Chemistry 212 Test 2 Name: ____________________
Fall 2022 (Please print)

Multiple Choice (5 points each, Put answers in CAPS in the left margin.)

1. Which of the following would have the highest boiling point? (Homework 11.24)

   A) 0.12 *m* C_2H_5OH C) 0.30 *m* CaF_2 E) pure H_2O
   B) 0.35 *m* NH_3 D) 0.19 *m* KI

2. A solution of $H_2SO_{4\,(aq)}$ with a molal concentration of 4.48 *m* has a density of 1.135 g/mL. What is the molar concentration of this solution?

   A) 2.74 *M* B) 3.53 *M* C) 4.16 *M* D) 4.39 *M* E) 4.48 *M*

3. What is the value of K_C for the reaction: $N_{2\,(g)} + 3\,H_{2\,(g)} \rightleftharpoons 2\,NH_{3\,(g)}$ at 249 ºC. $K_P = 0.216$

   A) 1.18×10^{-4} B) 2.52×10^{-3} C) 0.216 D) 90.2 E) 396

4. Which of the following is the correct equilibrium expression (K_C) for the reaction:
   $SnO_{2\,(s)} + 2\,CO_{(g)} \rightleftharpoons Sn_{(s)} + 2\,CO_{2\,(g)}$

   A) $\dfrac{[CO_2]^2}{[CO]^2}$ C) $\dfrac{[Sn][CO_2]}{[SnO_2][CO]}$ E) $\dfrac{[Sn][CO_2]^2}{[SnO_2][CO]^2}$

   B) $\dfrac{[CO]^2}{[CO_2]^2}$ D) $\dfrac{[SnO_2][CO]^2}{[Sn][CO_2]^2}$

5. In the previous equilibrium which of the following will cause no change in the position of the equilibrium?

   A) Adding SnO_2. C) Adding HCl. E) (A) and (D)
   B) Adding CO. D) Reducing the container volume.

6. Which of the following would you expect to be **most** acidic? (See Discussion Question #4.)

   A) HIO_3 B) $HBrO_2$ C) HBrO D) HIO E) $HClO_4$

7. Which of the following is false?

   A) The stronger an acid or base, the weaker is its conjugate.
   B) H_3O^+ is the strongest acid that can exist in water.
   C) Group IA oxides form basic solutions.
   D) The majority of acids are weak acids.
   E) A Lewis base is an electron pair acceptor.

8. When a weak acid neutralizes a strong base, the final solution will be __________.

   A) acidic B) basic C) neutral (pH = 7)
   D) unable to determine with the given information

Discussion questions (You must show your work to receive credit!)

1. For the reaction A + B $\longrightarrow$ C the following data were collected:

[A] (M)	[B] (M)	rate (Ms^{-1})
0.35	0.35	12.1
0.35	0.70	24.2
0.70	0.35	48.4

a) What is the rate law for this reaction?
b) What is the value of the rate constant for this reaction? (8 points)

a) General rate law: rate = $k[A]^x[B]^y$

$$\frac{rate_1}{rate_2} = \frac{k[A]_1{}^x[B]_1{}^y}{k[A]_2{}^x[B]_2{}^y}$$

$$\frac{12.1\ Ms^{-1}}{24.2\ Ms^{-1}} = \frac{\cancel{k(0.35\ M)^x}(0.35\ M)^y}{\cancel{k(0.35\ M)^x}(0.70\ M)^y}$$

$$\frac{1}{2} = \frac{(0.35\ M)^y}{(0.70\ M)^y} = \left(\frac{0.35}{0.70}\right)^y = \left(\frac{1}{2}\right)^y$$

y = 1

$$\frac{12.1\ Ms^{-1}}{48.4\ Ms^{-1}} = \frac{k(0.35\ M)^x\cancel{(0.35\ M)^y}}{k(0.70\ M)^z\cancel{(0.35\ M)^y}}$$

$$\frac{1}{4} = \frac{(0.35\ M)^x}{(0.70\ M)^x} = \left(\frac{0.35}{0.70}\right)^x = \left(\frac{1}{2}\right)^x$$

x = 2

Thus, the rate law is: rate = $k[A]^2[B]$

b) $12.1\ Ms^{-1} = k(0.35\ M)^2(0.35\ M)$

$k = 282\ M^{-2}s^{-1}$

2. Provide a physical explanation of why solids are not included in equilibrium expressions. (6 points)

Solids are in a different phase from the other materials in the equilibrium. The presence of a solid ensures that the concentration of that material in the solution remains constant because as any that is produced will be removed from solution and any consumed will be replaced. Essentially, it is adding or removing material as the reaction progresses.

3. The equilibrium constant for the reaction $H_2 + I_2 \rightleftharpoons 2\ HI$ is 55.6 at 425 ºC (all are gases). If 1.00 mol of hydrogen and 1.00 mol of iodine are allowed to equilibrate in a 5.00 L vessel, how many moles of hydrogen iodide are produced? What percentage of iodine is converted to hydrogen iodide? (10 points)

$[H_2]_i = \frac{1.00\ mol_{H2}}{5.00\ L} = 0.200\ M$ $[I_2]_i = \frac{1.00\ mol_{I2}}{5.00\ L} = 0.200\ M$

$[H_2]_e = 0.200 - x\ M$ $[I_2]_e = 0.200 - x\ M$ $[HI]_e = 2x$

$$K_C = \frac{[HI]^2}{[H_2][I_2]} = \frac{(2x)^2}{(0.200 - x)^2} = 55.6$$

$$\frac{2x}{0.200-x} = 7.46$$

$x = 0.158 \Rightarrow [HI]_e = 0.316\ M$

$$mol_{HI} = \frac{0.316\ mol_{HI}}{L} \times 5.0\ L = 1.58\ mol$$

% conversion = 100% - $\left(\frac{0.200\ M - 0.158\ M}{0.200\ M}\right)(100\%)$ = 79.0 %

4. For the reaction: $NaHCO_{3\,(aq)}$ + $NaOH_{(aq)}$ → $Na_2CO_{3\,(aq)}$ + $H_2O_{(\ell)}$, identify the acid, base, and their respective conjugates. (8 points)

   acid = $NaHCO_3$, base = NaOH, conjugate acid = water, conjugate base Na_2CO_3

5. Provide a physical explanation for your answer to multiple choice question 6. (6 points)

   Each of these acids has the basic structure H-O-X, where X = IO_2, BrO, Br, I, and ClO_3, respectively. There are two major factors that influence acidity, H-X bond polarity and H-X bond strength. For all five acids, the hydrogen is bound to an oxygen, so bond strength probably doesn't change much. HIO can be ruled out because Br (in HBrO) is more electronegative than I. For the remaining acids, the presence of oxygen, a very electronegative element, plays an important role. HBrO can be ruled out because $HBrO_2$ has one more oxygen bound to the Br. Differentiating between HIO_3 and $HBrO_2$ is challenging because Br is more electronegative than I, but HIO_3 has an extra oxygen. This would be a problem if $HClO_4$ didn't have the most electronegative central atom (Cl) and most oxygens (4), which makes it's H-O bond most polar and, so, most acidic.

5. What is the pH of a (12 points)

   a) 0.37 *M* aniline (C_6H_5N) solution? ($K_b = 3.9 \times 10^{-10}$)

   $C_6H_5N + H_2O \rightleftharpoons C_6H_5NH^+ + OH^-$ $\qquad K_b = \frac{[C_6H_5NH^+][OH^-]}{[C_6H_5N]}$

init	0.37 *M*	0 *M*	0 *M*
equil	0.37 – x	x	x

   $3.9 \times 10^{-10} = \frac{(x)(x)}{0.37 - x}$

   Since $[C_6H_5N]_i >> 100K_b$, assume x is negligible in the denominator

   $3.9 \times 10^{-10} = \frac{(x)(x)}{0.37}$

   x = $[OH^-] = 1.2 \times 10^{-5}$ *M* (0.37 – 0.000012 ≅ 0.37, so the assumption was OK)

   pOH = $-\log(1.2 \times 10^{-5})$ = 4.92

   pH = 14.00 – 2.94 = 9.08

   b) 0.76 *M* NaOAc (K_a(HOAc) = 1.8×10^{-5}) solution?

   $OAc^- + H_2O \rightleftharpoons HOAc + OH^-$ $\quad K_b = \frac{[HOAc][OH^-]}{[OAc^-]}$

init	0.76 *M*	0 *M*	0 *M*
equil	0.76 – x	x	x

   $K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.6 \times 10^{-10}$

   $5.6 \times 10^{-10} = \frac{(x)(x)}{0.76 - x}$

   Since $[F^-]_i >> 100K_b$, assume x is negligible in the denominator

   $5.6 \times 10^{-10} = \frac{x^2}{0.76}$

$x = [OH^-] = 2.06 \times 10^{-5}$ *M* $(0.76 - 3.4 \times 10^{-6} \cong 0.76$, so the assumption was OK)

$pOH = -\log(2.06 \times 10^{-5}) = 4.68$

$pH = 14.00 - 4.68 = 9.32$

6. If a buffer solution is 0.230 *M* in a weak acid (HA, $K_a = 4.1 \times 10^{-5}$) and 0.580 *M* in its conjugate base, what is its pH? What is its pH if 0.050 mol of NaOH is added to 1.00 L of this solution? (10 points)

$HA_{(aq)} \rightleftharpoons H^+_{(aq)} + A^-_{(aq)}$

a) $pK_a = -\log(K_a)$
$pK_a = -\log(4.1 \times 10^{-5}) = 4.39$
$pH = pK_a + \log\left(\frac{[A^-]}{[HA]}\right)$
$pH = 4.39 + \log\left(\frac{0.580}{0.230}\right) = 4.79$ (Homework 14.20)

b) [NaOH] = 0.050 *M*
Sodium hydroxide is a strong base and completely reacts with the weak acid.
[HA] = 0.230 *M* – 0.050 *M* = 0.180 *M*
$[A^-]$ = 0.580 *M* + 0.050 *M* = 0.630 *M*
$pH = 4.39 + \log\left(\frac{0.630}{0.180}\right) = 4.93$