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DIRECCION DE NUEVAS CREACIONES
Superintendencia de Industria y Comercio
E. S. D.



No. 14-039868- -00005-0000

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Act. 457 PROCEDIPPH Folios: 49

Trámite : 011
Evento : 378
Actuación : 457

Referencia : Expediente No. **14039868**
Asunto : REGISTRO - PATENTE PCT **CONVERSION OF GASEOUS CARBON DIOXIDE INTO AQUEOUS ALKALINE AND/OR ALKALINE EARTH BICARBONATE SOLUTIONS**
Solicitante : **SILICA DE PANAMA S.A.**
Clase : C01D 007/000, C01F 011/018

RECONOCIMIENTO DE EXAMEN DE PATENTABILIDAD DE LA USPTO

Yo, **LUZ CLEMENCIA DE PÁEZ**, obrando como apoderada del solicitante en el asunto antes identificado, respetuosamente manifiesto que de conformidad con lo dispuesto en la resolución No. 54093 de 2012, atentamente me permito solicitar el reconocimiento del resultado del examen de patentabilidad proferido por la Oficina de Propiedad Industrial de los Estados Unidos para la solicitud **US 13/136.153** equivalente a la solicitud de patente PCT/GB2012/051772 del asunto antes indicado. Lo anterior, teniendo en cuenta los siguientes documentos:

- Formulario de procedimiento acelerado de exámenes de patente (PPH).
- Resultado de examen de fondo proferido por la USPTO junto con su traducción a Español.
- Copia de las reivindicaciones que han sido determinadas como patentables u otorgables en la USPTO junto con su traducción a español.
- Tabla de correspondencia de las reivindicaciones que han sido determinadas como patentables u otorgables en la USPTO, y las presentadas originalmente ante la SIC.

"EXCELENCIA LEGAL EN UN MUNDO SIN FRONTERAS"

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A B O G A D O S

Pliego de reivindicaciones actualmente presentadas ante SIC como OSP	Reivindicaciones patentables u otorgables en la solicitud de la USPTO como OPP
1	1
2	1
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Cumplido así con lo dispuesto para que una solicitud sea aceptada en el Procedimiento Acelerado de Estudio de Solicitudes de Patentes entre la USPTO como Oficina de Primera Presentación (OPP) y la SIC como Oficina de Segunda Presentación (OSP), atentamente solicito que se continúe con el trámite correspondiente a esta solicitud de Patente de Invención.

Señor Director,


LUZ CLEMENCIA DE PAEZ
 C.C. 35.456.344 de Usaquén
 T.P.A. No. 23.555

 COLO-20954-0841-001-5
 MMS\MMSVID-275315\WPC20954
 No. M-2014-275315\MMS

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DIRECCIÓN DE NUEVAS CREACIONES
Procedimiento acelerado de exámenes de patente (pph)

1	NÚMERO DE SOLICITUD ANTE LA SIC	14.039.868
2	OFICINA DE PRIMERA PRESENTACIÓN (OPP)	Estados Unidos de América
3	NÚMERO(S) DE SOLICITUD O PUBLICACIÓN DE LA(S) SOLICITUD(ES) (OPP):	US 13/136.153
4	☐ REPRESENTANTE LEGAL ☒ APODERADO	
APELLIDOS DE PAEZ		NOMBRES LUZ CLEMENCIA
		IDENTIFICACIÓN C.C.35.456.344 T.P.23.555
DIRECCIÓN Cra 4a No. 72-35		No. TELÉFONO 3473611
CIUDAD Bogotá		CORREO ELECTRÓNICO cavelier@cavelier.com
PAÍS Colombia		No. RADICACIÓN O PROTOCOLO DE PODER GENERAL
5	CONDICIONES PARA ACCEDER A ESTE PROCESO:	
5.1. DATOS DE PRIORIDAD ☒ SI ☐ NO		
(33) PAÍS DE ORIGEN U.S.A		CÓDIGO PAÍS US
		(31) NÚMERO 13/136,153
		(32) FECHA(AAAA/MM/DD) 2011/07/25
5.2. DATOS SOLICITUD INTERNACIONAL PCT ☒ SI ☐ NO		
Solicitud Internacional No. PCT/GB2012/051772		Fecha 2012/07/24
Publicación Internacional No. WO/2013/014441 A1		Fecha 2013/01/31
El solicitante presenta una copia de la(s) reivindicación(es) patentable(s) u otorgable(s) de la solicitud de la Oficina de Primera Presentación que profirió el examen de patentabilidad, junto con una traducción al castellano. ☒ SI ☐ NO		

4

REQUISITOS PARA EL RECONOCIMIENTO DE LOS RESULTADOS DE EXÁMENES DE PATENTABILIDAD EFECTUADOS A SOLICITUDES EXTRANJERAS

Para que la Superintendencia de Industria y Comercio pueda reconocer los resultados de exámenes de patentabilidad producidos por otras Oficinas de Propiedad Industrial se debe cumplir con las siguientes condiciones:

(a) Al momento de solicitar el examen de patentabilidad, si el solicitante pide que se reconozcan exámenes de patentabilidad de otras oficinas extranjeras, deberá aportar junto con el pago de la tasa correspondiente, los siguientes anexos:

(i) Copia de las resoluciones, fallos o decisiones que han sido relevantes para la determinación de la patentabilidad de la(s) solicitud(es) en la Oficina que haya proferido el examen de patentabilidad que contienen reivindicaciones patentables u otorgables que son la base de la petición, y si es del caso, su traducción al castellano. ☒ SI ☐ NO

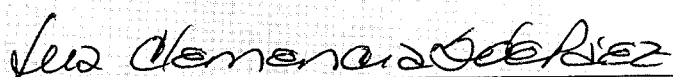
(ii) Copia de todas las reivindicaciones determinadas como patentables u otorgables en la Oficina que profirió el examen de patentabilidad y, si es del caso, su traducción al castellano. ☒ SI ☐ NO

(iii) Copia de los antecedentes, información o documentos citados por el examinador de la Oficina de Primera Presentación del examen de patentabilidad, en las resoluciones, fallos o decisiones correspondientes, incluyendo la literatura no patente. Los documentos de patente deberán presentarse siempre y cuando no estén disponibles para la Superintendencia de Industria y Comercio mediante el simple acceso a bases de datos gratuitas. ☐ SI ☒ NO

(iv) Una tabla de correspondencias de las reivindicaciones que han sido determinadas como patentables u otorgables en la solicitud de la Oficina que haya proferido el examen de patentabilidad. ☒ SI ☐ NO

6 TABLA DE CORRESPONDENCIA DE REIVINDICACIONES:

Pliego de reivindicaciones actualmente presentadas ante SIC como OSP	Reivindicaciones patentables u otorgables en la solicitud de la USPTO como OPP
1	1
2	1
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17	16
18	17
19	18
20	N/A

7. Firma	
Nombre y apellidos	Firma
LUZ CLEMENCIA DE PAEZ	
C.C. 35.456.344 DE Usaquén	Tarjeta Profesional 23.555

MMS/MMS/WPC20954/ID-275319



US008828338B2

(12) **United States Patent**
Lujano et al.(10) **Patent No.:** **US 8,828,338 B2**(45) **Date of Patent:** **Sep. 9, 2014**(54) **CONVERSION OF GASEOUS CARBON DIOXIDE INTO AQUEOUS ALKALINE AND/OR ALKALINE EARTH BICARBONATE SOLUTIONS**(75) Inventors: **Juan Lujano**, Caracas (VE); **Javier Revete**, Caracas (VE); **Norma Valencia**, Caracas (VE); **Luis Rivas**, Caracas (VE); **Nelson Socorro**, Caracas (VE)(73) Assignee: **Silica de Panama S.A.**, Caracas (VE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/136,153**(22) Filed: **Jul. 25, 2011**(65) **Prior Publication Data**

US 2013/0028828 A1 Jan. 31, 2013

(51) **Int. Cl.****C01F 11/00** (2006.01)**C01F 11/18** (2006.01)**B01J 39/02** (2006.01)**C01B 31/24** (2006.01)**C01D 7/00** (2006.01)**B01J 49/00** (2006.01)**B01J 39/14** (2006.01)(52) **U.S. Cl.**CPC **C01D 7/00** (2013.01); **C01F 11/181** (2013.01); **B01J 39/02** (2013.01); **C01B 31/24** (2013.01); **C01F 11/18** (2013.01); **C01P 2002/82** (2013.01); **B01J 49/0069** (2013.01); **C01P 2002/72** (2013.01); **B01J 49/0008** (2013.01); **B01J 39/14** (2013.01)USPC **423/157**; **423/158**; **423/165**; **423/181**; **423/184**; **423/189**(58) **Field of Classification Search**USPC **423/157**, **158**, **165**, **181**, **184**, **189**; **210/670**

See application file for complete search history.

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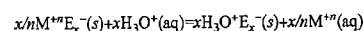
* cited by examiner

Primary Examiner — Steven Bos

(74) Attorney, Agent, or Firm — Donald S. Dowden

(57) **ABSTRACT**

A material with cationic exchanger properties is introduced into aqueous media, where the equilibriums of carbon dioxide dissolution take place. A cationic exchanger material $x/nM^{+n}E_x^-$ is used to capture hydronium cations (H_3O^+) according to:



where "x" stands for molar amount of the anionic centers of charge of the cationic exchanger material E_x^- balanced by x/n molar amount of metal M, "n" stands for the metal valence, and M is selected from the group consisting of 1A and/or 2A of the periodic table of elements. This capture of the hydronium cations, H_3O^+ , shifts certain reaction equilibriums to the right, according to Le Chatelier's principle, producing more bicarbonate, HCO_3^- , and/or carbonate, CO_3^{2-} , than would otherwise be obtained.

19 Claims, 11 Drawing Sheets

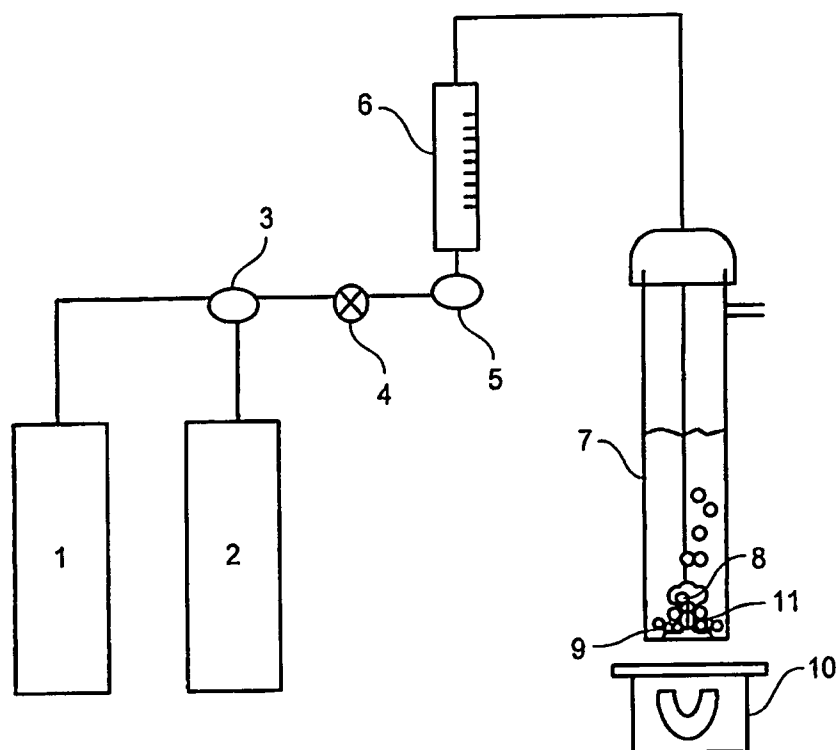


FIG. 1

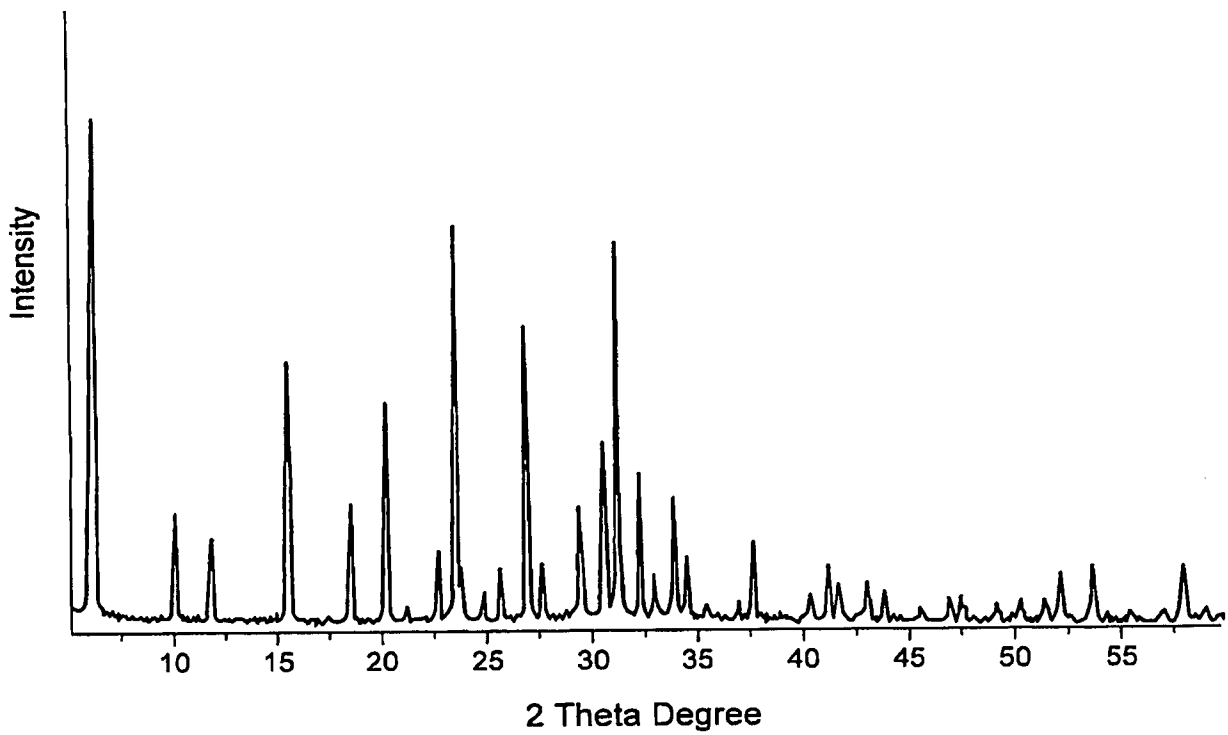


FIG. 2

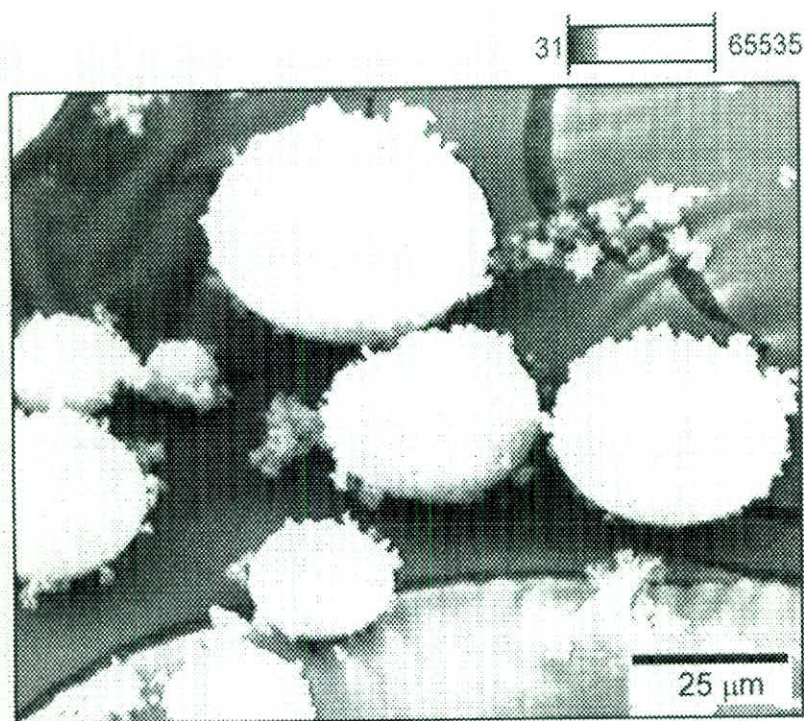


FIG. 3

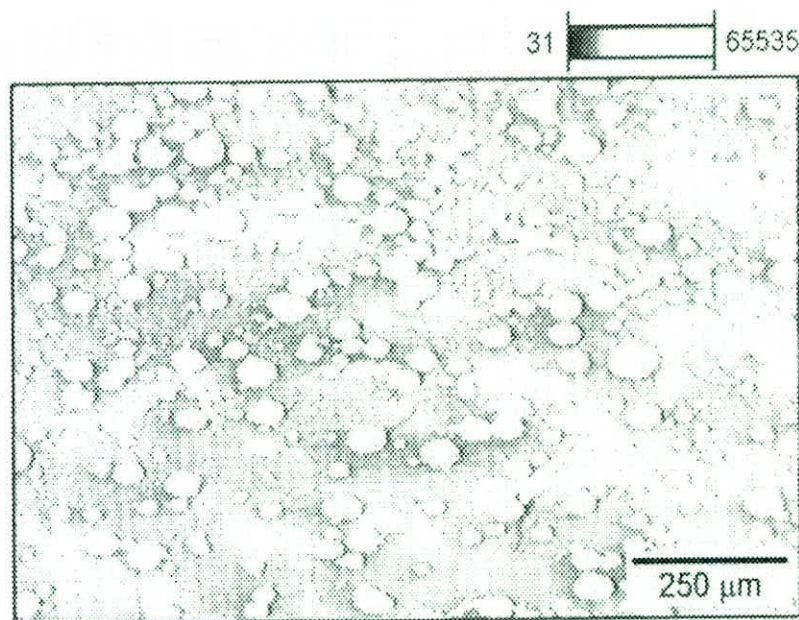


FIG. 4

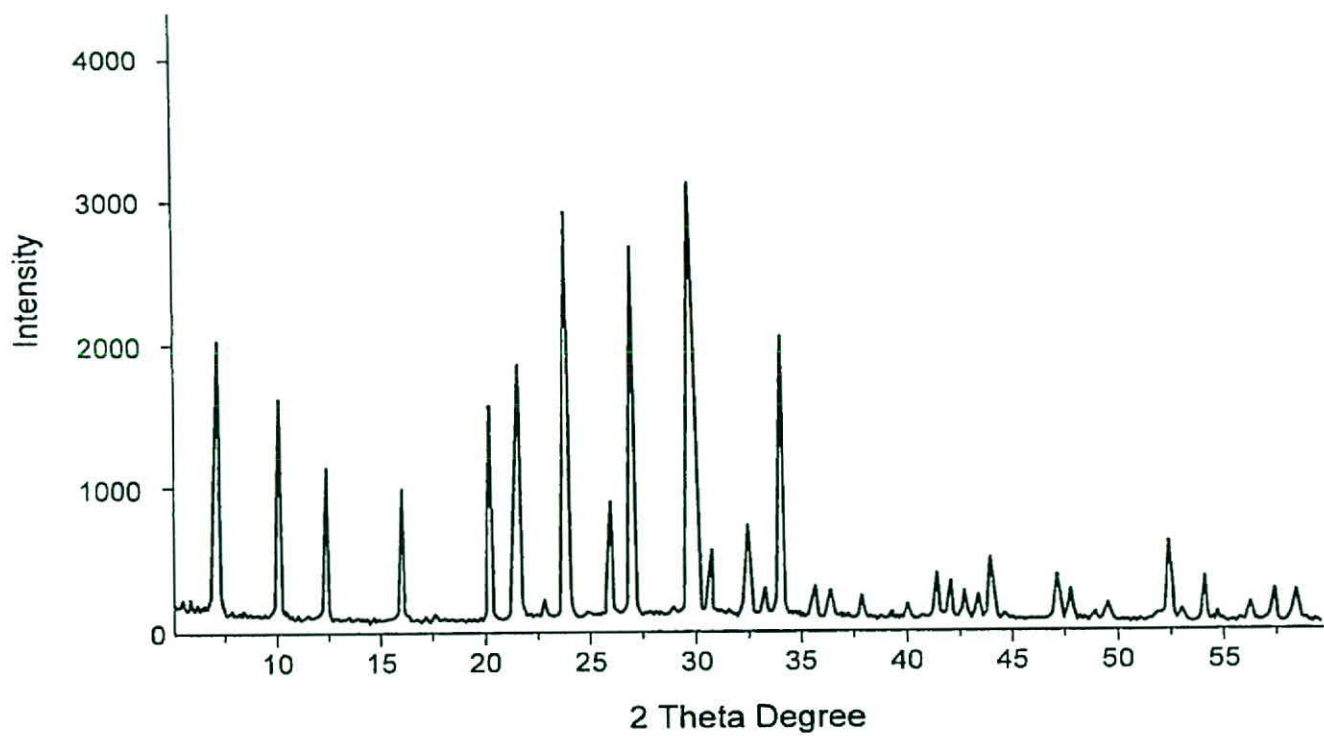


FIG. 5

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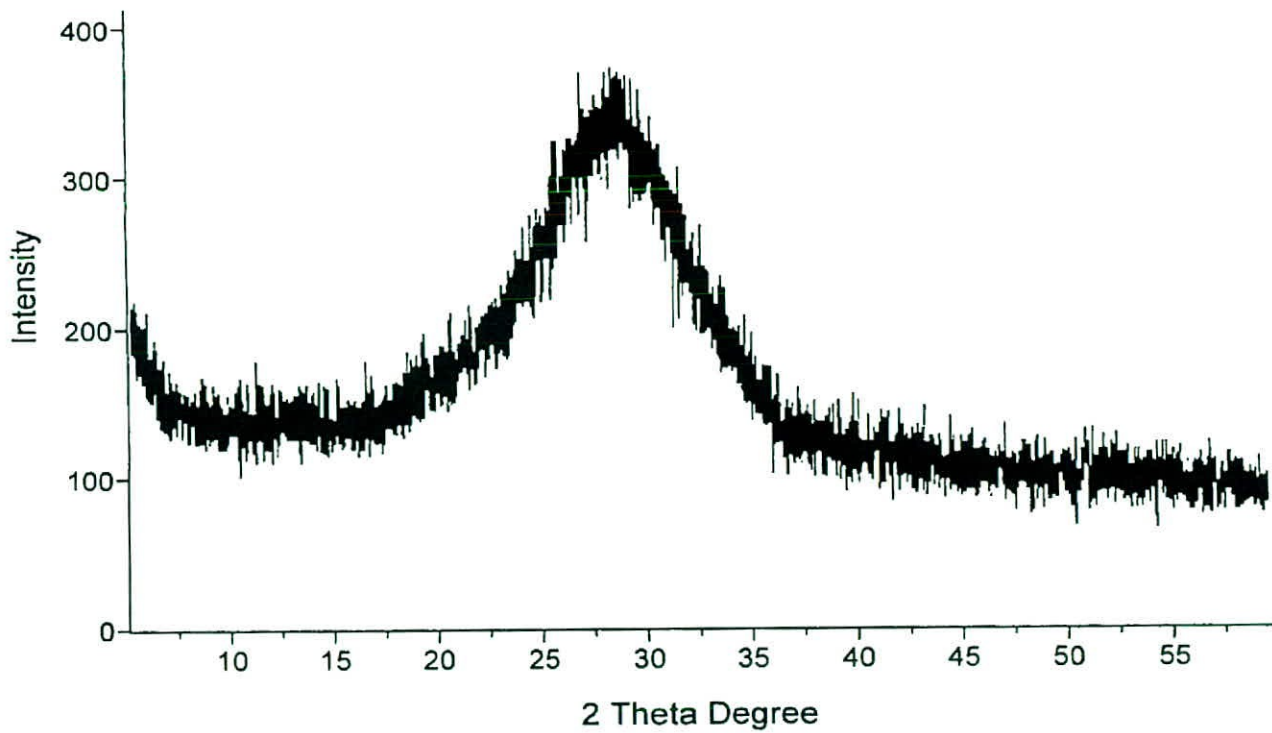


FIG. 6

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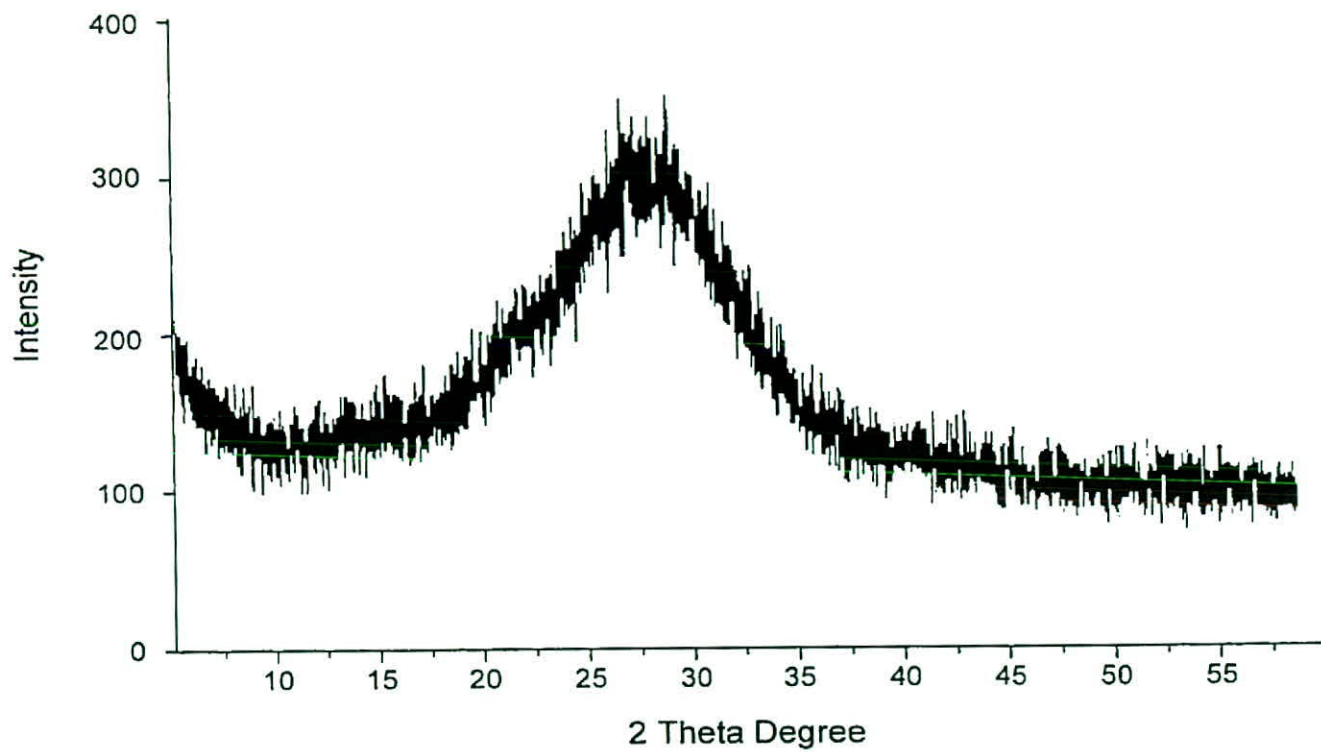


FIG. 7

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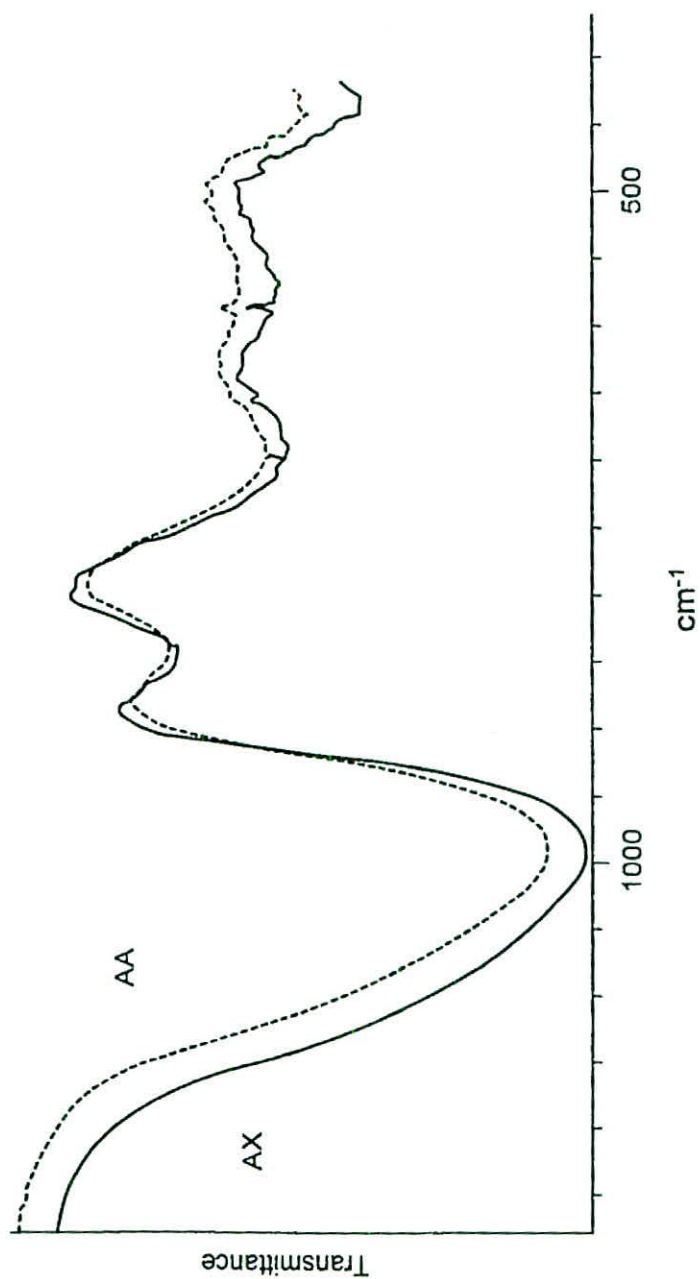


FIG. 8

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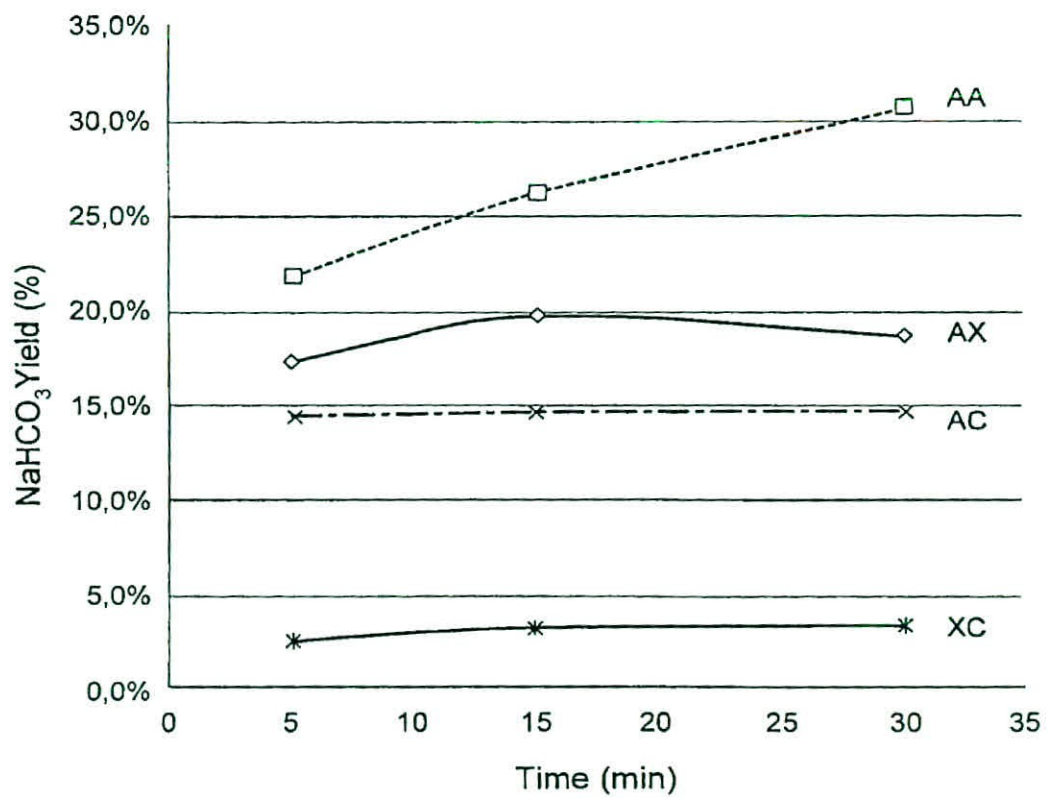


FIG. 9

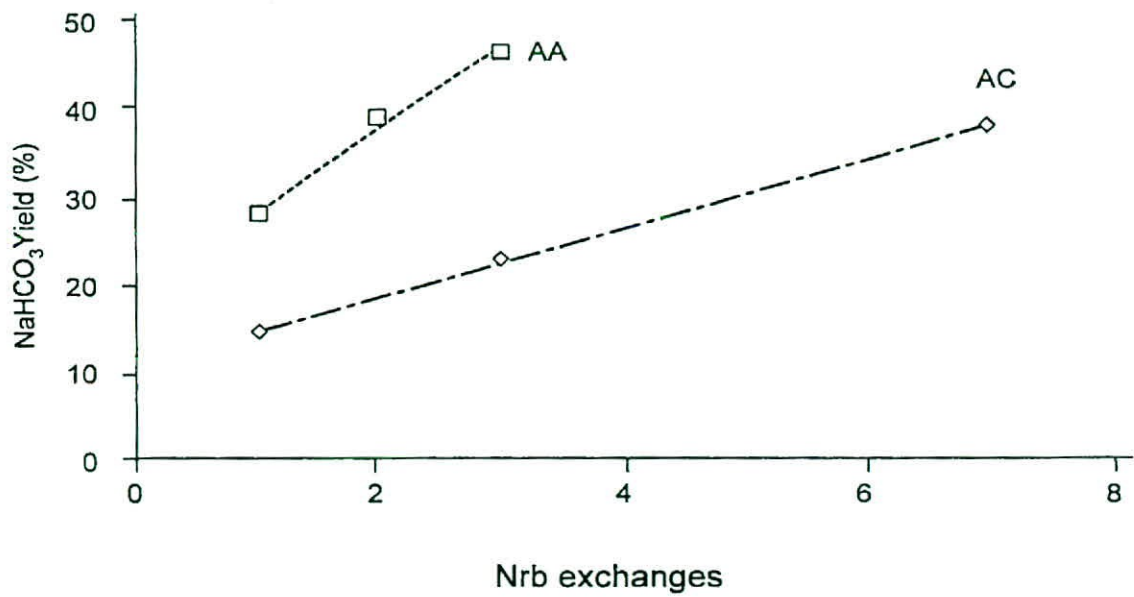
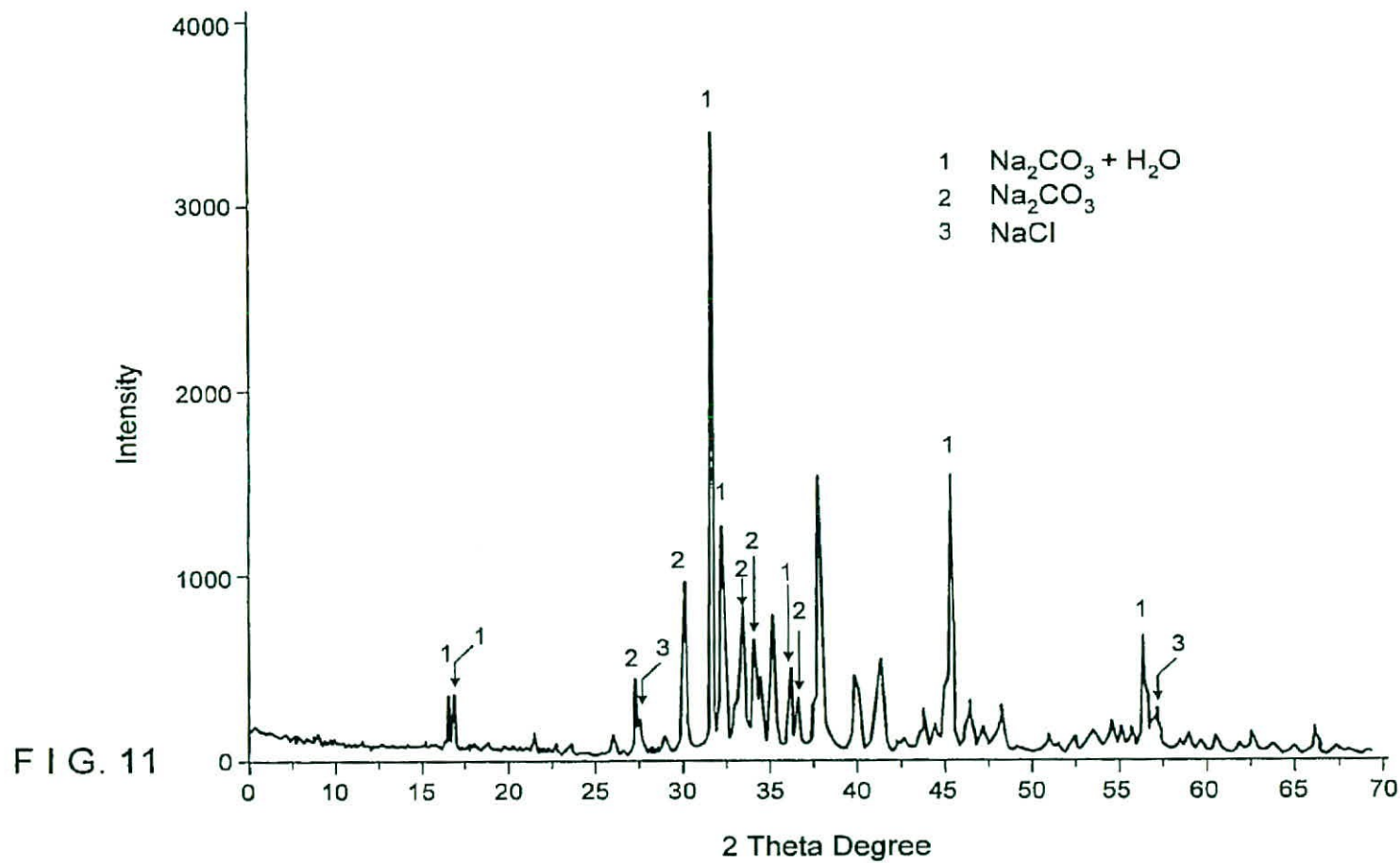


FIG. 10

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CONVERSION OF GASEOUS CARBON DIOXIDE INTO AQUEOUS ALKALINE AND/OR ALKALINE EARTH BICARBONATE SOLUTIONS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the conversion of gaseous carbon dioxide into an aqueous solution of alkaline and/or alkaline earth bicarbonate solutions useful for the production of solid alkaline bicarbonates, alkaline carbonates, and/or alkaline earth carbonates. In a preferred embodiment, the invention entails converting a feed stream of gaseous greenhouse carbon dioxide into an alkaline and/or alkaline earth bicarbonate solution using solid regenerable inorganic cationic exchanger materials, specifically either crystalline or amorphous silicoaluminates.

2. Description of the Prior Art

Most of the solid alkaline bicarbonates and carbonates are obtained from their aqueous solutions, by any evaporation or crystallization process. These bicarbonates and carbonates have numerous applications in daily life. To be mentioned, two of the most used are sodium carbonate and sodium bicarbonate.

Sodium bicarbonate (NaHCO_3) is one of the most widely used chemical commodities in the world. It is used in cooking as a leavening agent; in medicine as an antacid to treat chronic forms of metabolic acidosis and in cardiopulmonary resuscitation; in skin defoliants, toothpastes, cleaning agents, chemical fire extinguishers, and fungicides; for the biological control of wastewater; and as a dyeing agent in the textile industry.

Another alkali material, synthetically derived from aqueous solutions of sodium bicarbonate, is sodium carbonate (Na_2CO_3) or soda ash, which is used in large amounts in making glass, sodium silicates, soaps and detergents, and for flue gas desulfurization, among other things. Lithium carbonate and potassium carbonate are used in molten carbonate fuel cells. Alkaline earth metal carbonates are widely used in the synthesis of ceramics, as catalytic support for the preparation of carbon nanotubes, in the paper industry, and for cleaning solid surfaces by dry blasting. All of these alkaline bicarbonates and alkaline or alkaline earth carbonates are prepared using their aqueous solution as raw material. In particular, all of these sodium bicarbonate and sodium carbonate chemicals are prepared using an aqueous solution of alkaline or alkaline earth bicarbonate as raw material.

The main naturally occurring source of sodium bicarbonate is nahcolite (NaHCO_3), but it occurs frequently in association with trona mineral—trisodium hydrogencarbonate dihydrate or sodium sesquicarbonate ($\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$). One way to get a sodium bicarbonate solution is through a carbonation of a dissolution of trona mineral, after several processes for removing the impurities present in trona. However, high-quality reserves of sodium bicarbonate are unevenly distributed around the world and are a mineral resource that is being largely depleted. They are found mainly in Utah, California, Colorado and Wyoming, which makes this resource difficult to obtain in many developed and developing countries. Similarly, potassium bicarbonate solutions are obtained by bubbling carbon dioxide in a solution of potassium carbonate, as described in Ullmann's Encyclopedia of Industrial Chemistry, Vol A5, fifth edition. Wolfgang Gerhartz (ex ed), pp 173-174. New York, 1986.

A sodium bicarbonate solution can be obtained through the Solvay process using carbon dioxide. Also called the ammonia-soda process, this is a major conventional process for producing a synthetic sodium bicarbonate solution, which is the source for making refined sodium carbonate, Na_2CO_3 (soda ash), refined sodium bicarbonate, NaHCO_3 , and occasionally refined sodium sesquicarbonate, $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$. In the Solvay process, carbon dioxide (CO_2) is dissolved in water containing ammonia (NH_3) and sodium chloride (NaCl) to precipitate sodium bicarbonate (NaHCO_3), which is then separated by filtration.

Conventionally, this is carried out in two main steps: Ammonia gas is first introduced into sodium chloride brine, and only then, in another apparatus, is carbon dioxide gas introduced to make a sodium bicarbonate saturated solution, from which bicarbonate precipitates. Although the chemical reactions involved may seem simple, they are complex in reality. Considerable heat is evolved during the ammoniation of brine, and intense cooling is required for the necessary degree of ammonia saturation. Carbonation of ammoniated brine is also accompanied by the evolution of considerable heat, so that the apparatus must be cooled in order to improve yield, and the cooling must be controlled to form good crystals. Thus, the process is complex and intensive in energy use.

Because of the ammonia, the obtained sodium bicarbonate solution is contaminated with ammonium compounds such as ammonium carbonate ($(\text{NH}_4)_2\text{CO}_3$), ammonium bicarbonate (NH_4HCO_3) and ammonium carbamate ($\text{NH}_4\text{COONH}_2$). Most of these impurities end up in the final solid sodium bicarbonate and render it unfit for many uses, and additional refining steps are required for adjusting purity, regardless of the purity of the sodium chloride and carbon dioxide used.

Moreover, the Solvay process is not ecologically friendly; the management and safe disposal of chloride-containing waste streams is one of its major problems. And its cost is so high that many people in developing economies cannot afford sodium bicarbonate produced by this process.

In nature's carbon cycle, falling rainwater, with its high surface area, picks up carbon dioxide as it descends through the atmosphere. When fallen rainwater moves down through the topsoil, it may acquire additional quantities of carbon dioxide produced by the biological decomposition of organic matter. All of that carbon dioxide dissolved in water produces a weak carbonic acid, which can react with calcium carbonate deposits to produce calcium bicarbonate, which is more soluble in water than calcium carbonate. This mechanism increases the calcium content in groundwater. The same can be said for magnesium carbonate deposits, which are also soluble in water.

This natural process establishes typical bicarbonate content in rivers within the range of 30 mg/L to 400 mg/L (Water Quality and Its Control, James C. Lamb III, Chap 7, pp 131-135, John Wiley & Sons Inc. 1985). For the removal of calcium and magnesium bicarbonates to soften water, a practice of longstanding employs materials with cationic exchange properties. Such materials are in general called "zeolites," which in old field parlance refers to a set of materials with different compositions and structures, including bentonitic clay, synthetic gel-type minerals, lignite, soft coal, bitumens, and synthetic resins ("The Chemical Process Industries" R. Norm Shrive, Chap. 4, pp 47-50, 2^o Ed. McGraw-Hill Book Company. 1956). The following reaction represents the use of zeolite to soften water containing calcium bicarbonate:



A similar reaction may be written for other bicarbonates found in water, such as those of magnesium, calcium, etc.

However, a process in accordance with the above reaction is not efficient for producing large quantities of sodium bicarbonate from river water. Considering the low concentrations of bicarbonate mentioned above, it would require an enormous amount of time to get a solution with an appreciable concentration of sodium bicarbonate. The sodium bicarbonate would moreover be highly contaminated with bicarbonates of other cations, such as magnesium. Also, it must be realized that it is at least a two-step procedure, where the first step is carried out by nature—carbon dioxide captured by rain—and the second is a man made exchange using a sodium zeolite.

In U.S. Pat. No. 2,392,575 dated 1946, Tiger et. al. disclose a metathetical two-step conversion of common salt to sodium bicarbonate (NaHCO_3) through the net reaction:



This reaction is performed using an insoluble hydrogen "carbonaceous zeolite" (acid-treated sulfate lignite or soft coal) stripped of metallic cations. First, a sodium chloride solution is passed through a bed of such hydrogen carbonaceous zeolite. An excess of sodium chloride and hydrochloric acid is produced, leaving a sodium carbonaceous zeolite. Second, the sodium is contacted with a pressurized solution of carbonic acid obtained as a product of combustion. The hydrogen carbonaceous zeolite is regenerated, and a dilute solution of sodium bicarbonate is produced.

The hydrogen carbonaceous zeolite, the sodium chloride solution, and the solution of carbonic acid cannot be put all together in one simple step, because the sodium chloride exchange produces hydrochloric acid (HCl), which, together with the hydrogen carbonaceous zeolite, which is also acidic, would quickly decompose the sodium carbonate of the solution of pressurized carbonic acid into carbon dioxide gas (Chemical Characteristics and Structure of Cracking Catalysts, A. G. Oblad, T. H. Milliken, Jr., and G. A. Mills in Advances in Catalysis vol. 3, p 204, Academics Process, 1965). The high acidity level (a pH less than 4) hinders the formation of bicarbonate regardless of the length of time of the contact with the pressurized solution of carbonic acid.

There are several disadvantages with these relatively inexpensive hydrogen carbonaceous zeolites: low cationic exchange capacity (less than 1 meq/g), poor mechanical resistance (not suitable for pressurizing, bubbling, or a fluidized bed), and poor chemical stability to alkalis (sodium bicarbonate or sodium carbonate solutions), so that carbon particles go into the bicarbonate or carbonate solution and then peptize (F. Helfferich. Ion Exchange. Chap 2, pp 17-18. Dover Publications Inc. 1995; M Kodama, N. Shimisu, et al. Carbon 28 (1): 199-205 (1990)). Other types of carbonaceous materials, including cationic exchange resins, have better properties, but their initial cost, currently around \$10,000/m³, and regeneration cost both adversely affect the economics.

Amorphous silica aluminas and crystalline zeolites became available around the middle of the twentieth century. Their sodium forms are cheap, have high cationic exchange capacity, and can be used to perform the procedure disclosed in U.S. Pat. No. 2,392,575. To obtain the hydrogen form of such aluminosilicates, first the sodium form must be converted into the ammoniacal form through ion exchange with an ammonium salt solution and dried. Then, a calcination step at a temperature within the range of 400° C. to 500° C. produces the hydrogen form of the aluminosilicate, very often with severe loss of cationic exchange capacity. Only after

performing these preparatory steps can the procedure of U.S. Pat. No. 2,392,575 be performed.

In this procedure, a sodium chloride solution is passed through a permeable bed of the hydrogen form of these aluminosilicates. This produces hydrochloric acid, which causes a destructive acid attack on the aluminosilicates and a decomposition of the sodium bicarbonate as mentioned above. So in this procedure, the hydrogen form of these aluminosilicates does not improve the production of a sodium bicarbonate solution.

The prior art processes for obtaining sodium bicarbonate solutions clearly leave much to be desired.

OBJECTS AND SUMMARY OF THE INVENTION

An object of the invention is to obtain solutions of alkaline and/or alkaline earth bicarbonates that are free of impurities, from which chemicals of high quality can be obtained, including any of the following:

- sodium bicarbonate crystals
- other alkaline bicarbonates
- sodium carbonate
- other alkaline carbonates
- alkaline earth carbonates

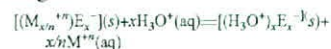
Other objects of the invention include the provision of a simple, economical and safe procedure for:

- capturing high levels of greenhouse carbon dioxide from the atmosphere anywhere on earth and converting it into solutions of bicarbonates, thereby ameliorating the effect of human activity on global climate;
- providing a new source of chemicals for coral reef remediation, abatement of water acidity, and treatment of hazardous materials;
- separating carbon dioxide from a mixture of gases; and
- producing solid alkaline bicarbonate, alkaline carbonate and/or alkaline earth carbonates for the industrial market.

Another object of the invention is to provide a process for attaining the above objects that takes advantage of the relatively low cost of sodium chloride and the worldwide surplus of gaseous carbon dioxide.

In addition, an object of the invention is to provide apparatus for carrying out the process of the invention.

The foregoing and other objects of the invention are attained in a preferred embodiment of the invention by a process comprising introducing a material $[(M_{x/n}^{+n})W_x^-]$ with cationic exchange properties into aqueous media, where the equilibriums of carbon dioxide dissolution take place and hydronium cations are produced. The cationic exchange material $[(M_{x/n}^{+n})E_x^-]$ captures hydronium cations (H_3O^+) according to:



where "x" stands for the molar amount of the anionic centers of charge of the cationic exchanger material $[(M_{x/n}^{+n})E_x^-]$ balanced by x/n molar amount of metal M, "n" stands for the metal valence, and "M" is selected from the group consisting of the elements in 1A and/or 2A of the periodic table of elements.

As explained below, this increases the yield of the desired chemicals in accordance with Le Chatlier's principle.

BRIEF DESCRIPTION OF THE DRAWING

A better understanding of the objects, features and advantages of the invention can be gained from a consideration of

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the following detailed description of its preferred embodiments, in conjunction with the appended drawing, wherein:

FIG. 1 is a schematic view of apparatus for carrying out a process according to the invention;

FIG. 2 is an X-ray diffraction pattern of a faujasite type X zeolite cationic exchange material;

FIG. 3 is a an image produced by a scanning electron microscope of microspheres of XC cationic exchange material, ranging in size between roughly 5 μm and 100 μm;

FIG. 4 is a scanning electron microscope image similar to the image in FIG. 3 but on a smaller scale;

FIG. 5 shows the X-ray diffraction pattern of an AC cationic exchange material;

FIG. 6 shows the X-ray diffraction pattern of an AX cationic exchange material;

FIG. 7 shows the X-ray diffraction pattern of an LTA cationic exchange material;

FIG. 8 shows the FT-infrared spectra of AA and AX cationic exchange materials;

FIG. 9 shows the sodium bicarbonate yields for AA, AX, AC and XC cationic exchange materials as a function of time;

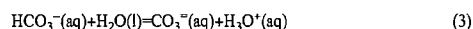
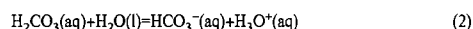
FIG. 10 shows the sodium bicarbonate yields for AA and AC materials as a function of the number of cationic exchange cycles; and

FIG. 11 shows the X-ray diffraction pattern of a mixture of thermonatrite (Na₂CO₃·H₂O) and Sodium carbonate (Na₂CO₃)

DETAILED DESCRIPTION OF THE INVENTION

The present invention makes use of the carbonate chemistry that occurs when carbon dioxide (CO₂) dissolves in water through a set of reactions yielding hydronium cations (H₃O⁺) and bicarbonate anions (HCO₃⁻) in aqueous media. If hydronium cations (H₃O⁺) are replaced by alkaline cations or alkaline earth cations, an alkaline or alkaline earth bicarbonate is formed. This invention takes advantage of the property of some materials to exchange their nonframework alkaline cations for hydronium cations (H₃O⁺) in aqueous media, therefore making possible the replacement mentioned above. These alkaline and/or earth alkaline bicarbonates, e.g. sodium bicarbonate (NaHCO₃) in aqueous solution can be recovered from the aqueous media through evaporation, crystallization, solid-liquid separation and drying in order to get solid alkaline bicarbonate or alkaline earth bicarbonate or mixtures of carbonates and bicarbonates suitable to be transformed into the most valuable high bulk density alkaline carbonate.

In aqueous (aq) media, there is a shift of the equilibriums among carbon dioxide (CO₂), carbonic acid (H₂CO₃), bicarbonate (HCO₃⁻) and carbonate (CO₃⁼), which takes place when gaseous (g) carbon dioxide dissolves in liquid (l) water according to following reactions:

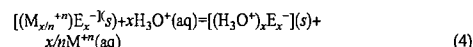


It is noticed that dissociation of carbonic acid (H₂CO₃) in reaction (2) and dissociation of bicarbonate anion (HCO₃⁻) in reaction (3) both yield the hydronium cation (H₃O⁺), which can be exchanged in the aqueous media.

The invention involves introducing a material [(M_{x/n}⁺⁺ⁿE_x⁻)] with cationic exchange properties into the aqueous media, where the equilibriums of carbon dioxide dissolution

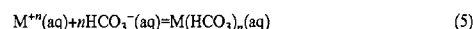
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take place, and the hydronium cations (H₃O⁺) are captured by the solid (s) cationic exchange material [(M_{x/n}⁺⁺ⁿE_x⁻)] disclosed herein, according to:



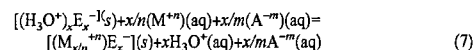
where "X" stands for molar amount of the anionic centers of charge of the cationic exchange material [(M_{x/n}⁺⁺ⁿE_x⁻)] balanced by x/n molar amount of metal M, "n" stands for the metal valence, and "M" is selected from the elements in group 1A and/or 2A of the periodic table of elements.

This capture of the hydronium cations, H₃O⁺, shifts the equilibriums set out in reactions (2) and (3) to the right, according to Le Chatelier's principle, producing more bicarbonate, HCO₃⁻, and/or carbonate, CO₃⁼, both of which can be combined with metal aqueous species, M⁺⁺ⁿ, in order to produce useful bicarbonates according to:



Thereafter, an aqueous solution of metallic bicarbonate is separated from the cationic exchange material by any of the liquid/solid separation methods of the art. This aqueous solution can undergo any crystallization process known or to be discovered in the art to produce a precipitate of bicarbonate and/or carbonate, which is then washed and dried.

The cationic exchanger material can be regenerated by ion exchange with an unsaturated solution of ionic salt of metal M⁺⁺ⁿ, replacing hydronium cations, H₃O⁺, in the used cationic exchanger material, [(H₃O⁺)_xE_x⁻], by fresh M⁺⁺ⁿ cations, making the used cationic exchanger material, [(H₃O⁺)_xE_x⁻], suitable for recycling, according to:



where A^{-m} stands for the anion of valence "m" selected from the group consisting of chlorides, sulfates, nitrates, α-hydroxy carboxylates, o-hydroxybenzoates, carboxylates, amine corrosion inhibitors, polyphosphate, and hexametaphosphates.

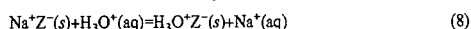
It is also desirable in this invention to provide, besides the cationic exchange material, x/nM⁺⁺ⁿ, other kinds of solid materials that can improve the transfer of carbon dioxide from gas phase to aqueous phase. The solid material can be silicas, aluminas, titanias, zirconias, iron oxides, oxo-hydroxides of them, carbons and biological catalysts as carbonic anhydrase as well their mixtures, whether crystalline and/or amorphous, provided that those solids have a specific surface area of at least 0.1 m²/g.

More particularly, our invention is concerned with the use of alkaline or/and alkaline earth aluminosilicate materials with cationic exchange properties such as crystalline zeolites and amorphous silica aluminas. Preferred crystalline aluminosilicates are zeolites of silicon-to-aluminum molar ratio lower than 100 as a cationic exchange material, especially with sodium LTA (Linde Type A) zeolite and sodium zeolites of the group of faujasites (zeolites X and Y), zeolite P, clinoptilolites, mordenites, ZSM-5, mutinaite and mixtures thereof.

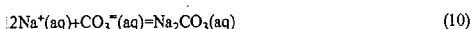
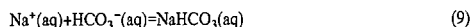
For example, our invention is concerned with the use of alkaline forms of crystalline and/or amorphous aluminosilicate materials in which atoms other than aluminum and silicon are substituted for some aluminum (e.g iron) and silicon (e.g germanium) atoms in tetrahedral coordination.

If work is done with a sodium zeolite material (Na⁺Z⁻), the hydronium cations, H₃O⁺, coming from carbonic acid and bicarbonate dissociations, as in reactions (2) and (3), are taken up by the sodium zeolite, and the sodium extra framework cation of the zeolite is replaced by the hydronium cation, shifting the equilibrium as follows:

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The sodium cations now in the aqueous media can combine with the bicarbonates, HCO_3^- , and carbonates, CO_3^{2-} , also present in this aqueous media, according to:



Sodium bicarbonate, NaHCO_3 , and/or sodium carbonate, Na_2CO_3 , are then precipitated using any process known or to be discovered in the art.

The present invention thus provides a method for producing sodium bicarbonate aqueous solutions that can be processed to yield solid sodium bicarbonate, sodium carbonates and their mixtures. This is accomplished by contacting an aqueous suspension of a cationic exchange material with a stream of carbon dioxide in an amount and for a time sufficient to cause carbon dioxide to dissolve in the aqueous suspension to produce hydronium cations (H_3O^+) and bicarbonate anions (HCO_3^-). The cationic exchanger material takes up hydronium cations (H_3O^+) from the aqueous media and releases the sodium cations to the aqueous suspension. Then liquid can be separated from the solid exchanger material and conveyed to an evaporator or crystallizer or any other device where solid sodium bicarbonate (NaHCO_3), or sodium carbonate or their mixtures are obtained.

Used cationic exchanger material is regenerated by contacting this material with a sodium chloride solution for a time adequate, at temperature below 100°C ., to cause sodium replacement in the cationic exchanger material. Finally, the cationic exchanger material is washed and reused.

The importance of carbon dioxide pressure to the bicarbonate concentration in the liquid phase is recognized. Carbon dioxide (CO_2) dissolution is mass-transfer-limited, and therefore reaction (1) appears slow.

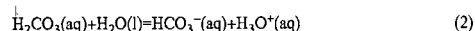


Most of the CO_2 exists in solution as dissolved CO_2 and not as H_2CO_3 as shown in reaction (1), but this does not affect the chemistry, and reaction (1) is conceptually simple.

The concentration of H_2CO_3 in solution is related to the partial pressure of CO_2 above the solution (P_{CO_2}) by reaction (11) where K_H is the Henry's Law Constant.



Carbonic acid ionizes in water via reaction (2). This reaction is essentially instantaneous.



The concentrations of the various species are related by reaction (12). K_{a1} is the first acidity constant of carbonic acid.



The expression for $[\text{H}_2\text{CO}_3]$ found in reaction (12) can be substituted in reaction (1), and the result rearranged to yield reaction (13). Reaction (13) demonstrates that the bicarbonate concentration depends on pH and CO_2 partial pressure

$$[\text{HCO}_3^-] = \frac{K_{a1} K_H P_{\text{CO}_2}}{[\text{H}_3\text{O}^+]} \quad (13)$$

There are many compositions of matter with cationic exchange properties, e.g. amorphous and crystalline forms of tetravalent metal acid salts, generally called single salts, with the general formula: $\text{M}(\text{IV})(\text{HXO}_4)_2 \cdot \text{NH}_2\text{O}$, where M represents Zr(IV), Ti(IV), Sn(IV), etc; and X represents P, W, Si,

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Mo, Se, As, etc. Still other natural silicoaluminate materials can be used, such as: cationic silica gels; feldspars; clays of the group of kaolinite, halloysites, smectites (bentonites, montmorillonites), illites, vermiculites, chlorites, sepiolites, attapulgites, palygorskites and their mixtures. Preferably, however, the invention is carried out with synthetics alkaline or alkaline earth silicoaluminate compositions with high cationic exchange capacity because they are readily and inexpensively available in the current market, and the scale-up processes are well known.

This invention can be carried out with exchangers whose exchangeable cations are elements of group 2A of the periodic table. However, exchanging univalent cations in solution, such as $[\text{H}_3\text{O}^+]$, with polyvalent cations, as in the case of any of elements in group 2A of the periodic table, requires a high initial concentration of $[\text{H}_3\text{O}^+]$ cations in the aqueous phase and takes a relatively long time, because of the affinity of cationic exchanger material for polyvalent cations.

Another problem is that the alkaline earth bicarbonates may produce practically insoluble carbonates and precipitate over the cation exchanger material during the process of carbon dioxide conversion, bringing fouling problems. Other types of exchangeable cations are those of the first transition metal series, whose bicarbonates, e.g. nickel bicarbonate, can be obtained using this invention. However, most of these cations pose disposal problems.

Some of the many advantages of the invention are described below.

The excess carbon dioxide in the atmosphere is a problem that the present invention can address. The consensus among atmospheric scientists is that the activities of humans are affecting the climate of the planet, primarily by the production of greenhouse gases. While some argue that Earth is overdue for a new Ice Age, it is generally acknowledged that, even if that is so on a geological timescale, the immediate threat, say for the rest of the 21st century or even for several centuries, is not cooling but global warming, rising sea levels, and resultant changing weather patterns. Global warming causes species of flora and fauna that have adapted over long periods to a particular ecological niche to retreat to higher elevations and latitudes. But there is no retreat above the tops of mountain ranges or beyond Earth's poles. Global warming by itself, without considering secondary effects such as rising sea levels and changing weather patterns, will likely cause the extinction of many species.

The main greenhouse gas in terms of effect on climate is carbon dioxide; water vapor is the second most important. Rising global temperatures due to excess atmospheric carbon dioxide increase water vapor in the atmosphere, causing a positive feedback loop.

Carbon dioxide is produced by the burning of fossil fuels and other combustible materials and by the decomposition of carbonates in the cement, glass, silica and silicate industries. Sensors atop Mauna Loa in Hawaii reveal, as reported by the New York Times on Dec. 22, 2010, that not only is the carbon dioxide level rising relentlessly, but also the pace of that rise is accelerating. By the end of the century, atmospheric carbon dioxide levels may be double those before the Industrial Revolution.

Greenhouse gases, including particularly carbon dioxide, pose a threat that must be addressed. The steps that are being taken fall short of what is needed. Various measures, including cap-and-trade, stricter CAFE standards, international treaties and voluntary conservation, have met varying degrees of acceptance and resistance by governments and private citizens.

These considerations demonstrate the need for a low-cost procedure that can be coupled with carbon-dioxide-emitting industries to capture carbon dioxide and convert it into compounds that pose little or no harm to the environment. In accordance with the present invention, it is possible to take carbon dioxide emissions, to fix the carbon dioxide using an aqueous solution of bicarbonate, and to deliver this solution to a coral reef, where it can be fixed as carbonate into a calcareous skeleton. There is evidence that sodium bicarbonate solutions are useful for promoting coral growth (e.g., Francesca Marubini and Brenda Thake, *Limnology and Oceanography*, vol. 44, No 3. Part 1, pp 716-720, May 1999), which also might be useful for coral reef water acidity remediation.

To decrease carbon dioxide emissions from burning fossil combustibles, another possibility is to send bicarbonate solutions to a bioreactor as a nutrient for algae or fungi making sulfur- and nitrogen-free biocombustibles or biogas. Still another possibility is conversion of this solution of bicarbonate into some other chemical compound. In this connection, there is incipient research about the catalytic conversion of sodium bicarbonate into formic acid (Bing Wu et al. *Catalysis Today*, 148: 405-410 (2009)), which is an important basic chemical for biodegradable disinfectants, where the lowest environmental impact is sought and no residues are allowed. It is also used as a preservative and antibacterial agent, in natural rubber manufacturing, as a chemical building block in the chemical and pharmaceutical industries, and as a non-flammable solvent for hydrogen storage. Also, sodium bicarbonate solution is a raw material for other important chemical commodities including ethyl chlorocarbonate, diethyl carbonate, and urea.

In the cationic exchanger regeneration, the anion of the regenerant salt ends as an acid. If the salt is sodium chloride or sodium sulfate (Na_2SO_4), the acid is hydrochloric acid or sulfuric acid, respectively. If common salt (NaCl) and water of good quality are used in the regeneration of the cationic exchanger material, and provided that this NaCl be separated from the acid solution if it is the case, a valuable, good-quality hydrochloric acid can be obtained. This acid is an important chemical in numerous applications, for example producing chlorides and acidizing petroleum wells. Hydrochloric acid can be captured by iron-rich clays to produce water treatment chemicals such as iron (III) chloride and polyaluminum chloride. The former is used in the electronics industry, in ore reduction and refining for the production of tin and tantalum, as a pickling and metal-cleaning agent, for pH adjustment, and in general cleaning. It is also used for electroplating, removing scale from boilers, neutralizing basic systems, deionizing water for the food and pharmaceutical industries, making more space in depleted gas and oil reservoirs, for carbon dioxide sequestration, manufacturing fertilizers and dyes, and hydrolyzing starch and proteins in the preparation of various food products; as a laboratory reagent, catalyst and solvent in various organic syntheses; and in the photographic and textile industries.

In accordance with the invention, a simple procedure for sequestering carbon dioxide in a bicarbonate solution can be coupled with a carbon dioxide emitting facility to mitigate carbon dioxide emission into the atmosphere and recycle the raw materials used. One example is the precipitation of silica from sodium silicate. In this process, sodium carbonate (Na_2CO_3) is used, and significant amounts of carbon dioxide are generated. In accordance with the invention, this carbon dioxide can be fixed as a bicarbonate solution and later transformed into solid sodium carbonate. The sodium sulfate or sodium chloride present in the liquid filtrate because of the

precipitation of silica comes into contact with the used hydrogen form of the cationic exchanger material and thereby regenerates the cationic exchanger material and restores either hydrochloric acid or sulfuric acid to the process. In this way, a decrease a carbon dioxide emissions may be achieved through recycling the acids and the sodium carbonate.

In accordance with the invention, the acid solution coming from the regeneration step of the used cation exchanger material can put in contact with a basic solution whose metal belongs to group 1A or 2A of the periodic table and is preferably the same metal as the exchanging metal of the cationic exchanger material. This neutralization reaction produces the salt used as regenerant plus water, which can be separately recovered by any known method of physical separation. Said basic solution can be obtained by dissolving in water a solid metal hydroxide of the groups above mentioned, up to a convenient pH between 7.5 and 12. However, it is known that certain alkaline aluminosilicates (aluminum-rich zeolites, feldspars) or hydrothermally treated slurries of alkaline silica gel have the property of hydrolyzing water, producing in consequence an alkaline basic solution having a pH between 8 and 11. This basic solution can be separated from the aluminosilicate or alkaline silica-gel materials and put in contact with the acid solution coming from the regeneration step of the used cationic exchanger material. The basic solution will then neutralize the acid solution and yield a solution of the regenerant salt that can be cycled with appropriate adjustment of the concentration. As can be seen, a raw material for this invention can be something as abundant in nature as the carbon dioxide in the atmosphere and as cheap as common salt.

The following examples will further convey an understanding of the invention. The analytical procedures used in all the examples are as follows:

The Cationic Exchange Capacity (CEC), expressed as the ratio of milliequivalents of hydrogen (meq) to the dry basis mass (g) of the sample of synthesized materials as well as commercial materials, is evaluated by titrimetry. A sample size of 0.5 g dry basis is used in all determinations. In a 250 mL conical flask is placed an amount of the sample along with a magnetic bar. Then 50 mL of 0.1 N hydrochloric acid is added. The system is stirred at room temperature for at least one hour. After that, the agitation is stopped, and sedimentation is allowed until a clear solution is obtained. An aliquot of 25 mL of the supernatant solution is taken to another 250 mL conical flask, and 25 mL of demineralized water is added. This solution is titrated with a solution of 0.1 N of sodium hydroxide, using a mixed indicator of methylene blue—neutral red that gives a sharp color change from violet-blue to green at pH 7. Finally, the acid milliequivalents consumed are calculated as the difference between the initial and the final acid milliequivalents. CEC is the ratio of this difference to the dry basis mass.

For the determination of the alkaline bicarbonate or the earth alkaline bicarbonate in the filtrate, the method used is that described in Hamilton, L. F. et al. (*Calculations of Analytical Chemistry*, pp 190-195. McGraw-Hill Book Company, Seventh Edition, 1969). Previously, the presence of carbonate in solution is tested with a phenolphthalein test. It is positive for carbonate if a pink and negative if colorless. The alkaline bicarbonate or earth alkaline bicarbonate solution is titrated with a 0.1 N of hydrochloric acid solution using a mixed indicator of methyl orange—indigo carmine, which changes from green to magenta with a neutral-grey color at a pH of about 4. Because of the hydrolysis, the initial cation exchanger material slurry is basic, and a small amount of

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atmospheric carbon dioxide is taken. Therefore, the results reported in the examples are the net yield of bicarbonate.

In all examples, considering the CEC (meq/g), the dry basis mass in grams (Mzd) of cationic exchanger material tested is such that the mass of alkaline bicarbonate or earth alkaline bicarbonate produced in solution is 2.5 g. That is, this value represents 100% of the yield if all the equivalents of the cationic exchanger material are exchanged, according to:

$$Mzd(g) = 1/CEC * 1000 * 2.5 * 1/84.01 \quad (14)$$

The wet basis mass of the cationic exchanger material in grams (Mzw) is in accordance with the following reaction:

$$Mzw(g) = Mzd / (1 - LOI/100) \quad (15)$$

where LOI is the percent of mass loss of the cationic exchange material taken at an arbitrary temperature of 700° C.

FIG. 1 shows apparatus suitable for carrying out the process of the invention. In a well-cleaned gas-washing flask 7, an amount of cationic exchanger material 11 is charged. In the flask 7 is added previously boiled and room temperature tempered demineralized water, to get an agitated slurry using a magnetic stirrer plate 10 and a magnetic bar 9. The water-to-cationic exchanger material volume ratio is 0.5 to 10, and from 50% to 80% of the total volume of flask 7 is filled. On/off valve 4 is opened, a stream of nitrogen gas from a source 2 is allowed to flow at a rate from 50 ml/min to 500 ml/min, as measured by rotameter 6, and a gas diffuser 8 is introduced into flask 7. The time of nitrogen flowing is from 5 minutes to 60 minutes. Then a change in three-way valve 3 allows a carbon dioxide gas flow from source 1 at a rate from 100 ml/min to 1 L/min; carbon dioxide gas flow time is from 5 minutes to 1 hour.

After this cationic exchanger time, carbon dioxide gas flow is reduced by means of flow control valve 5, and the gas diffuser 8 is removed from the flask 7. The cationic exchanger material slurry is discharged into a Büchner filtering device, where a liquid sodium bicarbonate solution filtrate is obtained. The cationic exchanger material is washed at least once with hot demineralized water at a temperature between 30° C. and 50° C., so that the water-to-cationic exchanger material volume ratio is between 1 and 20. The whole filtrate is conveyed to an evaporation device, where finally a solid alkaline bicarbonate, alkaline carbonate, and/or alkaline earth carbonate and their mixtures are obtained.

Used cationic exchanger material is regenerated by contact with a soluble alkaline and/or earth alkaline salt solution, so that the solution has one to ten times the exchange milliequivalents of the mass of cationic exchanger material used, a temperature from 30° C. to 100° C. for at least 5 minutes, and a liquid-to-solid ratio between 0.5 and 10. Immediately after the cationic exchanger material is separated from the regenerant solution, the solid is washed at least once with hot demineralized water at a temperature between 30° C. and 100° C. The water-to-cationic exchanger material volume ratio is between 1 and 20. Optionally, the solid is dried for at least 1 hour (1 h) at a temperature of at least 80° C. This dried and regenerated cationic exchanger material is used again for a new cationic exchanger with carbonic acid.

In accordance with the invention one may employ as cationic exchanger material $[(M_{x/n}^{+n})E_x^-]$, where its composition of matter is a silicoaluminate or substituted silicoaluminate represented by the general empirical formula



where: "M" stands for a non framework exchangeable metal of the group 1A and/or 2A, "n" stands for the valence of the metal, "v" stands for the molar ratio of the anionic centers of

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tetrahedral aluminum, "v" stands for the molar ratio of the anionic centers of tetrahedral "Z", "Z" stands for all elements of the first transition metals series, Zr, Nb, and elements from groups 5A and 3A of the periodic table, "y" stands for the molar ratio of non anionic centers of tetrahedral silicon, $(v+w)/n$ is the number of exchangeable cations of valence n, and "m" stands for the number of water molecules adsorbed on external and internal surfaces of the solid cationic exchanger material, so that: $v+w \neq 0$; $v+w \leq y$ and $y/(v+w) < 100$.

It is also within the scope of the invention to detect an X-ray diffraction pattern of the composition of matter.

The following experimental examples demonstrate the process more specifically and support the claims of the present invention. The experiments are cited only as examples and not by way limitation, and the scope of the invention is not in any way restricted or limited by these examples.

Example 1

A blank or control run was made without any cationic exchanger material. Into a well-cleaned 250 mL gas washing flask 7, 150 mL of previously boiled and room temperature tempered demineralized water was added. The on/off valve 4 was opened, a stream of nitrogen gas coming from source 2 at a pressure of 14 psig was allowed to flow at a rate of at least 250 mL/min, and a gas diffuser (8) was introduced into the flask 7. The time of nitrogen flowing was at least 5 minutes. Then a change in three-way valve 3 allows a 14 psig carbon dioxide gas flow from source 1 at a rate of at least 250 mL/min. The carbon dioxide gas flow time was 30 minutes at room temperature.

The amount of the bicarbonate (as anion) formed was 238 mg/L using the analytical procedure previously mentioned.

Example 2

In this example an XC sodium form cationic exchanger material was examined. This is a commercial microsphere of faujasite type X zeolite, whose X ray diffraction pattern is shown in FIG. 2. The silicon-to-aluminum (mol/mol) ratio given by chemical analysis and specific BET surface area (S) is shown in table 1 of example 3. FIG. 3 presents a picture of scanning electron microscopy displaying a general view of microspheres of XC material, ranging in size between roughly 5 µm and 100 µm. FIG. 4 shows a picture of scanning electron microscopy of the microspheres of this XC cationic exchanger material.

Into a well-cleaned gas washing flask 7, a mass of cationic exchanger material XC was charged, and the procedure described in example 1 was carried out. The carbon dioxide gas flow time was also 30 minutes.

Using the analytical procedure previously mentioned, the amount of the bicarbonate (as anion) formed was 427 mg/L, and the phenolphthalein test for carbonate was negative.

This cationic exchanger material used in accordance with the invention is the one with the lowest yield of sodium bicarbonate of all cationic exchanger materials tested; however, the yield is almost twice that of the blank or control run, indicating that the equilibrium toward the formation of bicarbonate is shifted by the introduction of a cationic exchanger material into the aqueous media, where simultaneously dissolution of carbon dioxide is taking place.

Example 3

This example examines various sodium-form cationic exchanger materials of the aluminosilicate type. Besides the

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cationic exchange describe in example 2, the characteristics of others are shown in Table 1 below. FIG. 5 shows an X-ray diffraction pattern of the AC material, which represents a typical A zeolite. The AC material comprises a set of microspheres with a size distribution similar to that shown in FIG. 3. The AA and AX materials are both X-ray amorphous materials whose patterns are shown in FIG. 6 and FIG. 7 respectively. These materials are obtained from gels typical for synthesis of zeolites A and X respectively, but their syntheses were quenched before the crystal growth stages to obtain small nuclei and so a greater external surface. FIG. 8 shows the infrared spectra of AA and AX materials in the framework range of zeolite 380 cm⁻¹ to 1300 cm⁻¹. They display some bands of a typical IR pattern for zeolites, showing that a small range ordering exists in both materials. Their absorption pattern is characterized by the following frequency ranges in cm⁻¹: 1300 cm⁻¹-900 cm⁻¹, very strong; 900 cm⁻¹-800 cm⁻¹ medium; 750 cm⁻¹-650 cm⁻¹, medium; 650 cm⁻¹-520 cm⁻¹ weak; 500 cm⁻¹-420 cm⁻¹ medium.

Each of these materials was examined following the procedure used in example 2. The mass of cationic exchange material used for the evaluation ranges between 6 g and 9 g, and was determined as described above, according to CEC and LOI parameters. For each material, the run times are 5, 15 and 30 minutes. In all of the cases examined, the phenolphthalein test for carbonate was negative, which indicates that these materials are selective to produce sodium bicarbonate. The sodium bicarbonate yields in each case are shown in FIG. 9. It is noted that the equilibrium toward the formation of bicarbonate is shifted by the introduction of a cationic exchange material in the aqueous media, where simultaneously dissolution of carbon dioxide is taking place. The AA material produces the best results. Surprisingly, the amorphous materials AC and AX produce a better yield of sodium bicarbonate than do well crystallized materials and much more than does the mere bubbling of carbon dioxide in water shown in example 1.

This is not intended to give a definitive explication, but it is possible that diffusion problems of carbon dioxide gas into internal surfaces of the nanopores of these crystalline materials or into embedded exchanging sites in the bulk of the amorphous materials prevent the achievement of the expected total conversion of the CEC of each material. The sodium bicarbonate yield seems to be related to the abundance of aluminum in the external surface area of these cationic exchange materials. The equilibrium shifting from carbon dioxide gas to bicarbonate by cationic exchanger materials is real, but availability of the exchanging sites is also important.

TABLE 1

Material	Si/Al (mol/mol)	CEC (meq/g)	Crystallinity	S BET (m2/g)	S external (m2/g)
AC	1.3	6.2	A zeolite Type	8	4
XC	1.7	4.5	X zeolite type	770	11
AA	1.4	5.6	Amorphous	55	32
XA	1.8	5.7	Amorphous	38	21

Example 4

In this example, cationic exchanger materials selected from example 3 are used in successive cycles of cationic exchange with carbonic acid followed by intermediate regeneration with a sodium chloride solution. The idea is to determine the enrichment in sodium bicarbonate for each cycle, keeping in each cycle the same amount of original mother

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liquor used at the beginning. The selected materials are AC and AA. The characteristics of these materials are described in example 3. The procedure for carbonic acid exchange is the same as in example 1. The carbonic acid exchange run time was 30 min for each cycle. The procedure for the regeneration step is described above. The regeneration was carried out using a solution of sodium chloride with 2 times the milliequivalents of the mass of used cationic exchanger material, a liquid-to-solid ratio of 2, a temperature of 40° C., and 30 minutes of regeneration time. After that, the material was dried at 100° C. for 2 hrs. To keep the same mass of cationic exchanger material, a small makeup (around 100 mg) was done before beginning a new acid carbonic exchange cycle. In each cycle, an aliquot of 20 ml was removed from the mother liquor for sodium bicarbonate analysis. This aliquot was replaced by adding the same volume of a sodium bicarbonate solution. The replacement volume has the same mass of sodium bicarbonate as the removed aliquot. The enrichment of sodium bicarbonate for each cycle is shown in FIG. 10.

In the case of both cationic exchanger materials, there was an increase of the amount of sodium bicarbonate after each cycle, which shows that a regeneration of the used exchanging sites takes place in the case of each material. The relative efficiency of sodium bicarbonate production was the same as that observed in FIG. 9 and example 3, where the yield of AA material was greater than that of AC at 30 min of cationic exchanger with carbonic acid. The slopes of the graphs shown in FIG. 10 represent the percentage increase in sodium bicarbonate yield by cycle, which for AA and AC materials are about 9.15 and 3.87, respectively. Perhaps the equilibrium condition between carbon dioxide with a sodium bicarbonate solution limits the yield, but still carbon dioxide to bicarbonate equilibrium shifting by the cationic exchanger materials was observed. This indicates that it is possible that 100% yield can be attained by using successive cycles with regeneration cycles in between.

Example 5

This example uses the procedure of example 2, except that, instead of using fresh demineralized water, a solution of 2.5 g of sodium bicarbonate analytical grade in 150 ml of demineralized water was prepared, and a mass of regenerated AC material was introduced after the 7th cycle. This was done in order to simulate the number of cycles necessary to achieve 100% yield of sodium bicarbonate. An increase of 3.79% over the amount of sodium bicarbonate in solution was obtained, in good agreement with what is expected from the slope of the AC line in FIG. 9 and example 4. It shows that the regenerated cation exchanger material can be used again after several cycles.

Example 6

A mass of regenerated AA material after the 3rd cycle of example 4 (FIG. 9) was evaluated with 150 ml of fresh demineralized water following the procedure of example 2. A yield of 27% was obtained, which is very close to the result obtained in the first cycle, indicating that regenerability is also achieved in amorphous cationic exchanger materials.

Example 7

In this example, the sodium bicarbonate liquor obtained in example 4 for AA material, after its separation from the liquor, was evaporated to dryness at 90° C. A powder X-ray diffraction analysis was made using Cu radiation K-Alpha1

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[Å] 1,54060. The obtained diffraction pattern is presented in FIG. 11. The sodium chloride (NaCl) was introduced for instrumental correction in the peaks position. The rest of the peaks are identified as a mixture of sodium carbonates (thermonatrite, $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$, and sodium carbonate Na_2CO_3) according to the base data of the JCPDS (Join Committee of Powder Diffraction Standards) 8-448 for thermonatrite and 37-451 for sodium carbonate. This shows that solid carbonates can be obtained from a sodium bicarbonate solution using cation exchanger materials by shifting the equilibrium of carbon dioxide gas dissolution to bicarbonate.

Example 8

A mass of regenerated AA material was evaluated with 150 ml of fresh demineralized water. At a location 1,700 meters above sea level, with an absolute pressure of 0.83 atm at 27° C., a stream of ambient air at 0.47 L/min was passed through the gas-washing flask of FIG. 1. The procedure of the example 2 was followed, with a continuous run time of 24 hours. A yield of 7% of sodium bicarbonate was obtained. Considering ideal gas behavior of the carbon dioxide, it represents a capture of 30% of the total carbon dioxide introduced for the run time examined. This example shows that carbon dioxide can be removed from a mixture of gases and that by this invention atmospheric carbon dioxide can be fixed into valuable chemical commodities including carbonates, bicarbonates and acids of high quality. Also, this invention can be used as a separation method and further still as analytical method to quantify carbon dioxide provided that the milliequivalents of the cationic exchanger are not exhausted and the flow of incoming gas is conveniently adjusted. This result indicates that by scaling up this procedure it is possible simultaneously to capture and to convert at high levels atmospheric carbon dioxide in a simple, economical and safe way in any location on the planet.

Example 9

This example examines a sodium form cationic exchanger material, which is a type X zeolite whose lattice is partially isomorphously substituted with iron, that is, iron atoms as well as aluminum atoms are exchanging sites.

This material was evaluated following the procedure of example 2, and a yield of 3% was obtained. This shows that other kinds of atoms can be included in the composition of the aluminosilicate materials, provided that these atoms have a chemical tetrahedral coordination suitable for making exchanges, namely a tetrahedral structure.

Example 10

In this example an aluminium salt, aluminium trichloride (AlCl_3) was homogeneously deposited on a surface of silica gel micro spheres whose size distribution ranges 0.8 mm-1.2 mm. This silica gel support has 300 m^2/g , a pore volume of 1.2 cc/g and an average pore diameter of 13 nm. After calcination, the material was put in contact with a solution of sodium chloride such that the equivalents of sodium were 1.5 times that of the aluminum. The CEC of the material was of 3.9 meq/g. A mass of 7.6 g of this material, dry basis, was evaluated for carbon dioxide conversion to sodium bicarbonate using the same procedure of the example 2, the carbon dioxide flow was 250 mL/min. The yield of sodium bicarbonate at 30 min was 57%. In comparison with the results of the crystalline materials of the example 2, there is a improvement

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in the yield of the bicarbonate, which pointing to a better exposure of the exchanging site to the carbonic acid in this cationic exchanger material.

Example 11

In this example, a cation exchanger material with the same characteristics of the example 8 was evaluated for carbon dioxide conversion to sodium bicarbonate using the same procedure of the example 10. This time suspending the material in 150 mL of spring water with the following composition:

Calcium=96 mg/L; Sodium=10.60 mg/L; Magnesium=6.1 mg/L; Potassium=3.7 mg/L; Bicarbonate=297 mg/L; Chlorine=22.6 mg/L; Sulfate=9.3 mg/L; pH=7.2. The net yield of sodium bicarbonate was 30%. This indicates that besides demineralized water, at least some mineral spring water can be used in this invention.

Example 12

In this example, an amount of XC material, whose properties are said in table 1, is ionic exchange with a solution of potassium chloride 1,5 times the milliequivalents of the sodium at XC material mass. The ionic exchange was carried out with a liquid-to-solid ratio of 2, a temperature of 40° C., and 30 minutes of exchanging time. After that, the material was dried at 100° C. for 2 hrs. In this way a potassium XC material is obtained. This material was examined for carbon dioxide conversion according to the procedures said in the example 2. A yield of 4% of sodium bicarbonate was obtained. This shows that other alkaline metals than sodium in the cationic exchanger material can end as a bicarbonate in solution.

Example 13

In this example, an amount of AC material, whose properties are indicated in table 1, is ionically exchanged with a solution of calcium chloride once the milliequivalents of the sodium at AC material mass. The ionic exchange was carried out with a liquid-to-solid ratio of 2, a temperature of 40° C., and 30 minutes of exchanging time. After that, the material was dried at 100° C. for 2 hrs. In this way a calcium AC material is obtained. This material was examined for carbon dioxide conversion according to the procedures set out in the example 2. A yield of 10% of calcium bicarbonate was obtained. This shows that an alkaline earth metal on the cationic exchanger material can end as a bicarbonate in solution. However it is recognized that calcium bicarbonate exists only in aqueous solution and is not known as a solid phase.

CONCLUSION

The ammonia-soda process has been well established since the end of nineteenth century to produce massively synthetic sodium bicarbonate. To our knowledge there is no known process that takes advantage of the faster and simpler cationic exchange mechanism to produce, in a single step, significant amounts of a synthetic alkaline bicarbonate and/or earth alkaline bicarbonate solution with a suitable concentration and purity to crystallize alkaline bicarbonates or any other alkaline carbonates and their mixture, or earth alkaline carbonate. Perhaps the low solubility of carbon dioxide in pure water (0.034 mol/L) at 25° C. and 1 atm, the very low rate of carbon dioxide hydration reaction, versus the high rate of dehydration of the carbonic acid (H_2CO_3) (according to equation 1),

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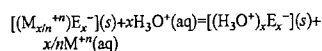
all of which mean that in a solution of carbon dioxide in water, only about 0.1% exists in the form of carbonic acid, and the relative small value of the first acidity constant ($pK_1=3.4$) have discouraged the bicarbonate-carbonate industry from looking at other possibilities based on cationic exchange. In any case, despite these seeming physical-chemical impediments, this invention demonstrates that contacting an insoluble alkali metal or earth alkaline form of an inorganic cationic exchanger material within an aqueous medium where carbon dioxide gas is introduced or generated shifts the carbon dioxide dissolution equilibrium toward bicarbonate production.

It is not obvious that both of the problems noted above excess carbon dioxide being released into the atmosphere and the lack of an ecologically friendly and inexpensive process for the manufacture of alkaline bicarbonates or alkaline earth bicarbonates can be addressed by a single manufacturing process; yet that is exactly what the present invention accomplishes.

The processes disclosed herein are different embodiments of our invention. Many modifications of these processes will occur to those skilled in the art upon consideration of this disclosure. The invention is not limited to the disclosed processes but includes all such modifications thereof as fall within the scope of the appended claims.

The invention claimed is:

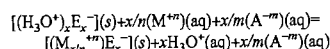
1. A process for making aqueous solutions of alkaline bicarbonates and/or alkaline earth bicarbonates comprising the steps of: dissolving gaseous carbon dioxide in water to produce an aqueous solution containing bicarbonates, HCO_3^- ; and further containing hydronium cations, H_3O^+ , introducing a solid cationic exchanger material $[(M_{x/n})^{+n}E_x^-]$ to capture the hydronium cations, H_3O^+ and produce used cationic exchanger material $[(\text{H}_3\text{O}^+)_xE_x^-]$, according to:



where "X" stands for a molar amount of anionic centers of charge of the cationic exchanger material $[(M_{x/n})^{+n}E_x^-]$ balanced by x/n molar amount of non framework metal M, "n" stands for the metal valence, and "M" is selected from the group consisting of Group 1A and Group 2A of the periodic table of elements; whereby the capture of the hydronium cations, H_3O^+ , increases the yield of the bicarbonates, and regenerating the used cationic exchanger material, $[(\text{H}_3\text{O}^+)_xE_x^-]$, by ion exchange with an unsaturated solution of ionic salt of metal M^{+n} such that the equivalents of the metal M^{+n} is at least 0.5 times the equivalents of E_x^- .

2. A process according to claim 1 wherein the regenerating step is performed by ion exchange with an unsaturated solution of ionic salt of metal M^{+n} , and comprising replacing hydronium cations, H_3O^+ , in the used cationic exchanger material $[(\text{H}_3\text{O}^+)_xE_x^-]$, by fresh M^{+n} cations, making the used exchanger material $[(\text{H}_3\text{O}^+)_xE_x^-]$ suitable for recycling.

3. A process according to claim 1 wherein the regenerating step is performed by ion exchange with an unsaturated solution of ionic salt of metal M^{+n} , and comprising replacing hydronium cations, H_3O^+ , in the used cationic exchanger material $[(\text{H}_3\text{O}^+)_xE_x^-]$, by fresh M^{+n} cations, making the used exchanger material $[(\text{H}_3\text{O}^+)_xE_x^-]$ suitable for recycling according to:



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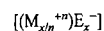
where A^{-m} stands for the anion of valence "m" selected from the group consisting of chloride, sulfate, nitrate, α -hydroxy carboxylate, o-hydroxybenzoate, amine, polyphosphate and hexametaphosphate.

4. A process according to claim 1 comprising the step of passing the aqueous solution of bicarbonates through a crystallization process to produce a precipitate of alkaline bicarbonates and/or alkaline carbonates.

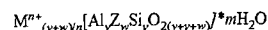
5. A process according to claim 4 comprising washing and drying the precipitate.

6. A process according to claim 1 comprising employing, as cationic exchanger material, a composition of matter having a cation exchange capacity greater than 0.001 miliequivalents per gram dry basis, and/or with a specific surface at least $0.1 \text{ m}^2/\text{g}$.

7. A process according to claim 6 comprising employing, as cationic exchange material, a silicoaluminate or substituted silicoaluminate



represented by the general empirical formula



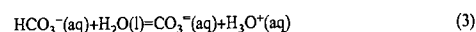
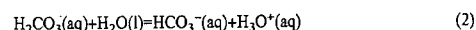
where: "v" stands for the molar ratio of the anionic centers of tetrahedral aluminum, "w" stands for the molar ratio of tetrahedral anionic centers "Z", wherein "Z" stands for all elements of the first transition metals series, Zr, Nb, and elements from groups 5A and 3A of the periodic table, "y" stands for the molar ratio of non anionic centers of tetrahedral silicon, $(v+w)/n$ is the number of exchangeable cations of valence n, and "m" stands for the number of water molecules adsorbed on external and internal surfaces of the solid cationic exchanger material, so that: $v+w \neq 0$; $v+w \leq y$ and $y/(v+w) < 100$.

8. A process according to claim 7 comprising detecting an X-ray diffraction pattern of the composition of matter.

9. A process according to claim 1 comprising employing, as cationic exchanger material $[(M_{x/n})^{+n}E_x^-]$, synthetic or natural alkaline and/or alkaline earth LTA zeolite and sodium zeolites selected from the group consisting of faujasite, zeolite X, zeolite Y, zeolite P, clinoptilolite, mordenite, ZSM-5, mutinaite, feldspar, expansible clay, bentonite, montmorillonite, and mixtures thereof.

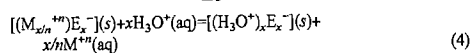
10. A process according to claim 1 further comprising augmenting the activity of cationic exchange material $[(M_{x/n})^{+n}E_x^-]$ by introducing into the aqueous solution solid material selected from the group consisting of silica, alumina, titania, zirconia, iron oxide, and mixtures thereof having a specific surface area of at least $0.1 \text{ m}^2/\text{g}$.

11. A process comprising the steps of: dissolving gaseous carbon dioxide in water according to the following reactions:

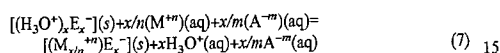


where reactions (2) and (3) both yield aqueous media containing hydronium cations, H_3O^+ , which are exchanged in the aqueous media, and introducing a cationic exchanger material $[(M_{x/n})^{+n}E_x^-]$ into the aqueous media, where equilibria of carbon dioxide dissolution take place and the hydronium cations, H_3O^+ , are captured by the cationic exchanger material $[(M_{x/n})^{+n}E_x^-]$ and produce used cationic exchanger material $[(\text{H}_3\text{O}^+)_xE_x^-]$ according to:

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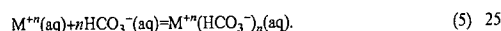


where "x" stands for a molar amount of anionic centers of charge of the cationic exchanger material $[(M_{x/n})^{+n}E_x^-]$ balanced by x/n molar amount of metal M, "n" stands for metal valence, and "M" is selected from Group 1A or Group 2A of the periodic table of elements, and regenerating the used cationic exchanger material $[(H_3O^+)_xE_x^-]$ by ion exchange with an unsaturated solution of ionic salt of metal M^{+n} , replacing hydronium cations, H_3O^+ , in the used cationic exchanger material $[(H_3O^+)_xE_x^-]$ by fresh M^{+n} cations, according to



where A^{-m} stands for the anion of valence "m" selected from the group consisting of chloride, sulfate, nitrate, α -hydroxy carboxylate, o-hydroxybenzoate, amine, polyphosphate and hexametaphosphate.

12. A process according to claim 11 comprising the step of combining the bicarbonate with aqueous alkaline metal species, M^{+n} , to produce an aqueous solution of alkaline bicarbonate or alkaline earth bicarbonate according to:



13. A process according to claim 12 comprising the step of separating the aqueous solution of alkaline bicarbonate or alkaline earth bicarbonate from the cationic exchanger material.

14. A process according to claim 12 where the cationic exchanger material is stripped at least once with a stream of water at a temperature between 10° C. and 90° C.

15. A process according to claim 11 where the cationic exchanger material is stripped at least once with a stream of water at a temperature between 10° C. and 90° C.

16. A process according to claim 13 comprising the step of passing the aqueous solution of alkaline bicarbonate or alkaline earth bicarbonate through a crystallization process to produce a precipitate of alkaline bicarbonate and/or alkaline carbonate, or alkaline earth carbonate.

17. A process according to claim 16 comprising the steps of washing and drying the precipitate.

18. A process for producing solid alkaline bicarbonate and/or alkaline earth carbonate, comprising the steps of:

contacting an aqueous suspension of a cationic exchanger material with a stream of carbon dioxide in an amount and for a time sufficient to cause carbon dioxide to dissolve in the aqueous suspension to produce hydro-

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num cations (H_3O^+) and alkaline and/or alkaline earth bicarbonate anions (HCO_3^-);

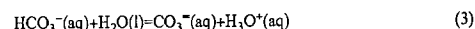
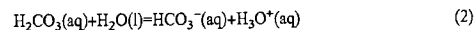
whereby the cationic exchanger material takes up hydronium cations (H_3O^+) from the aqueous suspension and releases alkaline cations and/or alkaline earth cations to the aqueous suspension, thereby becoming used cationic exchanger material;

separating liquid from the used cationic exchanger material;

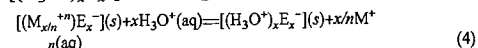
precipitating solid alkaline bicarbonate and/or alkaline carbonate, or alkaline earth carbonate from the liquid, and regenerating the used cationic exchanger material, $[(H_3O^+)_xE_x^-]$, by ion exchange with an unsaturated solution of ionic salt of metal M^{+n} , where "n" stands for the metal valence, and "M" is selected from the group consisting of Group 1A and Group 2A of the periodic table of elements, such that the equivalents of the metal M^{+n} is at least 0.5 times the equivalents of E_x^- .

19. A process comprising the steps of:

dissolving gaseous carbon dioxide in water according to the following reactions:



where reactions (2) and (3) both yield aqueous media containing hydronium cations, H_3O^+ , which are exchanged in the aqueous media, and introducing a cationic exchanger material $[(M_{x/n})^{+n}E_x^-]$ into the aqueous media, where equilibria of carbon dioxide dissolution take place and the hydronium cations, H_3O^+ , are captured by the cationic exchanger material $[(M_{x/n})^{+n}E_x^-]$ and produce used cationic exchanger material $[(H_3O^+)_xE_x^-]$ according to:



where "x" stands for a molar amount of anionic centers of charge of the cationic exchanger material $[(M_{x/n})^{+n}E_x^-]$ balanced by x/n molar amount of metal M, "n" stands for metal valence, and "M" is selected from Group 1A or Group 2A of the periodic table of elements, and

regenerating the used cationic exchanger material $[(H_3O^+)_xE_x^-]$ by ion exchange with an unsaturated solution of ionic salt of metal M^{+n} , replacing hydronium cations, H_3O^+ , in the used cationic exchanger material $[(H_3O^+)_xE_x^-]$ by fresh M^{+n} cations.

* * * * *



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15444 7590 07/11/2014
Donald S. Dowden
46 Winthrop Street
South Hamilton, MA 01982

EXAMINER

BOS, STEVEN J

ART UNIT

PAPER NUMBER

1736

DATE MAILED: 07/11/2014

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/136,153	07/25/2011	Juan Lujano	PR101	7110

TITLE OF INVENTION: Conversion of gaseous carbon dioxide into aqueous alkaline and/or alkaline earth bicarbonate solutions

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	\$480	\$0	\$0	\$480	10/14/2014

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

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(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/136,153	07/25/2011	Juan Lujano	PR101	7110

TITLE OF INVENTION: Conversion of gaseous carbon dioxide into aqueous alkaline and/or alkaline earth bicarbonate solutions

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	\$480	\$0	\$0	\$480	10/14/2014

EXAMINER	ART UNIT	CLASS-SUBCLASS
BOS, STEVEN J	1736	423-157000

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☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/136,153	07/25/2011	Juan Lujano	PR 101	7110
15444	7590	07/11/2014	EXAMINER	
Donald S. Dowden 46 Winthrop Street South Hamilton, MA 01982			BOS, STEVEN J	
			ART UNIT	PAPER NUMBER
			1736	

DATE MAILED: 07/11/2014

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. **DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.** Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Examiner-Initiated Interview Summary	Application No.		Applicant(s)	
	13/136,153		LUJANO ET AL.	
	Examiner		Art Unit	
	Steven Bos		1736	

All participants (applicant, applicant's representative, PTO personnel):

(1) Steven Bos. (3) _____

(2) Donald S. Dowden. (4) _____

Date of Interview: 6-27-2014.

Type: ☒ Telephonic ☐ Video Conference
☐ Personal [copy given to: ☐ applicant ☐ applicant's representative]

Exhibit shown or demonstration conducted: ☐ Yes ☒ No.
If Yes, brief description: _____

Issues Discussed ☐ 101 ☐ 112 ☐ 102 ☐ 103 ☒ Others
(For each of the checked box(es) above, please describe below the issue and detailed description of the discussion)

Claim(s) discussed: all of record.

Identification of prior art discussed: none.

Substance of Interview
(For each issue discussed, provide a detailed description and indicate if agreement was reached. Some topics may include: identification or clarification of a reference or a portion thereof, claim interpretation, proposed amendments, arguments of any applied references etc...)

On June 12, 2014 the examiner contacted Mr. Dowden to suggest formality changes to the claims in the form of a supplemental amendment. On June 27, 2014 the examiner contacted Mr. Dowden who agreed to the changes listed in the Examiner's amendment.

Applicant recordation instructions: It is not necessary for applicant to provide a separate record of the substance of interview.

Examiner recordation instructions: Examiners must summarize the substance of any interview of record. A complete and proper recordation of the substance of an interview should include the items listed in MPEP 713.04 for complete and proper recordation including the identification of the general thrust of each argument or issue discussed, a general indication of any other pertinent matters discussed regarding patentability and the general results or outcome of the interview, to include an indication as to whether or not agreement was reached on the issues raised.

☐ Attachment

/Steven Bos/ Primary Examiner, Art Unit 1736	
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Notice of Allowability	Application No. 13/136,153	Applicant(s) LUJANO ET AL.	
	Examiner Steven Bos	Art Unit 1736	AIA (First Inventor to File) Status No

-- **The MAILING DATE of this communication appears on the cover sheet with the correspondence address--**
 All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to the amendment and remarks filed 6-23-2014.
☐ A declaration(s)/affidavit(s) under 37 CFR 1.130(b) was/were filed on _____.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are 1,3-14,16-19,21 and 22. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

- a) ☐ All b) ☐ Some *c) ☐ None of the:

1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. _____.
3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

* Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.

- ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

- | | |
|--|---|
| 1. ☐ Notice of References Cited (PTO-892) | 5. ☒ Examiner's Amendment/Comment |
| 2. ☐ Information Disclosure Statements (PTO/SB/08),
Paper No./Mail Date _____ | 6. ☐ Examiner's Statement of Reasons for Allowance |
| 3. ☐ Examiner's Comment Regarding Requirement for Deposit
of Biological Material | 7. ☐ Other _____. |
| 4. ☒ Interview Summary (PTO-413),
Paper No./Mail Date _____. | |

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Application/Control Number: 13/136,153
Art Unit: 1736

Page 2

The present application is being examined under the pre-AIA first to invent provisions.

An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in a telephone interview with Donald S. Dowden on June 27, 2014.

The application has been amended as follows:

In claim 3, delete the last two lines and insert --of chloride, sulfate, nitrate, α -hydroxy carboxylate, o-hydroxybenzoate, amine, polyphosphate and hexametaphosphate--.

In claim 7, last line, delete the “_” under the period.

In claim 10, line 3, delete the “_” between “of” and “silica”.

In claim 11, delete the last three lines and insert --of chloride, sulfate, nitrate, α -hydroxy carboxylate, o-hydroxybenzoate, amine, polyphosphate and hexametaphosphate--.

In claim 17, line 2, delete “and/or” and replace with --or--.

In claim 22, four lines from the bottom, delete the “_” after “regenerating”.

35

Application/Control Number: 13/136,153
Art Unit: 1736

Page 3

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Steven Bos whose telephone number is (571)272-1350. The examiner can normally be reached on Monday thru Friday, 9AM to 6PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Stan Silverman can be reached on 571-272-1358. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

Steven Bos
Primary Examiner
Art Unit 1736

sjb

/Steven Bos/
Primary Examiner, Art Unit 1736



DEPARTAMENTO DE COMERCIO DE LOS ESTADOS UNIDOS
Oficina de marcas y patentes de los Estados Unidos
Dirección: Comisionado de patentes
Código postal 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTIFICACIÓN DE APROBACIÓN Y TASA(S) ADEUDADA(S)

15444 7590 07/11/2014
Donald S. Dowden
46 Winthrop Street
South Hamilton, MA 01982

EXAMINADOR

BOS, STEVEN J

UNID ART NÚMERO DE DOCUMENTO

1736

FECHA DE ENVÍO: 07/11/2014

SOLICITUD NO.	FECHA DE PRESENTACIÓN	NOMBRE DEL INVENTOR	NO. DE EXPEDIENTE DE ABOGADO	NO. DE CONFIRMACIÓN
13/136,153	07/25/2011	Juan Lujano	PR101	7110

TÍTULO DE LA INVENCIÓN: Conversión de dióxido de carbono gaseoso en soluciones acuosas de bicarbonato alcalino y/o alcalinotérreo						
TIPO DE SOLICITUD	ESTADO DE LA ENTIDAD	TASA DE EMISIÓN ADEUDADA	TASA DE PUBL. ADEUDADA	TASA DE EMISIÓN PREV. PAGO	TOTAL DE TASA(S) ADEUDADA(S)	FECHA DE VENCIMIENTO
No provisional	PEQUEÑA	\$480	\$0	\$0	\$480	10/14/2014

LA SOLICITUD IDENTIFICADA ANTERIORMENTE SE HA EXAMINADO Y ESTÁ APROBADA PARA EMISIÓN COMO UNA PATENTE. EL PROCESO SOBRE LOS MÉRITOS ESTÁ CERRADO. ESTA NOTIFICACIÓN DE APROBACIÓN NO ES UN OTORGAMIENTO DE DERECHOS DE PATENTE. ESTA SOLICITUD ESTÁ SUJETA A RETIRO DE LA EMISIÓN A INICIATIVA DE LA OFICINA O A PETICIÓN DEL SOLICITANTE. VER 37 CFR 1.313 Y MPEP 1308.

LA TASA DE EMISIÓN Y LA TASA DE PUBLICACIÓN (DE REQUERIRSE) DEBE PAGARSE DENTRO DE TRES MESES A PARTIR DE LA FECHA DE LA ENTREGA DE ESTA NOTIFICACIÓN O ESTA SOLICITUD SE CONSIDERARÁ ABANDONADA. ESTE PLAZO LEGAL NO PUEDE EXTENDERSE. VER 35 U.S.C. 151. LA TASA DE EMISIÓN ADEUDADA INDICADA ANTERIORMENTE NO REFLEJA UN CRÉDITO POR NINGUNA TASA DE EMISIÓN PAGADA PREVIAMENTE EN ESTA SOLICITUD. SI UNA TASA DE EMISIÓN SE HA PAGADO ANTERIORMENTE EN ESTA SOLICITUD (COMO SE MUESTRA ARRIBA), LA DEVOLUCIÓN DE LA PARTE B DEL PRESENTE FORMATO SE CONSIDERARÁ UNA SOLICITUD PARA RESOLICITAR LA TASA DE EMISIÓN PAGADA PREVIAMENTE HACIA LA TASA DE EMISIÓN AHORA ADEUDADA.

COMO RESPONDER A ESTA NOTIFICACIÓN:

I. Revisar el ESTADO DE LA ENTIDAD que se muestra arriba. Si el ESTADO DE LA ENTIDAD se muestra como PEQUEÑA o MICRO, verificar si todavía aplica el derecho a ese estado de la entidad.
el ESTADO DE LA ENTIDAD es el mismo al que se muestra arriba, pagar la TOTALIDAD DE TASA(S) ADEUDADA(S) mostradas arriba.
Si el ESTADO DE LA ENTIDAD cambia por el que se muestra arriba, en la PARTE B – TRANSMISIÓN DE TASA(S), complete la sección número 5 titulada “Cambio en el Estado de la Entidad (del estado indicado arriba)”.
A efectos de la presente notificación, las tasas de pequeña entidad son la mitad de la cantidad de las tasas sin descontar, y las tasas de micro entidad son la mitad de la cantidad de las tasas de pequeña entidad.

II. LA PARTE B – TRANSMISIÓN DE TASA(S), o su equivalente, debe completarse y devolverse a la Oficina de Marcas y Patentes de los Estados Unidos (USPTO) con su TASA DE EMISIÓN y TASA DE PUBLICACIÓN (si se necesita). Si usted está cargando la(s) tasa(s) a su cuenta de depósitos, se debe completar la sección “4b” de la Parte B – Transmisión de Tasa(s) y se debe entregar una copia extra del formato. Si se presenta un equivalente de la Parte B, se debe realizar claramente una solicitud para reaplicar una tasa de emisión previamente pagada y puede haber retrasos en el procesamiento debido a la dificultad en reconocer el documento como un equivalente de la Parte B.

III. Toda la comunicación relacionada a la presente solicitud debe dar el número de solicitud. Por favor dirija todas las comunicaciones previas a la emisión a la dirección interna de TASA DE EMISIÓN a menos que se indique lo contrario.

RECORDATORIO IMPORTANTE: Las patentes de utilidad que se emitan de solicitudes presentadas en o después del 12 de dic. de 1980, pueden requerir el pago de tasas de mantenimiento. Es responsabilidad del titular de la patente asegurar el pago oportuno de las tasas de mantenimiento a su vencimiento.

PARTE B – TRANSMISIÓN DE TASA(S)

Complete y envíe este formato, junto con la(s) tasa(s) aplicables, a: **Correo** Dirección interna TASA DE EMISIÓN
Comisionado de patentes
Apartado de correos 1450
Alexandria, Virginia 22313-1450
o **Fax** (571)-273-2885

INSTRUCCIONES: Este formato debe usarse para transmitir la TASA DE EMISIÓN y TASA DE PUBLICACIÓN (si se requiere). Los campos 1 a 5 deben completarse cuando sea apropiado. Toda la correspondencia posterior, incluyendo la Patente, órdenes de anticipo y notificación de tasas de mantenimiento serán enviadas a la dirección de correspondencia actual como se indica, a menos que se corrija a continuación o se indique lo contrario en el Campo 1, (a) indicando una nueva dirección de correspondencia; y/o (b) indicando una "DIRECCIÓN DE TASA" separada para notificaciones de tasa de mantenimiento.

DIRECCIÓN DE CORRESPONDENCIA ACTUAL (Nota: use el Campo 1 para cualquier cambio de dirección)

15444 7590 07/11/2014
Donald S. Dowden
46 Winthrop Street
South Hamilton, MA 01982

Nota: Solamente se puede usar un certificado de envío para envíos nacionales de la Transmisión de Tasa(s). Este certificado no puede usarse para ningún otro documento adjunto. Cada documento adicional, tal como una cesión o dibujo formal, debe tener su propio certificado de envío o transmisión.

Certificado de envío o transmisión

Por la presente certifico que esta Transmisión de Tasa(s) está siendo depositada en el Servicio Postal de los Estados Unidos con suficiente franqueo para correo de primera clase en un sobre dirigido a la Dirección Interna de TASA DE EMISIÓN, dirección arriba, o transmitida por fax a la USPTO (571) 273-2885, en la fecha indicada a continuación.

(Nombre del depositante)
(Firma)
(Fecha)

SOLICITUD NO.	FECHA DE PRESENTACIÓN	NOMBRE DEL INVENTOR	NO. DE EXPEDIENTE DE ABOGADO	NO. DE CONFIRMACIÓN
13/136,153	07/25/2011	Juan Lujano	PR101	7110

TÍTULO DE LA INVENCIÓN: Conversión de dióxido de carbono gaseoso en soluciones acuosas de bicarbonato alcalino y/o alcalinotérreo

TIPO DE SOLICITUD	ESTADO DE LA ENTIDAD	TASA DE EMISIÓN ADEUDADA	TASA DE PUBL. ADEUDADA	TASA DE EMISIÓN PREV. PAGO	TOTAL DE TASA(S) ADEUDADA(S)	FECHA DE VENCIMIENTO
No provisional	PEQUEÑA	\$480	\$0	\$0	\$480	10/14/2014
EXAMINADOR	UNID ART	CLASE - SUBCLASE				
BOS, STEVEN J	1736	423-157000				

1. Cambio de dirección de correspondencia o indicación de "Dirección de Tasas" (37 CFR 1.363).

- ☐ Cambio de dirección de correspondencia (o formato de Cambio de Dirección de Correspondencia PTO/SB/122) adjunto.
- ☐ Indicación de "Dirección de Tasa" (o formato de indicación "Dirección de Tasa" PTO/SB/47; Rev 03-02 o más reciente) adjunta. Se requiere el uso de un Número de Cliente.

2. Para impresión en la primera página de la patente, lista

- (1) los nombres de hasta 3 abogados de patente registrados o agentes O, de manera alternativa,
- (2) el nombre de una sola firma (que tenga como miembro un abogado o agente registrado) y los nombres de hasta 2 abogados de patente registrados o agentes. Si no hay ningún nombre enumerado, no se imprimirá ningún nombre.

1. _____
2. _____
3. _____

3. NOMBRE DEL CESIONARIO Y DATOS DE RESIDENCIA A IMPRIMIR EN LA PATENTE (en imprenta o a máquina)

POR FAVOR TENGA EN CUENTA: A menos que abajo se identifique un cesionario, no aparecerán datos del cesionario en la patente. Si abajo se identifica un cesionario, el documento se ha presentado para su registro como se establece en 37 CFR 3 11. Completar este formato NO es un sustituto para presentar una cesión.

(A) NOMBRE DEL CESIONARIO

(B) RESIDENCIA: (CIUDAD y ESTADO O PAÍS)

Por favor marque la categoría o categorías de cesionario apropiada (no estará impreso en la patente): ☐ Individual ☐ Sociedad u otro grupo empresarial privado ☐ Gobierno

4a. Se entrega(n) la(s) siguiente(s) tasa(s):

- ☐ Tasa de emisión
- ☐ Tasa de publicación (no se permite descuento de entidad pequeña)
- ☐ Orden de avance - # de copias _____

4b. Pago de tasa(s): (Por favor primero reaplique cualquier tasa de emisión pagada previamente mostrada antes)

- ☐ Se adjunta un cheque.
- ☐ Pago con tarjeta de crédito. Formato PTO-2038 se encuentra adjunto.
- ☐ Por la presente el Director está autorizado a cobrar la(s) tasa(s) requeridas, cualquier deficiencia, o acreditar cualquier pago excesivo al Número de Cuenta de Depósito _____ (adjunte una copia extra de este formato).

5. Cambio en estado de la entidad (del estado indicado arriba)

- ☐ Solicitante certificando estado de micro entidad. Ver 37 CFR 1.29
- ☐ Solicitante afirmando estado de entidad pequeña. Ver 37 CFR 1.27
- ☐ Solicitante cambiando a estado de tasa regular sin descuento.

NOTA: En ausencia de una certificación válida de Estado de Micro Entidad (ver formato PTO/SB/15A y 15B) no se aceptará expedir el pago de la tasa en la cantidad de micro entidad a riesgo de abandono de la solicitud.

NOTA: Si la solicitud estaba anteriormente bajo el estado de micro entidad, seleccionar esta casilla se tomará como una notificación de pérdida del derecho a estado de micro entidad.

NOTA: Seleccionar esta casilla se tomará como una notificación de pérdida del derecho a estado de pequeña o micro entidad, como sea procedente.

NOTA: este formato debe ser firmado de conformidad con 37 CFR 1.31. Ver 37 CFR 1.4 para los requisitos de firmas y certificaciones.

Firma autorizada _____	Fecha _____
Nombre escrito o en letra imprenta _____	No. de Registro _____



OFICINA DE MARCAS Y PATENTES DE LOS ESTADOS UNIDOS

DEPARTAMENTO DE COMERCIO DE LOS
ESTADOS UNIDOS
Oficina de marcas y patentes de los Estados
Unidos
Dirección: Comisionado de patentes
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SOLICITUD NO.	FECHA DE PRESENTACIÓN	NOMBRE DEL INVENTOR	NO. DE EXPEDIENTE DE ABOGADO	NO. DE CONFIRMACIÓN
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Donald S. Dowden 46 Winthrop Street South Hamilton, MA 01982				
			EXAMINADOR BOS, STEVEN J	
			UNID ART	NÚMERO DE DOCUMENTO
			1736	
FECHA DE ENVÍO: 07/11/2014				

Determinación de ajuste del término de patente bajo 35 U.S.C. 154 (b)
(solicitudes presentadas en o después del 29 de mayo de 2000)

La Oficina ha dejado de proporcionar un cálculo de ajuste de término de patente (PTA) con la notificación de aprobación.

La sección 1(h)(2) de la Ley AIA de Correcciones Técnicas modificada 35 U.S.C. 154(b)(3)(B)(i) para eliminar el requerimiento de que la Oficina proporciona una determinación de ajuste del término de patente con la notificación de aprobación. Ver Revisiones al ajuste de término de patente, 78 Fed. Reg. 19416, 19417 (1 de abril de 2013). Por lo tanto, la Oficina ya no proporciona una determinación de ajuste del término de patente inicial con la notificación de aprobación. La Oficina continuará proporcionando una determinación de ajuste del término de patente con la Carta de Notificación de Emisión que se envía por correo al solicitante aproximadamente tres semanas antes de la fecha de emisión de la patente, e incluirá el ajuste del término de patente en la patente. Cualquier solicitud para reconsiderar la determinación de ajuste del término de la patente (o el restablecimiento de ajuste del término de patente) debe seguir el proceso señalado en 37 CFR 1.705.

Cualquier pregunta relacionada con la determinación de la Extensión o Ajuste del Término de Patente debe dirigirse a la Oficina de Administración Legal de Patentes en (571)-272-7702. Las preguntas relacionadas a los pagos de cuotas de emisión y publicación deben dirigirse al Centro de Servicio al Cliente de la Oficina de Publicación de Patente al 1-(888)-786-0101 o (571)-272-4200.

La ley de reducción de trámites (PRA) de 1995 requiere que las agencias federales obtengan la aprobación de la Oficina de Administración y Presupuesto del Gobierno de Estados Unidos (OMB) antes de solicitar la mayor parte de la información de parte del público. Cuando la OMB aprueba la solicitud de la agencia para recopilar información por parte del público, la OMB (i) proporciona un número de control OMB válido y una fecha de expiración para que la agencia muestre en el instrumento que será utilizado para la recopilación de la información y; (ii) requiere que la agencia informe al público acerca de la relevancia legal del número de control de la OMB de acuerdo con 5 CFR 1320.5(b).

La información recopilada por la PTOL-85 parte B es requerida por 37 CFR 1.311. La información se solicita para obtener y conservar un beneficio por parte del público el cual es presentar (y por parte de la USPTO procesar) una solicitud. De forma confidencial es regida por 35 U.S.C. 122 y 37 CFR 1.14. Esta recopilación está prevista para ser completada en 12 minutos, incluyendo la recolección, la preparación, y la entrega del formato de solicitud debidamente diligenciado a la USPTO. El tiempo variará dependiendo de los casos individuales. Cualquier comentario sobre la cantidad de tiempo requerido para diligenciar este formato y/o sugerencias para reducir la declaración, deberá ser enviado a la oficina del Director de Información, a la oficina de Marcas y Patentes de los Estados Unidos, al Departamento de Comercio de los Estados Unidos, código postal 1450, Alexandria, Virginia 22313-1450. **NO ENVIAR LAS TASAS O FORMATOS DELIGANCIADOS A ESTA DIRECCIÓN. ENVIARLAS A: Comisionado de patentes código postal 1450, Alexandria, Virginia 22313-1450.** Bajo la ley de reducción de trámites (PRA) de 1995, ninguna persona tiene que responder a una recopilación de información a menos que muestre un número de control OMB válido.

Declaración de Ley de Privacidad

La Ley de Privacidad de 1974 (P.L. 93-579) exige que se le dé cierta información en relación con su presentación del formato adjunto relacionado con una solicitud de patente o patente. En consecuencia, de conformidad con los requerimientos de la Ley, por favor tenga en cuenta que: (1) la autoridad general para la recolección de esta información es 35 U.S.C. 2(b) (2); (2) la entrega de la información solicitada es voluntaria; y (3) el propósito principal para el cual se usa la información por parte de la Oficina de Marcas y Patentes de los EE.UU. es procesar y/o examinar su comunicación relacionada a una solicitud de patente o patente. Si usted no suministra la información solicitada, la Oficina de Marcas y Patentes de los EE.UU. no podrá procesar y/o examinar su comunicación, lo que puede resultar en la finalización de las actuaciones o el abandono de la solicitud o el vencimiento de la patente.

La información proporcionada por usted en el presente formato estará sujeta a los siguientes usos de rutina:

1. La información en este formato será tratada confidencialmente en la medida permitida bajo la Ley de Libertad de Información (5 U.S.C. 552) y la Ley de Privacidad (5 U.S.C. 552a). Registros de este sistema de registros pueden revelarse al Departamento de Justicia para determinar si se necesita revelar estos registros por la Ley de Libertad de Información.
2. Se puede revelar un registro de este Sistema de registros, como uso de rutina, en el curso de presentación de evidencia a un tribunal, magistrado, o tribunal administrativo, incluyendo divulgaciones al abogado opositor en el curso de negociaciones de conciliación.
3. Se puede revelar un registro en este Sistema de registros, como uso de rutina, a un Miembro del Congreso enviándole una solicitud relativa a un individuo, a quien le corresponde el registro, cuando el individuo ha solicitado ayuda del Miembro con respecto a la materia del registro.
4. Se puede revelar un registro en este sistema de registros, como uso de rutina, a un contratista de la Agencia que necesite la información con el fin de realizar un contrato. Los receptores de la información estarán obligados a cumplir con los requerimientos de la Ley de Privacidad de 1974, en su versión modificada, conforme a 5 U.S.C. 552a(m).
5. Se puede revelar un registro relacionado con una Solicitud Internacional presentada bajo el Tratado de Cooperación de Patente en este sistema de registros, como uso de rutina, a la Oficina Internacional de la Organización de Propiedad Intelectual, conforme al Tratado de Cooperación de Patente.
6. Se puede revelar un registro en este sistema de registros, como uso de rutina, a otra agencia federal para fines de revisión de Seguridad Nacional (35 U.S.C. 181) y para revisión conforme a la Ley de Energía Atómica (42 U.S.C. 218(c)).
7. Se puede revelar un registro de este sistema de registros, como uso de rutina, al Administrador, Servicios Generales, o su designado, durante una inspección de registros realizado por la GSA como parte de la responsabilidad de esa agencia para recomendar mejoras en la práctica del manejo de los registros y programas, bajo la autoridad de 44 U.S.C. 2904 y 2906. Tal revelación debe realizarse de acuerdo con las regulaciones de la GSA que rigen la inspección de registros para este propósito, y cualquier otro directivo (i.e. GSA o de Comercio) relevante. Tal revelación no se usará para hacer determinaciones sobre individuos.
8. Se puede revelar un registro de este sistema de registros, como uso de rutina, al público después de cada publicación de la solicitud conforme a 35 U.S.C. 122(b) o la expedición de una patente conforme a 35 U.S.C. 151. Adicionalmente, un registro puede revelarse, sujeto a las limitaciones de 37 CFR 1.14, como uso de rutina, al público si el registro fue presentado en una solicitud que se abandonó o en donde los trámites terminaron y cuya aplicación se referencia tanto por una solicitud publicada, una solicitud abierta a la inspección pública o una patente expedida.
9. Se puede revelar un registro de este sistema de registros, como uso de rutina, a una agencia del orden público Federal, Estatal, o local, si la USPTO se da cuenta de una violación o violación potencial de la ley o reglamento.

Resumen de entrevista iniciada al examinador	Solicitud No. 13/136,153	Solicitante(s) LUJANO ET AL.
	Examinador Steven Bos	Unid Art 1736

Todos los participantes (solicitante, representante del solicitante, personal de la Oficina de Marcas y Patentes):

(1) Steven Bos. (3) _____
(2) Donald S. Dowden (4) _____

Fecha de la entrevista: 6-27-2014.
Tipo: ☒ Telefónico ☐ Videoconferencia
 ☐ Personal [copia entregada a: ☐ solicitante ☐ representante del solicitante]

Pruebas presentadas o demostración realizada: ☐ Si ☒ No
En caso afirmativo, descripción breve: _____

Asuntos discutidos ☐ 101 ☐ 112 ☐ 102 ☐ 103 ☒ otros
(Para cada una de las cajas marcadas arriba, por favor describa a continuación el asunto y la descripción detallada de la discusión)

Reivindicación(es) discutida(s): todas las registradas.
Identificación de anterioridad discutida: ninguna.

Fondo de la entrevista
(Para cada asunto discutido, proporcione una descripción detallada e indique si se alcanzó un acuerdo. Algunos temas pueden incluir: identificación o aclaración de una referencia o una parte de la misma, interpretación de las reivindicaciones, modificaciones propuestas, argumentos de cualquiera de las referencias aplicadas, etc...)

El 12 de junio de 2014, el examinador contactó al Sr. Dowden para sugerirle cambios formales a las reivindicaciones en la forma de una modificación complementaria. El 27 de junio de 2014 el examinador contactó al Sr. Dowden quien estuvo de acuerdo con los cambios enumerados en la modificación del Examinador.

Instrucciones de inscripción para el solicitante: No es necesario que un solicitante proporcione un registro separado del fondo de la entrevista.

Instrucciones de inscripción para el examinador: Los examinadores deben resumir el fondo de cualquier entrevista de registro. Un registro adecuado y completo del fondo de una entrevista debe incluir los puntos listados en MPEP 713.04 para el registro adecuado y completo, incluyendo la identificación de la orientación general de cada argumento o tema discutido, una indicación general de cualquier otro asunto pertinente discutido en relación a la patentabilidad y los resultados generales de la entrevista, incluir una indicación sobre si se llegó a un acuerdo sobre los temas tratados o no.

☐ Adjunto

/Steven Bos/ Examinador Principal, Unidad de Art 1736	
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Notificación de autorización	Solicitud No. 13/136,153	Solicitante(s) LUJANO ET AL.	
	Examinador Steven Bos	Unid Art 1736	Estado AIA (Primer inventor a presentar) No

-- La FECHA DE ENVÍO de la presente comunicación aparece en la carátula con la dirección de correspondencia --
 Al ser autorizadas todas las reivindicaciones, EL PROCESO SOBRE LOS MÉRITOS ESTÁ (O PERMANECE) CERRADO en esta solicitud. Si no se incluye adjunto (o se envió anteriormente), se enviará una Notificación de Autorización (PTOL-85) u otra comunicación apropiada a su debido tiempo. **ESTA NOTIFICACIÓN DE AUTORIZACIÓN NO ES UN OTORGAMIENTO DE DERECHOS DE PATENTE.** La presente solicitud está sujeta a retirarse de la emisión por la iniciativa de la Oficina o a petición del solicitante. Ver 37 CFR 1.313 y MPEP 1308.

- ☒ La presente comunicación responde a la modificación y anotaciones presentadas el 6-23-2014.
☐ El _____ se presentó una(s) declaración(es)/declaración(es) juramentada(s) bajo 37 CFR 1.130(b).
- ☐ Se realizó una elección por parte del solicitante en respuesta a un requisito de restricción establecido durante la entrevista el _____. el requisito y elección de restricción se han incorporado a la presente acción.
- ☒ La(s) reivindicación(es) autorizada(s) es(son) 1, 3-14, 16-19, 21 y 22. Como resultado de la(s) reivindicación(es) autorizada(s), podría ser elegible para el beneficio del programa de examen acelerado de patentes (**Patent Prosecution Highway**) en una oficina de propiedad intelectual participante para la solicitud correspondiente. Para más información, por favor ver <http://uspto.gov/patents/init events/pph/Index.jsp> o envíe una pregunta a PPHfeedback@uspto.gov.
- ☐ Se reconoce una reivindicación para prioridad extranjera bajo 35 U.S.C. § 119(a)-(d) o (f).
Copias certificadas:
 a) ☐ Todas b) ☐ Algunas *c) ☐ Ninguna de:
 1. ☐ las copias certificadas de los documentos de prioridad se han recibido.
 2. ☐ las copias certificadas de los documentos de prioridad se han recibido en la Solicitud No. _____.
 3. ☐ las copias de las copias certificadas de los documentos de prioridad se han recibido en esta solicitud de etapa nacional de la Oficina Internacional (Norma PCT 17.2(a)).
 * Copias certificadas no recibidas: _____.

El Solicitante tiene TRES MESES A PARTIR DE LA "FECHA DE ENVÍO" de esta comunicación para presentar una respuesta cumpliendo con los requisitos que se indican a continuación. El cumplimiento inoportuno dará como resultado el ABANDONO de la presente solicitud.
ESTE PERIODO DE TRES MESES NO SE PUEDE EXTENDER.

- ☐ Se deben entregar DIBUJOS CORREGIDOS (como "hojas de reemplazo").
☐ incluyendo cambios requeridos por la Modificación/Comentario del Examinador adjunto o en la acción oficial del Documento No./Fecha de envío _____.

Marcas identificativas tales como el número de solicitud (ver 37 CFR 1.84(c)) deben escribirse en los dibujos en frente (no en la parte de atrás) de cada hoja. La(s) hoja(s) de reemplazo deben estar marcadas como tal en el encabezado de acuerdo con 37 CFR 1.121(d).

- ☐ Debe entregarse EL DEPÓSITO DE y/o INFORMACIÓN sobre el depósito de MATERIAL BIOLÓGICO. Tenga en cuenta el comentario del examinador adjunto en relación al REQUERIMIENTO PARA EL DEPÓSITO DE MATERIAL BIOLÓGICO.

Adjunto(s)

1. ☐ Notificación de Referencias citadas (PTO-892)	5. ☒ Modificación/Comentario del examinador
2. ☐ Declaraciones de divulgación de información (PTO/SB/08) Documento No./ Fecha de envío _____.	6. ☐ Declaración del examinador de las razones para la Autorización
3. ☐ Comentario del examinador en relación al requerimiento para Depósito de Material Biológico	7. ☐ Otros _____.
4. ☒ Resumen de la entrevista (PTO-413), Documento No./Fecha de envío _____.	

La presente solicitud se examina bajo las disposiciones del primero en inventar de la pre-AIA.

A continuación encontrará una modificación al registro por parte del examinador. En caso de que los cambios y/o adiciones no sean aceptables por parte del solicitante, se debe presentar una modificación como lo dispone 37 CFR 1.312. Para asegurar la consideración de tal modificación, DEBE entregarse a más tardar el pago de la tasa de emisión.

La autorización para esta modificación del examinador se dio en una entrevista telefónica con Donald S. Dowden el 27 de junio de 2014.

La solicitud se ha modificado de la siguiente manera:

En la reivindicación 3, eliminar las dos últimas líneas e insertar --de cloruro, sulfato, nitrato, α -hidroxi carboxilato, o-hidroxibenzoato, amina polifosfato y hexametafosfato--.

En la reivindicación 7, última línea, eliminar el “_” bajo el punto.

En la reivindicación 10, línea 3, eliminar el “_” entre “de” y “sílice”.

En la reivindicación 11, eliminar las últimas tres líneas e insertar --de cloruro, sulfato, nitrato, α -hidroxi carboxilato, o-hidroxibenzoato, amina polifosfato y hexametafosfato--.

En la reivindicación 17, línea 2, eliminar “y/o” y reemplazarla con --o--.

En la reivindicación 22, cuatro líneas desde la parte inferior, eliminar el “_” después de “regenerando”.

Cualquier pregunta relacionada a la presente comunicación o comunicaciones anteriores por parte del examinador deben dirigirse a Steven Bos cuyo número de teléfono es (571)272-1350.

El examinador puede usualmente encontrarse disponible de lunes a viernes de 9am a 6pm.

En caso de que el intento de contactar al examinador no sea exitoso, el supervisor del examinador, Stan Silverman puede localizarse en el 571-272-1358. El número de fax para la organización donde se asigna esta solicitud o trámite es 571-273-8300.

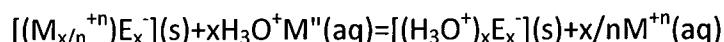
La información relacionada al estado de una solicitud se puede obtener del sistema de recuperación de la información de solicitud de patente (PAIR). La información del estado para solicitudes publicadas puede obtenerse tanto de PAIR privado como de PAIR público. La información del estado para solicitudes aún no publicadas se encuentra disponible solamente a través del PAIR privado. Para más información sobre el sistema PAIR, ver <http://pair-direct.uspto.gov>. En caso de que tenga alguna pregunta sobre el acceso al sistema PAIR privado, contacte el Centro Electrónico de Negocios (EBC) al 866-217-9197 (teléfono gratuito). Si requiere asistencia de un representante de servicio al cliente de la USPTO o acceder al sistema de información automatizado, contáctese al 800-786-9199 (EN EE.UU. O CANADÁ) o 571-272-1000.

Steven Bos
Examinador principal
Unidad de Art 1736

sjb

/Steven Bos/
Examinador principal, Unidad de Art 1736

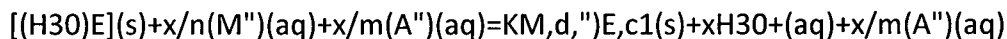
1. Un proceso para la fabricación de soluciones acuosas de bicarbonatos alcalinos y/o bicarbonatos alcalinotérreos que comprende las etapas de: disolver el dióxido de carbono gaseoso en agua para producir una solución acuosa que contiene bicarbonatos, HCO_3^- ; y que además contiene cationes hidronio, H_3O^+ , que introducen un material de intercambio catiónico sólido $[(\text{M}_{x/n}^{+n})\text{E}_x^-]$ para capturar los cationes hidronio, H_3O^+ , y producir material de intercambio catiónico usado $[(\text{H}_3\text{O}^+)_x\text{E}_x^-]$, de acuerdo con:



donde "X" representa una cantidad molar de los centros aniónicos de carga del material de intercambio catiónico $[(\text{M}_{x/n}^{+n})\text{E}_x^-]$ equilibrado por la cantidad molar x/n del metal M sin estructura, "n" representa la valencia del metal, y "M" se selecciona a partir del grupo que consta del grupo 1A y del Grupo 2A de la tabla periódica de elementos; por lo que la captura de los cationes hidronio, H_3O^+ , aumenta el rendimiento de los bicarbonatos, y la regeneración del material de intercambio catiónico usado, $[(\text{H}_3\text{O}^+)_x\text{E}_x^-]$, mediante intercambio iónico con una solución no saturada de la sal iónica de metal M^{+n} de manera que los equivalentes del metal M^{+n} son al menos 0,5 veces los equivalentes de E_x^- .

2. Un proceso de acuerdo con la reivindicación 1, en donde la etapa de regeneración se lleva a cabo mediante intercambio iónico con una solución no saturada de la sal iónica del metal M^{+n} , y que comprende la sustitución de cationes hidronio, H_3O^+ , en el material de intercambio catiónico usado $[(\text{H}_3\text{O}^+)_x\text{E}_x^-]$, por cationes M^{+n} nuevos, lo que hace que el material de intercambio usado $[(\text{H}_3\text{O}^+)_x\text{E}_x^-]$ sea adecuado para su reciclaje.

3. Un proceso de acuerdo con la reivindicación 1, en donde la etapa de regeneración se lleva a cabo mediante intercambio iónico con una solución no saturada de la sal iónica del metal M^{+n} , y que comprende la sustitución de cationes hidronio, H_3O^+ , en el material de intercambio catiónico usado $[(\text{H}_3\text{O}^+)_x\text{E}_x^-]$, por cationes M^{+n} nuevos, lo que hace que el material de intercambio usado $[(\text{H}_3\text{O}^+)_x\text{E}_x^-]$ sea adecuado para su reciclaje de acuerdo con:



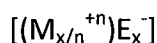
donde A^{+m} representa el anión de valencia "m" seleccionado del grupo que consiste en cloruro, sulfato, nitrato, carboxilato de α -hidroxi, o-hidroxibenzoato, amina, polifosfato y hexametáfosfato.

4. Un proceso de acuerdo con la reivindicación 1, que comprende la etapa de pasar la solución acuosa de bicarbonatos a través de un proceso de cristalización para producir un precipitado de bicarbonatos alcalinos y/o carbonatos alcalinos.

5. Un proceso de acuerdo con la reivindicación 4, que comprende lavar y secar el precipitado.

6. Un proceso de acuerdo con la reivindicación 1, que comprende emplear, como material de intercambio catiónico, una composición de materia que tiene una capacidad de intercambio catiónico mayor que 0.001 miliequivalentes por gramo en base seca, y/o con una superficie específica de al menos 0.1 m²/g.

7. Un proceso de acuerdo con la reivindicación 6, que comprende emplear, como material de intercambio catiónico, un silicoaluminato o silicoaluminato sustituido



representado por la fórmula empírica general



donde: "v" representa la relación molar de los centros aniónicos de aluminio tetraédrico, "w" representa la relación molar de los centros aniónicos tetraédricos "Z", en donde "Z" representa todos los elementos de la primera serie de metales de transición, Zr, Nb y elementos de los grupos 5A y 3A de la tabla periódica, "y" representa la relación molar de los centros no aniónicos de silicio tetraédrico, (v+w)/n es el número de cationes intercambiables de valencia n, y "m" representa el número de moléculas de agua adsorbidas en superficies externas e internas del material de intercambio catiónico sólido, de manera que: v+w>0; v+wy and y/(v+ w)<100.

8. Un proceso según la reivindicación 7, que comprende la detección de un patrón de difracción de rayos X de la composición de la materia.

9. Un proceso de acuerdo con la reivindicación 1, que comprende emplear, como material de intercambio catiónico [(M_{x/n}⁺ⁿ)E_x⁻], alcalino sintético o natural y/o alcalinotérreo LTA Zeolita y zeolitas de sodio seleccionado del grupo que consiste de faujasita, zeolita X, zeolita Y, zeolita P, clinoptilolita, mordenita, ZSM-5, mutinaite, feldespato, arcilla expansible, bentonita, montmorillonita, y mezclas de los mismos.

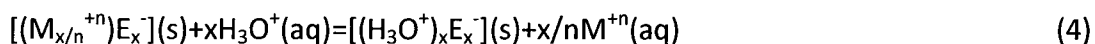
10. Un proceso de acuerdo con la reivindicación 1, que comprende además aumentar la actividad de material de intercambio catiónico [(M_{x/n}⁺ⁿ)E_x⁻] al introducir en la solución acuosa material sólido seleccionado del grupo que consiste en sílice, alúmina, titania, zirconia, óxido de hierro y mezclas de los mismos, los cuales poseen un área superficial específica de al menos 0.1 m²/g.

11. Un procedimiento que comprende las etapas de:

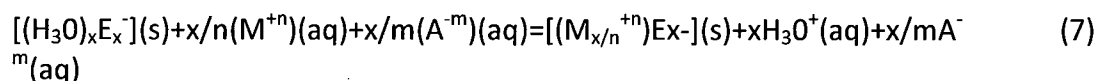
disolver el dióxido de carbono gaseoso en agua de acuerdo con las siguientes reacciones:



donde las reacciones (2) y (3) producen medio acuoso que contiene cationes hidronio, H_3O^+ , que se intercambian en el medio acuoso, y que introducen un material de intercambio catiónico $[(\text{M}_{x/n}^{+n})\text{E}_x^-]$ en el medio acuoso, donde los equilibrios de la disolución de dióxido de carbono se llevan a cabo y los cationes hidronio, H_3O^+ , son capturados por el material de intercambio catiónico $[(\text{M}_{x/n}^{+n})\text{E}_x^-]$, y producen material de intercambio catiónico utilizado $[(\text{H}_3\text{O}^+)_x\text{E}_x^-]$ de acuerdo a:



donde "x" representa una cantidad molar de los centros aniónicos de carga del material de intercambio catiónico $[(\text{M}_{x/n}^{+n})\text{E}_x^-]$ equilibrado por una cantidad molar x/n de metal M, "n" representa la valencia del metal, y "M" se selecciona del grupo 1A o grupo 2A de la tabla periódica de elementos, y regenera el material de intercambio catiónico usado $[(\text{H}_3\text{O}^+)_x\text{E}_x^-]$ por intercambio iónico con una solución no saturada de la sal iónica de metal M^{+n} , en sustitución de hidronio cationes, H_3O^+ , en el material de intercambio catiónico usado $[(\text{H}_3\text{O}^+)_x\text{E}_x^-]$ por cationes M^{+n} nuevos, de acuerdo con



donde A^{-m} representa el anión de valencia "m" seleccionado del grupo que consiste en cloruro, sulfato, nitrato, carboxilato de α -hidroxi, o-hidroxibenzoato, amina, polifosfato y hexametafosfato.

12. Un proceso de acuerdo con la reivindicación 11, que comprende la etapa de combinar el bicarbonato con especies de metal alcalino acuoso, M^{+n} , para producir una solución acuosa de bicarbonato alcalino o bicarbonato alcalinotérreo de acuerdo con:



13. Un proceso de acuerdo con la reivindicación 12, que comprende la etapa de separar la solución acuosa de bicarbonato alcalino o bicarbonato alcalinotérreo del material de intercambio catiónico.
14. Un proceso según la reivindicación 12, donde el material de intercambio catiónico se separa al menos una vez con una corriente de agua a una temperatura entre 10°C. y 90°C.
15. Un proceso según la reivindicación 11, donde el material de intercambio catiónico se separa, al menos una vez, con una corriente de agua a una temperatura entre 10°C. y 90°C.
16. Un proceso de acuerdo con la reivindicación 13, que comprende la etapa de pasar la solución acuosa de bicarbonato alcalino o bicarbonato alcalinotérreo a través de un proceso de cristalización para producir un precipitado de bicarbonato alcalino y/o carbonato alcalino, o carbonato alcalinotérreo.
17. Un proceso de acuerdo con la reivindicación 16, que comprende las etapas de lavado y secado del precipitado.
18. Un proceso para producir bicarbonato alcalino sólido y/o carbonato alcalinotérreo, que comprende las etapas de: poner en contacto una suspensión acuosa de un material de intercambio catiónico con una corriente de dióxido de carbono en una cantidad y durante un tiempo suficiente para hacer que el dióxido de carbono se disuelva en la suspensión acuosa, para producir cationes hidronio (H_3O^+) y alcalino y/o aniones bicarbonato alcalinotérreo (HCO_3^-);

Por lo cual el material de intercambio catiónico ocupa cationes hidronio (H_3O^+) de la suspensión acuosa y libera cationes alcalinos y/o cationes alcalinotérreos a la suspensión acuosa, convirtiéndose así en el material de intercambio catiónico usado;

la separación de líquido a partir del material de intercambio catiónico usado;

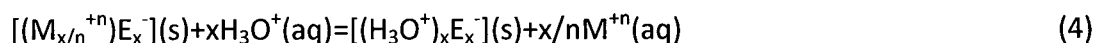
la precipitación de bicarbonato sólido alcalino y/o carbonato alcalino, o carbonato alcalinotérreo alcalino del líquido, y regeneración del material de intercambio catiónico usado, $[(\text{H}_3\text{O}^+)_x\text{E}_x^-]$, mediante el intercambio iónico con una solución no saturada de la sal iónica de metal M^{+n} , donde "n" representa la valencia del metal, y "M" se selecciona entre el grupo que consiste del grupo 1A y del Grupo 2A de la tabla periódica de elementos, de manera que los equivalentes del metal M^{+n} es al menos 0,5 veces los equivalentes de E_x^- .

19. Un procedimiento que comprende las etapas de:

disolver el dióxido de carbono gaseoso en agua de acuerdo con las siguientes reacciones:



donde las reacciones (2) y (3) producen medio acuoso que contiene cationes hidronio, H_3O^+ , que se intercambian en el medio acuoso, y que introducen un material de intercambio catiónico $[(\text{M}_{x/n}^{+n})\text{E}_x^-]$ en el medio acuoso, donde los equilibrios de la disolución de dióxido de carbono se llevan a cabo y los cationes hidronio, H_3O^+ , son capturados por el material de intercambio catiónico $[(\text{M}_{x/n}^{+n})\text{E}_x^-]$, y producen material de intercambio catiónico utilizado $[(\text{H}_3\text{O}^+)_x\text{E}_x^-]$ de acuerdo a:



donde "x" representa una cantidad molar de los centros aniónicos de carga del material de intercambio catiónico $[(\text{M}_{x/n}^{+n})\text{E}_x^-]$ equilibrado por la cantidad molar x/n de metal M, "n" representa la valencia del metal, y "M" se selecciona del Grupo 1A o grupo 2A de la tabla periódica de elementos,

la regeneración del material de intercambio catiónico usado $[(\text{H}_3\text{O}^+)_x\text{E}_x^-]$ por intercambio iónico con una solución no saturada de la sal iónica de metal M^{+n} , en sustitución de cationes hidronio, H_3O^+ , en el material de intercambio catiónico usado $[(\text{H}_3\text{O}^+)_x\text{E}_x^-]$ por cationes M^{+n} nuevos.