



US 20090019970A1

(19) **United States**

(12) **Patent Application Publication**  
**Ritchie et al.**

(10) **Pub. No.: US 2009/0019970 A1**

(43) **Pub. Date: Jan. 22, 2009**

(54) **PROCESS FOR RECOVERY OF METAL VALUES FROM MATERIALS CONTAINING ARSENIC AND/OR ANTIMONY**

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(21) Appl. No.: **12/067,060**

(22) PCT Filed: **Oct. 19, 2006**

(86) PCT No.: **PCT/AU06/01549**

§ 371 (c)(1),  
(2), (4) Date: **Aug. 19, 2008**

(30) **Foreign Application Priority Data**

Oct. 19, 2005 (AU) ..... 2005905785

**Publication Classification**

(51) **Int. Cl.**  
**C22B 3/08** (2006.01)  
**C22B 11/00** (2006.01)  
(52) **U.S. Cl.** ..... **75/744; 75/743**

(57) **ABSTRACT**

A method for the recovery of metal values from a metal value-bearing material containing arsenic and/or antimony and a source of sulphate ions such as sulphide ore or concentrate is disclosed. In one form the method comprises the steps of: (a) providing a feed stream comprising a metal value-bearing material containing arsenic and/or antimony and a source of sulphate ions; (b) subjecting the feed stream to oxidative conditions under elevated temperature and pressure conditions in the presence of at least one component selected to decrease the effective concentration of free acid generated during the pressure oxidation step and promote the formation of pH-stable iron (III) sulphate products, thereby forming a slurry comprising a metal value-containing leach solution and a solid leach residue containing pH-stable iron (III) sulphate products and environmentally stable iron-arsenic and/or iron-antimony products; (c) separating the metal value-containing leach solution from the solid leach residue; (d) recovering the metal value (s) from the metal value-containing leach solution; and (e) recovering precious metal values, if present, in the solid leach residue by cyanide leaching.

**PROCESS FOR RECOVERY OF METAL  
VALUES FROM MATERIALS CONTAINING  
ARSENIC AND/OR ANTIMONY**

FIELD OF THE INVENTION

**[0001]** The present invention relates to a pressure oxidation process for the recovery of metal values, in particular copper and optionally gold and other precious metal values, from metal value-bearing materials containing arsenic and/or antimony.

**[0002]** The present invention relates more particularly but not exclusively to a process of sequestering arsenic and/or antimony in a stable iron-arsenic and/or iron-antimony compound or compounds from a metal value-bearing material containing arsenic and/or antimony.

**[0003]** The present invention also relates more particularly but not exclusively to a process by which the recovery of the metal values can be increased by enhancing the formation of a stable iron-arsenic and/or iron-antimony compound or compounds from a metal value-bearing material containing arsenic and/or antimony.

**[0004]** The present invention also relates more particularly but not exclusively to a process by which recovery of metal values can be enhanced by inclusion of a post-pressure oxidation digestion-conditioning step prior to solid/liquid separation and recovery of metal values, in particular copper and optionally gold and other precious metal values, from the separated solid and/or liquid phases.

**[0005]** The present invention also relates more particularly but not exclusively to a process by which recovery of metal values, particularly gold and other precious metals, can be enhanced by means of promotion of the formation of pH-stable pressure oxidation residues for efficient metal recovery through manipulation of the pressure oxidation solution chemistry to limit free acid levels and/or promote the precipitation and stability of an iron-containing residue, particularly jarosite.

BACKGROUND OF THE INVENTION

**[0006]** In this specification, where a document, act or item of knowledge is referred to or discussed, this reference or discussion is not an admission that the document, act or item of knowledge or any combination thereof was at the priority date:

**[0007]** (i) part of common general knowledge; or

**[0008]** (ii) known to be relevant to an attempt to solve any problem with which this specification is concerned.

**[0009]** Many base metals are sourced from sulphide ores. For example, copper sulphide minerals such as chalcopyrite [CuFeS<sub>2</sub>] contribute to the majority of global copper production. There are also many deposits that contain copper in the form of arsenic-bearing minerals, primarily enargite [Cu<sub>3</sub>AsS<sub>4</sub>] and tennantite [Cu<sub>12</sub>As<sub>4</sub>S<sub>13</sub>], and/or antimony-bearing minerals such as tetrahedrite [Cu<sub>12</sub>Sb<sub>4</sub>S<sub>13</sub>].

**[0010]** Any process for recovery of metal values from metal sulphide-bearing materials that also contain arsenic requires consideration of the form to which the arsenic component reports and the environmental impact upon its disposal.

**[0011]** Pyrometallurgical treatment of metal-bearing sulphide materials that also contain arsenic is generally regarded as technically and economically undesirable, as most of the

arsenic reports as flue dust and a speiss phase. Safe disposal of these arsenic-containing materials involves considerable cost and technical disincentives.

**[0012]** By contrast, many hydrometallurgical processes for treating copper sulphide materials that also contain arsenic are directed towards the generation of an acidic sulphate solution containing soluble copper, which is typically recovered therefrom by a combination of solvent extraction and electrowinning. The arsenic component of the feed material is converted into an insoluble arsenic-containing phase such as scorodite [FeAsO<sub>4</sub>·2H<sub>2</sub>O]. This arsenic-containing phase can be safely disposed of in a conventional tailings impoundment. The copper leaching stage may be conducted under oxidizing conditions at a temperature above ambient and a pressure above atmospheric in a process commonly referred to as pressure oxidation.

**[0013]** The kinetics of the copper leaching stage of such a treatment are frequently slow and there is generally coprecipitation of an iron-copper-arsenate-sulphate compound or compounds, leading to copper losses to the leach stage solid residue and thus to the overall process.

**[0014]** Many copper sulphide materials that contain arsenic and/or antimony often also contain precious metals (gold and silver) and any process to treat the copper-arsenic-antimony sulphide material must also employ economically viable treatment stages to recover the precious metal content. In the pressure oxidation process described above, the precious metals generally report to the solid residue generated by the leach process. These precious metals are usually recovered by re-pulping and cyanidation. The presence of meta-stable solid iron compounds such as basic ferric sulphate [Fe(OH)SO<sub>4</sub>] and any copper-containing precipitates such as an iron-copper-arsenate-sulphate in the residue decompose (break down) under the alkaline pH conditions required for gold/silver cyanidation leaching and as a result increase lime and cyanide consumption, decreasing the economic efficiencies of the overall process. In other words, the abovementioned solid components present in the leach residue break down during the cyanidation step, generating excess acid and reactive sulphate compounds that must be subsequently neutralised. The breakdown of the abovementioned solid components under alkaline conditions may also release copper and other metals in a form which is reactive with the cyanide ion, thereby increasing cyanide consumption.

**[0015]** In summary, many of the hydrometallurgical processes currently employed to treat arsenic- and/or antimony-containing copper sulphide materials suffer from unacceptable copper losses to the leach residue. Moreover, if the feed materials also contain precious metals, then current processing conditions also lead to the generation of solid residues that result in unacceptably high lime and cyanide consumption.

**[0016]** The present invention seeks to overcome at least some of the aforementioned disadvantages.

SUMMARY OF THE INVENTION

**[0017]** According to one aspect of the present invention there is provided a method for the recovery of metal values from a metal value-bearing material containing arsenic and/or antimony and a source of sulphate ions such as sulphide ore or concentrate, the method comprising the steps of:

**[0018]** (a) providing a feed stream comprising a metal value-bearing material containing arsenic and/or antimony and a source of sulphate ions;

- [0019] (b) subjecting the feed stream to oxidative conditions under elevated temperature and pressure conditions in the presence of at least one component selected to decrease the effective concentration of free acid generated during the pressure oxidation step and/or promote the formation of pH-stable iron(III) sulphate products, thereby forming a slurry comprising a metal value-containing leach solution and a solid leach residue containing pH-stable iron(III) sulphate products and environmentally stable iron-arsenic and/or iron-antimony products;
- [0020] (c) separating the metal value-containing leach solution from the solid leach residue;
- [0021] (d) recovering the metal value(s) from the metal value-containing leach solution; and
- [0022] (e) recovering precious metal values, if present, in the solid leach residue by cyanide leaching.
- [0023] The slurry from step (b) may be maintained at a temperature in the range of from about 70° C. to about 100° C. for a period in the range of from about 15 minutes to about 4 hours prior to separating the metal value-containing solution from the solid leach residue.
- [0024] According to another aspect of the present invention there is provided a method for the recovery of metal values from a metal value-containing feed material containing arsenic and/or antimony and a source of sulphate ions such as a sulphide ore or concentrate, the method comprising the steps of:
- [0025] (a) providing a feed stream of metal value-containing material containing arsenic and/or antimony and a source of sulphate ions;
- [0026] (b) subjecting the feed stream to acidic oxidative conditions under elevated temperature and pressure conditions in the presence of at least one iron-containing compound and/or at least one chemical agent, wherein the iron-containing compound and/or chemical agent is selected to decrease the effective free acid concentration generated during the pressure oxidation step and/or promote the formation of pH-stable iron(III) sulphate products, thereby forming a metal value-containing solution and a solid leach residue containing pH-stable iron(III) sulphate products and environmentally stable iron-arsenic and/or iron-antimony products;
- [0027] (c) separating the metal value-containing solution from the solid leach residue;
- [0028] (d) recovering the metal value(s), if desired, from the metal value-containing solution; and
- [0029] (e) recovering precious metal values, if present, in the solid leach residue by cyanide leaching.
- [0030] The metal value-containing solution and solid leach residue obtained from step (b) may be maintained at a temperature in the range of from about 70° C. to about 100° C. for a period in the range of from about 15 minutes to about 4 hours prior to separating step (c).
- [0031] According to another aspect of the present invention there is provided a process for recovery of metal values from a metal value-bearing material containing arsenic and/or antimony and a source of sulphate ions such as sulphide ore or concentrate, the process comprising the following major steps of:
- [0032] (a) providing a feed stream comprising a metal value-bearing material containing arsenic and/or antimony and a source of sulphate ions;
- [0033] (b) subjecting the feed stream to oxidative conditions under elevated temperature and pressure conditions in the presence of at least one iron-containing compound and/or at least one chemical agent, wherein the iron-containing compound and/or chemical agent is selected to decrease the effective concentration of free acid generated during the pressure oxidation step and/or promote the formation of pH-stable iron(III) sulphate products, thereby forming a slurry comprising a metal value-containing leach solution and a solid leach residue containing pH-stable iron(III) sulphate products and environmentally stable iron-arsenic and/or iron-antimony products;
- [0034] (c) maintaining the slurry obtained from step (b) at a temperature in the range of from about 70° C. to about 100° C. for a period in the range of from about 15 minutes to about 4 hours;
- [0035] (d) separating the metal value-containing leach solution from the solid leach residue;
- [0036] (e) recovering the metal value(s) from the metal value-containing leach solution; and
- [0037] (f) recovering precious metal values, if present, in the solid leach residue by cyanide leaching.
- [0038] According to another aspect of the invention there is provided a method for recovering one or more metal values from a metal value-containing feed material containing arsenic and/or antimony comprising the steps of:
- [0039] (a) providing the feed material to a pressure oxidation reactor;
- [0040] (b) subjecting the feed material within the pressure oxidation reactor to pressure oxidation in the presence of at least one component selected to decrease the amount of free acid generated during the pressure oxidation and/or promote the formation of pH-stable iron (III) sulphate products, to form a slurry comprising:
- [0041] (i) a metal value-containing solution; and
- [0042] (ii) a solid leach residue comprising the pH-stable iron(III) sulphate products and environmentally stable iron-arsenic and/or iron-antimony products;
- [0043] (c) separating the metal value-containing solution from the solid leach residue; and
- [0044] (d) recovering the metal values from the metal value-containing solution.
- [0045] According to another aspect of the invention there is provided a pressure oxidation process for recovering one or more metal values from a metal value-bearing material containing arsenic and/or antimony, the process comprising the step of providing to the process at least one component selected to promote the formation of solids that are sufficiently stable under pressure oxidation conditions such that the recovery of the one or more metal values is enhanced.
- [0046] The terms “pressure oxidation” or “pressure oxidation step” or “oxidative conditions under elevated temperature and pressure” as used herein refer to a high temperature/high pressure leach process operated under acidic oxidising conditions.
- [0047] One particular aspect of the present invention is based upon the realisation that it is possible to adjust the processing conditions such that they limit the formation of insoluble copper-containing precipitates during the high temperature pressure leaching process to extract metal values

such as copper from a metal value-bearing material such as a sulphide ore or concentrate that also contains arsenic and/or antimony.

**[0048]** Another particular aspect of the present invention is based upon the realisation that it is possible to adjust the processing conditions that promote the formation of solid iron(III) sulphate containing-products in the residue derived from the pressure leaching process that are stable under the alkaline pH conditions at ambient temperature that are used to recover the precious metals from said residue by cyanidation. For convenience, this solid iron(III) sulphate containing-product is referred to as a "pH stable iron(III) sulphate". The result of the correct selection of the high temperature pressure leaching conditions for treating metal value-bearing materials containing arsenic and/or antimony is that the majority of the arsenic and/or antimony reports to a solid residue as an environmentally stable mixed iron-arsenic and/or iron-antimony solid species mixed with pH-stable iron(III) sulphate products.

**[0049]** In addition, copper losses to the residue are minimised by limiting the precipitation of a copper-iron-sulphate-arsenate, while cyanidation of the precious metals content of the leach residue is enhanced because of the promotion of precipitation of pH-stable iron(III) sulphate products such as jarosite-type minerals rather than basic iron sulphate.

**[0050]** The present invention is accordingly concerned with the development of economically viable conditions that can at least partially achieve one or more of (a) minimising copper losses to the leach residue, (b) ensuring that the arsenic and/or antimony components of the feed material report to the residue in an environmentally stable form, and (c) preventing the formation of solid residues that break down during the precious metal cyanidation step and a concomitant increase in lime and cyanide consumption in the case where the initial feed material contains recoverable precious metals.

**[0051]** Preferably, the metal value-bearing material containing arsenic and/or antimony is a copper-bearing material containing arsenic and/or antimony, in particular a copper sulphide containing arsenic and/or antimony, and even more preferably a mixed copper-gold sulphide containing arsenic and/or antimony. Typically the metal value-containing feed material is an ore or concentrate that contains arsenic and/or antimony, and includes but is not limited to:

**[0052]** (a) an ore or concentrate that contains recoverable base and other metals including but not limited to copper, nickel, cobalt, zinc and the platinum group metals;

**[0053]** (b) an ore or concentrate that contains precious metals recoverable by cyanidation, especially gold and silver; and

**[0054]** (c) an ore or concentrate that contains recoverable base and other metals including but not limited to copper, nickel, cobalt, zinc and the platinum group metals, as well as recoverable precious metals, especially gold and silver.

**[0055]** Typically, the pH-stable iron(III) sulphate product formed in the abovementioned pressure leach step is composed of one or more jarosite-type minerals, such as hydronium, sodium, potassium or ammonium jarosite. In one preferred embodiment of the present invention, the pH-stable iron(III) sulphate product is sodium jarosite or a solid solution of hydronium and sodium jarosite.

**[0056]** While it is common for a metal value-bearing material containing arsenic and/or antimony such as a copper sulphide ore or concentrate containing arsenic and/or anti-

mony to also contain at least trace amounts of iron compounds, the inventors have advantageously found that the presence of additional iron compounds in the feed material subjected to the pressure leaching process also promotes the formation of copper-free secondary ferric sulphate minerals that also contain arsenic and/or antimony. Preferably, the molar ratio of Fe:(As+Sb) in the feed material to step (b) is greater than about 1:1 on a molar basis, preferably greater than about 2:1 and more preferably greater than about 4:1. Thus by ensuring that the Fe:(As+Sb) ratio in the feed material to step (b) is greater than about 1:1, preferably greater than about 2:1 and more preferably greater than about 4:1, the bulk of the arsenic and/or antimony in the feed material reports to the residue as an environmentally stable iron-arsenate and/or iron-antimonate phase, rather than as a copper-iron-sulphate-arsenate/antimonate.

**[0057]** The inventors have found that the iron compounds suitable for the abovementioned modification to the Fe:(As+Sb) molar ratio of the feed material are such compounds that are readily solubilised under the acidic high temperature/high pressure leach conditions of the invention. The particle size of the suitable iron compounds will typically be such that the solubilisation kinetics are compatible with the retention time in the high temperature/high pressure leach stage.

**[0058]** Provided that the requirement for rapid solubilisation under the high temperature/high pressure leach conditions is met, the chemical valency of the iron compounds added to the feed material to adjust the Fe:(As+Sb) molar ratio to the required level is not thought to be critical. This is because, under the operating conditions of the high temperature/high pressure leach step (b), substantially all ferrous iron [Fe(II)] will be rapidly oxidised to the ferric [Fe(III)] state. In other words, the iron compounds may be ferrous or ferric compounds, or mixed ferrous/ferric compounds. However, it is preferred that the iron compounds are in the ferric state since this reduces the oxygen consumption during the high temperature/high pressure leach step.

**[0059]** In one preferred embodiment of the invention, the iron compounds are derived from pyrite, in particular calcined pyrite produced under conditions that favour the formation of FeS, FeO, Fe<sub>3</sub>O<sub>4</sub> or gamma-Fe<sub>2</sub>O<sub>3</sub> over the formation of alpha-Fe<sub>2</sub>O<sub>3</sub>, since the former iron compounds are more readily solubilised compared with the latter iron compound.

**[0060]** During the high temperature/high pressure leach step there are many competing chemical reactions relating to the formation and precipitation of different iron-containing species, such as, for example, basic ferric sulphates, hematite, and jarosite. Promotion of precipitation of jarosite and/or hematite over basic ferric sulphate is favoured by the presence of suitable chemical reactions that decrease the effective concentration of free acid generated during the high temperature/high pressure leach step.

**[0061]** In one preferred embodiment of the invention, the chemical agents added to the feed material being subjected to the high temperature/high pressure leach step comprise metal salts which directly participate in the formation of jarosite-type compounds, in particular soluble alkali metal ion salts such as those of sodium or potassium, and ammonium salts, all of which form stable jarosite-type minerals of the general formula MFe<sub>3</sub>(SO<sub>4</sub>)<sub>2</sub>(OH)<sub>6</sub> where M=Na, K and NH<sub>4</sub>, respectively. The formation of these jarosite-type minerals decreases the effective concentration of free acid in the leach slurry under the prevailing high temperature/high pressure

leach conditions. The addition of such soluble alkali metal ion salts also increases the temperature at which jarosite type minerals tend to form in preference to basic iron sulphate type minerals during the pressure oxidation process at any given acid concentration. The ability to operate at higher temperatures while promoting the formation of pH-stable iron(III) sulphate products over basic iron sulphate type minerals provides economic advantages in the form of enhanced leaching reaction kinetics and shorter required residence times

**[0062]** In another preferred embodiment of the invention, the chemical agents also comprise soluble sulphate salts whose cations are merely spectator ions and as such do not participate in any precipitation reactions. The preferred chemical agents particularly include magnesium and/or zinc sulphate. Addition of a suitable soluble sulphate increases the concentration of the bisulphate ion present in the high temperature/high pressure leach slurry and decreases the effective concentration of free acid at temperature from that which would otherwise be experienced at a given feed solids composition and concentration (% solids). The soluble sulphate salts may be added directly to the high temperature/high pressure leach step or generated by reacting carbonate and/or hydroxide salts of magnesium and/or zinc in the high temperature/high pressure leach step. In another preferred embodiment of the invention, the soluble zinc salt may be introduced by the leaching of zinc sulphide minerals that may be present in the feed material.

**[0063]** In a further preferred embodiment of the invention, the chemical reagents may also comprise bases or carbonates, in particular limestone or lime, which directly consume acid and decrease the effective concentration of free acid in the high temperature/high pressure leach step.

**[0064]** In the case of copper sulphides containing arsenic and/or antimony, copper dissolution in the high temperature/high pressure leach step is optimized by addition of iron compounds to the reaction vessel, typically an autoclave, in sufficient quantities to favour precipitation of environmentally stable secondary iron-arsenate and/or iron-antimonate and/or iron-arsenate-sulphate and/or iron-antimonate-sulphate phases within the autoclave rather than the precipitation of copper-containing arsenate-antimonate residues, thereby limiting the copper content of the residue and maximising the soluble copper content of the resultant liquid stream available for copper recovery by a combination of solvent extraction and electrowinning or by means of another suitable recovery method.

**[0065]** By means of limiting the copper content of the solid leach residue and efficient separation of the soluble copper from the solid leach residue, the economics of precious metals recovery from the leach residue by cyanidation is enhanced as the extent of the reaction between copper and the cyanide leachant is significantly reduced, thus lowering the overall cyanide consumption.

#### DETAILED DESCRIPTION OF THE INVENTION

**[0066]** In accordance with various aspects of the present invention, a metal value-bearing material containing arsenic and/or antimony that also constitutes a source of sulphate ions is provided for processing. The metal value-bearing material may be an ore, a concentrate, or any other material from which metal values, in particular copper and precious metals such as gold and silver, may be recovered. The present invention is equally applicable to other metal value-bearing materials containing arsenic and/or antimony such as various ores

and concentrates containing other valuable metals such as nickel, cobalt, zinc and the platinum-group metals.

**[0067]** For convenience, however, the description of the preferred embodiments of the invention is restricted to copper-containing materials that also contain arsenic and/or antimony. The copper-containing material is preferably a copper sulphide ore or concentrate that contain arsenic and/or antimony, and particularly applies to ores and/or concentrates that contain tennantite ( $\text{Cu}_{12}\text{As}_4\text{S}_{13}$ ), enargite ( $\text{Cu}_3\text{AsS}_4$ ) and tetrahedrite ( $\text{Cu}_{12}\text{Sb}_4\text{S}_{13}$ ), and to other ores or concentrates containing copper sulphide minerals such as, for example, chalcopyrite ( $\text{CuFeS}_2$ ), chalcocite ( $\text{Cu}_2\text{S}$ ), bornite ( $\text{Cu}_5\text{FeS}_4$ ), covellite ( $\text{CuS}$ ), when contaminated with arsenic- and antimony-bearing material.

**[0068]** Geologically, gold is frequently associated with metal sulphide ores such as, for example, pyrite, chalcopyrite, galena, arsenopyrite and stibnite. Gold is also often present in sulphide concentrates produced from such ores. Accordingly, a preferred embodiment of the present invention is particularly advantageous in connection with the recovery of copper and precious metals, such as gold, from mixed gold/copper ores or concentrates containing arsenic and/or antimony.

**[0069]** Thus, the metal value-bearing material is preferably a mixed gold/copper ore or concentrate containing arsenic and/or antimony, and more preferably, a mixed gold/copper sulphide ore or concentrate containing arsenic and/or antimony. Typically, the mixed gold/copper sulphide ore is a tennantite-enargite-chalcopyrite-pyrite ore.

**[0070]** The metal value-bearing material typically undergoes comminution, flotation, blending and/or slurry formation, as well as chemical and/or physical conditioning to afford a feed stream which, in turn, is subjected to a high temperature/high pressure oxidative leach step and a series of downstream unit stages to afford recovery of the contained metal values.

**[0071]** The specific conditions applicable to the comminution, flotation and conditioning stages are determined by the chemical and physical properties of the metal value-bearing ore material. As a general rule, these specific conditions are designed to yield a concentrate that optimises recovery versus grade. These specific conditions do not have a direct bearing on the application of the preferred embodiments of the present invention. As such, the present invention is specifically concerned with the treatment of a dewatered concentrate exiting the comminution, flotation and conditioning circuits.

**[0072]** The dewatered concentrate stream is repulped with water, preferably process waters including but not limited to magnesium and/or zinc containing solutions recycled from the copper recovery circuit, hereinafter referred to as neutral barren solution (NBS). The repulped concentrate stream may undergo an additional regrinding step to yield a finer particle size than the natural particle size produced from the flotation concentrator if desired to facilitate a reduction in the residence time of the downstream high temperature/high pressure leach step.

**[0073]** After the metal value-bearing concentrate stream has been suitably prepared as a slurry, the slurry is fed to an agitated pressure vessel, preferably an autoclave, and subjected to pressure oxidation. Typically the high temperature/high pressure leaching process is carried out in a suitable pressure vessel, preferably an autoclave, at a temperature in the range of from about 180° C. to about 250° C., preferably from about 190° C. to about 230° C. The optimum temperature depends on many factors, including but not limited to, the

mineralogical composition of the feed, the sulphide sulphur content of the feed, the particle size distribution of the feed, and the pulp density. As a general rule, the higher temperatures in the above ranges provide for shorter retention times and/or a reduction and/or elimination of the need for regrinding of the feed material prior to the high temperature/high pressure leach step.

**[0074]** The high temperature/high pressure leaching process is typically carried out a total pressure sufficiently high to provide an oxygen partial pressure inside the autoclave of between about 100 kPa and 1500 kPa, preferably in the range of from about 400-1000 kPa, taking into account the partial pressure of steam and other non-condensable gases within the autoclave such as nitrogen and carbon dioxide. Oxygen is typically delivered to the autoclave at a pressure above that inside the autoclave and is introduced to the autoclave through spargers that discharge the oxygen gas beneath the autoclave agitators. The autoclave agitators are designed to maximise oxygen mass transfer from the gas phase to the feed slurry.

**[0075]** The high temperature/high pressure leaching step is typically conducted over a period of about 20 minutes to about 4 hours and more preferably to about 2 hours, with higher operating temperatures and a finer feed particle size facilitating shorter reaction times.

**[0076]** Under the high temperature/high pressure leaching process conditions, solid metal sulphide minerals within the feed material are oxidised to the corresponding soluble metal sulphates. That is, the metal values are released into solution. The actual oxidation/dissolution reactions for each metal sulphide mineral are a reflection of the chemical composition of that mineral as well as the temperature and free acidity of the leach slurry, but the overall reaction can be simplified as shown in reaction (1).



**[0077]** The arsenic and antimony components of the feed material are oxidised to the arsenate ( $AsO_4^{3-}$ ) and antimonite ( $SbO_3^{3-}$ ) species, respectively.

**[0078]** Some of the solubilised metal values then reprecipitate within the autoclave and report to the solid phase component on the autoclave slurry as metal oxides and/or metal mixed hydroxyl-sulphates and/or metal-sulphate-arsenate-antimonate species.

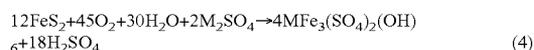
**[0079]** Iron may report to the solid phase component of the autoclave slurry as one or more different iron-containing compounds during the high temperature/high pressure leach process, the identity of such phases being determined by a specific set of operating conditions. For example, the formation of basic iron sulphate is favoured by high operating temperatures and high free acid concentrations. Under such conditions, the oxidation of pyrite ( $FeS_2$ ), a significant component of many metal sulphide concentrates, can be represented by reaction (2).



**[0080]** The reaction of pyrite to form hematite (alpha  $Fe_2O_3$ ) is favoured by high temperatures and low free acid concentrations according to reaction (3).



**[0081]** The formation of jarosite is favoured by low operating temperatures and the presence of cations such as  $Na^+$ ,  $K^+$  or  $NH_4^+$ , according to reaction (4) where  $M=Na$ ,  $K$  or  $NH_4$ .



**[0082]** Hydronium jarosite, in which  $M=H_3O^+$ , the hydronium ion of free acid, takes the place of  $Na$ ,  $K$  or  $NH_4$  is also favoured by low operating temperatures in the absence of such cations. Jarosite solid solutions in which  $M$ =varying proportions of  $Na$ ,  $K$ ,  $NH_4$  and/or  $H_3O^+$  may also be formed by varying the quantity of  $Na$ ,  $K$ , or  $NH_4$  present.

**[0083]** Arsenate and antimonate species formed by the oxidation of the arsenic and antimony components of the feed material may precipitate as the respective iron(III) arsenate and iron(III) antimonate phases, but may also substitute for sulphate in, for example, the jarosite phase. The precipitation of arsenate as hydrated iron(III) arsenate,  $FeAsO_4\cdot 2H_2O$ , also known as scorodite, and the partial replacement of sulphate by arsenate in various jarosite phases is well documented in the scientific literature. Jarosite is sometimes referred to as a scavenger for both arsenate and antimonate. The formation of hydrated iron(III) arsenate and/or arsenic-containing jarosite materials in the present invention is of considerable environmental benefit since these materials are known to be environmentally stable and can be safely discharged into and stored in conventional residue storage impoundments.

**[0084]** Under typical prior art operating conditions for the high temperature/high pressure leaching of mixed copper/gold metal sulphide concentrates containing arsenic and/or antimony, formation of basic iron sulphate and hematite are favoured. The basic iron sulphate and hematite report to the solid residue resulting from the high temperature/high pressure leach process. When the solid residue is washed, repulped and then subjected to cyanidation in order to extract the precious metal values therein, there is an uneconomically high consumption of lime and cyanide. This is because the lime reacts directly with the basic iron sulphate during the adjustment of the pH to a value of 10 or higher that is required for the precious metal cyanidation step.

**[0085]** In the present invention, additional iron compounds are added to the feed material to the high temperature/high pressure leach step in order to promote the formation of jarosite rather than basic iron sulphate. Under these conditions the jarosite phase acts as an efficient scavenger for any soluble arsenate and/or antimonate formed during the pressure oxidation reactions. Moreover, the jarosite phase does not itself react with lime when the precious metals are recovered from the leach residue by cyanidation.

**[0086]** Preferably, the total iron content of the feed material added to the high temperature/high pressure leach process is such that the molar ratio of  $Fe:(As+Sb)$  is greater than about 1:1, preferably greater than about 2:1 and more preferably greater than about 4:1. Apart from facilitating the formation of arsenic- and antimony-containing jarosite phases which do not react with lime in cyanidation, the high  $Fe:(As+Sb)$  molar ratio reduces and/or prevents the formation and precipitation of a mixed copper-iron-arsenate-antimonate-sulphate phase.

**[0087]** The iron compounds added to the metal value-bearing feed material in order to adjust the molar ratio of  $Fe:(As+Sb)$  to the desired level are of a mineral/chemical composition and particle size such that they are readily solubilised under the acidic high temperature/high pressure leach conditions.

**[0088]** The valency of the iron in the iron compounds is not thought to be critical because under the operating conditions of the high temperature/high pressure leach process, substantially all iron(II) will be oxidised to Fe(III). In other words the iron compounds may be ferrous or ferric compounds or mixed ferrous/ferric compounds, provided that they are soluble under the high temperature/high pressure leach conditions.

However, it is preferred that the iron compounds are pre-treated to maximize the ferric content and minimise any contained sulphide content in order to lower the overall oxygen consumption required during the high temperature/high pressure leach step.

**[0089]** In a preferred embodiment of the present invention the iron compounds are derived from pyrite, in particular calcined pyrite produced by oxidative conditions with the calciner operated in such a fashion as to produce a calcined pyrite with a significant portion of the iron present in a form readily capable of being solubilised in the autoclave under the high temperature/high pressure leach conditions, such as for example, FeS, FeO, Fe<sub>3</sub>O<sub>4</sub> or gamma-Fe<sub>2</sub>O<sub>3</sub>, rather than alpha-Fe<sub>2</sub>O<sub>3</sub> produced in a conventional pyrite roaster, or the higher sulphide containing FeS<sub>2</sub> of uncalcined pyrite.

**[0090]** In a further embodiment of the present invention, the iron compounds may be sourced from recycled process solutions containing iron sulphate, preferably in the ferric form, although the process solutions may also carry minor amounts of ferrous iron as well. Alternatively, the iron compounds may be iron-containing precipitates from various other parts of the overall process, such as the iron-containing precipitate produced during minor impurity removal ahead of or subsequent to metal value recovery steps such as copper recovery by a combination of solvent extraction and electrowinning.

**[0091]** The iron compounds may be mixed with the metal value-bearing feed stream before it is transferred to the high temperature/high pressure autoclave leach vessel, or the iron compounds may be separately transferred to the autoclave before or after introduction of the feed stream to the autoclave.

**[0092]** One of the preferred embodiments of the present invention incorporates the addition of specific chemical agents which decrease the effective concentration of free acid generated during the high temperature/high pressure leaching process thereby affording the precipitation of pH stable iron (III) sulphate compounds and avoiding the precipitation of a basic ferric sulphate. One group of chemical agents includes metal salts that directly participate in the formation of jarosite-type compounds, in particular sodium, potassium and ammonium jarosites. Such metal salts include soluble alkali metal (sodium and potassium) and ammonium sulphate. Typically the molar ratio of the added metal salt per mole of iron present in the feed should be at least about 1:3 and preferably at least about 1:2, that is, an excess of metal salt above the stoichiometric requirement.

**[0093]** Another group of chemical agents that have the ability to decrease the effective concentration of free acid generated during the high temperature/high pressure leaching process comprise soluble sulphate salts whose cations are merely spectator ions and which do not participate in any precipitation reactions. Addition of soluble sulphate increases the concentration of the bisulphate ion present at the operating high temperature and decreases the effective concentration of free acid that would otherwise be experienced at the given temperature, feed solids composition and pulp density.

**[0094]** The soluble sulphate salts may be directly added to the high temperature/high pressure leaching step or generated by reacting carbonate or hydroxide salts of the appropriate metals. The inventors have established that the appropriate metal sulphate salts include those of magnesium and zinc. Typically, magnesium is added as magnesium carbonate (magnesite), magnesium oxide, dolomite, or mixtures thereof.

**[0095]** The soluble sulphate salts, once added to or generated by the overall process, may be conveniently recycled in process water used for feed preparation and/or autoclave quench water once the copper or other dissolved metal values have been recovered from the leach solution.

**[0096]** The chemical agents may also comprise carbonates and other bases, in particular limestone and lime, which directly consume acid and decrease the effective concentration of free acid during the high temperature/high pressure leaching process. Typically, bases are added in an amount necessary to yield less than about 60 g/L sulphuric acid in solution in the product from the high temperature/high pressure leach step, as measured by titration of slurry samples at ambient temperature.

**[0097]** The chemical agents may be mixed with the feed stream before it is transferred to the autoclave for the high temperature/high pressure leach step, or the chemical agents may be separately transferred to the autoclave before or after introduction of the feed stream to the autoclave.

**[0098]** During the high temperature/high pressure leaching step metal values, in particular copper, may be solubilised to form a metal value-containing solution. It is envisaged that the metal values will be recovered from the metal value-containing solution by well understood methods and techniques. For example, where the metal value is copper, copper is typically recovered from the copper-containing solution by a combination of solvent extraction and electrowinning. However, other metal recovery processes such as cementation or precipitation of an intermediate product such as a hydroxide or sulphide could be employed.

**[0099]** Precious metal values, especially gold, contained in the feed material will report to the solid residue formed during the high temperature/high pressure leach process. It is envisaged that the precious metal values will be recovered from the solid residue by washing to remove entrained acid and soluble metal values, repulping and treating the consequent slurry by a combination of conventional cyanidation, activated carbon, stripping, electrowinning and smelting techniques.

**[0100]** In a preferred embodiment of the present invention, it has been found to be advantageous to maintain the slurry discharged from the autoclave at a temperature above about 70° C. and preferably in the range of from about 85-100° C. for a period in the range of from about 15 minutes to about 4 hours in an agitated tank or tanks before it is subsequently cooled to ambient temperature and subjected to solid/liquid separation by counter current decantation and thickening ahead of the precious metals recovery unit steps. This compares with prior art that incorporates rapid cooling of the autoclave discharge slurry to ambient temperature by means of a series of flash vessels and subsequent solid/liquid separation processes generally conducted below about 70° C. The advantage of this slow cooling or digestion-conditioning step disclosed in the present invention relates to the fact that any remaining basic ferric sulphate and/or copper-iron-sulphate-arsenate-antimonate in the leach slurry will be converted into a pH-stable iron(III) sulphate and/or redissolve, which in the case of copper-iron-sulphate-arsenate-antimonate will release soluble copper, respectively. By this means, the lime consumption required and, in the case of copper-containing feed materials, the cyanide consumption required for precious metal cyanidation should be reduced, while any copper losses to the solid leach residue should also be reduced.

**[0101]** By application of the preferred embodiments of the present invention copper recoveries in excess of 95% and

lime consumption of less than 15 kg/t of solid residue can be expected from a wide range of copper/gold sulphide ores and concentrates that also contain appreciable arsenic and/or antimony contents.

**[0102]** In summary, the advantages of the present invention compared with prior art include but are not limited by the following:

**[0103]** (a) enhanced recovery of metal values, typically copper and precious metals, by preventing the coprecipitation of metal values in the solid residue discharged from the high temperature/high pressure step;

**[0104]** (b) prevention of the formation of unstable basic iron sulphate species in the solid residue discharged from the high temperature/high pressure step, or from the hot conditioning step in a preferred embodiment, that consume excessive lime during the recovery of the precious metals by cyanidation; and

**[0105]** (c) generate arsenic- and/or antimony-containing residues that can be stored in conventional residue storage impoundments without causing unacceptable environmental outcomes.

#### DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

**[0106]** Preferred embodiments of the present invention will now be further described by reference to the following examples. The process conditions reflected therein are intended to exemplify various aspects of the invention, and are not intended to limit the scope of the claimed invention. Numerous variations and modifications will suggest themselves to persons skilled in the relevant art, in addition to those already described, without departing from the basic inventive steps. All such variations and modifications are to be considered within the scope of the present invention, the nature of which is to be determined from the foregoing description.

#### Example

**[0107]** This example outlines the general scope of the preferred embodiments of the present invention as applied to the continuous processing of a run-of-mine tennantite-energite-chalcopyrite-pyrite ore containing on average 1.7% Cu and 4.1 g/t Au. A simplified flowsheet of a preferred embodiment of the present invention is shown in FIG. 1.

**[0108]** After crushing and grinding, a copper concentrate typically containing 16% Cu, 6% As and 28 g/t Au is produced by rougher, scavenger and cleaner flotation banks using the appropriate flotation reagent regime. The copper concentrate is directed to a copper concentrate dewatering circuit where the free moisture content is reduced to about 10%.

**[0109]** A suitable pyrite concentrate, which may or may not also contain a significant gold content, is transferred to a pyrite calcinations circuit. The air and feed rates to the calciner as well as the operating temperature are controlled such that the formation of alpha-hematite in the calciner product is minimised. In this way the iron content of the calcined product is readily soluble in the subsequent high temperature/high pressure leach step. Hot calcined pyrite is discharged, cooled and then combined with water to form a slurry.

**[0110]** The copper concentrate is repulped with neutral barren solution (NBS) that exits the impurity removal stage and is then subjected to a regrinding stage, if required, so that the

particle size  $P_{80}$  is less than about 50 micron, preferably about 38 micron, and more preferably about 25 micron.

**[0111]** The reground copper concentrate, and optionally iron-arsenic and/or iron-antimony residues generated during prior high temperature/high pressure leach cycles, is mixed with the required amount of calcined pyrite in a suitable agitated autoclave feed storage tank such that the Fe:(As+Sb) molar ratio of the autoclave feed is greater than about 1:1, preferably greater than about 2:1 and more preferably greater than about 4:1.

**[0112]** Soluble salts of sodium and potassium and/or a suitable source of magnesium and/or zinc may be added individually or in combination to the autoclave feed storage tank in a slight excess of the stoichiometric amounts that are required to facilitate the precipitation of the bulk of the iron in the feed as sodium or potassium or hydronium jarosite, optionally in combination with hematite but without the formation of appreciable basic iron sulphate, within the high temperature/high pressure autoclave while simultaneously ensuring that the free acid concentration of the autoclave slurry is no greater than about 60 g/L and preferably about 40 g/L.

**[0113]** The combined slurry is directed to the first compartment of a multi-compartment high pressure autoclave fitted with a plurality of agitators by means of a centrifugal pump feeding a positive displacement, piston driven diaphragm pump at an operating pressure of preferably over 300 kPa higher than the steam saturation pressure at the operating temperature of the autoclave. This operating pressure will generally be over 2000 kPa.

**[0114]** High pressure steam is supplied to the autoclave for initial heat-up and on an as-needed basis.

**[0115]** Each compartment of the autoclave is fitted with a quench water system by which a controlled flow of quench water can be directly injected into each compartment such that the desired operating temperature, typically in the range of from about 190-230° C., is continuously maintained. Alternatively, if required, each autoclave compartment can be equipped with a suitable cooling coil, the flow of coolant being controlled in order to maintain the desired operating temperature.

**[0116]** Oxygen at 94% or greater purity is delivered from a cryogenic oxygen plant to the autoclave by bottom entry spargers entering beneath the autoclave agitators at a pressure of greater than 2000 kPa. The bottom impeller on the agitators is of the Rushton or Smith turbine design in order to maximise oxygen mass transfer to the feed slurry.

**[0117]** Following the required retention time, typically 20 minutes to about 2 hours, the processed slurry is discharged from the autoclave via a suitable flash vessel, cooled to a temperature of about 85-100° C. and stored at this temperature for a period of about 15 minutes to about 4 hours in a suitable agitated digestion/conditioning tank. From there the conditioned autoclave slurry is subjected to solid/liquid separation via a series of conventional counter current thickeners.

**[0118]** The thickened underflow is washed to remove entrained leach solution, filtered and the resultant cake forwarded to a conventional gold cyanidation circuit.

**[0119]** The thickener overflow contains the dissolved copper content of the feed and is directed to a partial neutralisation (PN) circuit as pregnant leach solution (PLS). As the PLS contains a relatively high sulphuric acid concentration, typically 30-60 g/L, excess acid is neutralised by addition of a limestone slurry in order to achieve a final PLS free acidity of

about 2 to 5 g/L (pH approximately 1.5). After solid/liquid separation to remove precipitated solids, principally gypsum, the neutralised PLS is clarified before the copper is recovered by conventional solvent extraction and electrowinning techniques.

**[0120]** The raffinate from the solvent extraction circuit is then subjected to an impurity removal (IR) step by addition of limestone and lime slurries. After removal of precipitated solids by thickening, the clarified neutral barren solution is used in a variety of appropriate duties, including repulping of the incoming dewatered copper concentrate, filter wash water and as autoclave quench water.

**[0121]** If required, the precipitated solids from the partial neutralization (PN) and/or impurity removal (IR) steps may be recycled to the high temperature/high pressure leach process as sources of iron-containing and/or acid consuming products.

**[0122]** In the preceding description of the invention and in the claims which follow, except where the context requires otherwise due to express language or necessary implication, the words "comprise" or variations such as "comprises" or "comprising" are used in an inclusive sense, i.e., to specify the presence of the stated features, but not to preclude the presence or addition of further features in various embodiments of the invention.

**[0123]** It is to be understood that this invention and the preferred embodiments are not limited to the particular materials described, as these may vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present invention in any way.

**[0124]** It is also noted that, as used herein, the singular forms of "a", "an" and "the" include the plural unless the context clearly requires otherwise. Unless defined otherwise, all technical and scientific terms herein have the same meanings as commonly understood by one of ordinary skill in the art to which this invention belongs.

1. A method for the recovery of metal values from a metal value-bearing material containing arsenic and/or antimony and a source of sulphate ions, the process comprising the steps of:

- (a) providing a feed stream comprising a metal value-bearing material containing arsenic and/or antimony and a source of sulphate ions;
- (b) subjecting the feed stream to oxidative conditions under elevated temperature and pressure conditions in the presence of at least one component selected to decrease the effective concentration of free acid generated during the pressure oxidation step and promote the formation of pH-stable iron(III) sulphate products, thereby forming a slurry comprising a metal value-containing leach solution and a solid leach residue containing pH-stable iron (III) sulphate products and environmentally stable iron-arsenic and/or iron-antimony products;
- (c) separating the metal value-containing leach solution from the solid leach residue;
- (d) recovering the metal value(s) from the metal value-containing leach solution; and
- (e) recovering precious metal values, if present, in the solid leach residue by cyanide leaching.

2. A method according to claim 1, wherein the slurry from step (b) is maintained at a temperature in the range of from about 70° C. to about 100° C. for a period in the range of from

about 15 minutes to about 4 hours prior to separating the metal value-containing solution from the solid leach residue.

3. A method according to claim 1, wherein said metal value-bearing material is a copper-bearing material containing arsenic and/or antimony and a source of sulphate ions.

4. A method according to claim 1, wherein said source of sulphate ions is a sulphide ore or ore concentrate.

5. A method according to claim 1, wherein said at least one component selected to decrease the effective concentration of free acid generated during the pressure oxidation step and promote the formation of pH-stable iron(III) sulphate products includes an iron-containing component.

6. A method according to claim 1, wherein said at least one component selected to decrease the effective concentration of free acid generated during the pressure oxidation step and/or promote the formation of pH-stable iron(III) sulphate products further includes a chemical agent.

7. A method according to claim 5, wherein said iron-containing component provides a source of soluble iron and is added to the feed stream before pressure oxidation such that the molar ratio of iron to arsenic and/or antimony in the feed stream is greater than about 1:1, preferably greater than about 2:1 and more preferably greater than about 4:1.

8. A method according to claim 5, wherein said iron-containing component includes at least one component selected from pyrite concentrate, calcined pyrite concentrate and any recovered iron-containing residues formed during a pressure oxidation process.

9. A method according to claim 8, wherein said calcined pyrite concentrate is substantially free of alpha  $\text{Fe}_2\text{O}_3$  and contains one or more compounds selected from  $\text{FeS}$ ,  $\text{FeO}$ ,  $\text{Fe}_3\text{O}_4$  and gamma  $\text{Fe}_2\text{O}_3$ .

10. A method according to claim 1, wherein said at least one component selected to decrease the effective concentration of free acid generated during the pressure oxidation step and promote the formation of pH-stable iron(III) sulphate products includes a chemical agent.

11. A method according to claim 6, wherein said chemical agent includes at least one material sourced from limestone or lime, or one or more soluble salts containing magnesium, sodium, potassium and/or ammonium.

12. A method according to claim 11, wherein said chemical agent is added in an amount sufficient to promote the formation of a jarosite phase containing sodium, potassium and/or ammonium and to limit the formation of any pH-unstable or meta-stable solid ferric sulphate products during pressure oxidation.

13. A method according to claim 11, wherein said one or more soluble salts containing magnesium includes one or more compounds selected from magnesium oxide, magnesium hydroxide, magnesium carbonate (magnesite) and magnesium-calcium carbonate (dolomite).

14. A method according to claim 1, wherein said at least one component is added to the feed stream prior to step (b).

15. A method according to claim 1, wherein said feed stream is an ore or ore concentrate containing said metal values, and wherein said metal values include a base metal selected from the group consisting of copper, nickel, cobalt, zinc and platinum.

16. A method according to claim 1, wherein said feed stream is an ore or ore concentrate containing said metal values, and wherein said metal values include a precious metal of gold and/or silver.

17. A method for the recovery of metal values from a metal value-containing feed material containing arsenic and/or antimony and a source of sulphate ions, the method comprising the steps of:

- (a) providing a feed stream of metal value-containing material containing arsenic and/or antimony and a source of sulphate ions;
- (b) subjecting the feed stream to acidic oxidative conditions under elevated temperature and pressure conditions in the presence of at least one iron-containing compound and/or at least one chemical agent, wherein the iron-containing compound and/or chemical agent is selected to decrease the effective free acid concentration generated during the pressure oxidation step and promote the formation of pH-stable iron(III) sulphate products, thereby forming a metal value-containing solution and a solid leach residue containing pH-stable iron(III) sulphate products and environmentally stable iron-arsenic and/or iron-antimony products;
- (c) separating the metal value-containing solution from the solid leach residue;
- (d) recovering the metal value(s), if desired, from the metal value-containing solution; and
- (e) recovering precious metal values, if present, in the solid leach residue by cyanide leaching.

18. A method according to claim 17, wherein the metal value-containing solution and solid leach residue obtained from step (b) is maintained at a temperature in the range of from about 70° C. to about 100° C. for a period in the range of from about 15 minutes to about 4 hours prior to separating step (c).

19. A process for recovery of metal values from a metal value-bearing material containing arsenic and/or antimony and a source of sulphate ions, the process comprising the steps of:

- (a) providing a feed stream comprising a metal value-bearing material containing arsenic and/or antimony and a source of sulphate ions;
- (b) subjecting the feed stream to oxidative conditions under elevated temperature and pressure conditions in the presence of at least one iron-containing compound and/or at least one chemical agent, wherein the iron-containing compound and/or chemical agent is selected to decrease the effective concentration of free acid generated during the pressure oxidation step and promote the formation of pH-stable iron(III) sulphate products, thereby forming a slurry comprising a metal value-containing leach solution and a solid leach residue containing pH-stable iron(III) sulphate products and environmentally stable iron-arsenic and/or iron-antimony products;
- (c) maintaining the slurry obtained from step (b) at a temperature in the range of from about 70° C. to about 100° C. for a period in the range of from about 15 minutes to about 4 hours;
- (d) separating the metal value-containing leach solution from the solid leach residue;
- (e) recovering the metal value(s) from the metal value-containing leach solution; and
- (f) recovering precious metal values, if present, in the solid leach residue by cyanide leaching.

20. A method for recovering one or more metal values from a metal value-containing feed material containing arsenic and/or antimony, the method comprising the steps of:

- (a) providing the feed material to a pressure oxidation reactor;

- (b) subjecting the feed material within the pressure oxidation reactor to pressure oxidation in the presence of at least one component selected to decrease the amount of free acid generated during the pressure oxidation and/or promote the formation of pH-stable iron(III) sulphate products, to form a slurry comprising:
  - (i) a metal value-containing solution; and
  - (ii) a solid leach residue comprising the pH-stable iron(III) sulphate products and environmentally stable iron-arsenic and/or iron-antimony products;
- (c) separating the metal value-containing solution from the solid leach residue; and
- (d) recovering the metal values from the metal value-containing solution.

21. A method according to claim 1, wherein prior to the step of recovering the metal value(s) from the metal value-containing leach solution, the pH is reduced to a pH of less than about pH 2.

22. A pressure oxidation process for recovering one or more metal values from a metal value-bearing material containing arsenic and/or antimony, comprising the step of providing to the process at least one component selected to promote the formation of solids that are sufficiently stable under pressure oxidation conditions such that the recovery of the one or more metal values is enhanced.

23. A process according to claim 22, wherein said at least one component is selected to promote the formation of solids that do not significantly bind said one or more metal values.

24. A process according to claim 22, wherein the at least one component is selected to promote the formation of solids capable of binding arsenic and/or antimony.

25. A process according to claim 22, wherein said one or more metal values include a base metal and a precious metal and wherein said at least one component promotes the formation of solids that are stable under alkaline conditions of cyanidation processes used to recover precious metal values following the recovery of base metal values.

26. A process according to claim 22, wherein said at least one component is an iron-containing compound.

27. A process according to claim 22, wherein said at least one component further includes at least one chemical agent.

28. A process according to claim 22, wherein said at least one component is a chemical agent.

29. A method for the recovery of metal values from a metal value-containing feed material containing arsenic and/or antimony and a source of sulphate ions, the method comprising the steps of:

- (a) providing a feed stream of metal value-containing material containing arsenic and/or antimony and a source of sulphate ions;
- (b) subjecting the feed stream to acidic oxidative conditions under elevated temperature and pressure conditions to form a metal value-containing solution and a solid leach residue;
- (c) maintaining a temperature in the range of from about 70° C. to about 100° C. for a period in the range of from about 15 minutes to about 4 hours prior to separating step (d) to promote the formation of pH-stable iron(III) sulphate products;
- (d) separating the metal value-containing solution from the solid leach residue;
- (e) recovering the metal value(s), if desired, from the metal value-containing solution; and
- (f) recovering precious metal values, if present, in the solid leach residue by cyanide leaching.