DESCRIPTION

TITLE OF INVENTION: METHOD FOR PRODUCING CARBONATE OR BICARBONATE OF ALKALI METAL

TECHNICAL FIELD

[0001]

The present invention relates to a method for producing a carbonate or bicarbonate of an alkali metal.

Priority is claimed on Japanese Patent Application No. 2024-040341, filed March 14, 2024, the content of which is incorporated herein by reference.

BACKGROUND ART

[0002]

Alkali metal bicarbonates, such as sodium bicarbonate, are produced by crystallization from an aqueous solution. For example, the so-called ammonia-soda process has long been known, in which ammonia and carbon dioxide are introduced, in this order, into an aqueous solution containing sodium ions to obtain sodium bicarbonate crystals.

In addition, as a method for obtaining a carbonate and/or bicarbonate of an alkali metal, a method has been known that involves supplying a gas containing carbon dioxide to an aqueous solution of an alkali metal hydroxide or an alkali metal carbonate to perform carbonation and bicarbonation. For example, there is a method in which an aqueous sodium carbonate solution and a gas containing carbon dioxide are continuously supplied to and reacted in a tank in which sodium bicarbonate is suspended, thereby precipitating sodium bicarbonate.

Patent Document 1 discloses a method for producing sodium bicarbonate in

which an aqueous sodium hydroxide solution or an aqueous sodium carbonate solution is reacted with carbon dioxide to obtain a sodium bicarbonate solution, and the solution is cooled to precipitate sodium bicarbonate crystals.

[0003]

Patent Document 2 discloses a method in which an aqueous sodium hydroxide solution and a gas containing carbon dioxide are combined in advance, and then supplied into a storage tank containing an alkaline aqueous solution to precipitate sodium bicarbonate.

[0004]

Meanwhile, Patent Document 3 discloses an apparatus for efficiently recovering carbon dioxide, in which carbon dioxide is supplied without electric power through a perforated plate into a reaction tank storing an aqueous alkali metal hydroxide solution.

[0005]

Patent Document 4 discloses a method for producing a sodium bicarbonate slurry by supplying combustion exhaust gas containing carbon dioxide to an aqueous sodium carbonate solution generated in a caprolactam production process using a microbubbler, which is a high-pressure nozzle-type disperser.

[0006]

Patent Document 5 discloses a method for producing sodium bicarbonate by reacting an aqueous sodium carbonate solution with carbon dioxide, in which the carbon dioxide is supplied in the form of fine bubbles having an average diameter of 0.1 mm or less using a swirling collision-type mixer.

Citation List

Patent Documents

[0007]

Patent Document 1: Japanese Unexamined Patent Application, First Publication No. H03-275509

Patent Document 2: Japanese Unexamined Patent Application, First Publication No. 2012-206872

Patent Document 3: Japanese Unexamined Patent Application, First Publication No. 2023-65903

Patent Document 4: Korean Patent No. 10-2205282

Patent Document 5: Korean Patent No. 10-2313559

SUMMARY OF INVENTION

Technical Problem

[0008]

The present inventors considered that since the production of a carbonate and a bicarbonate is performed by bringing an aqueous solution of an alkali metal hydroxide or an aqueous solution of an alkali metal carbonate, which is a liquid, into contact with a gas containing carbon dioxide, which is a gas, to dissolve carbon dioxide into these aqueous solutions, reducing carbon dioxide into fine bubbles to increase the dissolution rate would lead to increasing the utilization rate of carbon dioxide and increasing the generation rate of the carbonate and the bicarbonate.

[0009]

However, Patent Documents 1 and 2 do not take this point into consideration and merely supply the gas containing carbon dioxide through a tube. Accordingly, only a portion of the supplied carbon dioxide reacts with the alkali metal hydroxide or the alkali metal carbonate, that is, the utilization rate of the carbon dioxide is low, and, in some cases, equipment for recovering unreacted carbon dioxide is required.

[0010]

In Patent Document 3, the carbon dioxide is supplied through a perforated plate, so that, although the absorption rate of the carbon dioxide is improved, the improvement cannot be said to be sufficient. In addition, when a bicarbonate precipitates, there is also a risk that the perforated plate may become clogged.

[0011]

In Patent Document 4, although the carbon dioxide is supplied using the apparatus referred to as a microbubbler, the conversion rate of the carbon dioxide remains at approximately 60%. The cause is considered to be that the carbon dioxide is not sufficiently formed into fine bubbles in the aqueous sodium carbonate solution.

[0012]

In Patent Document 5, although pressurized carbon dioxide is supplied in the form of fine bubbles using a reactor composed of a bubble reactor maintained under a pressure condition of 4 bar and an absorption tower, the utilization rate of the carbon dioxide remains at approximately 90%. The cause is likewise considered to be that the carbon dioxide bubbles are not sufficiently reduced in size.

[0013]

The present invention has been made in view of the above circumstances, and an object thereof is to provide a production method that, in producing a carbonate or bicarbonate of an alkali metal, enables reactions such as carbonation of an alkali metal hydroxide and bicarbonation of an alkali metal carbonate to be performed at a high rate, enables effective utilization of a gas having a low carbon dioxide concentration, and can increase the utilization rate of the carbon dioxide.

Solution to Problem

[0014]

As a result of intensive studies, the present inventors have found that the above

problems can be solved by supplying sufficiently fine carbon dioxide-containing bubbles to an aqueous solution (a) of at least one alkali metal compound selected from the group consisting of an alkali metal hydroxide, an alkali metal carbonate, and an alkali metal chloride, and have completed the present invention.

The present invention includes the aspects described below.

[1] A method for producing a carbonate or bicarbonate of an alkali metal, the method including: supplying carbon dioxide-containing bubbles, which are bubbles of a gas containing carbon dioxide, to an aqueous solution (a) of at least one alkali metal compound selected from the group consisting of an alkali metal hydroxide, an alkali metal carbonate, and an alkali metal chloride,

in which, when the aqueous solution (a) is an aqueous solution of an alkali metal chloride, ammonia is supplied to the aqueous solution (a) before the carbon dioxide-containing bubbles are supplied, and

the carbon dioxide-containing bubbles have a size such that a d50 is 100 μm or less and a d90 is 150 μm or less.

[2] The method according to [1], in which the carbonate or bicarbonate of the alkali metal is lithium carbonate, sodium carbonate, potassium carbonate, lithium bicarbonate, sodium bicarbonate, or potassium bicarbonate.

[3] The method according to [1] or [2], in which a concentration of the carbon dioxide in the gas containing carbon dioxide is 10 vol% or more.

[4] The method according to any one of [1] to [3], in which the carbon dioxide-containing bubbles have a size such that a d50 is 50 to 90 μm and a d90 is 100 to 150 μm.

[5] A method for producing an alkali metal bicarbonate, including:

filtering a slurry in which an alkali metal bicarbonate obtained by the method according to any one of [1] to [4] has precipitated;

adding, to a resulting filtrate, a first aqueous solution (a) of at least one alkali metal compound selected from the group consisting of an alkali metal hydroxide, an alkali metal carbonate, and an alkali metal chloride to obtain a second aqueous solution (a);

supplying carbon dioxide-containing bubbles to the second aqueous solution (a) to obtain a third aqueous solution (a) of a carbonate or bicarbonate of an alkali metal;

concentrating the obtained third aqueous solution (a) by removing water therefrom to obtain a fourth aqueous solution (a); and

supplying carbon dioxide-containing bubbles to the obtained fourth aqueous solution (a) to precipitate an alkali metal bicarbonate.

[6] A method for producing a powder of an alkali metal bicarbonate, including:

obtaining an aqueous solution or slurry containing an alkali metal bicarbonate by the method according to any one of [1] to [5]; and

subjecting the obtained aqueous solution or slurry to a dewatering treatment and a drying treatment to obtain a powder of the alkali metal bicarbonate.

[7] The method for producing a powder of an alkali metal bicarbonate, in which an average particle size (d50) of the powder of the alkali metal bicarbonate is 100 μm or less.

Advantageous Effects of Invention

[0015]

According to the present invention, it is possible to provide a production method that, in producing a carbonate or bicarbonate of an alkali metal, enables reactions such as carbonation of an alkali metal hydroxide and bicarbonation of an alkali metal carbonate to be performed at a high rate, enables effective utilization of a gas having a low carbon dioxide concentration, and can increase the utilization rate of the carbon dioxide.

BRIEF DESCRIPTION OF DRAWINGS

[0016]

[FIG. 1] A flow diagram representing an example of a production method according to the present invention.

[FIG. 2] A flow diagram representing another example of the production method according to the present invention.

DESCRIPTION OF EMBODIMENTS

[0017]

The meanings of the terms used in the present specification are as follows.

A numerical range expressed with "to" means a numerical range having the numerical values preceding and following "to" as the lower limit value and the upper limit value.

"d10", "d50", and "d90" refer to a 10% diameter, a 50% diameter (median diameter), and a 90% diameter, in that order, on a cumulative distribution curve of bubble (or particle) volume with respect to bubble (or particle) size.

"Utilization rate of carbon dioxide" means the ratio, expressed as a percentage, of the calculated value (B) of the amount of carbon dioxide gas, the amount being required to convert all of the alkali metal compound in the aqueous solution (a) used into the carbonate or bicarbonate of the alkali metal, to the amount (A) of carbon dioxide gas supplied for producing the carbonate or bicarbonate of the alkali metal.

[0018]

Hereinafter, the present invention will be described but is not limited by the examples in the following description.

A method for producing a carbonate or bicarbonate of an alkali metal according to the present embodiment includes supplying carbon dioxide-containing bubbles, which

are bubbles of a gas containing carbon dioxide, to an aqueous solution (a) of at least one alkali metal compound selected from the group consisting of an alkali metal hydroxide, an alkali metal carbonate, and an alkali metal chloride. Here, when the aqueous solution (a) is an aqueous solution of an alkali metal chloride, ammonia is supplied to the aqueous solution (a) before the carbon dioxide-containing bubbles are supplied.

[0019]

<<Aqueous Solution (a)>>

The aqueous solution (a) is an aqueous solution of at least one alkali metal compound selected from the group consisting of an alkali metal hydroxide, an alkali metal carbonate, and an alkali metal chloride.

The upper limit of the concentration of the alkali metal compound in the aqueous solution (a) is the saturation concentration of the alkali metal compound.

The concentration of the alkali metal compound in the aqueous solution (a) is preferably 3% or more, and more preferably 5% or more.

The lower limit of the concentration of the alkali metal compound in the aqueous solution (a) is preferably such that, when the alkali metal compound reacts with carbon dioxide to produce sodium bicarbonate, the resulting concentration of sodium bicarbonate exceeds the solubility of sodium bicarbonate at 0°C.

In particular, the concentration of sodium carbonate in the aqueous solution (a) is preferably 6 to 25%, and more preferably 10 to 20%. When the concentration is equal to or more than the above-described lower limit, the amount of sodium bicarbonate produced by reaction with carbon dioxide tends to exceed the solubility of sodium bicarbonate, and sodium bicarbonate tends to precipitate. In addition, when the concentration is equal to or less than the above-described upper limit, the amount of sodium bicarbonate in a slurry containing the produced sodium bicarbonate is moderate,

and the viscosity of the slurry does not become excessively high, thereby facilitating handling.

[0020]

<Alkali Metal>

Examples of the alkali metal include lithium, sodium, and potassium. When these alkali metals are used, a carbonate or bicarbonate, such as lithium carbonate, lithium bicarbonate, sodium carbonate, sodium bicarbonate, potassium carbonate, and potassium bicarbonate, is obtained as a target product of the method according to the present embodiment.

[0021]

<<Carbon Dioxide-Containing Bubbles>>

The carbon dioxide-containing bubbles are bubbles of a gas containing carbon dioxide.

The gas containing carbon dioxide is not particularly limited as long as the concentration of the carbon dioxide is 10 vol% or more, and usable gases include not only mixed gases of carbon dioxide and air or nitrogen gas, such as exhaust gas from a combustion furnace, exhaust gas from a glass melting furnace, and gas generated by neutralization of a carbonate, but also high-purity carbon dioxide gas. The carbon dioxide concentration is preferably 30 vol% or more, and more preferably 50 vol% or more. The upper limit of the carbon dioxide concentration is not particularly limited, and may be 100 vol%.

[0022]

In the production method according to the present embodiment, the carbon dioxide-containing bubbles, which are minute bubbles of the gas containing carbon dioxide, are formed and supplied to the aqueous solution (a) of the alkali metal

compound described above.

As for the size of the above-described carbon dioxide-containing bubbles, the d50 is 100 μm or less and the d90 is 150 μm or less. The carbon dioxide-containing bubbles having such a size can be obtained by appropriately adjusting conditions of a known fine bubble adjustment method.

[0023]

The "fine bubble" is a generic term for microbubbles having a diameter of 1 to 100 μm and nanobubbles having a diameter of less than 1 μm. When a large number of microbubbles are generated in water, white turbidity occurs. On the other hand, since the nanobubbles are extremely small, the water remains transparent. By forming the gas containing carbon dioxide into fine bubbles, the dissolution rate of the carbon dioxide can be increased, and almost all of the supplied carbon dioxide can react with the alkali metal compound, thereby allowing the carbon dioxide to react without loss. Accordingly, not only does the conventional equipment for recovering unreacted carbon dioxide become unnecessary, but the reaction can also proceed at a sufficient reaction rate even with a gas having a low carbon dioxide concentration. Furthermore, the method also has the advantage that a tank containing the aqueous solution (a) of the alkali metal compound described above need not be pressurized and that a simple apparatus operating at atmospheric pressure can be used as a reaction apparatus.

[0024]

An apparatus for producing such fine bubbles is not particularly limited, and examples thereof include the following.

(Example 1) An apparatus that supplies gas to a suction side of a pressure pump and converts the gas drawn into the pressure pump into fine bubbles by a mixing blade rotating at high speed in the pressure pump; specific example thereof include "Vortex

turbo mixer pump" (trade name) manufactured by Nikuni Co., Ltd.

(Example 2) An apparatus in which a low-pressure portion is formed in a liquid flow by the Venturi effect (by narrowing a flow passage through which a pressurized liquid flows to increase a flow rate and create a low-pressure portion), and gas is supplied to the low-pressure portion and formed into fine bubbles; specific examples thereof include "YJ nozzle" (trade name) manufactured by EnviroVision Co., Ltd. and "Aqua Transfer Nozzle" (trade name) manufactured by Water Navi Co., Ltd.

(Example 3) An apparatus that radially ejects water from a disk rotating at high speed to form a negative-pressure portion in a central portion, draws in gas, and forms fine bubbles; specific examples thereof include "Spinor" (trade name) manufactured by Water Navi Co., Ltd.

[0025]

The size of the carbon dioxide-containing bubbles can be measured, for example, by focused beam reflectance measurement. The measurement can be performed using a particle size analyzer (trade name: Particle Track) manufactured by Mettler-Toledo K.K., employing Focused Beam Reflectance Measurement (FBRM). In the present specification, the size distribution of the carbon dioxide-containing bubbles is represented by the 10% diameter (d10), the 50% diameter (median diameter, d50), and the 90% diameter (d90) on the cumulative distribution curve of bubble volume with respect to bubble size.

In the present embodiment, use of carbon dioxide-containing bubbles having a d50 of 100 μm or less and a d90 of 150 μm or less can sufficiently increase the utilization rate of the carbon dioxide in carbonation of an alkali metal hydroxide and bicarbonation of an alkali metal carbonate or an alkali metal chloride.

From the viewpoint of further ensuring the effects of the present invention, the

d50 is preferably 50 to 90 μm, and more preferably 60 to 80 μm; and the d90 is preferably 100 to 150 μm, and more preferably 100 to 130 μm.

In the present invention, so-called fine bubbles having a bubble diameter of 1 μm or less need not be present. The minimum value of the bubble diameter of the carbon dioxide-containing bubbles is not particularly limited, but is preferably more than 1 μm, or 10 μm or more from the viewpoint of ease of adjusting the carbon dioxide-containing bubbles. With the method according to the present invention, the utilization rate of the carbon dioxide can be sufficiently increased even when fine bubbles having a bubble diameter of 1 μm or less are not present.

[0026]

<<Supply of Carbon Dioxide-Containing Bubbles to Aqueous Solution (a)>>

When the above-described alkali metal compound is an alkali metal hydroxide, the temperature of the aqueous solution (a) during supply of the carbon dioxide-containing bubbles is not particularly limited and is preferably 0°C to 80°C. The lower the temperature, the greater the solubility of carbon dioxide in the aqueous solution (a) of the alkali metal hydroxide, but 0°C or higher is preferred because there is no risk of freezing. On the other hand, the solubility of carbon dioxide in the aqueous solution (a) of the alkali metal hydroxide decreases as the temperature increases; therefore, 80°C or lower is preferred because the production rate of the alkali metal carbonate is unlikely to decrease. The temperature of the aqueous solution (a) is more preferably 20°C to 60°C, and still more preferably 30°C to 50°C.

[0027]

When the above-described alkali metal compound is an alkali metal carbonate, the temperature of the aqueous solution (a) during supply of the carbon dioxide-containing bubbles is not particularly limited and is preferably 0°C to 80°C. The lower

the temperature, the greater the solubility of carbon dioxide in the aqueous solution of the alkali metal carbonate, but 0°C or higher is preferred because there is no risk of freezing. On the other hand, the solubility of carbon dioxide in the aqueous solution (a) of the alkali metal carbonate decreases as the temperature increases; therefore, 80°C or lower is preferred because the production rate of the alkali metal carbonate is unlikely to decrease. In addition, although the solubility of the alkali metal bicarbonate produced increases as the temperature increases, 80°C or lower is preferred because a greater amount of the alkali metal bicarbonate produced precipitates. The temperature of the aqueous solution (a) is more preferably 20°C to 70°C, and still more preferably 25°C to 50°C.

The period for which the carbon dioxide-containing bubbles are supplied to the aqueous solution (a) is not particularly limited, provided that the desired reaction can proceed sufficiently, but is generally 0.2 to 16 hours and preferably 0.5 to 8 hours.

[0028]

When the alkali metal compound is an alkali metal chloride such as sodium chloride, ammonia is supplied to the aqueous solution (a) before the carbon dioxide-containing bubbles are supplied. In this case, the procedure and conditions, except for the use of the carbon dioxide-containing bubbles, may be those of a known ammonia-soda process.

[0029]

One specific aspect of the method according to the present invention is described below.

Carbon dioxide-containing bubbles are supplied to an aqueous solution (a) of an alkali metal carbonate (a first aqueous solution (a)) to obtain a slurry in which an alkali metal bicarbonate is precipitated, and then an aqueous solution of an alkali metal

hydroxide (a first aqueous solution (a)) is added to a filtrate (b) obtained by filtering the slurry, thereby obtaining a second aqueous solution (a). Carbon dioxide-containing bubbles are supplied to the second aqueous solution (a) to convert the second aqueous solution (a) into an aqueous solution of an alkali metal carbonate, and then the resulting aqueous solution is concentrated by removing water to obtain a third aqueous solution (a). Carbon dioxide-containing bubbles are supplied again to the concentrated aqueous solution of the alkali metal carbonate (the third aqueous solution (a)) to precipitate an alkali metal bicarbonate.

The filtrate (b) obtained by filtering the slurry in which the alkali metal bicarbonate is precipitated is, in other words, a saturated aqueous solution of the alkali metal bicarbonate. Therefore, in the present invention, employing such a process allows the saturated aqueous solution of the alkali metal bicarbonate to be reused as a raw material for producing the alkali metal bicarbonate, so that the alkali metal and carbon dioxide used as raw materials can be recovered in their entirety as the alkali metal bicarbonate without loss.

The reason for removing water from and thus concentrating the aqueous solution of the alkali metal carbonate as described above is that, as this series of operations is repeated, the volume of the slurry in which the alkali metal bicarbonate is precipitated gradually increases, requiring an extremely large tank to contain the slurry. For example, when the alkali metal is sodium or potassium, aqueous sodium hydroxide or potassium hydroxide solutions are available only at a concentration of up to 48%, and unless water is removed, the volume of the slurry in which sodium bicarbonate or potassium bicarbonate is precipitated gradually increases. When the concentration of the aqueous alkali metal hydroxide solution can be adjusted to 66%, it is not necessary to remove water.

[0030]

The method for removing water from and thus concentrating the aqueous solution of the alkali metal carbonate as described above is not particularly limited; however, supplying fine bubbles of a gas having a low water vapor partial pressure to the aqueous solution is most preferred because water can be removed with less equipment. The apparatuses described above can be used to generate the fine bubbles. It is sufficient to provide a pump and pipe for circulating the aqueous solution and a pipe for the gas.

As another method, a method using a so-called packed column can be mentioned. This method uses a packed column containing packing such as Pall rings, in which the aqueous solution is sprayed from above and allowed to flow downward while a gas having a low water vapor partial pressure is supplied upward from below, thereby bringing the gas and liquid into contact with each other. However, the method requires a packed column in addition to the pump and pipe for circulating the aqueous solution and the pipe for the gas.

As a further example of the method, a method in which the aqueous solution is heated to evaporate water can be mentioned. Examples of heating methods include a method that involves providing a vessel containing the aqueous solution with an external jacket or immersing a coiled pipe in the aqueous solution, and passing steam at atmospheric pressure or higher or high-temperature hot water through the jacket or coiled pipe. However, in addition to the pump and pipe for circulating the aqueous solution and the pipe for the gas, the method requires equipment for generating steam or high-temperature hot water and supplying the steam or hot water to the vessel containing the aqueous solution.

[0031]

A first embodiment of the method according to the present invention is

described below with reference to FIG. 1; however, this embodiment is merely an example of an embodiment of the present invention, and the present invention is not limited by this example.

FIG. 1 is a flow diagram showing an example of the production method according to the present invention, and shows an example of the overall configuration of a sodium bicarbonate production apparatus for carrying out the method according to the present invention.

[0032]

In FIG. 1, a concentration adjustment tank 1 for an aqueous sodium carbonate solution is a tank operated at atmospheric pressure and having a stirring device 2. In addition, an aqueous sodium carbonate solution 3 is contained in the concentration adjustment tank 1. The aqueous sodium carbonate solution 3 is adjusted to a predetermined concentration by a method described later. The aqueous sodium carbonate solution 3 adjusted to the predetermined concentration is fed through a feed pipe 5 to a sodium bicarbonate precipitation tank 6 using a vortex turbo mixer pump 4. The sodium bicarbonate precipitation tank 6 is a tank operated at atmospheric pressure and having a stirring device 7. A liquid 8 in the sodium bicarbonate precipitation tank is initially the concentration-adjusted aqueous sodium carbonate solution. While the liquid is circulated through a circulation pipe 10 in the sodium bicarbonate precipitation tank 6 using a vortex turbo mixer pump 9, a gas containing carbon dioxide is supplied through a supply pipe 11 for gas containing carbon dioxide to a suction side of the vortex turbo mixer pump 9, and introduced into the circulating liquid as fine bubbles having d50 and d90 values within the ranges described above. As the introduction of the gas containing carbon dioxide proceeds, the pH of the liquid 8 in the sodium bicarbonate precipitation tank decreases, and the liquid becomes cloudy as sodium bicarbonate precipitates.

Finally, when the pH of the liquid 8 in the sodium bicarbonate precipitation tank reaches 8.5 or less, the supply of the gas containing carbon dioxide is stopped, thereby obtaining a sodium bicarbonate slurry.

[0033]

The sodium bicarbonate slurry is withdrawn through a feed pipe 12 using the vortex turbo mixer pump 9. Subsequently, the withdrawn sodium bicarbonate slurry is filtered using a centrifugal dewatering machine 13. A sodium bicarbonate cake obtained by centrifugal dewatering is sent through a feed pipe 14 to drying equipment 15, and dried by the drying equipment 15 to obtain a sodium bicarbonate powder 16. During the centrifugal dewatering, a filtrate 17 is also generated. The filtrate 17 is saturated sodium bicarbonate water. After being collected in a filtrate recovery tank 18, the solution is returned to the concentration adjustment tank 1 for the aqueous sodium carbonate solution through a filtrate feed pipe 20 by a filtrate feed pump 19.

[0034]

In the concentration adjustment tank 1 for the aqueous sodium carbonate solution, sodium hydroxide is added to the filtrate 17 through a sodium hydroxide addition pipe 21. The addition of sodium hydroxide increases the pH of the aqueous solution to approximately 14. Thereafter, while the aqueous solution is circulated through a circulation pipe 22 in the concentration adjustment tank 1 for the aqueous sodium carbonate solution using the vortex turbo mixer pump 4, carbon dioxide is supplied through a gas supply pipe 23 for gas containing carbon dioxide to a suction side of the vortex turbo mixer pump 4, and introduced into the circulating aqueous solution as fine bubbles having d50 and d90 values within the ranges described above. As the gas containing carbon dioxide is introduced, the pH of the liquid 8 in the concentration adjustment tank 1 for the aqueous sodium carbonate solution decreases. When the pH

finally reaches the pH of an aqueous sodium carbonate solution (= approximately 12), the supply of the gas containing carbon dioxide is stopped, thereby obtaining an aqueous sodium carbonate solution. Subsequently, while the aqueous sodium carbonate solution is circulated using the circulation pipe 22 in the concentration adjustment tank 1 for the aqueous sodium carbonate solution using the vortex turbo mixer pump 4, air is supplied through an air supply pipe 24 to the suction side of the vortex turbo mixer pump 4, and introduced into the circulating solution as fine bubbles. As the air is introduced, water evaporates from the aqueous sodium carbonate solution, thereby concentrating the solution and adjusting it to a predetermined sodium carbonate concentration.

[0035]

A second embodiment of the method according to the present invention is described below with reference to FIG. 2; however, this embodiment is merely an example of an embodiment of the present invention, and the present invention is not limited by this example.

FIG. 2 is a flow diagram showing another example of the production method according to the present invention, and shows an example of the overall configuration of a sodium bicarbonate production apparatus for carrying out the method according to the present invention.

[0036]

The second embodiment differs from the first embodiment in that a YJ nozzle is used, instead of the vortex turbo mixer pump, as the apparatus for generating fine bubbles of the gas containing carbon dioxide.

In FIG. 2, the liquid in the concentration adjustment tank 1 for the aqueous sodium carbonate solution is supplied to a YJ nozzle 27 by a magnet pump 25. The gas containing carbon dioxide is supplied through the supply pipe 23 to a central portion of

the YJ nozzle 27, and is formed into fine bubbles in the YJ nozzle, with d50 and d90 values within the ranges described above. As a result, the aqueous sodium carbonate solution 3 is obtained in the concentration adjustment tank 1 for the aqueous sodium carbonate solution.

[0037]

Similarly, the liquid in the sodium bicarbonate precipitation tank 6 is supplied to a YJ nozzle 28 by a magnet pump 26. The gas containing carbon dioxide is supplied through the supply pipe 11 to a central portion of the YJ nozzle 28, and is formed into fine bubbles in the YJ nozzle, with d50 and d90 values within the ranges described above. As a result, sodium bicarbonate precipitates in the sodium bicarbonate precipitation tank 6, and a sodium bicarbonate slurry is obtained.

[0038]

With the method according to the present invention for producing a carbonate or bicarbonate of an alkali metal, the utilization rate of carbon dioxide can be increased. Here, the utilization rate of carbon dioxide is preferably 95% or more, more preferably 98% or more, and most preferably 100%.

Although the method according to the present invention for producing a carbonate or bicarbonate of an alkali metal has been described above, the present invention is not limited to the configurations described for the embodiments above, and the configurations may be modified as appropriate without departing from the gist of the present invention.

[0039]

Furthermore, according to the present production method, the bicarbonation reaction of the alkali metal carbonate can be carried out at a high rate, thereby obtaining small particles of an alkali metal bicarbonate (for example, sodium bicarbonate) having

an average particle size of 100 μm or less. Therefore, the present production method also facilitates pulverization for producing a fine powder product of an alkali metal bicarbonate having an average particle size of 8 to 15 μm (approximately 10 μm). Since the fine powder product has a large specific surface area, it is suitable as an alkali metal bicarbonate (for example, sodium bicarbonate) for treating flue gas generated at thermal power generation facilities, waste incineration facilities, biomass power generation facilities, and the like, that is, for removing acid gases contained in the flue gas.

Here, the "average particle size" is a volume-based cumulative 50% diameter (= median diameter, d50), and the small alkali metal bicarbonate particles preferably have an average particle size of 100 μm or less, more preferably 50 μm or less, still more preferably 35 μm or less, even more preferably 25 μm or less, particularly preferably 20 μm or less, and most preferably 10 μm or less.

That is, according to one aspect of the present invention, there is provided a method for producing a powder of an alkali metal bicarbonate, the method including obtaining an aqueous solution or slurry containing an alkali metal bicarbonate by the production method described above, and

subjecting the obtained aqueous solution or slurry to a dewatering treatment and a drying treatment to obtain a powder of the alkali metal bicarbonate.

The dewatering treatment and the drying treatment may be performed by known methods. For example, the treatments may be performed under conditions such that the resulting powder has a moisture content of 1.0 mass% or less, or 0.1 mass% or less. The above-described moisture content can be measured by a known method, such as a method described in Japanese Unexamined Patent Application, First Publication No. 2003-83947.

Examples

[0040]

The present invention is described in detail below by way of Examples, but is not limited thereto. Unless otherwise specified, “part” and “%” mean “part by mass” and “mass%”.

[0041]

Examples 1 to 5 and 9 are examples according to the present invention, and Examples 6 to 8 and 10 are Comparative Examples.

[0042]

<<Measurement Methods and Evaluation Methods>>

(Size of Carbon Dioxide-Containing Bubbles)

The size of the carbon dioxide-containing bubbles was measured using a particle size analyzer (trade name: Particle Track G400) manufactured by Mettler-Toledo K.K., employing Focused Beam Reflectance Measurement (FBRM). Specifically, in FIG. 1 or FIG. 2, the bubble size was measured by immersing a measurement probe in the aqueous sodium carbonate solution 3 or the liquid 8 in the sodium bicarbonate precipitation tank. The bubble-size distribution was represented by the 10% diameter (d10), the 50% diameter (median diameter, d50), and the 90% diameter (d90) on the cumulative distribution curve of bubble volume with respect to bubble size.

[0043]

(Utilization Rate of Carbon Dioxide)

The utilization rate (%) of carbon dioxide (UR1) during sodium bicarbonate precipitation was defined as the ratio, expressed as a percentage, of the calculated value (B) of the amount of carbon dioxide gas, the amount being required to convert all of the sodium carbonate in the aqueous sodium carbonate solution used into sodium bicarbonate, to the amount (A) of carbon dioxide gas actually supplied for the sodium

bicarbonate precipitation. That is, the utilization rate of carbon dioxide (UR1) can be calculated by the following expression (1).

Utilization rate (UR1) of carbon dioxide during sodium bicarbonate precipitation (%) = Calculated value of amount of carbon dioxide gas required to convert all sodium carbonate into sodium bicarbonate (B, unit: L)/Amount of carbon dioxide gas actually supplied (A, unit: L) × 100 Expression (1)

In addition, the utilization rate (%) of carbon dioxide (UR2) during adjustment of the aqueous sodium carbonate solution was defined as the ratio, expressed as a percentage, of the calculated value (D) of the required amount of carbon dioxide gas, to the amount (C) of carbon dioxide gas supplied to convert the mixture of the filtrate obtained by centrifugal dewatering and sodium hydroxide into the aqueous sodium carbonate solution. That is, the utilization rate of carbon dioxide (UR2) can be calculated by the following expression (2).

Utilization rate (UR2) of carbon dioxide during adjustment of aqueous sodium carbonate solution (%) = Calculated value of carbon dioxide gas required to convert mixture of filtrate and sodium hydroxide into aqueous sodium carbonate solution (D, unit: L)/Amount of carbon dioxide gas actually supplied (C, unit: L) × 100 Expression (2)

[0044]

(Average Particle Size d50 of Sodium Bicarbonate)

Using a Microtrac FRA particle size distribution analyzer manufactured by Nikkiso Co., Ltd., the particle size distribution of sodium bicarbonate particles dispersed in a mixed solvent (methanol = 11%, ethanol = 88%, and isopropanol = 1%) was measured, and the volume-based cumulative 50% diameter (median diameter, d50) was determined.

[0045]

(Example 1)

The apparatus of the first embodiment shown in FIG. 1 was used. First, 800 g of sodium carbonate powder and 4000 g of deionized water were charged into the concentration adjustment tank 1 for an aqueous sodium carbonate solution, having an internal volume of 8 L, and stirred to obtain 4800 g of an aqueous sodium carbonate solution having a concentration of 16.7%. Next, the aqueous solution was transferred to the sodium bicarbonate precipitation tank 6 having an internal volume of 8 L, and then the vortex turbo mixer pump 9 was started and the aqueous solution was circulated using the circulation pipe 10. A KTM15ND02S model manufactured by Nikuni Co., Ltd. was used as the vortex turbo mixer pump 9. The circulation flow rate was 20 L/min. Immediately after the circulation was started, carbon dioxide gas (carbon dioxide concentration: 100 vol%) was supplied at a rate of 1.0 L/min to the suction-pipe side of the vortex turbo mixer pump 9, and introduced into the aqueous solution as fine bubbles. Regarding the size of the carbon dioxide bubbles, d50 = 63 μm and d90 = 107 μm. The temperature of the aqueous solution during the introduction of carbon dioxide was 25°C to 35°C. After 169 minutes from the start of supply of the carbon dioxide-containing bubbles, the liquid in the sodium bicarbonate precipitation tank 6 became a cloudy sodium bicarbonate slurry with a pH of 8.0. The utilization rate of carbon dioxide (UR1) was 100%.

[0046]

The sodium bicarbonate slurry was filtered using the centrifugal dewatering machine 13 to obtain 1117 g of a centrifugal dewatering cake and 4015 g of a filtrate. An H-110F model manufactured by KOKUSAN Co., Ltd. was used as the centrifugal dewatering machine 13. The centrifugal dewatering cake was dried in a carbon dioxide

atmosphere at 80°C to obtain 893 g of sodium bicarbonate powder. The average particle size d50 of the obtained sodium bicarbonate powder was 31 μm. When 200 g of the obtained sodium bicarbonate powder was pulverized for 30 minutes using a pulverizer (model SP-3, manufactured by NYLAB LLC.) at a blade rotation speed of 4,000 rpm, a fine powder product having an average particle size d50 of 11 μm was obtained.

Meanwhile, the filtrate was saturated sodium bicarbonate water (concentration: 9.3%). The filtrate was returned to the concentration adjustment tank 1 for the aqueous sodium carbonate solution, and 886 g of a 48% aqueous sodium hydroxide solution was added thereto. Thereafter, the vortex turbo mixer pump 4 was started, and the resulting solution was circulated using the circulation pipe 22. The circulation flow rate was 20 L/min. A KTM15ND02S model manufactured by Nikuni Co., Ltd. was used as the vortex turbo mixer pump. Immediately after the circulation was started, carbon dioxide gas was supplied at a rate of 1.0 L/min to the suction-pipe side of the vortex turbo mixer pump 4, and introduced into the circulating solution as fine bubbles. Regarding the size of the carbon dioxide bubbles, d50 = 63 μm and d90 = 106 μm. After 69 minutes, the liquid in the concentration adjustment tank 1 for the aqueous sodium carbonate solution became an aqueous sodium carbonate solution having a pH of 12.0, a weight of 5037 g, and a sodium carbonate content of 800 g. The utilization rate of carbon dioxide (UR2) was 100%.

[0047]

Subsequently, the vortex turbo mixer pump 4 was started, and while the aqueous sodium carbonate solution was circulated using the circulation pipe 22 at a circulation flow rate of 20 L/min, air was supplied at a rate of 1.0 L/min to the suction-pipe side of the vortex turbo mixer pump 4, and introduced into the circulating solution as fine bubbles. The aqueous sodium carbonate solution in the concentration adjustment tank 1

for the aqueous sodium carbonate solution was gradually concentrated by evaporation of water, and after 9 hours, the weight of the aqueous sodium carbonate solution became 4800 g. The sodium carbonate content was 800 g, the same amount as in the initially adjusted aqueous sodium carbonate solution.

Various conditions and results are shown in Table 1 and Table 2.

[0048]

(Example 2)

The same procedure as in Example 1 was carried out except that, in the sodium bicarbonate precipitation tank 6, the gas to be added to the suction-pipe side of the vortex turbo mixer pump 9 was changed to a mixed gas of carbon dioxide at 0.3 L/min and air at 0.7 L/min, and the mixed gas was formed into fine bubbles and supplied. Regarding the size of bubbles of the mixed gas containing carbon dioxide, d50 = 75 μm and d90 = 143 μm. The temperature of the aqueous solution during the introduction of carbon dioxide was 25°C to 35°C. After 563 minutes from the start of supply of the carbon dioxide-containing bubbles, the liquid in the sodium bicarbonate precipitation tank became a cloudy sodium bicarbonate slurry with a pH of 8.0. The utilization rate of carbon dioxide (UR1) was 100%. Because the concentration of the carbon dioxide in the gas containing carbon dioxide was 30 vol%, the reaction time became long, but the utilization rate of carbon dioxide (UR1) was 100%.

The conditions and results are shown in Table 1 and Table 2.

[0049]

(Example 3)

The apparatus of the second embodiment shown in FIG. 2 was used. The same procedure as in Example 1 was carried out except that, as an apparatus for producing the carbon dioxide-containing bubbles, a YJ nozzle was used instead of the vortex turbo

mixer pump. As the YJ nozzle, a YJ-6 inline model (trade name) was used.

First, 800 g of sodium carbonate powder and 4000 g of deionized water were charged into the concentration adjustment tank 1 for an aqueous sodium carbonate solution, having an internal volume of 8 L, and stirred to obtain 4800 g of an aqueous sodium carbonate solution having a concentration of 16.7%. Next, the aqueous solution was transferred to the sodium bicarbonate precipitation tank 6 having an internal volume of 8 L, and then the magnet pump 26 was started and the aqueous solution was circulated using the circulation pipe 10. As the magnet pump, a stainless-steel motor pump, model MM-254 (trade name), manufactured by Maruhachi Pump Mfg. Co., Ltd., was used. The circulation flow rate was 20 L/min. Immediately after the circulation was started, carbon dioxide gas was supplied at a rate of 1.0 L/min to the YJ nozzle 28, and introduced into the circulating solution as fine bubbles. Regarding the size of the carbon dioxide bubbles, d50 = 63 μm and d90 = 102 μm. The temperature of the aqueous solution during the introduction of carbon dioxide was 25°C to 35°C. After 169 minutes from the start of supply of the carbon dioxide-containing bubbles, the liquid in the sodium bicarbonate precipitation tank became a cloudy sodium bicarbonate slurry with a pH of 8.0. The utilization rate of carbon dioxide (UR1) was 100%.

[0050]

The sodium bicarbonate slurry was filtered using the centrifugal dewatering machine 13 to obtain 1117 g of a centrifugal dewatering cake and 4015 g of a filtrate. An H-110F model manufactured by KOKUSAN Co., Ltd. was used as the centrifugal dewatering machine. The centrifugal dewatering cake was dried in a carbon dioxide atmosphere at 80°C to obtain 893 g of sodium bicarbonate powder.

[0051]

Meanwhile, the filtrate was saturated sodium bicarbonate water (concentration:

9.3%). The filtrate was returned to the concentration adjustment tank 1 for the aqueous sodium carbonate solution, and 886 g of a 48% aqueous sodium hydroxide solution was added thereto. Thereafter, the magnet pump 25 was started, and the resulting solution was circulated using the circulation pipe 22. As the magnet pump, a stainless-steel motor pump, model MM-254 (trade name), manufactured by Maruhachi Pump Mfg. Co., Ltd., was used. The circulation flow rate was 20 L/min. Immediately after the circulation was started, carbon dioxide gas was supplied at a rate of 1.0 L/min to the YJ nozzle 27, and introduced into the circulating solution as fine bubbles. Regarding the size of the carbon dioxide bubbles, d50 = 63 μm and d90 = 103 μm. After 69 minutes, the liquid in the concentration adjustment tank 1 for the aqueous sodium carbonate solution was an aqueous sodium carbonate solution having a pH of 12.0, a weight of 5037 g, and a sodium carbonate content of 800 g. The utilization rate of carbon dioxide (UR2) was 100%.

[0052]

Subsequently, the magnet pump 25 was started, and while the aqueous sodium carbonate solution was circulated using the circulation pipe 22 at a circulation flow rate of 20 L/min, air was supplied at a rate of 1.0 L/min to the YJ nozzle 27 and introduced into the circulating solution as fine bubbles. The aqueous sodium carbonate solution in the concentration adjustment tank 1 for the aqueous sodium carbonate solution was gradually concentrated by evaporation of water, and after 9 hours, the weight of the aqueous sodium carbonate solution became 4800 g. The sodium carbonate content was 800 g, the same amount as in the initially adjusted aqueous sodium carbonate solution.

The conditions and results are shown in Table 1 and Table 2.

[0053]

(Example 4)

The same procedure as in Example 3 was carried out except that, in the sodium bicarbonate precipitation tank 6, the carbon dioxide was supplied such that the supply rate of carbon dioxide to be added to the YJ nozzle 28 was changed to 3.0 L/min. Regarding the size of the carbon dioxide bubbles, d50 = 65 μm and d90 = 108 μm. The temperature of the aqueous solution during the introduction of carbon dioxide was 25°C to 35°C. After 56 minutes from the start of supply of the carbon dioxide-containing bubbles, the liquid in the sodium bicarbonate precipitation tank became a cloudy sodium bicarbonate slurry with a pH of 8.0. Even when the supply flow rate of carbon dioxide was increased, the utilization rate of carbon dioxide (UR1) was 100%, so that the reaction proceeded at a high rate.

The conditions and results are shown in Table 1 and Table 2.

[0054]

(Example 5)

The same procedure as in Example 3 was carried out except that, in the sodium bicarbonate precipitation tank 6, the carbon dioxide was supplied such that the supply rate of carbon dioxide to be added to the YJ nozzle 28 was changed to 5.0 L/min. Regarding the size of the carbon dioxide bubbles, d50 = 72 μm and d90 = 124 μm. The temperature of the aqueous solution during the introduction of carbon dioxide was 25°C to 35°C. After 34 minutes from the start of supply of the carbon dioxide-containing bubbles, the liquid in the sodium bicarbonate precipitation tank became a cloudy sodium bicarbonate slurry with a pH of 8.0. Even when the supply flow rate of carbon dioxide was increased, the utilization rate of carbon dioxide (UR1) was 100%, so that the reaction proceeded at a high rate.

[0055]

(Example 6)

800 g of sodium carbonate powder and 4000 g of deionized water were charged into the sodium bicarbonate precipitation tank 6 having an internal volume of 8 L, and stirred to obtain 4800 g of an aqueous sodium carbonate solution having a concentration of 16.7%. Next, in the sodium bicarbonate precipitation tank 6, instead of adding carbon dioxide by forming it into fine bubbles using the vortex turbo mixer pump 9 or the YJ nozzle 28, carbon dioxide was blown out at a rate of 1.0 L/min and added using a cylindrical gas injection pipe (trade name: Kerami Filter, pore size: 50 μm) manufactured by Koshin Rikagaku Seisakusho. The size of the carbon dioxide bubbles was large, with a d50 of 168 μm and a d90 of 306 μm. The temperature of the aqueous solution during the introduction of carbon dioxide was 25°C to 35°C. It took a long time of 277 minutes for the liquid in the sodium bicarbonate precipitation tank to become a cloudy sodium bicarbonate slurry with a pH of 8.0, and the utilization rate of carbon dioxide (UR1) was 61%.

The conditions and results are shown in Table 1 and Table 2.

[0056]

(Example 7)

800 g of sodium carbonate powder and 4000 g of deionized water were charged into the sodium bicarbonate precipitation tank 6 having an internal volume of 8 L, and stirred to obtain 4800 g of an aqueous sodium carbonate solution having a concentration of 16.7%. Next, in the sodium bicarbonate precipitation tank 6, instead of adding carbon dioxide by forming it into fine bubbles using the vortex turbo mixer pump 9 or the YJ nozzle 28, a stainless steel tube having a diameter of 4 mmφ was installed in the sodium bicarbonate precipitation tank, and carbon dioxide was blown out at a rate of 1.0 L/min and added. The size of the carbon dioxide bubbles in the aqueous sodium carbonate solution was, by visual observation, several millimeters to several tens of millimeters.

The temperature of the aqueous solution during the introduction of carbon dioxide was 25°C to 35°C. The carbon dioxide was added for 169 minutes in the same manner as in Example 1, but the pH of the liquid in the sodium bicarbonate precipitation tank was as high as 10.0, the liquid did not become cloudy, and sodium bicarbonate did not precipitate. The conditions and results are shown in Table 1 and Table 2.

[0057]

(Example 8)

The addition of carbon dioxide in Example 7 was continued even after 169 minutes. A temperature of the aqueous solution during the introduction of carbon dioxide was 25°C to 35°C. It took an extremely long time of 1020 minutes for the liquid in the sodium bicarbonate precipitation tank to become a cloudy sodium bicarbonate slurry with a pH of 8.0. The utilization rate of carbon dioxide (UR1) was 17%. The conditions and results are shown in Table 1 and Table 2.

[0058]

[Table 1]

Example	Sodium bicarbonate precipitation tank											Centrifugal dewatering		Drying
	Amount of carbon dioxide required to convert into sodium bicarbonate (B)	Supplying method of gas containing carbon dioxide	Flow rate of carbon dioxide actually added	Time of carbon dioxide actually added	Amount of carbon dioxide actually added		Size of carbon dioxide-containing bubbles			Utilization rate of carbon dioxide (UR1)	pH of slurry	Weight of cake	Weight of filtrate	Sodium bicarbonate powder
							d10 (μm)	d50 (μm)	d90 (μm)					
	(L)	(-)	(L/min)	(min)	(L)	(g)				(%)	(-)	(g)	(g)	(g)
1	169	Fine bubbles using vortex turbo mixer pump	1.0	169	169	332	31	63	107	100	8.0	1117	4015	893
2	169	Fine bubbles using vortex turbo mixer pump	0.3	563	169	332	33	75	143	100	8.0	1117	4015	893
3	169	Fine bubbles using YJ nozzle	1.0	169	169	332	29	63	102	100	8.0	1117	4015	893
4	169	Fine bubbles using YJ nozzle	3.0	56	169	332	30	65	108	100	8.0	1117	4015	893
5	169	Fine bubbles using YJ nozzle	5.0	34	169	332	33	72	124	100	8.0	1117	4015	893
6	169	Injection from Kerami Filter	1.0	277	277	544	74	168	306	61	8.0	-	-	-
7	169	Blowing out from 4 φ tube	1.0	169	169	332	Several millimeters to several tens of millimeters (visual observation)			-	10.0	-	-	-
8	169	Blowing out from 4 φ tube	1.0	1020	1020	2004	Several millimeters to several tens of millimeters (visual observation)			17	8.0	-	-	-

[0059]

[Table 2]

Example	Concentration adjustment tank for aqueous sodium carbonate solution															
	Amount of filtrate charged after centrifugal dewatering		Amount of 48% aqueous sodium hydroxide solution added	Amount of carbon dioxide required to convert into sodium carbonate	Supplying method of gas containing carbon dioxide	Flow rate of carbon dioxide actually added	Time of carbon dioxide actually added	Size of carbon dioxide-containing bubbles			Amount of carbon dioxide actually added		Utilization rate of carbon dioxide (UR2)	Amount of evaporated water	Adjusted weight	Adjusted sodium carbonate amount
	Weight	Weight of sodium bicarbonate						d10	d50	d90						
	(g)	(g)	(g)	(L)	(-)	(L/min)	(min)	(μm)	(μm)	(μm)	(L)	(g)	(%)	(g)	(g)	(g)
1	4015	375	886	69	Fine bubbles using vortex turbo mixer pump	1.0	69	31	63	106	69	136	100	237	4800	800
2	4015	375	886	69	Fine bubbles using vortex turbo mixer pump	1.0	69	31	63	106	69	136	100	237	4800	800
3	4015	375	886	69	Fine bubbles using YJ nozzle	1.0	69	30	63	103	69	136	100	237	4800	800
4	4015	375	886	69	Fine bubbles using YJ nozzle	1.0	69	30	63	103	69	136	100	237	4800	800
5	4015	375	886	69	Fine bubbles using YJ nozzle	1.0	69	30	63	103	69	136	100	237	4800	800
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[0060]

(Example 9)

Using the apparatus of the first embodiment shown in FIG. 1, potassium salts were used in place of sodium salts. First, 835 g of potassium carbonate and 1600 g of deionized water were charged into the concentration adjustment tank 1 having an internal volume of 8 L, and stirred to obtain 2435 g of an aqueous potassium carbonate solution having a concentration of 34.3%. Next, the aqueous solution was transferred to the precipitation tank 6 having an internal volume of 8 L, and then the vortex turbo mixer

pump 9 was started and the aqueous solution was circulated using the circulation pipe 10. A KTM15ND02S model manufactured by Nikuni Co., Ltd. was used as the vortex turbo mixer pump. The circulation flow rate was 20 L/min. Immediately after the circulation was started, carbon dioxide gas was supplied at a rate of 1.0 L/min to the suction-pipe side of the vortex turbo mixer pump 9, and introduced into the circulating solution as fine bubbles. The carbon dioxide bubbles had a d50 of 63 μm and a d90 of 107 μm. A temperature of the aqueous solution during the introduction of carbon dioxide was 25°C to 35°C. After 136 minutes, the liquid in the potassium bicarbonate precipitation tank became a cloudy potassium bicarbonate slurry with a pH of 8.3. The utilization rate of carbon dioxide (UR1) was 100%.

The potassium bicarbonate slurry was filtered using the centrifugal dewatering machine 13 to obtain 668 g of a centrifugal dewatering cake and 2033 g of a filtrate. An H-110F model manufactured by KOKUSAN Co., Ltd. was used as the centrifugal dewatering machine. The centrifugal dewatering cake was dried in a carbon dioxide atmosphere at 80°C to obtain 605 g of potassium bicarbonate powder.

[0061]

Meanwhile, the filtrate was a saturated aqueous solution of potassium bicarbonate (concentration: 29.8%). The filtrate was returned to the concentration adjustment tank 1, and 706 g of a 48% aqueous potassium hydroxide solution was added thereto. Thereafter, the vortex turbo mixer pump 4 was started, and while the resulting solution was circulated using the circulation pipe 22 at a circulation flow rate of 20 L/min, air was supplied at a rate of 1.0 L/min to the suction-pipe side of the vortex turbo mixer pump 4 and introduced into the circulating solution as fine bubbles. The aqueous potassium carbonate solution in the concentration adjustment tank 1 was gradually concentrated by evaporation of water, and after 12 hours, the weight of the aqueous

potassium carbonate solution became 2435 g. The potassium carbonate content was 835 g, which was the same as in the initially adjusted aqueous potassium carbonate solution.

The conditions and results are shown in Table 3 and Table 4.

[0062]

[Table 3]

Example	Potassium bicarbonate precipitation tank											Centrifugal dewatering		Drying
	Amount of carbon dioxide required to convert into potassium bicarbonate (B)	Supplying method of gas containing carbon dioxide	Flow rate of carbon dioxide actually added	Time of carbon dioxide actually added	Amount of carbon dioxide actually added		Size of carbon dioxide-containing bubbles			Utilization rate of carbon dioxide (UR1)	pH of slurry	Weight of cake	Weight of filtrate	Potassium bicarbonate powder
							d10	d50	d90					
	(L)	(-)	(L/min)	(min)	(L)	(g)	(μm)	(μm)	(μm)	(%)	(-)	(g)	(g)	(g)
9	136	Fine bubbles using vortex turbo mixer pump	1.0	136	136	267	31	63	107	100	8.3	668	2033	605

[0063]

[Table 4]

Example	Concentration adjustment tank for aqueous potassium carbonate solution															
	Amount of filtrate charged after centrifugal dewatering		Amount of 48% aqueous potassium hydroxide solution added	Amount of carbon dioxide required to convert into potassium carbonate	Supplying method of gas containing carbon dioxide	Flow rate of carbon dioxide actually added	Time of carbon dioxide actually added	Size of carbon dioxide-containing bubbles			Amount of carbon dioxide actually added		Utilization rate of carbon dioxide (UR2)	Amount of evaporated water	Adjusted weight	Adjusted potassium carbonate amount
	Weight	Weight of potassium bicarbonate						d10	d50	d90						
	(g)	(g)	(g)	(L)	(-)	(L/min)	(min)	(μm)	(μm)	(μm)	(L)	(g)	(%)	(g)	(g)	(g)
9	2033	605	706	0	-	-	-	-	-	-	-	-	-	304	2435	835

[0064]

(Example 10)

The average particle size d50 of general-purpose industrial-grade sodium bicarbonate (product name: KF) manufactured by AGC Inc. was 150 μm. When 200 g of the powder was pulverized for 30 minutes using the same pulverizer as in Example 1

under the condition that the rotation speed of the blade was 4,000 rpm, the average particle size d50 could only be reduced to 33 μm. Therefore, when a second pulverization was performed under the same conditions, the average particle size d50 became 23 μm; and when a third pulverization was performed under the same conditions, a fine powder product having an average particle size d50 of 13 μm was finally obtained. It was more difficult to pulverize than the sodium bicarbonate powder of Example 1. The relationship between the pulverization conditions and the average particle size in Example 1 and Example 10 is shown in Table 5.

[0065]

[Table 5]

Example	Pulverization condition (number of pulverizations)	Average particle size d50 of sodium bicarbonate powder
1	No pulverization	31
	Once	11
10	No pulverization	150
	Once	33
	Twice	23
	Three times	13

REFERENCE SIGNS LIST

[0066]

1 Concentration adjustment tank for aqueous sodium carbonate solution

2, 7 Stirring device

3 Aqueous sodium carbonate solution

4, 9 Vortex turbo mixer pump

5 Feed pipe

6 Sodium bicarbonate precipitation tank

8 Liquid in sodium bicarbonate precipitation tank

10, 22 Circulation pipe

11 Supply pipe for gas containing carbon dioxide

12 Withdrawal of sodium bicarbonate slurry

13 Centrifugal dewatering machine

14 Sodium bicarbonate cake obtained by centrifugal dewatering

15 Drying equipment

16 Sodium bicarbonate powder

17 Filtrate

18 Filtrate recovery tank

19 Filtrate feed pump

20 Filtrate feed pipe

21 Sodium hydroxide addition pipe

23 Supply pipe for gas containing carbon dioxide

24 Air supply pipe

25, 26 Magnet pump

27, 28 YJ nozzle

CLAIMS

[Claim 1] A method for producing a carbonate or bicarbonate of an alkali metal, the method comprising: supplying carbon dioxide-containing bubbles, which are bubbles of a gas containing carbon dioxide, to an aqueous solution (a) of at least one alkali metal compound selected from the group consisting of an alkali metal hydroxide, an alkali metal carbonate, and an alkali metal chloride,

wherein, when the aqueous solution (a) is an aqueous solution of an alkali metal chloride, ammonia is supplied to the aqueous solution (a) before the carbon dioxide-containing bubbles are supplied, and

the carbon dioxide-containing bubbles have a size such that a d50 is 100 μm or less and a d90 is 150 μm or less.

[Claim 2] The method according to Claim 1, wherein the carbonate or bicarbonate of the alkali metal is lithium carbonate, sodium carbonate, potassium carbonate, lithium bicarbonate, sodium bicarbonate, or potassium bicarbonate.

[Claim 3] The method according to Claim 1 or 2, wherein a concentration of the carbon dioxide in the gas containing carbon dioxide is 10 vol% or more.

[Claim 4] The method according to Claim 1 or 2, wherein of the carbon dioxide-containing bubbles have a size such that a d50 is 50 to 90 μm and a d90 is 100 to 150 μm.

[Claim 5] A method for producing an alkali metal bicarbonate, comprising:

filtering a slurry in which an alkali metal bicarbonate obtained by the method according to Claim 1 or 2 has precipitated;

adding, to a resulting filtrate, a first aqueous solution (a) of at least one alkali metal compound selected from the group consisting of an alkali metal hydroxide, an alkali metal carbonate, and an alkali metal chloride to obtain a second aqueous solution (a);

supplying carbon dioxide-containing bubbles to the second aqueous solution (a) to obtain a third aqueous solution (a) of a carbonate or bicarbonate of an alkali metal;

concentrating the obtained third aqueous solution (a) by removing water therefrom to obtain a fourth aqueous solution (a); and

supplying carbon dioxide-containing bubbles to the obtained fourth aqueous solution (a) to precipitate an alkali metal bicarbonate.