

A PREPARATION OF SODIUM BICARBONATE FROM CARBON DIOXIDE

Field of the invention

The present invention relates to the field of chemical and chemical engineering science in relation to a preparation of sodium bicarbonate from carbon dioxide.

5 Background of the invention

Global warming is a current global issue which adversely affects humanity, animal, and environment. The issue is mainly caused by greenhouse gas, especially carbon dioxide (CO₂), which results from human activities, e.g. waste incineration, cooking, and agriculture. However, carbon dioxide produced during industrial processing is a major cause of greenhouse gas.

10 To reduce the emission and enhance the value of carbon dioxide (CO₂), there is a process development to make the most of it, e.g. using carbon dioxide (CO₂) as a foaming agent in food and beverage industry such as soft drink production, converting carbon dioxide (CO₂) to urea for agricultural purposes, and using carbon dioxide (CO₂) as a reactant for the production of chemicals which could be a raw material for petrochemical industry.

15 Sodium bicarbonate (NaHCO₃) or baking powder has white powder property. It is mostly found in a layer of rock in the ground and considered as a natural mineral. Mostly, it has been used in food, animal feed, medical, and cleaning industries. Sodium bicarbonate (NaHCO₃) or baking powder can now be synthesized from a reaction between sodium ion (Na⁺) and carbon dioxide (CO₂) by a process known by those skilled in the art as Solvay process, which is found by Ernest
20 Solvay, a Belgian chemical industrialist, in 1861.

According to a patent database, there are some prior arts regarding a preparation of sodium bicarbonate as shown in the following examples.

A US patent application, publication no. US2622004A, invention titled "Cyclic process for production of sodium bicarbonate and ammonium chloride" describes a synthesis of sodium
25 bicarbonate (NaHCO₃) from a process by which ammonia, water, sodium chloride (NaCl), and carbon dioxide (CO₂) are used as a reactant at the preferred reaction temperature of 28 to 60 degree Celsius. This process always results in such by-product as ammonium chloride (NH₄Cl).

An international patent application, publication no. WO2012050437A3, invention titled
30 "Production of sodium bicarbonate from a basic process stream – treatment of a gas flow containing carbon dioxide obtained from burning at least one organic waste or feed stream, on the

one hand to produce sodium bicarbonate – quenching the gas flow using an alkaline aqueous liquid”; a European patent application, publication no. EP1858807A1, invention titled “Method for obtaining sodium carbonate crystals”; a Korean patent no. KR101571251B1; a US patent application, publication no. US4405592A, invention titled “Process for producing anhydrous sodium carbonate crystal”; and a US patent application, publication no. US3751560A, invention titled “Multi-stage process for the preparation of sodium bicarbonate” describes a preparation of sodium bicarbonate (NaHCO_3) or baking powder from a reaction between sodium hydroxide (NaOH) and carbon dioxide (CO_2).

Besides, a preparation of sodium bicarbonate (NaHCO_3) or baking powder from a reaction between such reactants as sodium carbonate (NaCO_3), water, and carbon dioxide (CO_2) is mentioned in the international journal, titled “ CO_2 capture and re-use at a waste incinerator”, published in Energy Procedia 86 (2016) 47-55 for the 8th academic conference of Trondheim Conference on Capture, Transport and Storage.

The above-mentioned background of the invention obviously shows the development of a preparation of sodium bicarbonate (NaHCO_3) or baking powder from a reaction between sodium ions (Na^+) and carbon dioxide (CO_2), which has been continually developed from the past until now. The present invention discloses the use of carbon dioxide (CO_2), sodium carbonate (Na_2CO_3) which is also known as soda ash or washing soda, and ammonia solution as a reactant for the preparation of sodium bicarbonate (NaHCO_3) or baking powder at the atmospheric pressure and reaction temperature of less than 60 degree Celsius without by-products.

Summary of the invention

The present invention relates to a preparation of sodium bicarbonate from carbon dioxide (CO_2), which comprises of the following steps: prepare sodium compound solution by dissolving sodium compound in deionized water; prepare ammonia solution by dissolving ammonia in deionized water; mix sodium compound solution and ammonia solution together at temperature-controlled conditions and release carbon dioxide into the mixture, resulting in sodium bicarbonate product with white solid property; filter the product out of the solution and wash it with organic solvent; and let it dry at room temperature.

The objective of the present invention is to provide a preparation of sodium bicarbonate from carbon dioxide with a simple and highly safe process, resulting in highly purified sodium bicarbonate at atmospheric pressure conditions and reaction temperature of less than 60 degree Celsius without by-products. The invention is applicable to industrial manufacturing, apt for using

in other industries, and also reduces the emission and enhances the value of carbon dioxide from a natural gas separation process.

Brief description of the drawings

Figure 1 shows x-ray diffraction patterns of sodium bicarbonate (NaHCO_3), which can be produced when using a process according to the present invention at different concentration of reactive ammonia solution.

Figure 2 shows a relation between a percentage of sodium bicarbonate (NaHCO_3), which can be produced when using a process according to the present invention, and reaction time, comparing at the operating pressure of 1 bar and 1.3 bar.

Figure 3 shows a relation between a percentage of sodium bicarbonate (NaHCO_3), which can be produced when using a process according to the present invention, and operating pressure, comparing at the operating pressure of 1-5 bar.

Detailed description of the invention

The present invention relates to a preparation of sodium bicarbonate (NaHCO_3) from carbon dioxide (CO_2). It starts from mixing sodium compound solution and ammonia solution; then causing a reaction between carbon dioxide (CO_2) and a mixture of sodium compound and ammonia solution; and separating that prepared sodium bicarbonate solid product. The preparation process is as follows:

- A. Weigh a specified amount of sodium compound and dissolve it in deionized water wherein the sodium compound is chosen from either sodium carbonate (Na_2CO_3) or sodium hydroxide (NaOH) or combination thereof. The preparation temperature of sodium compound is between 20 to 60 degree Celsius.
- B. Weigh a specified amount of ammonia and dissolve it in deionized water. The preparation temperature of ammonia solution is between 20 to 60 degree Celsius.
- C. Mix the substance obtained from A. and B. together until the final concentration of sodium compound and ammonia is desirable. Preferably, the final concentration of mixed solution is between 1 to 10 mol/liter for sodium compound and 1 to 5 mol/liter for ammonia solution.
- D. Continuously release carbon dioxide (CO_2) into the mixture obtained from C. to cause a reaction at proper duration, temperature, and pressure until having a white solid product.

Preferably, the concentration of carbon dioxide (CO₂) which is used as a reactant is between 99.5 to 99.9% by volume.

For the feeding of carbon dioxide (CO₂), which is used as a reactant, into the mixed solution of sodium compound and ammonia solution, the feeding rate is 0.1 to 0.5 liter/minute per total liquid volume of 0.2 liter; the operating pressure is between 1 to 5 bar; the preferred temperature is between 20 to 60 degree Celsius; and the preferred duration of feeding carbon dioxide (CO₂) into the mixed solution of sodium compound and ammonia solution is between 1 to 10 hours.

E. The white solid product obtained from D. will be filtered out of the solution by such method as filter paper until it is dry and wash it again with organic solvent. Let it dry at room temperature for 5 to 10 days and weigh it, wherein the organic solvent for washing the white solid product obtained from a reaction between carbon dioxide (CO₂) and mixed solution of sodium compound and ammonia solution is alcohol organic solvent, preferably ethanol. Then, perform identification test for sodium bicarbonate by analyzing its purity and crystal structure, using an analytical technique of x-ray diffraction (XRD) in comparison with a sodium bicarbonate standard material.

The product obtained from chemical reaction will be calculated into percent yield, based on the following equation:

$$\text{Percent yield} = 100 * \text{actual yield} / \text{theoretical yield}$$

wherein actual yield is the amount of product obtained from test or reaction and theoretical yield is the amount of product obtained from chemical equation of complete reaction.

Percent yield is less than 100% since sodium bicarbonate product can partially dissolve in water. It is found that the solubility of sodium bicarbonate is 96 grams per 1 liter of water at the temperature of 20 degree Celsius, and also found incomplete reaction at test condition.

One or more embodiment of the present invention will be described in detail with reference to examples of a preparation of sodium bicarbonate solid product according to the present invention. However, it is not intended to limit one or more embodiment of the present invention. The following examples are provided to show certain embodiment in terms of its function. It will be clearly understood by those skilled in the art that the present invention is not limited by certain embodiment illustrated in these examples.

Example 1

This example describes a preparation process of sodium bicarbonate solid product by a reaction between sodium carbonate (Na_2CO_3), ammonia solution, and carbon dioxide (CO_2) at atmospheric pressure, and also describes a concentration result of ammonia solution which is used as a reactant per a prepared amount of sodium bicarbonate solid product as follows:

- 5 Weigh sodium carbonate (Na_2CO_3) 63.6 grams and dissolve it in deionized water and prepare ammonia solution at the concentration of 0 to 3.72 mol/liter without deionized water.

- Mix those prepared sodium carbonate solution and ammonia solution together until the final mixed solution volume is 200 milliliters and the final concentration of mixed solution of sodium carbonate solution and ammonia solution is 3 and 2.66 mol/liter respectively. Then, release
10 carbon dioxide with the concentration of 99.9% by volume into the mixed solution in an open container with the flow rate of 200 milliliters/minute to allow reactions for 5 hours at the temperature of 25 degree Celsius and atmospheric pressure until having a white solid product.

- Filter the white solid product out of the solution by paper filter no. 1 until it is dry and wash it again with ethanol organic solvent. Then, let it dry at room temperature for 5-10 days to eliminate
15 moisture.

Weigh the obtained white solid product for the calculation of percent yield. The result is shown in Table 1. Then, take the white solid product to perform identification test of sodium bicarbonate by using an analytical technique of x-ray diffraction in comparison with a sodium bicarbonate standard material, and a commercial sodium bicarbonate product.

- 20 Table 1 The concentration results of ammonia solution which is used as a reactant per the percent yield

The final concentration of ammonia solution in mixed solution (mol/liter)	Percent yield
0	21.85
0.53	20.85
1.59	34.74
2.66	38.13
3.72	38.01

According to Table 1, it is found that an increasing concentration of ammonia solution which is used as a reactant significantly helps increase percent yield, and the proper concentration

of ammonia solution which is 2.66 mol/liter can increase percent yield of sodium bicarbonate solid product when there is no ammonia solution in the system from 21.85% to 38.13%.

Besides, an increasing concentration of ammonia solution which is used as a reactant does not affect product purity since unfamiliar peak is not found in synthesized samples when analyzing the obtained sodium bicarbonate solid product, using an analytical technique of x-ray diffraction. However, the peak intensity of synthesized sodium bicarbonate samples does not comply with a sodium bicarbonate standard material since the obtained product has different crystallography as shown in Figure 1.

Example 2

A preparation method is similar to those of Example 1 except the duration for feeding carbon dioxide (CO₂) into a mixed solution of sodium compound and ammonia solution, which is between 1 to 10 hours, providing test results as shown in Table 2.

Table 2 The duration results for feeding carbon dioxide (CO₂) into a mixture of sodium carbonate solution and ammonia solution per the percent yield of prepared sodium bicarbonate product

Duration for feeding carbon dioxide into a mixed solution	Percent yield
1 hour	1.4
2 hours	14.01
3 hours	28.29
4 hours	34.61
5 hours	38.19
6 hours	38.38
7 hours	38.10

According to Table 2, it is found that an increasing reaction duration significantly increases percent yield of sodium bicarbonate solid product and there is only a few changes of percent yield after 5 hours, which signifies that the proper reaction duration for a synthesis of sodium bicarbonate from carbon dioxide (CO₂) is 5 hours.

Example 3

A preparation method is similar to those of Example 1 except the use of sodium hydroxide (NaOH) as a reactant, wherein, before the feeding of carbon dioxide, the final concentration of sodium ion in a mixed solution is 6 mol/liter. There is also a description of the concentration results of ammonia solution which is used as a reactant per the volume of prepared sodium bicarbonate solid product as shown in Table 3.

Table 3 The concentration results of ammonia which is used as a reactant per the percent yield of prepared sodium bicarbonate solid product when using sodium hydroxide as a reactant

Concentration of reactive ammonia solution (mol/liter)	Percent yield
0	0.5
1.59	30.1

According to Table 3, it is found that the percent yield of prepared sodium bicarbonate significantly increases when there is ammonia in the system.

Example 4

A preparation method is similar to those of Example 1 except the final concentration of ammonia in a mixed solution before the feeding of carbon dioxide, which is 1.59 mol/liter. Additionally, there is a comparison of the use of sodium hydroxide (NaOH) and sodium chloride (NaCl) as a reactive sodium compound at the final concentration of sodium ion before the feeding of carbon dioxide and ammonia into a mixture, which is 6 and 1.59 mol/liter respectively, providing test results as shown in Table 4.

Table 4 The results for each type of reactive sodium compound per the percent yield of prepared sodium bicarbonate at the final concentration, before the feeding of carbon dioxide, of sodium ion and ammonia solution in a mixed solution of 6 and 1.59 mol/liter

Type of reactive sodium compound	Percent yield
Sodium carbonate (Na_2CO_3) = Example 1	34.74
Sodium hydroxide (NaOH)	30.1
Sodium chloride (NaCl)	18.2

According to the test results, it is found that type of reactive sodium compound affects percent yield of prepared sodium bicarbonate. Besides, when using sodium chloride (NaCl) as a reactive sodium compound, in accordance with Solvay process, there is always an occurrence of such by-product as ammonium chloride (NH₄Cl).

5 Example 4

A preparation method is similar to those of Example 2 except the operating pressure of 1.3 bar under a pressure controllable container, providing test results as shown in Figure 2 which signifies increasing percent yield of prepared sodium bicarbonate when operating pressure is increasing.

10 Example 5

A preparation method is similar to those of Example 1 except the operating pressure of 1-5 bar under a pressure controllable container, providing test results as shown in Figure 2 which signifies increasing percent yield of prepared sodium bicarbonate when operating pressure is significantly increasing from 1 to 3 bar and there is only a few changes of percent yield after the
15 operating pressure is greater than 3 bar.

In many possible embodiments wherein the principle of disclosed invention might be used, the disclosed embodiment is only a preferred example of the invention and should not limit the scope of the invention.

An additional description of the following definition of terms and methods is provided to
20 better describe disclosure of the present invention and to suggest those skilled in the art to apply the disclosure into practice.

Unless stated otherwise, the total amount of component, molecular weight, percentage, temperature, time, etc. as described in specifications or claims can be understood even modified by the word “approximately” unless implicitly or explicitly stated otherwise. Those mentioned
25 numerical variable is an estimate that might be up to desirable properties and/or inspection limitations under a standard testing condition/method which can be understood by those skilled in the art when directly or explicitly distinguishing the embodiment from that previously described.

Unless described otherwise, all the technical and scientific terms used herein have the same meaning as that understood by those skilled in the art. Though similar or equivalent methods and
30 materials described herein can be used for the practice or test of the present disclosure, preferred

method and material samples will be further described. The methods, materials, and samples show certain embodiment or do not intend for limitation purposes.

It would be obvious to those skilled in the art that a definition of terms might be combined to further describe a certain compound, e.g. group 7 of the periodic table is known by those skilled
5 in the art as the halogens.

Certain atoms in the structure, e.g. carbon, hydrogen or hydrogen atom, are sometimes depicted in characters. For instance, $-\text{CH}_2\text{CH}_2-$ will be understood by those skilled in the art that it is a general technique in chemical field to shorten and simplify the description of organic chemistry.

10 A functional group is a specific group of atoms within molecules that are responsible for the characteristic chemical reactions of those molecules. Examples of functional group include, but not limited to, alkane, alkene, alkyne, halo (fluoro, chloro, bromo, iodo), hydroxy (OH), carbonyl (ketone), aldehyde (HCOR), ester (COOR), and carboxylate (COO^-).

Alcohol is an organic compound including at least one hydroxyl group. It might be
15 monohydric alcohol including one -OH group, dihydric alcohol or diol including such two -OH groups as glycol, trihydric alcohol or triol including such three -OH as glycerol, polyhydric alcohol or polyol including three or more -OH groups.

Best mode of the invention

The best method of invention is as described in detailed description of the invention.