METHOD AND APPARATUS FOR CARBON CAPTURE COUPLED HYDROGEN PRODUCTION

FIELD OF THE INVENTION

[0001] The present disclosure relates to the field of carbon capture technologies, and specifically, to a method and an apparatus for carbon capture coupled hydrogen production.

BACKGROUND OF THE INVENTION

[0002] Currently, global warming is one of major environmental problems of the world. Carbon dioxide is a major greenhouse gas. Existing technologies of carbon capture, utilization and storage (CCUS), especially Direct Air Capture technology as well as hydrogen production by electrolysis of water are too expensive to promote, and corresponding storage, transportation and consumption technologies are immature, which severely limits development of these technologies. Currently, a liquid amine solvent–based adsorption method is a major carbon dioxide capture method. However, being highly corrosive, toxic, and volatile and having high costs, an existing liquid amine solvent whose regeneration consumes a great deal of energy is a major obstacle to development of the capture technology. Moreover, the foregoing method can be used for capturing carbon dioxide from only flue gas or the like in which carbon dioxide has relatively high enrichment, but cannot be applied to capture of carbon dioxide from air or the like in which carbon dioxide has low enrichment. According to an airborne carbon dioxide capture technology developed in recent years, carbon dioxide is adsorbed by using a liquid alkaline solution and a solid amine membrane, and CO_2 in a wide enrichment range can be captured.

[0003] However, the foregoing airborne carbon dioxide capture technology has the following problem: a great deal of energy is consumed in regenerating a carbon dioxide adsorbent. When a solid amine membrane is used as an adsorbent for capturing carbon dioxide in air, economic costs of the technology in commercial utilization are high because costs of an amine adsorbent are high. In another technical route, a liquid alkali solution is used as an absorption solution, and an adsorbent is regenerated via a chemical reaction including the following two steps: Step 1: carbon dioxide is combined with the alkali solution to form a carbonate solution. At the same time, an absorption solution is regenerated; Step 2: calcium hydroxide reacts with the carbonate solution obtained in the first step, to form calcium carbonate precipitate. Then, calcination is carried out to form high-purity carbon dioxide and regenerate calcium hydroxide. In this technical route,

calcination of calcium carbonate requires high energy consumption and massive device investment, and thus having high economic costs.

[0004] In WO2011123817A3 and CN102605383A, an alkaline ion exchange membrane is used for carbon capture. However, the membrane has severe use conditions and high costs, and thus having no commercial utilization value. In AU2009290161B2, an alkaline ion exchange membrane is used; and carbon dioxide enters an electrolytic cell in a gaseous form, and is combined with an alkaline solution in the cell via a gas diffusion layer, to form a NaOH-$NaHCO_3$-Na_2CO_3 mixed solution. However, no high-purity alkaline solution can be formed for regeneration; and because a concentration of carbon dioxide required for supplementation is relatively high, electrolysis cannot be implemented after capture of carbon dioxide in air. In US9095813B2, an alkaline solution–based absorption technology is used; and two chemical loops are required for reducing a gas adsorbent. As a result, system design is complex; construction costs are high; and it is hard to implement a control system. Moreover, a regeneration chemical loop requires heat supply for 900°C combustion, greatly increasing energy loss and carbon emission; and a calcium oxide adsorbent is easy to deactivate, causing a great need of calcium carbonate for supplementation. In US20170113184A1 and EP2160234A1, an airborne CO_2 capture apparatus also adopts a solid membrane–based capture technology; and steam is required for reducing an absorbent. As a result, CO_2 emission is also increased; and only a problem in capturing CO_2 can be resolved, but a problem in using CO_2 cannot be resolved.

[0005] In a conventional technology, there is also the following solution: potassium hydroxide is used to absorb CO_2, thereby obtaining potassium carbonate. Then, potassium carbonate is electrolyzed via an ionic membrane, where a mixed solution of potassium bicarbonate and potassium carbonate, and gases of O_2 and CO_2 are generated in an anode; and H_2 and a KOH solution are obtained in a cathode. Therefore, regeneration of an absorption solution is achieved. However, there are following three problems: Problem 1: to avoid reaction between potassium bicarbonate in the anode and potassium hydroxide in the cathode in an electrolysis process, in most cases, an ion exchange membrane is used to separate a catholyte chamber from an anolyte chamber, but costs of an ionic membrane are relatively high because the ionic membrane is expensive, and mainly because use conditions of the ionic membrane are severe. Moreover, a complex purification process also limits an application range of the ionic membrane. Problem 2: generally, when KOH absorbs low-concentration CO_2, for example, CO_2 in air, only a KOH-K_2CO_3 mixed solution can be obtained, and it is hard to completely convert KOH into K_2CO_3. As a result, a utilization rate of KOH is too low. To completely convert KOH into potassium carbonate, air throughput needs to be increased, which makes both a CO_2 absorption rate and CO_2 utilization efficiency in a later period

too low. Problem 3: if a mixed solution of potassium carbonate that contains a specific content of potassium hydroxide is introduced into an anolyte solution, efficiency of acidizing potassium carbonate in the anode is reduced.

SUMMARY

[0006] The present disclosure mainly aims to provide a method and an apparatus for carbon capture coupled hydrogen production, to resolve the problem that capture costs of CO_2 in a wide concentration range and hydrogen production costs are relatively high in .

[0007] To achieve the foregoing objective, according to an aspect of the present disclosure, a method for carbon capture coupled hydrogen production is provided, including the following steps: step S1: capturing low-concentration CO_2 by using a solution of an alkali metal hydroxide, to obtain a low-concentration CO_2 absorption solution, where the low-concentration CO_2 absorption solution contains an alkali metal carbonate and the alkali metal hydroxide; step S2: dividing the low-concentration CO_2 absorption solution into a first portion of the low-concentration CO_2 absorption solution and a second portion of the low-concentration CO_2 absorption solution; and capturing high-concentration CO_2 by using the first portion of the low-concentration CO_2 absorption solution, to obtain a high-concentration CO_2 absorption solution, where the high-concentration CO_2 absorption solution contains the alkali metal carbonate and an alkali metal bicarbonate; and step S3: performing electrolysis by using the second portion of the low-concentration CO_2 absorption solution as a catholyte solution, using the high-concentration CO_2 absorption solution as an anolyte solution, and using a non-ionic diaphragm as a diaphragm, to obtain H_2 and a cathodic discharge liquid at an electrolytic cathode, and obtain O_2, CO_2, and an anodic discharge liquid at an electrolytic anode; and performing step S1 by using the cathodic discharge liquid, where the cathodic discharge liquid contains the alkali metal carbonate and the alkali metal hydroxide; and the anodic discharge liquid contains the alkali metal carbonate and the alkali metal bicarbonate.

[0008] Further, the alkali metal hydroxide is KOH, the alkali metal carbonate is K_2CO_3, and the alkali metal bicarbonate is $KHCO_3$; or the alkali metal hydroxide is NaOH, the alkali metal carbonate is Na_2CO_3, and the alkali metal bicarbonate is $NaHCO_3$.

[0009] Further, in step S2, the first portion of the low-concentration CO_2 absorption solution accounts for 10% to 90% of the low-concentration CO_2 absorption solution by volume percent.

[0010] Further, step S3 further includes: performing electrolysis by using the anodic discharge liquid as the anolyte solution, where preferably, a concentration of carbonate radicals in the

catholyte solution ranges from 0.1 M to 6 M, and a concentration of hydroxy radicals in the catholyte solution ranges from 0.1 M to 10 M; and more preferably, the concentration of carbonate radicals in the catholyte solution ranges from 0.5 M to 3 M, and the concentration of hydroxy radicals in the catholyte solution ranges from 3 M to 7 M; and preferably, a concentration of carbonate radicals in the anolyte solution ranges from 0.1 M to 6.5 M, and a concentration of bicarbonate radicals in the anolyte solution ranges from 0.1 M to 3 M; and more preferably, the concentration of carbonate radicals in the anolyte solution ranges from 2 M to 5 M, and the concentration of bicarbonate radicals in the anolyte solution ranges from 0.6 M to 1.5 M.

[0011] Further, the non-ionic diaphragm is one or more of a porous polymer diaphragm, a Zirfon film, a polyphenylene sulfide film, a polysulfone film, or a polyether sulfone film; preferably, the non-ionic diaphragm is the porous polymer diaphragm; and more preferably, a polymer layer on a surface of the porous polymer diaphragm is one or more of a carboxylate ion resin layer, polyphenylene sulfide, polysulfone, or polyether sulfone.

[0012] According to another aspect of the present disclosure, an apparatus for carbon capture coupled hydrogen production is provided, including: a low-concentration CO_2 absorption unit, having an inlet for a solution of an alkali metal hydroxide, an inlet for a first to-be-captured raw material that contains low-concentration CO_2, an outlet for a first portion of a low-concentration CO_2 absorption solution, an outlet for a second portion of the low-concentration CO_2 absorption solution, and an outlet for a first exhaust gas, where the low-concentration CO_2 absorption unit is configured to capture low-concentration CO_2 by using the solution of the alkali metal hydroxide, to obtain the low-concentration CO_2 absorption solution; and the low-concentration CO_2 absorption solution contains an alkali metal carbonate and the alkali metal hydroxide; a high-concentration CO_2 absorption unit, having an inlet for the first portion of the low-concentration CO_2 absorption solution, an inlet for a second to-be-captured raw material that contains high-concentration CO_2, an outlet for a high-concentration CO_2 absorption solution, and an outlet for a second exhaust gas, where the inlet for the first portion of the low-concentration CO_2 absorption solution is connected to the outlet for the first portion of the low-concentration CO_2 absorption solution; the high-concentration CO_2 absorption unit is configured to capture high-concentration CO_2 by using the first portion of the low-concentration CO_2 absorption solution, to obtain the high-concentration CO_2 absorption solution; and the high-concentration CO_2 absorption solution contains the alkali metal carbonate and an alkali metal bicarbonate; and an electrolysis unit, having an inlet for a catholyte solution, a non-ionic diaphragm, an inlet for an anolyte solution, an outlet for a cathodic discharge liquid, an outlet for an anodic discharge liquid, an outlet for H_2, and an outlet for a mixed gas of O_2 and CO_2, where the inlet for the catholyte solution is connected to the

outlet for the second portion of the low-concentration CO_2 absorption solution; the outlet for the catholyte solution is connected to the inlet for the solution of the alkali metal hydroxide; the inlet for the anolyte solution is connected to the outlet for the high-concentration CO_2 absorption solution; and the electrolysis unit is configured to electrolyze the second portion of the low-concentration CO_2 absorption solution and the high-concentration CO_2 absorption solution, to obtain H_2 and the cathodic discharge liquid at an electrolytic cathode, and obtain O_2, CO_2, and the anodic discharge liquid at an electrolytic anode, where the cathodic discharge liquid contains the alkali metal carbonate and the alkali metal hydroxide; and the anodic discharge liquid contains the alkali metal carbonate and the alkali metal bicarbonate.

[0013] Further, the low-concentration CO_2 absorption unit includes a low-concentration absorption tower, where the inlet for the solution of the alkali metal hydroxide and the outlet for the first exhaust gas are formed in a top of the low-concentration absorption tower; and the inlet for the first to-be-captured raw material that contains low-concentration CO_2, the outlet for the first portion of the low-concentration CO_2 absorption solution, and the outlet for the second portion of the low-concentration CO_2 absorption solution are formed in a bottom of the low-concentration absorption tower; and the high-concentration CO_2 absorption unit includes a high-concentration absorption tower, where the inlet for the first portion of the low-concentration CO_2 absorption solution and the outlet for the second exhaust gas are formed in a top of the high-concentration absorption tower; and the inlet for the second to-be-captured raw material that contains high-concentration CO_2 and the outlet for the high-concentration CO_2 absorption solution are formed in a bottom of the high-concentration absorption tower.

[0014] Further, the electrolysis unit includes an electrolytic cell, having a cathode chamber and an anode chamber; the non-ionic diaphragm is disposed between the cathode chamber and the anode chamber; the electrolytic cathode is disposed in the cathode chamber; the electrolytic anode is disposed in the anode chamber; the cathode chamber has the inlet for the catholyte solution, the outlet for the cathodic discharge liquid, and the outlet for H_2; and the anode chamber has the inlet for the anolyte solution, the outlet for the anodic discharge liquid, and the outlet for the mixed gas of O_2 and CO_2.

[0015] Further, the high-concentration CO_2 absorption unit further includes a high-concentration CO_2 absorption solution tank, disposed on a pipeline through which the inlet for the anolyte solution is connected to the outlet for the high-concentration CO_2 absorption solution, and disposed on one side of the outlet for the high-concentration CO_2 absorption solution.

[0016] Further, the electrolysis unit further includes a cathodic feed liquid tank, disposed on a pipeline through which the inlet for the catholyte solution is connected to the outlet for the second portion of the low-concentration CO_2 absorption solution; and/or a cathodic discharge liquid tank, disposed on a pipeline through which the outlet for the catholyte solution is connected to the inlet for the solution of the alkali metal hydroxide; and/or an anodic liquid storage tank, disposed on a pipeline through which the inlet for the anolyte solution is connected to the outlet for the high-concentration CO_2 absorption solution, and disposed on one side of the inlet for the anolyte solution.

[0017] According to the technical solutions of the present disclosure, in one aspect, CO_2 in a wide concentration range that includes low-concentration CO_2 and high-concentration CO_2 can be absorbed and captured by using an alkaline solution as an absorbent; and in another aspect, a non-ionic diaphragm is used to electrolyze low-concentration CO_2 and high-concentration CO_2, and product absorption coupled hydrogen production are performed, so that an absorption solution can be regenerated, and high-concentration CO_2 as well as additional products of H_2 and O_2 can be obtained. According to the present disclosure, a low-concentration CO_2 absorption solution is used as a catholyte solution, and a high-concentration CO_2 absorption solution is used as an anolyte solution. Under a condition that no ionic membrane is used, a concentration increase of CO_3^{2-} in an electrolytic cathode can restrain substance diffusion caused by a concentration difference, so that diffusion of HCO_3^- and CO_3^{2-} from the electrolytic anode to the cathode is reduced. Moreover, in preference to OH^-, CO_3^{2-} having more electric charges undergoes electromigration, so that electromigration of CO_3^{2-} to the anode is reduced. Electrolyzing a working fluid obtained after capture of carbon dioxide can not only regenerate an alkaline absorption solution and obtain a high-purity product gas, but also recycle a capture solution and reduce regeneration costs of the absorption solution. In addition, usage of the non-ionic diaphragm greatly reduces costs of an electrolytic cell, avoids severe restriction imposed by an ionic membrane on the electrolyte solution and the electrolytic cell, and simplifies an impurity removal purification process of the CO_2 absorption solution, thereby further reducing CO_2 capture costs. In summary, according to the method of the present disclosure, capture of CO_2 in a wide concentration range can be realized; electrolysis is performed by using a non-ionic diaphragm, to implement regeneration of an absorption solution coupled hydrogen production; capture costs of CO_2 in a wide concentration range can be reduced; additional products of H_2 and O_2 can be obtained; and hydrogen production costs can be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The accompanying drawing of this specification which constitutes a part of the present disclosure provides further understanding of the present disclosure. The schematic example of the present disclosure and description thereof are intended to explain the present disclosure and are not intended to constitute an improper limitation to the present disclosure. In the accompanying drawing:

[0019] FIG. 1 is schematic diagram of an apparatus for CO_2 capture coupled hydrogen production according to an example of the present disclosure.

[0020] Reference numerals in the foregoing drawing are as follows:

[0021] 1: low-concentration CO_2 absorption unit; 2: high-concentration CO_2 absorption unit; 3: electrolysis unit; 11: low-concentration absorption tower; 21: high-concentration absorption tower; 22: high-concentration CO_2 absorption solution tank; 31: electrolytic cell; 32: anodic liquid storage tank; 33: cathodic feed liquid tank; 34: cathodic discharge liquid tank; 311: cathode chamber; 312: anode chamber; and 313: non-ionic diaphragm.

DETAILED DESCRIPTION

[0022] It should be noted that, on the premise of no conflict, the embodiments and the features thereof in the present disclosure may be combined with each other. The present disclosure is described below in detail with reference to the accompanying drawings and the embodiments.

[0023] It should be noted that, in the specification and claims of the present disclosure, terms such as “first” and “second” are intended only to distinguish between similar objects but do not necessarily indicate a specific order or sequence. It should be understood that data termed in such a way is interchangeable under appropriate circumstances, so that the embodiments of the present disclosure described herein can be implemented in other orders than the order illustrated or described herein. Moreover, the terms “include”, “have”, and any variants thereof mean to cover the non-exclusive inclusion, for example, a process, method, system, product, or device that includes a series of steps or units is not necessarily limited to those expressly listed steps or units, but may include other steps or units not expressly listed or inherent to such a process, method, system, product, or device. In addition, solution-related terms “more”, “less”, “medium concentration”, “low concentration”, and “high concentration” in the specification and claims of the present disclosure represent a relatively high concentration, a relatively low concentration, and a relatively medium concentration of related solutions in different steps, but do not impose restriction on specific concentrations.

[0024] It should be noted that, terms "low-concentration CO_2" and "high-concentration CO_2" in the specification and claims of the present disclosure are merely used to distinguish between CO_2-containing materials that have different concentrations of CO_2. For example, "low-concentration CO_2" may mean that a volume concentration of carbon dioxide is 1% or less than 1% (for example, CO_2 in air); and "high-concentration CO_2" may mean that a volume concentration of carbon dioxide is greater than 1% (for example, CO_2 in flue gas). "1%" is not an absolute value distinguishing between low-concentration CO_2 and high-concentration CO_2, is merely used as an example, and may be adjusted according to an actual condition in an actual operation process.

[0025] It should be noted that, "solution" in the present disclosure is an aqueous solution unless otherwise specified.

[0026] As described in BACKGROUND OF THE INVENTION of the present disclosure, capture costs of CO_2 in a wide concentration range and hydrogen production costs are relatively high in a conventional technology. To resolve the foregoing problem, in a typical implementation of the present disclosure, a method for carbon capture coupled hydrogen production is provided, including the following steps: step S1: capturing low-concentration CO_2 by using a solution of an alkali metal hydroxide, to obtain a low-concentration CO_2 absorption solution, where the low-concentration CO_2 absorption solution contains an alkali metal carbonate and the alkali metal hydroxide; step S2: dividing the low-concentration CO_2 absorption solution into a first portion of the low-concentration CO_2 absorption solution and a second portion of the low-concentration CO_2 absorption solution; and capturing high-concentration CO_2 by using the first portion of the low-concentration CO_2 absorption solution, to obtain a high-concentration CO_2 absorption solution, where the high-concentration CO_2 absorption solution contains the alkali metal carbonate and an alkali metal bicarbonate; and step S3: performing electrolysis by using the second portion of the low-concentration CO_2 absorption solution as a catholyte solution, using the high-concentration CO_2 absorption solution as an anolyte solution, and using a non-ionic diaphragm as a diaphragm, to obtain H_2 and a cathodic discharge liquid at an electrolytic cathode, and obtain O_2, CO_2, and an anodic discharge liquid at an electrolytic anode; and performing step S1 by using the cathodic discharge liquid, where the cathodic discharge liquid contains the alkali metal carbonate and the alkali metal hydroxide; and the anodic discharge liquid contains the alkali metal carbonate and the alkali metal bicarbonate.

[0027] According to the present disclosure, first, low-concentration CO_2 is captured by using a solution of an alkali metal hydroxide, to obtain a low-concentration CO_2 absorption solution that contains an alkali metal carbonate and the alkali metal hydroxide, where the alkali metal hydroxide

is not completely converted into the alkali metal hydroxide; and then, high-concentration CO_2 is captured by using a first portion of the low-concentration CO_2 absorption solution, to obtain a high-concentration CO_2 absorption solution that contains the alkali metal carbonate and an alkali metal bicarbonate, where a content of the alkali metal bicarbonate is low. Therefore, absorption and capture of CO_2 in a wide concentration range including a low concentration and a high concentration are realized. Electrolysis is performed by using the other portion of the low-concentration CO_2 absorption solution as a catholyte solution, using the high-concentration CO_2 absorption solution as an anolyte solution, and using a non-ionic diaphragm as an electrolyte diaphragm; and a hydrogen evolution reaction of the low-concentration CO_2 absorption solution that contains the alkali metal carbonate and the alkali metal hydroxide occurs in a cathode, to generate H_2. At the same time, under the action of an electric field force, alkali metal ions in the anolyte solution cross the diaphragm, enter the electrolytic cathode, and form regenerated alkali metal hydroxide with OH^- generated in a hydrogen evolution and reduction reaction of water molecules, where an alkali metal carbonate-alkali metal hydroxide mixed solution having an increased concentration of the alkali metal hydroxide is obtained in the electrolytic cathode; and O_2, CO_2, and an alkali metal carbonate-alkali metal bicarbonate regenerated solution are obtained at an anode of an electrolytic cell.

[0028] In one aspect, CO_2 in a wide concentration range that includes low-concentration CO_2 and high-concentration CO_2 can be absorbed and captured by using an alkaline solution as an absorbent. In another aspect, a non-ionic diaphragm is used to electrolyze low-concentration CO_2 and high-concentration CO_2, and product absorption coupled hydrogen production are performed, so that an absorption solution can be regenerated, and high-concentration CO_2 as well as additional products of H_2 and O_2 can be obtained. According to the present disclosure, a low-concentration CO_2 absorption solution is used as a catholyte solution, and a high-concentration CO_2 absorption solution is used as an anolyte solution. Under a condition that no ionic membrane is used, a concentration increase of CO_3^{2-} in an electrolytic cathode can restrain substance diffusion caused by a concentration difference, so that diffusion of HCO_3^- and $CO3^{2-}$ from the electrolytic anode to the cathode is reduced. Moreover, in preference to OH^-, CO_3^{2-} having more electric charges undergoes electromigration, so that electromigration of CO_3^{2-} to the anode is reduced. Electrolyzing a working fluid obtained after capture of carbon dioxide can not only regenerate an alkaline absorption solution and obtain a high-purity product gas, but also recycling a capture solution and reduce regeneration costs of the absorption solution. In addition, usage of the non-ionic diaphragm greatly reduces costs of an electrolytic cell, avoids severe restriction imposed by an ionic membrane on the electrolyte solution and the electrolytic cell, and simplifies an impurity

removal purification process of the CO_2 absorption solution, thereby further reducing CO_2 capture costs. In summary, according to the method of the present disclosure, capture of CO_2 in a wide concentration range can be realized; electrolysis is performed by using a non-ionic diaphragm, to implement regeneration of an absorption solution coupled hydrogen production; capture costs of CO_2 in a wide concentration range can be reduced; additional products of H_2 and O_2 can be obtained; and hydrogen production costs can be reduced.

[0029] The alkali metal in the present disclosure may be Li, Na, K, or Rb. For the purposes of further improving effects of absorbing CO_2 and electrolyzing an absorption solution, and further reducing costs, the alkali metal is preferably K or Na. In a preferred implementation, the alkali metal hydroxide is KOH, the alkali metal carbonate is K_2CO_3, and the alkali metal bicarbonate is $KHCO_3$; or the alkali metal hydroxide is NaOH, the alkali metal carbonate is Na_2CO_3, and the alkali metal bicarbonate is $NaHCO_3$. In an example in which the alkali metal hydroxide is KOH, Reaction formulas in operation of the method of the present disclosure are as follows:

[0030] Capture of low-concentration CO_2: $CO_2 + 2KOH \rightarrow K_2CO_3 + H_2O$, where KOH is not converted completely, and a KOH-K_2CO_3 mixed solution is obtained.

[0031] Capture of high-concentration CO_2: $CO_2 + KOH \rightarrow KHCO_3$, remaining KOH is converted completely, and a K_2CO_3-$KHCO_3$ mixed solution is obtained.

[0032] Electrolysis:

[0033] Cathodic reaction: $4H_2O + 4K^+ + 4e^- \rightarrow 2H_2 + 4KOH$.

[0034] Anodic reaction: $2K_2CO_3 - 4e^- \rightarrow 4K^+ + O_2 + 2CO_2$.

[0035] Total reaction of the electrolysis: $2K_2CO_3 + 4H_2O \rightarrow 4KOH + 2H_2 + O_2 + 2CO_2$.

[0036] To allocate the low-concentration CO_2 absorption solution more reasonably, in a preferred implementation, in step S2, the first portion of the low-concentration CO_2 absorption solution accounts for 10% to 90% of the low-concentration CO_2 absorption solution by volume percent; and high-concentration CO_2 capture is performed on a solution that contains an appropriate amount of unreacted alkali metal hydroxide, so that electrolytic volumes of the high-concentration CO_2 absorption solution used as the anolyte solution and the low-concentration CO_2 absorption solution used as the catholyte solution fit each other better.

[0037] In a preferred implementation, step S3 further includes: performing electrolysis by using the anodic discharge liquid as the anolyte solution, thereby recycling the anodic discharge liquid. Preferably, a concentration of carbonate radicals in the catholyte solution ranges from 0.1 M to 6 M, and a concentration of hydroxy radicals in the catholyte solution ranges from 0.1 M to 10 M;

and more preferably, the concentration of carbonate radicals in the catholyte solution ranges from 0.5 M to 3 M, and the concentration of hydroxy radicals in the catholyte solution ranges from 3 M to 7 M; and preferably, a concentration of carbonate radicals in the anolyte solution ranges from 0.1 M to 6.5 M, and a concentration of bicarbonate radicals in the anolyte solution ranges from 0.1 M to 3 M; and more preferably, the concentration of carbonate radicals in the anolyte solution ranges from 2 M to 5 M, and the concentration of bicarbonate radicals in the anolyte solution ranges from 0.6 M to 1.5 M. This further facilitates capture of CO_2 in a wide concentration range using the solution of the alkali metal hydroxide, and fast performance of an electrolysis process, without increasing energy consumed in electrolysis due to a high ion concentration and an increase of viscosity.

[0038] As described above, according to the method for carbon capture coupled hydrogen production of the present disclosure, because the catholyte solution and the anolyte solution are absorption solutions having different concentrations of CO_2, a good electrolysis effect can be achieved without using an ion exchange membrane that has high costs; and restriction of severe use conditions of an ionic membrane is avoided. In a preferred implementation, the non-ionic diaphragm is one or more of a porous polymer diaphragm, a Zirfon film, a polyphenylene sulfide film, a polysulfone film, or a polyether sulfone film; preferably, the non-ionic diaphragm is the porous polymer diaphragm; and more preferably, a polymer layer on a surface of the porous polymer diaphragm is one or more of a carboxylate ion resin layer, polyphenylene sulfide, polysulfone, or polyether sulfone. Carboxylate radicals or the like that carry negative charges may assist in diffusion of OH^- in the cathode to the anode, thereby helping improve current efficiency. The foregoing non-ionic diaphragm may further reduce costs while ensuring electrolysis efficiency.

[0039] In another typical implementation of the present disclosure, an apparatus for carbon capture coupled hydrogen production is further provided. As shown in FIG. 1, the apparatus includes: a low-concentration CO_2 absorption unit 1, having an inlet for a solution of an alkali metal hydroxide, an inlet for a first to-be-captured raw material that contains low-concentration CO_2, an outlet for a first portion of a low-concentration CO_2 absorption solution, an outlet for a second portion of the low-concentration CO_2 absorption solution, and an outlet for a first exhaust gas, where the low-concentration CO_2 absorption unit 1 is configured to capture low-concentration CO_2 by using the solution of the alkali metal hydroxide, to obtain the low-concentration CO_2 absorption solution; and the low-concentration CO_2 absorption solution contains an alkali metal carbonate and the alkali metal hydroxide; a high-concentration CO_2 absorption unit 2, having an inlet for the first portion of the low-concentration CO_2 absorption solution, an inlet for a second to-be-captured raw material that contains high-concentration CO_2, an outlet for a high-

concentration CO_2 absorption solution, and an outlet for a second exhaust gas, where the inlet for the first portion of the low-concentration CO_2 absorption solution is connected to the outlet for the first portion of the low-concentration CO_2 absorption solution; the high-concentration CO_2 absorption unit 2 is configured to capture high-concentration CO_2 by using the first portion of the low-concentration CO_2 absorption solution, to obtain the high-concentration CO_2 absorption solution; and the high-concentration CO_2 absorption solution contains the alkali metal carbonate and an alkali metal bicarbonate; and an electrolysis unit 3, having an inlet for a catholyte solution, a non-ionic diaphragm, an inlet for an anolyte solution, an outlet for a cathodic discharge liquid, an outlet for an anodic discharge liquid, an outlet for H_2, and an outlet for a mixed gas of O_2 and CO_2, where the inlet for the catholyte solution is connected to the outlet for the second portion of the low-concentration CO_2 absorption solution; the outlet for the catholyte solution is connected to the inlet for the solution of the alkali metal hydroxide; the inlet for the anolyte solution is connected to the outlet for the high-concentration CO_2 absorption solution; and the electrolysis unit 3 is configured to electrolyze the second portion of the low-concentration CO_2 absorption solution and the high-concentration CO_2 absorption solution, to obtain H_2 and the cathodic discharge liquid at an electrolytic cathode, and obtain O_2, CO_2, and the anodic discharge liquid at an electrolytic anode, where the cathodic discharge liquid contains the alkali metal carbonate and the alkali metal hydroxide; and the anodic discharge liquid contains the alkali metal carbonate and the alkali metal bicarbonate.

[0040] In a use process, low-concentration CO_2 is captured in the low-concentration CO_2 absorption unit 1 by using the solution of the alkali metal hydroxide, to obtain the low-concentration CO_2 absorption solution that contains the alkali metal carbonate and the alkali metal hydroxide. Then, one portion of the low-concentration CO_2 absorption solution is introduced into the electrolytic cathode; the other portion of the low-concentration CO_2 absorption solution is introduced into the high-concentration CO_2 absorption unit 2, to absorb high-concentration CO_2, and obtain the high-concentration CO_2 absorption solution that contains the alkali metal carbonate and the alkali metal bicarbonate, where a content of the alkali metal bicarbonate is low; and the high-concentration CO_2 absorption solution is introduced into the electrolytic anode for electrolysis. An oxygen evolution reaction of an alkali metal carbonate-alkali metal bicarbonate mixed solution occurs in the anode, to obtain O_2, CO_2, and a mixed solution of low-concentration alkali metal carbonate and medium-concentration alkali metal bicarbonate. The mixed solution of the low-concentration alkali metal carbonate and the medium-concentration alkali metal bicarbonate is mixed with the high-concentration CO_2 absorption solution. The mixture is introduced into an anodic feed liquid apparatus, and then enters the electrolysis unit 3 for cycling.

A hydrogen evolution reaction of an alkali metal carbonate-alkali metal hydroxide mixed solution occurs in the cathode, to obtain H_2, and the cathodic discharge liquid that contains the alkali metal carbonate and the alkali metal hydroxide, where a concentration of the alkali metal hydroxide is increased. Then, the cathodic discharge liquid enters the low-concentration CO_2 absorption unit 1, to continue capture of low-concentration CO_2. In the low-concentration CO_2 absorption unit, a mixed solution that contains less alkali metal carbonate and more alkali metal hydroxide is consumed by CO_2, to obtain a mixed solution that contains more alkali metal carbonate and more alkali metal hydroxide. One portion of the obtained solution enters the electrolytic cathode; and the other portion of the obtained solution enters the high-concentration CO_2 absorption unit 2. The cycle is repeated for continuous operation.

[0041] Gradient absorption of CO_2 in a wide concentration range can be realized by using the foregoing apparatus. Electrolysis is performed by using the non-ionic diaphragm, to implement regeneration of the KOH absorption solution, so that capture costs of CO_2 in a wide concentration range can be reduced. Coupling hydrogen production is performed, to obtain additional products of H_2 and O_2, thereby reducing hydrogen production costs. A flow rate of the first portion of the low-concentration CO_2 absorption solution may be adjusted by using a flow regulating valve.

[0042] Specifically, as shown in FIG. 1, in a preferred implementation, the low-concentration CO_2 absorption unit 1 includes a low-concentration absorption tower 11, where the inlet for the solution of the alkali metal hydroxide and the outlet for the first exhaust gas are formed in a top of the low-concentration absorption tower 11; and the inlet for the first to-be-captured raw material that contains low-concentration CO_2, the outlet for the first portion of the low-concentration CO_2 absorption solution, and the outlet for the second portion of the low-concentration CO_2 absorption solution are formed in a bottom of the low-concentration absorption tower 11; and the high-concentration CO_2 absorption unit 2 includes a high-concentration absorption tower 21, where the inlet for the first portion of the low-concentration CO_2 absorption solution and the outlet for the second exhaust gas are formed in a top of the high-concentration absorption tower 21; and the inlet for the second to-be-captured raw material that contains high-concentration CO_2 and the outlet for the high-concentration CO_2 absorption solution are formed in a bottom of the high-concentration absorption tower 21.

[0043] In a preferred implementation, the electrolysis unit 3 includes an electrolytic cell 31, having a cathode chamber 311 and an anode chamber 312, where the non-ionic diaphragm 313 is disposed between the cathode chamber 311 and the anode chamber 312; the electrolytic cathode is disposed in the cathode chamber 311; the electrolytic anode is disposed in the anode chamber

312; the cathode chamber 311 has the inlet for the catholyte solution, the outlet for the cathodic discharge liquid, and the outlet for H_2; and the anode chamber 312 has the inlet for the anolyte solution, the outlet for the anodic discharge liquid, and the outlet for the mixed gas of O_2 and CO_2.

[0044] In a preferred implementation, the high-concentration CO_2 absorption unit 2 further includes a high-concentration CO_2 absorption solution tank 22, disposed on a pipeline through which the inlet for the anolyte solution is connected to the outlet for the high-concentration CO_2 absorption solution, and disposed on one side of the outlet for the high-concentration CO_2 absorption solution.

[0045] In a preferred implementation, the electrolysis unit 3 further includes a cathodic feed liquid tank 33, disposed on a pipeline through which the inlet for the catholyte solution is connected to the outlet for the second portion of the low-concentration CO_2 absorption solution; and/or a cathodic discharge liquid tank 34, disposed on a pipeline through which the outlet for the catholyte solution is connected to the inlet for the solution of the alkali metal hydroxide; and/or an anodic liquid storage tank 32, disposed on a pipeline through which the inlet for the anolyte solution is connected to the outlet for the high-concentration CO_2 absorption solution, and disposed on one side of the inlet for the anolyte solution.

[0046] The first to-be-captured raw material A1 containing low-concentration CO_2 enters the absorption tower 11, and is captured by the solution of the alkali metal hydroxide fed herein, to obtain the first exhaust gas B1 to be exhausted, and obtain the low-concentration CO_2 absorption solution that contains the alkali metal carbonate and the alkali metal hydroxide. One portion of the low-concentration CO_2 absorption solution is introduced into the cathodic feed liquid tank 33, and then enters the cathode chamber 311 for electrolysis. The other portion of the low-concentration CO_2 absorption solution is introduced into the absorption tower 22, to capture the second to-be-captured raw material A2 that contains high-concentration CO_2, thereby obtaining the second exhaust gas B2 to be exhausted, and obtaining the high-concentration CO_2 absorption solution that contains the alkali metal carbonate and the alkali metal bicarbonate, where a content of the alkali metal bicarbonate is low. One portion of the high-concentration CO_2 absorption solution is introduced into the high-concentration CO_2 absorption solution tank 22, then enters the anodic liquid storage tank 32, and finally enters the anode chamber 312 for electrolysis.

[0047] A hydrogen evolution reaction occurs in the cathode chamber 311, to obtain H_2, and the cathodic discharge liquid that contains the alkali metal carbonate and the alkali metal hydroxide, where a concentration of the alkali metal hydroxide is increased. The cathodic discharge liquid enters the cathodic discharge liquid tank 34, and returns to the absorption tower 11, to continue

capture of low-concentration CO_2. An oxygen evolution reaction occurs in the anode chamber 312, to obtain O_2, CO_2, and a mixed solution of low-concentration alkali metal carbonate and medium-concentration alkali metal bicarbonate. The mixed solution enters the anodic liquid storage tank 32, and then is recycled and enters the anode chamber 312 for electrolysis.

[0048] Concentrations of the catholyte solution and the anolyte solution may be controlled to be appropriate values via water replenishing and/or mixing ratio adjustment, thereby further improving electrolysis efficiency. In addition, the catholyte solution contains K_2CO_3 (> 0.5 M) having a specific concentration. Existence of CO_3^{2-} in the cathode may reduce and/or restrain diffusion of HCO_3^- and CO_3^{2-} in the anode to the cathode, but cannot completely avoid the diffusion. Therefore, in a preferred implementation, when electrolysis is not performed, the catholyte solution and the anolyte solution are pumped out of the electrolytic cell. In the anodic liquid storage tank, a ratio of the anodic discharge liquid to the high-concentration CO_2 absorption solution may range from 0.2:1 to 2:1. This facilitates cycling of the electrolysis process.

[0049] The method and apparatus for carbon capture coupled hydrogen production of the present disclosure have wide application prospects in the following application fields: the CO_2 capture and utilization field, the hydrogen energy field, and the like. Application scenarios that may be involved include, but are not limited to, the following: (1) in areas rich in renewable energy, such as wind energy and solar energy, and areas suitable for construction of nuclear power plants, the foregoing energy sources are used to generate electricity and capture CO_2 in air, thereby reducing a content of CO_2 in air while making full use of various energy sources; (2) Industrial flue gases of power plants, cement plants, metallurgic plants, and the like contain a large amount of CO_2 and medium- and low-temperature waste heat. When the method and apparatus of the present disclosure are used in the foregoing industrial fields, the waste heat of the flue gas is used as a heat source for regeneration of an alkaline solution absorbent, so that CO_2 capture can be performed without an additional heat source. Therefore, a dual objective of industrial energy conservation and CO_2 emission reduction is achieved; and a by-product hydrogen gas can also be obtained. (3) When the method and apparatus of the present disclosure are used in the energy storage field of renewable energy such as wind energy and solar energy, a gas product of the present disclosure contains CO_2 and H_2, and thus can be used to synthesize secondary fuel such as methanol. When the present disclosure is used in the energy storage field, renewable energy may be converted into fuel chemical energy for storage. This may resolve problems in aspects of energy storage stability, timeliness, transportation, or the like of the renewable energy.

[0050] The present disclosure is further described in detail below with reference to specific examples. These examples should not be understood as a limitation to the protection scope of the present disclosure.

[0051] Example 1

[0052] An apparatus for CO_2 capture coupled hydrogen production in Example 1 is shown in FIG. 1.

[0053] Air that contained low-concentration CO_2 entered the absorption tower 11, and was captured by a KOH solution fed herein, to obtain a first exhaust gas B1 to be exhausted, and obtain a low-concentration CO_2 absorption solution that contains K_2CO_3 and KOH. One portion of the low-concentration CO_2 absorption solution was introduced into the cathodic feed liquid tank 33, and then entered the cathode chamber 311 for electrolysis. The other portion of the low-concentration CO_2 absorption solution was introduced into the absorption tower 22, to capture a flue gas that contained high-concentration CO_2, thereby obtaining a second exhaust gas B2 to be exhausted, and obtaining a high-concentration CO_2 absorption solution that contained K_2CO_3 and $KHCO_3$, where a content of $KHCO_3$ was low. One portion of the high-concentration CO_2 absorption solution was introduced into the high-concentration CO_2 absorption solution tank 22, then entered the anodic liquid storage tank 32, and finally entered the anode chamber 312 for electrolysis.

[0054] A hydrogen evolution reaction occurred in the cathode chamber 311, to obtain H_2, and a cathodic discharge liquid that contained K_2CO_3 and KOH, where a concentration of KOH was increased. The cathodic discharge liquid entered the cathodic discharge liquid tank 34, and returned to the absorption tower 11, to continue capture of low-concentration CO_2. An oxygen evolution reaction occurs in the anode chamber 312, to obtain O_2, CO_2, and a mixed solution of low-concentration K_2CO_3 and medium-concentration $KHCO_3$. The mixed solution entered the anodic liquid storage tank 32, and then was recycled and entered the anode chamber 312 for electrolysis. The electrolyte diaphragm was a porous polymer diaphragm whose surface was polymerized with a carboxylate ion resin layer.

[0055] The first portion of the low-concentration CO_2 absorption solution accounts for 50% of the low-concentration CO_2 absorption solution. The catholyte solution is a mixed solution of 2M K_2CO_3 and 5M KOH. The anolyte solution is a mixed solution of 3M K_2CO_3 and 1M $KHCO_3$.

[0056] Example 2

[0057] Examples 2 to 6 differ from Example 1 in concentrations of ions in the catholyte solution and the anolyte solution. For details, refer to Table 1.

Table 1

	Catholyte solution		Anolyte solution	
	Concentration of carbonate radicals	Concentration of hydroxy radicals	Concentration of carbonate radicals	Concentration of bicarbonate radicals
Example 1	2	5	3	1
Example 2	0.1	0.1	0.1	0.1
Example 3	0.5	3	2	0.6
Example 4	3	7	5	1.5
Example 5	6	10	6.5	3
Example 6	6.5	11	7	4

[0058] Example 7

[0059] Example 7 differs from Example 1 in that the first portion of the low-concentration CO_2 absorption solution accounts for 10% of the low-concentration CO_2 absorption solution.

[0060] Example 8

[0061] Example 8 differs from Example 1 in that the first portion of the low-concentration CO_2 absorption solution accounts for 90% of the low-concentration CO_2 absorption solution.

[0062] Comparative Example 1

[0063] CO_2 in a wide concentration range was captured by using a KOH aqueous solution, to obtain K_2CO_3 for electrolysis. An ion exchange resin membrane was used as an electrolyte diaphragm. A mixed solution of $KHCO_3$ and K_2CO_3 and a mixed gas of CO_2 and O_2 were generated in the anode. H_2 and a regenerated KOH solution were obtained in the cathode.

[0064] In Examples 1 to 8 and Comparative Examples 1 and 2, electrolysis was performed at current density of 2000 A/m^2 (Faraday efficiency was 100%). When a capture amount of CO_2 is 1 kg, yields of H_2 and O_2, a regeneration amount of KOH, and energy consumed in electrolysis are shown in Table 2.

Table 2

	Capture amount of CO_2	Yield of H_2	Yield of O_2	Regeneration amount of KOH	Energy consumed in electrolysis
Example 1	1 kg	0.52 m^3	0.24 m^3	2.57 kg	3.80 kWh
Example 2	1 kg	0.46 m^3	0.26 m^3	2.35 kg	4.57 kWh
Example 3	1 kg	0.48 m^3	0.25 m^3	2.39 kg	4.42 kWh
Example 4	1 kg	0.51 m^3	0.23 m^3	2.56 kg	3.91 kWh
Example 5	1 kg	0.47 m^3	0.26 m^3	2.37 kg	5.48 kWh
Example 6	1 kg	0.53 m^3	0.27 m^3	2.50 kg	6.55 kWh

Example 7	1 kg	0.49 m^3	0.24 m^3	2.53 kg	4.01 kWh
Example 8	1 kg	0.52 m^3	0.23 m^3	2.49 kg	3.96 kWh
Comparative Example 1	1 kg	0.42 m^3	0.21 m^3	2.33 kg	5.76 kWh

[0065] It can be learned from the above that compared with the Comparative Examples, the examples have the following advantages. Because the method and apparatus for CO_2 capture coupled hydrogen production of the present disclosure were used, CO_2 in a wide concentration range that includes low-concentration CO_2 and high-concentration CO_2 can be absorbed and captured by using an alkaline solution as an absorbent. In addition, a non-ionic diaphragm was used to electrolyze low-concentration CO_2 and high-concentration CO_2, and product absorption coupled hydrogen production was performed, so that an absorption solution can be regenerated, and high-concentration CO_2 as well as additional products of H_2 and O_2 can be obtained. According to the present disclosure, a low-concentration CO_2 absorption solution is used as a catholyte solution, and a high-concentration CO_2 absorption solution is used as an anolyte solution. A concentration increase of CO_3^{2-} in an electrolytic cathode can restrain substance diffusion caused by a concentration difference, so that diffusion of HCO_3^- and $CO3^{2-}$ from the electrolytic anode to the cathode is reduced. Moreover, in preference to OH^-, CO_3^{2-} having more electric charges undergoes electromigration, so that electromigration of CO_3^{2-} to the anode is reduced. No ionic diaphragm may be used, which greatly reduces costs of an electrolytic cell, avoids severe restriction imposed by an ionic diaphragm on the electrolyte solution and the electrolytic cell, and implements recycling of a capture solution and regeneration of an alkaline absorption solution, thereby further reducing CO_2 capture costs. In summary, according to the method of the present disclosure, capture of CO_2 in a wide concentration range can be realized; electrolysis is performed by using a non-ionic diaphragm, to implement regeneration of an absorption solution coupled hydrogen production; capture costs of CO_2 in a wide concentration range can be reduced; additional products of H_2 and O_2 can be obtained; and hydrogen production costs can be reduced.

[0066] The above descriptions are merely preferred embodiments of the present disclosure and are not intended to limit the present disclosure, and various changes and modifications may be made to the present disclosure by those skilled in the art. Any modifications, equivalent substitutions, improvements, and the like made within principles of the present disclosure shall be included in the protection scope of the present disclosure

CLAIMS

1. A method for carbon capture coupled hydrogen production, characterised by comprising the following steps:

step S1: capturing low-concentration CO_2 by using a solution of an alkali metal hydroxide, to obtain a low-concentration CO_2 absorption solution, wherein the low-concentration CO_2 absorption solution comprises an alkali metal carbonate and the alkali metal hydroxide;

step S2: dividing the low-concentration CO_2 absorption solution into a first portion of the low-concentration CO_2 absorption solution and a second portion of the low-concentration CO_2 absorption solution; and capturing high-concentration CO_2 by using the first portion of the low-concentration CO_2 absorption solution, to obtain a high-concentration CO_2 absorption solution, wherein the high-concentration CO_2 absorption solution comprises the alkali metal carbonate and an alkali metal bicarbonate; and

step S3: performing electrolysis by using the second portion of the low-concentration CO_2 absorption solution as a catholyte solution, using the high-concentration CO_2 absorption solution as an anolyte solution, and using a non-ionic diaphragm as a diaphragm, to obtain H_2 and a cathodic discharge liquid at an electrolytic cathode, and obtain O_2, CO_2, and an anodic discharge liquid at an electrolytic anode; and performing step S1 by using the cathodic discharge liquid, wherein the cathodic discharge liquid comprises the alkali metal carbonate and the alkali metal hydroxide; and the anodic discharge liquid comprises the alkali metal carbonate and the alkali metal bicarbonate.

2. The method according to claim 1, characterised in that the alkali metal hydroxide is KOH, the alkali metal carbonate is K_2CO_3, and the alkali metal bicarbonate is $KHCO_3$; or

the alkali metal hydroxide is NaOH, the alkali metal carbonate is Na_2CO_3, and the alkali metal bicarbonate is $NaHCO_3$.

3. The method according to claim 1 or 2, characterised in that in step S2, the first portion of the low-concentration CO_2 absorption solution accounts for 10% to 90% of the low-concentration CO_2 absorption solution by volume percent.

4. The method according to any one of claims 1 to 3, characterised in that step S3 further comprises: performing electrolysis by using the anodic discharge liquid as the anolyte solution,

preferably, a concentration of carbonate radicals in the catholyte solution ranges from 0.1 M to 6 M, and a concentration of hydroxy radicals in the catholyte solution ranges from 0.1 M to 10 M; and more preferably, the concentration of carbonate radicals in the catholyte solution ranges

from 0.5 M to 3 M, and the concentration of hydroxy radicals in the catholyte solution ranges from 3 M to 7 M; and

preferably, a concentration of carbonate radicals in the anolyte solution ranges from 0.1 M to 6.5 M, and a concentration of bicarbonate radicals in the anolyte solution ranges from 0.1 M to 3 M; and more preferably, the concentration of carbonate radicals in the anolyte solution ranges from 2 M to 5 M, and the concentration of bicarbonate radicals in the anolyte solution ranges from 0.6 M to 1.5 M.

5. The method according to any one of claims 1 to 4, characterised in that the non-ionic diaphragm is one or more of a porous polymer diaphragm, a Zirfon film, a polyphenylene sulfide film, a polysulfone film, or a polyether sulfone film; preferably, the non-ionic diaphragm is the porous polymer diaphragm; and more preferably, a polymer layer on a surface of the porous polymer diaphragm is one or more of a carboxylate ion resin layer, polyphenylene sulfide, polysulfone, or polyether sulfone.

6. An apparatus for carbon capture coupled hydrogen production, characterised by comprising:

a low-concentration CO_2 absorption unit (1), having an inlet for a solution of an alkali metal hydroxide, an inlet for a first to-be-captured raw material that comprises low-concentration CO_2, an outlet for a first portion of a low-concentration CO_2 absorption solution, an outlet for a second portion of the low-concentration CO_2 absorption solution, and an outlet for a first exhaust gas, wherein the low-concentration CO_2 absorption unit (1) is configured to capture low-concentration CO_2 by using the solution of the alkali metal hydroxide, to obtain the low-concentration CO_2 absorption solution; and the low-concentration CO_2 absorption solution comprises an alkali metal carbonate and the alkali metal hydroxide;

a high-concentration CO_2 absorption unit (2), having an inlet for the first portion of the low-concentration CO_2 absorption solution, an inlet for a second to-be-captured raw material that comprises high-concentration CO_2, an outlet for a high-concentration CO_2 absorption solution, and an outlet for a second exhaust gas, wherein the inlet for the first portion of the low-concentration CO_2 absorption solution is connected to the outlet for the first portion of the low-concentration CO_2 absorption solution; the high-concentration CO_2 absorption unit (2) is configured to capture high-concentration CO_2 by using the first portion of the low-concentration CO_2 absorption solution, to obtain the high-concentration CO_2 absorption solution; and the high-concentration CO_2 absorption solution comprises the alkali metal carbonate and an alkali metal bicarbonate; and

an electrolysis unit (3), having an inlet for a catholyte solution, a non-ionic diaphragm, an inlet

for an anolyte solution, an outlet for a cathodic discharge liquid, an outlet for an anodic discharge liquid, an outlet for H_2, and an outlet for a mixed gas of O_2 and CO_2, wherein the inlet for the catholyte solution is connected to the outlet for the second portion of the low-concentration CO_2 absorption solution; the outlet for the catholyte solution is connected to the inlet for the solution of the alkali metal hydroxide; the inlet for the anolyte solution is connected to the outlet for the high-concentration CO_2 absorption solution; and the electrolysis unit (3) is configured to electrolyze the second portion of the low-concentration CO_2 absorption solution and the high-concentration CO_2 absorption solution, to obtain H_2 and the cathodic discharge liquid at an electrolytic cathode, and obtain O_2, CO_2, and the anodic discharge liquid at an electrolytic anode, wherein the cathodic discharge liquid comprises the alkali metal carbonate and the alkali metal hydroxide; and the anodic discharge liquid comprises the alkali metal carbonate and the alkali metal bicarbonate.

7. The apparatus according to claim 6, characterised in that

the low-concentration CO_2 absorption unit (1) comprises a low-concentration absorption tower (11), wherein the inlet for the solution of the alkali metal hydroxide and the outlet for the first exhaust gas are formed in a top of the low-concentration absorption tower (11); and the inlet for the first to-be-captured raw material that comprises low-concentration CO_2, the outlet for the first portion of the low-concentration CO_2 absorption solution, and the outlet for the second portion of the low-concentration CO_2 absorption solution are formed in a bottom of the low-concentration absorption tower (11); and

the high-concentration CO_2 absorption unit (2) comprises a high-concentration absorption tower (21), wherein the inlet for the first portion of the low-concentration CO_2 absorption solution and the outlet for the second exhaust gas are formed in a top of the high-concentration absorption tower (21), and the inlet for the second to-be-captured raw material that comprises high-concentration CO_2 and the outlet for the high-concentration CO_2 absorption solution are formed in a bottom of the high-concentration absorption tower (21).

8. The apparatus according to claim 6 or 7, characterised in that the electrolysis unit (3) comprises:

an electrolytic cell (31), having a cathode chamber (311) and an anode chamber (312), wherein the non-ionic diaphragm (313) is disposed between the cathode chamber (311) and the anode chamber (312); the electrolytic cathode is disposed in the cathode chamber (311); the electrolytic anode is disposed in the anode chamber (312); the cathode chamber (311) has the inlet for the

catholyte solution, the outlet for the cathodic discharge liquid, and the outlet for H_2; and the anode chamber (312) has the inlet for the anolyte solution, the outlet for the anodic discharge liquid, and the outlet for the mixed gas of O_2 and CO_2.

9. The apparatus according to any one of claims 6 to 8, characterised in that the high-concentration CO_2 absorption unit (2) further comprises a high-concentration CO_2 absorption solution tank (22), disposed on a pipeline through which the inlet for the anolyte solution is connected to the outlet for the high-concentration CO_2 absorption solution, and disposed on one side of the outlet for the high-concentration CO_2 absorption solution.

10. The apparatus according to any one of claims 6 to 9, characterised in that the electrolysis unit (3) further comprises:

a cathodic feed liquid tank (33), disposed on a pipeline through which the inlet for the catholyte solution is connected to the outlet for the second portion of the low-concentration CO_2 absorption solution; and/or

a cathodic discharge liquid tank (34), disposed on a pipeline through which the outlet for the catholyte solution is connected to the inlet for the solution of the alkali metal hydroxide; and/or

an anodic liquid storage tank (32), disposed on a pipeline through which the inlet for the anolyte solution is connected to the outlet for the high-concentration CO_2 absorption solution, and disposed on one side of the inlet for the anolyte solution.