AP Chemistry Unit 8 Easier Practice Set

Acids and Bases

Building Confidence with pH, Ka/Kb, Buffers, and Titrations

APChemistryRescue.com

📋 Practice Set Information

- **Total Points:** 75 points
- **Suggested Time:** 70–100 minutes
- **Questions:** 10 (scaffolded from pH calculations → weak acids/bases → buffers → titrations)
- **Topics:** pH/pOH, strong vs. weak acids/bases, Ka/Kb equilibria, percent ionization, buffers, Henderson-Hasselbalch, titration curves
- **Skills:** pH calculations (strong and weak), ICE tables with Ka/Kb, buffer pH using Henderson-Hasselbalch, interpreting titration curves

🔬 ESSENTIAL ACID-BASE FORMULAS & CONSTANTS

pH AND pOH:

$pH = -\log[H^+]$ | $[H^+] = 10^{(-pH)}$

$pOH = -\log[OH^-]$ | $[OH^-] = 10^{(-pOH)}$

$pH + pOH = 14.00$ | $[H^+][OH^-] = K_w = 1.0 \times 10^{(-14)}$

WEAK ACID/BASE EQUILIBRIA:

$HA \rightleftharpoons H^+ + A^-$ | $K_a = [H^+][A^-]/[HA]$

$B + H_2O \rightleftharpoons BH^+ + OH^-$ | $K_b = [BH^+][OH^-]/[B]$

$K_a \times K_b = K_w = 1.0 \times 10^{(-14)}$ (for conjugate pair)

BUFFERS (Henderson-Hasselbalch):

$$pH = pK_a + \log([A^-]/[HA])$$
$$pOH = pK_b + \log([BH^+]/[B])$$

PERCENT IONIZATION:

$$\% \text{ ionization} = ([H^+]_{eq} / [HA]_0) \times 100\%$$

STRONG ACIDS (memorize!)

- HCl (hydrochloric acid)
- HBr (hydrobromic acid)
- HI (hydroiodic acid)
- HNO_3 (nitric acid)
- H_2SO_4 (sulfuric acid)*
- $HClO_4$ (perchloric acid)

*First proton only

STRONG BASES (memorize!)

- LiOH, NaOH, KOH
- (Group 1 hydroxides)
- $Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$
- (Group 2 hydroxides)

100% ionization in water

⚗️ Key Concepts:

- **Strong acids/bases:**
  100% ionization → pH calculated directly from concentration
- **Weak acids/bases:**
  Partial ionization → use K_a or K_b with ICE table
- **Buffers:**
  Resist pH change; contain weak acid + conjugate base (or weak base + conjugate acid)
- **$pK_a = -\log(K_a)$**
  | Lower pK_a = stronger acid
- **Sig figs in pH:**
  Decimal places in pH = sig figs in $[H^+]$

Question 1: pH Scale and Strong Acid pH (6 points)

The pH scale measures the acidity or basicity of a solution:

ACIDIC	NEUTRAL	BASIC
pH < 7	pH = 7	pH > 7

0 1 3 7 11 13 14

(a) Calculate the pH of a **0.010 M HCl** solution. (HCl is a strong acid, so it ionizes 100%.)

For strong acids:

$[H^+]$ = [acid]_initial (100% ionization)

pH = $-\log[H^+]$

Work Space:

(b) Calculate the pH of a **0.0050 M HNO_3** solution.

Work Space:

(c) A solution has $[H^+] = 1.5 \times 10^{-4}$ M. Calculate the pH. How many significant figures should your answer have?

Work Space:

Question 2: Strong Base pH and pOH (7 points)

For strong bases, calculate pOH first, then pH.

(a) Calculate the pH of a **0.020 M NaOH** solution. (NaOH is a strong base.)

Steps:

1. $[OH^-]$ = 0.020 M (100% ionization)
2. pOH = $-\log[OH^-]$
3. pH = 14.00 − pOH

Work Space:

(b) A solution has pH = 11.50. Calculate $[OH^-]$.

Steps:

1. pOH = 14.00 − pH
2. $[OH^-]$ = 10^(−pOH)

Work Space:

(c) Explain why a solution with pH = 2 is **100 times more acidic** than a solution with pH = 4.

Work Space:

Question 3: Ka, Kb, and Conjugate Acid-Base Pairs (8 points)

For a conjugate acid-base pair, the relationship is:

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K_a × K_b = K_w = 1.0 × 10^(-14)
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(a) Acetic acid (CH_3COOH) has K_a = 1.8 × 10^{-5}. Calculate K_b for its conjugate base, acetate (CH_3COO^-).

Work Space:

(b) Ammonia (NH_3) has K_b = 1.8 × 10^{-5}. Calculate K_a for its conjugate acid, ammonium (NH_4^+).

Work Space:

(c) Which is the stronger acid: HF ($K_a = 6.8 \times 10^{-4}$) or HCN ($K_a = 6.2 \times 10^{-10}$)? Explain using K_a values.

Work Space:

(d) If an acid has $K_a = 1.0 \times 10^{-7}$, is it stronger or weaker than its conjugate base? Explain by calculating K_b.

Work Space:

Question 4: Weak Acid pH with ICE Table (10 points)

Calculate the pH of a **0.100 M solution of acetic acid** (CH_3COOH), $K_a = 1.8 \times 10^{-5}$.

$$CH_3COOH(aq) \rightleftharpoons H^+(aq) + CH_3COO^-(aq)$$

(a) Set up an ICE table for this equilibrium.

ICE Table:

	CH_3COOH	H^+	CH_3COO^-
Initial (M)			
Change (M)			
Equilibrium (M)			

(b) Write the K_a expression and substitute equilibrium concentrations from your ICE table.

Work Space:

(c) Apply the **small K_a approximation**: 0.100 − x ≈ 0.100 (valid because K_a is small). Solve for x = [H⁺].

Approximation:

$$K_a = \frac{x \cdot x}{0.100} = \frac{x^2}{0.100}$$

$$x^2 = K_a \times 0.100$$

$$x = \sqrt{K_a \times 0.100}$$

Work Space:

(d) Check the validity of the approximation: Is (x / 0.100) × 100% < 5%?

Work Space:

(e) Calculate the **pH** and **percent ionization**.

Work Space:

Question 5: Buffer pH (Henderson-Hasselbalch) (9 points)

A buffer contains **0.50 M CH_3COOH** (K_a = 1.8×10^{-5}) and **0.75 M CH_3COONa** (sodium acetate, which provides CH_3COO^-).

Henderson-Hasselbalch Equation:

$$pH = pK_a + \log([A^-]/[HA])$$

(a) Calculate **pK_a** from K_a. Use pK_a = −log(K_a).

Work Space:

(b) Identify the **weak acid (HA)** and **conjugate base (A^-)** in this buffer.

Work Space:

(c) Calculate the **pH of the buffer** using Henderson-Hasselbalch. Show all work.

Work Space:

(d) If you add a small amount of **HCl** to this buffer, which component (CH_3COOH or CH_3COO^-) will react with the HCl? What is the purpose of this reaction?

Work Space:

Question 6: Buffer Conceptual Understanding (7 points)

(a) What is a buffer? What two components must be present?

Work Space:

(b) Explain how a buffer resists pH change when a small amount of **strong base (OH^-)** is added.

Work Space:

(c) A buffer works best when pH ≈ pK_a. Why? What is the ratio $[A^-]/[HA]$ when pH = pK_a?

Work Space:

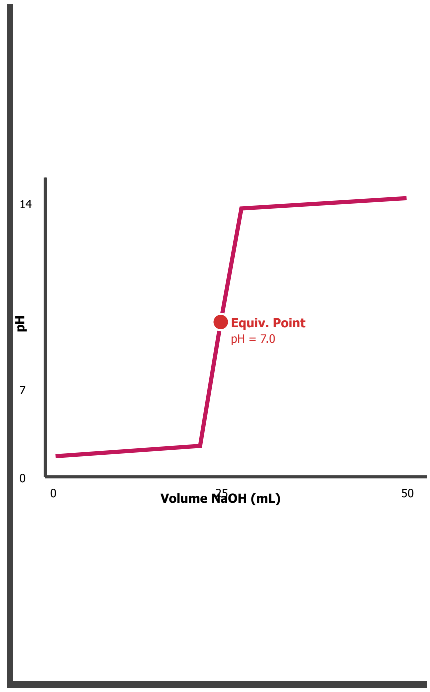
(d) Can you make a buffer from a **strong acid** (HCl) and its conjugate base (Cl^-)? Explain why or why not.

Work Space:

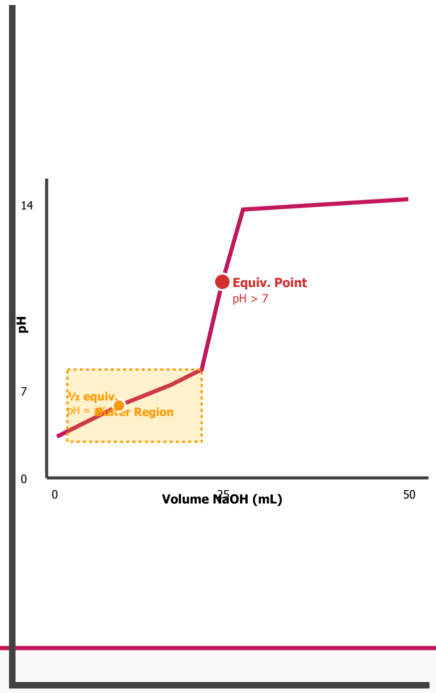
Question 7: Titration Curves (9 points)

Below are two titration curves: (A) Strong acid + Strong base, (B) Weak acid + Strong base.

Curve A: HCl + NaOH



Curve B: CH_3COOH + NaOH



(a) In Curve A (strong acid + strong base), what is the pH at the equivalence point? Why is it exactly 7.0?

Work Space:

(b) In Curve B (weak acid + strong base), why is the pH at the equivalence point **greater than 7**?

Work Space:

(c) What is the significance of the **half-equivalence point** on Curve B? What is the relationship between pH and pK_a at this point?

Work Space:

(d) Why does Curve B have a **buffer region** (gentle slope before equivalence point) while Curve A does not?

Work Space:

Question 8: Weak Base pH Calculation (8 points)

Calculate the pH of a **0.150 M ammonia (NH_3)** solution. K_b = 1.8 × 10^{-5}.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

(a) Write the K_b expression for ammonia.

Work Space:

(b) Set up an ICE table and solve for $[OH^-]$ using the small K_b approximation.

Work Space (ICE table and calculation):

(c) Calculate **pOH**, then **pH**.

Work Space:

Question 9: Salt Hydrolysis (6 points)

When salts dissolve in water, they can affect the pH through **hydrolysis**.

(a) Predict whether a solution of $\mathbf{NaCH_3COO}$ (sodium acetate) will be acidic, basic, or neutral. Explain using the acetate ion (CH_3COO^-).

Hint:

Na^+ is the conjugate of a strong base (NaOH) and doesn't affect pH. What about CH_3COO^-?

Work Space:

(b) Predict whether a solution of **NH_4Cl** (ammonium chloride) will be acidic, basic, or neutral.

Work Space:

(c) Predict whether a solution of **NaCl** will be acidic, basic, or neutral. Explain.

Work Space:

Question 10: Conceptual Synthesis (5 points)

(a) Why can't you use Henderson-Hasselbalch equation for a solution containing **only** a weak acid (no conjugate base present)?

Work Space:

(b) A student claims: "A buffer with pH = 7 is always the best buffer." Explain why this is not necessarily true. When is a buffer most effective?

Work Space:

(c) Explain why adding water to a buffer **dilutes** the buffer but doesn't significantly change the pH.

Work Space:

END OF PRACTICE SET

Total: 75 points | Answer key begins on next page

📘 COMPLETE ANSWER KEY & SCORING GUIDE

Question 1: pH Scale and Strong Acid pH (6 points)

(a) pH of 0.010 M HCl (2 points):

HCl is a strong acid, so $[H^+]$ = 0.010 M

$$\text{pH} = -\log[H^+] = -\log(0.010) = -\log(1.0 \times 10^{-2}) = 2.00$$

(1 pt for $[H^+]$ = 0.010 M; 1 pt for pH calculation)

(b) pH of 0.0050 M HNO_3 (1.5 points):

$$\text{pH} = -\log(0.0050) = -\log(5.0 \times 10^{-3}) = 2.30$$

(1.5 pts)

(c) pH from $[H^+]$ and sig figs (2.5 points):

$$\text{pH} = -\log(1.5 \times 10^{-4}) = 3.82$$

$[H^+]$ has 2 significant figures, so pH should have **2 decimal places**: pH = 3.82. (1 pt for calculation; 1 pt for sig figs; 0.5 pt for explanation)

Rule: Decimal places in pH = sig figs in $[H^+]$ (because pH is a logarithm).

Scoring: (a) 2 pts; (b) 1.5 pts; (c) 2.5 pts

Question 4: Weak Acid pH with ICE Table (10 points)

(a) ICE table (2 points):

	CH_3COOH	H^+	CH_3COO^-

Initial (M)	**0.100**	**≈0**	**0**
Change (M)	**−x**	**+x**	**+x**
Equilibrium (M)	**0.100 − x**	**x**	**x**

(2 pts for correct setup)

(b) K_a expression (1.5 points):

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = \frac{x \cdot x}{0.100 - x} = \frac{x^2}{0.100 - x}$$

(1.5 pts)

(c) Solve using approximation (3 points):

Assume 0.100 − x ≈ 0.100:

$$1.8 \times 10^{-5} = \frac{x^2}{0.100}$$

$$x^2 = (1.8 \times 10^{-5})(0.100) = 1.8 \times 10^{-6}$$

$$x = \sqrt{1.8 \times 10^{-6}} = 1.34 \times 10^{-3} \text{ M}$$

(1 pt for approximation setup; 1 pt for algebra; 1 pt for answer)

(d) Check validity (1.5 points):

$$\frac{x}{0.100} \times 100\% = \frac{1.34 \times 10^{-3}}{0.100} \times 100\% = 1.34\%$$

Since 1.34% < 5%, the approximation is **valid**. (1 pt for calculation; 0.5 pt for conclusion)

(e) pH and percent ionization (2 points):

$$\text{pH} = -\log(1.34 \times 10^{-3}) = 2.87$$

$$\text{Percent ionization} = \frac{[H^+]_{eq}}{[HA]_0} \times 100\% = \frac{1.34 \times 10^{-3}}{0.100} \times 100\% = 1.34\%$$

(1 pt for pH; 1 pt for % ionization)

Scoring: (a) 2 pts; (b) 1.5 pts; (c) 3 pts; (d) 1.5 pts; (e) 2 pts

Question 5: Buffer pH (Henderson-Hasselbalch) (9 points)

(a) Calculate pK_a (2 points):

$$pK_a = -\log(K_a) = -\log(1.8 \times 10^{-5}) = 4.74$$

(2 pts)

(b) Identify acid and base (1.5 points):

Weak acid (HA): CH_3COOH (0.50 M)

Conjugate base (A^-): CH_3COO^- (0.75 M, from CH_3COONa)

(1.5 pts)

(c) Calculate pH (4 points):

$$\text{pH} = pK_a + \log\left(\frac{[A^-]}{[HA]}\right) = 4.74 + \log\left(\frac{0.75}{0.50}\right)$$

$$= 4.74 + \log(1.5) = 4.74 + 0.18 = 4.92$$

(1 pt for formula; 1 pt for substitution; 1 pt for log calculation; 1 pt for final answer)

(d) Reaction with HCl (1.5 points):

The **conjugate base CH_3COO^-** will react with HCl (strong acid, source of H^+). (1 pt)

Reaction: $CH_3COO^- + H^+ \rightarrow CH_3COOH$

Purpose: The acetate ion **neutralizes the added H^+**, preventing a large pH drop. The buffer resists pH change by converting strong acid into weak acid. (0.5 pt)

Scoring: (a) 2 pts; (b) 1.5 pts; (c) 4 pts; (d) 1.5 pts