<u>STUDY GUIDE</u> - *Ch. 3.3* - *Acid & basic conditions affect living organisms* **NAME: ______________________**

- **<u>PHYSICALLY PRINT OUT</u> this PDF and <u>HANDWRITE</u> (with a black or blue pen) your answers directly on this PDF.** *Typed or digitally-written work is **not** be accepted. Do **not** answer questions on separate paper.*
- **Importantly, study guides are <u>NOT GROUP PROJECTS</u>!!!** *You, and you alone, are to answer the questions as you **read** your assigned textbook. You are **not** to share answers with other students. You are **not** to copy any answers from any other source, including the internet.*
- **Get in the habit of writing <u>LEGIBLY</u>, neatly, and in a <u>medium-sized font.</u>** *AP essay readers and I will skip grading anything that cannot be easily read so start perfect your handwriting, and don't write so large you can't add all the relevant details and key elaborations in the space provided.*
- **<u>SCAN</u> physical documents in color and with good resolution. Then, upload your final work as <u>PDFs</u> to Archie.** *Avoid uploading dark, shaded, washed out, side ways, or upside down scans of homework. Keep completed physical study guides organized in your biology binder to use as future study and review tools.*
- **<u>READ FOR UNDERSTANDING</u> and not merely to complete an assignment.** ***First**, read a section quickly to get an overview of the topic covered. Then, read it a **second** time slowly, paraphrasing each paragraph **out loud** and analyzing every figure. Finally, read it a **third** time as you answer the study guide questions if assigned and to start building your memory. Try to write answers out in your own words when possible and to purposefully and accurately use all new terminology introduced.*

1. a. Water is a polar molecule made of two <u>polar covalent bonds</u>. The O-H polar covalent bond in a water molecule is the region between the O atom and an H atom, where an electron from the O and an electron from the H (the bonding electrons) travel back and forth between the electron clouds of these two atoms as the positively charged nuclei of the O and H atoms attract these outermost, negatively-charged valence electrons.

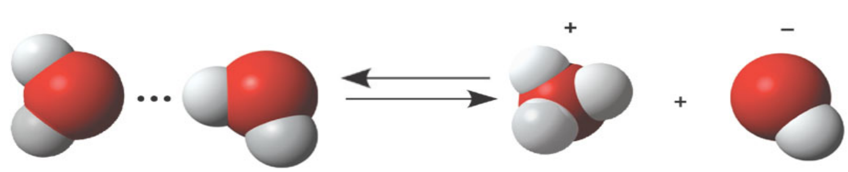
   Because O is *significantly more electronegative* than H (the nuclei of O exerts a greater force of attraction on electrons than that of H), the bonding electrons involved in the covalent bond between O and H are not shared equally between these two atoms. Though sometimes the H atom *(composed of just one electron and one proton)* holds on to its own electron <u>and</u> manages to temporarily "borrow" a valence electron from the O to complete H's valence shell (to now have 2 electrons in its 1s orbital), more often, the opposite occurs and the H atom ends up having "lost" its one electron instead to O's electron cloud for a period of time. **During these moments when the H's electron is being borrowed by O, the H atom is really only a proton sitting near an O atom.**

   Though this only proton of the H is attracted to the negative electron cloud of the O atom within the same water molecule during this time, **the strong pull on the bonding electrons by O's nucleus, the thermal energy causing kinetic movement of atoms and subatomic particles, and the attraction by this lone proton to the often negatively-charged Os of other nearby neighboring water molecules may cause the H's proton to "break free" and move away from the O and, thus, entire original water molecule.** When this happens the electron from the H is left behind in the electron cloud of the O. We say now that the **water molecule has <u>dissociated</u>. The water molecule has lost a <u>proton</u>** (also called an H^+ ion = a proton minus its one electron that used to make up a full neutral H atom) **to its surrounding environment.** We say that the water molecule has *"donated a proton to the solution."*

   When this occurs, the O atom in the original water molecule holds on to electron it temporarily borrowed from the H atom, yet now what remains of the water molecule (after the proton from the H atom left the water molecule) is no longer neutral. **The original water molecule has become a <u>polyatomic ion</u>, a molecule with a <u>net charge</u>, in this case a molecule with a net charge of - 1** (the total number of protons in the O and the second H of water do not equal the total number of electrons in the O and the second H of the water molecule).

   At the same time, the lost proton (H^+ ion), which has a +1 charge, is now free to be attracted to a *neighboring water molecule's O atom*, due to the strongly negatively-charged area of this other water O's electron cloud. **The neighboring water now also becomes a molecule with a <u>net charge</u>, this time a <u>polyatomic ion</u> with a net + 1 charge** since this neighboring water molecule gained a proton, but did not gain an extra electron.

   In summary, **because of the highly polar nature of the covalent bond between O and H in a water molecule, water molecules can dissociate.** Label the diagram below, demonstrating the **<u>dissociation of a water molecule</u>**. *This dissociation of water is reversible.* Provide the **<u>full names AND molecular formulas for each molecule</u>** shown below.



b. The dissociation of molecular water (H_2O) is reversible. While sometimes one water molecule loses a proton (H^+) and becomes a hydroxide ion (OH^-), a second water becoming a hydronium ion (H_3O^+), other times a proton (H^+) from a hydronium ion (H_3O^+) rejoins with a hydroxide ion (OH^-), reforming **molecular water** (H_2O). This process is ***always*** occurring in liquid water and a state of dynamic equilibrium is eventually reached. What is occurring when we reach this state of **dynamic equilibrium**?

c. When **pure water** has reached a state of dynamic equilibrium, **are water molecules or the hydronium and hydroxide ions that form from dissociated water molecules more prevalent** in the liquid?

d. What is the **concentration of EACH (polyatomic) ion (in Molarity) that results when water dissociates** at 25°C, assuming the liquid is made up of pure water with no other types of ions added to it. **Remember that the unit of concentration, Molarity (M), is equivalent to mol per liter (mol/L). M = mol/L.** Remember too that brackets **[ ]** are used in chemistry to symbolize concentration (molarity) of a solute in solution. *Don't forget to also always include units with any measurement.*

In pure water, [H_3O^+] = ______________________ **In pure water, [HO^-]** = ______________________

Note that though H+ ions never exist alone, always combining with a water molecule to form hydronium ions (H_3O^+), H+ ions (also called protons) are usually used to represent (H_3O^+).

3. What is the **pH scale used for**?

4. a. What is an **acid**?

b. How does the addition of an acid to water, **change the concentrations of H^+ ions in solution relative to that of pure water**?

c. Why does the concentration of **H^+ ions in solution** change wit the addition of an acid? *(How does an acid work?)*

5. a. What is a **base**?

b. How does the addition of a base to water, **change the concentrations of H^+ ions in solution relative to that of pure water**?

c. Explain both the direct and the indirect **ways the two different categories of bases work** to alter the concentration of H^+ in solution

Method #1 some bases use to altering H^+ concentration =

Method #2 some bases use to altering H^+ concentration =

Acids and bases are compounds that, when added to water or a water-based (aqueous) solution, change the proton concentration in the aqueous solution. **Keep in mind though that not all solutes or compound added to a solution change the proton concentration of the solution.** Solutes that do not affect proton concentration would not be considered an acid or a base, therefore.

Also note that **if both an acid and a base are added to a solution at the same time, they would have opposing effects on the proton concentration.** The proton concentration of the aqueous solution either wouldn't change as much or may not change at all as it would have if only the acid or only the base were added, the final result depending on how strong the respective acid and base are and the concentration of acid and base added.

6. a. What do we call **an aqueous solution** in which $[H^+] = [HO^-]$?

   b. What do we call **an aqueous solution** in which $[H^+] > [HO^-]$?

   c. What do we call **an aqueous solution** in which $[H^+] < [HO^-]$?

7. What is the difference between a **strong acid or strong base and a weak acid or weak base**?

   Strong acids and bases =

   Weak acids and bases =

8. The following reactions occur when a particular acid or base is placed in water. Identify if the starting compound is a weak or strong acid or a weak or strong base?

   a. $CH_3COOH \leftrightarrows CH_3COO^- + H^+$

   b. $CaOH \rightarrow Ca^{2+} + 2OH^-$

   c. $HNO_3 \rightarrow H^+ + NO_3^-$

9. a. The product of H^+ and OH^- concentrations is a constant. What is this **water constant**?

b. Explain **why when the [H+] rises, the [OH-] drops** in an aqueous solution. Remember, [ ] indicates molar concentration.

c. Explain **why when the [H+] drops, the [OH-] rises** in an aqueous solution.

10. a. Let's review our mathematical notation and understanding for a moment before proceeding. The concentration of H^+ in a particular solution is 10^{-2}M. Express this concentration as a **fraction** without using a superscript?

10^{-2}M => $\frac{\text{numerator}}{\text{denominator}}$ M => _______ M

b. Express this concentration of 10^{-2}M of protons as a **decimal** (without using scientific notation).

10^{-2}M => 0 . ? M => _______________ M

c. If another solution has a concentration of protons of 10^{-6}M, does this second solution have a **greater or lower concentration of protons** than the solution that had a H^+ concentration of 10^{-2}M?

d. Express 10^{-6}M of protons as a **fraction** without using a superscript?

10^{-6}M => $\frac{\text{numerator}}{\text{denominator}}$ M => _______ M

e. Express this concentration of 10^{-6}M of protons as a **decimal** (without using scientific notation).

10^{-6}M => 0 . ? M => _______________ M

Remember that the unit of concentration M (molar) is equivalent to mol/L (one mole being equivalent to 6.022×10^{23} number of particles or Avogadro's Number of particles, which is roughly 602,200,000,000,000,000,000,000 particles). So in a solution with 10^{-2}M protons, there are 1/100 moles (one hundredth of a mole) of H^+ in every 1 L of solvent or 0.01 moles of H^+ per liter while in a solution with 10^{-6}M protons, there are 1/1,000,000 moles (one millionth of a mole) of H^+ in every 1 L of solvent or 0.000001 moles of H^+ per liter. **This means that in a liter of solution with a proton concentration of 10^{-2}M, you have $6.022 \times 10^{23} \div 100$ or 6.022×10^{21}** (6,022,000,000,000,000,000,000) **protons while in a liter of solution with a proton concentration of 10^{-6}M, you have $6.022 \times 10^{23} \div 1{,}000{,}000$ or 6.022×10^{17}** (602,200,000,000,000,000) **protons per 1 L of solvent.**

11. Returning to the water constant, if an acid is added to a basic solution, which causes the [H^+] in solution to change from 10^{-9}M to 10^{-5}M, describe the change that occurred in the concentration of [HO^-] in solution? ***Show all your work, including any formula used while indicating which numbers with units you plugged in where to achieve an answer.***

12. a. Provide the **formula used to calculate pH of a aqueous solution**?

b. **The pH scale ranges from 0 to 14.** What is the **pH of a neutral solution** and why? ***Use the pH formula to answer.***

pH of neutral solution = _____ *(Note that pH has no units)*

Reason =

13. **Pure water is neutral and, therefore, has a pH of 7.** A neutral aqueous solution (a solution where water is the solvent and a solute has been added that is not an acid or a base) would also have a pH of 7. Acids and bases cause a change in an aqueous solution's pH since they change the concentration of protons in the solution.

a. How does the **addition of an acid to pure water affect the pH value of the solution**?

b. How does the **addition of a base to pure water affect the pH value of the solution**?

14. a. Using the formula for pH, what is the pH of 0.01 M HCl (a solution into which you add 0.01 moles of HCl for every 1L of water), considering HCl is a strong acid that dissociates completely in water? ***Show your work, which includes showing how you plug in the values (with proper units) into each formula you use be it the water constant formula to the pH formula or both, depending on what is needed.*** *Understand that if you add 0.01 mol of HCl to a solution, HCl will "break apart" into H^+ ions and Cl^- ions as HCL is a strong acid, so you will actually end up with* ***0.01 mol of Cl^+ AND 0.01 mol of H^+ ions*** *in solution.*

(Check your answers by going to the Ch.3.3 ***Concept Check Question #2*** *in Appendix A of your textbook)*

b. Using the formula for pH, what is the pH of 0.05 M KOH (a solution into which you add 0.05 moles of KOH for every 1L of water), considering KOH is a strong base that dissociates completely in water? ***Show your work, which includes showing how you plug in the values (with proper units) into each formula you use be it the water constant formula to the pH formula or both, depending on what is needed.*** *Understand that if you add 0.05 mol of KOH to a solution, KOH will "break apart" into K^+ ions and OH^- ions as KOH is a strong base, so you will actually end up with* ***0.05 mol of K^+ AND 0.05 mol of OH^- ions*** *in solution.*

15. a. Because the **pH scale is logarithmic**, each numerical change represents a **10x** change in hydrogen ion concentration. We could be multiplying the concentration of protons by a factor of ten *(10X, 100X, 1,000X, 10,0000X)* or dividing the concentration of protons by a factor of ten *(1/10 X, 1/100 X, 1/1,000 X, 1/10,000 X)*.

If hydrogen ions are **added** to a solution, will the solution's **pH drop or rise**?

If hydrogen ions are **removed** from a solution, will the solution's **pH drop or rise**?

b. Let's assume you have two solutions of equal volumes. Compared to the basic solution at pH 9, the acidic solution at pH 4 has _______________ **times** as many hydrogen ions.
*(Check your answers by going to the Ch.3.3 **Concept Check Question #1** in Appendix A of your textbook)*

Let's assume you have two solutions of equal volumes. Compared to the acidic solution at pH 1, the more basic solution at pH 4 (though this is still considered an acidic solution overall) has _______________ **times** as many hydrogen ions.

c. Does a solution with a pH of 8 have a **higher or lower** concentration of ions compared to one with a pH of 14?

d. **Describe the difference in the concentration of protons** between the solution of pH 8 and the one with a pH of 14? *(Work your pH formula backwards and figure out the **molar concentration of protons** in the solution with a pH is 8 and the solution with a pH of 14. Don't forget the units! Then, **compare** the actual proton concentrations.)*

e. Explain the difference between a solution of pH of 6 and a pH of 7 in terms of H^+ concentration. Again, don't just say that these solutions differ in H^+ concentration, **explain how they do.** Does one have a larger or smaller proton concentration **and** by what factor?

16. In general, **why are small changes in pH so important in biology?**

17. a. Even a slight change in pH can be harmful! Biological fluids have ways of trying to prevent changes that would be damaging. **<u>What is a buffer</u>**?

b. **<u>How does a buffer work</u>**?

c. Write out the formula for and then explain the **<u>carbonic acid buffer system in human blood</u>.**

⇔

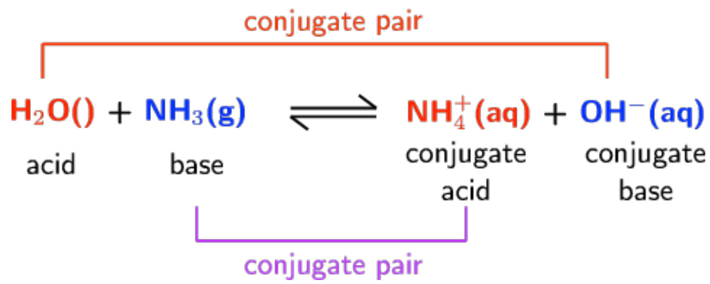
A buffer is a <u>weak acid</u>, which dissociates - when added to an aqueous solution - into a <u>proton</u> and a <u>conjugate base</u>. This conjugate base can associate with a proton to form back the weak acid. The **reaction thus is reversible**, the forward or reverse reaction being favored depending on the concentration of protons in solution. When the concentration of protons drops, the forward reaction is favored. When the concentration of protons increases, the reverse reaction is favored.

- Remember, **<u>Le Chatelier's Principle</u>**, which states that changes in the concentration of a system will result in predictable and opposing changes in the system in order to achieve a new equilibrium state. Stated otherwise, **if the concentration of a substance is changed, the equilibrium will shift to minimize the effect of that change.**
  - ➡ If the concentration of a reactant of a reversible reaction at equilibrium is increased, the equilibrium will shift in the direction of the reaction that uses the reactants, so that the reactant concentration decreases again. ***The forward reaction is favored.***
  - ➡ If the concentration of a product of a reversible reaction at equilibrium is increased, the equilibrium will shift in the direction of the reaction that uses the product, so that the product concentration decreases again. ***The reverse reaction is favored.***

d. In 17.c, identify which compound is the weak acid and which is the conjugate (*weak)* base*?*

Weak Acid = ______________________________ **Conjugate Base =** ______________________________

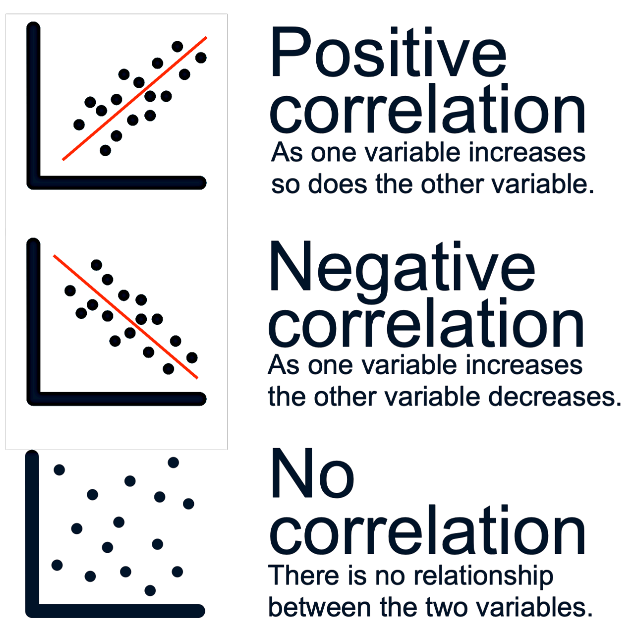
A buffer could also be a <u>weak base</u>, which associates - when added to an aqueous solution - with a <u>proton</u> to form a <u>conjugate acid</u>. This conjugate acid can later dissociate back into a proton and the weak base. The **reaction thus is reversible**, the forward or reverse reaction being favored depending on the concentration of protons in solution. When the concentration of protons drops, the reverse reaction is favored. When the concentration of protons increases, the forward reaction is favored. Ex: $NH_3 + H^+ \leftrightarrow NH_4^+$



18. a. Study figure 3.12 after reading the text on the acidification of our oceans. What is and what causes **ocean acidification**? (FYI: The same reaction that happens in liquid water also happens in the atmosphere with gaseous H_2O resulting later in **acid precipitation**, a.k.a. acid rain).

b. A lower pH (higher H^+ concentrations) in the ocean can harm all of its living organisms. Why does the **rise in ocean [H^+] specifically also threaten marine organisms like corals and animals that build shells**?

19. A **scatter plot** is a set of points plotted on a horizontal and vertical axes. Scatter plots are important in statistics because they can **show the extent of correlation**, if any, between the values of observed quantities or phenomena (called variables). **Two or more variables considered to be related, in a statistical context, if their values change so that as the value of one variable increases or decreases so does the value of the other variable (although it may be in the opposite direction).** A correlation between variables, however, does not automatically mean that the change in one variable is the **cause** of the change in the values of the other variable.



Read through the **Scientific Skills Exercise: Interpreting a Scatter Plot with a Regression Line** at the end of the chapter. Provide your answers to the questions posed below.

1. a.

b.

c.

d.

2.

3. a. Part 1:

a. Part 1:

b. Part 1:

b. Part 2:

c. Part 1:

c. Part 2:

4. a.

b.

20. Acetic acid can be a buffer, similar to carbonic acid. The dissociation reaction is $CH_3COOH \leftrightarrows CH_3COO^- + H^+$ Identify the acid, base, proton acceptor, and proton donor.

Weak acid = ______________________________ **Conjugate base =** ______________________________

Proton Acceptor = ______________________________ **Proton Donor =** ______________________________

(Check your answers by going to the Ch.3.3 ***Concept Check Question #3*** *in Appendix A of your textbook)*

21. Given a liter of pure water and liter solution of acetic acid, what would happen to the pH, in general, if you added 0.01 mol of a strong acid to each and **why**? Use the reaction from question #20 above to explain the results.

pH of Pure Water =

pH of the Aqueous Solution of Acetic Acid =

(Check your answers by going to the Ch.3.3 ***Concept Check Question #4*** *in Appendix A of your textbook)*

22. Proceed to the TEST YOUR UNDERSTANDING section at the end of the chapter. **Study your chapter sections and all Ch.3 study guides first!** Then, do your best to try to answer these from memory first in order to test how well you grasped the material before. If you are unsure, return to the relevant section of your chapter and restudy any pertinent material to refresh your memory. *(Check some of your answers by going to the Ch.3 Test Your Understanding answers in Appendix A of your textbook)*

1. _____ 2. ______ 3. ______ 4. ______ 5. ______

6.

7.