food for thought

"Food for Thought" explores the relationship between food/drink and chemical engineering processes/concepts.

POP!

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Here's a fun open-ended design exercise for you and your students.* How much CO_2 does it take to carbonate a typical can of soda pop? And knowing that, can you come up with an easy-to-use home system for beverage carbonation? As your class will likely know, the current consumer solution to this problem is high-pressure home carbonation systems like the SodaStream®. But as with any design problem, that's only one solution. Let's travel back to 1956 and the design path of another attempted solution to this challenge, a story that ends in the production of — dare I say — the most chemically-engineered candy available.

First, let's start by solving our problem. It turns out different manufacturers and different products use different levels of carbonation, so we have a reasonable range of carbonation levels to choose from. I'm going to apply some first-principles thinking — soda merely carbonated to *saturation* will lack the driving force, when exposed to atmospheric pressure, to produce a satisfying fizz when opened unless we first introduce a bunch of nucleation sites (no, not gonna add another spoonful of sugar to my soda, thank you). Running at 4x saturation should provide enough supersaturation to kick things up a notch. The Henry's law constant for CO_2 in water at room temperature is about $k^0 = 0.034$ mol/kg-bar.[1] Thus, four times saturation ought to be 0.14 mol/kg or (playing fast and loose with density) about 6 g of CO_2 in a liter of soda, which turns out to be a pretty typical value.[2] Thus, to manufacture this soda using 100% CO_2 gas, we'd want to apply it to our uncarbonated soda at a pressure of at least 4 bar, or about 58 psi. Now we know what we're trying to do — trap water while exposing it to CO_2 at this pressure for a sufficient amount of time for it to equilibrate.

If you've ever seen a SodaStream, you can observe that it achieves this by using capsules of high pressure CO_2 that are then mated with your target beverage in a heavy-walled bottle, securely sealed to the capsule.[3] This is a fine solution if you work with a consumer products company that makes small appliances. But what if your employer is a consumer products company that makes food? Is there a non-device version of this?

There are lots of good reasons to find a non-device solution. By mass, beverages are mostly water, and water is heavy and therefore relatively expensive to ship. If you could make a powdered substance that consumers add to water in their own home, you could sell it for significantly less than soda while still maintaining a healthy profit margin due to decreased shipping and packaging.

What if.... we make a flavored and sweetened powder (think lemonade mix) that also has high pressure CO_2 in it? Is that possible? Well, when you look at a drink mix, it looks like sugar crystals that have been dusted with color and citric acid and other flavor elements. But all of those things are solids at room temperature, so just mixing CO_2 into this isn't going to be effective. But what if, rather than sugar crystals with dry flavors, we made essentially a giant hard candy with the same ingredients, then crunched it up into smaller particles?

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That gets us our drink mix and a substance into which we can dissolve high pressure CO_2. So here's the approach — make a batch of appropriately flavored sugar candy syrup. While it is liquid, pressurize it with pure CO_2 at over 4 bar (to provide sufficient driving force), then allow the candy to cool into a solid. Run that through a pulverizer and voila, powdered lemonade soda![4]

We should try it! Well, it has in fact been tried *and* patented. Patent US3012893A was issued to William A. Mitchell and General Foods in 1961 for the 1956 invention of this very process and its product.[4] Mr. Mitchell was an industrial chemist who held patents for a truly staggering number of food innovations readily recognizable to anyone who ate at a potluck supper in the US in the 1970s or 80s: instant pudding and Jell-O®, boxed angel food cake, Cool-Whip®, and Tang®.[5] You might notice that powdered carbonated beverages don't appear on that list. Well, while the process above works, the CO_2 tends to be trapped in the sugar solution in high pressure bubbles that fracture their way out of the candy as soon as it gets wet. To turn this into a carbonated beverage, you'd need to add a sufficient quantity of the powder to the water, seal the bottle, and wait as the sugar dissolves and the CO_2 pressurizes the bottle. Dissolving the sugar could be speeded by heating, but that drives the CO_2 out of solution, so it's more effective to wait for dissolution instead. Not the best feature for a beverage that's trying to compete with either Kool Aid® or canned soda for children, a market not famous for its patience. Further, even the most carbonated candy they were able to produce didn't quite carry the mass of high pressure CO_2 needed to give the carbonation levels desired.[4]

*Wondering how to fold this into class? I recommend it as a 15-minute small-group estimation and brainstorming exercise, ending with a report-out sharing students' estimated CO_2 pressure and approach (similar to the estimation problems done on YouTube™ Fridays).[6] Scale the time for the level of student — this could be a late-semester MEB exercise, a practical application for Thermodynamics, or even a warm-up for technical brainstorming in Capstone Design.

While this product was a bust for its intended purpose, it made it to market as a candy. It turns out that small pieces of this CO_2-candy, when wet on the tongue, crackle and gently explode (if it's even possible to put those two thoughts together). The sound is fun, the effect is surprising, and the flavor is, well, like pretty much any other lollipop. And thus, out of the ashes of at-home-soda-mix arose the world's first high pressure candy, Pop Rocks®.[4] This candy is still available, and if you (or your students) have never tried it, I recommend a tasting party as a cap to this design problem. Pop Rocks are an excellent reminder that open-ended design problems are just that — sometimes you find multiple innovative solutions to the original problem, sometimes you get one or none, and sometimes you end up solving a problem that you didn't even realize was seeking a solution until you found it!

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