Announcements – 10/4/00

- ***Quiz and Demos on Friday***

- **Problem Set Solutions**
  - ***Now ONLINE!***

1

Charles' Law Example

- If a gas occupies **1.00 L** at **25.0 °C** and, after heating, expands to a volume of *2.00 L*, to what *temperature* was the gas heated?

$$\frac{V_1}{V_2} = \frac{T_1}{T_2} \Rightarrow \mathbf{T_2 = \frac{T_1 V_2}{V_1}}$$

$$T_2 = \frac{(25.0 + 273.15)(2.00\ L)}{(1.00\ L)} = \mathbf{596.3\ K}$$

$$T_2 = 596.3\ K - 273.15 = \mathit{323.15\ ^oC}$$

$$= \underline{\mathbf{323.\ ^oC}}$$

2

Avogadro's Law

- Recall: *Equal volumes of gases (at the same temperature and pressure) contain equal number of molecules.*

So, it follows that:

Volume $\propto$ # mol gas

(at constant temperature and pressure)

3

Ideal Gas Law

- Puts together all of the three previous laws:

Boyle:	P-V @ constant T and n
Charles:	V-T @ constant P and n
Avogadro:	V-n @ constant P and T

So: **PV = nRT** Ideal Gas Law

R = *universal gas constant* = **0.082058 L-atm-mol^{-1}-K^{-1}**

(In S.I. Units: R **= 8.3145 J-mol^{-1}-K^{-1}**)

4

Standard Temp and Pressure

- **One implication of IGL**: *at a particular T and P, a fixed amount of ANY GAS will occupy the same volume*

-Define a ***reference condition:***

T= 0°C (=273.15 K)

P = 1 atm

Standard Temp and Pressure:
STP

Solving IGL for VOLUME: **V = nRT/P**

$$= \frac{(1\ \text{mol})(0.08206)(273.15\ \text{K})}{1\ \text{atm}}$$

= ***22.41 L***

(volume occupied by 1 mol of ANY GAS at STP)

5

Tips for using the IGL

- There are FOUR variables!
  -you've gotta know THREE to find the 4th one
- **UNITS! UNITS! UNITS!**
  -convert all quantities to appropriate units

  V = *L*, **P** = *atm*, **T** = *K*, **n** = *mol*

  -use dimensional analysis to check your units
  -HINT: look at the units of **R** as a final check:
  (0.08206 *L-atm/mol-K*)

6

Example: P, V and T changes

- For a *fixed amount* (n mol) of gas:

$P_1V_1 = nRT_1$ - *initial condition*

$P_2V_2 = nRT_2$ - *final condition*

So: $\frac{P_1V_1}{T_1} = \boldsymbol{nR} = \frac{P_2V_2}{T_2}$

Leaving:

$$\boldsymbol{\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}}$$

7

How does this relate to Chemistry?

- What *mass* of Cu will be produced by the reduction of excess CuO by **250. mL H_2** at **1.025 atm** and **15.0°C**?

Oxidation

$CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(l)$

Reduction

Excess	250. mL	***? grams***
	1.025 atm	
	15.0 °C	

8

The Solution: Gas Stoichiometry

Strategy:

vol/press/temp → mol H_2 → *mol Cu* → *g Cu*

PV = nRT: *solve for n*

$$n = \frac{PV}{RT} = \frac{(1.025\ \text{atm})(0.250\ \text{L})}{(0.08206\ \text{L-atm/mol-K})(288.15\text{K})} = 0.010837\ mol\ H_2$$

$$0.010837\ \text{mol}\ H_2 \times \frac{1\ \text{mol Cu}}{1\ \text{mol}\ H_2} \times \frac{63.546\ \text{g Cu}}{1\ \text{mol Cu}} = 0.68855\ g\ Cu$$

= ***0.689 g Cu***

Gas Density

- Density (d) = mass/volume
- Rearranging IGL:

$$\frac{n}{V} = \frac{P}{RT}$$

- Convert mol → grams (mass):

$$\frac{MW \times n}{V} = \frac{P \times MW}{RT}$$

- Now we have density:

$$d = \frac{P(MW)}{RT} = g/L$$

Gas Density:

-varies with PRESSURE

-varies with TEMPERATURE

-varies with MOLAR MASS

Molar Mass Determination

- If a sample of an unknown gas weighs *0.893 grams* and occupies a volume of *250. mL at STP*, what is its **molar mass** (MW)?

  MW (molar mass) = g/mol

  -solve IGL for mol (n): $n = \frac{PV}{RT} = \frac{(1\ atm)(0.250\ L)}{(0.08206)(273.15\ K)}$

  $n = 0.0111534\ mol$

  So: MW = 0.893 g/0.0111534 mol = *80.065 g/mol*

  = ***80.1 g/mol***

11

Gas Mixtures

- Dalton's Law of Partial Pressures:

  *The **TOTAL PRESSURE** of a gas mixture is the **SUM of the pressures** exerted by each of the gases in the mixture.*

$$\mathbf{P_{total} = P_1 + P_2 + P_3 + \ldots\ldots}$$

At constant Temp and Volume:

$$P_1 = n_1 (RT/V) \rightarrow P_1 \propto n_1$$

- partial pressure of a gas in a mixture is proportional to the number of mol of that gas in the mixture

12