CHE 1302

Basic Principles of Modern Chemistry II

Week 9

Hello and welcome to the weekly resources for Chemistry 1302! This resource covers topics typically taught by professors during the 9th week of classes.

On our website, https://baylor.edu/tutoring, you'll find the following links:

"Online Study Guide Resources" – If you don't see the topics you're learning right now, click here to find the weekly resources for the rest of the semester!

"How to Participate in Group Tutoring" - See if there is a Chemistry 1302 group tutoring session being hosted this semester – these are weekly question/answer sessions taught by our master tutors!

You can also view tutoring times for your course or schedule a private 30-minute appointment! Check out the website to learn more. You can also give us a call at (254)710-4135, or drop in. Our hours are Monday-Thursday 9 am – 8 pm on class days.

KEY WORDS: Ions as Acids and Bases, pH, Common Ion Effect

TOPIC OF THE WEEK: Ions in Water

"Predict whether the following salts will form acidic, basic, or neutral solutions."

HOW TO SOLVE:

1. Split the salt into its cation and anion counterparts. Some tips on identifying these:
    a. Remember that metals like to form cations, and halogens like to form anions. This is because they want to have full valence shells!
    b. Look for the polyatomic cations/anions that you've memorized.
    c. Example: CsCl → Cs^+, Cl^-
2. Work the problem like a **backwards neutralization**. Remember, in a neutralization, an acid and base form a salt and water. In this case, we start with salt and water and make acid and base. After separating the components of the salt, write their reactions with water.
    a. Metal cations will associate with the OH^- of water. $A^+ + 2H_2O \rightleftharpoons AOH + H_3O^+$
        i. $Cs^+ + 2H_2O \rightleftharpoons CsOH + H_3O^+$
    b. Nonmetal cations will lose a proton to the OH^- of water. $HA^+ + H_2O \rightleftharpoons A + H_3O^+$
    c. Anions will take an H^+ from water. $A^- + H_2O \rightleftharpoons HA + OH^-$
        i. $Cl^- + H_2O \rightleftharpoons HCl + OH^-$
    d. To put this another way:
        i. The cation can be traced to a parent base
            1. If metal cation: parent base = corresponding metal hydroxide, ex. CsOH

            2. If non-metallic: parent base = cation minus a proton
        ii. The anion can be traced to a parent acid, ex. HCl
3. So, to determine whether a solution is acid, basic, or neutral:
    a. Look at the cation/anion behaviors in water (this is what we've determined in the previous steps). Write out the equations.
    b. For each one, whichever side has the weaker acid/base will be favored in the equilibrium (this is because a strong acid is very good at giving away its proton. So not a lot of protonated acid will be left at equilibrium—instead, it'll be the deprotonated acid).
        i. $Cs^+ + 2H_2O \rightleftharpoons CsOH + H_3O^+$ Metal hydroxides are strong bases, so the left side is favored.
        ii. $Cl^- + H_2O \rightleftharpoons HCl + OH^-$ Hydrochloric acid is a strong acid, so the left side is favored.
    c. If the side favored is the side with H_3O^+, the solution is acidic. If the side favored is the side with OH^-, the solution is basic. If the side favored does not have either of these, it is neutral.
        i. Neutral
        ii. Neutral
    d. Once you've done this for both equations,
        i. Neutral + neutral = neutral neutral!
        ii. neutral + basic = basic
        iii. acidic + neutral = acidic
        iv. acidic + basic = compare Ka of the cation to Kb of the anion
            1. Ka>Kb → acidic (the acid is better at donating its proton than the base is at accepting one)
            2. Kb>Ka→basic (the base is better at accepting a proton than the acid is at donating one)

Highlight 1: Salts in Water: Acidic or Basic

"Predict whether the following salts will form acidic, basic, or neutral solutions."

1. Look at the cation/anion behaviors in water (this is what we've determined above). Write out the equations.
2. For each one, whichever side has the weaker acid/base will be favored in the equilibrium (this is because a strong acid is very good at giving away its proton. So not a lot of protonated acid will be left at equilibrium—instead, it'll be the deprotonated acid).
    a. $Cs^+ + 2H_2O \rightleftharpoons CsOH + H_3O^+$ Metal hydroxides are strong bases, so the left side is favored.
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3. If the side favored is the side with H_3O^+, the solution is acidic. If the side favored is the side with OH^-, the solution is basic. If the side favored does not have either of these, it is neutral.
    a. Neutral
    b. Neutral

4. Once you've done this for both equations,
   a. Neutral + neutral = neutral neutral!
   b. neutral + basic = basic
   c. acidic + neutral = acidic
   d. acidic + basic = compare Ka of the cation to Kb of the anion
      i. Ka>Kb → acidic (the acid is better at donating its proton than the base is at accepting one)
      ii. Kb>Ka→basic (the base is better at accepting a proton than the acid is at donating one)

Highlight 2: pH

pH is a way to express how much H_3O^+ (hydronium) is in a solution. The "H" stands for hydronium. P means negative log, so pH = -log[H_3O^+]

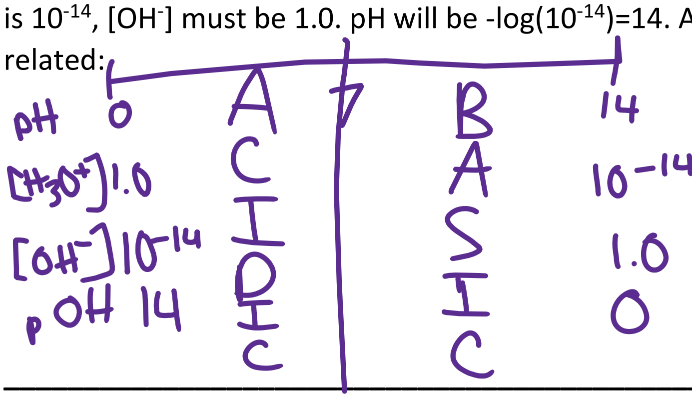
How low and high can pH go? To answer this question, we need to look at something called the autoionization of water:

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

The K for this equation, called K_w, is 1.0x10^{-14}. This means that $[H_3O^+][OH^-] = 1.0 * 10^{-14}$

So, by knowing the [H_3O^+], we can also calculate the [OH^-]. Likewise, by knowing pH, we can calculate pOH. Hydronium concentration can be anything between 1.0 (lots of protons, very acidic) and 10^{-14} (very basic).

If [H_3O^+] is 1.0, [OH^-] must be $10^{-14,}$ to satisfy the equation above. pH will be -log(1)=0. If [H_3O^+] is 10^{-14}, [OH^-] must be 1.0. pH will be -log(10^{-14})=14. And the ratios in-between will be similarly related:



Highlight 3: Common Ion Effect

The **ionization** of a weak acid or base is affected by the addition of a **common ion** from a strong electrolyte, thus affecting the **pH**.

For example, let's look at the ionization equation of NH_3 in water: $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

Addition of NH_4Cl (producing NH_4^+) will increase Q. To try to remedy this, the equilibrium will shift to the left. This will suppress the ionization (decrease $[OH^-]$) and increase $[NH_3]$, making the solution less basic.

Why is it called a "common ion?" This shift in the equilibrium is the result of the addition of an ion that is already involved.

[The common-ion effect | Khan Academy - YouTube]

Check Your Understanding

1. Determine whether each of the following salts will form acidic or basic solutions: NaHCO3, NH4NO3
2. If pH is 4, what is pOH? What is [H3O+]?
3. What would happen to the pH if you were to add hydronium to the following equilibrium:

$$HC_2H_3O_2 + H_2O \rightleftharpoons H_3O^+ + C_2H_3O_2^-$$

Things You May Struggle With

1. On salt rules: If the anion's acid is strong, and the cation's base is weak, the solution will be acidic. If the anion's acid is weak and the cation's base is strong, the solution will be basic. If both are strong, the solution will be neutral. If both are weak, compare the Ka values! This is something that you can memorize, but to avoid memorizing, you can write out the equations and solve as described above.
2. The value of K_w is not always 10^{-14}. The K_w value is temperature dependent ($K_w = 10^{-14}$ at 25°C).
3. Make sure you know which acids/bases are weak/strong; this will help with the salt questions.
4. When working problems, don't forget Kb can be obtained when you are given Ka. Note: Ka x Kb = K

That's all this week! Please reach out if you have any questions and don't forget to visit the Tutoring Center website for further information at www.baylor.edu/tutoring. Answers to Check Your Learning are below.

1. Basic, acidic
2. 10, 0.0004 M
3. Shift left, decreasing pH