Name:_____ Date: _____

There are 8 questions totaling 106.5 (scored out of 100 pts) points. PLEASE look over the entire examination (10 pages total) BEFORE you begin to ensure your packet is complete. REMEMBER: The best place to start your exam may not be at the beginning! You have 2.75 hours to complete this examination and may only use a basic scientific calculator, the resource sheet and the periodic table provided. When specified, all work must be shown for credit AND all answers must be expressed with the proper amount of significant figures. A scratch sheet will be provided by the instructor; please staple when you submit your exam. If you need further clarification, please speak with the instructor. **HONOR CODE:** ***I certify that the work presented in this examination is my own and that the rules set-forth for this examination were followed.***

Signature:_____

Please answer Questions 1 (a-m) carefully; no partial credit! Point values are clearly stated on most problems. Questions 1(a-l) BLANKS are worth 1.5 pts each, unless otherwise specified. Show ALL work for Questions 2-8.

1. Please provide the appropriate response for each below.
   a. An industrial chemist, always interested in increasing the yield of products, finds a reaction with $K_c = 1 \times 10^0$ at 300 ^oC. At equilibrium, which predominates? **Circle one.**

      i. Products are only present
      ii. Reactants are only present
      iii. Products predominate
      iv. Reactants predominate
      v. Both are present roughly at the same amount

   b. Consider two separate equilmolar solutions: a strong base solution and a strong acid solution.

      Compared to the strong acid, the strong base will have a: _____ pH, a _____ $[OH^-]$ and a _____ $[H_3O^+]$. *For each blank, answer* ***higher*** *or* ***lower.*** *(4.5 pts total; 1.5 pts each)*

   c. Consider the reaction: **2 CO** ***(g)*** $\Leftrightarrows$ **CO_2** ***(g)*** **+ C** ***(s)***
      The equilibrium expression (K_c) for the reaction is : *(3 pts)*

   d. True or False? ***Circle one.*** Lactic acid dissociates 100% in an aqueous solution.

   e. True or False? ***Circle one.*** F^- is a proton acceptor.

   f. $Ba(OH)_2$ is the *best* example of a Bronsted-Lowry Base ***or*** Arrhenius Base ***or*** Lewis Base.

   g. Which solution yields a lower $[H_3O^+]$ in solution: 0.100 M HNO_3 ***or*** 0.100 M H_2CO_3 ? ***Circle one.***

   h. At 25 ^oC, a solution has a 0.033 M $Ba(OH)_2$ and 0.011 M KOH concentration. The pH of the solution is:

      _____ and the $[H_3O^+]$ = _____ . ***MUST HAVE correct # SF here!*** *(3 pts)*

i. A solution contains aqueous $C_5H_5NH^+$ and Cl^-. The solution is: acidic, basic ***or*** neutral. ***Circle one.***

j. A solution contains aqueous NH_4CN. The solution is: acidic, basic ***or*** neutral. ***Circle one.***

k. The conjugate base of $H_2PO_4^-$ is: _____.

l. A pH of a 0.100 M benzoic acid solution is: _____. ***Watch SF's!*** *(5.5 pts)*

2. Consider the reactions and their respective equilibrium constants:

RXN 1: $NO\ (g) + \frac{1}{2}\ Br_2\ (g) \rightleftharpoons NOBr\ (g)$ $K_p = 5.3 \times 10^{-2}$

RXN 2: $2\ NO\ (g) \rightleftharpoons N_2\ (g) + O_2\ (g)$ $K_p = 2.1 \times 10^{30}$

a. What is the K_c **value** for RXN 1, above? Show work for credit. *(5 pts)*

b. Use the above reactions and their equilibrium constants to predict the equilibrium constant for this reaction *(5 pts)*: $\mathbf{N_2\ (g) + O_2\ (g) + Br_2\ (g) \rightleftharpoons 2\ NOBr\ (g)}$

3. Consider the reaction below at 298 K. At equilibrium, the partial pressures are 155 torr, 312 torr and 1.59 torr for H_2, S_2 and H_2S respectively. What is the K_p for the reaction? *(8 pts)*

2 H_2S *(g)* $\Longleftrightarrow$ **2 H_2 *(g)* + S_2 *(g)*** K_p = _____

4. Consider the reaction below, with $K_c = 3.9 \times 10^{-3}$. A mixture initially contains 0.390 M H_2S and 0.500 M SO_2 at a certain temperature. Calculate the equilibrium concentration of water. **Show all work for credit.** *(8 pts)*

2 H_2S *(g)* + SO_2 *(g)* $\Longleftrightarrow$ **3 S *(s)* + 2 H_2O *(g)***

5. At a certain temperature, ***triethylamine***, a weak base, has a K_b of 4.50×10^{-2}. **Show all work for credit, watch your S.F. and clearly "BOX" your final answers.** *(13 pts total)*
   a. The K_a of the triethylamine's conjugate is _____. *(2.5 pts)*

   b. Calculate the ***percent ionization/association of 2.00 M triethylamine*** at this temperature. *(9 pts)*

   c. Calculate the ***pH of the solution***. *(1.5 pts)*

6. Consider the *endothermic* reaction below at 298 K. **For each question, assume equilibrium conditions.**

$$N_2(g) + 3H_2(g) \Leftrightarrow 2\,NH_3(g) \qquad K_p = 6.26 \times 10^{-22},\ \Delta H = +$$

a. If the generated ammonia is siphoned off, removing it from the system, which direction, if any, is favored to re-establish equilibrium? *(2 pts)*

b. If the temperature is decreased, which direction, if any, is favored to re-establish equilibrium? *(2 pts)*

c. If the volume of the system is increased, which direction, if any, is favored to re-establish equilibrium? *(2 pts)*

d. If a student measures the partial pressures for ammonia, nitrogen and hydrogen as 0.33 atm, 0.22 atm, and 0.11 atm, respectively**,** is the system at equilibrium? _____. Which direction, if any, does the reaction need to proceed to achieve equilibrium? _____

(5 pts total; 2.5 pts each)

e. Which of the stresses (if any) indicated in Questions 6a, 6b, and 6c will results in a **changed** equilibrium constant? List letter(s) here, if any: _____. *(2 pts)*

7. Rank the following substances in order of increasing basicity when dissolved separately, to 0.200 M in water. **P**rovide correct ***LETTERS*** in blanks below. Use scratch paper, as needed. Be careful here; very little partial credit! *(12 pts)*

a. **HIO** **b. $LiClO_4$** **c. $NaC_3H_5O_3$** **d. $C_5H_{10}NH_2Cl$** **e. NH_3** **f. HIO_2**

_____ < _____ < _____ < _____< _____ < _____

Low pH → **High pH**

8. A solution contains 3.00 M arsenic acid, H_3AsO_4. Calculate the concentrations of ALL species at equilibrium and determine the pH. You will likely need a scratch (2nd page) to answer this question. *Don't forget about water equilibria!* ***Show all work for credit.*** *Use additional scratch paper, as needed. (15 pts)*

Question 8, cont.

RESOURCE SHEET

R = 0.08206 L * atm /mol*K
$K_p = K_c(RT)^{\Delta n}$
$K_w = 1.0 \times 10^{-14} = [H_3O^+][OH^-]$
$K_a * K_b = K_w$
$pH = -\log[H_3O^+]$
$[H_3O^+] = 10^{-pH}$
pH + pOH = 14

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$ Quadratic EQN

Table 1: Acid Dissociation Constants at 25 °C

Name	Formula	K_{a1}	K_{a2}	K_{a3}
Benzoic	$HC_7H_5O_2$	6.5×10^{-5}		
Hydrocyanic	HCN	4.9×10^{-10}		
Hypoiodous	HIO	2.3×10^{-11}		
Lactic	$HC_3H_5O_3$	1.4×10^{-4}		
Phenol	HC_6H_5O	1.3×10^{-10}		
Ascorbic	$H_2C_6H_6O_6$	8.0×10^{-5}	1.6×10^{-12}	
Iodous	HIO_2	2.3×10^{-5}		
Arsenic acid	H_3AsO_4	5.5×10^{-3}	1.7×10^{-7}	5.1×10^{-12}

Table 2: Base Dissociation Constants at 25 °C

Name	Formula	K_b
Ammonia	NH_3	1.76×10^{-5}
Piperidine	$C_5H_{10}NH$	1.33×10^{-3}

SCRATCH SHEET **NAME:_____**