CARBON DIOXIDE CAPTURE FROM FLUE GAS USING DRY REGENERABLE SORBENTS

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ABSTRACT

Four grades of sodium bicarbonate and two grades of trona were characterized in terms of particle size distribution, surface area, pore size distribution, and attrition. Surface area and pore size distribution determinations were conducted after calcination of the materials. The sorbent materials were subjected to thermogravimetric testing to determine comparative rates and extent of calcination (in inert gas) and sorption (in a simulated coal combustion flue gas mixture). Selected materials were exposed to five calcination/sorption cycles and showed no decrease in either sorption capacity or sorption rate. Process simulations were conducted involving different heat recovery schemes. The process is thermodynamically feasible. The sodium-based materials appear to have suitable physical properties for use as regenerable sorbents and, based on thermogravimetric testing, are likely to have sorption and calcination rates that are rapid enough to be of interest in full-scale carbon sequestration processes.

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1.0 INTRODUCTION

Increasing amounts of anthropogenic CO₂ emitted to the atmosphere are believed to be a significant factor in global climate change. The Department of Energy's (DOE's) carbon sequestration roadmap makes large point sources of CO₂ emissions (e.g., conventional pulverized-coal steam power plants, natural gas-fired combined cycle plants, and advanced power generation systems) primary targets for carbon sequestration. Development of technologies to implement carbon sequestration at these large point sources is expected to have a rapid and significant impact on anthropogenic CO₂ emissions. This technology development will provide an opportunity for the United States to take the lead in mitigating global greenhouse gas emissions.

Although various processes are available for CO₂ separation, only liquid amine-based systems are used commercially. Adoption of these commercial amine-based separation processes for removing CO₂ from flue gas has been hindered by the severe reduction in capacity and the rapid degradation of conventional amines caused by the typical contaminants (e.g., O₂, SO₂, HCl, and particles) found in flue gas. These problems, combined with the high capital and operating costs needed to remove CO₂ from large volumes of flue gas at low pressure, low temperature, and low concentration, increase the cost of CO₂ sequestration by several orders of magnitude compared with DOE's target of \$10 per ton of carbon emissions avoided.

Use of sodium bicarbonate (NaHCO₃) is proposed as the basis for a dry, regenerable sorbent technology to economically capture CO₂ from dilute flue gas streams. Sodium bicarbonate, or "baking soda," is commonly used to capture HCl and SO₂ from the flue gas but not to capture CO₂. Note that NaHCO₃ decomposes on heating according to the reaction

which releases CO₂. Conversely, NaHCO₃ is formed by

In this reaction, CO₂ is absorbed from a flue gas stream by NaHCO₃. Several patents (Krieg, et al., 1984; Sarapata et al., 1987; and Falotico, 1993) describe processes and process improvements to optimize Reaction (2).

The NaHCO_3 can be subsequently regenerated by heating via Reaction (1). In effect, this chemistry enables CO_2 to be separated from a low-pressure flue gas stream and converted into a pure CO_2 stream for subsequent use or sequestration.

HCl and SO_2 in the flue gas are also absorbed by NaHCO_3 according to the following reactions:

In fact, Reactions (3) and (4) are industrially used for removal of acidic compounds from incinerator and furnace stack gases (Maziuk, 1996). Commercial-grade NaHCO_3 has also been used as an in-duct injection sorbent for removal of SO_2 and HCl from hydrogen chloride flue gas streams generated in coal-fired power plants. Despite significantly better performance of NaHCO_3 over limestone, its use for SO_2 removal has gained limited commercial acceptance in the electric utility industry primarily because of its high cost when considered for one-time use (not regenerated).

2.0 EXPERIMENTAL

2.1 Material Characterization

2.1.1 Material Specifications

Samples of four grades of NaHCO_3 material were supplied by Church and Dwight. These materials are designated as grades 1, 3, 4, and 5. (Grade 2 is a U.S. Pharmacopoeia [USP]-certified material that is identical to grade 4.) Two grades of trona (natural sodium sesquicarbonate, $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$) were supplied by Solvay Minerals (Houston, Texas). These materials are designated T-50 and T-200. Approximately 500 g of each material was supplied initially, and then 23 kg (50 lb) sacks of each material were supplied. Subsamples of approximately 900 g of each of the four grades of NaHCO_3 and two grades of trona were sent from RTI to Louisiana State University (LSU). Specification sheets for the four grades of NaHCO_3 and two grades of trona are included in Appendix A.

2.1.2 Particle Size Determinations

Particle size distributions of the six materials, as received, were determined using a sieve shaker apparatus.

2.1.3 BET Measurements

Brunauer-Emmett-Teller (BET) surface area determinations were conducted with a Quantachrome Nova 1000 instrument. The Nova 1000, shown schematically in Figure 1, has a pore diameter range of 3.5 to 2000 Å and an accuracy of 0.1 percent. The minimum resolvable pressure is 0.016 torr. Determinations were conducted on all six materials as received and on all six materials after overnight calcination at 125°C (257°F). In addition, NaHCO₃ grades 3 and 5 were tested after calcination for 3 hours at 125°C (257°F), and grade 3 was tested after calcination for 3 hours at 200°C (392°F). The outgassing temperature for all determinations was 250°C (482°F).

2.1.4 Porosimetry

Mercury porosimetry determinations were conducted with a Micromeritics AutoPore II 9220 instrument coupled to a personal computer equipped with AutoPore II software, version 3.01. Triple distilled mercury was used for all determinations. Measurement of pore volume, pore volume distribution, and median pore diameter by mercury intrusion provides a direct indication of diffusional resistance associated with the sorbents. Determinations were conducted on all six materials, as received, and after calcination overnight at 125°C (257°F).

2.1.5 Attrition

Attrition determinations were conducted in accordance with ASTM D 5757-95, Standard Test Method for Determination of Attrition and Abrasion of Powdered Catalysts by Air Jets. Determinations were conducted on the six materials, and air jet indexes were calculated for each material.

Figure 1. NOVA 1000 flow diagram.

2.2 Thermogravimetric Analysis

Thermogravimetric analysis (TGA) testing was conducted with a TA Instruments TGA 2050 system with automated temperature programming and data acquisition. The system has a temperature range of ambient to 1000°C (1832°F), a capacity of 1.0 g, a sensitivity of 0.2 µg and an accuracy of ±0.1 percent. The system operates on a null-balance principal, using a highly sensitive transducer coupled to a taut-band suspension system to detect minute changes in the mass of a sample. An optically actuated servo loop maintains the balance arm in the horizontal reference (null) position by regulating the amount of current flowing through the transducer coil. An infrared light emitting diode and a pair of photosensitive diodes detect movement of the beam. A flag at the top of the balance arm controls the amount of light reaching each photosensor. As sample weight is lost or gained, the beam becomes unbalanced, causing the light to strike the photodiodes unequally. The unbalance signal is fed into the control program, where it is zeroed. This changes the amount of current supplied to the meter movement, causing the balance to rotate back to its null (zero) position. The amount of current required is directly proportional to the change in the mass of the sample.

Although the TGA 2050 has a vertical sample/furnace configuration, the gas flow across the sample is horizontal. The gas enters the furnace through a side arm and flows directly across

the sample located in an open pan. A low volume of inert gas, which flows through the balance chamber, prevents back-diffusion of the reactant gas or sample effluents into the balance chamber. The furnace incorporates a quartz liner between a bifilar-wound heating element and the sample measurement area. This arrangement results in a small internal volume, which further reduces the opportunity for back-diffusion of the sample off-gases into the balance chamber by ensuring rapid transfer of the gases out the furnace exit port.

The system is shown schematically in Figure 2.

Figure 2. Thermogravimetric analyzer (TA TGA 2050) schematic.

Tests were conducted with samples of 30 to 40 mg initial mass. Testing was conducted to determine relative CO₂ sorption rates for the materials after calcination, the effect of calcination time on sorption rate and capacity, the relative regenerability of the sorbents, the effect of temperature on sorption rate, and the potential for hydration of the calcined materials.

2.3 Process Simulation

A process simulation was conducted using ASPEN-PLUS software based on removal of CO₂ from coal combustion flue gas. The simulation produced material and energy balances for a

process in which indirect heat exchange from the flue gas is used to regenerate the sorbent, and hot CO₂ is used to convey the regenerated sorbent to the carbonation reactor.

3.0 RESULTS AND DISCUSSION

3.1 Material Specifications

Specifications for the four grades of NaHCO₃ and the two grades of trona, as provided by the manufacturers, are included in Appendix A.

3.1.1 Particle Size Determinations

Particle size distributions for as-received and calcined NaHCO₃ samples were determined using the sieve shaker method. Results are shown in Table 1.

Table 1. Particle Size Distributions of Fresh and Calcined Sodium Bicarbonate Materials

	sbc grade 1 fresh	sbc grade 1 calcined overnight at 125°C in air	sbc grade 2 fresh	sbc grade 2 calcined overnight at 125°C in air	sbc grade 3 fresh	sbc grade 3 calcined overnig ht at 125°C in air	sbc grade 5 fresh	sbc grade 5 calcined overnight at 125°C in air
Particle Size Distribution (%)								
297 microns	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0
-120 microns	0.0	0.0	0.0	1.0	0.0	0.7	27.7	29.7
-52 microns	0.0	0.0	8.6	8.8	0.0	0.0	63.9	60.3
-37 microns	8.6	8.7	65.6	64.4	1.0	1.0	5.7	7.3
-13 microns	19.9	20.4	13.6	13.1	0.7	1.3	0.0	0.3
-22 microns	43.8	41.5	8.3	9.2	10.3	10.5	1.4	0.6
-53 microns	27.7	29.4	4.0	2.9	88.0	86.6	1.4	1.8
Arithmetic Mean Microns	60.7	60.2	100.2	104.4	31.6	33.3	169.4	170.3
Harmonic Mean Microns	48.6	47.9	89.4	92.3	28.6	28.9	150.2	148.2

3.1.2 BET Measurements

BET surface area data for fresh and calcined NaHCO_3 materials are given in Table 2. Calcination was carried out in air at 125°C (257°F).

The BET surface areas of the different grades of NaHCO_3 varied widely, ranging from 1.3 to $5.9 \text{ m}^2/\text{g}$. Following overnight calcination, the surface areas of the materials converged to approximately $2.6 \text{ m}^2/\text{g}$. This involved a decrease in surface area for grades 2, 3, and 5 and an increase for grade 1. In addition, the difference in surface area between the samples calcined for 3 hours and those calcined overnight suggests that changes to the internal structure of the particles take place relatively slowly at the temperatures of interest.

Table 2. BET Surface Areas of Sodium Bicarbonate Materials

Material	Processing	Surface Area (m^2/g)
Grade 1	Fresh	1.3
Grade 1	Calcined overnight	2.5
Grade 2	Fresh	5.2
Grade 2	Calcined overnight	2.4
Grade 3	Fresh	3.7
Grade 3	Calcined 3 hours	3.5
Grade 3	Calcined overnight	2.7
Grade 5	Fresh	5.9
Grade 5	Calcined 3 hours	2.1
Grade 5	Calcined overnight	2.5

3.1.3 Mercury Porosimetry

Mercury porosimetry data for fresh and calcined samples of NaHCO_3 are summarized in Table 3. Similar data for fresh and calcined trona samples are shown in Table 4.

As expected, the porosity of the fresh (uncalcined) materials increases by a factor of 5 to 8 for two grades of NaHCO_3 that were tested, as well as for the coarser grade of trona. The porosities of the four grades of NaHCO_3 after overnight calcination in air at 125°C (257°F) are relatively consistent, at 46 to 55 percent. The grade 3 material developed the greatest porosity, as well as the largest average pore diameter. The trona samples reached porosities of 39.8 and 59.5 percent after calcining, and the T-200 material had a greater average pore diameter than any of the NaHCO_3 materials.

Table 3. Pore Volume and Pore Area Data for Sodium Bicarbonate Materials

		sbc grade 1 fresh	sbc grade 1 calcined overnight at 125°C in air	sbc grade 2 fresh	sbc grade 2 calcined overnight at 125°C in air	sbc grade 3 calcined 3 hours at 125°C in air	sbc grade 3 calcined overnight at 125°C in air	sbc grade 5 calcined 3 hours at 125 °C in air	sbc grade 5 calcined overnight at 125 °C in air
Mercury Porosimetry Data									
Total Intrusion Volume	ml/g	0.0454	0.3908	0.0295	0.3562	0.5	0.775	0.1138	0.358
Total Pore Area	m ² /g	5.7	14.7	6.6	12.4	12.1	20.2	7.1	12.1
Median Pore Diameter (vol)	Å	76,426	3,531	10,389	3,320	65,260	51,357	3,425	3,846
Median Pore Diameter (area)	Å	51	72	53	87	62	63	59	86
Average Pore Diameter (4V/A)	Å	320	1065	179	1150	1787	1532	644	1183
Bulk Density	g/ml	1.84	1.19	2.08	1.34	0.84	0.71	1.82	1.34
Apparent Density	g/ml	2.01	2.21	2.22	2.58	1.52	1.57	2.30	2.58
Porosity	%	8.4	46.3	6.1	47.9	45.0	54.8	20.7	48.1
Stem Volume Used	%	10	42	6	40	54	52	26	46

Table 4. Pore Volume and Pore Area Data for Trona Materials

		Trona T-50 Fresh	Trona T-50 Calcined overnight at 125° C	Trona T-200 Fresh	Trona T-200 Calcined overnight at 125°C
Mercury Porosimetry Data					
Total Intrusion Volume	ml/g	0.0294	0.2517	0.3481	0.7056
Total Pore Area	m ² /g	7.3	9.4	14.9	11.7
Median Pore Diameter (vol)	Å	7,410	2,833	68,950	49,258
Median Pore Diameter (area)	Å	42	100	41	91
Average Pore Diameter (4V/A)	Å	162	1074	938	2415
Bulk Density	g/ml	2.03	1.58	1.17	0.84
Apparent Density	g/ml	2.16	2.63	1.97	2.08
Porosity	%	6.0	39.8	40.6	59.3
Stem Volume Used	%	8	44	48	70

Based on data from two grades of NaHCO₃ that were tested after calcination for 3 hours as well as after overnight calcination, porosity continued to increase. In the case of the grade 5 material, the porosity more than doubled between the 3-hour sample and the overnight sample. The average pore volume also increased significantly with extended calcination time for the grade 5 sample, although it decreased slightly for the grade 3 material. The calcined trona samples reached comparable porosities and pore volumes to the NaHCO₃ samples, although the pores of the calcined T-200 were much larger than those of any of the other samples.

3.1.4 Attrition

Attrition test data and calculated attrition indexes are given in Table 5.

Based on the results of the attrition tests, the most durable NaHCO₃ materials are grades 1 and 5, and the T-50 trona is superior to the finer grade T-200. These attrition values are comparable with commercial catalyst materials such as fluid catalytic cracking (FCC) catalyst and fluidizable zinc titanate sorbents.

Table 5. Attrition Test Data (ASTM D-5757-95) for Sodium Bicarbonate and Trona Materials

Material	Fines Loss (%)	Loss at 5 Hours (%)	Loss at 24 Hours (%)	Recovery (%)	Attrition Index
SBC #1	3.90	13.06	65.72	95.48	2.29
SBC #2	6.18	36.39	70.30	98.32	7.55
SBC #3	9.85	29.74	31.13	99.85	4.97
SBC #5	0.06	2.02	2.33	102.36	0.49
T-50	5.55	12.72	n/a	99.97	1.79
T-200	17.99	49.80	81.07	99.61	7.95

n/a = not available

3.2 Thermogravimetric Analysis

3.2.1 Comparison of Sorbent Materials

The four grades of NaHCO_3 were tested to measure the relative rates of reactivity following calcination. The test data shown in Figure 3 are the result of runs in which samples were initially calcined in helium at 130°C (266°F) resulting in conversion of NaHCO_3 to sodium carbonate with a weight loss due to evolution of CO_2 equal to about 37 percent of the initial mass. After reaching constant weight, the sample was exposed to a simulated flue gas, composed of 11 percent CO_2 , 74 percent nitrogen, 7 percent oxygen and 7 percent steam, and the temperature was decreased to 70°C (158°F). In this atmosphere the samples reacted with CO_2 , as indicated by the increase in mass. These reactions were not carried out to completion. The gas was then changed to helium and the temperature ramped to 200°C (392°F) (for the tests on grades 1, 3, and 5) and the sample masses fell rapidly to the calcined weight. The dry gas flow rate for all tests was 100 cc/min. Based on these tests, the most reactive materials (based on initial mass gains) were grades 1 and 2.

The two grades of trona were tested in a similar way; the data are shown in Figure 4. The initial weight loss due to calcination, 28 to 29 percent, is less than that of the NaHCO_3 samples reflecting the composition of trona, which is intermediate between NaHCO_3 and Na_2CO_3 in terms of chemical formula. The slight difference in the mass of CO_2 evolved from the two grades of trona is likely due to a difference in the amount of inert materials. The reactivity of the two grades, in terms of CO_2 sorption, is comparable and both samples rapidly returned to their calcined mass upon reheating.

Figure 3. Comparison of reactivities of different grades of sodium bicarbonate.

Figure 4. Comparison of reactivities of different grades of trona.

3.2.2 Hydration Tests

Sorption of moisture by NaHCO_3 at temperatures of interest would potentially decrease the capacity for CO_2 , complicate processing, and diminish the usefulness of the material as a sorbent. In order to determine whether hydration of these materials would occur, the four grades of NaHCO_3 (Figure 5) and two grades of trona (Figure 6) were tested. Samples were first calcined in dry helium to constant weight at 130°C (266°F). After one hour, the temperature was ramped down to 70°C (158°F). The temperature was then maintained at 70°C (158°F), and steam was added to the gas, resulting in a composition of approximately 94 percent helium and 6 percent steam. Samples were exposed to this gas mixture for two to three hours and neither the NaHCO_3 nor the trona gained mass. Based on these data, it became evident that the hydration of the sorbent would not interfere with the use of these materials as CO_2 sorbents.

3.2.3 Multiple Cycle Tests

In order to determine whether the activity and/or the capacity of the sorbent materials would decrease when subjected to repeated calcination/sorption cycles, NaHCO_3 grade 3 (Figure 7) and trona T-200 (Figure 8) were subjected to multiple cycle testing. Fresh samples of the materials were calcined at 130°C (266°F) in helium, and then the temperature was decreased to 70°C (158°F) and the samples were exposed to a simulated flue gas (composed of 11 percent CO_2 , 74 percent nitrogen, 7 percent oxygen, and 7 percent steam). The materials rapidly gained mass as a result of CO_2 sorption. After the materials regained about half of the calcination mass loss, the gas was switched back to dry helium and the samples were recalcined at 130°C (266°F). This process was repeated four times and no noticeable decrease in either the rate of CO_2 capture or the extent of subsequent calcination was observed. Note that while the figures illustrate only the first four cycles, data from the fifth cycle was comparable to that of the first four. Based on these data, it is unlikely that any irreversible changes in pore structure or size distribution occurred. This is an important finding as the basis for the proposed process relies upon the reversible nature of the sodium bicarbonate to sodium carbonate transformation.

Figure 5. Calcination of sodium bicarbonate and subsequent exposure of sodium carbonate to a steam/helium mixture.

Figure 6. Calcination of trona and subsequent exposure of sodium carbonate to a steam/helium mixture.

Figure 7. Multicycle calcination/sorption testing of sodium bicarbonate, grade 3.

Figure 8. Multicycle calcination/sorption testing of trona T-200.

3.3 Process Simulation

3.3.1 General Process Description

Process simulations using ASPEN-PLUS software were performed based upon a flue gas produced by the combustion of coal with air. The coal composition consisted in 85.8 percent C, 5.4 percent and 6.7 percent O (wt). Air used contained 20 percent excess O₂. Table 6 presents the composition of the flue gas produced by the combustion of coal under these conditions.

Table 6. Flue Gas Composition From Combustion of Coal

Component	Mol %
N ₂	79.2
O ₂	2.7
CO ₂	11.55
H ₂ O	6.5

In simplified form, the process consists of two reactors, one carbonator and one regenerator. In the carbonator, the CO₂ present in the flue gas reacts at 65°C (149°F) with stoichiometric amounts of Na₂CO₃ and H₂O to form NaHCO₃ through the following exothermic reaction:

The effluent gas from the carbonator is then sent to the stack and the solid product of this reaction is sent to the regenerator where calcination of the NaHCO₃ takes place at 110°C (230°F). Inside the regenerator the reverse endothermic reaction occurs as follows:

The solid carbonate product of this reactor is then continuously returned to the carbonator. Gas product from the regenerator consisting of CO₂ and H₂O is sent to sequestration.

3.3.2 Simulation Parameters

The parameters used in the simulation were the removal efficiency (percent CO₂ removed from the flue gas) and the energy requirement (Kcal/mol of CO₂ removed). The major energy demand in the process occurs at the regeneration stage where the endothermic calcination reaction requires heat to decompose the sodium bicarbonate (NaHCO₃) to sodium carbonate

(Na_2CO_3). Table 7 presents a comparison of key preliminary simulation parameters using a basis of 100 kmols of flue gas from Table 6.

The Na_2CO_3 (baseline) process in Table 7 refers to the ideal case of CO_2 removal through reaction (2) providing the heat of reaction needed at 110°C (230°F) [reaction (1)]. Heat integration 1 refers to preliminary simulation results using the process simulation scheme described in the following section. In these results, only the stoichiometric amount of Na_2CO_3 needed to react with the CO_2 present in the flue gas was used in the carbonator. Heat integration 2 refers to simulation results using the same process simulation scheme as in heat integration 1 but using a 50 percent excess of Na_2CO_3 for heating purposes.

Table 7. Process Comparison of Simulation Parameters in CO_2 Removal From Flue Gas

Process	Kcal/mol CO_2	% CO_2 Removal
Na_2CO_3 (baseline)	32.42	N/A
Heat Integration-1	28.37	87%
Heat Integration-2	27.3	87%

With heat integration 1, the overall thermal efficiency is improved and reflected in a reduction of the energy required from 32.4 kcal/mol for the baseline process to 28.4 kcal/mol. The 50 percent excess in Na_2CO_3 used in heat integration 2 resulted in a 4 percent decrease in energy required from the heat integration 1 case, but the process was restricted by the flue gas inlet temperature to the regenerator as described in the following section.

3.3.3 Process Description

Figure 9 shows the process diagram employed in the coal combustion flue gas simulations performed in this section.

Process stream 1 consisting of 100 kmols of flue gas at 175°C (347°F), 1 atm, with composition described in Table 6 is cooled by a sodium bicarbonate recycle (stream 9) to 110°C (230°F). This cooled flue gas (stream 3) is then mixed for conveying purposes with the solid product of the regenerator reactor (stream 14) consisting of 11.55 kmol of Na_2CO_3 to produce the gas-solid stream 15. Stream 15 is then saturated with 5.68 kmol of water (which is removed from the concentrated CO_2 stream prior to sequestration) at 70°C (158°F) (stream 6)

Figure 9. Basic process flow diagram for CO₂ capture using Na₂CO₃.

producing the carbonator reactor feed stream 13. This feed stream, consisting of a mixture of flue gas, saturated water, and solid Na_2CO_3 at 57°C (135°F), is fed to the carbonator reactor. A Gibbs free energy minimization technique was used to determine the thermodynamic extent of the reaction (Gibbs Reactor). In this reactor, the 11.5 kmol CO_2 contained in the flue gas reacts at 65°C (149°F) with the stoichiometric amount of Na_2CO_3 to form NaHCO_3 through reaction (1).

The reactor heat duty is 313,239 kcal/hour, which is to be removed from the vessel. The effluent of this reactor (stream 2) is then separated in a cyclone and the solid product containing 20.30 kmol of NaHCO_3 and 1.39 kmol of unreacted Na_2CO_3 (stream 19) is mixed with stream 17 consisting of 5 kmols of an equimolar mixture of CO_2 and H_2O for conveying purposes. This fluidized mixture (stream 20) is preheated with the gas product of the regenerator (stream 18) and further preheated with the flue gas (stream 1) to 174°C (345°F) (stream 4) prior to entering the regeneration reactor.

In the regenerator, calcination [reaction (2)], which is the reverse of reaction (1), occurs at 110°C (230°F) producing 10.15 kmols of CO_2 , 10.15 kmols of H_2O and 10.15 kmols of Na_2CO_3 . The heat duty of this reactor is 287,394 kcal/hour which must be added to the vessel. Regenerator product (stream 11) is sent to a cyclone separator where 11.5 kmols of Na_2CO_3 (stream 14) are separated from the gas product. This gas product (stream 12), consisting of 25.3 kmols of an equimolar mixture of CO_2 and H_2O is divided, with 5 kmols constituting the CO_2 recycle stream (stream 17). The remainder forms the CO_2 product to sequestration (stream 18), which is cooled using the sodium bicarbonate recycle stream that is sent to the regenerator and then further cooled with the gas product of the carbonator reactor (stack gases) to separate the condensed water. The condensed water (stream 6) is sent to the carbonator and the remainder of gas stream 8, consisting of 10.12 kmols of CO_2 and 4.47 kmols of H_2O , is sent to sequestration. Finally, the separated gas product from the carbonator reactor (stream 10) at 65°C (149°F) is heated to 75°C (167°F) by heat exchange with the CO_2 rich gas prior to sequestration. The stack gas (stream 16) consists of 79.20 kmols of N_2 , 2.7 kmols of O_2 , 1.42 kmols of CO_2 , and 2.091 kmols of H_2O . Results of different simulations are discussed in the following section.

3.3.4 Simulation Results

Based on the process described above [inlet flue gas temperature of 175°C (347°F)], simulations were conducted at different carbonator reaction temperatures. In the first case, only the stoichiometric amount of Na_2CO_3 was used in the carbonator; in the second case, a 50 percent excess of Na_2CO_3 was used.

As expected, based on thermodynamic analysis, the lower the carbonation temperature, the greater the CO_2 removal. At 60°C (140°F), a CO_2 removal of 93 percent was achieved. However, as carbonation temperature increased, the removal efficiency decreased to about 72 percent at 75°C (157°F).

The simulation results are based on two main variables responsible for the reduction in the regenerator heat duty affect CO_2 removal cost. First, the inlet temperature of the flue gas stream (1) in the diagram of Figure 10, restricts the maximum inlet temperature of reactants to the regenerator because the flue gas is used to heat the regenerator feed stream. Therefore, the hotter the inlet flue gas stream, the higher temperature of the feed to the regenerator, and the lower the heat duty of this reactor. The second variable is the excess of Na_2CO_3 that acts as a heat transfer media from the carbonator to the regenerator. Preliminary calculations used only 50 percent excess but it may be possible to increase this recycle to values as high as 200 percent excess under some conditions.

4.0 CONCLUSIONS

Both NaHCO_3 and trona can be readily calcined and the resulting material used to recover CO_2 from flue gas. Based on TGA tests of one grade of NaHCO_3 and one grade of trona, carried through five cycles of calcination and sorption, the materials do not appear to decrease in either sorption capacity or reactivity in contaminant free flue gas. Calcined materials do not appear to hydrate or absorb water from humidified inert gas streams at temperatures of interest. Several grades of sorbent have acceptable attrition rates.

The process is thermodynamically feasible and the rate of sorption, as measured by TGA tests, is rapid enough to suggest that a full-scale process to sequester CO_2 from flue gas using

sodium based sorbents is feasible. The economics of the process depend to a large extent on the development of process schemes which incorporate heat integration.

5.0 REFERENCES

Falotico, A.J., "Dry Carbonation of Trona." PCT Application No.: PCT/US92/06321 (WO 93/11010), assigned to Church and Dwight Co., Inc. June 10, 1993.

Krieg., J.P., et al., "Dry Carbonation Process." U.S. Patent No.: 4,459,272, assigned to Church and Dwight Co., Inc. July 10, 1984.

Maziuk, J., "Comparison of Dry Sorbent Injection of Sodium Bicarbonate, Lime and Carbon and Their Control of Dioxins/Furans, Mercury, Chlorides and Sulfur Dioxide." Presented in the Annual Meeting of Air and Waste Management Association. 1996.

Sarapata, J.S., et al., "Method for the Preparation of a Bicarbonate Sorbent in Flue Gas Desulfurization." U.S. Patent No.: 4,664,893, assigned to Church and Dwight Co., Inc. May 12, 1987.

Appendix A

Sorbent Material Specifications

Church & Dwight Co., Inc.
Specialty Products Division
Performance Products Group
469 North Harrison Street
Princeton, NJ 08540-5297
Phone (800) 221-0453
Fax (609) 497-7176

Grade: #1 (U.S.P. Powdered)

Product Specifications -

Granulation Guarantee

Sieve Size	Microns	Cum. % Retained (W/W)	
		Minimum	Maximum
USS 100	149	0	2
200	74	20	45
325	44	60	100

Typical Values**

Granulation

Sieve Size	Cum. % Retained
USS 100	Trace*
200	30-40
325	70-75

Bulk Density (lbs./ft³) 63
(gms./l) 1000

*Trace is less than 1% (W/W)

**Informational, not part of guaranteed specifications

Principal Uses-

Cake, Pancake and Ready-Mixes • Candies • Self-Rising Flour
Pharmaceuticals • Fire Extinguishers • Dentifrices • Food
Colors • Textiles • Photography • Explosives • Catalyst
Manufacture • Paper Making • Chemicals • Antibiotic Manufacture

SODIUM BICARBONATE

SPECIFICATIONS

All sodium bicarbonate manufactured by Church & Dwight meets—or exceeds—rigid government and industry standards. Products bearing the U.S.P. designation meet the chemical specifications given in the United States Pharmacopoeia, as shown below. These specifications insure that the product is of a high enough quality for use in pharmaceuticals. It also meets the specifications of the Food Chemicals Codex, which sets the standards for chemicals used in the food industry. Arm & Hammer sodium bicarbonate also meets Federal Specifications, EE-B-87c (October 3, 1972) and O-S-576f (August 3, 1974) and the Veterans Administration Standard Specification.

Food grade quality sodium bicarbonate is classified by the Food and Drug Administration as a substance “generally recognized as safe” (GRAS) for use as a food ingredient under 21 CFR 184.1736. Bicarb is also permissible as a component in paper and paper-board used for food packaging under 21 CFR, parts 176.170 and 176.180.

United States Pharmacopoeia (U.S.P.) Specifications: Sodium bicarbonate contains not less than 99.0 percent and not more than 100.5 percent of NaHCO_3 calculated on a dry basis.

Identification: “A solution of it responds to the tests for “Sodium” and for “Bicarbonate.””

Loss on Drying: Not more than 0.25% of its weight

Insoluble Substances: “Dissolve 1 g. in 20 ml. of water; the resulting solution is complete and clear.”

Normal Carbonate: Meets test
Ammonia: Meets test
Sulfate: 150 ppm as SO_4 Max.
Chloride: 150 ppm as Cl Max.
Arsenic: 2 ppm Max.
Heavy metals: 5 ppm Max.

Assay-dry basis: Not less than 99.0% nor more than 100.5% of NaHCO_3 .

Food Chemicals Codex (F.C.C.) Specifications:

Description: “A white crystalline powder. It is stable in dry air, but slowly decomposes in moist air. Its solutions, when freshly prepared with cold water, without shaking, are alkaline to litmus. The alkalinity increases as the solutions stand, are agitated, or are heated. One gram dissolves in 10 ml. of water. It is insoluble in alcohol. A 1 in 10 solution gives positive tests for Sodium and for Bicarbonate.

Specifications:

Assay: Not less than 99%, NaHCO_3 after drying

Ammonia: Passes test

Arsenic (as As): Not more than 3 parts per million (0.0003 percent).

Heavy metals (as Pb): Not more than 5 parts per million (0.0005 percent).

Insoluble substances: Passes test.

Loss on drying: not more than 0.25 percent by weight.

TABLE 1 General Properties of Church & Dwight Sodium Bicarbonate

Empirical Formula	NaHCO_3
CAS Number	144-55-8
Other Names	Bicarbonate of soda Sodium acid carbonate Baking soda Chemical Abstract Name: carbonic acid monosodium salt
Appearance	White crystalline powder
Taste	Slightly alkaline
Molecular Weight	84.01
Thermal Decomposition	Decomposes without melting into Na_2CO_3 , H_2O and CO_2 (see figure 1)
Specific Density: g/cc	2.22
Specific Heat: cal/g°C at 22°C	
Btu/lb°F at 72°F	0.249
Solubility in Water	See figure 2
Solubility in Alcohol	Insoluble
Specific Gravity of Aqueous Solutions	See figure 3
Alkali Equivalent	1 lb. NaHCO_3 = 0.3690 lb. Na_2O
Acid Equivalent	1 lb. NaHCO_3 = 0.432 lb. HCl
Carbon Dioxide Equivalent	1 lb. NaHCO_3 = 0.523 lb. CO_2
pH. 1% Solution at 77°F	Approximately 8.3 See figure 4

Church & Dwight Co., Inc.
Specialty Products Division
Performance Products Group
469 North Harrison Street
Princeton, NJ 08540-5297
Phone (800) 221-0453
Fax (609) 497-7176

Grade: #3 (U.S.P. Fine Powdered)

Product Specifications -

Granulation Guarantee

Sieve Size	Microns	Cum. % Retained (W/W)	
		Minimum	Maximum
USS 100	149	0	Trace*
140	105	0	5
200	74	0	20
325*	44	17	22

*Alpine Jet Sieve

Typical Values**

Granulation

Sieve Size	Cum. % Retained
USS 140	<1
200	1-2
325	22

Bulk Density (lbs./ft³) 56
(gms./l) 900

*Trace is less than 1% (W/W)

**Informational, not part of guaranteed specifications

Principal Uses-

Sponge Rubber and Plastics • Health and Beauty Aids

SODIUM BICARBONATE

SPECIFICATIONS

All sodium bicarbonate manufactured by Church & Dwight meets—or exceeds—rigid government and industry standards. Products bearing the U.S.P. designation meet the chemical specifications given in the United States Pharmacopoeia, as shown below. These specifications insure that the product is of a high enough quality for use in pharmaceuticals. It also meets the specifications of the Food Chemicals Codex, which sets the standards for chemicals used in the food industry. Arm & Hammer sodium bicarbonate also meets Federal Specifications, EE-B-87c (October 3, 1972) and O-S-576f (August 3, 1974) and the Veterans Administration Standard Specification.

Food grade quality sodium bicarbonate is classified by the Food and Drug Administration as a substance “generally recognized as safe” (GRAS) for use as a food ingredient under 21 CFR 184.1736. Bicarb is also permissible as a component in paper and paper-board used for food packaging under 21 CFR, parts 176.170 and 176.180.

United States Pharmacopoeia (U.S.P.) Specifications: Sodium bicarbonate contains not less than 99.0 percent and not more than 100.5 percent of NaHCO_3 calculated on a dry basis.

Identification: “A solution of it responds to the tests for “Sodium” and for “Bicarbonate.””

Loss on Drying: Not more than 0.25% of its weight
Insoluble Substances: “Dissolve 1 g. in 20 ml. of water; the resulting solution is complete and clear.”

Normal Carbonate: Meets test
Ammonia: Meets test
Sulfate: 150 ppm as SO_4 Max.
Chloride: 150 ppm as Cl Max.
Arsenic: 2 ppm Max.
Heavy metals: 5 ppm Max.
Assay-dry basis: Not less than 99.0% nor more than 100.5% of NaHCO_3 .

Food Chemicals Codex (F.C.C.) Specifications:

Description: “A white crystalline powder. It is stable in dry air, but slowly decomposes in moist air. Its solutions, when freshly prepared with cold water, without shaking, are alkaline to litmus. The alkalinity increases as the solutions stand, are agitated, or are heated. One gram dissolves in 10 ml. of water. It is insoluble in alcohol. A 1 in 10 solution gives positive tests for Sodium and for Bicarbonate.

Specifications:
Assay: Not less than 99%, NaHCO_3 after drying
Ammonia: Passes test
Arsenic (as As): Not more than 3 parts per million (0.0003 percent).
Heavy metals (as Pb): Not more than 5 parts per million (0.0005 percent).
Insoluble substances: Passes test.
Loss on drying: not more than 0.25 percent by weight.

TABLE 1 General Properties of Church & Dwight Sodium Bicarbonate

Empirical Formula	NaHCO_3
CAS Number	144-55-8
Other Names	Bicarbonate of soda Sodium acid carbonate Baking soda Chemical Abstract Name: carbonic acid monosodium salt
Appearance	White crystalline powder
Taste	Slightly alkaline
Molecular Weight	84.01
Thermal Decomposition	Decomposes without melting into Na_2CO_3 , H_2O and CO_2 (see figure 1)
Specific Density: g/cc	2.22
Specific Heat: cal/g°C at 22°C	
Btu/lb°F at 72°F	0.249
Solubility in Water	See figure 2
Solubility in Alcohol	Insoluble
Specific Gravity of Aqueous Solutions:	See figure 3
Alkali Equivalent	1 lb. NaHCO_3 = 0.3690 lb. Na_2O
Acid Equivalent	1 lb. NaHCO_3 = 0.432 lb. HCl
Carbon Dioxide Equivalent	1 lb. NaHCO_3 = 0.523 lb. CO_2
pH. 1% Solution at 77°F	Approximately 8.3 See figure 4

Church & Dwight Co., Inc.
Specialty Products Division
Performance Products Group
469 North Harrison Street
Princeton, NJ 08540-5297
Phone (800) 221-0453
Fax (609) 497-7176

Grade: #4 (U.S.P. Granular)

Product Specifications -

Granulation Guarantee

Sieve Size	Microns	Cum. % Retained (W/W)	
		Minimum	Maximum
USS 80	177	0	Trace*
100	149	0	2
200	74	80	100
325	44	93	100

Typical Values**

Granulation

Sieve Size	Cum. % Retained
USS 100	1
200	82
325	96

Bulk Density (lbs./ft³) 65
(gms./l) 1050

*Trace is less than 1% (W/W)

**Informational, not part of guaranteed specifications

Principal Uses-

Baking Powders • Pharmaceuticals • Health and Beauty Aids
• Donut Premixes

SODIUM BICARBONATE

SPECIFICATIONS

All sodium bicarbonate manufactured by Church & Dwight meets—or exceeds—rigid government and industry standards. Products bearing the U.S.P. designation meet the chemical specifications given in the United States Pharmacopoeia, as shown below. These specifications insure that the product is of a high enough quality for use in pharmaceuticals. It also meets the specifications of the Food Chemicals Codex, which sets the standards for chemicals used in the food industry. Arm & Hammer sodium bicarbonate also meets Federal Specifications, EE-B-87c (October 3, 1972) and O-S-576f (August 3, 1974) and the Veterans Administration Standard Specification.

Food grade quality sodium bicarbonate is classified by the Food and Drug Administration as a substance “generally recognized as safe” (GRAS) for use as a food ingredient under 21 CFR 184.1736. Bicarb is also permissible as a component in paper and paper-board used for food packaging under 21 CFR, parts 176.170 and 176.180.

United States Pharmacopoeia (U.S.P.) Specifications: Sodium bicarbonate contains not less than 99.0 percent and not more than 100.5 percent of NaHCO_3 calculated on a dry basis.

Identification: “A solution of it responds to the tests for “Sodium” and for “Bicarbonate.””

Loss on Drying: Not more than 0.25% of its weight
Insoluble Substances: “Dissolve 1 g. in 20 ml. of water; the resulting solution is complete and clear.”

Normal Carbonate: Meets test
Ammonia: Meets test
Sulfate: 150 ppm as SO_4 Max.
Chloride: 150 ppm as Cl Max.
Arsenic: 2 ppm Max.
Heavy metals: 5 ppm Max.
Assay-dry basis: Not less than 99.0% nor more than 100.5% of NaHCO_3 .

Food Chemicals Codex (F.C.C.) Specifications:

Description: “A white crystalline powder. It is stable in dry air, but slowly decomposes in moist air. Its solutions, when freshly prepared with cold water, without shaking, are alkaline to litmus. The alkalinity increases as the solutions stand, are agitated, or are heated. One gram dissolves in 10 ml. of water. It is insoluble in alcohol. A 1 in 10 solution gives positive tests for Sodium and for Bicarbonate.

Specifications:
Assay: Not less than 99%, NaHCO_3 after drying
Ammonia: Passes test
Arsenic (as As): Not more than 3 parts per million (0.0003 percent).
Heavy metals (as Pb): Not more than 5 parts per million (0.0005 percent).
Insoluble substances: Passes test.
Loss on drying: not more than 0.25 percent by weight.

TABLE 1 General Properties of Church & Dwight Sodium Bicarbonate

Empirical Formula	NaHCO_3
CAS Number	144-55-8
Other Names	Bicarbonate of soda Sodium acid carbonate Baking soda Chemical Abstract Name: carbonic acid monosodium salt
Appearance	White crystalline powder
Taste	Slightly alkaline
Molecular Weight	84.01
Thermal Decomposition	Decomposes without melting into Na_2CO_3 , H_2O and CO_2 (see figure 1)
Specific Density: g/cc	2.22
Specific Heat: cal/g°C at 22°C	
Btu/lb°F at 72°F	0.249
Solubility in Water	See figure 2
Solubility in Alcohol	Insoluble
Specific Gravity of Aqueous Solutions:...	See figure 3
Alkali Equivalent	1 lb. NaHCO_3 =0.3690 lb. Na_2O
Acid Equivalent	1 lb. NaHCO_3 =0.432 lb. HCl
Carbon Dioxide Equivalent	1 lb. NaHCO_3 =0.523 lb. CO_2
pH. 1% Solution at 77°F	Approximately 8.3 See figure 4

CHURCH & DWIGHT CO., INC.
CN 5297

469 North Harrison Street
Princeton, NJ 08540
800-221-0453

Grade: #5 (U.S.P. Coarse Granular)

Product Specifications—

Granulation Guarantee

Sieve Size	Microns	Cum.% Retained (W/W)	
		Minimum	Maximum
USS 60	250	0	8
70	210	0	35
100	149	65	100
170	88	95	100

Typical Values**

Granulation

Sieve Size	Cum.% Retained
USS 60	3
70	10-20
100	66-74
170	96-98

Bulk Density (lbs./ft.³) 61
(gms./l) 980

**Informational, not part of guaranteed specifications

Principal Uses—

Antacid Preparations · Effervescent Salts and Other Pharmaceuticals
· Denture Cleansers · Detergents · Dry Bleaches · Carbonated Beverage Mixes

SODIUM BICARBONATE

SPECIFICATIONS

All sodium bicarbonate manufactured by Church & Dwight meets – or exceeds – rigid government and industry standards. Products bearing the U.S.P. designation meet the chemical specifications given in the United States Pharmacopoeia, as shown below. These specifications insure that the product is of a high enough quality for use in pharmaceuticals. It also meets the specifications of the Food Chemicals Codex, which sets the quality for chemicals used in the food industry. Arm & Hammer sodium bicarbonate also meets the quality requirements imposed by Federal Specifications, EE-B-87c (October 3, 1972) and O-S-576f (August 3, 1974) and the Veterans Administration Standard Specification.

Food grade quality sodium bicarbonate is classified by the Food and Drug Administration as a substance "generally recognized as safe" (GRAS). Bicarb is also permissible as a component in paper and paper-board used for food packaging under 21 CFR, parts 176.170 and 176.180.

United States Pharmacopoeia (U.S.P.) Specifications: Sodium bicarbonate contains not less than 99.0 percent and not more than 100.5 percent of NaHCO_3 calculated on a dry basis. Identification: "A solution of it responds to the tests for 'Sodium,' and for 'Bicarbonate.'"

Loss on Drying: Not more than 0.25% of its weight

Insoluble Substances: "Dissolve 1 g. in 20 ml. of water: the resulting solution is complete and clear."

Carbonate: Meets test

Ammonia: Meets test

Sulfate: 150 ppm as SO_4

Chloride: 150 ppm as Cl

Arsenic: 2 ppm Max.

Heavy metals: 5 ppm Max.

Assay-dry basic: Not less than 99.0% nor more than 100.5% of NaHCO_3 .

Food Chemicals Codex (F.C.C.)

Specifications:

Description: "A white crystalline powder. It is stable in dry air, but slowly decomposes in moist air. Its solutions, when freshly prepared with cold water, without shaking, are alkaline to litmus. The alkalinity increases as the solutions stand, are agitated, or are heated. One gram dissolves in 10 ml. of water. It is insoluble in alcohol. A 1 in 10 solution gives positive tests for Sodium and for Bicarbonate.

Specifications:

Assay: Not less than 99% NaHCO_3 after drying.

Limits of Impurities:

Ammonia: Passes test

Arsenic (as As): Not more than 3 parts per million (0.0003 percent).

Heavy metals (as Pb): Not more than 5 parts per million (0.0005 percent).

Insoluble substances: Passes test.
Loss on drying: not more than 0.25 percent by weight.

TABLE 1 General Properties of Church & Dwight Sodium Bicarbonate

Empirical Formula:	NaHCO_3
CAS Number:	144-55-8
Other Names:	Bicarbonate of soda Sodium acid carbonate Baking soda
Chemical Abstract Name:	carbonic acid monosodium salt
Appearance:	White crystalline powder
Taste:	Slightly alkaline
Molecular Weight:	84.01
Thermal Decomposition:	Decomposes without melting into Na_2CO_3 , H_2O and CO_2 (see figure 1)
Specific Density: g/cc.	2.22
Specific Heat: cal/g°C at 22°C,	
Btu/lb°F at 72°F:	0.249
Solubility in Water:	See figure 2
Solubility in Alcohol:	Insoluble
Specific Gravity of Aqueous Solutions:	See figure 3
Alkali Equivalent:	1 lb. $\text{NaHCO}_3 = 0.3690$ lb. Na_2O
Acid Equivalent:	1 lb. $\text{NaHCO}_3 = 0.432$ lb. HCl
Carbon Dioxide Equivalent:	1 lb. $\text{NaHCO}_3 = 0.523$ lb. CO_2
pH, 1% Solution at 77°F:	Approximately 8.3 See figure 4

FIGURE 1 THERMAL DECOMPOSITION

FIGURE 2 SOLUBILITY IN WATER

FIGURE 3 SPECIFIC GRAVITY OF AQUEOUS SOLUTIONS

FIGURE 4 pH

Solvay T-50[®]

(Natural Sodium Sesquicarbonate)

Technical Data Sheet

April 2000

	Typical	Specification	
		Minimum	Maximum
$\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$	93.5%	90.0%	
Free Moisture	0.01%		0.05%
H ₂ O Insoluble	6.4%		10.0%
NaCl	0.1%		0.30%
Bulk Density	69.0 lbs/cf		
pH (1% solution)	10.1		

U.S. Mesh Screen Sizes	Typical Cumulative Weight Percent
+ 20	34
+ 40	68
+100	94
+140	98
-140	2

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A-9

Solvay Minerals, Inc.
3333 Richmond Avenue, Houston, Texas 77098-3099
Mailing Address: P.O. Box 27328, Houston, Texas 77227-7328
Telephone: 713/525-6800 FAX: 713/525-7804

Solvay Minerals

a Passion for Progress

Solvay Minerals, Inc., Green River, WY.

Date: May 11, 2000

Supersedes edition: 11-10-97

Purpose of revision: General Format Update

Issued by: P. J. Luzmoor, Safety/Training Dept.

HMIS: H = 1 F = 0 R = 0 PERSONAL PROTECTION = E

The following information is based upon our current knowledge and experience of our product and is not exhaustive. It applies to the product as defined by the specifications. In case of combinations of mixtures, one must confirm that no new hazards are likely to exist. In any case, the user is not exempt from observing all legal, administrative and regulatory procedures relating to the product, personal hygiene, and integrity of the work environment. (Unless noted to the contrary, the technical information applies only to pure product).

Telephone #-General 1-800-443-2785 (Solvay Minerals, Inc., Customer Service-Houston, TX.)

Telephone #-Emergencies (USA) 1-307-872-6688 (Solvay Minerals, Green River, WY.)

Telephone #-Emergencies (USA) 1-800-424-9300 (CHEMTREC)

Telephone #-Emergencies (INTERNATIONAL/MARITIME) 1-703-527-3887 (CHEMTREC)

Telephone #-Emergencies (CANADA) 1-613-966-6666 (CANUTEC)

Telephone #-Emergencies (MEXICO) 91-800-00-214 (MEX.REPUBLIC)-0-11-52-5-575-0838 (SETIQ)

1. PRODUCT IDENTIFICATION

1.1 Product Name: **T-50®**

1.2 Chemical Name: NATURAL SODIUM SESQUICARBONATE.

1.3 Synonyms: MECHANICALLY REFINED TRONA.

1.4 Trade Names: T-50®.

1.5 Formula: $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$

1.6 Molecular Weight: 226

1.7 CAS No.: 6106-20-3

2. COMPOSITION/INFORMATION ON INGREDIENTS

INGREDIENTS/FORMULA	CAS#	PERCENT
Sodium Carbonate- Na_2CO_3	0497-19-8	42-44%
Water- H_2O	7732-18-5	14-15%
Sodium Bicarbonate- NaHCO_3	0144-55-8	33-35%
Silica, Crystalline		
Quartz- O_2Si	14808-60-7	<0.4%
H_2O Insolubles	NA	6-10%

SOLVAY T-200® (Natural Sodium Sesquicarbonate)

Technical Data Sheet
January 1998

Typical Analysis

$\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$	97.5%
Free Moisture	0.01%
H ₂ O Insoluble	2.3%
NaCl	0.1%
Bulk Density	49.0 lbs/cf

Sieve Opening	Typical Weight Percent
<70 μm	75
<28 μm	50
<6 μm	10

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Solvay Minerals, Inc.
3333 Richmond Avenue, Houston, Texas 77098-3099
Mailing Address: P.O. Box 27328, Houston, Texas 77227-7328
Telephone: 713/525-6800 Fax: 713/525-7804

Solvay Minerals

a Passion for Progress®

Solvay Minerals, Inc., Green River, WY.

Date: May 11, 2000

Supersedes edition: 10-17-97

Purpose of revision: General Format Update

Issued by: P J Luzmoor, Safety/Training Dept.

HMIS: H = 1 F = 0 R = 0 PERSONAL PROTECTION = E

The following information is based upon our current knowledge and experience of our product and is not exhaustive. It applies to the product as defined by the specifications. In case of combinations of mixtures, one must confirm that no new hazards are likely to exist. In any case, the user is not exempt from observing all legal, administrative and regulatory procedures relating to the product, personal hygiene, and integrity of the work environment. (Unless noted to the contrary, the technical information applies only to pure product).

Telephone#-General 1-800-443-2785(Solvay Minerals, Inc., Customer Service-Houston, TX.)

Telephone#-Emergencies(USA) 1-307-872-6688(Solvay Minerals, Green River, WY.)

Telephone#-Emergencies(USA) 1-800-424-9300(CHEMTREC)

Telephone#-Emergencies(INTERNATIONAL/MARITIME) 1-703-527-3887(CHEMTREC)

Telephone#-Emergencies(CANADA) 1-613-966-6666(CANUTEC)

Telephone#-Emergencies(MEXICO) 91-800-00-214(MEX.REPUBLIC)-0-11-52-5-575-0838(SETIQ)

1. PRODUCT IDENTIFICATION

1.1 Product Name: T-200®

1.2 Chemical Name: NATURAL SODIUM SESQUICARBONATE.

1.3 Synonyms: MECHANICALLY REFINED TRONA.

1.4 Trade Names: T-200®.

1.5 Formula: $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$

1.6 Molecular Weight: 226

1.7 CAS No.: 6106-20-3

2. COMPOSITION/INFORMATION ON INGREDIENTS

INGREDIENTS/FORMULA	CAS#	PIN#	PERCENT
Sodium Carbonate- Na_2CO_3	0497-19-8	None	46%
Water- H_2O	7732-18-5	None	16%
Sodium Bicarbonate- NaHCO_3	0144-55-8	None	36%
Silica, Crystalline			
Quartz- O_2Si	14808-60-7	None	<0.4%
H_2O Insolubles	NA	None	<2%

3. HAZARD IDENTIFICATION

3.1 T-200® an odorless, light brown powder.

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