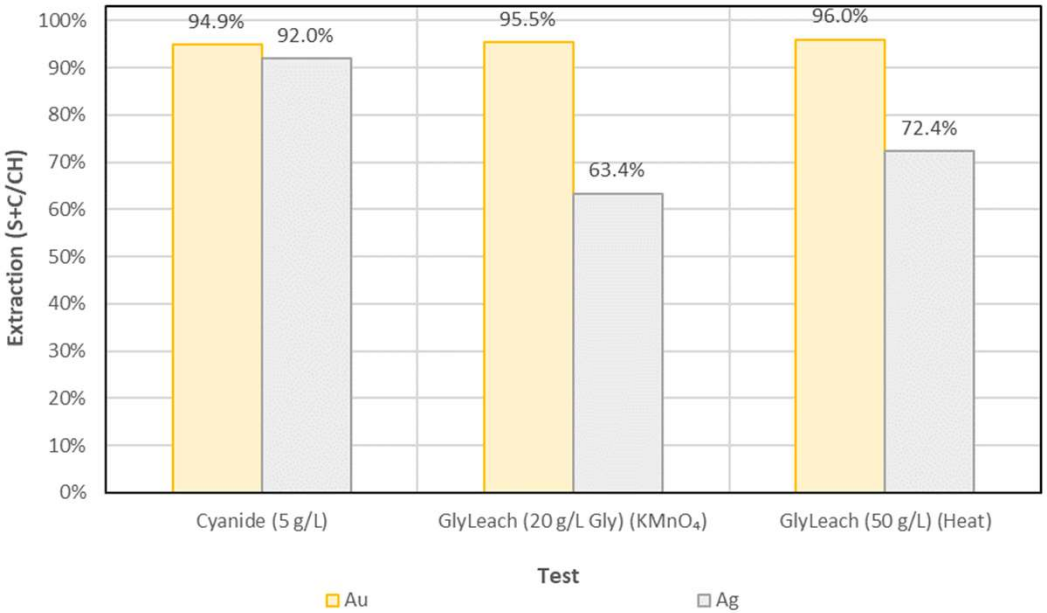


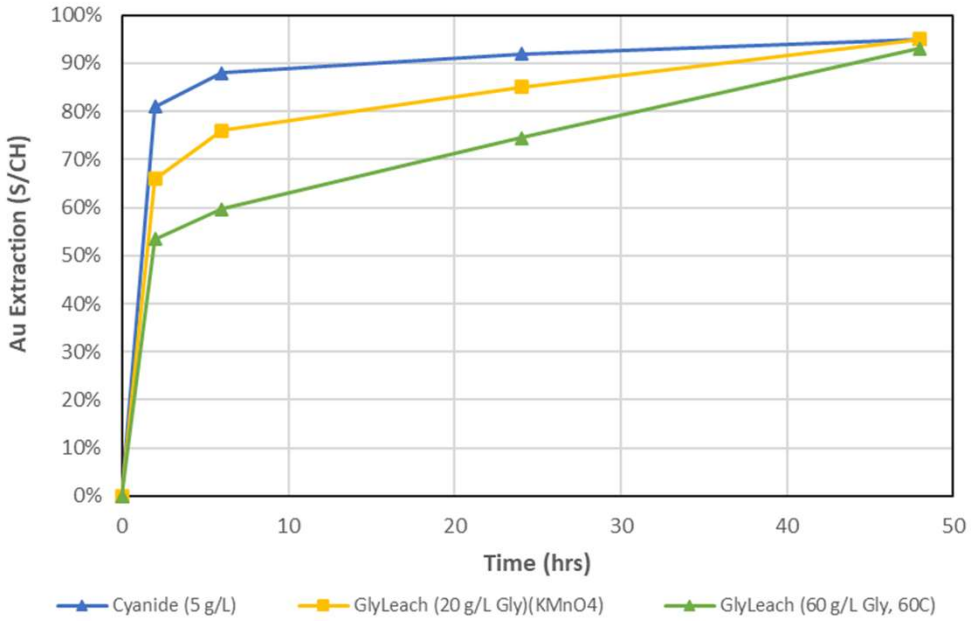
Conditions	Cyanide	Glycine+Reagen
Glycine, g/l	0.0	2.0
Cyanide, ppm	1000	0.0
pH	10.5	10.5
KMnO4, g/l	0.0	2.0

Bottle Roll, Room Temperature, 33% Solids, pH 10.5, 2 g/L Glycine, 2 g/L KMnO4

Ore Leaching Examples

Example 1 - 17.6 g/t Au, 1,245 g/t Ag, 203 g/t Cu

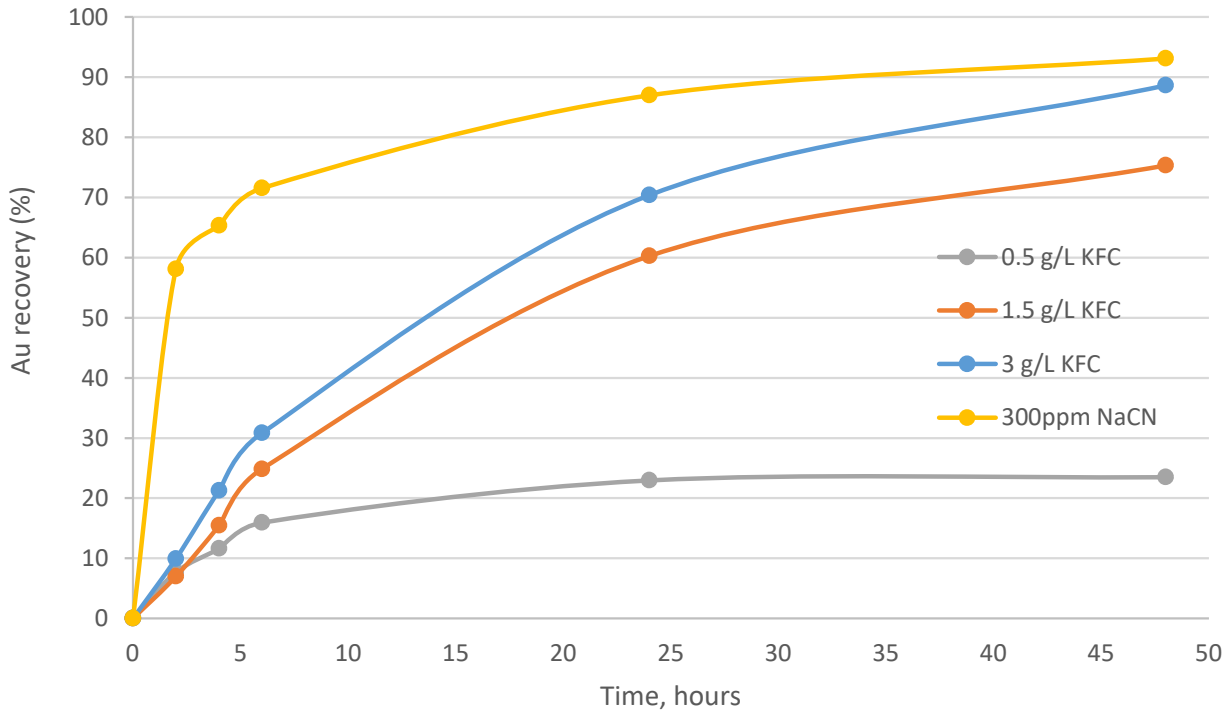




BRTs, 40% Solids, pH 10.5 and room temperature (except last test at 60°C)

Glycine-Ferricyanide

Gold leaching in Glycine-ferricyanide system

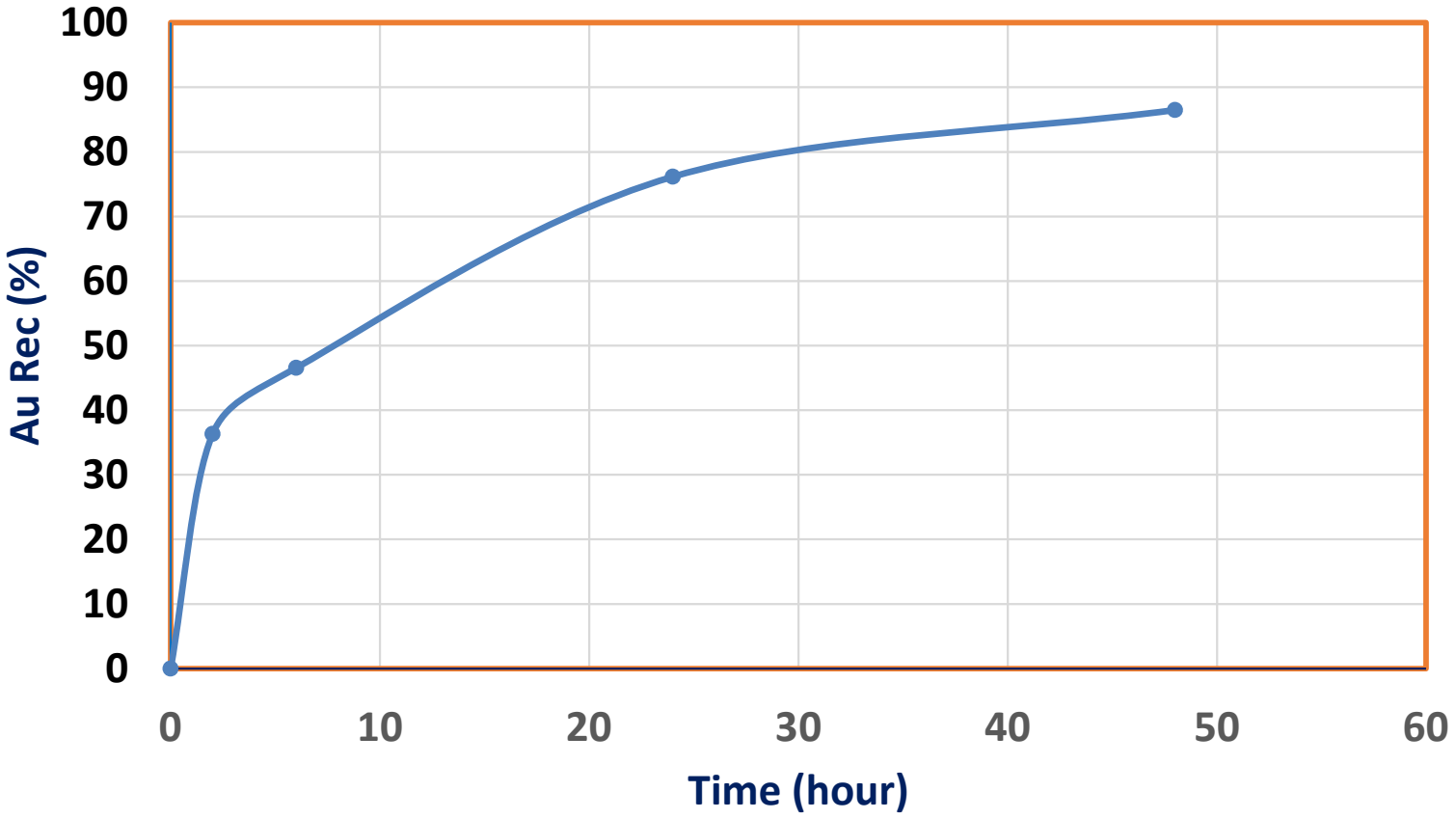


Conditions	Cyanide	Glycine+Reagent
Glycine, g/l	0.0	7.5
Cyanide, ppm	300	0.0
pH	10.5	10.5
KFC, g/l	0.0	0.5, 1.5, 3

Bottle Roll, Room Temperature, 33% Solids

Bottle Roll, Room Temperature, 33% Solids, pH 10.5, RT

GT™ Leaching of BOX concentrate



Bottle Roll,, pH 1.0, 7.8% solids, 20 kg/t GT, Room Temperature.

GT™ Leaching

Advantages

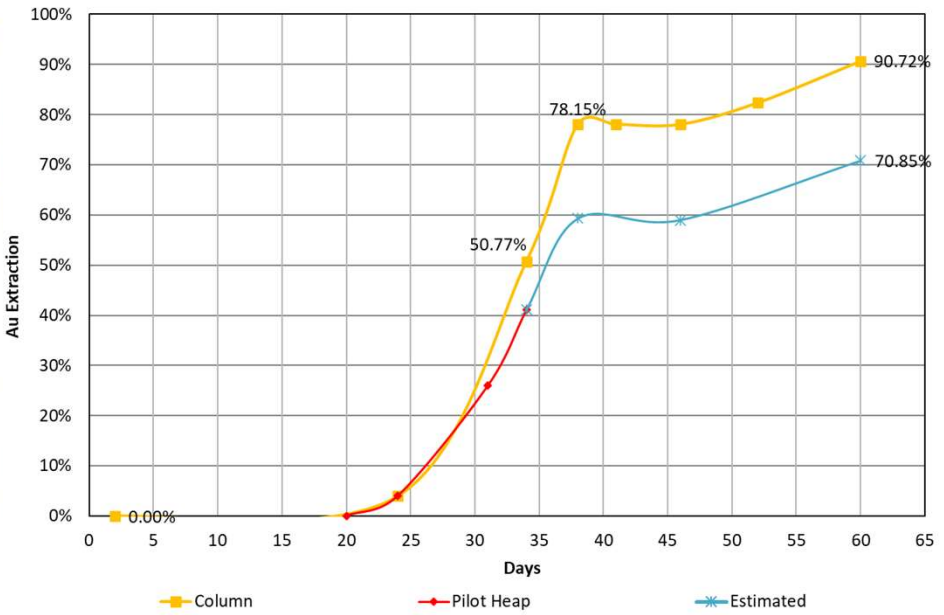
- Low thiourea consumption
- Low thiourea concentration during the leaching
- Leaching at a wide range of pH and Eh
- Glycine complexes ferric and base metals during the leaching
- Activated carbon can be used to recover gold from solutions
- Leaching in an acidic medium for POX, BIOX and Albion process

Disadvantages:

- Glycine should be recycled
- Glycine can be adsorbed on the clay minerals or consumed by bacteria in acidic medium

GT™ - Heap Demonstration (Chile)

- Draslovka is committed to conducting 10 demonstration with the Glycine Leaching Technology in 2023
- We have trialed the GT™ in heap demonstration, but it was prematurely stopped at short time than it was required



GlyLeach™ and GT™ (Optimum conditions)

- Heated glycine (>45°C) and high pH (>12) for glycine only leaching system
- Alternatively adding an oxidant at ambient temperature such as permanganate, peroxide or ferricyanide
- GT™ required pH<3 and pH>1 and ferric present
- Gold can be recovered onto activated carbon, ion exchange resins or Merrill Crowe Precipitation
- Any copper or any other base metals in solution through precipitation, IX or SX

Learnings

- ❑ An oxidant or temperature is required to improve leaching kinetics
- ❑ Glycine needs a minimum, but excess only increases copper extraction
- ❑ Metal stability is a problem if not sufficient reagent in solution
- ❑ Once the metals have been recovered, glycine can be easily recycled.
- ❑ Glycine main losses (<5%) occur through adsorption and water loss in the residue
- ❑ High [Temperature, glycine concentration and pH] significantly improves gold leaching.

Publications in cyanide-free glycine based leach

Hydrometallurgy

journal homepage: www.elsevier.com/locate/hydromet

Gold leaching from oxide ores in alkaline glycine solutions in the presence of permanganate

E.A. Oraby [a,b], J.J. Eksteen [a,*], G.M. O'Connor [a]

minerals

MDPI

Article

Extraction of Gold and Copper from Flotation Tailings Using Glycine-Ammonia Solutions in the Presence of Permanganate

Huan Li [1], Elsayed Oraby [1,2,*], Jacques Eksteen [1] and Tanmay Mali [1]

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Gold extraction from paleochannel ores using an aerated alkaline glycine lixiviant for consideration in heap and in-situ leaching applications

E.A. Oraby[a,c], J.J. Eksteen[a,*], A. Karrech[b], M. Attar[b]

[a] Faculty of Science and Engineering, Western Australian School of Mines: Minerals, Energy and Chemical Engineering, Curtin University, GPO Box U1987, Perth, WA 6845, Australia
[b] Department of Civil, Environmental and Mining Engineering, The University of Western Australia, Australia
[c] Mining and Metallurgical Engineering, Faculty of Engineering, Assiut University, Egypt

Minerals Engineering

journal homepage: www.elsevier.com/locate/mineng

Extraction of precious metals from waste printed circuit boards using cyanide-free alkaline glycine solution in the presence of an oxidant

Huan Li [a], Elsayed Oraby [a,b], Jacques Eksteen [a,*]

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Conclusions

- GlyLeach™ can extract gold without cyanide
- GlyLeach™ process for gold will be more expensive than cyanide due to needing more reagent, oxidant and temperature preliminary economics suggest it will be still viable for gold deposits >3 g/t
- GT™ has shown to be able to leach gold and some residual copper but further testing to illustrate the economics is needed
- Both methods show the base and precious metals can be recovered from solution using existing process.
- Glycine in the presence of permanganate or KFC showed very promising competitive gold recovery compared with cyanide.
- Gold glycinate has high affinity to the carbon adsorption
- Glycine-permanganate or KFC is suitable for free milling gold ores at lower reagents consumptions. For sulfidic resources, high oxidant concentrations are required

Questions?