Chem 1B
Test- Review #1

1. (a) At a certain temperature, an equilibrium mixture contains 0.478 mol CH_4, 0.478 mol H_2O, 1.522 mol CO, and 1.566 mol H_2, in a 10.0-L sealed reaction vessel. Calculate the equilibrium constant K_c for the following reaction: $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$

   (b) For the same mixture, what is the equilibrium constant K_c for the reaction?

$$CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$$

   (c) For reaction (b), is the reaction at equilibrium if the same mixture were placed in a 1.00-L vessel at the same temperature? Explain. In which direction the equilibrium would shift if the mixture is not at equilibrium?

2. At a certain temperature, an equilibrium mixture contains the following substances: $[O_2] = 4.2 \times 10^{-3}\ M$, $[SO_2] = 3.8 \times 10^{-3}\ M$, and $[SO_3] = 4.1 \times 10^{-3}\ M$. Calculate the equilibrium constant K_c for the following reactions:

   (a) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ (b) $SO_{3(g)} \rightleftharpoons SO_{2(g)} + \frac{1}{2} O_{2(g)}$

3. Ammonium carbamate ($NH_2CO_2NH_4$) decomposes when heated and, in a sealed vessel, the following equilibrium is established,

$$NH_4CO_2NH_2(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$$

   with $K_p = 2.9 \times 10^{-3}$ at 25°C. (a) Calculate the total gas pressure at equilibrium. (c) If 5.00 g $NH_4CO_2NH_2$ was introduced into an evacuated 5.00-L reaction vessel and the above equilibrium is established at 25°C, how many grams of solid $NH_4CO_2NH_2$ still remains at equilibrium? ($R = 0.0821\ ^{L.atm}/_{mol.K}$)

4. Given the equilibrium constants for the following reactions:

   (1) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$; $K_{c1} = 2.3 \times 10^{-19}$

   (2) $2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$; $K_{c2} = 1.1 \times 10^{-5}$

   Calculate K_c for the following reaction at the same temperature.

$$NO_2(g) \rightleftharpoons \frac{1}{2} N_2(g) + O_2(g)$$

5. Identify each of the following as strong acid or weak acid:

   (a) $HBr_{(aq)}$:_____________ (b) $HCl_{(aq)}$:______________ (c) $HF_{(aq)}$:______________

   (d) HCOOH:_____________ (e) CH_3COOH:____________ (f) HNO_3:_______________

   (g) H_2SO_4:____________ (h) H_3PO_4:______________ (*i*) $HClO_2$:______________

6. In each of the following pairs of acids, indicate the one with stronger conjugate bases:

(a) HNO_2 and HNO_3 (b) H_3PO_3 and H_2SO_3 (c) HOCl and HOBr

(d) H_2SO_3 and $HClO_3$ (e) CH_3CO_2H and CCl_3CO_2H (f) H_2S and H_2Se

7. (a) Determine the pH and percent ionization of 0.20 *M* nitrous acid, HNO_2 ($K_a = 4.0 \times 10^{-4}$).

(b) A solution of 0.10 *M* $HClO_2$ (chlorous acid) has the same pH as that of 0.030 *M* HCl. What is the K_a of chlorous acid.

8. (a) Calculate the pH of 0.10 M NH_3 solution ($K_{b(NH3)} = 1.8 \times 10^{-5}$), which ionizes as follows:

$$NH_{3(aq)} + H_2O \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

(b) What is the value of K_a for NH_4^+ in the following equilibrium:

$$NH_4^+{}_{(aq)} + H_2O \rightleftharpoons NH_{3(aq)} + H_3O^+{}_{(aq)} ;$$

Calculate the pH of 0.10 *M* NH_4Cl solution. ($K_w = 1.0 \times 10^{-14}$)

9. Predict whether each of the following solutions is neutral, acidic or basic? In each case, write the chemical equation to support your reasoning.

(a) $NaF_{(aq)}$

(b) $KNO_{3(aq)}$

(c) $Al(NO_3)_{3(aq)}$

(d) $Na_2CO_{3(aq)}$

10. Buffer solutions of specific pH maybe prepared by mixing solutions of weak acid with salts of their conjugate bases in the right proportions. Suppose the following solutions are available to make buffer solutions of various pH's:

0.10 *M* CH_3CO_2H ($K_a = 1.8 \times 10^{-5}$); 0.10 *M* $NaCH_3CO_2$;
0.10 *M* HNO_2 ($K_a = 4.0 \times 10^{-4}$); 0.10 *M* $NaNO_2$;
0.10 *M* NH_3 ($K_b = 1.8 \times 10^{-5}$); 0.10 *M* NH_4Cl;
0.10 *M* NaH_2PO_4 ($K_a = 6.3 \times 10^{-8}$); and 0.10 *M* Na_2HPO_4;

(a) Which pair of solution would you use to prepare buffer solutions with the following pH's?

(*i*) pH = 3.50; (*ii*) pH = 5.00; (*iii*) pH = 7.50; (*iv*) pH = 9.00

(b) What is the molar ratio of conjugate base to acid: (*i*) in a buffer solution with pH = 5.00; (*ii*) in a buffer solution with pH = 9.00?

11. A buffer solution is prepared by dissolving 5.1 g sodium acetate ($NaCH_3CO_2$; molar mass = 82.03 g/mol) in 100.0 mL of 0.20 *M* acetic acid, CH_3CO_2H ($K_a = 1.8 \times 10^{-5}$). (a) Calculate molar ratio of acetate ion to acetic acid, $[CH_3CO_2^-]/[CH_3CO_2H]$, and the buffer pH. (b) What is the pH of the resulting solution if 0.012 mole of HCl is added without altering the total volume of solution?

12. A 40.0-mL sample of 0.100 *M* hypochlorous acid (HClO) is titrated with 0.100 *M* NaOH. The following pH values were measured at various points in the titration:

Volume of NaOH added (mL):	0.0	10.0	20.0	30.0	40.0
pH of solution mixture:	4.35	7.05	7.50	?	?

(a) Determine the K_a values of formic acid: (*i*) using initial pH (that is, pH before NaOH is added), and (*ii*) using pH value after 20.0 mL of NaOH is added. Calculate the average K_a value. (b) Using the average K_a, predict the pH of the solution after 30.0 mL of 0.100 *M* NaOH is added. (c) Determine the pH of the solution at equivalent point (after 40.0 mL of 0.100 *M* NaOH has been added).

13. A 50.0-mL solution of 0.100 *M* potassium hydrogen phthalate (KHP; (HP^- has $K_a \sim 4.0 \times 10^{-6}$) is titrated with 0.100 *M* of NaOH. Calculate the pH of the solution:
(a) before NaOH is added;
(b) after 25.0 mL of NaOH is added;
(c) after 50.0 mL of NaOH is added, and
(d) After 75.0 mL of NaOH is added.

14. For each of the following acid-base titrations in which each solution used is approximately 0.10 *M*, determine the expected pH at equivalent points, and indicate which acid-base indicator, phenolphthalein ($pK_a \sim 9$) or methyl red ($pK_a \sim 5$) may be used to determine the end-point.

(a) HCl(aq) - NaOH(aq) titration

(b) KHP(aq) - NaOH(aq) titration; (HP^- has $K_a \sim 4.0 \times 10^{-6}$)

(c) NH_3(aq) - HCl(aq) titration; (K_b of $NH_3 = 1.8 \times 10^{-5}$; K_a of $NH_4^+ = 5.6 \times 10^{-10}$)

15. Saturated solution of silver phosphate contains 7.4×10^{-3} g of Ag_3PO_4 in 1.00 L of solution. (a) What is the solubility of Ag_3PO_4 in mole per liter? (b) Calculate the K_{sp} for Ag_3PO_4.
(Molar mass of Ag_3PO_4 = 418.67 g/mol)

16. Saturated solution of magnesium hydroxide, $Mg(OH)_2$, has pH = 10.42. (a) Determine the solubility (in mol/L) and the K_{sp} of $Mg(OH)_2$. (b) What is the solubility of $Mg(OH)_2$ in solution that is buffered at pH = 9.00? (c) How many grams of $Mg(OH)_2$ will dissolve in 1.00 L of solution buffered at pH = 9?

17. A 25.0 mL solution of 0.100 *M* $Pb(NO_3)_2$ is added to 25.0 mL of 0.200 *M* NaBr. (a) How many grams of $PbBr_2$ precipitate will form? (b) What are the concentrations of Pb^{2+}, NO_3^-, Na^+, and Br^-, respectively, in the saturated solution containing $PbBr_2$ precipitate? ($PbBr_2$ has $K_{sp} = 4.6 \times 10^{-6}$)

18. For the following equilibrium: $Cu^{2+}(aq) + 4NH_3(aq) \rightleftharpoons Cu(NH_3)_4^{2+}(aq)$; $K_f = 1.12 \times 10^{13}$

(a) If 5.0 mL of 0.10 *M* $Cu(NO_3)_2$ is added to 20.0 mL of 2.0 *M* NH_3 solution, and the above equilibrium is established, calculate the molar concentration of Cu^{2+}, $Cu(NH_3)_4^{2+}$, NH_3, and NO_3^-, respectively, in the equilibrium mixture?
(b) If the solubility equilibrium: $Cu(OH)_2(s) \rightleftharpoons Cu^{2+}(aq) + 2\ OH^-(aq)$, has $K_{sp} = 2.2 \times 10^{-20}$, what is the value of K_c for the following equilibrium:

$$Cu(OH)_2(s) + 4NH_4(aq) \rightleftharpoons Cu(NH_3)_4^{2+}(aq) + 2\ OH^-(aq)$$

19. Given the following equilibria in aqueous solution:

$$AgBr(s) \rightleftharpoons Ag^+(aq) + Br^-(aq); \quad K_{sp} = 5.0 \times 10^{-13}$$
$$Ag^+_{(aq)} + 2S_2O_3^{2-}(aq) \rightleftharpoons Ag(S_2O_3)_2^{3-}(aq); \quad K_f = 2.9 \times 10^{13}$$

(a) What is K_c for the following equilibrium?

$$AgBr(s) + 2S_2O_3^{2-}(aq) \rightleftharpoons Ag(S_2O_3)_2^{3-}(aq) + Br^-(aq);$$

(b) Determine the molar solubility of AgBr in solution of 0.50 *M* $Na_2S_2O_3$.
(c) How many grams of AgBr will dissolve in 5.0×10^2 mL of 0.50 *M* $Na_2S_2O_3$?

20. You are provided with the following reagents for cations analysis: 6 *M* HCl, 6 *M* NaOH, 6 *M* NH_3, and 3 *M* H_2SO_4. Which reagent would you use to separate cations in the following mixtures? With the help of relevant chemical equations, explain briefly how each pair of cations would be separated using your reagent of choice? (*Hint*: check the Solubility Rules and determine which cations form complex ions with NH_3 and/or OH^-.)

(a) Ag^+ and Ba^{2+} (b) Ba^{2+} and Cu^{2+} (c) Cu^{2+} and Fe^{3+} (d) Cr^{3+} and Fe^{3+}

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Answers

1. (a) $K_c = 0.256$; (b) = $K_c' = 3.91$;
   (c) No. Reducing the volume will increase pressure and equilibrium will shift to the left;
2. (a) $K_c = 280$; (b) $K_c' = 6.0 \times 10^{-2}$
3. (a) $K_p = 2.92 \times 10^{-3}$; (b) $P_{total} = 0.270$ atm; (c) 3.56 g of $NH_4CO_2NH_2$ remains;
4. $K_c = 6.9 \times 10^6$
5. (a) strong (b) strong; (c) weak; (d) weak; (e) weak (f) strong
   (g) strong (h) weak (*i*) weak
6. (a) HNO_2 (b) H_3PO_3 (c) HOBr (d) H_2SO_3 (e) CH_3CO_2H (f) H_2S
7. (a) pH = 2.05; % ionization = 4.5%; (b) $HClO_2$ has $K_a = 1.3 \times 10^{-2}$
8. (a) pH = 11.13; (b) $K_a = 5.6 \times 10^{-10}$; pH = 5.13
9. (a) basic (b) neutral (c) acidic (d) basic
10. (a) (*i*) HNO_2-$NaNO_2$ (*ii*) CH_3CO_2H- $NaCH_3CO_2$ (*iii*) NaH_2PO_4- Na_2HPO_4
    (*iv*) NH_4Cl-NH_3 (b) (*i*) $[CH_3CO_2^-]/[CH_3CO_2H] = 1.8/1$; (*ii*) $[NH_3]/[NH_4^+] = 0.56/1$
11. (a) pH = 5.23; (b) pH = 4.93
12. (a) (*i*) $K_a = 2.0 \times 10^{-8}$ (*ii*) $K_a = 3.2 \times 10^{-8}$; (*iii*) Average $K_a = 2.6 \times 10^{-8}$;
    (b) pH = 8.06; (c) pH = 10.14
13. (a) initial pH = 3.20; (b) pH = 5.40; (c) At equivalent point, pH = 9.05;
14. Suitable indicators: (a) Phenolphthalein or Methyl Red; (b) Phenolphthalein (c) Methyl Red
15. (a) solubility of $Ag_3PO_4 = 1.8 \times 10^{-5}$ mol/L; (b) $K_{sp} = 2.8 \times 10^{-18}$;
16. (a) Solubility of $Mg(OH)_2 = 1.3 \times 10^{-4}$ mol/L; $K_{sp} = 8.8 \times 10^{-12}$ (b) 0.090 mol/L
17. (a) precipitate = 0.92 g of $PbBr_2$;
    (b) $[Pb^{2+}] = 0.0105$ mol/L; $[Br^-] = 0.0210$ mol/L; $[Na^+] = [NO_3^-] = 0.10$ *M*
18. (a) $[Cu^{2+}] = 3.3 \times 10^{-16}$ *M*; $[Cu(NH_3)_4^{2+}] = 0.020$ *M*; $[NH_3] = 1.5$ *M*
    (b) $K_c = 2.5 \times 10^{-7}$;
19. (a) $K_c = 1\underline{4}.5$; (b) solubility of AgBr = 0.22 mol/L; (c) mass of AgBr dissolved = 21 g
20. (a) Add 6 *M* HCl: AgCl will form precipitate; Ba^{2+} remains in solution ($BaCl_2$ is soluble)
    (b) Add 3 *M* H_2SO_4: $BaSO_4$ will form precipitate; $CuSO_4$ is soluble;
    (c) Add 6 *M* NH_3: $Fe(OH)_3$ will form precipitate; Cu^{2+} forms complex ion $Cu(NH_3)_4^{2+}$ and remains in solution;
    (d) Add excess 6 *M* NaOH: $Fe(OH)_3$ will form precipitate; Cr^{3+} forms complex ion $Cr(OH)_4^-$ and remains in solution.