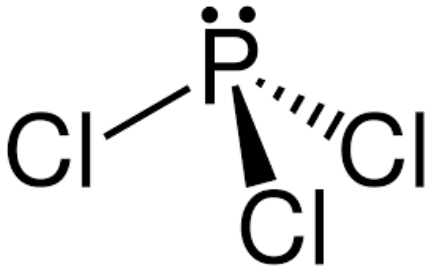
MEDIUM PACKET 1 ANSWER KEY

1. Is PCl_3 planar or non-planar? Justify your response by drawing the lewis structure.



Non-planar

2. Determine the Ka for carbonic acid (H_2CO_3) given that a 34.0 mL sample of 0.14 M carbonic acid has a pH 3.50 at 25.0˚C.

[H3O+] = 10^-pH = 10^-3.50 = 0.000316 M = [HCO3-]

Ka = [HCO3-][H3O+] / [H2CO3] = (0.000316)^2 / (0.14-0.000316 M) = **(7.14 x 10^-7)**

OR (7.15 x 10^-7)

3. All of the following reactions are examples of redox reactions except for one. Write in the space below which reaction does not follow the rules of redox chemistry.

(i) $Zn + Cu^{2+} \longrightarrow Zn^{2+} + Cu$

(ii) $2\ Fe(s) + O_2(aq) + 2\ H_2O(l) \longrightarrow 2\ FeO \cdot H_2O(s)$

(iii) $AgCl_3 + H_2O \longrightarrow Al(OH)_3 + HCl$

(iii) $IO_3^-(aq) + H^+ + I^-(aq) \longrightarrow H_2O(l) + I_3^-(aq)$

MEDIUM PACKET 2 ANSWER KEY

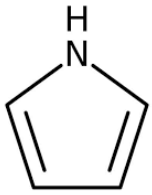
1. What intermolecular forces are present in a sample of HBr (*l*)?

London dispersion (or **Van der Waals**) forces and **dipole-dipole forces**

2. Is $\Delta S^\circ < 0$, $= 0$, or > 0 for the reaction: $2SO_3(g) \rightarrow O_2(g) + 2SO_2(g)$

$\Delta S^\circ > 0$

3. How many electrons are in resonance in pyrrole?



6 electrons

The 4 pi-electrons in double bonds and the nitrogen lone pair

MEDIUM PACKET 3 ANSWER KEY

1. What is the pH at the equivalence point of a titration between 25.12g of acetic acid in 100mL water and 0.1M NaOH? (K_a of acetic acid = $1.76 * 10^{-5}$)

25.12g / 60.052g/mol = 0.418mol
0.418mol NaOH / 0.1M = 4.18L NaOH
0.418mol acetate / (4.18L + 0.100L) = 0.098M acetate

$K_b = K_w / K_a = 1.0 * 10^{-14} / 1.76 * 10^{-5} = 5.68 * 10^{-10}$
$5.68 * 10^{-10} = [OH^-][HOAc] / [OAc^-] = x^2 / 0.098 - x$
$x = [OH^-] = 7.45 * 10^{-6}$
$pOH = -\log(7.45 * 10^{-6}) = 5.13$
pH = 14 - 5.13 = **8.87**

2. The reaction $CO + 3H_2 \rightarrow CH_4 + H_2O$ is entirely in the gas phase. Consider a system at equilibrium. If an inert gas is added to the system, and total pressure is kept constant, which way will equilibrium shift?

Left

3. W, X, Y, Z are four different elements in the first 20 elements of the periodic table. Knowing that:
   i. The common cation of W has the same electron configuration with the anion of Z.
   ii. Y and Z belong to the same group, and they can form 2 common chemical compounds.
   iii. X and Z belong to the same period, and they can form 2 common gaseous compounds.
   iv. W and X can form W_3X_2.

   Identify these four elements: **W= Mg , X=N , Y=S, Z=O**

MEDIUM PACKET 4 ANSWER KEY

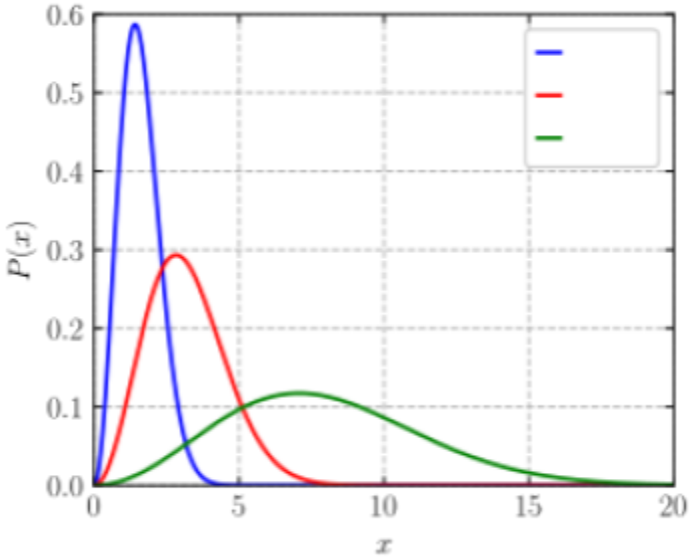
1. What do you call a process in which no heat transfer takes place?
   An adiabatic process

2. Which two phases of matter merge into a single phase at the “critical point” ?
   Liquid and gas

3. Which is not a colligative property: vapor pressure, boiling point, osmolarity, viscosity?
   Viscosity

MEDIUM PACKET 5 ANSWER KEY

For a given sample of ideal gas at a fixed temperature, not all particles (atoms/molecules) are traveling at the same speed. The fraction of particles at each speed is predicted by the Maxwell-Boltzmann distribution equation, which can be plotted as P(x) vs. x. Show below is an example of a Maxwell-Boltzmann distribution plot.



1. If the red line represents Ne gas at 298 K, which color curve (green or blue) could represent Ne gas at 500 K?

   Green

2. If the red line represents Ne gas at 298 K, which color curve (green or blue) could represent Ar gas at 298 K?

   Blue

3. What does the area under the curve between speeds of 0 and 10 mean?
   The **probability** of a gas molecule having a speed between 0 and 10

MEDIUM PACKET 6 ANSWER KEY

1. Order the following elements of increasing ionic radius: F^+, O, Cl^-

$F^+ < O < Cl^-$

2. A mixture of gas is contained in a vessel and the equation is given below. The partial pressures of H_2, I_2, and 2HI are 0.057 atm, 0.035 atm, and 0.022 atm respectively. The Kp value of the reaction at 460 degrees celsius is 49. Determine if the reaction will proceed forward or backward.

$$H_2(g)+I_2(g) \rightarrow 2HI(g)$$

$Qp=(0.022^2)/(0.035)(0.057) = 0.2426$

$Qp\ (0.2426) < Kp\ (49)$

The reaction will proceed forward

3. 1.0 mol of HNO_2 was added with 0.30 mol of KOH to 1.0L of water. Assume the volume does not change. Knowing the pKa of HNO_2 is 3.35, what is the pH of the resulting solution?

pH = **2.98**

MEDIUM PACKET 7 ANSWER KEY

1. Rank the second ionization energy of the following elements: Ne Li C

(least) ___C____ < ___Ne____ < ____Li___ (most)

2. Calculate the acid dissociation constant, K_a, for a solution containing 0.29M lactic acid with a pOH of 10.21.

pH = 14 - 10.21 = 3.79

$[H_3O^+] = 10^{-3.79} = 0.000162$ $[H_3O^+] = x$

$$K_a = \frac{(x)(x)}{0.29 - x} = \frac{(0.000162)(0.000162)}{0.29 - 0.000162} = 9.1 \cdot \mathbf{10^{-8}}$$

3. Given the reaction: $2\ HI\ (g) \rightleftharpoons I_2\ (g) + H_2\ (g)$

If the volume is reduced by half at a constant temperature, does the reaction shift towards the products, shift towards the reactants, or does nothing happen?

Nothing happens

MEDIUM PACKET 8 ANSWER KEY

1. Which molecule has the highest bond order and which has the lowest: SO_2 NO_3^- XeF

   Highest:___SO_2_____ Lowest:____XeF_____

   NO_3^- = 4/3 SO_2 = 3/2 XeF = 1
   Highest: SO_2 Lowest: XeF

2. A solution containing 0.12 M of HCl is titrated with a solution of NaOH with a molarity of 0.76 M. Calculate the pH of the titration solution before any titrant is added.

   0.12 M HCl = 0.12 H_3O^+
   pH = -log(0.12) = **0.92**

3. A first-order reaction has a half-life of 15 minutes, how much time is required for this reaction to 63% complete.

   $t_{1/2} = 0.63; k = \frac{0.693}{15\ mins} = 0.0462\ min^{-1}$

   $ln\left(\frac{[A]_t}{[A]_0}\right) = -kt; ln\,(63\%) = -0.0462 \times t \rightarrow t = \frac{ln\,(0.63)}{-0.0462} \simeq 10.0\ mins$

MEDIUM PACKET 9 ANSWER KEY

1. In the reaction, $[A] + [B] \rightarrow [C] + [D]$, the rate law looks like: $Rate = k[A]^m[B]^n$, where k is some constant. Given the following experimental data where $[B]$ is held constant, what is the value of n?

	[A] (in M)	
Experiment	Time = 0 s	Time = 10 s
1	0.10	0.9
2	0.20	0.19
3	0.30	0.29

$n = 0$

2. $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l) + CO_2(g)$

There are 3.5 g of $CaCO_3$ in a closed 2L container. 60 mL of 1M HCl solution is added to the container. Assume that the CO_2 produced behaves like an ideal gas. Calculate its pressure (3 significant digits). (Temperature: 298K, R=0.08206 $L \cdot atm \cdot mol^{-1} \cdot K^{-1}$)

$n(CaCO_3) = \frac{m(CaCO_3)}{M(CaCO_3)} = \frac{3.5g}{(40.08+12.01+16.00\times3)g/mol} = 0.035\ mol$

$n(HCl) = c(HCl) \times V(HCl) = 1M \times 0.06L = 0.06\ mol$

$HCl\ is\ the\ limiting\ reactant$

$n(CO_2)\ produced\ equals\ to\ \frac{1}{2} \times n(HCl) = 0.03\ mol$

$P(CO_2) = \frac{nRT}{V} = \frac{0.03\times0.08206\times298}{2} = 0.367\ atm$

3. There is great current interest in developing fuel cells based on the reaction:

$$2CH_3OH_{(l)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 4H_2O_{(l)}.$$

Write a balanced equation for the half-reaction that occurs in acid solution for such a fuel cell at the anode and cathode.

anode: $CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-$

cathode: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

MEDIUM PACKET 10 ANSWER KEY

1. $CH_4(g) + CO_2(g) \rightarrow 2H_2(g) + 2CO(g)$

   The reaction takes place in a closed container with a volume of 3L. The total pressure at the beginning of the reaction is 3.6 atm. The partial pressure of CH_4 is 2.6 atm, H_2 is 0.4 atm, CO is 0.6 atm. Knowing that K for this reaction is 4.8×10^2, calculate the equilibrium partial pressure for CO_2 (3 sig figs)..

	CH_4	CO_2	H_2	CO
I	$2.6\ atm$	0	0.4 atm	0.6 atm
C	+x	+x	-2x	-2x
E	$(2.6 + x)$	x	(0.4-2x)	0.6-2x

$K = 4.8 \times 10^2 = \frac{(0.4-2x)^2 \cdot (0.6-2x)^2}{(2.6+x) \cdot x} \Rightarrow x = 0.0000461\ atm$

$P(CO_2) = 0.0000461\ atm$ = **4.61 x 10^{-5} atm**

2. A hot metal cube 1cc (cubic centimeter) in volume was placed into a cup of water. The water was previously 23°C but increased in temperature to 32°C. Before removing the cube, the volume of the system in the cup was measured to be 34cc. The heat capacity of water is 4.186J/g°C. What was the change in heat of the system?

   T_{water} = 32-23 = 9 ℃
   1 mL cube + 33 mL water = 33 g water
   $\Delta H = mC\Delta T = (33\ g)(4.186)(9)$
   $\Delta H = 1243\ J$

3. Consider the reaction: $[A] + [B] \leftrightarrow [C]$ at 400°K. The forward reaction rate constant is 11min^{-1}, and the arrhenius constant, A, is $5 \cdot 10^7 min^{-1}$. A catalyst is added and the activation energy of the forward reaction, E_a, is reduced by 5 kJ/mol. What is the new rate constant of the forward reaction?

   49.5min^{-1}

MEDIUM PACKET 11 ANSWER KEY

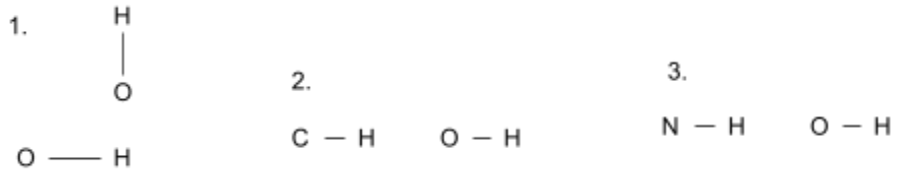
1. Write out the name of the following compound: $Mn_2(SO_3)_3$
   Manganese (III) sulfite

2. Rank the following compounds from smallest number of oxygens to most:
   Bromic acid, perchloric acid, iodous acid, dihydrogen monoxide
   Dihydrogen monoxide (H_2O) < iodous acid (HIO_2) < bromate ($HBrO_3$) < perchloric acid ($HClO_4$)

3. What's the bond order of an O-O bond in ozone (O_3)? (1.5)

MEDIUM PACKET 12 ANSWER KEY

1. Determine if hydrogen bonds can exist in the structures below. If they do exist, draw dashed lines of where the bond would occur



There should be dashed lines in #1 and #3.
#2 cannot form hydrogen bonds.

2. The density of gaseous form of sulfur is 2.857g/L under standard conditions. What is the molecular formula of sulfur in this case?

$2.857\ g/L \times 22.4\ L/mol = 63.9968\ g/mol$

For $S_n \Rightarrow n = \frac{63.9968\ g/mol}{32.066\ g/mol} \simeq 2$, the molecular formula of sulfur in this case is S_2

3. Solution A has a pH of 10. Solution B has a pH of 5. How many times more acidic is Solution B than Solution A?

100,000 times more acidic OR 10^5 times more acidic

MEDIUM PACKET 13 ANSWER KEY

1. Under standard conditions, a glass jar filled with air has a mass of 152.34 g. When it is filled with oxygen, it has a mass of 152.37 g. What is its mass when it is filled with nitrogen? (M(air) $\simeq 28.97\ g/mol$)

Under standard conditions, the pressure and temperature of the gas is constant. Since the gasses are in the jar, the volume of the gas is also constant. Therefore, all the gasses in the jar have the same moles.

$\Delta m = 152.37g - 152.34g = (31.998 - 28.97)n$

$n = 0.00990753$ mol

Mass of the jar = 152.34 g - 0.00990753 mol $\times\ 28.97 g/mol$=152.053g

Mass when filled with nitrogen = 152.053 g + 0.00990753 mol × 28.014 g/mol = **152. 331 g.**

2. Determine if a 20 mL solution of 0.03M $AgNO_3$ and 50 mL of 0.1 M K2SO4 will form a precipitate. (Given: Ksp for Ag_2SO_4 = 1.2 x 10^{-5})

Find new molarities of Ag+ and SO42-

Ag+: 0.02*0.03= 0.0006 moles ⇒ 0.0006/0.03 = 0.02

SO42-: 0.1*0.05-0.005 moles ⇒ 0.005/0.03 = 0.17

Mass action

(0.02)^2(0.17) = 0.000068

Qsp>Ksp ⇒ **will precipitate**

3. A 5L vessel holds a reaction where in the forward direction, the system is exothermic. A stress is applied to the system and where the temperature is increased but the moles of mixture and the volume remain constant. Will the reaction proceed forwards, backwards, or is more information needed?

More information needed. Le Chatelier is ambiguous in this case.

MEDIUM PACKET 14 ANSWER KEY

1. The term used to describe the concentration of the enzyme-substrate complex in a single-substrate, single-product reaction: _____
   Steady state

2. Consider the following reaction: **$3C(s) + 4H_2(g) \rightarrow C_3H_8(g)$**

If you have 2.3g of C(s) and 5L of $H_2(g)$ at STP, what is the limiting reagent and how much product (in grams) will be formed? Assume there are 22.4 L/mol of gas at STP.

5L H_2 x 1mol/22.4L = .223 moles of H_2 gas
.223 moles of H_2/ 4 moles per reaction = 0.0558
2.3 g of C x 1mol/ 12.011g = 0.191 moles of C(s)
0.191 moles of C(s)/ 3 moles per reaction = 0.0638
H_2 (g) is the limiting reagent

0.223 moles/4 = 0.05575 moles of product formed
0.05575 mol * 44.1g/ mol C_3H_8 = **2.46 grams formed**

3. What do you call the slowest step in a chemical reaction that determines the overall rate of chemical reaction?
   Rate determining step