

Strong and weak acids, pH and buffer solutions

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Worksheet

Name: _____ Date: _____ Class: _____

These problems train you to move between concentration, pH, K_a and pK_a , and to treat buffers and titration curves quantitatively. Early problems use strong acids and bases; later ones combine weak acids, mole ratios and the Henderson-Hasselbalch equation.

The level suits A Level, IB Chemistry, CBSE Class 11-12 and senior WAEC and NECO students. Give pH values to two decimal places and show every logarithm step.

Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB R3.1

Problem 1 Conjugate pairs in ammonia (easy)

In a school lab in Lagos, Chiamaka dissolves ammonia in water: $\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$.

1. State the Brønsted-Lowry definition of a base.
2. Identify the acid and the base on the left-hand side.
3. Name the two conjugate pairs.

Problem 2 pH of dilute hydrochloric acid (easy)

Bilal in Lahore makes 0.0250 mol/dm^3 hydrochloric acid for a rust-removal test.

1. Write the equation for the ionisation of HCl in water.
2. Calculate $[\text{H}^+]$.
3. Calculate the pH to 2 decimal places.

Problem 3 Hydrogen ion concentration from pH (easy)

A rainwater sample collected in Leeds has pH 4.60.

1. Calculate $[\text{H}^+]$ in mol/dm^3 .
2. Compare it with neutral water, where $\text{pH} = 7.00$. How many times larger is $[\text{H}^+]$?

Problem 4 pOH and pH of sodium hydroxide (easy)

Kofi in Accra prepares 0.0040 mol/dm^3 sodium hydroxide to test a soap sample.

1. Calculate $[\text{OH}^-]$.
2. Calculate pOH.
3. Calculate pH using $\text{pH} + \text{pOH} = 14$.

Problem 5 Comparing acid strength by pKa (easy)

Benzoic acid has $K_a = 6.3 \times 10^{-5} \text{ mol/dm}^3$ and chloroethanoic acid has $\text{p}K_a = 2.85$.

1. Calculate $\text{p}K_a$ of benzoic acid.
2. Decide which acid is stronger and give a reason.
3. Calculate K_a of chloroethanoic acid.

Problem 6 pH of methanoic acid (medium)

Mei in Singapore tests 0.150 mol/dm^3 methanoic acid, HCOOH ($K_a = 1.6 \times 10^{-4} \text{ mol/dm}^3$), for a descaling project.

1. Write the expression for K_a .
2. Calculate $[\text{H}^+]$ using the usual approximations.
3. Calculate the pH.
4. Show that the approximation is acceptable.

Problem 7 Percentage ionisation of ethanoic acid (medium)

Diego in Texas has 0.0500 mol/dm^3 ethanoic acid ($K_a = 1.8 \times 10^{-5} \text{ mol/dm}^3$) from a vinegar experiment.

1. Calculate $[\text{H}^+]$.
2. Calculate the percentage of molecules ionised.
3. Predict whether the percentage ionised rises or falls on dilution to 0.0050 mol/dm^3 and give a reason.

Problem 8 Diluting nitric acid (medium)

Emma in Leeds takes 10.0 cm^3 of 1.00 mol/dm^3 nitric acid and adds water until the total volume is 500 cm^3 .

1. Calculate the new concentration of H^+ .
2. Calculate the pH.
3. Calculate the volume of water added.

Problem 9 Excess acid after partial neutralisation (medium)

Wanjiru in Nairobi mixes 30.0 cm^3 of 0.120 mol/dm^3 HCl with 20.0 cm^3 of 0.100 mol/dm^3 NaOH .

1. Calculate the moles of H^+ and OH^- before mixing.
2. Calculate the moles of H^+ left over.
3. Calculate the final pH.

Problem 10 K_a from a measured pH (medium)

A student in Pune measures pH 2.85 for 0.200 mol/dm^3 of an unknown weak monoprotic acid HA .

1. Calculate $[H^+]$.
2. Calculate K_a .
3. Calculate pK_a .

Problem 11 A lactic acid buffer (medium)

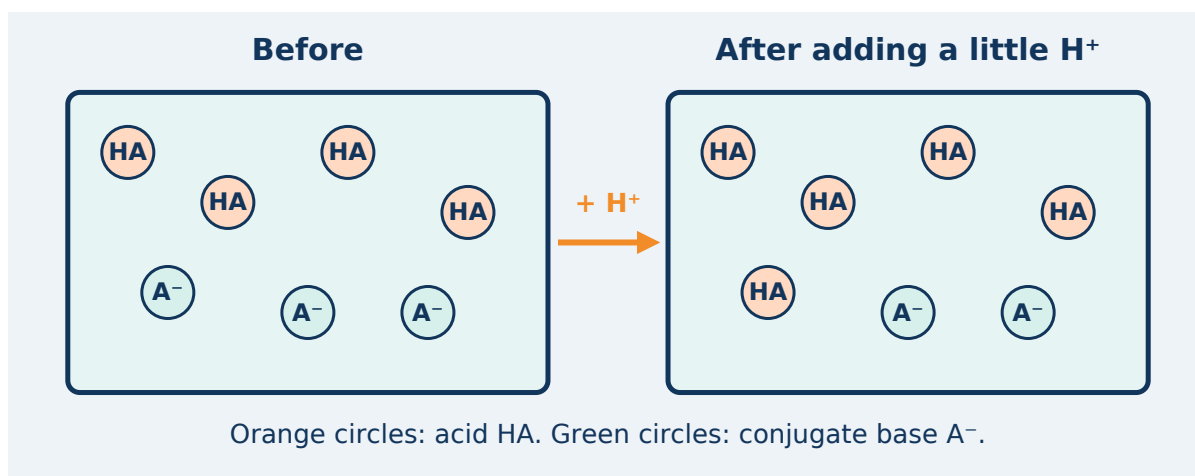
A sports drink buffer contains 0.30 mol/dm^3 lactic acid ($pK_a = 3.85$) and 0.15 mol/dm^3 sodium lactate.

1. Write the Henderson-Hasselbalch equation.
2. Calculate the pH of the buffer.

Problem 12 How a buffer neutralises added acid (medium)

The diagram shows a buffer of ethanoic acid (HA) and ethanoate ions (A^-) before and after a little H^+ is added.

1. Write an ionic equation for the reaction that removes the added H^+ .
2. Describe the change in the numbers of HA and A^- particles.
3. Explain why the pH changes only slightly.



A buffer before and after a little H^+ is added.

Problem 13 Ionic product of water at 50°C (medium)

At 50°C the ionic product of water is $K_w = 5.5 \times 10^{-14} \text{ mol}^2/\text{dm}^6$. Aarav measures pure water at this temperature.

1. Calculate $[H^+]$ in pure water.
2. Calculate the pH.
3. State whether the water is acidic, neutral or alkaline, and explain.

Problem 14 pH of aqueous ammonia (medium)

Chiamaka makes 0.100 mol/dm^3 ammonia solution. For $\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$, $K_b = 1.8 \times 10^{-5} \text{ mol/dm}^3$.

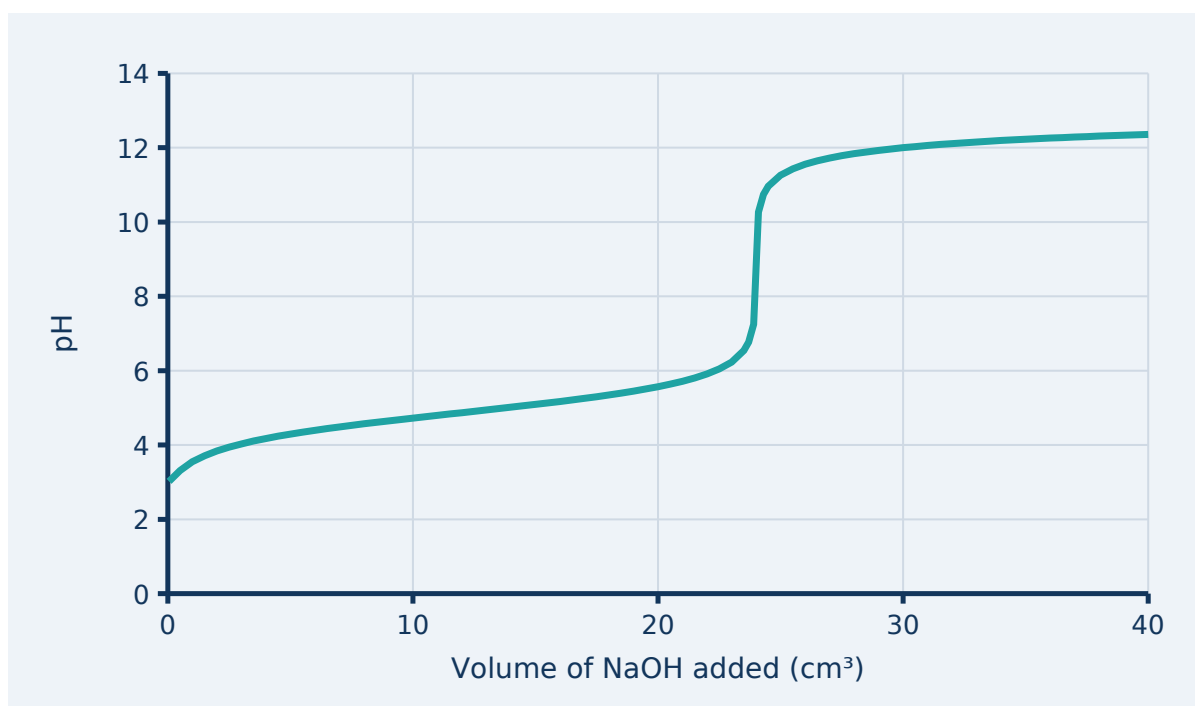
1. Calculate $[\text{OH}^-]$ using $[\text{OH}^-] = \sqrt{K_b \times c}$.

2. Calculate pOH.
3. Calculate pH.

Problem 15 Reading pKa from a titration curve (medium)

Kofi titrates 30.0 cm³ of an unknown weak acid with 0.100 mol/dm³ NaOH and plots the curve shown. The candidates are propanoic acid, ethanoic acid and benzoic acid (pKa 4.87, 4.74 and 4.20).

1. Read the volume at the equivalence point.
2. Read the pH at half that volume.
3. Identify the acid and calculate its Ka.

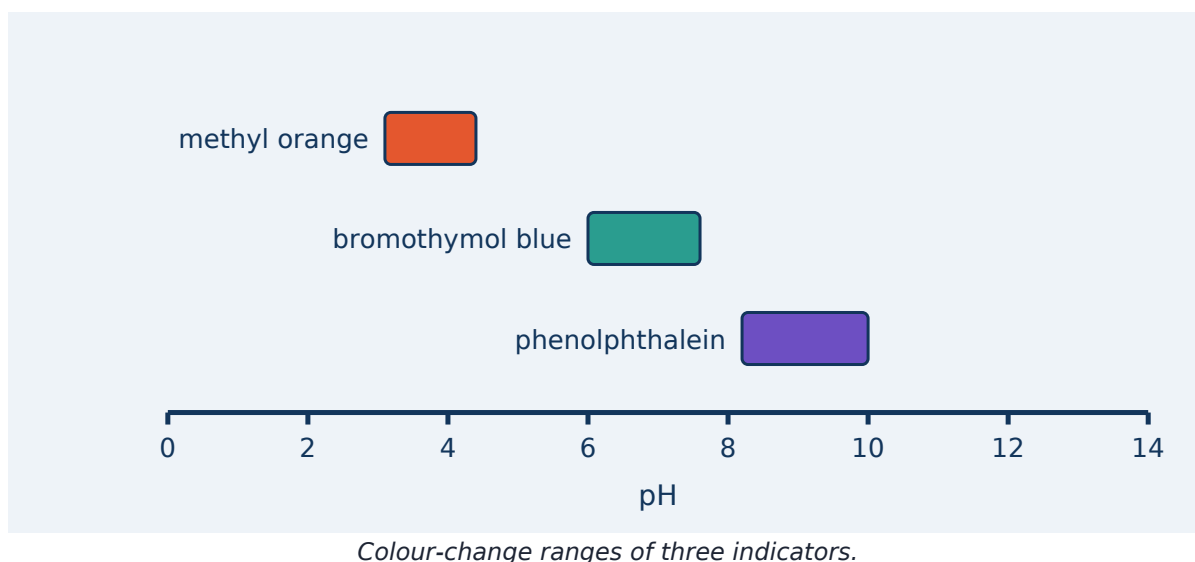


pH curve for a weak acid titrated with 0.100 mol/dm³ NaOH.

Problem 16 Equivalence point and indicator (hard)

Emma titrates 25.0 cm³ of 0.100 mol/dm³ ethanoic acid ($K_a = 1.8 \times 10^{-5}$ mol/dm³) with 0.100 mol/dm³ NaOH. The chart shows the ranges of three indicators.

1. Calculate the concentration of sodium ethanoate at equivalence.
2. Calculate Kb of the ethanoate ion ($K_w = 1.0 \times 10^{-14}$) and the pH at equivalence.
3. Choose the suitable indicator and justify your choice.

**Problem 17 Preparing an ammonia buffer** (hard)

Mei needs 250 cm³ of buffer with pH 9.40. She has 100 cm³ of 0.200 mol/dm³ ammonium chloride (pK_a of NH₄⁺ = 9.25) and 1.00 mol/dm³ ammonia solution.

1. Calculate the required ratio [NH₃]/[NH₄⁺].
2. Calculate the moles of NH₃ needed.
3. Calculate the volume of ammonia solution to add.

Problem 18 Adding acid to a buffer and to water (hard)

Diego has 500 cm³ of a buffer containing 0.100 mol/dm³ ethanoic acid and 0.100 mol/dm³ sodium ethanoate (pK_a 4.74). He adds 0.0100 mol of HCl; the volume change is negligible.

1. Calculate the initial pH.
2. Calculate the moles of acid and base after the addition, then the new pH.
3. Calculate the pH if the same HCl is added to 500 cm³ of pure water of pH 7.0.
4. Compare the two pH changes.

Problem 19 Mixing weak acid and alkali (hard)

Bilal mixes 40.0 cm³ of 0.150 mol/dm³ benzoic acid (pK_a 4.20) with 10.0 cm³ of 0.200 mol/dm³ NaOH.

1. Calculate the moles of benzoic acid and of NaOH.
2. Calculate the moles of benzoic acid and benzoate present after reaction.
3. Calculate the pH.
4. Calculate the volume of NaOH needed to reach equivalence.

Problem 20 A very dilute acid (hard)

Kofi claims that 1.0 × 10⁻⁸ mol/dm³ hydrochloric acid has pH 8.00.

1. Explain why this cannot be right.

2. Calculate the correct pH. Let $x = [\text{H}^+]$ in total, so that $x = 1.0 \times 10^{-8} + [\text{OH}^-]$ (the H^+ from water equals $[\text{OH}^-]$) and $x[\text{OH}^-] = 1.0 \times 10^{-14}$.