Chem 108: Lab

Week 15

Sign in
Pick up Papers
Choose a partner for today's experiment

Chem 108: Lab

Due Today:

Acid-Base Titration

Complete Individual Report form pp.94-96.

Include clear calculations with units.

Name: ______________________

Section: __________

Report Form – Acid Base Titration

Part 1–Standardization of NaOH Solution

Molarity of HCl used	
Titration	
Base buret, final re	
Base buret, initial r	
Volume of base us	
Molarity of NaOH (	
Average molarity o	

Show the calculations fo
for one titration.

Part 2–Determination of Unknown Acid

Unknown code						
Average Molarity of Base from Part 1			0.2099 mol/L			
Titration	1	2	3	4	5	6
Base buret, final reading (mL)						
Base buret, initial reading (mL)						
Volume of base used (mL)*						
Molarity of unknown acid (M)*						
Average molarity of unknown (M)*			M			

Show the calculations for each of the entries in the Data Table marked with * on the calculations page for one titration.

Unkown Acid Neutralization

Net Ionic Equation/ Calculation

$$H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$$

acid base water

25.00 mL of $M_{H+\ aq}$ = ? (unknown acid solution) was titrated with a sodium hydroxide solution, M_{OH-} = ? 0.2162 M. It required 24.20 mL as an average of three trials which were within +/- 0.20 mL to reach a faint pink color.

$$?M_{H+} = [M_{OH-} \times V_{OH-} / V_{H+}]\,[?\ mol_{H+} / ?\ mol_{OH-}]$$

$$= \frac{0.2162\ mol_{OH-} \times 0.02420\ L_{OH-} \times 1\ mol_{H+}}{L_{OH-} \times 0.02500\ L_{H+} \times 1\ mol_{OH-}} = 0.2093\ M_{H+}$$

Today's Experiment
Gas Stoichiometry

http://chemconnections.org/general/chem108/Magnesium-Zinc-wo.1.mov

Experimentally Determining Moles of Hydrogen

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

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

Using Partial Pressures

the Ideal Gas Law & Stoichiometry

Dr. Ron Rusay

- Refer to the Procedure section pp. 54-56. The following slides correspond to the instructions in the procedure.

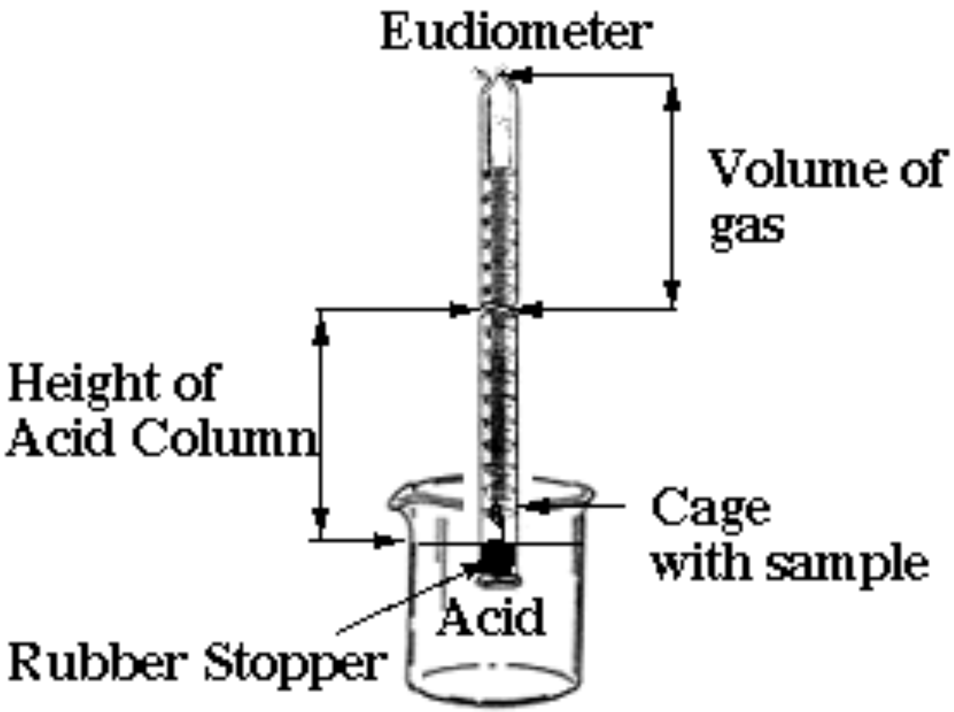
Chem 108/ Dr. Rusay

Equipment

100 mL eudiometer
buret clamp
red alcohol thermometer
ruler
ring stand
large beaker (at least 400 mL)
wash bottle w/ deionized water

Procedure

Refer to the on-line movie and the on-line notes for today's class, and then complete Part I of the Report Form. After completing Part I, obtain a metal sample envelope from Dr. R. Record its number and the mass of magnesium in the report form. Make a cage around the piece of magnesium using fine copper wire. First fold the ribbon several times to make it as compact as possible. NOTE: The cage must be tight enough so that the metal cannot fall out as it reacts and looses size. If too much wire is used and the cage is too tight, the reaction may be very slow. Leave a tail of copper wire about 10 cm long. Pour approximately 20 mL of dilute (6 M) hydrochloric acid into a clean 100 mL eudiometer. This does not need to be measured accurately nor does the exact volume need to be known. Carefully and slowly fill the rest of the eudiometer with deionized water so as to avoid mixing of the water and the acid. Insert the magnesium sample in the eudiometer so that it is ~ 10 cm from the stopper (when it is upside down) and fix its position by placing the copper wire tail against the wall of the eudiometer pressing against a one-hole rubber stopper as illustrated in the presentation. When inserting the rubber stopper, let the excess water come out through the hole. Make sure no air is trapped in the tube as it will later be measured as hydrogen gas causing error. Cover the hole in the stopper with your finger and invert the eudiometer in a large beaker partly filled with water and clamp it to a ring stand using a buret clamp. The acid solution, being denser than the water, mixes slowly and concentrates down the eudiometer until it reacts with the metal producing hydrogen gas.



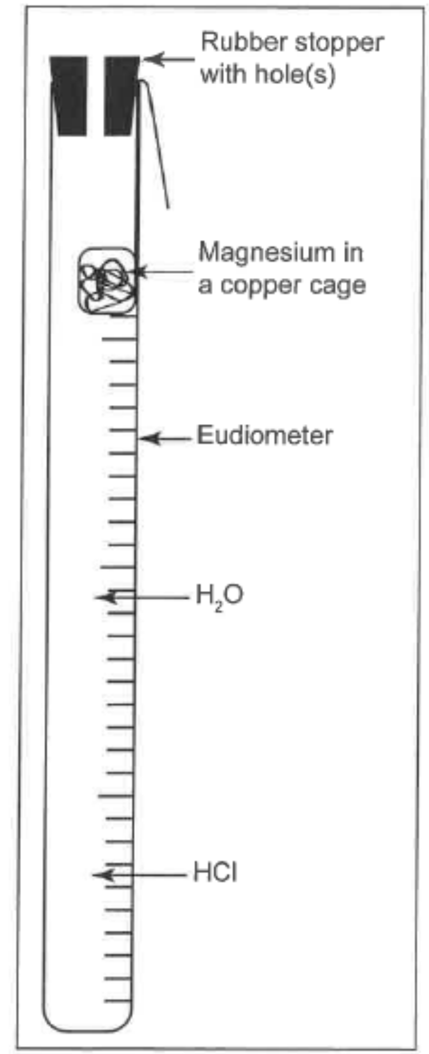
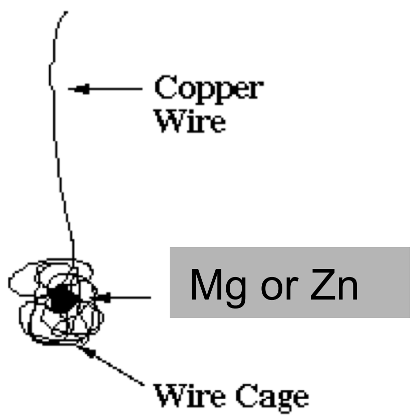
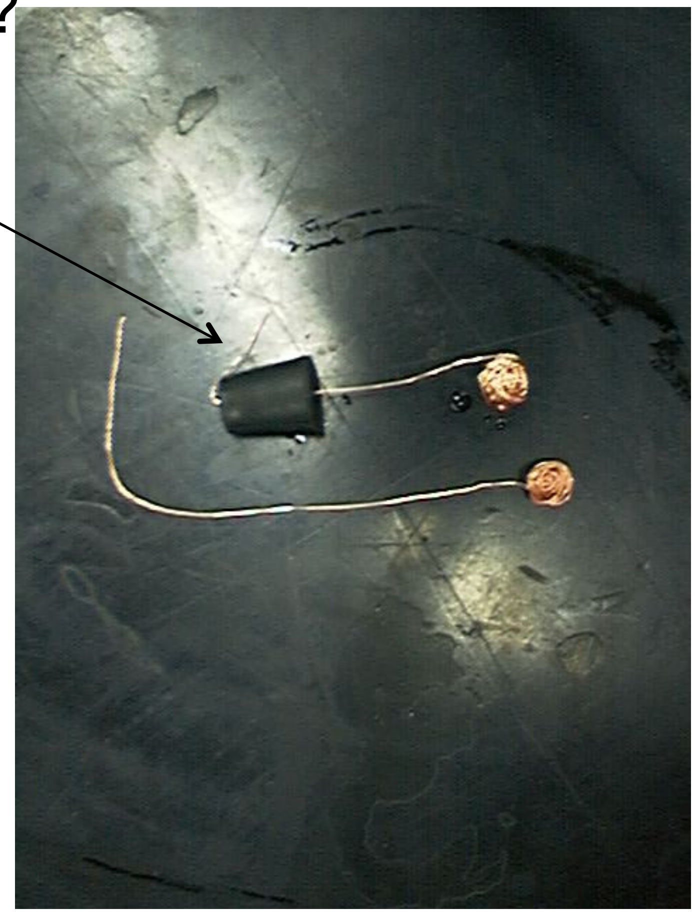


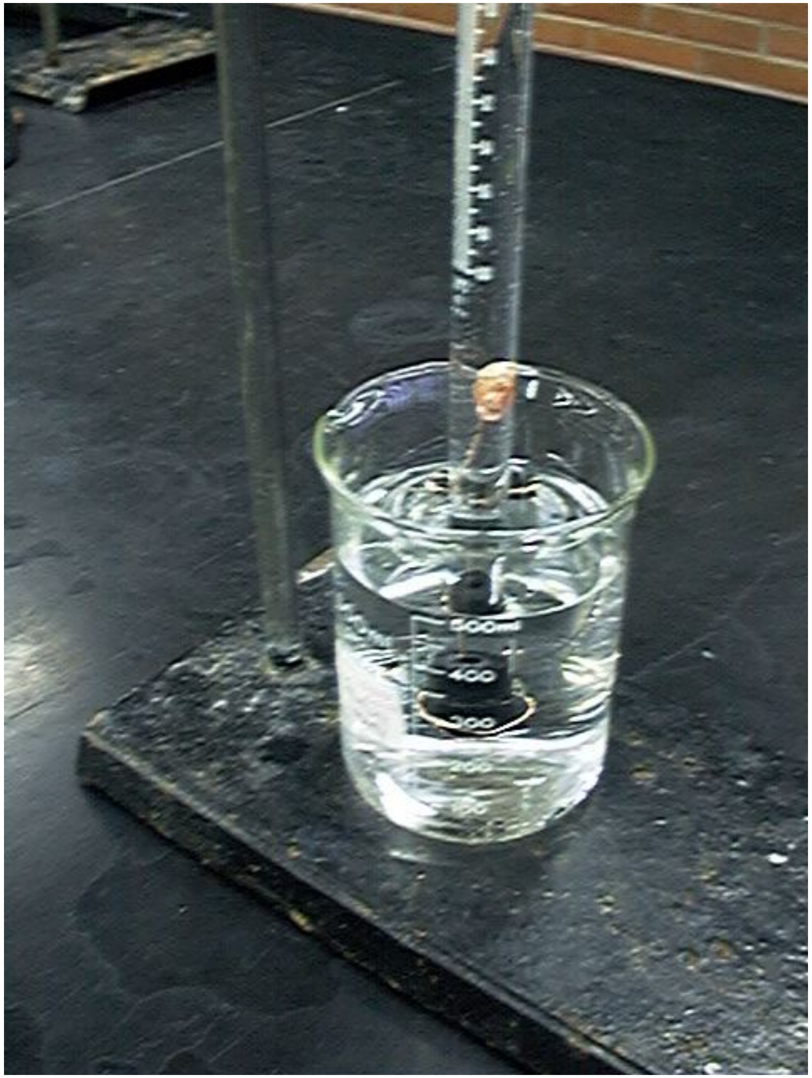
Figure 1–Eudiometer

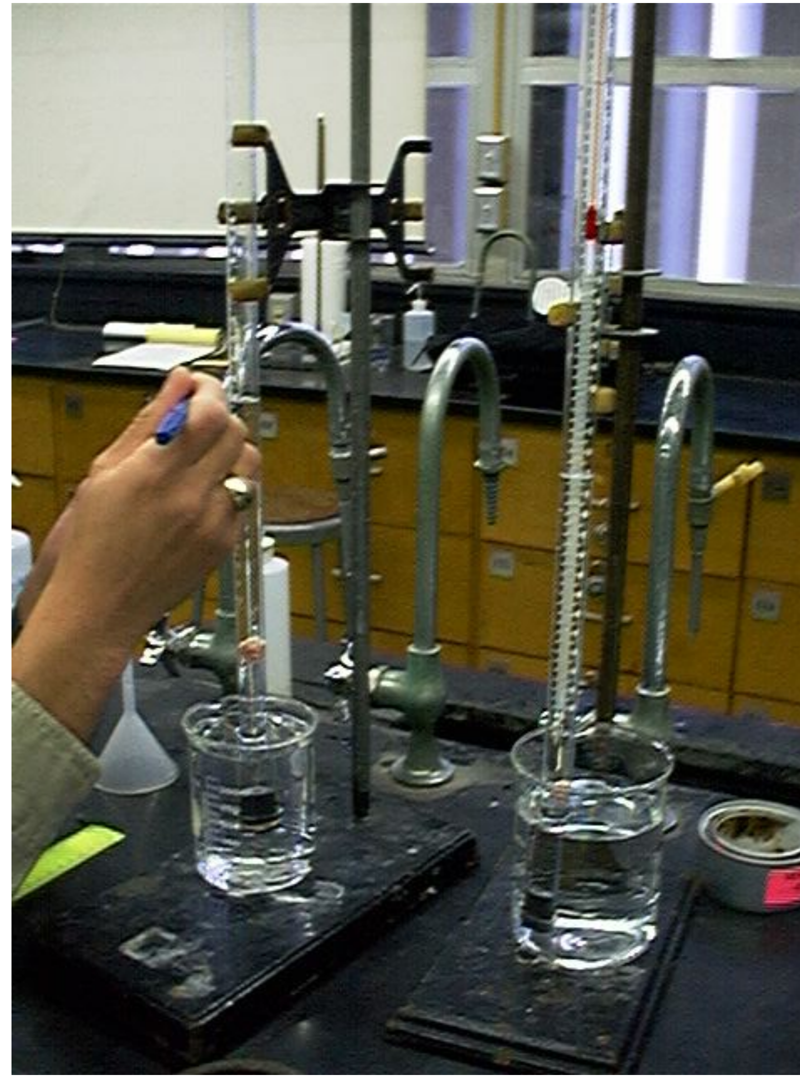
What is wrong with this set up?





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





$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

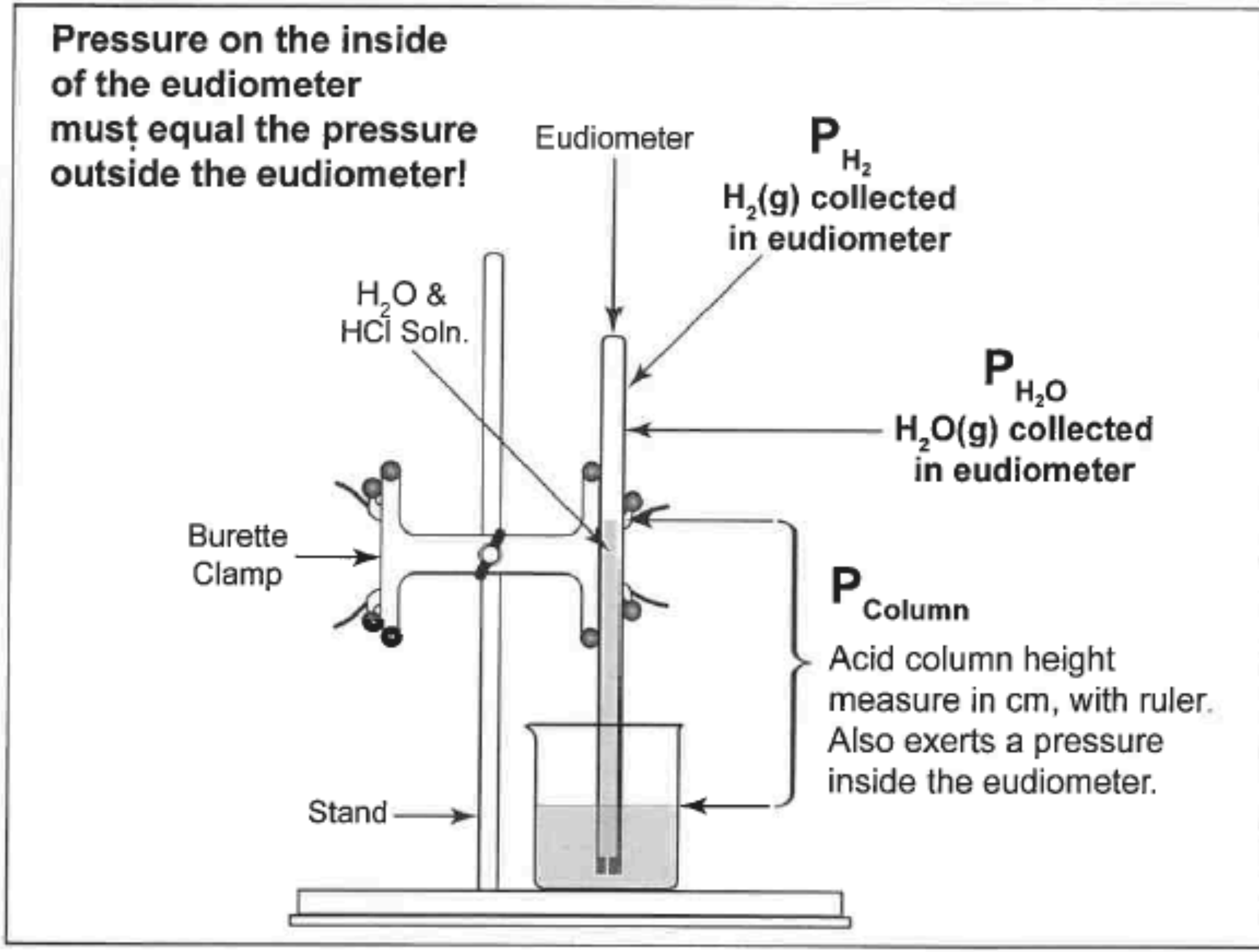

Pressure on the inside of the eudiometer must equal the pressure outside the eudiometer!
Eudiometer
P_{H_2}
$H_2(g)$ collected in eudiometer
H_2O & HCl Soln.
P_{H_2O}
$H_2O(g)$ collected in eudiometer
Burette Clamp
P_{Column}
Acid column height measure in cm, with ruler. Also exerts a pressure inside the eudiometer.
Stand

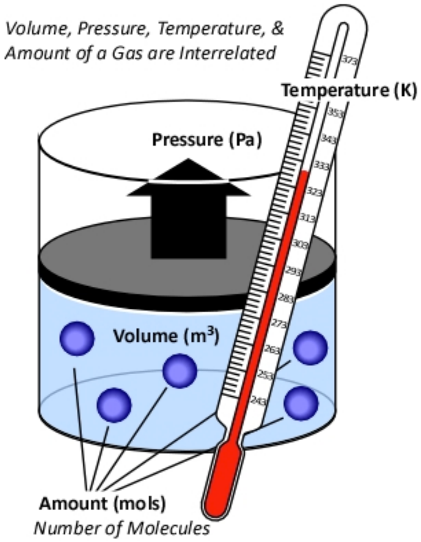
Figure 2

- Refer to the Gas Stoichiometry Report Form, pg. 58-59
- Experimental data is to be obtained for the reaction of a known mass of magnesium metal:

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

- The volume of hydrogen, pressure and temperature determined and recorded.
- Moles of hydrogen is calculated using Ideal Gas Law calculations, then calculating mass of the starting magnesium from the number of moles of hydrogen.

Background
Ideal Gas Law



PV = n RT

- **R = "proportionality" constant**
  = 0.08206 L atm K^{-1} mol^{-1}
- **P = pressure of gas in atm**
- **V = volume of gas in liters**
- **n = moles of gas**
- **T = temperature of gas in Kelvin**

Standard Conditions Temperature, Pressure & Moles

- "STP"

- For 1 mole of a gas at STP:
- P = 1 atmosphere
- T = **0°C (273.15 K)**
- The molar volume of an ideal gas is ***22.42*** liters at STP

Isobaric process: pressure constant
Isochoric process: volume constant
Isothermal process: temperature constant

IDEAL GAS LAW
$PV = nRT$
or
$V = \frac{nRT}{P}$

Boyle's law
(fixed n and T)
$V = \frac{\text{constant}}{P}$

$P_1 V_1 = P_2 V_2$
$P \uparrow \quad V \downarrow$

Charles's law
(fixed n and P)
$V = \text{constant} \times T$

$V_1 / T_1 = V_2 / T_2$
$V \uparrow \quad T \uparrow$

Avagadro's law
(fixed P and T)
$V = \text{constant} \times n$

$V_1 / n_1 = V_2 / n_2$
$V \uparrow \quad n \uparrow$

Combined Gas Law
$P_1V_1 / T_1 = P_2V_2 / T_2$

Standard Conditions (STP)
273 K, 1.0 atm,
R = 0.08206 L atm/ K mol
@STP
1 mole of any "ideal" gas has a volume of 22.4 Liters.

Hydrogen & the Ideal Gas Law

$$n_{H_2(g)} = PV / RT$$

- **n = moles $H_2(g)$**
- **P $H_2(g)$ = pressure of $H_2(g)$ in atm (mm Hg → atm)**
- **V = experimental volume (mL→ L)**
- **T = experimental temperature (^oC → K)**

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

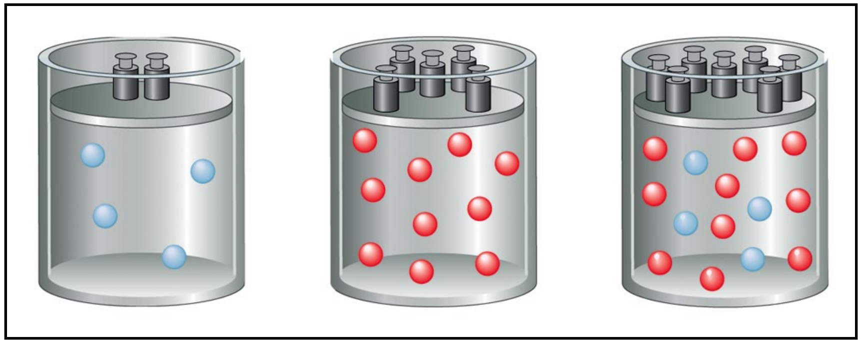
$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

Total Pressure:
Sum of the Partial Pressures

- For a mixture of gases, the total pressure is the sum of the pressures of each gas in the mixture.

$$P_{Total} = P_1 + P_2 + P_3 + \ldots$$

$$P_{Total} \propto n_{Total}$$



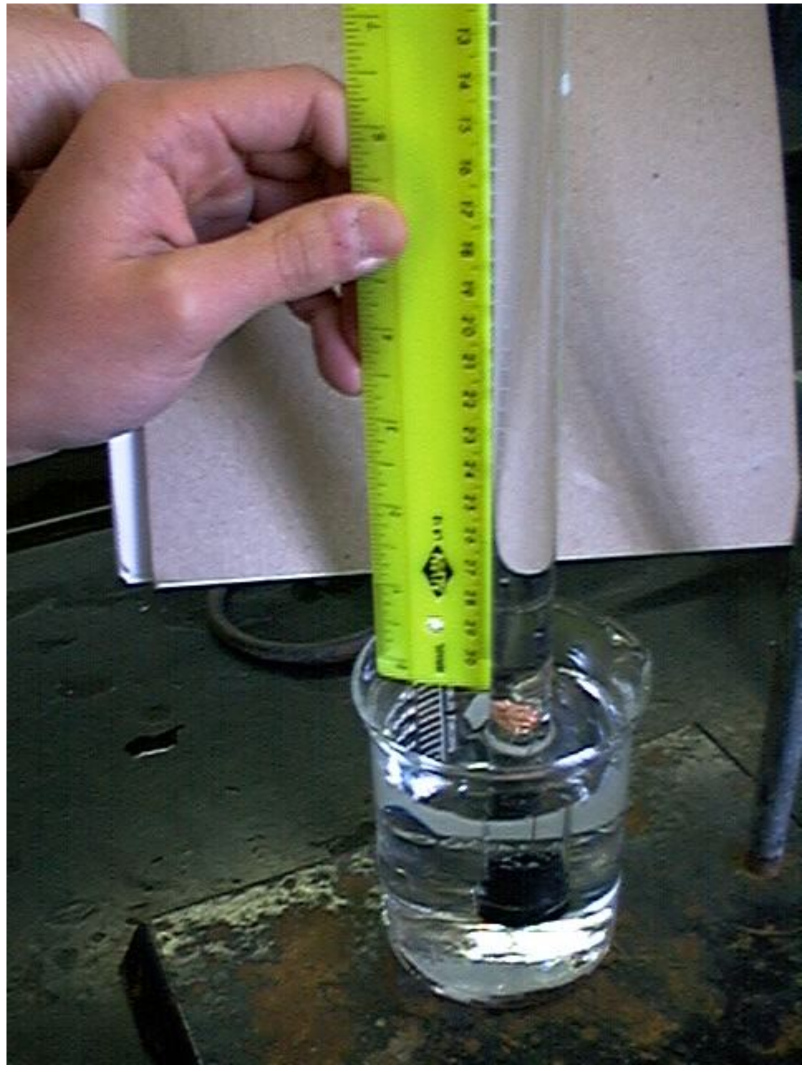
$$n_{Total} = n_1 + n_2 + n_3 + \ldots$$

•$P_{H_2(g)}$ = P Total (barometric) - $P_{H_2O\,(g)}$ [*TABLE*] - $P_{HCl\,(g)}$

P HCl (g) =

HCl Height (mm) ÷ 12.95

Density Hg is 12.95 times > density HCl(aq)



0.772 mm Hg/cm of acid solution

P HCl (g) =

HCl Height (mm) x 0.0772

Density Hg is 12.95 times > density HCl(aq)

Ideal Gas Law:
Moles / Avogadro's Law

$$n_{H_2(g)} = PV / RT$$

- **n = moles $H_2(g)$**
- **$P_{H_2(g)}$ = pressure of $H_2(g)$ in atm (mm Hg → atm)**
- **$P_{H_2(g)}$ = P Total (barometric) - $P_{H_2O(g)}$ [*TABLE*] - $P_{HCl(g)}$**
- **V = experimental volume (mL → L)**
- **T = experimental temperature (^oC → K)**
- **R** = **0.082057338** L atm K^{-1} mol^{-1} **(constant)**

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

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

- Refer to Report Form Part I: (Example uses Zinc.)

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

Mole Calculations:

- Stoichiometry Calculation
- Ideal Gas Law Calculations
- Comparison (% Error)

Complete Report Form with Calculations; Needed to get unknown Mg(s) sample(s).

Report Form – Gas Stoichiometry

Part I – Sample Data for Mass of Zinc

Chemical Reaction		
DATA COLLECTED		
Volume of hydrogen collected*	81.5 mL	L
Temperature of hydrogen	22.[illegible]	K
Barometric pressure*	29.98 in Hg	mm Hg
Height of solution in eudiometer from benchtop		19.2 cm
Height of solution in beaker from benchtop		10.0 cm
CALCULATIONS AND RESULTS		
Difference in liquid levels of solution in eudiometer and beaker*		
Aqueous vapor pressure at temperature of hydrogen		mm Hg
Pressure caused by acid column* (Difference in cm)*(0.772 mm Hg/cm)		mm Hg
Pressure of hydrogen alone*	mm Hg	atm
Moles of hydrogen*		moles
Moles of zinc*		moles
Mass of zinc (calculated)*		g

Show the calculations for each of the entries in the Data Table marked with * on the calculations page.

Question: If the mass of zinc used was 0.21 g, what is the percent error for your calculated mass of zinc? Show your work below.

Stoichiometry

Moles Hydrogen / Mass of Zinc

(Part I: Zinc Calculation)

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

$$\text{mol}_{H_2(g)} = \text{mol}_{Zn(s)}$$

mass (g) $_{Zn(s)}$ = mol Zn(s) x Molar Mass $_{Zn(s)}$

$$Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$$

Zinc Example Calculation

- Complete Report Form pg. 58 Part I:

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

Mole Calculations:

- Stoichiometry Calculation
- Ideal Gas Law Calculations
- Comparison (% Error)

Report Form – Gas Stoichiometry

Part I – Sample Data for Mass of Zinc

Chemical Reaction		
DATA COLLECTED		
Volume of hydrogen collected*	81.5 mL	L
Temperature of hydrogen*	22.0 °C	K
Barometric pressure*	29.98 in Hg	mm Hg
Height of solution in eudiometer from benchtop		19.2 cm
Height of solution in beaker from benchtop		10.0 cm
CALCULATIONS AND RESULTS		
Difference in liquid levels of solution in eudiometer and beaker*		
Aqueous vapor pressure at temperature of hydrogen		mm Hg
Pressure caused by acid column:* (Difference in cm)*(0.772 mm Hg/cm)		mm Hg
Pressure of hydrogen alone*	mm Hg	atm
Moles of hydrogen*		moles
Moles of zinc*		moles
Mass of zinc (calculated)*		g

Show the calculations for each of the entries in the Data Table marked with * on the calculations page.

Question: If the mass of zinc used was 0.21 g, what is the percent error for your calculated mass of zinc? Show your work below.

Moles : Ideal Gas Law

(Part I: Zinc Calculation Example)

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

$$n_{H_2(g)} = PV / RT$$

- **n = moles $H_2(g)$**
- **P $H_2(g)$ = pressure of $H_2(g)$ in atm (mm Hg → atm)**
- **P $H_2(g)$ = P Total (barometric) - P H_2O (g) [*TABLE*] - P HCl (g)**
- **V = experimental volume (mL→ L)**
- **T = experimental temperature (°C → K)**

R = **0.082057338** L atm K^{-1} mol^{-1}

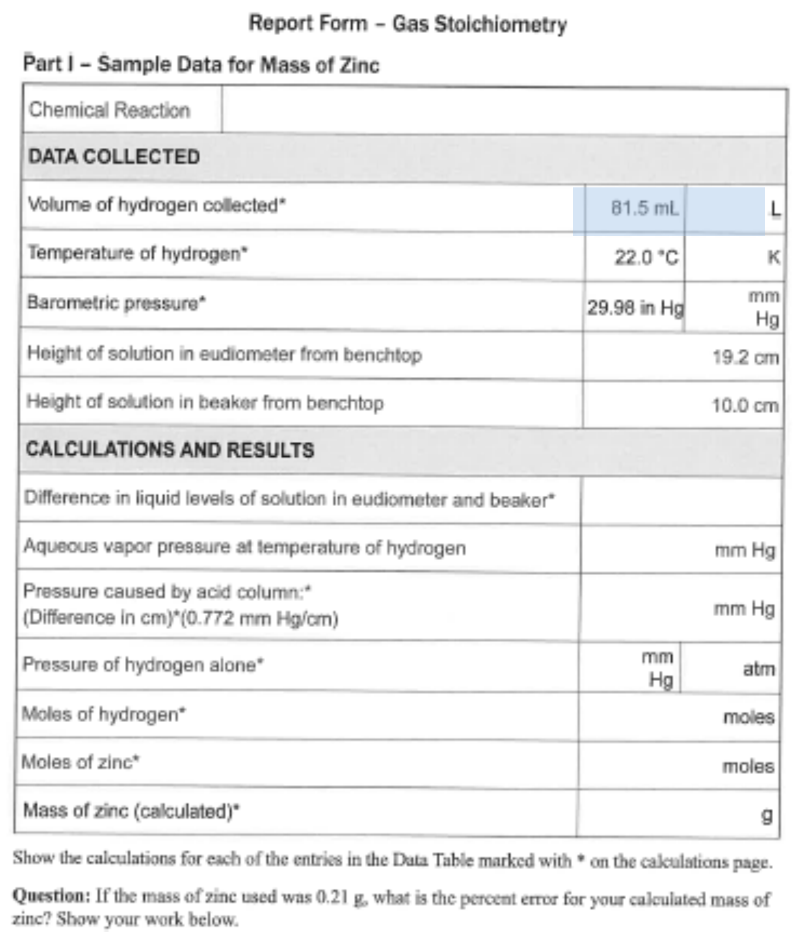
Moles : Ideal Gas Law

(Part I: Zinc Calculation Example)

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

$n_{H_2(g)} = PV / RT$

V = experimental volume (mL→ L)



Report Form – Gas Stoichiometry

Part I – Sample Data for Mass of Zinc

Chemical Reaction		
DATA COLLECTED		
Volume of hydrogen collected*	81.5 mL	L
Temperature of hydrogen*	22.0 °C	K
Barometric pressure*	29.98 in Hg	mm Hg
Height of solution in eudiometer from benchtop		19.2 cm
Height of solution in beaker from benchtop		10.0 cm
CALCULATIONS AND RESULTS		
Difference in liquid levels of solution in eudiometer and beaker*		
Aqueous vapor pressure at temperature of hydrogen		mm Hg
Pressure caused by acid column:* (Difference in cm)*(0.772 mm Hg/cm)		mm Hg
Pressure of hydrogen alone*	mm Hg	atm
Moles of hydrogen*		moles
Moles of zinc*		moles
Mass of zinc (calculated)*		g

Show the calculations for each of the entries in the Data Table marked with * on the calculations page.

Question: If the mass of zinc used was 0.21 g, what is the percent error for your calculated mass of zinc? Show your work below.

R = 0.082057338 L atm K^{-1} mol^{-1}

Moles : Ideal Gas Law

(Part I: Zinc Calculation Example)

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

$$n_{H_2(g)} = PV / RT$$

V = experimental volume (mL→ L)

T = experimental temperature (°C → K)

$$R = 0.082057338 \text{ L atm K}^{-1} \text{ mol}^{-1}$$

Report Form – Gas Stoichiometry

Part I – Sample Data for Mass of Zinc

Chemical Reaction			
DATA COLLECTED			
Volume of hydrogen collected*	81.5 mL		L
Temperature of hydrogen*	22.0 °C		K
Barometric pressure*	29.98 in Hg		mm Hg
Height of solution in eudiometer from benchtop			19.2 cm
Height of solution in beaker from benchtop			10.0 cm
CALCULATIONS AND RESULTS			
Difference in liquid levels of solution in eudiometer and beaker*			
Aqueous vapor pressure at temperature of hydrogen			mm Hg
Pressure caused by acid column:* (Difference in cm)*(0.772 mm Hg/cm)			mm Hg
Pressure of hydrogen alone*	mm Hg		atm
Moles of hydrogen*			moles
Moles of zinc*			moles
Mass of zinc (calculated)*			g

Show the calculations for each of the entries in the Data Table marked with * on the calculations page.

Question: If the mass of zinc used was 0.21 g, what is the percent error for your calculated mass of zinc? Show your work below.

Moles : Ideal Gas Law

(Part I: Zinc Calculation Example)

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

$$n_{H_2(g)} = PV / RT$$

V = experimental volume (mL → L)

T = experimental temperature (°C → K)

$P_{H_2(g)}$ = pressure of $H_2(g)$ in atm (mm Hg → atm)

$P_{H_2(g)}$ = P Total (barometric) - $P_{H_2O(g)}$ [*TABLE*] - $P_{HCl(g)}$

$$R = 0.082057338\ \text{L atm K}^{-1}\ \text{mol}^{-1}$$

Report Form – Gas Stoichiometry

Part I – Sample Data for Mass of Zinc

Chemical Reaction		
DATA COLLECTED		
Volume of hydrogen collected*	81.5 mL	L
Temperature of hydrogen*	22.0 °C	K
Barometric pressure*	29.98 in Hg	mm Hg
Height of solution in eudiometer from benchtop		19.2 cm
Height of solution in beaker from benchtop		10.0 cm
CALCULATIONS AND RESULTS		
Difference in liquid levels of solution in eudiometer and beaker*		
Aqueous vapor pressure at temperature of hydrogen		mm Hg
Pressure caused by acid column:* (Difference in cm)*(0.772 mm Hg/cm)		mm Hg
Pressure of hydrogen alone*	mm Hg	atm
Moles of hydrogen*		moles
Moles of zinc*		moles
Mass of zinc (calculated)*		g

Show the calculations for each of the entries in the Data Table marked with * on the calculations page.

Question: If the mass of zinc used was 0.21 g, what is the percent error for your calculated mass of zinc? Show your work below.

Moles : Ideal Gas Law

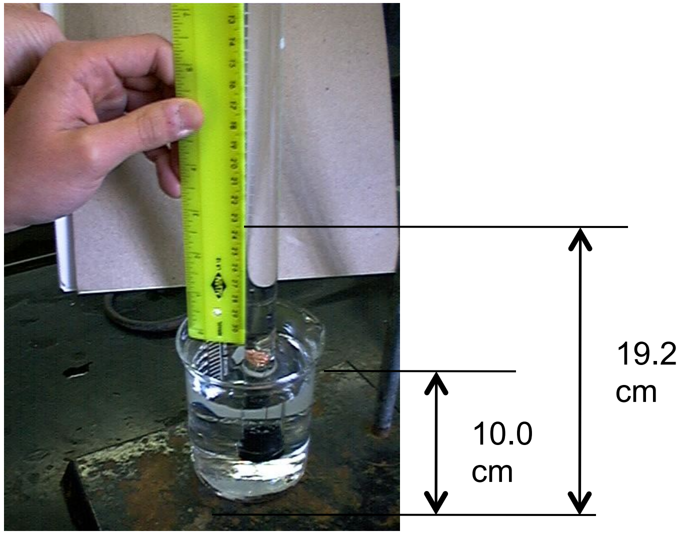
Part I: Hydrogen Calculation, (*Refer to Form's Data*)

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

$$n_{H_2(g)} = PV / RT$$

- **n = moles $H_2(g)$**
- **P $H_2(g)$ = pressure of $H_2(g)$ in atm (mm Hg → atm)**
- **P $H_2(g)$ = 29.98 inches Hg (barometric) - 19.8 mm Hg H_2O (g) [*TABLE*]**
  - P HCl (g)

P HCl (g)



R = **0.082057338** L atm K^{-1} mol^{-1}

• $P_{H_2(g)}$ = P Total (barometric) - $P_{H_2O(g)}$ [*TABLE*] - $P_{HCl(g)}$

P HCl (g) =

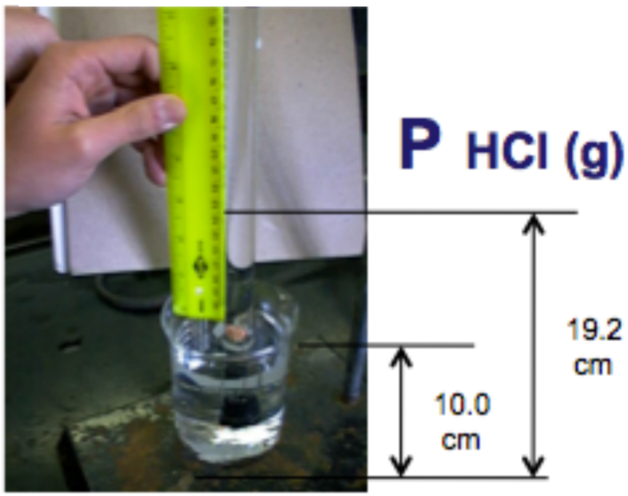
19.2 cm Hg - 10.0 cm Hg = 92 mm Hg

HCl Height (mm) ÷ 12.95

= 7.1 mm Hg

Density Hg is 12.95 times > density HCl(aq)

P HCl (g)



0.772 mm Hg/cm of acid solution

P HCl (g) =

19.2 cm Hg - 10.0 cm Hg = 92 mm Hg

HCl Height (mm) x 0.0772

= 7.1 mm Hg

Density Hg is 12.95 times > density HCl(aq)

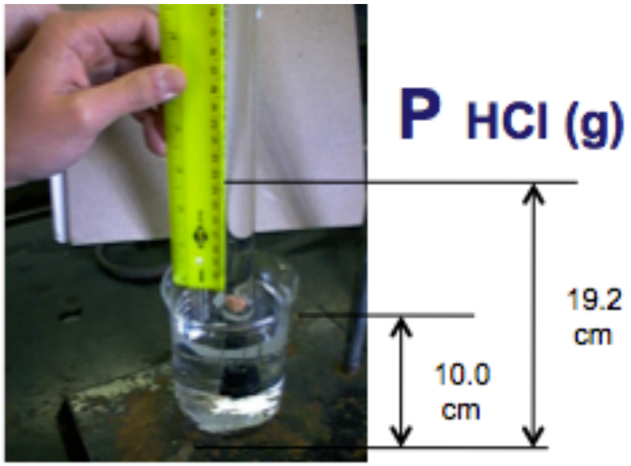
$P_{H_2(g)}$ = 761.5 mm Hg (barometric)

- 19.8 mm Hg H_2O (g) - 7.1 mm Hg HCl (g)

= 734.6 mm Hg

= 734.6 mm Hg / 760.0 mm Hg / 1.000 atm

= 0.9666 atm



Moles : Ideal Gas Law

(Part I: Hydrogen Calculation)

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

$$n_{H_2(g)} = PV / RT$$

- **n = moles $_{H_2(g)}$**
- **P $_{H_2(g)}$ = 0.9666 atm**
- **V = 0.0815 L**
- **T = 295.1 K**

R = **0.08206** L atm K^{-1} mol^{-1}

$n_{H_2(g)}$ = 0.00325 **moles** $_{H_2(g)}$ = 0.00325 **moles** $_{Zn(s)}$

% Error

Theoretical Mass Zinc vs. Experimental

(Part I: Calculation)

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

mass (g) Zn(s) = mol Zn(s) x Molar Mass Zn(s)

= 0.00325 moles Zn(s) x 65.37 g/mol **Zn(s)**

$$\textbf{\% Error} = \frac{\text{experimental grams Zn(s) - theoretical grams Zn(s)}}{\text{theoretical grams Zn(s)}} \times 100$$

$$= \frac{0.213\ \text{g} - 0.21\ \text{g}}{0.21\ \text{g}} \times 100$$

= 1.4 %

(Part II) Magnesium

$$Mg(s) + 2H^{+}(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$

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

Mole Calculations:

- Stoichiometry Calculation
- Ideal Gas Law Calculations
- Comparison (% Error)

Bring Report Forms to Dr. R Having Part I: Zinc (with calculations) completed to get unknown Mg(s) sample(s).

Name: ______________

Section: ________

Part II – Mass of Magnesium

Chemical Reaction		
DATA COLLECTED		
Unknown number		
Volume of hydrogen collected*	mL	L
Temperature of hydrogen*	°C	K
Barometric pressure*	inches Hg	mm Hg
Height of solution in eudiometer from benchtop	cm	
Height of solution in beaker from benchtop	cm	
CALCULATIONS AND RESULTS		
Difference in liquid levels of solution in eudiometer and beaker*	cm Acid Solution	
Aqueous vapor pressure at temperature of hydrogen	mm Hg	
Pressure caused by acid column:* (Difference in cm) * (0.772 mmHg/cm)	mm Hg	
Pressure of hydrogen alone*	mm Hg	atm
Moles of hydrogen*	moles	
Moles of magnesium*	moles	
Mass of magnesium*	g	

Show the calculations for each of the entries in the Data Table marked with * on the calculations page.

(Part II) Magnesium

$$Mg(s) + 2H^{+}(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$

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

Mole Calculations:

- Stoichiometry Calculation
- Ideal Gas Law Calculations
- Comparison (% Error)

Get equipment from stockroom and complete data acquisition for Part II.

Have individual Report Forms checked before leaving lab today.

Name: ________________

Section: ________

Part II – Mass of Magnesium

Chemical Reaction		
DATA COLLECTED		
Unknown number		
Volume of hydrogen collected*	mL	L
Temperature of hydrogen*	°C	K
Barometric pressure*	inches Hg	mm Hg
Height of solution in eudiometer from benchtop		cm
Height of solution in beaker from benchtop		cm
CALCULATIONS AND RESULTS		
Difference in liquid levels of solution in eudiometer and beaker*		cm Acid Solution
Aqueous vapor pressure at temperature of hydrogen		mm Hg
Pressure caused by acid column:* (Difference in cm) * (0.772 mmHg/cm)		mm Hg
Pressure of hydrogen alone*	mm Hg	atm
Moles of hydrogen*		moles
Moles of magnesium*		moles
Mass of magnesium*		g

Show the calculations for each of the entries in the Data Table marked with * on the calculations page.

Molar Mass of any Gas

(Hydrogen for example)

- $PV = n RT$
- n = g of gas/ MM_{gas} [MM_{gas} = g/mol]
- PV = (g of gas/ MM_{gas})RT
- MM_{gas} = g of gas/V (RT/P)

Density of gas

- MM_{gas} = g of gas/V (RT/P)
- MM_{gas} = density of gas (RT/P)