# Experiment / Simulation

# 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*

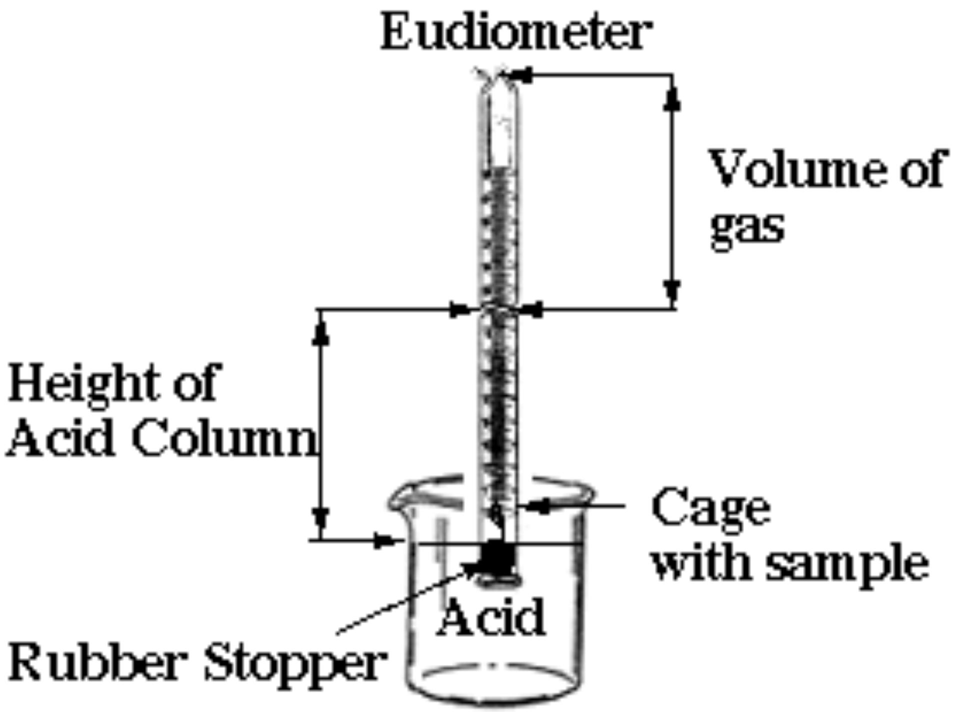
- Refer to the Procedure section pp. 53-57. The following slides correspond to the instructions in the procedure.

**Equipment**

From the stockroom:
- 100 mL eudiometer
- buret clamp
- digital thermometer
- meter stick

From common equipment shelves:
- ring stand

From your drawer:
- large beaker (at least 400 mL)
- wash bottle



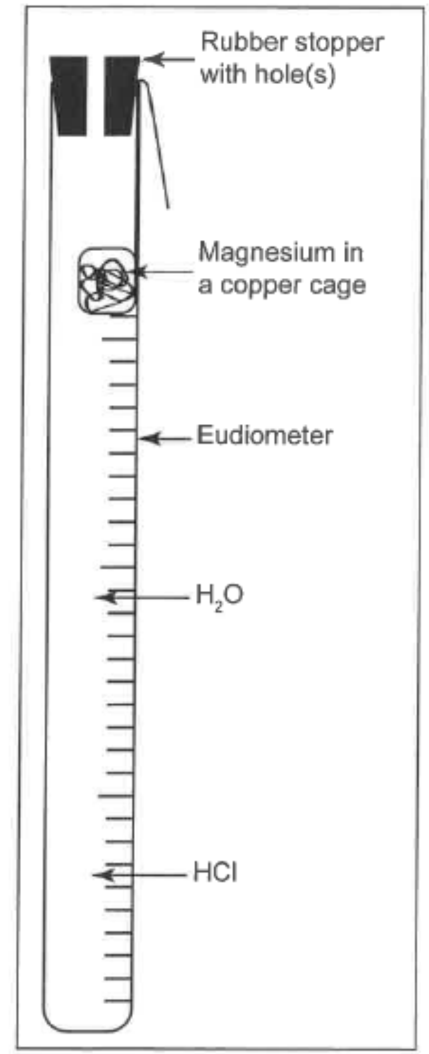
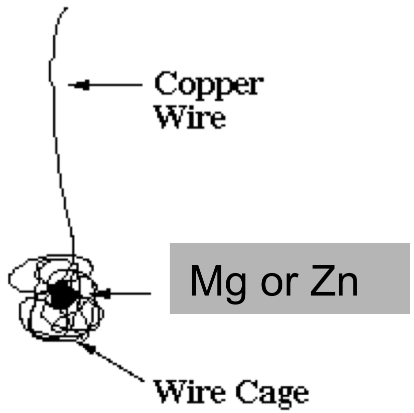
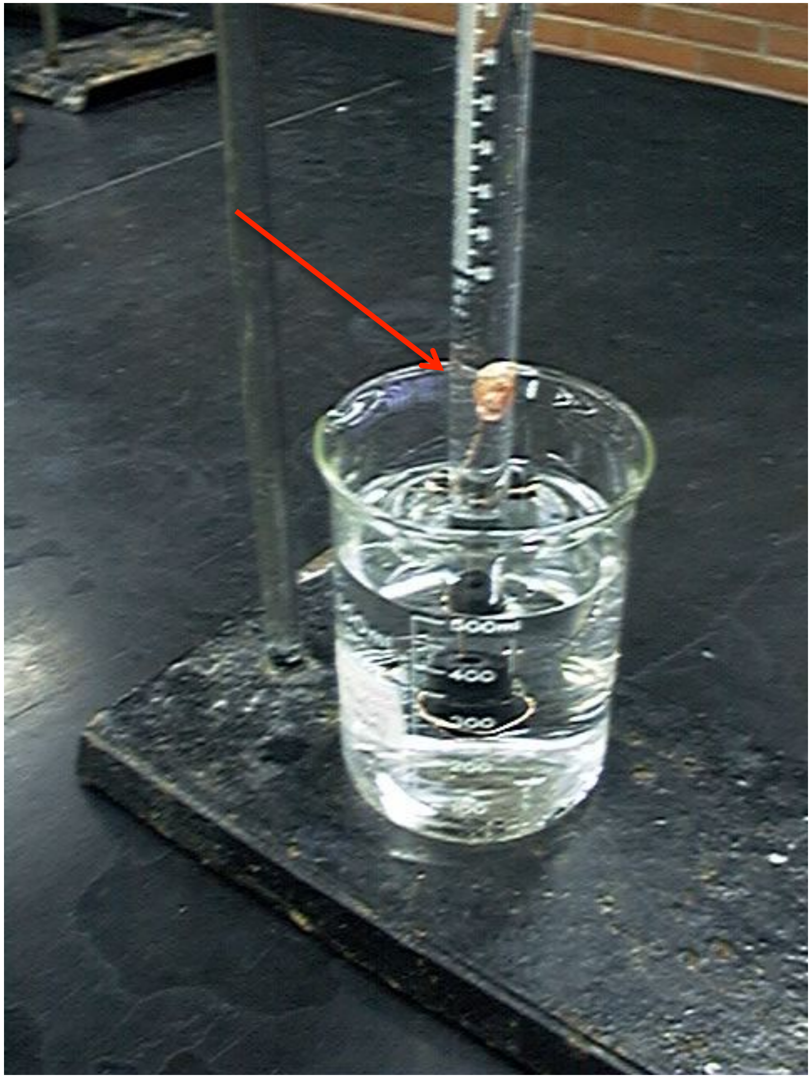




*Figure 1–Eudiometer*

What is wrong with this set up?




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



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

Refer to the Gas Stoichiometry Report Form, pg. 58-59

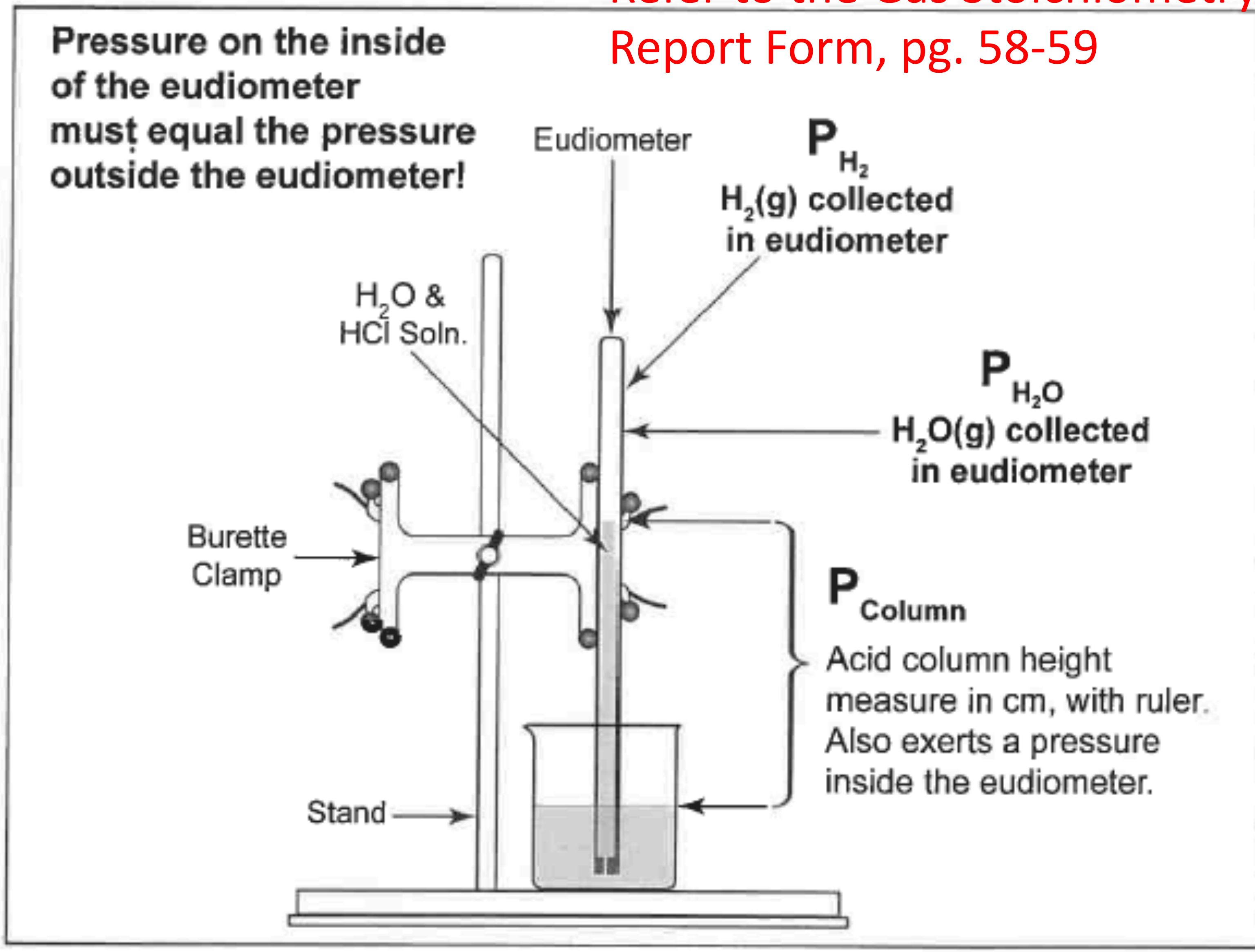



*Figure 2*

# *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 (°C → K)**
- **R** = **0.082057338** L atm $K^{-1}$ $mol^{-1}$ **(constant)**

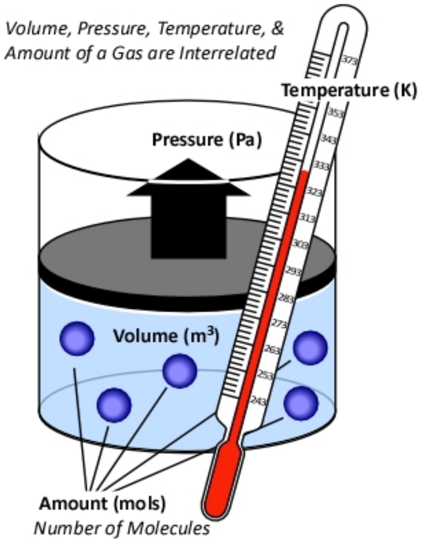
$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

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

- Refer to the Gas Stoichiometry Report Form, pg. 58-59
- Individual experimental data is to be obtained on-line for the reaction of an unknown mass of magnesium metal:

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

- 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 $T$)
$V = \frac{\text{constant}}{P}$

$P_1 V_1 = P_2 V_2$

$P$ ↑ $V$ ↓

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

$V_1 / n_1 = V_2 / n_2$

$V$ ↑ $n$ ↑

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

$V_1 / T_1 = V_2 / T_2$

$V$ ↑ $T$ ↑

**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)**

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

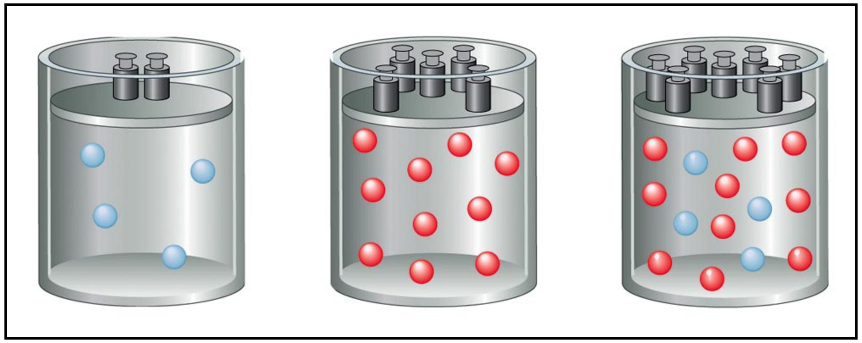
$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

# *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.

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

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



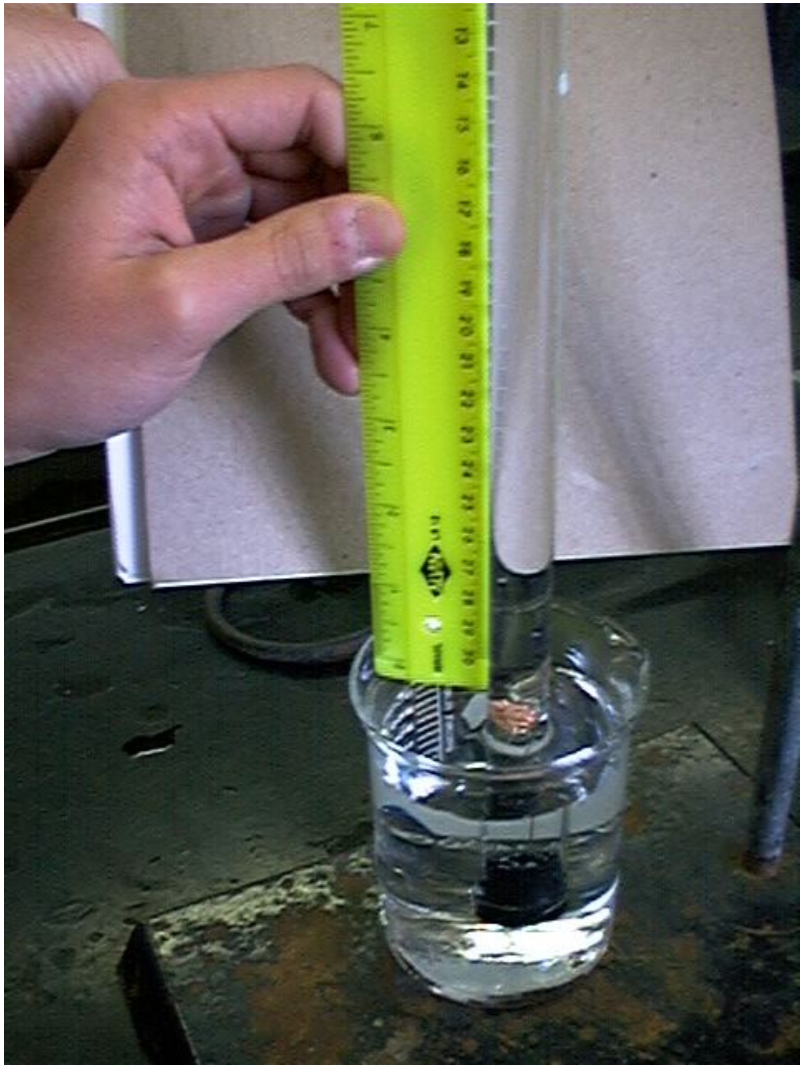
$$n_{Total} = n_1 + n_2 + n_3 + \ldots$$

•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)*

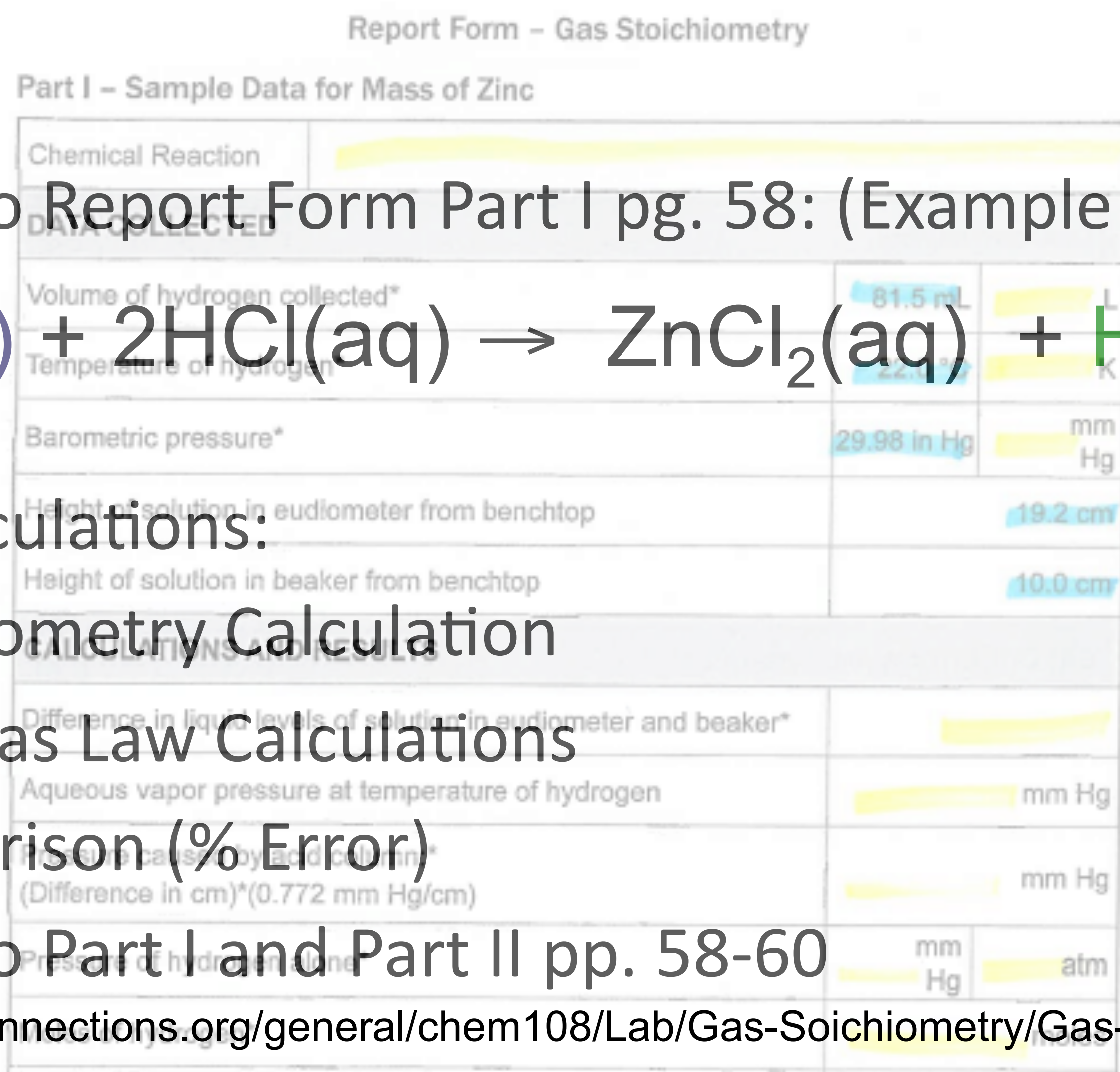


**P HCl (g) =**

*HCl Height (mm) x 0.0772*

*Density Hg is 12.95 times > density HCl(aq)*

*0.772 mm Hg/cm of acid solution*


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 | | 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 |

- Refer to Report Form Part I pg. 58: (Example uses Zinc.)

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

Mole Calculations:

- Stoichiometry Calculation
- Ideal Gas Law Calculations
- Comparison (% Error)
- Refer to Part I and Part II pp. 58-60

http://chemconnections.org/general/chem108/Lab/Gas-Soichiometry/Gas-unk-roster.htm

| DVC ID# | Unknown Code | Volume of H2 collected (mL) | Temp. of H2 (°C) | Barometric Pressure (inches Hg) | Height of solution in eud. From benchtop (cm) | Height of solution in beaker from benchtop (cm) |
|---|---|---|---|---|---|---|
| | Zn Example | 81.5 | 22.0 | 29.96 | 19.2 | 10.0 |

# *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 $_{Zn(s)}$**

# Zinc Example Calculation

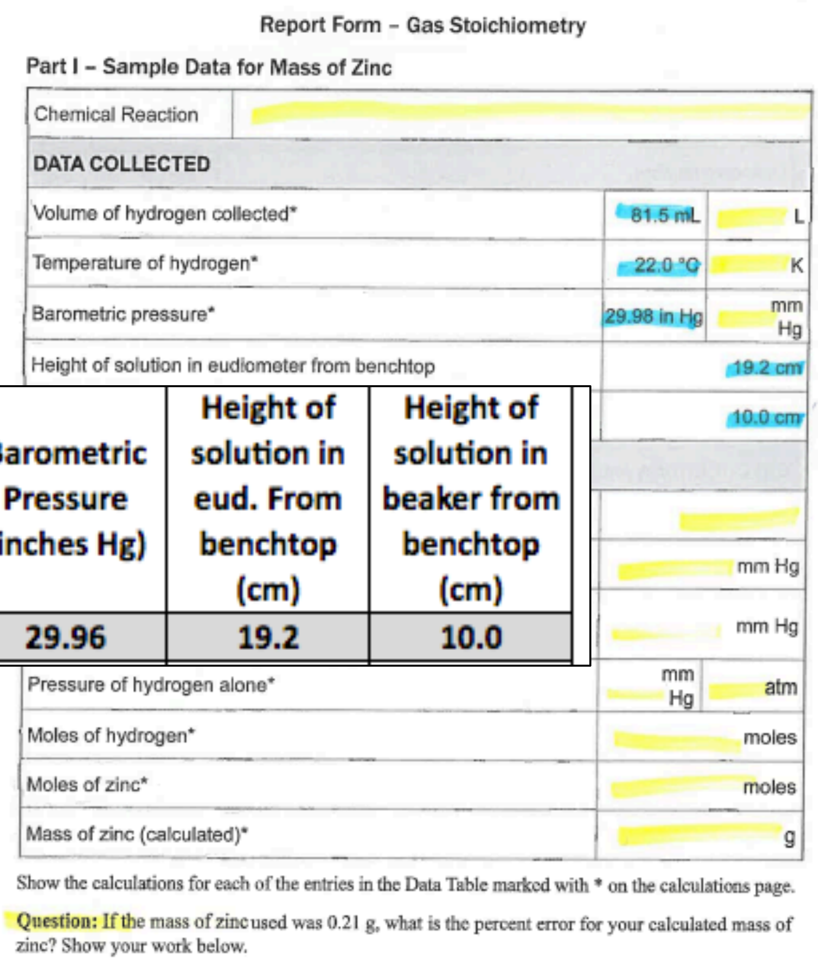
- Report Form pg. 58 Part I:

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

Mole Calculations:

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

| DVC ID# | Unknown Code | Volume of H2 collected (mL) | Temp. of H2 (°C) | Barometric Pressure (inches Hg) | Height of solution in eud. From benchtop (cm) | Height of solution in beaker from benchtop (cm) |
|---|---|---|---|---|---|---|
| | Zn Example | 81.5 | 22.0 | 29.96 | 19.2 | 10.0 |


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 |
| | | 10.0 cm |
| | | |
| | | mm Hg |
| | | 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 ($^oC$ → 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)**

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

**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)**

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

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 L atm $K^{-1}$ $mol^{-1}$**

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.

## VAPOR PRESSURE OF WATER AT DIFFERENT TEMPERATURES

| Temp (°C) | Vapor Pres (mm Hg) | Temp (°C) | Vapor Pres (mm Hg) |
|---|---|---|---|
| 0 | 4.6 | 25 | 23.5 |
| 5 | 6.5 | 26 | 25.2 |
| 10 | 9.2 | 27 | 26.7 |
| 15 | 12.8 | 28 | 28.3 |
| 16 | 13.6 | 29 | 30.0 |
| 17 | 14.5 | 30 | 31.8 |
| 18 | 15.5 | 35 | 42.2 |
| 19 | 16.5 | 40 | 55.3 |
| 20 | 17.5 | 45 | 71.9 |
| 21 | 18.6 | 50 | 92.5 |
| 22 | 19.8 | 60 | 149.4 |
| 23 | 21.1 | 70 | 233.7 |
| 24 | 22.4 | 100 | 760.0 |

# *Moles : Ideal Gas Law*

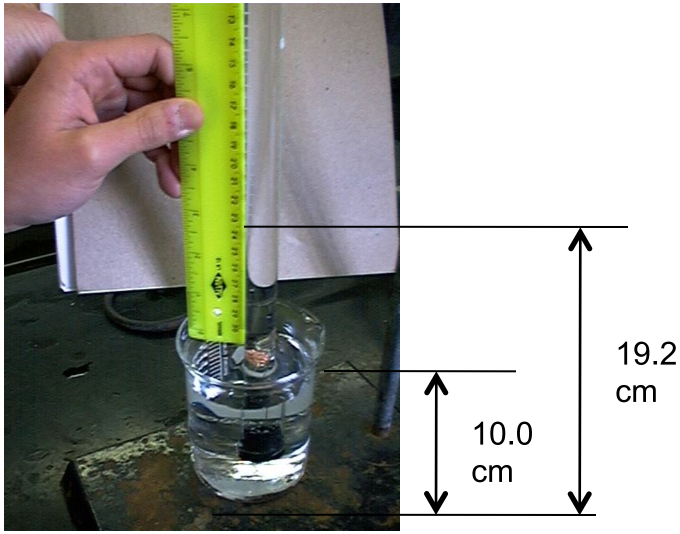
## Part I: Hydrogen Calculation, (*Refer to Form's Data*)

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

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

- **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 HCl

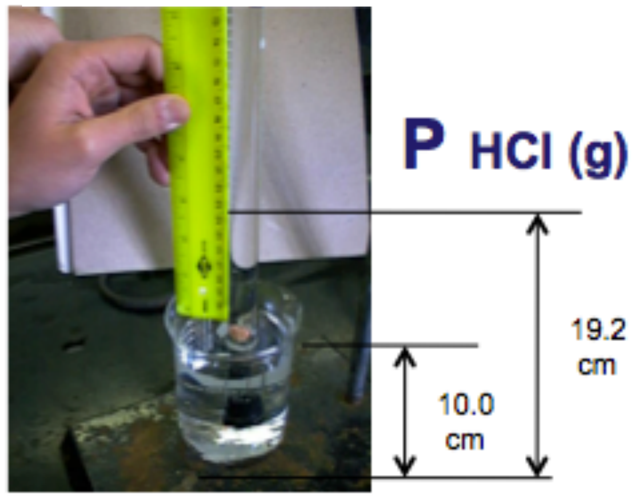
*HCl Height (mm) ÷ 12.95*

= 7.10 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 HCl

*HCl Height (mm) x 0.0772*

= 7.10 mm Hg

---

*Density Hg is 12.95 times > density HCl(aq)*

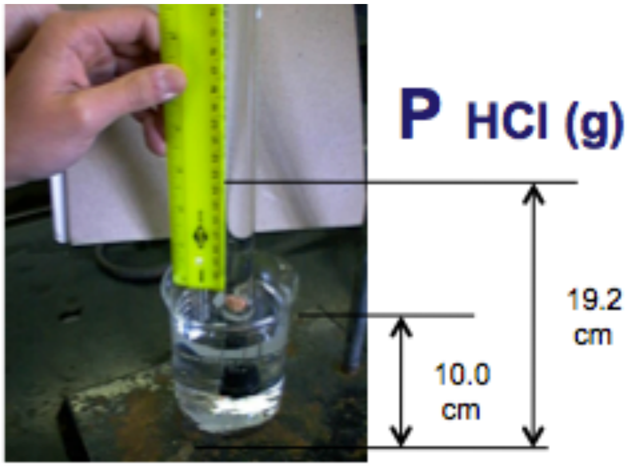
$P_{H_2(g)}$ = 761.5 mm Hg (barometric)

- 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)**

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

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

**= 1.4 %**

# (Part II) Magnesium

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

Mole Calculations:

- Stoichiometry Calculation
- Ideal Gas Law Calculations

Follow Zinc example calculation as a guide.

% Error will not be calculated.

Get individual unknown # & data on-line: http://chemconnections.org/general/chem108/Lab/Gas-Soichiometry/Gas-unk-roster.htm

Complete calculations and questions then submit form:

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.