# The Shaken-Soda Syndrome

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The next time you're sitting around with nothing to do, find two identical cans of a carbonated beverage of your choice and roll them down an incline. Perhaps you won't be surprised to discover that they roll at the same rate. Now, shake up one of the cans and repeat the experiment. You'll be delighted to discover that the shaken can now loses the race.

This experiment was demonstrated by Robin McGlohn during "Show and Tell" at a meeting of the Northern California/Nevada Section of the American Association of Physics Teachers. Physics teachers being, well, physics teachers, the question of "why?" arose instantaneously. Certainly, the indisputable answer is that the shaking creates a change in the amount of energy being transferred to the rotational motion of the fluid inside the can as it rolls. This leaves less energy for the translational motion of the center of mass of the can-fluid system. As we all know, the answers to scientific questions lead not to answers so much as to better questions. The next question as to the mechanism for this energy transfer was the topic of much speculation. The experiments described below demonstrate a strongly suggestive, but not conclusive answer.

Many of the suggested mechanisms involve the premise that the pressure in the shaken can is larger than in the unshaken can. If you have ever opened a shaken carbonated drink, it sure seems obvious that the pressure is higher after shaking. However, you can check this directly by making a chamber with a pressure gauge. The fact is that once the carbon dioxide in the soda pressurizes the chamber and comes to equilibrium, the pressure is unchanged when the soda is shaken. This can be seen qualitatively by squeezing a plastic bottle of soda, then shaking it. It is roughly just as easy to squeeze.

Why then do carbonated beverages explode out of containers after they are shaken? Chemists will explain that releasing the pressure in the bottle by opening it causes the carbon dioxide in the soda to become less soluble. Therefore, the carbon dioxide will start leaving the fluid. The rate at which it leaves is a complex function of not only the pressure drop but the number of nucleation sites available in the container. This can be seen by watching the bubbles rise in a glass. They tend to form at specific spots on the side where a piece of dirt or an imperfection in the glass provides a site. The shaking introduces bubbles into the fluid and each bubble acts as a nucleation site. The explosion is caused by the very large number of nucleation sites, not by the imagined increase in pressure due to the shaking.

Having ruled out pressure alone as the mechanism, searching for the source of the "shaken-soda syndrome" (since we are all seriously addicted to jargon, this will be referred to as $S^3$ from now on) evolved to timing rolling cans of

**Fig. 1: A can rolls down the incline through a speed trap created by two lasers (background) and two laser switches (foreground). The first beam is at the top of the incline and the second is 50 cm away. The block at the top of the incline ensures that the cans always start at the same place.**

**Table I: Times for rolling fluids in 12-oz cans.**

| Fluid | Unshaken | Shaken |
|---|---|---|
| Diet Coke | 1.86 s | 2.04 s |
| Regular Pepsi | 1.86 s | 2.15 s |
| Hawaiian Punch | 1.82 s | 1.90 s |
| Bud Light | 1.85 s | 2.20s |

**Table II: Times for rolling fluids in aluminum canister.**

| Fluid | Unshaken | Shaken |
|---|---|---|
| Tap water | 1.74 s | 1.75 s |
| Soapy water | 1.97 s | 2.15 s |
| Flat Coke | 1.75 s | 1.96 s |

**Table III: Times for flat Coke vs time between trials.**

| Time | Unshaken | Shaken |
|---|---|---|
| initial | 1.75 s | 1.96 s |
| 15 min | 1.86 s | 1.96 s |
| 2 hr | 1.78 s | 1.93 s |

various fluids down an incline. The angle of the incline was small so as to increase the time and reduce the fractional uncertainty in the measurements. The angle was set at 2.3° for convenience. Two PASCO laser switches were used to time the first 50 cm down the ramp. Figure 1 is a photograph of the experiment.

Some test subjects were purchased at a local supermarket. They included 12-oz cans of Diet Coke, regular Pepsi, Hawaiian Punch (a noncarbonated fruit punch packed in nitrogen), and Bud Light (which, you can rest assured, was kept sealed during all the experiments). The average times for several trials are shown in Table I. The standard deviations were roughly 0.05 s. All four fluids demonstrated $S^3$ to varying degrees. Since the Hawaiian Punch exhibits $S^3$, the presence of carbon dioxide doesn't seem to be involved. In addition, there appears to be no simple correlation with sugar because Diet Coke is sugar free, yet shows $S^3$.

Once carbon dioxide and sugar are excluded from soda, pretty much all that is left is bubbles and water. To test these effects, three fluids were chosen: tap water, soapy water (1.0 L of water to 10 mL of Joy dishwashing liquid), and flat regular Coke (left open for a full day). The lower the mass of the container the better, so the aluminum canister in which one liter ethyl ether is usually shipped and stored was chosen. In addition, if $S^3$ is related to some property of aluminum, it will not affect the results. Note this can actually has a capacity of 1.2 L. The results are summarized in Table II.

The fact that tap water shows no $S^3$ lends credence to the hypothesis that bubbles in the fluid are responsible. The strong effect in soapy water tends to confirm this theory. Yet, the fact that flat soda also shows a strong effect initially might tend to discredit the bubble hypothesis. However, shaking a clear plastic bottle of flat Coke reveals that it is an even "foamier" fluid than carbonated Coke.

The validity of the foamy flat Coke idea was checked by delaying the time between shaking the can and rolling it down the incline. Table III shows the results of three consecutive experiments. The can was rolled without shaking, then shaken and rolled. We waited 15 minutes after the first shaking, rolled the can without further shaking, then shook the can again and rolled it. Two hours then elapsed and the can was again rolled without additional shaking, then shaken and rolled for the last time. Notice that 15 minutes after being shaken, the can had still not returned to its "unshaken" time. Two hours after shaking, however, the can had relaxed to the unshaken time. Visually examining the other liter of flat Coke remaining in the 2-L plastic bottle verified the fact that after 15 minutes the bubbles from the initial shaking are still present, while two hours after shaking the bubbles are gone.

From a conceptual point of view, bubbles provide a compelling argument to explain $S^3$. The bubbles that attach themselves to the surface of the can create a stronger link between the can and the fluid than direct fluid-can contact. This linkage, presumably brought about by the surface tension between the bubbles and the can, transfers energy to the fluid more efficiently than the fluid itself rubbing against the can.

As stated earlier, good science leads to better questions such as, can a complete theory of foamy fluids inside rolling containers be developed to lead to a more complete verification of bubbles as the cause of $S^3$? Anyone interested in pursuing this challenge should study several papers[1-3] on rotating cylinders interacting with fluids. Then move on to learn about the interaction of bubbles with surfaces, which involves a deep understanding of surface tension. This author (knowing his own limitations) will merely quote Shakespeare, "The journey ends when lovers meet." In other words, I'm satisfied to be pretty darn sure it's the bubbles!

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## References

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