Designing Effervescent Formulations

Reactions

Effervescence is the result of a reaction between an acid and a carbonate source.

Acid + Carbonate ⟶ Salt + Water + Carbon Dioxide

The Carbon Dioxide is released as a gas that forms the effervescent bubbles in water.

Sodium Bicarbonate and Sodium Carbonate are the most common carbonate sources used, although potassium bicarbonates and carbonates may be used to take advantage of their greater solubility or where dietary sodium is a concern.

$$NaHCO_3 + H^+X^- \longrightarrow NaX + H_2O + CO_2$$

$$Na_2CO_3 + 2H^+X^- \longrightarrow 2NaX + H_2O + CO_2$$

Formulation Considerations

The triggering event for the effervescent reaction is dissolution of the ingredients in water, which brings the acid and carbonate salt into intimate contact. This is also critical to the stability of effervescent formulations. Any inadvertent addition of water, like use of hydrated forms of the ingredients, or vapor transmission through the package can initiate the reaction. Note also in the reactions above that a molecule of water is released each time a molecule of carbon dioxide is formed, which has the effect of self-perpetuating the premature reaction once initiated.

For this reason, all raw materials must be as dry as possible. The manufacturing environment is typically humidity controlled. Packaging materials are used that minimize exposure of the product and limit moisture transmission.

From the reactions above it can be seen that sodium carbonate requires twice as much acid as sodium bicarbonate to release the same amount of carbon dioxide. It is also important to note that the pH of sodium carbonate is significantly higher than the bicarbonate (11.6 vs. 8.4) which may be of concern for product safety.

Sodium carbonate can however form a very stable monohydrate that keeps the water molecule safely locked away over a wide temperature range. It is sometimes used in combination with the bicarbonate to help protect the formula from small amounts of moisture. A product called Effer-soda® is available from SPI Pharma™. It is sodium bicarbonate that has been heat treated to convert a portion of the bicarbonate surface to carbonate to incorporate this protective advantage in a single material.

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Often a larger particle size sodium bicarbonate (No. 5) is used to formulate effervescent products. In compressed tablets, the No. 5 compacts readily when pressed. In powdered products, the larger particle limits the amount of surface area exposed and thereby prolongs the fizzing action.

The choice of acid plays a critical choice in the performance of an effervescent system. The organic acids, citric, fumaric, adipic and malic are commonly used and are compared in the table to the right.

Citric acid is the most common. It is quite soluble in water, making the neutralization of the carbonate and release of carbon dioxide rapid. It is trivalent, able to neutralize three acid groups. Fumaric on the other hand is much less soluble in water and would increase the time of release significantly.

The acids are included in the formulation at stoichiometric equivalence to the carbonate being used as a minimum. Higher than stoichiometric amounts will generally drive the reaction more quickly.

References:
"Effervescent Technology Primer", Allen H. Rau, Cosmetics and Toiletries® magazine December 2001

https://www.spipharma.com/en/products/functional-excipients/effer-soda

Acid	Molecular Weight	Acid Groups	Solubility in Water
Citric	192.12	3	64.3% @ 30°C
Fumaric	116.07	2	0.63g/100g @ 25°C
Adipic	146.14	2	1.4g/100g @ 15°C
Malic	134.08	2	55.8g/100g @ 20°C

? **For more information or to discuss your formulation, please feel free to contact our Technical Service group.**

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