EXPERIMENT 9C

DETERMINATION OF THE IDEAL GAS CONSTANT, R

10-27-2021 WBH

MATERIALS: Gas bottle, 600 mL beaker, 25 x 150 mm test tube, preassembled stoppers and tubing for gas-tight connections, ring-stand (2), clamp (2), hose clamp, Bunsen burner, glass wool, pipet bulb, potassium chlorate, manganese (IV) oxide.

PURPOSE: The purpose of this experiment is (1) to measure the volume, temperature, and number of moles of oxygen gas generated by heating potassium chlorate and (2) use these values along with the atmospheric pressure measured with a barometer to calculate the ideal gas constant.

LEARNING OBJECTIVE(S): By the end of this experiment, the midshipmen should be able to demonstrate the following proficiencies:

1. Proper use of gas-collection apparatus and gas-tight connections
2. Proper use of an Eco-celli barometer
3. Determination of the partial pressure and volume of a gas collected over water
4. Application of the ideal gas law and stoichiometry to experimentally determine R.

FOR PRE-LAB ASSIGNMENT, see page 9C-7

BACKGROUND

The ideal gas law relates the physical properties of gases through the ideal gas constant (R). The properties accounted for in this law are pressure (P), volume (V), temperature (T) in Kelvin, and amount (moles = n). The amount of any gas is proportional to its pressure and volume, and inversely proportional to temperature.

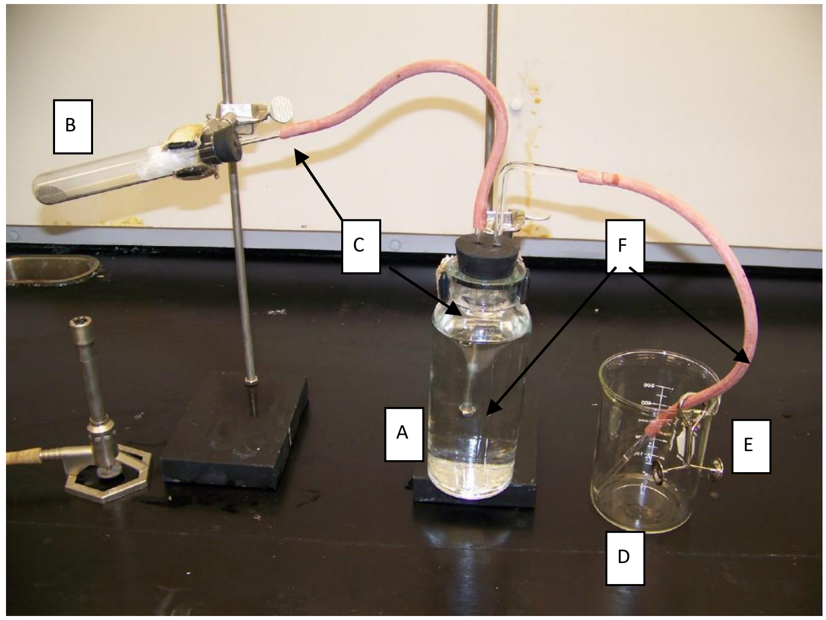
The value of the ideal gas constant R can be found experimentally by determining the number of moles of a gas that occupies a particular measured volume at a known pressure and temperature. This information is obtained in this lab by generating a known amount of oxygen gas via decomposition of potassium chlorate and collecting the gas over water.

The standard value of R varies depending on the units in which it is given; careful attention to (and understanding of) SI units and unit conversions is essential for success in this lab.

PROCEDURE

*** dispose of ALL solid waste in the receptacle provided in the instructor hood unless otherwise instructed***

1. Assemble the apparatus as shown in the following figure (1):



a.) The bottle (**A**) should be clamped at the neck and the test tube (**B**) held at a shallow angle and supported by a second ring stand. The bottle and test tube are connected by the gas inlet tubing (**C**).

b.) The bottle should be filled with water, and the beaker (**D**) filled with 100 mL of water.

c.) The pinch clamp (**E**) should be placed on the outlet siphon (**F**), as close to the end in the collection beaker as is practicable.

d.) Remove the test tube and ensure that it is dry inside, then insert enough potassium chlorate to fill the round bottom of the tube when held vertically (about **2.0 g**).

e.) Mix the potassium chlorate thoroughly with a pinch of manganese (IV) oxide (MnO_2), which acts as a catalyst.

f.) Insert a plug of glass wool into the mouth of the tube and weigh the tube and its contents on an ***analytical*** balance.

g.) Before replacing the test tube on the apparatus, open the pinch clamp (**E**) on the outlet siphon (**F**) and prime the siphon by forcing air into the inlet tube (**C**) *with a pipet bulb* until the entire outlet siphon tube is filled with water, then close the clamp to keep it primed. The whole length of **F** needs to be filled with water. Make sure the bottle is still at least 2/3 filled with water.

h.) Replace the test tube on the rubber stopper with a ***gentle twisting motion*** to insure a safe and gas-tight connection.

i.) With the outlet tube opening *under* the beaker water, raise the beaker so that the water in the beaker and in the bottle are at the same level, then open the pinch clamp. If the pressure in the bottle is greater than that of the atmosphere, water will flow from the bottle into the beaker. If the internal pressure is lower, water will be forced into the bottle by the atmosphere. After time to equilibrate (about 15 seconds) close the pinch clamp. The air in the test tube and the bottle is now at the prevailing barometric pressure.

j.) Empty the water from the collecting beaker (D) and replace the beaker before proceeding. Make sure the nozzle from tubing **F** is inside the collecting beaker.

Get instructor approval of your apparatus before proceeding.

Instructor's initials ____________

2. Open the pinch clamp. A few drops of water should run into the beaker, but no more. If a significant amount of water escapes, you have a leak. (If so, reset the apparatus and try again. Possible problems: the pinch clamp may be too far from the end of the siphon, the apparatus may not be effectively gas-tight, or the pressure in the bottle was not adjusted properly.) Otherwise, proceed to step 3.

3. Gently tap the tube containing potassium chlorate in order to distribute the solid along the side of the tube.

4. With the pinch clamp open, heat ***gently*** with a ***small*** flame that is moved back and forth under the test tube, gradually proceeding from the bottom toward the top of the tube as the chlorate melts and decomposes (Do not allow the rubber stopper to come in contact with the molten potassium chlorate or the flame!). Keep the rate of heating just sufficient to produce a steady flow of water from the nozzle into the beaker. If heating is too rapid, pressure will build up in the bottle and blow out the stopper. Stop heating when you have collected about **300 mL** of water in the collection beaker or when the water level in the bottle drops to around **two inches** above the siphon inlet in the bottle, whichever comes first.

5. With the pinch clamp ***open*** and the nozzle below the water level in the beaker, let the apparatus cool to room temperature. Keep the pinch clamp open and make sure the nozzle remains below the water level in the beaker while the test tube cools – some water will be pulled from the beaker back into the bottle by suction generated as the apparatus cools. (The test tube should feel as cool to the touch as the bottle before you can proceed to step 7.)

6. While the apparatus is cooling: (1) Read the barometer and measure the temperature of the water in the beaker; and (2) **Record your observations** of the heating process in the space provided (Data Section, p. 4)

7. When the test tube has cooled, observe the difference in the relative water levels in the bottle and the beaker. Slowly raise or lower the beaker (keeping the nozzle under water) until the level of water in the beaker is the same as that in the bottle; then close the pinch clamp. The mixture of oxygen and air in the test tube and the bottle is now at the prevailing barometric pressure.

8. Measure the volume of the water collected (equal to the volume of gas produced) using your graduated cylinder.

9. Weigh the test tube and its contents once again to find the weight of the oxygen evolved.

10. Repeat steps 1-9 again for a second set of results. There should still be enough unreacted $KClO_3$ remaining in the test tube (after the first heating) for a second trial. Assuming that you use the same tube for the second trial, the initial mass (Mass of tube with $KClO_3$ and MnO_2) for Data Set 2 will simply be the same value as the Mass of tube and reaction residue for Data Set 1.

Clean Up:

1. Dispose of all chemical waste in the designated waste container in the instructor hood.
2. Rinse any equipment with deionized H_2O if necessary.
3. Make sure areas near the balances are cleaned.

Name____________________________ Section____________________________

Partner____________________________ Date______________________________

Data Section
Experiment 9C

INCLUDE THE APPROPRIATE SIGNIFICANT FIGURES

	Data Set 1:	Data Set 2:
Mass of tube with $KClO_3$ and MnO_2 (g)		
Mass of tube and reaction residue after water has been collected (g)		
Volume of water collected (mL)		
Temperature of water collected (°C)		
Atmospheric Pressure		
Partial Pressure of H_2O		

Observation(s):

[1] Values for the vapor pressure of water at different temperatures can be found in the CRC Handbook, on a placard near the barometer in your laboratory, or on the Chemistry Department Plebe Chemistry website (Laboratory Resources/Other Appendices/Appendix K: Properties of Water).

DATA TREATMENT (show work in space provided)

1. Using the barometric pressure and the appropriate vapor pressure value for water, calculate the partial pressure of oxygen in the bottle for *each set of data*.

2. Calculate the number of moles of oxygen in the bottle for *each set of data*.

3. Calculate the value of R from *each set of data*, in $L \cdot atm \cdot mol^{-1} \cdot K^{-1}$. Show your work!

4. Average the R value of the two data sets.

QUESTIONS

1. Calculate the % error of your average value of R from the literature value given in your textbook.

2. The ideal gas constant, R, can be expressed with a variety of units. Convert your average value of R to the thermodynamic form, $J \cdot mol^{-1} \cdot K^{-1}$ (realize that this is equivalent to $L \cdot kPa \cdot mol^{-1} \cdot K^{-1}$, where 1 atm = 101.325 kPa).

3. Does the fact that air is present in the test tube prior to decomposing the $KClO_3$ affect the calculated value of R? Why or why not? Explain your answer.

4. Assume a student neglects to equilibrate the fluid levels in the bottle and collecting beaker ***after*** the reaction has stopped. If the level of the water in the collecting beaker is 2 inches above the liquid level in the bottle, will this affect the calculated value of R? Will your value be too high, too low, or unchanged? Explain your answer.

Name___________________________ Section___________________________

Date_____________________________

PRE-LAB ASSIGNMENT

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1. What is the mathematical expression of the ideal gas law?

2. Balance the following equation:

$$\_\_\_\_\_\_\ KClO_3\ (s) \xrightarrow{\Delta} \_\_\_\_\_\_\ KCl\ (s) + \_\_\_\_\_\ O_2\ (g)$$

3. Review the experimental procedure and examine figure (1). Then, answer these questions based on the following data: Initial weight of the test tube, including 2.0 g of potassium chlorate mixed with a pinch of MnO_2 catalyst, was 30.800 grams. After heating, the mass of the tube and reside was 30.500 grams.

   a) How many moles of $KClO_3$ (122.55 g/mol) were decomposed in the reaction?

   b) What substance(s) remain in the test tube after heating?

   c) How many moles of oxygen gas (O_2) were produced by the reaction?

   d) What is the relationship between volume of oxygen generated and volume of water collected in the beaker (pushed out of the bottle)?

   e) Besides the O_2 generated by the reaction, what *other* gas is also present the bottle? (remember that oxygen was bubbled through water)

   f) What is the relationship between the partial pressure of oxygen gas in the bottle (P_{O2}) and the atmospheric pressure in the room (P_{atm}), once the bottle and beaker water levels are matched (step 7)?