

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

Monday 12 January 2026

07:00 UK Time

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



J A N 2 6 C H 0 3 0 1

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

0 1

This question is about iron and its ions.

Fe acts as a heterogeneous catalyst in the Haber Process.

The Fe catalyst is replaced about every 5 years because it is gradually poisoned by sulfur compounds.

0 1 . 1

Define heterogeneous when applied to a catalyst.

[1 mark]

0 1 . 2

State how sulfur compounds poison the catalyst.

[1 mark]

$\text{Fe}^{3+}(\text{aq})$ ions act as a homogeneous catalyst in the reaction between I^- ions and $\text{S}_2\text{O}_8^{2-}$ ions.

0 1 . 3

Give the full electron configuration of the Fe^{3+} ion.

[1 mark]

0 1 . 4

State why the activation energy for the reaction between I^- ions and $\text{S}_2\text{O}_8^{2-}$ ions is very high.

[1 mark]



0 1 . 5

Write **two** equations to show how Fe^{3+} ions can catalyse the reaction between I^- ions and $\text{S}_2\text{O}_8^{2-}$ ions.

[2 marks]

Equation for first reaction

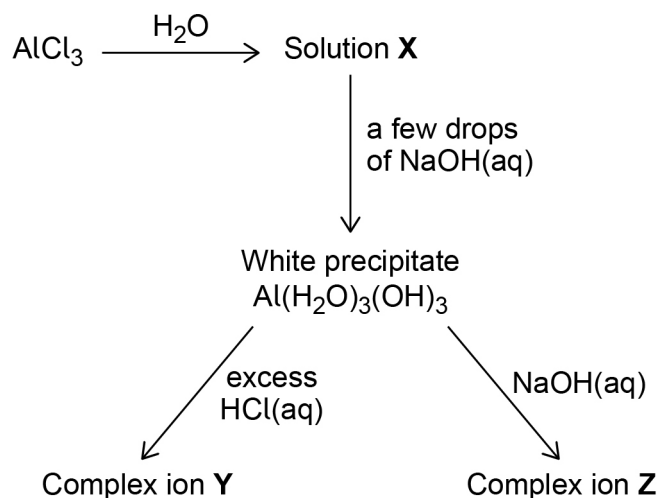
Equation for second reaction

6**Turn over for the next question****Turn over ►**

0 2

Figure 1 shows some reactions of aluminium compounds.

Figure 1



0 2 . 1

Identify the major aluminium-containing complex ion in solution **X**.

[1 mark]

0 2 . 2

Write an ionic equation for the reaction of the white precipitate with an excess of hydrochloric acid to form complex ion **Y**.

Describe what is observed in this reaction.

[2 marks]

Ionic equation

Observation

0 2 . 3

Identify complex ion **Z**.

[1 mark]



0	2	.	4
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Anhydrous aluminium chloride exists as Al_2Cl_6 molecules at 180°C

Draw a diagram to show the bonding in Al_2Cl_6

Use — to show covalent bonds.

Use $\rightarrow$ to show co-ordinate (dative covalent) bonds.

[1 mark]

5

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0	3
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This question is about Period 3 elements and their compounds.

0	3	.	1
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0.250 g of sodium is reacted with an excess of distilled water in a beaker.

After the reaction is complete, the resulting solution is transferred, with washings, to a 500 cm³ volumetric flask.

The solution is then made up to the mark using distilled water.

Calculate the pH, at 298 K, of the final solution.

The value of K_w is $1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ at 298 K

Give your answer to 2 decimal places.

[4 marks]

pH of final solution _____



0 3 . 2

A Period 3 element is reacted separately with oxygen and with chlorine.

The oxide and chloride formed are added to separate samples of water.

A few drops of Universal Indicator are added to each mixture.

The indicator shows no colour change in the mixture formed when the oxide is added to water.

The indicator turns red in the mixture formed when the chloride is added to water.

Which is the element?

Tick (✓) **one** box.

[1 mark]

Sodium

☐

Aluminium

☐

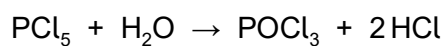
Phosphorus

☐

0 3 . 3

PCl_5 reacts with cold water in two stages.

In the first stage, POCl_3 is formed.



The POCl_3 then reacts with water to produce phosphoric(V) acid and more hydrochloric acid.

Write an equation for the reaction of POCl_3 with water.

[1 mark]

6

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0	4
---	---

This question is about copper(II) complex ions.

0	4	.	1
---	---	---	---

A solution containing $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$ ions appears blue.

Explain why the solution has a blue colour.

[3 marks]

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

An excess of aqueous sodium carbonate is added to a solution that contains aqueous Cu^{2+} ions.

State what is observed in this reaction.

Write an equation for the reaction.

[2 marks]

Observation _____

Equation _____

0	4	.	3
---	---	---	---

When an excess of hydrochloric acid is added to a solution that contains aqueous Cu^{2+} ions a yellow-green solution is formed.

Identify the type of reaction occurring.

Give the formula of the complex ion formed.

[2 marks]

Type of reaction _____

Complex ion _____



0 4 . 4

Aqueous ammonia is added drop by drop to a solution that contains aqueous Cu^{2+} ions until ammonia is in excess.

State what you would observe after a few drops of aqueous ammonia are added.

State what you would observe after an excess of aqueous ammonia is added.

Give the formula of the copper-containing complex formed after adding an excess of aqueous ammonia.

[3 marks]

Observation after a few drops of $\text{NH}_3(\text{aq})$ _____

Observation after excess $\text{NH}_3(\text{aq})$ _____

Formula of the copper-containing complex _____

0 4 . 5

What type(s) of isomerism is shown by the complex ion $[\text{Cu}(\text{C}_2\text{O}_4)_2(\text{H}_2\text{O})_2]^{2-}$?

Tick (✓) **one** box.

[1 mark]

Cis-trans isomerism only

☐

Optical isomerism only

☐

Both *cis-trans* isomerism
and optical isomerism

☐

11

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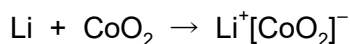


0 5

This question is about electrochemical cells.

0 5 . 1

A lithium cell is rechargeable. The overall equation when the cell is used (discharging) is shown.



Write an equation for the reaction that occurs at the negative lithium electrode when the cell is discharging.

Write an equation for the reaction that occurs at the positive lithium cobalt oxide electrode when the cell is discharging.

[2 marks]

Negative lithium electrode equation

Positive lithium cobalt oxide electrode equation

0 5 . 2

A nickel–zinc cell is another example of a rechargeable cell.

Table 1 shows the half-equation data for the cell.**Table 1**

Electrode half-equation	$E^\ominus / \text{V}$
$\text{NiO}(\text{OH}) + \text{H}_2\text{O} + \text{e}^- \rightarrow \text{Ni}(\text{OH})_2 + \text{OH}^-$	+0.49
$\text{Zn}(\text{OH})_2 + 2 \text{e}^- \rightarrow \text{Zn} + 2 \text{OH}^-$	+1.24

Write an equation for the overall reaction that occurs when the cell is recharging.

[2 marks]



0	5	.	3
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Fuel cells are an alternative to rechargeable cells.

Explain how fuel cells can maintain a constant EMF without recharging.

[1 mark]

5

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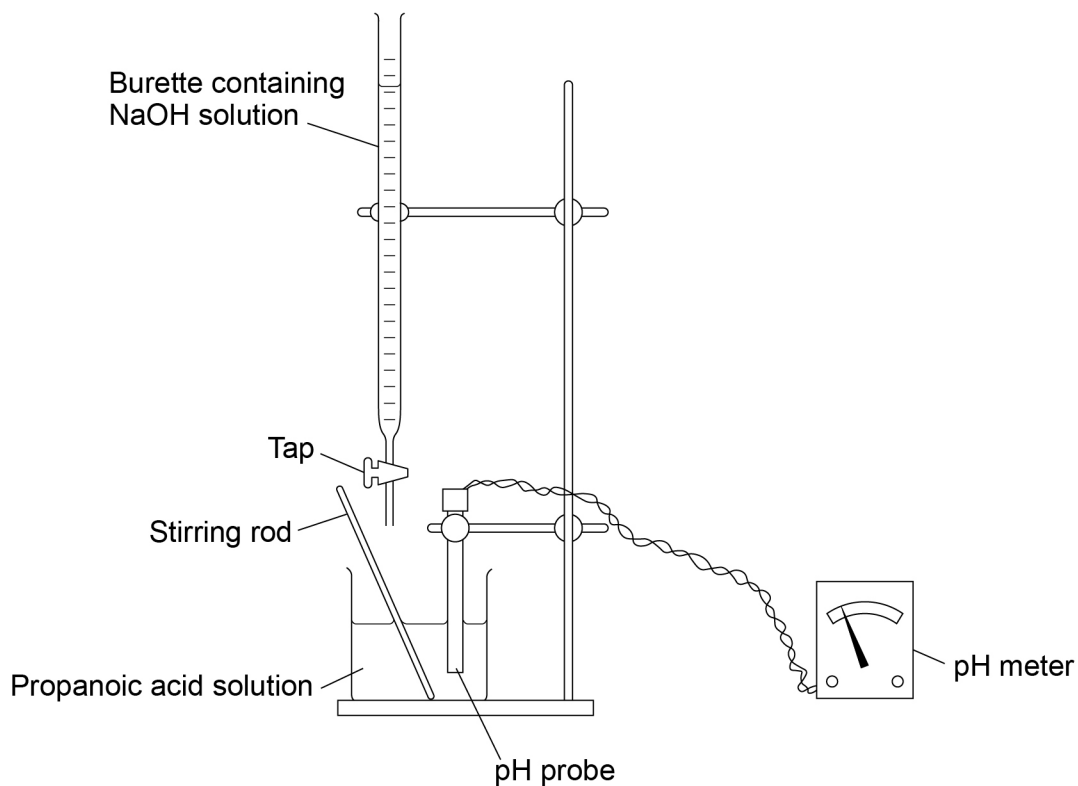


0 6

Figure 2 shows the equipment used in a titration at 290 K.

A student uses the data from the titration to draw a weak acid–strong base pH curve.

Figure 2



Method

1. Rinse the burette with distilled water and fill it with sodium hydroxide to 0.00 cm^3
2. Transfer 25.0 cm^3 of propanoic acid to a clean dry beaker with a measuring cylinder.
3. Add $0.100 \text{ mol dm}^{-3}$ NaOH from the burette in 1 cm^3 portions and stir the mixture.
4. Measure the pH after each addition.
5. Continue until 50 cm^3 of NaOH have been added.

0 6

. 1

Suggest **three** improvements to this method.

[3 marks]

1 _____

2 _____

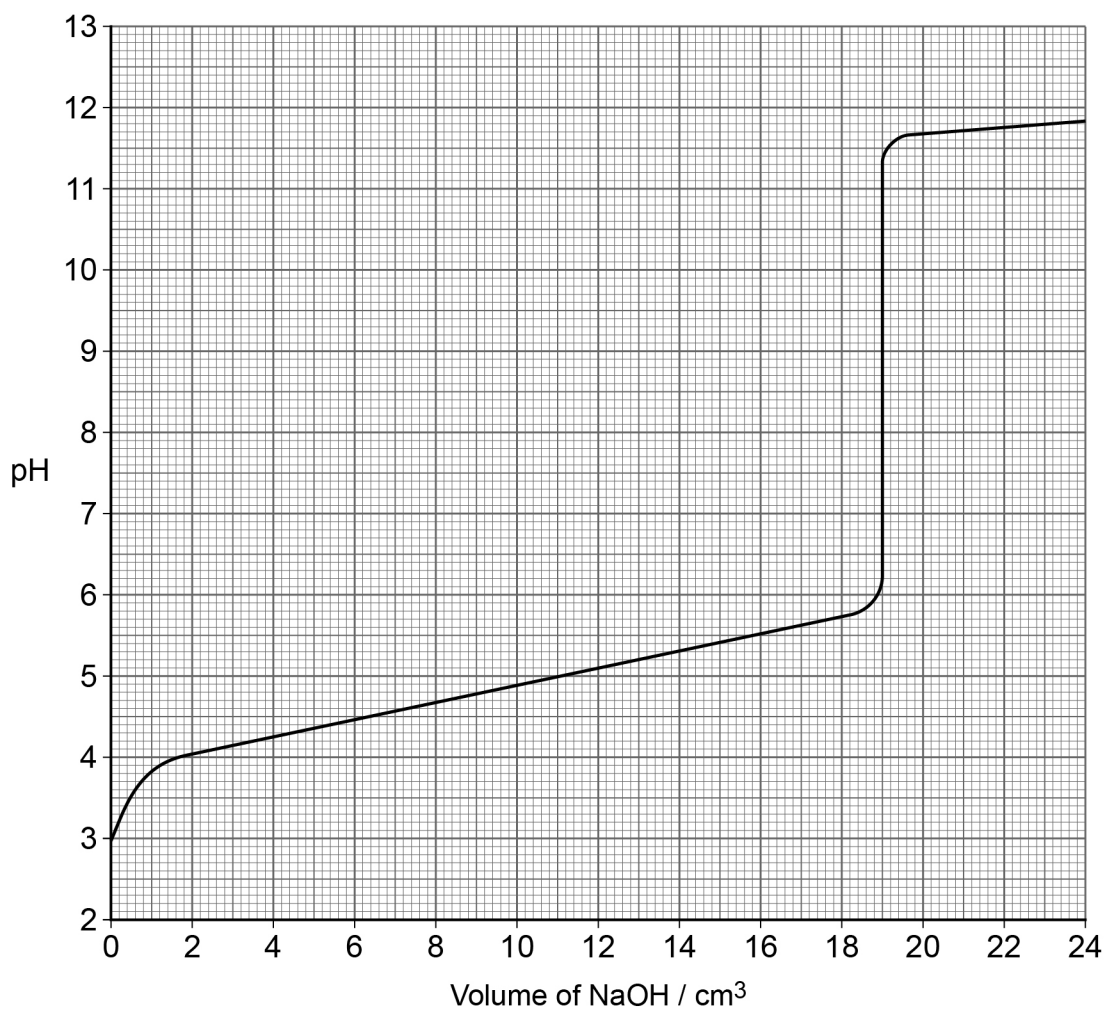
3 _____

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The improvements to the method are made and the student repeats the titration. **Figure 3** shows the results.

Figure 3



0 6 . 2

Write an equation for the reaction of propanoic acid ($\text{CH}_3\text{CH}_2\text{COOH}$) with sodium hydroxide.

[1 mark]



0 6 . 3

Use **Figure 3** to calculate the concentration, in mol dm^{-3} , of the propanoic acid in the 25.0 cm^3 sample.

[2 marks]

Concentration of propanoic acid _____ mol dm^{-3}

0 6 . 4

In this titration, the pH of the solution formed when half of the acid has been reacted is equal to the $\text{p}K_{\text{a}}$ of the acid.

Use the pH of the solution formed when half of the acid has been reacted to calculate the K_{a} of propanoic acid at 290 K

[2 marks]

K_{a} of propanoic acid _____ mol dm^{-3}

0 6 . 5

Which indicator is the most suitable for a titration between propanoic acid and sodium hydroxide?

Tick (✓) **one** box.

[1 mark]

Indicator	pH range	Tick (✓) one box
Methyl orange	3.1 – 4.4	
Bromocresol purple	5.2 – 6.8	
Thymolphthalein	9.3 – 10.5	
Indigo carmine	11.6 – 13.0	

Turn over ►



0 6 . 6

Another student does the same titration but uses a faulty pH meter that gives readings 0.5 units higher than the actual pH.

How would the volume of sodium hydroxide at equivalence in this titration compare with the volume of sodium hydroxide at equivalence from the titration used to give **Figure 3** on **page 14**?

Tick (✓) **one** box.

[1 mark]

Larger

☐

The same

☐

Smaller

☐

0	6	.	7
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A student prepares a buffer solution by reacting aqueous 3-chloropropanoic acid ($\text{ClCH}_2\text{CH}_2\text{COOH}$) with sodium hydroxide at 298 K

The student adds 1.80 g of sodium hydroxide to 500 cm^3 of a 0.150 mol dm^{-3} solution of 3-chloropropanoic acid.

At 298 K, the acid dissociation constant (K_a) for 3-chloropropanoic acid is $7.94 \times 10^{-5} \text{ mol dm}^{-3}$

Calculate the pH of this buffer solution at 298 K
Give your answer to 2 decimal places.

[6 marks]

pH _____

16

Turn over ►



0 7

This question is about enthalpy changes.

Table 2 shows some enthalpy change data.

Table 2

	Enthalpy change / kJ mol^{-1}
Enthalpy of atomisation of barium	176
First ionisation energy of barium	502
Second ionisation energy of barium	966
Enthalpy of atomisation of bromine	112
Enthalpy of vaporisation of bromine	30.7
Electron affinity of bromine	-342
Enthalpy of formation of barium bromide	-755

0 7

. 1

Use data from **Table 2** to calculate the bond dissociation enthalpy, in kJ mol^{-1} , of a Br-Br bond.

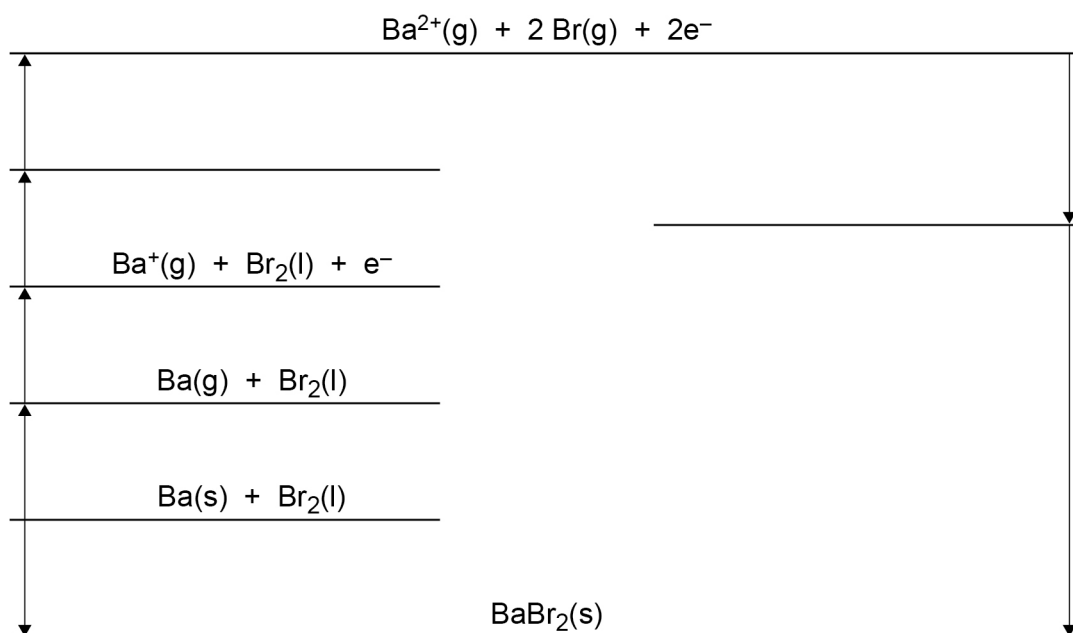
[2 marks]

Bond dissociation enthalpy _____ kJ mol^{-1}



Figure 4 shows a partly completed Born–Haber cycle for barium bromide. The cycle is **not** drawn to scale.

Figure 4



- 0 7 . 2** Complete the Born–Haber cycle by writing the formulas, including state symbols, of the appropriate species on each of the two blank horizontal lines in **Figure 4**. **[2 marks]**

- 0 7 . 3** Use **Figure 4** and data from **Table 2** to calculate the enthalpy of lattice formation of barium bromide. **[2 marks]**

Enthalpy of lattice formation _____ kJ mol^{-1}

Question 7 continues on the next page

Turn over ►



Enthalpies of lattice formation can be calculated from experimental data using a Born–Haber cycle or calculated using the perfect ionic model.

0 7 . 4 State **one** assumption made when using the perfect ionic model.

[1 mark]

Table 3 shows data for some enthalpies of lattice formation.

Table 3

Compound	Enthalpy of lattice formation / kJ mol^{-1}	
	from Born–Haber cycle	using perfect ionic model
Magnesium iodide	–2328	–1943
Barium iodide	–1878	–1830

0 7 . 5 **Table 3** includes enthalpy of lattice formation data obtained using the perfect ionic model.

The value calculated using the perfect ionic model for magnesium iodide is more negative than the value calculated using the perfect ionic model for barium iodide.

Suggest why.

[2 marks]

0 7 . 6 In **Table 3**, the two values for barium iodide are similar but the two values for magnesium iodide are very different.

Suggest why the values for magnesium iodide are very different.

[1 mark]



0 7 . 7

Anhydrous magnesium iodide dissolves in water as shown.

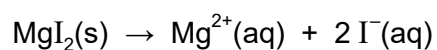


Table 4 shows some enthalpy change data.

Table 4

	$\Delta H / \text{kJ mol}^{-1}$
Enthalpy of lattice formation of $\text{MgI}_2(\text{s})$	−2328
Hydration enthalpy of $\text{Mg}^{2+}(\text{g})$	−1920
Hydration enthalpy of $\text{I}^{-}(\text{g})$	−293

Use the data in **Table 4** to calculate the enthalpy of solution, in kJ mol^{-1} , of anhydrous magnesium iodide.

[2 marks]Enthalpy of solution _____ kJ mol^{-1}

12

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0 8

Tungsten metal (W) can be obtained by reducing tungsten(VI) oxide with carbon under certain conditions.

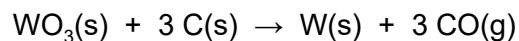


Table 5 shows some data for the substances in this reaction.

Table 5

	Enthalpy of formation ($\Delta_f H$) / kJ mol^{-1}	Entropy (S) / $\text{J K}^{-1} \text{mol}^{-1}$
WO₃(s)	−840	83.3
C(s)		5.70
W(s)		33.0
CO(g)	−111	198

0 8 . 1

Explain why $\Delta_f H$ data does **not** need to be given for C(s) or W(s).

[1 mark]

0 8 . 2

Use the data from **Table 5** and the expression $\Delta G = \Delta H - T\Delta S$ to calculate the temperature, in K, when this reaction becomes feasible.

[6 marks]

Temperature _____ K

Turn over ►



Tungsten(VI) oxide can also be reduced using hydrogen.

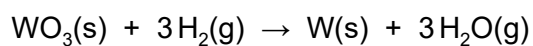


Table 6 shows the value of ΔG at different temperatures for this reaction.

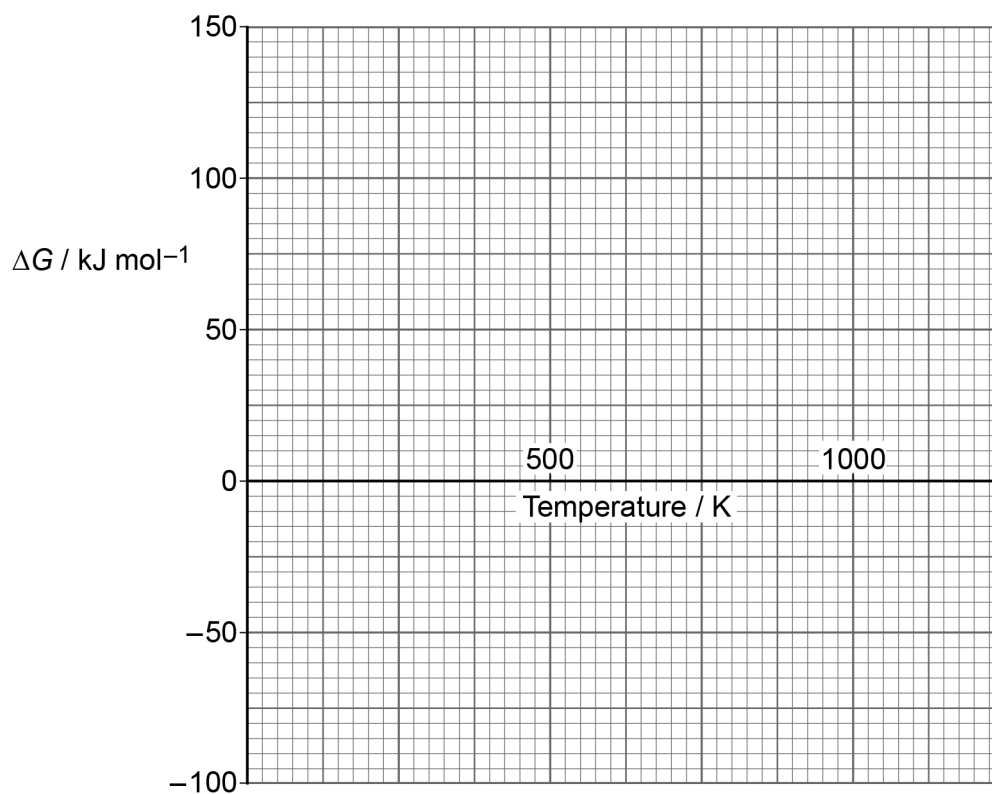
Table 6

Temperature / K	$\Delta G / \text{kJ mol}^{-1}$
500	50
750	18
1000	-15
1250	-45

0 8 . 3 Plot the data from **Table 6** on **Figure 5**.

[2 marks]

Figure 5



0	8	.	4
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Use the completed **Figure 5** to calculate the values of ΔH , in kJ mol^{-1} , and ΔS , in $\text{J K}^{-1} \text{mol}^{-1}$ for this reaction.

[3 marks]

ΔH _____ kJ mol^{-1}

ΔS _____ $\text{J K}^{-1} \text{mol}^{-1}$

12

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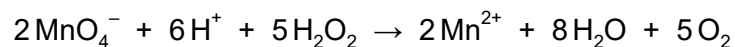


0	9
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This question is about the reaction between hydrogen peroxide and manganate(VII) ions.

0	9	.	1
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In acidic conditions, hydrogen peroxide reduces manganate(VII) ions to Mn^{2+} ions.



A 20.0 cm^3 sample of hydrogen peroxide is transferred to a 250 cm^3 volumetric flask.

The flask is then filled up to the mark using distilled water and shaken to mix the solution.

25.0 cm^3 of the diluted hydrogen peroxide solution are acidified and then titrated with $0.0200\text{ mol dm}^{-3}$ potassium manganate(VII) solution.

24.65 cm^3 of potassium manganate(VII) solution are required.

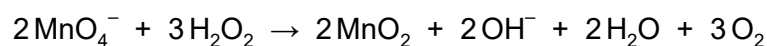
Calculate the concentration, in g dm^{-3} , of the original sample of hydrogen peroxide.

[5 marks]

Concentration of the original sample of hydrogen peroxide _____ g dm^{-3}



In alkaline conditions, hydrogen peroxide reduces manganate(VII) ions to MnO_2



0 9 . 2

The experiment in Question **09.1** is repeated in alkaline conditions. 24.65 cm^3 of $0.0200\text{ mol dm}^{-3}$ potassium manganate(VII) solution are used in acidic conditions.

Which volume of $0.0200\text{ mol dm}^{-3}$ potassium manganate(VII) solution is needed in alkaline conditions?

Tick (✓) **one** box.

[1 mark]

More than 24.65 cm^3

☐

Exactly 24.65 cm^3

☐

Less than 24.65 cm^3

☐

0 9 . 3

Deduce a half-equation for the reduction of aqueous MnO_4^- ions to MnO_2 in alkaline conditions.

[1 mark]

END OF QUESTIONS

7



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