Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level CHEMISTRY

Paper 1 Inorganic and Physical Chemistry

Tuesday 10 June 2025 Morning Time allowed: 2 hours

Materials

For this paper you must have:
- the Periodic Table/Data Booklet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 105.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
TOTAL	

Answer **all** questions in the spaces provided.

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0 1 This question is about some Group 2 elements and their compounds.

0 1 . 1 Magnesium is reacted with titanium(IV) chloride to extract titanium metal.

Give the equation for this reaction.

State the role of magnesium in this reaction.

[2 marks]

Equation

Role of magnesium

0 1 . 2 Complete **Table 1** by giving the formula of a suitable calcium compound for each use.

[2 marks]

Table 1

Use	**Formula of calcium compound**
Decrease acidity of soil	
Remove SO_2 from flue gases in power stations	

0 1 . 3 Magnesium hydroxide is used to relieve the symptoms of indigestion by neutralising stomach acid.

Suggest why magnesium hydroxide is safer than sodium hydroxide as a treatment for indigestion.

[1 mark]

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An ionic compound of a Group 2 element dissolves in water to form solution **X**.

Separate samples of solution **X** are tested to identify the ions.

Table 2 shows the observations.

Table 2

	Reagent added	**Observation**
Test 1	NaOH(aq)	White precipitate
Test 2	HNO_3(aq) and $AgNO_3$(aq)	Cream precipitate

0 1 . 4 Identify the Group 2 cation in solution **X**.

Give an ionic equation for the reaction that occurs in **Test 1**.

[2 marks]

Group 2 cation _____

Ionic equation

_____

Question 1 continues on the next page

Do not write outside the box

0 1 . 5 Identify the anion in solution **X**.

Give an ionic equation, including state symbols, for the reaction that occurs in **Test 2**.

Explain why $AgNO_3(aq)$ is acidified.

[3 marks]

Anion _____

Ionic equation

_____

Explanation _____

_____

_____

0 1 . 6 Give one **property** of barium sulfate that makes it useful in hospitals.

[1 mark]

_____

_____

11

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0 2 This question is about ionisation energies.

0 2 . 1 Explain why beryllium is the element with the highest first ionisation energy in Group 2.

[2 marks]

0 2 . 2 Give an equation, including state symbols, to show the process that occurs when the **second** ionisation energy of beryllium is measured.

[1 mark]

0 2 . 3 Predict which element in Period 3 has the lowest **second** ionisation energy.

[1 mark]

Question 2 continues on the next page

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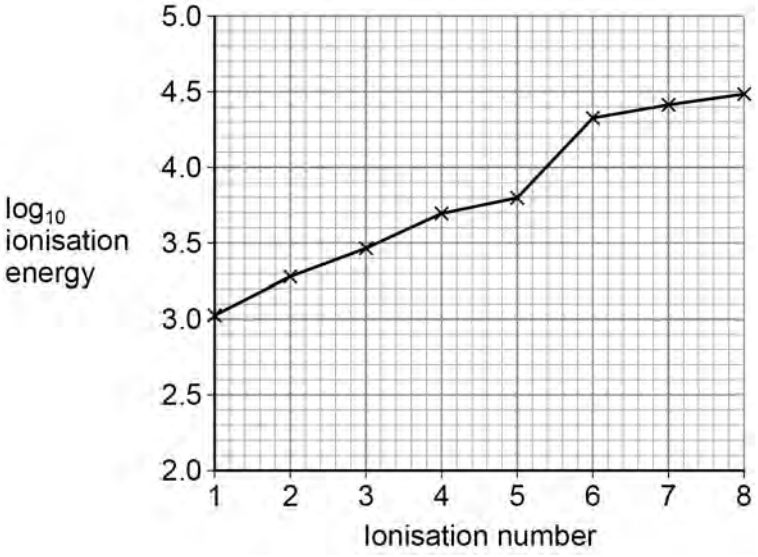
0 2 . 4 **Figure 1** shows a plot of $\log_{10}$(ionisation energy) for a Period 3 element.

The ionisation energies are measured in kJ mol^{-1}

Figure 1



Deduce the identity of this element.

Explain your answer.

[3 marks]

Element _____

Explanation _____

_____

_____

0 2 . 5 Use **Figure 1** to determine the **third** ionisation energy, in kJ mol^{-1}, of this element.

[1 mark]

_____ kJ mol^{-1}

8

Do not write outside the box

0 3 This question is about the chemistry of copper.

0 3 . 1 Deduce the number of unpaired electrons in a Cu^{2+} ion.

[1 mark]

0 3 . 2 Describe how water acts as a ligand in the formation of $[Cu(H_2O)_6]^{2+}$

[1 mark]

0 3 . 3 A solution of sodium carbonate is added to a blue solution containing $[Cu(H_2O)_6]^{2+}$ ions.

State what is observed.

Give an equation for the reaction.

[2 marks]

Observation

Equation

Question 3 continues on the next page

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0 3 . 4 When a solution containing $[Cu(H_2O)_6]^{2+}$ ions reacts with an excess of concentrated hydrochloric acid, a ligand exchange reaction occurs.

$$[Cu(H_2O)_6]^{2+}(aq) + 4\,Cl^-(aq) \rightarrow [CuCl_4]^{2-}(aq) + 6\,H_2O(l)$$

Blue Yellow

The shape and the colour of the $[CuCl_4]^{2-}$ ion are different from the shape and the colour of the $[Cu(H_2O)_6]^{2+}$ ion.

Explain

- the shape of each complex ion and why these shapes are different
- how colour arises in complex ions
- why the $[CuCl_4]^{2-}$ ion has a yellow colour, different from the blue colour of the $[Cu(H_2O)_6]^{2+}$ ion.

[6 marks]

Do not write outside the box

0 3 . 5 An excess of water, followed by an excess of concentrated aqueous ammonia, is added to a solution containing $[CuCl_4]^{2-}$ ions.

State what is observed.

Give an equation for the overall change that occurs.

[2 marks]

Observation _____

Equation

Question 3 continues on the next page

Do not write outside the box

A solution contains $\mathbf{M}_2[Cu(C_2O_4)_2(H_2O)_2]$ where **M** is a metal.

A student does a titration to determine the identity of **M**.

- 2.52 g of solid $\mathbf{M}_2[Cu(C_2O_4)_2(H_2O)_2]$ are dissolved in dilute sulfuric acid.
- This solution is transferred to a volumetric flask and made up to 250 cm^3 with dilute sulfuric acid.
- A 25.0 cm^3 portion is pipetted into a conical flask.
- The mixture in the conical flask is heated to 60 °C and then titrated with 0.0200 mol dm^{-3} $KMnO_4$ solution.
- Several titrations are done and the student's results are shown in **Table 3**.

In this titration, only the $C_2O_4^{2-}$ ions react with the MnO_4^- ions.
2 mol of MnO_4^- ions react with 5 mol of $C_2O_4^{2-}$ ions.

Table 3

	Rough	**1**	**2**	**3**
Final reading / cm^3	29.5	28.60	30.35	34.05
Initial reading / cm^3	0.0	0.00	1.55	5.55
Titre / cm^3	29.5	28.60	28.80	28.50

0 3 . 6 Give an equation for the reaction between $C_2O_4^{2-}$ ions and MnO_4^- ions in acidic solution.

[1 mark]

Do not write outside the box

0 3 . 7 Calculate the mean titre from the student's results.

[1 mark]

_____ cm^3

0 3 . 8 Calculate the M_r of $\mathbf{M}_2[Cu(C_2O_4)_2(H_2O)_2]$

Identify **M**.

[7 marks]

M_r of $\mathbf{M}_2[Cu(C_2O_4)_2(H_2O)_2]$ _____

Identity of **M** _____

Question 3 continues on the next page

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0 3 . 9 Draw the structure of **two** stereoisomers of the complex ion in $\mathbf{M}_2[Cu(C_2O_4)_2(H_2O)_2]$ and include the charge on each structure.

[2 marks]

Structure 1

Structure 2

23

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Turn over for the next question

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0 4 Nitrogen dioxide gas is formed when magnesium nitrate is heated.

$$2\,Mg(NO_3)_2(s) \rightarrow 2\,MgO(s) + 4\,NO_2(g) + O_2(g)$$

Table 4 shows some thermodynamic data.

Table 4

Substance	$Mg(NO_3)_2(s)$	$MgO(s)$	$NO_2(g)$	$O_2(g)$
$\Delta_f H^\ominus$ **/ kJ mol^{-1}**	–790	–602	+34	0
$S^\ominus$ **/ J K^{-1} mol^{-1}**	+164	+27	+240	+205

0 4 . 1 Give the standard conditions indicated by the symbol $^\ominus$ in $\Delta_f H^\ominus$ and $S^\ominus$

[1 mark]

0 4 . 2 Use the equation and the data in **Table 4** to calculate the temperature at which this reaction becomes feasible.

[5 marks]

Temperature _____ K

Do not write outside the box

Nitrogen dioxide can also be produced in a reaction between ammonia and oxygen.

$$4\,NH_3(g) + 7\,O_2(g) \rightleftharpoons 4\,NO_2(g) + 6\,H_2O(g) \qquad \Delta H^{\ominus} = -1132 \text{ kJ mol}^{-1}$$

Table 5 shows some bond enthalpy values.

Table 5

	N–H	O=O	O–H
Mean bond enthalpy / kJ mol^{-1}	388	496	463

0 4 . 3 Assume that the bonds between N and O in NO_2 are the same.

Calculate the mean bond enthalpy, in kJ mol^{-1}, for a bond between N and O in NO_2

[3 marks]

Bond enthalpy _____ kJ mol^{-1}

0 4 . 4 An alloy of platinum and rhodium is used as a catalyst in the reaction.

What type of catalyst is this?

[1 mark]

Tick (✓) **one** box.

Autocatalyst ☐

Heterogeneous catalyst ☐

Homogeneous catalyst ☐

Question 4 continues on the next page

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0 4 . 5 Some ammonia and oxygen are reacted and the mixture is left to reach equilibrium at a fixed temperature.

Explain why increasing the temperature of this equilibrium mixture decreases the mole fraction of NO_2 in the equilibrium mixture.

[2 marks]

12

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0 5 This question is about the halogens and some of their compounds.

0 5 . 1 Explain why chlorine has a lower boiling point than bromine.

[2 marks]

0 5 . 2 Bromine reacts with fluorine to form BrF_3

Determine the oxidation state of bromine and of fluorine in BrF_3

[1 mark]

Oxidation state of Br _____ Oxidation state of F _____

0 5 . 3 Draw the shape of a BrF_3 molecule.

Include any lone pairs of electrons that influence the shape.

Explain why the BrF_3 molecule has the shape you have drawn.

[2 marks]

Shape

Explanation of shape _____

Do not write outside the box

0 5 . 4 Solid sodium bromide reacts with concentrated sulfuric acid.

Two reactions occur

- an acid-base reaction
- a redox reaction.

Give an equation and an observation for each reaction.

[4 marks]

Equation for acid-base reaction

Observation for acid-base reaction

Equation for redox reaction

Observation for redox reaction

0 5 . 5 Iodide ions reduce copper(II) ions in aqueous solution to form a precipitate of copper(I) iodide.

Give an equation for this redox reaction.

[1 mark]

10

Turn over ►

Do not write outside the box

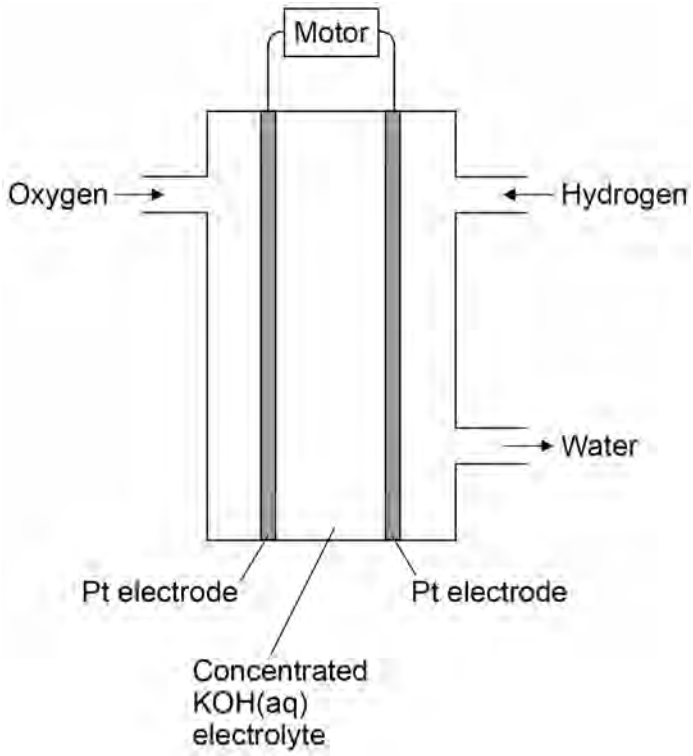
0 6 An alkaline hydrogen-oxygen fuel cell uses hydrogen and oxygen to produce electricity.

The overall equation for the reaction is

$$2\,H_2(g) + O_2(g) \rightarrow 2\,H_2O(l)$$

Figure 2 represents an alkaline hydrogen-oxygen fuel cell in use to power a motor.

Figure 2



0 6 . 1 Give a half-equation for the reaction occurring, in alkaline conditions, at each electrode.

[2 marks]

At negative electrode

At positive electrode

Do not write outside the box

0 6 . 2 Suggest why it is **not** necessary to replace the KOH electrolyte during the operation of this fuel cell.

[1 mark]

0 6 . 3 Describe how the reactions at the electrodes generate an electric current that can power the motor in the external circuit.

[2 marks]

0 6 . 4 This fuel cell uses pure oxygen, rather than air, as an oxidising agent.

Suggest the identity of the gas in air that would react with the KOH and affect the efficient operation of the cell.

[1 mark]

0 6 . 5 When an alkaline hydrogen-oxygen fuel cell is used to power the motor in a car, the hydrogen can be stored as a liquid.

Suggest an advantage of storing hydrogen as a liquid.

[1 mark]

Question 6 continues on the next page

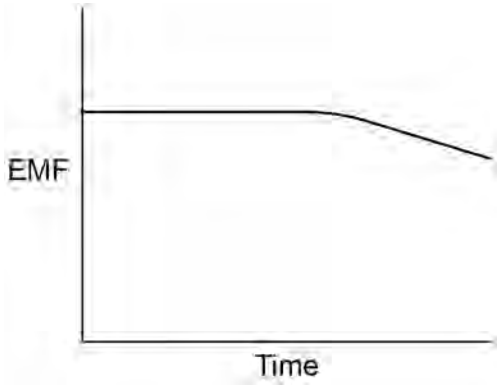
Do not write outside the box

0 6 . 6 Which graph shows the change in EMF, with time, for an alkaline hydrogen-oxygen fuel cell?

[1 mark]

Tick (✓) **one** box.

A



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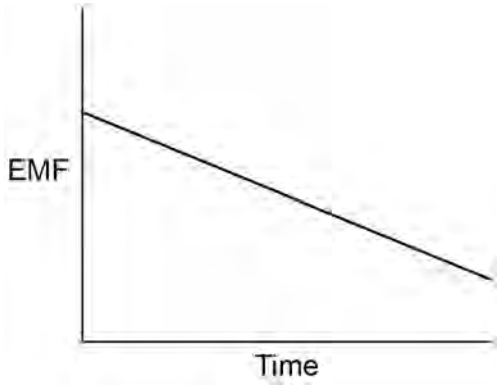

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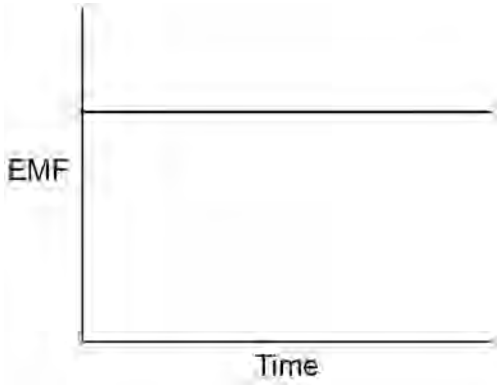

0 6 . 7 An acidic hydrogen-oxygen fuel cell has different reactions at the electrodes.

Suggest why the EMF of the acidic hydrogen-oxygen fuel cell is the same as that of the alkaline hydrogen-oxygen fuel cell.

[1 mark]

9

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0 7 This question is about vanadium and some of its compounds.

0 7 . 1 State the block in the Periodic Table that contains vanadium.

[1 mark]

0 7 . 2 Suggest why vanadium can be pulled into thin wires.

[1 mark]

0 7 . 3 Vanadium(V) oxide is a catalyst in the Contact process.

$$2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3(g)$$

Give **two** equations to show how vanadium(V) oxide acts as a catalyst in this process.

[2 marks]

Equation 1

Equation 2

Question 7 continues on the next page

Do not write outside the box

0 7 . 4 **Table 6** shows some electrode half-equations and their standard electrode potentials.

Table 6

Electrode half-equation	$E^{\ominus}$ / V
$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$	+1.00
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$	+0.34
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	–0.14
$V^{3+}(aq) + e^- \rightarrow V^{2+}(aq)$	–0.26

Sn reduces VO_2^+ in acidic solution.

Use the data in **Table 6** to deduce an overall equation for the reaction that occurs.

[2 marks]

Vanadium(III) sulfate is a pale yellow solid at room temperature.

0 7 . 5 Explain why vanadium(III) sulfate has a high melting point.

[2 marks]

Do not write outside the box

0 7 . 6 When vanadium(III) sulfate dissolves in water, the vanadium-containing species formed is acidic.

Give an equation to show how vanadium(III) sulfate dissolves in water to form the acidic vanadium-containing species.

Explain why the vanadium-containing species is acidic.

[3 marks]

Equation

Explanation

0 7 . 7 Compound **Q** is found in crude oil and has the molecular formula $C_{33}H_{34}N_4VO_4$

A sample of **Q** is ionised by electrospray ionisation in a time of flight (TOF) mass spectrometer. The spectrum produced shows that the vanadium in **Q** is ^{51}V

Give an equation to show how **Q** is ionised using electrospray ionisation.

Determine the *m*/*z* value of the molecular ion formed in this ionisation process.

[2 marks]

Equation

m/*z*

Question 7 continues on the next page

Do not write outside the box

0 7 . 8 A sample of vanadium contains only ^{49}V and ^{51}V

The relative atomic mass of vanadium in this sample is 50.97

Calculate the percentage abundance of ^{51}V in this sample.

[2 marks]

Percentage abundance of ^{51}V _____

15

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0 8 This question is about acids and bases.

0 8 . 1 Nitric acid is a strong acid.

Calculate the pH of 0.150 mol dm^{-3} nitric acid.

Give your answer to 2 decimal places.

[2 marks]

pH _____

0 8 . 2 Propanoic acid is a weak acid.

Calculate the concentration of a solution of propanoic acid with pH = 2.89 at 25 °C

The acid dissociation constant (K_a) for propanoic acid at 25 °C is 1.35×10^{-5} mol dm^{-3}

[4 marks]

Concentration _____ mol dm^{-3}

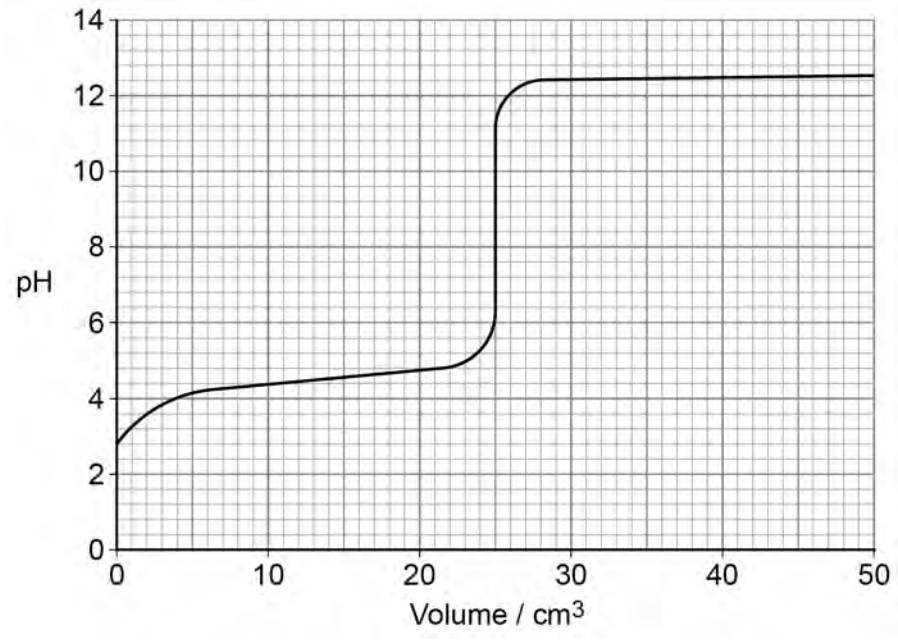
Question 8 continues on the next page

Do not write outside the box

A student records the pH as an alkali is added to an acid.

Figure 3 shows the pH curve for this reaction.

Figure 3



0 8 . 3 Which of these combinations gives the pH curve shown in **Figure 3**?

[1 mark]

Tick (✓) **one** box.

Strong alkali added to strong acid ☐

Strong alkali added to weak acid ☐

Weak alkali added to strong acid ☐

Weak alkali added to weak acid ☐

Do not write outside the box

0 8 . 4 Different indicators change colour across different pH ranges.

Tick (✓) the box of **each** indicator that would change colour at the equivalence point in **Figure 3**.

[1 mark]

Name of indicator	pH range	
Methyl orange	3.2–4.4	
Bromocresol green	3.8–5.4	
Cresol red	7.2–8.8	
Naphtholphthalein	7.3–8.7	
Cresolphthalein	8.2–9.8	
Indigo carmine	11.5–14.0	

Question 8 continues on the next page

Do not write outside the box

Buffer solution **B** is made by dissolving 0.656 g of sodium ethanoate (M_r = 82.0) in 50 cm^3 of 0.120 mol dm^{-3} ethanoic acid.

This buffer solution has pH = 4.87

0 8 . 5 Explain, qualitatively, how this buffer solution resists pH change when a small amount of sodium hydroxide solution is added.

[2 marks]

Do not write outside the box

0 8 . 6 Calculate the pH **change** that occurs when 1.50 cm^3 of 0.200 mol dm^{-3} HCl(aq) are added to buffer solution **B**.

Give your answer to 2 decimal places.

The acid dissociation constant (K_a) for ethanoic acid at 25 °C is 1.78×10^{-5} mol dm^{-3}

[7 marks]

pH change _____

17

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