CARBONATION

Carbonation is the process of introducing carbon dioxide (CO_2) gas into water or into a beverage. Soft drinks containing CO_2 are called carbonated soft drinks and are referred to as CSDs. This - category of beverages makes up almost half of all world soft drink sales. When a carbonated drink is poured into a glass, the CO_2 gas in the beverage is liberated in the form of small bubbles that rise quickly to the surface, where they burst and release the gas. This also happens in one's mouth when drinking the beverage, causing the tingling, tickling effect typical of all CSDs.

The formation of gas bubbles in a liquid, technically referred to as effervescence, is what we commonly call fizz, sparkle, bubbles, and so forth. In nature, we find this effervescence in some spring waters containing CO_2 that was absorbed underground at high pressures. In CSDs, carbonation is a man-made process of physically introducing CO_2 gas under pressure into the beverage (or into water with which the final beverage can be prepared).

CARBON DIOXIDE (CO_2)

Carbon dioxide is a natural gas. It is present in the air at a very low level of about 0.03% by volume. It is a vital substance to the plant kingdom for the process of photosynthesis, in which it is converted, using water and sunlight energy, into carbohydrates. These, in turn, serve as nutrients for the growing plant and help to build its main cellular structural component, cellulose.

Carbon dioxide can exist in three forms: gas, solid (dry ice), and liquid (under certain pressure levels). It has physical and chemical properties that render it ideal for the role it plays in carbonated beverages:

- It is a nontoxic, colorless, and odorless gas that does not impart any flavor to the beverage.
- It is nonflammable and presents no fire hazard when handled.
- It is soluble in water and dissolves easily in the beverage.
- Its solubility can be controlled by regulating the temperature and pressure relationship.
- In water, it forms a weak acid (carbonic acid) that gives the beverage its typical tart taste note.
- The carbonic acid can retard the growth of many common microorganisms.
- Carbonic acid easily releases CO_2 gas to create effervescence when the beverage is consumed.

Carbon dioxide is produced in various industrial chemical processes, where it is often a by-product of sufficient volumes to warrant further processing into the purified product used in the soft drinks industry. This is most commonly supplied to the bottler in the pressurized liquid CO_2 form by specialist industrial gas-producing companies. This liquid CO_2 can be delivered in gas cylinders. However, in most reasonably sized soft drink operations, the liquid CO_2 is normally transported to the bottler's site and transferred into refrigerated bulk storage pressure vessels owned and maintained by the supplier. These liquid CO_2 plants on the bottler's site are designed to deliver CO_2 in its gaseous form when drawn off for production purposes.

Soft drink companies have strict specifications regarding purity and general quality of liquid CO_2. It is recommended to only deal with suppliers that can meet these specifications. A bottler does not normally have the equipment or the expertise for testing for specification details. However, some basic routine testing of CO_2 for taste, odor, and appearance can be performed. This is done by gently bubbling some CO_2 gas that is drawn from an on-line sampling source through a sweetened and acidified water solution simulating an average beverage product. After a specified time of dispersing the CO_2 in the solution, it is tested for taste, odor, and appearance against a control solution. There should be no off-tastes or off-odors in the test sample, which should also be clear of any turbidity or foreign matter.

Also, to ensure the quality of the CO_2 used in production, bottlers may install in-line activated carbon cartridge filters. These would remove any taste or odor defects that could be introduced in the supply lines from the CO_2 vessels that were installed by the company.

Impurities related to off-tastes and off-odors can be present in the CO_2, but this would be a rare occasion. However, one must be continuously on guard against such occurrences, as they can be costly to a company should defective final product reach the trade and the consumer. I think that effective, routine, on-line periodic quality testing for taste and odor would normally pick up such defects in time to prevent suspect stocks from going out into the trade.

GAS VOLUMES

Water at 15.6°C (60°F) and at 1 Atm of pressure will dissolve a quantity of CO_2 equal to its own volume. In other words, 1 liter of water at this temperature and pressure can absorb 1 liter of CO_2. At 15.6°C (60°F) and at 1 Atm of pressure, CO_2 has a density of 1.86 (air = 1.00). This means that at these conditions, 1 liter of water would contain 1.86 g of dissolved CO_2. At different temperatures and pressures, the volume of CO_2 capable of being dissolved in 1 liter of water will change. At temperatures below 15.6°C and at pressures above 1 Atm, there could be more than 1 liter of CO_2 dissolved in the water.

It has, therefore, become a practice to speak of the amount of CO_2 dissolved in a CSD in terms of how many CO_2 volumes it contains. These are called gas volumes, and they are the unit of measurement for the level of carbonation in a CSD. The relationship between temperature and pressure in the water determines how many volumes of CO_2 it can dissolve. This is governed by somewhat complex physical chemistry principles known as the gas laws. To carbonate a beverage to a target gas volume, the beverage must be at a certain temperature. A corresponding pressure for that temperature must be applied in order to allow the required amount of CO_2 to be dissolved. In a similar manner, to measure the amount of CO_2 in a bottled CSD or, in other words, to measure the beverage gas volume, the pressure in the bottle must be determined as well as the temperature of the beverage at the time of the test. By the gas laws principles, the volume (or weight) of the dissolved CO_2 can be calculated. (Gas volume testing will be described in the following section of this chapter.) We do not need to perform such calculations, as the scientists have made life easy for us.

Gas volume charts were prepared covering all the practical temperature and pressure values that could be encountered in soft drink carbonation testing. By looking up the temperature of the sample and the pressure measured in the bottle at the time of testing, a corresponding gas volume value is indicated.

Gas volume charts are available from suppliers of carbonation testing equipment. For interest sake, a small section of a nominal gas volume chart is given in Table 12.1 to give the reader an idea of how this works. Looking at the gas volume chart section in Table 12.1, one can see the interaction of temperature and pressure on the carbonation level in a beverage. If, for example, a gas volume test indicated a pressure of 30psi at a beverage temperature of 10°C, the corresponding carbonation would be 3.6 gas volumes. As the temperature values increase for a specific pressure column in the chart, the gas volume will decrease. For a specific temperature row, as the pressure increases, the gas volume will increase. This is in accordance with the CO_2 solubility properties discussed previously. The gas volume chart is needed for carbonation testing with manually operated testing equipment. Instead of using a chart, gas volume calculators are available in which the gas volume value is instantly displayed after manually entering the relevant temperature and pressure values into the instrument. Sophisticated computerized testing equipment is also available, with which the entire carbonation test is controlled electronically. There is no need for the chart or calculator, as the computer records the temperature and pressure data and calculates the gas volume, which is then displayed on the LCD screen of the instrument.

Carbonating the Beverage

Most CSD operations use the system of water-to-syrup proportioning at the filling machine. In such systems, a liquid mixture of syrup and water is obtained at the target Brix of the final beverage to be filled. All that is needed to convert this liquid to final beverage is to carbonate it at the specified gas volume of the beverage flavor.

Different flavors have characteristic carbonation levels. Colas, lemonades, ginger ales, tonic waters, and soda waters usually have high gas volume values between 3.0 and 4.0. Fruit flavors and cream sodas tend to have lower carbonation levels in the range of 2.5 to 2.8 gas volume. Sparkling mineral waters normally have gas volumes below 2.0. To carbonate a specific final beverage at the filling machine, the production operators will know from experience to what temperature it must be cooled and at what pressure to feed the CO2 gas into the liquid. If necessary, the operator will consult a gas volume chart and set temperature and pressure levels accordingly. For the higher gas volume products, the operator will normally work around a temperature of less than 10°C and at pressures around 30 psi or higher. Equipment capabilities and limitations may also influence the operator’s chosen temperature and pressure settings.

The beverage to be carbonated can first be cooled in a separate cooling unit and then carbonated in a dedicated carbonator unit. Many filling machines have a unit called a carbo-cooler that does these two processes of chilling and carbonation simultaneously. After the cooling and carbonating process, the liquid, which to all intents and purposes is now actually a carbonated final beverage, is transferred to the filler bowl. The filler bowl is kept under CO2 pressure for two main reasons. First, the “head” pressure in the bowl keeps the dissolved CO2 of the beverage in the liquid. Second, there is the matter of counter-pressure. Most fillers work on the gravity-filling principle — the beverage runs out of the bowl, by the force of gravity, through the filling valves, and into the bottles or cans.

In order to achieve this gentle gravity-induced flow of liquid from filler bowl into bottle, the pressure formed from the dissolved CO2 in the bottle as it is being filled must be negated. If not, the bottle would, at a certain stage of its filling operation, contain enough CO2 pressure to stop the inflow from the filler. Therefore, the bowl must contain a pressure equal to that in the bottle in order to allow for a free flow of beverage through the filling valve, into the bottle. This pressure in the filler bowl is the counter-pressure mentioned above.

Another issue related to the carbonation aspects of CSD filling is that of snifting. In order to provide the free gravity flow of beverage from the bowl into the bottle, the entire system of bottle, filler valve, and filler bowl must be “airtight” — it must be one continuous system without any leaks. For this purpose, the filler bowl operation is designed so that in a certain stage of its revolution on its axis, the empty bottle is raised upward, and its mouth is pressed firmly against the rubber cup of the filling valve, creating an airtight seal. However, as the bottle is slowly filled, the CO2 in its headspace is compressed, and a stage arrives where it must be released from the bottle. This is to allow further filling and to prevent the bottle from bursting under the increased pressure. This removal of excess pressure is achieved by opening the snift valve of the filling valve, again at a certain stage in the cycle of the revolving bowl. In all my years spent working in or visiting at bottling plants, I never ceased to marvel at the ingenuity involved in a CSD filler bowl operation. The two instances mentioned above, the snifting and counterpressure devices, are but a few of many other instances of what I consider “mechanical wonders” involving the machining precision, timing, synchronization, and general engineering inventiveness that can be observed in a single rotation of a filler bowl unit.