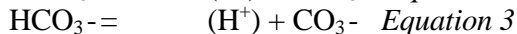
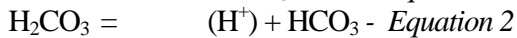


## Sodium Bicarbonate Chemistry

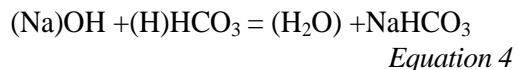
Sodium bicarbonate is commonly known as baking soda. It is used in cooking, as a cleaning agent or in tooth paste. Medical grade sodium bicarbonate is also used for preparation of dialysate solution. The sodium bicarbonate solution in dialysis clinics is often referred to as "Bicarb Concentrate." Bicarb concentrate is mixed with acetic acid solution or citric acid to prepare dialysate solution.

### What is sodium bicarbonate?

When carbon dioxide (CO<sub>2</sub>) dissolves in water, it forms carboxylic acid (H<sub>2</sub>CO<sub>3</sub>). *Equation 1* At an alkaline pH, it dissociates into bicarbonate ions carrying one negative charge (HCO<sub>3</sub><sup>-</sup>) *Equation 2*. At an even higher pH, it further dissociates into carbonate ions (CO<sub>3</sub><sup>--</sup>) carrying two negative charge. *Equation 3*.



With the addition of sodium hydroxide (NaOH), sodium bicarbonate (NaHCO<sub>3</sub>) is formed. In addition, sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>) is also formed, depending on the amount of sodium hydroxide added.



### Reversible nature of bicarbonate.

Reactions of carbonate species shown above are fully reversible. The carbonate can change from CO<sub>2</sub> gas to bicarbonate and back to gas depending on the pH of the solution. At a high pH above 9.0 the reaction moves toward complete ionization of carbonate ions. At pH below 4.0, the reaction turns toward CO<sub>2</sub> gas which then escapes into air. At the mid-range pH, bicarbonate ions become predominant.

The reversible nature of the bicarbonate makes the solution extremely unstable. The composition of the bicarbonate solution can change rapidly if not stored properly. The most

common problem encountered is the loss of bicarbonate as CO<sub>2</sub> gas thus causes the solution pH to rise.

### Factors affecting the composition of bicarbonate solution.

One most critical factor affecting the composition of a bicarbonate solution is the pH of the solution. When exposed to acid, the bicarbonate solution can quickly convert into CO<sub>2</sub> gas. The reaction is nearly instantaneous so that even a transient drop of pH to below 4.0 can cause a substantial loss of bicarbonate as CO<sub>2</sub> gas. It is, therefore, important that when mixing bicarbonate solution with an acid concentrate, the pH of the solution be maintained at a near neutral pH and not to drop below pH 4.0. This is more easily obtained if the acid is mixed into the bicarbonate solution instead of mixing bicarbonate into acid solution.

Another common factor is exposure of the bicarbonate solution to an open air space. The CO<sub>2</sub> gas can only escape into the air from the liquid/air interface. When a bicarb jar is only partially filled, the surface area of the liquid/air interface relative to the total volume of the solution is much larger compared to a fully filled jar. For this reason, a partially filled bicarbonate solution loses its CO<sub>2</sub> content more easily, thus changing the composition of the solution.

Excessive stirring of the solution increases the total exposure of the bicarbonate to air and hasten the release of CO<sub>2</sub> gas into the air. When dissolving sodium bicarbonate into water, the

solution should be stirred slowly with minimum turbulence. Placing a cap to the container will also reduce the loss of CO<sub>2</sub> into the air. A sealed tight system will restrict the flow of air and prevent the loss of CO<sub>2</sub> into an open air space

### **What happen when the sodium bicarbonate solution lost its CO<sub>2</sub> content?**

The pH of the solution goes up. The pH of a solution is determined by the ratio of acid and base components in the solution. In the sodium bicarbonate solution, sodium as sodium hydroxide is the base component and bicarbonate as carboxylic acid is the acid component. When the carboxylic acid is lost as CO<sub>2</sub> gas while sodium base remains in the solution, the base to acid ratio increases. As a consequence, the solution becomes more alkaline and the pH goes up.

A freshly prepared sodium bicarbonate solution should have a pH of 8.0. When the pH of the solution increases to 8.5, substantial loss of CO<sub>2</sub> has already occurred. If the solution is subsequently used in the preparation of a dialysate solution, the final dialysate solution may have a dangerously high pH which may then induce the patient into alkalosis coma. It is important that the pH of a bicarbonate solution be monitored closely and maintained at around pH 8.0 or less than pH 8.2. (Refer to the separate writing on pH Measurement)

### **How to measure bicarbonate concentration?**

When a bicarbonate solution is manually prepared, it is likely that an error will occur occasionally. The bicarbonate solution used in the dialysis usually contain near saturation or about 9.5 % of sodium bicarbonate. If any error occurs, it is usually towards under-saturation, i.e. too much dilution of the solution. This results in a dialysate solution with too low pH, which may cause acidosis to the patient. The concentration of bicarbonate solution is a another critically important parameter that requires careful and frequent monitoring.

The most commonly used method for measuring

the concentration of bicarbonate solution is the use of a hydrometer. Hydrometer measures the apparent specific gravity of a solution, which then is used as an indication of the solution's concentration. Although this method is widely accepted in the renal dialysis profession, errors and lack of precision are common. An alternative method with a refractometer has proven to be simple, easy to use and extremely accurate. It requires only two drops of sample and takes less than a minute to read the results. (Refer to the separate writing on Specific Gravity)

The bicarbonate solution can also be analyzed with a clinical instrument measuring total CO<sub>2</sub>. However, the potential errors in sample handling and the delay in having the results available make such an approach impractical.

### **Bicarbonate as a buffer solution.**

A buffer is a solution which resists changes of pH upon addition of exogenous (outside) acid or base into the solution. For example, pure water has no or very little buffering capacity. Even a very tiny amount acid or base will cause the pH to swing from very low (less than 2.0) to very high (more than 9.0), respectively. Bicarbonate has some buffering capacity though quite weak. Unfortunately, it works the best at the pH range around 8.5. At the desired pH range of 7.2 to 7.6 for dialysate, the pH of the solution is unstable and can readily be affected by a small change in the acid/base composition of the solution. Such a change may not be detected by the measurement of conductivity. When conductivity is used as the only means of monitoring the consistency of a dialysate preparation, it is not sufficient and does not provide assurance of the correct dialysate pH. Confirmation of the dialysate pH with a pH strip or a pH meter before each dialysis treatment is essential. (Refer to the separate writing on Acid, Base and Buffer Solution)

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