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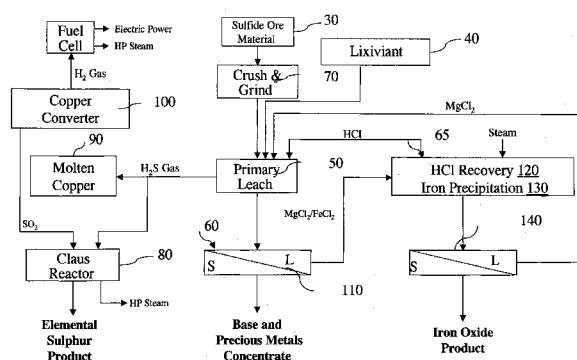
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(54) Title: PROCESS FOR RECOVERING IRON AS HEMATITE FROM A BASE METAL CONTAINING ORE MATERIAL



(57) Abstract: The present invention relates generally to processes for mineral extraction and ore processing and more specifically, to processes for recovering iron as a hematite product of high purity from a base metal containing ore material and to processes for recovering base metals from base metal containing materials. A process for recovering iron as hematite from a base metal containing material involves performing a leaching step on the base metal containing material at atmospheric pressure in the absence of an oxidant, using a lixiviant to obtain a solid residue and a leachate containing dissolved iron therein. The lixiviant includes an acid and a chloride. The acid may be selected from the group consisting of an organic acid, sulfurous acid, sulfuric acid and hydrochloric acid. The chloride may be selected from the group consisting of magnesium chloride, calcium chloride, sodium chloride, potassium chloride, ferrous chloride and lithium chloride. Hydrogen sulfide gas formed during the leaching step is stripped from the leachate in a continuous fashion and reacted with sulfur dioxide gas in a Claus reaction to obtain elemental sulfur and steam. Following separation of the leachate from the solid residue, the leachate may be further treated to recover at least some of the iron as a hematite product of high purity, as well as, the constituent acid and chloride of the lixiviant for reuse in the leach circuit. One of the leachate and the solid residue may thereafter be subjected to a series of base metal recovery steps and/or value metal recovery steps. The process may be applied to recover iron as hematite and base metals from sulfide ore materials and laterite ore materials.

PROCESS FOR RECOVERING IRON AS HEMATITE FROM A BASE METAL CONTAINING ORE MATERIAL

FIELD OF THE INVENTION

0001 The present invention relates generally to processes for mineral extraction and ore processing and more specifically, to processes for recovering iron as hematite from a base metal containing ore material and to processes for recovering base metals from base metal containing materials.

BACKGROUND OF THE INVENTION

0002 Various hydrometallurgical techniques have been developed for recovering base metals, such as zinc, nickel, copper and cobalt, from base metal sulfide and oxide ores. One such technique involves leaching the base metal sulfide ore with a lixiviant that promotes dissolution of one or more base metals in the leaching solution. The base metals may then be recovered by using known base metal separation techniques. Over the years, various compounds have been used individually as leaching agents in the lixiviant, for instance, sulfuric acid, hydrochloric acid, ferric chloride, ferric sulfate, cupric chloride and magnesium chloride. Of late, much work has been done in the area of chloride-based leaching processes.

0003 One such chloride-based leaching process is described in United States Patent Publication No. 2005/0118081 of Harris et al. The process involves leaching a base metal sulfide ore at atmospheric pressure with a lixiviant containing a relatively low concentration of hydrochloric acid and a high chloride concentration. More specifically, the lixiviant used in this process comprises hydrochloric acid, a chloride and an oxidant. The chloride may be an alkali metal chloride, magnesium chloride, calcium chloride and mixtures thereof. The oxidant may be an alkali metal peroxide, an alkali metal perchlorate, magnesium perchlorate, alkali metal chlorate, earth metal perchlorate, chlorine, alkali metal hypochlorite, hydrogen peroxide and peroxysulfuric acid, and mixtures thereof. The leaching step yields a solid residue and a base metal-rich leachate which contains dissolved iron therein. The sulfur from the leachate and solid residue may be removed by forming and stripping hydrogen sulfide during the leaching step. Some or all of the hydrogen sulfide may then be converted to elemental sulfur. A by-product of this conversion reaction is energy. The base-metal rich leachate may be subjected to base metal recovery steps (which may include an additional

leaching step) and/or value metal recovery steps to extract the nickel, copper, zinc and cobalt and any dissolved platinum group metals, gold and silver.

0004 In this process, iron is first removed from the pregnant leachate by precipitating an iron oxide (hematite or spinel) using a magnesium oxide additive and effecting a solid/liquid separation step. The magnesium oxide is obtained from a pyrohydrolysis reaction of spent magnesium chloride, which also recovers hydrochloric acid for recycle. The process only contemplates the recovery of hydrochloric acid formed as a by-product of the pyrohydrolysis, for reuse in the leach circuit.

0005 Iron is and has always been considered a major problem in hydrometallurgical processes. In atmospheric processes, the iron is usually precipitated as an oxy-hydroxide, and in higher temperature autoclave processes, as an impure hematite.

0006 United States Patent No. 3,682,592 issued to Kovacs describes a process for recovering HCl gas and ferric oxide from waste hydrochloric acid steel mill pickle liquors (commonly referred to as "WPL"). WPL typically contains water, 18 to 25% weight of ferrous chloride (FeCl_2), less than 1% weight ferric chloride (FeCl_3), small amounts of free hydrochloric acid and small amounts of organic inhibitors. The process of Kovacs includes two steps namely, a first oxidation step and a second thermal decomposition step. During the first oxidation step, the ferrous chloride in the WPL is oxidized using free oxygen to obtain ferric oxide and an aqueous solution containing ferric chloride. No hydrochloric acid is liberated at this stage. The first oxidation step is carried out under pressure (preferably, 100 p.s.i.g.) and at an elevated temperature (preferably, 149°C).

0007 During the second step, the resultant ferric chloride solution is thermally decomposed to obtain ferric oxide and HCl gas, which is recovered as hydrochloric acid. More specifically, the resultant solution is heated up to $175\text{-}180^\circ\text{C}$ at atmospheric pressure. The HCl is stripped off at a concentration of 30% with >99% recovery and good quality hematite is produced. While recovery of hydrochloric acid and hematite may be achieved using this process, its application tends to be limited to liquors containing only ferrous/ferric chlorides. When other chlorides are present in the solution, for instance, magnesium chloride, the activity of the chloride ions and protons tends to be too high to permit any reaction to take place simply by heating the solution to the desired temperature. Accordingly, this process

tends not to be well adapted for use in leaching processes involving chlorides other than ferric chloride.

0008 J.E. Dutrizac and P.A. Riveros in a technical paper entitled "Precipitation of Hematite from Ferric Chloride Media", Hydrometallurgy 46 (1997), pages 85-104, showed that it was possible to precipitate a pure form of hematite from dilute ferric chloride systems, but that only a small part of the total iron could be precipitated. The presence of additional chlorides further suppressed hematite precipitation, as did hydrochloric acid above 0.6M in concentration. The system used was closed (in an autoclave) and no attempt was made to recover the hydrochloric acid. J.E. Dutrizac, in an earlier paper, "Jarosite Formation in Chloride Media", Proceedings of the Aus. IMM, No. 278, June, 1981, pages 23-32, similarly showed that jarosites could be precipitated from chloride solutions containing sulfate ions. But, as with hematite, the presence of a very small amount of hydrochloric acid, this time less than 0.1M suppressed the reaction. Only alkali and lead jarosites and not hydronium jarosite could be formed. To date, no methods to recover substantial amounts of iron in a useful form have been developed for application in chloride-based leaching processes.

0009 Other chloride-based circuits have also been proposed for the recovery of nickel and cobalt amongst other metals. One such circuit is disclosed in International PCT Publication Number No. WO 02/053788 of Lalancette. This published patent application describes a method for the recovery of base and precious metals using various extractive chloridation techniques. Lalancette teaches effecting chloridation using chlorine in the presence of a source of chloride ions, such as sodium chloride, potassium chloride and calcium chloride. This chloridation is followed by a lixiviation step using hydrochloric acid. This type of chloridation may be carried out at low temperatures (40-50°C) or high temperatures (500-600°C). Additionally, Lalancette describes performing chloridation by leaching a base metal mixture containing substantial amounts of iron with hydrochloric acid at a temperature of 100°C, in the presence of an oxidant. This chloridation transforms part of the iron into ferric chloride which, in sulfide ores, can only be achieved in the presence of an oxidant. The ferric chloride solution is then heated to evaporation while in the presence of moisture. Thereafter, the resultant ferric chloride is subjected to hydrolysis to thereby transform it into ferric oxide and hydrochloric acid. According to Lalancette, the metal chlorides remaining in the final solid mixture are not affected by this mild hydrolysis and can be separated from the ferric oxide solids by leaching with water. However, experiments conducted by the applicant have

shown that this is not the case. More specifically, it was found that the metal chlorides would hydrolyse to a greater or lesser degree depending on the temperature and thus would be lost in the iron residue.

0010 In light of the foregoing, it would be advantageous to be able to separate and selectively recover substantial amounts of iron from a base metal sulfide ore in a generally useful and relatively pure form, while avoiding the need for an energy-intensive and expensive step such as pyrohydrolysis. It would be further desirable to have the recovery of iron in this fashion occur within a process which tends to yield generally high rates of recovery for base metals, permits recovery of elemental sulfur and the acid constituent in the lixiviant, as well as generates some energy.

0011 Efficient iron removal also tends to pose significant challenges in the recovery of base metals from laterite ores using chloride-based leaching processes. United States Patent Publication No. 2004/0228783 of Harris et al. describes a process for the recovery of value metals from material containing base metal oxides in which iron is simultaneously leached and precipitated from the laterite ore along with base metals. The lixiviant used in the leaching step may comprise magnesium chloride and hydrochloric acid. Optionally, the lixiviant may further include an oxidant. The leachate contains solubilised base metals, such as nickel, cobalt, manganese, copper, aluminum, zinc and chromium and a solid residue that contains iron. The leach is conducted under conditions at which at least some, and preferably all or substantially all, of the iron that is leached from the ore is immediately hydrolyzed and precipitated as hematite and/or magnetic iron oxide. The resultant leachate may contain only residual amounts of iron.

0012 This process however tends to suffer from an important drawback. The precipitating iron in the process of Harris et al. tends to coat the unleached particles, and therefore inhibits the dissolution of nickel and cobalt, thereby rendering the process inoperable for most ores. Additionally, the process disclosed in Harris et al. has been found to be ineffective in controlling the dissolution of magnesium during the leaching step, thereby tending to make that process not suitable for the processing of low-iron, high-magnesium, saprolite ores.

0013 Other chloride-based leaching processes are also known. Recently, in a presentation by A. John Moyes of Intec, entitled "The Intec Nickel Laterite Process," presented at ALTA

2005 Ni/Co 10, Perth, W. Australia, May 16-18, 2005, a process was described wherein the limonite fraction of a laterite ore is leached by hydrochloric acid in a solution of calcium and sodium chlorides. The process can be operated in either one or two stages, the first stage being at 100-110°C, and the second, or if a single-stage process, at 150-220°C. In this process, both dissolved iron and magnesium are precipitated via the use of lime (CaO), iron as hematite and magnesium as MgO. The process requires the substantial addition of sulfuric acid to regenerate the hydrochloric acid, with the sulfate being controlled by the further addition of lime. The process is remarkably complex, and appears to suffer from all the disadvantages of both chloride and sulfate circuits. In particular, there tends to be large quantities of residue and no provision for the recycling of sulfuric acid. Moreover, the process needs to be carried out under pressure leach conditions and tends to be suitable for the treatment of the limonite fraction only.

0014 Another leaching process is disclosed in International PCT Publication Number No. WO 02/08477 of Lalancette. This published patent application describes a method of recovering nickel and cobalt from laterite ores including an ore conditioning step, an acid leaching step, a nickel and cobalt recovery step, a hydrochloric acid recycling step and a magnesium oxide and iron oxide recovery step. Prior to treatment, the ore is conditioned by grinding and screening and is contacted with hydrogen chloride and water vapour such that a significant amount of hydrochloric acid is absorbed by the ore. Thereafter, the acid saturated and partly reacted ore is heated to approximately 90-100°C and leaching is performed with hydrochloric acid to obtain a lixiviate containing water soluble nickel, cobalt, iron, chromium and magnesium chlorides and an insoluble residue. The lixiviate is then filtered from the insoluble residue to produce a head solution.

0015 Lalancette describes two processes by which the nickel and cobalt can be recovered along with hydrochloric acid and iron oxide. One process involves recovering the nickel and cobalt from the head solution using techniques such as electrowinning and solvent extraction, specific-ion exchange resins and sulfide precipitation. Following the recovery of nickel and cobalt, the leftover solution containing ferrous chloride, magnesium chloride and chromium chloride along with excess acid can be evaporated in the presence of a potassium chloride solution to yield a solid residue of the chlorides. This residue may be roasted in the presence of air and steam at temperatures ranging from 450 to 475°C to oxidize the ferrous chloride to iron oxide and produce gaseous hydrochloric acid. The foregoing circuit is complex, and may

not yield a hematite product of high purity. This is because some of the magnesium will form its oxychloride, otherwise known as "Sorel Cement," and as a result it will not be possible to wash this magnesium out of the hematite, since the oxychloride is markedly insoluble.

0016 The second process taught by Lalancette requires heating the head solution at temperatures ranging from 130 to 180°C and removing the water and HCl in a stream of air. Lalancette teaches that at these temperatures the addition of KCl is not necessary. The ferrous chloride is oxidized to ferric chloride and then subsequently hydrolyzed to ferric oxide. The chromium chloride is converted to Cr₂O₃, while the other metals remain as their respective chlorides which may be separated using standard techniques. However, experiments have found that at temperatures of 130-180°C, magnesium chloride remains liquid and ferric iron will not hydrolyse and precipitate because of the high chloride and proton activity conferred on the system by the magnesium chloride.

0017 In light of the foregoing, it would appear that a hydrometallurgical process that allows the recovery of iron while minimizing or at least controlling the dissolution of magnesium without the shortcomings of the known, previously described, processes, is required.

SUMMARY OF THE INVENTION

0018 In accordance with a broad aspect of the present invention, a process for recovering iron material from a base metal containing material is provided. The process includes providing the base metal containing material and providing a lixiviant comprising an acid and a chloride. The acid may be selected from the group consisting of an organic acid, sulfurous acid, sulfuric acid and hydrochloric acid. The chloride may be selected from the group consisting of magnesium chloride, calcium chloride, sodium chloride, potassium chloride, ferrous chloride and lithium chloride. The process further includes performing a leaching step on the base metal containing material at atmospheric pressure in the absence of an oxidant, using the lixiviant to obtain a solid residue and a leachate containing dissolved iron therein, and separating the leachate from the solid residue. The leachate is then treated to recover therefrom at least some of the iron as a hematite product of high purity.

0019 In an additional feature, the base metal containing material is selected from the group consisting of an ore, a concentrate and an intermediate material. In another feature, the base metal containing material is sulfide ore material. The sulfide ore material contains at least one

base metal selected from the group consisting of nickel, copper, zinc and cobalt. Optionally, the sulfide ore material contains at least one of gold, silver and a platinum group metal. The sulfide ore material may be selected from the group consisting of pyrrhotite, pentlandite, chalcopyrite, pyrite, arsenopyrite, galena and sphalerite.

0020 In another feature, the base metal containing material is an oxidic ore material. The oxidic ore material is a laterite ore material. The laterite ore material may be one of a limonite ore material, a saprolite ore material, a hematitic clay material and a serpentinite material. The laterite ore material contains at least one base metal selected from the group consisting of nickel, manganese, magnesium, copper and cobalt.

0021 In a further feature, the concentration of the chloride in the lixiviant is adjusted to obtain a solubility of between about 75% and about 95% of its saturation point. In yet another feature, magnesium chloride is selected as the chloride.

0022 In still another feature, the acid in the lixiviant is an organic acid. The organic acid may be selected from the group consisting of acetic acid, tartaric acid and citric acid.

0023 In another feature, the acid is hydrochloric acid and the chloride is magnesium chloride. The concentration of magnesium chloride in the lixiviant is adjusted to at least about 300g/L. In an additional feature, the concentration of magnesium chloride in the lixiviant is adjusted to between about 340g/L and 420 g/L.

0024 In a further feature, the leaching step is performed at a temperature between about 20°C and about the boiling point of the lixiviant. In still another feature, the leaching step is performed at a temperature between about 105°C and about 110°C.

0025 In an additional feature, the step of treating the leachate to recover therefrom at least some of the iron as a hematite product of high purity, includes heating the leachate to distill the hydrochloric acid therefrom, and simultaneously subjecting the leachate to a precipitation step to promote the formation of the hematite product. Preferably, the leachate is heated to a temperature of between about 190°C and about 250°C and most preferably, between about 220°C and about 250°C. In another feature, the leachate is heated to a temperature of at least about 180°C and the precipitation step includes one of adding water and adding steam to the leachate. In a further feature, the precipitation step includes one of adding water and

adding steam to the leachate. Further still, the process further includes separating the precipitate from the remaining leachate and drying the precipitate.

0026 In another feature, the process further includes recovering the chloride from the remaining leachate.

0027 In yet another feature, the base metal containing material is a sulfide ore material and the process further includes removing hydrogen sulfide gas formed during the leaching step. Optionally, the hydrogen sulfide is stripped in a continuous manner.

0028 In one feature, the base metal containing material is a sulfide ore material and the solid residue is an upgraded base metal concentrate. In another feature, the base metal containing material is a laterite ore material and the leachate is a base metal-rich leachate.

0029 In accordance with another broad aspect of the present invention, a process for recovering a base metal from a base metal containing material is provided. The process includes providing the base metal containing material and providing a lixiviant. The lixiviant includes an acid and a chloride. The acid is selected from the group consisting of an organic acid, sulfurous acid, sulfuric acid and hydrochloric acid. The chloride is selected from the group consisting of magnesium chloride, calcium chloride, sodium chloride, potassium chloride, ferrous chloride and lithium chloride. The process further includes performing a leaching step on the base metal containing material at atmospheric pressure in the absence of an oxidant, using the lixiviant to obtain a solid residue and a leachate containing dissolved iron therein and then separating the leachate from the solid residue. The leachate is then treated to recover therefrom at least some of the iron as a hematite product of high purity, prior to one of the leachate and the solid residue being subjected to a series of base metal recovery steps.

0030 In another feature, the base metal containing material is a sulfide ore material, and the process further includes removing hydrogen sulfide gas formed during the leaching step. Optionally, the hydrogen sulfide is stripped in a continuous manner and reacted with sulfur dioxide gas in a Claus reaction to obtain elemental sulfur and steam.

0031 In a further feature, the base metal containing material is a sulfide ore material and the solid residue is an upgraded base metal concentrate. The upgraded base metal concentrate is

subjected to a series of base metal recovery steps that includes providing a second lixiviant comprising an acid and a chloride. The acid may be selected from the group consisting of an organic acid, sulfurous acid, sulfuric acid and hydrochloric acid. The chloride may be selected from the group consisting of magnesium chloride, calcium chloride, sodium chloride, potassium chloride, ferrous chloride and lithium chloride. The process further includes performing a second leaching step on the upgraded base metal concentrate at atmospheric pressure, using the second lixiviant to obtain second solid residue and a second leachate containing at least one base metal dissolved therein. The second leachate is then separated from the second solid residue and treated to recover therefrom the at least one base metal.

0032 In an additional feature, the base metal containing material contains at least one of gold, silver and a platinum group metal and the second solid residue is an upgraded value metal concentrate. The upgraded value metal concentrate is subjected to at least one value metal recovery step. In another feature, the base metal containing material contains at least one of gold, silver and a platinum group metal and the second leachate is a value metal-rich leachate. The value metal-rich leachate is subjected to at least one value metal recovery step.

0033 In a further feature, the base metal containing material is a laterite ore material and the leachate is a base metal-rich leachate. The base metal-rich leachate is subjected to a series of base metal recovery steps.

BRIEF DESCRIPTION OF THE DRAWINGS

0034 The embodiments of the present invention shall be more clearly understood with reference to the following detailed description of the embodiments of the invention taken in conjunction with the accompanying drawings, in which:

0035 **FIG. 1** is a schematic representation of a process according to an embodiment of the invention involving the removal of iron material from a sulfide ore material using a lixiviant in a leaching step to obtain a solid residue in the nature of an upgraded base metal concentrate and a leachate containing dissolved iron therein;

0036 FIG. 2 is a schematic representation of a process for recovering base metals and value metals from the upgraded base metal concentrate obtained by the process shown in FIG. 1; and

0037 FIG. 3 is a schematic representation of a process according to another embodiment of the invention involving the removal of iron material from a laterite ore material using a lixiviant in a leaching step to obtain a solid residue and a base metal-rich leachate.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

0038 The description which follows, and the embodiments described therein are provided by way of illustration of an example, or examples of particular embodiments of principles and aspects of the present invention. These examples are provided for the purposes of explanation and not of limitation, of those principles of the invention. In the description that follows, like parts and/or steps are marked throughout the specification and the drawings with the same respective reference numerals.

0039 With regard to nomenclature, the term “ore material” as it is used throughout the specification in connection with the processes described herein, means an ore and any material derived from the processing of an ore, including without limiting the foregoing, any metal processing by-product (i.e. flue dust and furnace baghouse dust), any intermediate material produced during the treatment of an ore (i.e. slags, calcines, impurity residues, dross and anode slimes), any concentrate, any matte such as a converter matte, or any tailings from the processing of an ore.

0040 Referring to FIG. 1, there is shown a schematic representation of a process in accordance with an embodiment of the invention, designated generally with reference numeral 20. Broadly speaking, the process 20 involves the removal of iron material from a base metal containing ore material using a lixiviant during a leaching step. More specifically, the process 20 includes the following steps: providing a base metal containing material in the nature of a sulfide ore material (step 30); providing a lixiviant (step 40); performing a leaching step on the sulfide ore material at atmospheric pressure, using the lixiviant to obtain a solid residue and a leachate containing dissolved iron therein (step 50); separating the leachate from the solid residue (step 60); and treating the leachate to recover therefrom at least some of the iron as a hematite product of high purity (step 65).

0041 In the present embodiment, the sulfide ore material contains relatively substantial amounts of sulfur and iron, as well as one or more base metals, such as, nickel, copper, zinc and cobalt. The sulfide ore material may further contain one or more value metals such as gold, silver or a platinum group metal (PGM). The type and quantity of the value metal contained in the sulfide ore material will depend on the source of the ore material. Suitable sulfide ore materials for use in process 20 include pyrrhotite, pentlandite, chalcopyrite, pyrite, arsenopyrite, galena, sphalerite and any aggregates and/or mixtures thereof.

0042 In the present embodiment, the sulfide ore material does not require substantial treatment (i.e. roasting or flotation) prior to being subjected to the process shown in FIG. 1. However, it may be advantageous to perform certain well-known physical conditioning steps on the sulfide ore material. For instance, the sulfide ore material may be subjected to beneficiation or may be crushed and/or ground (at step 70) as shown in FIG. 1. The performance of such conditioning steps tends to improve the overall efficiency of the process by reducing the residence time of the lixiviant in the sulfide ore material and by encouraging the dissolution of iron in the leachate thereby leading to a reduction in the volume of solid residue obtained from the leaching step 50.

0043 The lixiviant used in the leaching step 50 includes an acid and a chloride. Contrary to other known hydrometallurgical processes applicable to sulfide ore materials, the lixiviant does not contain an oxidant and the leaching step is carried out under predominantly reducing conditions. The acid in the lixiviant may be an organic acid, sulfurous acid, sulfuric acid or hydrochloric acid. The preferred acid is hydrochloric acid. Examples of an organic acid that may be used in performing the leaching step 50, include acetic acid, tartaric acid and citric acid.

0044 The lixiviant employs relatively low concentrations of acid. The amount of acid to be used in the lixiviant tends to depend on the chemical composition of the sulfide ore material. Different sulfide ore materials require different amounts of acid in the lixiviant. However, where hydrochloric acid is selected, it has been found that between about 500 kg to about 1000 kg (100% dry basis) of hydrochloric acid may be needed for each tonne of sulfide ore material to be leached. Preferably, the amount of acid in the lixiviant is substantially stoichiometric. However, in certain instances, it may be desirable to add acid in an amount slightly in excess of the stoichiometric amount. For example, in the case of pyrrhotite,

between about 100% and about 110% of the stoichiometric amount of acid may be used. It is believed that the high activity of H^+ ions in the high strength chloride solution may make the use of close to stoichiometric concentrations of acid in the lixiviant possible.

0045 The chloride constituent in the lixiviant may be magnesium chloride, calcium chloride, sodium chloride, potassium chloride, lithium chloride, ferrous chloride or mixtures thereof. The preferred chloride for use in the lixiviant is magnesium chloride as it tends to be more readily recycled than the other specified chlorides. Magnesium chloride is most preferred where the acid employed in the lixiviant is hydrochloric acid. As will be explained in greater detail below, where the lixiviant includes hydrochloric acid, it will be possible to precipitate more of the iron in the leachate as hematite or magnetite during a hydrolytic distillation stage. The hematite or magnetite thus formed is of high purity and may be easily recovered.

0046 Where magnesium chloride is used in the lixiviant with hydrochloric acid, there exists the possibility that magnesium oxychloride may be formed during the hydrolytic distillation stage, the formation of which would contaminate the hematite and result in a loss of chloride from the system. However, the risk of this occurrence tends to be relatively small. On the other hand, magnesium chloride tends not to suffer from some of the drawbacks associated with some of the other above-identified chlorides. For instance, sodium chloride and potassium chlorides are prone to crystallisation and calcium chloride tends to form a stable sulfide, which on oxidation causes insoluble calcium sulfate (gypsum) to precipitate, resulting in significant scaling problems in the reactors and piping.

0047 The chloride concentration of the lixiviant prior to leaching is adjusted to obtain a solubility in the range of 75-95% of its saturation. This adjustment will yield different amounts of chloride ion initially in solution given that the solubility of the specified chlorides varies considerably. The chloride concentration may also be adjusted to take into account the concentration of iron in the sulfide ore material. In the preferred embodiment, the chloride concentration will be adjusted so as to yield between about 30g/L and about 50g/L of ferrous chloride at the end of the leaching step 50. It should be appreciated that the concentration of chloride ions and acid in the lixiviant is selected to maximize dissolution of iron in the lixiviant.

0048 Preferably, the concentration of magnesium chloride in the lixiviant should be at least 300 g/L. However, the optimum concentration of magnesium chloride has been determined to be between about 340g/L and about 420 g/L. The concentration of chloride has been determined to be important in the kinetics of the leaching reactions, and on the vapour pressure of both water and hydrochloric acid above the reaction slurry. Higher total chloride concentrations lead to increased kinetics and lower vapour pressures of water but higher in hydrochloric acid.

0049 During the leaching step 50, the sulfide ore material is contacted and leached with the lixiviant to obtain a solid residue and a leachate containing dissolved iron therein. Following the leaching step 50, a majority of the leachable iron in the source sulfide ore material will be in solution. Preferably, at least 70% of the iron will be dissolved in the leachate and more preferably, the leachate will contain over 90% of the iron. Somewhat lower values may be obtained where the ore material being treated is very pyritic (or refractory).

0050 The leaching step 50 may be conducted in a single reactor, or in a plurality of reactors arranged either in series or in parallel. In the preferred embodiment, the leaching step 50 is carried out in three or more leaching reactors. These leaching reactors may be pressurized or unpressurized vessels. Preferably, the leaching step 50 is carried out in an unpressurized vessel (i.e. at atmospheric or ambient pressure). The use of an unpressurized vessel tends to be less cost intensive. In contrast to certain known prior art processes which require elevated pressures and temperatures to obtain reaction kinetics sufficiently rapid to enable a viable commercial process, the leaching step 50 tends to achieve satisfactory reaction kinetics at atmospheric pressure.

0051 The leaching step 50 may be conducted as a continuous process or a batch process. If conducted as a continuous process, the leaching may be performed co-currently, countercurrently, or in any other suitable manner known in the art. The leaching step 50 may also be conducted in a pachuca.

0052 The leaching step 50 may be carried out at a temperature that lies in the range of about 20°C to about the boiling point of the lixiviant at ambient pressure, (which is about 120°C). The filterability of the leach residue has been found to be greatly enhanced at temperatures greater than about 105°C due to the dehydrating effects of the chloride lixiviant. In view of

the foregoing, the temperature at which the leaching step 50 may be conducted, is preferably between 105°C and about 110°C.

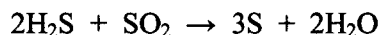
0053 It should be noted that whilst the pH is usually an important parameter in hydrometallurgical processes, the pH tends not to have an important role in the leaching step 50. It may however be used as an indicator of the reaction progress or as a control mechanism. Similarly, the redox (or oxidation-reduction) potential (Eh) tends not to be a significant parameter of the leaching step 50. Preferably, the leaching conditions are maintained at the natural oxidation-reduction potential of the system, which tends to be reducing. However, in contrast to most leach circuits, there is no requirement in the present embodiment to control the redox potential.

0054 In this embodiment, leaching of the sulfide ore material is controlled to permit the dissolution of iron only - no substantial amounts of base metals or value metals are dissolved within the leachate. The base metals and any value metals in the sulfide ore material remain in the solid residue. As will be explained below in greater detail, in this embodiment, the solid residue obtained from the leaching step 50 is an upgraded base metal concentrate upon which may be further processed to recover the base metals and any value metals contained therein.

0055 Hydrogen sulfide gas is formed during the leaching step 50 as the sulfur in the sulfide ore material is converted to hydrogen sulfide under reducing conditions. The hydrogen sulfide thus formed is removed from the lixiviant at step 70. Preferably, the hydrogen sulfide gas is stripped from the lixiviant in a continuous manner to ensure the concentration of hydrogen sulfide in the lixiviant is kept relatively low. An inert (non-oxidizing) carrier gas (for instance, argon or nitrogen) may be added to the lixiviant solution to aid in the stripping of the hydrogen sulfide. Alternatively, the leaching step 50 may be conducted under a relatively small negative pressure (vacuum) to remove the hydrogen sulfide gas formed.

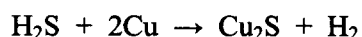
0056 It is believed that the high proton activity achievable at the low acid concentrations herein permits the process to be operated under conditions that cause the formation of hydrogen sulfide rather than elemental sulfur or sulfate ion, so-called reductive leaching conditions at low redox potential.

0057 In the preferred embodiment, at least one portion of the hydrogen sulfide gas is reacted (at step 80) with sulfur dioxide gas, in a Claus reaction to recover an elemental sulfur product and steam, according to the following chemical reaction:



0058 The Claus reaction may be carried out in one or more stages, using one or more catalysts. High rates of recovery in the order of 94% to 97% of elemental sulfur may be achieved. It will thus be appreciated that reacting the sulfur dioxide gas in a Claus reaction allows for the recovery of the intrinsic energy in the sulfide ore material. Advantageously, the high-pressure steam produced by this reaction may be used to supply and/or sustain the energy requirements of the processing and refining operations, thereby potentially resulting in substantial savings in operating costs.

0059 The remaining portion of the hydrogen sulfide gas (and preferably, at least one third of the hydrogen sulfide gas formed) is reacted with molten copper (at step 90) at a temperature between about 1200°C and about 1500°C. Thus reacted, the hydrogen sulfide is absorbed rapidly and directly into the molten copper to thereby form cuprous sulfide, Cu_2S , and liberate pure hydrogen gas (approximately greater than 99.5% pure), according to the following chemical equation:



0060 The hydrogen gas so liberated may be collected for use as a clean energy source. For instance, it could be employed as clean fuel to power the oxy-fuel burners of a pyrohydrolysis reactor used for further refining the upgraded base metal concentrate obtained. Preferably though, most of the hydrogen gas will be used in a fuel cell (i.e. a solid oxide fuel cell) or in a co-generation plant to produce electric power and high-pressure steam. The electric power thus generated could be used to supply some or all of the energy requirements of the plant and associated township. As an illustrative example, a typical sulfide ore containing about 30% sulfur at a treatment rate of 5000 to 10,000 tonnes ore/day would generate at least 10 MW of electric power using existing solid oxide fuel cell technology. Clearly, recovering the useful energy from a sulfide ore in this manner alleviates the requirement for the generation of on-site power and heat energy from the burning of fossil fuels such as coal, oil or natural

gas, and furthermore, eliminates the production of the greenhouse gases associated with the burning of these fuels. Moreover, substantial savings in energy costs may be achieved.

0061 Preferably, the cuprous sulfide formed at step 90 is exposed to oxygen (i.e. "blown") at step 100 as in any typical copper converter to re-form the elemental molten copper and liberate sulfur dioxide gas. Since both of the reactions with the molten copper (steps 90 and 100) are kinetically fast, only a relatively small amount of copper need be employed to perform step 90. As a result, the reactor may be run on a continuous basis. Alternatively, the cuprous sulfide may be sold to a copper smelter if desired and fresh copper may be supplied to carry out step 90.

0062 A portion of the sulfur dioxide gas formed at step 90 may be used as an oxidant in a lixiviant in an additional leaching step carried out to further refine the upgraded base metal concentrate (as further explained below). The remaining portion may be employed in the Claus reaction carried out at step 80. Alternatively, the sulfur dioxide may be converted to sulfuric acid, or collected as liquid sulfur dioxide for sale or re-use.

0063 It should be appreciated that while it is contemplated that a portion of the hydrogen sulfide stripped from the lixiviant will be diverted directly toward a Claus reactor for use in step 80 such that less than the entire amount of hydrogen sulfide will be reacted with molten copper, it should be appreciated that this need not be the case in every application. In alternative applications, all the hydrogen sulfide gas could be used in step 90.

0064 Moreover, while in the preferred embodiment, the hydrogen sulfide stripped from the lixiviant is reacted to molten copper at step 80 to obtain cuprous sulfide and hydrogen gas, it should be appreciated that other uses may be made of the hydrogen sulfide gas. In an alternative embodiment, the hydrogen sulfide may be contacted with a solution of a metal or metalloid to thereby form a sulfide, in particular a solution of a copper salt or one containing arsenic - which sulfide may be used in further base metal refining steps. In still another embodiment, the hydrogen sulfide could be burned directly in air to generate steam and a high-strength stream of sulfur dioxide which may be recovered separately as liquid sulfur dioxide.

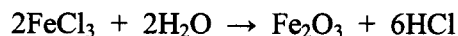
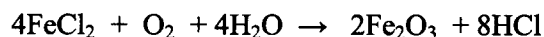
0065 A solid residue in the nature of an upgraded base metal concentrate and a leachate containing ferrous chloride and the initial chloride salt (in this case magnesium chloride) is

obtained following the leaching step 50. The solid residue and leachate are subjected to a solid/liquid separation step 110, following which the upgraded base metal concentrate is subjected to a series of base metal recovery steps and the leachate is treated for the recovery of an iron product and recycled hydrochloric acid.

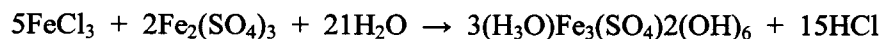
0066 In these very high chloride concentration brines, it tends not to be necessary to add a base to precipitate the iron, nor to invoke pyrohydrolysis (which is a high temperature and energy intensive reaction at ~700°C to 950°C) to recover the acid. It has been found that by heating the leachate to a temperature of at least 180°C in the presence of additional moisture/water (step 120) and simultaneously subjecting the remaining leachate to a precipitation (step 130), then at least some of the iron could be precipitated as a hematite product of high purity and the hydrochloric acid could be distilled from the leachate. Where no additional moisture/water is supplied, it may be necessary to heat the leachate to at least about 190°C to precipitate the iron as hematite. Preferably, the leachate will be heated to a temperature between about 190°C and about 250°C, and most preferably, between about 220°C and about 250°C.

0067 In the present embodiment, the precipitation step 130 involves air/oxygen sparging (although, other suitable oxidants may be used) and adding sufficient moisture/water to hydrolyse the iron to thereby promote the formation of a hematite precipitate. The precipitate thus obtained is a high-purity, easily filterable, crystalline hematite product. The water required for the reaction may be most conveniently added as steam, the latter also providing the heat necessary for distilling the hydrochloric acid from the leachate.

0068 The iron may be oxidized by air and hydrolysed by water to form hematite according to following chemical reactions:



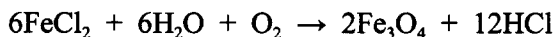
0069 Where the leachate contains appreciable amounts of sulfate ion, then after the ferrous iron has been oxidized, a mixture of hematite and jarosite may be formed with jarosite being formed according to the following chemical reaction:



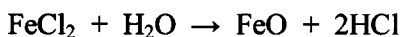
0070 This jarosite reaction also liberates hydrochloric acid, and importantly acts as a control for any sulfate in the system. Both the hematite and jarosite formed are highly crystalline in these high chloride systems, and consequently settle and filter very easily, unlike in corresponding sulfate or dilute chloride systems.

0071 Alternatively, if the chloride used in the lixiviant is magnesium chloride, or if appreciable quantities of magnesium have been dissolved in the leaching step, then magnesium sulfate, which has a much lower solubility than magnesium chloride, will precipitate and will form instead of jarosite.

0072 While in this embodiment, the iron is precipitated out of the remaining leachate as hematite, this need not be the case in all applications. In an alternative embodiments, other iron product precipitates could be obtained. More specifically, if only a limited quantity of air is added during the precipitation step, magnetite will be formed according to following chemical reactions:



0073 Alternatively, if air or oxygen is completely absent during the precipitation step, the iron will precipitate as ferrous oxide according to the following chemical reaction:



0074 Following the precipitation step 130, the remaining leachate (now an iron-depleted, magnesium chloride liquor) and the hematite product are then subjected to a solid/liquid separation step 140. The hematite product thus recovered may be dried and sold, or simply disposed of. In the preferred embodiment, the magnesium chloride liquor is regenerated and recycled for use in the process 20. As shown in FIG. 1, the recycled magnesium chloride liquor and the recycled hydrochloric acid may be combined to form some of the lixiviant used in leaching step 50. It should be appreciated that the recycled magnesium chloride liquor, the recycled hydrochloric acid and the sulfide ore material may be combined in any particular order prior to being introduced into the reactor(s) in which leaching step 50 is conducted. However, it is preferred that sulfide ore material and the recycled magnesium chloride liquor be combined prior to the recycled hydrochloric acid being added.

0075 Turning now to the upgraded base metal concentrate, following the solid/liquid separation step 110, the upgraded base metal concentrate is subjected to a series of base metal recovery steps that include performing a second leaching step 150. This, however, need not be the case in every application. In an alternative embodiment, the upgraded base metal concentrate may be subjected to flotation to obtain separate base metal concentrates and a precious metal concentrate.

0076 Except as otherwise set forth below, the second leaching step 150 is carried out substantially as set out in United States Patent Application Publication No. 2005/0118081 of Harris et al., the disclosure of which is hereby incorporated by reference. To facilitate understanding, the second leaching step 50 is briefly described below.

0077 With reference to FIG. 2, during the second leaching step 150 the upgraded base metal concentrate is contacted and leached with a second lixiviant to obtain a solid residue in the nature of a value metal concentrate and a leachate containing predominantly all of the base metals and any iron remaining from the primary leach circuit, in solution. The value metal concentrate and the base metal rich-leachate are subjected to a solid/liquid separation step 160, following which the value metal concentrate is treated to extract one or more value metals therefrom and the base metal rich-leachate is subjected to a series of base metal recovery steps as explained in greater detail below. The solid/liquid separation step 160 may employ any known technique for effecting such separation including pressure or vacuum filtration, countercurrent decantation or centrifuge.

0078 The second leaching step 150 may be carried out a temperature that lies in the range of about 20°C to about the boiling point of the lixiviant at ambient pressure, (which is about 120°C). The leaching conditions, in particular, the lixiviant, redox potential (Eh) and pH, may be controlled to dissolve predominantly all of the base metals and remaining iron from the upgraded base metal concentrate. The value metals, such as, the platinum group metals (PGMs), gold and silver are not substantially leached - these remain in the solid residue to be recovered by any means known in the art. For instance, the value metal concentrate may be subjected to a leaching step to dissolve the PGMs, gold and silver. The lixiviant used for this leaching step could be the same as that employed in the first and second leach circuits, except that the redox potential for the system would be increased preferably to greater than about

700 mV and, more preferably, to greater than about 800 mV. Known PGM separation steps could then be performed to recover the PGMs, gold and silver present.

0079 While not preferred, in the event, some of the PGMs gold and silver came to be present in the second leachate, then some or all of the leachate could be subjected to one or more PGM separation steps to recover the value metals. For instance, value metal recovery could be effected by cementation with metallic copper, zinc or organic or inorganic reductants.

0080 In this embodiment, the lixiviant used in the second leaching step 150 includes an acid, an oxidant, and a chloride. Preferably, the lixiviant includes the remaining leachate from the precipitation step 130 (that is, a solution of ferric chloride and magnesium chloride). By recycling the remaining leachate for use in the second leaching step 150, the addition of external reagents may be avoided.

0081 It will however be appreciated that a lixiviant similar or substantially similar to that used in the primary leach (that is, a lixiviant comprising an acid and a chloride, but no oxidant) could also be employed successfully in leaching certain base metals (i.e. nickel and cobalt). In one embodiment, the leachate (containing ferrous chloride and magnesium chloride) obtained following the first leaching step 50, could be employed in the second leaching step 150.

0082 In alternative embodiments, other combinations of acid, chloride and oxidant may be used to constitute the lixiviant. In this regard and as in the primary leach circuit, the acid may be an organic acid, sulfurous acid, sulfuric acid or hydrochloric acid - with hydrochloric acid being the preferred acid. The oxidant may be a mixture of sulfur dioxide and oxygen and/or air. The sulfur dioxide formed during the "blowing" of cuprous sulfide at step 100 could be used as a constituent of the second lixiviant. However, it will be appreciated that other oxidants, taken alone or in combination, may be used to similar advantage. For instance, any of the following compounds could be suitable oxidants for the second lixiviant: alkali metal peroxides, alkaline earth metal peroxides, alkali metal perchlorates, alkaline earth metal perchlorates, ammonium perchlorate, magnesium perchlorate, alkali metal chlorates, alkaline earth metal chlorates, alkali metal hypochlorites, alkaline earth metal hypochlorite, chlorine, hydrogen peroxide and peroxysulfuric acid.

0083 The chloride may be magnesium chloride, calcium chloride, sodium chloride, potassium chloride, lithium chloride, ferrous chloride or mixtures thereof and moreover, may be the same chloride as the one used in the primary leach circuit. The use of magnesium chloride in the second lixiviant is particularly favoured, since it is amenable to a pyrohydrolysis step (if necessary), as further described below.

0084 As in the primary leach circuit, hydrogen sulfide gas may be formed during the leaching step 150 as the remaining sulfur in the upgraded base metal concentrate material is converted to hydrogen sulfide under reducing conditions. The hydrogen sulfide thus formed may be stripped from the lixiviant in a continuous manner. The stripping of hydrogen sulfide may be facilitated by adding an inert (non-oxidizing) carrier gas to the lixiviant solution.

0085 While the formation of hydrogen sulfide in the secondary leach circuit is preferred, in contrast to the process described in United States Patent Application Publication No. 2005/0118081 of Harris et al., this is not strictly required because most of the sulfur in the sulfide ore material was removed as hydrogen sulfide in the primary leaching step 50. The formation of sulfates (most obviously from the use of the preferred oxidant i.e. the mixture of sulfur dioxide and oxygen) in the secondary leach circuit can be tolerated, since the sulfate ion concentration may be easily controlled by the formation of jarosite and/or magnesium sulfate.

0086 Removal of any remaining iron in solution occurs at step 170. Accordingly, where hydrogen sulfide is formed during the leaching step 150, it will be possible to distil the hydrochloric acid and precipitate hematite from the leachate by heating the leachate to a temperature of at least 180°C in the presence of additional moisture/water and simultaneously subjecting the remaining leachate to a precipitation step, as in the primary leach circuit. As mentioned above, where no additional moisture/water is supplied, it may be necessary to heat the leachate to at least about 190°C to precipitate the iron as hematite. Preferably, the leachate will be heated to a temperature between about 190°C and about 250°C, and most preferably, between about 220°C and about 250°C.

0087 Where sulfates are present in the leachate, hydrolytic distillation may be carried out to precipitate jarosite. If there is insufficient iron present for this purpose, then some may be added from the primary leach circuit. The jarosite thus obtained tends to be very pure and

may be easily filtered. A solid/liquid separation step 175 is then carried out to separate the hematite or jarosite precipitate from the leachate.

0088 Once the remaining iron has been removed 180, the base metal-rich leachate may be subjected to a series of base metal recovery steps. These steps may be carried out in accordance with any known base metal extraction process including ion exchange, solvent extraction, electrowinning or sulfide precipitation. The use of electrowinning may be particularly advantageous, since power generated from process 20 either in the form high-pressure steam or hydrogen gas may be used. In accordance with the foregoing process, high rates of base metal extraction may be obtained. For instance, using this process, recovery rates of greater than 95% have been achieved for nickel and cobalt, and greater than 85% for copper.

0089 Hydrochloric acid may be recovered and recycled after each metal removal step in a manner analogous to that carried out in the primary leach circuit, thereby obviating the need to neutralize the acid with a base. The value metal-depleted leachates may also be treated to regenerate the chloride and acid constituents of the lixiviant.

0090 Furthermore, magnesium oxide (magnesia) and hydrochloric acid may be obtained by subjecting the base metal-depleted leachate to a pyrohydrolysis step. As previously mentioned, the oxy-fuel burners of the pyrohydrolysis reactor could be fuelled by the hydrogen gas generated at step 90. The magnesium oxide thus produced may be used in the recovery of base metals - more specifically, to effect neutralization and precipitation of certain metal products (e.g. cobalt and nickel oxide). The use of magnesium oxide for neutralization and precipitation is advantageous because the required amount of magnesium oxide may be produced by the system. Moreover, the addition of magnesium oxide does not add any further ions in the leachate, which would otherwise require the use of additional treatment steps.

0091 The principles of the present invention are illustrated by the following examples:

Example 1

0092 A sample of a polysulfide ore, analyzing 45.3% Fe, 1.46% Cu, 0.78% and 32.2% S, was crushed to 100% passing 100 mesh and leached in 360 g/L MgCl_2 solution at 105°C.

Concentrated hydrochloric acid was added in increments of 200 kg/tonne and allowed to react for one hour. Finally, 1200 kg/tonne of sodium hypochlorite as oxidant was added with 1000 kg/tonne of hydrochloric acid to the solids residue. The oxidant addition was not optimised. The results achieved are shown in Table 1 below.

Table 1

Acid Addition (kg/tonne)	Extraction (%)		
	Fe	Cu	Ni
200	0	0	0
400	51.7	0.5	0.2
600	82.8	0.0	0.0
800	92.8	10.2	23.3
1000	92.1	19.0	33.2
1000 + NaOCl	95.4	67.1	75.4

0093 The results showed no reaction until after the addition of 200 kg/tonne, with the optimum being between 600 and 800 kg/tonne. Predominantly all of the iron was leached and negligible quantities of base metals. The addition of oxidant resulted in significant leaching of the base metals.

Example 2

0094 The same sample of polysulfide ore was leached under identical conditions, in a series of separate tests, except that the acid was added all at once. The results achieved are shown in Table 2 below.

Table 2

Acid Addition (kg/tonne)	Time (min.)	Extraction (%)			
		Fe	Cu	Ni	S
600	0	69.3	0.2	28.2	48.6
	30	74.2	0.1	17.7	
	60	75.7	0.2	12.8	
650	0	76.5	0.6	30.6	51.0
	30	78.6	0.7	27.3	
	60	78.9	0.1	20.6	
700	0	81.1	1.6	14.5	72.1
	30	88.5	1.6	13.5	
	60	91.7	0.1	9.5	
750	0	89.3	1.4	26.3	80.9
	30	90.3	3.7	25.8	
	60	91.7	3.7	22.3	
800	0	89.9	3.0	25.1	-
	30	91.3	7.3	27.8	
	60	92.8	13.0	33.5	

0095 The results showed that the reaction was essentially instantaneous, with only a relatively small increase in iron extraction with time. Both iron and sulfur extraction increased with increasing acid addition. At higher acid addition, the extraction of nickel became significant, whereas copper was harder to leach.

Example 3

0096 The filtrate from the above tests, analyzing 37.5 g/L iron, all as ferrous, was heated up to close to its boiling point with air sparging. The iron was seen to oxidize as the solution colour changed from green to red, and as water was removed as condensate. However, when the volume in the reactor was maintained approximately constant by the addition of water and the temperature maintained at around 180°C, then red solids analyzing 69.4% Fe (99.2% hematite), which were subsequently shown to be entirely hematite by X-Ray diffraction analysis, were formed. The condensate generated was collected. When the off-gas temperature was maintained at greater than 109°C, the hydrochloric acid content of the condensate was in the range 0.5-3.0 g/L. When the temperature of the vapour phase was allowed to increase to greater than 109°C, then the concentration of the hydrochloric acid was as high as 3.0-3.5M.

0097 The results of this test show that in the presence of magnesium chloride, ferrous iron could easily be oxidised without recourse to a pressure vessel (unlike in the PORI Process described earlier). Additionally, the test demonstrates that by adding water at a high temperature, hydrolysis to hematite was effected and HCl was recovered. The recovered HCl was, however, relatively dilute under these conditions.

Example 4

0098 500g of pure copper metal was heated up to 1200°C, and hydrogen sulfide gas was passed into it at a rate of 1 L/min. for a period of 1.5 hours. Hydrogen gas of greater than 99.5% purity was obtained, with a conversion rate of greater than or equal to 99% for the hydrogen sulfide. Thereafter, air was blown into the cuprous sulfide so formed at a rate of 2 L/min. for a period of 3.5 hours to achieve regeneration of the molten copper.

Example 5

0099 A sample of primary leach residue, analyzing 20.0% Fe, 2.12% Ni, 4.56% Cu and 0.35% Co was leached in a solution of 400 g/L magnesium chloride and sufficient ferric chloride to account for 150% of the stoichiometric requirement for all of the above metals. The leach was carried out for 6 hours at a temperature of 118°C, after which time, 83% Fe, 99.5% Ni, 99.8% Cu and 68.1% Co extraction was achieved.

00100 This example demonstrates the magnesium chloride/ferric chloride solution generated during the oxidation of the primary leach liquor is a very effective lixiviant for the first stage leach residue, resulting in very high extractions of copper (from chalcopyrite) and nickel (from pentlandite).

00101 As will be apparent to a person skilled in the art, this process for iron removal may be used to similar advantage with other types of ore materials. More specifically, the process has been successfully applied to remove iron material from oxidic ore materials. Referring now to FIG. 3, there is shown a schematic representation of a process designated with reference numeral 200 in accordance with another embodiment of the invention, which involves the removal of iron material from an oxidic ore material.

00102 Preferably, the oxidic ore material to be treated contains nickel oxide, cobalt oxide, zinc oxide and/or copper oxide. In the embodiment shown, the oxidic ore material is a laterite ore material. The laterite ore material may be a limonite ore material, a saprolite ore material, a hematitic clay material or a serpentinite material. The laterite ore material may contain various profiles of the afore-mentioned materials. For instance, the laterite ore material may comprise a low-magnesium, high-iron limonite and high-magnesium, low-iron saprolite. While there may be some operational advantages associated with treating a laterite ore material having a single profile, this need not be the case in every application. In certain applications, it may be desirable to have a laterite ore material with various profiles treated within the same system. In these applications, the need to sort the laterite ore material prior to carrying out the leaching step may be obviated.

00103 Process 200 is generally similar to process 20 used to treat the sulfide ore material, in that it includes the steps of: providing a base metal containing material (in this case, a laterite ore material) 210; providing a lixiviant 220; performing a leaching step on the laterite ore material at atmospheric pressure, using the lixiviant to obtain a solid residue and a base metal-rich leachate containing dissolved iron therein 230; separating the leachate from the solid residue 240; and treating the leachate to recover therefrom iron as a hematite product of high purity (step 245).

00104 In the present embodiment, the laterite ore material does not require substantial treatment (i.e. roasting or flotation) prior to being subjected to the leaching step 230.

However, as discussed in the context of process 20, it may be advantageous to perform certain well-known physical conditioning steps (i.e. beneficiation, crushing and/or grinding) on the laterite ore material to improve the overall efficiency of the process.

00105 The lixiviant used in the leaching step 230 is similar to that used in the leaching step 50. It includes an acid and a chloride. The acid in the lixiviant may be an organic acid (such as, acetic acid, tartaric acid and citric acid), sulfurous acid, sulfuric acid or hydrochloric acid. Although, hydrochloric acid is preferred. The amount of acid to be used in the lixiviant tends to depend on the iron content in the laterite ore material. Generally speaking, the higher the content of iron in the laterite ore material, the more acid will be required needed to put the iron in solution.

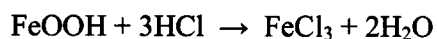
00106 The chloride constituent in the lixiviant may be magnesium chloride, calcium chloride, sodium chloride, potassium chloride, lithium chloride, ferrous chloride or mixtures thereof. Magnesium chloride is the preferred chloride, particularly where the acid employed in the lixiviant is hydrochloric acid.

00107 The chloride concentration in the lixiviant prior to leaching is adjusted to obtain a solubility in the range of about 75% to about 95% of its natural solubility and more preferably, between about 85% to 95%. This adjustment will yield different amounts of chloride ion in solution given that the solubility of the specified chlorides varies considerably. For instance, calcium is more soluble than magnesium, which in turn is more soluble than sodium. The chloride concentration may also be adjusted to take into account the concentration of iron in the laterite ore material. It should be appreciated that the concentration of chloride ions and acid in the lixiviant is selected to maximize dissolution of iron and the base metals in the lixiviant and to ultimately, to effect recovery of at least 90% of the base metals.

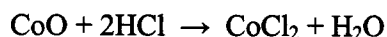
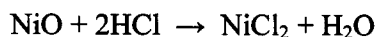
00108 Preferably, the concentration of magnesium chloride in the lixiviant will be in the range of about 300g/L to about 420 g/L. Where the laterite ore material is high-iron, low-magnesium saprolite ore material, a magnesium chloride concentration of about 360g/L has been found to be suitable. However, where the laterite ore material is a low-iron, high-magnesium limonite ore material, a higher concentration of magnesium chloride is preferred, more specifically, in the range of about 380 g/L to 400g/L.

00109 During the leaching step 230, the laterite ore material is contacted and leached with the lixiviant to obtain a solid residue and a base metal-rich leachate containing dissolved iron therein. Following the leaching step 230, a majority of the iron in the laterite ore material will be in solution. Preferably, at least 70% of the iron will be dissolved in the leachate and more preferably, the leachate will contain over 90% of the iron found in the laterite ore material. The iron thus dissolved may be either ferrous or ferric. Generally speaking, the greater the amount of iron dissolved in the leachate, the greater the amount of base metals will be put into solution. This is because when the iron dissolves, the base metals previously held in the iron matrix (most commonly nickel, cobalt and manganese) are released into the leachate.

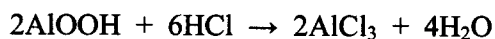
00110 For example, iron, which is largely present as goethite in laterite nickel ores, may be solubilized according to the following reaction:



00111 During leaching of the goethite (FeOOH), nickel and cobalt, which are largely bound within this matrix, are also released and become solubilized according to the following reaction:



00112 Additionally, it has been found that where the laterite ore material being treated contains significant quantities of aluminum (i.e. kaolin), during the leaching step 230, at least a portion of the aluminum tends to dissolve in the leachate to form aluminum chloride according to the following reaction:



00113 It should be noted that the leaching step 230 may be carried out under conditions that tend to control the leaching of magnesium. For instance, magnesium leaching could be inhibited by using a relatively high initial magnesium chloride concentration in the lixiviant. For example, the lixiviant may be prepared with an initial magnesium chloride concentration that is greater than about 380 g/L, and more preferably, greater than about 400 g/L.

00114 Moreover, in an alternative embodiment, an organic acid which has a sparingly soluble magnesium salt, could be used as the constituent acid in the lixiviant. Tartaric acid and citric acid have been found to be effective for the control of dissolved magnesium in such instances. In other embodiments, it may be desirable to allow some magnesium to be leached. This magnesium could be used as a source of cations in the lixiviant. Alternatively, it may be used to obtain a magnesium product, for example magnesium oxide. In still other embodiments, the leaching of magnesium may be inhibited by using a lixiviant with a chloride other than magnesium chloride and ensuring the lixiviant is saturated by the alkaline earth metal cation selected.

00115 The leaching step 230 may be conducted in a single reactor, or in a plurality of reactors arranged either in series or in parallel. These leaching reactors may be pressurized or unpressurized vessels. Preferably, the leaching step 230 is carried out in an unpressurized vessel (i.e. at atmospheric or ambient pressure). The use of an unpressurized vessel tends to be less cost intensive.

00116 In like fashion to leaching step 50, the leaching step 230 may be conducted as a continuous process or a batch process. If conducted as a continuous process, the leaching may be performed co-currently, countercurrently, or in any other suitable manner known in the art. The leaching step 230 may also be conducted in a pachuca or as a heap leach.

00117 The leaching step 230 may be carried out at a temperature that lies in the range of about 20°C to about the boiling point of the lixiviant at ambient pressure, (which is about 120°C). Preferably, the temperature at which the leaching step 50 may be conducted, is between about 105°C and about 110°C.

00118 Whilst, typically, the pH is an important parameter in hydrometallurgical processes, the pH tends not to have an important role in the leaching step 230. Similarly, the redox potential (Eh) tends not to be a significant parameter of the leaching step 230. While it is preferred that the leaching conditions be maintained at the natural oxidation-reduction potential of the system, unlike most leach circuits, there is no requirement in the present embodiment to control the redox potential.

00119 A solid residue in the nature of a solid residue and a leachate containing the initial chloride salt (in this case magnesium chloride), ferrous chloride and ferric chloride is

obtained following the leaching step 230. The solid residue and leachate are subjected to a solid/liquid separation step 250, following which the leachate is treated for the recovery of at least some of the iron as a hematite product of high purity and recycled hydrochloric acid, and further subjected to a series of base metal recovery steps. Where the leachate obtained also contains aluminum chloride, it will be possible to recover therefrom aluminum as an alumina product.

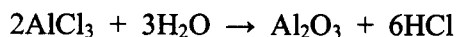
00120 In these very high chloride concentration brines, it tends not to be necessary to add a base to precipitate the iron, nor to invoke pyrohydrolysis to recover the acid. As explained above in the context of process 20, the iron could be precipitated as hematite and the hydrochloric acid could be distilled from the leachate, by heating the leachate to a temperature of at least 180°C in the presence of additional moisture/water (step 260) and simultaneously subjecting the remaining leachate to a precipitation (step 270). As mentioned previously, where no additional moisture/water is supplied, it may be necessary to heat the leachate to at least about 190°C to precipitate the iron as hematite. Preferably, the leachate will be heated to a temperature between about 190°C and about 250°C, and most preferably, between about 220°C and about 250°C.

00121 The precipitation step 270 is generally similar to precipitation step 130 described earlier, in that it involves air sparging and adding sufficient moisture/water to hydrolyse the iron to thereby promote the formation a hematite precipitate. The precipitate thus obtained is a high-purity, easily filterable, crystalline hematite product. The water required for the reaction may be most conveniently added as steam, the latter also providing the heat necessary for distilling the hydrochloric acid from the leachate.

00122 In some instances, it may be preferable to add a small amount of a catalyst, preferably oxalic acid, to the magnesium chloride-ferric chloride solution. Such a catalyst has the advantage of significantly improving the reaction kinetics, enhancing the yield of hematite and increasing the concentration of the hydrochloric acid distilled off.

00123 In this manner, the iron is advantageously removed as hematite without co-precipitating any of the base metals. The high chloride brine environment allows for extremely selective precipitation due to the highly crystalline nature of the precipitates.

00124 It has been found that where the leachate contains aluminum chloride, aluminum may be precipitated as a highly crystalline form of alumina (Al_2O_3) and the hydrochloric acid could be distilled from the leachate in a manner not unlike that used to recover the iron as hematite and in accordance with the following chemical reaction:



00125 More specifically, the leachate may be heated to a temperature of between about 160°C and about 190°C (preferably, between about 175°C and about 185°C) and simultaneously subjected to a precipitation step similar to precipitation step 270.

00126 While it has been shown that iron chloride and aluminum chloride can be hydrolysed by neutralization at relatively low pH to form their respective oxides and recover hydrochloric acid, it will be appreciated by those skilled in the art that any metal chloride can be treated in a similar fashion to yield its metal oxide and recover hydrochloric acid.

00127 The remaining leachate (now iron-and-aluminum-depleted) and the hematite and alumina products are then subjected to a solid/liquid separation step 280 which may be performed using any known technique including vacuum filtration. Once recovered, the hematite and alumina may be dried and sold, or simply discarded.

00128 Following the solid/liquid separation step 280, the remaining (base metal-rich) leachate, is subjected to a first and second series of base metal recovery steps 290. The first series of base metal recovery steps are carried out to extract from the leachate, base metals other than nickel and cobalt. The first series of steps may be carried in accordance with any known base metal extraction process including ion exchange, solvent extraction, electrowinning or precipitation. The remaining leachate may further be treated with chemical additives to precipitate manganese, copper, zinc, manganese and cobalt as well as any trace amounts of iron, aluminum and/or chromium that may be present. While the first series of the base metal recovery steps are performed, the nickel and cobalt are maintained in solution.

00129 Subsequently, a second series of base metal recovery steps may be performed on the remaining leachate to recover the nickel using hydrolytic distillation in a manner analogous to hematite described above. More specifically, nickel may be recovered from the leachate as nickel oxide by adding seed of the said nickel oxide, raising the temperature close to the

boiling point of the leachate under vacuum and adding water or steam, or simply as a nickel hydrate. The steam itself may be used to raise the temperature. The nickel oxide so produced is coarse and crystalline, and may be separated by any manner known in the art. It will be thus be appreciated that in accordance with the foregoing process high rates of base metal extraction may be obtained. For instance, using this process, recovery rates of greater than 90% have been achieved for nickel and cobalt.

00130 The leachate may also be treated to regenerate the chloride and acid constituents of the lixiviant. More specifically, hydrochloric acid may be recovered and recycled after each metal removal step in a manner analogous to that carried out in the primary leach circuit of process 20, thereby obviating the need to neutralize the acid with a base.

00131 The magnesium chloride solution may be recycled as well. One portion of the recycled magnesium chloride may be returned to the leach circuit whereas as another portion may be used in a pyrohydrolysis reaction to form magnesium oxide (magnesia) and hydrochloric acid. The magnesium oxide thus produced may be sold or used in the recovery of base metals - more specifically, to effect neutralization and precipitation of certain metal products (e.g. cobalt and nickel hydroxides). The use of magnesium oxide for neutralization and precipitation is advantageous because the required amount of magnesium oxide may be produced by the system. Moreover, the addition of magnesium oxide does not add any further ions in the leachate, which would otherwise require the use of additional treatment steps.

00132 The principles of the present invention are illustrated by the following examples:

Example 6

00133 A sample of saprolitic nickel laterite ore was ground to 95% passing 400 mesh, and analysing 16.8% Mg, 3.1% Ni and 9.4% Fe, was leached at 20% solids loading in a magnesium chloride brine at 100°C over a period of 7 hours. Hydrochloric acid (36.5% HCl) was added to the slurry in increments of 75 kg/tonne, and allowed to react for one hour. The results obtained are shown in the Table 1 below.

Table 3

Acid Addition (kg/tonne)	Extraction, %		
	Mg	Ni	Fe
75	36.2	31.8	2.0
150	30.6	50.6	20.1
225	26.2	58.7	33.2
300	39.7	69.4	54.7
375	46.6	76.9	70.5
450	58.4	83.0	84.9
525 (final)	69.3	88.8	95.6

00134 These results demonstrate that in order to get high nickel extraction from this ore, it was necessary to add a high level of acid (525 kg/t), which in turn resulted in high accompanying iron and magnesium dissolution.

Example 7

00135 Samples of the same ore as used in Example 6 were leached for a period of up to six hours at 100°C in magnesium chloride brines at 20% solids loading with the addition of 150 kg/tonne of hydrochloric acid. The initial concentration of magnesium chloride was varied from 345 g/L to 380 g/L. The results are shown in Table 2 below.

Table 4

MgCl ₂ (g/L)	Time (hour)	Extraction, %		
		Mg	Ni	Fe
345	1	48.9	52.0	11.0
	6	40.4	52.9	2.1
360	1	31.8	52.5	11.8
	6	34.0	55.6	2.7
380	1	10.7	46.8	14.8
	6	12.1	51.4	13.9

00136 These results clearly demonstrate that the extent of magnesium leaching decreases significantly as the initial magnesium chloride concentration is increased without any appreciable loss in nickel (or iron) extraction, and therefore that magnesium dissolution can be suppressed by higher initial magnesium concentrations.

Example 8

00137 The test at 380 g/L magnesium chloride concentration shown in Table 4 above was repeated with similar results, which were statistically analysed. The nickel extraction equation derived was:

$$\%Ni \text{ Extraction} = 1.62 \text{ time (hours)} + 41.8$$

00138 This equation had an r^2 value of 0.99, indicating that it was highly probable to be correct. Extrapolating the result indicated that 90% Ni extraction could be achieved by leaching at the conditions of the test for a period of 30 hours, which is not practical. However, micrographic examination of the leach residue showed that the unleached particles were coated with precipitated hematite, and therefore it was unlikely that leaching would continue as predicted by the equation since the hematite covering would passivate the mineral and inhibit leaching. In light of the foregoing, the acid addition levels and the duration of the leaching for one hour as shown in Example 6 are therefore to be preferred.

Example 9

00139 Samples of the saprolitic ore used in the tests above were leached in 360 g/L magnesium chloride brine at 100°C for a period of six hours at 20% solids loading. In the first test, citric acid was added to give the equivalent proton addition to hydrochloric acid at 150 kg/t, and in the second test, tartaric acid was used. Nickel extraction was in the range of 50-55% for both acids, demonstrating that weak organic acids can equally be used as the source of protons as well as a strong acid such as hydrochloric.

Example 10

00140 A solution containing 360 g/L magnesium chloride and 43.0 g/L ferric iron was heated under a slight vacuum to its boiling point, and 50 g/L of hematite seed added. Water was pumped slowly into the reactor, and the distillate collected. The experiment was continued until the acidity of the distillate dropped below 5 g/L HCl. The total solids were then collected, washed and dried, and submitted for X-Ray diffraction analysis, which showed the solids to contain only hematite, and chemical analysis showed a purity of greater than 99%. Acid and iron balances showed that 73.5% of the iron in the original solution had been precipitated. The temperature of the solution, always under a slight vacuum, rose to as

high as 182°C, and the distillate collected was 1.1M in HCl. The reaction was continued for a period of 20 hours.

00141 This example shows that it is possible to precipitate and recover soluble iron with a high recovery from high chloride concentration solutions by a simple hydrolytic distillation method, without the need to add any neutralizing agent. The recovered solids are a highly pure form of hematite. The example also demonstrates that hydrochloric acid can also be effectively and simultaneously recovered without recourse to high temperature methods such as spray roasting or pyrohydrolysis. However, the kinetics of the reaction carried out in this manner are slow.

Example 11

00142 Four different ore types from one deposit, saprolite analysing 0.89% Ni, 0.11% Co, 22.7% Fe, 8.05% Mg; limonite analysing 0.7% Ni, 0.15% Co, 39.2% Fe, 0.53% Mg; hematitic clay analysing 0.57% Ni, 0.094% Co, 28.7% Fe, 1.77% Mg; and weathered serpentinite analysing 0.85% Ni, 0.058% Co, 14.0% Fe, 12.9% Mg, were leached at 20% solids (80% -150 mesh) in 360 g/L magnesium chloride brine at 105°C for 1-4 hours. Hydrochloric acid was added as below in Table 3.

Table 5

Sample	Acid, (kg/tonne)	Time (hour)	Extraction, %			
			Ni	Co	Fe	Mg
Sap	100	4	22.7	32.3	14.3	0
Lim	100	4	12.9	25.4	7.4	0
Serp	100	4	37.5	49.6	21.9	7.3
Clay	100	4	13.9	30.0	10.9	0
Sap	400	4	71.6	92.8	83.7	32.3
Lim	400	4	51.4	80.7	43.0	32.7
Serp	400	4	88.4	94.9	90.0	45.7
Clay	400	4	44.2	79.0	58.0	19.8
Sap	600	1	86.3	94.4	89.0	8.1
Lim	600	1	64.9	90.9	59.0	5.9
Serp	600	1	95.0	94.0	90.0	49.0
Clay	600	1	61.5	87.8	77.0	11.4

00143 The results show that all horizons of a laterite ore body are readily amenable to being leached, but that some ore types require more acid than others. The results also show that an increasing amount of acid is required to effect high metal extraction.

Example 12

00144 A solution containing 360 g/L MgCl_2 and 48 g/L Fe (III) was heated up to 155°C. A total of 1 g/L oxalic acid was added. The final iron concentration was 1.6 g/L, representing a recovery of 96.7% of the contained iron, compared to only 73.5% as described in Example 10. The X-Ray diffraction analysis of the solids showed only the presence of hematite. When the experiment was repeated, but using a vertical condenser, the concentration of the distilled hydrochloric acid was 3.7M.

Example 13

00145 A solution containing 360 g/L MgCl_2 and 58 g/L Fe (III) was heated up to a temperature of between 230-240°C and water was added to maintain the volume constant. In 12 hours, over 96% of the iron was precipitated as hematite and over 96% of the HCl was recovered. The maximum HCl concentration attained was 1.6M.

Example 14

00146 The above experiment was repeated except that instead of water, additional feed solution was injected, as might be the case in a continuous circuit, and the temperature allowed to rise to 245°C. In four hours, 45% of the total iron added was precipitated as hematite and the equivalent amount of HCl recovered. At 245°C, the concentration of the recovered HCl was 6.3M, equivalent to the HCl azeotrope.

00147 Examples 13 and 14 demonstrate that as fresh solution is added, iron recovery kinetics are increased and higher strength hydrochloric acid are recovered.

Example 15

00148 The experiment of Example 14 was repeated but with aluminum chloride instead of ferric chloride, and with the temperature maintained between 180°C and 210°C. In this case, 60% of the aluminum was precipitated as alumina (shown to be Al_2O_3 by X-Ray diffraction)

and the corresponding acid recovered. In this case, the HCl concentration of the condensate attained 8.7M at a temperature of 210°C.

00149 This example demonstrates that the technique is applicable to other metal chlorides than ferric.

Example 16

00150 The experiment of Example 13 was repeated, except that the temperature was maintained at 180°C for four hours and neither water nor fresh feed solution was added. No reactions of any kind were observed. The solution remained liquid. This example demonstrates that no solids were formed from a magnesium chloride-ferric chloride mixture at 180°C.

00151 Embodiments illustrating the separate application of the process on sulfide ore materials and on laterite ore materials have been described. However, it should be appreciated that a process performed in accordance with the principles of the present invention could also be carried out on a mixture of sulfide and oxide-based ore materials to similar advantage.

00152 Although the foregoing description and accompanying drawings relate to specific preferred embodiments of the present invention and specific processes for the removal of iron from ore materials as presently contemplated by the inventors, it will be understood that various changes, modifications and adaptations, may be made without departing from the spirit of the invention.

CLAIMS

1. A process for recovering iron as hematite from a base metal containing material, the process comprising:

providing the base metal containing material;

providing a lixiviant comprising an acid and a chloride; the acid being selected from the group consisting of an organic acid, sulfurous acid, sulfuric acid and hydrochloric acid; the chloride being selected from the group consisting of magnesium chloride, calcium chloride, sodium chloride, potassium chloride, ferrous chloride and lithium chloride;

performing a leaching step on the base metal containing material at atmospheric pressure in the absence of an oxidant, using the lixiviant to obtain a solid residue and a leachate containing dissolved iron therein;

separating the leachate from the solid residue; and

then treating the leachate to recover therefrom at least some of the iron as a hematite product of high purity.

2. The process of claim 1 wherein providing the base metal containing material includes selecting the base metal containing material from the group consisting of an ore, a concentrate and an intermediate material.

3. The process of claim 1 wherein providing the base metal containing material includes selecting a sulfide ore material as the base metal containing material.

4. The process of claim 3 wherein the sulfide ore material selected contains at least one base metal selected from the group consisting of nickel, copper, zinc and cobalt.

5. The process of claim 4 wherein the sulfide ore material selected contains at least one of gold, silver and a platinum group metal.

6. The process of claim 3 the sulfide ore material selected is chosen from the group consisting of pyrrhotite, pentlandite, chalcopyrite, pyrite, arsenopyrite, galena and sphalerite.

7. The process of claim 1 wherein providing the base metal containing material includes selecting an oxidic ore material as the base metal containing material.
8. The process of claim 7 wherein the oxidic ore material selected is a laterite ore material.
9. The process of claim 8 the laterite ore material selected is one of a limonite ore material, a saprolite ore material, a hematitic clay material and a serpentinite material.
10. The process of claim 8 wherein the laterite ore material selected contains at least one base metal selected from the group consisting of nickel, manganese, magnesium, copper and cobalt.
11. The process of claim 1 wherein providing the base metal containing material includes crushing the base metal containing material.
12. The process of claim 1 wherein providing a lixiviant further includes adjusting the concentration of the chloride to obtain a solubility of between about 75% and about 95% of its saturation point.
13. The process of claim 1 wherein providing a lixiviant includes selecting magnesium chloride as the chloride.
14. The process of claim 13 wherein providing a lixiviant includes selecting an organic acid as the acid.
15. The process of claim 14 wherein the organic acid selected from the group consisting of acetic acid, tartaric acid and citric acid.
16. The process of claim 1 wherein providing a lixiviant includes selecting hydrochloric acid as the acid.
17. The process of claim 16 wherein providing a lixiviant includes selecting magnesium chloride as the chloride.
18. The process of claim 17 wherein providing a lixiviant further includes adjusting the concentration of magnesium chloride therein to at least about 300g/L.

19. The process of claim 18 wherein the concentration of magnesium chloride in the lixiviant is adjusted to between about 340g/L and 420 g/L.
20. The process of claim 1 wherein the leaching step is performed at a temperature between about 20°C and about the boiling point of the lixiviant.
21. The process of claim 20 wherein the leaching step is performed at a temperature between about 105°C and about 110°C.
22. The process of claim 17 wherein treating the leachate to recover therefrom at least some of the iron as a hematite product of high purity, includes:
- heating the leachate to distill the hydrochloric acid therefrom; and
- simultaneously subjecting the leachate to a precipitation step to promote the formation of the hematite product.
23. The process of claim 22 wherein the leachate is heated to a temperature of between about 190°C and about 250°C.
24. The process of claim 23 wherein the leachate is heated to a temperature of between about 220°C and about 250°C.
25. The process of claim 22 wherein:
- the leachate is heated to a temperature of at least about 180°C; and
- the precipitation step includes one of adding water and adding steam to the leachate.
26. The process of claim 22 wherein the precipitation step includes one of adding water and adding steam to the leachate.
27. The process of claim 22 further comprising separating the hematite product from the remaining leachate.
28. The process of claim 22 wherein the precipitation step includes further adding a catalyst to the leachate.
29. The process of claim 28 wherein the catalyst is oxalic acid.

30. The process of claim 22 further comprising recovering the chloride from the remaining leachate.
31. The process of claim 17 wherein:
- the base metal containing material is a sulfide ore material; and
- the process further includes removing hydrogen sulfide gas formed during the leaching step.
32. The process of claim 31 wherein the step of removing includes stripping the hydrogen sulfide in a continuous manner.
33. The process of claim 1 wherein:
- the base metal containing material is a sulfide ore material; and
- the solid residue is an upgraded base metal concentrate.
34. The process of claim 1 wherein:
- the base metal containing material is a laterite ore material; and
- the leachate is a base metal-rich leachate.
35. A process for recovering a base metal from a base metal containing material, the process comprising:
- providing the base metal containing material;
- providing a lixiviant comprising an acid and a chloride; the acid being selected from the group consisting of an organic acid, sulfurous acid, sulfuric acid and hydrochloric acid; the chloride being selected from the group consisting of magnesium chloride, calcium chloride, sodium chloride, potassium chloride, ferrous chloride and lithium chloride;
- performing a leaching step on the base metal containing material at atmospheric pressure in the absence of an oxidant, using the lixiviant to obtain a solid residue and a leachate containing dissolved iron therein;

separating the leachate from the solid residue;

then treating the leachate to recover therefrom at least some of the iron as a hematite product of high purity; and

subjecting one of the leachate and the solid residue to a series of base metal recovery steps.

36. The process of claim 35 wherein providing the base metal containing material includes selecting the base metal containing material from the group consisting of an ore, a concentrate and an intermediate material.

37. The process of claim 35 wherein providing the base metal containing material includes selecting a sulfide ore material as the base metal containing material.

38. The process of claim 37 wherein the sulfide ore material selected contains at least one base metal selected from the group consisting of nickel, copper, zinc and cobalt.

39. The process of claim 38 wherein the sulfide ore material selected contains at least one of gold, silver and a platinum group metal.

40. The process of claim 37 the sulfide ore material selected is chosen from the group consisting of pyrrhotite, pentlandite, chalcopyrite, pyrite, arsenopyrite, galena and sphalerite.

41. The process of claim 35 wherein providing the base metal containing material includes selecting an oxidic ore material as the base metal containing material.

42. The process of claim 41 wherein the oxidic ore material selected is a laterite ore material.

43. The process of claim 41 the laterite ore material selected is one of a limonite ore material, a saprolite ore material, a hematitic clay material and a serpentinite material.

44. The process of claim 41 wherein the laterite ore material selected contains at least one base metal selected from the group consisting of nickel, manganese, copper and cobalt.

45. The process of claim 35 wherein providing the base metal containing material includes crushing the base metal containing material.

46. The process of claim 35 wherein providing a lixiviant further includes adjusting the concentration of the chloride to obtain a solubility of between about 75% and about 95% of its saturation point.
47. The process of claim 35 wherein providing a lixiviant includes selecting magnesium chloride as the chloride.
48. The process of claim 47 wherein providing a lixiviant includes selecting an organic acid as the acid.
49. The process of claim 48 wherein the organic acid selected is one of tartaric acid and citric acid.
50. The process of claim 35 wherein providing a lixiviant includes selecting hydrochloric acid as the acid.
51. The process of claim 50 wherein providing a lixiviant includes selecting magnesium chloride as the chloride.
52. The process of claim 51 wherein providing a lixiviant further includes adjusting the concentration of magnesium chloride therein to at least about 300g/L.
53. The process of claim 52 wherein the concentration of magnesium chloride in the lixiviant is adjusted to between about 340g/L and 420 g/L.
54. The process of claim 35 wherein the leaching step is performed at a temperature between about 20°C and about the boiling point of the lixiviant.
55. The process of claim 54 wherein the leaching step is performed at a temperature between about 105°C and about 110°C.
56. The process of claim 35 wherein treating the leachate to recover therefrom at least some of the iron as a hematite product of high purity, includes:

heating the leachate to distill the hydrochloric acid therefrom; and

simultaneously subjecting the leachate to a precipitation step to promote the formation of the hematite product.

57. The process of claim 56 wherein the leachate is heated to a temperature of between about 190°C and about 250°C.
58. The process of claim 56 wherein the leachate is heated to a temperature of between about 220°C and about 250°C.
59. The process of claim 56 wherein:
- the leachate is heated to a temperature of at least about 180°C; and
- the precipitation step includes one of adding water and adding steam to the leachate.
60. The process of claim 56 wherein the precipitation step includes one of adding water and adding steam to the leachate.
61. The process of claim 56 wherein the precipitation step includes further adding a catalyst to the leachate.
62. The process of claim 61 wherein the catalyst is oxalic acid.
63. The process of claim 56 further comprising separating the hematite product from the leachate.
64. The process of claim 56 further comprising recovering the chloride from the leachate.
65. The process of claim 51 wherein:
- the base metal containing material is a sulfide ore material; and
- the process further includes removing hydrogen sulfide gas formed during the leaching step.
66. The process of claim 65 wherein the step of removing includes stripping the hydrogen sulfide in a continuous manner.
67. The process of claim 65 further comprising reacting the hydrogen sulfide gas with sulfur dioxide gas in a Claus reaction to obtain elemental sulfur and steam.

68. The process of claim 35 wherein:

the base metal containing material is a sulfide ore material; and

the solid residue is an upgraded base metal concentrate.

69. The process of claim 68 further comprising subjecting the solid residue to a series of base metal recovery steps.

70. The process of claim 69 wherein:

the lixiviant is a first lixiviant;

the leaching step is a first leaching step;

the leachate is a first leachate;

the solid residue is a first solid residue; and

the step of subjecting the solid residue to a series of base metal recovery steps, includes:

providing a second lixiviant comprising an acid and a chloride; the acid being selected from the group consisting of an organic acid, sulfurous acid, sulfuric acid and hydrochloric acid; the chloride being selected from the group consisting of magnesium chloride, calcium chloride, sodium chloride, potassium chloride, ferrous chloride and lithium chloride;

performing a second leaching step on the first solid residue at atmospheric pressure, using the second lixiviant to obtain a second solid residue and a second leachate containing at least one base metal dissolved therein; and

separating the second leachate from the second solid residue; and

recovering from the second leachate the at least one base metal.

71. The process of claim 70 wherein the second lixiviant further includes an oxidant.

72. The process of claim 70 wherein:

the base metal containing material contains at least one of gold, silver and a platinum group metal;

the second solid residue is an upgraded value metal concentrate; and

the process further includes subjecting the second solid residue to at least one value metal recovery step.

73. The process of claim 72 wherein:

the base metal containing material contains at least one of gold, silver and a platinum group metal;

the second leachate is a value metal-rich leachate; and

the process further includes subjecting the value metal-rich leachate to at least one value metal recovery step.

74. The process of claim 69 wherein:

the lixiviant is a first lixiviant;

the leaching step is a first leaching step;

the leachate is a first leachate;

the solid residue is a first solid residue; and

the step of subjecting the solid residue to a series of base metal recovery steps, includes:

providing a second lixiviant comprising ferric chloride and magnesium chloride;

performing a second leaching step on the first solid residue at atmospheric pressure, using the second lixiviant to obtain a second solid residue and a second leachate containing at least one base metal dissolved therein; and

separating the second leachate from the second solid residue; and

recovering from the second leachate the at least one base metal.

75. The process of claim 35 wherein:

the base metal containing material is a laterite ore material; and

the leachate is a base metal-rich leachate.

76. The process of claim 75 further comprising subjecting the base metal-rich leachate to a series of base metal recovery steps.

77. A process for recovering a base metal from a laterite ore material, the process comprising:

providing the laterite ore material;

providing a lixiviant comprising hydrochloric acid and magnesium chloride;

performing a leaching step on the laterite ore material at atmospheric pressure in the absence of an oxidant, using the lixiviant to obtain a solid residue and a leachate containing dissolved iron therein;

separating the leachate from the solid residue;

heating the leachate to distill the hydrochloric acid therefrom; and

simultaneously subjecting the leachate to a precipitation step to urge the formation of a hematite product of high purity; and

subjecting one of the leachate and the solid residue to a series of base metal recovery steps.

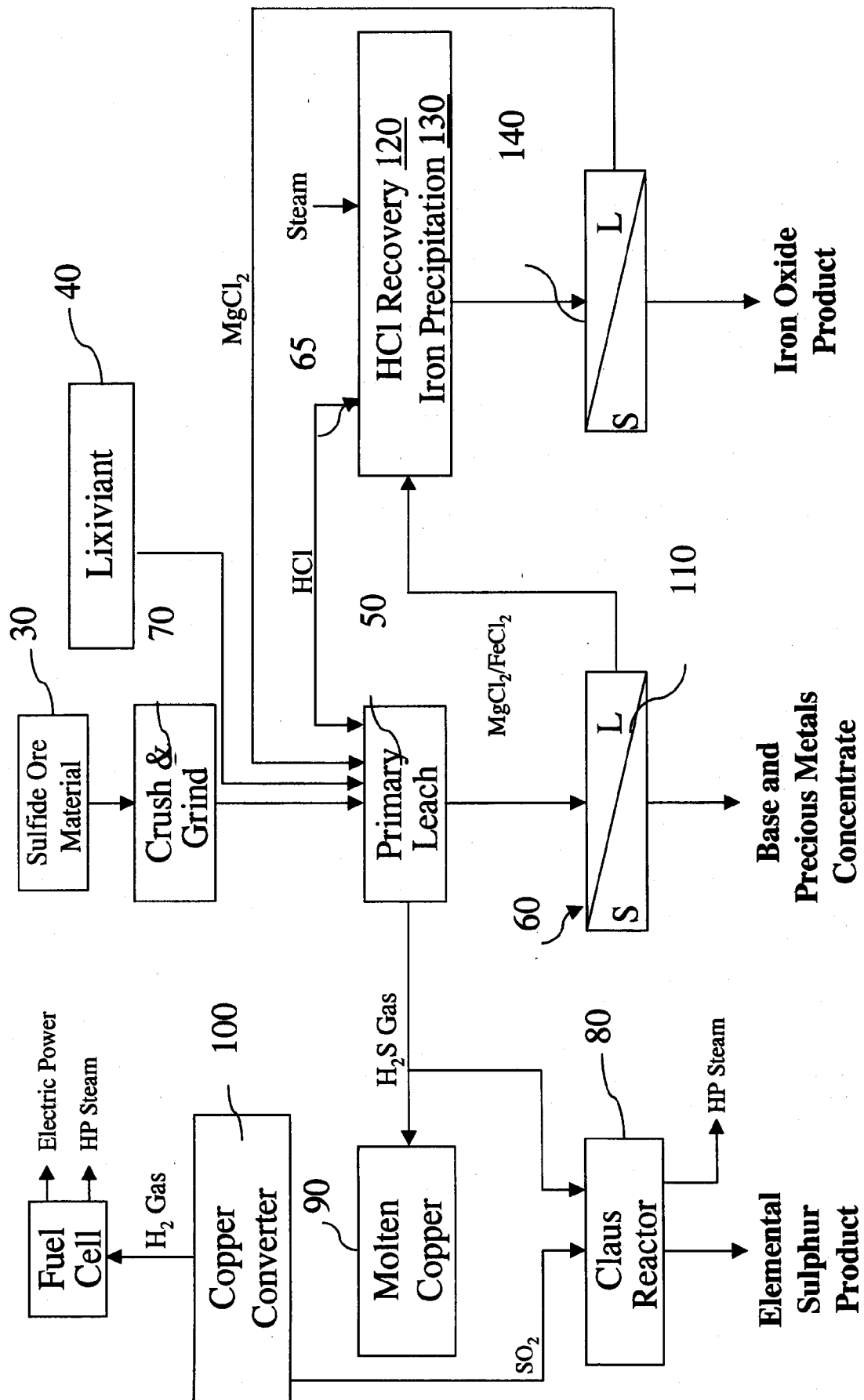


Figure 1

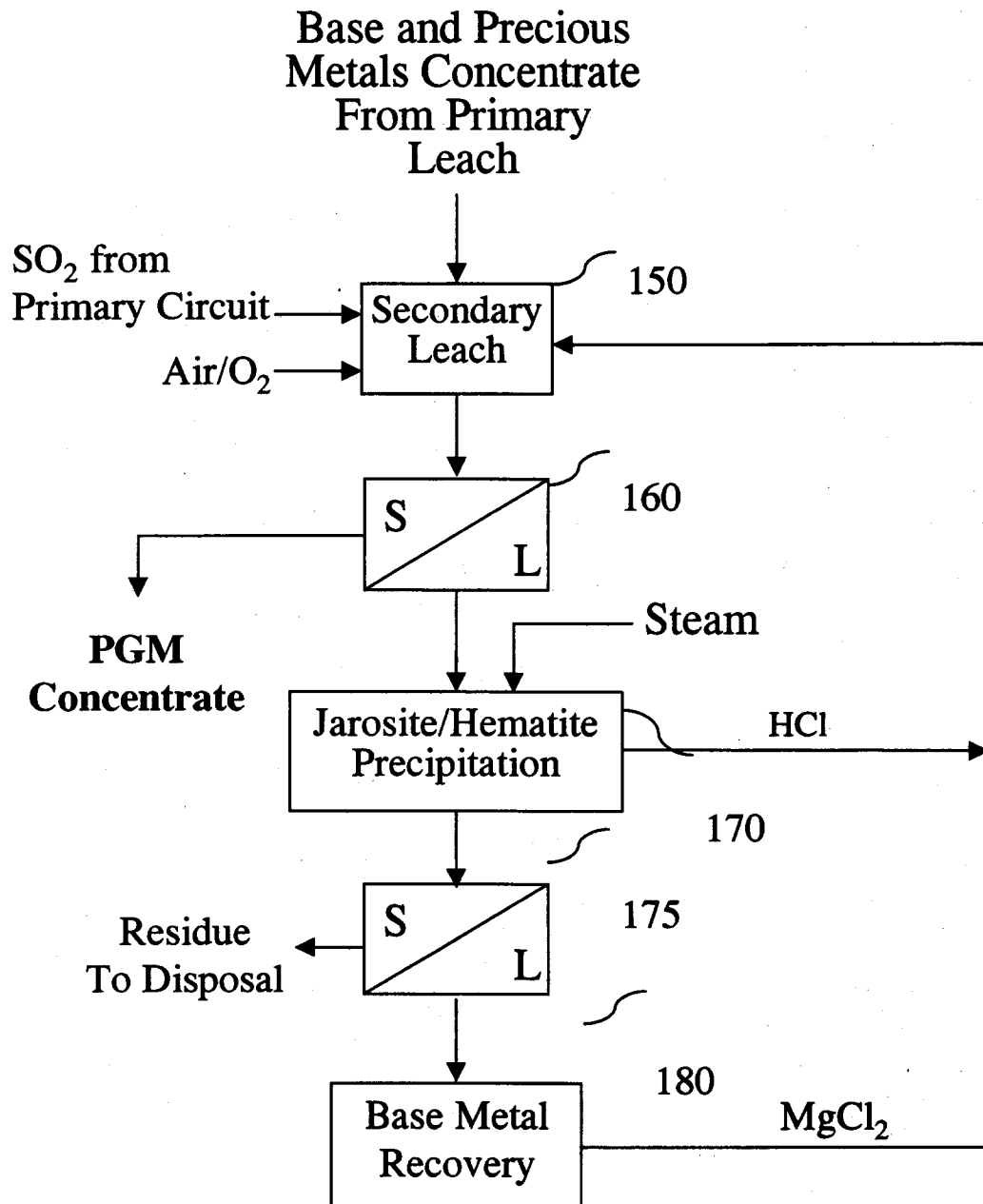


Figure 2

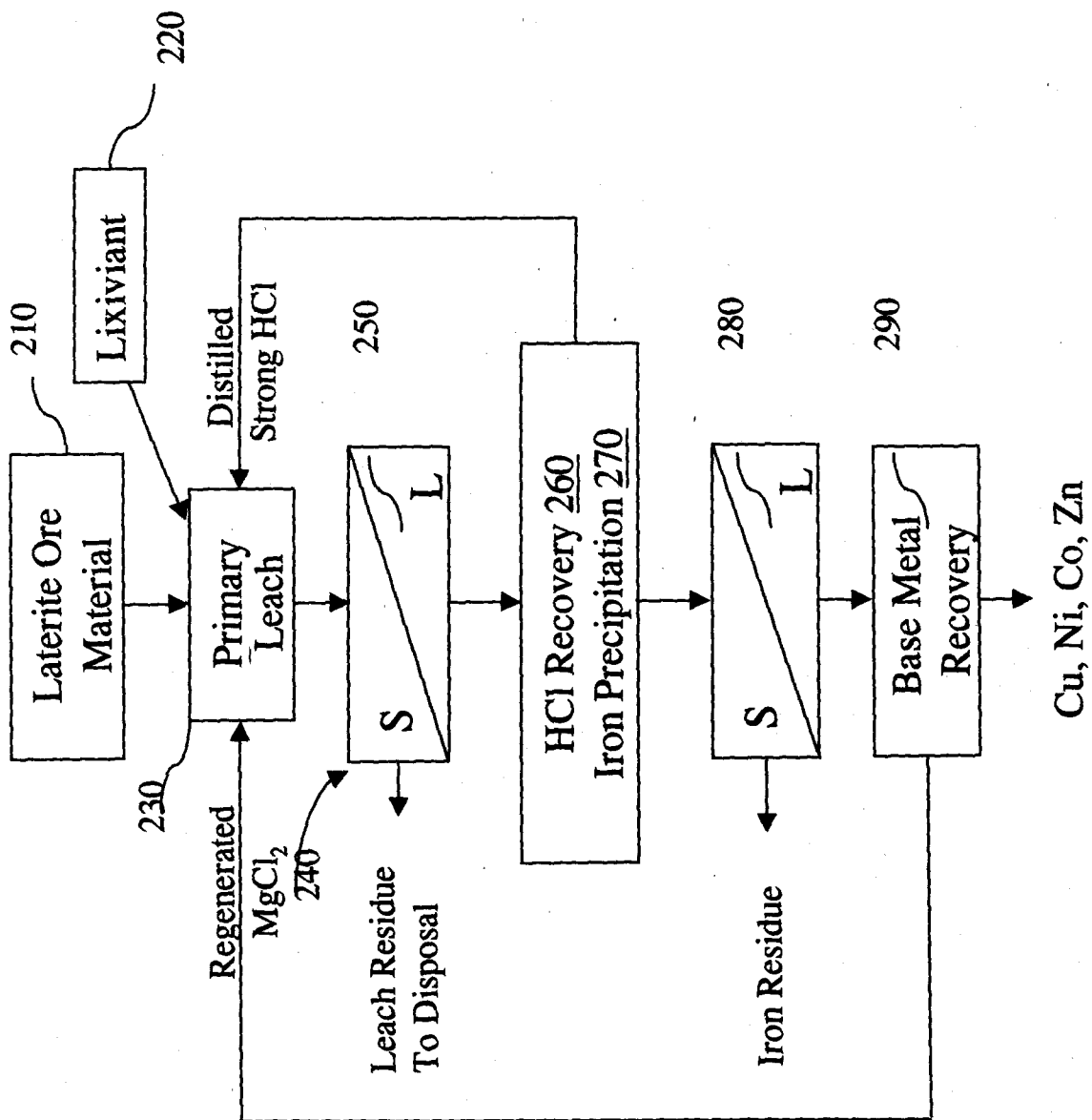


Figure 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2006/002038

A. CLASSIFICATION OF SUBJECT MATTER

IPC: **C22B 3/06** (2006.01) , **C22B 3/08** (2006.01) , **C22B 3/10** (2006.01) , **C22B 3/16** (2006.01) , **C22B 3/44** (2006.01)
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)

IPC 8: C22B-3/06, 3/08, 3/10, 3/16, 3/44 USPC: 423, 75 CPC: 53/287, 306, 327, 371

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
CAPlus, Espacenet, WEST, CPD, Scopus

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	CA 2,548,225 (HARRIS et al.) 16 November 2004 (16-11-2004) * claims *	1, 2, 7-13, 16-21, 34-36, 41-47, 50-55, 75, 76 22, 23, 25-30, 56, 57, 59-64, 77
Y	WO 02/08477 (LALANCETTE) 31 January 2002 (31-01-2002) * p. 7, 8, 11, 13; claims 1, 24-30; figure 2 *	22, 23, 25-30, 56, 57, 59-64, 77
A	Raudsepp, R. and Beattie, M.J.V., Iron control in chloride systems. Proceedings from International Symposium on Iron Control in Hydrometallurgy, Toronto, Canada, 19-22 October, pp. 163-182.	1-77
A	Riveros, P.A. and Dutrizac, J.E., The precipitation of hematite from ferric chloride media, Hydrometallurgy 46 (1997), pp. 85-104.	1-77

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"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)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

26 February 2007 (26-02-2007)

Date of mailing of the international search report

5 April 2007 (05-04-2007)

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INTERNATIONAL SEARCH REPORTInternational application No.
PCT/CA2006/002038

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Riveros, P.A. and Dutrizac, J.E., Hematite precipitation from ferric chloride media at atmospheric pressure: a new approach to iron control and recycling. Proceedings of the REWAS'99, San Sebastián, Spain, 5-9 September, 1999: TMS Fall 1999 Extraction and Process Metallurgy Meeting, pp. 663-673.	1-77

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CA2006/002038

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		EP1627087 A1	22-02-2006
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