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.

$\Delta H < 0 \rightsquigarrow$ generate $q$

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]

a. cooling the sample

$s \rightarrow aq + q$

$\downarrow T \rightarrow$ "want" $\uparrow T$ : generate $q \rightarrow \uparrow r_f \rightarrow \uparrow r_q$ : $\uparrow$ solubility

or $\Delta G = -RT\ln K = \Delta H - T\Delta S$

$\ln K = -\frac{\Delta H}{RT} + \frac{\Delta S}{R}$

$\downarrow T$ & $\Delta H < 0 \rightarrow \uparrow \ln K \rightarrow \uparrow K$ : $\uparrow$ solubility

b. adding sodium nitrate

$NaOH_{(s)} \rightleftharpoons Na^+_{(aq)} + OH^-_{(aq)}$ ; $Q = [Na^+][OH^-]$

$+ NaNO_3 \rightarrow \uparrow [Na^+] \rightarrow \uparrow Q \rightarrow \downarrow Q$ to reestablish eq $\rightarrow \uparrow$ solid

$\downarrow$ solubility

c. adding ~~magnesium~~ barium nitrate

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

$\downarrow$

$\uparrow$ solubility $\leftarrow \uparrow (OH^-)$ & $[Na^+]$

2. In the reaction: $H_{2(g)} + 3\,N_{2(g)} \rightleftharpoons 2\,NH_{3(g)}$, if the initial partial pressure of $H_2$, $N_2$, and $NH_3$ are 1.0, 2.0, and 3.0 atm, respectively and the equilibrium partial pressure of $N_2$ is 1.5 atm, what is the numeric value of Kp ? [10 points}

i) $H_2 + 3N_2 \rightleftharpoons 2NH_3$

| | 1 | 1 | 2 | 3 |
|---|---|---|---|---|
| C | | -0.17 | -0.5 | +0.33 |
| E | | 0.83 | 1.5 | 3.33 |

ii) $K_p = \frac{P_{NH_3}^2}{P_{H_2} P_{N_2}^3} = \frac{3.33^2}{0.83\,(1.5)^3} = 3.96$

show eqn, but no need to derive eqn

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

a. If Kc = 10, then Kp = ? in: $H_{2(g)} + Cl_{2(g)} \rightleftarrows 2\,HCl_{(g)}$

2 pt / 3

$K_c = K_p = 10$

bc $K_p = K_c (RT)^n$ ; $n = 2 - (1+1) = 0$

b. If Kp = 10, then Kc = ? in: $H_{2(g)} + 3\,N_{2(g)} \rightleftarrows 2\,NH_{3(g)}$

2 pt / 3

$K_p = K_c (RT)^{2-4} = K_c (RT)^{-2}$

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

$= 2.5986$

$\approx 6.0 \cdot 10^3$

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

10 pt @

a. $10^3$ ~~$10^{-3}$~~ keep

i)

| | $H_2$ | + $Cl_2$ | ⇌ $2HCl$ |
|---|---|---|---|
| I | 2 | 3 | 0 |
| Δ | −x | −x | +2x |
| E | 2−x | 3−x | 2x |

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

$10^3 = \dfrac{4x^2}{(2-x)(3-x)}$ ⇝ $x = 1.98$ → $[HCl] = 3.97\,M$

or no $K \gg 1$, assume all limiting reactant behaves product → $[HCl] = 4\,M$

a. $10^{-3}$

i)

| | $H_2$ | + $Cl_2$ | ⇌ $2HCl$ |
|---|---|---|---|
| I | 2 | 3 | 0 |
| Δ | −x | −x | +2x |
| E | 2−x | 3−x | 2x |

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

$10^{-3} = \dfrac{(2x)^2}{(2-x)(3-x)} \approx \dfrac{4x^2}{2(3)}$ bc $K \ll 1$

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

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

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

a. 2.0 mM benzoic acid

i) $HBz \rightleftharpoons H^+ + Bz^-$

| | | | |
|---|---|---|---|
| I | 2 mM | 0 | 0 |
| C | $-x$ | $+x$ | $+x$ |
| E | $2\text{ mM} - x$ | $x$ | $x$ |

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

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

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

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

b. 5.0 mM ethylamine

i) $EtNH_2 + H_2O \rightleftharpoons OH^- + EtNH_3^+$

| | | | |
|---|---|---|---|
| I | 5 mM | 0 | 0 |
| C | $-x$ | $+x$ | $+x$ |
| E | $5\text{ mM} - x$ | $x$ | $x$ |

ii) $K_b = \dfrac{[OH^-][EtNH_3^+]}{[EtNH_2]}$

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

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

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

iv) $pH + pOH = 14$

$pH = 14 - pOH = 14 - 2.75 = 11.25$