



11: Buffers

- What is a buffer?
 - Calculating pH
 - Weak acids / bases
 - Equilibrium constants of acids / bases
 - Hendersen-Hasselbach Equation
 - Buffer capacity
 - Preparing buffers
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What is a buffer?

- Solution that resists changes in pH when
 - Small amounts of acid or base are added
 - Dilution occurs
 - Consists of either:
 - Weak acid / conjugate base pair
 - OR
 - Weak base / conjugate acid pair
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What is a Buffer?

- Two things to know about a buffer:
 - pH that buffer creates
 - Buffer capacity

Weak Acids and Bases



Acid/Base Conjugate Pair



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Base/Acid Conjugate Pair



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Acid / Base Equilibrium Constants



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{A}^-]}{[\text{HA}]}$$



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

Some Acid Constants

Name	Formula	K_a
Phosphoric acid	H_3PO_4	7.5×10^{-3}
Hydrofluoric acid	HF	7.2×10^{-4}
Nitrous acid	HNO_2	4.5×10^{-4}
Formic acid	HCO_2H	1.8×10^{-4}
Benzoic acid	$\text{C}_6\text{H}_5\text{CO}_2\text{H}$	6.3×10^{-5}
Acetic acid	$\text{CH}_3\text{CO}_2\text{H}$	1.8×10^{-5}
Propanoic acid	$\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$	1.3×10^{-5}

The "p" function

$$pX = -\log (X)$$

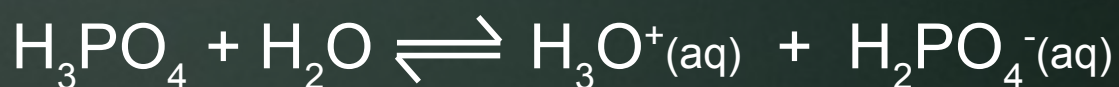
SO....

$$pH = -\log ([H_3O^+])$$

$$pK_a = -\log (K_a)$$

$$pK_b = -\log (K_b)$$

Example



$$K_a = \frac{[H_3O^+][H_2PO_4^-]}{[H_3PO_4]} = 7.5 \times 10^{-3}$$

$$pK_a = -\log (7.5 \times 10^{-3}) = 2.12$$

Henderson-Hasselbalch Equation



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{A}^-]}{[\text{HA}]}$$

Using p-functions, can derive:

$$\text{pH} = \text{p}K_a + \log\left(\frac{[\text{A}^-]}{[\text{HA}]}\right)$$

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Henderson-Hasselbalch Equation




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

Using p-functions, can derive:


$$\text{pOH} = \text{p}K_b + \log\left(\frac{[\text{BH}^+]}{[\text{B}]}\right)$$

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Buffer Capacity

- Definition: Moles of strong acid or base needed to change pH ± 1 of 1 L of buffer
 - For best buffer capacity, use conjugate pair with $\text{pK}_a = \text{pH} \pm 1$
 - Larger $[\text{HA}]$ and $[\text{A}^-]$ yields greater buffer capacity
 - Most buffers are 0.01 to 0.10 M
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Making a Buffer: Questions to Consider

- What pH do you want?
 - Conjugate pair with pK_a close to pH
 - What volume is needed?
 - How strong do you need to make buffer?
 - Buffering capacity
 - Concentration of acid / base
 - Limitations on conjugate pair?
 - Availability
 - Expense
 - Incompatible with your system (i.e. toxic)?
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How to Attain your pH?

- Method 1: Use Henderson-Hasselbalch to calculate exact amounts
- Method 2: Add amount of acid needed. Titrate with strong base (NaOH) and pH meter
- Method 3: Combination
 - Use Henderson-Hasselbalch to calculate
 - Add amount of acid needed
 - “Titrate” with conjugate base and pH meter

Today's Lab

- Make two buffers with pH = 5.0
 - Different buffering capacities
- Determine the buffering capacity

- Pre-lab question: Mass of sodium acetate to make 100 mL buffer at pH = 5.0, with 5.0 mL of 0.50 M acetic acid