OXFORD

INTERNATIONAL AQA EXAMINATIONS

Please write clearly in block capitals.

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

Surname _____

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Candidate signature _____

INTERNATIONAL A-LEVEL
CHEMISTRY (9620)

Unit 3: Inorganic 2 and Physical 2

Wednesday 6 June 2018 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.
- 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	
TOTAL	

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ANSWER IN THE SPACES PROVIDED

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

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0 1 One of the characteristics of transition metals is that they form complexes.

0 1 . 1 A solution contains aqueous copper(II) ions.
When an excess of chloride ions is added to this solution, a reaction occurs in which there is a change in the co-ordination number of the copper ion.

- Write an equation for the reaction.
- State the type of reaction occurring.
- State the name of the shape of the complex ion formed.
- Give a reason for the change in co-ordination number.

[4 marks]

Equation _____

Type of reaction _____

_____

Name of the shape of the complex ion _____

Reason for change in co-ordination number _____

_____

0 1 . 2 Explain why transition metal complexes are coloured.

[3 marks]

_____

_____

_____

_____

_____

_____

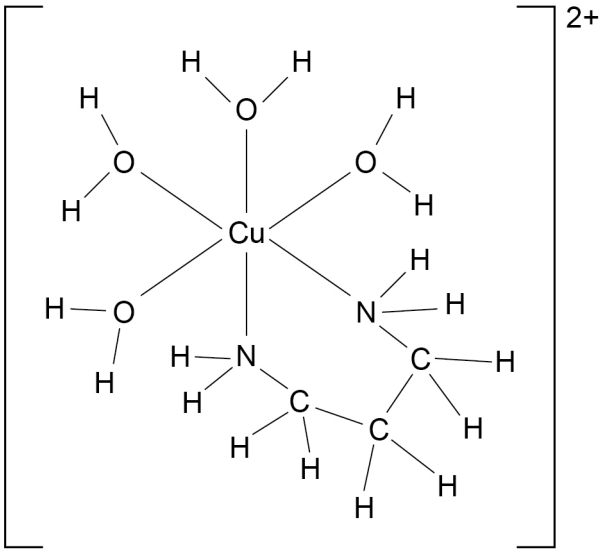
Do not write outside the box

0 1 . 3 State why there is often a colour change when there is a change in ligand in a reaction involving a complex.

[1 mark]

Figure 1 shows the structure of a complex ion of copper.

Figure 1



0 1 . 4 State the co-ordination number of copper in the complex ion shown in **Figure 1**.

[1 mark]

Do not write outside the box

0 1 . 5 Name the species that acts as a bidentate ligand in the complex ion shown in **Figure 1**.

State how this species can act as a bidentate ligand.

[2 marks]

Name _____

How species acts as a bidentate ligand _____

_____

_____

0 1 . 6 Identify a reagent that could be used in a test to show that $[Fe(H_2O)_6]^{3+}$ is a better proton donor than $[Fe(H_2O)_6]^{2+}$

Describe the expected result of your test.

[2 marks]

Reagent _____

_____

Observations _____

_____

_____

_____

13

Turn over for the next question

Do not write outside the box

0 2 This question is about some Period 3 oxides and chlorides.

0 2 . 1 Suggest why silicon dioxide can be described as an acidic oxide even though it is insoluble in water.

[1 mark]

Table 1 shows the melting points of some Period 3 oxides.

Table 1

	Na_2O	SO_2	SO_3
Melting point / K	1548	200	290

0 2 . 2 Explain, in terms of structure and bonding, why sodium oxide has a high melting point.

[3 marks]

0 2 . 3 Explain why sulfur trioxide has a higher melting point than sulfur dioxide.

[2 marks]

Do not write outside the box

A small amount of each of the Period 3 chlorides NaCl, $MgCl_2$, $AlCl_3$ and PCl_5 is added to separate samples of deionised water.

The pH values of the resulting solutions are measured.

0 2 . 4 State why NaCl forms a neutral solution.

[1 mark]

Both $AlCl_3$ and PCl_5 form acidic solutions.

0 2 . 5 The equation for the reaction of $AlCl_3$ with water is

$$AlCl_3 + 6H_2O \rightarrow [Al(H_2O)_6]^{3+} + 3Cl^-$$

Explain why the solution formed is acidic. Use an equation in your answer.

[2 marks]

0 2 . 6 Identify the **two** acids formed when PCl_5 reacts with water.

[1 mark]

10

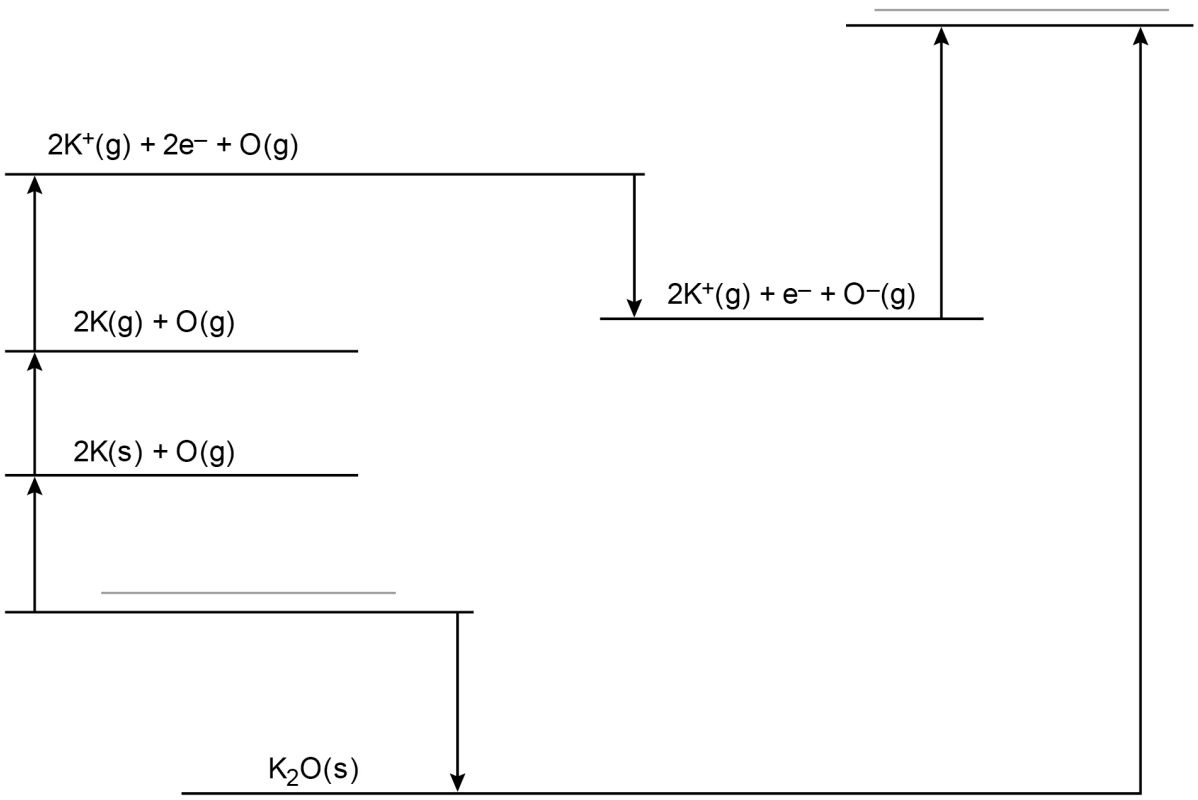
Do not write outside the box

0 3 Born–Haber cycles can be used to show the enthalpy changes involved in the formation of an ionic compound.

Figure 2 shows an incomplete Born–Haber cycle for the formation of potassium oxide (K_2O).

The Born–Haber cycle is not to scale.

Figure 2



0 3 . 1 Complete **Figure 2** by writing the formulae, including state symbols, of the appropriate species on each of the two blank lines.

[2 marks]

Do not write outside the box

Table 2 shows the enthalpy changes involved in the formation of potassium oxide.

Table 2

Enthalpy change	**ΔH/kJ mol^{-1}**
Enthalpy of atomisation of potassium	+90
Enthalpy of formation of potassium oxide	–362
Enthalpy of atomisation of oxygen	+248
First electron affinity of oxygen	–142
First ionisation energy of potassium	+418
Second electron affinity of oxygen	+844

0 3 . 2 Give the meaning of the term enthalpy of atomisation.

[2 marks]

_____

_____

_____

_____

0 3 . 3 Suggest why the second electron affinity of oxygen is endothermic.

[1 mark]

_____

0 3 . 4 Use the data in **Table 2** to calculate the enthalpy of lattice dissociation of potassium oxide.

[3 marks]

enthalpy of lattice dissociation = _____ kJ mol^{-1}

Turn over ►

Do not write outside the box

0 3 . 5 A theoretical value for the enthalpy of lattice dissociation can be calculated using a perfect ionic model.

The theoretical enthalpy of lattice dissociation for silver fluoride is +870 kJ mol^{-1}

Explain why the theoretical enthalpy of lattice dissociation for silver fluoride is different from the experimental value calculated using a Born–Haber cycle.

[2 marks]

0 3 . 6 The theoretical enthalpy of lattice dissociation for silver chloride is +770 kJ mol^{-1}

Explain why this value is less than the value for silver fluoride.

[2 marks]

12

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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0 4 Ethyne gas (C_2H_2) is manufactured from methane in a reversible reaction.

$$2CH_4(g) \rightleftharpoons C_2H_2(g) + 3H_2(g) \quad \Delta H = +377 \text{ kJ mol}^{-1}$$

0 4 . 1 What is the effect of increasing the pressure on the equilibrium yield of ethyne and on the equilibrium constant (K_p) for this reaction?

[1 mark]

Tick (✓) **one** box.

	Yield of ethyne	**Value of K_p**	
A	decreases	increases	☐
B	decreases	stays the same	☐
C	increases	decreases	☐
D	increases	stays the same	☐

0 4 . 2 Write an expression for K_p for the manufacture of ethyne from methane.

[1 mark]

K_p

Do not write outside the box

0 4 . 3 At a given temperature a sealed flask contains an equilibrium mixture of 0.10 mol of methane, 0.18 mol of ethyne and 0.52 mol of hydrogen. The pressure in the flask at equilibrium is 500 kPa

Calculate the value of K_p under these conditions.
Give your answer to three significant figures.

State the units of K_p

[4 marks]

K_p _____ Units _____

6

Turn over for the next question

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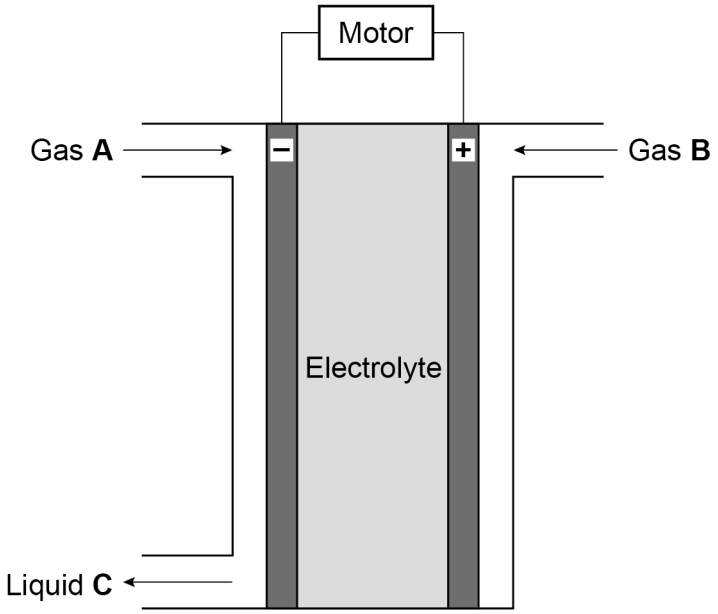
0 5 **Figure 3** represents an alkaline fuel cell.

Figure 3



0 5 . 1 Give **two** reasons why it is **not** correct to describe the cell in **Figure 3** as a rechargeable cell.

[2 marks]

1 _____

_____

2 _____

_____

0 5 . 2 Gas **B** is oxygen.

Identify Gas **A** and Liquid **C**.

[2 marks]

Gas **A** _____

Liquid **C** _____

Do not write outside the box

0 5 . 3 It would be cheaper to use air instead of pure oxygen. One disadvantage of using air is that the carbon dioxide in the air would react with the electrolyte and decrease the life of the cell.

Complete the equation for the reaction between carbon dioxide and the electrolyte, KOH

[1 mark]

$CO_2 + 2KOH \rightarrow$ _____ + _____

0 5 . 4 An equation for the reaction at the positive electrode is

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

Write an equation for the reaction at the negative electrode.

[1 mark]

_____

0 5 . 5 Use the **two** equations in Question **05.4** to deduce an overall equation for the fuel cell.

[1 mark]

_____

7

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0 6 The combustion of glucose to form carbon dioxide and water can be represented by the equation

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

This reaction is exothermic.

0 6 . 1 Explain why the entropy change, ΔS, for this reaction is positive.

[1 mark]

_____

_____

0 6 . 2 The combustion of glucose is feasible at all temperatures.

Suggest a reason why glucose does **not** spontaneously combust when added to gaseous oxygen at room temperature.

[1 mark]

_____

_____

Question 6 continues on the next page

Do not write outside the box

Methane reacts with steam according to the equation

$$CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g) \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$

The entropy change, ΔS, for the reaction is +216 J K^{-1} mol^{-1}

Some entropy values are shown in **Table 3**.

Table 3

Substance	**$CH_4(g)$**	**$H_2O(g)$**	**$CO(g)$**
Entropy/J K^{-1} mol^{-1}	186	189	198

0 6 . 3 Calculate the entropy, S, in J K^{-1} mol^{-1} of hydrogen gas.

[2 marks]

Entropy _____ J K^{-1} mol^{-1}

0 6 . 4 Calculate the Gibbs free-energy change, ΔG, for the reaction of methane with steam at 150 °C

Give units for your answer.

[3 marks]

ΔG _____ units _____

Do not write outside the box

0 6 . 5 Use your answer to Question **06.4** to explain whether the reaction is feasible at 150 °C

[1 mark]

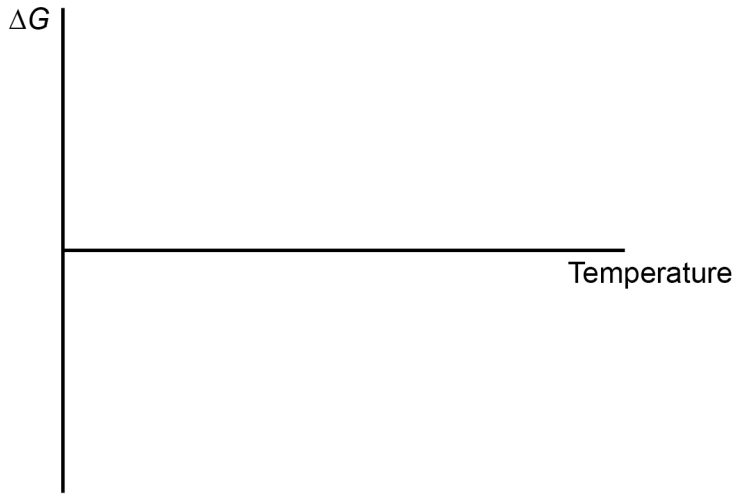
_____

_____

0 6 . 6 Draw a line on **Figure 4** to show how ΔG for the reaction of methane with steam varies with temperature.

[1 mark]

Figure 4



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0 7 Hydrated ammonium iron(III) sulfate has the formula $NH_4Fe(SO_4)_2.xH_2O$

0 7 . 1 Describe **two** simple test-tube reactions that could be used to identify the three ions contained in a solution of ammonium iron(III) sulfate.

Give the expected observations.

[5 marks]

Test tube reaction 1 _____

Observation(s) _____

_____

_____

Test tube reaction 2 _____

Observation(s) _____

_____

_____

Question 7 continues on the next page

Do not write outside the box

A sample of hydrated ammonium iron(III) sulfate was analysed to determine the value of *x* in the formula.

Step 1
4.82 g of hydrated ammonium iron(III) sulfate were dissolved in 100 cm^3 of water.
An excess of zinc was added to the solution.
The iron(III) ions were reduced according to the equation

$$2Fe^{3+}(aq) + Zn(s) \rightarrow 2Fe^{2+}(aq) + Zn^{2+}(aq)$$

Step 2
The excess zinc was removed from the solution and the volume made up to 250 cm^3 with distilled water.

Step 3
25.0 cm^3 of the solution were acidified and titrated with
0.0151 mol dm^{-3} potassium manganate(VII) solution.
13.25 cm^3 of the potassium manganate(VII) solution were needed to oxidise the iron(II) ions.
The equation for the reaction that occurred is

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

0 7 . 2 Name a compound that is added to provide the H^+ ions in **Step 3**.

[1 mark]

_____

0 7 . 3 State the colour change that occurs at the end point of this titration.

Give a reason for the colour change.

[2 marks]

Colour change _____

Reason _____

_____

_____

Do not write outside the box

0 7 . 4 Calculate the relative formula mass of $NH_4Fe(SO_4)_2.xH_2O$ and the value of x.

[5 marks]

relative formula mass _____

value of x _____

13

Turn over for the next question

Do not write outside the box

0 8 Ozone reacts with nitrogen dioxide

$$O_3(g) + 2NO_2(g) \rightarrow N_2O_5(g) + O_2(g)$$

The rate equation for the reaction is

$$rate = k[O_3][NO_2]$$

The rate of the reaction was investigated.
The data from one experiment are shown in **Table 4**.

Table 4

Initial $[O_3]$ / mol dm^{-3}	**Initial $[NO_2]$ / mol dm^{-3}**	**Initial rate / mol dm^{-3} s^{-1}**
3.0×10^{-4}	2.0×10^{-3}	4.0×10^{-9}

0 8 . 1 Suggest why it is **not** possible to confirm the rate equation for this reaction using the data shown in **Table 4**.

[1 mark]

0 8 . 2 Suggest **two** additional experiments in this investigation needed to confirm the rate equation.

[1 mark]

Do not write outside the box

0 8 . 3 Suggest a two-step mechanism for the reaction of ozone with nitrogen dioxide in which the first step is the rate determining step.

[2 marks]

First step _____

_____

Second step _____

_____

Question 8 continues on the next page

Do not write outside the box

The effect of temperature on the value of the rate constant for a different reaction was investigated. The data obtained are shown in **Table 5**.

Table 5

Experiment	Temperature, T / K	Rate constant, k / mol^{-2} dm^{6} s^{-1}	$1 / T$ / K^{-1}	ln k
1	293	1.00×10^{-6}	3.41×10^{-3}	–13.8
2	313	4.40×10^{-6}	3.19×10^{-3}	–12.3
3	335	1.92×10^{-5}	2.99×10^{-3}	–10.9
4	350	6.20×10^{-5}	2.86×10^{-3}	–9.69
5	370	2.20×10^{-4}	2.70×10^{-3}	–8.42

0 8 . 4 Use the units of the rate constant in **Table 5** to deduce the overall order of this reaction.

[1 mark]

_____

_____

overall order _____

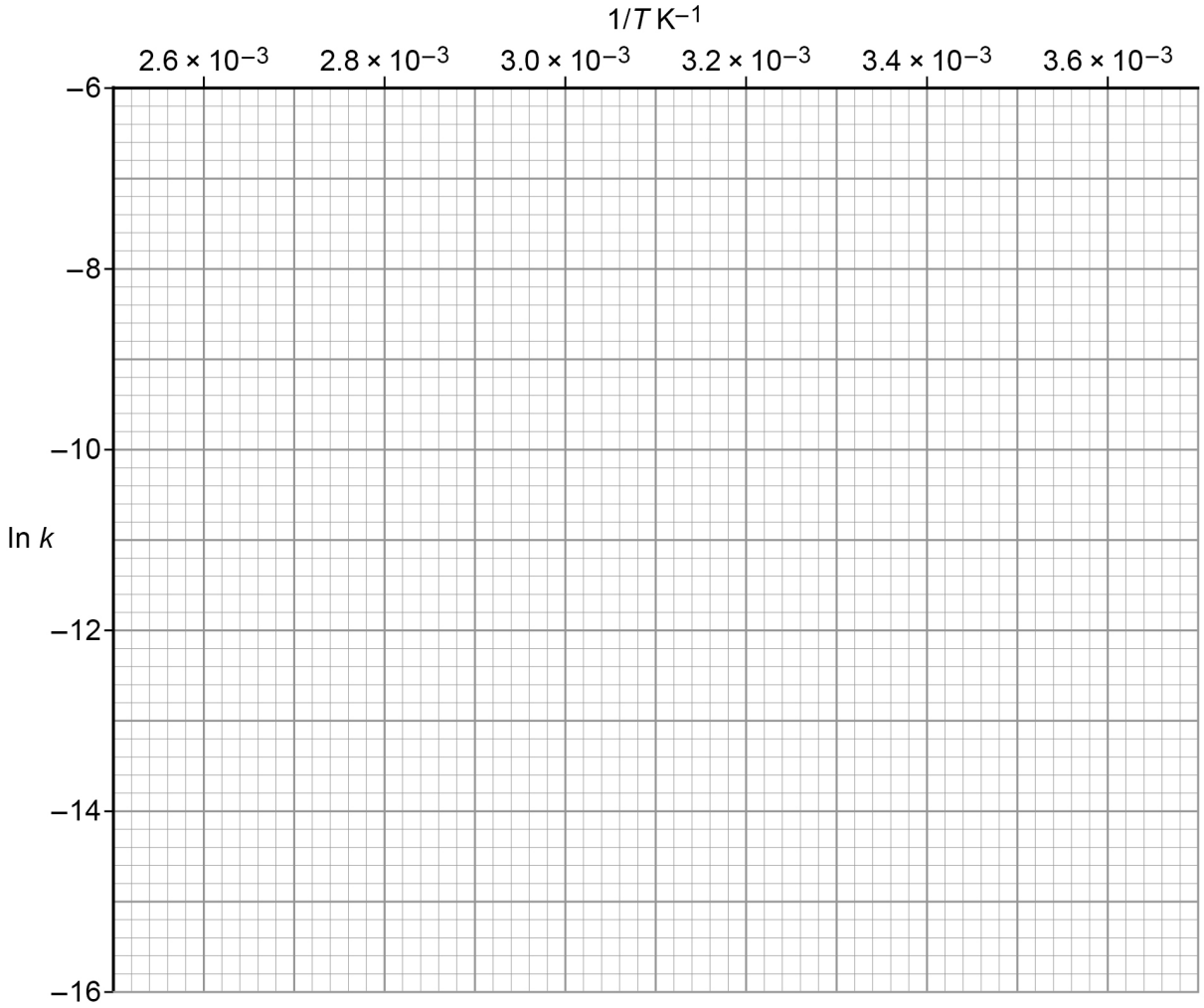
Do not write outside the box

0 8 . 5 Plot a graph of ln k against $1/T$ using the axes provided.

Draw a line of best fit and determine its gradient.

[3 marks]

Figure 5



Gradient = _____ K

Question 8 continues on the next page

Do not write outside the box

0 8 . 6 The rate constant, k, is related to the temperature, T, as shown in the equation

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

Use the equation and the gradient of your graph in Question **08.5** to calculate the value in kJ mol^{-1} for the activation energy, E_a, of the reaction.

The value of the gas constant, R, is 8.31 J K^{-1} mol^{-1}

(If you were unable to answer Question **08.5** you should use the value –4500 kJ mol^{-1} This is **not** the correct answer.)

[2 marks]

Activation energy _____ kJ mol^{-1}

10

END OF QUESTIONS

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