



Trial Examination 2023

Suggested Solutions

QCE Chemistry Units 3&4

Paper 2

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SECTION 1**QUESTION 1 (7 marks)**

- a) Spectrum 1 belongs to the alcohol. There is a broad absorption band at $3200\text{--}3600\text{ cm}^{-1}$, which is characteristic of an alcohol. This band does not appear in the other two spectra. In spectra 2 and 3, there is an absorption peak at 1700 cm^{-1} , which indicates $\text{C}=\text{O}$. This is present in esters and ketones, but not alcohols.

[3 marks]

*1 mark for deducing spectrum 1.**1 mark for explaining the band at $3200\text{--}3600\text{ cm}^{-1}$ in spectrum 1.**1 marking for explaining the peak at 1700 cm^{-1} in spectra 2 and 3.**Note: Spectrum 1 is ethanol, spectrum 2 is ethyl ethanoate and spectrum 3 is propanone.**Students are not required to identify the compounds in order to obtain full marks.*

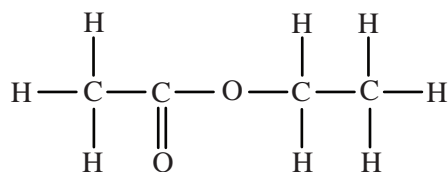
- b) Any two of:

- The molar mass is 88 m/z ($(4 \times 12.01) + (8 \times 1.01) + (2 \times 16.00) = 88.12\text{ g mol}^{-1}$).
- The base ion peak is 43 m/z , indicating CH_3CO^+ .
- There is a peak at 29 m/z , indicating C_2H_5^+ .

[2 marks]

1 mark for each feature identified.

- c)

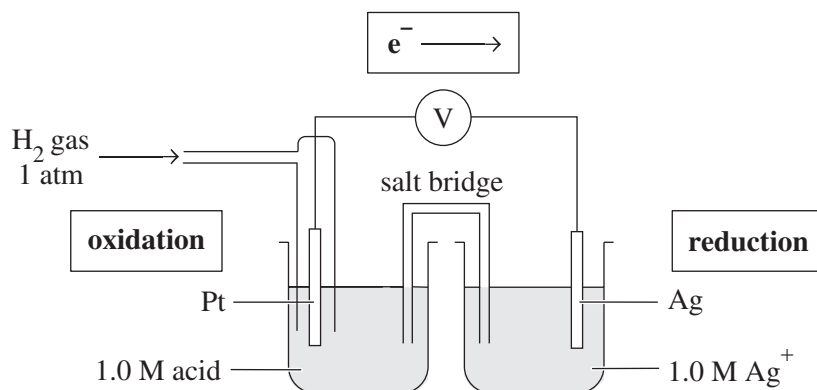
**IUPAC name:** ethyl ethanoate

[2 marks]

*1 mark for drawing the structural formula.**1 mark for deducing the IUPAC name.*

QUESTION 2 (11 marks)

a)



[3 marks]

1 mark for each correct label.

- b) i) **Oxidation:** $\text{H}_2(\text{g}) \rightarrow 2\text{H}^+(\text{aq}) + 2\text{e}^-$
Reduction: $\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}(\text{s})$

[2 marks]

1 mark for each half-equation.

- ii) $\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}(\text{s}) \quad E^\circ = +0.80 \text{ V}$
 $\text{H}_2(\text{g}) \rightarrow 2\text{H}^+(\text{aq}) + 2\text{e}^- \quad E^\circ = 0.00 \text{ V}$
 $E^\circ_{\text{cell}} = 0.80 - 0.00 = 0.80 \text{ V}$

[2 marks]

1 mark for identifying the standard electrode potentials of the half-cells.

1 mark for calculating the cell potential (E°).

- c) In the hydrogen half-cell, hydrogen gas (H_2) molecules are oxidised to hydrogen ions (H^+), so there are excess positive ions in the half-cell. In the silver half-cell, silver ions (Ag^+) are reduced to silver atoms, resulting in a deficiency of positive ions in the half-cell. To maintain electrical neutrality, negative ions move through the salt bridge from the silver half-cell to the hydrogen half-cell, and positive ions move through the salt bridge from the hydrogen half-cell to the silver half-cell.

[2 marks]

1 mark for explaining the direction of the positive H^+ ions' movement.

1 mark for explaining the direction of the negative ions' movement.

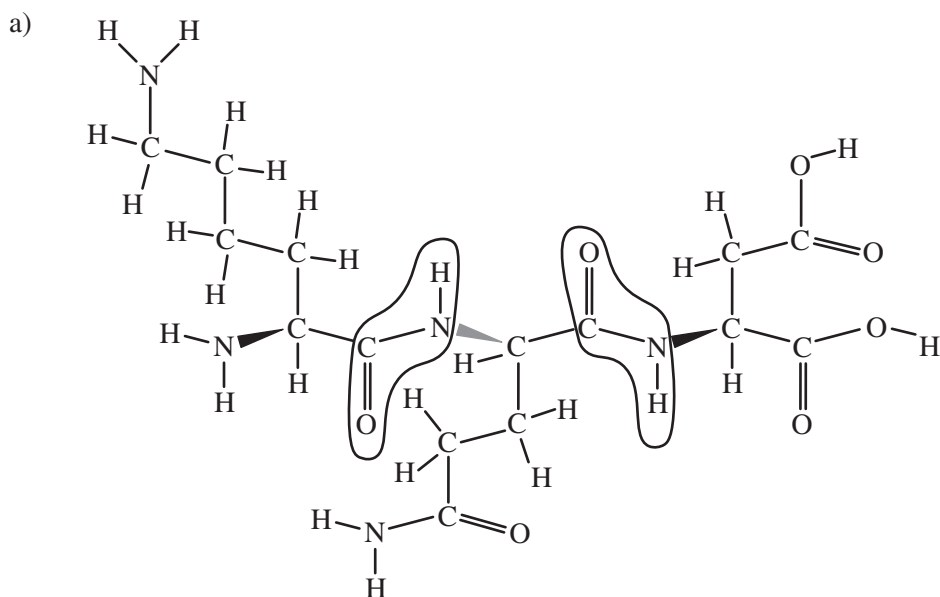
- d) The addition of chloride ions (Cl^-) to the silver nitrate solution in the silver half-cell would cause silver chloride to precipitate. Subsequently, the concentration of Ag^+ in the silver half-cell would be reduced. The balanced redox equation is $2\text{Ag}^+(\text{aq}) + \text{H}_2(\text{g}) \rightleftharpoons 2\text{Ag}(\text{s}) + 2\text{H}^+(\text{aq})$. The lower concentration of Ag^+ would cause the cell's equilibrium to favour the reverse reaction, meaning that the cell potential would be reduced.

[2 marks]

1 mark for explaining that the concentration of Ag^+ would be reduced due to the formation of silver chloride.

1 mark for determining that the cell potential would be reduced and using the balanced redox equation.

QUESTION 3 (5 marks)



[1 mark]

1 mark for circling both peptide links.

- b) Lysine has two NH_2 groups, one COOH group and six carbons in the chain. (The COOH group forms a peptide link with the NH_2 group in glutamine, forming water as a by-product.)

Glutamine has two NH_2 groups, one COOH group and five carbons in the chain. (The COOH group bonds with the NH_2 group in aspartic acid, forming water as a by-product.)

Aspartic acid has one NH_2 group, one COOH group and four carbons in the chain.

[3 marks]

1 mark for deducing lysine and explaining reasoning.

1 mark for deducing glutamine and explaining reasoning.

1 mark for deducing aspartic acid and explaining reasoning.

- c) Lys-Gln-Asp

[1 mark]

1 mark for identifying the peptide using amino acid symbols.

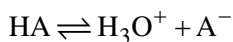
QUESTION 4 (8 marks)

- a) Titration 1: ethanoic acid (CH_3COOH) – The initial pH is 3.0, which indicates a weak acid.
 Titration 2: hydrochloric acid (HCl) – The initial pH is 1.0, which indicates a strong acid.

[2 marks]

*1 mark for deducing the acid used in each titration.**1 mark for explaining reasoning.*

- b) $\text{CH}_3\text{COOH}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{CH}_3\text{COONa}(\text{aq}) + \text{H}_2\text{O}(\text{l})$



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{A}^-]}{[\text{HA}]}$$

Since the CH_3COOH is a weak acid, $[\text{HA}]$ can be considered to be 0.1 mol L^{-1} .

Calculating the concentration of H_3O^+ gives:

$$\begin{aligned} [\text{H}_3\text{O}^+][\text{A}^-] &= K_a \times 0.1 \\ &= 1.8 \times 10^{-5} \times 0.1 \\ &= 1.8 \times 10^{-6} \end{aligned}$$

Since CH_3COOH dissociates equally into H_3O^+ and CH_3COO^- , $[\text{H}_3\text{O}^+]$ and $[\text{A}^-]$ are the same.

Calculating the pH gives:

$$\begin{aligned} [\text{H}_3\text{O}^+]^2 &= 1.8 \times 10^{-6} \\ [\text{H}_3\text{O}^+] &= 1.3416 \times 10^{-3} \text{ mol L}^{-1} \end{aligned}$$

$$\begin{aligned} \text{pH} &= -\log_{10}[\text{H}_3\text{O}^+] \\ &= 2.87 \\ &= 3.0 \end{aligned}$$

[3 marks]

*1 mark for using the dissociation constant formula.**1 mark for calculating the concentration of H_3O^+ .**1 mark for calculating the pH.*

- c) In titration 1, the equivalence point is greater than 7.0 due to the presence of sodium ethanoate (CH_3COONa). This is a weak base that undergoes hydrolysis with water to produce hydroxide ions (OH^-), making the solution slightly basic at this point.

[2 marks]

*1 mark for identifying that the equivalence point is greater than 7.**1 mark for explaining how the conjugate base caused the greater equivalence point.*

- d) Phenolphthalein would have been preferred because it is suitable for both titrations, whereas methyl red is not. This is because the pH range of methyl red (4.4–6.2) would not be suitable for titration 1, which has a midpoint of approximately 5.0, meaning that methyl red would start to change colour well before the equivalence point of the titration.

[1 mark]

1 mark for explaining why methyl red would not have been suitable for titration 1.

QUESTION 5 (7 marks)

- a) Changing the temperature changes the equilibrium constant (K_c) of a reaction. Since the forward reaction is exothermic, by using a low temperature of 350–550°C, more NH_3 is produced. Since there are more molecules produced from the reverse reaction, using a high pressure of 100–200 atm causes the system to favour the forward reaction to produce more NH_3 .

[2 marks]

*1 mark for explaining the low temperature.**1 mark for explaining the high pressure.*

- b) i) The finely ground oxide has a greater surface area to adsorb molecules.

[1 mark]

1 mark for stating that the finely ground oxide has a greater surface area.

- ii) The gases do not adsorb onto the catalyst surface at each pass. Cooling maintains the temperature – if the temperature changed, the K_c would change – and results in liquid NH_3 as the end product.

[2 marks]

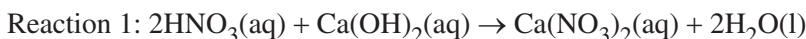
*1 mark for explaining that the gases do not adsorb.**1 mark for explaining why cooling is used with reference to the K_c .*

c)

Factor	Explanation
In step 1 ($\text{S}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{SO}_2(\text{g})$, $\Delta H = -297 \text{ kJ mol}^{-1}$), excess oxygen is not used. The sulfur to oxygen ratio is kept at 1 : 1.	The reaction occurs so rapidly that if excess oxygen were used, it would pass over the catalyst and not react.
Step 2 ($2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$, $\Delta H = -196 \text{ kJ mol}^{-1}$) is the most crucial step to control.	The reaction is reversible and needs to be maintained in the forward direction.

[2 marks]

1 mark for each explanation.

QUESTION 6 (6 marks)

Reaction 2 was used to neutralise the mixture, which indicates that the base calcium hydroxide ($\text{Ca}(\text{OH})_2$) was the excess reagent in reaction 1.

In reaction 1, 1.0 mol of $\text{Ca}(\text{OH})_2$ reacts with 2.0 mol of nitric acid (HNO_3).

$$\therefore \frac{n(\text{Ca}(\text{OH})_2)}{n(\text{HNO}_3)} = \frac{1}{2}$$

Calculating the reacted and total amounts of $\text{Ca}(\text{OH})_2$ to determine the excess amount of $\text{Ca}(\text{OH})_2$ gives:

$$\begin{aligned} n(\text{Ca}(\text{OH})_2 \text{ reacted}) &= \frac{n(\text{HNO}_3)}{2} \\ &= \frac{0.050 \times 0.10}{2} \\ &= 0.0025 \text{ mol} \end{aligned}$$

$$\begin{aligned} n(\text{Ca}(\text{OH})_2 \text{ total}) &= 0.060 \times 0.10 \\ &= 0.0060 \text{ mol} \end{aligned}$$

$$\begin{aligned} n(\text{Ca}(\text{OH})_2 \text{ excess}) &= 0.0060 - 0.0025 \\ &= 0.0035 \text{ mol} \end{aligned}$$

In equation 2, 1.0 mol of $\text{Ca}(\text{OH})_2$ reacts with 1.0 mol of sulfuric acid (H_2SO_4).

$$\therefore \frac{n(\text{Ca}(\text{OH})_2)}{n(\text{H}_2\text{SO}_4)} = \frac{1}{1}$$

Determining the amount of H_2SO_4 gives:

$$n(\text{H}_2\text{SO}_4) = n(\text{Ca}(\text{OH})_2 \text{ excess}) = 0.0035 \text{ mol}$$

Calculating the volume of H_2SO_4 gives:

$$\begin{aligned} V(\text{H}_2\text{SO}_4) &= \frac{0.0035}{0.050} \\ &= 0.070 \text{ L} \\ &= 70.0 \text{ mL} \end{aligned}$$

[6 marks]

1 mark for writing the balanced equation for reaction 1.

1 mark for writing the balanced equation for reaction 2.

1 mark for calculating the reacted and total amounts of $\text{Ca}(\text{OH})_2$.

1 mark for calculating the excess amount of $\text{Ca}(\text{OH})_2$.

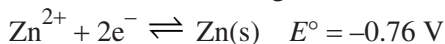
1 mark for determining the amount of H_2SO_4 .

1 mark for calculating the volume of H_2SO_4 .

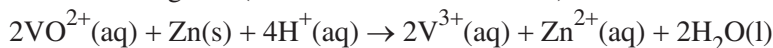
QUESTION 7 (6 marks)

Vanadium (V) is present as the ion VO_2^+ . For a feasible reaction to take place, the emf of the reaction must be positive.

To act as a reducing agent, zinc (Zn) must provide electrons to the vanadium species. Therefore, the potential of Zn must be more negative than that of the reactions involving the vanadium species.

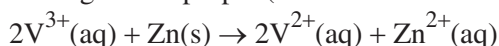


From blue to green (V oxidation state +4 to +3):



$$E^\circ_{\text{cell}} = 0.34 - (-0.76) = 1.10 \text{ V}$$

From green to purple (V oxidation state +3 to +2):

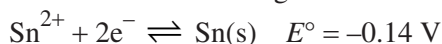


$$E^\circ_{\text{cell}} = -0.26 - (-0.76) = 0.50 \text{ V}$$

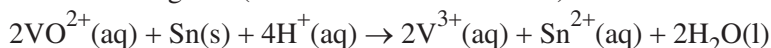
For each reaction, the emf is positive.

Therefore, Zn can reduce V from oxidation state +4 to +2 and would cause the colour of the solution to change from blue to purple.

To act as a reducing agent, tin (Sn) must provide electrons to the vanadium species. Therefore, the potential of Sn must be more negative than that of the reactions involving the vanadium species.

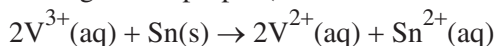


From blue to green (V oxidation state +4 to +3):



$$E^\circ_{\text{cell}} = 0.34 - (-0.14) = 0.48 \text{ V}$$

From green to purple (V oxidation state +3 to +2):



$$E^\circ_{\text{cell}} = -0.26 - (-0.14) = -0.12 \text{ V}$$

For the first reaction, the emf is positive. The last reaction has a negative emf; therefore, Sn can reduce V from oxidation state +4 to +3, but it cannot reduce it from oxidation state +3 to +2. This means, it would cause the colour of the solution to change from blue to green only.

[6 marks]

1 mark for calculating E°_{cell} for Zn reducing V from +4 to +3.

1 mark for calculating E°_{cell} for Zn reducing V from +3 to +2.

1 mark for determining that Zn would change the solution colour from blue to purple.

1 mark for calculating E°_{cell} for Sn reducing V from +4 to +3.

1 mark for calculating E°_{cell} for Sn reducing V from +3 to +2.

1 mark for determining that Sn would not change the solution colour from blue to purple.

Note: Chemical equations are not required to obtain full marks.