



Aqueous Equilibria Unit Activity – Thinking about Solutions **KEY**

PART I

1. Write the equilibrium expression for the following:
 $\text{CH}_3\text{COOH}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \leftrightarrow \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$

$$K = \frac{[\text{CH}_3\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{COOH}]}$$

2. Given that $K = 1.8 \times 10^{-5}$ for this reaction, does it favor products or reactants?
 $K < 1$, therefore reactants will be favored.

3. Decide whether $\Delta G^\circ_{\text{reaction}}$ is “+” or “-”.

If $K < 1$, $\Delta G^\circ_{\text{reaction}} > 0$, “+,” that is the reaction is nonspontaneous.

If you are unsure, you can confirm this with the all-important equation relating $\Delta G^\circ_{\text{reaction}}$ to K :

$$\Delta G^\circ_{\text{reaction}} = -RT \ln K$$

At standard conditions $R = 8.314 \text{ J/molK}$ and $T = 298 \text{ K}$

$$\Delta G^\circ_{\text{reaction}} = -(8.314 \frac{\text{J}}{\text{mol} \cdot \text{K}})(298 \text{ K})[\ln(1.8 \times 10^{-5})]$$

$$\Delta G^\circ_{\text{reaction}} = 27068 \frac{\text{J}}{\text{mol}} \text{ or roughly } 27.1 \frac{\text{kJ}}{\text{mol}}$$

There is a large, positive $\Delta G^\circ_{\text{reaction}}$ as expected by such a small K .

4. If you start with 0.2 M concentration of CH_3COOH and no products, do you expect to have a higher concentration of CH_3COOH or CH_3COO^- at equilibrium?

There will still be more reactants, a higher concentration of CH_3COOH at the end, although there will be some products as well.

5. Start with a 0.2 molar solution of CH_3COOH and assume 0 concentration of the products. What will be the concentrations of all the species in the equilibrium mixture given that the $K = 1.8 \times 10^{-5}$ for this reaction as written.

R	$\text{CH}_3\text{COOH}(\text{aq}) +$	$\text{H}_2\text{O}(\text{l}) \leftrightarrow$	$\text{CH}_3\text{COO}^-(\text{aq}) +$	$\text{H}_3\text{O}^+(\text{aq})$
I	0.2 M		0	0
C	-x		+x	+x
E	0.2 M-x		x	x

$$K = \frac{[\text{CH}_3\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{COOH}]}$$

$$K = \frac{x^2}{0.2 - x}$$

Since our value for K is so small (smaller than 10^{-3}), we can assume x is negligible

$$1.8 \times 10^{-5} = \frac{x^2}{0.2}$$

$$(1.8 \times 10^{-5})(0.2) = x^2$$

$$x = \sqrt{3.6 \times 10^{-6}}$$

$$x = 1.9 \times 10^{-3}$$

$$[\text{CH}_3\text{COOH}] = 0.2 - 1.9 \cdot 10^{-3} = 0.198 \text{ M}$$

$$[\text{CH}_3\text{COO}^-] = 1.9 \cdot 10^{-3} \text{ M}$$

$$[\text{H}_3\text{O}^+] = 1.9 \cdot 10^{-3} \text{ M}$$

CLICKER QUESTION - BE PREPARED TO ENTER YOUR ANSWERS FOR #5.

PART II

READ THIS IMPORTANT INFORMATION:

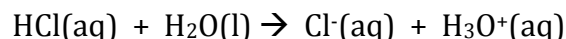
Strong acids and weak acids both dissociate or ionize in water to form protonated water (called a “hydronium ion,” H_3O^+), and the anion of the acid (what is left of the molecule after the “acidic” proton is removed from the rest of the molecule.) Strong bases dissociate to form a cation and the hydroxide ion (OH^-) that is capable of accepting a proton in solution, whereas weak bases are typically nitrogen-containing molecules that will accept a proton. Before we can begin to study acid/base chemistry we have to be able recognize compounds as acids or bases as strong or weak and understand how they behave in aqueous solutions.

The difference is where the equilibrium lies ... far to the left or far to the right.

Strong acids lie so far to the right that one can assume, for dilute solutions of strong acids, the extent of ionization is 100%.

For example, the K for $\text{HCl}(\text{aq}) = 1.3 \times 10^6 \approx \infty$

1. Calculate the concentration of hydronium ion for the dissociation reaction for the strong acid hydrochloric acid, given a starting concentration of 0.2 molar HCl. Assume 100% ionization.



If the reaction goes 100%, we should have 100% products in the end with 0 reactants

Since there is no change in volume, and everything in the reaction is in a 1:1 stoichiometric ratio, we can leave our units in terms of M

If you have a reaction where the volumes are changing, it is BEST to work your RICE table in moles.

R	$\text{HCl}(\text{aq}) +$	$\text{H}_2\text{O}(\text{l}) \leftrightarrow$	$\text{Cl}^-(\text{aq}) +$	$\text{H}_3\text{O}^+(\text{aq})$
I	0.2 M		0	0
C	-0.2 M		+0.2 M	+0.2 M
E	0 M		0.2 M	0.2 M

$$[\text{H}_3\text{O}^+] = 0.2 \text{ M}$$

2. Compare the concentration of hydronium ion from the dissociation of acetic acid, to the dissociation of hydrochloric acid. Although, the acids started with the same



molar concentration of un-dissociated compound, the amount of hydronium ion is quite different. Please explain this observation.

The $[H_3O^+]$ in the HCl solution is much higher than in the acetic acid solution ($0.2M > 1.9 \times 10^{-3} M$)

HCl is a strong acid and so it completely dissociates in water, it has a large K value. Essentially all of its reactant acidic protons leave the HCl compound to form H_3O^+ product. Acetic acid has a small K value so only a few of the reactant acidic protons on acetic acid leave the compound to form the product H_3O^+ in solution. That is, there are more reactants than products at equilibrium. The concentration of H_3O^+ in solution is therefore much higher in the HCl solution in which essentially 100% of the acidic protons are forming H_3O^+ product.

PART III

Demonstration

Putting Acetic Acid and Hydrochloric Acid in Water.

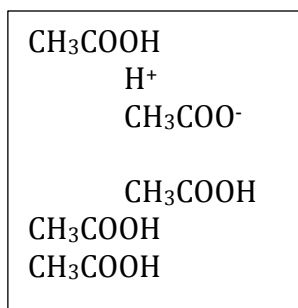
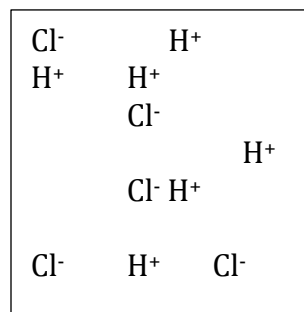
Write your microscopic and macroscopic description of our demonstration please:

With pure water, the light bulb is not lit

With 1M acetic acid, the light bulb IS lit

With 1M HCl, the light bulb is VERY bright

It is the concentration of ions that causes the electricity to flow. The more ions, the more electricity, the brighter the light.



Include Indicator

The reactant the chemical equation in PART I question (1) is called Acetic Acid. Acetic acid is considered a weak acid because its equilibrium lies far to the left. This means that when placed in water, only a small % of the compound dissociates or ionizes to form the anion of the acid and protonated water, or hydronium ion.

Strong Electrolyte vs. Weak Electrolyte

Acid Base Brain Dump



1. Think about everything you know about acids and bases and write it down here. Be prepared to share a statement with the class if called upon.

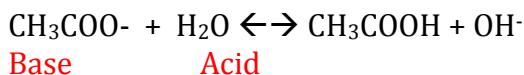
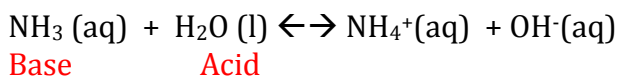
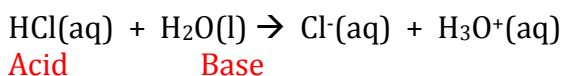
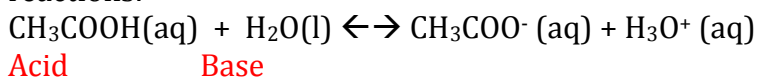
Acids: Corrosive, sour, citrus, stomach acid, HCl, H₂SO₄, vinegar, Red on Litmus paper

Bases: Slippery, bitter, soap, Draino, baking soda, NaOH, Blue on Litmus paper

Both: Can be dangerous.

The Brønsted-Lowry definition of an acid is that the compound is a proton donor, and the Brønsted-Lowry definition of a base is that the compound is a proton acceptor. Each time a proton is donated across a chemical change one compound is acting like an acid and another is acting like a base.

2. Label what is acting like an acid and what is acting like a base in the following reactions:



WHOLE CLASS CHECK IN... WHOLE CLASS CHECK IN

In the context Brønsted-Lowry acids and bases, if an acid transfers a proton the “deprotonated” compound is referred to as the “conjugated base”. Conversely a base that accepts a proton becomes a “conjugate acid” upon protonation. For the reactions below identify the conjugate acids and bases in the products.

