On-line activities for gases (KMT)

Below is the list of experiments (real, video based and data-based) that students can perform as labs when studying gases and KMT. For each experiment we provide goals, equipment (if needed) and rubrics for self-assessment. Rubrics can be found at https://sites.google.com/site/scientificabilities/rubrics

1. Application experiment: size of molecules

Goals: a) estimate the size of a molecule;
b) identify assumptions in the mathematical procedure.
Equipment: none.
Rubrics for self-assessment: Ability to collect and analyze experimental data, Rubrics G1, G2, and G5 and Ability to conduct an application experiment, Rubrics D 7 and D8.

In this experiment [https://youtu.be/EDzdRHYDLeI] we used a pipette to put 4 drops of oil mixed with benzene on the surface of water. As the drops spread, benzene evaporates and only oil remains in the droplets.
a. Use the data that you can collect from the video to estimate the size of one molecule of oil. Note that the numbers on the ruler show centimeters.
b. State what assumptions you made to make your estimate.
c. Compare your estimate with the known values for the size of oil molecules.

2. Testing experiment: balloon in a jar

Goal: to make a prediction based on the hypothesis under test;
Equipment: none.
Rubrics for-self assessment: Ability to conduct a testing experiment C1, C4, and C7.
In the experiment in the video [https://mediaplayer.pearsoncmg.com/assets/_frames.true/secs-egv2e-testing-the-model-of-moving-gas-particles-pushing-on-the-surface], a partially inflated (and tied) balloon will be placed in the bell-jar and the air will be removed by the vacuum pump.
a. Use your knowledge of particles and their motion to make predictions about what the balloon will do when the air is pumped out of the bell-jar (state one prediction for each idea being tested). Write down your predicted outcome(s) and explain how your predictions are based on the hypothesis of particles and their motion.
b. Then watch the experiment. Which of your predictions was consistent with the experimental outcome? What is your judgment on each of the ideas you were testing?

3. Application experiments: the lowest possible temperature

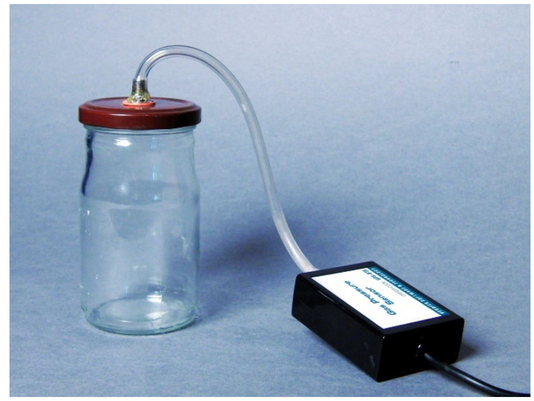
Goal: to estimate the lowest possible temperature using two independent methods and compare the results

Equipment: none

Rubrics for self-assessment Ability to conduct an application experiment D4, D5, D7, and D8.

Experiment 1:

You have an air-filled glass jar (height 11 cm), which is tightly closed and attached to a gas pressure sensor (see the photo on the right).



The glass jar is initially immersed in a water bath of temperature $T_1 = 23°C$. Then you successively immerse the glass jar in water baths of temperatures $T_2 = 1°C$ and $T_3 = 98°C$ and record the corresponding gas pressure once it reaches a stable value:

$$T_1 = 23°C \qquad P_1 = 98.8 \text{ kPa}$$
$$T_2 = 1°C \qquad P_2 = 90.6 \text{ kPa}$$
$$T_3 = 98°C \qquad P_3 = 122.6 \text{ kPa}$$

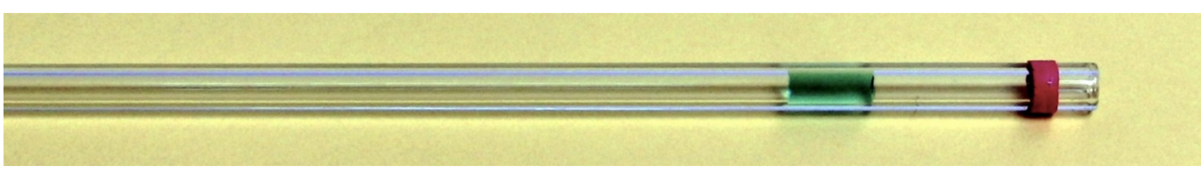
Assume the air in the jar can be modeled as an ideal gas.

a. Estimate the number of moles of air in the glass jar. (*Hint:* estimate the missing data from the photo).

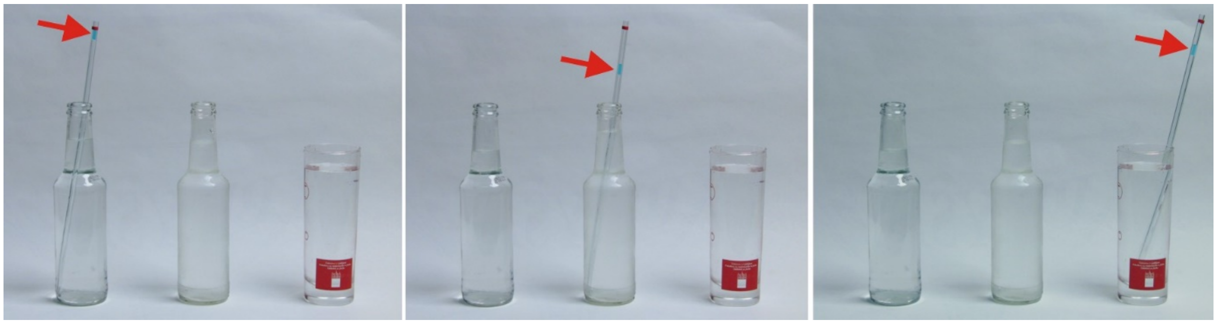
b. Plot three points in a pressure-versus-temperature graph for the equilibrium states reached during the experiment. Based on this graph, estimate the temperature of absolute zero (in degrees Celsius).

Experiment 2:

You have an air-filled glass tube with an inner diameter of 3.0 mm. One end is sealed and the other end is closed by a water drop that can move freely (see the photo below).



The tube is initially immersed in a water bath of temperature $T_1 = 59\ °C$. The length of the air column in the tube (between the sealed end of the tube and the lower surface of the water drop) is 273 mm. You successively immerse the glass tube in water baths of temperatures $T_2 = 6\ °C$ and $T_3 = 26\ °C$ and record the length of the corresponding air column (you should wait until the water drop stops moving). All three steps of the experiment are shown in the figures below.



You obtained the following data:

$$T_1 = 59°C \qquad L_1 = 273 \text{ mm}$$
$$T_2 = 6°C \qquad L_2 = 227 \text{ mm}$$
$$T_3 = 26°C \qquad L_3 = 239 \text{ mm}$$

Answer the following questions (assume the air in the glass tube can be modeled as an ideal gas).

a. Estimate the number of moles of air in the glass tube. Indicate any additional assumptions that you made.

b. Plot three points in a volume-versus-temperature graph for the equilibrium states reached during the experiment. Based on this graph, estimate the temperature of absolute zero (in degrees Celsius).

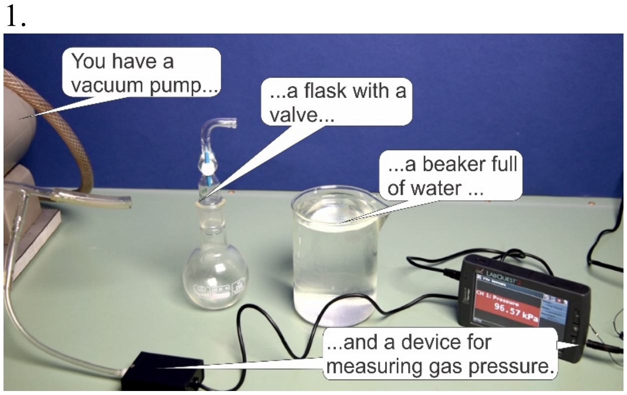
c. Compare the estimate of the absolute zero from this experiment to the estimate from the experiment 1. Are they the same or different? How do you know?

4. Application experiment: air and water

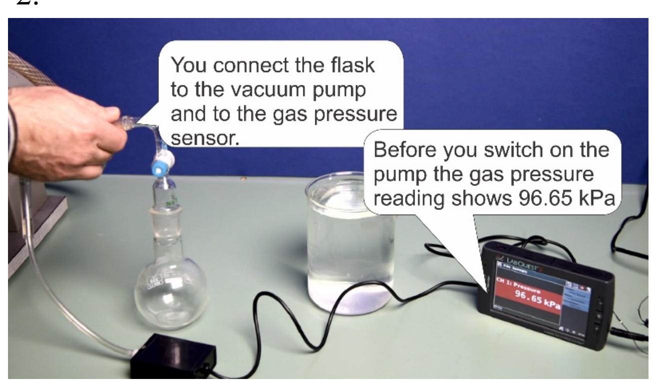
Goals: to collect data from available sources
Equipment: none
Rubrics for self-assessment: Ability to conduct an application experiment D4, D5, D7, and D8, Ability to collect and analyze data: G1, G2 and G5.

Part 1: Application experiment

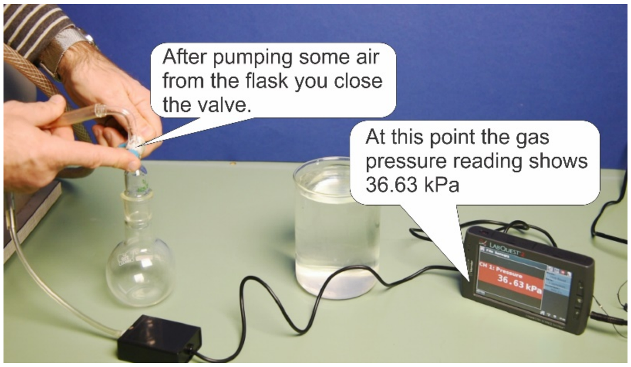
1.



2.



3.

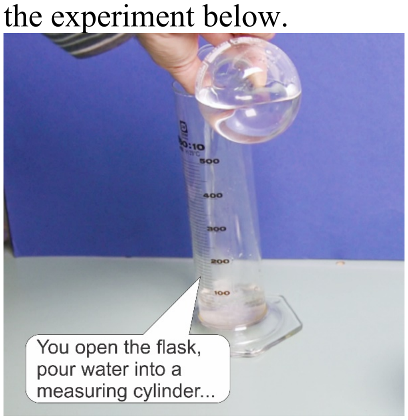


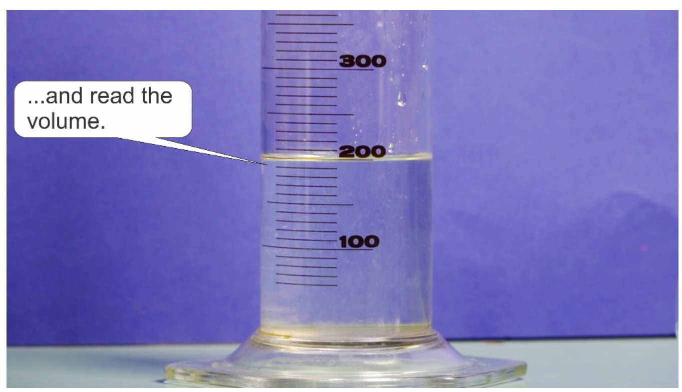
4.

a. You determined that the total volume of the flask with the part before the valve is 320 ± 3 ml. In the manual of the gas pressure sensor, you found that the instrumental uncertainty of the gas reading is $\pm$ 3 kPa .

b. Determine how much water will flow into the flask. Your result should include the experimental uncertainty. Indicate any assumptions that you made. Show all steps of your work.

c. Compare your prediction about how much water will flow into the flask with the outcome of the experiment below.





Note: each division on the cylinder represents 10 ml.

d. Is the result that you obtained in the first part of the activity consistent with the outcome of the experiment? If yes, explain how you know.

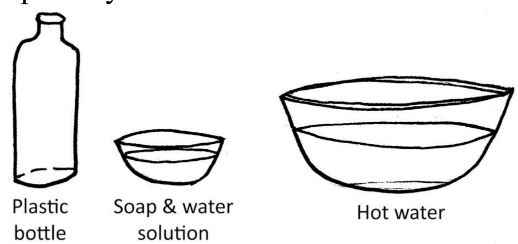
e. If it is not consistent, resolve any discrepancies and present the revised solution.

5. Observational experiment: soap bubbles

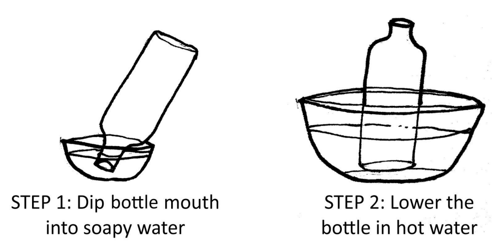
Goal: Apply knowledge of gas laws to analyze a new phenomenon

Equipment: Plastic water bottle (~0.5 liter and with the cap removed), a small container with clear dish-soap & water solution suitable for making bubbles (make sure the bubble solution doesn't foam), a larger container with hot water (around 50°C, the hottest water that you can tolerate if you put your hand in), a length measuring instrument such as a ruler, measuring cups, a thermometer if you have one.

Rubrics for self-assessment: Ability to collect and analyze data G1, G2, and G5, Ability to represent information in multiple ways A5 and A8.



a. Take the plastic bottle and dip the open mouth of the bottle into the container with soapy water (see figure below, step 1). Check if the thin film appears across the opening and that it remains intact. Do not squeeze the bottle! Then, lower the bottom of the bottle in the container with hot water so that water covers about one third of the bottle (see figure below, step 2). Again, make sure you do not squeeze the bottle. Watch the behavior of the soap film. Once it stops changing shape, use the length measuring instrument to measure the size of the new shape of the soap film (keep the bottle in the hot water container at all times). Take a picture if you can or make a video of the process! In addition, determine the total volume of the plastic bottle by using a measuring cup. Measure or estimate the air temperature in the room where you are performing the experiment. Estimate the uncertainty in all of your measurements.



b. Describe what you observe. Draw force diagrams for a small part of the film

- before the bottle is put into hot water
- as the bubble starts to expand
- when the bubble stops expanding.

c. Use the representations to explain why the film starts bulging out and why it stops bulging. Then, think of possible experiments to test your explanations. Describe the experiments and, if you have necessary equipment, carry them out. If you do not have the equipment, skip the testing experiment.

d. Estimate the temperature of hot water in which you placed the plastic bottle by using your previous measurements (the size of the bubble and the total volume of the plastic bottle). If you do not have the measurements, here are our measurements: total volume of the plastic bottle $V = 525\ \text{ml} \pm 5\ \text{ml}$, final diameter of the bubble $d_{\text{bubble}} = 35\ \text{mm} \pm 2\ \text{mm}$ and the ambient temperature was 25°C.

Indicate any assumptions that you made. Evaluate your result. In case you measured the temperature of hot water directly by using a thermometer, compare both results. Are the results consistent? Explain.