Claims

1. A process for producing ammonia and aqueous sulfuric acid from ammonium-sulfate-rich waters, executed in an operating mode selected from the group of the following operating modes: semi-batch, feed-and-bleed and single pass;
said process having the following non-chronological steps:

a) providing at least one electrochemical cell having the following features:

i) the electrochemical cell includes an anodic electrode chamber in which an anode is arranged;

ii) the electrochemical cell includes a cathodic electrode chamber in which a cathode is arranged;

iii) the electrochemical cell includes a stack having the following structure:

- the stack has repeating units, the number of repeating units is exactly *n*, where *n* is a natural number;
- the stack has primary compartments, the number of primary compartments is exactly *n*;
- the stack has secondary compartments, the number of secondary compartments is exactly *n*;
- the stack has separators, the number of separators is exactly *s*, where *s* is calculated as follows: *s = 2*n-1;*
- the primary and secondary compartments are arranged alternately in the stack and are each separated from one another by a separator;
- each separator is either an anion-conducting membrane or a bipolar membrane;
- the number *a* of separators that are an anion-conducting membrane is determined as follows:
  a = 1 when *n* = 1, and *a* = *n*-1 when *n* > 1;
- the number *b* of separators that are a bipolar membrane is determined as follows:
  b = 0 when *n* = 1, and *b* = *n* when *n* > 1;
- when n > 1, the separators that are an anion-conducting membrane and the separators that are a bipolar membrane are arranged alternately within the stack;
- each primary compartment is arranged on the anode side of an adjoining bipolar membrane, where the adjoining bipolar membrane does not need to be part of the stack;

- each secondary compartment is arranged on the cathode side of an adjoining bipolar membrane, where the adjoining bipolar membrane does not need to be part of the stack;

iv) the electrochemical cell includes two end membranes, the first end membrane being arranged between the stack and anodic electrode chamber, the second end membrane being arranged between the stack and the cathodic electrode chamber, both end membranes being identically selected from the group consisting of the following membrane types: anion-conducting membrane, cation-conducting membranes, bipolar membrane;

v) each bipolar membrane is arranged in the electrochemical cell such that its positively charged portion is facing towards the anode, while its negatively charged portion is facing towards the cathode;

b) providing an electrical voltage source;

c) providing an ammonium-sulfate-rich water comprising water and ammonium sulfate;

d) providing an acidic electrolyte comprising water and sulfuric acid;

e) providing an electrode rinse solution comprising water, sulfuric acid and/or ammonium sulfate;

f) charging the primary compartments of the electrochemical cell with the ammonium-sulfate-rich water;

g) charging the secondary compartments of the electrochemical cell with the acidic electrolyte;

h) rinsing the electrode chambers with electrode rinse solution;

i) charging the electrochemical cell with an electrical voltage drawn from the electrical voltage source such that there is an electrical potential between the anode and the cathode;

j) discharging ammonia water from the primary compartments of the electrochemical cell;

k) discharging aqueous sulfuric acid from the secondary compartments of the electrochemical cell;

l) removing ammonia from the ammonia water, affording an ammonia-depleted water.

2. The process according to Claim 1, wherein the electrochemical cell has exactly one anodic electrode chamber, exactly one cathodic electrode chamber, exactly one stack and exactly two end membranes, and wherein the first end membrane directly adjoins the stack and anodic electrode chamber and that the second end membrane directly adjoins the stack and cathodic electrode chamber.

3. The process according to Claim 1 or 2, wherein the stack consists of the compartments and separators listed in Claim 1.

4. The process according to Claim 1, 2 or 3, wherein at least one compartment and/or at least one electrode chamber is spanned by a spacer.

5. The process according to any of Claims 1 to 4, executed in a system comprising a large number of electrochemical cells connected to the electrical voltage source in parallel.

6. The process according to any of Claims 1 to 5, wherein the ammonia is removed from the ammonia water by stripping with air or nitrogen.

7. The process according to any of Claims 1 to 6, wherein the ammonia is removed from the ammonia water at a pressure of between 0 hPa and 1013 hPa.

8. The process according to Claim 1, executed in semi-batch operating mode,
wherein the ammonium-sulfate-rich water is provided in a primary reservoir vessel, wherein the ammonia-depleted water is transported to the primary reservoir vessel, and wherein a portion of the contents of the primary reservoir vessel is from time to time withdrawn and replaced with fresh ammonium-sulfate-rich water;
and/or wherein the acidic electrolyte is provided in a secondary reservoir vessel, wherein the aqueous sulfuric acid is transported to the secondary reservoir vessel, and wherein a portion of the contents of the secondary reservoir vessel is from time to time withdrawn and replaced with fresh acidic electrolyte or water.

9. The process according to Claim 1, executed in feed-and-bleed operating mode,
wherein the ammonium-sulfate-rich water is provided in a primary reservoir vessel, wherein the ammonia-depleted water is transported to the primary reservoir vessel, and wherein a portion of the contents of the primary reservoir vessel is continuously withdrawn and replaced with fresh ammonium-sulfate-rich water;
and/or wherein a portion of the ammonia-depleted water is ahead of transportation to the primary reservoir vessel continuously withdrawn and replaced with fresh ammonium-sulfate-rich water;
and/or wherein the acidic electrolyte is provided in a secondary reservoir vessel, wherein the aqueous sulfuric acid is transported to the secondary reservoir vessel, and wherein a portion of the contents of the secondary reservoir vessel is continuously withdrawn and replaced with fresh acidic electrolyte or water

and/or wherein a portion of the aqueous sulfuric acid is ahead of transportation to the primary reservoir vessel continuously withdrawn and replaced with fresh acidic electrolyte or water.

10. The process according to Claim 1, executed in single pass operating mode, wherein fresh ammonium-sulfate-rich water is continuously provided and ammonia-depleted water continuously discharged;
and/or wherein fresh acidic electrolyte is continuously provided and aqueous sulfuric acid continuously discharged.

11. The process according to any of Claims 8, 09 or 10, wherein the fresh ammonium-sulfate-rich water contains ammonium sulfate in a concentration of between 30% and 40% by weight based on the mass of the fresh ammonium-sulfate-rich water, where the pH of the fresh ammonium-sulfate-rich water measured using a glass electrode at 20°C is between 5 and 9.

12. The process according to any of Claims 1 to 11, wherein the electrode rinse solution is provided in a rinsing tank, and wherein the electrode rinse solution is continuously circulated from the rinsing tank into the two electrode chambers and from there back into the rinsing tank.

13. The process according to Claim 12, wherein the electrode rinse solution is passed successively through one electrode chamber and then through the other electrode chamber.

14. The process according to Claim 12 or 13, wherein the pH of the electrode rinse solution is continuously monitored, with water and/or sulfuric acid metered in if the nominal pH is exceeded and/or water and/or ammonium sulfate metered in if the pH falls below it.

15. The process according to any of Claims 12 to 14, wherein the filling level of the rinsing tank is continuously monitored, with electrolyte rinse solution run off if the nominal filling level is exceeded and/or water and/or sulfuric acid and/or ammonium sulfate metered in if the filling level falls below it.