Experiment 9

DETERMINATION OF THE IDEAL GAS CONSTANT, R

MATERIALS:

600 mL beaker, 100 mL graduated cylinder, pyrex test tube fitted with a one-hole rubber stopper and glass elbow, 16 oz. glass bottle fitted with a two hole-rubber stopper, rubber tube, pinch clamp, glass wool, MnO_2, $KClO_3$.

DISCUSSION:

For an ideal gas, the volume, V, for a given mass of gas is directly proportional to its absolute temperature, T, and inversely proportional to its pressure, P. If n is the number of moles of gas, the relationship of volume, pressure and number of moles is given by the ideal gas law.

$$PV = nRT \tag{1}$$

where R is a proportionality constant. Solving for R,

$$R = \frac{PV}{nT}$$

R is known as the ideal gas constant. The units of R are energy per Kelvin per mole and its numerical value depends on the units used to express P and V. Thus, if P is in atmospheres and V is in liters, R will be expressed in liter-atmospheres per Kelvin per mole.

In this experiment, the value of R will be determined by measurement of pressure, volume, temperature and number of moles of a sample of oxygen gas which will be produced by the decomposition of $KClO_3$, potassium chlorate. The physical properties of oxygen, when measured at room temperature, closely resemble those of an ideal gas.

A sample of potassium chlorate will be placed in a test tube and heated to produce oxygen, O_2, gas. There is a loss of material in the test tube as the reaction proceeds because oxygen is liberated as a gas. The number of moles of oxygen liberated, n, can be expressed as

$$n = \frac{\text{loss of material in test tube}}{\text{molar mass of oxygen}}$$

The volume, V, occupied by the sample of oxygen produced will be measured by the displacement of water. For each mL of oxygen liberated, 1 mL of water will be displaced. The pressure of the sample, P, will equal the atmospheric pressure minus the pressure caused by the pressure of the water molecules in the gas phase (vapor pressure of water).

The temperature, T, of the gas will be measured with a thermometer when the system is in equilibrium with the surroundings. When n, V, P and T are all known, R may be calculated.

PROCEDURE:

Assemble the apparatus as shown in the diagram. The bottle should be clamped at the neck and the test tube supported only by the glass tubing. The bottle should be filled with water up to the neck. In the dry test tube place enough potassium chlorate to fill the round bottom of the tube when held vertically. Mix the potassium chlorate thoroughly with a pinch of manganese(IV) oxide, MnO_2, which acts as a catalyst. Put a plug of glass wool into the mouth of the tube and weigh the tube and its contents on an analytical balance. Before replacing the test tube on

the apparatus open the pinch clamp and blow through the open tube with a pipet bulb into the bottle until the entire rubber siphon tube is filled with water; then close the pinch clamp to keep it full. Replace the test tube on the rubber stopper with a twisting motion to insure a gas-tight connection. Dip the nozzle into a beaker of water, raise the beaker so that the water in the beaker and in the bottle are at the same level, and open the pinch clamp. If the pressure in the bottle is greater than atmospheric, water will flow from the bottle into the beaker; if less, water will be forced into the bottle by the atmosphere. After about 15 seconds close the pinch clamp, empty the beaker and replace it under the nozzle. The air in the test tube and the bottle is now at the prevailing barometric pressure. At this point have your instructor check your apparatus before proceeding.

Instructor's initials_____

Open the pinch clamp. A few drops of water should run into the beaker, but no more. If this does not happen, either the apparatus is not gas-tight or the pressure in the bottle was not adjusted properly.

Tap the tube containing potassium chlorate in order to distribute it along the side of the tube. With the pinch clamp open, heat gently with a small flame, gradually proceeding from the bottom along the tube as the chlorate melts and decomposes (Do not allow the rubber stopper to come in contact with the molten potassium chlorate). Keep the rate of heating just sufficient to produce a small 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.

When the level of the water in the bottle is about one inch from the end of the siphon tube, stop heating. 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. (The test tube should feel as cool to the touch as the bottle.)

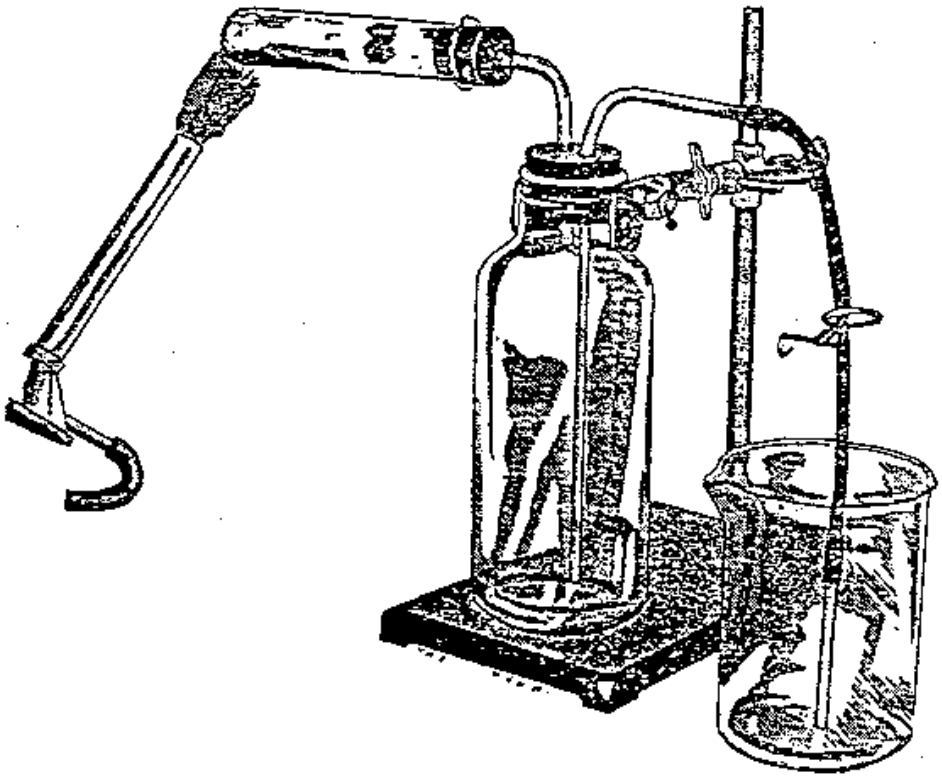
While the apparatus is cooling, read the barometer and measure the temperature of the water in the beaker.

When the test tube has cooled, slowly raise or lower the beaker (keeping the nozzle under water) until the level of water in it 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.

The volume of oxygen evolved, measured at barometric pressure and room temperature over water, is equal to the volume of water pushed over into the beaker. Measure the volume of the water collected using your graduated cylinder. Weigh the test tube and its contents once again to find the weight of the oxygen evolved.

If time permits, do a second trial.

**Dispose of the potassium chlorate in the proper waste area, not in the trash can.



Name _____ Section _____

Partner _____ Date _____

DATA SECTION
Experiment 9

Analytical balance number: _____

Mass of test tube, $KClO_3$, MnO_2 and glass wool	Trial 1	Trial 2
Before heating	_____	_____
After heating	_____	_____
Mass of oxygen evolved	_____	_____
Moles of O_2 gas evolved, n	_____	_____
Temperature of oxygen, T	_____	_____
Barometric pressure	_____	_____
Vapor pressure of water at T[1]	_____	_____
Pressure of "dry" oxygen, P	_____	_____
Volume of oxygen (volume of water collected), V	_____	_____

[1] Values for the vapor pressure of water are given in Appendix K.

DATA TREATMENT
Experiment 9

1. a. Calculate the value of R in units of liter-atmospheres per K per mole from your data. Show your work. Be sure to include units.

Trial 1

Trial 1: _____

Trial 2

Trial 2: _____

b. Calculate the average of your two R values.

Average: _____

c. Calculate the % deviation of your average value of R from the literature value.

_____ %

2. Calculate the volume per mole of oxygen under the conditions of the experiment. (Use your average value of R.)

_____ liters/mole at _____ °C and _____ atm

3. Calculate the volume per mole of oxygen at STP conditions. (Use your average value of R.)

_____ liters/mole at _____ °C and _____ atm

Questions:

1. a. As indicated in the discussion section on page E9-1, the units of the ideal gas constant, R, are energy per Kelvin per mole. At times, it is necessary to use the ideal gas constant in units of Joules per Kelvin per mole. Using your average value of R and the conversion of 1 liter-atm = 101.27 J, calculate the value of R in units of J/mole-K.

   b. Calculate the % error of your value of R determined in part a from the literature value of R in J/mole-K.

2. How would the value of R be affected if all the potassium chlorate does not decompose? Will your value be too high, too low or unchanged? Explain your answer.