Cyanide Leach

What to consider

Cyanide methods are applied to samples from many stages of the mining cycle. These methods can be used in exploration on large-sized soil or sediment samples to identify anomalies, or drill samples with known mineralisation to identify cyanide soluble minerals.

Cyanide leaches are also a routine analytical method used during resource drilling as a first pass estimation of how an ore will behave during cyanide hydrometallurgical processing.

The use of cyanide leaches for trace gold determinations in exploration samples can be used to reduce the impact of nuggety Au in samples as they can be used on much larger sample sizes than other wet chemistry and fire assay methods.

The large sample size utilised in bulk leach extractable gold (BLEG) methods can help decrease the influence of nuggety gold making results more reproducible. With these methods, samples from 1kg to 3kg are treated with a cyanide solution and bottle rolled to increase the interaction between reagent and sample. Even with agitation Au encapsulated in silica, or very large Au grains may not be fully dissolved by BLEG methods (Hoffman, et al., 1998). Also, no matter how large a sample is treated, the influence of nuggety Au will impact results in some areas (Arne and MacFarlane, 2014) and for this reason a baseline study is always recommended to determine the effectiveness of any method for a region.

Another advantage to utilising a cyanide leach is the low detection limit (0.02ppb) available with ALS's super trace method, offered in both 25g and 50g aliquots (Au-CN43, Au-CN44). These low detection limits are due to the stability of the Au-CN complex formed, coupled with lower matrix effects and lower dilution factor compared to an aqua regia digestion. Analysis is performed by an ICP-MS instrument optimised for sensitivity to achieve the ultra-trace detection limits.

Cyanide leaches are also used to analyse the Au, Ag and Cu content of samples during exploration and resource drilling. Information about the mineralogy of Cu mineralisation can be gained from sequential leaches that digest different Cu minerals (Parkison and Bhappu, 1995; Anderson, 1998). Cyanide leaches are effective at leaching secondary sulphides and bornite, which are not as effectively digested by sulfuric or citric acids. This allows cyanide to be used in conjunction with other selective leaches to identify Cu mineralogy at the earliest stages of exploration and resource drilling providing quantitative mineralogy rather than qualitative values from logging. An example of a sequential leaching protocol is proposed by Parkison and Bhappu (1995) and outlined in the table on the next page.

Cyanide leaches are also an effective part of an assay program to provide early indication of ore processability by cyanide hydrometallurgy. Cyanide analytical methods are indicative only and not suitable for metallurgical assessments.

Complexities of cyanide leach

The behaviour of cyanide on geological samples has been the focus of research for decades due to its application in many hydrometallurgical metal extractions.

Sequential Analysis Method	Mineralogy Targeted	Geological Classification
Water Soluble	Halides and Sulphates	Oxide Zone Step / Total > 50%
Sulphuric or Citric Acid	Oxides, Carbonates, Silicates	
Cyanide	Secondary Sulphide sand Bornite	Secondary Sulphide Zone Step / Total > 50%
Total Digestion	Chalcopyrite	Primary Sulphide Zone Step / Total > 50%

The effectiveness of a cyanide leach is impacted by many parameters such as temperature, agitation (oxygen in the system), concentration of cyanide, ratio of reagent to sample, grain surface area, pH and sample mineralogy. All the parameters that affect cyanide leach, excluding the sample mineralogy, can be customised.

Sample mineralogy can affect the cyanidation process in both detrimental and beneficial ways. The most familiar and common issue is preg-robbing but others such as sulphides preferentially using up the cyanide, galvanic interactions and the presence of other metal ions can impact the method.

Preg-Robbing

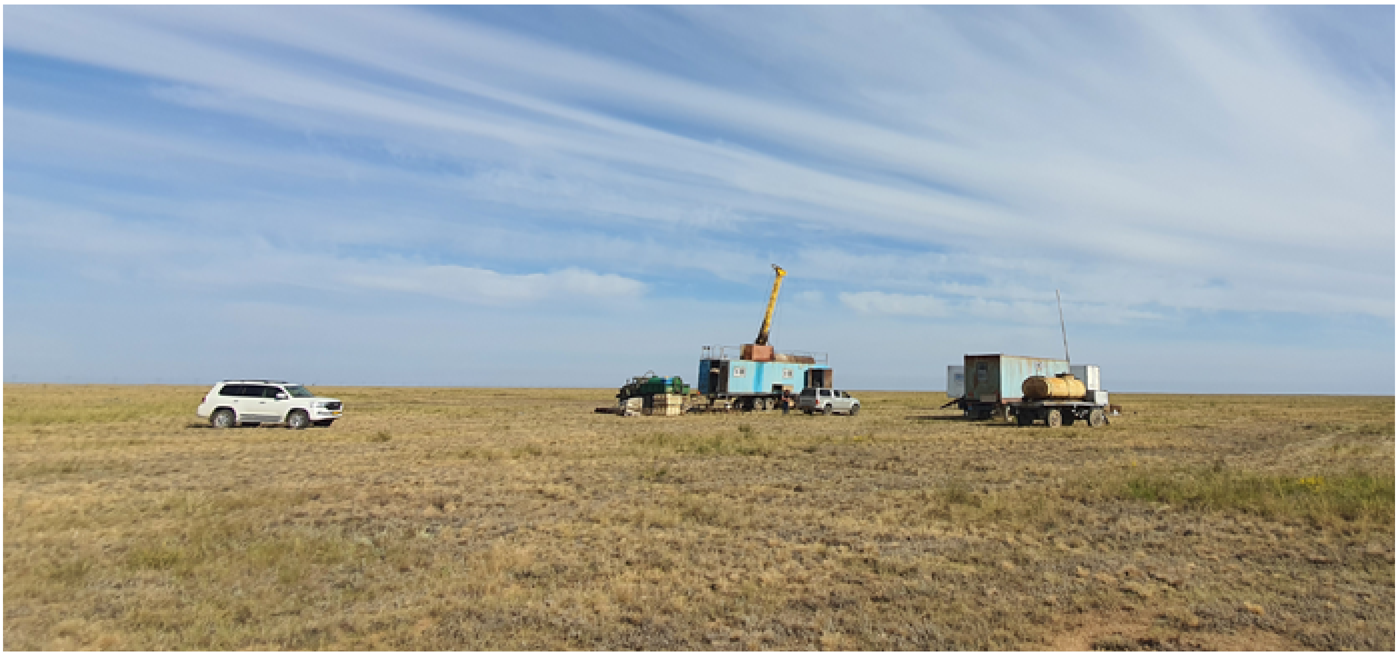
Gold dissolved as an aurocyanide complex can be removed (robbed) from the solution by adsorption onto carbonaceous matter similar to how it is adsorbed onto activated carbon (Marsden and House, 1960; Yang et al., 2013). The result is lower Au values than measured by other total extraction methods such as fire assay. The ability of a sample matrix to preg-rob in a cyanide leach can be problematic for traditional hydrometallurgical cyanide extraction, and therefore very important to identify.

ALS offers methods to determine the propensity for a sample to preg-rob in a cyanide leach. This involves two leaches on each sample: one regular leach (Au AA31a), and one leach spiked with a known concentration of Au (Au-AA31) and comparing the results from the two.

If a sample has no preg-robbing tendency the result from the Au-AA31 (leach plus spike) will be equivalent to the Au-AA31a (no spike) result plus the concentration of the spike. High preg-robbing ability would indicate that the ore, if treated with cyanide, would have the ability to scavenge Au from the cyanide solution and reduce Au recovery.

The Au-AA31a (no spike) method will inform how much of the Au can be leached from the sample. This analysis alone will not indicate if Au is being adsorbed by preg-robbing minerals within the sample matrix. This pair of methods is particularly useful when combined with a fire assay method to determine the total concentration of Au in the sample being tested for a more complete understanding of Au leachability.

Most preg-robbing is attributable to carbon, often from shales, but chalcopyrite can behave in the same way. Chalcopyrite removes Au from solution by reduction at the mineral surface (Marsden and House, 1960) resulting in a similar effect to carbon. As chalcopyrite has a relatively low solubility in cyanide, it can remain in the sample to preg-rob from the solution during the leach.



ALS Code	Analyte	Range (ppm)	Description
Au-AA13	Au	0.03-50	Au, Ag, Cu by cyanide leach with AAS finish. 30g sample is added to a closed vessel and agitated for 1 hour.
Ag-AA13	Ag	0.03-350	
Cu-AA13	Cu	0.1-2000	
Au-AA14	Au	0.01-200	Au by cyanide leach with AAS finish. 12hr Leach. Up to 1kg sample
Au-AA15a	Au	0.001-125	Au by accelerated cyanide leach using LeachWELL Assay Tabs™ with AAS finish. 4hr Leach. 500g sample
Au-AA15b	Au	0.001-125	Au by accelerated cyanide leach using LeachWELL Assay Tabs™ with AAS finish. 4hr Leach. 1kg sample
Au-AA15c	Au	0.001-125	Au by accelerated cyanide leach using LeachWELL Assay Tabs™ with AAS finish. 4hr Leach. 2kg sample
Au-AA15d	Au	0.001-125	Au by accelerated cyanide leach using LeachWELL Assay Tabs™ with AAS finish. 4hr Leach. 3kg sample
Au-AA31	Au	0.03-500	Au Preg Rob Leach with Gold Spike. 10g sample per method
Au-AA31a	Au	0.03-500	Au Preg Rob Leach without Gold Spike. 10g sample per method
Au-CN43™	Au	5ppt-1ppm	Au by cyanide extraction with ICP-MS finish. 25g sample. Dynamic extraction.
Au-CN44™	Au	5ppt-1ppm	Au by cyanide extraction with ICP-MS finish. 50g sample. Dynamic extraction
Au-CN12*	Au	0.0001-10	Bulk Leach Extractable Gold (BLEG) extraction and ICP-MS finish. Up to 1kg of sample
Au-AA12**	Au	0.0001-10	BLEG extraction and AA finish. Up to 1kg of sample
Au-CN11*	Au	0.001-50	BLEG extraction and ICP-MS finish. Up to 500g of sample
Au-AA11	Au	0.001-10	BLEG extraction and AA finish. Up to 500g of sample
Cu-AA17	Cu	0.001%-10%	Cu by cyanide leach with AAS finish. 2g sample.

* Ag, Cu and Pd may also be reported by these methods for an additional fee
** Ag, Cu, Pb and Zn may also be reported for an additional fee

Galvanic interactions

Galvanic interactions involve the transfer of electrons between sulphides when in direct contact with Au or Au alloys that can both enhance and hinder dissolution. When Au is in contact with chalcopyrite the dissolution rate is reduced significantly and chalcocite can act as an anode and stop dissolution entirely (Marsden and House, 2006). Other sulphides can produce a beneficial effect on Au dissolution rates, for example pyrrhotite and galena can enhance Au dissolution as will pyrite.

Preferential consumption of cyanide

Some minerals react with cyanide solution in preference to Au and use up the cyanide and oxygen in the reagent before Au can be dissolved.

Copper in particular can cause problems during Au cyanidation as many Cu minerals (chalcocite, bornite, enargite, covellite, copper oxides, and copper carbonates) are extremely soluble in cyanide and react preferentially, leaving Au unrecovered (Marsden and House, 2006; Estay, et.al., 2013). To ensure all leachable Au is dissolved when digesting a Cu bearing sample additional cyanide can be used in the digestion. Alternatively, the residue from a cyanide digestion can be analysed by fire assay to determine the Au remaining in the sample after the leach.

Cation effects

Trace amounts of certain divalent cations can have a significant beneficial effect on the Au dissolution rate (Pb, Hg, Tl, and Bi). These elements depolarise the Au surface and prevent or reduce passivation, which in turn accelerates Au leaching rates. Even small amounts (5 to 10mg/L) of sulphide ions have a significant retarding effect on Au dissolution rates, but this effect can be alleviated by the addition of Pb to the digestion although Pb >20mg/L will act as a retardant to Au dissolution (Marsden and House, 2006).

The above issues highlight that cyanide methods may not yield Au values equal to those produced by the total extraction fire assay technique. As the fire assay process removes the sample matrix the interaction of other elements is eliminated, whereas for cyanide leaches these elements remain in the sample and can interact in complex ways. Although very effective for sulphides a cyanide leach does

not break down silicates effectively. Therefore, Au that is encapsulated within silicate minerals will not be taken into solution. For these reasons certified reference materials that have Au defined by a total Au method are likely to report lower than stated values when analysed using a cyanide method and this variability should be taken into consideration.

Many of these issues require mineralogical investigation including growth relationships between minerals, in combination with wet chemistry methods. ALS mineralogy and metallurgy offer a range of methods for mineralogical characterisation which can identify potential problematic minerals and relationships in ore. Please contact ALS to discuss methods that will best suit your project..

ALS has well-established safety, monitoring and neutralisation protocols for cyanide solution disposal to ensure the safety of our employees and minimise impact on the environment.

References

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