pK_a & Buffers

Unit: Acids & Bases

MA Curriculum Frameworks (2016): N/A

Mastery Objective(s): (Students will be able to…)

- Calculate pH from [H^+] and pOH from [OH^-].
- Identify acids and bases from their pK_a values.
- Select an appropriate indicator for a desired pH range.

Success Criteria:

- pH and pOH are calculated correctly.
- Acids and bases are correctly identified from their pK_a values.
- Indicator changes color in a pH range that includes the pH of the given acid or base.

Tier 2 Vocabulary: acid, base, indicator

Language Objectives:

- Explain why higher [H^+] results in a lower pH.

Notes:

Acid-base chemistry is largely equilibrium chemistry in which the solvent, usually H_2O, plays a significant role.

As stated earlier, water dissociates into H^+ and OH^- ions. Acids and bases change the concentrations of H^+ and OH^- ions in solution, which can have significant effects on the behavior of the solution.

<u>acid dissociation constant</u> (K_a): is the equilibrium constant for the dissociation of an acid. For the "generic" acid HA:

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

The greater the K_a value, the stronger the acid. (Remember your negative exponents! *E.g.,* 10^{-5} is *<u>greater</u>* than 10^{-7}.)

<u>pK_a</u> = −log K_a (analogous to pH). The lower (or more negative) the pK_a, the stronger the acid.

When exactly 50 % of the acid HA is neutralized, [HA] = [A^-], and the above formula reduces to K_a = [H^+]. This means that pH = pK_a when the acid is half-neutralized.

Use this space for summary and/or additional notes:

base dissociation constant (K_b): is the equilibrium constant for the dissociation of a base. For the "generic" base B:

$$K_b = \frac{[HB^+][OH^-]}{[B]}$$

We can use the concept of pK_a to add to our definitions of strong acids and bases:

strong acid: an acid with a pK_a lower than that of H_3O^+ (1.0). Strong acids include HCl, HBr, HI, H_2SO_4 and HNO_3.

Strong acids dissociate completely into H^+ and the corresponding anion. The dissociated H^+ converts H_2O molecules to H_3O^+ ions.

weak acid: an acid with a pK_a higher than that of H_3O^+ (1.0), but less than 7.0 (the pH of a neutral solution at 25 °C).

strong base: a base whose conjugate acid is weaker than H_2O (*i.e.,* whose conjugate acid has a pK_a higher than 14). Hydroxides are strong bases because they release OH^-. However, note that aqueous $Mg(OH)_2$ ***acts*** more like a weak base because the limited solubility of $Mg(OH)_2$ results in a concentration of OH^- that is similar to that produced by a weak base.

Strong bases either release OH^- ions directly into solution, or form OH^- ions by pulling H^+ off of H_2O molecules.

weak base: a base whose conjugate acid has a pK_a higher than 7.0 but less than 14.

Use this space for summary and/or additional notes:

Buffers

buffer: a weak acid or base that prevents the pH of a solution from changing drastically until it neutralizes the buffer.

For example, if you have a fish tank, you want to keep the pH from getting too low, you could add $NaHCO_3$. The reaction:

$$H^+ + HCO_3^- \rightleftharpoons H_2CO_3$$

occurs around pH 6.4. As acid accumulates in your fish tank, it will react with the HCO_3^- ions, and the pH will remain above 6.4 until all of the HCO_3^- ions have been converted to H_2CO_3.

Buffers can work in either direction—to absorb acid or base. If you use a combination of two buffers (one above and one below your desired pH), you can keep the pH within a narrow range.

In fact, water acts as a buffer, but over a very wide pH range. The pH of an aqueous solution is limited, because stronger acids just convert more H_2O to H_3O^+, and stronger bases just convert more H_2O to OH^-. The presence of water effectively keeps the pH between 1 and 14. In fact, the reason your biology teacher taught you that the pH range goes from 1–14 is because acid-base reactions in biology all happen in aqueous environments.

Use this space for summary and/or additional notes:

Homework Problems

1. Rank the following acids from strongest to weakest, based on their pK_a values. Refer to of your Chemistry Reference Tables.

Based on pKa values in "Table P. *pKa* Values for Common Acids" on page 513 of your Chemistry Reference Tables, rank the following ten compounds in order, from the strongest acid to the strongest base.

HF, HCN, HCl, HPO_4^{2-}, HNO_3, H_2O, CH_3COOH, NH_4^+, H_2SO_4, H_2CO_3

1. _______
2. _______
3. _______
4. _______
5. _______
6. _______
7. _______
8. _______
9. _______
10. _______

11. The wastes from fish in a fish tank produce acids, which cause the pH of the water in the tank to decrease over time. Which acid-base pair from the table of *pKa* Values for Common Acids would be most effective at keeping the pH from dropping below 7.0. Explain.

Use this space for summary and/or additional notes: