Please write clearly in block capitals.

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

Surname ______________________

Forename(s) ______________________

Candidate signature ______________________
I declare this is my own work.

A-level
CHEMISTRY

Paper 1 Inorganic and Physical Chemistry

Tuesday 2 June 2020 Afternoon Time allowed: 2 hours

Materials
For this paper you must have:
- the Periodic Table/Data Booklet, provided as an insert (enclosed)
- 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 105.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
TOTAL	

Do not write outside the box

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

0 1 This question is about enthalpy changes.

0 1 . 1 **Figure 1** shows a Born–Haber cycle for the formation of strontium chloride, $SrCl_2$

Figure 1

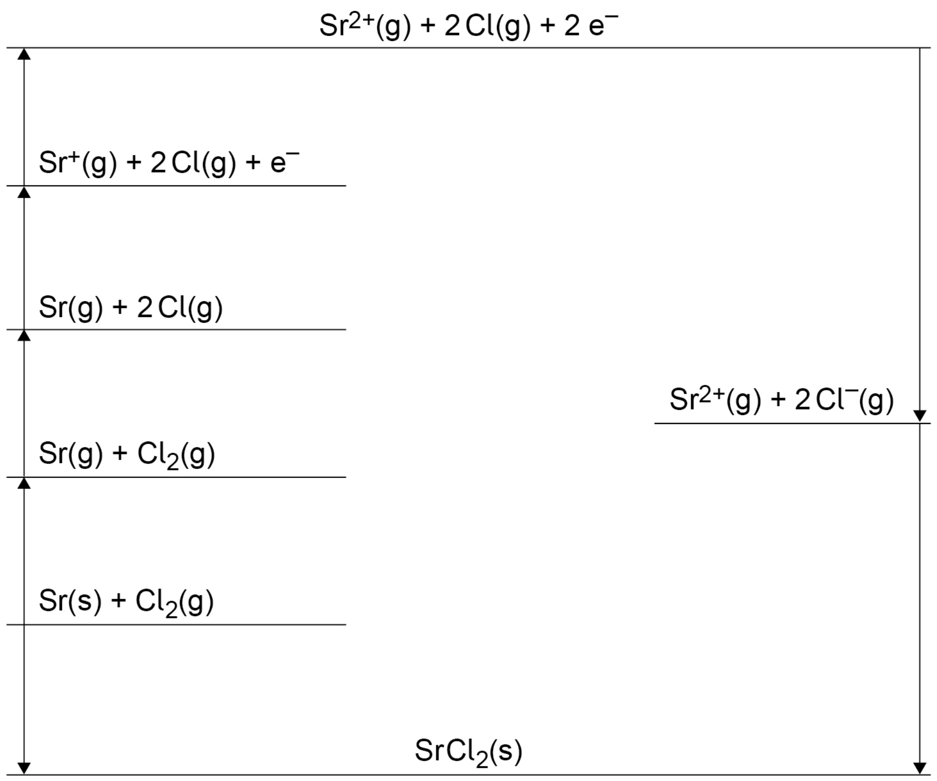

Table 1 shows some thermodynamic data.

Table 1

	Enthalpy change / kJ mol^{-1}
First ionisation energy of strontium	+548
Second ionisation energy of strontium	+1060
Enthalpy of atomisation of chlorine	+121
Enthalpy of atomisation of strontium	+164
Enthalpy of formation of strontium chloride	–828
Enthalpy of lattice formation of strontium chloride	–2112

Do not write outside the box

Use the data in **Table 1** to calculate a value for the electron affinity of chlorine.
[3 marks]

Electron affinity ____________________ kJ mol^{-1}

0 1 . 2 Draw a line from **each** substance to the enthalpy of lattice formation of that substance.
[1 mark]

Substance	**Enthalpy of lattice formation / kJ mol^{-1}**
$MgCl_2$	–2018
MgO	–2493
$BaCl_2$	–3889

Question 1 continues on the next page

Do not write outside the box

Table 2 shows the theoretical lattice enthalpy, based on a perfect ionic model, and an experimental value for the enthalpy of lattice formation of silver chloride.

Table 2

	Theoretical	**Experimental**
Enthalpy of lattice formation / kJ mol^{-1}	–770	–905

0 1 . 3 State why there is a difference between the theoretical and experimental values.

[1 mark]

0 1 . 4 **Table 3** shows enthalpy of hydration values for ions of some Group 1 elements.

Table 3

	$Li^+(g)$	**$Na^+(g)$**	**$K^+(g)$**
Enthalpy of hydration / kJ mol^{-1}	–519	–406	–322

Explain why the enthalpy of hydration becomes less exothermic from Li^+ to K^+

[2 marks]

Do not write outside the box

0 1 . 5 Calcium bromide dissolves in water.

Table 4 shows some enthalpy data.

Table 4

	Enthalpy change / kJ mol^{-1}
Enthalpy of solution of calcium bromide	–110
Enthalpy of lattice formation of calcium bromide	–2176
Enthalpy of hydration of calcium ions	–1650

Use the data in **Table 4** to calculate the enthalpy of hydration, in kJ mol^{-1}, of bromide ions.

[3 marks]

Enthalpy of hydration of bromide ions ____________________ kJ mol^{-1}

10

Turn over for the next question

Do not write outside the box

0 2 This question is about the isotopes of chromium.

0 2 . 1 Give the meaning of the term relative atomic mass.

[2 marks]

____

____

____

____

0 2 . 2 A sample of chromium containing the isotopes ^{50}Cr, ^{52}Cr and ^{53}Cr has a relative atomic mass of 52.1

The sample contains 86.1% of the ^{52}Cr isotope.

Calculate the percentage abundance of each of the other two isotopes.

[4 marks]

Abundance of ^{50}Cr ______________ %   Abundance of ^{53}Cr ________________ %

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0 2 . 3 State, in terms of the numbers of fundamental particles, **one** similarity and **one** difference between atoms of ^{50}Cr and ^{53}Cr

[2 marks]

Similarity ______________________________

____

Difference ______________________________

____

____

The sample of chromium is analysed in a time of flight (TOF) mass spectrometer.

0 2 . 4 Give **two** reasons why it is necessary to ionise the isotopes of chromium before they can be analysed in a TOF mass spectrometer.

[2 marks]

1 ______________________________

____

2 ______________________________

____

Question 2 continues on the next page

Do not write outside the box

0 2 . 5 A $^{53}Cr^{+}$ ion travels along a flight tube of length 1.25 m
The ion has a constant kinetic energy (*KE*) of 1.102 × 10^{-13} J

$$KE = \frac{mv^2}{2}$$

m = mass of the ion / kg
v = speed of ion / m s^{-1}

Calculate the time, in s, for the $^{53}Cr^{+}$ ion to travel down the flight tube to reach the detector.

The Avogadro constant, L = 6.022 × 10^{23} mol^{-1}

[5 marks]

Time ____________________ s

15

Turn over for the next question

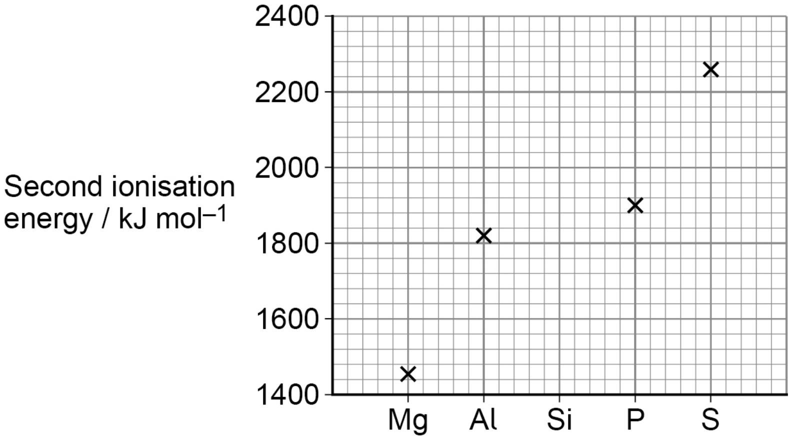
Turn over ►

Do not write outside the box

0 3 This question is about Period 3 elements.

Figure 2 shows the **second** ionisation energies of some elements in Period 3.

Figure 2



0 3 . 1 Draw a cross (x) on **Figure 2** to show the **second** ionisation energy of silicon.

[1 mark]

0 3 . 2 Identify the element in Period 3, from sodium to argon, that has the highest **second** ionisation energy.

Give an equation, including state symbols, to show the process that occurs when the **second** ionisation energy of this element is measured.

If you were unable to identify the element you may use the symbol **Q** in your equation.

[2 marks]

Element ____________________

Equation

____

0 3 . 3 Explain why the atomic radius decreases across Period 3, from sodium to chlorine.

[2 marks]

____

____

____

____

Do not write outside the box

0 3 . 4 Identify the element in Period 3, from sodium to chlorine, that has the highest electronegativity.

[1 mark]

---

0 3 . 5 Phosphorus burns in air to form phosphorus(V) oxide.
Give an equation for this reaction.

[1 mark]

7

Turn over for the next question

Do not write outside the box

0 4 Propanoic acid (C_2H_5COOH) is a weak acid.

The acid dissociation constant (K_a) for propanoic acid is 1.35×10^{-5} mol dm^{-3} at 25 ^{o}C

0 4 . 1 State the meaning of the term weak acid.

[1 mark]

____

____

0 4 . 2 Give an expression for the acid dissociation constant for propanoic acid.

[1 mark]

K_a

0 4 . 3 A student dilutes 25.0 cm^3 of 0.500 mol dm^{-3} propanoic acid by adding water until the total volume is 100.0 cm^3

Calculate the pH of this diluted solution of propanoic acid.

Give your answer to 2 decimal places.

[4 marks]

pH ____________________

0 4 . 4 A buffer solution with a pH of 4.50 is made by dissolving *x* g of sodium propanoate (C_2H_5COONa) in a solution of propanoic acid. The final volume of buffer solution is 500 cm^3 and the final concentration of the propanoic acid is 0.250 mol dm^{-3}

Calculate *x* in g

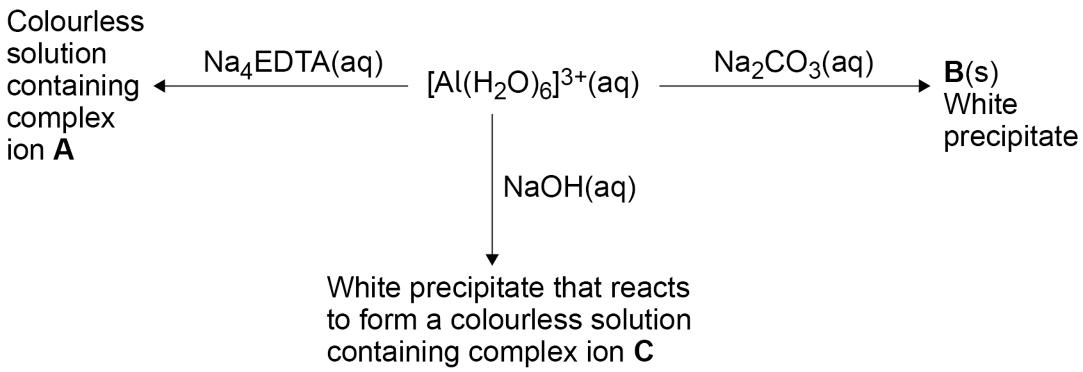
For propanoic acid, $K_a = 1.35 \times 10^{-5}$ mol dm^{-3}

[6 marks]

x __________________________________ g

12

0 5 Some reactions of the $[Al(H_2O)_6]^{3+}(aq)$ ion are shown.



0 5 . 1 Give the formula of the white precipitate **B**.

State **one** other observation when $Na_2CO_3(aq)$ is added to a solution containing $[Al(H_2O)_6]^{3+}(aq)$ ions.

Give an equation for this reaction.

[3 marks]

Formula of **B** ______________________________

Observation ______________________________

Equation

____

0 5 . 2 Give the formula of the complex ion **C**.

State **one** condition needed for the formation of **C** from $[Al(H_2O)_6]^{3+}(aq)$ and NaOH(aq).

Give an equation for this reaction.

[3 marks]

Formula of **C** ______________________________

Condition ______________________________

Equation

____

Do not write outside the box

0 5 . 3 Deduce the formula of the complex ion **A**.

[1 mark]

____

0 5 . 4 Explain, with the use of an equation, why a solution containing $[Al(H_2O)_6]^{3+}$ has a pH <7

[3 marks]

Equation

____

Explanation ____

____

____

____

____

10

Turn over for the next question

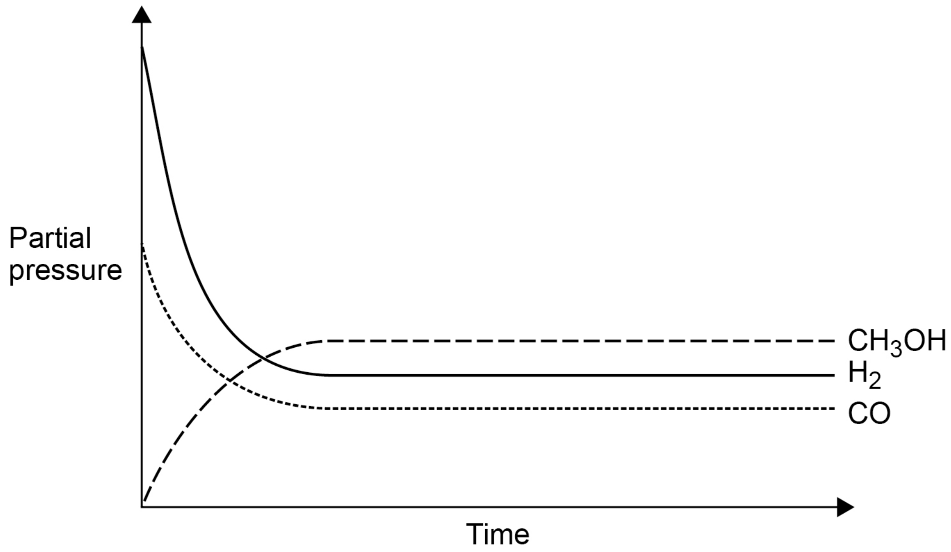
Do not write outside the box

0 6 Methanol can be manufactured in a reversible reaction as shown.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H^{\ominus} = -91 \text{ kJ mol}^{-1}$$

Figure 3 shows how the partial pressures change with time at a constant temperature.

Figure 3



0 6 . 1 Draw a cross (x) on the appropriate axis of **Figure 3** when the mixture reaches equilibrium.

[1 mark]

0 6 . 2 A 0.230 mol sample of carbon monoxide is mixed with hydrogen in a 1:2 mol ratio and allowed to reach equilibrium in a sealed flask at temperature *T*.
At equilibrium the mixture contains 0.120 mol of carbon monoxide.
The total pressure of this mixture is 1.04×10^4 kPa

Calculate the partial pressure, in kPa, of hydrogen in the equilibrium mixture.

[4 marks]

Partial pressure of hydrogen ______________________ kPa

Do not write outside the box

0 6 . 3 Give an expression for the equilibrium constant (K_p) for this reaction.

State the units.

[2 marks]

K_p

Units ______________________

0 6 . 4 Some more carbon monoxide is added to the mixture in Question **06.2**. The new mixture is allowed to reach equilibrium at temperature *T*.

State the effect, if any, on the partial pressure of methanol and on the value of K_p

[2 marks]

Effect on partial pressure of methanol ______________________

Effect on value of K_p ______________________

0 6 . 5 State the effect, if any, of the addition of a catalyst on the value of K_p for this equilibrium.
Explain your answer.

[2 marks]

Effect on value of K_p ______________________

Explanation ______________________

____

____

11

Turn over for the next question

Do not write outside the box

0 7 The melting point of XeF_4 is higher than the melting point of PF_3

Explain why the melting points of these two compounds are different.

In your answer you should give the shape of each molecule, explain why each molecule has that shape and how the shape influences the forces that affect the melting point.

[6 marks]

Do not write outside the box

6

Do not write outside the box

0 8 A student does an experiment to determine the percentage by mass of sodium chlorate(I), NaClO, in a sample of bleach solution.

Method:

- Dilute a 10.0 cm^3 sample of bleach solution to 100 cm^3 with distilled water.
- Transfer 25.0 cm^3 of the diluted bleach solution to a conical flask and acidify using sulfuric acid.
- Add excess potassium iodide to the conical flask to form a brown solution containing I_2(aq).
- Add 0.100 mol dm^{-3} sodium thiosulfate solution ($Na_2S_2O_3$) to the conical flask from a burette until the brown solution containing I_2(aq) becomes a colourless solution containing I^-(aq).

The student uses 33.50 cm^3 of sodium thiosulfate solution.

The density of the original bleach solution is 1.20 g cm^{-3}

The equations for the reactions in this experiment are

$$ClO^-(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow Cl^-(aq) + H_2O(l) + I_2(aq)$$

$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

0 8 . 1 Use all the information given to calculate the percentage by mass of NaClO in the original bleach solution.

Give your answer to 3 significant figures.

[7 marks]

Percentage by mass ______________________

0 8 . 2 The total uncertainty from two readings and an end point error in using a burette is ± 0.15 cm^3

What is the total percentage uncertainty in using the burette in this experiment?

[1 mark]

Tick (✓) **one** box.

0.45% ☐

0.90% ☐

1.34% ☐

8

Turn over for the next question

Do not write outside the box

0 9 This question is about sodium halides.

0 9 . 1 State what is observed when silver nitrate solution is added to sodium fluoride solution.

[1 mark]

____

0 9 . 2 State **one** observation when solid sodium chloride reacts with concentrated sulfuric acid.

Give an equation for the reaction.

State the role of the chloride ions in the reaction.

[3 marks]

Observation ____

Equation

____

Role ____

0 9 . 3 Give an equation for the redox reaction between solid sodium bromide and concentrated sulfuric acid.

Explain, using oxidation states, why this is a redox reaction.

[3 marks]

Equation

____

Explanation ____

____

____

____

0 9 . 4 State what is observed when aqueous chlorine is added to sodium bromide solution.

Give an ionic equation for the reaction.

[2 marks]

Observation ____

Ionic equation

____

9

Do not write outside the box

1 0 Methanol is formed when carbon dioxide and hydrogen react.

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

Table 5 contains enthalpy of formation and entropy data for these substances.

Table 5

	$CO_2(g)$	$H_2(g)$	$CH_3OH(g)$	$H_2O(g)$
$\Delta_f H$ / kJ mol^{-1}	–394	0	–201	–242
S / J K^{-1} mol^{-1}	214	131	238	189

1 0 . 1 Use the equation and the data in **Table 5** to calculate the Gibbs free-energy change (ΔG), in kJ mol^{-1}, for this reaction at 890 K

[6 marks]

ΔG ________________________ kJ mol^{-1}

Turn over ►

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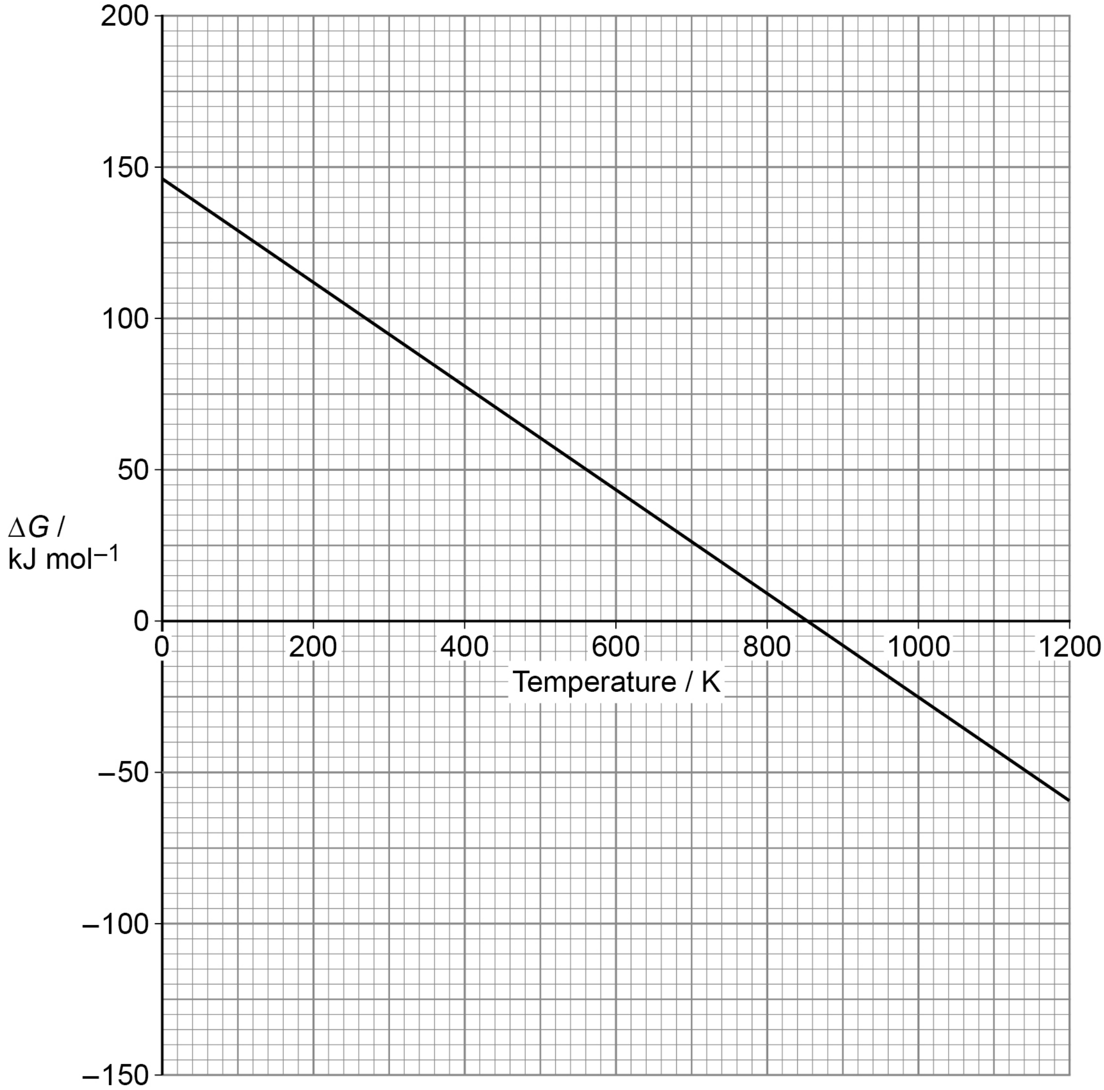
Figure 4 shows how the Gibbs free-energy change varies with temperature in a different gas phase reaction.

The straight line graph for this gas phase reaction has been extrapolated to zero Kelvin.

Figure 4



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1 0 . 2 Use the values of the intercept and gradient from the graph in **Figure 4** to calculate the enthalpy change (ΔH), in kJ mol^{-1}, and the entropy change (ΔS), in J K^{-1} mol^{-1}, for this reaction.

[4 marks]

ΔH _______________ kJ mol^{-1}

ΔS _______________ J K^{-1} mol^{-1}

1 0 . 3 State what **Figure 4** shows about the feasibility of the reaction.

[1 mark]

____

____

____

11

Turn over ►

Do not write outside the box

1 1 This question is about a glucose–oxygen fuel cell.

When the cell operates, the glucose ($C_6H_{12}O_6$) molecules react with water at the negative electrode to form carbon dioxide and hydrogen ions.

Oxygen gas reacts with hydrogen ions to form water at the positive electrode.

1 1 . 1 Deduce the half-equation for the reaction at the negative electrode.

[1 mark]

____

1 1 . 2 Deduce the half-equation for the reaction at the positive electrode.

[1 mark]

____

1 1 . 3 Give the equation for the overall reaction that occurs in the Glucose–oxygen fuel cell.

[1 mark]

____

1 1 . 4 The negative electrode is made of carbon and the positive electrode is made of platinum.

Give the conventional representation for the glucose–oxygen fuel cell.

[2 marks]

____

____

1 1 . 5 State what must be done to maintain the EMF of this fuel cell when in use.

[1 mark]

____

6

END OF QUESTIONS

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