

Please write clearly in block capitals.

Centre number

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Candidate number

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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	



J U N 2 0 7 4 0 5 1 0 1

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

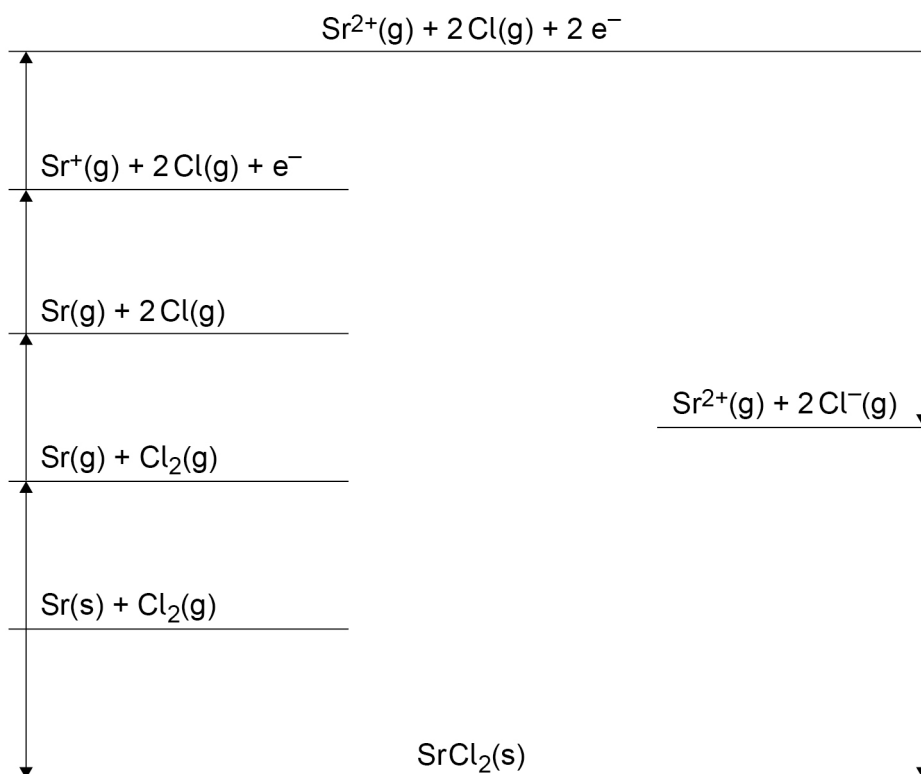


Table 1 shows some thermodynamic data.

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



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}
<div>MgCl₂</div>	<div>−2018</div>
<div>MgO</div>	<div>−2493</div>
<div>BaCl₂</div>	<div>−3889</div>

Question 1 continues on the next page

Turn over ►



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

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

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

[2 marks]



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

Turn over ►



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

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

Turn over ►

0 2 . 5

A $^{53}\text{Cr}^+$ 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 $^{53}\text{Cr}^+$ ion to travel down the flight tube to reach the detector.

The Avogadro constant, $L = 6.022 \times 10^{23} \text{ mol}^{-1}$

[5 marks]

Time _____ s

15



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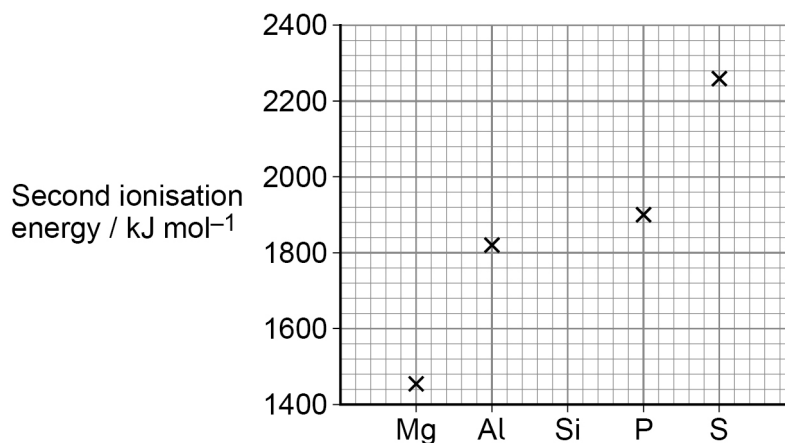


0 3

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]



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

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0	4
---	---

Propanoic acid ($\text{C}_2\text{H}_5\text{COOH}$) is a weak acid.

The acid dissociation constant (K_a) for propanoic acid is $1.35 \times 10^{-5} \text{ mol dm}^{-3}$ at 25°C

0	4	.	1
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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 $0.500 \text{ mol dm}^{-3}$ 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 ($\text{C}_2\text{H}_5\text{COONa}$) 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, $K_a = 1.35 \times 10^{-5}\text{ mol dm}^{-3}$

[6 marks]

x _____ g

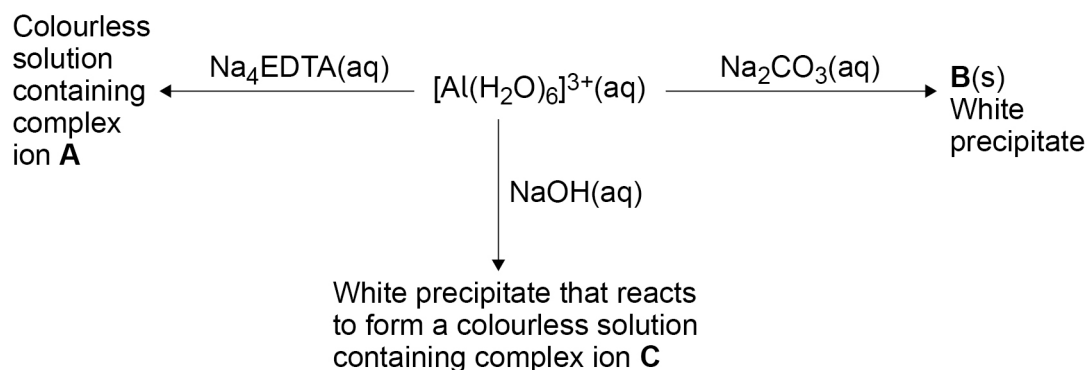
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0 5

Some reactions of the $[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ ion are shown.



0 5 . 1

Give the formula of the white precipitate **B**.

State **one** other observation when $\text{Na}_2\text{CO}_3(\text{aq})$ is added to a solution containing $[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ 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 $[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ and $\text{NaOH}(\text{aq})$.

Give an equation for this reaction.

[3 marks]

Formula of **C** _____

Condition _____

Equation _____



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 $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ has a pH < 7

[3 marks]

Equation

Explanation _____

10

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0 6

Methanol can be manufactured in a reversible reaction as shown.

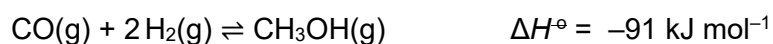
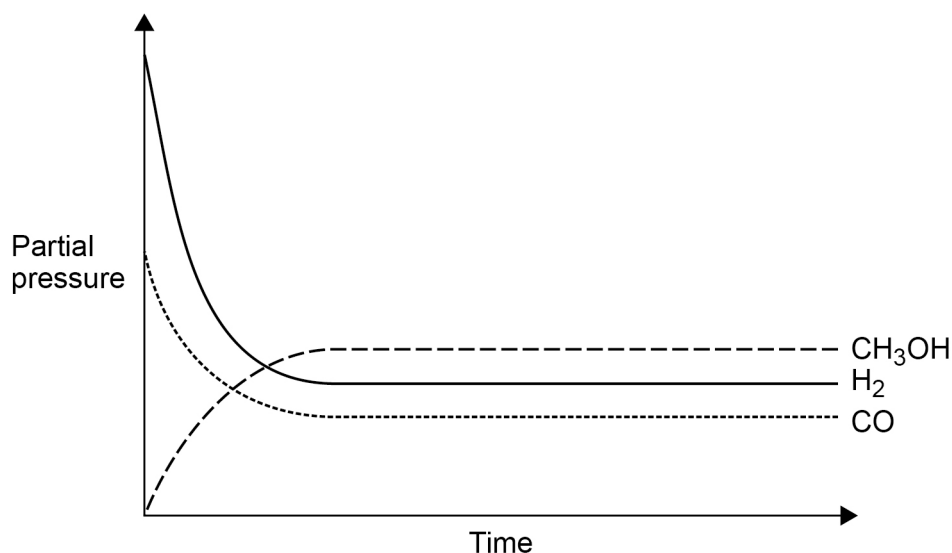


Figure 3 shows how the partial pressures change with time at a constant temperature.

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



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

Turn over ►



[6 marks]

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6

0 8

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

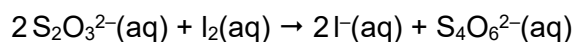
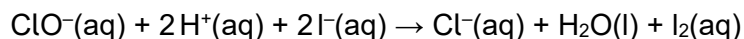
Method:

- Dilute a 10.0 cm³ sample of bleach solution to 100 cm³ with distilled water.
- Transfer 25.0 cm³ 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 I₂(aq).
- Add 0.100 mol dm⁻³ sodium thiosulfate solution (Na₂S₂O₃) to the conical flask from a burette until the brown solution containing I₂(aq) becomes a colourless solution containing I⁻(aq).

The student uses 33.50 cm³ 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



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 $\pm 0.15 \text{ cm}^3$

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

Turn over ►



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



1 0

Methanol is formed when carbon dioxide and hydrogen react.

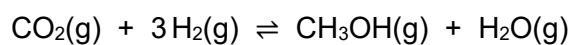


Table 5 contains enthalpy of formation and entropy data for these substances.

Table 5

	CO₂(g)	H₂(g)	CH₃OH(g)	H₂O(g)
$\Delta_f H / \text{kJ mol}^{-1}$	–394	0	–201	–242
$S / \text{J K}^{-1} \text{mol}^{-1}$	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}

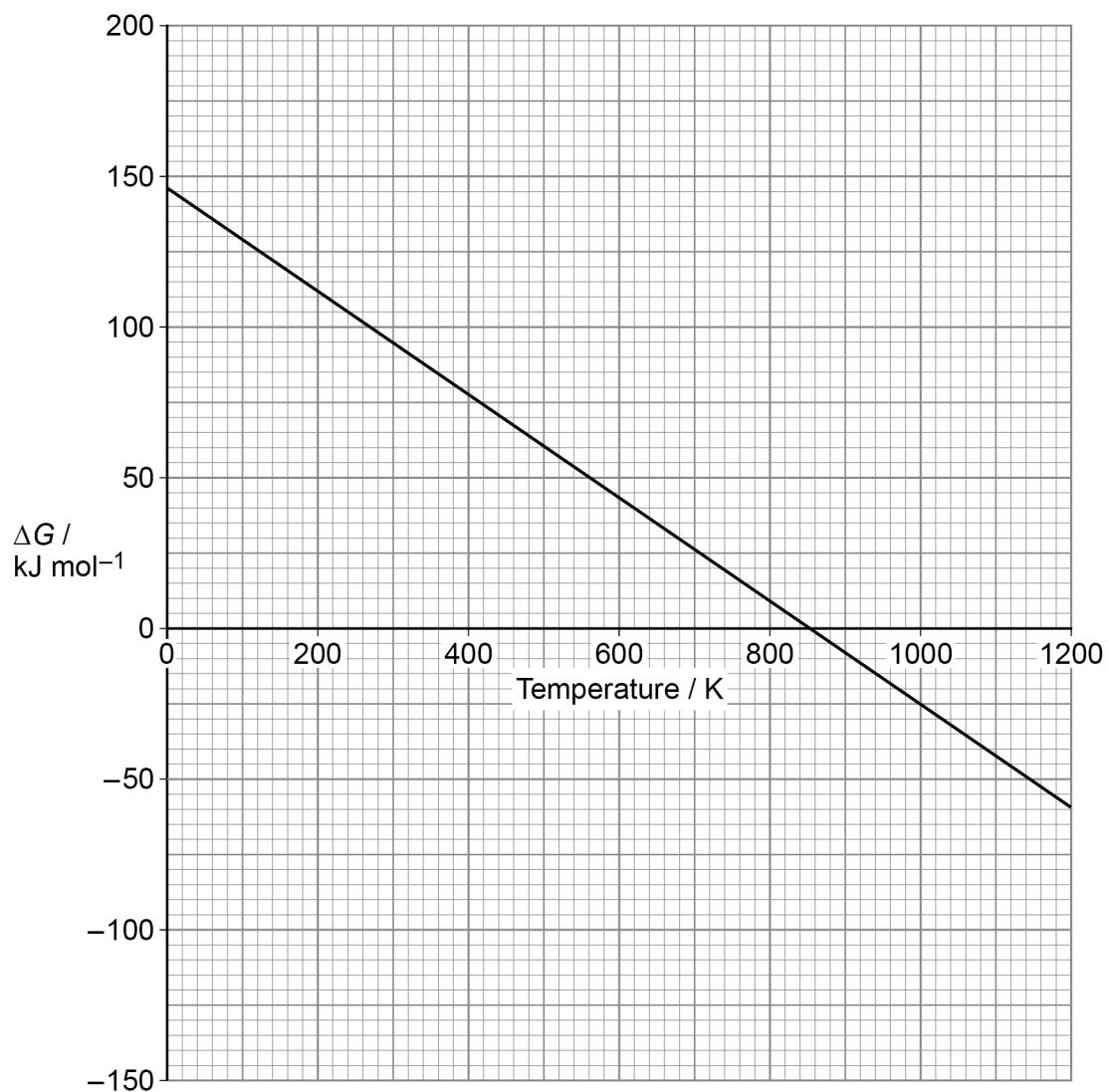
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Figure 4 shows how the Gibbs free-energy change varies with temperature in a different gas phase reaction.

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

Figure 4



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 $\text{J K}^{-1} \text{mol}^{-1}$, for this reaction.

[4 marks] ΔH _____ kJ mol^{-1} ΔS _____ $\text{J K}^{-1} \text{mol}^{-1}$

1 0 . 3

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

[1 mark]

11

Turn over ►

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

When the cell operates, the glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) 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
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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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