



KWANTLEN
POLYTECHNIC
UNIVERSITY

CHEMISTRY 1210 – SPRING 2017

EXAM 1

February 9th 2017

Name:

ANS KEY

Student #:

_____ / 40

Time allowed: 1h50

Only approved calculators are permitted
Cell phones and other electronics must be turned off
"What is 'HIJKLMNO'? – H₂O"
Good Luck – Bonne chance – Suerte

$$T_k = T_c + 273.15$$

$$K_w = 1.0 \times 10^{-14} \text{ (at } 25^\circ\text{C)}$$

Assume all acid-base questions are at 25°C unless specified

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\ln \left(\frac{K_{eq1}}{K_{eq2}} \right) = \frac{\Delta H^\circ}{R} \left(\frac{T_1 - T_2}{T_1 T_2} \right)$$

$$k_p = k_c (RT)^{\Delta n}$$

- 1) **(1 pt)** What is a chemical equilibrium? It is a chemical reaction... (circle one)
- a) ...that is balanced precariously on the edge of a lab bench, but somehow manages to not fall off
 - b) ...where the concentration of the products is equal to the concentrations of the reactants which is defined by a constant
 - c) ...where both the forward and reverse reaction are taking place at the same rate
 - d) ...where the concentration of the products is a constant when conditions are changed

- 2) **(1 pt)** Which of the following is the strongest acid: (circle one)

- a) H_3PO_4 , phosphoric acid, $K_a = 7.1 \times 10^{-3}$
- b) H_2CO_3 , carbonic acid, $K_a = 4.3 \times 10^{-7}$
- c) NH_3 , ammonia, $K_b = 1.7 \times 10^{-5}$
- d) $\text{C}_7\text{H}_6\text{O}_2$, benzoic acid, $K_a = 6.3 \times 10^{-5}$

- 3) **(1 pt)** Which of the following salts would be acidic? (NH_3 , $K_b = 1.7 \times 10^{-5}$; H_2CO_3 $K_{a1} = 4.3 \times 10^{-7}$, $K_{a2} = 5.6 \times 10^{-11}$) (circle one)

- a) NaCl
- b) NH_4Cl
- c) CaCO_3
- d) KClO_4

- 4) **(2 pts)** What is a weak diprotic base, give one example and show its reactions with water.



A BASE THAT CAN ACCEPT TWO H^+

5) (3 pts) The Haber reaction is used to produce ammonia



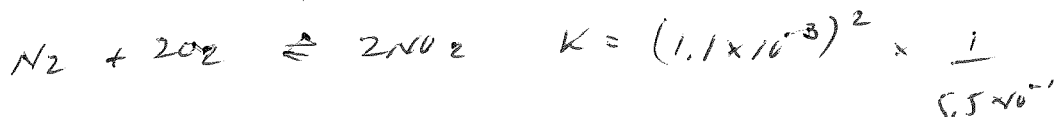
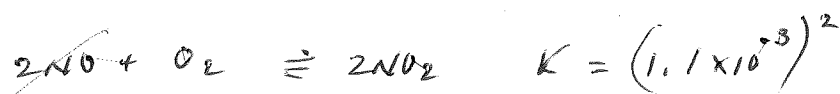
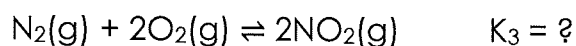
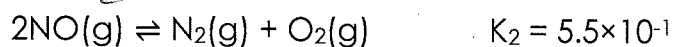
A mixture of $\text{H}_2(\text{g})$, $\text{N}_2(\text{g})$ and $\text{NH}_3(\text{g})$ is brought to equilibrium at 3000°C . Describe how the reaction conditions, a-b-c, could be modified to increase the yield of $\text{NH}_3(\text{g})$.

a) Concentration (reactants): *increase the concentrations*

b) Pressure: *increase the pressure*

c) Temperature: *decrease the temperature*

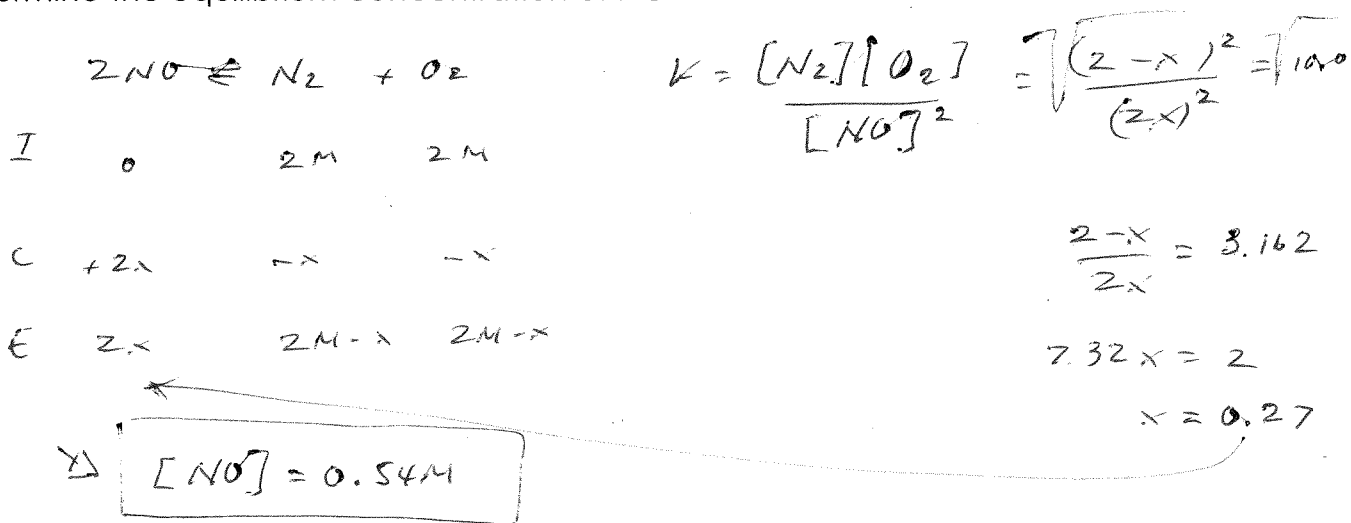
6) (2 pts) Based on the following two reactions and equilibrium constants, determine the value of K_3 .



$$K = 2.2 \times 10^{-6}$$

7) (4 pts) Consider the reaction: $2\text{NO}(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + \text{O}_2(\text{g})$, for which $K_c = 10.0$ at 200°C . A 5.00 L vessel is filled with 10.0 mol of $\text{N}_2(\text{g})$ and 10.0 mol of $\text{O}_2(\text{g})$

a) Determine the equilibrium concentration of NO



b) Determine the K_p for this reaction at 200°C ? (use $R=0.08314 \text{ L bar/mol K}$)

$$K_p = K_c (RT)^{\Delta n} = 10.0$$

$$K_p = K_c = \boxed{10.0}$$

10) (4 pts) $\text{H}_3\text{PO}_4(\text{aq})$ is an acid, with $K_{a1} = 6.9 \times 10^{-3}$; $K_{a2} = 6.3 \times 10^{-8}$; $K_{a3} = 4.8 \times 10^{-13}$.

Consider a 7.0 M solution of H_3PO_4 .

a) Determine the pH of this solution



I	7.0	0	0
C	-x	+x	+x
E	7.0-x	x	x
	↑		
	ASSUME ≈ 7.0		

$$\frac{x^2}{7.0} = 6.9 \times 10^{-3}$$

$$x = 0.22 \text{ M}$$

$\text{pH} = 0.66$

b) Determine the equilibrium concentration of PO_4^{3-} in this solution



I	0.22	0	0.22
C	-x	+x	+x
E	0.22-x	x	0.22+x
	ASSUME ≈ 0.22	x	ASSUME ≈ 0.22

$$\frac{x(0.22)}{0.22} = 6.3 \times 10^{-8}$$

$$x = 6.3 \times 10^{-8}$$



I	6.3×10^{-8}	0	0.22
C	-x	+x	+x
E	6.3×10^{-8}	x	0.22

$$\frac{x(0.22)}{6.3 \times 10^{-8}} = 4.8 \times 10^{-13}$$

$x = 1.4 \times 10^{-19} \text{ M}$

- 8) (2 pts) A solution is prepared as follows: 24.5 g of NaOH (40.0 g/mol) is dissolved in a 250.0 mL volumetric flask. A 15.00 mL sample of the first solution is diluted to 100.0 mL in a second volumetric flask. Determine the pH of the final solution.

$$24.5 \text{ g NaOH} \times \frac{1 \text{ mol}}{40.0 \text{ g}} = \frac{0.6125 \text{ mol}}{0.250 \text{ L}} = 2.45 \text{ M initial}$$

$$2.45 \text{ M} \times \frac{15.00 \text{ mL}}{100.0 \text{ mL}} = 0.3675 \text{ M NaOH} \times \frac{1 \text{ OH}^-}{1 \text{ NaOH}} = 0.3675 \text{ M OH}^-$$

$$\text{pOH} = 0.435$$

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

$$\boxed{\text{pH} = 13.56}$$

- 9) (2 pts) Determine the pOH of a 0.45 M solution of HCl at 50.0°C. $K_w = 1.0 \times 10^{-14}$ at 25°C, and the autohydrolysis of water reaction has $\Delta H^\circ = +55.8 \text{ kJ/mol}$. (use $R = 8.314 \text{ J/mol K}$)

$$\ln\left(\frac{K_1}{1.0 \times 10^{-14}}\right) = \frac{55.8 \times 10^3 \text{ J/mol}}{8.314 \text{ J/mol K}} \left(\frac{323 - 298}{323 \cdot 298} \right)$$

$$K_1 = 5.716 \times 10^{-14} = [\text{H}_3\text{O}^+][\text{OH}^-]$$

$$\uparrow$$

$$0.45 \text{ M}$$

$$[\text{OH}^-] = 1.27 \times 10^{-13}$$

$$\boxed{\text{pOH} = 12.90}$$

11) (4 pts) Benzoic acid has a $K_a = 6.3 \times 10^{-5}$. Determine the pH of:

a) A 0.100 M benzoic acid solution



I	0.1	0	0
C	-x	+x	+x
E	0.1-x	x	x

ASSUME ≈ 0.1

$$\frac{x^2}{0.1} = 6.3 \times 10^{-5}$$

$$x = [\text{H}_3\text{O}^+] = 2.51 \times 10^{-3}$$

$$\text{pH} = 2.60$$

b) A 0.500 M sodium benzoate solution (benzoate is the conjugate base of benzoic acid)



I	0.500	0	0
C	-x	+x	+x
E	0.500-x	x	x

ASSUME ≈ 0.500

$$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{6.3 \times 10^{-5}} = 1.59 \times 10^{-10}$$

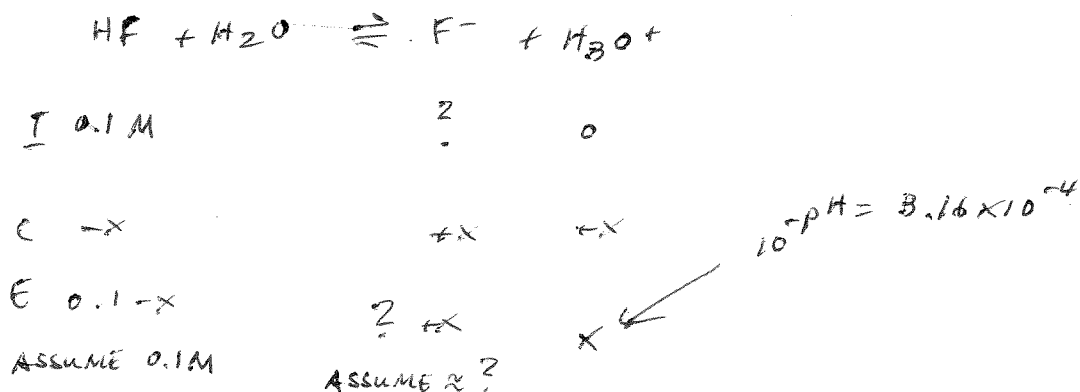
$$\frac{x^2}{0.500} = 1.59 \times 10^{-10}$$

$$x = [\text{OH}^-] = 8.91 \times 10^{-6}$$

$$\text{pOH} = 5.05$$

$$\text{pH} = 8.95$$

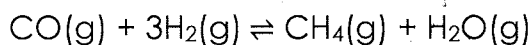
- 12) (2 pts) Determine the mass of sodium fluoride NaF (42.0 g/mol) that needs to be added to 1.50 L of 0.100 M hydrofluoric acid HF ($K_a = 6.6 \times 10^{-4}$) to prepare a solution with a pH of 3.50.



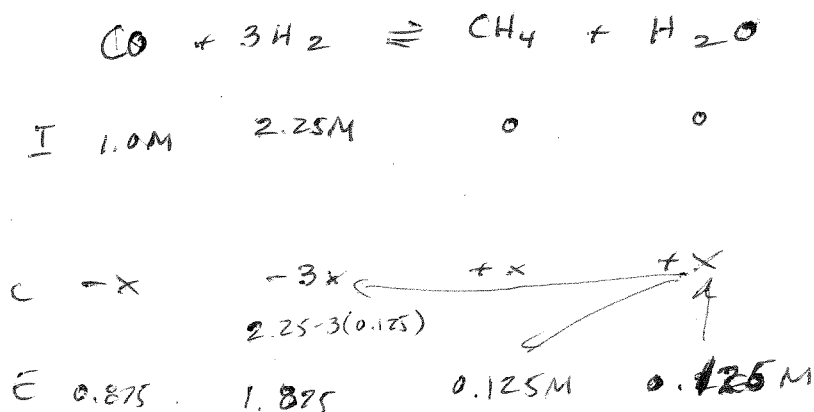
$$\frac{(3.16 \times 10^{-4})^2}{0.1} = 6.6 \times 10^{-4}$$

$$x = 0.209 \text{ M} \times 1.50 \text{ L} = 0.313 \text{ moles} \times \frac{42.09 \text{ g}}{\text{mol}} = \boxed{13 \text{ g NaF}}$$

- 13) (2 pts) Consider the following reaction:



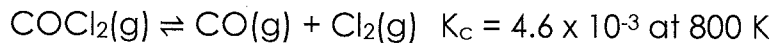
When $2.00/2.0$ mol of CO(g) is mixed with $4.50/2.0$ mol of H₂(g) in a 2.0 L vessel at 250°C and the reaction is allowed to reach equilibrium, it is determined that $0.250/2.0$ mol of H₂O(g) are present at equilibrium. Determine K_c at 250°C.



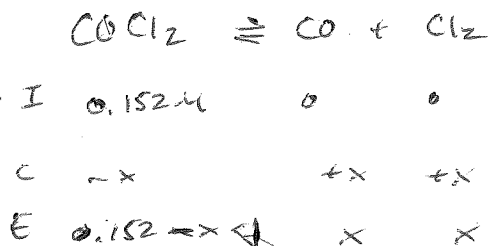
$$K_c = \frac{[\text{CH}_4][\text{H}_2\text{O}]}{[\text{CO}][\text{H}_2]^3} = \frac{(0.125)^2}{(0.875)(1.875)^3} = \boxed{2.71 \times 10^{-3}}$$

14) (2 pts) Consider the following equilibrium:

$$15.09 \times \frac{1 \text{ mol}}{98.99} = 0.152 \text{ mol}$$



If a sample of 15.0 g of $\text{COCl}_2(\text{g})$ (98.9 g/mol) is placed in a 1.00 L flask at 800 K and the reaction is allowed to reach an equilibrium, determine the equilibrium concentration of $\text{COCl}_2(\text{g})$.



$$\frac{x^2}{0.152 - x} = 4.6 \times 10^{-3}$$

$$x^2 = 0.992 \times 10^{-4} - 4.6 \times 10^{-3} x$$

$$x^2 + 4.6 \times 10^{-3} x - 6.992 \times 10^{-4} = 0$$

$$x = \frac{-4.6 \times 10^{-3} \pm \sqrt{(4.6 \times 10^{-3})^2 - (4)(1)(-6.992 \times 10^{-4})}}{2}$$

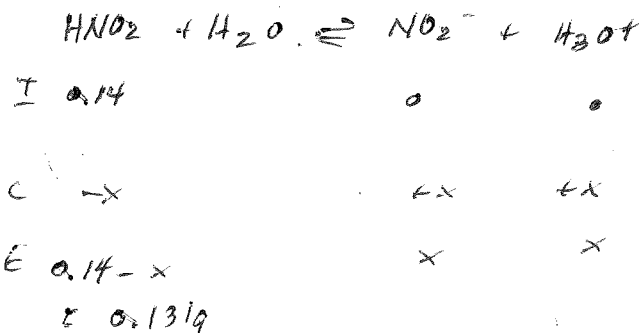
$$x = 0.024$$

$$[\text{COCl}_2] = 0.128 \text{ M}$$

↑
CANNOT MAKE
ASSUMPTION
 $\frac{0.152}{4.6 \times 10^{-3}} = 33$

15) (4 pts) A 0.14 M HNO_2 solution is 5.75% ionized.

a) Calculate the pH of this solution



$$\frac{x}{0.14} \times 100\% = 5.75$$

$$x = 8.05 \times 10^{-3} \text{ M}$$

$$\text{pH} = 2.09$$

b) Determine the K_a of HNO_2

$$K_a = \frac{[\text{NO}_2^-][\text{H}_3\text{O}^+]}{[\text{HNO}_2]} = \frac{(8.05 \times 10^{-3})^2}{0.13195} = 4.91 \times 10^{-4}$$

