



**Test Papers
Hub.**

QCAA Chemistry Units 3 & 4 Practice Paper 1

External Assessment: Paper 2 — Extended Response & Problem Solving

Perusal 10 minutes · Working time 90 minutes · Extended response and problem solving · 58 marks in all

How to use this booklet

- Perusal time – 10 minutes. Working time – 90 minutes. Write using black or blue pen.
- A QCAA-approved scientific or graphics calculator may be used. A formula and data sheet is provided at the back of the paper.
- Attempt ALL questions (1 – 14). Show all relevant working, formulae, substitutions and units.
- Worked solutions follow the paper: every question has step-by-step working and a key takeaway.

EXTENDED RESPONSE

58 marks · Attempt ALL questions (1 – 14) · Allow 90 minutes

Answer all questions in the spaces provided. Show all relevant working and reasoning; unsupported final answers may not receive full marks.

Question 1 (6 marks)

The solubility product of CaF_2 is $K_{\text{sp}} = 3.9 \times 10^{-11}$ at 25°C : $\text{CaF}_2(\text{s}) \rightleftharpoons \text{Ca}^{2+} + 2\text{F}^-$.

(a) Calculate the solubility of CaF_2 in water, in mol L^{-1} . [4 marks]

(b) Equal volumes of a $8.2 \times 10^{-4} \text{ mol L}^{-1}$ solution of the cation and a $7.2 \times 10^{-3} \text{ mol L}^{-1}$ solution of the anion (ratio 1 : 2) are mixed. Calculate the ion product Q and state whether a precipitate forms. [2 marks]

Question 2 (6 marks)

A buffer is made by dissolving 0.18 mol of the conjugate base (the sodium salt of benzoic acid) and 0.23 mol of benzoic acid in water to give 1.00 L of solution. (K_{a} of benzoic acid = $6.30 \times 10^{-5} \text{ mol L}^{-1}$.)

(a) Calculate the pH of the buffer. [4 marks]

(b) What is the pH after $7.0 \times 10^{-3} \text{ mol}$ of HCl is added to the buffer (volume unchanged)? [2 marks]

Question 3 (5 marks)

A 25.0 mL sample of vinegar is diluted to 250.0 mL (a dilution factor of 10). A 10.0 mL aliquot of the diluted solution is titrated with 0.100 mol L^{-1} NaOH; the average titre is 24.0 mL. (Vinegar contains ethanoic acid, CH_3COOH , $M = 60.05 \text{ g mol}^{-1}$.)

(a) What is the concentration of ethanoic acid in the original vinegar? [4 marks]

(b) What is the mass of ethanoic acid in 100 mL of the original vinegar? [1 mark]

Question 4 (4 marks)

A current of 5.2 A flows for 15 minutes through a solution containing aluminium ions, depositing aluminium metal at the cathode. (Faraday constant = $96\,485 \text{ C mol}^{-1}$.)

Calculate the mass of aluminium deposited.

Question 5 (3 marks)

Consider the alkanes with the molecular formula C_6H_{14} .

How many structural isomers (including the straight-chain compound) exist for this formula?

Question 6 (3 marks)

Eth-1-ene ($\text{CH}_2=\text{CH}_2$) reacts with steam and a phosphoric acid catalyst.

WORKED SOLUTIONS

Answers & worked solutions

EXTENDED RESPONSE

Question 1 (6 marks) [Solubility]

The solubility product of CaF_2 is $K_{\text{sp}} = 3.9 \times 10^{-11}$ at 25°C : $\text{CaF}_2(\text{s}) \rightleftharpoons \text{Ca}^{2+} + 2\text{F}^-$.

(a) Calculate the solubility of CaF_2 in water, in mol L^{-1} .

(a) Answer: $2.14 \times 10^{-4} \text{ mol L}^{-1}$

- Let the solubility be s . Then $[\text{cation}] = s$ and $[\text{anion}] = 2s$.
- $K_{\text{sp}} = s \times (2s)^2 = 4s^3$
- $s = \sqrt[3]{(3.9 \times 10^{-11} \div 4)} = 2.14 \times 10^{-4} \text{ mol L}^{-1}$

(b) Equal volumes of a $8.2 \times 10^{-4} \text{ mol L}^{-1}$ solution of the cation and a $7.2 \times 10^{-3} \text{ mol L}^{-1}$ solution of the anion (ratio 1 : 2) are mixed. Calculate the ion product Q and state whether a precipitate forms.

(b) Answer: $Q = 5.31 \times 10^{-9}$; $Q > K_{\text{sp}}$ so a precipitate forms

- Mixing equal volumes halves each concentration: $[\text{cation}] = 4.1 \times 10^{-4} \text{ mol L}^{-1}$, $[\text{anion}] = 3.6 \times 10^{-3} \text{ mol L}^{-1}$.
- $Q = [\text{cation}] \times [\text{anion}]^2 = 5.31 \times 10^{-9}$
- Compare with $K_{\text{sp}} = 3.9 \times 10^{-11}$: Q is greater than K_{sp} , so a precipitate forms.

LOS: Solubility

KEY TAKEAWAY

$K_{\text{sp}} = [\text{cation}]^a [\text{anion}]^b$: write the ion concentrations in terms of the solubility s (remembering multiples like $2s$). A precipitate forms when the ion product Q exceeds K_{sp} .

Question 2 (6 marks) [Acids and bases]

A buffer is made by dissolving 0.18 mol of the conjugate base (the sodium salt of benzoic acid) and 0.23 mol of benzoic acid in water to give 1.00 L of solution. (K_{a} of benzoic acid = $6.30 \times 10^{-5} \text{ mol L}^{-1}$.)

(a) Calculate the pH of the buffer.

(a) Answer: 4.09

- For a buffer: $\text{pH} = \text{pK}_{\text{a}} + \log_{10}([\text{A}^-] \div [\text{HA}])$.
- $\text{pK}_{\text{a}} = -\log_{10}(6.30 \times 10^{-5}) = 4.20$.
- $\text{pH} = 4.20 + \log_{10}(0.18 \div 0.23) = 4.09$

(b) What is the pH after $7.0 \times 10^{-3} \text{ mol}$ of HCl is added to the buffer (volume unchanged)?

(b) Answer: 4.06

- The added H^+ reacts with the conjugate base: $\text{A}^- + \text{H}^+ \rightarrow \text{HA}$, so $n(\text{A}^-) = 0.18 - 7.0 \times 10^{-3} = 0.173 \text{ mol}$ and $n(\text{HA}) = 0.23 + 7.0 \times 10^{-3} = 0.237 \text{ mol}$.
- $\text{pH} = 4.20 + \log_{10}(0.173 \div 0.237) = 4.06$ — the pH hardly changes, which is the function of a buffer.

LOS: Acids and bases