membrane is permeable only to cations. The membrane may be a cation-exchange membrane. In the electrolytic cell, the first spent aqueous scrubbing liquid is regenerated by electrolysis. In regenerating the spent aqueous scrubbing liquid, a number of electrolytic cells connected in parallel may be used. Before being fed to the anode chamber, the spent aqueous scrubbing liquid may be filtered to remove particulate matter.

In one aspect, the present disclosure refers to a method of scrubbing a gas comprising carbon dioxide to deplete the gas of carbon dioxide (CO2), the method comprising the steps of scrubbing the gas in a scrubber with a first alkaline, aqueous scrubbing liquid to dissolve carbon dioxide (CO2) as hydrogen carbonate (HCO3-) and/or as carbonate (CO32-) in the first alkaline, aqueous scrubbing liquid, thereby providing a first spent aqueous scrubbing liquid comprising hydrogen carbonate (HCO3-) and/or carbonate (CO32-), the first spent aqueous scrubbing liquid having a pH from 7 to 9, feeding the first spent aqueous scrubbing liquid to an anode chamber of an electrolytic cell comprising the anode chamber and a cathode chamber separated by a membrane, regenerating the first spent aqueous scrubbing liquid in the electrolytic cell by electrolysis, the electrolysis increasing the pH of the first spent aqueous scrubbing liquid in the cathode chamber, the electrolysis further depleting the first spent aqueous scrubbing liquid of hydrogen carbonate (HCO3-) and of carbonate (CO32-) in the anode chamber by decreasing the pH, the regeneration further comprising generating gaseous hydrogen in the cathode chamber and a gaseous mixture of oxygen and carbon dioxide (CO2) in the anode chamber by electrolysis, and withdrawing regenerated alkaline, aqueous scrubbing liquid from the cathode chamber and re-circulating it to the scrubber wherein the gaseous hydrogen is withdrawn from the cathode chamber, and the gaseous mixture of oxygen and carbon dioxide is withdrawn from the anode chamber.

In electrolysis, water is converted into oxygen and hydronium ions (H_3O^+) at the anode, whereas water is converted into hydrogen and hydroxide ions (OH^-) at the cathode. The electrolysis thus increases the pH of the first spent aqueous scrubbing liquid in the cathode chamber and depletes the first spent aqueous scrubbing liquid of hydrogen carbonate (HCO_3^-) and of carbonate (CO_3^{2-}) in the anode chamber, by decreasing the pH to shift the equilibrium towards carbonic acid in turn shifted into carbon dioxide. The regeneration further comprises generating gaseous hydrogen in the cathode chamber and a gaseous mixture of oxygen and carbon dioxide in the

anode chamber by electrolysis. The chemical reactions and description of the operation of the processes are further described in the Detailed Description herein further below.

The method further comprises the step of withdrawing regenerated alkaline, aqueous scrubbing liquid from the cathode chamber and re-circulating it to the scrubber.

One key difference from the set-up of commercially available amine scrubbers is that the scrubbing liquid in the present method is regenerated by electrochemistry, while scrubbers in the art typically use large amounts of heat for regeneration of the scrubbing liquid used in the scrubber.

According to the present method, in regenerating the scrubbing liquid its pH is increased. Further, the regeneration, as already explained, also generates carbon dioxide and hydrogen, which may be used downstream for synthesis of organic compounds, such as methanol, thus adding further value to the process. The process is ideal for processes such as downstream Power-to-X processes.

The gaseous hydrogen is withdrawn from the cathode chamber and the gaseous mixture of oxygen and carbon dioxide is withdrawn from the anode chamber.

Withdrawing hydrogen, oxygen and carbon dioxide from the regeneration process is advantageous as hydrogen and oxygen can be used to generate electricity, e.g. by a fuel cell, to operate the process partly. Further, hydrogen and carbon dioxide (CO_2) can be used for synthesis of organic compounds, e.g. methanol, thereby compensating for the cost of running the process.

membrane. The anode chamber comprises an anode inlet for receiving the spent aqueous scrubbing liquid from the scrubber arrangement and an anode outlet for withdrawing oxygen and carbon dioxide. The regeneration arrangement may further comprise a filter for filtering spent aqueous scrubbing liquid to be fed to the anode inlet of the anode chamber. Further, the cathode chamber comprises an outlet for withdrawing regenerated aqueous scrubbing liquid and hydrogen. The outlet for spent aqueous scrubbing liquid of the scrubber is in flow communication with the inlet for the spent aqueous scrubbing liquid of the anode chamber. Similarly, the outlet for regenerated aqueous scrubbing liquid of the cathode chamber is flow communication with the inlet for the alkaline, aqueous scrubbing liquid of the scrubber.

In another aspect, the present disclosure refers to a system for scrubbing a gas comprising carbon dioxide to deplete the gas of carbon dioxide, the system comprising a scrubber arrangement (200) for scrubbing a gas with an alkaline, aqueous scrubbing liquid to dissolve carbon dioxide as hydrogen carbonate (HCO3-) and/or as carbonate (CO32-) in the alkaline, aqueous scrubbing liquid, thereby providing a spent aqueous scrubbing liquid comprising hydrogen carbonate (HCO_3^-) and/or carbonate (CO_3^{2-}), the spent aqueous scrubbing liquid having a pH from 7 to 9; and a regeneration arrangement for regenerating the spent aqueous scrubbing liquid by electrolysis, wherein the scrubber arrangement comprises a scrubber, the scrubber having an inlet for the gas to be scrubbed and an outlet for gas depleted of carbon dioxide, the scrubber further having an inlet for receiving the alkaline, aqueous scrubbing liquid and an outlet for withdrawing spent aqueous scrubbing liquid, and the regeneration arrangement comprises an electrolytic cell, comprising an anode chamber and a cathode chamber separated by a membrane, the anode chamber comprising an anode inlet for receiving the spent aqueous scrubbing liquid and an anode outlet for withdrawing oxygen and carbon dioxide, and the cathode chamber comprising an outlet for withdrawing regenerated aqueous scrubbing liquid and hydrogen, wherein the outlet for spent aqueous scrubbing liquid of the scrubber is in flow communication with the inlet for the spent aqueous scrubbing liquid of the anode chamber, and the outlet for regenerated aqueous scrubbing liquid of the cathode chamber is in flow communication with the inlet for the alkaline, aqueous scrubbing liquid of the scrubber for re-circulating the regenerated aqueous scrubbing liquid to the scrubber.

An advantage of this system is that it comprises both a scrubber arrangement and a regeneration arrangement where output from the scrubber arrangement can be regenerated by electrolysis and reused in the scrubber arrangement, enabling and optimizing a complete, energy and cost efficient system of depleting gas of carbon dioxide, driven by electrical power.

According to one example, the scrubber arrangement comprises a first and a second buffer tank for alkaline, aqueous scrubbing liquid. Further, the scrubber comprises at least a first and a second absorber. It may comprise more than two absorbers. Further, a number of scrubbers may be used. A number of scrubbers may be either connected in series or in parallel.

The first absorber comprises an inlet for receiving alkaline, aqueous scrubbing liquid from the first buffer tank. Further, the first absorber comprises an outlet for withdrawing spent aqueous scrubbing liquid from first absorber to feed to an inlet of the first buffer tank. Thus, alkaline, aqueous scrubbing liquid may be circulated between the first absorber and the first buffer tank. While the presence of the first buffer tank is preferred, it may according to some examples be dispensed with and the alkaline, aqueous scrubbing liquid may be re-circulated over the first absorber by a first pipe system connecting the inlet and the outlet of the first absorber. Further, the first buffer tank is in flow communication with the inlet for the spent aqueous scrubbing liquid of the anode chamber.

The second absorber comprises an inlet for receiving alkaline, aqueous scrubbing liquid from the second buffer tank. Further, the second absorber comprises an outlet for withdrawing spent aqueous scrubbing liquid from second absorber to feed to an inlet of the second buffer tank. Thus, alkaline, aqueous scrubbing liquid may be circulated between the second absorber and the second buffer tank. While the

CLAIMS

1. A method of scrubbing a gas comprising carbon dioxide to deplete the gas of carbon dioxide (CO_2), the method comprising the steps of:

- scrubbing the gas in a scrubber (210) with a first alkaline, aqueous scrubbing liquid to dissolve carbon dioxide (CO_2) as hydrogen carbonate (HCO_3^-) and/or as carbonate (CO_3^{2-}) in the first alkaline, aqueous scrubbing liquid, thereby providing a first spent aqueous scrubbing liquid comprising hydrogen carbonate (HCO_3^-) and/or carbonate (CO_3^{2-}), the first spent aqueous scrubbing liquid having a pH from 7 to 9;
- feeding the first spent aqueous scrubbing liquid to an anode chamber of an electrolytic cell (310) comprising the anode chamber (313) and a cathode chamber (312) separated by a membrane (311);
- regenerating the first spent aqueous scrubbing liquid in the electrolytic cell (310) by electrolysis, the electrolysis increasing the pH of the first spent aqueous scrubbing liquid in the cathode chamber (312), the electrolysis further depleting the first spent aqueous scrubbing liquid of hydrogen carbonate (HCO_3^-) and of carbonate (CO_3^{2-}) in the anode chamber (313) by decreasing the pH, the regeneration further comprising generating gaseous hydrogen in the cathode chamber (312) and a gaseous mixture of oxygen and carbon dioxide (CO_2) in the anode chamber (313) by electrolysis; and
- withdrawing regenerated alkaline, aqueous scrubbing liquid from the cathode chamber (312) and re-circulating it to the scrubber (210);

wherein:

- the gaseous hydrogen is withdrawn from the cathode chamber (312); and
- the gaseous mixture of oxygen and carbon dioxide is withdrawn from the anode chamber (313).

2. The method according to claim 1, wherein the first alkaline, aqueous scrubbing liquid comprises a dissolved metal hydroxide, such as one or more of dissolved potassium hydroxide (KOH), dissolved sodium hydroxide (NaOH), and dissolved lithium hydroxide (LiOH); preferably the first alkaline, aqueous scrubbing liquid comprises potassium hydroxide (KOH).

3. The method according to claim 1 or 2, wherein the method further comprises a step of separating the gaseous mixture of oxygen and carbon dioxide into:

- a first stream rich in oxygen and/or depleted of carbon dioxide; and
- a second stream rich in carbon dioxide and/or depleted of oxygen.

4. The method according to any one of the preceding claims, wherein hydrogen withdrawn from the cathode chamber (312) is used as a fuel to provide electricity; preferably in a fuel cell.

5. The method according to any one of the preceding claims, wherein the method further comprises:

- withdrawing an aqueous stream still comprising some hydrogen carbonate (HCO_3^-) from the anode chamber (313);
- concentrating, such as by reversed osmosis, the withdrawn aqueous stream comprising some hydrogen carbonate (HCO_3^-) to provide a concentrated stream comprising hydrogen carbonate (HCO_3^-); and
- re-circulating the concentrated stream comprising hydrogen carbonate (HCO_3^-) to the electrolytic cell (310).

6. The method according to any one of the preceding claims, wherein the scrubbing of the gas is performed at least in a first stage and in a second stage, the regenerated alkaline, aqueous scrubbing liquid withdrawn from the cathode chamber (312), being fed as a second alkaline, aqueous scrubbing liquid to the second stage of scrubbing downstream of the first stage of scrubbing, and wherein a second spent scrubbing liquid, resulting from the second stage of scrubbing, at least partly is fed as the first alkaline, aqueous scrubbing liquid to the first stage of scrubbing upstream of the second stage of scrubbing, the pH of the second alkaline, aqueous scrubbing liquid being higher than the pH of the first alkaline, aqueous scrubbing liquid; preferably the pH of the second alkaline, aqueous scrubbing liquid being 12 to 14 and the pH of the first alkaline, aqueous scrubbing liquid being 8 to 10.

7. The method according to claim 6, wherein:

- the regenerated alkaline, aqueous scrubbing liquid withdrawn from the cathode chamber (312) is mixed with a part of the second spent scrubbing liquid to provide the second alkaline, aqueous scrubbing liquid, whereby the pH of the second alkaline, aqueous scrubbing liquid is lower than the pH of the regenerated alkaline, aqueous scrubbing liquid withdrawn from the cathode chamber (312); and/or

- part of the second spent scrubbing liquid is mixed with a part of a first spent scrubbing liquid, resulting from the first stage of scrubbing, to provide the first alkaline, aqueous scrubbing liquid, whereby the pH of the first alkaline, aqueous scrubbing liquid being higher than the pH the first spent scrubbing liquid.

8. The method according to any one of the preceding claims, wherein part of the regenerated alkaline, aqueous scrubbing liquid is re-circulated to the cathode (312) chamber; optionally the regenerated alkaline, aqueous scrubbing liquid being diluted by an aqueous stream before re-circulating it to the cathode chamber (312), preferably said aqueous stream being provided by withdrawing an aqueous stream still comprising some hydrogen carbonate (HCO_3^-) from the anode chamber (313) and concentrating it, such as by reversed osmosis, to provide an aqueous stream depleted of hydrogen carbonate (HCO_3^-) and a concentrated stream comprising hydrogen carbonate (HCO_3^-);.

9. The method according to any one of the preceding claims, wherein carbon dioxide (CO_2) and/or oxygen (O_2) withdrawn from the anode chamber (313) is compressed into liquid carbon dioxide and/or compressed oxygen (O_2).

10. A system for scrubbing a gas comprising carbon dioxide to deplete the gas of carbon dioxide, the system comprising:

- a scrubber arrangement (200) for scrubbing a gas with an alkaline, aqueous scrubbing liquid to dissolve carbon dioxide as hydrogen carbonate (HCO_3^-) and/or as carbonate (CO_3^{2-}) in the alkaline, aqueous scrubbing liquid, thereby providing a spent aqueous scrubbing liquid comprising hydrogen carbonate (HCO_3^-) and/or carbonate (CO_3^{2-}), the spent aqueous scrubbing liquid having a pH from 7 to 9; and

- a regeneration arrangement (300) for regenerating the spent aqueous scrubbing liquid by electrolysis, wherein:

- the scrubber arrangement comprises a scrubber (210), the scrubber having an inlet (213) for the gas to be scrubbed and an outlet (214) for gas depleted of carbon dioxide, the scrubber (210) further having an inlet (212') for receiving the alkaline, aqueous scrubbing liquid and an outlet (211'') for withdrawing spent aqueous scrubbing liquid; and

- the regeneration arrangement comprises an electrolytic cell (310), comprising an anode chamber (313) and a cathode chamber (312) separated by a

membrane (311), the anode chamber (313) comprising an anode inlet (313') for receiving the spent aqueous scrubbing liquid and an anode outlet (313'') for withdrawing oxygen and carbon dioxide, and the cathode chamber (312) comprising an outlet (312'') for withdrawing regenerated aqueous scrubbing liquid and hydrogen;

wherein the outlet (211'') for spent aqueous scrubbing liquid of the scrubber (210) is in flow communication with the inlet (313') for the spent aqueous scrubbing liquid of the anode chamber (313), and the outlet (312'') for regenerated aqueous scrubbing liquid of the cathode chamber (312) is in flow communication with the inlet (212') for the alkaline, aqueous scrubbing liquid of the scrubber (210) for re-circulating the regenerated aqueous scrubbing liquid to the scrubber.

11. The system according to claim 10, wherein the scrubber arrangement (200) comprises a first (230) and a second (240) buffer tank for alkaline, aqueous scrubbing liquid, the scrubber (210) further comprising at least a first (211) and a second (212) absorber, wherein

the first absorber (211) comprises an inlet (211') for receiving alkaline, aqueous scrubbing liquid from the first buffer tank (230), and an outlet (211'') for withdrawing spend aqueous scrubbing liquid from the first absorber (211) to feed to an inlet of the first buffer tank (230), whereby aqueous scrubbing liquid may be circulated between the first absorber (211) and the first buffer tank (230);

the first buffer tank (230) is in flow communication with the inlet (313') for the spent aqueous scrubbing liquid of the anode chamber (313);

the second absorber (212) comprises an inlet (212') for receiving alkaline, aqueous scrubbing liquid from the second buffer tank (240), and an outlet (212'') for withdrawing spent aqueous scrubbing liquid from second absorber (212) to feed to an inlet of the second buffer tank (240), whereby aqueous scrubbing liquid may be circulated between the second absorber (212) and the first buffer tank (230);

the outlet (312'') for regenerated aqueous scrubbing liquid of the cathode chamber (312) is in flow communication with the inlet (212') of the second absorber (212); and

the outlet (212'') of the second absorber (212) is in flow communication with the inlet (211') of the first absorber (211).

12. The system according to claim 11, wherein the scrubber arrangement further comprises:

a third buffer tank (220) for regenerated aqueous scrubbing liquid, the third buffer tank (220) being in flow communication with the outlet (312'') for regenerated aqueous scrubbing liquid of the cathode chamber (312) and with the inlet (212') of the second absorber (212); and/or

a fourth buffer tank (250) for spent aqueous scrubbing liquid, the fourth buffer tank (250) being in flow communication with the first buffer tank (230) and with an inlet (313') for the spent aqueous scrubbing liquid of the anode chamber (313).

13. The system according to claim 10 or 11, wherein the regeneration arrangement (300) further comprises:

- a first compressor unit (320) for compressing hydrogen withdrawn from the cathode chamber (312); and/or

- a second compressor unit (330) for compressing oxygen and carbon dioxide withdrawn from the anode chamber (313), and/or a first gas separator (340) for separating oxygen and carbon dioxide withdrawn from the anode chamber (313) from each other.

14. The system according to claim 10 to 13, wherein the regeneration arrangement (300) further comprises a concentrator (350), such as a filter, for concentrating an aqueous stream comprising some hydrogen carbonate (HCO_3^-) withdrawn from the anode chamber (313) to provide a concentrated stream comprising hydrogen carbonate (HCO_3^-) and an aqueous stream depleted of hydrogen carbonate (HCO_3^-), the concentrator (350) being in flow communication with the electrolytic cell (310) such that:

the aqueous stream comprising some hydrogen carbonate (HCO_3^-) may be withdrawn from the anode chamber (313) and fed to the concentrator (350);

the concentrated stream comprising hydrogen carbonate (HCO_3^-) may be withdrawn from the concentrator (350) and fed to the anode chamber (313); and

the aqueous stream depleted of hydrogen carbonate (HCO_3^-) may be withdrawn from the concentrator (350) and fed to the cathode chamber (312);

optionally the regeneration arrangement (300) further comprising:

- a first balance tank (360) for regenerated alkaline, aqueous scrubbing liquid, the first balance tank (360) having a first inlet (361) for receiving regenerated alkaline, aqueous scrubbing liquid, a second inlet (362) for receiving the aqueous stream depleted of hydrogen carbonate (HCO_3^-) withdrawn from the concentrator (350), and an

outlet (363) for feeding diluted regenerated alkaline, aqueous scrubbing liquid to the cathode chamber (313) of electrolytic cell (310); and/or

- a second balance tank (370) for spent aqueous scrubbing liquid, the second balance tank (370) having a first inlet (371) for receiving spent aqueous scrubbing liquid from the scrubber arrangement (200), a second inlet (372) for receiving the concentrated stream comprising hydrogen carbonate (HCO_3^-) from the concentrator (350), and an outlet (373) for feeding spent aqueous scrubbing liquid to the anode chamber (313) of electrolytic cell (310).