NAME DATE STARTED TARGET END DATE

GCE A LEVEL — CHEMISTRY UNIT 3 QUESTION PACK

1095-01 (Legacy CH5) · New spec Unit 3 Topic 7 · A2 unit, first sat 2017, 80 marks, 1h 45min paper

REVISE.wales

CHEMISTRY — UNIT 3 · Acid-Base Equilibria — pH, K_a & Buffers

Topic 3.9 — Brønsted-Lowry acids and bases, K_a / pK_a, pH of strong and weak acids, buffer solutions, titration curves and indicators

Brønsted-Lowry conjugate acid/base pairs, K_a & pK_a, calculating pH of strong / weak acids and bases, buffer composition (Henderson–Hasselbalch), titration-curve shapes and selecting indicators by pK_{In}.

Legacy 2008 specification

Estimated time for entire question pack: ~1 h 23 min

Derived from the legacy CH5 paper's pace of ~1.3 min/mark, padded for long-prose and calculation answers (52 marks over 4 questions).

*You are advised to **not** attempt to complete all of this in one sitting.*

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every question from the legacy WJEC CH5 papers (2008 modular spec, Jun 2010 – Jun 2016) that maps onto the new-spec A2 Unit 3 Topic 3.9.

Questions are ordered by source paper date.

INSTRUCTIONS

Use black ink or black ball-point pen. Show all working — quality of written communication will affect marks. A calculator is allowed. You will need the WJEC Periodic Table / Data Booklet.

For Examiner's use only

Q	Source	Max	Mark
1	Jun 10 Q2	13	
2	Jun 13 Q3	15	
3	Jun 14 Q2	12	
4	Jun 16 Q2	12	
Total		**52**	

Acid-Base Equilibria — pH, K_a & Buffers — what the new spec asks

WJEC GCE A Level Chemistry (from 2015) · Unit 3: Physical & Inorganic Chemistry · Topic 3.9.

Brønsted-Lowry definitions

- Acid: proton (H^+) donor.
- Base: proton acceptor.
- Conjugate pairs differ by one H^+ (e.g. CH_3COOH / CH_3COO^-).
- Water is amphiprotic.

K_w & pH

- $K_w = [H^+][OH^-] = 1.0 \times 10^{-14}$ $mol^2\ dm^{-6}$ at 25 °C.
- Increases with T (water self-ionisation endothermic).
- $pH = -\log_{10}[H^+]$; $pOH = -\log_{10}[OH^-]$; pH + pOH = 14 at 25 °C.
- Strong acid HA → full dissociation, $[H^+] = c$.

K_a & weak acid pH

- $HA \rightharpoonup H^+ + A^-$; $K_a = [H^+][A^-] / [HA]$.
- $pK_a = -\log_{10} K_a$.
- Assume $[H^+] = [A^-] = x$, $[HA] \approx c_0$.
- $\Rightarrow [H^+] = \sqrt{(K_a \cdot c_0)}$.

Buffers

- Weak acid + salt of conjugate base (e.g. CH_3COOH + CH_3COONa).
- Resists pH change on adding small amounts of H^+ or OH^-.
- $pH = pK_a + \log([A^-]/[HA])$ (Henderson–Hasselbalch).
- Maximum buffer capacity when $[A^-] = [HA] \Rightarrow pH = pK_a$.

Titration curves

- Strong acid + strong base: sharp jump 3 → 11 at equivalence.
- Weak acid + strong base: gradual rise; equivalence pH > 7.
- Strong acid + weak base: equivalence pH < 7.
- Weak + weak: no sharp jump; cannot determine equivalence accurately.

Indicators

- Indicator $HIn \rightharpoonup H^+ + In^-$: pK_{In} determines colour-change range.
- Choose indicator with pK_{In} within the equivalence-region jump.
- Methyl orange (pK_{In} 3.7) for strong acid / weak base.
- Phenolphthalein (pK_{In} 9.3) for weak acid / strong base.

Acid-Base Equilibria — pH, K_a & Buffers in one page

Quick-reference notes — revisit before each question.

Strong vs weak

Strong: full dissociation in water (HCl, HNO_3, H_2SO_4, NaOH).
Weak: partial dissociation (CH_3COOH, NH_3) ⇒ $K_a < 1$.

pH (strong acid)

$[H^+]$ = c (acid concentration). pH = $-\log_{10}$ c. Example: 0.10 M HCl ⇒ pH 1.00.

pH (weak acid)

$[H^+] = \sqrt{(K_a\ c)}$. Example: 0.10 M CH_3COOH ($K_a = 1.7\times10^{-5}$) ⇒ $[H^+] = 1.3\times10^{-3}$, pH 2.87.

Buffer pH

pH = $pK_a + \log([A^-]/[HA])$. Adding equal amounts: pH = pK_a. Resists change because of large reservoirs of HA & A^-.

Titration choice

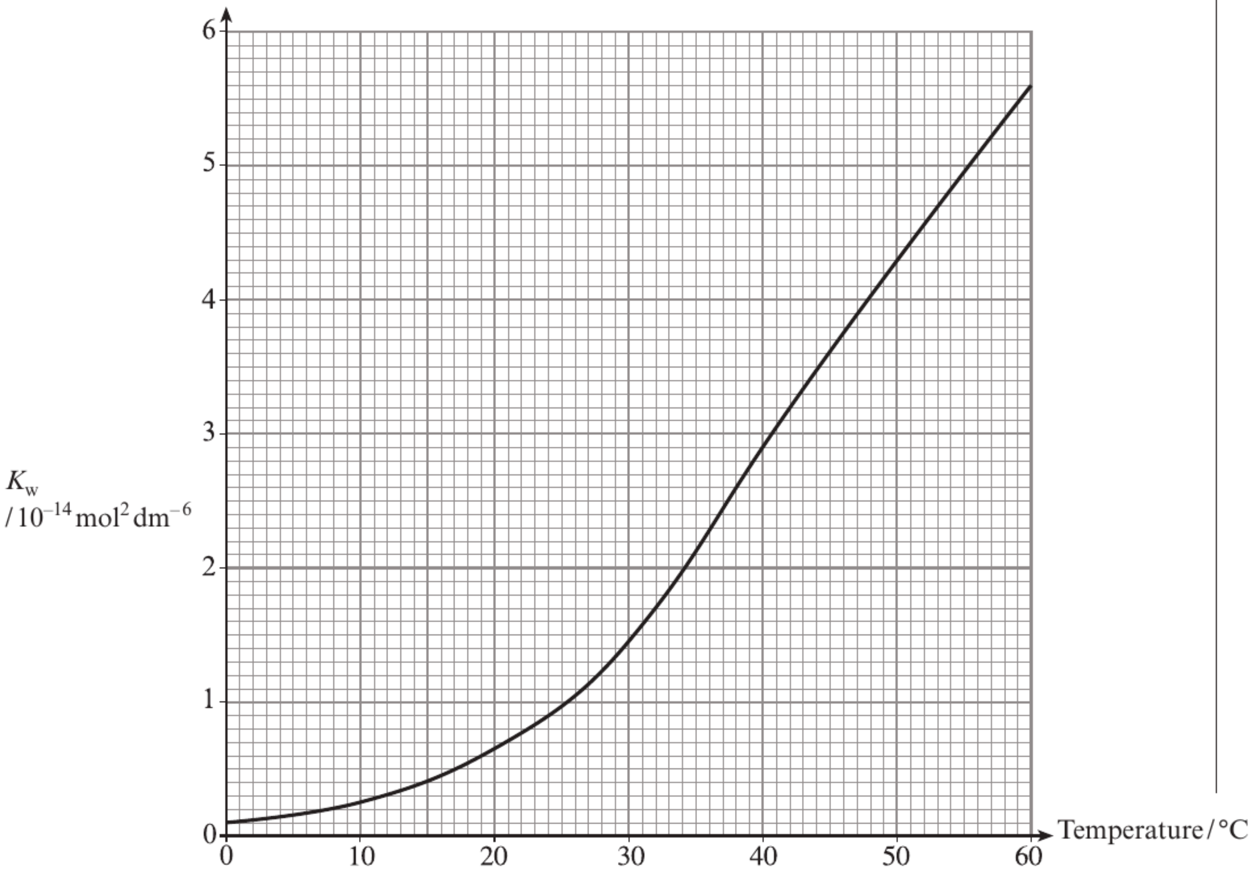
Strong+strong: methyl orange OR phenolphthalein.
Weak acid + strong base: phenolphthalein.
Strong acid + weak base: methyl orange.

Equivalence point

Moles acid = moles base added. For weak/strong pairs, the salt formed hydrolyses ⇒ equivalence pH ≠ 7.

Examiner only

2. *(a)* The diagram shows the variation of the ionic product of water, K_w, with temperature.



(i) Give the expression for the ionic product of water, K_w. [1]

(ii) By reference to the diagram, and giving your reasoning, state whether the ionisation of water is an exothermic or an endothermic process. [1]

....

....

(iii) Use the diagram to determine the value ($mol^2\,dm^{-6}$) of K_w at 50 °C. [1]

....

....

(iv) Hence calculate $[H^+]$ and the pH of pure water at 50 °C. [2]

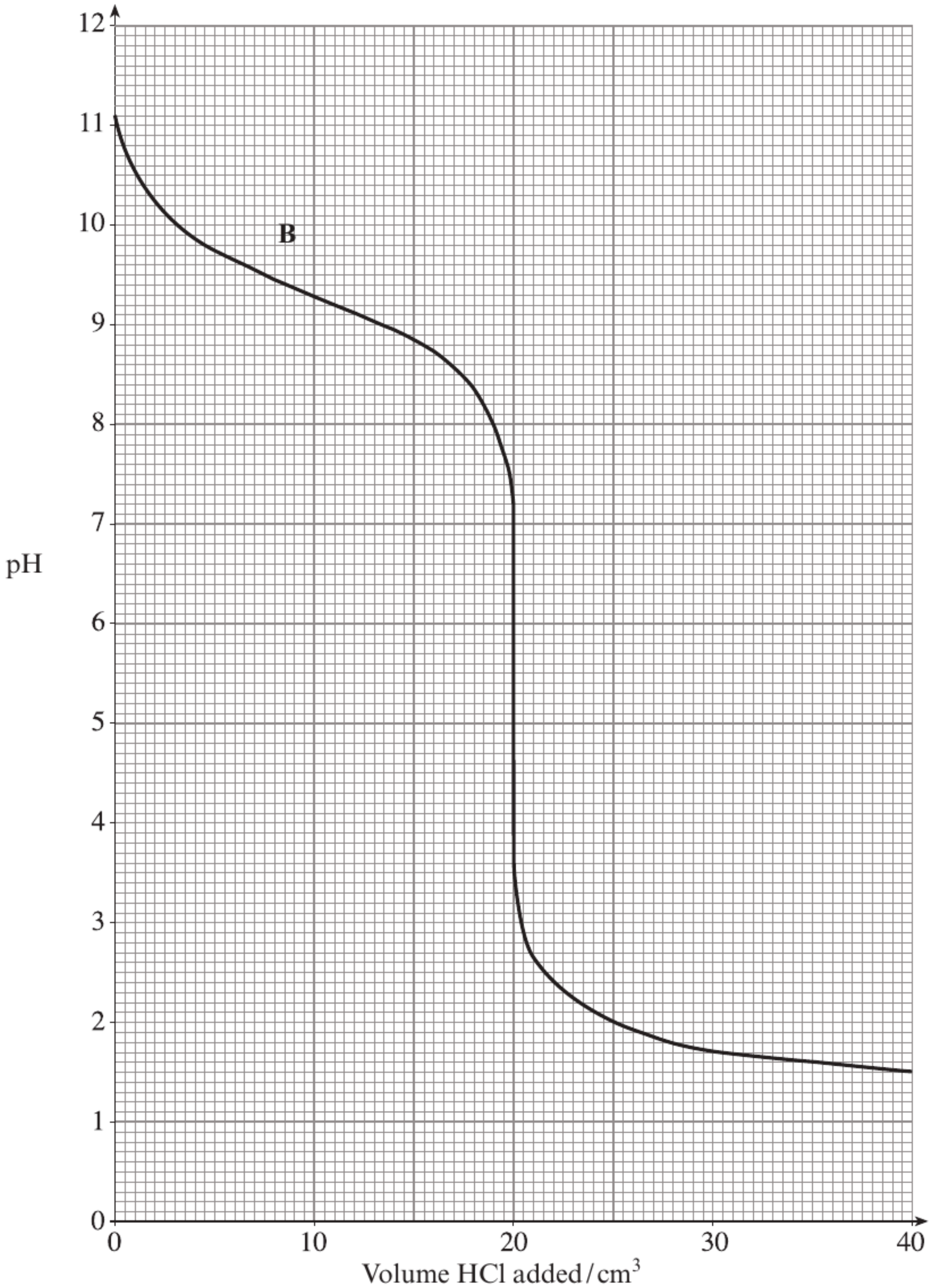
....

....

Examiner only

(b) The diagram below shows how pH changes during the course of a titration when hydrochloric acid of concentration 0.100 mol dm^{-3} is added from a burette to 25.0 cm^3 of aqueous ammonia.

$$NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$$



(i) Calculate, to **two** significant figures, the concentration of the aqueous ammonia solution. [3]

....

....

....

1095 01 07

Examiner only

(ii) Explain why a buffering effect occurs in the region of the curve marked with the letter **B**, where a mixture of NH_3(aq) and NH_4Cl(aq) is present. [3]

....

....

....

....

....

(iii) Giving your reasoning, state which of the following indicators would be suitable for the titration of ammonia against hydrochloric acid. [2]

Indicator	pH range
Bromothymol blue	6.0 - 7.6
Methyl red	4.2 - 6.3
Methyl yellow	2.9 - 4.0
Phenolphthalein	8.2 - 10.0

....

....

....

Total [13]

3. *Read the passage below and then answer the questions in the spaces provided.*

Acids Through The Ages

The ancient Greeks started to classify materials as salt-tasting, sweet-tasting, sour-tasting and bitter-tasting. In this classification acids were those considered to be sour-tasting – the name comes from the Latin *acere*.

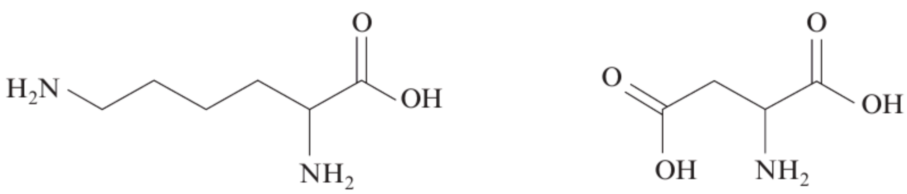
Taste continued to be an important consideration – even today many people would think of the sour taste of a lemon as being typical of an acid. However it was found that, as well as taste, these compounds had other properties in common. The dye litmus had been extracted from lichens and it was found that acids changed the colour of this to red. They also corroded metals.

Many acids were identified – citric acid could be extracted from citrus fruit and methanoic acid could be extracted, by distillation, from red ants. Methanoic acid used to be called formic acid since the biological term for an ant is *formica*.

The modern classification of acids is based on the theory suggested by Lowry and Brønsted although more recent classifications, based on electron pair donation, have been suggested by Lewis.

Using the Lowry-Brønsted classification both citric acid and methanoic acid are described as being weak. For methanoic acid, HCOOH, the value of the acid dissociation constant, K_a, is 1.75×10^{-4} mol dm^{-3}.

Acids have a wide variety of uses in modern chemistry. They can, for example, be used as catalysts in hydrolysis reactions and work is currently being done to investigate the possibility of obtaining biofuels by the hydrolysis of farm waste such as straw. In some situations however acids can destroy catalytic effects. The tertiary structure and therefore the shape of the active sites of some enzyme catalysts can be maintained by ionic attractions. This could arise, for example, when the enzyme involves the amino acids lysine and aspartic acid. The NH_2 on the lysine can be protonated to give a positive ion, whilst the COOH can be deprotonated to give a negative ion. Attraction between oppositely charged ions holds the shape but if the pH is altered and one of the charges is lost the shape can change and the enzyme becomes denatured.



lysine aspartic acid

The possible alteration of the shapes of molecules in biological systems means that it is important that the pH of, for example shampoos, is maintained within a small range. For best results shampoo should stay at a pH just below 7.

- End of passage -

Examiner only

(a) State what is meant by a Lowry-Brønsted acid. *(line 12)* [1]

(b) Define pH. [1]

(c) David and Peter were discussing acids and bases. David said that you could decide whether an acid was strong or weak by measuring the pH of the acid solution. He said that the strong acid would have a lower pH. Peter said that he felt that the strength of the acid was not the only factor that affected pH.

Discuss the factors that affect pH. [4]
QWC [1]

(d) Methanoic acid is a weak acid.

(i) Write the expression for the acid dissociation constant, K_a, of methanoic acid. [1]

(ii) Using the information in *lines 16* and *17* of the article, calculate the pH of 0.10 mol dm^{-3} methanoic acid. [3]

pH = ...

Examiner only

(e) The article *(line 29)* states that it is important to maintain the pH of shampoo within a small range.

(i) What name is given to a system designed to maintain pH within a small range? [1]

....

(ii) The pH of a shampoo is maintained within a small range by using a weak acid, RCOOH, and its sodium salt, RCOONa.

Explain how this mixture maintains pH within a small range. [3]

....

....

....

....

....

....

Total [15]

Total Section A [40]

BLANK PAGE

Examiner only

2. *(a)* Write an expression for the ionic product of water, K_w, giving its units, if any. [2]

K_w =

Units ....

(b) (i) The value for K_w at 298 K is 1.0×10^{-14}. Explain why the pH of pure water at this temperature has a value of 7. [2]

....

....

....

(ii) Calculate the pH of the final solution if 10 cm^3 of 0.10 mol dm^{-3} hydrochloric acid is added to 990 cm^3 of pure water. [2]

pH = ...

(c) Calculate the pH of a solution which is 0.010 mol dm^{-3} with respect to ethanoic acid and 0.020 mol dm^{-3} with respect to sodium ethanoate at 298 K. [3]

[K_a for ethanoic acid = 1.78×10^{-5} mol dm^{-3} at 298 K]

pH = ...

Examiner only

(d) If 10 cm^3 of 0.10 mol dm^{-3} hydrochloric acid is added to 990 cm^3 of the solution described in *(c)* the change in pH is only 0.06. Explain why this change in pH is much smaller than that in *(b)*(ii). [3]

....

....

....

....

....

....

Total [12]

12

1095 010005

Examiner only

2. Acids can be considered to be strong or weak and concentrated or dilute.

(a) For an aqueous solution of an acid, explain the difference between the meaning of the terms *weak acid* and *dilute acid*. [2]

....

....

....

....

(b) The grids opposite show titration curves for the addition of aqueous sodium hydroxide solution to 25.0 cm^3 of aqueous acid.

From the list below, choose which acids were used to give curves **A** and **B** giving reasons for your answer.

W	0.1 mol dm^{-3} HCl
X	0.001 mol dm^{-3} HCl
Y	0.1 mol dm^{-3} CH_3COOH
Z	0.001 mol dm^{-3} CH_3COOH

(K_a for CH_3COOH = 1.8×10^{-5} mol dm^{-3})

(i) Curve **A** [2]

....

....

....

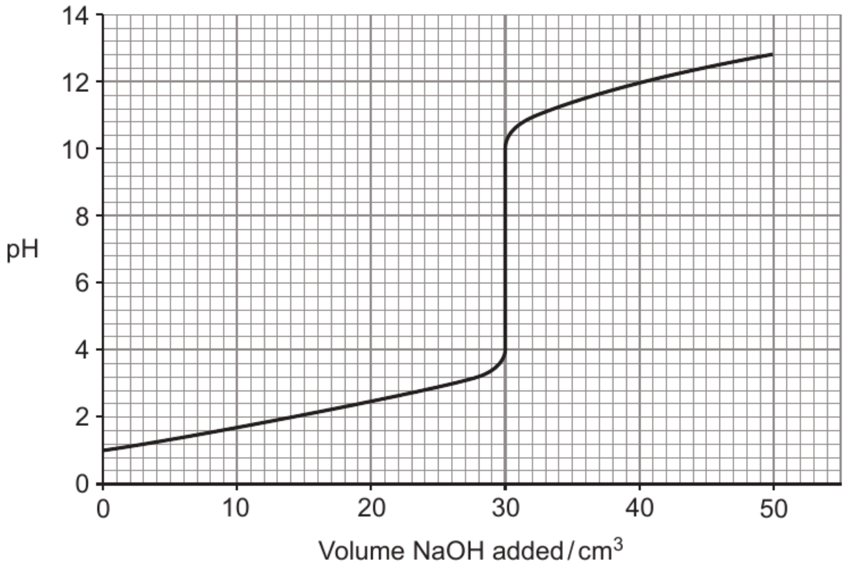
(ii) Curve **B** [3]

....

....

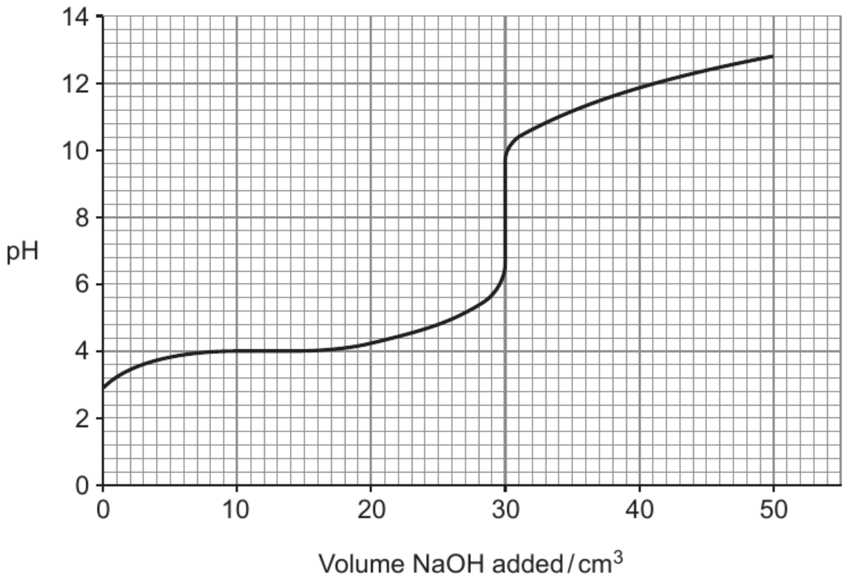
....

Titration curves of acid-alkali reactions



Curve A

1095
010007



Curve B

Examiner only

(iii) State, giving a reason, which of the following indicators would be **most** suitable for titration **B**. [2]

Indicator	pH range
methyl orange	3.4 – 4.8
chlorophenol red	4.8 – 6.4
thymol blue	8.0 – 9.6
brilliant cresyl blue	10.8 – 12.0

....

....

....

(iv) Calculate the concentration of the aqueous sodium hydroxide solution used in titration **A**. [2]

Concentration = ... mol dm^{-3}

(c) Aqueous ammonia reacts with hydrochloric acid to form the salt ammonium chloride, NH_4Cl. Give a reason why the pH value for a solution of NH_4Cl is less than 7. [1]

....

....

....

Total [12]

12

1095
010009

BLANK PAGE

END OF QUESTION PACK

4 questions · 52 marks · ~1 h 23 min
Source: WJEC CH5 (2008 modular spec, Jun 2010 – Jun 2016)
Curated for WJEC Chemistry 2015 spec A2 Unit 3 — Topic 7 (3.9)