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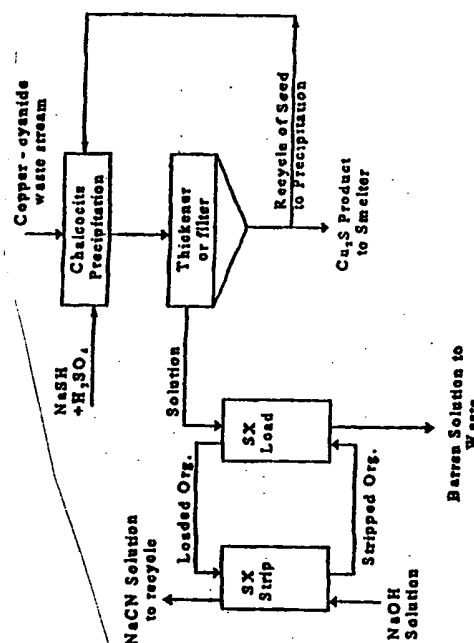
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54 Titre: Cyanide recovery by solvent extraction.

57 Abrégé:

The invention provides a process for recovering hydrogen cyanide from an aqueous solution by extracting the hydrogen cyanide into an organic solvent phase. The organic solvent may comprise a neutral organophosphorous compounds, such as compounds selected from the group consisting of alkyl or aryl substituted phosphates, phosphonates and phosphine oxides. In alternative embodiments the organophosphorous compound is tri-butyl phosphate, di-butyl-butyl-phosphonate or tri-alkyl phosphine oxides. The organic solvent may be diluted in an organic diluent, such as an aliphatic or kerosene-type diluent. Alternative dilutions may be used, such as 75%, 50% or 25%. In some embodiments, the pH of the aqueous solution containing dissolved cyanide may be adjusted to between 2 and 8, or between 3 and 7, or between 4 and 6. The organic solvent may be contacted following extraction with a basic aqueous solution to strip cyanide from the organic solvent into a basic aqueous cyanide strip solution. The stripped organic solvent may then be returned to the loading process, to extract HCN from fresh aqueous solution.

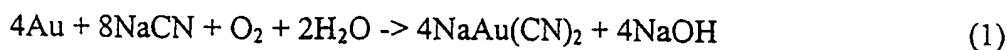


FIELD OF THE INVENTION

The invention is in the field of processes for the recovery of cyanide from aqueous solutions, particularly waste solutions from gold ore processing operations.

BACKGROUND OF THE INVENTION

Cyanide solutions are widely used in a number of chemical processes. A common use of cyanide is in the leaching of gold. The chemistry by which cyanide leaches gold may be expressed as follows:



Gold is usually present in very low concentrations in naturally occurring ores and in concentrates derived from such ores. Typical gold concentrations are in the range of from about 1 g/tonne for some ores to about 1000 g/tonne for some concentrates. In the leaching process, cyanide is typically added to ores or concentrates at elevated pH to keep cyanide in solution and to thereby prevent the formation and evolution of highly toxic HCN gas. To help maximize the efficiency of leaching, cyanide is typically added in excess of the stoichiometric amount required for leaching in accordance with reaction 1. The excess cyanide is required in part because cyanide typically reacts with other minerals, is oxidized or volatilizes from the system.

Following leaching, gold may be recovered by a number of processes, such as zinc cementation or carbon adsorption, leaving a barren solution. The presence of excess cyanide in the barren solution at the end of the gold leaching and recovery operation creates a disposal problem for gold leaching plants. A variety of approaches may be taken to address this problem. The cyanide may be discharged to the environment if the cyanide concentration is sufficiently low. The cyanide may be destroyed using a chemical or biological treatment method, such as known methods of SO₂/air treatment, alkaline chlorination, biological oxidation, hydrogen peroxide

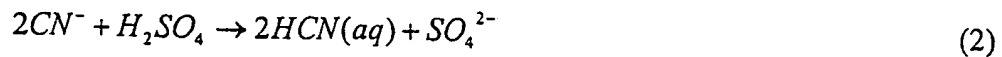
treatment or Caro's acid treatment. The cyanide may be recovered for recycle by known methods such as AVR (acidification, volatilization and re-neutralization), AFR (acidification, filtration and reneutralization), or MNR (Metallgesellschaft Natural Resources) processes, the Cyanisorb™ process, or the Augment™ process.

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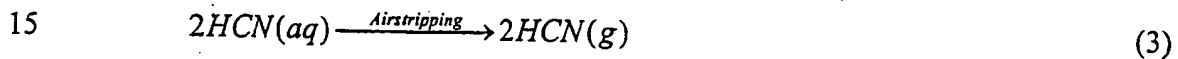
The AVR process has been of interest to gold processors for a long time. The process involves addition of acid to a waste cyanide solution followed by volatilization of HCN gas, reneutralization and scrubbing of volatile HCN from the stripping air, in accordance with the reactions 2, 3 and 4.

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Acidification:

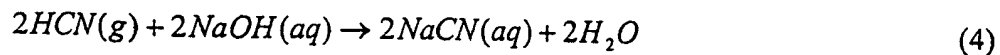


Volatilization:



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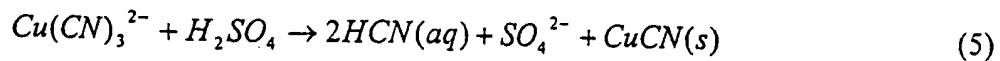
Reneutralization:



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NaCN recovered from the reneutralization step of an AVR process may be returned to a leaching process. The AVR process may be particularly useful when cyanide is present as metal complexes such as copper cyanides. As shown in equation 5, two of the three cyanides in the copper cyanide complex may be recovered by this method while copper is recovered as a CuCN precipitate.

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The AVR method suffers from a number of potentially important drawbacks, including volatilization of dangerous HCN gas and inefficiencies that may raise costs. Volatile HCN is acutely toxic, which raises important safety concerns, particularly in areas where there is a higher risk of leaching plant disruption due for example to power outages. HCN is a soluble acid that is difficult to strip using air so that the size

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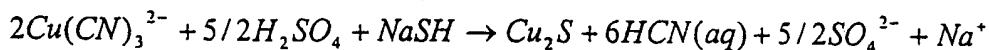
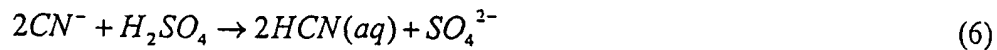
and cost (capital and operating) for volatilization operations may be significant. Also, the large volumes of gas typically used for volatilization must be scrubbed with NaOH to ensure good cyanide recovery and to minimize HCN loss in any discharged 'tail' gas, a process that may further raise costs.

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A second known method of dissolved cyanide recovery is the MNR process. This process differs slightly from the AVR process in that NaSH (sodium hydrosulfide) is added during acidification. The NaSH is thought to maximize cyanide recovery by converting base metal cyanides to metal sulfides, as shown in equations 6 through 9.

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Acidification and Sulfidization



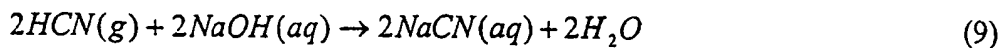
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Volatilization



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Reneutralization



The MNR process suffers from many of the same drawbacks as the AVR process, since HCN is volatilized and scrubbed.

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It is an object of the invention to provide a process for the recovery of cyanide from aqueous solutions that may be used as an alternative to known processes such as volatilization and reneutralization of HCN as part of AVR or MNR processes.

30 SUMMARY OF THE INVENTION

The invention provides a process for recovering hydrogen cyanide from an aqueous solution by extracting the hydrogen cyanide into an organic solvent phase.

The organic solvent may comprise a neutral organophosphorous compounds, such as compounds selected from the group consisting of alkyl or aryl substituted phosphates, phosphonates and phosphine oxides. In alternative embodiments the organophosphorous compound is tri-butyl phosphate, di-butyl-butyl-phosphonate or tri-alkyl phosphine oxides. The organic solvent may be diluted in an organic diluent, such as an aliphatic or kerosene-type diluent. Alternative dilutions may be used, such as 75%, 50% or 25%. In some embodiments, the pH of the aqueous solution containing dissolved cyanide may be adjusted to between 2 and 8, or between 3 and 7, or between 4 and 6. The organic solvent may be contacted following extraction with a basic aqueous solution to strip cyanide from the organic solvent into a basic aqueous cyanide strip solution. The stripped organic solvent may then be returned to the loading process, to extract HCN from fresh aqueous solution.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a conceptual flowsheet for HCN Recovery using solvent extraction (SX) loading and stripping. The generation of an HCN containing stream is shown via the MNR generation of a copper sulfide precipitate.

Figure 2 is a conceptual flowsheet showing a prior art AVR Process.

Figure 3 is a conceptual flowsheet showing a prior art MNR Process.

Figure 4 is a graph showing extraction of HCN with 100% Cyanex 923.

Figure 5 is a graph showing extraction of HCN with 100% DBBP.

Figure 6 is a graph showing extraction of HCN with 100% TBP.

Figure 7 is a graph showing extraction of HCN with 50% Cyanex 923.

Figure 8 is a graph showing extraction of HCN with 50% DBBP.

Figure 9 is a graph showing extraction of HCN with 50% TBP.

Figure 10 is a graph showing extraction of HCN with 25% Cyanex 923.

5 Figure 11 is a graph showing extraction of HCN with 25% DBBP.

Figure 12 is a graph showing extraction of HCN with 25% TBP.

10 Figure 13 is a graph showing extraction of HCN by Various Reagents at 100%
Reagent Strength.

Figure 14 is a graph showing extraction of HCN by Various Reagents at 50%
Reagent Strength.

15 Figure 15 is a graph showing extraction of HCN by Various Reagents at 25%
Reagent Strength

Figure 16 is a schematic McCabe-Thiele Isotherm for Cyanide Recovery
Using 100% Cyanex 923.

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DETAILED DESCRIPTION OF THE INVENTION

The invention provides methods of using organic solvent extractants such as organophosphorous compounds to extract HCN from aqueous solutions such as ore processing waste solutions (such as gold ore processing waste solutions). In some
25 embodiments, the extraction may serve to substantially remove HCN from the aqueous solution. The aqueous solutions may be acidic, or acidified, to improve the equilibrium of HCN partition between aqueous and organic phases during extraction. In alternative embodiments, organophosphorous solvents may be selected from the group consisting of tri-butyl phosphate, di-butyl-butyl-phosphonate and tri-alkyl
30 phosphine oxides. Stripping of cyanide from the organic extractant may be effected in accordance with the invention by contacting the solvent with a basic aqueous strip

solution, such as a NaOH solution, for example of pH between 10 and 14 or preferably between 10.5 and 11.5.

5 Exemplified embodiments of the processes of the invention utilize various solvent extractants: Cyanex 923, di-butyl-butyl-phosphonate (DBBP) and tri-butyl phosphate (TBP). The strength of HCN extraction may vary, for example as follows: Cyanex 923 > DBBP > TBP. The extractant may be diluted with a diluent, such as a kerosene type diluent. As shown in the examples herein, the strength of extraction may drop in proportion to the volume % of the active ingredient in the formulated
10 organic solution. In some embodiments, a dilution of organic solvent of approximately 50% may be preferred in order to adequately entrain or solvate the organic solvent in the organic phase and so reduce the extent to which the organic solvent dissolves in, and is lost to, the aqueous phase during extraction.

15 The aqueous cyanide solution treated by organic extraction in accordance with the invention preferably has a pH at which a substantial proportion of the cyanide is present in the form of dissolved hydrogen cyanide. Accordingly, the processes of the invention may be carried out following known techniques of acidification for aqueous cyanide solutions, such as are used in AVR, AFR or MNR processes. In alternative
20 embodiments of the invention, the pH of the aqueous solution containing dissolved cyanide may be adjusted to between 2 and 8, between 3 and 7, or between 4 and 6, prior to or coincidentally with organic extraction.

Alternative embodiments of the processes of the invention may be tested using
25 column contactors to optimize processes for achieving low concentrations of organic solvents and cyanide in barren effluent following treatment of solutions in accordance with the invention. Alternative processes may be tested on particular leaching plant effluent solutions. In alternative embodiments, treated solutions may contain metal cyanides, such as copper and zinc cyanides, that are removed as base metal sulfides
30 using an MNR-like process, prior to cyanide recovery.

The following examples illustrate the loading and stripping of HCN using three organic solvent types and three different concentrations of HCN in the organic solutions. The three solvent types were: tributyl phosphate (TBP, $(C_4H_9)_3PO_4$), dibutyl butyl phosphonate (DBBP, $(C_4H_9O)_2POC_4H_9$) and Cyanex 923 (a mixture of liquid phosphine oxides, $X_3P=O$ where X is an alkyl or aryl substituent, commercially available from Cytex Industries Inc., New Jersey).

The organic solvents used in the processes of the invention are preferably relatively insoluble in water and capable of forming an organic phase separable from the aqueous phase that is being treated, to preferentially solvate HCN in the organic phase. The terms "HCN" or "hydrogen cyanide" as used herein refer to molecular hydrogen cyanide, as distinct from the aqueous ionic species H^+ and CN^- . The aqueous solubility of an organic solvent in water may be expressed in units of mass percent of solute (S) at 25°C, equal to $100 \times \text{mass of solute} / (\text{mass of solute} + \text{mass of water})$. In some embodiments, it may be preferable to use an organic solvent with an aqueous solubility less than 1, less than 0.1 or less than 0.05 mass percent, to reduce loss of solvent and contamination of the aqueous solution (the aqueous solubility of selected organic solvents in units of mass percent of solute may be found in standard references such as the CRC Handbook of Chemistry and Physics, CRC Press, which indicates for example that the aqueous solubility of tributyl phosphate is 0.039%). Selected organic solvents of the invention may be liquids at 25°C and may be relatively non-volatile, to avoid losses from evaporation and reduce risks associated with flammable volatile solvents (for example having boiling points above 75°C or above 100°C, for example the boiling point of tributyl phosphate is given in the 79th Edition of the CRC Handbook as 177°C). Suitable solvents may for example be selected from the group consisting of neutral organic compounds, neutral polar organic compounds or neutral polar organophosphorous compounds. In some embodiments, the solvents may be selected from the group consisting of organophosphorous compounds, such as alkyl or aryl phosphates, alkyl or aryl phosphonates or alkyl or aryl phosphine oxides, wherein the alkyl substituents may optionally be lower alkyl groups of C_1 to C_{10} and may optionally be branched or unbranched.

Organic liquids containing TBP, DBBP and Cyanex 923 were prepared at 100%, 50% and 25% extractant strength. The diluent used for 50% and 25% extractant was Exxsol D-80 extractant (available from Exxon). Alternative organic
5 diluents may be used, such as liquids derived from petroleum, including aliphatic liquid mixtures.

In various embodiments, aqueous cyanide solutions for treatment were prepared to contain about 0.0077 M NaCN (0.377 g/L NaCN and 0.200 g/L CN⁻) and
10 0.001 M NaOH. A known sample volume was titrated with 0.125 M H₂SO₄ to pH 4.00 ± 0.05 to determine the required amount of acid to add to convert NaCN to HCN. A mildly acid pH is preferably maintained to improve the equilibrium of extraction of the neutral HCN species into the organic solvent, and to avoid polymerization of HCN in the presence of CN⁻. In the exemplified embodiments, after acid addition the
15 aqueous solutions contained about 200 mg/L HCN and 600 ppm Na₂SO₄.

In the exemplified embodiments, various phase ratios of aqueous and organic solutions were tested, using flasks or separatory funnels. Acid was added to the solutions for extraction to maintain an acid pH in the aqueous media. In the examples,
20 the vessels were sealed and the mixtures were stirred vigorously for 20 minutes. After this the mixtures were allowed to settle. To assay samples for cyanide content, aqueous phase samples were added to a NaOH solution and titrated with a known AgNO₃ solution (~0.018 M) using rhodamine as the titration end-point indicator. Loaded organic solution samples (*i.e.* the organic phase loaded with HCN following
25 extraction) were stripped with 1 M NaOH, usually at an aqueous to organic (A/O) ratio of 1. Samples of the stripped aqueous solutions were titrated with AgNO₃. Blank tests were also performed in which the aqueous phases were deionized water.

In the case of 100% tributylphosphate, the aqueous phases after loading were
30 clear. These were analyzed without further clarification. A test was done to confirm that there was no interference from organic entrainment. In all other tests, the aqueous phases were centrifuged prior to analysis. In alternative embodiments of the

invention, solutions may be treated by centrifugation or settling to remove particulates. In the exemplary embodiments, organic phases were generally centrifuged prior to stripping only if they were cloudy, otherwise they were stripped without further clarification.

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The HCN values disclosed for the examples herein are corrected for the blank results. In the case of Cyanex 923 the blank values were substantial. For the other two reagents the effect of the blank was small. The organic solutions were generally stripped at A/O 1 and usually a 10.00 mL sample was analyzed. The value of the blank titre could thus be directly subtracted from the sample titre. For the aqueous phases the blank was done at A/O 1. Thus at an A/O 4, for instance, the amount extracted was assumed to be ¼ of that at A/O 1, and at A/O 0.25, 4 times that at A/O 1. These values were subtracted from the aqueous HCN result. To illustrate, for 100% Cyanex 923 the aqueous blank sample at A/O 1 gave a titre corresponding to 0.39 mg/L HCN. For A/O 0.25, where there is four times as much organic as aqueous, it is assumed that the blank aqueous solution would indicate about $4 \times 0.39 = 1.6$ mg/L as HCN. This was subtracted from the titration result for the aqueous phase.

The equilibrium loading results are shown in Tables 2-10 and Figures 4-15. In each case the loading curves fitted well to straight lines. At all strengths of reagent, Cyanex 923 loaded the HCN most strongly. The slope of the lines on the plots is a measure of the distribution factor for the system. Distribution factor is defined as follows:

$$D_{HCN} = \frac{[HCN]_{org}}{[HCN]_{aq}}$$

A value of distribution factor greater than 1 indicates affinity for the organic solution. A value of distribution factor less than 1 indicates an affinity for the aqueous solution. In alternative embodiments, extraction conditions may be selected so that the distribution factor is at least 2.5, 3.5, 4.5, 5.5, 6.5, 7.5, 8.5, 9.5, 10 or 11 (see Table 1).

The lowest aqueous HCN levels detected were found at A/O 0.25. For Cyanex 923 this was 4 mg/L, for dibutylbutylphosphonate, 7 mg/L and for tributylphosphate, 13 mg/L. Mass balances were generally 94% or greater. In the case of
5 dibutylbutylphosphonate it was found that 2.6 mL of the aqueous phase dissolved in 20 mL of the organic phase. This was factored into the mass balance calculation, assuming 1.3 mL of aqueous dissolved per 10 mL of organic. The pH of the aqueous phases after loading for the A/O 0.25 mixtures were measured. The pH values were 3.9 or less.

10 Stripping of the organic phases, such as Cyanex 923, with 1 M NaOH may result in cloudy mixtures, and the clouding may persist following centrifugation. Alternative aliphatic diluents may be used in some embodiments to change the characteristics of the extraction and, where desirable, to ameliorate the formation of salts or other species that may interfere with extraction efficiencies.

15 In the examples, different phase separation behaviour was noted for different mixtures. In alternative embodiments the A/O ratio may be adjusted to obtain optimal phase separations and extraction efficiencies in accordance with routine experimental variation of this parameter, as taught herein. In the present examples, at 100% reagent
20 strength (*i.e.* 100% organic solvent), for Cyanex 923, phases separated within 1.5 minutes. For A/O 0.5 (50% organic solvent in diluent) phase separation took 4 minutes. For A/O 0.25 the mixture had to be centrifuged to induce separation. With tributylphosphate phase separation took 1-2 minutes, except for A/O 8 which required 4 minutes. With dibutylbutylphosphonate at higher A/O ratios phase separation took
25 about 1 minute or less. At A/O 0.25 and 0.5 the mixtures did not separate. Aqueous/Organic mixtures may be centrifuged or allowed to settle to improve phase separation.

Table 1. The distribution factors for each concentration

Organic Reagent	Concentration %	D_{HCN}
Cyanex 923	25	3.50
	50	6.92
	100	11.85
(BuO) ₂ BuPO	25	2.06
	50	3.99
	100	7.19
(BuO) ₃ PO	25	1.73
	50	3.88
	100	8.08

Table 2. Extraction of HCN with 100% Cyanex 923.

A/O of Sample	Aq. Vol. (mL)	Org. Vol. (mL)	Estd. Final Aq. Vol. (mL)	Aq. HCN (mg/L)	Org. HCN (mg/L)	Mass Balance (%)
8	80	10	82.841	79.3	937.2	95.2
4	60	15	62.13	49.0	583.0	93.9
2	40	20	41.42	28.2	335.7	94.1
1	25	25	25.887	15.1	181.2	94.1
0.5	25	50	25.887	8.5	94.0	94.0
0.25	15	60	15.532	4.0	49.5	96.6

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Table 3. Extraction of HCN with 100% DBBP.

A/O of Sample	Aq. Vol. (mL)	Org. Vol. (mL)	Estd. Final Aq. Vol. (mL)	Aq. HCN (mg/L)	Org. HCN (mg/L)	Mass Balance (%)
7.93651	103.5	12.6	101.9	101.2	730.9	99.0
4	62.1	15	60.2	68.9	495.8	99.9
2	41.4	20	38.8	41.7	291.6	98.0
1	25.9	25	22.6	22.9	163.0	97.9
0.5	20.7	40	15.5	12.5	86.2	97.7
0.25	10.4	40	5.2	6.8	43.9	96.4

10 Table 4. Extraction of HCN with 100% TBP.

A/O of Sample	Aq. Vol. (mL)	Org. Vol. (mL)	Estd. Final Aq. Vol. (mL)	Aq. HCN (mg/L)	Org. HCN (mg/L)	Mass Balance (%)
8	40	5	41.408	100.2	817.2	99.8
4	40	10	41.409	67.7	542.0	99.7
1.9861	20	10.07	20.703	40.1	323.3	99.1
1	10	10	10.354	20.0	180.8	97.7
0.5	10	20	10.351	12.9	97.4	101.0
0.25	10	40	10.352	12.8	49.8	103.0

Table 5. Extraction of HCN with 50% Cyanex 923.

A/O of Sample	Aq. Vol. (mL)	Org. Vol. (mL)	Estd. Final Aq. Vol. (mL)	Aq. HCN (mg/L)	Org. HCN (mg/L)	Mass Balance (%)
4	60	15	62.137	74.7	508.3	97.2
2	40	20	41.423	44.2	318.2	97.4
1	25	25	25.89	25.4	179.6	97.9
0.50125	20	39.9	20.713	14.1	96.2	98.3
0.25	15	60	15.532	6.8	50.1	98.6

Table 6. Extraction of HCN with 50% DBBP.

A/O of Sample	Aq. Vol. (mL)	Org. Vol. (mL)	Estd. Final Aq. Vol. (mL)	Aq. HCN (mg/L)	Org. HCN (mg/L)	Mass Balance (%)
7.99574	75	9.38	77.65	132.7	523.1	96.9
2.5	50	20	51.768	75.1	309.7	96.4
0.25	20	80	20.707	11.6	48.0	97.5

Table 7. Extraction of HCN with 50% TBP.

A/O of Sample	Aq. Vol. (mL)	Org. Vol. (mL)	Estd. Final Aq. Vol. (mL)	Aq. HCN (mg/L)	Org. HCN (mg/L)	Mass Balance (%)
8	80	10	82.84	136.0	523.3	98.7
4	80	20	82.839	102.1	399.0	98.3
2.5	50	20	51.776	78.8	309.9	98.3
0.25	20	80	20.71	12.1	48.0	97.9

10 Table 8. Extraction of HCN with 25% Cyanex 923.

A/O of Sample	Aq. Vol. (mL)	Org. Vol. (mL)	Estd. Final Aq. Vol. (mL)	Aq. HCN (mg/L)	Org. HCN (mg/L)	Mass Balance (%)
8	80	10	82.827	139.1	478.4	98.2
2.5	50	20	51.763	81.2	296.4	97.6
0.25	20	80	20.713	11.1	48.5	99.1

Table 9. Extraction of HCN with 25% DBBP.

A/O of Sample	Aq. Vol. (mL)	Org. Vol. (mL)	Estd. Final Aq. Vol. (mL)	Aq. HCN (mg/L)	Org. HCN (mg/L)	Mass Balance (%)
8	80	10	82.855	160.4	326.6	98.6
2	50	25	51.785	99.1	209.4	98.8
0.25	20	80	20.715	21.2	46.7	99.4

Table 10. Extraction of HCN with 25% TBP.

A/O of Sample	Aq. Vol. (mL)	Org. Vol. (mL)	Estd. Final Aq. Vol. (mL)	Aq. HCN (mg/L)	Org. HCN (mg/L)	Mass Balance (%)
8	80	10	82.819	163.9	283.0	98.6
2.5	50	20	51.765	118.1	206.3	98.5
0.25	20	80	20.705	25.8	44.9	99.3

Alternative embodiments of the invention may utilize a number of extraction stages and alternative modes of contact of the organic and aqueous solution. Figure 16 is a schematic McCabe-Thiele isotherm for the recovery of cyanide from a 200 ppm solution. Five stages of countercurrent extraction are demonstrated to be sufficient to recover the cyanide down to less than 10 ppm (or less than 5 ppm). This extraction corresponds to greater than 95% cyanide recovery. In alternative embodiments, the concentration of HCN in the aqueous solution may for example be reduced to less than 100 ppm or 50 ppm. In alternative embodiments the proportion of HCN extracted from an aqueous solution may for example be at least 50%, at least 75% or at least 85%. At high pH (above 8 for example in some embodiments), the equilibrium may shift towards increasing concentrations of ionic CN^- and decreasing concentrations of neutral HCN. It may therefore be preferable to maintain a sufficiently low pH to favour the formation of HCN, which will be preferentially partitioned into the organic phase during extractions.

In some embodiments, a column type contactor may be preferred for extractions. Column contactors may have a number of advantages. A column may provide for a large number of stages, all within the same piece of equipment. A column may be sealed, so that HCN gas can not evolve into the surrounding atmosphere. Also, columns may be advantageously adapted for handling solids (crud), if solids are formed in the extraction process.

The testing and assay procedures set out herein may be used, together with known testing methods, to adapt the processes of the invention for use with alternative organic solvents (such as compounds with equivalent chemical and physical properties to the exemplified compounds, for example having similar polarity, aqueous solubility and HCN distribution factors), alternative diluents, alternative

concentrations of solvent in diluent, alternative extraction pHs, alternative extraction and phase separation protocols. Accordingly, the specific examples set out herein of the methods of the invention are merely illustrative of the alternative aspects of the broadly defined invention as claimed.

WHAT IS CLAIMED IS:

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1. A process for treating an aqueous ore processing waste solution containing dissolved hydrogen cyanide comprising extracting hydrogen cyanide from the solution with an organic solvent.
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2. The process of claim 1 wherein the organic solvent comprises a neutral polar organic compound.
3. The process of claim 1 wherein the organic solvent comprises an organophosphorous compound selected from the group consisting of alkyl or aryl substituted phosphates, phosphonates and phosphine oxides.
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4. The process of claim 3 wherein the organophosphorous compound is selected from the group consisting of tri-butyl phosphate, di-butyl-butyl-phosphonate and tri-alkyl phosphine oxides.
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5. The process of claim 3 wherein the organophosphorous compound is tri-butyl phosphate.
- 20 6. The process of claim 3 wherein the organophosphorous compound is di-butyl-butyl-phosphonate.
7. The process of claim 3 wherein the organophosphorous compound is a tri-alkyl phosphine oxide.
25
8. The process of any one of claims 1 through 7 wherein the pH of the aqueous solution containing dissolved cyanide is adjusted to between 2 and 8.
9. The process of any one of claims 1 through 7 wherein the pH of the aqueous solution containing dissolved cyanide is adjusted to between 3 and 7.
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10. The process of any one of claims 1 through 7 wherein the pH of the aqueous solution containing dissolved cyanide is adjusted to between 4 and 6.
- 5 11. The process of any one of claims 1 through 10 further comprising contacting the organic solvent, following the extracting step, with a basic aqueous solution to strip hydrogen cyanide from the organic solvent into a basic aqueous cyanide strip solution.
- 10 12. The process of claim 11 wherein the pH of the basic aqueous solution is between 10 and 14.
13. The process of claim 11 wherein the pH of the basic aqueous solution is between 10.5 and 11.5.
- 15 14. The process of any one of claims 1 through 13 wherein the organic solvent is diluted in an organic diluent.
15. The process of claim 14 wherein the concentration of the organic solvent in the organic diluent is at least 50%.
- 20 16. The process of any one of claims 1 through 15, wherein the HCN distribution factor of the organic solvent is greater than 2.5.
- 25 17. The process of any one of claims 1 through 15, wherein the HCN distribution factor of the organic solvent is greater than 5.
18. The process of any one of claims 1 through 17, wherein the organic solvent has an aqueous solubility of less than about 1% (by mass percent of solute at 25°C).
- 30 19. The process of any one of claims 1 through 18, wherein the organic solvent has a boiling point of greater than about 75°C.

20. The process of any one of claims 1 through 19, wherein the process is carried out to extract at least 50% of the hydrogen cyanide from the aqueous solution.
- 5 21. The process of any one of claims 1 through 19, wherein the process is carried out to extract at least 95% of the hydrogen cyanide from the aqueous solution.
22. The process of any one of claims 1 through 21, wherein the process is carried out to reduce the concentration of the hydrogen cyanide in the aqueous
10 solution to less than 10 ppm.
23. The process of any one of claims 1 through 22, wherein the ore processing waste solution is a gold ore processing waste solution.

Figure 1

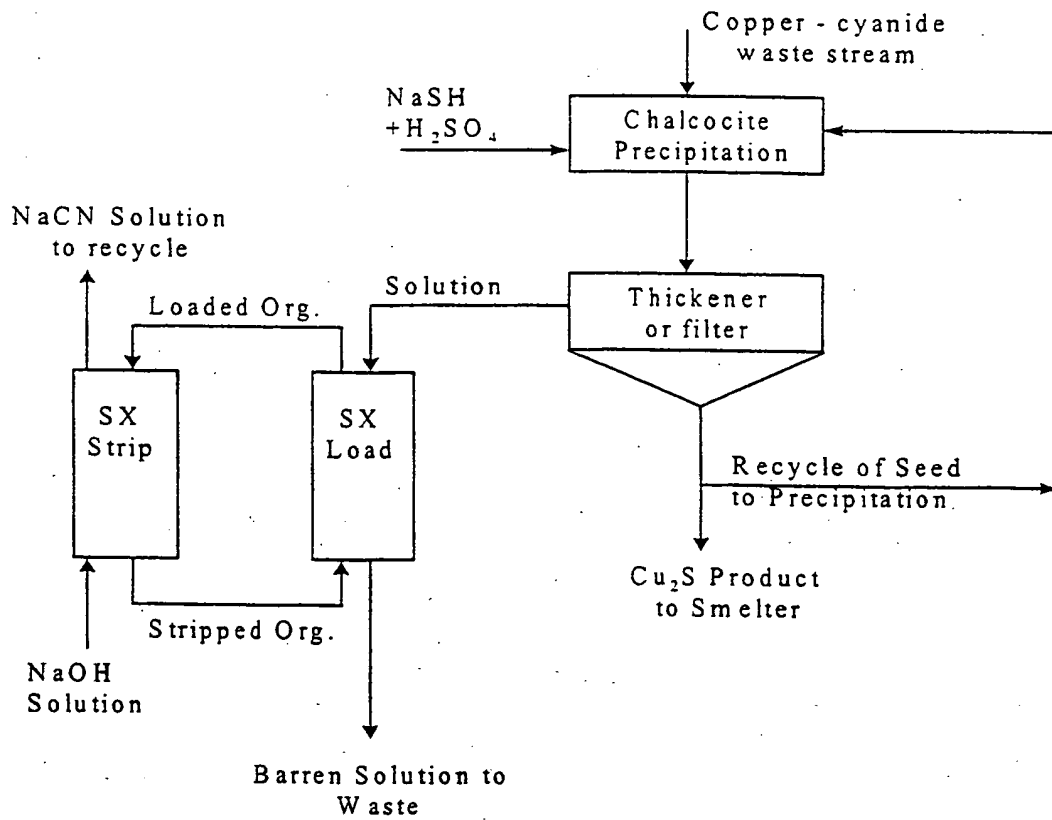
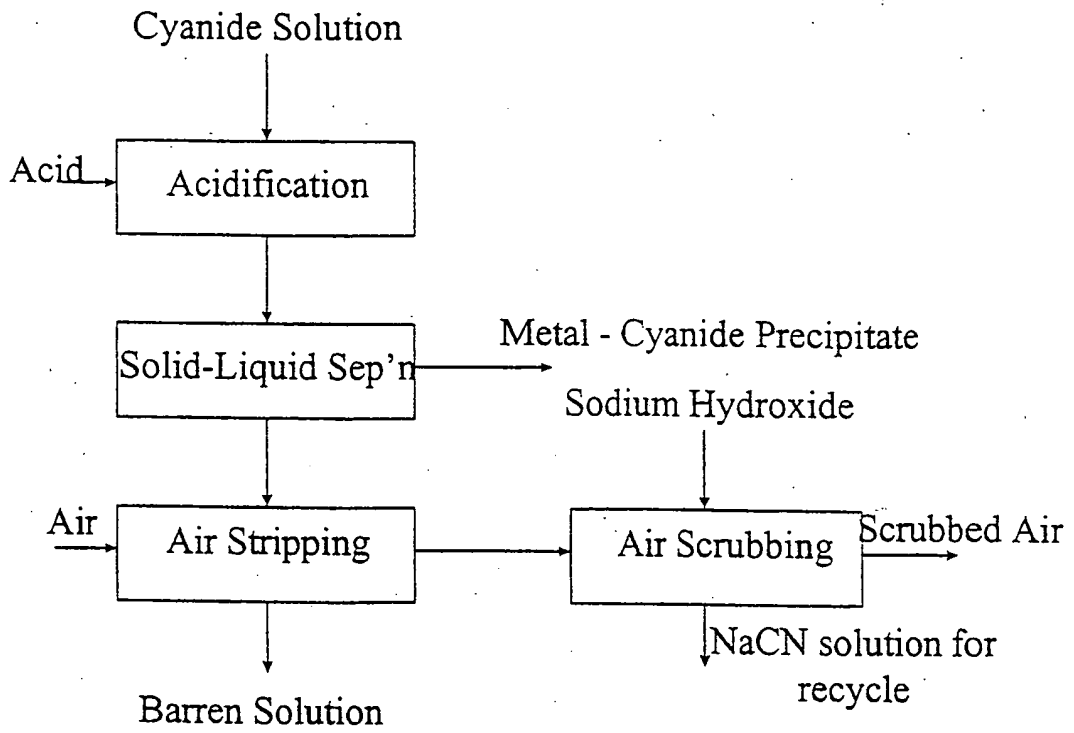


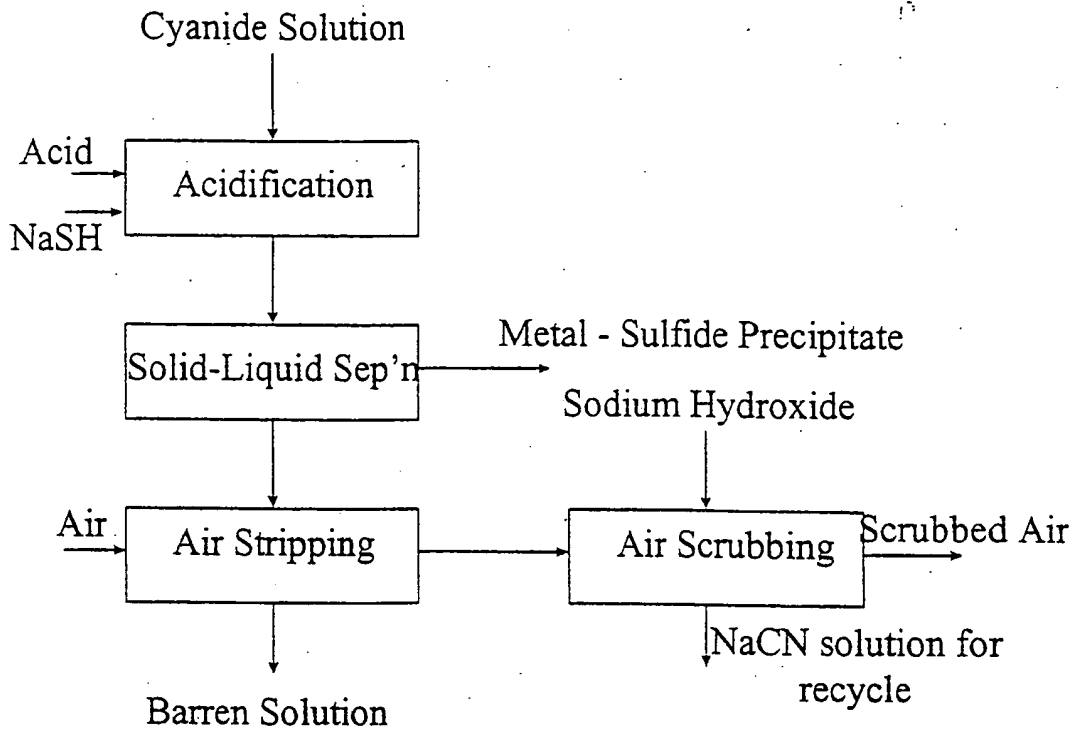
Figure 2

011485



Prior Art AVR Process

Figure 3



Prior Art MNR Process

100% Cyanex 923

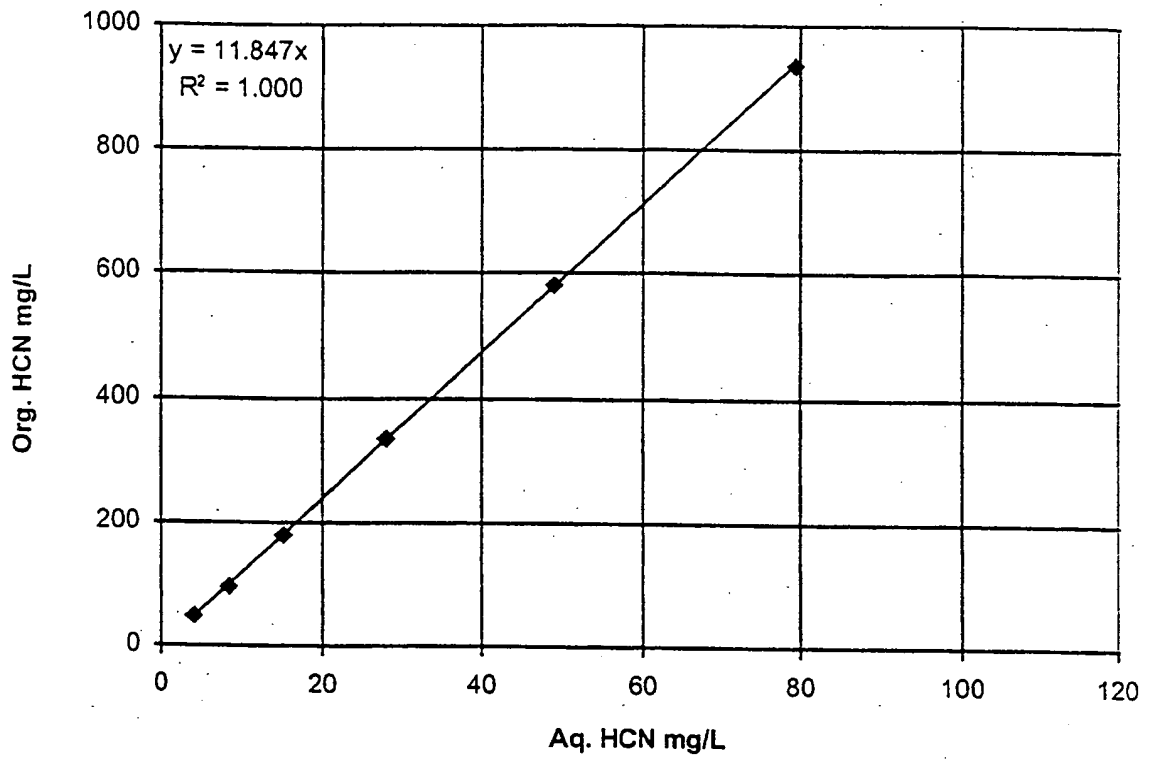


Figure 4

100% DBBP

011485

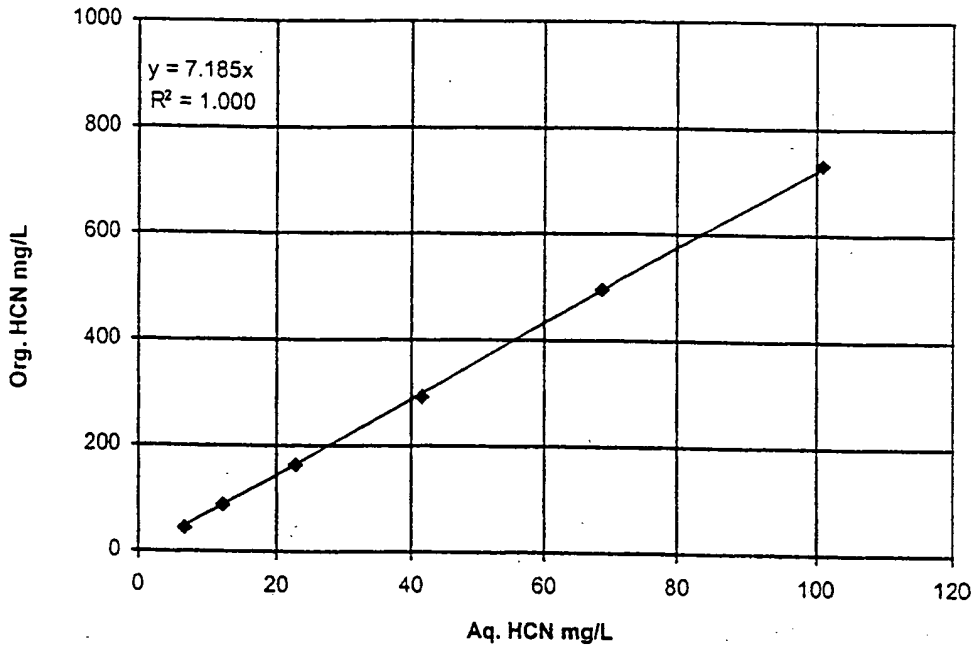


Figure 5

100% TBP

011485

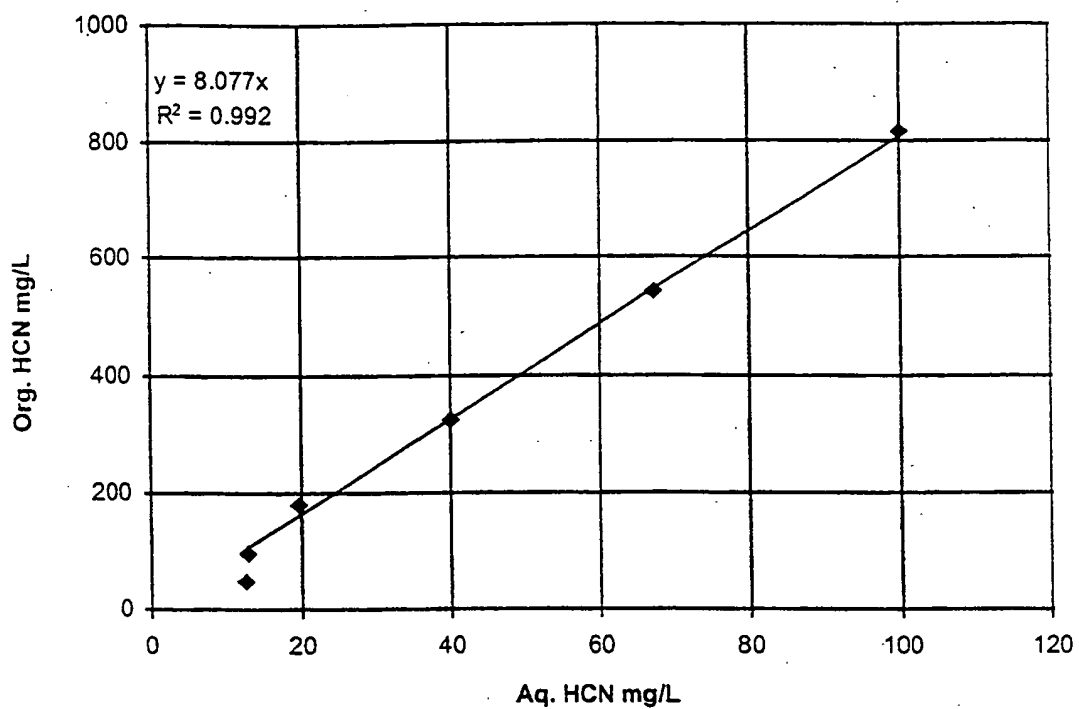


Figure 6

50% Cyanex 923

011485

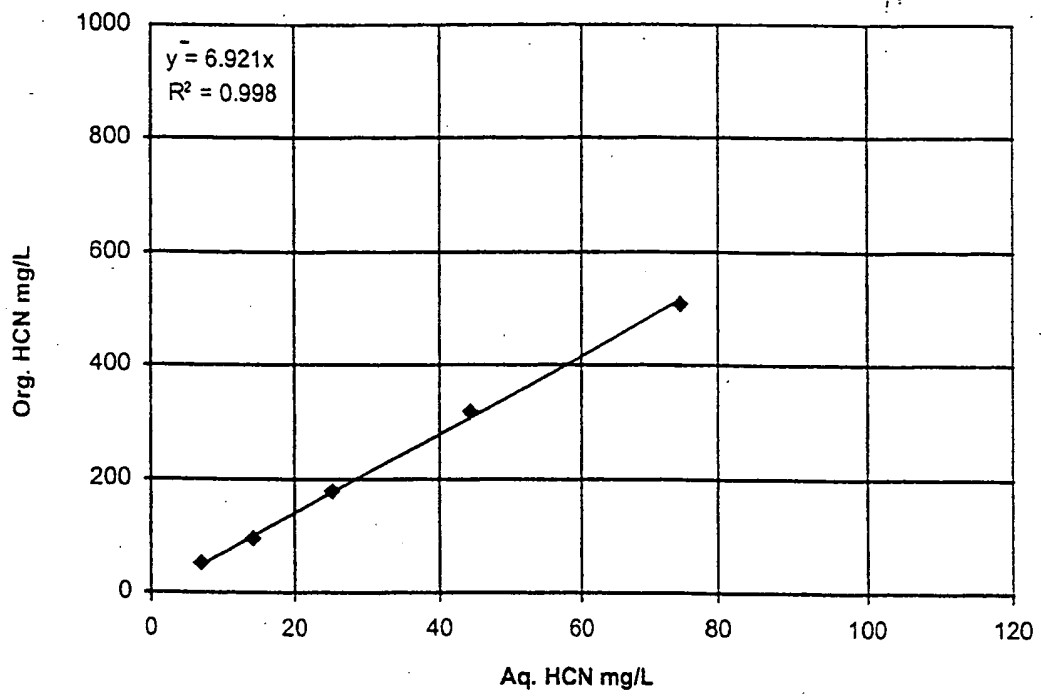


Figure 7

50% DBBP

011485

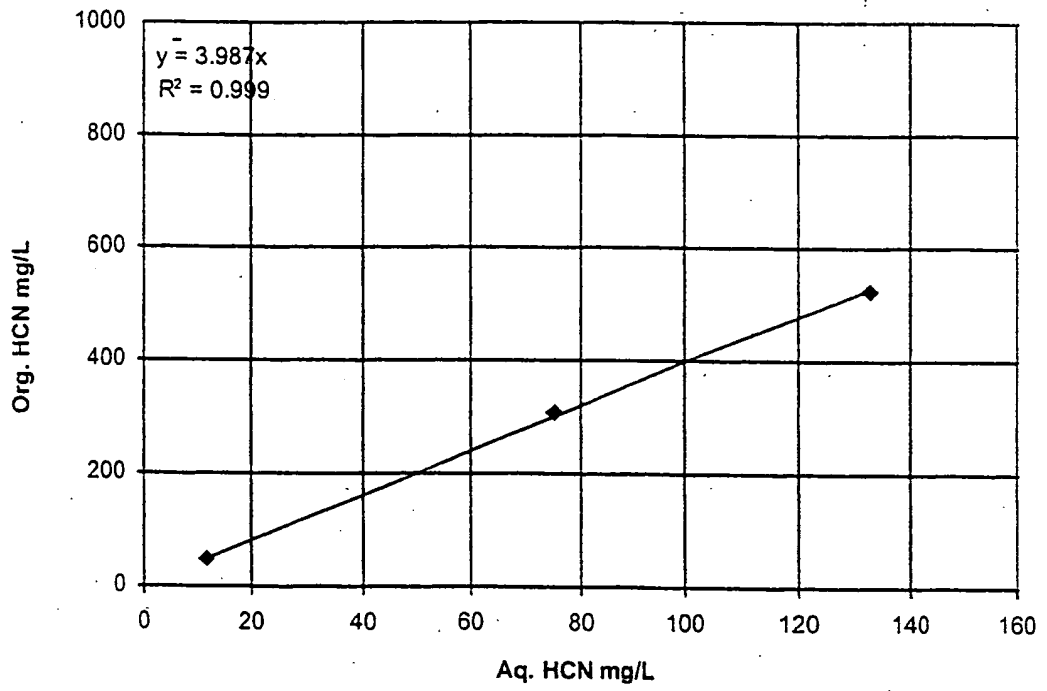


Figure 8

50% TBP

011485

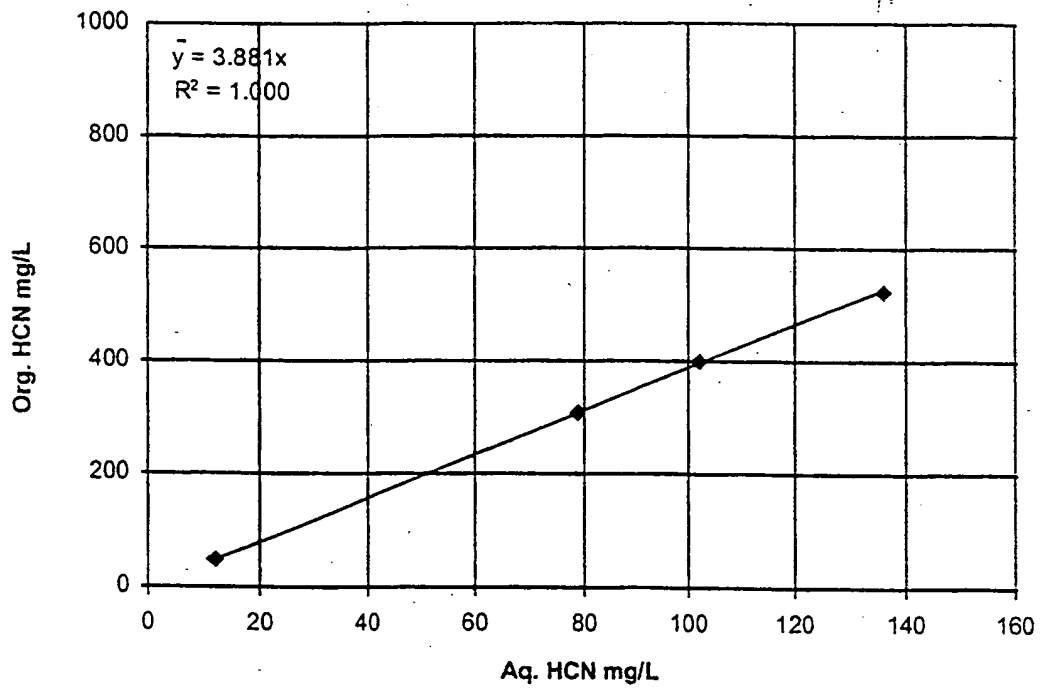


Figure 9

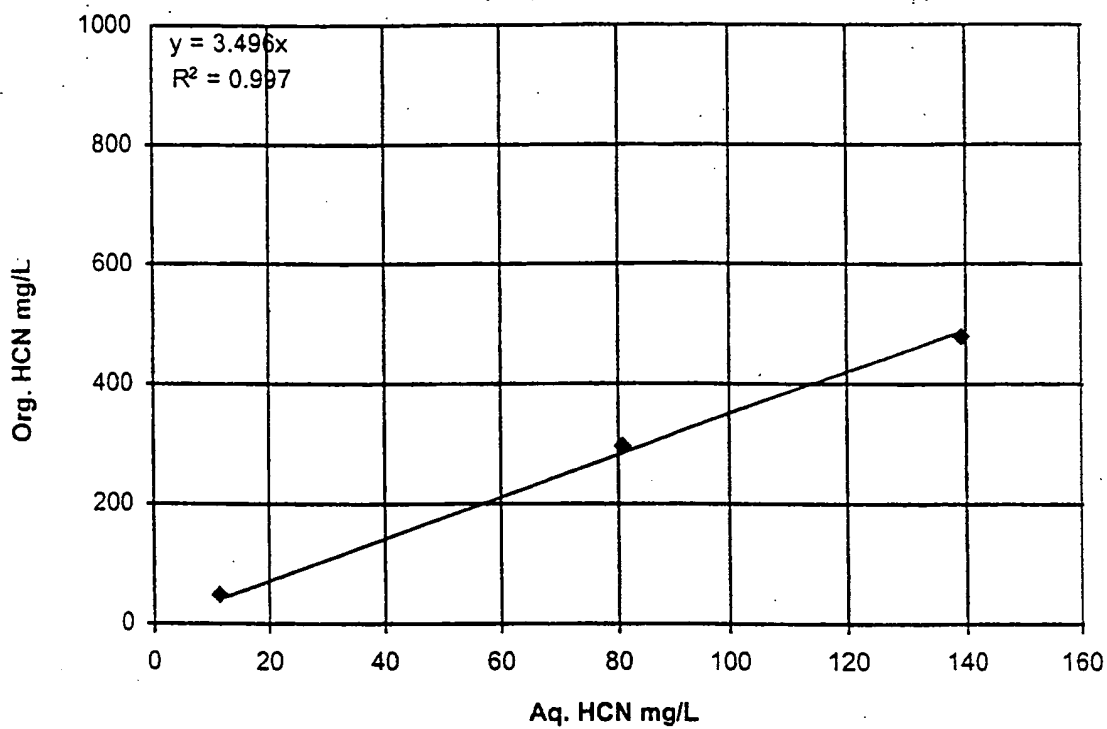


Figure 10

25% DBBP

011485

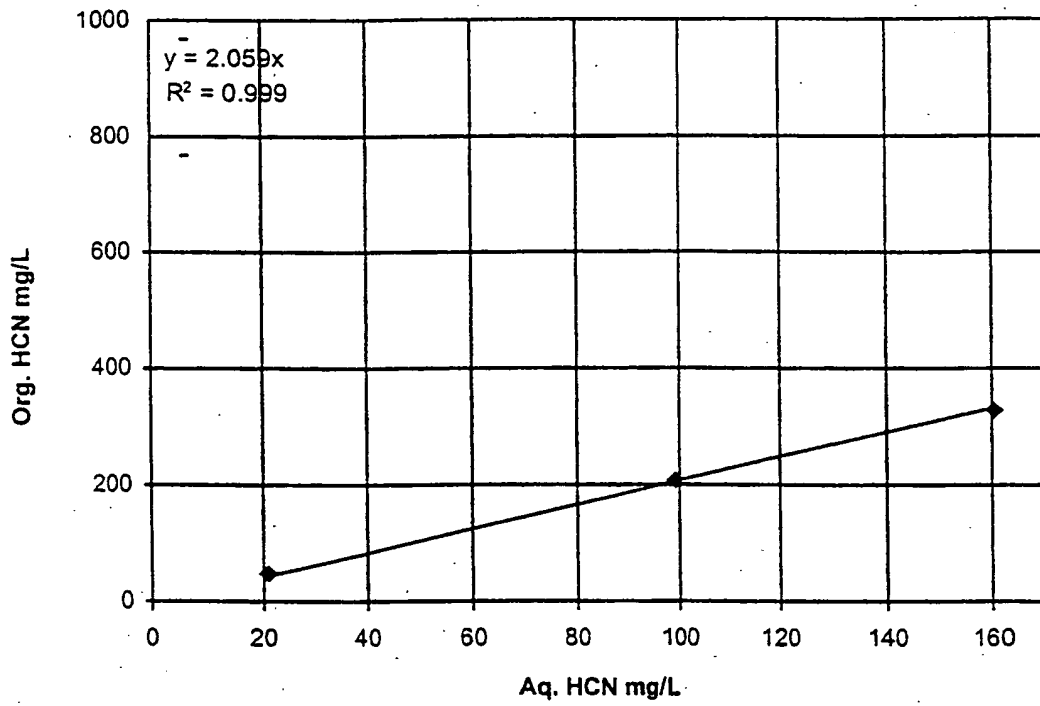


Figure 11

25% TBP

011485

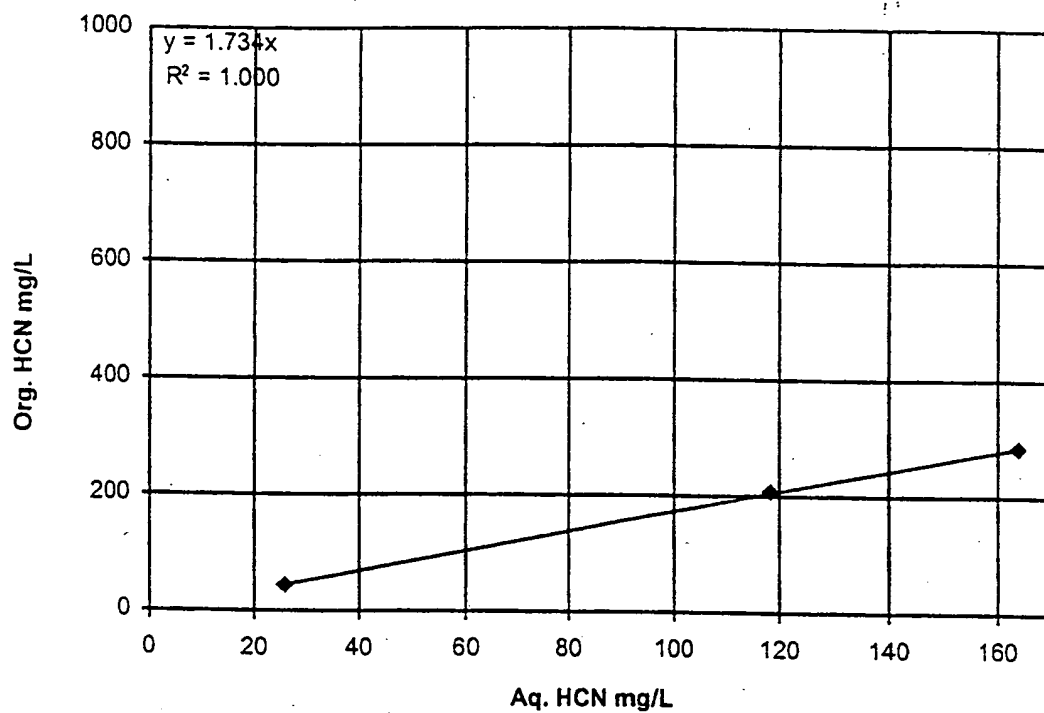


Figure 12

100% Reagent Strength

011485

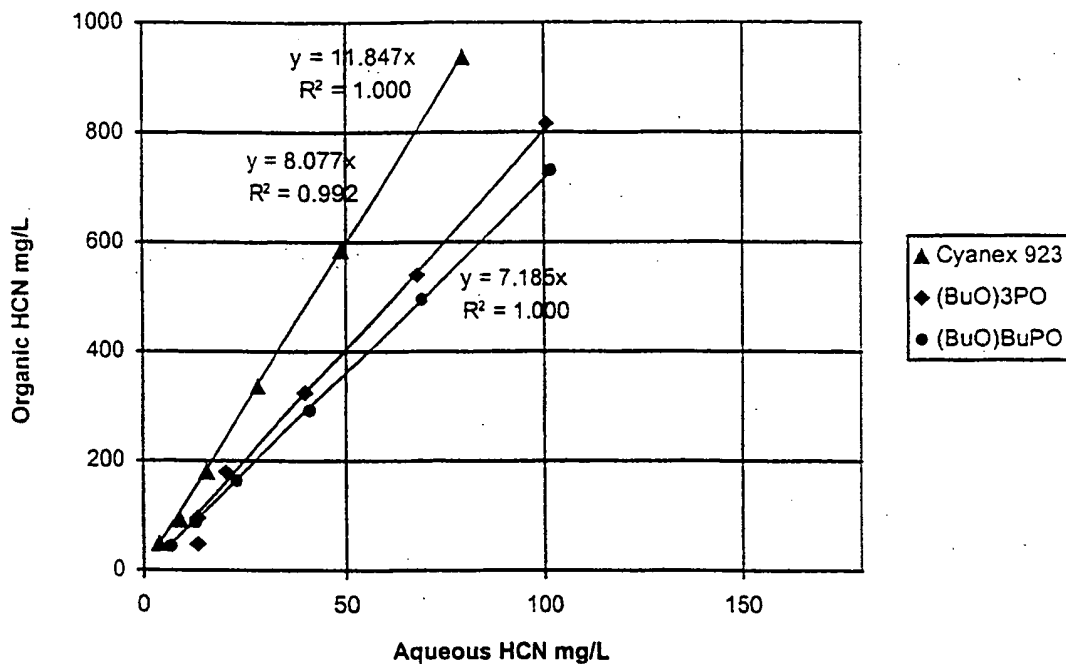


Figure 13

50% Reagent Strength

011485

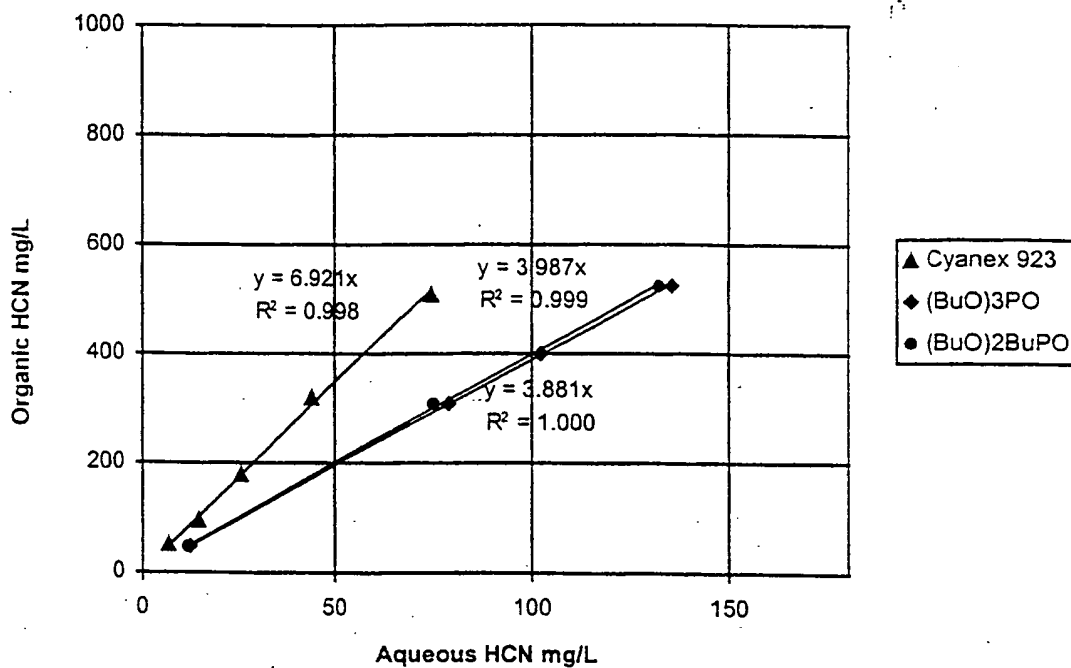


Figure 14

25% Reagent Strength

011485

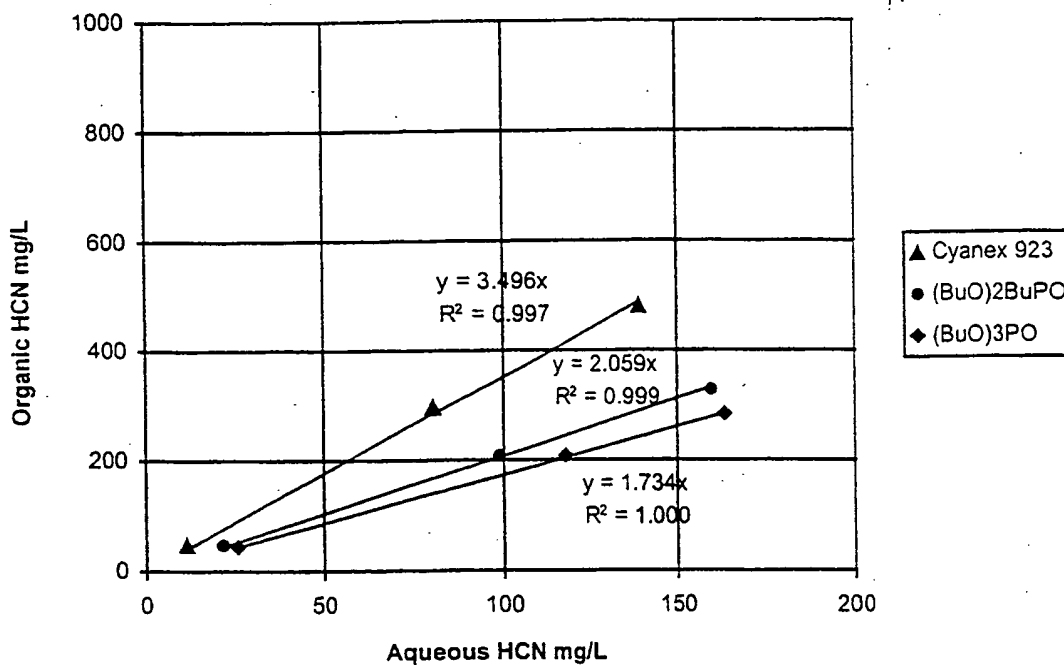


Figure 15

McCabe Thiele Isotherm

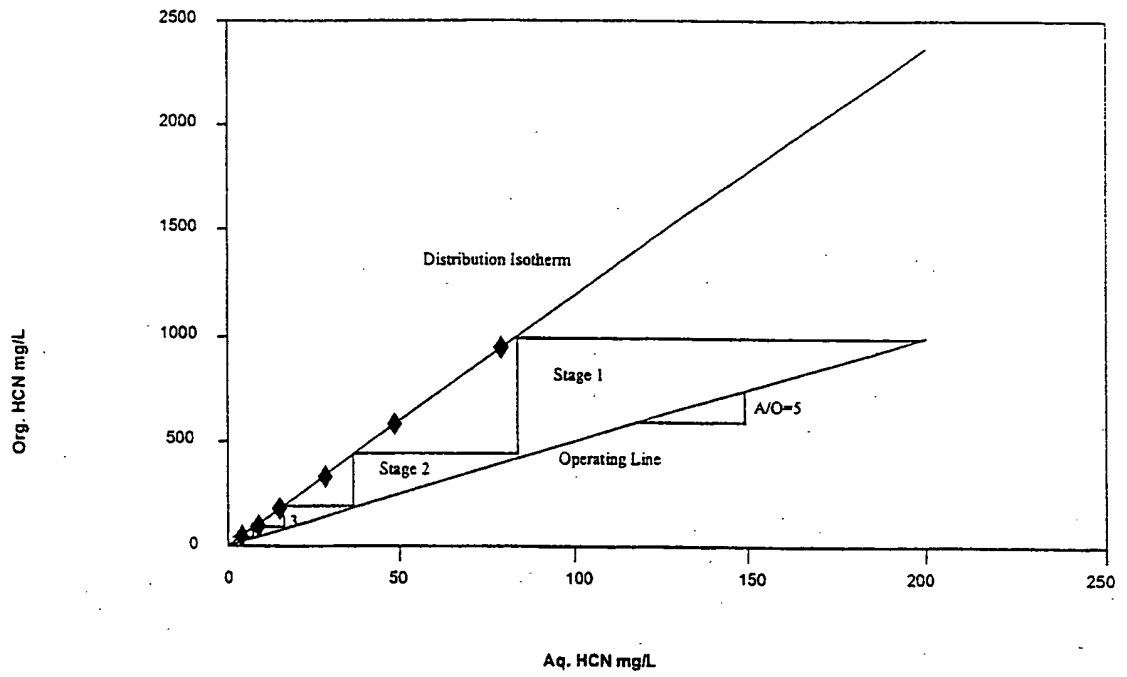


Figure 16