

Name: \_\_\_\_\_

date: \_\_\_\_\_

ch. 15 & 16 equilibrium test 70 points (5 ec) AP chemistry

**Academic Honesty:** The answers on this test are my own and I am using only the allowed set of notes as described in the syllabus. I have not discussed the test questions with anyone before or during the test nor have I seen the test questions prior to the exam. If you violate any of the preceding items or do not sign, your semester grade is a F.

Signature: \_\_\_\_\_

In problems involving any calculation, show your work in an organized manner, include (i) any relevant equation (or formula), (ii) conversion factor(s), (iii) put the proper units in your calculations and answer, and (iv) have the proper number of significant figures in your answer.

1. Dissolving solid sodium hydroxide in water increases the temperature of the solution. What is the effect of \_\_\_ on the solubility of sodium hydroxide in water? basis / rationale? [15 points]

5/10 a. cooling the sample

$\Delta H < 0 \rightarrow \text{exothermic}$   
 $\downarrow T \rightarrow \text{w/ } \uparrow T = \text{exothermic} \rightarrow \uparrow K_f \rightarrow \uparrow K = \uparrow \text{solubility}$

$\Delta G = -RT \ln K = \Delta H - T \Delta S$   
 $\ln K = -\frac{\Delta H}{RT} + \frac{\Delta S}{R}$   
 $\downarrow T \text{ w/ } \Delta H < 0 \rightarrow \uparrow \ln K \rightarrow \uparrow K = \uparrow \text{solubility}$

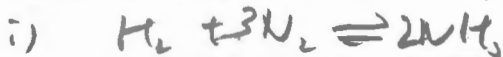
b. adding sodium nitrate

$\text{NaOH} \rightleftharpoons \text{Na}^+ + \text{OH}^-$ ;  $Q = [\text{Na}^+][\text{OH}^-]$   
 $+ \text{NaNO}_3 \rightarrow \uparrow [\text{Na}^+] \rightarrow \uparrow Q \rightarrow \downarrow Q \text{ to reestablish eq} \rightarrow \uparrow \text{solubility}$

c. adding <sup>barium</sup>magnesium nitrate

$\text{Ba}^{2+}$  reacts with  $\text{OH}^- \rightarrow \downarrow [\text{OH}^-] \rightarrow \downarrow Q \rightarrow \uparrow Q \text{ to reestablish eq} \rightarrow \uparrow \text{solubility}$

2. In the reaction:  $\text{H}_2(\text{g}) + 3 \text{N}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g})$ , if the initial partial pressure of  $\text{H}_2$ ,  $\text{N}_2$ , and  $\text{NH}_3$  are 1.0, 2.0, and 3.0 atm, respectively and the equilibrium partial pressure of  $\text{N}_2$  is 1.5 atm, what is the numeric value of  $K_p$ ? [10 points]



	1	1	2	3
$K_p$	-0.17	-0.5	+0.33	
E	0.83	1.5	3.33	

ii)  $K_p = \frac{P_{\text{NH}_3}^2}{P_{\text{H}_2} P_{\text{N}_2}^3} = \frac{3.33^2}{0.83 (1.5)^3} = 3.96$

show eqn, but no need to derive eqn

3. At 25 °C, what is \_\_\_? justify / rationale? [10 points]

a. If  $K_c = 10$ , then  $K_p = ?$  in:  $H_2(g) + Cl_2(g) \rightleftharpoons 2 HCl(g)$

2 pt  $K_c = K_p = 10$

3 b/c  $K_p = K_c (RT)^{\Delta n}$ ;  $n = 2 - (1+1) = 0$

b. If  $K_p = 10$ , then  $K_c = ?$  in:  $H_2(g) + 3 N_2(g) \rightleftharpoons 2 NH_3(g)$

2 pt  $K_p = K_c (RT)^{\Delta n} = K_c (RT)^{-2}$

3  $K_c = (RT)^2 K_p = [0.0821 (25+273)]^2 \cdot 10$   
 $= 2.5986$   
 $= 6.0 \cdot 10^3$

4. In regards to the reaction:  $H_2(g) + Cl_2(g) \rightleftharpoons 2 HCl(g)$ , if the initial concentration of  $H_2$  and  $Cl_2$  is 2.0 M and 3.0 M, respectively, where  $K_c = \underline{\hspace{2cm}}$ , what is the equilibrium concentration of  $HCl$ ? If you use any approximations, explicitly state it and its basis / rationale. [20 points]

10 pt

a.  $10^3$  ~~10<sup>3</sup>~~  $\cdot 10^3$  keep

i)  $H_2 + Cl_2 \rightleftharpoons 2 HCl$

	2	3	0
I			+2x
C	-x	-x	
E	2-x	3-x	2x

or  $K \gg 1$ , assume all limiting reactant become product  $\rightarrow [HCl] = 4 M$

ii)  $K = \frac{(HCl)^2}{(H_2)(Cl_2)}$

$10^3 \cdot \frac{4 \times 2}{(2-x)(3-x)} \rightarrow x = 1.98 \rightarrow [HCl] = 3.97 M$

a.  $10^{-3}$

i)  $H_2 + Cl_2 \rightleftharpoons 2 HCl$

	2	3	0
I			+2x
C	-x	-x	
E	2-x	3-x	2x

ii)  $K = \frac{(HCl)^2}{(H_2)(Cl_2)}$

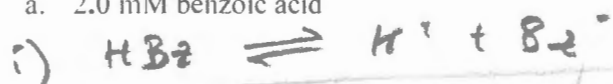
$10^{-3} = \frac{(2x)^2}{(2-x)(3-x)} \approx \frac{4x^2}{2(3)}$  b/c  $K \ll 1$

$x = \sqrt{\frac{6 \cdot 10^{-3}}{4}} = 0.039$

iii)  $[HCl] = 2(0.039) = 0.077 M$

5. What is the pH of \_\_\_? [20 points]

a. 2.0 mM benzoic acid



I	2 mM	0	0
C	-x	+x	+x
E	2 mM - x	x	x

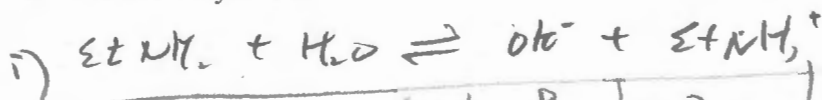
ii)  $K_a = \frac{[\text{H}^+][\text{Bz}^-]}{[\text{HBz}]}$

$6.5 \cdot 10^{-5} = \frac{x^2}{0.002 - x} \approx \frac{x^2}{0.002}$  b/c  $K_a \ll 1$

$x = 3.6 \cdot 10^{-4}$

iii)  $\text{pH} = -\log[\text{H}^+] = -\log(3.6 \cdot 10^{-4}) = 3.44$

b. 5.0 mM ethylamine



I	5 mM	0	0
C	-x	+x	+x
E	5 mM - x	x	x

ii)  $K_b = \frac{[\text{OH}^-][\text{EtNH}_3^+]}{[\text{EtNH}_2]}$

$6.4 \cdot 10^{-4} = \frac{x^2}{0.005 - x} \approx \frac{x^2}{0.005}$  b/c  $K_b \ll 1$

$x = 1.79 \cdot 10^{-3}$

iii)  $\text{pOH} = -\log[\text{OH}^-] = -\log(1.79 \cdot 10^{-3}) = 2.75$

iv)  $\text{pH} + \text{pOH} = 14$

$\text{pH} = 14 - \text{pOH} = 14 - 2.75 = 11.25$