Dougherty Valley HS Chemistry - AP
Equilibrium – Determination of an Equilibrium Constant

Worksheet #9

Name: **Period:** **Seat#:**

Required Sections: (Refer to R-15 for guidelines and requirements. Make note of any specific changes given by your teacher in class.)

Prelab: Purpose, Prelab Questions, Materials, Reagent Table, Procedures, and set up Data Tables before you get to class.
During Lab: Data section – Fill out your data table that is already set up from the prelab.
Post-lab: Calculation section, Discussion Questions section, Post-Lab Two Pager done on separate Worksheet.

REMINDER - USE R-15 TO ENSURE YOU FOLLOW ALL GUIDELINES/EXPECATIONS/ REQUIREMENTS

Introduction

The equilibrium state of a chemical reaction can be characterized by quantitatively defining its equilibrium constant, K_{eq}. Similarly, the dissociations of acids and bases can also be represented with an equilibrium expression, the equilibrium constants being K_a (for an acid) and K_b (for a base). These constants measure the extent to which an acid or base dissociates in a solution, or its “strength”. Because strong acids and bases dissociate nearly completely into their respective ions, they have large K values, and conversely, weak acids and bases have small K values. In this experiment, you will determine the value of K_a for the dissociation of acetic acid, a weak acid.

$$K_a = \frac{[products]}{[reactants]} = \frac{[H^+][A^-]}{[HA]}$$

It is important to note that the equilibrium **position** of a system is different from the equilibrium **constant.** The equilibrium position describes the specific combinations of individual concentrations of each species involved in the reaction, while the equilibrium constant describes the final ratio of products to reactants *at a specific temperature*. Equilibrium constants are temperature dependent, and therefore each reaction will have a different equilibrium constant at each temperature.

For example, if a certain reaction has a K of 1.6 at a set temperature, the concentrations of each species can infinitely vary, yet they all form the same ratio of 1.6. Look at the examples below – do you see that there are *lots* of numbers we can plug in that all end up giving us the same final numerical value of 1.6?

$$K_a = \frac{[products]}{[reactants]} = \frac{[H^+][A^-]}{[HA]} = \frac{[2][1]}{[1.25]} = \frac{[0.4][0.1]}{[0.025]} = \frac{[3.2][0.7]}{[1.4]} \quad etc \ldots etc \ldots etc = all\ equal\ 1.6$$

To find the value of K_{eq} at a given temperature, it is necessary to determine the molar concentration of each of the three species in solution at equilibrium. You will determine the concentrations by using a Vernier pH sensor to measure the amount of hydronium ion in the solution at equilibrium.

Objectives

- Experimentally determine the dissociation constant, K_a , for acetic acid for solutions of different initial concentrations.
- Observe how K_a changes with temperature.

Prelab Questions – *do not recopy the questions, just paraphrase them into your answers!*

For the following questions – show all work, include proper units in your work and on final answers.

1) For each of the solutions you will make in Step 3 of the procedure, calculate the amount of acetic acid needed to form 100 mL of each of the concentrations of solution listed in the table to the right. **You will start with a 1 M stock solution*** (Calculate ALL molarities, even if you are only assigned one by your teacher). Copy the table into your lab notebook and fill in volumes needed.

Molarity of Solution Needed	Volume of 1 M needed to make 100 mL
0.100	
0.200	
0.400	
0.500	

2) Write the equation for the dissociation of acetic acid ($HC_2H_3O_2$) being sure to include water and using the hydronium ion.
3) Write the equilibrium expression for the dissociation of acetic acid based on the equation you wrote in Q2.
4) Explain the difference between equilibrium constant and equilibrium position *in your own words*.
5) Watch the following videos and jot down notes so I know you actually watched them 😊
   a. https://tinyurl.com/2stwumyw
   b. https://tinyurl.com/y2494469 ***You can stop at time stamp 6:30*** (*please note that he says we don’t include water “because it is always around” – but it is really because it is a liquid and liquids have constant concentrations and don’t affect our equilibrium expressions!)

Video A *Video B*

Materials – *don't forget to use an MSDS to do your reagent table! Remember that a * means it should be in your reagent table!*

Chemicals
- * 1.0 M acetic acid
- * NaCl, rock salt (large crystals)

Equipment
- Computer with a USB port or with adaptor
- Logger Pro
- Vernier Interface
- Vernier pH sensor
- 400 mL beaker
- 125 mL flask
- Graduated cylinder
- Disposable pipette
- Ring stand
- Utility clamp
- Ice water
- DI water bottle
- Scoopula

Google Folder with Most MSDS Files
https://tinyurl.com/2cyva3ku
To help speed up your reagent table!

Flinn's MSDS Website
https://www.flinnsci.com/sds/
For anything that isn't in my Google folder.

DANGER: *Handle acetic acid with care. It can cause painful burns if it comes in contact with the skin. Alert your instructor if you get any of these chemicals on your skin during lab.*

Procedure

*****NOTE***** You may not be doing all concentrations listed in the prelab - the teacher may split it up so you perform multiple trials of one concentration and then share data with the other groups. Regardless of which or how many concentrations you do, you will be doing the prelab for all [ ]'s, and will be adding your data to the shared spreadsheet.

Shared Data Spreadsheet: **https://tinyurl.com/2p894e48** *Must be logged in with SRVUSD email to open file*

1) Obtain and wear goggles.
2) Measure 50 mL of distilled water into a graduated cylinder and pour it into a 125 mL flask.
3) Use a pipette to measure required volume (calculated in prelab question #2) of 1.0 M acetic acid into the flask. Fill the flask with distilled water to the 100 mL mark. Mix thoroughly.
4) Rinse the pH sensor with DI water and dry.
5) Use a utility clamp to secure a pH Sensor to a ring stand as shown in Figure 1.
6) Connect the probe to the computer interface. Open Graphical Analysis. Click the sensor icon in the bottom right corner. Calibrate the pH probe using your teacher's instructions. (If using Logger Pro, open the file "27 Acid Dissociation Ka" from *Chemistry with Vernier* folder of *LoggerPro*.)


figure 1

Dissociation at Room Temperature

7) Place the pH probe inside the flask. Let the pH reading stabilize, then record the reading.
   Do not let the pH probes hit or touch the sides of the flask! They are very fragile!
8) When done, unclamp the pH sensor and rinse with DI water and dry, then reattach.

Dissociation in Ice Bath

9) Place the flask into a 400 mL beaker, and then fill the beaker with ice water.
10) Add 4-5 scoopulas of NaCl to the salt water NOT the flask. Place beaker on ring stand.
11) Repeat Step 7 and 8.

Disposal and Cleanup

Your teacher will provide disposal and cleanup instructions.

	pH	
Concentration	**Room Temp**	**Ice Bath**
	Sample	

Data Table

Make your own data table! Remember, you need to make sure your data table has all required elements! A sample is provided below. You will need to add a descriptive title, units on all rows/columns, and a spot for qualitative data, the one below is not adequate! Remember to use enough space, make it look professional, etc!

Calculations - *Show all calculations, use proper dimensional analysis, units everywhere, proper sig figs, etc.*

Reminder You can either average your trial data and then perform the calculations once, or you can do the calc's for each trial and then average your results. Either way, be clear about what you are doing by showing all work, and be mindful of rounding issues. Do not forget to box final answers with units. **Record all values into a Results Table.**

**Note* - Perform the following calculations for each [acetic acid] that you did.*
USE AN ICE TABLE WHEN APPROPRIATE!

1. Calculate the $[H_3O^+]$ at equilibrium.
2. What will you use for the [acetate] and [acetic acid] at equilibrium?
3. Calculate the K_a for the room temp dissociation.
4. Calculate the K_a for the ice bath dissociation.

Solution [ ]	**Room Temp**	**Ice Bath**
$[H_3O^+]_{eq}$		
$[C_2H_3O_2^-]_{eq}$		Sample
$[HC_2H_3O_2]_{eq}$		
K_a		

Post Lab Discussion Questions – *Do not recopy the questions, just paraphrase them into your answer.*

1. How did a change in temperature affect the magnitude of the equilibrium constant? Increase, decrease, same?
2. Why did a change in temp affect the equilibrium constant? Discuss the equilibrium expression for this reaction, which species concentrations increased/decreased when temp changed, and how this affected the size of K_a.
3. Given the way the K_a value changed with temperature, what can we infer about the ΔH of the rxn? Endo/Exo?
4. What does the size of the K_a value tell us about the strength of the acid used? Explain.
5. Based on your lab findings, if the sol'n was heated instead of cooled, what would happen to the K_a value and why?