# Chemical and Physical Processes in Carbon Dioxide Absorption

Some of the information presented in this section is also contained in the previous Medical and Other Applications sections. For your convenience and due to the technical subject matter, some of the information is repeated.

**Chemical Process of Sodasorb $CO_2$ Absorption**

Sodasorb absorbent is a proprietary mixture of calcium hydroxide, sodium hydroxide, potassium hydroxide, and water.

Hydroxides are used in acid gas absorption because they are efficient, stable, and can be easily handled. They are derived from alkalies and alkaline earth metals and are the most efficient absorbers of carbon dioxide available.

The absorption of carbon dioxide ($CO_2$), or of any acid gas, by Sodasorb absorbent is a chemical process, not a physical one. The reaction is quite different from absorption by activated carbon, for example, which involves physical entrapment of gases.

In Sodasorb absorption, the $CO_2$ first reacts with water to form carbonic acid, subsequently reacting with the hydroxides to form soluble salts of both sodium and potassium carbonate. The soluble salts then react with the calcium hydroxide to form insoluble calcium carbonate. By-products include both heat and water.

Neutralization of $CO_2$ by Sodasorb may be expressed by the following equations:

(i) $CO_2 + H_20 \longleftrightarrow H_2CO_3$

(ii) $2H_2CO_3 + 2NaOH + 2\ KOH \rightarrow Na_2CO_3 + K_2CO_3 + 4\ H_20 + \text{Heat}$

(iii) $2\ Ca(OH)_2 + Na_2CO_3 + K_2CO_3 \rightarrow 2\ CaCO_3 + 2\ NaOH + 2\ KOH + \text{Heat}$

In (reaction i) the $CO_2$ dissolves at a rate governed by a number of physical chemical factors. The rate is not proportional to the partial pressure of the $CO_2$ which is in contact with the film of moisture coating the Sodasorb granules, but is greater because some of the $CO_2$ combines chemically with the water to form carbonic acid. The rate is directly proportional to the rate of removal of $H_2CO_3$ from solution by reaction with active hydroxide (reaction ii). Thus, the rapidity of removal of combined $CO_2$ is directly related to the availability of active hydroxide. Since the reaction between $H^+$ and $OH^-$ is instantaneous, forming water, reaction (ii) is extremely rapid and active hydroxides are quickly exhausted. Hence, equation (iii) must supply additional active hydroxide to keep the absorption of $CO_2$ progressing. The last reaction is, therefore, rate limiting.

All carbon dioxide absorbents contain dissociated sodium hydroxide (NaOH) and/or potassium hydroxide (KOH) which can damage tissue. Care should be taken to avoid direct physical contact or inhalation during use.

To assure adequate absorption of $CO_2$ under normal use conditions, including both sufficient total capacity and rapidity of reaction, a prime requirement is smoothness and evenness of the reaction. Our studies have shown that optimum absorption occurs when moisture content is between 12 and 19%. Below this range, absorptivity is slowed, and above 20% the rate is also slowed, but to a lesser degree. Moisture content can vary significantly; flushing with dry gas will dehydrate soda lime, while high $CO_2$ concentrations entering the absorber generate large quantities of water (reaction ii).

The relationship between caustic content and $CO_2$ absorbent activity is not clearly defined. Activity increases as caustic content rises to 3%, beyond which the rate of absorptivity continues to increase, but more slowly.

### Rate of $CO_2$ Absorption in Sodasorb Absorbent

In a properly packed and well designed canister, approximately 100 grams of Sodasorb will absorb 15 liters of carbon dioxide before the exit gas exceeds 1% carbon dioxide ($CO_2$). This assumes no significant amount of channeling through the absorbent. Hence, for an eight hour capacity, a canister should hold approximately 1 kilogram of Sodasorb absorbent.

High gas flows may impair the efficiency of $CO_2$ absorption, if caking or decreased wetting of the Sodasorb absorbent occur.

When residence time (time of contact between $CO_2$ and absorbent) is less than 1 second, $CO_2$ absorption capacity is greatly reduced.

### Exothermic Heat Generation

The chemical reaction of carbon dioxide with a strong base such as Sodasorb is exothermic, the heat of neutralization approximating 13,500 calories with the absorption of each gram molecular weight of carbon dioxide (44 grams or 22.4 liters). This heat is not evenly distributed throughout the canister because the reaction itself is zonal.

Heat of reaction does not appear to affect absorptive efficiency. Rising temperature indicates that carbon dioxide absorption is proceeding, but there is little direct correlation between the heat generated and the amount of absorptive activity. Warmth of the canister, therefore, should not be relied on as an index of the amount of absorption taking place.

A steep temperature gradient between the canister and the ambient air may result in proportionately rapid dissipation of the canister's heat of reaction. Ordinarily, the canister will remain warm to the touch long after the Sodasorb absorbent has been exhausted. This is especially the case when the canister is made of glass or plastic. A warm canister is not, in itself, a reliable sign of reactive capacity.

A cool canister usually indicates the absence of chemical activity and inadequate absorption. The user should rely primarily on a $CO_2$ monitor and time and volume calculations for determining the usefulness of the Sodasorb charge.

### Physical Process of $CO_2$ Absorption

**Granular Efficiency**—The availability of active hydroxide for $CO_2$ absorption is limited by the amount of calcium hydroxide ($Ca(OH)_2$) close to the absorbent surface which can regenerate active hydroxide from sodium carbonate ($Na_2CO_3$) and potassium carbonate ($K_2CO_3$) (reaction iii on page P-1). Hence, the larger the surface area or the more porous the granular solid, the larger the capacity of the system to absorb carbon dioxide. Expressed differently, the more irregular the external and internal surfaces of the granules, the more effective is absorptive action. This was empirically developed in the Grace laboratories and verified independently by other scientists.

Sodasorb granules have highly irregular or knobby surfaces, which expose a greater area of absorbent surface and increase the pore space in the canister. These coral-like granules readily conform to the inside shape of a canister, but their irregular surfaces do not readily fit together.

As a result, more surface is available for the absorption and the mass of granules is highly permeable to gas flow.

Sodasorb absorbent is produced to provide granules having maximum surface area, hardness, and toughness for resistance to abrasion, uniformity in mesh size, and consistency in quality.

**Air Flow Resistance** —All absorber systems should be checked before use to insure proper air flow characteristics. Flow resistance varies inversely with particle size. That is, the finer the granules, the greater the surface area exposed to air flow. When the space between the granules is small, there is more resistance to flow. Large particles offer less resistance, but have the disadvantage of providing a smaller total area for reaction.

There is a wide range of user conditions and no single granule size could be expected to meet all requirements. The most commonly used size today is 4-8 mesh material, which is used predominantly in medical equipment. However, Sodasorb absorbent can be manufactured into relatively large granules or as a fine powder.

The user must choose a specific granular size, based on their requirements for absorbing specific carbon dioxide concentrations with varying air flow velocities and flow patterns. There are also special absorber or scrubber apparatus requirements.

**Proper Filling of the Absorber Unit**—Efficient removal of carbon dioxide is largely dependent upon the proper packing of Sodasorb in the absorbent canister. If the shape of the canister is complex, the uniform distribution of the airflow through the absorbent will be difficult. A small space at the top of the Sodasorb compartment, to aid in initial distribution of the airflow, is recommended.

Shake all canisters prior to use to insure that granules are not clumped together and that an even distribution of granules fills the canister. Channeling will most likely occur when the canister is hastily or unevenly packed.

When using Indicator Sodasorb, the canister wall should be transparent, permitting visual inspection of the progressive exhaustion of the absorbent. Wall channeling is also readily apparent, permitting repacking of the canister before inefficient absorption occurs.