

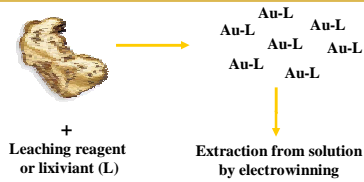
Spectroelectrochemical studies of the gold-electrolyte interface under thiosulfate based leaching conditions

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Introduction

Leaching of gold

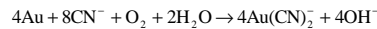


Ideal leaching reagent

- ✓ Low cost
- ✓ Reasonably simple chemistry
- ✓ Environmentally friendly
- ✓ Small consumption



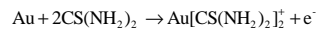
Cyanide¹



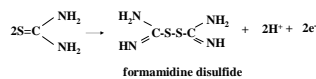
- ✓ Low cost
- ✓ Reasonably simple chemistry
- ✓ Small consumption
- ✗ Environmentally friendly



Thiourea²



- ✓ Low cost
- ✓ Reasonably simple chemistry
- ✗ Small consumption
- ✗ Environmentally friendly

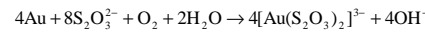


Leaching of gold by thiosulfate is the primary non-toxic alternative to the traditional cyanidation

Table 1. Toxicity values for cyanide, thiourea and thiosulfate obtained from MSDS

Compound	Toxicity in (ORL-RATLD50)
cyanide	6.4 mg/Kg
thiourea	125 mg/Kg
thiosulfate	> 2500 mg/Kg

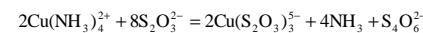
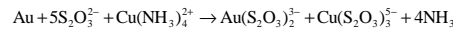
Thiosulfate-oxygen³



Decomposition of thiosulfate

Passivation of electrode

Thiosulfate-ammonia-copper⁴



Consumption of thiosulfate

Decrease in the rate of gold dissolution

Possible cause of passivation

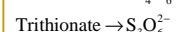
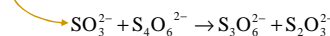
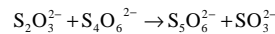
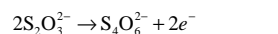
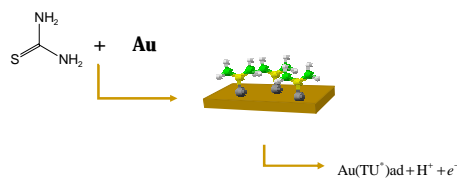


Table 3. Organic additives for the thiosulfate dissolution of gold⁶

Additive	Effect
Potassium ethyl xanthate	Completely passive
Thiourea	active
Thioacetamide	Similar effect to thiourea
Pyridine	Completely passive
Sulphanilamide	Active, but only in absence of O_2
Imidazole	passive

- ✓ The presence of organic additives usually leads to passivation of the gold surface

Adsorption of thiourea (TU) on gold⁷



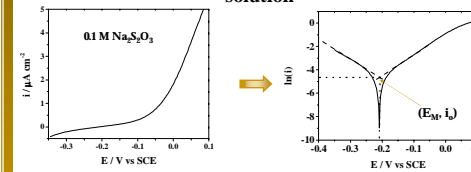
Good organic additives

- Perpendicular orientation
- Complex with gold at the metal surface
- Interaction through the sulfur atom

Experimental Results

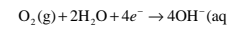
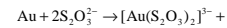
Electrochemical study of leaching of gold in thiosulfate solution

Linear sweep voltammetry of Au in thiosulfate solution



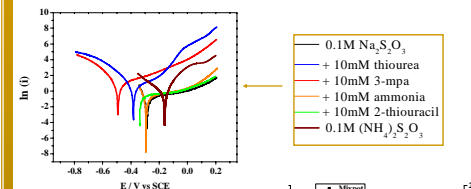
E_M = mixed potential
 i_0 = leaching current

	E_M / V	$i_0 / \mu\text{A cm}^{-2}$
$(\text{NH}_4)_2\text{S}_2\text{O}_3$	-0.161	1.174
$\text{Na}_2\text{S}_2\text{O}_3$	-0.286	0.415

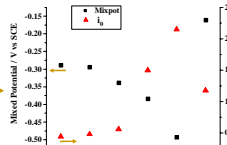


Organic Additives

Leaching of Au in 0.1 M $\text{S}_2\text{O}_3^{2-}$ + 10 mM additive



- 0.1M $\text{Na}_2\text{S}_2\text{O}_3$
- 10mM ammonia
- 10mM 2-thiouracil
- 10mM thiourea
- 10mM 3-mpa
- 0.1M $(\text{NH}_4)_2\text{S}_2\text{O}_3$



Rotating Ring Disk Electrode

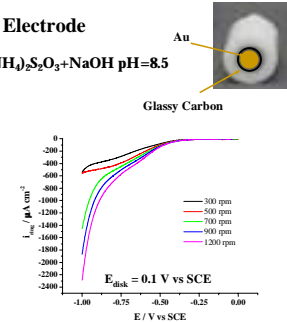
Leaching of gold in 0.1 M $(\text{NH}_4)_2\text{S}_2\text{O}_3$ + NaOH pH=8.5

- At Au disk
 - $\text{Au}(\text{s}) \rightarrow \text{Au}^+ + \text{e}^-$
 - Side reactions
- At glassy carbon Ring
 - $\text{Au}^+ + \text{e}^- \rightarrow \text{Au}(\text{s})$

Current Response

$$i_{disc} = i_{Au} + i_{sidering}$$

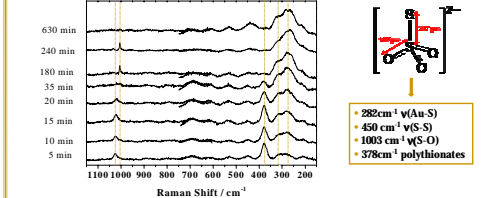
$$i_{ring} = -N i_{Au}$$



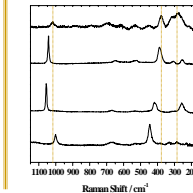
Identification of species present in the passive layer

Surface Enhanced Raman Spectroscopy

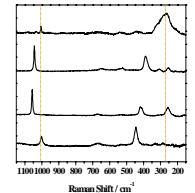
Au nanorods electrode in 0.1M $\text{Na}_2\text{S}_2\text{O}_3$



15 min



240 min



Conclusions

- ✓ Improvements in thiosulfate leaching of gold in the presence of 3-mercaptopropionic acid > thiourea > ammonium thiosulfate > 2-thiouracil.
- ✓ Kinetic studies of different leaching solutions using RRDE (Glassy Carbon-Gold).
- ✓ Au^+ produced from leaching reaction on Au disk is reduced on Glassy Carbon at $E = -0.55 \text{ V}$.
- ✓ Tetrathionate has been identified as an intermediate on the Au surface under thiosulfate leaching conditions.

References

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Funding

- ✓ Barrick Gold Corporation
- ✓ ElectroMetallurgy Consortium