**Why does the water rise?**

[Subtitle]

A new perspective on an old problem

[Subject symbol Matter and Energy M&E]

[For icons]

Time

15 - 30 minutes

Scope

From class 4

Concepts: heating and expansion of air, pressure, combustion;

[Introductory box]

Everyone knows that the candle goes out when the oxygen in the glass runs out. But is that the whole story? What exactly are you observing in this demonstration? Even when we're all looking at the same thing, we often see very different things.

What causes the liquid level in the glass to rise? This can be explained in different ways. What are the arguments for and against each explanation? Do those arguments fit all observations?

From observation alone, no scientific insight follows, especially not when more than one explanation seems plausible. The result of research is often the conclusion that more research is needed. Sometimes even for an old and stale problem like this...

The teacher performs the experiment but mainly directs the discussion to generate these insights.

[End of introductory box]

[38\_PD\_1, caption]

*Place the jam jar over the burning candle.*

**Required**

Candle; plate; glass; some water; optionally coloring; matches.

**Preparation**

Pour some water into the plate, if possible with coloring, place the candle in the middle and light it. Have the glass ready. It must be large enough that it does not touch the candle or flame when placed over it.

**Execution**

A detailed scenario for a Predict-Observe-Explain approach for this demo can be found at www.nvon.nl/showdefysica. You will find a rough, hypothetical lesson plan, with suggestions for questions and assignments.

[38\_PD\_2, caption:]

*The candle is extinguished. Why did the liquid level rise?*

If you place the glass over the burning candle, it will extinguish after a while, causing the water level in the glass to rise. At least three explanations are plausible for this:

1. The water takes the place of the oxygen that is consumed during combustion.

2. When the flame goes out, the temperature drops. According to the general gas law, then the pressure and/or volume decrease. Atmospheric pressure pushes water inward until a new equilibrium is reached.

3. Water is formed in the flame, which precipitates when the flame goes out. Then the number of particles in the gas decreases, so does the pressure. The atmosphere pushes water inward until a new equilibrium is reached.

Let students brainstorm arguments for and against each explanation, exchange them, and come to a conclusion. The teacher can also ultimately contribute their own input.

**Physics background**

(For explanation 3). With complete combustion of candle wax (mainly paraffin or stearin), roughly for every two molecules of O2, one molecule of CO2 and two molecules of H2O are formed. When the flame extinguishes, the temperature drops sharply in that area, and H2O precipitates there. The pressure in the glass quickly drops, the atmosphere pushes water inward until equilibrium is reached.

(For explanation 2). Heat release to the surroundings of the glass also causes pressure reduction according to the general gas law. However, this process is slow, while the liquid level rises noticeably quickly.

(For explanation 1). For every oxygen molecule in the air, exactly one water molecule is formed. If that precipitates, the resulting space can be filled by liquid. If we ignore the formation of CO2, then even explanation 1 (according to quite a few biology textbooks the 'correct' one) is somewhat true.

More important than the 'correct' explanation here is that students themselves come up with, defend, and evaluate arguments for the explanations. And that a need arises for empirical evidence.

**Tips**

Illustration of explanation 2: place an empty balloon over the opening of a bottle, and place it in a bowl of hot water (Liem, 1989, p. 36). Due to the heating of the air in the bottle, the balloon inflates, an illustration of Charles's law (V/T = constant if P and N do not change).

[38\_PD\_3, associated with the first tip, caption:]

*The balloon on the bottle inflates when you place the bottle in hot water.*

*Illustration of explanation 3:* bring some water in an empty soda can to a boil, then quickly invert it in a bowl of cold water, with the opening below the water surface. The can collapses because the water vapor condenses.

**Further research**

With three candles instead of one, the final water level is higher (Liem, 1987, p. 37). Which of the explanations does this observation correspond to?

**Safety and environment**

Hold the can in the illustration of explanation 3 with tongs or oven mitts.