OXFORD
INTERNATIONAL
AQA EXAMINATIONS

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INTERNATIONAL A-LEVEL
CHEMISTRY (9620)

Unit 3: Inorganic 2 and Physical 2

Tuesday 4 June 2019 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. Use pencil only for drawing.
- 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.
- 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).
- 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 **all** questions in the spaces provided.

0 1 This question is about two metal iodides.

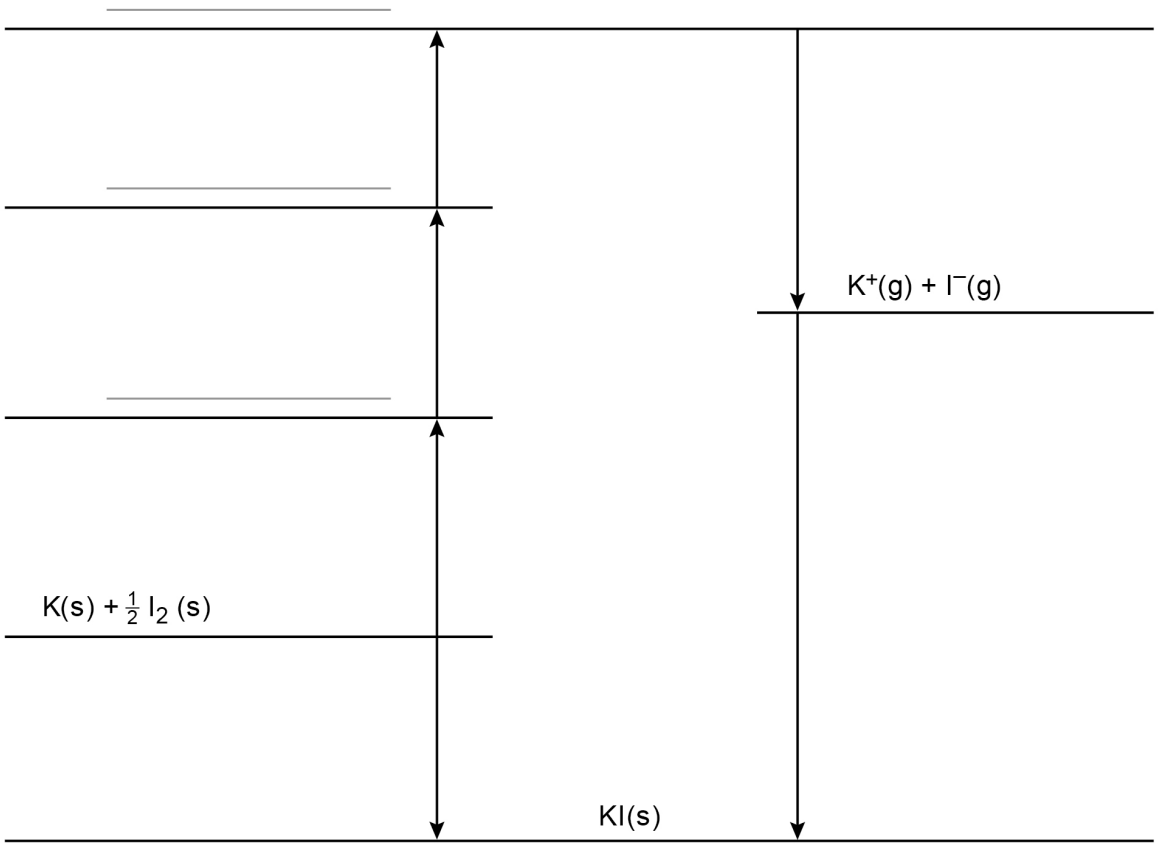
Table 1 shows some thermodynamic data.

Table 1

Enthalpy change	**$\Delta H^{\ominus}$ / kJ mol^{-1}**
Atomisation of potassium	+90
First ionisation energy of potassium	+418
Atomisation of iodine	+107
Electron affinity of iodine	–314
Lattice formation of potassium iodide	–629

Figure 1 shows an incomplete Born–Haber cycle for the formation of potassium iodide.

Figure 1



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0 1 . 1 State how **Figure 1** shows that the cycle is for the enthalpy of lattice formation, **not** the enthalpy of lattice dissociation.

[1 mark]

_____

_____

0 1 . 2 Complete **Figure 1** by writing the missing symbols for the species on the appropriate energy levels.

[3 marks]

0 1 . 3 Use **Figure 1** and the data in **Table 1** to calculate a value for the enthalpy of formation of potassium iodide.

[2 marks]

Enthalpy of formation _____ kJ mol^{-1}

Question 1 continues on the next page

Do not write outside the box

0 1 . 4 The value obtained in Question **01.3** is based on experimental data and using a Born–Haber cycle.

Enthalpies of lattice formation can also be determined by calculation using a perfect ionic model.

Table 2 shows the enthalpies of lattice formation for potassium iodide and silver iodide.

Table 2

Enthalpy change	**$\Delta H^{\ominus}$ / kJ mol^{-1}**	
	Born–Haber cycle	**Perfect ionic model**
Lattice formation of potassium iodide	–629	–632
Lattice formation of silver iodide	–876	–736

State what can be deduced about the bonding in each compound from the data in **Table 2**

[2 marks]

Potassium iodide _____

_____

_____

Silver iodide _____

_____

_____

Do not write outside the box

0 1 . 5 **Table 3** shows some thermodynamic data.

Table 3

Enthalpy change	**$\Delta H^{\ominus}$ / kJ mol^{-1}**
Hydration of K^+ (g)	–322
Hydration of I^- (g)	–293
Lattice formation of KI (s)	–629

Use the data in **Table 3** to calculate the enthalpy of solution of potassium iodide.

[2 marks]

Enthalpy of solution _____ kJ mol^{-1}

10

Turn over for the next question

Do not write outside the box

There are no questions printed on this page

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ANSWER IN THE SPACES PROVIDED

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0 2 Methanol is made in industry as shown.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \qquad \Delta H = -49 \text{ kJ mol}^{-1}$$

0 2 . 1 State why a higher equilibrium yield of methanol is obtained at a lower temperature.

[1 mark]

_____

_____

_____

0 2 . 2 Predict whether a high or low pressure increases the equilibrium yield of methanol. Give a reason for your prediction.

[2 marks]

Prediction _____

Reason _____

_____

_____

0 2 . 3 A catalyst is used in this industrial reaction.

What happens if a catalyst is **not** used?

Tick (✓) **one** box.

[1 mark]

The position of equilibrium will shift to the right. ☐

The value of enthalpy change will stay the same. ☐

The yield of methanol at equilibrium will decrease. ☐

Do not write outside the box

0 2 . 4 A mixture of 15.0 mol of carbon dioxide and 45.0 mol of hydrogen is heated in a container. At equilibrium, the mixture contains 6.3 mol of steam.

Calculate the amount, in moles, of each of the other substances in the equilibrium mixture.

$$CO_2(g) + 3\,H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

[3 marks]

Amount of $CH_3OH(g)$ _____ mol

Amount of $CO_2(g)$ _____ mol

Amount of $H_2(g)$ _____ mol

0 2 . 5 **Table 4** shows the amount, in moles, of each substance in the equilibrium mixture at a different temperature and at a total pressure of 2.50×10^6 Pa

Table 4

Substance	$CO_2(g)$	$H_2(g)$	$CH_3OH(g)$	$H_2O(g)$
Amount / mol	4.9	7.6	19.4	13.7

Calculate the partial pressure of methanol in this equilibrium mixture.

[2 marks]

Partial pressure of methanol _____ Pa

Do not write outside the box

0 2 . 6 Write an expression for the equilibrium constant (K_p) for this reaction.

[1 mark]

K_p

0 2 . 7 **Table 5** shows the partial pressures, in Pa, of each substance in another equilibrium mixture.

Table 5

Substance	$CO_2(g)$	$H_2(g)$	$CH_3OH(g)$	$H_2O(g)$
Partial pressure / Pa	1.68×10^6	2.64×10^6	8.34×10^6	1.76×10^6

Use the data in **Table 5** to calculate the value of K_p
Deduce the units of K_p

[2 marks]

K_p _____ units _____

12

Turn over for the next question

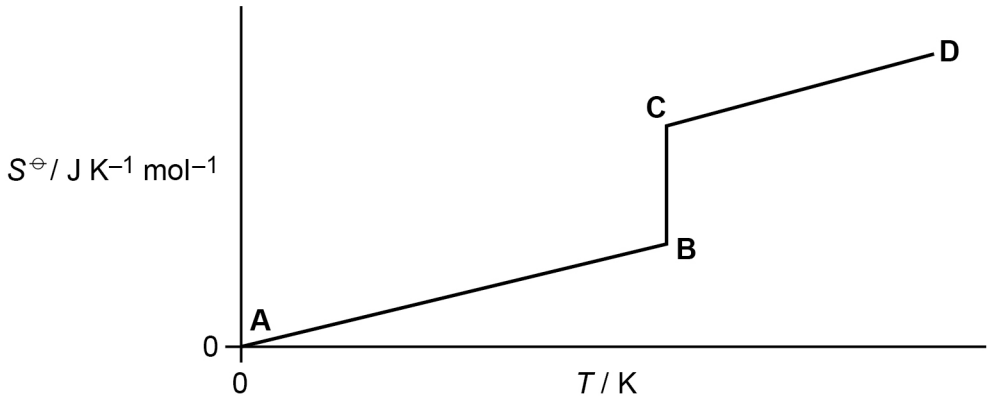
Do not write outside the box

0 3 Carbon dioxide changes directly from a solid to a gas at atmospheric pressure.

$CO_2(s) \rightarrow CO_2(g)$ $\Delta H^{\ominus} = +25\ kJ\ mol^{-1}$ $\Delta S^{\ominus} = +163\ J\ K^{-1}\ mol^{-1}$

Figure 2 shows how the entropy of carbon dioxide changes with temperature.

Figure 2



0 3 . 1 State why the value of $\Delta H^{\ominus}$ is positive for the change of state of carbon dioxide from solid to gas.

[1 mark]

_____

_____

0 3 . 2 State why carbon dioxide has zero entropy at a temperature of 0 K

[1 mark]

_____

_____

Do not write outside the box

0 3 . 3 Describe how the movement of the molecules changes during the three stages shown on **Figure 2**

[3 marks]

A to **B** _____

_____

B to **C** _____

_____

C to **D** _____

_____

0 3 . 4 Calculate the temperature, in K, at which the Gibbs free-energy change, ΔG, has a value of zero for the change of state of carbon dioxide from solid to gas.

[2 marks]

Temperature _____ K

7

Turn over for the next question

Do not write outside the box

0 4 This question is about determining a rate equation and an activation energy from experimental data.

The reaction between compounds **E** and **F** was investigated.

The data in **Table 6** were obtained in three experiments at a constant temperature.

Table 6

Experiment	Initial [E] / mol dm^{-3}	Initial [F] / mol dm^{-3}	Initial rate / mol dm^{-3} min^{-1}
1	1.3×10^{-2}	2.8×10^{-2}	3.2×10^{-3}
2	3.9×10^{-2}	2.8×10^{-2}	9.6×10^{-3}
3	3.9×10^{-2}	1.4×10^{-2}	2.4×10^{-3}

0 4 . 1 Use the data in **Table 6** to deduce the order of reaction with respect to **E** and the order of reaction with respect to **F**.

Determine the rate equation for this reaction.
Show your working.

[3 marks]

Order with respect to **E** _____

Order with respect to **F** _____

Rate equation _____

Do not write outside the box

0 4 . 2 Use data from **Table 6** to calculate a value for the rate constant (k), including units, for the reaction between **E** and **F**.

(If you were unable to determine a rate equation in Question **04.1**, you should assume that the equation is $rate = k[\mathbf{E}]^2[\mathbf{F}]^2$. This is not the correct equation.)

[2 marks]

k _____ units _____

Compound **G** decomposes on heating in a first order reaction.

The decomposition of **G** in a given volume of solution is investigated.

0 4 . 3 State why the rate of reaction doubles when the concentration of **G** doubles at a constant temperature.

[1 mark]

_____

_____

_____

0 4 . 4 Explain why the rate of reaction more than doubles when the temperature is increased by 20 °C at a constant concentration.

[2 marks]

_____

_____

_____

_____

_____

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0 4 . 5 The Arrhenius equation can be used to determine the activation energy (E_a) for the decomposition of **G**.

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

The rate constant for the decomposition of **G**, $k = 0.273\ \text{min}^{-1}$ at 400 K
The Arrhenius constant, $A = 3.27 \times 10^8\ \text{min}^{-1}$
The gas constant, $R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$

Use these data to determine a value for E_a (in kJ mol^{-1}) for the decomposition at 400 K

[3 marks]

E_a _____ kJ mol^{-1}

11

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Turn over for the next question

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0 5 At high temperatures, aluminium chloride exists as gaseous $AlCl_3$ molecules. On cooling, two molecules of $AlCl_3$ combine to form one molecule of Al_2Cl_6

0 5 . 1 Name the shape formed by the atoms in an $AlCl_3$ molecule.

State the bond angle in $AlCl_3$

[2 marks]

Name of shape _____

Bond angle _____

0 5 . 2 Co-ordinate bonds form when two $AlCl_3$ molecules combine together.

State how one of these bonds forms.

[1 mark]

_____

_____

0 5 . 3 Draw the structure of an Al_2Cl_6 molecule.
Show each covalent bond as a line (—) and each co-ordinate bond as an arrow (→).

[2 marks]

Do not write outside the box

0 5 . 4 Some anhydrous aluminium chloride is added to an excess of water.

Describe what is observed.
Write an equation for the reaction that occurs.
Suggest a possible value for the pH of the solution.

[3 marks]

Observation _____

_____

Equation

_____

pH of solution _____

0 5 . 5 A student added an excess of sodium carbonate solution to aluminium chloride solution.

State **two** observations the student would make.
Give an equation for the reaction that occurs.

[3 marks]

Observation 1 _____

_____

Observation 2 _____

_____

Equation

_____

11

Turn over for the next question

Do not write outside the box

0 6 **Table 7** shows the melting points of some Period 3 chlorides.

Table 7

	$MgCl_2$	$SiCl_4$
Melting point / K	987	204

Use your knowledge of structure and bonding to answer Questions **06.1** and **06.2**

0 6 . 1 Explain why magnesium chloride has a high melting point.

[2 marks]

0 6 . 2 Explain why silicon(IV) chloride has a low melting point.

[2 marks]

0 6 . 3 Both silicon(IV) chloride and phosphorus(V) chloride react with water to form a solution containing hydrochloric acid.

Write an equation for each reaction.

[2 marks]

Equation for silicon(IV) chloride reaction

Equation for phosphorus(V) chloride reaction

6

Do not write outside the box

0 7 This question is about properties of transition metal compounds.

0 7 . 1 Transition metal complexes can change colour when the oxidation state changes.

Give **two** other factors that can cause a change in the colour of a transition metal complex.

[2 marks]

1 _____

_____

2 _____

_____

0 7 . 2 The equation for the reaction that occurs in the Contact process is shown.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

Write **two** equations to show how vanadium(V) oxide acts as a catalyst in this reaction.
Give the change in oxidation state of vanadium in equation **2**.

[2 marks]

Equation 1

_____

Equation 2

_____

Change in oxidation state _____

Question 7 continues on the next page

Do not write outside the box

0 7 . 3 Vanadium(V) oxide is a heterogeneous catalyst.

Give the meaning of the term heterogeneous.

Suggest how the effect of a heterogeneous catalyst can be increased without using a higher temperature.

[2 marks]

Meaning of heterogeneous _____

_____

How the effect can be increased _____

_____

0 7 . 4 Iodide ions react slowly with peroxodisulfate ions ($S_2O_8^{2-}$) in aqueous solution as shown.

$$S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2$$

This reaction can be catalysed by adding an aqueous solution containing Fe^{2+} ions.

Explain, with the aid of equations, how Fe^{2+} ions catalyse the reaction between I^- ions and $S_2O_8^{2-}$ ions.

[4 marks]

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

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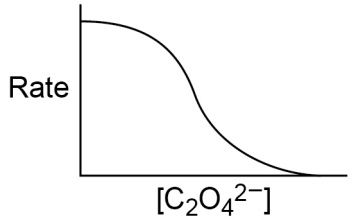
0 7 . 5 The overall equation for the oxidation of ethanedioate ions by manganate(VII) ions is shown.

$$2\,MnO_4^- + 16\,H^+ + 5\,C_2O_4^{2-} \rightarrow 2\,Mn^{2+} + 8\,H_2O + 10\,CO_2$$

This reaction is an example of autocatalysis.

Which graph represents the change that occurs during this reaction?
Tick (✓) **one** box.

[1 mark]



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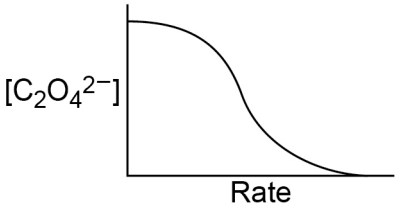

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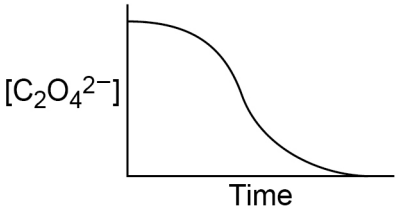

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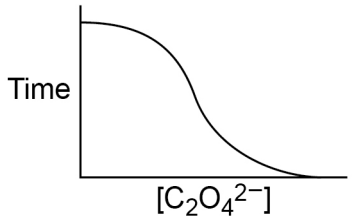

☐

0 7 . 6 A student adds an excess of a solution containing ethanedioate ions to a solution containing manganate(VII) ions.

State **one** observation that the student would make.

[1 mark]

_____

_____

12

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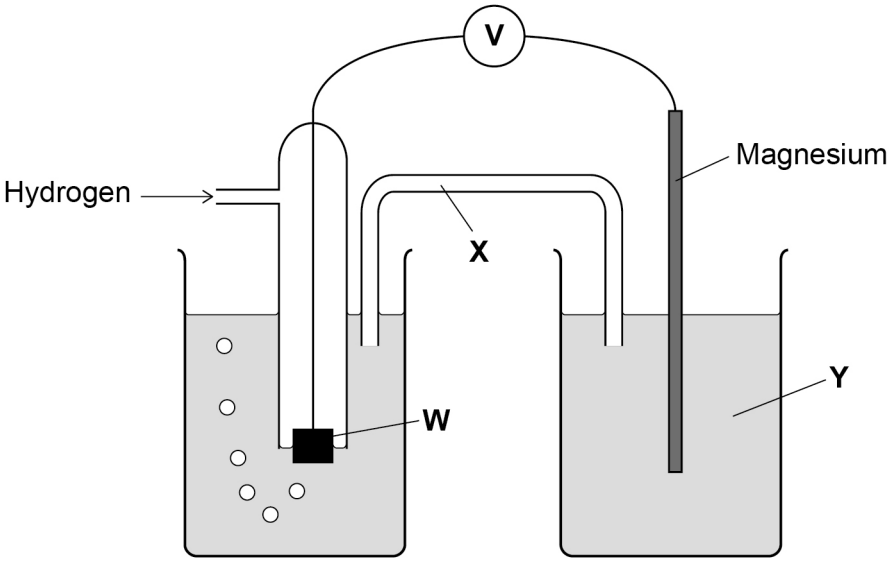
0 8 **Figure 3** shows a cell used to measure the standard electrode potential of the Mg^{2+}/Mg half-cell.

Figure 3



0 8 . 1 Identify a suitable substance that could be used for each of **W**, **X** and **Y**.

[3 marks]

W _____

X _____

Y _____

0 8 . 2 Identify **two** conditions needed in this cell for the measurement to be a **standard** electrode potential.

[2 marks]

1 _____

_____

2 _____

_____

Question 8 continues on the next page

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Table 8 shows some standard electrode potential data.

Table 8

Electrode half-equation	$E^{\ominus}$ / V
$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$	+1.00
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$	+0.34
$Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$	–0.41
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–0.76
$Cr^{2+}(aq) + 2e^- \rightarrow Cr(s)$	–0.91

0 8 . 3 Identify the strongest reducing agent in **Table 8**

[1 mark]

_____

0 8 . 4 Identify the species in **Table 8** that will oxidise $V^{3+}(aq)$ to $VO^{2+}(aq)$ but will **not** oxidise $VO^{2+}(aq)$ to $VO_2^+(aq)$.

[1 mark]

_____

0 8 . 5 An excess of solid zinc is added to a solution containing iron(III) ions.

Use the data in **Table 8** to explain why a reaction occurs.
Identify the products.

[2 marks]

Explanation _____

_____

_____

_____

_____

Products _____

Do not write outside the box

0 8 . 6 The conventional representation of a standard cell is shown.

$$Zn(s) \mid Zn^{2+}(aq) \parallel Cr^{3+}(aq), Cr^{2+}(aq) \mid Pt$$

Calculate the EMF of this cell.
Deduce an equation for the overall cell reaction.

[2 marks]

EMF _____

Equation

_____

11

END OF QUESTIONS

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