Paper Reference(s)   9CH0/01
Pearson Edexcel Level 3 GCE

Total Marks

Chemistry
Advanced
PAPER 1: Advanced Inorganic and Physical Chemistry

Time: 1 hour 45 minutes

In the boxes below, write your name, centre number and candidate number.

Surname	
Other names	
Centre Number	
Candidate Number	

Y67093RA

Pearson

YOU MUST HAVE

Scientific calculator, Data Booklet, ruler

YOU WILL BE GIVEN

Diagram Booklet, Periodic Table

INSTRUCTIONS

Answer ALL questions.

Answer the questions in the spaces provided in this Question Paper or in the separate Diagram Booklet – there may be more space than you need.

INFORMATION

The total mark for this paper is 90.

The marks for EACH question are shown in brackets – use this as a guide as to how much time to spend on each question.

For the question marked with an ASTERISK (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.

A Periodic Table is provided as a separate insert.

There may be spare copies of some diagrams.

ADVICE

Read each question carefully before you start to answer it.

Show all your working in calculations and include units where appropriate.

Check your answers if you have time at the end.

Answer ALL questions.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1   This question is about atomic structure and the Periodic Table.

(a) Look at the table for Question 1(a) in the Diagram Booklet. Complete the table to show the relative charges and masses for a neutron and an electron.
(2 marks)

(b) Atomic emission spectroscopy provides evidence for the existence of
(1 mark)

☐ A   atoms

☐ B   electrons

☐ C   isotopes

☐ D   quantum shells

Turn over

1   continued.

(c) Draw the shape of a p orbital.
(1 mark)

1 continued.

(d) Look at the table for Question 1(d) in the Diagram Booklet. The melting temperatures of two elements in Period 3 are given in the table.

Explain, in terms of the structure and bonding of each element, the difference between these values.
(3 marks)

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(continued on the next page)

Turn over

1 continued.

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(Total for Question 1 = 7 marks)

2   This question is about the elements in Group 2 of the Periodic Table.

(a) Magnesium powder is added to a beaker of water containing a few drops of Universal Indicator.

Look at the diagram for Question 2(a) in the Diagram Booklet. The apparatus is set up as shown and allowed to stand for a few days.

State TWO changes that will be SEEN after a few days.
(2 marks)

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2 continued.

**(b) Explain how the trend in the reactivity of the Group 2 elements is determined by their electronic configurations.
(3 marks)**

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(continued on the next page)

Turn over

2   continued.

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2   continued.

(c) Calcium reacts with chlorine.

$$Ca(s) \; + \; Cl_2(g) \; \longrightarrow \; CaCl_2(s)$$

Explain, in terms of electrons, why this is a redox reaction.
(2 marks)

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Turn over

2   continued.

(d) An experiment was carried out to determine the molar volume of hydrogen at room temperature.

0·035 g of magnesium was added to excess hydrochloric acid and $32 \, cm^3$ of hydrogen was produced.

$$Mg(s) \; + \; 2HCl(aq) \; \longrightarrow \; MgCl_2(aq) \; + \; H_2(g)$$

On page 15 calculate the molar volume of hydrogen from the results of this experiment.
Include units in your answer.
(2 marks)

Turn over

2   continued.

(Total for Question 2 = 9 marks)

3   This question is about the elements in Group 7 of the Periodic Table and some of their compounds.
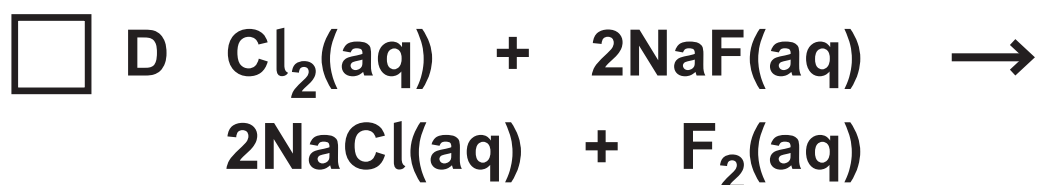
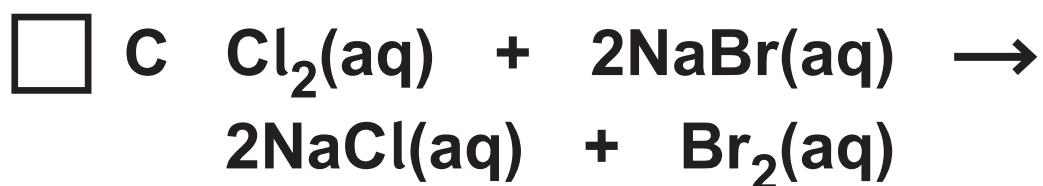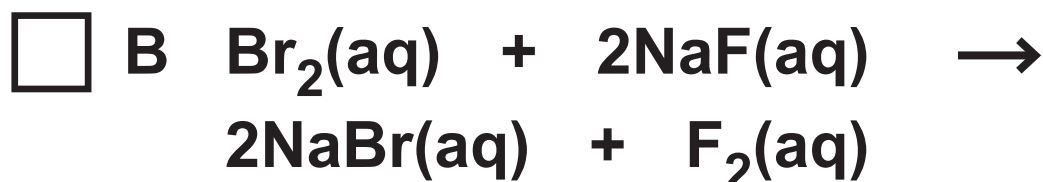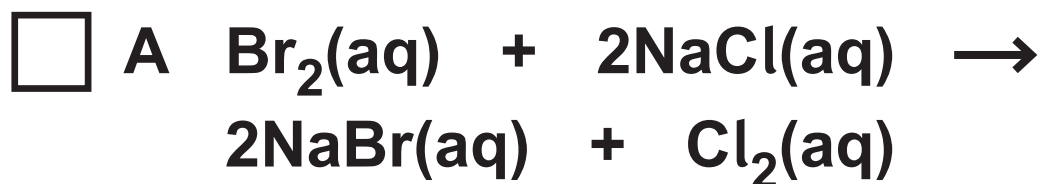(a) What is the colour of iodine in the solid and gas states?
(1 mark)

	Colour of iodine solid	Colour of iodine gas
☐ A	purple	brown
☐ B	purple	purple
☐ C	grey / black	brown
☐ D	grey / black	purple

(continued on the next page)

3 continued.

(b) Which of these reactions occurs?
    (1 mark)

☐ A $Br_2(aq)$ + $2NaCl(aq)$ →
    $2NaBr(aq)$ + $Cl_2(aq)$

☐ B $Br_2(aq)$ + $2NaF(aq)$ →
    $2NaBr(aq)$ + $F_2(aq)$

☐ C $Cl_2(aq)$ + $2NaBr(aq)$ →
    $2NaCl(aq)$ + $Br_2(aq)$

☐ D $Cl_2(aq)$ + $2NaF(aq)$ →
    $2NaCl(aq)$ + $F_2(aq)$

(continued on the next page)

Turn over

3   continued.

(c) The halogens can form halide ions during reactions.

Complete the electronic configuration of the chloride ion.
(1 mark)

$1s^2$ _____

_____

(continued on the next page)

3 **continued.**

(d) **Look at the equation for Question 3(d) in the Diagram Booklet. The standard electrode potentials for two half-equations involving bromine are given.**

   (i) **On page 20 explain why the disproportionation of bromine in water is NOT thermodynamically feasible under standard conditions. Include the overall equation for the disproportionation and its $E^{\ominus}_{cell}$ value.**
   (3 marks)

(continued on the next page)

3   continued.

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Turn over

3   continued.

(ii) Bromine disproportionates in water to a small extent at 298 K.

Give a possible reason why this reaction occurs.
(1 mark)

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(continued on the next page)

Turn over

3 continued.

(e) The hydrogen halides have the general formula HX, where X represents the symbol of the halogen.

(i) Look at the diagrams for Question 3(e)(i) in the Diagram Booklet. Which diagram shows the trend in the boiling temperatures of the hydrogen halides?
(1 mark)

☐ A Diagram A

☐ B Diagram B

☐ C Diagram C

☐ D Diagram D

(continued on the next page)

3   continued.

(ii) **What type of reaction occurs when ammonia gas reacts with hydrogen chloride gas?**
(1 mark)

☐ **A   acid-base**

☐ **B   displacement**

☐ **C   redox**

☐ **D   substitution**

(Total for Question 3 = 9 marks)

Turn over

4   This question is about structure and bonding.

(a) Ionic bonding is the strong electrostatic attraction between
(1 mark)

☐ A   anions and cations

☐ B   atoms and delocalised electrons

☐ C   cations and delocalised electrons

☐ D   two nuclei and a shared pair of electrons

(continued on the next page)

4   continued.

(b) Look at the diagram for Question 4(b) in the Diagram Booklet. An aqueous solution of copper(II) chromate(VI) was electrolysed using the apparatus shown in the diagram.

Deduce the colours of the solutions in regions **E** and **F** after the electrolysis has occurred.
(2 marks)

Colour in region **E**

_____

Colour in region **F**

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(continued on the next page)

Turn over

4   continued.

(c) Some ionic radii are given in the table.

Ion	Ionic radius / nm
Na^+	0·102
Mg^{2+}	0·072
Cl^-	0·180
Br^-	0·195

Deduce the FORMULA of the compound, formed from the ions in the table, that has the strongest ionic bonding.
(1 mark)

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(continued on the next page)

4   continued.

(d) Look at the table for Question 4(d) in the Diagram Booklet. The names of four substances are given.

(i) Which of these substances exists at room temperature as a giant lattice of oppositely charged ions?
(1 mark)

☐ A Substance **P**

☐ B Substance **Q**

☐ C Substance **R**

☐ D Substance **S**

(continued on the next page)

4   continued.

(ii) **Which of these substances has a high melting temperature, AND conducts electricity when solid and when molten?**
(1 mark)

☐ **A   Substance P**

☐ **B   Substance Q**

☐ **C   Substance R**

☐ **D   Substance S**

(continued on the next page)

4   continued.

*(e) Water has two significant anomalous properties:

- it has a higher melting temperature than hydrogen sulfide, H_2S, even though it has fewer electrons in its molecules

- the density of ice at 0°C is less than that of water at 0°C.

On pages 30 to 35 explain these properties.

You should include a labelled diagram to show the intermolecular forces between two molecules of water.
(6 marks)

Turn over

4 continued.

Turn over

4 continued.

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4   continued.

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4   continued.

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4 continued.

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4   continued.

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(Total for Question 4 = 12 marks)

Turn over

5   This question is about enthalpy changes and energy changes.

(a) Magnesium carbonate reacts with dilute hydrochloric acid at room temperature.

$MgCO_3(s) + 2HCl(aq) \longrightarrow$

$MgCl_2(aq) + CO_2(g) + H_2O(l)$

When the reaction is carried out in a sealed container with a constant volume, the heat energy change is not the same as the enthalpy change for this reaction.

Give a reason why this is so.
(1 mark)

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(continued on the next page)

Turn over

5   continued.

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(continued on the next page)

5   continued.

(b) State what is meant by the standard
enthalpy change of formation of
aluminium oxide, Al_2O_3(s). Include
standard conditions.
(3 marks)

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(continued on the next page)

Turn over

5 continued.

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(continued on the next page)

5 continued.

(c) Use the data in the table to answer the questions.

Enthalpy change	Value / kJ mol^{-1}
Enthalpy change of hydration of K$^+$	−322
Enthalpy change of hydration of Ca^{2+}	−1650
Enthalpy change of solution of KCl	+17·2
Lattice energy of KCl	−711

(i) Name the two properties of ions that affect the value of their enthalpy change of hydration.
(2 marks)

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Turn over

5 continued.

(ii) Look at the diagram for Question 5(c)(ii) in the Diagram Booklet. Calculate the enthalpy change of hydration for chloride ions by completing the energy cycle, including labels, and using the data in the table. (3 marks)

enthalpy change of hydration

for Cl⁻ ions _____ $kJ\,mol^{-1}$

(Total for Question 5 = 9 marks)

6 **This question is about acids and bases.**

(a) **State what is meant by a Brønsted-Lowry base.**
(1 mark)

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(b) **Write the ionic equation for the reaction between magnesium oxide and an acid.**
State symbols ARE required.
(2 marks)

Turn over

6   continued.

(c) Calculate the concentration of
hydrogen ions, in mol dm^{-3}, in a
solution with a pH of 9·43
(1 mark)

(continued on the next page)

Turn over

6   continued.

(d) The pH of two salt solutions, **J** and **K**, are

solution **J**   pH = 5

solution **K**   pH = 9

The solutions are equimolar.

Look at the table for Question 6(d) in the Diagram Booklet. Which acids and bases could form the salts in solutions **J** and **K**?
(1 mark)

(continued on the next page)

Turn over

6   continued.

(e) The ionic product of water, K_w, varies with temperature as shown.

Temperature / °C	K_w /mol^2 dm^{-6}
0	$0 \cdot 11 \times 10^{-14}$
10	$0 \cdot 29 \times 10^{-14}$
20	$0 \cdot 68 \times 10^{-14}$
30	$1 \cdot 47 \times 10^{-14}$
40	$2 \cdot 92 \times 10^{-14}$
50	$5 \cdot 48 \times 10^{-14}$

(i)   Look at the grid for Question 6(e)(i) in the Diagram Booklet. Determine the value of K_w at 45 °C by plotting a suitable graph.
You must show your working on the graph.
(3 marks)

K_w at 45 °C = _____

Turn over

6   continued.

(ii) The ionic product of water at $30\,°C$ is $1·47 \times 10^{-14}\,mol^2\,dm^{-6}$.

Calculate the pH of water at this temperature.
(3 marks)

Turn over

6   continued.

(f) Hydrochloric acid, with a concentration of $0 \cdot 100 \, \text{mol} \, \text{dm}^{-3}$, is added to $25 \cdot 0 \, \text{cm}^3$ of $0 \cdot 100 \, \text{mol} \, \text{dm}^{-3}$ aqueous sodium carbonate and the pH is measured.

Look at the graph for Question 6(f) in the Diagram Booklet. The titration curve is shown.

The reaction takes place in two steps. The equation for the reaction taking place in the first step is

$$Na_2CO_3(aq) \quad + \quad HCl(aq) \quad \longrightarrow$$
$$NaHCO_3(aq) \quad + \quad NaCl(aq)$$
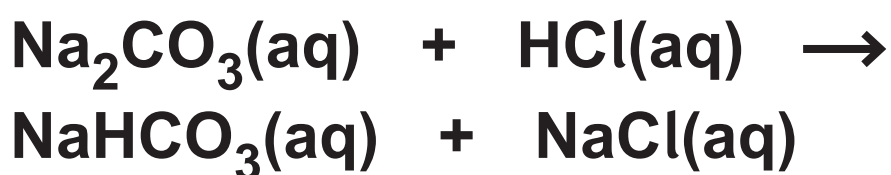
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6   continued.

(i)   Deduce a suitable indicator to identify the first equivalence point. Justify your answer using values from the Data Booklet. (2 marks)

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(continued on the next page)

Turn over

6   continued.

(ii) **Write the equation for the reaction taking place at the second equivalence point. State symbols are not required. (1 mark)**

(continued on the next page)

6   continued.

       (iii) Explain how the solution at point X on the graph can act as a buffer solution.
            (3 marks)

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(continued on the next page)

6 continued.

(Total for Question 6 = 17 marks)

7   This question is about chromium and some of its compounds.

(a) The common oxidation numbers of chromium are +2, +3 and +6.

Give a reason, in terms of ionisation energies, why chromium can show variable oxidation numbers.
(1 mark)

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(continued on the next page)

7 **continued.**

(b) The bonding in chromate(VI) ions, CrO_4^{2-}, is similar to that in sulfate(VI) ions, SO_4^{2-}.

On page 54 draw a possible dot-and-cross diagram for a chromate(VI) ion.
(2 marks)

Turn over

7   continued.

Turn over

7   continued.

(c) A student added some pieces of zinc to an acidified solution of potassium dichromate(VI).

Look at the table for Question 7(c) in the Diagram Booklet. Some standard electrode potentials are given in the table.

7   continued.

> **(i) Write the overall equation for the reduction of dichromate(VI) ions to chromium(III) ions by zinc in acid conditions.**
> **State symbols are not required.**
> **(2 marks)**

(continued on the next page)

7   continued.

   **(ii) Calculate $E^{\ominus}_{cell}$ for the reaction
          in (c)(i).
          (1 mark)**

(continued on the next page)

7 **continued.**

(iii) **Predict whether or not a further reduction of chromium(III) ions to chromium(II) ions will occur. Justify your answer.**
(1 mark)

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7   continued.

    (iv) Aqueous solutions containing chromium(III) ions and chromium(II) ions have different colours.

        Explain why these solutions DIFFER in colour.
        An explanation of the origin of the colours is not required.
        (2 marks)

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7   continued.

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(continued on the next page)

7   continued.

(d) An iron nail was analysed using the following outline procedure.

- An iron nail was placed in a beaker and excess dilute sulfuric acid was added.

- After all the iron had reacted to form iron(II) ions, the solution was made up to $1 \cdot 00 \, dm^3$ in a volumetric flask.

- $25 \cdot 0 \, cm^3$ portions of the solution were acidified and titrated with potassium dichromate(VI) solution of concentration $0 \cdot 0167 \, mol \, dm^{-3}$.

RESULTS

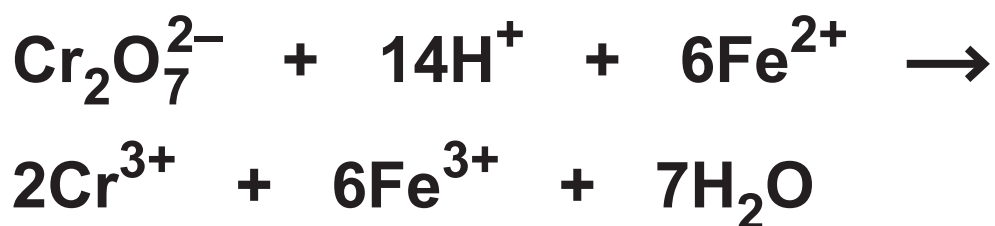mass of iron nail = $3 \cdot 54 \, g$

mean titre = $15 \cdot 50 \, cm^3$

7   continued.

The table shows the percentage by mass of iron in four different brands of nail.

Brand of nail	Percentage by mass of iron
A	92
B	94
C	96
D	98

Potassium dichromate(VI) in acid solution oxidises iron(II) ions as shown in the equation

$$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow$$

$$2Cr^{3+} + 6Fe^{3+} + 7H_2O$$

(continue your answer on the next page)

Turn over

7   continued.

Determine, using the experimental
data, the brand of nail that
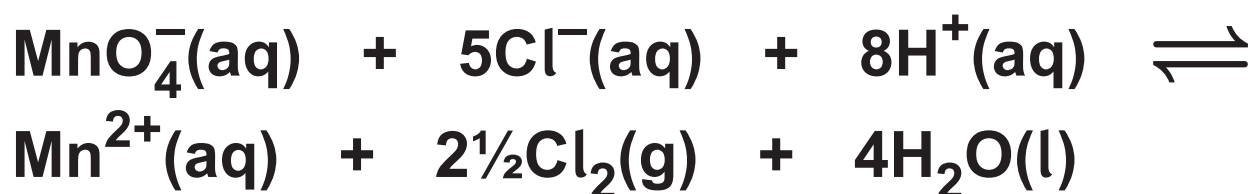was analysed.
(5 marks)

Turn over

7   continued.

(Total for Question 7 = 14 marks)

8 **This question is about electrode potentials, cells and equilibrium constants.**

   (a) Chlorine gas can be prepared by the oxidation of chloride ions with manganate(VII) ions in acid solution.

$$MnO_4^-(aq) \; + \; 5Cl^-(aq) \; + \; 8H^+(aq) \; \rightleftharpoons$$
$$Mn^{2+}(aq) \; + \; 2\tfrac{1}{2}Cl_2(g) \; + \; 4H_2O(l)$$
$$E^{\ominus}_{cell} = +0{\cdot}15 \text{ V}$$

   During this reaction, each manganate(VII) ion accepts five electrons.

(continued on the next page)

Turn over

8   continued.

On page 67 calculate the equilibrium constant, K, for this reaction at 298 K using the expression

$$\ln K = \frac{n E^{\ominus}_{cell} F}{RT}$$

where n is the number of electrons transferred in the overall equation, F is the Faraday constant ($96\,500\,C\,mol^{-1}$) and R is the gas constant ($8 \cdot 31\,J\,mol^{-1}\,K^{-1}$).
Units of K are not required.
(2 marks)

Turn over

8   continued.

$$\ln K = \frac{n E^{\ominus}_{cell} F}{RT}$$

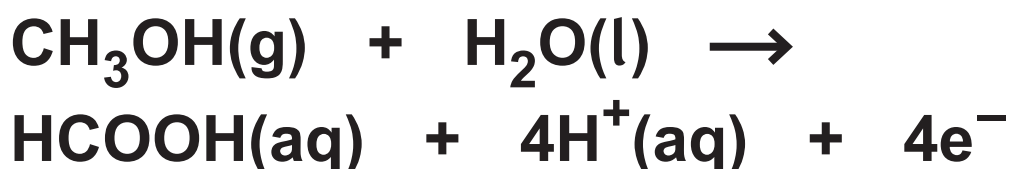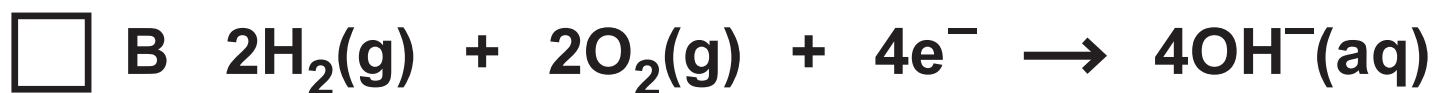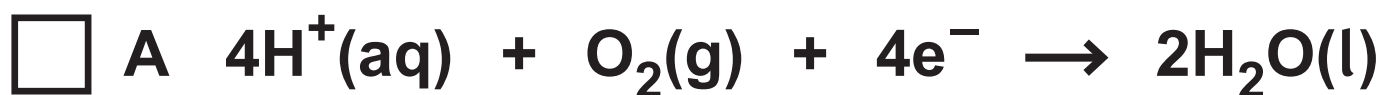**Turn over**

8   continued.

(b) A fuel cell produces a voltage from the reaction between a fuel and oxygen.

The reaction occurring at one electrode in a methanol fuel cell is

$CH_3OH(g)$ + $H_2O(l)$ $\longrightarrow$
$HCOOH(aq)$ + $4H^+(aq)$ + $4e^-$

Which reaction occurs at the other electrode?
(1 mark)

☐ A $4H^+(aq)$ + $O_2(g)$ + $4e^-$ $\longrightarrow$ $2H_2O(l)$

☐ B $2H_2(g)$ + $2O_2(g)$ + $4e^-$ $\longrightarrow$ $4OH^-(aq)$

☐ C $4OH^-(aq)$ $\longrightarrow$ $2H_2(g)$ + $2O_2(g)$ + $4e^-$

☐ D $2H_2O(l)$ $\longrightarrow$ $4H^+(aq)$ + $O_2(g)$ + $4e^-$

8   continued.

(c) Lead-acid batteries are used as storage cells in some cars.

The electrolyte is sulfuric acid, one electrode is lead and the other is lead(IV) oxide, PbO_2.

As the cell discharges, the lead and the lead(IV) oxide are both converted to solid lead(II) sulfate, $PbSO_4$, and the concentration of the sulfuric acid decreases.

On page 70 deduce, using the information given, the two half-equations occurring in the lead-acid battery.
State symbols ARE required.
(3 marks)

Turn over

8   continued.

Turn over

8   continued.

(d) When solid lead(II) sulfate is added to aqueous sodium iodide, an equilibrium is established.

$$PbSO_4(s) \; + \; 2I^-(aq) \; \rightleftharpoons \; PbI_2(s) \; + \; SO_4^{2-}(aq)$$

The expression for the equilibrium constant, K_c, for this reaction is

$$K_c = \frac{[SO_4^{2-}(aq)]}{[I^-(aq)]^2}$$

In an experiment, K_c may be determined by adding excess lead(II) sulfate to $25\cdot0\,cm^3$ of $0\cdot100\,mol\,dm^{-3}$ sodium iodide. The volume remains constant at $25\cdot0\,cm^3$. The mixture is left to reach equilibrium at room temperature.

(continued on the next page)

8   continued.

Ice-cold water is added to freeze
the position of equilibrium and the
mixture is then titrated with standard
silver nitrate solution.

The whole mixture requires $12 \cdot 20 \, cm^3$
of $0 \cdot 0500 \, mol \, dm^{-3}$ silver nitrate
solution to react with the
aqueous iodide ions at equilibrium.

$$Ag^+(aq) \ + \ I^-(aq) \ \longrightarrow \ AgI(s)$$

(continued on the next page)

8   continued.

Calculate the equilibrium concentrations of the sulfate ions and the iodide ions, and hence the value of K_c at room temperature. Give your answer to an appropriate number of significant figures and include units for K_c, if any.
(7 marks)

Turn over

8 continued.

Turn over

8   continued.

(Total for Question 8 = 13 marks)

TOTAL FOR PAPER = 90 MARKS
END OF PAPER