

## Taking a candle into the wine cellar

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

The task addresses the formation of carbon dioxide (CO<sub>2</sub>) as a product of alcoholic fermentation. From a physiological point of view, the task covers the fact that CO<sub>2</sub> is a respiratory poison that can lead to death. The third aspect is the suffocating effect of CO<sub>2</sub> on open flames.

### 2 Learning prerequisites and level of difficulty

In order to solve the task, the students must have prior knowledge from various fields of science. On the one hand, they should be sufficiently familiar with alcoholic fermentation to know that ethanol and carbon dioxide are formed from sugar. If fermentation experiments have been conducted in class, then the students should certainly remember the bubbling fermentation lock and the accompanying test conducted to detect CO<sub>2</sub> with “lime water” (Ca(OH)<sub>2</sub> solution).

They must also know that while carbon dioxide (along with water vapor) is a metabolic product of respiration, at higher concentrations it is a respiratory poison because it prevents oxygen in the air from binding with hemoglobin. The fact that it hinders combustion should also be well known.

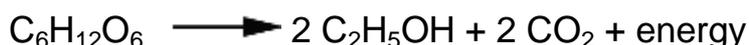
Note that students who have visited a wine cellar during a field trip or on vacation in a wine region, or who have had related experience at home, already know the answer. In this case, it is particularly important to make sure that the students’ reasoning of the answer is thoroughly conclusive.

The task is more difficult if it is done without a context story; then the reference to alcoholic fermentation must first be established.

### 3 Background on the task

Going into wine cellars with an open flame has a long tradition. Even before the chemical nature of various gases was known, vintners carried burning candles into fermentation cellars for their own safety. If the candle goes out, there is a risk of death. It means the CO<sub>2</sub> content in the air is so high that a person would suffocate if he or she stayed in the cellar any longer. Because CO<sub>2</sub> is odorless, it cannot be perceived without a tool.

The CO<sub>2</sub> is formed during the fermentation process according to the following reaction equation:



If the candle goes out – at a CO<sub>2</sub> concentration of >10 percent – then you should immediately leave the cellar.

You can find additional information, for example, by searching online with the phrase “CO<sub>2</sub> hazards in wine cellars”.

## 4 The task

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

Explain why it makes sense to go down into a cellar with a burning candle. Summarize your explanation in a short paragraph.

Because the context from which a task is developed fosters learning, depending on the teacher's assessment, a contextual scenario can be developed, such as the following:

After completing a unit on alcoholic fermentation, the class takes a field trip to visit a winery.

It's rather cramped in the cellar given the large number of barrels, so Nils doesn't hear everything that is explained there. While riding the bus back to school, he asks Johanna questions because she was always standing right up front.

"Tell me, what did the vintner say about the burning candle? Why did he take a candle into the cellar when it has electric lighting?"

Johanna, who has already answered ten questions, doesn't feel like answering any more and says,

"You can find that out for yourself if you think about it a little. In any case, he does it for his own safety."

The goal of working on this task is to find a corresponding reason and to explain the causes of the possible occurrence of high CO<sub>2</sub> concentrations, the associated danger, and the indicator function of the candle.

## 5 Variations

The task can be given more of a physics/chemistry emphasis by including the fact that the vintner holds the candle at about head level. The reason is that CO<sub>2</sub> is specifically heavier than air and therefore is more likely to be found in the air close to the ground in a fermentation cellar. If the CO<sub>2</sub> already affects the candle flame at head level, turning around is imperative.

To be able to solve the task with this focus, the students must already have basic knowledge about atomic structure and the properties of gases. They must also know that the molecular masses (as the sum of the atomic masses) differ according to the composition of the particles of a gas. Also necessary is knowledge of Avogadro's law, which states that equal volumes of gases under the same conditions (temperature, pressure) ideally contain an equal number of particles. On this basis, it is understood that different gases have different densities. The densities of air (N<sub>2</sub>/O<sub>2</sub>) and CO<sub>2</sub> behave like the molecular masses:

Gas		Molecular mass	Density under normal conditions
Nitrogen	N <sub>2</sub>	2 x 14 = 28	1.25 g/l
Oxygen	O <sub>2</sub>	2 x 16 = 32	1.43 g/l
Air			1.3 g/l
Carbon dioxide	CO <sub>2</sub>	12 + (2 x 16) = 44	1.98 g/l

## 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.

<p><b>Hint 1</b> 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.</p>	<p><b>Answer 1</b> We're supposed to figure out why a vintner takes a candle into the wine cellar for safety reasons.</p>
<p><b>Hint 2</b> Think about the dangers that a vintner can encounter in a wine cellar. What happens in a wine cellar?</p>	<p><b>Answer 2</b> Wine is stored in a wine cellar. Alcoholic fermentation takes place in the barrels.</p>
<p><b>Hint 3</b> Recall what you have learned about alcoholic fermentation.</p>	<p><b>Answer 3</b> During alcoholic fermentation, alcohol is produced from sugar by yeast. <math display="block">\text{C}_6\text{H}_{12}\text{O}_6 \longrightarrow 2 \text{C}_2\text{H}_5\text{OH} + 2 \text{CO}_2 + \text{energy}</math> From the reaction equation, we see that <math>\text{CO}_2</math> is formed as a by-product.</p>
<p><b>Hint 4</b> What do you know about carbon dioxide?</p>	<p><b>Answer 4</b> <math>\text{CO}_2</math> is formed during many combustion processes and during respiration. It is invisible and odorless, and at higher concentrations it can cause suffocation.</p>
<p><b>Hint 5</b> Now you know the danger that could lurk in the wine cellar. How can a candle help avoid this danger?</p>	<p><b>Answer 5</b> A candle flame goes out if there is no longer enough oxygen in the air and if the concentration of <math>\text{CO}_2</math> has increased significantly.</p>
<p><b>Hint 6</b> Now you have all the information you need to give and support an answer.</p>	<p><b>Answer 6</b> The vintner takes a candle into the cellar to determine whether too much <math>\text{CO}_2</math> is in the air. <math>\text{CO}_2</math> is formed as a by-product during alcoholic fermentation. If the <math>\text{CO}_2</math> concentration in the cellar is high, the vintner could suffocate. With a candle in his hand, he is warned in time because the flame goes out.</p>