



HU000035594T2

(19) **HU****MAGYARORSZÁG****Szellemi Tulajdon Nemzeti Hivatala**(11) Lajstromszám: **E 035 594**(13) **T2**

EURÓPAI SZABADALOM SZÖVEGÉNEK FORDÍTÁSA

(21) Magyar ügyszám: **E 13 712550**(22) A bejelentés napja: **2013. 03. 27.**(51) Int. Cl.: **C25B 1/00** (2006.01)**C01D 3/26** (2006.01)

(96) Az európai bejelentés bejelentési száma:

EP 20130712550

(86) A nemzetközi (PCT) bejelentési szám:

PCT/EP 13/056459

(97) Az európai bejelentés közzétételi adatai:

EP 2831307 A1 **2013. 10. 03.**

(87) A nemzetközi közzétételi szám:

WO 13144175

(97) Az európai szabadalom megadásának meghirdetési adatai:

EP 2831307 B1 **2017. 09. 13.**

(30) Elsőbbségi adatok:

12162533	2012. 03. 30.	EP
12162544	2012. 03. 30.	EP
201261619997 P	2012. 04. 04.	US
201261620033 P	2012. 04. 04.	US

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Szerves vas komplex só vizes oldatának stabilizálása

Az európai szabadalom ellen, megadásának az Európai Szabadalmi Közlönyben való meghirdetésétől számított kilenc hónapon belül, felszólalást lehet benyújtani az Európai Szabadalmi Hivatalnál. (Európai Szabadalmi Egyezmény 99. cikk(1))

A fordítást a szabadalmas az 1995. évi XXXIII. törvény 84/H. §-a szerint nyújtotta be. A fordítás tartalmi helyességét a Szellemi Tulajdon Nemzeti Hivatala nem vizsgálta.



(11) **EP 2 831 307 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention
of the grant of the patent:
13.09.2017 Bulletin 2017/37

(51) Int Cl.:
C25B 1/00 (2006.01) C01D 3/26 (2006.01)

(21) Application number: **13712550.6**

(86) International application number:
PCT/EP2013/056459

(22) Date of filing: **27.03.2013**

(87) International publication number:
WO 2013/144175 (03.10.2013 Gazette 2013/40)

(54) **STABILIZATION OF AN AQUEOUS SOLUTION OF AN ORGANIC IRON COMPLEX SALT**

STABILISIERUNG EINER WÄSSRIGEN LÖSUNG EINES ORGANISCHEN
EISENKOMPLEXSALZES

STABILISATION D'UNE SOLUTION AQUEUSE D'UN SEL DE FER COMPLEXE ORGANIQUE

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

(30) Priority: **30.03.2012 EP 12162533**
30.03.2012 EP 12162544
04.04.2012 US 201261619997 P
04.04.2012 US 201261620033 P

(43) Date of publication of application:
04.02.2015 Bulletin 2015/06

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EP 2 831 307 B1

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Description

[0001] The present invention pertains to a method for stabilizing an aqueous solution of an iron salt of an organic acid with a ferric component and a ferrous component of less solubility than the ferric component, in particular iron salt based on meso-tartaric acid (FeMTA), which can for instance be used as a non-caking agent for salt, in particular sodium chloride. The invention also pertains to a dispensing station for such an aqueous solution.

[0002] Sodium chloride tends to form large, agglomerated masses upon exposure to moisture, particularly during long periods of storage. These hardened masses are generally referred to as cakes. A non-caking agent is generally added to the sodium chloride to prevent caking. Classic non-caking agents include sodium ferrocyanide and potassium ferrocyanide. Because of the nitrogen content and because of the produced iron traces in the treated brines, it has been proposed to replace these non-caking agents with an iron salt of a hydroxypolycarboxylic acid, preferably being a mixture of tartaric acids comprising meso-tartaric acid (see WO 2000/059828, an iron salt of a mixture of tartaric acids comprising meso-tartaric acid is hereinafter also referred to as "a non-caking agent based on the Fe^{3+} salt of meso-tartaric acid" or "a non-caking agent comprising the Fe^{3+} salt of meso-tartaric acid"). The Fe^{3+} salt of meso-tartaric acid is hereinafter denoted as FeMTA. WO 2010/139587 discloses a non-caking agent based on the Fe^{3+} salt of meso-tartaric acid.

[0003] Non-caking agents for sodium chloride, also denoted hereinafter as "salt", are typically dissolved in water and stored as aqueous solutions before these are dispensed into an amount of salt. For instance, non-caking agents based on FeMTA are typically supplied as aqueous concentrates with a Fe concentration of, e.g., about 3.7 wt%. The non-caking solution is subsequently prepared for use by dilution with water. When the non-caking agent is dosed onto the salt, the Fe concentration is typically below about 3 wt%, e.g., within the range of 1.5 to 2.5 wt%, e.g., about 2.1 wt%, based on the total weight of the solution. Other concentrations can also be used, if so desired.

[0004] After a solution with a desired concentration and a desired pH is obtained, the aqueous solution is metered and sprayed or poured over the salt. Suitable set values for the pH of a non-caking aqueous solution based on FeMTA are between 3 and 5, e.g., between 4 and 4.5. The pH can for instance be adjusted as known in the art, but preferably by adding a solution of tartaric acid and/or hydrochloric acid. If the pH is below 3, the pH value is preferably adjusted by adding an aqueous solution of sodium hydroxide.

[0005] After production of an aqueous solution of a non-caking agent based on FeMTA, or preferably of FeMTA, typically about 1-3 wt%, sometimes 2-3 wt%, of the iron content of the solution is Fe^{2+} , the remainder being Fe^{3+} . The Fe^{2+} tends to precipitate as Fe(II)mesotartrate (hereinafter also denoted as the Fe(II) complex of mesotartronic acid or the Fe(II) salt of mesotartronic acid) because of its low solubility. This removes Fe^{2+} from the solution, which is balanced by the reduction of Fe^{3+} to fresh Fe^{2+} . Consequently some tartaric acid is oxidized to oxalic acid and other degradation products like CO_2 . This slow degradation process reduces the concentration of dissolved FeMTA over time and, consequently, the effectiveness of the solution as a non-caking agent.

[0006] It is an object of the invention to provide a method and a dispensing station for an aqueous solution with a stabilized dissolved content over a longer period of time.

[0007] The object of the invention is achieved with a process for stabilizing an aqueous solution of an iron salt of an organic acid with a ferric component and a ferrous component of less solubility than the ferric component, in particular an aqueous solution based on FeMTA, and preferably an aqueous solution of FeMTA, wherein the aqueous solution is at least partly subjected to electrolytic oxidation, as defined in claim 1. It is noted that stabilizing according to the invention means maintaining the effectiveness (functionality) of a solution of an iron salt of an organic acid as a non-caking agent by keeping said iron salt in solution. The iron salt of an organic acid is kept in solution according to this invention by reducing the amount of the ferrous component of less solubility by way of at least partly subjecting the solution to electrolytic oxidation.

[0008] More particularly, Fe^{2+} ions in an aqueous solution of non-caking agent according to the present invention, viz. an iron salt of an organic acid with a ferric component and a ferrous component of less solubility than the ferric component, are at least partly oxidized to form Fe^{3+} . Precipitation of the Fe(II) salt of the organic acid is thus at least partly prevented and in this way the Fe(III) salt of the organic acid is effectively stabilized.

In the preferred embodiment, this means that Fe^{2+} ions in the FeMTA solution are at least partly oxidized to form Fe^{3+} and precipitation of Fe(II)mesotartrate complex is prevented at least to a large extent. This way the FeMTA concentration can effectively be stabilized.

[0009] EP 0 517 234 relates to a method of regenerating an aluminium surface cleaning agent which is used in an aluminium surface cleaning bath. This method comprises the following steps: (a) supplying the cleaning agent to the anode chamber of an electrolytic tank being separated into an anode chamber and cathode chamber by a partition, said cleaning agent including ferrous ions reduced during the cleaning of the aluminium surface, (b) oxidizing the ferrous ions electrolytically into ferric ions, and (c) returning the cleaning agent containing the ferric ions to the cleaning bath from the electrolytic tank, wherein the cleaning agent is regulated to have a pH value of 0.6 - 2.0, wherein sulfuric acid, optionally together with nitric acid, is added to the cathode chamber of said electrolytic tank to regulate the pH value thereof, further including the step of replenishing iron ions by supplying ferric sulfate so as to replenish ferric ions and

sulfuric ions. Tartaric acid may be present in the cleaning solution. The aim here is to replenish an electron acceptor by way of electrolysis. This document does not disclose maintaining a solubility balance of a non-caking agent to keep said agent in solution over a longer period of time by using an electrolytic cell to oxidize Fe^{2+} . On the contrary, it discloses that a balance needs to be maintained as too many ferric ions will adversely affect the etching rate and in the case of a

[0010] The oxidation step according to the present invention can, e.g., be carried out in a circulation loop and/or in a batch of a prepared aqueous non-caking solution according to the present invention, preferably being a FeMTA based aqueous solution, and most preferably being a FeMTA solution. It can also be carried out in a dosing station where the prepared solution is metered and dispensed by spraying or pouring it over an amount of salt.

[0011] The electrolytic oxidation step can be carried out in one or more electrolytic cells comprising an anode and a cathode in an electrolyte, optionally separated by a separator. Oxidation of Fe^{2+} to Fe^{3+} takes place at the anode. To this end the aqueous non-caking agent solution according to the present invention, preferably the FeMTA based aqueous solution and most preferably the FeMTA solution, is passed along the anode in order to provide transport of Fe^{2+} towards the anode surface where it can be oxidized into Fe^{3+} under the influence of an electric potential.

The anode can be made of a suitable material that allows selective oxidation of Fe^{2+} without the oxidation of other species present in the aqueous mixture, preferably being the FeMTA mixture, and that does not oxidize under the process conditions. Suitable materials include, e.g., platinum, platinized titanium, carbon or $\text{RuO}_2/\text{IrO}_2$ coated titanium (DSA®) or any other stable electrode material.

[0012] At the cathode a reduction reaction takes place consuming electrons released at the anode. Suitable reduction reactions include, e.g., water reduction to produce hydrogen and hydroxyl ions or the reduction of protons to hydrogen.

[0013] Any other reaction can also be applied as long as the products are compatible with the electrode fluid and do not cause deactivation of the electrode.

[0014] The electrodes can be flat plates, gauze, wires or made of a suitable porous material such as foam, felt or a bed of particles.

[0015] To reduce the risk of reduction of Fe^{3+} to Fe^{2+} at the cathode a separator can be disposed between the anode and the cathode. The separator can be for example a porous or non-porous separator. Porous separators can be a porous diaphragm, for instance porous glass (e.g., sintered glass), porous polymeric or ceramic membranes or a non-woven porous material. Non-porous separators can for example be membranes, e.g., ion exchange membranes such as anion exchange membranes or cation exchange membranes. Alternatively, the electrolytic oxidation can take place in an electrolytic cell without a separator between the anode and the cathode.

[0016] The electrolytic cell can for instance comprise a catholyte of 1-3 M HCl aqueous solution, although higher or lower HCl concentrations can also be used if so desired. Depending on the electrochemical cell configuration and the optionally applied separator, alternative catholytes can also be used, such as aqueous solutions of salts, such as sodium chloride, sodium sulfate or any other suitable electrolyte.

[0017] If an electrolytic cell is used without a separator, reduction of Fe^{3+} at the cathode can for example be achieved by using a cathode with an electrode surface area which is smaller than the electrode surface area of the anode. The cathode surface area can for instance be less than 50%, e.g. less than 20%, e.g. less than 2% of the anode electrode surface area. Alternatively, or additionally, a cathode can be used of a material which is more selective towards reactions other than Fe^{3+} reduction, for example a platinum-containing cathode material which is more selective to the reduction of H^+ to H_2 . A further possible way to minimize reduction of Fe^{3+} at the cathode is to control flow conditions in such a way that only a small part of the aqueous solution of non-caking agent according to present invention and preferably the FeMTA solution is subjected to cathodic reduction.

[0018] The aqueous solution of non-caking agent preferably a non-caking agent solution based on FeMTA, and more preferably a FeMTA solution, can for example be circulated along the anode of one or more of the at least one electrolytic cells, e.g., via a loop operatively connected to a discharge for discharging the solution based on FeMTA, or preferably the FeMTA solution, e.g., to a dispensing station, and a supply for supplying fresh solution based on FeMTA, or preferably fresh FeMTA solution.

[0019] Although the aqueous solutions based on FeMTA may in practice for example have an iron content below 5 wt.% by weight of the total solution, it has been found that the FeMTA concentration can effectively be stabilized by subjecting the FeMTA based solution to an electrolytic oxidation step maintaining the Fe^{2+} content below, e.g., 3 wt.% by weight of the total iron content.

[0020] Preferably, at least 50 wt.%, e.g., at least 80 wt.% or at least 95 wt.% of the Fe^{2+} in the solution is oxidized to Fe^{3+} .

[0021] Typically, the aqueous solution based on FeMTA which is subjected to the electrolytic oxidation step according to the present invention comprises at least 0.0001 wt% of iron (i.e. the amount of Fe^{2+} and Fe^{3+} together) based on the total weight of said solution. It typically comprises at most 20 wt% of iron, preferably at most 10 wt% of iron, and most preferably at most 5 wt% of iron, based on the total weight of said solution.

[0022] The electric potential to be used in the electrolytic cell can be fine-tuned by routine optimization to maximize Fe^{2+} oxidation and to reduce the production of by-products.

[0023] The application also relates to a station for preparing an aqueous solution of a non-caking agent viz. an iron salt of an organic acid with a ferric component and a ferrous component of less solubility than the ferric component, preferably an aqueous solution comprising FeMTA, and most preferably an aqueous solution of FeMTA, said station comprising a circulation loop and/or a reservoir containing the solution, wherein the circulation loop and/or the reservoir comprise at least one electrolytic cell, as disclosed above.

[0024] If the electrolytic cell comprises a separator between the anode and the cathode, the anolyte space between the anode and the separator of the one or more electrolytic cells can for example be part of a circulation loop. The anode can for instance be made of a porous structure that is part of the circulation loop through which the anolyte fluid is transported. In such a case the anode and the separator may be wholly or partly positioned against each other.

[0025] The station can for instance form part of a dispensing station for dosing an aqueous solution according to the invention, which forms the subject-matter of claim 10, preferably a FeMTA based solution, and most preferably a FeMTA solution, as a non-caking agent, e.g., in salt, in particular sodium chloride in any grade of purity.

[0026] An exemplary embodiment of the invention will be further explained with reference to the accompanying drawing.

[0027] Figure 1: shows schematically an electrolyte cell for use with the present invention.

[0028] During storage of a concentrated and/or diluted aqueous solution according to the present invention, viz. of an iron salt of an organic acid with a ferric component and a ferrous component of less solubility than the ferric component, preferably being concentrated and diluted aqueous solutions based on FeMTA and most preferably being the concentrated and diluted aqueous FeMTA solutions, part of the Fe^{3+} content will be reduced to Fe^{2+} . Subsequently, the Fe^{2+} will precipitate from the solution as the Fe(II) salt of the organic acid, for instance $\text{Fe(II)mesotartrate}$, as soon as its solubility is crossed. To reduce this risk, the aqueous solution according to the present invention (preferably the FeMTA (based) aqueous solution) is subjected to an electrolytic oxidation step carried out with one or more electrolytic cells. Figure 1 shows an exemplary embodiment of such an electrolytic cell.

[0029] The electrolytic cell 1 comprises an anode 2 and a cathode 3. The anode 2 and the cathode 3 are separated by a non-porous ion exchange membrane 4.

[0030] A catholyte is circulated between a catholyte reservoir 5 and the catholyte space 6 between the cathode 3 and the membrane 4. In the shown example the catholyte comprises a 1-3 M HCl aqueous solution.

[0031] Similarly, an aqueous solution of non-caking agent (preferably being a FeMTA (based) solution) is circulated between an anolyte reservoir 7 and the anolyte space 8 between the anode 2 and the membrane 4.

[0032] An electric power supply unit 9 provides an electric potential difference between the anode 2 and the cathode 3. At the cathode 3 hydrogen ions (H^+) are electrochemically reduced to form hydrogen (H_2). Chloride (Cl^-) ions migrate from the catholyte space 6 via the ion exchange membrane 4 and the anolyte space 8 towards the anode 2. At the anode 2, Ferrous (Fe^{2+}) ions are oxidized to Ferric (Fe^{3+}) ions.

[0033] Oxidation of Fe^{2+} to Fe^{3+} reduces the Fe^{2+} content and consequently stops and reverses the precipitation of the Fe(II) salt of the organic acid, for example $\text{Fe(II)mesotartrate}$. So solid Fe(II) salt of the organic acid, e.g. $\text{Fe(II)mesotartrate}$, will slowly dissolve. This way, the content of the Fe^{3+} salt of the organic acid in the aqueous solution, e.g. the FeMTA content in the aqueous solution, is stabilized.

[0034] The aqueous solution e.g. the FeMTA solution, can be discharged from the reservoir to be dosed to an amount of sodium chloride, if so desired, and the aqueous solution of non-caking agent, e.g. the FeMTA solution, can be replenished with a fresh supply.

[0035] The present invention is further illustrated by the following examples.

Example 1

[0036] An electrochemical reactor was constructed in the form of a glass beaker with two graphite anode rods (diameter 10 mm x 50 mm high) vertically positioned and a 20 mm diameter glass tube with a glass frit in the bottom and containing platinum cathode wire gauze. An Ag/AgCl/saturated KCl reference electrode was positioned in the anode compartment near one of the graphite anodes. An aqueous solution based on FeMTA produced according to Example 4a of WO 2010/139587 with 15 hours of boiling was filtered prior to electrolysis to remove any precipitated $\text{Fe(II)mesotartrate}$. The electrochemical reactor was filled with an amount of the FeMTA solution. The level of the catholyte compartment was maintained lower than the level in the anolyte compartment by means of pumping out catholyte in order to create a net flow of FeMTA solution from the anolyte compartment via the glass frit into the catholyte compartment. The anode and cathode were connected to a DC power supply and an electric potential was applied between the anode and the cathode in such a way that the measured potential between anode and reference electrode was between +0.85 and +0.97 volts. The Fe(II) content of the solution was measured in samples taken during electrolysis and the results are shown in the table. The treated anolyte remained clear after more than one week, indicating that the FeMTA is stabilized by the electrochemical treatment.

Time	Anode Potential	Fe(II) content
[min]	[volts]	[wt% of total iron]
0	Not measured	1.74
110	0.85	1.38
220	Not measured	0.96
330	0.953	0.61
480	0.973	0.39

Example 2

[0037] An aqueous solution based on FeMTA was produced as described in Example 1. The pH of the solution was set at 4.35. It was used for metering onto an amount of salt using a dosing unit as described in EP2012/074188. After a while, greyish solids precipitated in the concentrated FeMTA buffer tank. A sample of these solids (Sample A) was analyzed with X-ray Diffraction (XRD) and Inductively Coupled Plasma Emission Spectrometry (ICP-ES) and chromatography.

[0038] More particularly, XRD investigations were performed in order to study the presence of *crystalline* phase(s) and to determine their chemical and structural composition. The diffractogram has been recorded on a Bruker D8 diffractometer, using a standard sample holder.

[0039] Settings: Cu K α irradiation, 2 θ range: 5-75°, 0.02° steps, 16.5 sec integration time per step, a variable divergence slit of 20 mm and a detector slit of 0.6 mm. A graphite monochromator was used to suppress fluorescence, a lower background signal thus being obtained.

[0040] The diffractogram was analyzed using the Topas software package from Bruker. A quantitative assignment of the *crystalline* phase(s) observed was made by Rietveld refinement using reference diffractograms taken from the ICDD, ICSD and/or COD database (ICDD, International Centre for Diffraction Data, Powder Diffraction file, Full File 2007, ICSD, International Crystal Structure Database, <http://www.fiz-karlsruhe.de/icdd.html>, COD, Crystallography Open Database, <http://www.crystallography.net/>).

The crystalline phase(s) of the sample could be identified with one single compound fitting all the measured diffraction positions. This structure was adopted from a similar Cobalt complex (COD- 2204721). See also Dai-Xi Li, Duan-Jun Xu and Yuan-Zhi Xu, Acta Crystallographica, Section E 60(12) (2004) 1982-1984). Because iron and cobalt are adjacent in the periodic table, are both divalent, and have a comparable atomic radius (156 and 150, respectively), the element replacement is justified.

[0041] The diffractogram of the sample is given in Figure 2, together with the model fit. The diffractogram of the model fitted the measured data very well, only slight discrepancies in measured and modelled intensity could be observed, which were caused by the measurement method which used a model to describe the beam and diffractometer geometry. The difference of the fit from the measured data is shown below the curves in grey.

[0042] The brutto formula of the complex was $\{[\text{Fe}(\text{C}_4\text{H}_4\text{O}_6)(\text{H}_2\text{O})_2](\text{H}_2\text{O})_n\}_m$.

A representation of the structure is given in Figure 3. The compound is an iron polymeric complex, where an iron atom is coordinated by two tartrate dianions and two water molecules in an octahedral geometry. The hydroxyl oxygen atom and one oxygen atom of each carboxyl group chelate to the iron atom, but the other oxygen atom of this carboxyl group is uncoordinated. The polymeric chains are linked to each other via hydrogen bonds to form cavities, which are filled with solvent water molecules.

[0043] Inductively Coupled Plasma Emission Spectrometry (ICP-ES) experiments were performed by digesting a sample of the solids by a closed vessel micro-wave destruction using nitric acid. The element concentrations were measured by radial viewed ICP-ES (Spectro Arcos NT). Scandium was used as internal standard.

[0044] The results are reported in Tables 1 and 2.

Table 1 : Main element concentrations as determined by ICP-ES.

Element (% m/m)	Solids from Sample A
Fe	21 - 22
Mn	0.39 - 0.41

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Table 2 : Minor and trace element concentrations as determined by ICP-ES.

Element (mg/kg)	Sample A	LOD* (mg/kg)
Al	8.8 - 11	1
As	< 10	10
B	< 2	2
Ba	3.2 - 3.9	0.1
Be	< 0.05	0.05
Ca	140 - 140	1
Cd	< 0.2	0.2
Co	32 - 32	1
Cr	3 - 3	1
Cu	64 - 67	1
Fe	see Table 1	1
K	< 10	10
Li	< 0.5	0.5
Mg	330 - 340	0.1
Mn	see Table 1	0.5
Mo	<5	5
Na	790 - 810	10
Ni	16 - 17	2
P	41 - 43	5
Pb	< 10	10
S	62 - 64	5
Sb	< 10	10
Se	< 20	20
Si	30 - 37	5
Sn	< 10	10
Sr	0.1 - 0.2	0.1
Ti	12 - 13	0.5
V	< 2	2
Zn	42 - 44	1
Zr	< 2	2
*LOD is level of detection		

[0045] Sample A was also analyzed via chromatography using as column a stainless steel tube, length 300 mm, internal diameter 7.8 mm, IOA 1000 Organic Acids, as supplied by Alltech (No. 9646), and as mobile phase sulfuric acid, $c(\text{H}_2\text{SO}_4) = 0.01 \text{ mol/l}$.

[0046] The results of the determination of meso- D,L-TA, and impurities are shown in Table 3.

Table 3: Results of the determination of TA and impurities in solid sample from mTA dosing

	Meso-TA (0 aq) (wt %)	D,L-TA (wt %)	Oxalic acid (0 aq) (wt %)	Dihydroxy malonic acid' (wt %)	Monohydroxy malonic acid (wt %)	Acetic acid (wt %)
Sample A	54.9	n.d.	0.1	< 0.1	0.1	< 0.1
Remark: n.d. = not detectable;						

Conclusions:

[0047] The bruto formula of the complex is $\{[\text{Fe}(\text{C}_4\text{H}_4\text{O}_6)(\text{H}_2\text{O})_2](\text{H}_2\text{O})_n\}_m$. The compound is an iron polymeric complex, where an iron atom is coordinated by two tartrate dianions and two water molecules in an octahedral geometry. The iron is in the 2+ state. The solids consist for 54.9 wt% of tartrate in the mesoform (the remainder being iron, water, and some minor impurities). Tartrates in the D or L form were not detected. Side products were also not detected. Sample A contained a large amount of iron (22 wt%) and a small amount of manganese (0.4 wt%). Some trace metals like calcium and magnesium were detected.

Example 3

[0048] An aqueous solution based on FeMTA was produced as described in Examples 1 and 2. The original pH 3.8 of this solution was decreased to 3.5 by the addition of 1M HCl and subsequently further in steps of 0.5 pH unit to ultimately pH 1. For comparative reasons a diluted (0.7 wt% Fe) aqueous solution of FeCl_3 was subjected to stepwise pH increase by addition of a diluted NaOH aqueous solution. At all these various pH values the free Fe^{3+} concentration was measured using an EG&G Instruments potentiostat/ galvanostat model 263A.

[0049] As shown in Figure 4, at a pH higher than 2.5, precipitation of $\text{Fe}(\text{OH})_3$ is observed. In the presence of meso-tartaric acid, at a pH above 2.5, Fe^{3+} remains in solution as it forms a complex with the meso-tartaric acid. If the pH increases over 4.5, however, this complex starts to break down and Fe^{3+} starts to precipitate from the solution as $\text{Fe}(\text{OH})_3$.

[0050] In Figure 4, the influence of the pH on the free Fe(III) concentration is shown, wherein

-♦- is used for the aqueous solution based on FeMTA

-■- is used for the aqueous FeCl_3 solution

Example 4 and Comparative Examples A-E

Samples:

[0051]

Sodium Chloride: Sanal P

- For Example 4: The additive is a FeMTA based solution (comprising 43.3 g of H_2O , 2.12 g of FeCl_3 , 0.43 g of racemic tartaric acid, 0.9 g of meso-tartaric acid, H_2O , and 3.28 g of sodium hydroxide). The mTA:Fe ratio is 1:1.
- For Comparative Examples A-E: The composition of additive solutions A-E can be found in Table 4. These are compositions according to EP 0 517 234.

[0052] The dosing conditions can also be found in Table 4.

Equipment

[0053] Powder Flow Analyzer/Rheometer, type TA-XT2i, from Stable Micro Systems.

[0054] The cakeability was determined by continuously measuring the force and torque imposed on the powder by a moving blade. When the force is plotted against the travelling depth in the sample, the integral underneath the curve equals the amount of consumed energy (CE).

Procedure

[0055] Salt was distributed in representative portions.

[0056] The following pretreatment was applied to determine the degree of caking.

- A plastic bag of suitable size was charged with 49 ± 0.1 g of salt.
- Additive solutions A, B, C, D, E and FeMTA solution and demineralized water were added to the salt samples, resulting in a water content of 2 wt% for each salt sample.
- Salt and liquid were mixed by hand in a closed plastic bag for about 2 minutes, until a visually homogeneous mixture was obtained.
- The resulting mixture was filled into the aeration cylinder.
- The sample was consolidated by applying a 1 kg weight using the rheometer.
- The sample was dried with compressed air, which was introduced through the bottom of the cylinder (1.5 l/min) for at least 12 hours.

[0057] After drying, the force to break the cake with the helical blade was measured over a distinct range of bed height (7-19 mm). From this the CE_4 value was calculated, which corresponds to the caking energy in mJ measured over a range of 4 mm bed height.

[0058] The settings of the rheometer are displayed in Table 5.1 and Table 5.2.

Table 4: composition of additive solutions A-E and concentrations for the addition to sodium chloride ("salt"):

Composition (g)	Comp. Ex. A	Comp. Ex. B	Comp. Ex. C	Comp. Ex. D	Comp. Ex. E
Fe(II)SO ₄ ·7H ₂ O	0.75	1.5	0.1	2.0	0.76
H ₂ SO ₄	1.27	0.98	0.48	2.88	0
HNO ₃	0.1	0.1	0.1	0.1	0.1
H ₂ O	97.88	97.4	99.32	95.01	99.14
DL tartaric acid	0.2	0.19	0.2	0.2	0.2
Total	100.20	100.18	100.20	100.19	100.20
pH	0.79	0.90	1.09	0.49	1.94
Addition to sodium chloride (49 g)					
Sample (μl)	100	50	748	37	98
H ₂ O (μl)	900	950	252	963	902

[0059] In Example 4: Dosing 25 μl of FeMTA solution per 49 g of sodium chloride, and 975 μl of water per 49 g of sodium chloride.

Table 5.1: Rheometer settings for sample pretreatment

Target	Value	Tip speed	Angle
Position	85	10	90
Force	1000	10	178
Position	80	10	2
Position	130	10	90

Table 5.2: Rheometer settings for the determination of the cakeability

Target	Value	Tip speed	Angle
Position	55	10	90
Position	30	5	175
Position	100	14	45
Shake	15	0	0
Position	130	10	90

Results

[0060] The caking energy of the samples was measured in fourfold. The results are summarized in Table 6.

Table 6: Caking energy of measured samples:

	CE ₄ (N.mm)						
Test	Blank	Additive sol. according to Ex. 4	Additive solution A	Additive solution B	Additive solution C	Additive solution D	Additive solution E
1	45	9	53	54	38	54	39
2	34	10	41	64	82	37	32
3	33	8	66	45	58	50	23
4	35	7	29	56	40	52	26
average	37	9	47	55	54	48	30

[0061] It has been proven that the degree of caking of sodium chloride treated with additive solutions A-E is equal to or significantly higher than the degree of caking of sodium chloride as such. The degree of caking of sodium chloride treated with additives A-E is significantly higher than the degree of caking of sodium chloride treated with the additive solution of Example 4, viz. the FeMTA based solution.

Claims

1. Process for stabilizing an aqueous solution comprising an iron complex of an organic acid with a ferric component and a ferrous component of less solubility than the ferric component, the solution having a pH between 3 and 5, wherein the solution is at least partly subjected to electrolytic oxidation.
2. Process according to claim 1 wherein the solution is an aqueous solution comprising an Fe³⁺ complex of meso-tartaric acid.
3. Process according to claim 2 wherein the electrolytic oxidation is carried out in at least one electrolytic cell (1), with a separated anode (2) and cathode (3).
4. Process according to claim 3 wherein the anode and cathode are separated by a porous or a non-porous separator (4).
5. Process according to claim 4 wherein the anode (2) and cathode (3) are separated by a non-porous separator (4) comprising an anion exchange membrane and/or a cationic exchange membrane.
6. Process according to claim 5 wherein the electrolytic cell (1) comprises a catholyte of 1 -3 M HCl aqueous solution.
7. Process according to any one of preceding claims 3 - 6 wherein an aqueous solution comprising FeMTA is circulated

along the anode (2) of one or more of the at least one electrolytic cells.

8. Process according to any one of the preceding claims wherein the aqueous solution comprising FeMTA has an iron content below 5 wt.% by weight of the total solution and wherein the electrolytic oxidation step is carried out to maintain the Fe²⁺ content below 3 wt.% by weight of the total iron content.

9. Process according to any one of the preceding claims wherein at least 50 wt.%, e.g., at least 90 wt.% or at least 95 wt.%, of the Fe²⁺ in the solution is oxidized to Fe³⁺.

10. Dispensing station for dosing an aqueous solution of an iron complex of an organic acid with a ferric component and a ferrous component of less solubility than the ferric component, preferably a non-caking agent based on FeMTA, on salt, wherein the dispensing station for dosing comprises:

- an electrolytic cell for the oxidation of Fe²⁺, said electrolytic cell comprising an anode (2), a cathode (3), and a separator (4) separating the anode from the cathode;
- means for metering the aqueous solution from the electrolytic cell and dispensing it by spraying or pouring it over an amount of the salt.

Patentansprüche

1. Verfahren zur Stabilisierung einer wässrigen Lösung mit einem Eisenkomplex einer organischen Säure mit einem Eisen(III)-haltigen Bestandteil und einem Eisen(II)-haltigen Bestandteil von geringerer Löslichkeit als der Eisen(III)-haltige Bestandteil, wobei die Lösung einen pH zwischen 3 und 5 aufweist, wobei die Lösung zumindest teilweise elektrolytischer Oxidation unterliegt.

2. Verfahren nach Anspruch 1, wobei die Lösung aus einer wässrigen Lösung mit einem Fe³⁺ Komplex von meso-Weinsäure besteht.

3. Verfahren nach Anspruch 2, wobei die elektrolytische Oxidation in mindestens einer elektrolytischen Zelle (1) mit einer getrennten Anode (2) und Kathode (3) durchgeführt wird.

4. Verfahren nach Anspruch 3, wobei die Anode und die Kathode durch ein poröses oder ein nicht poröse Trennelement (4) getrennt sind.

5. Verfahren nach Anspruch 4, wobei die Anode (2) und die Kathode (3) durch ein nicht poröses Trennelement (4) mit einer Anionenaustauschmembran und/oder einer Kationenaustauschmembran getrennt sind.

6. Verfahren nach Anspruch 5, wobei die elektrolytische Zelle (1) einen Katolyt von 1-3 M HCl wässriger Lösung umfasst.

7. Verfahren nach einem der vorhergehenden Ansprüche 3 bis 6, wobei eine wässrige Lösung mit FeMTA an der Anode (2) von einer oder mehr der mindestens einen elektrolytischen Zellen geleitet wird.

8. Verfahren nach einem der vorhergehenden Ansprüche, wobei die FeMTA umfassende, wässrige Lösung einen Eisengehalt unter 5 Gew-% der gesamten Lösung aufweist und wobei der elektrolytische Oxidationsschritt durchgeführt wird, um den Fe²⁺ Gehalt unter 3 Gew-% des gesamten Eisengehaltes zu halten.

9. Verfahren nach einem der vorhergehenden Ansprüche, wobei mindestens 50 Gew-%, z.B. mindestens 90 Gew-% oder mindestens 95 Gew-%, des Fe²⁺ in der Lösung zu Fe³⁺ oxidiert werden.

10. Abgabestation zur Dosierung einer wässrigen Lösung eines Eisenkomplexes einer organischen Säure mit einem Eisen(III)-haltigen Bestandteil und einem Eisen(II)-haltigen Bestandteil von geringerer Löslichkeit als der Eisen(III)-haltige Bestandteil, vorzugsweise einem nicht zusammenbackenden Wirkstoff auf der Basis von FeMTA, auf Salz, wobei die Abgabestation zur Dosierung Folgendes umfasst:

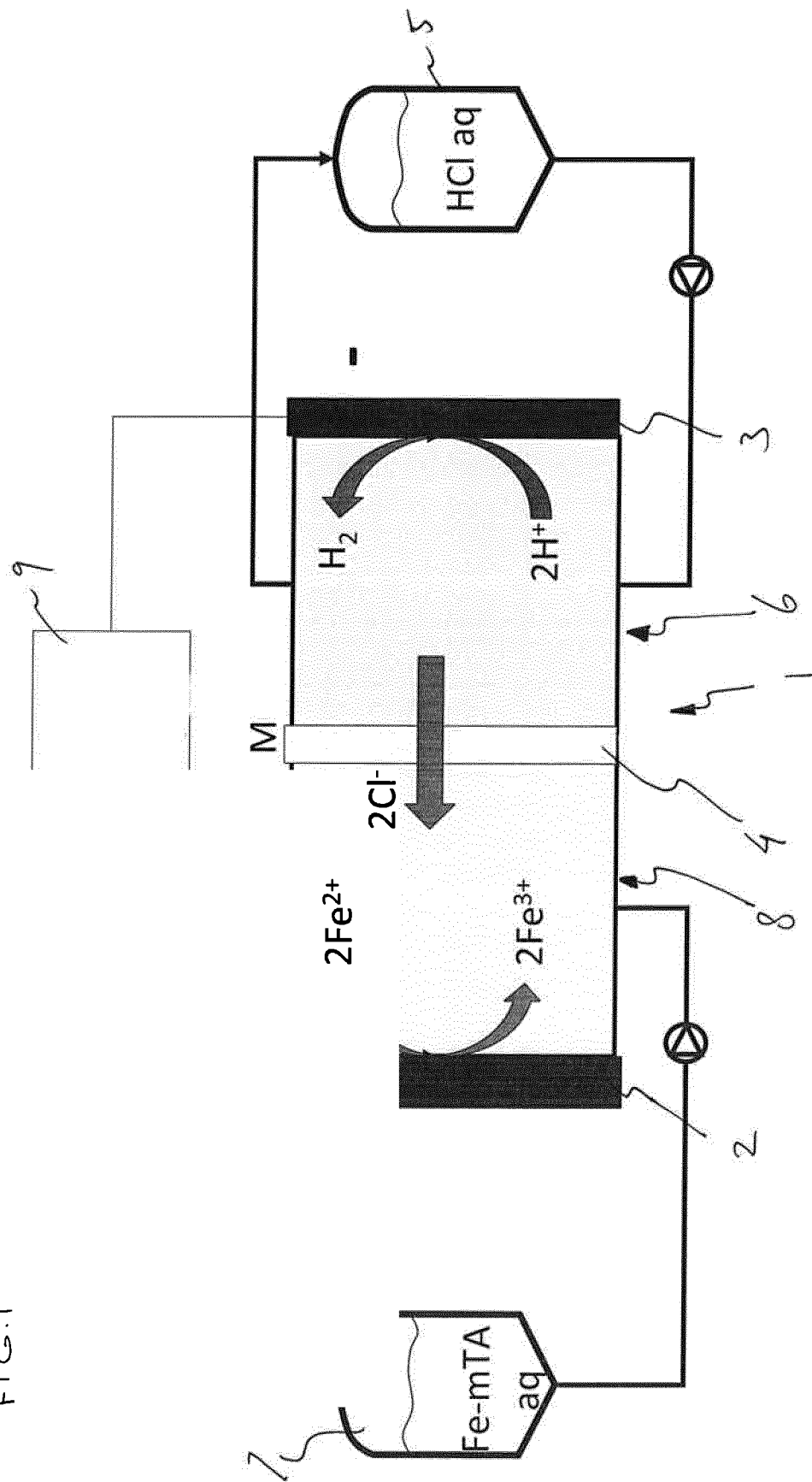
- eine elektrolytische Zelle für die Oxidation von Fe²⁺, wobei die elektrolytische Zelle eine Anode (2), eine Kathode (3) und ein Trennelement (4) umfasst, das die Anode von der Kathode trennt;
- Mittel zum Abmessen der wässrigen Lösung aus der elektrolytischen Zelle und deren Abgabe, indem sie über

eine Menge des Salzes gesprüht oder gegossen wird.

Revendications

1. Procédé de stabilisation d'une solution aqueuse comprenant un complexe de fer d'un acide organique avec un composant ferrique et un composant ferreux de solubilité inférieure à celle du composant ferrique, la solution ayant un pH compris entre 3 et 5, où la solution est au moins partiellement soumise à une oxydation électrolytique.
2. Procédé selon la revendication 1, dans lequel la solution est une solution aqueuse comprenant un complexe Fe^{3+} d'acide méso-tartrique.
3. Procédé selon la revendication 2, dans lequel l'oxydation électrolytique est effectuée dans au moins une cellule électrolytique (1), avec une anode (2) et une cathode (3) séparées.
4. Procédé selon la revendication 3, dans lequel l'anode et la cathode sont séparées par un séparateur (4) poreux ou non poreux.
5. Procédé selon la revendication 4, dans lequel l'anode (2) et la cathode (3) sont séparées par un séparateur non poreux (4) comprenant une membrane échangeuse d'anions et/ou une membrane échangeuse de cations.
6. Procédé selon la revendication 5, dans lequel la cellule électrolytique (1) comprend un catholyte de solution aqueuse de HCl à 1-3 M.
7. Procédé selon l'une quelconque des revendications précédentes 3 à 6, dans lequel une solution aqueuse comprenant du FeMTA est mise en circulation le long de l'anode (2) d'une ou de plusieurs de l'au moins une cellule électrolytique.
8. Procédé selon l'une quelconque des revendications précédentes, dans lequel la solution aqueuse comprenant du FeMTA a une teneur en fer inférieure à 5% en poids de la solution totale et dans lequel l'étape d'oxydation électrolytique est effectuée pour maintenir la teneur en Fe^{2+} inférieure à 3% en poids de la teneur totale en fer.
9. Procédé selon l'une quelconque des revendications précédentes, dans lequel au moins 50% en poids, par exemple, au moins 90% en poids ou au moins 95% en poids du Fe^{2+} dans la solution sont oxydés en Fe^{3+} .
10. Station de distribution pour doser une solution aqueuse d'un complexe de fer d'un acide organique avec un composant ferrique et un composant ferreux de solubilité inférieure à celle du composant ferrique, de préférence un agent non agglutinant à base de FeMTA, sur un sel, où la station de distribution pour le dosage comprend:
 - une cellule électrolytique pour l'oxydation de Fe^{2+} , ladite cellule électrolytique comprenant une anode (2), une cathode (3) et un séparateur (4) séparant l'anode de la cathode ;
 - un moyen pour doser la solution aqueuse à partir de la cellule électrolytique et pour la distribuer par pulvérisation ou coulée de celle-ci sur une quantité du sel.

FIG. 1



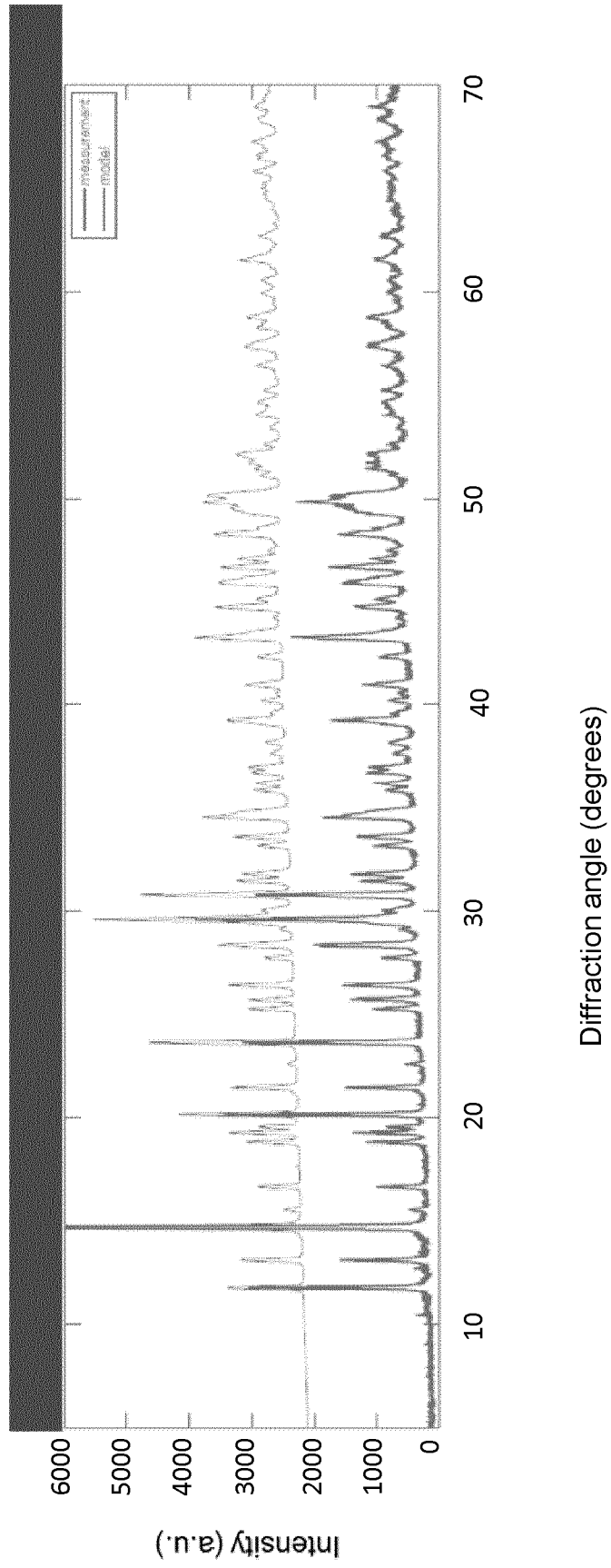


Figure 2

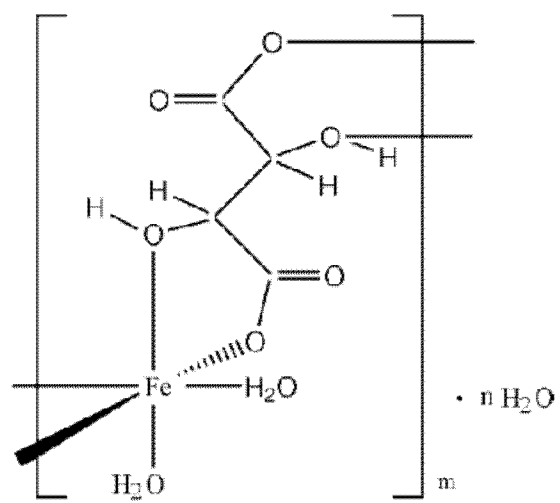


Figure 3

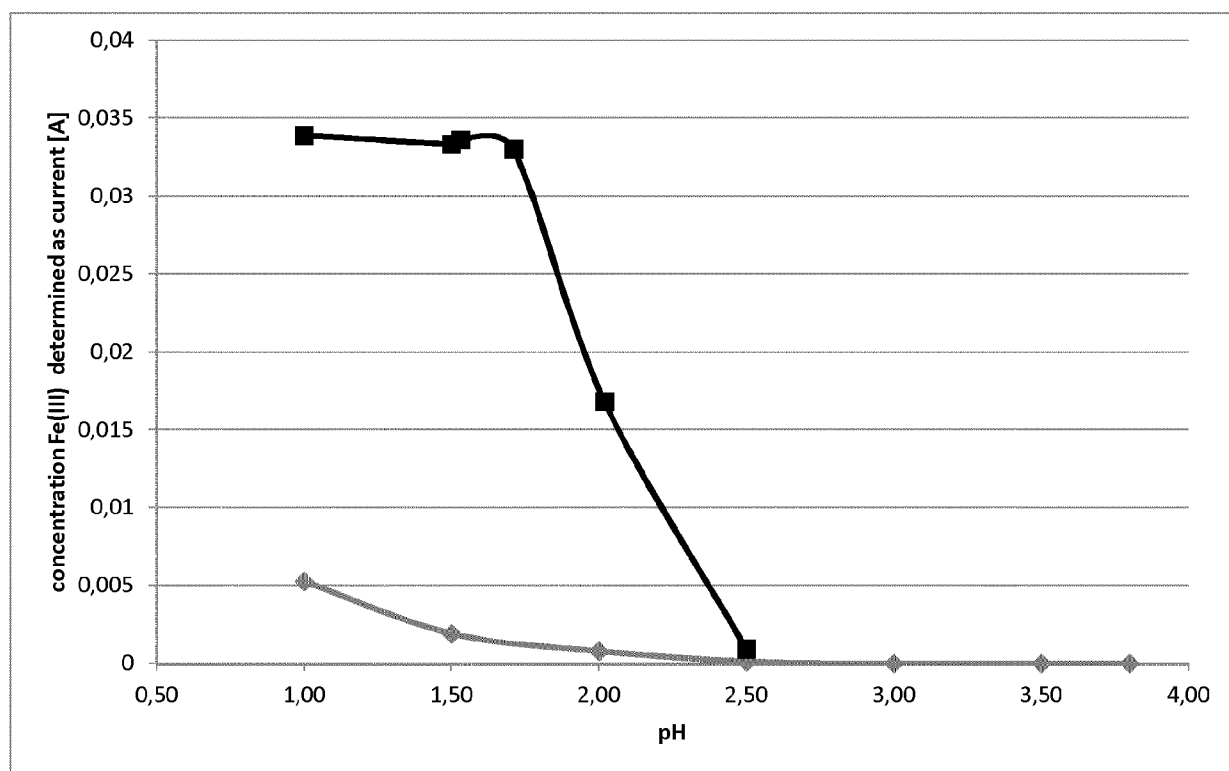


Figure 4

REFERENCES CITED IN THE DESCRIPTION

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Szabadalmi igénypontok

1. Eljárás szerves sav vas komplexét tartalmazó vizes oldat stabilizálására, amely tartalmaz egy vas(III) tartalmú komponenst és egy vas(II) tartalmú komponenst, amely kevésbé oldódik, mint a vas(III) komponens, ahol az oldat pH értéke 3 és 5 közötti, ahol az oldatot legalább részben elektrolitikus oxidálásnak tesszük ki.
2. Az 1. igénypont szerinti eljárás, ahol az oldat vizes oldat, amely mezo-borkósav Fe^{3+} komplexét tartalmazza.
3. A 2. igénypont szerinti eljárás, ahol az elektrolitikus oxidálást legalább egy elektrolitikus cellában (1) végezzük, amely elkülönített anódot (2) és katódot (3) tartalmaz.
4. A 3. igénypont szerinti eljárás, ahol az anód és a katód porózus vagy nem porózus elválasztó elemmel (4) van elkülönítve.
5. A 4. igénypont szerinti eljárás, ahol az anód (2) és katód (3) nem porózus elválasztó elemmel van elkülönítve, amely tartalmaz egy anioncserélő membránt és/vagy kationcserélő membránt.
6. Az 5. igénypont szerinti eljárás, ahol az elektrolitikus cella (1) 1-3 mol/l vizes HCl oldat katólitot tartalmaz.
7. A 3-6. igénypontok bármelyike szerinti eljárás, ahol FeMTA-t tartalmazó vizes oldatot keringtetünk a legalább egy elektrolitikus cella közül egy vagy több cella anódja (2) mentén.
8. Az előző igénypontok bármelyike szerinti eljárás, ahol az FeMTA-t tartalmazó vizes oldat vas tartalma 5 tömeg% alatti, a teljes oldatra vonatkoztatva, és ahol az elektrolitikus oxidálást megvalósításával az Fe^{2+} tartalmat 3 tömeg% alatt tartjuk, a teljes vas tartalomra vonatkoztatva.
9. Az előző igénypontok bármelyike szerinti eljárás, ahol az oldatban az Fe^{2+} legalább 50 tömeg%, például legalább 90 tömeg% vagy legalább 95 tömeg% részét Fe^{3+} állapotra oxidáljuk.
10. Adagoló eszköz szerves sav vas komplexét tartalmazó vizes oldat sóra történő adagolására, amely oldat tartalmaz egy vas(III) tartalmú komponenst és egy vas(II) tartalmú komponenst, amely kevésbé

oldódik, mint a vas(III) komponens, előnyösen FeMTA alapú, összesülést gátló hatóanyagot, ahol az adagoló eszköz tartalmaz:

- egy elektrolitikus cellát Fe^{2+} oxidálására, amely elektrolitikus cella tartalmaz egy anódot (2), egy katódot (3) és egy elválasztó elemet (4) az anód és a katód elkülönítésére;
- eszközöket az elektrolitikus cellából származó vizes oldat mérésére és adagolására, amelynek során azt a só egy mennyiségére permetezzük vagy öntjük.