OXFORD
INTERNATIONAL
AQA EXAMINATIONS

Please write clearly in block capitals.

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

Surname ____________________

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I declare this is my own work.

INTERNATIONAL A-LEVEL
CHEMISTRY (9620)

Unit 3: Inorganic 2 and Physical 2

Tuesday 18 January 2022 07:00 GMT Time allowed: 1 hour 30 minutes

Materials
For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert
- 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 80.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
TOTAL	

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

0 1 This question is about the Period 3 elements Na to S and their compounds.

0 1 . 1 A small piece of sodium is added to a beaker of cold water.
The sodium floats on the water.

Describe **two** other observations made when sodium reacts with water.

Write an equation, including state symbols, for the reaction.

[3 marks]

Observation 1 ______________________________

Observation 2 ______________________________

Equation

____

0 1 . 2 A Period 3 element (Na to S) reacts with oxygen to form a colourless gas.

Identify the element.

[1 mark]

____

0 1 . 3 Separate samples of solid sodium chloride and liquid silicon tetrachloride are added to water.
The pH of each solution formed is measured.

	pH
sodium chloride	7
silicon tetrachloride	0

Write an equation, including state symbols, to represent the process that occurs when each substance is added to water.

[2 marks]

Equation when sodium chloride is added to water

____

Equation when silicon tetrachloride is added to water

____

Do not write outside the box

0 1 . 4 A small amount of phosphorus(V) oxide is added to an excess of aqueous sodium hydroxide.

Write an equation for this reaction.

Draw the structure of the anion formed in this reaction.

[2 marks]

Equation

Structure

8

Turn over for the next question

Do not write outside the box

0 2 A colorimeter is used to determine the concentration of Fe^{3+} ions in a sample of aqueous iron(III) sulfate.

0 2 . 1 Give the full electron configuration of an Fe^{3+} ion.

[1 mark]

Solutions with different concentrations are prepared by adding different amounts of distilled water to 0.500 mol dm^{-3} aqueous iron(III) sulfate.

The absorption of light by these solutions is measured.

The results are shown in **Table 1**.

Table 1

Concentration of iron(III) sulfate / mol dm^{-3}	Absorbance / %
0.100	12
0.200	25
0.300	38
0.400	51
0.500	65

0 2 . 2 Calculate the volume, in cm^3, of water that must be added to 25.0 cm^3 of 0.500 mol dm^{-3} aqueous iron(III) sulfate to prepare the solution with a concentration of 0.300 mol dm^{-3}

[2 marks]

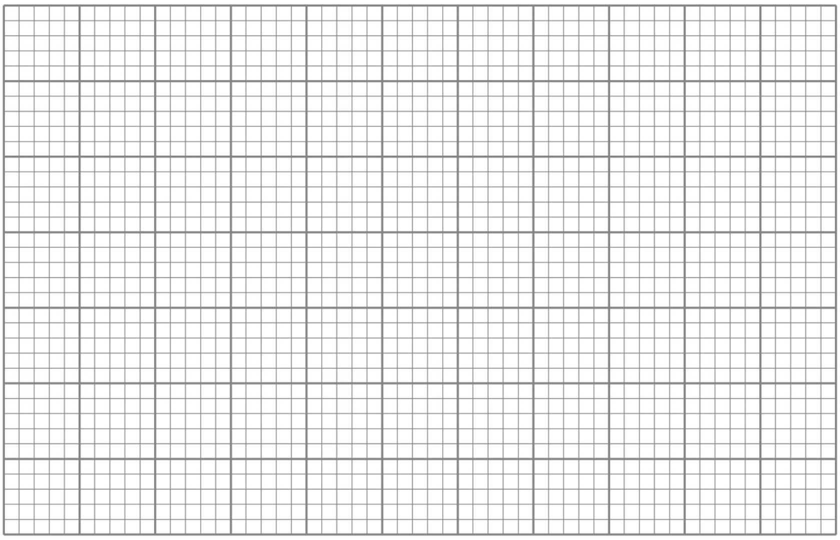
Volume_______________ cm^3

0 2 . 3 Plot the data from **Table 1** on the grid in **Figure 1**.

You should plot concentration of iron(III) sulfate on the x-axis and absorbance on the y-axis.

[2 marks]

Figure 1



0 2 . 4 The absorbance of a solution of iron(III) sulfate is measured as 44%

Use your graph in **Figure 1** to determine the concentration, in mol dm^{-3}, of Fe^{3+} ions in this solution.

[2 marks]

Concentration of Fe^{3+}(aq) ________________ mol dm^{-3}

Question 2 continues on the next page

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0 2 . 5 The wavelength of some light absorbed by the solution of iron(III) sulfate is 240 nm

Calculate the energy gap (ΔE), in J, between the ground state and the excited state of the d electrons.

You should assume that all the light absorbed is because of the movement of electrons between d orbitals.

The Planck constant, $h = 6.63 \times 10^{-34}$ J s
The speed of light, $c = 3.00 \times 10^{8}$ m s^{-1}

[2 marks]

ΔE ________________ J

9

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Turn over for the next question

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0 3 This question is about complex ions.

0 3 . 1 Ammonia is a monodentate ligand.

Write an equation for the reaction of an excess of ammonia with aqueous Cu^{2+} ions.

State the co-ordination number of copper in the complex ion formed in this reaction.

[2 marks]

Equation

____

Co-ordination number ____

0 3 . 2 Ethanedioate ions are bidentate ligands.

Draw the structure of the complex ion formed when an excess of sodium ethanedioate is added to aqueous Cu^{2+} ions.

Show the structure of the ligands and the overall charge on the complex.

State the type of isomerism shown by this complex.

[4 marks]

Structure

Type of isomerism ____

Do not write outside the box

The complex haem contains a multidentate ligand.

0 3 . 3 State the meaning of the term multidentate.

[1 mark]

0 3 . 4 Explain why carbon monoxide is toxic when it is inhaled.

[2 marks]

The complex ion $[Ag(NH_3)_2]^+$ is used to distinguish between aldehydes and ketones in a redox reaction.

0 3 . 5 Write a half-equation to show the reduction of $[Ag(NH_3)_2]^+$ in this redox reaction.

[1 mark]

0 3 . 6 Name the shape of $[Ag(NH_3)_2]^+$

[1 mark]

11

Turn over for the next question

Do not write outside the box

0 4 Iron(II) sulfate exists as the hydrated salt $FeSO_4.xH_2O$, where x is an integer.

A student completes an experiment to determine the value of x in $FeSO_4.xH_2O$ by titration with potassium manganate(VII)

Method

- 5.82 g of $FeSO_4.xH_2O$ are dissolved in distilled water.
- The solution is made up to 250 cm^3 in a volumetric flask.
- A 25.0 cm^3 portion of this solution is transferred to a conical flask.
- An excess of dilute sulfuric acid is added to the conical flask.
- 0.0150 mol dm^{-3} potassium manganate(VII) solution is added to the conical flask from a burette until there is a permanent colour change.

Table 2 shows the student's titration results.

Table 2

	Rough	**1**	**2**	**3**
Final volume / cm^3	36.20	39.60	36.55	43.00
Initial volume / cm^3	0.00	5.00	1.50	8.30
Titre / cm^3	36.20	34.60	35.05	34.70

Do not write outside the box

0 4 . 1 Calculate the mean titre, in cm^3, and use this to determine the value of x in $FeSO_4.xH_2O$

[6 marks]

Mean titre ____________ cm^3

Value of x ____________

0 4 . 2 State the colour change at the end point of the titration.

[1 mark]

____

7

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0 5 This question is about some test-tube reactions of aqueous solutions of iron(II) sulfate, iron(III) sulfate and aluminium sulfate.

0 5 . 1 Identify a reagent, or combination of reagents, that can be used to show that the solutions contain sulfate ions.

Describe what is observed.

[2 marks]

Reagent(s) ____________________

Observation ____________________

____

0 5 . 2 A green precipitate is formed when aqueous sodium hydroxide is added to aqueous iron(II) sulfate in a test tube.
When this test tube is left to stand in air, the green precipitate starts to turn brown.

Write an equation to show the formation of the green precipitate.

State the type of reaction occurring when the green precipitate turns brown.

[2 marks]

Equation

____

Type of reaction ____________________

Do not write outside the box

0 5 . 3 Aqueous sodium hydroxide is added to aqueous aluminium sulfate in a test tube.

Describe what is observed after a few drops of sodium hydroxide are added.

Write an equation for this reaction.

Describe what is observed after an excess of sodium hydroxide is added.

Write an equation for this reaction.

[4 marks]

Observation after a few drops of sodium hydroxide

____

Equation

____

Observation after excess of sodium hydroxide

____

Equation

____

0 5 . 4 Concentrated hydrochloric acid is added to aqueous iron(III) sulfate in a test tube.

Write an equation for this reaction.

[1 mark]

____

Question 5 continues on the next page

0 5 . 5 Aqueous sodium carbonate is added to separate samples of aqueous iron(II) sulfate and aqueous iron(III) sulfate.

Some observations are shown in **Table 3**.

Table 3

	Observation(s)
Reaction with iron(II) sulfate	Precipitate formed
Reaction with iron(III) sulfate	Precipitate formed and effervescence

Complete **Table 4** to state the colour and the formula of the precipitate formed in each reaction.

[4 marks]

Table 4

	Colour of the precipitate	Formula of the precipitate
Reaction with iron(II) sulfate		
Reaction with iron(III) sulfate		

0 5 . 6 The reaction of aqueous sodium carbonate with iron(III) sulfate produces a gas because $[Fe(H_2O)_6]^{3+}$ is acidic.

Identify the gas formed in this reaction.

Explain why $[Fe(H_2O)_6]^{3+}$ is acidic.

[3 marks]

Identity of gas ______________________________

Explanation ______________________________

____

____

____

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Turn over for the next question

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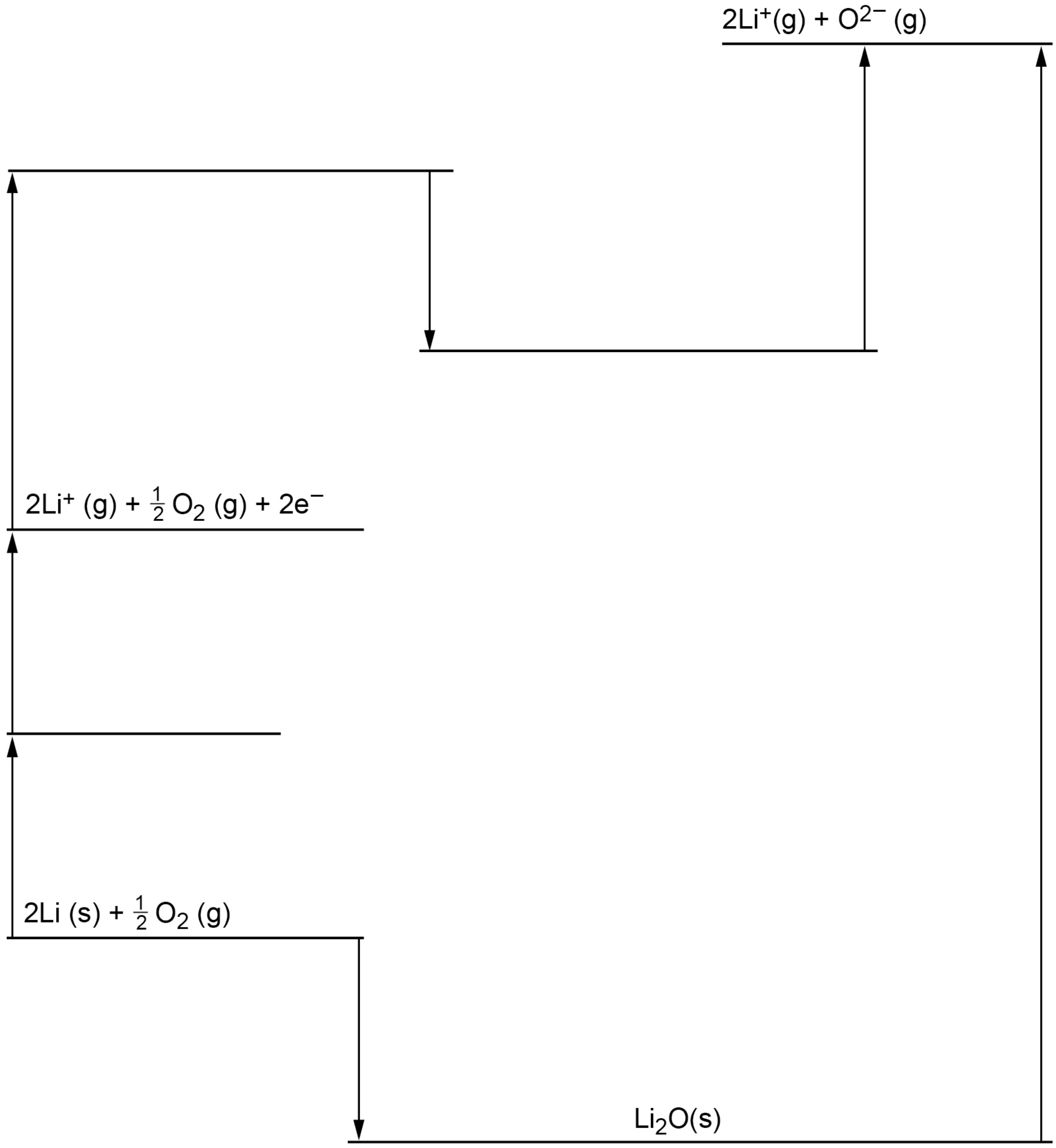
0 6 **Figure 2** shows an incomplete Born–Haber cycle for lithium oxide.

Figure 2



0 6 . 1 Write the formulas, including state symbols, of the appropriate species on each of the three blank horizontal lines in **Figure 2**.

[3 marks]

Do not write outside the box

Table 5 shows some enthalpy data.

Table 5

Enthalpy change	**Δ*H* / kJ mol^{-1}**
Enthalpy of atomisation of lithium	+159
Enthalpy of atomisation of oxygen	+248
First ionisation energy of lithium	+520
First electron affinity of oxygen	–142
Second electron affinity of oxygen	+844
Enthalpy of formation of lithium oxide	–596

0 6 . 2 Use **Figure 2** and **Table 5** to calculate the enthalpy of lattice dissociation, in kJ mol^{-1}, for lithium oxide.

[2 marks]

Enthalpy of lattice dissociation ________________ kJ mol^{-1}

Question 6 continues on the next page

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Lattice enthalpies can be calculated from experimental data using Born–Haber cycles. Theoretical values can be calculated using a perfect ionic model for a lattice.

Table 6 shows the experimental and theoretical lattice dissociation enthalpies for three silver halides.

Table 6

	Experimental lattice enthalpy / kJ mol^{-1}	**Theoretical lattice enthalpy / kJ mol^{-1}**
AgCl	+910	+860
AgBr	+904	+830
AgI	+890	+808

0 6 . 3 Explain why the values for the theoretical lattice dissociation enthalpy decrease from silver chloride to silver iodide.

[2 marks]

0 6 . 4 Explain why the difference between the experimental and theoretical values gets larger from silver chloride to silver iodide.

[1 mark]

8

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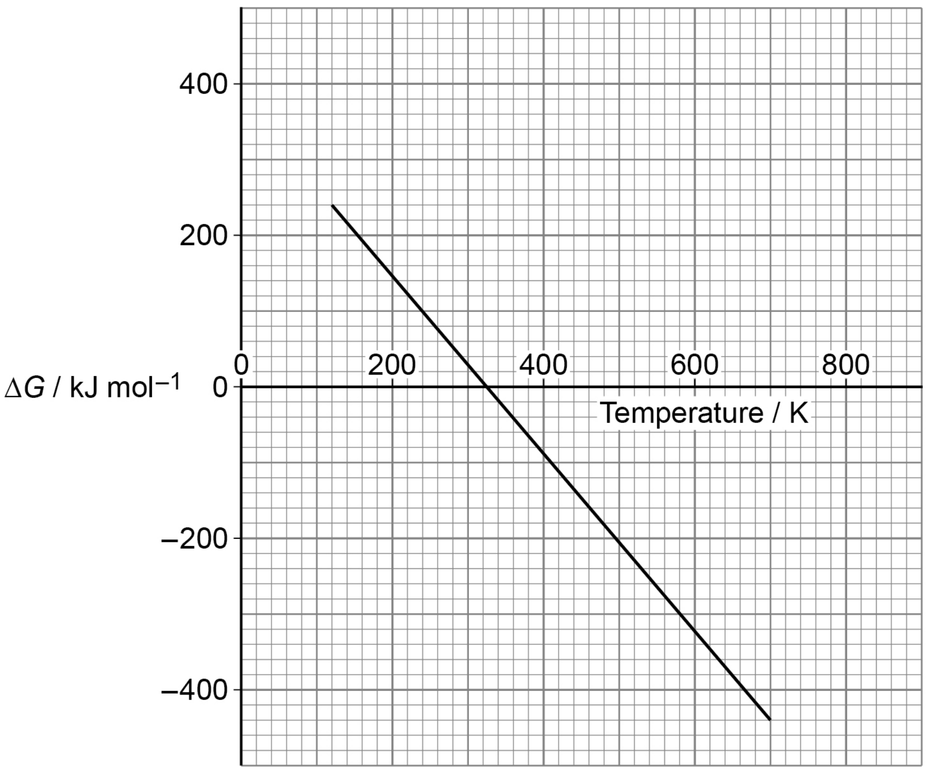
0 7 The relationship between the free energy change (ΔG) and temperature (T) is

$$\Delta G = \Delta H - T\Delta S$$

Figure 3 shows how ΔG varies with T for a reaction.

Figure 3



0 7 . 1 Use **Figure 3** to deduce a value for the enthalpy change (ΔH), in kJ mol^{-1}, for the reaction.

[1 mark]

Enthalpy change ____________________ kJ mol^{-1}

0 7 . 2 Use **Figure 3** to calculate a value for the entropy change (ΔS), in J K^{-1} mol^{-1}, for the reaction.

[2 marks]

Entropy change ____________________ J K^{-1} mol^{-1}

0 7 . 3 The reaction becomes feasible above a specific temperature.
Use **Figure 3** to determine this temperature.

[1 mark]

Temperature ____________________ K

4

Turn over ►

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0 8 Ethanoic acid (CH_3COOH) and chloroethanoic acid ($ClCH_2COOH$) are both weak acids.

Table 7 shows the acid dissociation constant (K_a) for each acid at 298 K

Table 7

	K_a / mol dm^{-3}
Ethanoic acid	1.74×10^{-5}
Chloroethanoic acid	1.38×10^{-3}

0 8 . 1 State the meaning of the term weak acid.

[1 mark]

____

____

0 8 . 2 Write an expression for the acid dissociation constant (K_a) for ethanoic acid.

[1 mark]

K_a

0 8 . 3 Calculate the pH of a 0.125 mol dm^{-3} aqueous solution of ethanoic acid at 298 K

Give your answer to **two** decimal places.

[2 marks]

pH ______________

Do not write outside the box

0 8 . 4 A buffer solution is prepared by dissolving 0.0266 mol of sodium chloroethanoate in 75.0 cm^3 of a 0.450 mol dm^{-3} aqueous solution of chloroethanoic acid.

A sample of 1.00 cm^3 of 1.50 mol dm^{-3} aqueous sodium hydroxide is added to the buffer solution.

Calculate the pH of the solution formed.
Give your answer to **two** decimal places.

For chloroethanoic acid, at 298 K, K_a = 1.38 × 10^{-3} mol dm^{-3}

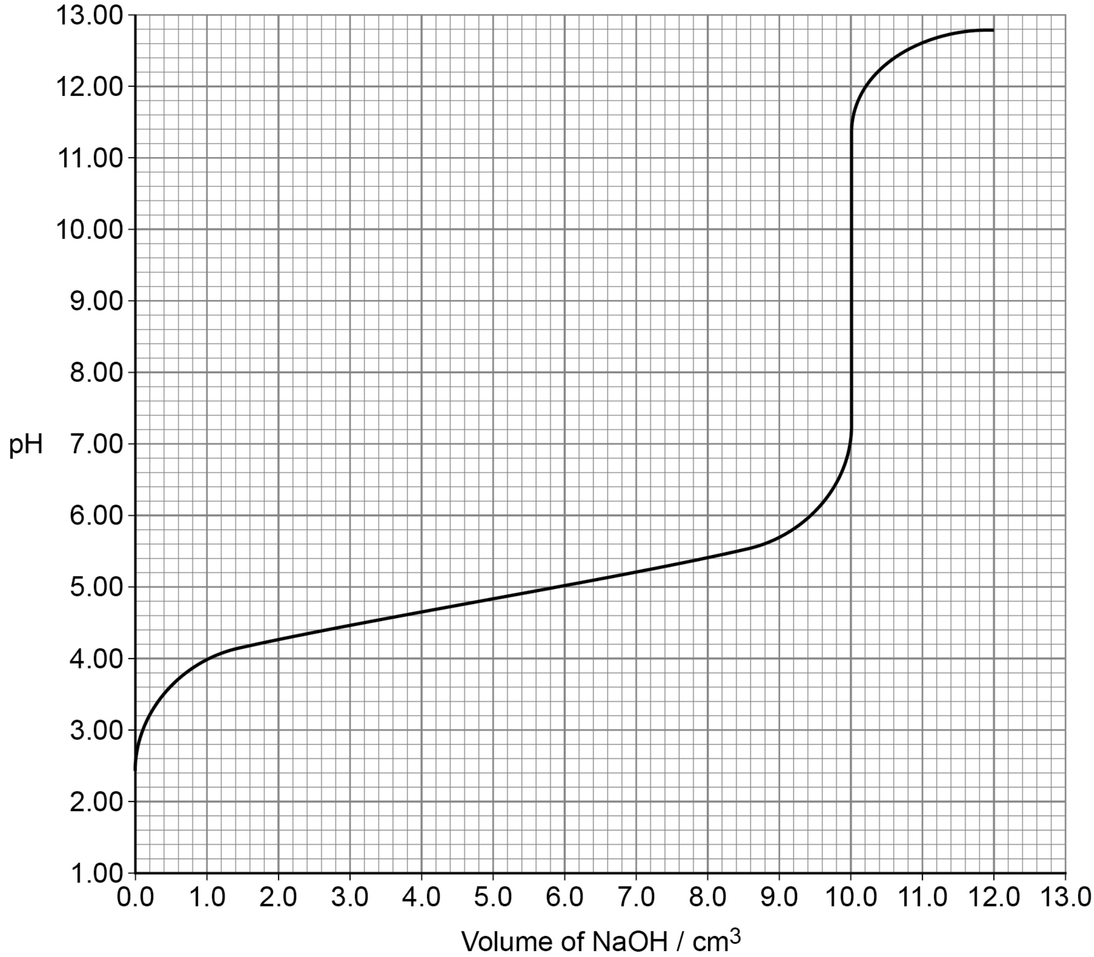
[6 marks]

pH ______________

Question 8 continues on the next page

Figure 4 shows a pH curve for the titration between propanoic acid (CH_3CH_2COOH) and sodium hydroxide (NaOH).

Figure 4



0 8 . 5 Use **Figure 4** to identify the volume of NaOH added at the end point of the titration. Use the pH at the point where half of this volume has been added to calculate a value for K_a, in mol dm^{-3}, of propanoic acid.

[2 marks]

K_a ______________ mol dm^{-3}

Do not write outside the box

Table 8 shows the pH ranges of three different indicators.

Table 8

	pH range
Bromophenol blue	3.0 to 4.6
Bromocresol purple	5.2 to 6.8
Thymolphthalein	9.3 to 10.5

0 8 . 6 Which indicator should be used in the titration in **Figure 4**?

Tick (✓) **one** box.

[1 mark]

Bromophenol blue ☐

Bromocresol purple ☐

Thymolphthalein ☐

13

Turn over for the next question

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0 9 **Table 9** shows some electrode potential data.

Table 9

Electrode half-equation	$E^\ominus$ / V
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$	+1.23
$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$	+0.40
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$2H_2O(l) + 2e^- \rightarrow 2OH^-(aq) + H_2(g)$	– 0.83

The conventional representation of an alkaline fuel cell is

$$Pt \mid H_2(g) \mid OH^-(aq), H_2O(l) \parallel O_2(g) \mid H_2O(l), OH^-(aq) \mid Pt$$

0 9 . 1 Use data from **Table 9** to calculate the EMF of this fuel cell.

[1 mark]

EMF ________________ V

Methane can also be used in fuel cells.
The overall cell reaction is

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

0 9 . 2 State **one** disadvantage of using methane instead of hydrogen in a fuel cell.

[1 mark]

____

____

0 9 . 3 Suggest **one** advantage of the reaction of methane and oxygen in a fuel cell compared with the combustion of methane.

[1 mark]

____

____

Do not write outside the box

0 9 . 4 In the methane fuel cell the overall cell reaction is

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

The half-equation for reduction is

$$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$$

Deduce the half-equation for the oxidation of methane in alkaline conditions.

[1 mark]

Half-equation

4

END OF QUESTIONS

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