Online Activity 5

Calculating the Ideal Gas Constant

Introduction

An **ideal gas** is a gas with no attractive forces between the gas particles and in which the gas particles have no volume. While no gas with these properties actually exists, gases often exhibit amazingly ideal behavior, thus allowing us to treat many gases as ideal gases with negligible error.

<u>The Ideal Gas Law</u>

The advantage of having gases behave ideally is that you can use the ideal gas law to predict the behavior of a gas under experimental conditions.

Ideal Gas Law: **PV= nRT**

P is the pressure in atmospheres
V is the volume in liters
n is the number of moles
T is the temperature in kelvin of the gas (K = °C + 273.15)
R is the ideal gas constant; in this lab we will use R with units of L atm/mol K

There are 2 limitations that must be met before a gas will behave ideally.

1. The pressure must be near atmospheric pressure or less. At this pressure, the atoms or molecules are spread out throughout the container and the effects of intermolecular attraction and atomic/molecular size are minimized.

2. The temperature must be approximately 100°C or more above the substance's boiling point to increase the rate of molecular movement to the point that the attractive forces become negligible

If these conditions are met a gas will behave nearly ideally and you can apply the ideal gas law.

<u>The Ideal Gas Constant, R</u>

The **ideal gas constant, R**, is derived from the ideal gas law with the following settings: P= 1atm, V= 22.4L (volume of 1 mole of gas at 1 atm), n= 1mol and T= 273.15K (0°C). Under these conditions, the calculated value of R is 0.08206 L•atm/mol•K. The value of **R** can be determined experimentally by measuring the other variables in the Ideal Gas Law equation, and solving for **R**. **R** is the same for all ideal gases. In this experiment, you will calculate the value of R experimentally. You will generate hydrogen gas by dissolving magnesium metal in aqueous hydrochloric acid. The balanced equation for this reaction is given below.

$$Mg(s) + 2\ HCl(aq) \rightarrow Mg^{2+}(aq) + H_2(g) + 2Cl^-(aq)$$

From the balanced equation, you can see that for every mole of magnesium metal used, 1 mole of hydrogen gas is produced. By measuring the mass of the magnesium used in the experiment, you can calculate the number of moles of Mg used, and thus determine the number of moles of hydrogen gas produced, n. The temperature, T, is measured with a thermometer, the pressure, P, can be calculated from the atmospheric pressure and the vapor pressure of water, and the volume of hydrogen gas produced, V, is measured experimentally after the reaction is complete. With these four pieces of information, you can calculate R, where R=PV/nT.

Calculation of n, V, P and T

Determining moles, volume, temperature, and pressure of H_2 gas

The moles of hydrogen produced, **n**, can be determined directly from the mass of magnesium metal, which will be provided to you. You will hold the volume constant in your simulation, and record the changes in temperature and pressure based on the number of moles that you input into the simulation. Once you have all of the variables, you can solve for the ideal gas constant.

In This Activity

For this week's experiment, you will be using a Phet simulation, developed by the University of Colorado at Boulder, to generate the data that you will use to solve for the Ideal Gas Constant, R. You will be starting with given masses of Magnesium. The masses that you will use for your four "trials" are 1,349.0g, 2,023.5g, 2,698.0g, and 3,372.5g. You will need to take these masses and convert them into a number of moles. Once you have the moles of magnesium, you will convert these values into moles of hydrogen gas. Once you have the moles of hydrogen gas, follow the link in the procedure to the Gas Properties Phet Simulation. You will use the simulation to "measure" the temperature and pressure of the "hydrogen gas" at a fixed volume. Once you have your temperature and pressure values, you will use the Ideal Gas Law to calculate the value of the constant, R.

Online Activity 5: Procedures and Data Sheet
(Submit as part of your informal report)

1. Calculate the number of moles of magnesium contained in the masses provided:

Trial 1: 1,349.0g — Moles Trial 1: ____________

Trial 2: 2,023.5g — Moles Trial 2: ____________

Trial 3: 2,698.0g — Moles Trial 3: ____________

Trial 4: 3,372.5g — Moles Trial 4: ____________

2. Use the balanced chemical equation to calculate the number of moles of H_2 gas for each trial.

Moles H_2 Trial 1: ____________

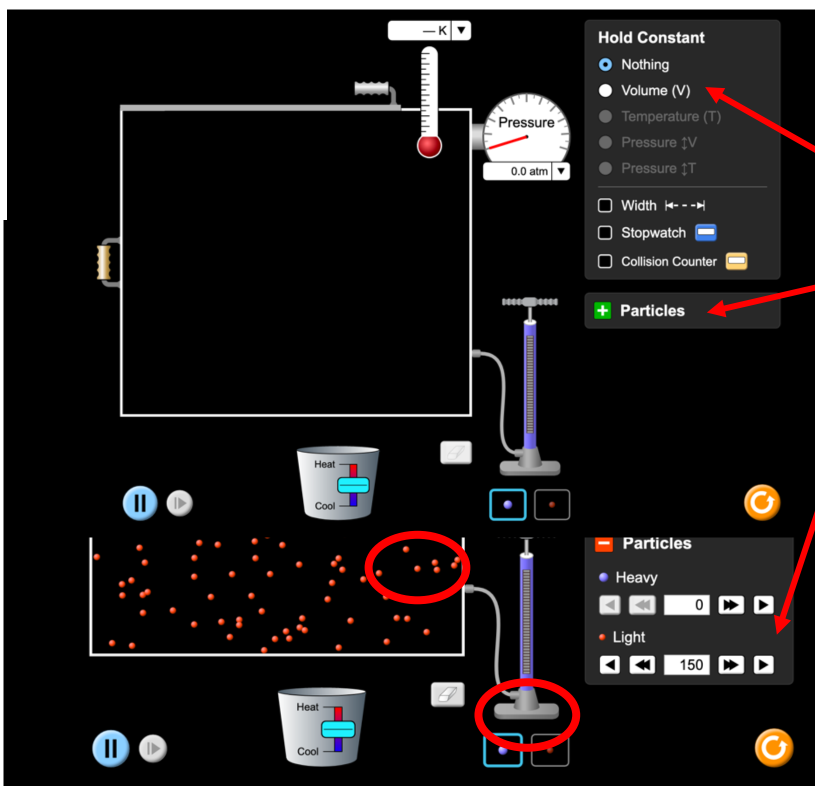
Moles H_2 Trial 2: ____________

Moles H_2 Trial 3: ____________

Moles H_2 Trial 4: ____________

3. Go to the Gas Properties Phet Simulation at the following address:

https://phet.colorado.edu/sims/html/gas-properties/latest/gas-properties_en.html



Select the Ideal Gas option, and you should see a simulation that looks like the image at left. Start by changing the "hold constant" selection to volume, then click by the plus sign in the green box next to particles.

You will be using the "light" particles, because the mass of a hydrogen molecule is quite small. Use the arrows to add the number of moles of gas molecules that you calculated for your first trial. The double arrows add particles in groups of 50 mol, the single arrow adds smaller amounts.

4. Once you have added particles, you will see temperature and pressure values. The temperature should be about 300K. The pressure will vary depending on the number of particles added. Record the temperature and the pressure for each number of moles of H_2 added. The pressure will fluctuate, but just try to pick a value in the middle of the range of values shown.

Trial 1: Temp: ______________ Pressure: ________________

Trial 2: Temp: ______________ Pressure: ________________

Trial 3: Temp: ______________ Pressure: ________________

Trial 4: Temp: ______________ Pressure: ________________

5. The volume, 212 L, has been pre-recorded on the attached data and report sheets. Use the moles of H_2, the temperature, the volume, and the pressure to calculate a value of R for each of your four trials, then calculate the average value of R.

Online Activity 5: Data Rubric (20pts)

Points

Data are neat and legible	5pts	_________pts
Significant figures (>80% correct)	3pts	_________pts
Units (>80% correct)	2pts	_________pts
All data are present and make sense	10pts	_________pts

Deductions (sliding scale based on TA discretion)

Lab area left unclean	-20pts	_________pts
Improper waste disposal	-20pts	_________pts
Disruptive behavior	-20pts	_________pts
Lab coat or safety glasses removed while in lab	-20pts	_________pts
Data sheet is missing TA signature	-20pts	_________pts
Other: ____________________________________		_________pts

Comments: ____

Grade for Data Sheet **_________pts**

Online Activity 5: Results Table
(**Submit as part of your Online Activity Report**)

Name: ____________________ Date: ________ Section: ________

Record all results with the correct number of significant figures and units

Gas Law Calculation Results

	Trial 1	Trial 2	Trial 3	Trial 4
Mass of magnesium				
Moles of magnesium				
Moles of hydrogen gas				
Pressure of hydrogen gas				
Volume of hydrogen gas	**212L**	**212L**	**212L**	**212L**
Temperature of hydrogen gas				
Ideal Gas Constant (R)				
Average R value				
Percent Error in Average R value				

Online Activity 5: Results Table Rubric (20pts)

<u>**Points**</u>

Tables are neat and legible	5pts	__________pts
Significant figures (>80% correct)	3pts	__________pts
Units (>80% correct)	2pts	__________pts
All results are present and make sense	10pts	__________pts

<u>**Deductions (sliding based on TA discretion)**</u>

Results to not match data	-20pts	__________pts
Plagiarism!!! Results are identical to another student	**-100pts**	**__________pts**

Other: ____ __________pts

Comments: ____

Grade for Results Table **__________pts**

Online Activity 5: Calculations

(Submit as part of your Online Activity report)

Moles of magnesium used

Show the calculations for the moles of magnesium that you recorded in the data section:

Trial 1: 1,349.0g — Moles Trial 1: ____________

Trial 2: 2,023.5g — Moles Trial 2: ____________

Trial 3: 2,698.0g — Moles Trial 3: ____________

Trial 4: 3,372.5g — Moles Trial 4: ____________

Moles of hydrogen produced (n)

Show the calculations Use the mole ratio from the balanced chemical equation to convert the moles magnesium into moles of H_2 gas.

$$Mg(s) + 2\ HCl(aq) \rightarrow H_2(g) + MgCl_2(aq)$$

Moles H_2 Trial 1: ____________

Moles H_2 Trial 2: ____________

Moles H_2 Trial 3: ____________

Moles H_2 Trial 4: ____________

Determination of the ideal gas constant (R)

Calculate the ideal gas constant, (R), by using the values for P, V, n and T that you calculated above in the Ideal Gas Law equation (PV = nRT). Perform this calculation for each of your 4 trials.

R value Trial 1: ____________

R value Trial 2: ____________

R value Trial 3: ____________

R value Trial 4: ____________

Average Experimental R Value
Calculate the average R value from your four trials.

Average Ideal Gas Constant _______________

Percent Error
See the Density lab for the percent error equation. Use the average experimental value of R for the experimental value and 0.08206 L atm/mol K for the actual value of R.

Percent error in R value _______________

Online Activity 5: Additional Questions
(Submit as part of your Online Activity report)

- Record all values with the correct number of significant figures and units.
- Place all answers on the line when provided.
- Show calculations for any numerical answers; **work must be shown to receive credit**.

You have the following reaction: $Mg(s) + 2\ HCl(aq) \rightarrow Mg^{2+}(aq) + H_2(g) + 2Cl^{-}(aq)$. Answer the following questions with the data given. The hydrogen gas is collected above the aqueous acid solution in an inverted graduated cylinder.

Moles of Mg metal:	0.0033mol
Temperature of gas	28.0°C
Atmospheric pressure:	1.02 atm.

1. What mass of magnesium metal (in mg) is present?

____

2. How many moles of hydrogen gas can be produced from the magnesium metal? Show work!

____

3. What is the pressure of the hydrogen gas in the graduated cylinder? (The gas is collected over water. The atmospheric pressure contains both the H_2 gas and water vapor – you will need to subtract out the vapor pressure of water. A table of water vapor pressures at different temperatures is provided below.)

____

4. How many milliliters of hydrogen gas will be produced?

____

5. Which of the values given determines the number of significant figures needed for your answer for question 4?

____

6. What do all the letters represent in the ideal gas law: PV = nRT.

P_______________ V_______________ n_______________ R_______________ T_______________

7. What 2 requirements must be met to assume a gas will act in an ideal way?

____

____

Vapor Pressure of Water at Different Temperatures

Temp. (°C)	Pressure (kPa)	Pressure (atm)	Pressure (torr)	Temp. (°C)	Pressure (kPa)	Pressure (atm)	Pressure (torr)
15	1.71	0.0169	12.8	23	2.80	0.0276	21.0
16	1.81	0.0179	13.6	24	2.99	0.0295	22.4
17	1.93	0.0190	14.5	25	3.16	0.0312	23.7
18	2.06	0.0203	15.5	26	3.36	0.0332	25.2
19	2.20	0.0217	16.5	27	3.59	0.0354	26.9
20	2.33	0.0230	17.5	28	3.77	0.0372	28.3
21	2.48	0.0245	18.6	29	4.00	0.0395	30.0
22	2.64	0.0261	19.8	30	4.24	0.0418	31.8