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CHEMISTRY WORKSHEET

ACID-BASE ICE TABLES

Course: SCH4U Grade 12 Chemistry

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50 Practice Problems with Answers and Detailed Solutions

FULL worksheet contains 50 representative problems on:

✓ weak acid pH, ✓ weak base pH, ✓ Ka and Kb from pH, ✓ percent ionization, ✓ common ion ICE tables, ✓ salt hydrolysis, ✓ partial neutralization, ✓ equivalence-point hydrolysis, ✓ exact quadratic calculations

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.

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

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

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	$BH^+ + H_2O \rightleftharpoons B + H_3O^+$	Acidic solution
Anion from weak acid	$A^- + H_2O \rightleftharpoons HA + OH^-$	Basic solution
Weak acid + weak base salt	Both ions hydrolyze	Compare K_a (cation) and K_a (anion)

Key relationships

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

$$HA_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + A^-_{(aq)}$$

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

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

$$B_{(aq)} + H_2O_{(l)} \rightleftharpoons BH^+_{(aq)} + OH^-_{(aq)}$$

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

pH relationships at 25 °C	Conjugate pairs: $K_a \times K_b$
$pH = -\log[H_3O^+]$ $[H_3O^+] = 10^{-pH}$ $pOH = -\log[OH^-]$ $[OH^-] = 10^{-pOH}$ $pH + pOH = 14.00$ $[H_3O^+][OH^-] = K_w = 1.0 \times 10^{-14}$	use $K_b = K_w/K_a$ for a conjugate base and $K_a = K_w/K_b$ for a conjugate acid

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

For amphiprotic ions such as HCO_3^-: $pH \approx \frac{pK_{a1} + pK_{a2}}{2}$

Common constants used in this worksheet

Acid or base	Constant	Acid or base	Constant
CH_3COOH	$K_a = 1.8 \times 10^{-5}$	NH_3	$K_b = 1.8 \times 10^{-5}$
HF	$K_a = 6.8 \times 10^{-4}$	$C_6H_5NH_2$	$K_b = 4.4 \times 10^{-10}$
HNO_2	$K_a = 4.5 \times 10^{-4}$	C_5H_5N	$K_b = 1.7 \times 10^{-9}$
HCN	$K_a = 3.5 \times 10^{-10}$	$HCOOH$	$K_a = 1.8 \times 10^{-4}$
HClO	$K_a = 3.2 \times 10^{-8}$	HCO_3^-	$K_{a2} = 4.7 \times 10^{-11}$

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Section 2 - Practice Problems

PART A - FUNDAMENTAL PROBLEMS

Problem 8

Calculate the pH of 0.0750 M HOCl if $K_a = 3.5 \times 10^{-8}$

PART B - INTERMEDIATE PROBLEMS

Problem 16

Use an exact ICE table calculation for 0.0200 M HF with $K_a = 6.8 \times 10^{-4}$; calculate pH and percent ionization

PART C - ADVANCED PROBLEMS

Problem 32

A 100.0 mL sample of 0.100 M NH_3 is mixed with 25.0 mL of 0.100 M HCl; after neutralization, use an ICE table to calculate pH

PART D - CHALLENGE PROBLEMS

Problem 45

A 25.0 mL sample of 0.150 M HF is mixed with 10.0 mL of 0.100 M NaOH; after neutralization, use an ICE table to calculate pH

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Section 3 - Solutions

PART A - FUNDAMENTAL PROBLEMS

Problem 8 Solution

Given: C_{HA} = 0.075 M; $K_a = 3.5 \times 10^{-8}$

$$HOCl_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OCl^-_{(aq)}$$

ICE setup: Initial: [HOCl] = 0.075 M, $[H_3O^+] = 0$, $[OCl^-] = 0$; Change: -x, +x, +x;

Equilibrium: [HOCl] = 0.075 - x, $[H_3O^+] = x$, $[OCl^-] = x$

Equilibrium expression: $K_a = x^2/(0.075 - x)$

The exact quadratic gives $x = [H_3O^+] = 5.12 \times 10^{-5}$ M; $pH = -\log(5.12 \times 10^{-5}) = 4.29$

Final answer: pH = 4.29

PART B - INTERMEDIATE PROBLEMS

Problem 16 Solution

Given: C_{HA} = 0.02 M; $K_a = 6.8 \times 10^{-4}$

$$HF_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + F^-_{(aq)}$$

ICE setup: Initial: [HF] = 0.02 M, $[H_3O^+] = 0$, $[F^-] = 0$;

Change: -x, +x, +x;

Equilibrium: [HF] = 0.02 - x, $[H_3O^+] = x$, $[F^-] = x$

Equilibrium expression: $K_a = x^2/(0.02 - x)$

The exact quadratic gives $x = [H_3O^+] = 3.36 \times 10^{-3}$ M; $pH = -\log(3.36 \times 10^{-3}) = 2.47$

Final answer: pH = 2.47; percent ionization = 16.8%

PART C - ADVANCED PROBLEMS

Problem 32 Solution

Given: 100.0 mL of 0.100 M NH_3 is mixed with 25.0 mL of 0.100 M HCl; $K_b(NH_3) = 1.8 \times 10^{-5}$

$$NH_{3(aq)} + H_3O^+_{(aq)} \rightarrow NH_4^+_{(aq)} + H_2O_{(l)}$$

Stoichiometry first: $n(NH_3) = 0.1000\ L \times 0.100\ M = 0.0100\ mol$; $n(HCl) = 0.0250\ L \times 0.100\ M = 0.00250\ mol$

After neutralization: 0.00750 mol NH_3 remains and 0.00250 mol NH_4^+ forms; total volume = 0.125 L

Initial ICE concentrations: $[NH_3] = 0.0600\ M$ and $[NH_4^+] = 0.0200\ M$

$K_b = x(0.0200 + x)/(0.0600 - x)$; $x = [OH^-] = 5.38 \times 10^{-5}\ M$; pOH = 4.27; pH = 9.73

Final answer: pH = 9.73

PART D - CHALLENGE PROBLEMS

Problem 45 Solution

Given: 25.0 mL of 0.150 M HF is mixed with 10.0 mL of 0.100 M NaOH;

$K_a(HF) = 6.8 \times 10^{-4}$

$$HF_{(aq)} + OH^-_{(aq)} \rightarrow F^-_{(aq)} + H_2O_{(l)}$$

Stoichiometry first: $n(HF) = 0.0250\ L \times 0.150\ M = 0.00375\ mol$;

$n(OH^-) = 0.0100\ L \times 0.100\ M = 0.00100\ mol$

After neutralization: HF remaining = 0.00275 mol; F^- formed = 0.00100 mol; total volume = 0.0350 L

Initial ICE concentrations: $[HF] = 0.0786\ M$ and $[F^-] = 0.0286\ M$

$K_a = x(0.0286 + x)/(0.0786 - x)$; $x = [H_3O^+] = 1.72 \times 10^{-3}\ M$

Final answer: pH = 2.76

Section 4 - Answer Key

Problem	Answer	Problem	Answer	Problem	Answer
8	pH = 4.29				
16	pH = 2.47; percent ionization = 16.8%				
32	pH = 9.73				
45	pH = 2.76				