OXFORD

INTERNATIONAL
AQA EXAMINATIONS

Please write clearly in block capitals.

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

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Candidate signature _____

I declare this is my own work.

INTERNATIONAL A-LEVEL

CHEMISTRY (9620)

Unit 3: Inorganic 2 and Physical 2

Wednesday 15 January 2020 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	

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

0 1 This question is about thermodynamics.

The equation for a reaction used to manufacture hydrogen is shown.

$$CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$$

Table 1 shows some data for this reaction.

Table 1

	Enthalpy of formation $\Delta_f H$ / kJ mol^{-1}	**Entropy S / J K^{-1} mol^{-1}**
$CH_4(g)$	–75	186
$H_2O(g)$	–242	189
$H_2(g)$	0	131
$CO(g)$	–111	214

0 1 . 1 Use data from **Table 1** to determine the enthalpy change, ΔH, in kJ mol^{-1}, for the reaction.

[2 marks]

ΔH _____ kJ mol^{-1}

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0 1 . 2 Use data from **Table 1** to determine the entropy change, ΔS, in $J\,K^{-1}\,mol^{-1}$, for the reaction.

[2 marks]

ΔS _____ $J\,K^{-1}\,mol^{-1}$

0 1 . 3 Use your answers to **Question 01.1** and **Question 01.2** to calculate the Gibbs free-energy change, ΔG, in $kJ\,mol^{-1}$, at 25 °C

State how your answer shows that this reaction is **not** feasible at 25 °C

(If you were unable to answer **Questions 01.1** or **01.2**, you should assume that the values are $\Delta H = +220\,kJ\,mol^{-1}$ and $\Delta S = +278\,J\,K^{-1}\,mol^{-1}$
These are **not** the correct values.)

[2 marks]

ΔG _____ $kJ\,mol^{-1}$

How answer shows reaction is not feasible

_____

_____

Do not write outside the box

0 1 . 4 Use your answers to **Question 01.1** and **Question 01.2** to determine the minimum temperature, in °C, at which this reaction is feasible.

(If you were unable to answer **Questions 01.1** or **01.2**, you should assume that the values are $\Delta H = +220\ \text{kJ mol}^{-1}$ and $\Delta S = +278\ \text{J K}^{-1}\ \text{mol}^{-1}$
These are **not** the correct values.)

[2 marks]

Temperature _____ °C

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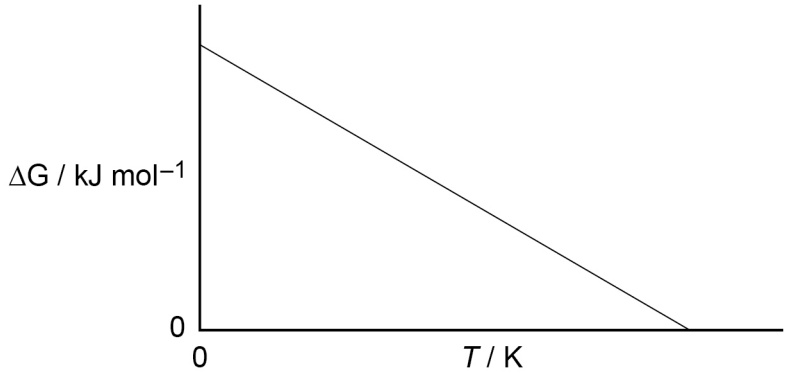
0 1 . 5 The graph shows how the free-energy change, ΔG, varies with temperature for a different reaction involving only gases.



Which of the following statements is correct about this graph?

[1 mark]

Tick (✓) **one** box.

There is a decrease in disorder during this reaction. ☐

The enthalpy change for this reaction is negative. ☐

The reaction becomes feasible at high temperature. ☐

9

Turn over for the next question

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0 2 This question is about compounds of silicon.

0 2 . 1 When chlorine gas is passed over a heated mixture of silicon dioxide and carbon, a reaction occurs to form silicon(IV) chloride and carbon monoxide.

Write an equation for this reaction.

[1 mark]

0 2 . 2 The melting points of two compounds of silicon are shown.

silicon dioxide	1713 °C
silicon(IV) chloride	–69 °C

Explain, in terms of structure and bonding, why silicon(IV) chloride has a lower melting point than silicon dioxide.

[4 marks]

5

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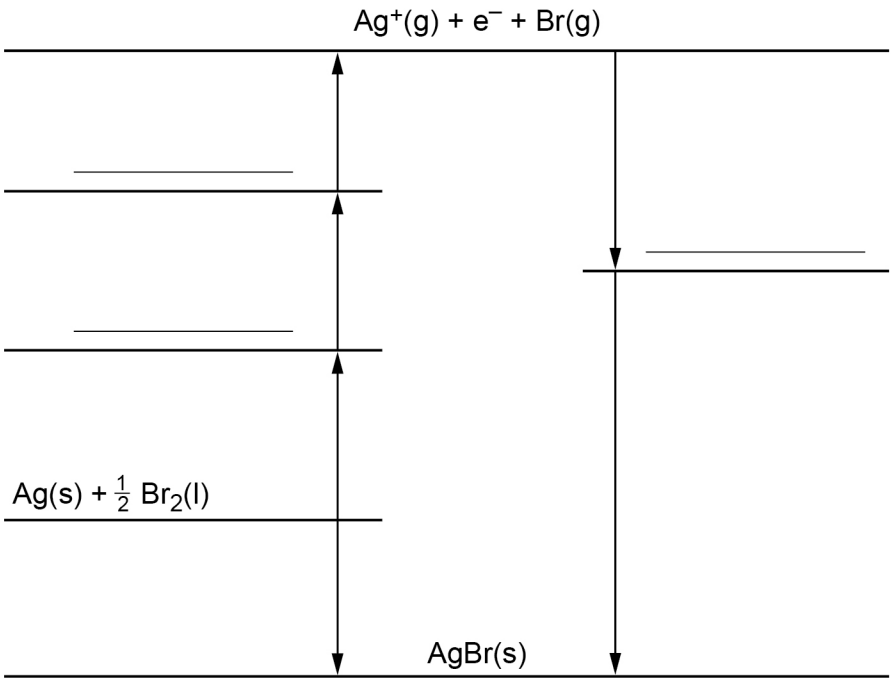
0 3 **Figure 1** shows an incomplete Born–Haber cycle for the formation of silver bromide, AgBr(s).

Figure 1



0 3 . 1 Complete **Figure 1** by writing the formulas, including state symbols, of the appropriate species on each of the three blank lines.

[3 marks]

Question 3 continues on the next page

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0 3 . 2 **Table 2** shows some enthalpy data.

Table 2

Enthalpy change	**ΔH / kJ mol^{-1}**
Atomisation of silver	+289
First ionisation energy of silver	+732
Atomisation of bromine	+112
Enthalpy of formation of silver bromide	–100
Lattice formation of silver bromide	–890

Calculate the electron affinity of bromine.

[2 marks]

Electron affinity _____ kJ mol^{-1}

0 3 . 3 In **Table 2**, the value of the enthalpy of lattice formation of silver bromide is an experimental value.
A theoretical value for the enthalpy of lattice formation can be calculated using a perfect ionic model.

Explain why the experimental value is more exothermic than the theoretical value.

[2 marks]

_____

_____

_____

_____

7

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Turn over for the next question

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0 4 Hydrated ammonium iron(II) sulfate has the formula $(NH_4)_2Fe(SO_4)_2.xH_2O$

The value of *x* in this formula can be calculated using results from this redox titration.

Method

- Dissolve a known mass of hydrated ammonium iron(II) sulfate in dilute sulfuric acid to make 250 cm^3 of solution.
- Titrate 25.0 cm^3 portions of this solution with a solution of potassium manganate(VII).

The half-equations for the reactions that occur during this titration are shown.

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

Results

Mass of hydrated ammonium iron(II) sulfate	8.37 g
Mean titre of potassium manganate(VII) solution	22.85 cm^3
Concentration of potassium manganate(VII) solution	0.0187 mol dm^{-3}

0 4 . 1 State the colour change at the end-point of the titration.

[1 mark]

Do not write outside the box

0 4 . 2 Use the results to calculate the relative formula mass of $(NH_4)_2Fe(SO_4)_2.xH_2O$

[4 marks]

Relative formula mass _____

0 4 . 3 Deduce the value of x in $(NH_4)_2Fe(SO_4)_2.xH_2O$

(If you were unable to calculate the relative formula mass in **Question 04.2**, you should use the value 356.0
This is **not** the correct value.)

[2 marks]

x _____

7

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0 5 This question is about some oxides and chlorides of Period 3 elements.

0 5 . 1 Sodium burns in air to form the oxide Na_2O

State **two** observations that could be made during this reaction.

[2 marks]

Observation 1 _____

_____

Observation 2 _____

_____

0 5 . 2 Aluminium reacts with chlorine to form the chloride Al_2Cl_6

Draw the structure of Al_2Cl_6
You should represent covalent bonds by a line (—) and co-ordinate bonds by an arrow (→).

[2 marks]

0 5 . 3 Write an equation for the reaction of PCl_5 with water.

[1 mark]

_____

Do not write outside the box

0 5 . 4 Write an equation for the reaction of P_4O_{10} with water.

Draw the structure of the acid formed.

[2 marks]

Equation

Structure

7

Turn over for the next question

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0 6 This question is about complexes containing transition metal ions.

0 6 . 1 The equation for a ligand substitution reaction in aqueous solution is shown.

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

Complete **Table 3** to show the features of each of the copper-containing species in this reaction.

[3 marks]

Table 3

Feature	**$[Cu(H_2O)_6]^{2+}$**	**$[CuCl_4]^{2-}$**
Colour		yellow-green
Shape	octahedral	
Oxidation state of copper	+2	

0 6 . 2 The equation for another ligand substitution reaction in aqueous solution is shown.

$$[Cu(H_2O)_6]^{2+} + EDTA^{4-} \rightarrow [Cu(EDTA)]^{2-} + 6\,H_2O$$

The enthalpy change for this reaction is very small.

Explain why $[Cu(EDTA)]^{2-}$ is more stable than $[Cu(H_2O)_6]^{2+}$

[2 marks]

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0 6 . 3 A solution containing $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ions appears deep blue when visible light passes through it.

Explain why it has a blue colour.

[3 marks]

0 6 . 4 A metal-aqua ion in aqueous solution has a concentration of approximately $0.3\ mol\ dm^{-3}$

Describe how a colorimeter can be used to measure the concentration of this solution accurately.

[3 marks]

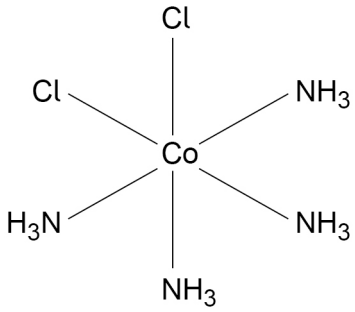
Question 6 continues on the next page

0 6 . 5 Many metal complexes exist as *cis-trans* isomers.

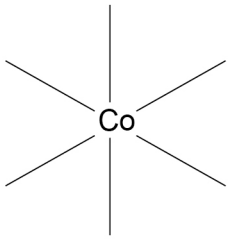
Complete the diagrams to show the missing ligands.

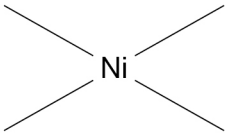
[2 marks]

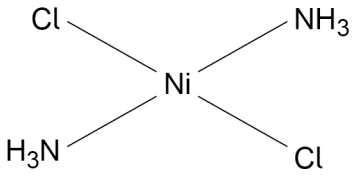
***Cis* isomer**



***Trans* isomer**







13

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0 7 This question is about Brønsted–Lowry acids and bases.

0 7 . 1 Phosphoric acid dissociates in three stages as shown.

$$H_3PO_4 \xrightarrow{\text{stage 1}} H_2PO_4^- \xrightarrow{\text{stage 2}} HPO_4^{2-} \xrightarrow{\text{stage 3}} PO_4^{3-}$$

Write equations to show how the HPO_4^{2-} ion can act either as an acid or as a base.

[2 marks]

As an acid

As a base

0 7 . 2 Chloric(VII) acid ($HClO_4$) is a strong acid.
An aqueous solution of this acid has a concentration of 1.57 mol dm^{-3}

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

[1 mark]

pH

Question 7 continues on the next page

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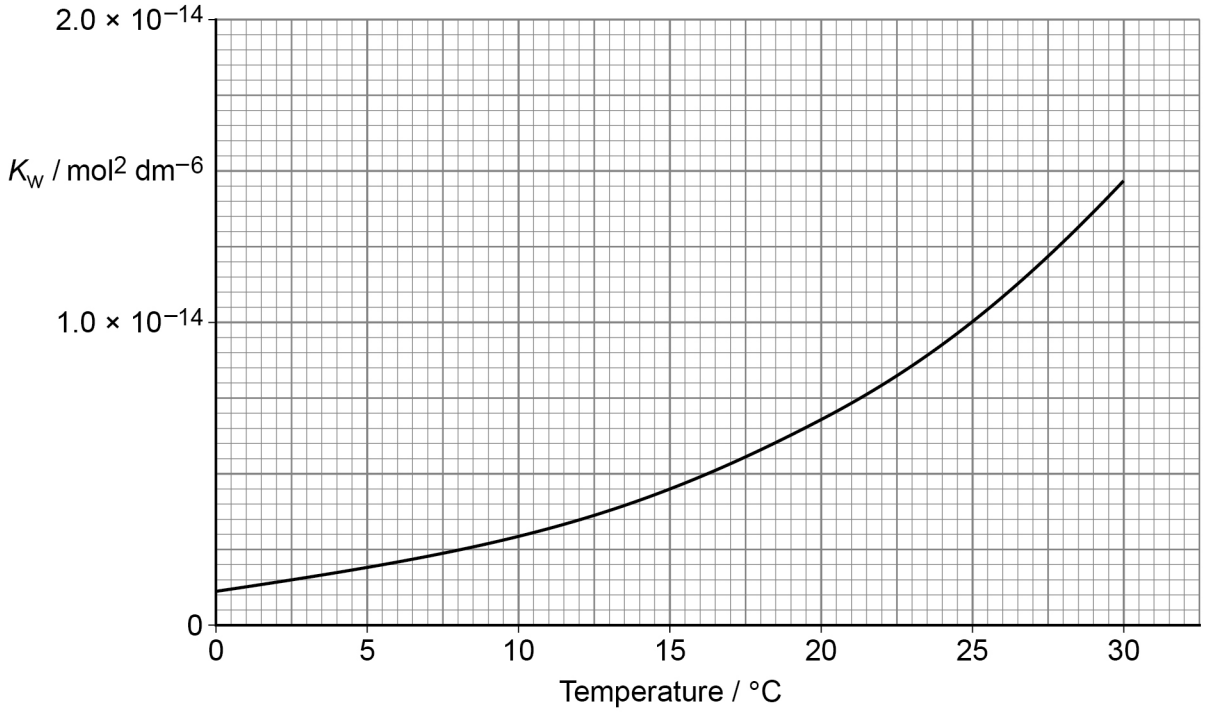
0 7 . 3 The value of the ionic product of water (K_w) varies with temperature as shown in **Figure 2**.

Figure 2



Use information from **Figure 2** and the expression for K_w to calculate the pH of water at 15 °C

Give your answer to two decimal places.

[3 marks].

pH_____

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0 7 . 4 Ethanoic acid is a weak acid with pK_a = 4.76 at 25 °C
An aqueous solution of ethanoic acid has a concentration of 0.83 mol dm^{-3}

Calculate the concentration, in mol dm^{-3}, of hydrogen ions in this solution at 25 °C
[3 marks]

Concentration of hydrogen ions _____ mol dm^{-3}

0 7 . 5 A student does a titration, using a suitable indicator, to determine the concentration of a solution of nitric acid.

Method

- Dissolve 7.02 g of hydrated sodium carbonate ($Na_2CO_3.10H_2O$) in water and make the solution up to 250 cm^3
- Titrate 25.0 cm^3 portions of this solution with the nitric acid solution.
- Calculate the mean titre of the nitric acid solution.

The equation for the reaction is shown.

$$Na_2CO_3 + 2\,HNO_3 \rightarrow 2\,NaNO_3 + H_2O + CO_2$$

The student's mean titre was 21.65 cm^3

Determine the concentration, in mol dm^{-3}, of the nitric acid solution.
[4 marks]

Concentration _____ mol dm^{-3}

13

Turn over ►

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0 8 This question is about solutions containing metal ions.

0 8 . 1 Explain why a solution containing $[Fe(H_2O)_6]^{3+}$ ions is more acidic than a solution containing $[Fe(H_2O)_6]^{2+}$ ions.

[2 marks]

A student adds some aqueous reagents, each in excess, to separate solutions containing metal-aqua ions.

Table 4 shows these tests and the observations recorded.

Table 4

Test	Metal-aqua ion	Reagent added to excess	Observations
1	$[Fe(H_2O)_6]^{2+}$	NaOH	green precipitate **X**
2	$[Al(H_2O)_6]^{3+}$	Na_2CO_3	white precipitate **Y**
3	$[Al(H_2O)_6]^{3+}$	NaOH	white precipitate that dissolves in excess NaOH to form a colourless solution **Z**
4	**M**	NH_3	brown precipitate

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0 8 . 2 Give the formulas of **X**, **Y** and **Z**.

[3 marks]

Green precipitate **X** _____

White precipitate **Y** _____

Colourless solution **Z** _____

0 8 . 3 Give **one** other observation that the student could make in Test **2**.

[1 mark]

_____

0 8 . 4 The student repeats Test **3**, but does **not** add an excess of aqueous NaOH
The student filters off the white precipitate and adds an excess of hydrochloric acid to the precipitate.

Write an equation for the reaction that occurs between the acid and the precipitate.

[1 mark]

_____

0 8 . 5 The white precipitate reacts with aqueous NaOH in Test **3** and reacts with hydrochloric acid in **Question 08.4**.

State the term used to describe this behaviour.

[1 mark]

_____

0 8 . 6 Give the formula of metal-aqua ion **M** in Test **4**.

[1 mark]

_____

9

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0 9 The equation for the reaction between two diatomic molecules is shown.

$$H_2(g) + X_2(g) \rightarrow 2\,HX(g)$$

The value of the rate constant, k, for this reaction varies with temperature.

Table 5 shows some data.

Table 5

T / K	$\frac{1}{T}$ / K^{-1}	k / $mol^{-1}\,dm^3\,s^{-1}$	ln k
568	1.76×10^{-3}	8.27×10^{-5}	–9.40
	1.60×10^{-3}	2.13×10^{-3}	–6.15
719	1.39×10^{-3}		–2.25
806	1.24×10^{-3}	1.82	0.60

0 9 . 1 Complete **Table 5.**

[2 marks]

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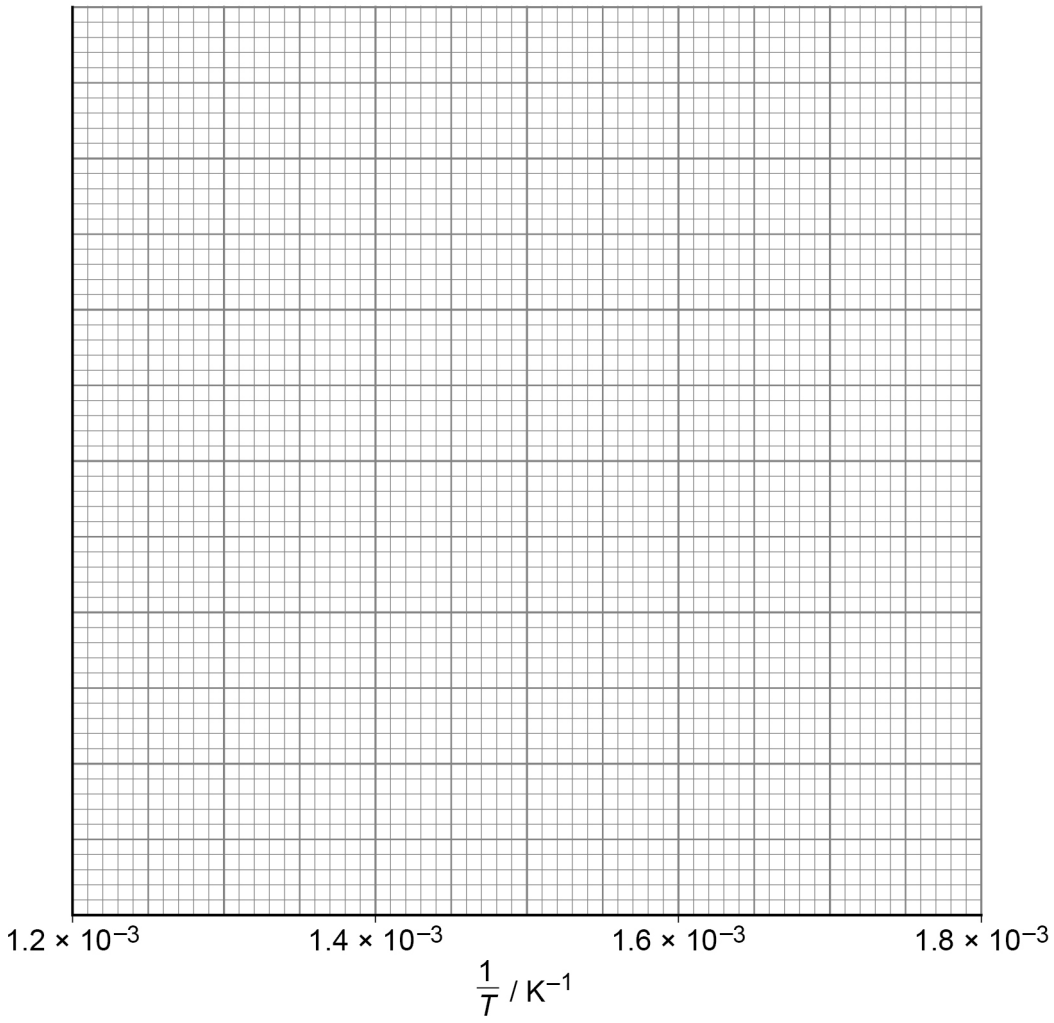
0 9 . 2 Draw a graph of ln k against $\frac{1}{T}$ on the grid.

[3 marks]



Question 9 continues on the next page

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0 9 . 3 The activation energy can be calculated using the equation

$$\ln k = \frac{-E_a}{RT} + \ln A$$

Use your graph from **Question 09.2** to calculate a value for the activation energy (E_a), in kJ mol^{-1}, for this reaction.

The gas constant, R = 8.31 J K^{-1} mol^{-1}

[2 marks]

Activation energy _____ kJ mol^{-1}

0 9 . 4 Use your graph from **Question 09.2** to determine a value for k at 675 K

[3 marks]

k _____ mol^{-1} dm^3 s^{-1}

10

END OF QUESTIONS

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