Fizzy water

Note:
This task is designed so that it can be solved with the incremental hints.
The hints are available on the media portal for printing, or the students can use them online on a tablet or smartphone via the QR code included on the worksheet.
The worksheet for the students and the hints for printing are available as separate files on the media portal of the Siemens Stiftung. General information on using tasks with incremental hints in the classroom is provided in the "Tasks with incremental hints – an introduction" document, which is also available on the media portal.

1 Topical aspects

This task deals with dissolving gases in liquids; in this specific case, carbon dioxide is dissolved in water. The students' challenge is to explain – that is, to model – the phenomenon of the formation of gas bubbles using a suitable scientific concept.

2 Learning prerequisites and level of difficulty

Students learn early on that components of air can be dissolved in water. Living organisms in the water attest to this: Plants absorb carbon dioxide and release oxygen, and fish remove oxygen from the water and release carbon dioxide via their gills. Sparkling mineral water, in which considerable amounts of carbon dioxide are dissolved, is common in everyday life; however, the ideas about the "spraying" that occurs when a shaken bottle of sparkling mineral water is opened are usually based on unclear assumptions.
The students should already have experience in conducting simple experiments. They should be divided into groups to conduct two simple experiments (see section 3) before working on the task. They can repeat these experiments while working on the task so that they can make specific observations.
Because the students, as they work on the task, must overcome some everyday notions in favor of a scientific explanation, the task has a medium to high level of difficulty.

3 Background on the task

More than 99 percent of the carbon dioxide in water is physically dissolved. The small portion that is chemically dissolved (by forming H^+, HCO_3^-, and CO_3^{2-}) is immaterial for the outgassing and spraying of sparkling mineral water.
The outgassing takes place relatively slowly because comparatively large amounts of energy are needed to form the initial small gas bubbles. This energy is available only to a limited extent at room temperature, which is why a bottle of sparkling mineral water that has been undisturbed can also be opened without a resulting spray. The outgassing can be facilitated, though, with any sort of "nucleation sites." In connection with the task, two different procedures are presented for this purpose, and the students should draw the right conclusions when they compare the two procedures:

- When a closed bottle of sparkling mineral water is shaken, small gas bubbles that subsequently facilitate the formation of larger gas bubbles are distributed throughout the liquid.
- When salt, sugar, or sand is sprinkled in a glass of sparkling mineral water, gas bubbles are also quickly formed. In this case, the solid particles serve as nucleation sites for bubble formation.

The fact that bubbles form in the first place has to do with the increased pressure used to force the carbon dioxide into the liquid; this means that bottles of sparkling mineral water contain an oversaturated solution, that is, considerably more carbon dioxide is dissolved in the water than would be under normal pressure. Since less and less gas can be dissolved in the water as the temperature increases, a shaken bottle of sparkling mineral water fizzes more vigorously in a warm state than when the bottle is chilled.
Similar effects that can be examined and analyzed with the students when they have completed the task are the formation of gas bubbles in water shortly before the water boils – dissolved components of air escape in this case – and the vigorous bubbling of water that has just started to boil when salt is sprinkled in – the salt crystals act as nucleation sites for the formation of steam bubbles.

4 The task

In principle, the task could also be solved based on the description of the two aforementioned experiments or after a demonstration by the teacher; however, the specific formulation of the task and hints assumes that the experiments will be conducted by groups of students after brief verbal instructions by the teacher:

- They will shake a half-full bottle of sparkling mineral water and observe the formation of bubbles after they open the bottle.
- They will fill a glass halfway with sparkling mineral water, sprinkle in a solid, and observe the formation of bubbles.

In the second experiment, different groups can also sprinkle different solid substances into the sparkling mineral water. Then they should briefly share their experiences. The result of this sharing should be that the fizzing is largely independent of the type of solid sprinkled in.
After the two experiments have been conducted, the students will receive the worksheet and the hints.

In the simplest form, the task can be formulated as follows:

> You have just conducted two experiments to make sparkling mineral water fizz. Find out what causes many bubbles to form quickly in the sparkling mineral water. Check your guesses with both experiments.
> If you want to actively check your previous observations or your guesses again, then you can conduct the experiments again.
> At the end, summarize your thoughts and formulate two or three sentences.

The required materials for one group include:

- One bottle of sparkling mineral water three-fourths full (full bottles cannot be shaken well).
- One glass filled halfway with sparkling mineral water from the bottle.
- Salt, sugar, or fine sand.

5 Variations

As already mentioned, the task can also be completed after the teacher presents the experiments. In this case, however, both experiments should be conducted multiple times to give the students the opportunity to make close observations.

6 Overview of the hints

Note: The hints have been prepared as a separate file for printing or can be used online via the QR codes on the worksheet. A video showing how the experiment is conducted is available on the media portal. The video is already integrated in the online hints.

Hint 1 Explain the task to each other again in your own words. State what you understood the task to be and what is still unclear to you.	**Answer 1** We're supposed to find an explanation for why sparkling mineral water fizzes after being shaken, or when we sprinkle salt, sugar, or sand into a glass of sparkling mineral water.
Hint 2 Recall what you know about sparkling mineral water. What gas does it contain that makes it bubble?	**Answer 2** Sparkling mineral water contains a lot of carbon dioxide. If you shake a bottle and then open it, the carbon dioxide forms so many bubbles that the water sprays out.
Hint 3 In order to clarify how the bubbles form, it's best for you to start with one of the two experiments: sprinkling a solid in sparkling mineral water. (You can also watch the related video named "Fizzy water.") What can you observe? Tip: If you conduct the experiment again, toss just a few grains of the solid into the sparkling mineral water.	**Answer 3** We observe that gas bubbles form on the grains of the solid. The more grains we toss in, the more vigorously the bubbles form.
Hint 4 Now conduct the experiment in which you shake the closed bottle. Where do the gas bubbles form in this case? Tip: If you conduct this experiment again, place the closed bottle on the table after you shake it and observe it for half a minute before you open it. Then open the seal and look closely to see what happens in the liquid.	**Answer 4** We see that after the bottle is shaken, many small bubbles are in the liquid. When we open the seal, we observe that large bubbles form where before there were small bubbles.
Hint 5 Now try to generalize your observations from the two experiments.	**Answer 5** After the bottle is shaken and opened, gas bubbles form from the small gas bubbles in an explosive manner. When a solid is sprinkled in, gas bubbles form on the solid grains. In both cases, something has been added to the water that triggers the formation of gas bubbles.

Hint 6	**Answer 6**
Now you have all the information you need to answer the question. By the way, the solid added to the water or the small gas bubbles are called “nucleation sites” for the formation of the large gas bubbles.	Shaking the bottle or sprinkling in a solid creates nucleation sites for the formation of gas bubbles. Ultimately, these nucleation sites cause the sparkling mineral water to “fizz” – if external pressure doesn’t prevent this.