



# BUFFER SOLUTIONS

Course: SCH4U Grade 12 Chemistry

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## 50 Practice Problems with Answers and Detailed Solutions

**FULL** worksheet contains 50 representative problems on:

✓ conjugate acid-base pairs, ✓ Henderson-Hasselbalch calculations, ✓ buffer preparation, ✓ weak acid or weak base buffers, ✓ added strong acid or base, ✓ buffer capacity, ✓ titration buffer regions

All problems are designed to reflect style and difficulty commonly seen on quizzes, tests, and final exams. Detailed solutions are included to help students understand the reasoning behind every step.

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### PART A - FUNDAMENTAL PROBLEMS

Problems 1-15. Simple calculations and basic applications

### PART B - INTERMEDIATE PROBLEMS

Problems 16-30. Typical unit test questions involving multiple steps

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### PART C - ADVANCED PROBLEMS

Problems 31-40. More challenging calculations requiring deeper understanding

### PART D - CHALLENGE PROBLEMS

Problems 41-50. Difficult exam-style questions combining multiple concepts

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SUITABLE FOR:

quizzes, unit tests and final exam preparation

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## Section 1 Essential Information

Salt hydrolysis happens when an ion from a salt reacts with water and changes  $[H_3O^+]$  or  $[OH^-]$ . The main idea is to identify whether each ion comes from a strong acid, strong base, weak acid, or weak base.

| Ion type                   | Hydrolysis behaviour                        | Main result                              |
|----------------------------|---------------------------------------------|------------------------------------------|
| Cation from strong base    | No important hydrolysis                     | Neutral effect                           |
| Anion from strong acid     | No important hydrolysis                     | Neutral effect                           |
| Cation from weak base      | $BH^+ + H_2O \rightleftharpoons B + H_3O^+$ | Acids solution                           |
| Anion from weak acid       | $A + H_2O \rightleftharpoons HA + OH^-$     | Basic solution                           |
| Weak acid + weak base salt | Both ions hydrolyse                         | Compare $K_a$ (cation) and $K_b$ (anion) |

### Key relationships

**Weak acid model:** HA reacts with water to form  $H_3O^+$  and  $A^-$



$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

**Weak base model:** B reacts with water to form  $BH^+$  and  $OH^-$



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

**pH relationships at 25 °C:**

$$pH = -\log[H_3O^+], \quad [H_3O^+] = 10^{-pH}$$

$$p[OH^-] = -\log[OH^-], \quad [OH^-] = 10^{-p[OH^-]}$$

$$pH + p[OH^-] = 14.00$$

$$[H_3O^+][OH^-] = K_w = 1.0 \times 10^{-14}$$

**Conjugate pairs:**  $K_a K_b = K_w$

use  $K_b = K_w/K_a$  for a conjugate base and  $K_a = K_w/K_b$  for a conjugate acid

$$\text{For weak acid + weak base salts } pH \approx 7.00 + \frac{1}{2} \log \left( \frac{K_b(\text{anion})}{K_a(\text{cation})} \right)$$

$$\text{For amphiprotic ions such as } HCO_3^- \quad pH \approx \frac{pK_1 + pK_2}{2}$$

### Common constants used in this worksheet

| Acid or base | Constant                    | Acid or base | Constant                    |
|--------------|-----------------------------|--------------|-----------------------------|
| $H_2N_2O_2$  | $K_a = 1.0 \times 10^{-4}$  | $HSO_4^-$    | $K_a = 1.0 \times 10^{-2}$  |
| $HF$         | $K_a = 6.6 \times 10^{-4}$  | $CH_3CO_2H$  | $K_a = 4.4 \times 10^{-5}$  |
| $HNO_2$      | $K_a = 4.5 \times 10^{-4}$  | $C_6H_5NH_2$ | $K_b = 1.7 \times 10^{-5}$  |
| $HClO$       | $K_a = 3.0 \times 10^{-8}$  | $HClO_2$     | $K_a = 1.0 \times 10^{-2}$  |
| $HClN$       | $K_a = 9.2 \times 10^{-10}$ | $HCO_3^-$    | $K_a = 4.7 \times 10^{-11}$ |

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## Section 2 Practice Problems

### Part A - Buffer Foundations and Direct pH Calculations

8. A buffer contains equal concentrations of  $\text{NH}_3$  and  $\text{NH}_4^+$ . The  $\text{pK}_b$  of  $\text{NH}_3$  is 4.75.

Calculate the pH

### Part B - Preparing Buffers and Stoichiometric Formation

16. Calculate the pH of a buffer containing 0.100 mol  $\text{CH}_3\text{COOH}$  and 0.150 mol  $\text{CH}_3\text{COO}^-$ .

Use  $\text{pK}_a = 4.74$

### Part C - Adding Strong Acid or Strong Base to a Buffer

32. A buffer contains 0.100 mol  $\text{HA}$  and 0.100 mol  $\text{A}^-$ . The  $\text{pK}_a$  is 4.74. Calculate the pH after

0.0100 mol  $\text{NaOH}$  is added

### Part D - Mixed Unit Test Style Buffer Problems

45. A 1.000 L buffer contains 0.250 mol/L  $\text{CH}_3\text{COOH}$  and 0.150 mol/L  $\text{CH}_3\text{COO}^-$ . Then 0.200

mol  $\text{HCl}$  is added. Use  $\text{pK}_a = 4.74$ . Calculate the final pH assuming final volume is 1.000 L

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## Section 3 Solutions

### Problem 8 Solution

**Given:**  $pK_b = 4.75$ ,  $n\text{NH}_4^+/n\text{NH}_3 = 1.00$

**Method:** For a weak base buffer, first calculate pOH, then convert to pH

**Calculations:**

$$pOH = pK_b + \log(n\text{BH}^+/n\text{B})$$

$$pOH = 4.75 + \log(1.00) = 4.75$$

$$pH = 14.00 - 4.75 = 9.25$$

**Final answer:**  $pH = 9.25$

### Problem 16 Solution

**Given:**  $n\text{CH}_3\text{COOH} = 0.100 \text{ mol}$ ,  $n\text{CH}_3\text{COO}^- = 0.150 \text{ mol}$ ,  $pK_a = 4.74$

**Method:** Use mole ratio in the Henderson-Hasselbalch equation

**Calculations:**

$$pH = 4.74 + \log(0.150/0.100)$$

$$pH = 4.74 + \log(1.50) = 4.916$$

**Final answer:**  $pH = 4.92$

### Problem 32 Solution

**Given:**  $n\text{HA} = 0.100 \text{ mol}$ ,  $n\text{A}^- = 0.100 \text{ mol}$ ,  $n\text{NaOH} = 0.0100 \text{ mol}$ ,  $pK_a = 4.74$

**Method:** Added  $\text{OH}^-$  consumes HA and produces  $\text{A}^-$

**Calculations:**

$$\text{After NaOH: } n\text{HA} = 0.100 - 0.0100 = 0.0900 \text{ mol}$$

$$\text{After NaOH: } n\text{A}^- = 0.100 + 0.0100 = 0.110 \text{ mol}$$

$$pH = 4.74 + \log(0.110/0.0900) = 4.827$$

**Final answer:**  $pH = 4.83$

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### Problem 45 Solution

**Given:**  $n\text{CH}_3\text{COOH} = 0.250 \text{ mol}$ ,  $n\text{CH}_3\text{COO}^- = 0.150 \text{ mol}$ ,  $n\text{HCl} = 0.200 \text{ mol}$ , final volume = 1.000 L

**Method:** First check whether added strong acid exceeds the amount of conjugate base

**Calculations:**

HCl consumes all 0.150 mol  $\text{CH}_3\text{COO}^-$

Excess  $\text{H}^+ = 0.200 - 0.150 = 0.0500 \text{ mol}$

$[\text{H}^+]$  from excess strong acid =  $0.0500 \text{ mol} / 1.000 \text{ L} = 0.0500 \text{ mol/L}$

$\text{pH} = -\log(0.0500) = 1.301$

**Final answer:**  $\text{pH} = 1.30$ ; buffer capacity is exceeded

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## Section 4 Answer Key

| Problem | Final Answer                 | Problem | Final Answer |
|---------|------------------------------|---------|--------------|
| 8       | pH = 9.25                    |         |              |
| 16      | pH = 4.92                    |         |              |
| 32      | pH = 4.83                    |         |              |
| 45      | pH = 1.30; capacity exceeded |         |              |

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