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(54) Title: PROCESS FOR DISSOLVING OR EXTRACTING AT LEAST ONE PRECIOUS METAL FROM A SOURCE MATERIAL CONTAINING THE SAME

(57) Abstract: New and useful processes are provided for leaching at least one precious metal contents from sources composed of or containing such metals. The leaching agents used are aqueous solutions of solvated alkali metal, alkaline earth metal, ammonium, and/or mono- and/or dihaloisocyanurate(s), and one or more alkali metal halides or alkaline earth metal halides, or ammonium halides. Compositions comprised of such aqueous solutions containing precious metal in the form of a solute are also provided.



PROCESS FOR DISSOLVING OR EXTRACTING AT LEAST ONE PRECIOUS METAL FROM A SOURCE MATERIAL CONTAINING THE SAME

TECHNICAL FIELD

[0001] This invention relates to hydrometallurgical processing involving extraction of at least one precious metal in a dissolved form from a source material containing such metal(s). At least one base metal may also be extracted from such source material.

BACKGROUND

[0002] Natural ores and mineral deposits have long been and continue to be an important source material for precious and base metals. Also, because of the rapid growth of the electronics industry, electronic wastes and scrap materials have become an ever-growing source for recovery and reuse of precious and base metals. Accordingly, attention has been focused over the years on ways of recovering precious metals, initially from ores and minerals and more recently from electronics waste and scrap materials as well as other waste or recycled products containing one or more precious metals.

[0003] Despite these continuing efforts some traditionally-used processes of different types remain in use even today. For example, gold is generally extracted from the ores by leaching with an alkaline cyanide solution. The major impetus to seek alternate lixiviants to cyanide arises from the environmental hazards posed by cyanide's toxicity. Care must be exercised to maintain cyanide solutions on the alkaline side in order to prevent the release of hydrogen cyanide gas. Also, leaching rates with alkaline cyanide solutions tend to be quite slow. For example, it has been reported that contact times in the range of ten to fifteen hours are common in extracting gold from ores using alkaline cyanide solutions.

[0004] A significant amount of literature has examined alternative extraction processes to cyanide for recovering gold as well as other precious metals from different ores. The alternate leaching agents include thiosulfate, thiourea, thiocyanate and halogens. Reagent decomposition and sulfur precipitation reduce the efficiency of the thio- reagents. Corrosivity and vapor loss have limited the use of elemental halogens, notably, Cl_2 and Br_2 . Use of DBDMH (1,3-dibromo-5,5-dimethylhydantoin) alleviated problems associated with vapor loss; however its low solubility in water (0.1 wt%) necessitated the need for larger quantities of aqueous solutions of the reagent, which makes controlling reagent dosage difficult.

[0005] In shipping and handling aqueous bromine compositions for various uses, especially for use in recovery of precious metals from ores at remote mining sites, the susceptibility of these compositions to freezing creates difficulties. Certain bromine compositions lack stability if subjected to a freeze/thaw cycle, and the susceptibility to freezing may also complicate packaging and shipping. Moreover, many known compositions have rather high freezing points, so that freezing can be a problem even at relatively moderate temperatures.

[0006] In addition to ores and minerals, there are many suitable sources of precious and other metals that offer the opportunity for economical recovery. In fact, many such sources are richer than ores with respect to metal content for recovery. Gold is available from numerous scrap sources, including wastes from industrial uses, gold plated electronic circuit boards, and as an alloy with copper, zinc, silver, or tin in the karat gold used in jewelry. Silver is available from photographic and X-ray film emulsions, from scrap sterling, and from numerous industrial sources. Platinum, palladium and other precious metals such as rhodium, osmium, and iridium are available from spent catalysts, as well as other industrial and/or jewelry scrap sources. However, as the prior art has shown, many efforts while workable, do not satisfy the requirements of less hazard, better economics, greater practicality, fewer material handling problems, reduced environmental concerns, and/or the like.

[0007] There is a need for improved hydrometallurgical processes for dissolving, leaching, and/or extracting precious and desirable base metals as well from a number of sources, thereby enabling recovery or isolation of such metals.

[0008] Further, it would be desirable to provide new leaching solutions from which precious leached metal(s) in suitable dissolved forms can be effectively and economically recovered.

[0009] It would be of advantage if a process could be found that is effective for the recovery of commercially useful base metals often associated with precious metals present in such source materials.

[0010] A novel method for recovery of precious and other metals by electrowinning, and the provision of novel electrolytic solutions useful in such electrowinning processes are also within the purview of this invention.

[0011] Still another objective of this invention is to provide a new way of regenerating used leachant solutions, *i.e.*, solutions which have already been used to remove or extract one or more metals, preferably at least one precious metal, from its source material.

NON-LIMITING SUMMARY OF THE INVENTION

[0012] This invention is effective for recovery of precious metals such as gold, palladium, silver, rhodium, or the like in water soluble form from which these precious metals can be conveniently recovered in economically satisfying yields. If appropriate sources containing mixtures of these precious metals exist or become available, the present process technology is deemed capable of recovering such metals, while at the same time providing aqueous solutions or slurries from which other precious metals (*e.g.*, platinum, osmium, iridium or the like) and/or base metals may be recovered by this or other suitable processing. Accordingly, this invention provides the opportunity of effectively fulfilling the above referred to need for improved hydrometallurgical processes for dissolving, leaching, and/or extracting precious metals and desirably base metals as well from a number of suitable sources thereby enabling recovery and isolation of such metals. Additionally, this invention makes possible the utilization of various commercially-available products that are already being produced by a number of industrial concerns for uses unrelated to usage pursuant to this invention. In most cases, only one or two simple low-cost steps readily convert and adapt such products for effective use in the practice of this invention. Thus in such cases, only relatively inexpensive equipment can be used to effect such conversion and adaptation for effective usage.

[0013] Also, this invention provides effective ways of achieving the above-referred-to advantages of providing new leaching solutions from which precious leached metal(s) in suitable dissolved forms can be effectively and economically recovered.

[0014] This invention provides the opportunity to accomplish still another desirable result referred to above, again in an efficient and a cost-effective manner. In this case, the desirable result is providing ways of recovering of commercially useful base metals often associated with precious metals.

[0015] Provided by this invention is a process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with:

- (I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dihaloisocyanurate source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide; or
- (II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or trihaloisocyanuric acid, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide.

In other words (C) is one of the following:

- 1) at least one solvated alkali metal halide;
- 2) at least one solvated ammonium halide;
- 3) at least one solvated alkaline earth metal halide;
- 4) at least one solvated alkali metal halide and at least one solvated ammonium halide;
- 5) at least one solvated alkali metal halide and at least one solvated alkaline earth metal halide;
- 6) at least one solvated ammonium halide and at least one solvated alkaline earth metal halide;
- 7) at least one solvated alkali metal halide, at least one solvated ammonium halide and at least one solvated alkaline earth metal halide.

The haloisocyanurates of (I) are one of the following:

- 8) at least one alkali metal monohaloisocyanurate;
- 9) at least one alkaline earth metal monohaloisocyanurate;
- 10) at least one ammonium monohaloisocyanurate;
- 11) at least one alkali metal dihaloisocyanurate;
- 12) at least one alkaline earth metal dihaloisocyanurate;
- 13) at least one ammonium dihaloisocyanurate; and
- 14) any combination of any two or more of 8)-13).

The haloisocyanuric acids of (II) are one of the following:

- 15) at least one monohaloisocyanuric acid;
- 16) at least one dihaloisocyanuric acid; and
- 17) at least one trihaloisocyanuric acid; and
- 18) a combination of any two or all three of 15)-17).

[0016] During the above processes at least one precious metal is extracted into a dissolved form of at least one said precious metal. It is also possible for at least one base metal to be extracted.

[0017] Individual or combinations of one or more alkali metal mono- and/or dihaloisocyanurates, ammonium mono- and/or dihaloisocyanurates, alkaline earth metal mono- and/or dihaloisocyanurates and/or isocyanuric acid in the solid state can be used as the source of the solvated mono- and/or dihaloisocyanurate(s) in forming the aqueous leaching solutions of this invention. According to the Material Data Sheet of Chem One Ltd., isocyanuric acid and cyanuric acid are synonymous and are also known as tricarbimide and triacyanic acid and isocyanuric acid and cyanuric acid have the CAS[®] registry number of 108-80-5 (Chemical Abstracts Service). Isocyanuric acid is capable of being converted into alkali metal, ammonium, or alkaline earth metal monohaloisocyanurate salts and/or into alkali metal, ammonium, or alkaline earth metal dihaloisocyanurate salts

[0018] Accordingly, the halogen atom content of the haloisocyanurate salts can be atom(s) of bromine, chlorine, iodine, or fluorine or, since there are 1 to 3 positions in the molecule available for substitution, combinations of different halogen atoms in the molecule may be possible, but perhaps at greater costs to produce. Preferred individual haloisocyanurate salts include sodium monobromoisocyanurate, sodium dibromoisocyanurate, potassium monobromoisocyanurate, potassium dibromoisocyanurate, lithium monobromoisocyanurate, lithium dibromoisocyanurate. The corresponding ammonium salts and the corresponding alkali earth metal salts are also useful in the practice of this invention.

[0019] Processes for producing polyhaloisocyanuric acid are described for example in U.S. Pat. No. 3,993,649. Process technology for producing haloisocyanurate salts such as sodium dichloroisocyanurate, potassium dichloroisocyanurate, and lithium dichloroisocyanurate is described in U.S. Pat. No. 4,005,087.

[0020] Also provided by this invention is a composition comprising at least one precious metal in the form of a solute in an aqueous medium which is:

- (I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dihaloisocyanurate source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide; or

(II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or trihaloisocyanuric acid, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide.

[0021] Also, provided by this invention are a number of additional processes, including the following:

[0022] A process for producing a composition comprising at least one precious metal dissolved in an aqueous medium, which process comprises producing or forming a solution or slurry of:

- (a) an aqueous leaching solution comprising (A) water, (B) at least one solvated mono- and/or dihaloisocyanurate source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide; or
- (b) an aqueous solution or slurry containing at least one solvated mono-, di-, and/or trihaloisocyanuric acid source and at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide;

whereby during the process at least one precious metal is extracted in a dissolved form containing at least one precious metal. Preferably, the halogen atoms of the solvated mono- and/or dihaloisocyanurate source(s) of (I) above are bromine atoms or chlorine atoms, or iodine atoms, although they may also be fluorine atoms. Of these, the halogen atoms are preferably bromine or chlorine with bromine being more preferred. Similarly, the halogen atoms of the haloisocyanuric acid of (II) above are bromine atoms or chlorine atoms, or iodine atoms, although they may also be fluorine atoms. Of these, the halogen atoms are preferably bromine or chlorine with bromine being more preferred.

[0023] Particularly preferred of the one or more solvated mono- and/or dihaloisocyanurate sources of (I) above are sodium dibromoisocyanurate and potassium dibromoisocyanurate with sodium dibromoisocyanurate being especially preferred. Of the mono-, di-, and/or trihaloisocyanuric acids of (II) above, the di- and trihaloisocyanuric acids are preferred, and of these, more preferred are dibromoisocyanuric acid, and tribromoisocyanuric acid, with tribromoisocyanuric acid being more preferred. Mixtures of the dibromo- and tribromoisocyanuric acids are also preferred.

[0024] The halogen atoms of the alkali metal halides and/or the alkaline earth metal halides and/or the ammonium halides in the above processes and in the above compositions are preferably chlorine, bromine and/or iodine atoms, with bromine atoms alone or in combination with chlorine atoms being more preferred. Bromine atoms are even more preferred. It is possible for fluorine atoms to be present. When iodine and/or fluorine atoms are present, it is preferred that atoms of at least one other halogen are also present and that the total number of fluorine atoms is less than the total number of the other halogen atoms.

[0025] As used herein including the claims, the terms “dissolve”, “dissolving”, “dissolved”, *etc.*, “leach”, “leaching”, “leachant”, *etc.*, and “extract” (as a verb), “extracting”, “extract” (as a noun), *etc.*, are used interchangeably. It matters not whether the extracting or leaching solution is quiescent, under agitation, or passing over and/or through the precious metal-containing source material being treated. Naturally, at least a portion of the precious metal in the precious metal-containing source material should be capable of being contacted by the leaching (extracting) solution. In other words, at least a portion of the precious metal should be susceptible to leaching (extracting) by contact with the leaching (extracting) solution being used. When necessary, pretreatment such as grinding, milling or other forms of mechanical subdividing of the precious metal-containing source may be used to expose surfaces of precious metal in its source material for contact by the leaching (extracting) solution to be used. Alternatively, pretreatment with acids or the like may be used to achieve this same objective. Still other methods of rendering the precious metal in its own source material accessible to leaching (extraction) through contact by the leaching (extracting) solution are known and can be used if necessary or desirable. In short, the precious metal in its source material used should be leachable (extractable).

[0026] Another way of achieving good leaching (extraction) of precious metal from its source material is to select a precious metal source material from which suitable amounts of precious metal can be leached (extracted) without any pretreatment to make this possible. It should of course be understood that this discussion about leaching (extraction) of precious metal, does not signify that the precious metal is to be leached (extracted) in solution as a free metal. This may possibly occur in some cases, but in other cases the precious metal leachant (extract) can be in the form of a complex or other chemical entity that is not simply pure dissolved precious metal in ionic form. The end result is in effect

the same because, in either case, the precious metal in some kind of dissolved form is removed from the rest of the source material.

[0027] The aqueous leaching solutions of this invention may be produced on site of the precious metal recovery or may be produced on a toll basis elsewhere and in any such case, stored for usage as needed. There are a number of types of aqueous solutions that may be formed and used pursuant to this invention that comprise at least one solvated mono- and/or dihaloisocyanurate source and at least one solvated alkali metal halide, and/or at least one solvated ammonium halide, and/or at least one alkaline earth metal halide, where the halogen atoms are preferably Cl and/or Br and/or I, but may be or include F atoms. In all cases involving ions from one or more alkali metal halides, the atomic ratio of halogen from isocyanurate(s) to total halide ions from alkali metal halide(s) and/or ammonium halide(s) and/or alkaline earth metal halide(s) is typically in the range of about 1:1 to about 1:20, and preferably in the range of about 1:1 to about 1:3. In all cases involving ions from one or more alkali metal halides, one or more ammonium halides and one or more alkaline earth metal halides, the atomic ratio of halide ions from isocyanurate(s) to total halide ions from alkali metal halide(s), one or more ammonium halides and alkaline earth metal halide(s) is typically in the same ratios as given above. This is accomplished by suitably proportioning the total number of active halogen atoms from the haloisocyanurates to the total number of halide atoms from the alkali metal halide(s), ammonium halide(s) and the alkaline earth metal halides(s).

[0028] The amount of mono- and/or dihaloisocyanurate in the solutions will vary depending upon a number of factors. In the case of the solutions used in the leaching (extracting) operations, the dissolved mono- and/or dihaloisocyanurate concentration can vary from as little as 2 grams/liter of water up to 20 grams per liter or even more depending upon the halogen atom, precious metal content of the precious metal source being used, the temperature of the solutions, the character of the precious metal source material, the particular leaching solution of this invention being used, the pretreatment if any and physical condition of the precious metal source being used, the amount of leaching solution being used, and the like. In any case where such factors have not been established, a few simple small scale trial experiments with different specified concentrations of the mono- and/or dihaloisocyanurate leaching solution of this invention should enable determination of desirable concentrations for use in a larger scale operation.

[0029] Solution concentrations are readily developed from the information and Examples presented herein, the yields achieved and application of common sense.

[0030] Leaching solutions to be used for recovery of precious metals from low grade ores should contain at least about 0.05 wt% preferably at least about 0.1 wt% of the leaching agent. Where the leaching solution is to be used for recovery of metal from such relatively high grade sources as jewelry scraps, karat gold, waste colloidal gold suspensions, and spent platinum metal catalysts, a stronger leaching solution is preferably used, for example, one containing between about 2 pounds and about 10 pounds of leaching agent per ton of solution or between about 1 and about 10 grams per liter. For purposes of this disclosure, a high grade source is one in which the metal to be recovered is present in a weight proportion of greater than 1%, and the metal to be extracted is accessible to the leaching solution without the necessity of chemically degrading non-metallic contaminants.

[0031] In systems containing both solvated bromine-containing and solvated chlorine-containing components, the bromine:chlorine atom ratio is preferably at least about 1:1. When the aqueous leaching solution contains in the range of about 0.01% to about 20% and preferably in the range of about 0.1% to about 5% by weight equivalent molecular bromine, the solution also contains in the range of about 0.01% to about 20% and preferably in the range of about 0.1% to about 5% by weight bromide ion, and in the range of about 0.01% to about 30% preferably in the range of about 0.1% to about 10% by weight total halide ion.

[0032] Further contemplated by the invention is a process for recovery of a precious metal or a base metal in metallic form, the process comprising direct current electrolysis of an electrowinning solution containing at least one mono- and/or dihaloisocyanurate compound or at least one mono-, di-, and/or haloisocyanuric acid and anions comprising a metal complexed with halogens derived from the reaction of the mono- and/or dihaloisocyanurate compound or at least one mono-, di-, and/or trihaloisocyanuric acid with the metal whereby during the process precious metal or base metal in metallic form is produced and electrodeposited. Deposition of a base metal separates it from the precious metal and thus provides a more concentrated form of the precious metal as well as the recoverable base metal.

[0033] Also included in the invention is a process for electrodeposition of a precious metal or base metal. The process comprises direct current electrolysis of an electrolytic

solution containing (i) a dissolved mono- and/or dihaloisocyanurate source or a dissolved at least one mono-, di-, and/or trihaloisocyanuric acid, and anions comprising the metal complexed with halogens, especially bromine, chlorine, or bromine and chlorine atoms, whereby during the process precious metal or base metal are electrodeposited.

[0034] It will be appreciated that it is possible to prepare aqueous solvated solutions of mono- and/or dihaloisocyanurate by mixing with water (a) isocyanuric acid, a halogen and/or (b) one or more alkali metal halide salts, and/or one or more ammonium halide salts and/or one or more alkaline earth metal salts of isocyanuric acid. The alkali metal halide, and/or alkaline earth metal halide and/or ammonium halide can be added before or after the addition of the isocyanuric acid or isocyanuric salts thereof referred to in (a) or (b) above. Also, they may be added concurrently.

[0035] Also included in the invention is a process by which the mono- and/or dihaloisocyanurate or mono-, di-, and/or trihaloisocyanuric acid can be pre-formed or generated in-situ by chemical or electrolytic oxidation of halides in presence of an isocyanurate source or isocyanuric acid (cyanic acid) source. The source of isocyanurate or isocyanuric acid could be from a used aqueous leaching solution or slurry so that an active aqueous leaching solution or slurry is regenerated. Some of the chemical oxidants for bromide oxidation include potassium peroxymonosulfate (Oxone[®]), sodium hypochlorite (bleach), chlorine and trichloroisocyanuric acid (Trichlor).

[0036] Other embodiments, features, variants, and advantages will become apparent from the ensuing description and appended claims.

FURTHER DETAILED DESCRIPTION OF THE INVENTION

[0037] In its preferred embodiments this invention utilizes aqueous solutions comprising aqueous solutions of solvated mono- and/or dibromoisocyanurates or aqueous solutions of combinations of solvated mono- and/or dibromoisocyanurates and solvated mono- and/or dichloroisocyanurates and/or aqueous solutions of solvated mono- and/or diiodoisocyanurates alone or in combination with either or both of solvated mono- and/or dibromoisocyanurates alone or solvated mono- and/or dibromoisocyanurates together with solvated mono- and/or dichloroisocyanurates in combination with solvated alkali metal halides and/or solvated alkaline earth metal halides. It is realized that if water is the sole solvent, the solvated substances can be referred to as “hydrated.” However, “solvated” is

used herein in case an innocuous amount of some highly oxidative-resistant organic protic solvent is present along with water in the solution.

[0038] This invention provides a number of individual novel processes, including the following:

- 1) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with
 - (I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dihaloisocyanurate source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide; or
 - (II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or trihaloisocyanuric acid, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide.
- 2) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dibromoisocyanurate source, (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide.
- 3) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with an aqueous leaching solution comprising (A) water, (B) at least one solvated mono-, di-, and/or tribromoisocyanuric acid source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide.
- 4) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dibromoisocyanurate source or at least one solvated mono-, di-, and/or tribromoisocyanuric acid source, and (C) at least one solvated alkali metal bromide and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide.

- 5) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dibromoisocyanurate source or at least one solvated mono-, di-, and/or tribromoisocyanuric acid source, and (C) at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride.
- 6) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dibromoisocyanurate source or at least one solvated mono-, di-, and/or tribromoisocyanuric acid source, and (C) at least one solvated sodium halide and/or at least one solvated potassium halide.
- 7) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dibromoisocyanurate source or at least one solvated mono-, di-, and/or tribromoisocyanuric acid source, and (C) solvated sodium bromide and/or solvated potassium bromide.
- 8) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dibromoisocyanurate source or at least one solvated mono-, di-, and/or tribromoisocyanuric acid source, and (C) solvated sodium chloride and/or solvated potassium chloride.
- 9) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dichloroisocyanurate source or at least one solvated mono-, di-, and/or trichloroisocyanuric acid source, and (C) at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride.

- 10) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dichloroisocyanurate source, (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide.
- 11) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or trichloroisocyanuric acid source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide.
- 12) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dichloroisocyanurate source or at least one solvated mono-, di-, and/or trichloroisocyanuric acid source, and (C) at least one solvated alkali metal bromide, and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide.
- 13) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dichloroisocyanurate source or at least one solvated mono-, di-, and/or trichloroisocyanuric acid source, and (C) at least one solvated sodium halide and/or at least one solvated potassium halide.
- 14) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dichloroisocyanurate source or at least one solvated mono-, di-, and/or trichloroisocyanuric acid source, and (C) solvated sodium bromide and/or solvated potassium bromide.
- 15) A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with an

aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dichloroisocyanurate source or at least one solvated mono-, di-, and/or trichloroisocyanuric acid source, and (C) solvated sodium chloride and/or solvated potassium chloride.

- 16) A process as in any of 1) to 15) wherein said precious metal comprises gold, palladium, silver, and/or rhodium.
- 17) A process as in 16) wherein the pH of said aqueous leaching solution or slurry is in the range of 7.5 ± 0.5 or less.
- 18) A process as in 17) wherein said precious metal comprises gold and wherein said pH is in the range about 4 to about 6.
- 19) A process as in 17) wherein said precious metal comprises palladium, silver, and/or rhodium and wherein said pH is in the range of 1 or less.

[0039] The use of one or more alkali metal iodides and/or one or more ammonium iodides and/or alkaline earth metal iodides as (C) in each of the above processes is also within the scope of this invention. However, the bromides or chlorides, or both, are preferred halides because of their effectiveness and their lower cost as compared to iodides. As noted earlier herein, the fluorides may be used.

[0040] Also provided by this invention are a number of new and useful compositions, including the following:

- 1) A composition comprising at least one precious metal
 - (I) in dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, and/or dihaloisocyanurate source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide; or
 - (II) in a dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, di-, and/or trihaloisocyanuric acid source and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide.
- 2) A composition comprising at least one precious metal in the form of a solute in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono- and/or dibromoisocyanurate source, (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide.

- 3) A composition comprising at least one precious metal in the form of a solute in an aqueous solution or slurry comprised of (A) water, (B) at least one solvated mono-, di-, and/or tribromoisocyanuric acid source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide.
- 4) A composition comprising at least one precious metal
 - (I) in dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, and/or dibromoisocyanurate source, and (C) at least one solvated alkali metal bromide and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide; or
 - (II) in a dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, di-, or tribromoisocyanuric acid source and (C) at least one solvated alkali metal bromide and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide.
- 5) A composition comprising at least one precious metal
 - (I) in dissolved form in an aqueous leaching solution or slurry comprised of or formed from (A) water, (B) at least one solvated mono-, and/or dibromoisocyanurate source, and (C) at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride; or
 - (II) in a dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, di-, or tribromoisocyanuric acid source and (C) at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride.
- 6) A composition comprising at least one precious metal
 - (I) in dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, and/or dibromoisocyanurate source, and (C) at least one solvated sodium halide and/or at least one solvated potassium halide; or
 - (II) in a dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, di-, or tribromoisocyanuric acid source and (C) at least one solvated sodium halide and/or at least one solvated potassium halide.
- 7) A composition comprising at least one precious metal

- (I) in dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, and/or dibromoisocyanurate source, and (C) solvated sodium bromide and/or solvated potassium bromide; or
 - (II) in a dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, di-, or tribromoisocyanuric acid source and (C) solvated sodium bromide and/or solvated potassium bromide.
- 8) A composition comprising at least one precious metal
- (I) in dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, and/or dibromoisocyanurate source, and (C) solvated sodium chloride and/or solvated potassium chloride; or
 - (II) in a dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, di-, or tribromoisocyanuric acid source and (C) solvated sodium chloride and/or solvated potassium chloride.
- 9) A composition comprising at least one precious metal
- (I) in dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono- and/or dichloroisocyanurate source, and (C) at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride; or
 - (II) in a dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, di-, and/or trichloroisocyanuric acid source and (C) at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride.
- 10) A composition comprising at least one precious metal in the form of a solute in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono- and/or dichloroisocyanurate source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide.
- 11) A composition comprising at least one precious metal in the form of a solute in an aqueous solution or slurry comprised of (A) water, (B) at least one solvated mono-, di-, and/or trichloroisocyanuric acid source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide.
- 12) A composition comprising at least one precious metal

- (I) in dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono- and/or dichloroisocyanurate source, and (C) at least one solvated alkali metal bromide and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide; or
 - (II) in a dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, di-, and/or trichloroisocyanuric acid source and (C) at least one solvated alkali metal bromide and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide.
- 13) A composition comprising at least one precious metal
- (I) in dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, and/or dichloroisocyanurate source, and (C) at least one solvated sodium halide and/or at least one solvated potassium halide; or
 - (II) in a dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, di-, and/or trichloroisocyanuric acid source and (C) at least one solvated sodium halide and/or at least one solvated potassium halide.
- 14) A composition comprising at least one precious metal
- (I) in dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, and/or dichloroisocyanurate source, and (C) solvated sodium bromide and/or solvated potassium bromide; or
 - (II) in a dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, di-, or trichloroisocyanuric acid source and (C) solvated sodium bromide and/or solvated potassium bromide.
- 15) A composition comprising at least one precious metal
- (I) in dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, and/or dichloroisocyanurate source, and (C) at least one solvated sodium chloride and/or solvated potassium chloride; or
 - (II) in a dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, di-, or trichloroisocyanuric acid source and (C) solvated sodium chloride and/or solvated potassium chloride.
- 16) A composition as in any of 1) to 15) wherein said precious metal comprises gold, palladium, silver, and/or rhodium.
- 17) A composition as in 16) wherein the pH of said aqueous leaching solution or slurry is in the range of 7.5 ± 0.5 or less.

18) A composition as in 17) wherein said precious metal comprises gold and wherein said pH in the range about 4 to about 6.

19) A composition as in 17) wherein said precious metal comprises palladium, silver, and/or rhodium and wherein said pH is in the range of 1 or less.

[0041] The use in each of the above compositions of (i) one or more alkali metal iodides and/or (ii) one or more alkaline earth metal iodides and/or (iii) one or more alkali metal fluorides and/or (iv) one or one alkaline earth metal fluorides is also within the practice of this invention. However, the bromides or chlorides, or both, are preferred halides because of their effectiveness and their lower cost as compared to iodides and fluorides.

[0042] Additionally provided by this invention are a number of new and useful processes for preparing an aqueous solution containing at least one precious metal extracted in a solvated form from its source material. These processes include the following:

a) A process for forming a solution or slurry containing a water-soluble form of at least one precious metal, for example, the process comprising contacting a precious metal-containing source material with:

(I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dihaloisocyanurate source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide; or

(II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or trihaloisocyanuric acid, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide;

whereby a leachate (leached product) is formed in said aqueous leaching solution containing in solution said at least one precious metal. Typically the leachate is recovered from said solution or slurry. When the source material additionally contains at least one base metal, optionally the leachate can also contain at least one base metal in solution.

b) A process for forming a solution or slurry containing a water-soluble form of at least one precious metal, the process comprising contacting a precious metal-containing source material with:

(I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dibromoisocyanurate source, and (C) at least one solvated

alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide; or

- (II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or tribromoisocyanuric acid, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide;

whereby a leachate (leached product) is formed in said aqueous leaching solution containing in solution said at least one precious metal. Typically the leachate is recovered from said solution or slurry. When the source material additionally contains at least one base metal, optionally the leachate can also contain at least one base metal in solution.

c) A process for forming a solution or slurry containing a water-soluble form of at least one precious metal, the process comprising contacting a precious metal-containing source material with:

- (I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dibromoisocyanurate source, and (C) at least one solvated alkali metal bromide and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide; or
- (II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or tribromoisocyanuric acid, and (C) at least one solvated alkali metal bromide and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide;

whereby a leachate (leached product) is formed in said aqueous leaching solution containing in solution said at least one precious metal. Typically the leachate is recovered from said solution or slurry. When the source material additionally contains at least one base metal, optionally the leachate can also contain at least one base metal in solution.

d) A process for forming a solution or slurry containing a water-soluble form of at least one precious metal, the process comprising contacting a precious metal-containing source material with:

- (I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dibromoisocyanurate source, and (C) at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride; or

- (II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or tribromoisocyanuric acid, and (C) at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride;

whereby a leachate (leached product) is formed in said aqueous leaching solution containing in solution said at least one precious metal. Typically the leachate is recovered from said solution or slurry. When the source material additionally contains at least one base metal, optionally the leachate can also contain at least one base metal in solution.

e) A process for forming a solution or slurry containing a water-soluble form of at least one precious metal, the process comprising contacting a precious metal-containing source material with:

- (I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dibromoisocyanurate source, and (C) solvated sodium bromide and/or solvated potassium bromide; or
- (II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or tribromoisocyanuric acid, and (C) solvated sodium bromide and/or solvated potassium bromide;

whereby a leachate (leached product) is formed in said aqueous leaching solution containing in solution said at least one precious metal. Typically the leachate is recovered from said solution or slurry. When the source material additionally contains at least one base metal, optionally the leachate can also contain at least one base metal in solution.

f) A process for forming a solution or slurry containing a water-soluble form of at least one precious metal, the process comprising contacting a precious metal-containing source material with:

- (I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dichloroisocyanurate source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide; or
- (II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or trichloroisocyanuric acid, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide;

whereby a leachate (leached product) is formed in said aqueous leaching solution containing in solution said at least one precious metal. Typically the leachate is recovered from said solution or slurry. When the source material additionally contains at least one base metal, optionally the leachate can also contain at least one base metal in solution.

g) A process for forming a solution or slurry containing a water-soluble form of at least one precious metal, the process comprising contacting a precious metal-containing source material with:

- (I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dichloroisocyanurate source, and (C) at least one solvated alkali metal bromide and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide; or
- (II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or trichloroisocyanuric acid, and (C) at least one solvated alkali metal bromide and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide;

whereby a leachate (leached product) is formed in said aqueous leaching solution containing in solution said at least one precious metal. Typically the leachate is recovered from said solution or slurry. When the source material additionally contains at least one base metal, optionally the leachate can also contain at least one base metal in solution.

h) A process for forming a solution or slurry containing a water-soluble form of at least one precious metal, the process comprising contacting a precious metal-containing source material with:

- (I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dichloroisocyanurate source, and (C) at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride; or
- (II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or trichloroisocyanuric acid, and (C) at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride;

whereby a leachate (leached product) is formed in said aqueous leaching solution containing in solution said at least one precious metal. Typically the leachate is recovered

from said solution or slurry. When the source material additionally contains at least one base metal, optionally the leachate can also contain at least one base metal in solution.

i) A process for forming a solution or slurry containing a water-soluble form of at least one precious metal, the process comprising contacting a precious metal-containing source material with:

- (I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dichloroisocyanurate source, and (C) solvated sodium chloride and/or solvated potassium chloride; or
- (II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or trichloroisocyanuric acid, and (C) solvated sodium chloride and/or solvated potassium chloride;

whereby a leachate (leached product) is formed in said aqueous leaching solution containing in solution said at least one precious metal. Typically the leachate is recovered from said solution or slurry. When the source material additionally contains at least one base metal, optionally the leachate can also contain at least one base metal in solution.

- j) A process as in any of a) to i) wherein said precious metal comprises gold, palladium, silver, and/or rhodium.
- k) A process as in j) wherein the pH of said aqueous leaching solution or slurry is in the range of 7.5 ± 0.5 or less.
- l) A process as in k) wherein said precious metal comprises gold and wherein said pH is in the range about 4 to about 6.
- m) A process as in k) wherein said precious metal comprises palladium, silver, and/or rhodium and wherein said pH is in the range of 1 or less.

[0043] Still another embodiment of this invention is a process for dissolving at least one precious metal from a material containing or composed of at least one precious metal in leachable form and optionally at least one base metal in leachable form, and/or for leaching at least one precious metal in leachable form from a source material comprising at least one precious metal, the process comprising the steps of:

- (A) forming or obtaining (*i.e.*, providing) a composition comprising
- (I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dihaloisocyanurate source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide (preferably where the halogen of said mono-

- and/or dihaloisocyanurate compound and of said metal halide being, independently, bromine, chlorine, or iodine, or a combination of at least two thereof, but which may be fluorine); or
- (II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or trihaloisocyanuric acid, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide (preferably where the halogen of said mono-, di-, and/or trihaloisocyanuric acid and of said metal halide being, independently, bromine, chlorine, or iodine, or a combination of at least two thereof, but which may be fluorine);
 - (B) contacting said material or source material with said composition whereby a leachate is formed containing said at least one precious metal and optionally at least one base metal; and
 - (C) recovering leachate from the remainder of the so-processed composition (*i.e.*, that which is left after such recovery).

Preferably, the precious metal comprises gold, palladium, silver, and/or rhodium. The pH of said aqueous leaching solution or slurry is in the range of 7.5 ± 0.5 or less. In the case of gold, the pH is preferably in the range about 4 to about 6 and in the case of palladium, silver, and/or rhodium the pH is preferably in the range of 1 or less.

[0044] Temperatures used in the leaching (extraction) operations of this invention can vary provided that under the pressure conditions at which the process is conducted, the leaching solution contains enough liquid water to enable leaching to occur. Desirably, however, temperatures of the leaching solution when in use are in the range of about ambient room temperature to about 60°C. Pressures may be atmospheric, autogenous, sub-atmospheric, or super-atmospheric. Atmospheric or autogenous pressures are usually preferred.

[0045] Because the metal leaching processes of the invention may be carried out without the use of any cyanide, it offers significant advantages from the standpoint of both safety and environmental protection. This translates into major cost advantages, since elaborate cyanide disposal facilities and procedures may be entirely eliminated.

[0046] The leaching processes of this invention enable recovery of precious metals from refractory ores and ores containing sulfide minerals and carbonaceous material. The processes are deemed capable of providing improved rates of leaching such ores as

compared to cyanide-based processing. While oxidative treatment of sulfide-containing or carbonaceous ores generally remains necessary, the oxidizing power of the leaching agents used pursuant to this invention is such that it may be used for this purpose as well. Generally, an acidic solution of the leaching agent is used for oxidative pre-leaching, while either an acidic or basic solution of the leaching agent is used for recovery of the metal from the ore after oxidation and removal of sulfides and excess carbonaceous material.

[0047] The process technology of this invention makes possible the recovery of metal values from gold ores, silver ores and other precious metal ores. Moreover, leaching using the leaching solutions of this invention is effective and advantageous for secondary recovery of precious metals from other source materials such as jewelry scraps, silver halide film emulsions, spent colloidal gold suspensions, gold plating from electronic circuit boards, spent platinum metal catalysts and the like. Further in accordance with the invention, the solvated mono- and/or dihaloisocyanurate source together with one or more solvated alkali metal halides and/or one or more alkaline earth metal halides may be utilized for leaching of the various base metals, particularly those which form halide complex anions such as aluminum, magnesium, chromium, iron, cobalt, nickel, copper, tin, bismuth, antimony, cadmium, lead, zinc, indium, gallium and arsenic.

[0048] Precious metal of particular interest in the practice of this invention include, without limitation, gold, silver, platinum, palladium, osmium, rhodium, and iridium.

[0049] Without being bound by theory, it appears reasonable to suggest that the leaching agent systems of this invention used may react with the with at least one precious metal in the source material to form an anion comprising the precious metal complexed with halogen, and that this complex anion has sufficient stability to remain in the leaching solution. Whatever the mechanism, the processes of this invention provide effective methods for recovery of precious metal(s) while optionally enabling recovery of at least one base metal as well, because of its separation or ready separability from the precious metal complex or other chemical entity form.

[0050] As noted above, another embodiment of this invention is a process which comprises preforming or generating *in situ* at least one solvated mono- and/or dihaloisocyanurate or at least one solvated mono-, di-, or trihaloisocyanuric acid by chemically or by electrolytically oxidizing at least one halide source in presence of at least one isocyanurate source such as isocyanuric acid or a water soluble salt of isocyanuric

acid. In a further embodiment, the source of isocyanurate can be a previously used lixiviant solution whereby the residual active lixiviant is regenerated either chemically or electrolytically. Some of the chemical oxidants for use in forming and/or regenerating mono- and/or dihaloisocyanurate include Oxone (potassium peroxydisulfate), bleach (sodium hypochlorite), chlorine and Trichlor (trichloroisocyanuric acid). The mixing of such oxidants with water can be conducted at any temperature in which the water remains in the liquid state *e.g.*, typically at ambient room temperatures or at temperatures up to about 60°C. Conventional forms of agitation can be used in forming such solutions.

[0051] The pH of the aqueous leaching solutions used in the practice of this invention can be readily adjusted if necessary to achieve optimum extraction or leaching conditions to the particular precious metal source being treated. For example, when using highly basic solutions, addition of mineral acids (*e.g.*, sulfuric acid, hydrobromic acid, hydrochloric acid, or the like) to reduce the pH is a convenient way of accomplishing pH adjustment. Precious metal sources which have extraction characteristics similar to gold can be effectively extracted or leached at pH levels in the range of about 7.5 ± 0.5 or less. In the case where the precious metal comprises gold, pH levels in the range of 4 to 6 are preferred. Operations conducted in this range tend to be more selective when at least some other dissolved metals are present. In the case where the precious metal comprises palladium, silver, and/or rhodium, pH levels in the range of about 1 or less are preferred. Continuous addition of such acids during the extraction or leaching operation is usually preferred. In any given situation, a few simple pilot tests with a given proposed aqueous leaching solution, a given precious metal source, and a selected acid to achieve optimum extraction at a given temperature will suffice.

[0052] For pre-leaching and oxidative treatment of carbonaceous ores, it is preferred that the treating solution be acidic. As in the case of alkaline leaching solutions, the acidic solution should contain at least about 0.05%, preferably at least about 0.1% by weight of the leaching agent. The pH is preferably in the range of between about 1 and about 7. Acids which may be used in the acidic leaching solution include, but are not limited to, hydrochloric acid, hydrobromic acid, hydroiodic acid, nitric acid, sulfuric acid and acetic acid.

[0053] The metal source material may be contacted with the leaching solution in any conventional fashion, for example, by causing the leaching solution to percolate through a mass of ore or other sources material. For use in this leaching technique, the ore is initially

crushed, typically to a particle size of less than 25 millimeters, and the particulate mass is placed on impermeable surfaces such as liners, sheeting or pads prior to initiating percolation of the leaching solution through the crushed source material.

[0054] Alternatively, the ore may be subjected to vat leaching or agitation leaching. In vat leaching, the ore is crushed, again typically to a particle size of less than 25 mm, and agglomerated, for example, with lime or cement. Leaching solution is passed through a bed of particulate ore contained within a leaching vessel. The solution may be passed either upwardly or downwardly through the bed of material; or the leaching solution and ore can be moved countercurrently through a continuous or cascade leaching system.

[0055] In agitation leaching, the ore is typically ground to a finer particle size, for example, to a size in which 50% by weight or more passes through a standard 200 mesh sieve. Thereafter, a leaching slurry is formed by suspending a source material in the leaching solution. Leaching rates are enhanced by agitating the leaching slurry to promote mass transfer from the solid source material to the leaching solution. However, while agitation is desirable, excessive shearing action is undesirable. Therefore, typically a propeller type agitator is used.

[0056] In leaching of ore, the ore is contacted with leaching solution in relative proportions equivalent to at least about 2 preferably at least about 5 pounds of mono- and/or dihaloisocyanurate source per ton of ore. For maximum productivity in slurry leaching, the solids content of the leaching slurry should not be greater than about 40% by weight. Leaching may be carried out at any temperature above ambient, but is preferably conducted at a temperature of between about 70° and about 140° F., *i.e.*, between about 20° and about 60°C. At temperatures in the aforesaid range, leaching proceeds very rapidly. In slurry leaching, complete and quantitative recovery of precious metal from ore may be accomplished within a contact time of one to two hours, or even less.

[0057] For oxidative pre-leaching of carbonaceous or sulfide bearing ore, the conditions employed are generally comparable to those used for leaching. For treatment of high grade ores, or in the case of secondary recovery, the pre-leaching oxidative treatment step is not normally necessary.

[0058] To recover the metal from the leachate, various techniques may be utilized. In some instances, particularly in the case of secondary recovery from a metal-rich source material, the leachate may be subjected directly to electrowinning or precipitation. In electrowinning, the metal to be recovered is preferably recovered on a cathode of the same

metal. Alternatively, an inert cathode may be used. Conventional inert anode materials, current densities, temperatures and other conditions conventionally appropriate for the particular metal to be recovered are utilized in the electrowinning process. In one advantageous application, the electrolytic system comprises a steel wool cathode and an ion exchange membrane for dividing the anodic and cathodic zones.

[0059] Where the leachate contains a precious metal, it is often feasible to recover it by contacting the leachate with a metal less noble than the leached metal, thereby precipitating the leached metal in metallic form. In the case of gold, precipitation may be carried out by methods known to the art, for example, in a Merrill-Crowe apparatus using zinc as the precipitating agent. In a preferred commercial technique, the leachate is contacted with zinc shavings or zinc powder in the presence of lead acetate, the lead acetate typically being provided as a coating on the surface of the zinc. In a still further alternative recovery method, the leachate may be contacted with an ion exchange resin effective for separating anionic precious metal complexes from aqueous solutions. Typical of these are resins selective for silver and/or gold such as AMBERJET™ 4200 Cl as sold by The Dow Chemical Company. The metal may then be recovered from the resin pyrolytically.

[0060] Where the leachate is derived from ore, particularly where it is obtained by leaching of refractory or other low grade ore, it is normally desirable to concentrate the metal before attempting to recover it in metallic form. A preferred method for concentrating the metal is by adsorption of halometal complex salts from the leachate onto activated carbon, followed by redissolution in a desorptive leaching solution. In accordance with the process of the invention, the desorbing agent contained in the desorption solution may comprise a solvated mono- and/or dihaloisocyanurate or mono-, di-, or trihaloisocyanuric acid systems of this invention, and the metal may ultimately be recovered from the desorbate by precipitation or electrowinning. Where the metal is redissolved in a solvated mono- and/or dihaloisocyanurate solution, the concentrated desorption solution is preferably substantially saturated with respect to solvated mono- and/or dihaloisocyanurate, and the desorbate contains 5 to 30 grams per liter of the desorbed metal. It is also preferred that the desorption solution be either alkaline in a pH range of about 7.5 to about 13, or acid in a pH range of between about 1 and about 5. Desorptive leaching of the metal from the activated carbon is preferably carried out at a temperature of between about 30°C and about 95°C at atmospheric pressure.

[0061] A desirable way of recovering precious metal(s) from the aqueous leaching (extraction) solution is to contact this solution with a suitable adsorption agent such as activated carbon or an adsorbent resin. Examples of suitable adsorbent resins are Dowex-21k resin and Reilex 425 ion exchange resin. The contacting may be effected in various ways such as stirring the adsorption agent in a body of the aqueous leaching solution and recovering the resultant metal-containing particles by a mechanical separation procedure such as filtration, centrifugation, decantation, or the like. Alternatively, the aqueous leaching solution can be passed through a bed of the adsorption agent whereby a bed of particles of adsorbed precious metal-containing product is formed for further treatment such as incinerating or smelting the carbon or resin particles to recover the precious metal(s). Alternatively, the precious metal may be recovered from the adsorptive resins by extraction of the precious metal-laden particles using eluants such as hydrochloric acid or acidified thiourea solution. Other methods known to the art *e.g.*, pyrolysis, may also be used for these recovery operations.

[0062] To regenerate the used aqueous lixiviant solutions, chemical oxidation with sodium hypochlorite solution, trichloroisocyanuric acid, or potassium peroxymonopersulfate converts the bromide in the used solution to bromine and thus should also be effective for oxidizing the other halides to halogens. Thus these reagents regenerate at least mono- and/or dibromoisocyanurate for reuse.

[0063] Electrowinning of a precious metal or base metal from a solvated mono- and/or dihaloisocyanurate solution comprises a useful method for recovery of such metals. Generally, the electrolytic solution used for electrowinning contains between about 5 and about 30 grams per liter, preferably at least about 15 grams per liter, of the desired metal in the form of halometal complex anions, and is substantially saturated with respect to solvated mono- and/or dihaloisocyanurate. When the electrowinning solution is acidic, it preferably has a pH of between about 4 and about 6. Where it is alkaline, it preferably has a pH of between about 7.5 and about 9. Application of a direct current through the solution breaks down the metal halide complex anions at the anode, resulting in the formation of free metal ions which are attracted to the cathode where they are reduced and the metal is deposited. The selection of anode and cathode materials, current density, electrode spacing, temperature and other conditions is governed by conventional practice for electrowinning of the particular metal involved. Thus, for example, in the case of gold electrowinning is preferably carried out at a temperature of not greater than about 140° F

(60° C), a current density of approximately 0.25 amps./ft.², a voltage of 1.9 to 2.1 volts, and an electrode spacing of not greater than about 2". As noted above, after electrowinning is complete, the spent electrolytic solution may be replenished with leaching agent, pH-adjusted as necessary, and recycled for leaching of additional source material.

[0064] Further in accordance with the invention, electrolytic solutions of the type described above in connection with electrowinning can be used for other electrodeposition processes, including electrorefining and electroplating. In electrorefining, the anode comprises the metal to be purified, and the electrolytic solution contains solvated mono- and/or dihaloisocyanurate and halogen complex anions of the metal which is to be deposited at the cathode as direct current is applied. In some instances, the metal to be refined is deposited at the cathode, while in other instances an impurity is deposited at the cathode while the metal to be refined is collected in the form of a sludge or mud as the anode disintegrates. For example, gold contaminated with silver may be refined by subjecting an anode of such material to electrolysis in a bath comprising solvated mono- and/or dihaloisocyanurate and halogenated silver complex anions. Silver is deposited at the cathode and as the anode disintegrates a mud rich in gold is collected by conventional means, for example, in a filter bag surrounding the anode. The mud is washed and the gold contained therein is melted down, formed into another anode, and subjected to further electrofining, this time in a bath comprising solvated mono- and/or dihaloisocyanurate and halogenated gold complex anions, with metallic gold being deposited at the cathode.

[0065] In electroplating, a part to be plated is immersed in a bath comprising a solvated mono- and/or dihaloisocyanurate and halogen complex anions of the metal to be deposited. The anode may be either inert or comprise the plating metal. In electrofining and electroplating, as in electrowinning, the temperatures, current densities, voltages, electrode spacings, *etc.*, are those conventionally used in the art.

[0066] The following Examples are provided for the purpose of illustration. They are not intended to limit the invention to only the details presented therein.

EXAMPLE 1

[0067] Tribromoisocyanuric acid was prepared by the method of L. S. de Almeida, P. M. Esteves, M. C. S. de Mattos, Synlett, 2006, 1515-1518. A saturated solution of tribromisocyanuric acid was prepared by stirring 0.5g of tribromoisocyanuric acid and 1.0g of sodium bromide in 100 mL of water for 2 hrs. The isocyanuric acid did not

dissolve completely. In to this slurry, a piece of gold wire (15 mg) was dropped and stirred for 48 hrs. at room temperature at a pH of 7. Analysis of the supernate from the resulting mixture showed 151 ppm of Au by ICP analysis indicating 100% recovery of gold.

EXAMPLE 2

[0068] A saturated solution of dibromoisocyanuric acid was prepared by stirring 1g of the dibromoisocyanuric acid (obtained from TCI America) and 1g of sodium bromide in 100 mL of water for 15 hrs. The clear supernate was decanted and analyzed. The yellow solution contained 0.83 wt% active bromine, pH =6.4 and had an ORP = 880 mV. This solution (50g) was stirred with a piece of gold wire (19 mg) overnight. The piece of gold wire dissolved completely and the solution contained 385 ppm of Au (100% recovery) by ICP analysis.

EXAMPLE 3

[0069] A saturated solution of was obtained by stirring 1g of sodium monobromoisocyanurate (obtained from TCI America) and 1g of sodium bromide in 100 mL of water overnight. The light yellow supernate was separated and analyzed. The supernate contained 0.11 wt% active bromine and pH = 7.8. The supernate (50g) was stirred with a piece of gold wire (17 mg) overnight. The wire did not dissolve at this pH. Two drops of 48% HBr solution was added to the mixture to bring the pH down to 6.3 and then stirred for 15 hrs. The wire dissolved and analysis of the solution by ICP showed 334 ppm of Au (98% recovery of gold).

EXAMPLE 4

[0070] To a solution of 1 g of sodium bromide and 10 g of 48% hydrobromic acid in 40 mL of water, 1 g of dibromoisocyanuric acid was added and magnetically stirred. The bromoisocyanuric acid did not dissolve completely in the mixture with a pH of <1. To the slurry was added a piece of silver foil (9 mg), a piece of palladium wire (0.5 mm diameter; 20 mg) and rhodium black powder (10 mg) and stirred at room temperature for 60 hours. A sample of the slurry was filtered through a syringe filter and the clear filtrate was analyzed for metals by ICP. ICP analysis showed 3 ppm of silver (2% recovery), 395 ppm of palladium (99% recovery) and 32 ppm of rhodium (16% recovery). As seen from the Examples, it is desirable when forming a leaching solution of this invention to separate the

supernatant liquid from any solids that may exist in the reaction mixture. The solids-free supernatant liquid is then used as the leaching solution. However, it is possible to use the slurry although this involves the need for separating the gold product from the other solids.

[0071] The above Examples illustrate various embodiments or features of this invention which comprise processes and compositions involving solutions containing precious metals including gold, palladium, silver, rhodium, or the like. Thus, one such embodiment is a process for forming a water-soluble form of such metals, the process comprising:

- A) forming or obtaining a composition comprising (i) an aqueous medium containing in the range of about 1 to about 100 grams/liter (preferably in the range of about 1 to about 20 grams/liter) of at least one solvated mono- and/or dihaloisocyanurate source or at least one solvated mono-, di-, and/or trihaloisocyanuric acid, and (ii) in the range of about 1 to about 100 grams/liter (preferably in the range of about 1 to about 20 grams/liter) of solvated sodium bromide;
- B) optionally acidifying said composition with a mineral acid to form a lixiviant solution having a pH in the range of about 7.5 ± 0.5 or less (preferably a pH in the range of about 4 to about 6 for gold, and preferably a pH in the range of about 1 or less for palladium, silver and/or rhodium), and optionally diluting said lixiviant solution with water to provide a diluted solution having a reduced active bromine content sufficient to leach gold, palladium, silver, and/or rhodium from a leachable source; and
- C) contacting said leachable source with said lixiviant solution whereby a leachate is formed containing gold, palladium, silver, and/or rhodium in solution, and optionally recovering leachate from the so-processed composition.

[0072] Another such embodiment is a composition comprising gold, palladium, silver and/or rhodium in the form of a solute or slurry in an aqueous medium comprising (A) water, (B) at least one solvated mono-, and/or di-, and/or tribromoisocyanuric acid, and (C1) solvated sodium bromide or (C2) solvated ammonium bromide or (C3) solvated alkaline earth metal bromide, or (C4) a combination of any two or all three of (C1), (C2), (C3), the solution having a pH in the range of about 7.5 ± 0.5 or less. In the case of gold, the pH of the solution or slurry is preferably in the range of about 4 to about 6. In the case of palladium, silver, and/or rhodium, the pH of the solution or slurry is preferably in the range of about 1 or less.

[0073] Preferably the leaching solutions of this invention have an oxidation potential of >600 mV, more preferably >750 mV; and/or preferably an "active" halogen concentration of 0.5 g/L to 75 g/L, more preferably, 1 g/L to 10 g/L; and/or preferably a halide to "active" halogen ratio of 100/1 to 1/5, more preferably 10/1 to 1/1.

[0074] If desired, the aqueous leaching solutions of this invention may be used in combination with other known precious metal lixivants such as, for example, 1,3-dibromo-5,5-dialkylhydantoins (*e.g.*, 1,3-dibromo-5,5-dimethylhydantoin) and/or N,N'-bromochloro-5,5-dialkylhydantoins (*e.g.*, N,N'-bromochloro-5,5-dimethylhydantoin).

[0075] As used herein, the term "about" modifying the quantity of an ingredient in the compositions of the invention or employed in the methods of the invention refers to variation in the numerical quantity that can occur, for example, through typical measuring and liquid handling procedures used for making concentrates or use solutions in the real world; through inadvertent error in these procedures; through differences in the manufacture, source, or purity of the ingredients employed to make the compositions or carry out the methods; and the like. The term "about" also encompasses amounts that differ due to different equilibrium conditions for a composition resulting from a particular initial mixture. Whether or not modified by the term "about", the claims include equivalents to the quantities.

[0076] The invention may comprise, consist, or consist essentially of the materials and/or procedures recited herein.

[0077] Except as may be expressly otherwise indicated, the article "a" or "an" if and as used herein is not intended to limit, and should not be construed as limiting, the description or a claim to a single element to which the article refers. Rather, the article "a" or "an" if and as used herein is intended to cover one or more such elements, unless the text expressly indicates otherwise.

[0078] This invention is susceptible to considerable variation in its practice. Therefore the foregoing description is not intended to limit, and should not be construed as limiting, the invention to the particular exemplifications presented hereinabove.

CLAIMS:

1. A process for extracting at least one precious metal from a source material containing at least one said metal, the process comprising contacting said source material with
 - (I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dihaloisocyanurate source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide; or
 - (II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or trihaloisocyanuric acid, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide.
2. A process as in Claim 1 wherein (B) comprises at least one solvated mono- and/or dibromoisocyanurate source.
3. A process as in Claim 1 wherein (B) comprises at least one solvated mono-, di-, and/or tribromoisocyanuric acid source.
4. A process as in Claim 1 wherein (B) comprises at least one solvated mono- and/or dibromoisocyanurate source or at least one solvated mono-, di-, and/or tribromoisocyanuric acid source, and wherein (C) comprises at least one solvated alkali metal bromide and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide.
5. A process as in Claim 1 wherein (B) comprises at least one solvated mono- and/or dibromoisocyanurate source or at least one solvated mono-, di-, and/or tribromoisocyanuric acid source, and wherein (C) comprises at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride.
6. A process as in Claim 1 wherein (B) comprises at least one solvated mono- and/or dibromoisocyanurate source or at least one solvated mono-, di-, and/or tribromoisocyanuric acid source, and wherein (C) comprises at least one solvated sodium halide and/or at least one solvated potassium halide.
7. A process as in Claim 6 wherein (C) comprises solvated sodium bromide and/or solvated potassium bromide.

8. A process as in Claim 6 wherein (C) comprises solvated sodium chloride and/or solvated potassium chloride.
9. A process as in Claim 1 wherein (B) comprises at least one solvated mono- and/or dichloroisocyanurate source.
10. A process as in Claim 1 wherein (B) comprises at least one solvated mono-, di-, and/or trichloroisocyanuric acid source.
11. A process as in Claim 1 wherein (B) comprises at least one solvated mono- and/or dichloroisocyanurate source or at least one solvated mono-, di-, and/or trichloroisocyanuric acid source, and wherein (C) comprises at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride.
12. A process as in Claim 1 wherein (B) comprises at least one solvated mono- and/or dichloroisocyanurate source or at least one solvated mono-, di-, and/or trichloroisocyanuric acid source, and wherein (C) comprises at least one solvated alkali metal bromide, and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide.
13. A process as in Claim 1 wherein (B) comprises at least one solvated mono- and/or dichloroisocyanurate source or at least one solvated mono-, di-, and/or trichloroisocyanuric acid source, and wherein (C) comprises at least one solvated sodium halide and/or at least one solvated potassium halide.
14. A process as in Claim 13 wherein (C) comprises solvated sodium bromide and/or solvated potassium bromide.
15. A process as in Claim 13 wherein (C) comprises solvated sodium chloride and/or solvated potassium chloride.
16. A process which comprises regenerating the aqueous leaching solution or slurry chemically or electrolytically from a used aqueous leaching solution or slurry formed by the process of any of Claims 1-15 and employed in extracting at least one precious metal from a source thereof.
17. A process as in Claim 16 where the regenerating is effected by contacting the used aqueous leaching solution or slurry with a chemical oxidant selected from the group consisting of potassium peroxydisulfate, sodium hypochlorite, chlorine, and trichloroisocyanuric acid.

18. A process as in Claim 1-15 wherein said aqueous leaching solution or slurry has a pH in the range of about 7.5 ± 0.5 or less.
19. A process as in Claim 18 wherein said precious metal is at least one precious metal selected from gold, palladium, silver, and rhodium.
20. A process as in Claim 19 wherein said precious metal comprises gold and wherein the pH is in the range of about 4 to about 6.
21. A process as in Claim 19 wherein said precious metal comprises palladium, silver, or rhodium or a mixture thereof and wherein the pH is in the range of 1 or less.
22. A composition comprising at least one precious metal
 - (I) in dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono- and/or dihaloisocyanurate source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide; or
 - (II) in dissolved form in an aqueous leaching solution or slurry comprised of (A) water, (B) at least one solvated mono-, di-, and/or trihaloisocyanuric acid source and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide.
23. A composition as in Claim 22 wherein (B) comprises at least one solvated mono- and/or dibromoisocyanurate source.
24. A composition as in Claim 22 wherein (B) comprises at least one solvated mono-, di-, and/or tribromoisocyanuric acid source.
25. A composition as in Claim 22 wherein (B) comprises at least one solvated mono- and/or dibromoisocyanurate source or at least one solvated mono-, di-, or tribromoisocyanuric acid source, and wherein (C) comprises at least one solvated alkali metal bromide and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide.
26. A composition as in Claim 22 wherein (B) comprises at least one solvated mono- and/or dibromoisocyanurate source or at least one solvated mono-, di-, or tribromoisocyanuric acid source, and wherein (C) comprises at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride.
27. A composition as in Claim 22 wherein (B) comprises at least one solvated mono- and/or dibromoisocyanurate source or at least one solvated mono-, di-, or

tribromoisocyanuric acid source, and wherein (C) comprises at least one solvated sodium halide and/or at least one solvated potassium halide.

28. A composition as in Claim 27 wherein (C) comprises solvated sodium bromide and/or solvated potassium bromide.

29. A composition as in Claim 27 wherein (C) comprises solvated sodium chloride and/or solvated potassium chloride.

30. A composition as in Claim 22 wherein (B) comprises at least one solvated mono- and/or dichloroisocyanurate source.

31. A composition as in Claim 22 wherein (B) comprises at least one solvated mono-, di-, and/or trichloroisocyanuric acid source.

32. A composition as in Claim 22 wherein (B) comprises at least one solvated mono- and/or dichloroisocyanurate source, or (B) comprises at least one solvated mono-, di-, and/or trichloroisocyanuric acid source; and wherein (C) comprises at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride.

33. A composition as in Claim 22 wherein (B) comprises at least one solvated mono- and/or dichloroisocyanurate source or at least one solvated mono-, di-, and/or trichloroisocyanuric acid source, and wherein (C) comprises at least one solvated alkali metal bromide and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide.

34. A composition as in Claim 22 wherein (B) comprises at least one solvated mono- and/or dichloroisocyanurate source or at least one solvated mono-, di-, and/or trichloroisocyanuric acid source, and wherein (C) comprises at least one solvated sodium halide and/or at least one solvated potassium halide.

35. A composition as in Claim 34 wherein (C) comprises solvated sodium bromide and/or solvated potassium bromide.

36. A composition as in Claim 34 wherein (C) comprises solvated sodium chloride and/or solvated potassium chloride.

37. A composition as in any of Claims 22-36 wherein said aqueous leaching solution or slurry has a pH in the range of about 7.5 ± 0.5 or less.

38. A composition as in Claim 37 wherein said precious metal is at least one precious metal selected from gold, palladium, silver, and rhodium.

39. A composition as in Claim 38 wherein said precious metal comprises gold and wherein the pH is in the range of about 4 to about 6.

40. A composition as in Claim 38 wherein said precious metal comprises palladium, silver, or rhodium or a mixture thereof and wherein the pH is in the range of 1 or less.

41. A process for forming a solution or slurry containing a water-soluble form of at least one precious metal, the process comprising contacting a precious metal-containing source material with:

- (I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dihaloisocyanurate source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide; or
- (II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or trihaloisocyanuric acid, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide;

whereby a leachate is formed in said aqueous leaching solution or slurry containing said at least one precious metal.

42. A process as in Claim 41 wherein (B) comprises at least one solvated mono- and/or dibromoisocyanurate source or at least one solvated mono-, di-, and/or tribromoisocyanuric acid.

43. A process as in Claim 42 wherein (C) comprises at least one solvated alkali metal bromide and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide.

44. A process as in Claim 43 wherein (C) comprises solvated sodium bromide and/or solvated potassium bromide.

45. A process as in Claim 42 wherein (C) comprises at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride.

46. A process as in Claim 41 wherein (B) comprises at least one solvated mono- and/or dichloroisocyanurate source or at least one solvated mono-, di-, and/or trichloroisocyanuric acid.

47. A process as in Claim 46 wherein (C) comprises at least one solvated alkali metal bromide and/or at least one solvated alkaline earth metal bromide, and/or at least one solvated ammonium bromide.
48. A process as in Claim 46 wherein (C) comprises at least one solvated alkali metal chloride and/or at least one solvated alkaline earth metal chloride, and/or at least one solvated ammonium chloride.
49. A process as in Claim 48 wherein (C) comprises solvated sodium chloride and/or solvated potassium chloride.
50. A process as in any of Claims 41-49 wherein said aqueous leaching solution has a pH in the range of about 7.5 ± 0.5 or less.
51. A process as in Claim 50 wherein said precious metal comprises gold, palladium, silver, or rhodium or any mixture of any two or more of these metals.
52. A process as in Claim 51 wherein said precious metal comprises gold and wherein said pH is in the range of about 4 to about 6.
53. A process as in Claim 51 wherein said precious metal comprises palladium, silver or rhodium or a mixture thereof and wherein said pH is in the range of 1 or less.
54. A process for dissolving at least one precious metal from a material containing or composed of at least one precious metal in leachable form and optionally at least one base metal in leachable form, and/or leaching at least one precious metal in leachable form from a source material comprising at least one precious metal, the process comprising the steps of:
- (A) forming or obtaining a composition comprising
 - (I) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono- and/or dihaloisocyanurate source, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide; or
 - (II) an aqueous leaching solution or slurry comprising (A) water, (B) at least one solvated mono-, di-, and/or trihaloisocyanuric acid, and (C) at least one solvated alkali metal halide and/or at least one solvated alkaline earth metal halide, and/or at least one solvated ammonium halide;
 - (B) contacting said material or source material with said composition whereby a leachate is formed in said composition containing said at least one precious metal and optionally at least one base metal; and

(C) recovering leachate from said composition.

55. A process for recovery of a precious metal or a base metal in metallic form, the process comprising direct current electrolysis of an electrowinning solution containing at least one mono- and/or dihaloisocyanurate compound or at least one mono-, di-, and/or trihaloisocyanuric acid and anions comprising a metal complexed with halogens derived from the mono- and/or dihaloisocyanurate compound or the at least one mono-, di-, and/or trihaloisocyanuric acid with the precious metal or base metal whereby during the process the precious metal or base metal in metallic form is produced and electrodeposited.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/070344

A. CLASSIFICATION OF SUBJECT MATTER
INV. C22B3/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C22B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 103 114 202 A (UNIV JILIN) 22 May 2013 (2013-05-22) the whole document	1-16, 18-55
X	& CN 103 114 202 K1 (UNIV JILIN) 22 May 2013 (2013-05-22) the whole document	1-16, 18-55
X	----- CN 101 215 633 A (SHI S) 9 July 2008 (2008-07-09) the whole document	1-16, 18-55
X	& CN 101 215 633 K1 (SHI S) 9 July 2008 (2008-07-09) the whole document ----- -/-	1-16, 18-55



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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INTERNATIONAL SEARCH REPORT

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	LEONARDO S. DE ALMEIDA ET AL: "A New Regioselective Bromination of Activated Aromatic Rings", SYNTHESIS, no. 2, 1 January 2006 (2006-01-01), pages 221-223, XP055175551, ISSN: 0039-7881, DOI: 10.1055/s-2005-918511 cited in the application the whole document -----	1-55

INTERNATIONAL SEARCH REPORT

Information on patent family members

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