

IMPROVEMENTS IN AND RELATING TO
THE DISSOLUTION OF NOBLE METALS

The present invention relates generally to the dissolution of noble metals. In particular the invention relates to a reagent suitable for the dissolution of metallic gold and to various applications thereof including the analysis of gold, the extraction of gold from its ores, the separation of gold from other noble metals and the treatment of gold deposits.

Gold is widely recognised as being a most difficult metal to dissolve. It has long been known that metallic gold can be dissolved by reagents such as aqua regia, thiourea, thiosulphates and acid chloride systems. It has also long been known that gold can be taken into aqueous solution and thereby "dissolved" by the formation of a water soluble complex in dilute aqueous cyanide solutions such as aqueous sodium cyanide and aqueous potassium cyanide. Such prior art techniques, however, suffer from substantial disadvantages. For example, thiourea and thiosulphate are subject to oxidative degradation and are thus prone to high consumption levels in extracting gold from its ores. Aqua regia is expensive, extremely corrosive, it readily dissolves base metals and dissolves gold relatively slowly in aqueous solution. Acid chloride systems also suffer from some of these disadvantages and are slow to dissolve gold. Forming a soluble cyanide complex is one of the less costly methods known for dissolving gold but the reaction is again rather slow.

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A further disadvantage is that the majority of these gold solvents are constrained in their use to either an acid or alkaline media. In addition, the use of a cyanide solution is frequently considered environmentally unacceptable.

5 It is an object of the present invention to provide an improved method for the dissolution of gold, applicable, in particular, to the extraction of gold from its ores and the in-situ treatment of gold deposits.

According to one aspect of the invention, there is provided a method for the extraction of metallic gold, in which the gold is leached from a gold-bearing ore by use of a composition comprising:

- (a) a solvent consisting of water, methanol, ethanol or a mixture thereof;
- 15 (b) at least one source of cations which source is able to highly dissociate in said solvent;
- (c) a halogen source capable of liberating bromine in the composition; and
- (d) sufficient acid or base such that the pH of the composition in contact with said gold is in the range of from 4.8 to 8.5.

According to another aspect, the invention provides a method for the separation of metallic gold from other noble metals or from gold-containing materials in which the gold is dissolved with a composition comprising:

- (a) a solvent consisting of water, methanol, ethanol or a mixture thereof;
- (b) at least one source of cations which source is able to highly dissociate in said solvent;
- 30 (c) a halogen source capable of liberating bromine in the composition; and
- (d) sufficient acid or base such that the pH of the composition in contact with the gold is in the range of from 4.8 to 8.5.

35 The composition preferably has a substantially neutral pH and most preferably a pH in the range of from 6.5 to 8.5.

For the solvent, water or mixed solvents in which water is the major component are preferred. For reasons of economy and availability, water is the most preferred solvent in practice.

5 The source of cations may be any substance which in the solvent highly dissociates and provides a source of cations. Where an atom or radical such as Fe is capable of providing cations having different oxidation states e.g. Fe^{2+} , Fe^{3+} the cation having the lowest stable oxidation state for
10 that atom or radical e.g. Fe^{2+} is preferred for use in accordance with the invention. It has also been found that cation sources which dissociate to an appreciable extent in the solvent to form a plurality of cations such as dibasic ammonium phosphate, ammonium sulphate and
15 potassium chromate are particularly suitable for use as the cation source in accordance with the present invention and compounds which yield an ammonium cation in the solvent are most preferred.

It has further been found that strong acids and bases
20 which are highly dissociated in aqueous media such as hydrochloric acid, sodium hydroxide and potassium hydroxide may act as a cation source in accordance with the invention. However, such compounds may react with other metals present in a given sample. For example should HCl be used as a
25 source of cations it would react with base metals in the gold ore being treated. Such a reaction may be useful as a pre-treatment step but may also interfere with the complexing reaction. Therefore following such pretreatment the pH may conveniently be adjusted to between 6.5 and 7.5 prior to
30 introduction of a halogen source according to the present invention. As can therefore be appreciated particular care should be taken to consider the possible interference from such side reactions when the cation source contains a strong

acid or strong base.

The term "halogen source" as used herein means elemental bromine in solid, liquid or gaseous form and any mixture, solution or compound which yields free bromine in the presence of gold and the other components of the composition. Elemental bromine may be introduced into the composition in gaseous form. It may also be introduced in liquid form, for example, as bromine liquid or bromine water. It is also within the scope of the invention for the halogen source to be introduced in the form of a compound capable of liberating bromine in the presence of gold and the other components of the composition. A halogen source which acts as a strong oxidizing agent and has increased solubility in the solvent in the presence of the cation source is particularly preferred for use in accordance with the invention.

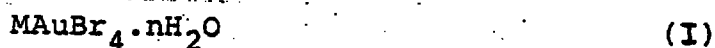
The halogen source preferably acts as a source of nascent bromine. Preferred halogen sources include inorganic or organic bromine-containing compounds from which bromine can be liberated in the reagent.

The composition employed according to the present invention may optionally include a strong oxidizing agent. The oxidizing agent should be highly dissociated in the

solvent. Preferably the oxidizing agent is selected from the group consisting of the peroxides including hydrogen peroxide, sodium peroxide and potassium peroxide and the permanganates including sodium permanganate and potassium permanganate. It has been found that the presence of a strong oxidizing agent maintains the activity of the composition over a longer period. Thus addition of a strong oxidizing agent may be desired even in cases where the dissolution rate would be thereby reduced. It has been found however that the dissolution rate in the presence of a strong oxidizing agent may be increased by adjusting the pH to a substantially neutral level, preferably in the range of from 6.5 to 7.5 and most preferably about 7.0.

As can be appreciated from the above, a wide variety of compounds can be used as the cation source and it may even be that the cation source also acts as an oxidizing agent. Particularly preferred examples of such compounds are potassium permanganate, potassium dichromate, ferric sulphate and sodium peroxide.

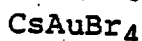
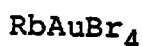
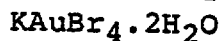
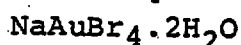
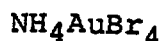
Use of a composition as employed according to the method of the invention facilitates the formation of highly water soluble salts of hydrobromauric acid. Such salts may be represented by the general formula:



where M is a cation

n is 0 or an integer.

Particularly preferred compounds according to general Formula (I) are those which exhibit high solubility in aqueous media including the following:



Accordingly, cation sources which promote the formation of such salts are preferred.

A particularly preferred composition comprises an aqueous solution of elemental bromine, NaCl and NaOH. This particularly preferred composition has the advantages of being economical to prepare, provides a source of Na^+ ions in solution, the presence of NaCl and particularly NaOH increases the solubility of liquid bromine in aqueous solution and promotes the formation of nascent active bromine. The function of NaCl in this particularly preferred composition is to provide a source of cations (Na^+). The choice of NaCl over other possible sources

(17)

of cations is largely economic and is not due to the presence of Cl^- anions. It has been found that with the exception of bromine containing anions such as Br^- or BrO_3^- the nature of the anion present does not significantly affect the dissolution rate according to the invention.

This particularly preferred composition provides a means for the rapid dissolution of metallic gold at ambient temperatures in both acid and alkaline environments. In many gold ores encountered in mining e.g. the ore from the Telfer Mine in North West Australia, the preferred composition provides selective dissolution of gold i.e. will not take more than trace quantities of base metal sulphides into solution. The preferred composition also provides a pregnant solution particularly suitable for recovery of the gold by known solvent extraction and carbon-in-pulp procedures. In addition to the above the composition is very practical in that it is relatively straight forward to prepare, operates in aqueous solution and the bromine can be recycled. The process effluents obtained from use of the particularly preferred composition are essentially non-toxic chlorides and bromides in dilute aqueous solution. Their relatively non-toxic nature is demonstrated by the fact that sodium, potassium and ammonium bromides were widely used as sedatives prior to the introduction of barbiturates and potassium bromide is used in agriculture for preserving vegetables and fruit.

It has been found that the gold dissolution composition employed according to the invention readily dissolves metallic gold at ambient temperatures. In view of the

speed of dissolution at ambient temperatures, no external heating is necessary although it has been found that the speed of the dissolution reaction increases appreciably with an increase in ambient temperatures. For example it has been observed that a 20°C increase in reaction temperature can result in an increase in dissolution rate of the order of 300% in acidic medium and of the order of 50% in alkaline medium. Preferably the method provided by the present invention is employed at temperatures in the range of from 10°C to 45°C.

When the composition as employed according to the invention is to be used in hot climates an alkaline medium is particularly preferred as less loss of bromine is likely to occur than in acidic medium at elevated temperatures.

It has further been found that when the halogen source is in combination with a source of sodium cations the composition is relatively specific in that it dissolves gold but does not dissolve other noble metals such as silver or platinum.

It has also been found that the composition may to some extent attack and dissolve metals in pure form such as aluminum, lead and iron but will not readily attack compounds containing such elements. It is accordingly recommended that contact between the composition and metals in their pure form is avoided. Therefore, reaction vessels and other equipment or apparatus which may come into contact with the composition employed according to the invention are preferably protected against attack. This may be effectively and economically achieved by application of a suitable plastics based surface coating to exposed metallic parts liable to corrosion. The rate of such corrosion is reduced by use in the practice of the invention of a composition which is alkaline or substantially neutral.

After the gold is taken into solution using the composition as employed according to the invention, the gold may be recovered from solution by a number of methods already

known to those skilled in the art for recovering gold cyanide complexes. Such techniques include solvent extraction using organic solvents for the complex, including methyl isobutylketone (MIBK), di-isobutyl ketone (DIBK) and ethyl ether. The metallic gold can be recovered from the solvent by distillation or reduction. It has been found that gold/bromine complexes formed in the practice of the invention are particularly suitable for extraction from the pregnant liquor with MIBK or DIBK.

Other known recovery techniques include the introduction of a reducing agent to the pregnant liquor. Examples of such techniques are zinc and aluminium precipitation whereby the metallic dust is introduced into the solution to precipitate metallic gold by displacement.

Other known recovery techniques suitable for use in recovering gold from the pregnant liquor include electrodeposition, carbon adsorption, and ion exchange. The recently developed carbon-in-pulp recovery method is particularly suitable for use in recovery of gold extracted in accordance with the present invention.

The composition employed according to the invention may be prepared in-situ at the treatment site or at a location remote from the treatment site. In the latter case care should be taken to avoid the escape of halogen vapour from the composition, preferably by storage of prepared composition in sealed containers.

The composition employed according to the invention may be prepared relatively simply by mixing the components thereof in the solvent. In a particular example the selected cation source is dissolved in the selected solvent. Generally the concentration of cation source is not more than 20 wt. % and preferably in the region of 1-10 wt.%. When addition of oxidizing agent is required, the oxidizing agent is preferably added to the solvent either immediately after or at the same time as the cation source. Preferably the concentration of oxidizing agent present in the final composition is not

higher than the concentration of the cation source.

Typically the concentration of the oxidizing agent in the composition is of the order of 1% w/v. Preferably the pH is then adjusted so that after the addition of the halogen source and mixing the composition with the material being treated, the final pH is preferably slightly alkaline, and most preferably about 7.5. Finally the halogen source is added. Preferably the halogen source provides a bromine concentration in the final composition of not more than 5 wt.%. Typically the bromine concentration in the composition is in the range of 0.3 to 3.0 wt.%. (approximately equivalent to 0.1%-1.0% v/v of liquid Br).

The application of the composition employed according to the invention to the commercial extraction of gold from its ore is compatible with known extraction techniques.

Typically the technique applied to a particular ore body varies with the characteristics of the ore and optimization testing is required in order to select an appropriate flow sheet and operating parameters. To illustrate the compatibility of the use of the composition with conventional extraction techniques a postulated flow sheet for an agitation leach extraction scheme is provided by Figure 1.

A preferred embodiment of the application of the invention to extraction of gold from its ore by an agitation leaching technique will now be described with reference to Figure 1. As indicated in Figure 1, the ore is comminuted to a fine mesh size to facilitate contact between the metallic gold and the dissolution composition. The degree of comminution depends primarily upon the coarseness of gold in the ore and will vary according to ore type. Typically such a mesh size would be of the order of 150-200.

Following comminution the ore slurry undergoes dewatering or thickening. The ore slurry is then transported to the agitation leaching tank where the dissolution composition is added. The concentration of the added composition may be substantially higher than that desired during the leaching phase to

take into account the moisture which will already be present with the ore.

5 The conditions of agitation, and particularly the length of agitation, will depend largely upon the anticipated time for complete dissolution of the gold. Typically the gold would be expected to be dissolved in less than two hours and most preferably the reaction time is likely to be between $\frac{1}{2}$ hour and one hour.

10 Following agitation leaching the contents of the agitation tank are passed to the solid liquid separation stage at which separation is undertaken by currently practised methods including countercurrent decantation thickeners and filtration. In an alternative arrangement not shown in Figure 1 the contents of the
15 agitation leach tank may be subjected to a carbon-in-pulp recovery process to recover the gold from the leach solution.

In the example process illustrated in Figure 1, the agitation leach stage is followed by clarification
20 and recovery of the dissolved gold from solution such as by solvent extraction with MIBK or DIBK. Following evaporation and distillation or reduction the raffinate from the solvent extraction is recycled and the gold residue passed to the smelter for further processing.

25 As will be appreciated by those skilled in the art, due to the volatility of the halogen component of the solution employed according to the invention, the agitation leach phase should preferably be a mechanical agitation and not agitation by aeration. Similarly, for
30 reasons of economy and industrial hygiene, it is preferred that the agitation stage and solid liquid separation stage be conducted in closed systems suitable for recovery of volatile halogen. The recovered halogen can be scrubbed and recycled to the agitation leach tank. For similar
35 reasons it is considered more appropriate to add the dissolution composition to the agitation leach tank rather than to the grinding mill.

The composition employed according to the invention may also be advantageously used for in-situ leaching of sub-

terranean deep lead gold deposits. The general technique of such treatments using aqueous cyanide solution to recover the gold is already established. The composition employed according to the present invention may be advantageously
5 used in such applications due firstly to the rapid dissolution time compared with aqueous cyanide solution and secondly to the fact that cation and halogen sources may be selected such that the by-products are environmentally compatible and non-toxic in a dilute form should they escape
10 into water courses or the like.

The composition employed according to the invention may also be advantageously used in the known technique of flooded heap leaching in the case of suitable ores. The rate of evaporation of the composition or components thereof
15 may be retarded by at least partially covering the flooded area. Such covering may be effected by floating a barrier on the surface of the leach solution. A sheet of plastics material which remains substantially inert when in contact with the leach solution forms a suitable barrier. A test
20 conducted on a "Nevoria" ore from Western Australia indicated that using a composition according to the present invention recovery of approximately 90% of the gold present can be achieved by the flooded heap leaching method within 1 day or even less at higher composition concentrations.
25 This contrasts with an average treatment time of around six months for a similar recovery using an aqueous cyanide leachant. In the test concerned it was found convenient to pass the pregnant gold bearing leach solution (which retained an excess of unexpended dissolution composition)
30 through a carbon column to recover the gold from the solution whereupon the solution was cycled through a fresh ore heap to extract the gold therefrom.

The composition employed according to the invention may also be advantageously used for the quantitative analysis
35 of gold-containing materials. Hitherto, such analysis was typically conducted on samples of approximately 50 grams of total material by aqua regia dissolution or fire assay techniques. The present invention may be conveniently used for the analysis of much larger samples.

40 In a typical and preferred example of a

quantitative analysis technique, a gold-containing sample having a total weight of 10 Kg. may be sealed in a vessel such as a cylinder of PVC together with an excess of dissolution composition. The contents of the vessel may be
5 mixed such as by rotation of a cylindrical vessel at low speed e.g. about 40 r.p.m. for a period sufficient for complete dissolution of all gold present e.g. about one hour. After sufficient mixing to allow complete dissolution of all gold present, an adsorption medium such as activated
10 carbon may be added to the vessel. The mixing is continued for a period sufficient for complete adsorption of all gold present e.g. about 15 minutes.

The contents of the vessel may then undergo solid/
liquid separation such as by passing the contents over a sieve
15 of a size suitable to retain the solid phase comprising the adsorption medium. The solid adsorption medium may then be washed and ignited. The ignited residue which contains the extracted gold may be taken up into a measured quantity e.g. about 10 c.c. of liquid, preferably a dissolution
20 composition as employed in the method of the invention. The concentration of gold in the liquid may then be determined by known methods such as atomic adsorption determination.

The ability of this analysis technique to be applied to a large sample enables the sample to be more representative
25 of an ore body. Further the detection limit is 0.0001 ppm compared with a limit for the aqua regia method of 0.1 ppm using atomic absorption. Additional features of the analysis technique described are that the test solution obtained is substantially free of interfering salts. The cost of the
30 dissolution composition is substantially less than for other methods and the technique can be conveniently carried out at least partially in the field using makeshift or mobile laboratory facilities.

• Sea water or brackish (brine) water are often the only
35 available sources of water close to a mine site. Neither source is suitable for cyanidation; however both can be advantageously employed in the practice of the present invention.

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To facilitate the further understanding of the invention it is convenient to now provide a number of Examples which demonstrate preferred techniques in accordance therewith.

5

EXAMPLES 1-42

A series of tests of dissolution rate was conducted using various dissolution compositions to determine the rate at which the compositions dissolve 999 fine gold strip. These tests involved weighing a sample of gold strip having a surface area of 1 cm² and suspending the strip so as to be fully immersed in the composition for one hour. During immersion of the gold strip the vessel and its contents were rotated at a constant 40 r.p.m. The gold strip was then removed from the composition, washed, dried and re-weighed to determine the weight loss.

Examples 1 and 10 are comparative tests in which the composition contains a halogen source in the absence of a cation source. Examples 2-9 and 11-42 include examples of the use of a composition according to the invention, as well as other compositions in which the pH of the compositions has been unadjusted. The results of the test series are summarised in Table A.

TABLE A

GOLD DISSOLUTION RATES IN AQUEOUS SOLUTION

<u>EXAMPLE NO.</u>	<u>HALOGEN SOURCE</u>	<u>CATION SOURCE</u>	<u>pH</u>	<u>DISSOLUTION RATE</u> (mg/cm ² /hr)	<u>SOLUTION TEMP.</u> (°C)
1	0.1% v/v Br	-	2.8	0.7	17
2	"	1% w/v NaCl	3.15	6	17
3	"	1% w/v NaCl 0.07% w/v NaOH	7.3	4.3	17
4	"	2.5% w/v NaCl	3.45	12.4	17
5	"	2.5% w/v NaCl 0.07% w/v NaOH	7.3	4.3	17
6	"	5.0% w/v NaCl	3.6	18.6	17
7	"	5.0% w/v NaCl 0.07% w/v NaOH	7.4	4.8	17
8	"	10.0% w/v NaCl	3.8	22.8	17
9	"	10.0% w/v NaCl 0.07% w/v NaOH	7.3	4.8	17
10	1.0% v/v Br	-	2.8	6.3	16
11	"	1% w/v NaCl	3.15	188	17

TABLE A CONTINUED

<u>EXAMPLE NO.</u>	<u>HALOGEN SOURCE</u>	<u>CATION SOURCE</u>	<u>pH</u>	<u>DISSOLUTION RATE</u> (mg/cm ² /hr)	<u>SOLUTION TEMP.</u> (°C)
12	1.0% v/v Br	1% w/v NaCl 1.0% w/v NaOH	7.56	117	17
13	"	2.5% w/v NaCl	3.3	198	17
14	"	2.5% w/v NaCl 1.0% w/v NaOH	7.5	111	17
15	"	5.0% w/v NaCl	3.35	247	17
16	"	5.0% w/v NaCl 1.0% w/v NaOH	7.4	126	17
17	"	10.0% w/v NaCl	3.4	256	17
18	"	10.0% w/v NaCl 1.0% w/v NaOH	7.4	140	17
19	"	0.8% w/v NaOH	7.5	158	16
20	"	1% NH ₄ Cl w/v	1.6	220	16
21	"	1% Na ₂ O ₂ v/v	7.1	129	16
22	"	" (elapsed time 5 hrs.)	7.15	92.4	16
23	"	1% Na ₂ O ₂ v/v 0.05% NaOH w/v	7.4	110	16
24	"	1% KMnO ₄ w/v	2.8	10.6	16
25	"	1% NaCl w/v 1% KMnO ₄ w/v	3.15	140.6	16
26	"	1% NaCl w/v 1% KMnO ₄ w/v 0.8% w/v NaOH	7.4	162	16

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16/

TABLE A CONTINUED

EXAMPLE NO.	HALOGEN SOURCE	CATION SOURCE	pH	DISSOLUTION RATE (mg/cm ² /hr)	SOLUTION TEMP. (°C)
27	1.0% v/v Br	1% w/v NaBr	3.35	250	16
28	"	1% w/v NaBr 0.6% w/v NaOH	7.35	207.4	16
29	"	1% w/v ZnBr ₂	4.8	163.6	13
30	"	1% w/v K ₂ CrO ₄	5.6	91.7	13
31	"	1% w/v Li ₂ B ₄ O ₇	6.55	130.6	13
32	"	1% w/v FeSO ₄ ·7H ₂ O	2.10	71.2	13
33	"	1% w/v Fe ₂ (SO ₄) ₃ ·9H ₂ O	2.0	5.0	13
34	"	1% w/v NH ₄ I	6.93	134.2	20
35	"	1% w/v NH ₄ NO ₃	6.83	143.8	20
36	"	1% w/v (NH ₄) ₂ HPO ₄	7.82	176.7	20
37	"	1% w/v (NH ₄) ₂ SO ₄	6.87	174.6	20
38	"	1% w/v NH ₄ .Cl	6.76	152.0	20
39	"	1.2% w/v NaCl	3.6	92.4	20
40	"	1.2% w/v NaCl	3.1	272.0	45 (start) 33 (finish - hr.)

TABLE A CONTINUED

<u>EXAMPLE</u> <u>NO.</u>	<u>HALOGEN</u> <u>SOURCE</u>	<u>CATION SOURCE</u>	<u>pH</u>	<u>DISSOLUTION</u>	<u>SOLUTION</u>
				<u>RATE</u> (mg/cm ² /hr)	<u>TEMP.</u> (°C)
41	1.0% v/v Br	1.2% w/v NaOH	7.8	81.2	20
42	"	1.2% w/v NaOH	7.2	131.2	45 (start) 33 (finish - 1 hr)

The results shown in Table A may be compared with published values for gold dissolution in aqueous cyanide and Aqua Regia as shown in Table B and the halogen corrosion rates for gold shown in Table C.

TABLE B

	<u>Concentration</u>	<u>Temp. °C.</u>	<u>mg/cm²/hr*</u>
<u>Aqueous Cyanide</u>	0.1% NaCN + air	25	2.36
	0.1% NaCN + 99.5% O ₂	25	12.63
<u>Aqua Regia</u>	10% aq. soln.	Room	0.03
	concentrated	Room	54.0

* Source - Gold Recovery, Properties & Applications Edited by E.M. Wise: D.Van Nostrand Company, Inc. Princeton, New Jersey.

TABLE C

	Concentration	Temp. °C.	mg/cm ² /hr*
Chlorine:	Dry gas	270	26.7
5	Dry gas	Room	0.003
	Moist gas	Room	0.36
	Sat. soln. in H ₂ O	Room	0.63
Bromine:	Dry liquid	Room	0.74
	Moist liquid	Room	0.28
	Sat. Soln. in H ₂ O	-	0.73
10	Iodine: Moist liquid	Room	Nil

* Source - Corrosion Handbook Ed. H. Uhlig John Wiley & Sons Inc. New York, N.Y.

Soln. vols. 25 ml.

15 Specimen area 12.9 cm²

Aeration by natural convection.

EXAMPLE 43

20 In this Example a sample of ore from the Telfer Gold Mine in north-west Australia was used to test the recovery of gold to solution using a dissolution composition as employed according to the invention.

The sample was assayed as containing 9.8 ppm of gold.

25 The composition was prepared by first preparing a saline solution to which liquid bromine was added. The resultant composition comprised an aqueous solution containing 10% w/v NaCl and 0.4% v/v bromine. The brominated solution was at the ambient temperature of 16°C and its pH was 1.4.

30 A sample of ore was placed on a glass reaction vessel and sufficient prepared composition added to produce a 50 wt.% solids content. The vessel was sealed and shaken to facilitate uniform wetting of the solids. The bottle and contents were rotated during the test and samples of pulp drawn off after reaction times of 5, 20 and 30 minutes.
35 Each sample was filtered and the clear filtrate subjected to assay by Atomic Absorption with the following results.

Recovery to SolutionReaction Time

	<u>5 min.</u>	<u>20 min.</u>	<u>30 min.</u>
p.p.m. Au	6.0	8.0	9.4
%	61	82	96

The results tabulated above show that after only 30 minutes reaction time 96% of the gold in the ore sample was recovered to solution by use of a composition according to the invention.

This result is in contrast to the results of a cyanide bottle test carried out on the same ore which indicates that a reaction time of approximately 24 hours is required in order to obtain a comparable percentage recovery.

EXAMPLE 44

A sample of an oxide ore from the Paddington Gold Mine was used to test the ability of the composition employed according to the invention to extract gold from coarse crushed ores. A first portion of the sample was crushed to pass through a 75 mesh screen and a second portion was treated in the form of coarse material not subjected to crushing.

Both portions were assayed and then treated with a composition comprising an aqueous solution containing 0.4 % v/v/ bromine and 0.4 percent w/v sodium hydroxide. The composition was used at the ambient temperature of 16°C and had a pH of 7.4.

Each portion of the ore sample was separately placed in a cylindrical P.V.C. reaction vessel and the prepared reagent solution added to produce a slurry containing approximately 50% solids by weight. The vessel was sealed and rotated at 40 r.p.m. for 60 minutes. Samples of the slurry were then withdrawn and filtered and the clear filtrate assayed by atomic adsorption. In both cases 100% of the assayed gold in the ore sample was recovered to solution by use of the composition according to the invention even though the ore had not been crushed in the case of the second

portion. Thus, for this particular ore use of a composition according to the invention can provide a substantial cost saving in that the cost of crushing the ore before recovering the gold is avoided.

5 It is to be appreciated that the speed of dissolution can be affected significantly by various physical factors such as temperature, pH, freshness of reagents and purity of the gold so that the dissolution rates reported in the various examples are not always directly comparable
10 one with the other.

However, a number of general observations can be made. Firstly it is noted that all of the results show a dissolution rate many times the rates given in Table B for aqueous aqua regia and aqueous cyanide. Secondly the
15 addition of a source of cations to an aqueous solution of the halogen source substantially increases the rate of dissolution.

CLAIMS:

1. A method for the extraction of metallic gold, in which the gold is leached from a gold-bearing ore by use of a composition comprising;
 - (a) a solvent consisting of water, methanol, ethanol or a mixture thereof;
 - (b) at least one source of cations which source is able to highly dissociate in said solvent;
 - (c) a halogen source capable of liberating bromine in the composition; and
 - (d) sufficient acid or base such that the pH of the composition in contact with said gold is in the range of from 4.8 to 8.5.
2. A method for the separation of metallic gold from other noble metals or from gold-containing materials, in which the gold is dissolved with a composition comprising:
 - (a) a solvent consisting of water, methanol, ethanol or a mixture thereof;
 - (b) at least one source of cations which source is able to highly dissociate in said solvent;
 - (c) a halogen source capable of liberating bromine in the composition; and
 - (d) sufficient acid or base such that the pH of the composition in contact with the gold is in the range of from 4.8 to 8.5.
3. A method as claimed in Claim 1 or Claim 2, wherein the pH of the composition is not less than 5.6.
4. A method as claimed in Claim 1 or Claim 2, wherein the pH of the composition is not less than 6.5.
5. A method as claimed in any one of the preceding claims, conducted at a temperature in the range of from 10°C to 45°C.
6. A method as claimed in Claim 1, further comprising separating said composition from the ore after leaching.



7. A method as claimed in Claim 6, further comprising the step of recovering the gold from said composition.
8. A method as claimed in Claim 1 or Claim 6 or Claim 7, wherein said composition is agitated together with the ore for a period of less than two hours.
9. A method as claimed in Claim 1 or Claim 6 or Claim 7, wherein said ore is in a subterranean deep lead and leaching is performed according to the known in-situ leaching method.
10. A method as claimed in Claim 1 or Claim 6 or Claim 7, wherein leaching of the ore is performed according to the known flooded heap leaching method.
11. A method as claimed in any one of the preceding claims, wherein gold dissolved by the composition is recovered by solvent extraction, electro-deposition, carbon absorption or ion exchange.
12. A method as claimed in any one of the preceding claims, wherein the halogen source is bromine, bromine liquid or bromine water.
13. A method as claimed in any one of Claims 1 to 11, wherein the halogen source is a bromine-containing compound.
14. A method as claimed in any one of the preceding claims, wherein the halogen source is capable of liberating bromine in the composition in a concentration range of from 0.3 to 3.0 wt.%.
15. A method for the extraction of metallic gold as claimed in Claim 1 and substantially as described in Example 44 herein.
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