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

Handouts

- Select a partner and get 2 handouts which replace Lab Manual pp. .
- Quickly read the Background section.

Chem 108/ Dr. Rusay

"Ideal" Gases, Stoichiometry, Gas "Laws"
Moles, Molar Masses & Gas Densities

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

Background

Some metals such as zinc and magnesium react with aqueous acids, which are compounds containing hydrogen that when dissolved in water produce positive hydrogen ions (protons) in the aqueous solution, eg. $HCl_{(aq)}$, hydrochloric acid. One of the products of the metal reacting with the proton in the single displacement reaction is hydrogen gas, which is formed when the reactive metal looses one or more electrons to form a cation as one of the products in the aqueous solution. The reaction is an oxidation-reduction as well as a single displacement, where the proton gains an electron to form a hydrogen atom, which then combines with another hydrogen atom to form a diatomic hydrogen molecule.

$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$
$Zn(s) + 2H^+(aq) \rightarrow Zn^{+2}(aq) + H_2(g)$

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$
$Mg(s) + 2H^+(aq) \rightarrow Mg^{+2}(aq) + H_2(g)$

Handouts

- Refer to the Procedure section and follow the next few slides that correspond to the instructions

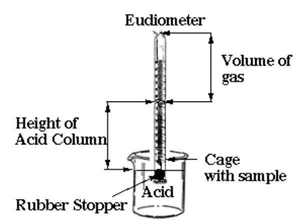
Chem 108/ Dr. Rusay

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.



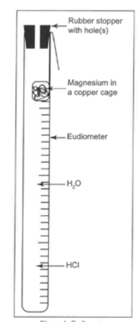
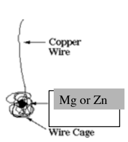
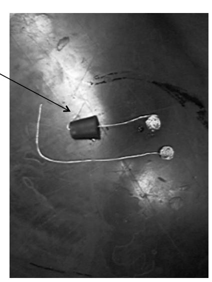


Figure 1–Eudiometer

What is wrong with this set up?





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

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

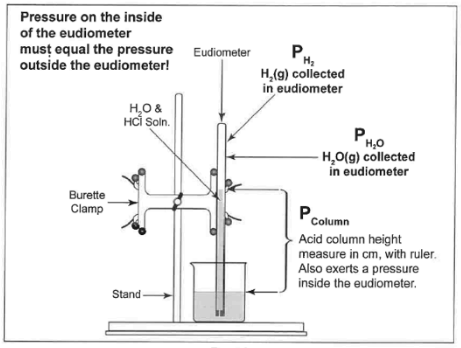
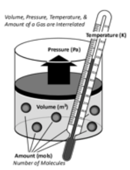


Figure 2

Handouts

- Refer to the Gas Stoichiometry replacement Report Form
- 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 calculated using Ideal Gas Law calculations and compared to calculated theoretical moles.



Background
Ideal Gas Law

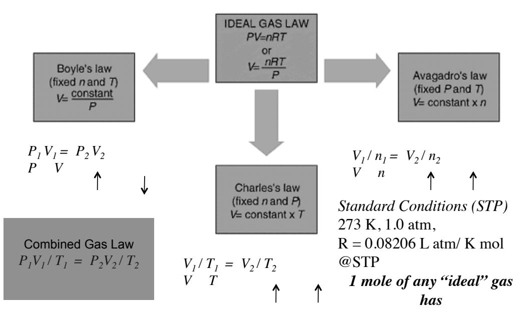
PV = n RT

- **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



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 (°C → K)**

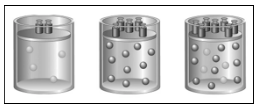
$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

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.

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

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



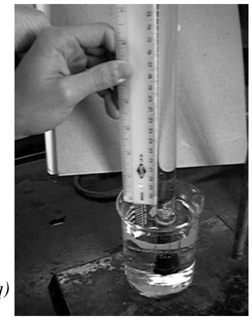
$$n_{Total} = n_1 + n_2 + n_3 + \ldots$$

•**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

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)**

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$
$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

Handouts

- Refer to Report Form Part I: Example using Zinc

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

Mole Calculations:

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

Stoichiometry
Theoretical Moles Hydrogen
(Part I: Zinc Calculation)

$$n_{H_2(g)} = n_{Zn(s)}$$

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

mass (g) Zn(s) = mass sample (g) = 0. 2100 g

$$\textbf{moles } H_2(g) = \textbf{moles } Zn(s) = \frac{\textbf{mass sample (g)}}{\textbf{Molar Mass } Zn(s)}$$

$$= \frac{0.2100 \text{ g } Zn(s)}{65.39 \text{ g/mol } Zn(s)} = 0.003211 \text{ moles } Zn(s)$$

= 0.003211 moles
(Theoretical Moles Hydrogen)

Moles : Ideal Gas Law
(Part I: Experimental 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** $H_2(g)$ **= 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

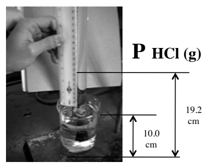
Part I: Hydrogen Calculation, (*Refer to Form's Data*)

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

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

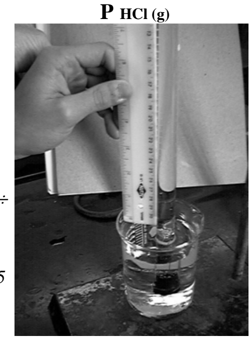
- **n = moles** $H_{2(g)}$
- **P** $H_{2(g)}$ **= pressure of** $H_2(g)$ **in atm (mm Hg → atm)**
- **P** $H_{2(g)}$ **= 29.98 inches Hg (barometric) - 19.8 mm Hg** H_2O **(g)** [*TABLE*] - **P HCl (g)**
- **V = 81.5 mL (mL→ L)**
- **T = 22.0 °C (°C → K)**

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)



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) =

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)

0.772 mm Hg/cm of acid solution

Moles : Ideal Gas Law

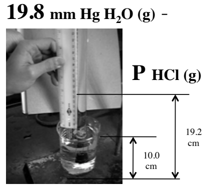
(Part I: Hydrogen Calculation)

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

$n_{H_2(g)} = PV / RT$ = 0.00325 **moles** $H_{2(g)}$

- **n = moles** $H_{2(g)}$
- **P** $H_{2(g)}$ **= pressure of** $H_2(g)$ **in atm (mm Hg → atm)**
- **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**
- **= 0.9666 atm**
- **V = 0.0815 L**
- **T = 295.1 K**

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



% Error

Theoretical Moles Hydrogen vs. Experimental

(Part I: Calculation)

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

mass (g) Zn(s) = mass sample (g) = 0. 2100 g

= 0.003211 moles $H_{2(g)}$ **theoretical**

$$\% \text{ Error} = \frac{\text{experimental moles } H_{2(g)} - \text{theoretical moles } H_{2(g)}}{\text{theoretical moles } H_{2(g)}} \times 100$$

$$= \frac{0.00325 \text{ moles} - 0.003211 \text{ moles}}{0.003211 \text{ moles}} \times 100$$

= 1.32 %

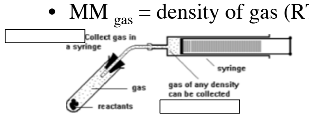
Molar Mass of any Gas

(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)



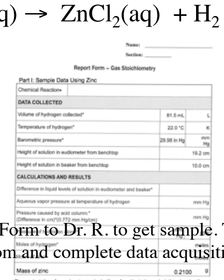
Magnesium Sample

- Complete Report Form replacement 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)



Name:

Section:

Report Form – Gas Stoichiometry

Part I: Sample Data Using 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
[illegible]		[illegible]
Moles of hydrogen*		moles
[illegible]		moles
Mass of zinc	0.2100	g

Show calculations for each entry marked with an * and include a calculation showing the % Error.

Bring completed Report Form to Dr. R. to get sample. Then get equipment from stockroom and complete data acquisition for Part II.

Have checked before leaving lab today.

Related Quiz Questions

Experimentally Determining Moles of Hydrogen

QUESTION

The density of an unknown atmospheric gas pollutant was experimentally determined to be 1.964 g/ L @ 0 °C and 760 torr.

- *What is the molar mass of the gas?*
- *What might the gas be?*

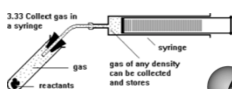
A) CO *B) SO_2* *C) H_2O* *D) CO_2*

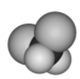
QUESTION

Freon-12, CF_2Cl_2, a "safe" compressible gas, was widely used from 1935-1994 as a refrigerant in refrigerators, freezers, and air conditioning systems. However, it had been shown to be a greenhouse gas and to catalytically destroy the ozone layer in a ratio of >14,000:1. It was phased out and banned.

200. ml of Freon-12 was collected by syringe. It weighed 0.927 grams, had a temperature of 30.0°C (303.1K), and a pressure of 730 mm of Hg (. What is the experimental molar mass of Freon-12?

A. 12.1 g/mol
B. 84 g/mol
C. 92.7 g/mol
D. 115 g/mol
E. 121. g/mol





R = **0.082** L atm K^{-1} mol^{-1}

QUESTION

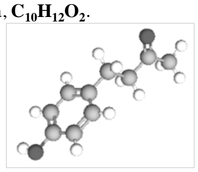
0.0820 grams of a volatile compound in the gas phase, which smells like fresh raspberries, was trapped in a syringe. It had a volume of 12.2 mL at 1.00 atmosphere of pressure and 25.0°C. What is the molar mass of this pleasant smelling compound ?

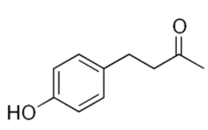
A) 13.8 g/mol
B) 164 g/mol
C) 40.9 g/mol
D) 224 g/mol

QUESTION

For the compound that smells like fresh raspberries, the following structure matches its molecular formula, $\mathbf{C_{10}H_{12}O_2}$.

A) TRUE
B) FALSE





QUESTION

Which sequence represents the gases in order of increasing density at STP?

A) Fluorine < Carbon monoxide < Chlorine < Argon

B) Carbon monoxide < Fluorine < Argon < Chlorine

C) Argon < Carbon monoxide < Chlorine < Fluorine

D) Fluorine < Chlorine < Carbon monoxide < Argon

QUESTION

Real gases exhibit their most "ideal" behavior at which relative conditions?

A) Low temperatures and low pressures
B) High temperatures and high pressures
C) High temperatures and low pressures
D) Low temperatures and high pressures