EXPERIMENT

K_a OF ACETIC ACID

INTRODUCTION

A weak acid must be studied in terms of its equilibrium constant in order to determine the concentration of H_3O^+ ions in its solution. For example, for the general acid, HX, the equilibrium reaction would be

$$HX_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + X^-_{(aq)}$$

and the equilibrium constant expression would be given by

$$K_a = \frac{[H_3O^+][X^-]}{[HX]}$$

K_a is constant at a given temperature and is characteristic of the acid, HX, regardless of the manner in which the acid solution was prepared.

In today's experiment you will determine the value of the equilibrium constant, K_a, for acetic acid by measuring the pH of the acid solution. Also, you will study the effect of adding an additional amount of one of the ions involved in the equilibrium which according to Le Chatelier's principle shifts the equilibrium so as to consume some of the added ions.

SAFETY PRECAUTIONS

1. Wear safety goggles at all times while in the laboratory.
2. The acids and salts to be used are in fairly dilute solutions, but may be irritating to the skin. Wash if they are spilled and inform the instructor.

PROCEDURE

CHECK OUT A pH PEN FROM THE STOCKROOM

1. Add **about** 20 ml of **0.10 M** of $HC_2H_3O_2$ into a clean dry labeled small Erlenmeyer flask.
2. Add **about** 20 ml of **1.0 M** $HC_2H_3O_2$.into a clean dry labeled small beaker.
3. Add **about** 10 ml of **1.0 M** $NaC_2H_3O_2$ into a clean dry labeled test tube

A. COMMON ION EFFECT

1. In one well of a spot plate, add a drop of methyl orange indicator to 5.00 ml of **0.10 *M*** $HC_2H_3O_2$. Record the color.
2. Add a few drops of 1.0 M $NaC_2H_3O_2$ to the above solution. Record the color change. You will see the color better if there is a white background behind the spot plate. Put a white sheet of paper under the spot plate.
3. Answer the questions on the report sheet.

B. THE IONIZATION CONSTANT, K_a, FOR ACETIC ACID

1. At your desk, prepare the following solutions into the wells of a clean dry spot plate
   a. Fill 2/3 of a well with 0.10 *M* $HC_2H_3O_2$.
   b. Fill 2/3 of a second well with 1.0 *M* $HC_2H_3O_2$.
   c. In a third well add 4.00 ml of 1.0 *M* $HC_2H_3O_2$ and 1.00 ml of 1.0 *M* $NaC_2H_3O_2$.
   d. In a fourth well add 2.00 ml of 1.0 *M* $HC_2H_3O_2$ and 3.00 ml of 1.0 *M* $NaC_2H_3O_2$.
   e. In a fifth well , add 1.00 ml of solution (d) above and 4.00 ml distilled H_2O

2. Measure the pH of each of the above solutions using the pH pen. Calculate the H_3O^+ concentration for each solution from the measured pH value.

3. For mixtures c, d, and e, calculate the new concentrations of $HC_2H_3O_2$ and $C_2H_3O_2^-$. Show complete setups, showing any trace sources of ions or any difference between original and equilibrium concentrations.

4. Fill in the chart on your report sheet for each of the above solutions. Calculate K_a for each of the above solutions. How constant is K_a?

5. Calculate your average K_a value for acetic acid, and the precision of your result.

REPORT SHEET:
Ka ACETIC ACID

Name _____
Last First
INSTRUCTOR'S INITIAL _____

A. COMMON ION EFFECT

1. Write the equation for the ionization of acetic acid in aqueous solution.

_____

What is the color of methyl orange in 0.10 M acetic acid solution?

_____

Use the chart of pH Ranges and Colors of Indicators posted on the bulletin board in the lab to estimate the pH range of solutions from the indicator color.
The pH of 0.10 M acetic acid solution is equal to or less than:

_____

2. When 1.0 M $NaC_2H_3O_2$ is mixed with 0.10 M $HC_2H_3O_2$:
   a. What is the common ion added? _____

   b. What is the new color of methyl orange? _____

   From the indicator color the estimated pH is equal to or higher than_____

   c. How did the pH change upon the addition of the common ion?

   _____
   (increased, or decreased)

3. Due to the addition of the common ion:
   a. the concentration of the H_3O^+ was therefore: _____
   (increased, or decreased)

   b. the position of equilibrium shifted to the: _____
   (right, or left)

B. THE EQUILIBRIUM CONSTANT FOR THE IONIZATION OF ACETIC ACID, K_a

a. 0.1 M $HC_2H_3O_2$

Measured pH= _____

$[H_3O^+]$ calculated from the measured pH :

$[H_3O^+]$ = _____M

Calculation of K_a :

$$HC_2H_3O_{2(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$$

Initial Conc.				
Change in Conc.				
Equi. Conc.	Setup:		Setup:	Setup:

Write the equilibrium constant expression for the above equation.

K_a = _____

Calculate the numerical value of the ionization constant, K_a .

Setup:

K_a= _____

b) 1.0 M $HC_2H_3O_2$

Measured pH= _____

$[H_3O^+]$ calculated from the measured pH :

$[H_3O^+]$ = _____ M

Calculation of K_a :

$$HC_2H_3O_{2(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$$

Initial Conc.				
Change in Conc.				
Equi. Conc.	Setup:		Setup:	Setup:

Write the equilibrium constant expression for the above equation.

K_a = _____

Calculate the numerical value of the ionization constant, K_a .

Setup:

K_a= _____

c. 4.00 ml of 1.0 M $HC_2H_3O_2$ and 1.00 ml of 1.0 M $NaC_2H_3O_2$

Measured pH= _____

$[H_3O^+]$ calculated from the measured pH :

$[H_3O^+]$ = _____ M

Calculate the new concentration of $HC_2H_3O_2$:

Setup:

$M_{HC_2H_3O_2}$ = _____M

Calculate the new concentration of $NaC_2H_3O_2$:

Setup:

$M_{C_2H_3O_2^-}$ = _____M

Calculation of K_a :

$$HC_2H_3O_{2(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$$

Initial Conc.				
Change in Conc.				
Equi. Conc.				

Write the equilibrium constant expression for the above equation.

K_a = _____

Calculate the numerical value of the ionization constant, K_a .

Setup:

K_a= _____

d. 2.00 ml of 1.0 M $HC_2H_3O_2$ and 3.00 ml of 1.0 M $NaC_2H_3O_2$

Measured pH= _____

$[H_3O^+]$ calculated from the measured pH :

$[H_3O^+]$ = _____ M

Calculate the new concentration of $HC_2H_3O_2$:
Setup:

$M_{HC_2H_3O_2}$= _____M

Calculate the new concentration of $NaC_2H_3O_2$:
Setup:

$M_{C_2H_3O_2^-}$ = _____M

Calculation of K_a :

$$HC_2H_3O_{2(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$$

Initial Conc.				
Change in Conc.				
Equi. Conc.	Setup:		Setup:	Setup:

Write the equilibrium constant expression for the above equation.

K_a = _____

Calculate the numerical value of the ionization constant, K_a .
Setup:

K_a= _____

e. <u>1.00 ml of mixture (d) and 4.00 ml distilled water</u>.

Measured pH= _____

$[H_3O^+]$ calculated from the measured pH :

$[H_3O^+]$ = _____ M

Calculate the new concentration of $HC_2H_3O_2$:

<u>Setup:</u>

$M_{HC_2H_3O_2}$= _____M

Calculate the new concentration of $NaC_2H_3O_2$:

<u>Setup:</u>

$M_{C_2H_3O_2^-}$ = _____M

<u>Calculation of K_a</u> :

$$HC_2H_3O_{2(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$$

Initial Conc.				
Change in Conc.				
Equi. Conc.	Setup:		Setup:	Setup:

Write the equilibrium constant expression for the above equation.

K_a = _____

Calculate the numerical value of the ionization constant, K_a .

<u>Setup:</u>

K_a= _____

INSTRUCTOR'S APPROVAL _____

Within reasonable experimental error, do you think that the K_a for acetic acid is a constant ?

_____

Find average experimental value of K_a for acetic acid.

<u>Setup:</u>

K_a(Average) = _____

Find the precision of your experiment.
Standard deviation:
Setup:

Answer= _____

Percent deviation:
Setup:

Answer= _____

Accepted value of K_a for $HC_2H_3O_2$: **K_a (accepted)= 1.8 x 10^{-5}**

Find the accuracy of the average experimental K_a value.
Setup:

% error=_____%

EXERCISE

1. COMMON ION EFFECT

a. Calculate the $[H_3O^+]$ concentration in 0.45 M solution of barbituric acid, $HC_4H_3N_2O_3$. K_a for barbituric acid is 1.0×10^{-5}. **Show the complete setup.**

$[H_3O^+]$ = _____

b. Predict the effect of adding sodium barbiturate, $NaC_4H_3N_2O_3$, to the acid solution in (a) above.

i) The position of equilibrium will shift to the: _____
(right ,or left)

ii) The $[H_3O^+]$ will: _____
(increase, or decrease)

c. Calculate $[H_3O^+]$, if 0.25 mole Na $C_4H_3N_2O_3$ is added to a 1.0 liter of the barbituric acid solution in (a) above. (Assume there is no substantial volume change upon the addition of $NaC_4H_3N_2O_3$). **Show the complete setup**.

$[H_3O^+]$ = _____M

Does your result agree with your prediction in (b) above? _____

2. DILUTION EFFECT ON THE PERCENT IONIZATION OF A WEAK ACID

a. A weak acid, HX, is 1.3 % ionized in 0.20 M solution. What percent of HX is ionized in a 0.030 M solution? **Show the complete setup**.

percent ionization_____%

b. From your result in (a) above answer the following questions:

i) How did the percent of ionization change upon dilution?

_____
(increased, or decreased)

ii) How did the $[H_3O^+]$ concentration of the above weak acid change upon dilution?

_____
(increased, or decreased)

3) In 0.45 M benzoic acid, $HC_7H_5O_2$, the $[H_3O^+]$ is 5.4×10^{-3} M. Calculate the value of the equilibrium constant, K_a. Show the complete set up.

K_a = _____