

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

Forename(s)

Candidate signature

I declare this is my own work.

INTERNATIONAL A-LEVEL CHEMISTRY (9620)

Unit 3: Inorganic 2 and Physical 2

Wednesday 4 June 2025

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	
10	
11	
TOTAL	



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

0 1

This question is about Period 3 elements and their compounds.

0 1 . 1

A small piece of sodium is placed in a large bowl of cold water.

The sodium floats, moves on the surface and reacts completely to form a colourless solution.

Give **one** other observation.

Write an equation for this reaction.

[2 marks]

Observation _____

Equation _____

0 1 . 2

Some magnesium is reacted in oxygen to form a white solid.

After cooling, a small volume of water is added to the white solid in a test tube. A couple of drops of universal indicator are then added to the mixture in the test tube. The universal indicator turns blue showing that the solution formed is alkaline.

Write an equation, including state symbols, for the reaction of magnesium with oxygen.

Explain why the solution formed is alkaline.

[2 marks]

Equation _____

Explanation _____



A Period 3 element forms an oxide that is insoluble in water.
The oxide reacts with sodium hydroxide but does **not** react with hydrochloric acid.

Tick (✓) **one** box.

[1 mark]

11

11

11

SO₂ and PCl₅ react with water to form different anions.

Draw the structure, including the charge, of an anion formed when SO_2 reacts with water.

Draw the structure, including the charge, of an anion formed when PCl_5 reacts with water.

[2 marks]

Structure of anion formed when SO_2 reacts with water	Structure of anion formed when PCl_5 reacts with water

7

Turn over ►



0 2

This question is about copper(II) complexes.

0 2 . 1

Give the full electron configuration of Cu^{2+} **[1 mark]**

In a colorimetry experiment, a student determines the concentration of Cu^{2+} ions in an aqueous solution of CuSO_4

The student prepares a series of aqueous solutions with known concentrations of CuSO_4

The student uses a colorimeter to measure the absorbance of light at 620 nm for each of these solutions.

Table 1 shows the results of the colorimetry experiment.

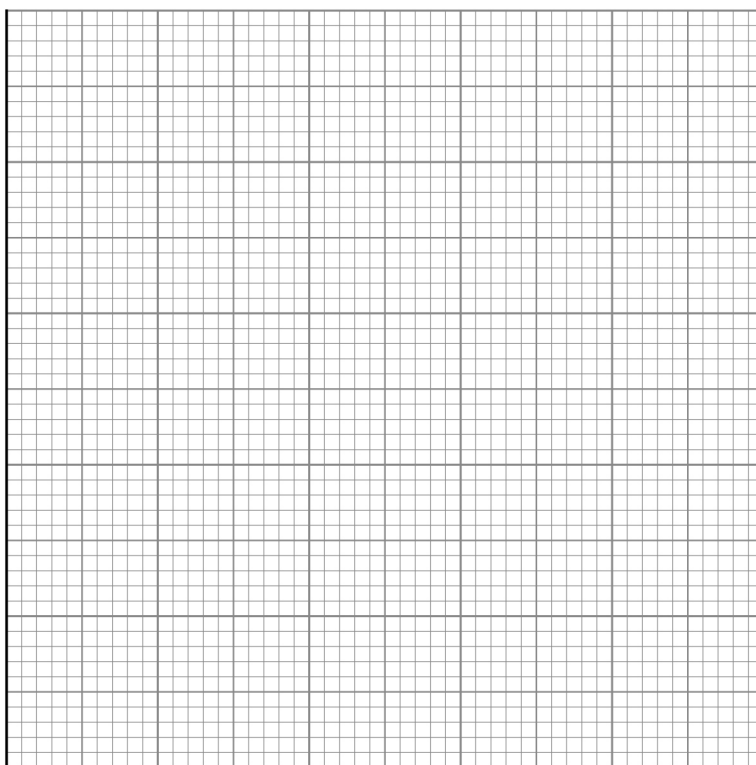
Table 1

$[\text{CuSO}_4] / \text{mol dm}^{-3}$	Absorbance
0.00	0.00
0.10	0.17
0.20	0.33
0.30	0.50
0.50	0.83

The student also records an absorbance of 0.68 for the aqueous CuSO_4 solution with unknown concentration.



0 2 . 2

Plot the data from **Table 1** on the grid in **Figure 1**.You should plot absorbance on the y-axis and $[\text{CuSO}_4]$ on the x-axis.Use your graph to determine the concentration, in mol dm^{-3} , of CuSO_4 in the solution with unknown concentration.**[3 marks]****Figure 1**Unknown $[\text{CuSO}_4]$ _____ mol dm^{-3} **Question 2 continues on the next page****Turn over ►**

0	2	.	3
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Calculate the energy gap (ΔE), in J, between the ground state and excited state of the d electrons.

You should assume that all the light absorbed at 620 nm is because of the movement of electrons between the d orbitals.

The Planck constant, $h = 6.63 \times 10^{-34} \text{ J s}$

The speed of light, $c = 3.00 \times 10^8 \text{ m s}^{-1}$

[2 marks]

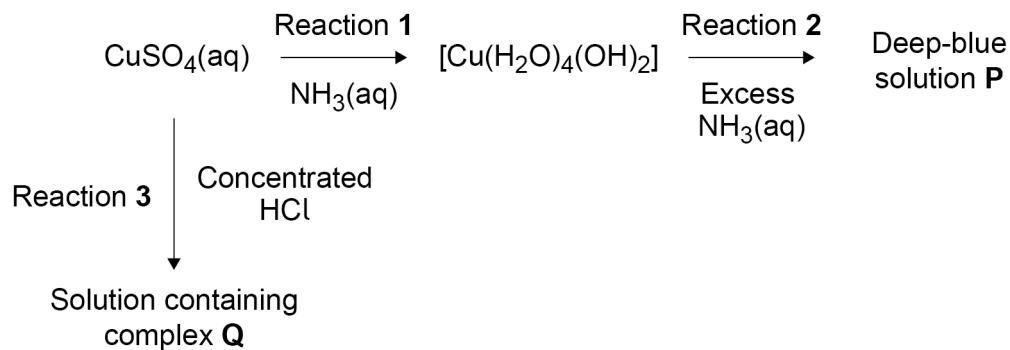
ΔE _____ J



In a different experiment, a student does some test-tube reactions using an aqueous solution of copper(II) sulfate.

Figure 2 shows the reactions and some observations made by the student.

Figure 2



0 2 . 4 Describe what is observed in Reaction 1.

State the type of reaction occurring.

[2 marks]

Observation _____

Type of reaction _____

0 2 . 5 Write an equation for Reaction 2.

State the type of reaction occurring.

[2 marks]

Equation

Type of reaction _____

0 2 . 6 Write an equation for the formation of complex **Q** in Reaction 3.

[1 mark]

Equation

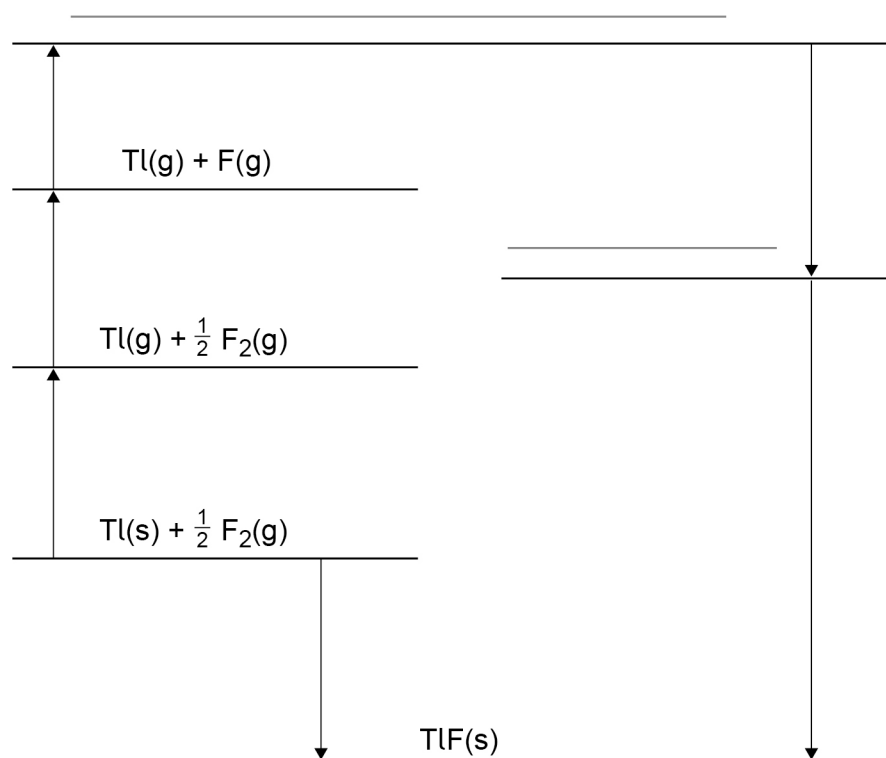


0 3

This question is about compounds of thallium, a metallic element in Group 3 (13).

Figure 3 shows an incomplete Born–Haber cycle for the formation of the ionic compound thallium(I) fluoride, TlF. The diagram is not to scale.

Figure 3



0 3 . 1

Write formulas, including state symbols, of the appropriate species on each of the two blank horizontal lines in **Figure 3**.

[2 marks]

0 3 . 2

Give the meaning of enthalpy of lattice formation.

[1 mark]



Table 2 shows the enthalpy changes involved in the formation of thallium(I) fluoride.

Table 2

Enthalpy change	$\Delta H / \text{kJ mol}^{-1}$
Bond enthalpy of fluorine	+158
Enthalpy of atomisation of thallium	+182
Enthalpy of formation of thallium(I) fluoride	−435
Electron affinity of fluorine	−328
First ionisation energy of thallium	+589

0 3 . 3

Use the data in **Table 2** to calculate a value for the enthalpy of lattice formation of thallium(I) fluoride.

[2 marks]

Lattice formation enthalpy _____ kJ mol^{-1}

A value for the enthalpy of lattice formation is calculated using a Born–Haber cycle.
A value is also calculated by using the perfect ionic model.

0 3 . 4

State the meaning of the perfect ionic model.

[1 mark]

Turn over ►



Table 3 shows values for the enthalpy of lattice formation for thallium(I) chloride and potassium chloride.

The first value is calculated using a Born–Haber cycle and the second is calculated using the perfect ionic model.

The values for potassium chloride are given as a comparison.

Table 3

	Value using Born–Haber cycle / kJ mol^{-1}	Value using perfect ionic model / kJ mol^{-1}
Lattice formation enthalpy of TlCl	–747	–641
Lattice formation enthalpy of KCl	–711	–705

0 3 . 5

Suggest why the two values for thallium(I) chloride are different.

[1 mark]

7



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0	4
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This question is about ionic solids and their aqueous solutions.

Anhydrous magnesium sulfate (MgSO_4) dissolves in water to give an aqueous solution.

0	4	.	1
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Write an equation, including state symbols, for the process that occurs when anhydrous magnesium sulfate dissolves in water.

[1 mark]

0	4	.	2
---	---	---	---

In an experiment, a student determines the enthalpy change when magnesium sulfate dissolves.

The student dissolves 1.78 g of magnesium sulfate in water at 20.0 °C to give a solution with a total mass of 50.0 g

The temperature of the solution rises to 26.4 °C

Calculate a value for the enthalpy change, in kJ mol^{-1} , when magnesium sulfate dissolves in water.

The specific heat capacity of the solution is $4.18 \text{ J K}^{-1} \text{ g}^{-1}$

[3 marks]

Enthalpy of solution _____ kJ mol^{-1}



0 4 . 3

Write an equation, including state symbols, for the reaction for which the enthalpy change is equal to the enthalpy of hydration of the magnesium ion.

[1 mark]

Table 4 shows some enthalpy of hydration values.

Table 4

	Mg ²⁺	Ca ²⁺
Enthalpy of hydration / kJ mol ⁻¹	-1920	-1650

0 4 . 4

Suggest why the value for the enthalpy of hydration for Mg²⁺ is more exothermic than the value for Ca²⁺

[2 marks]

7

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0 5

This question is about free energy and entropy.

The equation for the extraction of magnesium from its oxide using carbon is

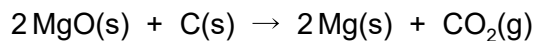


Table 5 shows some standard entropy values at 298 K

Table 5

	MgO(s)	C(s)	Mg(s)	CO ₂ (g)
$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$	26.9	5.7	32.7	214

0 5 . 1

State why the standard entropy of carbon at 298 K is **not** zero.

[1 mark]

0 5 . 2

Use the standard entropy values in **Table 5** to calculate the value of the standard entropy change ($\Delta S^\ominus$), in $\text{J K}^{-1} \text{mol}^{-1}$, for the reaction.

[2 marks]

$\Delta S^\ominus$ _____ $\text{J K}^{-1} \text{mol}^{-1}$



0 5 . 3 The standard enthalpy change ($\Delta H^\ominus$) at 298 K for the reaction is $+804 \text{ kJ mol}^{-1}$

Use this value and your answer to Question **05.2** to calculate a value for the Gibbs free-energy change ($\Delta G^\ominus$), in kJ mol^{-1} , at 298 K for the reaction. Give your answer to 3 significant figures.

State what your value of $\Delta G^\ominus$ shows about the feasibility of the reaction.

(If you could not calculate a value for the entropy change in Question **05.2** you should use the value $189.4 \text{ J K}^{-1} \text{ mol}^{-1}$
This is **not** the correct answer.)

[4 marks]

$\Delta G^\ominus$ _____ kJ mol^{-1}

Feasibility of the reaction _____

7

Turn over for the next question

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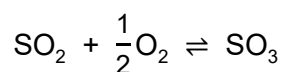


0 6

This question is about V_2O_5

V_2O_5 is used as a heterogeneous catalyst in the Contact Process.

The V_2O_5 catalyses the oxidation of SO_2 to SO_3

**0 6 . 1**

State what is meant by heterogeneous.

[1 mark]

0 6 . 2

Write **two** equations to show how V_2O_5 acts as a catalyst in the Contact Process.

[2 marks]

Equation 1

Equation 2

0 6 . 3

State why a support medium may be needed when using heterogeneous catalysts.

[1 mark]



V_2O_5 reacts with an excess of NaOH to form Na_3VO_4

V_2O_5 reacts with an excess of HNO_3 to form aqueous VO_2^+ ions.

0 6 . 4

Identify the property shown by V_2O_5 in its reactions with NaOH and with HNO_3

[1 mark]

0 6 . 5

Suggest an equation for the reaction of V_2O_5 with OH^- ions to form VO_4^{3-}

[1 mark]

0 6 . 6

Suggest an equation for the reaction of V_2O_5 with H^+ ions to form VO_2^+

[1 mark]

0 6 . 7

VO_2^+ ions can be reduced using zinc in acidic solution.

In an experiment, an excess of zinc is added to an acidic solution containing VO_2^+ ions in a boiling tube.

A cotton wool plug is inserted into the end of the boiling tube.

The reaction is left until no further reduction takes place.

Which is the correct reacting ratio for the overall reaction that takes place?

Tick (✓) **one** box.

[1 mark]

$2VO_2^+ : Zn$

☐

$3VO_2^+ : 2Zn$

☐

$2VO_2^+ : 3Zn$

☐

$VO_2^+ : 2Zn$

☐


0	7
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This question is about the redox titration between Fe^{2+} and MnO_4^-

In an experiment, a student determines the percentage purity of iron in iron wire.

Method

- The mass of the iron wire is 1.39 g
- The wire is reacted with 50 cm^3 of dilute sulfuric acid. All of the iron in the wire is converted to $\text{Fe}^{2+}(\text{aq})$
- The resulting solution is made up to 250 cm^3 in a volumetric flask with distilled water.
- 25.0 cm^3 of this solution are transferred to a conical flask and acidified by adding a further 25 cm^3 of dilute sulfuric acid.
- $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII) solution is added from a burette until there is a permanent colour change.
- 23.20 cm^3 of the potassium manganate(VII) solution are needed for a complete reaction.

0	7
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1

Determine the percentage purity of the iron in the wire.

[5 marks]

Percentage purity of iron _____



Table 6 shows some electrochemical data.

Table 6

	$E^\ominus / \text{V}$
$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}$	+1.52
$\text{NO}_3^- + 2\text{H}^+ + \text{e}^- \rightarrow \text{NO}_2 + \text{H}_2\text{O}$	+0.81
$\text{Fe}^{3+} + \text{e}^- \rightarrow \text{Fe}^{2+}$	+0.77
$2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$	0.00

0 7 . 2

Use **Table 6** to explain why nitric acid can **not** be used to acidify the solution in this experiment.

[2 marks]

7

Turn over for the next question

Turn over ►



0 8

This question is about some test-tube reactions of $\text{Fe}^{2+}(\text{aq})$ and $\text{Fe}^{3+}(\text{aq})$

A student does some test-tube reactions on aqueous solutions of two iron-containing salts, **X** and **Y**.

Table 7 shows the results of the tests.

Table 7

Test	Reagent	Aqueous solution of Salt X	Aqueous solution of Salt Y
1	Add $\text{NaOH}(\text{aq})$ drop by drop until in excess	Brown precipitate forms No further change in excess	Green precipitate forms No further change in excess
2	Add $\text{Na}_2\text{CO}_3(\text{aq})$	Brown precipitate forms Effervescence	Green precipitate forms
3	Add $\text{HCl}(\text{aq})$ then $\text{BaCl}_2(\text{aq})$	No visible change	White precipitate forms

0 8 . 1

Write an ionic equation to show the formation of the green precipitate in **Test 1**.

[1 mark]

0 8 . 2

Write an ionic equation to show the formation of the brown precipitate in **Test 2**.

[1 mark]

0 8 . 3

Give the formula of the green precipitate formed in **Test 2**.

[1 mark]

0 8 . 4

Give the formula of the white precipitate formed in **Test 3**.

[1 mark]



0	8	.	5
---	---	---	---

The aqueous solution of salt **X** is thought to contain chloride ions.

Identify a reagent, or combination of reagents, that can be used in a test-tube reaction to show that the solution of **X** contains chloride ions.

Describe the expected observation.

[2 marks]

Reagent(s) _____

Observation _____

6

Turn over for the next question

Turn over ►



0	9
---	---

This question is about acids and alkalis.

0	9	.	1
---	---	---	---

A student makes a saturated solution of strontium hydroxide.
The student determines the pH of the solution to be 13.51 at 298 K

Calculate the mass of strontium hydroxide needed to make 250 cm³ of the saturated solution.

$$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6} \text{ at } 298 \text{ K}$$

[5 marks]

Mass of strontium hydroxide _____ g



0	9	.	2
---	---	---	---

A student makes a buffer solution by adding 0.0500 mol of solid sodium ethanoate to 250 cm³ of 0.100 mol dm⁻³ aqueous ethanoic acid.

Calculate the pH of the buffer solution.

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

K_a of ethanoic acid is 1.78×10^{-5} mol dm⁻³

[4 marks]

pH _____

9

Turn over for the next question

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1 0

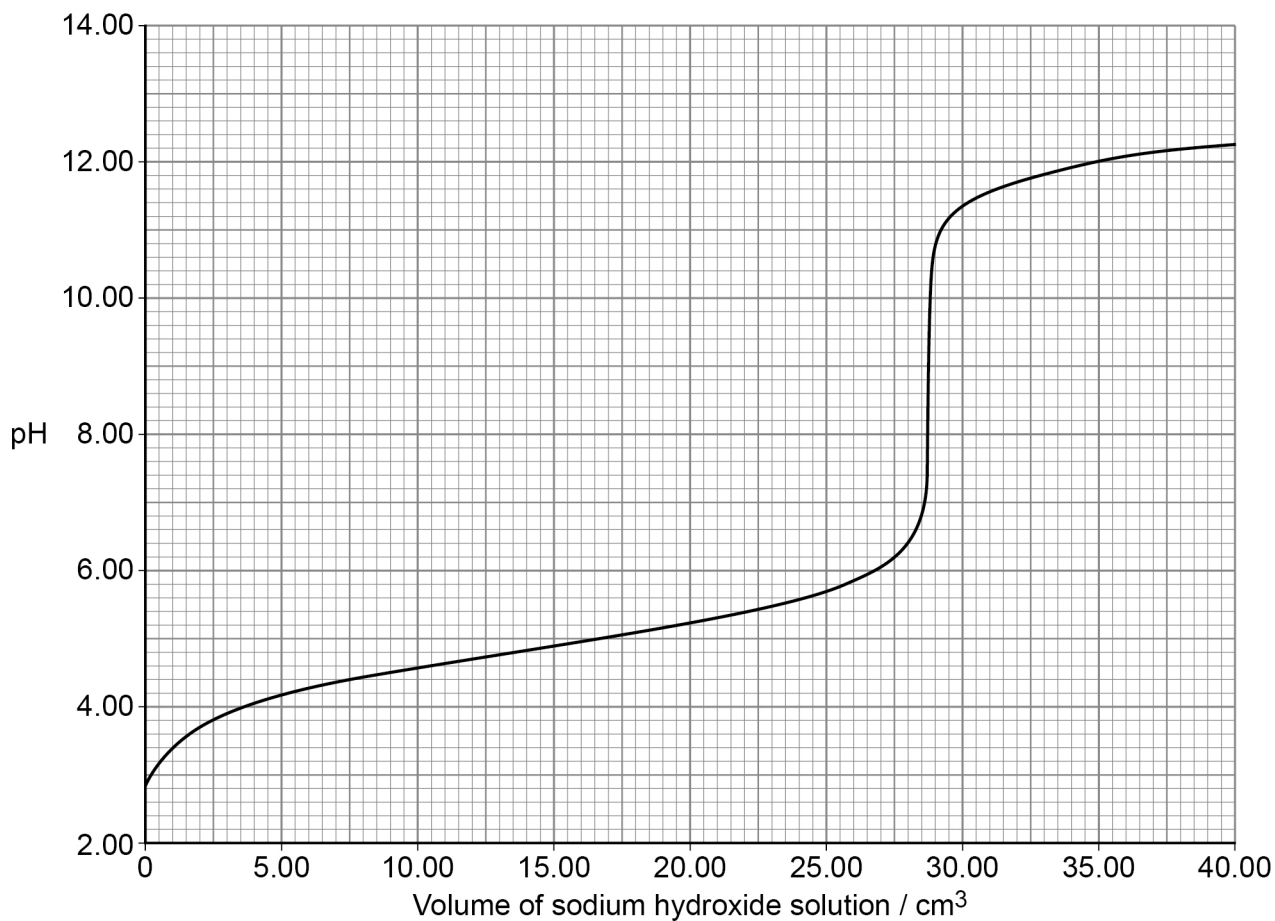
A student adds aqueous sodium hydroxide from a burette to 25.0 cm^3 of a solution of a monoprotic acid of concentration $0.100 \text{ mol dm}^{-3}$

The student measures the pH of the mixture until 40.00 cm^3 of sodium hydroxide have been added.

The student plots a titration curve using their results.

Figure 4 shows the student's titration curve.

Figure 4



1 0 . 1

State **two** features of the graph that show that the acid used is a weak acid.

[2 marks]

Feature 1 _____

Feature 2 _____



1 0 . 2

Between 25 cm³ and 30 cm³ the student adds the sodium hydroxide solution in smaller volumes between pH measurements to produce a more accurate curve.

Explain why these smaller volumes of sodium hydroxide solution are added.

[1 mark]

1 0 . 3

Use the graph in **Figure 4** to decide the approximate concentration of the sodium hydroxide used.

Tick (✓) **one** box.

[1 mark]

The concentration of NaOH is less than 0.100 mol dm⁻³

☐

The concentration of NaOH is exactly 0.100 mol dm⁻³

☐

The concentration of NaOH is greater than 0.100 mol dm⁻³

☐

1 0 . 4

Table 8 shows some indicators and their pH ranges.

Table 8

Indicator	Bromocresol green	Bromothymol blue	Thymolphthalein	Clayton yellow
pH range	3.8–5.2	5.8–7.2	9.3–10.5	12.2–13.2

A student chooses thymolphthalein as a suitable indicator for this titration.

Justify the student's choice.

[1 mark]

5

Turn over ►



1	1
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This question is about a methanoic acid fuel cell.

Pure methanoic acid (HCOOH) is a liquid that is a possible fuel for cells.

1	1	.	1
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Write a half-equation for the oxidation of methanoic acid to form carbon dioxide and hydrogen ions.

[1 mark]

1	1	.	2
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Write a half-equation for the reduction of oxygen, in acidic conditions, to form water.

[1 mark]

1	1	.	3
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Write an equation for the overall reaction in the fuel cell.

[1 mark]

1	1	.	4
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Hydrogen can also be used in fuel cells.

Suggest **one** advantage of using methanoic acid instead of hydrogen in a fuel cell.

Suggest **one** disadvantage of using methanoic acid instead of hydrogen in a fuel cell.

[2 marks]

Advantage _____

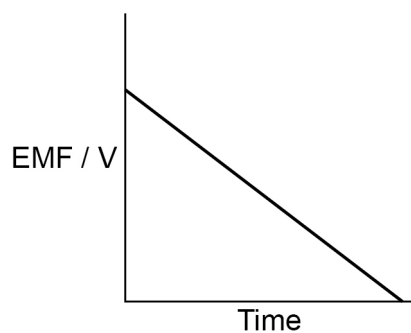
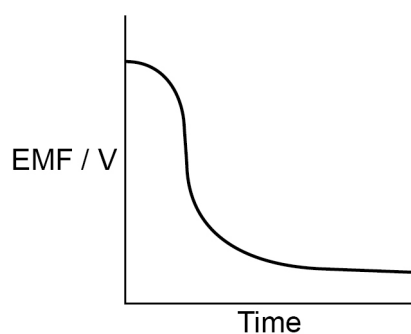
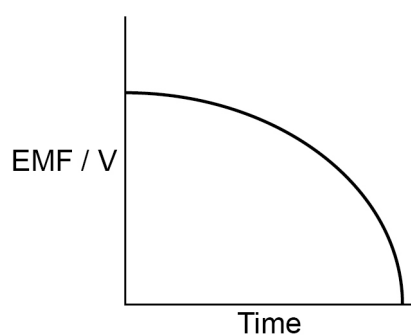
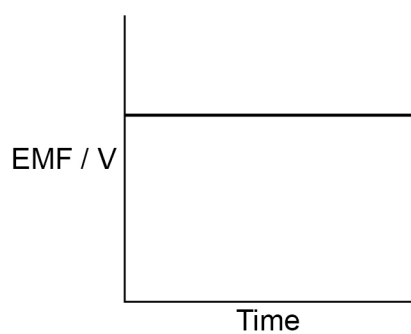
Disadvantage _____



1 1 . 5 Which of the following graphs shows the EMF of a fuel cell against time?

Tick (✓) **one** box.

[1 mark]

☐☐☐☐

END OF QUESTIONS



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