A

AQA

Surname _____

Other Names _____

Centre Number _____

Candidate Number _____

Candidate Signature _____

I declare this is my own work.

A-level
CHEMISTRY

Paper 1 Inorganic and Physical Chemistry

7405/1

Time allowed: 2 hours

At the top of the page, write your surname and other names, your centre number, your candidate number and add your signature.

[Turn over]

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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.**
- **Answer ALL questions.**
- **You must answer the questions in the spaces provided. Do NOT write 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.**

DO NOT TURN OVER UNTIL TOLD TO DO SO

Answer ALL questions in the spaces provided.

0 1

This question is about enthalpy changes for calcium chloride and magnesium chloride.

0 1 . 1

State the meaning of the term enthalpy change.
[1 mark]

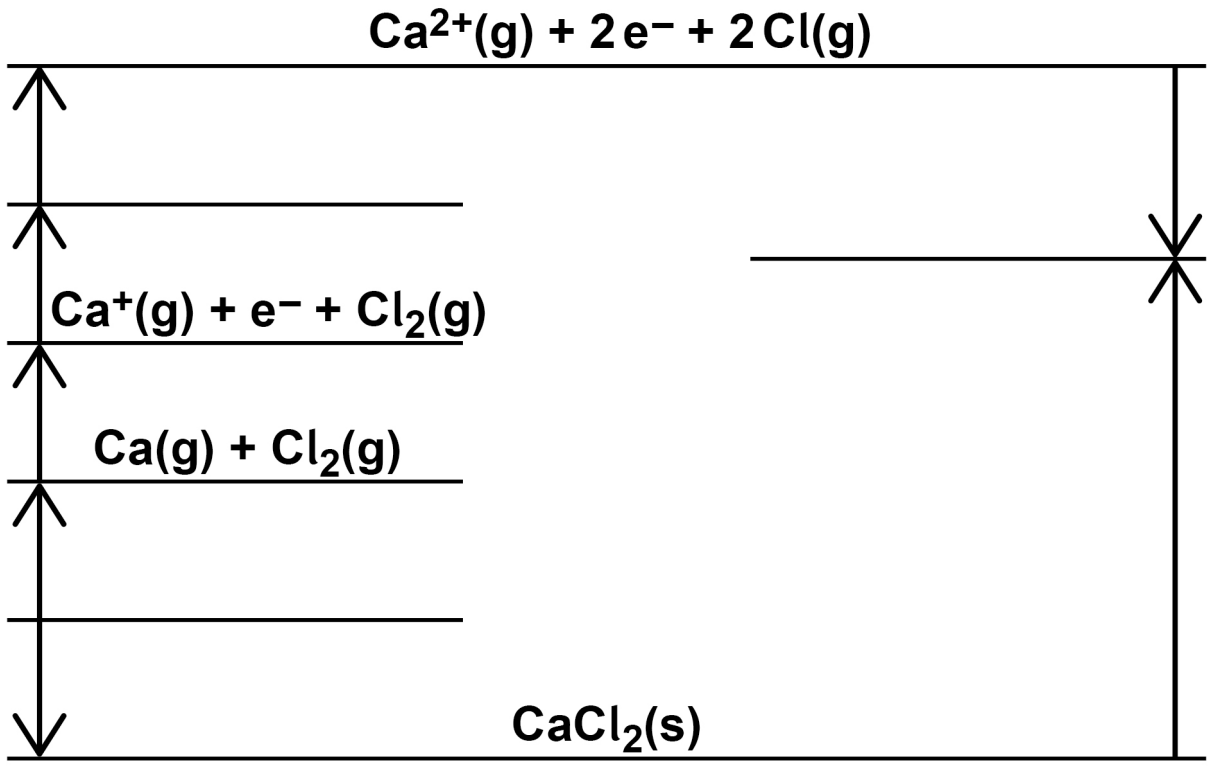
_____

_____

_____

FIGURE 1, on the opposite page, shows an incomplete Born–Haber cycle for the formation of calcium chloride.

FIGURE 1



0 1 . 2

Complete FIGURE 1 by writing the formulas, including state symbols, of the appropriate species on each of the three blank lines. [3 marks]

0 1 . 3

TABLE 1 shows some enthalpy data.

TABLE 1

	Enthalpy change / kJ mol^{-1}
Enthalpy of formation of calcium chloride	–795
Enthalpy of atomisation of calcium	+193
First ionisation energy of calcium	+590
Second ionisation energy of calcium	+1150
Enthalpy of atomisation of chlorine	+121
Electron affinity of chlorine	–364

Use FIGURE 1, on page 5, and the data in TABLE 1 to calculate a value for the enthalpy of lattice dissociation of calcium chloride. [2 marks]

Enthalpy of lattice dissociation _____ kJ mol^{-1}

[Turn over]

0 1 . 4

Magnesium chloride dissolves in water.

Give an equation, including state symbols, to represent the process that occurs when the enthalpy of solution of magnesium chloride is measured. [1 mark]

---

0 1 . 5

TABLE 2 shows some enthalpy data.

TABLE 2

	Enthalpy change / kJ mol^{-1}
Enthalpy of lattice dissociation of $MgCl_2$	+2493
Enthalpy of hydration of $Mg^{2+}(g)$	–1920
Enthalpy of hydration of $Cl^-(g)$	–364

Use your answer to Question 01.4 and the data in TABLE 2 to calculate a value for the enthalpy of solution of magnesium chloride. [2 marks]

Enthalpy of solution _____ **kJ mol^{-1}**

[Turn over]

0 1 . 6

The enthalpy of hydration of $Ca^{2+}(g)$ is –1650 kJ mol^{-1}

Suggest why this value is less exothermic than that of $Mg^{2+}(g)$ [2 marks]

11

0 2

This question is about atomic structure.

0 2 . 1

Define the mass number of an atom. [1 mark]

0 2 . 2

Complete TABLE 3 to show the numbers of neutrons and electrons in the species shown. [2 marks]

TABLE 3

	Number of protons	Number of neutrons	Number of electrons
^{46}Ti	22		
$^{49}Ti^{2+}$	22		

0 2 . 3

A sample of titanium contains four isotopes, ^{46}Ti, ^{47}Ti, ^{48}Ti and ^{49}Ti

This sample has a relative atomic mass of 47.8

In this sample the ratio of abundance of isotopes ^{46}Ti, ^{47}Ti and ^{49}Ti is 2:2:1

Calculate the percentage abundance of ^{46}Ti in this sample. [3 marks]

Abundance of ^{46}Ti _____ %

6

0 3

This question is about elements in Period 3 and their compounds.

0 3 . 1

When a piece of sodium is added to 200 cm^3 of water in a large beaker a vigorous reaction occurs. The temperature of the water increases by 25 °C

Give an equation, including state symbols, for the reaction of sodium with water.

Suggest why it is dangerous to react a similar piece of sodium with 10 cm^3 of water in a boiling tube.
[2 marks]

Equation

Why it is dangerous

0 3 . 2

Give an equation for the reaction of phosphorus(V) oxide with water.

Suggest a pH for the solution formed. [2 marks]

Equation

pH

0 3 . 3

Explain, in terms of crystal structure and bonding, why silicon(IV) oxide has a higher melting point than phosphorus(V) oxide. [4 marks]

[Turn over]

0 3 . 4

An element in Period 3 forms an oxide that is insoluble in water.

This oxide reacts with sulfuric acid and with aqueous potassium hydroxide.

Give the formula for this oxide.

Give an equation for the reaction of this oxide with sulfuric acid. [2 marks]

Formula _____

Equation

_____

0 3 . 5

Give the formula of a hydroxide of an element in Period 3 used in medicine. [1 mark]

_____

0 3 . 6

Identify the element in Period 3, from sodium to chlorine, that has the largest atomic radius. [1 mark]

[Turn over]

12

0 4

This question is about iron and its ions.

0 4 . 1

Discuss the role of iron as a heterogeneous catalyst in the Haber process.

$$3\,H_2 + N_2 \rightleftharpoons 2\,NH_3$$

Your answer should include:

- **the meaning of the term heterogeneous catalyst**
- **how iron acts as a heterogeneous catalyst**
- **the factors that affect the efficiency and lifetime of the catalyst.**

[6 marks]

[Turn over]

[Turn over]

0 4 . 2

Fe^{2+} ions catalyse the reaction between peroxodisulfate(VI) ions and iodide ions in aqueous solution.

$$S_2O_8^{2-}(aq) + 2\,I^-(aq) \longrightarrow 2\,SO_4^{2-}(aq) + I_2(aq)$$

Explain why this reaction is slow before the catalyst is added.

Give TWO equations to show how Fe^{2+} ions catalyse this reaction. [4 marks]

Why reaction is slow before catalyst added

Equation 1

Equation 2

0 4 . 3

Give a reason why Zn^{2+} ions do NOT catalyse the reaction in Question 04.2. [1 mark]

[Turn over]

0 4 . 4

Iron reacts with dilute hydrochloric acid to form iron(II) chloride and hydrogen.

$Fe(s) + 2\ HCl(aq) \longrightarrow FeCl_2(aq) + H_2(g)$

A 0.998 g sample of pure iron is added to 30.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid.

One of these reagents is in excess and the other reagent limits the amount of hydrogen produced in the reaction.

Calculate the maximum volume, in m^3, of hydrogen gas produced at 30 °C and 100 kPa.

Give your answer to 3 significant figures.

In your answer you should identify the limiting reagent in the reaction.

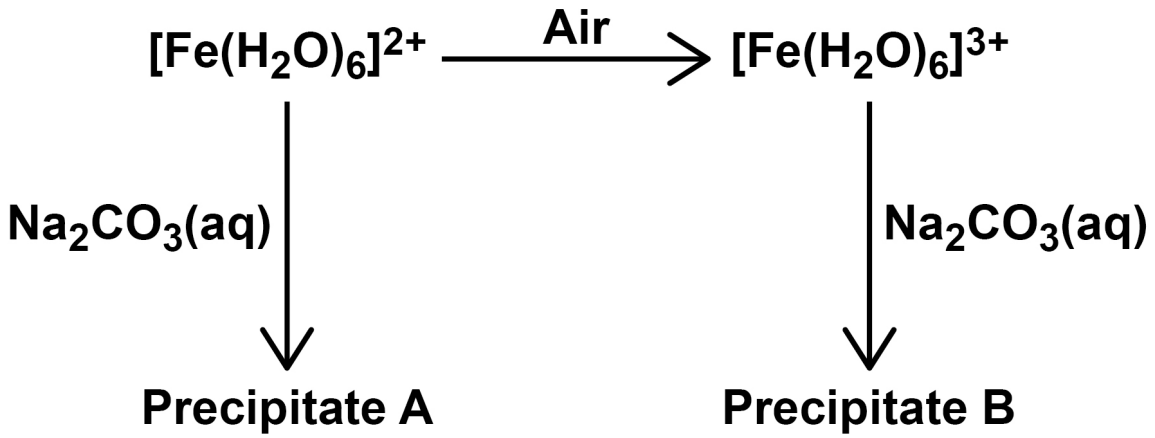
The gas constant, R = 8.31 J K^{-1} mol^{-1} [6 marks]

Volume of hydrogen _____ **m^3**

[Turn over]

FIGURE 2 shows some reactions of iron ions in aqueous solution.

FIGURE 2



0 4 . 5

Identify A and state its colour. [2 marks]

Identity _____

Colour _____

0 4 . 6

Give the formula of B and state its colour.

Give an ionic equation for the reaction of $[Fe(H_2O)_6]^{3+}$ with aqueous Na_2CO_3 to form B. [3 marks]

Formula _____

Colour _____

Ionic equation

_____

[Turn over]

0 4 . 7

Explain why an aqueous solution containing $[Fe(H_2O)_6]^{3+}$ ions has a lower pH than an aqueous solution containing $[Fe(H_2O)_6]^{2+}$ ions. [3 marks]

25

0 5

This question is about the equilibrium

$$2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3(g)$$

0 5 . 1

State and explain the effect, if any, of a decrease in overall pressure on the equilibrium yield of SO_3
[3 marks]

Effect _____

Explanation _____

_____

_____

_____

[Turn over]

0 5 . 2

A 0.460 mol sample of SO_2 is mixed with a 0.250 mol sample of O_2 in a sealed container at a constant temperature.

When equilibrium is reached at a pressure of 215 kPa, the mixture contains 0.180 mol of SO_3

Calculate the partial pressure, in kPa, of SO_2 in this equilibrium mixture. [4 marks]

Partial pressure of SO_2 _____ kPa

[Turn over]

0 5 . 3

A different mixture of SO_2 and O_2 reaches equilibrium at a different temperature.

TABLE 4 shows the partial pressures of the gases at equilibrium.

TABLE 4

Gas	Partial pressure / kPa
SO_2	1.67×10^2
O_2	1.02×10^2
SO_3	1.85×10^2

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

Calculate the value of the equilibrium constant for this reaction and give its units. [3 marks]

K_p

K_p _____

Units _____

[Turn over]

0 5 . 4

What is the effect on the value of K_p if the pressure of this equilibrium mixture is increased at a constant temperature?

$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$

[1 mark]

Tick (✓) ONE box.

The value of K_p

☐ **increases.**

☐ **stays the same.**

☐ **decreases.**

11

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[Turn over]

0 6

This question is about pH.

Pure water dissociates slightly.

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \qquad \Delta H = +57 \text{ kJ mol}^{-1}$$

The equilibrium constant, $K_c = \dfrac{[H^+][OH^-]}{[H_2O]}$

The ionic product of water, $K_w = [H^+][OH^-]$

0 6 . 1

Explain why $[H_2O]$ is not shown in the K_w expression.
[1 mark]

TABLE 5 shows how K_w varies with temperature.

TABLE 5

Temperature / °C	K_w / mol^2 dm^{-6}
10	2.93×10^{-15}
20	6.81×10^{-15}
25	1.00×10^{-14}
30	1.47×10^{-14}
50	5.48×10^{-14}

0 6 . 2

Explain why the value of K_w increases as the temperature increases. [2 marks]

0 6 . 3

Give the expression for pH.

Calculate the pH of pure water at 50 °C

Give your answer to 2 decimal places.

Explain why water is neutral at 50 °C [4 marks]

Expression _____

Calculation

pH _____

Explanation _____

_____

_____

[Turn over]

A pH meter is calibrated using a calibration graph.

To create the calibration, the pH meter is used to measure the pH of separate solutions, each with a known, accurate pH.

FIGURE 3, on the opposite page, shows the calibration graph.

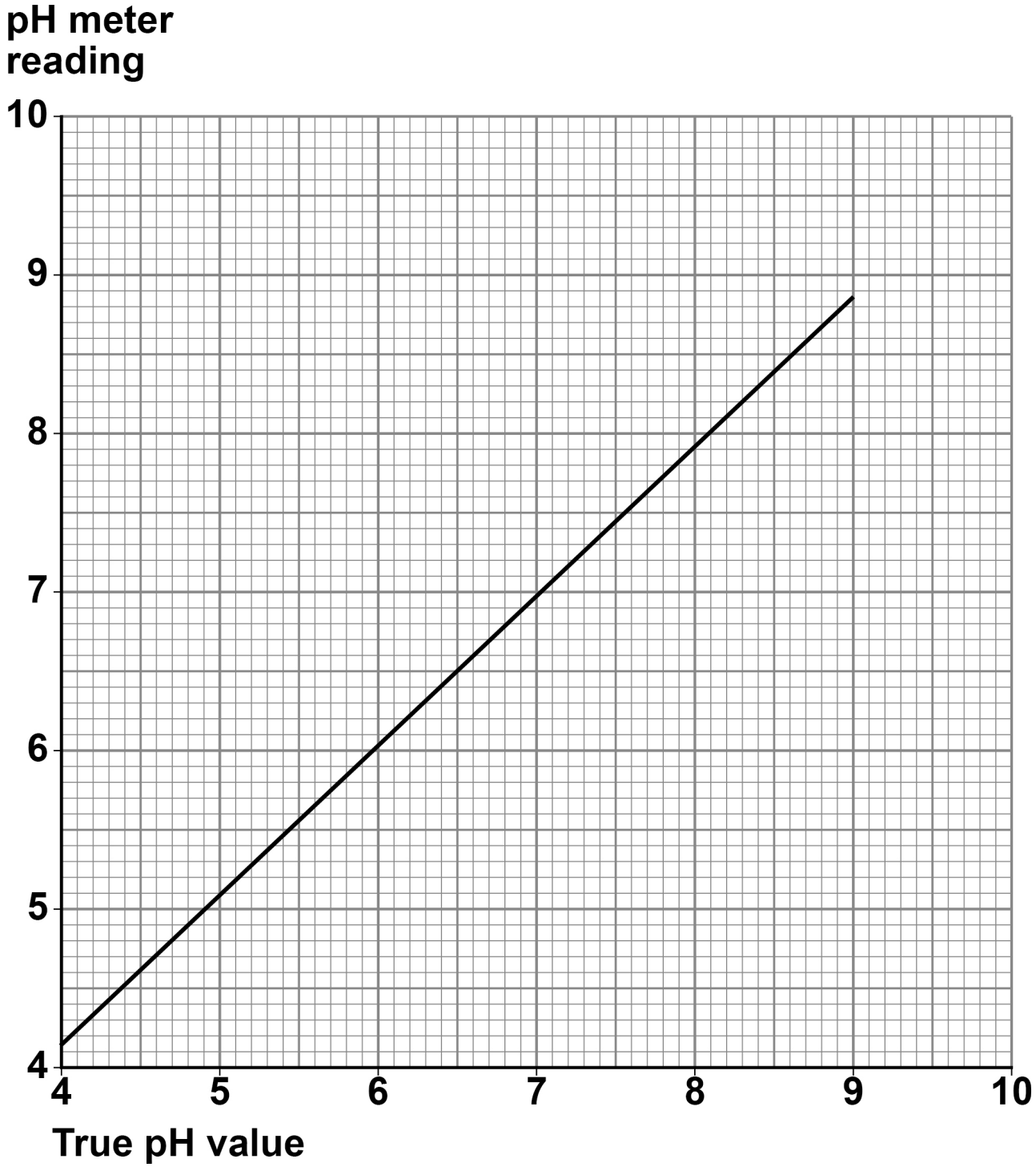
0 6 . 4

Use FIGURE 3 to give the true pH value when the pH meter reading is 5.6 [1 mark]

0 6 . 5

Suggest why the pH probe is washed with distilled water between each of the calibration measurements. [1 mark]

FIGURE 3



[Turn over]

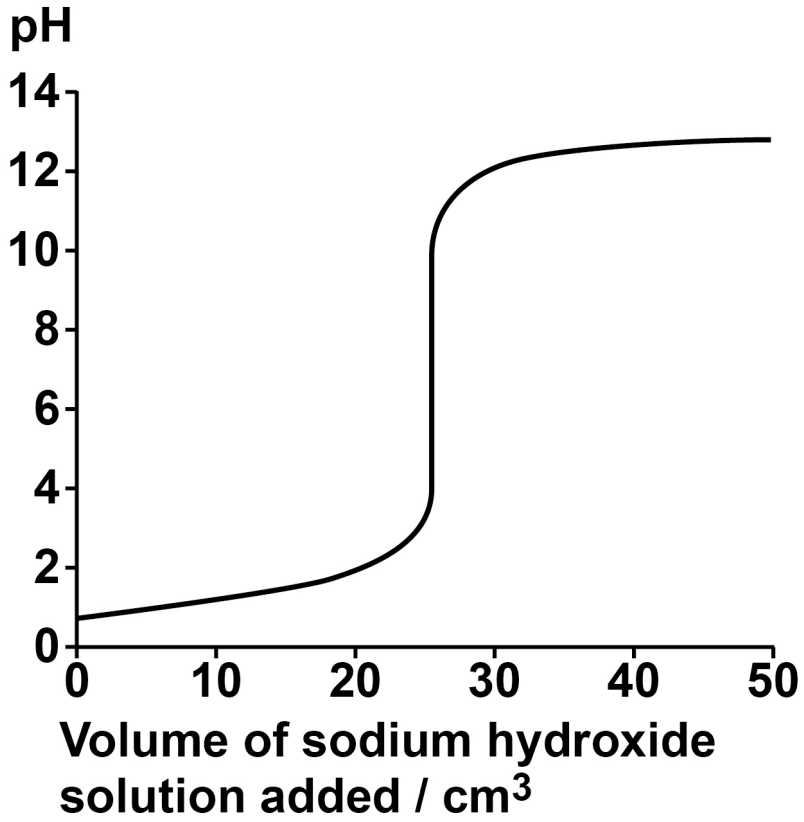
0 6 . 6

The calibrated pH meter is used to monitor the pH during a titration of hydrochloric acid with sodium hydroxide.

Explain why the volume of sodium hydroxide solution added between each pH measurement is smaller as the end point of the titration is approached. [1 mark]

FIGURE 4 shows the pH curve for a titration of hydrochloric acid with sodium hydroxide solution.

FIGURE 4



[Turn over]

TABLE 6 shows data about some indicators.

TABLE 6

Indicator	pH range	Colour at low pH	Colour at high pH
Bromocresol green	3.8 – 5.4	yellow	blue
Phenol red	6.8 – 8.4	yellow	red
Thymolphthalein	9.3 – 10.5	colourless	blue

The student plans to do the titration again using one of the indicators in TABLE 6 to determine the end point.

0 6 . 7

State why all three of the indicators in TABLE 6 are suitable for this titration. [1 mark]

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[Turn over]

0 6 . 8

36.25 cm^3 of 0.200 mol dm^{-3} sodium hydroxide solution are added to 25.00 cm^3 of 0.150 mol dm^{-3} hydrochloric acid.

Calculate the pH of the final solution at 25 °C

K_w = 1.00 × 10^{-14} mol^2 dm^{-6} at 25 °C [5 marks]

pH _____

[Turn over]

16

0 7

This question is about thermodynamics.

Consider the reaction shown.

$$2\ Al_2O_3(s) + 3\ C(s) \longrightarrow 4\ Al(s) + 3\ CO_2(g)$$

TABLE 7 shows some thermodynamic data.

TABLE 7

Substance	$Al_2O_3(s)$	Al(s)	C(s)	$CO_2(g)$
$\Delta_f H^{\ominus}$ / kJ mol^{-1}	–1669	0	0	–394
$S^{\ominus}$ / J K^{-1} mol^{-1}	51	28	6	214

0 7 . 1

Explain why the standard entropy value for carbon dioxide is greater than that for carbon. [1 mark]

0 7 . 2

State the temperature at which the standard entropy of aluminium is 0 J K^{-1} mol^{-1} [1 mark]

[Turn over]

REPEAT OF TABLE 7

Substance	$Al_2O_3(s)$	Al(s)	C(s)	$CO_2(g)$
$\Delta_f H^{\ominus}$ / kJ mol^{-1}	–1669	0	0	–394
$S^{\ominus}$ / J K^{-1} mol^{-1}	51	28	6	214

0 7 . 3

Use the equation and the data in TABLE 7 to calculate the minimum temperature, in K, at which this reaction becomes feasible. [7 marks]

Minimum temperature _____ **K**

[Turn over]

9

0 8

This question is about electrode potentials and electrochemical cells.

0 8 . 1

State the meaning of the term electrochemical series.
[1 mark]

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[Turn over]

TABLE 8 shows some electrode potentials.

TABLE 8

	$E^{\ominus}$ / V
$[Fe(H_2O)_6]^{2+}(aq) + 2\ e^- \longrightarrow Fe(s) + 6\ H_2O(l)$	–0.44
$H^+(aq) + e^- \longrightarrow \frac{1}{2}\ H_2(g)$	0.00
$[Co(NH_3)_6]^{3+}(aq) + e^- \longrightarrow [Co(NH_3)_6]^{2+}(aq)$	+0.11
$[Fe(H_2O)_6]^{3+}(aq) + e^- \longrightarrow [Fe(H_2O)_6]^{2+}(aq)$	+0.77
$VO_2^+(aq) + 2\ H^+(aq) + e^- \longrightarrow VO^{2+}(aq) + H_2O(l)$	+1.00
$[Co(H_2O)_6]^{3+}(aq) + e^- \longrightarrow [Co(H_2O)_6]^{2+}(aq)$	+1.81

0 8 . 2

State TWO conditions needed for the following half-cell to have $E^{\ominus} = 0.00$ V

$$H^+(aq) + e^- \longrightarrow \frac{1}{2} H_2(g)$$

[1 mark]

0 8 . 3

Identify the weakest reducing agent in TABLE 8.
[1 mark]

[Turn over]

REPEAT OF TABLE 8

	$E^{\ominus}$ / V
$[Fe(H_2O)_6]^{2+}(aq) + 2\ e^- \longrightarrow Fe(s) + 6\ H_2O(l)$	–0.44
$H^+(aq) + e^- \longrightarrow \frac{1}{2}\ H_2(g)$	0.00
$[Co(NH_3)_6]^{3+}(aq) + e^- \longrightarrow [Co(NH_3)_6]^{2+}(aq)$	+0.11
$[Fe(H_2O)_6]^{3+}(aq) + e^- \longrightarrow [Fe(H_2O)_6]^{2+}(aq)$	+0.77
$VO_2^+(aq) + 2\ H^+(aq) + e^- \longrightarrow VO^{2+}(aq) + H_2O(l)$	+1.00
$[Co(H_2O)_6]^{3+}(aq) + e^- \longrightarrow [Co(H_2O)_6]^{2+}(aq)$	+1.81

0 8 . 4

Use half-equations from TABLE 8 to deduce an equation for the reduction of VO_2^+ to form VO^{2+} in aqueous solution by iron. [2 marks]

0 8 . 5

Use data from TABLE 8 to explain why $[Co(H_2O)_6]^{3+}(aq)$ will undergo a redox reaction with $[Fe(H_2O)_6]^{2+}(aq)$

Give an equation for this reaction. [2 marks]

Explanation _____

_____

_____

_____

Equation

_____

0 8 . 6

Suggest why the TWO cobalt(III) complex ions in TABLE 8 have different electrode potentials. [1 mark]

_____

_____

_____

[Turn over]

8

0 9

This question is about the development of lithium cells.

The value of $E^{\ominus}$ for lithium suggests that a lithium cell could have a large EMF.

TABLE 9 shows some electrode potential data.

TABLE 9

	$E^{\ominus}$ / V
$Li^+(aq) + e^- \longrightarrow Li(s)$	–3.04
$2\ H_2O(l) + 2\ e^- \longrightarrow H_2(g) + 2\ OH^-(aq)$	–0.83
$\frac{1}{2}\ I_2(s) + e^- \longrightarrow I^-(aq)$	+0.54

0 9 . 1

Use data in TABLE 9 to explain why an aqueous electrolyte is NOT used for a lithium cell. [2 marks]

0 9 . 2

In the 1970s lithium-iodine cells became a common power source for heart pacemakers. Lithium iodide is the final product of the cell reaction.

Use the data in TABLE 9 to calculate the cell EMF of a standard lithium-iodine cell. [1 mark]

0 9 . 3

An EMF value for a commercial lithium-iodine cell is 2.80 V

Suggest why this value is different from the value calculated in Question 09.2. [1 mark]

[Turn over]

0 9 . 4

In some lithium cells, lithium perchlorate ($LiClO_4$) is used as the electrolyte.

Deduce the oxidation state of chlorine in $LiClO_4$
[1 mark]

In other lithium cells, lithium cobalt oxide electrodes AND lithium electrodes are used.

0 9 . 5

Give an equation for the reaction that occurs at the positive lithium cobalt oxide electrode. [1 mark]

---

0 9 . 6

Give an equation for the reaction that occurs at the negative lithium electrode. [1 mark]

END OF QUESTIONS

7

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

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

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For Examiner's Use	
Question	Mark
1	
2	
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