Chem 1412 Spring 2016 – Daily Quiz #25 Name _____

Potentially Useful Information

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

Questions

1. Carbonic acid (H_2CO_3) is a diprotic acid. The K_as are as follows:
   $K_{a1} = 4.3 \times 10^{-7}$
   $K_{a2} = 4.7 \times 10^{-11}$
   What is the pH of a 0.222 M solution of phosphoric acid?

   A. 6.37
   B. 7.92
   C. 3.57
   D. 2.46
   E. 6.53

RICE table

Reaction	$H_2CO_3 \rightleftharpoons$	H^+	HCO_3^-
Initial	2.22	0	0
Change	-x	+x	+x
Equilibirum	2.22 -x	+x	+x

You will ignore K_{a2} because it is much smaller than K_{a1}.

$$4.3 \times 10^{-7} = \frac{x^2}{0.222 - x}$$

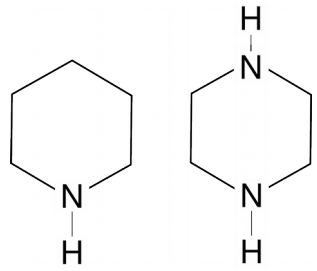
assume x is small

$$x = \sqrt{(4.3 \times 10^{-7})(0.222)} = 3.09 \times 10^{-4}$$

pH = -log(3.09 x 10^{-4}) = 3.57

2. Which of these compounds is the stronger base (the one more likely to become protonated?)

   A. Piperidine
   B. Piperazine
   C. They are the same.



piperidine piperazine

The electronegativity of the extra nitrogen in piperazine pulls electrons away from the hydrogens. This makes the nitrogens less likely to accept a proton.

piperidine $pK_b = 2.79$
piperazine $pK_b = 4.19$

3. Which of the following will produce an acidic solution in water?
   X. NH_4NO_3
   Y. NaCl
   Z. NaF

   A. X and Y
   B. X
   C. Y
   D. Z
   E. Y and Z

   Na^+ and Cl^- are derived from a strong base (NaOH) and a strong acid (HCl) and so are neutral in solution.

   NH_4NO_3 produces NO_3^- which is derived from a strong acid and therefore neutral and NH_4^+, which makes an acidic solution:

   $$NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$$

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4. Which of the following will produce an basic solution in water?
   X. NH_4NO_3
   Y. NaCl
   Z. NaF

   A. X and Y
   B. X
   C. Y
   D. Z
   E. Y and Z

   $$F^- + H_2O \rightleftharpoons HF + OH^-$$

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5. Which of the following will produce an neutral solution in water?
   X. NH_4NO_3
   Y. NaCl
   Z. NaF

   A. X and Y
   B. X
   C. Y
   D. Z
   E. Y and Z

   See the answer to question 3.

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6. If you add 0.1 M $NaNO_3$ to 0.1 M HNO_3 (see the reaction below) will the pH change?
   $HNO_3(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + NO_3^-(aq)$

   A. No, because neither Na^+ or NO_3^- will change the pH.
   B. No, because of Le Châtliers Principle.
   C. Yes, because Na^+ will change the pH.
   D. Yes, because of Le Châtliers Principle.
   E. Yes, because NO_3^- will change the pH.

   When you add NO_3^-, you are adding a product, which, by Le Châtliers Principle, will cause the reaction to shift toward reactants. Here, this causes a reduction in the $[H_3O^+]$, which raises the pH. This is called the common ion effect (NO_3^- is the common ion.)

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7. If you add 0.3 M $NaHSO_3$ to a solution of 0.1 M H_2SO_3 (see reaction), how will the pH change?

$$H_2SO_3(aq) + H_2O(aq) \rightleftharpoons H_3O^+(aq) + HSO_3^-(aq)$$

A. It will stay the same.
B. It will go down.
C. It will go up.

By adding HSO_3^-, you are adding a product, which, Le Châtliers Principle, shifts the reaction toward the reactants. This decreases the concentration of H_3O^+ so the pH will go up. This is also the common ion effect.

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8. Consider the acid base reaction below and choose the base-conjugate acid pair from the list.

$$CH_3NH_2(aq) + H_2O(\ell) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$$

	base	conjugate acid
A.	CH_3NH_2	$CH_3NH_3^{\pm}$
B.	CH_3NH_2	OH^-
C.	H_2O	OH^-
D.	H_2O	$CH_3NH_3^+$

E. None of the above.

CH_3NH_2 accepts a proton so it is the base (Brønsted-Lowry). $CH_3NH_3^+$ is derived from the base, so it is the conjugate acid.

CHEM 1412 MWF Spring 2016

Worksheet #25 – pH of Salts and the Common Ion Effect – Key

Name _____ Team_____

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pH of Salts and the Common Ion Effect

Why?

The addition of some salts to water causes a change in pH. Other salts don't cause a change in pH. Which salts cause changes to the pH and does the pH go up or down? How can you calculate the pH? What happens to the pH when you add a neutral salt, such as $NaNO_2$ to a dilute solution of HNO_2? Stay tuned.

Learning Objectives

Students should be able to:

- Predict whether a salt solution will be acidic or basic.
- Calculate the pH of salt solutions.
- Predict whether the addition of a salt to an acid-base equilibrium will cause the pH of a solution to increase or decrease.
- Calculate the pH of solutions in the presence of added salt.

Resources

Gilbert, 16.6 and 16.7

ChemTours

No ChemTours today.

Videos

pH of Salts
https://vimeo.com/20873043
This video summarizes the basic pH effects of salts. 10:12 minutes.

Calculation of the pH of 0.1 M Sulfuric Acid
https://www.youtube.com/watch?v=6exH6k9k60o
This video works out the problem presented in the book on p 797. 12:11 minutes

Prerequisites

Equilibrium, algebra, K_a, K_b, K_w, conjugate acid, and conjugate base.

Vocabulary

Common ion effect.

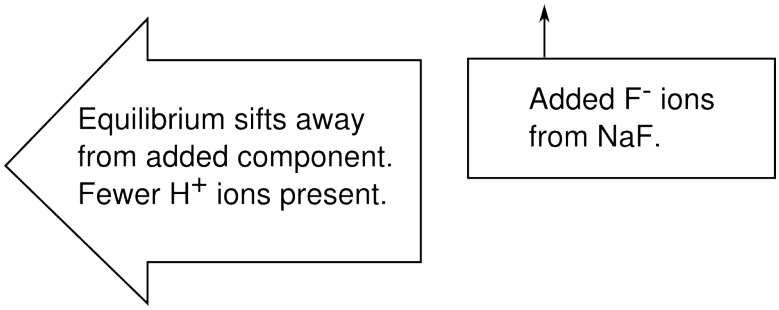
Focus Information

Common Ion Effect

Good news! If you have been paying attention, you already know this! The common ion effect is just Le Chatlier's principle! In the common ion effect, the addition oft salts that have a common ion with a weak acid can change the pH. For instance, consider what happens when you add NaF to the reaction below.

Good news! If you have been paying attention, you already know this! The common ion effect is just Le Chatlier's principle! In the common ion effect, he addition oft salts that have a common ion with a weak acid can change the pH. For instance, consider what happens when you add NaF to the reaction below.

$$HF(aq) \rightleftharpoons H^+(aq) + F^-(aq)$$



That was easy! By the way, when the $[H^+]$ goes down, the pH goes up.

Key Questions

1. What is the pH of a 0.5 M solution of NaCl?

   Answer ___pH 7.0___

   Salts that consist of the cations of strong bases and the anions of strong acids have no effect on pH when dissolved in water.

Worksheet 25

2. Are solutions of the following salts acidic, basic or neutral? For acidic or basic solutions write the appropriate chemical equation.

a. $NaNO_2$ Basic $NO_2^- + H_2O \rightleftharpoons HNO_2 + OH^-$

b. $NaNO_3$ Neutral

c. $C_5H_5NHClO_4$ Acidic $C_5H_5NH^+ \rightleftharpoons C_5H_5N + H^+$

d. NH_4NO_2 Acidic $NH_4^+ \rightleftharpoons NH_3 + H^+$

Note NH_4^+ $pK_a = 9.25$, NO_2^- $pK_b = 10.85$

NH_4^+ is a stronger acid than NO_2^- is a base. $pK_a < pK_b$

e. KOCl Basic $OCl^- + H_2O \rightleftharpoons HOCl + OH^-$

f. CO_2 Acidic $CO_2 + H_2O \rightleftharpoons H_2CO_3$

g. SO_3 Acidic $SO_3 + H_2O$? H_2SO_4

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3. Arrange the following 0.10 M solutions in order of most acidic to most basic.

KOH, KNO_3, KCN, NH_4Cl, HCl

Answer ___$HCl > NH_4Cl > KNO_3 > KCN > KOH$_____

HCl = strong acid
NH_4Cl – NH_4^+ is the conjugate acid of a weak base – produces an acid solution
KNO_3 – NO_3^- is the conjugate base of a strong acid – this is neutral
KCN – CN^- is the conjugate base of a weak acid – produces a basic solution
KOH – strong base

Worksheet 25

4. a. What are K_b and pK_b for $H_2BO_3^-$?

$$H_3BO_3(aq) \rightleftharpoons H_2BO_3^-(aq) + H^+(aq) \qquad K_a = 5.4 \times 10^{-10}$$

K_b = 1.9 x 10^{-5} pK_b = 4.72

$$K_b = \frac{K_w}{K_a} = \frac{1\times10^{-14}}{5.4\times10^{-10}} = 1.9\times10^{-5} \qquad pK_b = -\log(1.9 \times 10^{-5}) = 4.72$$

b. What are K_a and pK_a for $(CH_3)_2NH_2^+$?

$$(CH_3)_2NH(aq) + H_2O(\ell) \rightleftharpoons (CH_3)_2NH_2^+(aq) + OH^-(aq) \qquad K_b = 5.9 \times 10^{-4}$$

K_b = 1.7 x 10^{-11} pK_b = 10.77

$$K_b = \frac{K_w}{K_a} = \frac{1\times10^{-14}}{5.9\times10^{-4}} = 1.7\times10^{-11} \qquad pK_b = -\log(1.7 \times 10^{-11}) = 10.77$$

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5. Calculate the pH of a 0.10 M solution of NaOCl. The pK_a of HOCl is 3.5 x 10^{-8}.

Answer 10.23

The reaction is: OCl^- + H_2O ? HOCl + OH^-

You need to calculate the K_b from the K_a:

K_b for OCl^- = $\frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{3.5 \times 10^{-8}} = 2.86\times10^{-7}$

RICE table

Reaction	$OCl^-(\ell) + H_2O(\ell) \rightleftharpoons$	HOCl	OH^-
Initial	0.10	0	0
Change	-x	+x	+x
Equilibirum	0.10-x	x	x

$K_b = \frac{(x)(x)}{0.1 - x}$ assume x is small

$2.86 \times 10^{-7} = \frac{x^2}{0.1}$ $x = \sqrt{2.86 \times 10^{-8}} = 1.69 \times 10^{-4}$

check x is small $\frac{1.69 \times 10^{-4}}{0.1} \times 100 = 0.17\%$ so x is small!

$[OH^-] = 1.69 \times 10^{-4}$ pOH = 3.77 pH = 14.00 – 3.77 = 10.23

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6. Calculate the pH of a 0.25 M solution of methylamine chloride (CH_3NH_3Cl) in water. The K_b for methylamine (CH_3NH_2) is 4.38×10^{-4}.

Answer 5.622

methylamine chloride disassociates in water to $CH_3NH_3^+$ and Cl^-. The chloride ion has no affinity for protons so the equilibrium we are interested in is:

$$CH_3NH_3^+ \rightleftharpoons CH_3NH_2 + H^+$$

so the equilibrium we want is:

$K_a = \frac{[CH_3NH_2][H^+]}{[CH_3NH_3^+]}$ so we need to calculate K_a from the K_b that we have:

$K_w = K_a \times K_b$ and $K_a = \frac{K_w}{k_b} = \frac{1.00 \times 10^{-14}}{4.38 \times 10^{-4}} = 2.283 \times 10^{-11}$

RICE table

Reaction	$CH_3NH_3^+ \rightleftharpoons$	CH_3NH_2	H^+
Initial	0.25	0	0
Change	-x	+x	+x
Equilibirum	0.25-x	x	x

$K_a = 2.28\underline{3}\times10^{-11} = \dfrac{x^2}{0.25-x}$ assuming x is small,

$x = \sqrt{0.25\times2.28\underline{3}\times10^{-11}} = 2.38\underline{9}\times10^{-6}$

check x is small: $\dfrac{2.389\times10^{-6}}{0.25}\times100 = 0.0010$ Yes!

check x is correct: $K_a = 2.28\underline{3}\times10^{-11} = \dfrac{(2.389\times10^{-6})^2}{0.25} = 2.2829\times10^{-11}$ Yes!

calculate the pH: = -log $[H^+]$ `=` -log ($2.38\underline{9}\times10^{-6}$) = 5.62$\underline{1}$8 = 5.622

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7. For each case below indicate whether the equilibrium shifts to the right or to the left with the addition of the compound indicated and say whether the pH increases or decreases after you add the compound.

a. $HF(aq) \rightleftharpoons H^+(aq) + F^-(aq)$ add $BaF_2(aq)$

Reaction shifts _____left___ pH goes _____up_____

b. $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ add NH_4NO_3

Reaction shifts _____left___ pH goes ____down___

c. $CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$ add $CH_3NH_3Cl(aq)$
methylamine

Reaction shifts ____left____ pH goes ____down___

d. $CH_3COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COO^-(aq)$ add $CH_3COONa(aq)$
acetic acid acetate (soduim acetate)

Reaction shifts _____left___ pH goes _____up_____

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8. You make two solutions
   Solution A = 0.1 M NH_4Cl

   Solution B = 0.1 M $NH_4Cl(aq)$ + 0.1 M $NH_3(aq)$

   a. Will solution A be acidic or basic?

   Answer _____acidic_____ $NH_4^+(aq) + H_2O(l) \leftrightarrow NH_3(aq) + H_3O^+(aq)$

   b. Which solution will have the lower pH?

   Answer _____solution A_____

   Solution A: $NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$
   In solution B, the addition of extra NH_3 drives the equilibrium to the left, thus lowering the $[H^+]$ and raising the pH.

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9. Calculate the pH of a solution containing 0.20 M $HC_2H_3O_2$ (acetic acid) K_a 1.8 x 10^{-5} and 0.50 M $NaC_2H_3O_2$ (sodium acetate).

   Answer ____pH = 5.14_____

   $HC_2H_3O_2 \rightleftharpoons C_2H_3O_2^- + H^+$

   RICE table

Reaction	$HC_2H_3O_2 \rightleftharpoons$	$[C_2H_3O_2^-]$	$[H^+]$
Initial	0.2	0.5	0
Change	-x	+x	+x
Equilibirum	0.2-x	0.5-x	+x

   Note: $[C_2H_3O_2^-]_0$ = 0.5 M because the $NaC_2H_3O_2$ dissociates in solution.

$$K_a = 1.8\times10^{-5} = \frac{[H^+][C_2H_3O_2^-]}{[HC_2H_3O_2]} = \frac{(x)(0.50+x)}{0.20-x} = \frac{(x)(0.50)}{(0.20)}$$

(assuming x is small in both cases) Solving for x,

$$x = \frac{(1.8\times10^{-5})(0.2)}{(0.5)} = 7.2\times10^{-6}$$ check x is small: $\frac{7.2\times10^{-6}}{0.20}\times100\% = 3.6\times10^{-3}\%$

pH = -log(7.2 x 10^{-6}) = 5.14