

## **CLAIMS**

1. A hydrometallurgical process for extracting one or more saleable metals selected from the group consisting of: precious elements comprising platinum group metals (PGMs), gold and silver; base metals comprising nickel, cobalt, copper, zinc, uranium, thorium, manganese, cadmium, molybdenum, titanium, and tin; rare earth elements (REE) yttrium and scandium; and rare elements comprising vanadium, germanium and gallium from a feed material containing saleable metals comprising or consisting of any one or more of a metalliferous ore or metalliferous feedstock; a concentrate; a solid residue from a hydrometallurgical process; and a solid residue after solid-liquid separation of a product slurry from hot sulphuric acid leaching under pressure and/or atmospheric conditions from the metalliferous ore or metalliferous feedstock, concentrate or solid residue, the process comprising or consisting of subjecting the feed material to the following steps:
  - a) leaching with hot hydrochloric acid or brine under pressure and/or atmospheric conditions either with no added oxidant or reductant or with an added reductant, to produce a product slurry comprising saleable and gangue metal chlorides in a hydrochloric acid solution and a solid residue containing saleable metals consisting of any one or more of PGMs, gold, silver, and minor associated base metals, REEs, or rare metals;
  - b) subjecting the hydrochloric acid or brine solution comprising metal chlorides from step a) to a purification and/or upgrade step comprising any one or more of solvent extraction, ion exchange (IX), chelating, molecular recognition technology (MRT), sorption including with polymeric sorbents; precipitation using hydroxides, ammonia, carbonates or sulphides, electrowinning or reduction to produce an intermediate solution product and one or more intermediate solid residues comprising secondary scavenged value metals and gangue elements;
  - c) subjecting the intermediate solution products from step b) to one or more steps comprising preboil, rectification, distillation, adsorption, reboil, pyrohydrolysis, spray roasting, sulfate precipitation and hydrothermal processing thereby to yield one or more of hydrochloric acid, calcium, iron and saleable metals for recovery, or residual gangue material for disposal and a barren solution;
  - d) separating the intermediate solid residue from step b) by solid-liquid separation, and leaching the separated intermediate solid residue in an oxidising

- chlorination leach to produce soluble saleable metal chlorides in a chlorination pregnant leach solution (PLS) and a solid waste product;
- e) subjecting the chlorination PLS comprising metal chlorides from step d) to any one or more of ion exchange (IX), chelation, molecular recognition technology (MRT), sorption including with polymeric sorbents, solvent extraction, precipitation using hydroxides, ammonia, carbonates or sulphides, electrowinning or reduction to produce a secondary intermediate solution product and a solid residue containing saleable metals consisting of any one or more of PGMs, gold and silver, and optionally any one or more of associated base, REE and rare metals;
  - f) subjecting the secondary intermediate solution product or solid residue from step e) to one or more techniques comprising preboil, rectification, distillation, adsorption, reboil, pyrohydrolysis, spray roasting, sulfate precipitation and hydrothermal processes to yield one or more of hydrochloric acid, calcium, iron and saleable metals for recovery or residual gangue material for disposal and a barren solution; and
  - g) recovery of saleable metals consisting of any one or more of PGMs, gold and silver, and optionally any one or more of associated base, REE and rare metals from the solid residue.
2. The hydrometallurgical process according to claim 1, wherein the process further comprises or consists of the steps of subjecting the solid residue from step a) to heat treatment under oxidising, neutral or reducing conditions followed by addition of the heat-treated solid residue to step d).
3. The hydrometallurgical process according to claim 2, wherein the heat-treated solid residue is subjected to a second leaching step in hot hydrochloric acid under pressure and/or atmospheric conditions either with no added oxidant or reductant or with an added reductant, to produce a product slurry comprising saleable and gangue metal chlorides in a hydrochloric acid solution and a solid residue containing saleable metals consisting of any one or more of PGMs, gold, silver, and minor associated base metals, REEs, or rare metals, followed by further processing according to steps c) to g).

4. The hydrometallurgical process according to any one of claims 1 to 3, wherein the chlorination PLS from step d), and/or or the intermediate solution product from either step b) or e) are further subjected to one or more purification and/or upgrading techniques comprising IX, chelating, MRT, sorption including with polymeric sorbents, solvent extraction, precipitation using hydroxides, ammonia, carbonates or sulphides, electrowinning and reduction to produce further intermediate solid residues containing saleable metals consisting of PGMs, gold and silver, and optionally associated valuable base, REE and rare metals for recovery and further intermediate solution products that are added to step f).
5. The hydrometallurgical process according to any one of claims 1 to 4, wherein the solid/liquid separation of the solid residue containing saleable metals from the product slurry from hot sulphuric acid leaching under pressure and/or atmospheric conditions includes filtration.
6. The hydrometallurgical process according to any one of claims 1 to 5, wherein the process further comprises or consists of a step of separating, including by filtration, solid residue from the saleable metal chlorides in solution from step a), b), d), e) and, where relevant from the further intermediate solution products and then providing the resultant separated solution to the next step in the process.
7. The hydrometallurgical process according to any one of claims 1 to 6, wherein the feed material ore, concentrate, metalliferous feedstock or residue is processed by crushing, milling, is as-mined, and/or is subjected to a beneficiation step comprising any one or more of crushing, grinding, screening, sizing, classification, magnetic separation, electrostatic separation, flotation and gravity separation, thereby to concentrate the valuable metals or reject a gangue component and to produce an intermediate ore product for providing to step a).
8. The hydrometallurgical process according to any one of claims 2 to 7, wherein the heat treatment is performed at from or about 80 – 750 °C for up to 120 minutes.

9. The hydrometallurgical process according to claim 8, wherein the heat treatment includes a second heat treatment performed at from or about 500 –1000 °C for up to 120 minutes, or about 700 – 1000 °C for 30 to 120 minutes, under oxidizing, neutral or reducing conditions.
10. The hydrometallurgical process according to claim 9, wherein the heat treatment includes a third heat treatment performed at from or about 100 – 600 °C for up to 240 minutes, or about 100 – 400 °C for 60 - 180 minutes, under oxidizing, neutral or reducing conditions.
11. The hydrometallurgical process according to either claim 9 or 10, wherein the heat treatment is performed as individual steps of a sequential heat treatment process, or as one combined step.
12. The hydrometallurgical process according to any one of claims 2 to 11, wherein the heat treatment generates off-gases and such off-gases are sparged into the slurry in step a) or the hydrochloric acid solution in step b) or the chlorination PLS in step e).
13. The hydrometallurgical process according to any one of claims 2 to 12, wherein any one or more reducing gas comprising syngas, carbon monoxide and hydrogen are sparged into the slurry in step a) or the hydrochloric acid solution in step b) or the chlorination PLS in step e).
14. The hydrometallurgical process according to any one of claims 1 to 13, wherein the chlorination PLS of step d) and/or the intermediate solution product of step b), step e) and/or where relevant the further intermediate solution products are subjected to a sorption step whereby saleable metals are adsorbed on to a resin or sorbent and base metals are discharged in a solution.
15. The hydrometallurgical process according to any one of claims 1 to 14, wherein the chlorination PLS of step d) and/or the solution product of step b), step e) and/or where

relevant the further intermediate solution products are subjected to precipitation and purification comprising any one or more of the following steps:

- A. subjecting the any one or more of the chlorination PLS of step d) or the intermediate solution product of step b), step e) and/or where relevant the further intermediate solution products, to sulphide precipitation, thereby to produce a product slurry comprising a solid residue containing elemental sulphur, metal sulphides and/or alloys and a discharge solution;
- B. performing solid-liquid separation, comprising by filtration, on the product slurry of A. to separate the solid residue from step A. from the discharge solution, at temperatures of between about or from 10 - 130 °C;
- C. subjecting the solid residue from step B. to a series of purification and recovery steps comprising or consisting of:
  - C.i. sublimation of the solid residue at temperatures of between about or from 200 - 500 °C, thereby to remove sulphur and produce a solid residue and a sulphur distillate product;
  - C.ii. optionally dissolving the solid residue of step C.i. in a suitable solvent for sulphur, comprising any one or more of aromatic hydrocarbons; chlorinated or sulphidised hydrocarbons; and sulphur-containing ligands, at temperatures of between about 10 - 130 °C, thereby to remove sulphur and produce a solid residue and a sulphur distillate product;
  - C.iii. pressure oxidation leaching the solid residue from step C.i. and/or where relevant step C.ii., at temperatures of between about or from 110 - 230 °C;
  - C.iv. atmospheric sulphuric acid leaching the solid residue from step C.iii. at temperatures of between about or from 10 - 110 °C to yield a slurry comprising a solid residue comprising saleable metals and a sulphate leachate solution;
  - C.v. separating the solid residue comprising saleable metals from the sulphate leachate solution in the slurry of step C.iv. by solid-liquid separation, comprising filtration, at temperatures of between about or from 10 - 130 °C;
  - C.vi. optionally subjecting the sulphate leachate solution from step C.v. to a sorption step thereby adsorbing saleable metals to a resin or sorbent and discharging base metals in a solution; and
  - C.vii. subjecting the sulphate leachate solution from step C.v. and, where relevant, the discharge solution from step C.vii. to one or more techniques comprising ageing, evaporation, precipitation and recycling; and

- D. optionally subjecting the discharge solution from step B. to a sorption step thereby adsorbing saleable metals to a resin or sorbent and discharging base metals in a solution.
16. The hydrometallurgical process according to claim 15, wherein the discharge solution from step B. and/or the intermediate solution product from step b), e) and/or where relevant the further intermediate solution products are subjected to a hydrochloric acid, calcium and residual base metal recovery and separation step comprising or consisting of:
- I. feeding the discharge solution and/or the intermediate solution product into a preboil evaporator together with seed gypsum thereby to generate a hydrochloric acid gas and gypsum precipitate, followed by solid-liquid separation to yield precipitated gypsum for recovery and a treated discharge solution;
  - II. (a) feeding the treated discharge solution from step I. to a sulphuric acid rectification column or reboiler together with sulphuric acid, thereby to generate a hydrochloric acid gas and a sulphuric acid solution comprising saleable and/or recoverable base and/or rare metals; or
  - II. (b) feeding the discharge solution from step I. to a hydrothermal, spray roaster or pyrohydrolysis reactor to yield a slurry comprising a solid iron oxide residue for recovery and a base and/or rare metals solution, followed by solid-liquid separation;
  - III. subjecting the sulphuric acid solution generated in step II. (a) and/or the base and/or rare metals metal solution from step II. (b) to a cooling and aging step to crystallise the metal sulphate salts for recovery and/or recycling, or to one or more steps comprising sorption, evaporation and precipitation for recovery and/or recycling; and
  - IV. subjecting the hydrochloric acid gas of step I. or step II. to distillation and absorption, thereby to recover a hydrochloric acid solution.
17. The hydrometallurgical process according to claim 16, wherein the recovered hydrochloric acid is recycled back into the hydrochloric acid leach step a) and/or the chlorination leach step d).
18. The hydrometallurgical process according to any one of claims 1 to 17, wherein the barren solution from step c) and/or step f) are recycled to step b) as makeup water, thereby allowing for reuse of hydrochloric acid.

19. The hydrometallurgical process according to any one of claims 1 to 18, wherein the saleable metal sulphates in solution of the feed material consist of one or more metal sulphate salts of copper, nickel, cobalt, rhodium, ruthenium, iridium, vanadium, germanium, gallium and scandium.
20. The hydrometallurgical process according to any one of claims 1 to 19, wherein the feed material comprises or consists of one of an individual material and a blend of refractory and non-refractory materials differing in nature.
21. The hydrometallurgical process according to any one of claims 1 to 20, wherein the process further comprises or consists of subjecting the hydrochloric acid solution of step a) and/or the chlorination PLS of step d) to ageing for crystallisation of silica, comprising or consisting of the steps of:
  - AA. feeding the hydrochloric acid solution or chloride PLS into a holding vessel;
  - BB. adding seed silica solids to the chloride solution of AA.;
  - CC. allowing the chloride solution to stand at ambient temperature until a solid residue comprising silica is precipitated out of solution;
  - DD. separating the precipitated solid residue comprising silica from the solution of step CC. to produce a silica-depleted solution; and
  - EE. feeding the silica-depleted solution of step DD. into step a).
22. The hydrometallurgical process according to any one of claims 1 to 21, wherein the process comprises or consists of subjecting any one or more of the hydrochloric acid solution of step a), the chlorination PLS of step d), the intermediate solution products from step b) and e), and the further intermediate solution products to concentration to produce a concentrated solution by any one or more of the following steps:
  1. evaporation and condensation recovery of HCl from the solution(s); and
  2. filtration or membrane-based separation, comprising reverse osmosis (RO) or nanofiltration (NF) of the solution(s).
23. The hydrometallurgical process according to any one of claims 1 to 22, wherein any one or more of the sorption steps of the process comprise any one or more of the following steps:
  - (aaa) contacting the solution with an ion exchange (IX) resin or sorbent thereby adsorbing saleable metals, comprising any one or more of gold, silver and PGMs to the resin or sorbent and discharging base metals in a solution;

- (bbb) eluting the adsorbed saleable metals from the IX resin or sorbent and precipitating the the saleable metals from the eluate using a reductant and where PGMs are present, using a caustic or ammoniacal solution to form a high-grade value metal concentrate or individual value metal products;
- (ccc) directly incinerating the loaded resin or sorbent to produce a high-grade value metal concentrate or individual value metal products; and
- (ddd) optionally, further processing of the saleable metals produced by any of steps (aaa) to (ccc).
24. The hydrometallurgical process according to claim 23, wherein elution step (bbb) performed using a solution comprising acidic thiourea, salts of sulphite or hydrosulphite or chloride.
25. The hydrometallurgical process according to any one of claims 1 to 24 wherein the hydrochloric acid leach solution of step a) and/or the chlorination leach solution of step d) contain iron chloride, further comprising step of treatment by any one or more of pressure, precipitation, crystallization, concentration by evaporation, reverse osmosis, membrane filtration, comprising nanofiltration, solvent extraction, ion exchange, sparging/rectification, pyrohydrolysis and hydrothermal processes to produce an iron-bearing product.
26. The hydrometallurgical process according to any one of claims 1 to 25, wherein the hydrochloric acid or brine leach solution of step a), b) or c) is neutralised with limestone to precipitate ferric hydroxide and other gangue elements and produce a calcium chloride filtrate, which is evaporated and the calcium removed by sulphuric acid addition and recycling of the hydrochloric acid, brine or calcium chloride filtrate to step a) or d).
27. The hydrometallurgical process according to any one of claims 1 to 26, wherein the chlorination leaching medium of step d) comprises hydrochloric acid or saline brine in conjunction with an oxidising agent comprising chlorine, hypochlorite, hydrogen peroxide and the leaching step is performed under oxidising conditions, thereby to generate a chlorination PLS containing one or more saleable elements comprising or consisting of PGMs, Au, Ag, Ni, Co, Cu, REE, Y, Sc, U, Th, Zn, Mn, Cd, Mo, V, Sn and Ti.



28. The hydrometallurgical process according to any one of claims 1 to 27, wherein the chlorination PLS generated in step d) contains one or more saleable elements comprising or consisting of PGMs, Au, Ag, Ni, Co, Cu, REE, Y, Sc, U, Th, Zn, Mn, Cd, Mo, V, Sn and Ti, further comprising or consisting of a step of separation and/or recovery of the one or more saleable elements by any one or more of solvent extraction, IX, precipitation using hydroxides, carbonates or sulphides, electrowinning and reduction.
29. The hydrometallurgical process according to any one of claims 1 to 28, wherein the chlorination leaching step d) comprises a chloride leaching medium that has a pH of between about 2.5 and 7.5 held at a temperature in the range of between about or from 50-150 °C.
30. The hydrometallurgical process according to any one of claims 1 to 29, wherein the chlorination leaching step d) comprises a chloride leaching medium with a free acidity of between about or from 50 to 300 g/L HCl held at a temperature in the range of between about or from 50-150 °C.
31. The hydrometallurgical process according to any one of claims 1 to 29, wherein the chlorination leaching step d) is performed by atmospheric or pressure autoclave leaching with saline brine under oxidising conditions.
32. A hydrometallurgical process for extracting one or more saleable metals selected from the group consisting of precious elements comprising platinum group metals (PGMs), gold and silver; base metals comprising nickel, cobalt, copper, zinc, uranium, thorium, manganese, zinc, cadmium, molybdenum, titanium, tin; rare earth elements (REE), yttrium and scandium; and rare elements comprising vanadium, germanium and gallium from a feed material containing saleable metals, comprising or consisting of any one or more of a metalliferous ore; a concentrate; a solid residue from a hydrometallurgical process; and a solid residue after solid-liquid separation of a product slurry from hot sulphuric acid leaching under pressure and/or atmospheric conditions from the metalliferous ore, concentrate or solid residue, the process comprising or consisting of the following steps comprising or consisting of:
  - i. leaching with hot hydrochloric acid or brine under pressure and/or atmospheric conditions with no added oxidant or reductant or with an added reductant, to

- produce a product slurry comprising saleable and gangue metal chlorides in hydrochloric acid solution and a solid residue containing saleable metals; and
- ii. subjecting the product slurry of step i. to conventional smelting and refining techniques.
33. A hydrometallurgical process according to claim 32, wherein the product slurry of step i. is subjected to scavenging recovery of any one or more dissolved PGMs, base metals, iron and sulphur species by any one or more techniques comprising precipitation, crystallisation, reduction, ion exchange and solvent extraction, and concentration steps comprising vacuum crystallisation and membrane separation.
34. A hydrometallurgical process according to claim 32, wherein the product slurry of step i. is filtered by solid-liquid separation and the filtered solution is subjected to scavenging recovery of any one or more dissolved PGMs, base metals, iron and sulphur species by any one or more techniques comprising precipitation, crystallisation, reduction, ion exchange and solvent extraction, and concentration steps comprising vacuum crystallisation and membrane separation.
35. A hydrometallurgical process according to any one of claims 32 to 24, wherein the solid residue from the hot sulphuric acid leaching is smelted prior to step i. leaching with hot hydrochloric acid or brine.