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with solutions

CHEMISTRY WORKSHEET

ACID-BASE TITRATION

Course: SCH4U Grade 12 Chemistry

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50 Practice Problems with Answers and Detailed Solutions

FULL worksheet contains 50 representative problems on:

✓ pH at equivalence point, ✓ strong acid-strong base, ✓ weak acid-strong base, ✓ weak base-strong acid, ✓ polyprotic acids, ✓ back titration, ✓ purity analysis.

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	$BH^+ + H_2O \rightleftharpoons B + H_3O^+$	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:

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

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

$$pH + pOH = 14.00$$

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

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
$H_2N_2O_2$	$K_a = 1.8 \times 10^{-4}$	HSO_4^-	$K_a = 1.2 \times 10^{-2}$
HF	$K_a = 6.8 \times 10^{-4}$	$H_2PO_4^-$	$K_a = 4.4 \times 10^{-3}$
HNO_2	$K_a = 4.5 \times 10^{-4}$	$C_6H_5NH_2$	$K_b = 3.7 \times 10^{-4}$
$HClO$	$K_a = 3.0 \times 10^{-8}$	HCO_3^-	$K_a = 4.7 \times 10^{-11}$
$HClO_2$	$K_a = 1.2 \times 10^{-2}$	H_2O	$K_w = 1.0 \times 10^{-14}$

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Section 2 - Practice Problems

Part A - Fundamental Problems

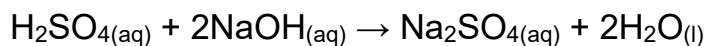
Problem 8

Calculate the initial pH of a 0.0250 mol/L HCl solution before any titrant is added

Part B - Intermediate Problems

Problem 16

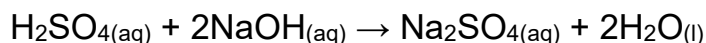
A 10.00 mL sample of H_2SO_4 is titrated with 0.1500 mol/L NaOH. Concordant titres are 22.42 mL, 22.38 mL, and 22.40 mL. Calculate the concentration of H_2SO_4



Part C - Advanced Problems

Problem 32

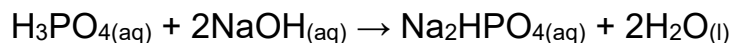
A 5.00 mL sample of H_2SO_4 is diluted to 250.0 mL. A 25.00 mL aliquot of the diluted solution requires 18.75 mL of 0.1000 mol/L NaOH. Calculate the concentration of the original H_2SO_4 sample



Part D - Challenge Problems

Problem 45

A 20.00 mL sample of H_3PO_4 is titrated to the second equivalence point with 32.40 mL of 0.2000 mol/L NaOH. Calculate the concentration of H_3PO_4



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Section 3 - Solutions

Problem 8 Solution

Given: HCl is a strong acid and $c_{\text{HCl}} = 0.0250 \text{ mol/L}$

Find: initial pH

For a strong monoprotic acid, $[\text{H}^+]$ equals the acid concentration

Formula: $\text{pH} = -\log[\text{H}^+]$

$[\text{H}^+] = 0.0250 \text{ mol/L}$

$\text{pH} = -\log(0.0250) = 1.602$

Final answer: $\text{pH} = 1.60$

Significant figures note: pH is rounded to 2 decimal places after keeping guard digits in intermediate concentration or equilibrium calculations

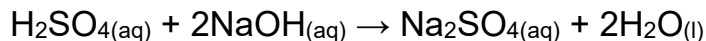
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Problem 16 Solution

Given: $V_{\text{H}_2\text{SO}_4} = 10.00 \text{ mL} = 0.01000 \text{ L}$, $c_{\text{NaOH}} = 0.1500 \text{ mol/L}$, titres = 22.42 mL, 22.38 mL, 22.40 mL

Find: $c_{\text{H}_2\text{SO}_4}$

Average the titres, then use the 2:1 NaOH:H₂SO₄ mole ratio



average $V_{\text{NaOH}} = 22.40 \text{ mL} = 0.02240 \text{ L}$

$n_{\text{NaOH}} = 0.1500 \text{ mol/L} \cdot 0.02240 \text{ L} = 0.003360 \text{ mol}$

$n_{\text{H}_2\text{SO}_4} = 0.003360 \text{ mol} / 2 = 0.001680 \text{ mol}$

$c_{\text{H}_2\text{SO}_4} = 0.001680 \text{ mol} / 0.01000 \text{ L} = 0.1680 \text{ mol/L}$

Final answer: 0.1680 mol/L H₂SO₄

Significant figures note: Final result is reported to 4 significant figures because the titration volumes and standard concentration are given to 4 significant figures

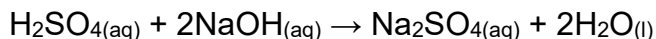
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Problem 32 Solution

Given: 5.00 mL original sample diluted to 250.0 mL; 25.00 mL aliquot uses 18.75 mL of 0.1000 mol/L NaOH

Find: original CH_2SO_4

Use diprotic stoichiometry for the aliquot, scale to the full diluted flask, then divide by the original sample volume



$$n_{\text{NaOH}} \text{ in aliquot} = 0.1000 \text{ mol/L} \cdot 0.01875 \text{ L} = 0.001875 \text{ mol}$$

$$n_{\text{H}_2\text{SO}_4} \text{ in aliquot} = 0.001875 \text{ mol} / 2 = 0.0009375 \text{ mol}$$

$$\text{scale factor} = 250.0 \text{ mL} / 25.00 \text{ mL} = 10.00$$

$$n_{\text{H}_2\text{SO}_4} \text{ in original 5.00 mL sample} = 0.0009375 \text{ mol} \cdot 10.00 = 0.009375 \text{ mol}$$

$$c_{\text{original}} = 0.009375 \text{ mol} / 0.00500 \text{ L} = 1.875 \text{ mol/L}$$

Final answer: 1.88 mol/L H_2SO_4

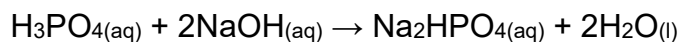
Significant figures note: The original 5.00 mL volume has 3 significant figures, so the final concentration is reported to 3 significant figures

Problem 45 Solution

Given: $V_{\text{acid}} = 20.00 \text{ mL} = 0.02000 \text{ L}$, $V_{\text{NaOH}} = 32.40 \text{ mL} = 0.03240 \text{ L}$, $c_{\text{NaOH}} = 0.2000 \text{ mol/L}$

Find: CH_3PO_4

At the second equivalence point, 2 mol OH^- have reacted with each mole of H_3PO_4



$$n_{\text{NaOH}} = 0.2000 \text{ mol/L} \cdot 0.03240 \text{ L} = 0.006480 \text{ mol}$$

$$n_{\text{H}_3\text{PO}_4} = 0.006480 \text{ mol} / 2 = 0.003240 \text{ mol}$$

$$c_{\text{H}_3\text{PO}_4} = 0.003240 \text{ mol} / 0.02000 \text{ L} = 0.1620 \text{ mol/L}$$

Final answer: 0.1620 mol/L H_3PO_4

Significant figures note: Final result is reported to 4 significant figures because the titration volumes and standard concentration are given to 4 significant figures

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Section 4 - Answer Key

Problem	Answer
8	pH = 1.60
16	0.1680 mol/L H ₂ SO ₄
32	1.88 mol/L H ₂ SO ₄
45	0.1620 mol/L H ₃ PO ₄

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