1 Introduction

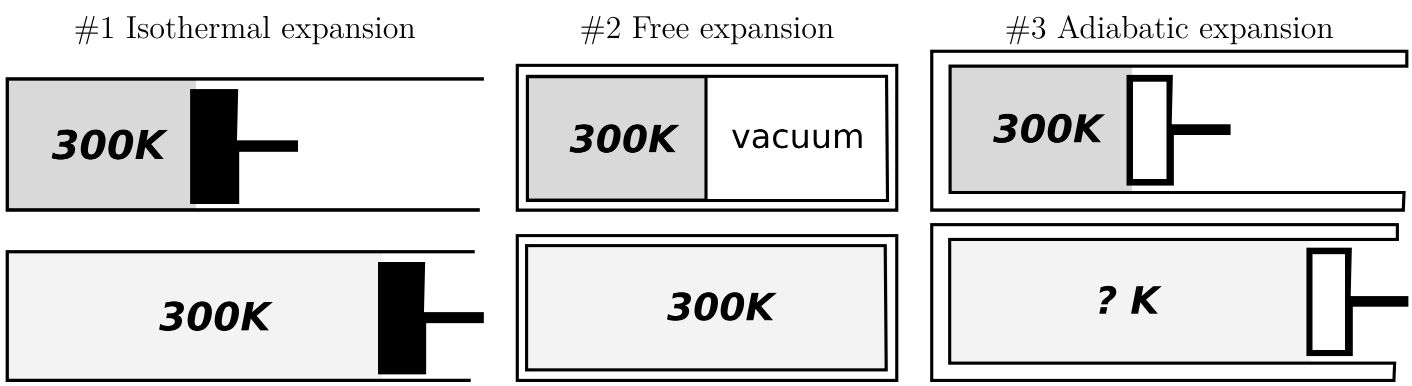
I always tell them that this quiz will only be graded on whether they did it, in hopes of reducing their level of fear. The "activity" really begins after they've finished the quiz. I put a table on the board of the various ΔS and ask them to share their answers to each question with their little white boards (but raising hands would be okay). I make someone volunteer to explain why they chose what they did in each case. Students naturally will start asking questions, and the challenge will be in getting them to stop... and in trying to provide answers that will satisfy them.

Student handout Consider the three processes described below.

Process #1 Five moles of an ideal gas are initially confined in a one-liter cylinder with a movable piston, at a temperature of 300 K. Slowly the gas expands against the movable piston, while the cylinder is in contact with a thermal reservoir at 300 K. The temperature of the gas remains constant at 300 K while the volume increases to two liters.

Process #2 A thin plastic sheet divides an insulated two-liter container in half. Five moles of the same ideal gas are confined to one half of the container, at a temperature of 300 K. The other half of the container is a vacuum. The plastic divider is suddenly removed and the gas expands to fill the container. No work is done on or by the gas. The final temperature of the gas is also 300 K.

Process #3 The same cylinder as in process #1 is thermally insulated and then allowed to slowly expand, starting at 300 K, to twice its original size (two liters).



1. Consider the change in the entropy of the gas for process 1, 2 and 3. We'll call these changes ΔS_1, ΔS_2 and ΔS_3. Are these changes positive, negative, or zero? Please explain your reasoning.

2. Is ΔS_1 greater than, less than, or equal to ΔS_2? How do each of these compare with ΔS_3? Please explain.

3. Consider the change in entropy of the surroundings for process 1, 2 and 3. We'll call these changes $\Delta S_{\text{surr-1}}$, $\Delta S_{\text{surr-2}}$ and $\Delta S_{\text{surr-3}}$. Are these changes positive, negative, or zero? Please explain.

2 Student Conversations

One confusion that comes up is how to find ΔS. Sometimes we use $\int dQ/T$ (for reversible processes), but sometimes we don't do so, and instead argue based on the initial and final states.

The main confusion, however, is where the entropy comes from in the case of the free expansion. One correct answer is to explain that entropy is simply created when something irreversible is done, which is a natural consequence of the Second Law. I also explain that entropy is *not* something that is conserved. This is troubling to them, and the same question repeats... which possibly means I don't have the best answer for it. Students wonder if entropy can be "real", if it can be created willy-nilly like this, so I end up emphasizing that it *is* real, and that it can be measured.

One student asked if entropy could be measured *directly*, to which I answered that it can't be measured directly, but neither can energy. In both cases one is forced to measure other properties and infer the energy or entropy. But that this doesn't mean that we aren't actually measuring them.

Finally, after we've talked about the properties of entropy, students are liable to ask what entropy really *is*. Eventually I relent and give a preview of the statistical interpretation.

3 Wrap-up

Some groups of students will have many questions that will threaten to push the group past the time limit. At some point, it may be best to simply state what the answers actually are, and that if students are still confused as to why, they should contact you. During the discussion, students may have made compelling arguments for incorrect solutions, and it is important to point out where their logic was flawed, so as to ensure students end up with a solid understanding.