OXFORD

INTERNATIONAL AQA EXAMINATIONS

Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____

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	

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

Do not write outside the box

0 1 This question is about two metal iodides.

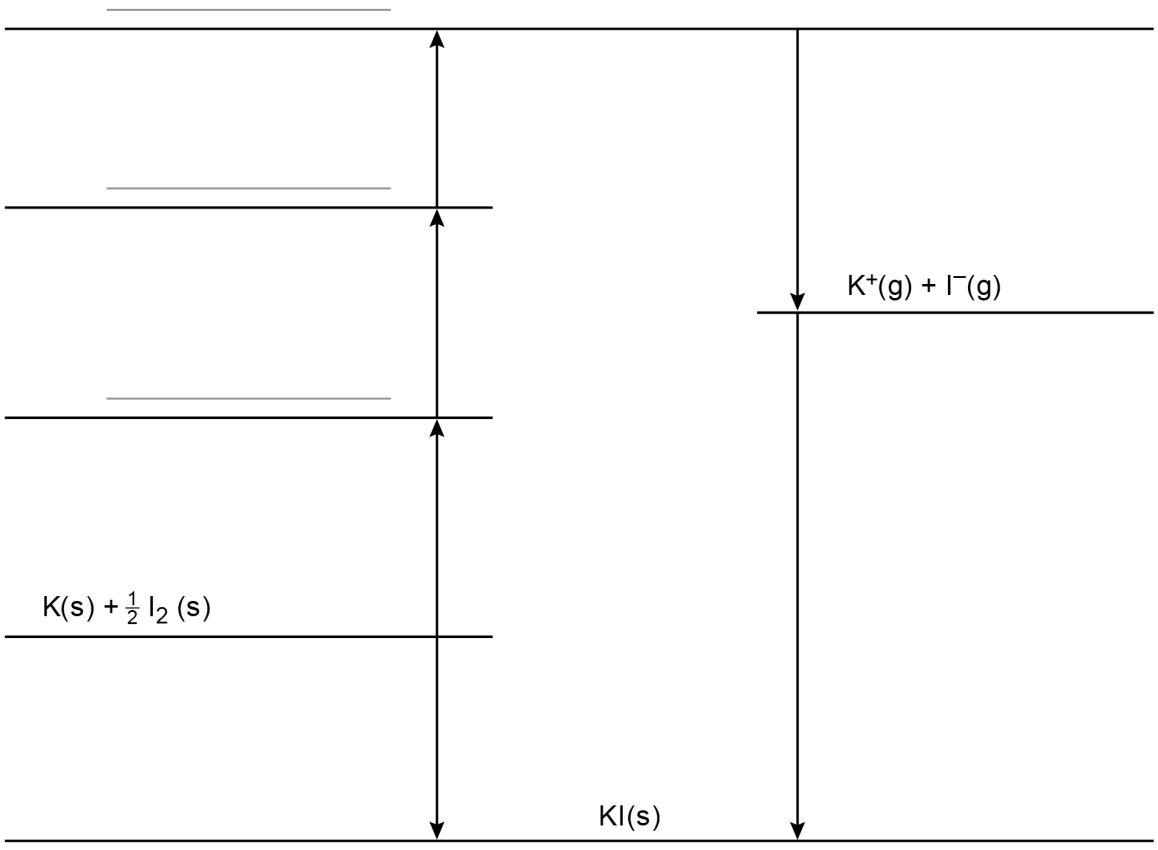
Table 1 shows some thermodynamic data.

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



Do not write outside the box

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 _____

_____

_____

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

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

0 2 Methanol is made in industry as shown.

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

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

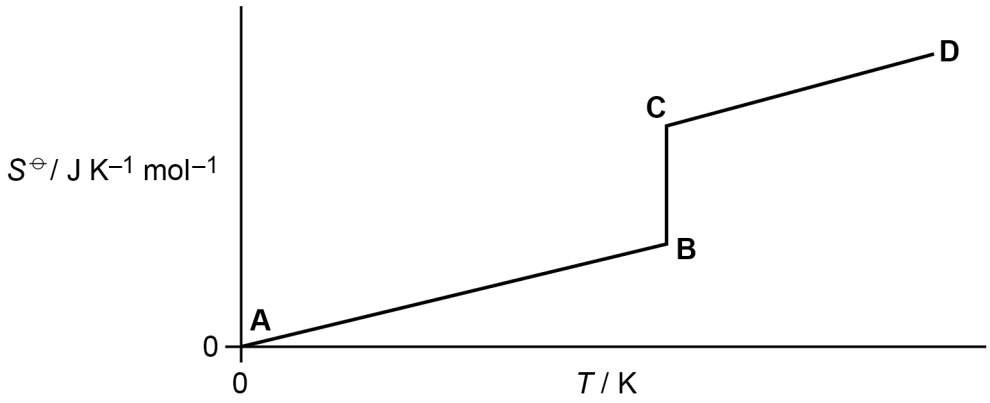
Do not write outside the box

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, Δ*G*, 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]

Do not write outside the box

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

Do not write outside the box

Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

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.

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

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]

Do not write outside the box

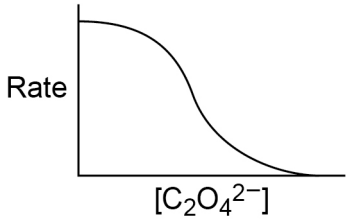
0 7 . 5 The overall equation for the oxidation of ethanedioate ions by manganate(VII) ions is shown.

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

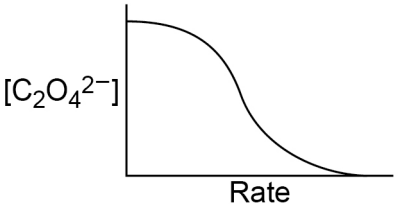
This reaction is an example of autocatalysis.

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

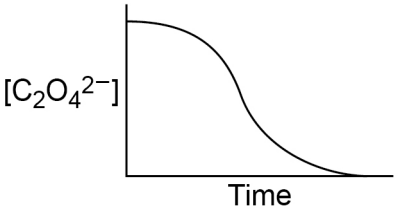
[1 mark]



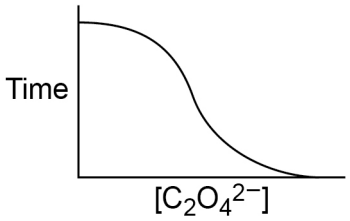
☐



☐



☐



☐

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

Turn over ►

Do not write outside the box

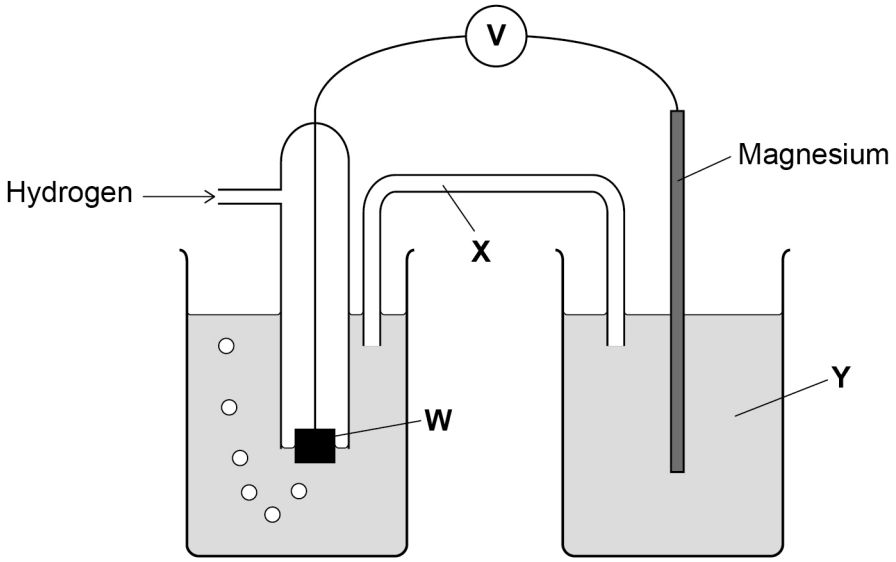
There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

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

Do not write outside the box

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

Do not write outside the box

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

Do not write outside the box

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

Do not write outside the box

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**