

## pK<sub>a</sub> & Buffers

**Unit:** Acids & Bases

**MA Curriculum Frameworks (2016):** N/A

**Mastery Objective(s):** (Students will be able to...)

- Calculate pH from [H<sup>+</sup>] and pOH from [OH<sup>-</sup>].
- Identify acids and bases from their pK<sub>a</sub> 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<sub>a</sub> 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<sup>+</sup>] results in a lower pH.

**Notes:**

Acid-base chemistry is largely equilibrium chemistry in which the solvent, usually H<sub>2</sub>O, plays a significant role.

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

acid dissociation constant (K<sub>a</sub>): 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<sub>a</sub> value, the stronger the acid. (Remember your negative exponents! *E.g.*, 10<sup>-5</sup> is greater than 10<sup>-7</sup>.)

pK<sub>a</sub> = -log K<sub>a</sub> (analogous to pH). The lower (or more negative) the pK<sub>a</sub>, the stronger the acid.

When exactly 50 % of the acid HA is neutralized, [HA] = [A<sup>-</sup>], and the above formula reduces to K<sub>a</sub> = [H<sup>+</sup>]. This means that pH = pK<sub>a</sub> when the acid is half-neutralized.

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

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

We can use the concept of  $\text{p}K_a$  to add to our definitions of strong acids and bases:

strong acid: an acid with a  $\text{p}K_a$  lower than that of  $\text{H}_3\text{O}^+$  (1.0). Strong acids include HCl, HBr, HI,  $\text{H}_2\text{SO}_4$  and  $\text{HNO}_3$ .

Strong acids dissociate completely into  $\text{H}^+$  and the corresponding anion. The dissociated  $\text{H}^+$  converts  $\text{H}_2\text{O}$  molecules to  $\text{H}_3\text{O}^+$  ions.

weak acid: an acid with a  $\text{p}K_a$  higher than that of  $\text{H}_3\text{O}^+$  (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  $\text{H}_2\text{O}$  (*i.e.*, whose conjugate acid has a  $\text{p}K_a$  higher than 14). Hydroxides are strong bases because they release  $\text{OH}^-$ . However, note that aqueous  $\text{Mg}(\text{OH})_2$  acts more like a weak base because the limited solubility of  $\text{Mg}(\text{OH})_2$  results in a concentration of  $\text{OH}^-$  that is similar to that produced by a weak base.

Strong bases either release  $\text{OH}^-$  ions directly into solution, or form  $\text{OH}^-$  ions by pulling  $\text{H}^+$  off of  $\text{H}_2\text{O}$  molecules.

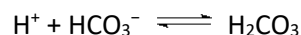
weak base: a base whose conjugate acid has a  $\text{p}K_a$  higher than 7.0 but less than 14.

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## 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  $\text{NaHCO}_3$ . The reaction:



occurs around pH 6.4. As acid accumulates in your fish tank, it will react with the  $\text{HCO}_3^-$  ions, and the pH will remain above 6.4 until all of the  $\text{HCO}_3^-$  ions have been converted to  $\text{H}_2\text{CO}_3$ .

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  $\text{H}_2\text{O}$  to  $\text{H}_3\text{O}^+$ , and stronger bases just convert more  $\text{H}_2\text{O}$  to  $\text{OH}^-$ . 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.

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**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  $pK_a$  values in "Table P.  $pK_a$  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,  $\text{HPO}_4^{2-}$ ,  $\text{HNO}_3$ ,  $\text{H}_2\text{O}$ ,  $\text{CH}_3\text{COOH}$ ,  $\text{NH}_4^+$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{H}_2\text{CO}_3$

- |          |          |           |
|----------|----------|-----------|
| 1. _____ | 5. _____ | 8. _____  |
| 2. _____ | 6. _____ | 9. _____  |
| 3. _____ | 7. _____ | 10. _____ |
| 4. _____ |          |           |

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  $pK_a$  Values for Common Acids would be most effective at keeping the pH from dropping below 7.0. Explain.

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