

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

**Chemistry**

**Advanced**

**PAPER 1: Advanced Inorganic and Physical  
Chemistry**

Total Marks

**Monday 12 June 2023 – Morning**

**Time: 1 hour 45 minutes**

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

<b>Surname</b>					
<b>Other names</b>					
<b>Centre Number</b>					
<b>Candidate Number</b>					

**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.**

**(continued on the next page)**

**INFORMATION continued.**

**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 d-block elements.**

**(a) Look at the graph for Question 1(a) in the Diagram Booklet. Which of the labels 1–4 identifies a d-block element in Period 4?  
(1 mark)**

☐ **A 1**

☐ **B 2**

☐ **C 3**

☐ **D 4**

**(continued on the next page)**

**Turn over**

**1 continued.**

**(b) State what is meant by the term  
d-block element.  
(1 mark)**

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**(Total for Question 1 = 2 marks)**

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**2 Chemists often use the term ‘orbital’ when considering atomic structure.**

**(a) State what is meant by the term orbital.  
(2 marks)**

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**(continued on the next page)**

**Turn over**

**2 continued.**

**(b) Look at the table for Question 2(b) in the Diagram Booklet. Draw diagrams to show the shape of an s and a p orbital.**

**(2 marks)**

**(c) What is the electronic configuration of a copper atom?**

**(1 mark)**

☐ **A**  $[\text{Ar}]4s^13d^{10}$

☐ **B**  $[\text{Ar}]4s^23d^9$

☐ **C**  $[\text{Ar}]4s^24p^13d^8$

☐ **D**  $[\text{Ar}]4s^24p^23d^7$

**(Total for Question 2 = 5 marks)**

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**Turn over**

**3 This question is about compounds containing elements from Group 7.**

**(a) Which change occurs when concentrated sulfuric acid is added to potassium bromide?  
(1 mark)**

- ☐ **A bromide ions oxidise sulfuric acid forming sulfur**
- ☐ **B bromide ions oxidise sulfuric acid forming sulfur dioxide**
- ☐ **C bromide ions reduce sulfuric acid forming sulfur**
- ☐ **D bromide ions reduce sulfuric acid forming sulfur dioxide**

**(continued on the next page)**



**3 continued.**

**(b) Chemists can test for the presence of bromide ions in solution by adding a small amount of acidified silver nitrate solution.**

**The solubility of the precipitate in aqueous ammonia is then tested.**

**(continued on the next page)**

**3(b) continued.**

**(i) Which statement is correct for bromide ions?  
(1 mark)**

- ☐ **A a white precipitate forms that dissolves in concentrated ammonia only**
- ☐ **B a white precipitate forms that dissolves in both dilute and concentrated ammonia**
- ☐ **C a cream precipitate forms that dissolves in concentrated ammonia only**
- ☐ **D a cream precipitate forms that dissolves in both dilute and concentrated ammonia**

**(continued on the next page)**

**3(b) continued.**

**(ii) Give a reason why the  
silver nitrate must be acidified.  
(1 mark)**

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**(continued on the next page)**

**3(b) continued.**

- (iii) Explain which acid needs to be used to acidify the silver nitrate solution and why other acids are unsuitable.  
(2 marks)**

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**(continued on the next page)**

**Turn over**

**3 continued.**

**(c) Look at the chemical equation for Question 3(c) in the Diagram Booklet.**

**Iodine trichloride forms a dimer,  
 $\text{I}_2\text{Cl}_6$ , in the solid state.**

**When molten, it is suggested that it  
breaks down as shown.**

**(continued on the next page)**

**3(c) continued.**

- (i) Draw a labelled diagram of a simple experiment to confirm this dissociation has occurred, stating the positive result.**

**(2 marks)**

**Result**

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**3(c) continued.**

**(ii) What is the shape of the  $\text{ICl}_4^-$  ion?  
(1 mark)**

- ☐ **A octahedral**
- ☐ **B square planar**
- ☐ **C tetrahedral**
- ☐ **D trigonal bipyramidal**

**(continued on the next page)**

**3(c) continued.**

- (iii) The equilibrium position for the dissociation of molten  $\text{I}_2\text{Cl}_6$  lies to the left.**



**What is the most likely numerical value of  $K_c$  for this equilibrium?  
(1 mark)**

- ☐ **A**  $1.0 \times 10^6$
- ☐ **B**  $5.0 \times 10^3$
- ☐ **C** 1.0
- ☐ **D**  $5.0 \times 10^{-3}$

**(Total for Question 3 = 9 marks)**

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- 4 Look at the graph for Question 4 in the Diagram Booklet. It shows the melting temperatures of some elements in Period 3.**

**Explain the variations in melting temperature across the period in terms of the structure and bonding in these elements.**

**(6 marks)**

**Answer space continues on the next 5 pages.**

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**Turn over**

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**Turn over**

**4 continued.**

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**Turn over**

**4 continued.**

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**Turn over**

**4 continued.**

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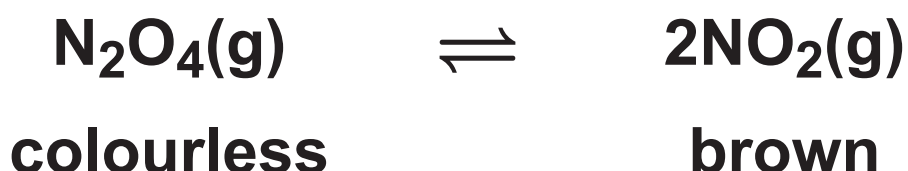
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**(Total for Question 4 = 6 marks)**

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- 5 This question is about the decomposition of dinitrogen tetroxide. The reaction eventually reaches equilibrium.



- (a) The table shows values of  $\Delta G$  at different temperatures for this reaction.

Temperature / K	$\Delta G / \text{kJ mol}^{-1}$
350	-4.0
400	-13
450	-22
500	-31
550	-40

(continued on the next page)

**5(a) continued.**

- (i) Look at the grid for Question 5(a)(i) in the Diagram Booklet. Plot a graph of  $\Delta G$  against temperature. (2 marks)**

**(continued on the next page)**



**5(a) continued.**

- (ii) Calculate the entropy change of the system,  $\Delta S_{\text{system}}$ , in  $\text{J K}^{-1} \text{mol}^{-1}$ , using your straight line from the graph in (a)(i) and the equation shown.  
(3 marks)**

$$\Delta G = -T\Delta S_{\text{system}} + \Delta H$$

**5(a) continued.**

**(iii) What feature of the graph in (a)(i) gives the enthalpy change of the reaction?  
(1 mark)**

- ☐ **A intercept of the x-axis**
- ☐ **B (intercept of the x-axis)  $\times -1$**
- ☐ **C intercept of the y-axis**
- ☐ **D (intercept of the y-axis)  $\times -1$**

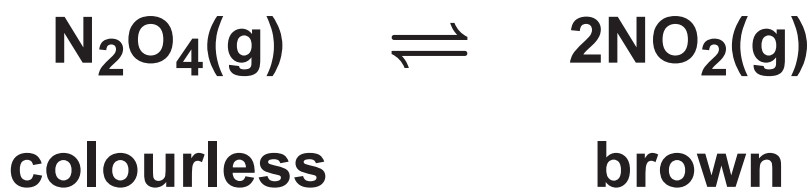
**(continued on the next page)**

**5 continued.**

**(b) Look at the table for Question 5(b) in the Diagram Booklet. What happens to the position of the equilibrium and the colour of the mixture when the pressure is increased?**

**The volume of the system remains constant.**

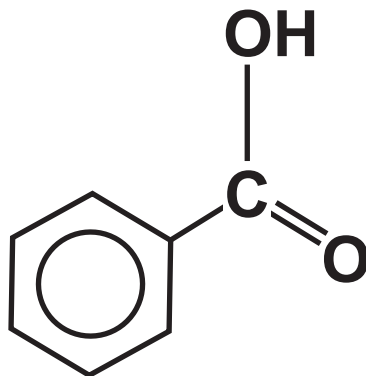
**(1 mark)**



**(Total for Question 5 = 7 marks)**

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- 6 Benzoic acid is a weak acid found in cranberries.**



**$\text{C}_6\text{H}_5\text{COOH}$  – benzoic acid**

- (a) Look at the table for Question 6(a) in the Diagram Booklet. Which of these answers identifies the types of species present when benzoic acid is mixed with nitric acid?  
(1 mark)**

**(continued on the next page)**

**6 continued.**

**(b) The ionic salts sodium benzoate and potassium benzoate are both used as food preservatives.**

**Explain why the melting temperature of sodium benzoate is higher than the melting temperature of potassium benzoate.  
(2 marks)**

**Answer space continues on the next page.**

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**Turn over**

**6(b) continued.**

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**(continued on the next page)**

**6 continued.**

**(c) The value of  $K_a$  for benzoic acid =  $6.28 \times 10^{-5} \text{ mol dm}^{-3}$ .**

**(i) Write the expression for the acid dissociation constant,  $K_a$ , of benzoic acid.  
(1 mark)**

**(continued on the next page)**

**Turn over**

**6(c) continued.**

- (ii) Calculate the mass  
of benzoic acid needed to prepare  
250 cm<sup>3</sup> of a solution with a  
pH = 3.51  
(4 marks)**

**Answer space continues on the next page.**



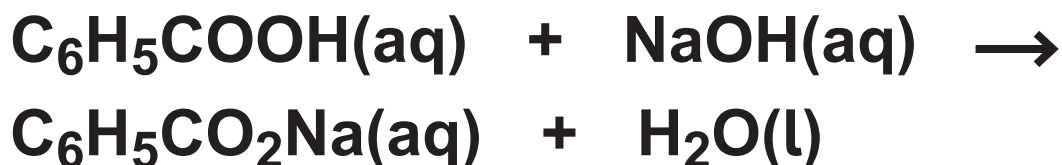
**6(c)(ii) continued.**

**(continued on the next page)**

**Turn over**

**6 continued.**

**(d) Weak acids such as benzoic acid can be neutralised by sodium hydroxide solution.**



**(i) Which of these could be used to show the end-point of a titration of benzoic acid with sodium hydroxide solution?  
(1 mark)**

☐ **A bromothymol blue**

☐ **B litmus**

☐ **C methyl orange**

☐ **D phenolphthalein**

**(continued on the next page)**

**Turn over**

**6(d) continued.**

- (ii) Another weak acid found in cranberries is quinic acid,  $\text{C}_6\text{H}_7(\text{OH})_4\text{COOH}$ . It is neutralised by sodium hydroxide solution in a similar way to benzoic acid.**

**A  $25.0\text{ cm}^3$  sample of  $0.500\text{ mol dm}^{-3}$  quinic acid solution was neutralised under standard conditions in a polystyrene cup using  $25.0\text{ cm}^3$  of  $0.800\text{ mol dm}^{-3}$  of sodium hydroxide solution. This resulted in a temperature rise of  $2.9^\circ\text{C}$ .**

**Calculate the standard enthalpy change of neutralisation,  $\Delta_{\text{neut}}\text{H}^\ominus$ , of quinic acid in  $\text{kJ mol}^{-1}$ .  
(3 marks)**

**(continued on the next page)**

**Turn over**

**6(d)(ii) continued.**

**[Assume the density of both  
solutions is  $1.0 \text{ g cm}^{-3}$ .  
specific heat capacity of solution  
formed =  $4.18 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$ ]**

**Answer space continues on the next page.**

**6(d)(ii) continued.**

**(continued on the next page)**

**Turn over**

**6(d) continued.**

- (iii) The standard enthalpy change of neutralisation of the weak acid HCN by sodium hydroxide is  $-11.7 \text{ kJ mol}^{-1}$  while that of the strong acid HCl is  $-57.9 \text{ kJ mol}^{-1}$ .**

**Explain the difference between these values.**

**(2 marks)**

**Answer space continues on the next page.**

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**Turn over**

**6(d)(iii) continued.**

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**(Total for Question 6 = 14 marks)**

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**7 This question is about chromium and chromium compounds.**

**(a) Naturally occurring chromium has four isotopes,  $^{50}\text{Cr}$ ,  $^{52}\text{Cr}$ ,  $^{53}\text{Cr}$  and  $^{54}\text{Cr}$ .**

**State what is meant by the term isotopes.  
(2 marks)**

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**(continued on the next page)**



**7 continued.**

**(b) Both chromium and calcium can form ions with a +2 charge.**

**(i) Complete the electronic configuration of a  $\text{Cr}^{2+}$  ion.  
(1 mark)**

**$1s^2$**  \_\_\_\_\_  
\_\_\_\_\_

**(continued on the next page)**

**7(b) continued.**

- (ii) Look at the table for Question 7(b)(ii) in the Diagram Booklet. Explain which of chromium or calcium most easily forms a +2 ion using all of the data in the table.  
(3 marks)**

**Answer space continues on the next page.**

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**Turn over**

**7(b)(ii) continued.**

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**(continued on the next page)**

**7 continued.**

**(c) Chromium(III) sulfate,  $\text{Cr}_2(\text{SO}_4)_3$ , dissolves in water to form the complex ion  $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ .**

**(i) State the colour of this complex ion.  
(1 mark)**

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**(continued on the next page)**

**7(c) continued.**

- (ii) Explain why the aqueous solution of this complex ion has an acidic pH by considering the interaction between the metal ion and the ligands.  
(2 marks)**

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**Turn over**

**7 continued.**

- (d) A student researching the role of dichromate(VI) ions,  $\text{Cr}_2\text{O}_7^{2-}$ , as an oxidising agent made the statement shown.**

**‘Standard electrode potential data shows that it is never feasible for a  $1.00 \text{ mol dm}^{-3}$  solution of potassium dichromate(VI) to oxidise the chloride ions in hydrochloric acid.’**

**Look at the chemical equations for Question 7(d) in the Diagram Booklet. Comment on this statement using the data and equilibria shown. (4 marks)**

**Answer space continues on the next 3 pages.**

**7(d) continued.**

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**Turn over**

**7(d) continued.**

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**Turn over**



**7(d) continued.**

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**(Total for Question 7 = 13 marks)**

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**\*8 Transition metals and their compounds can act as catalysts in many reactions such as the ones shown:**

- **platinum, Pt, in the catalytic converters of vehicles**
- **manganese(II) ions,  $\text{Mn}^{2+}(\text{aq})$ , in the oxidation of ethanedioate ions,  $\text{C}_2\text{O}_4^{2-}(\text{aq})$  by manganate(VII) ions,  $\text{MnO}_4^{-}(\text{aq})$ .**
- **Compare and contrast the role of the catalysts in these reactions.  
(6 marks)**

**Answer space continues on the next 6 pages.**

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**Turn over**

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**(Total for Question 8 = 6 marks)**

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**9 This question is about silver compounds.**

**(a) Look at the diagram for Question 9(a) in the Diagram Booklet. It shows a Born–Haber cycle for the formation of silver(I) oxide,  $\text{Ag}_2\text{O}$ . All quantities are measured in  $\text{kJ mol}^{-1}$ .**

**(i) Complete the diagram by adding appropriate species and state symbols to the empty boxes. (2 marks)**

**(ii) Explain why the value for the first electron affinity of oxygen is negative and the value for the second electron affinity is positive. (3 marks)**

**Answer space continues on the next 2 pages.**

**9(a)(ii) continued.**

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**Turn over**

**9(a)(ii) continued.**

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**(continued on the next page)**

**9(a) continued.**

**(iii) Calculate a value for the standard enthalpy change of atomisation of silver,  $\Delta_{\text{at}}H^\ominus$ , using the Born–Haber cycle.  
(3 marks)**

**Answer space continues on the next page.**

**9(a)(iii) continued.**

**(continued on the next page)**

**Turn over**

**9 continued.**

**(b) Look at the table for Question 9(b) in the Diagram Booklet. Another silver compound is silver chloride, AgCl. Values for its lattice energy can be found by experiment or by theoretical calculation.**

**(i) Give TWO assumptions used in the model to calculate the theoretical lattice energy.  
(2 marks)**

**Answer space continues on the next page.**

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**Turn over**

**9(b)(i) continued.**

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**(continued on the next page)**

**9(b) continued.**

- (ii) Explain the difference in the two values for the lattice energy of silver chloride by considering the possible bonding models.  
(3 marks)**

**Answer space continues on the next page.**

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**Turn over**



**9(b)(ii) continued.**

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**(Total for Question 9 = 13 marks)**

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**10 Manganese compounds can be used to determine the amounts of dissolved molecular oxygen in water samples.**

**(a) Draw the dot-and-cross diagram for an oxygen molecule,  $O_2$ .  
Show outer shell electrons only.  
(1 mark)**

**(continued on the next page)**

**Turn over**

**10 continued.**

**(b) The solubility of oxygen in water under standard conditions is  $1.22 \times 10^{-3} \text{ mol dm}^{-3}$ .**

**Comment on this value by considering the type and strength of the intermolecular forces in**

- pure water**
- pure oxygen**
- a mixture of water and oxygen.**

**Detailed descriptions of the forces involved are not required.  
(4 marks)**

**Answer space continues on the next page.**

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**Turn over**

**10(b) continued.**

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**10(b) continued.**

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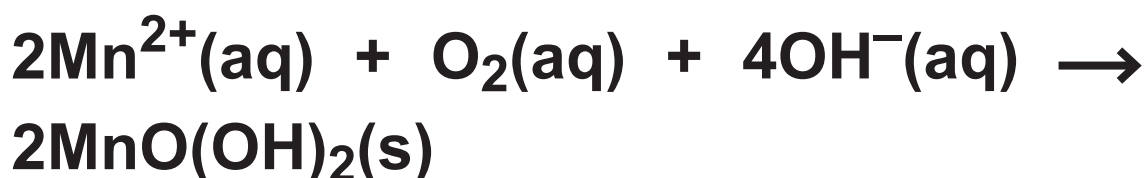
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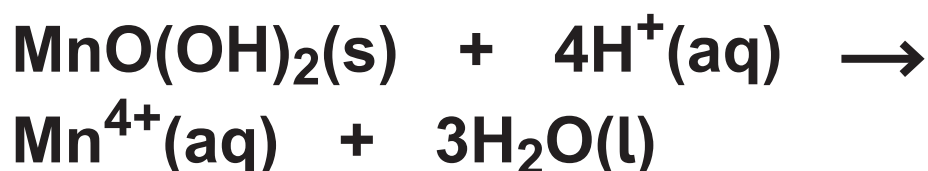
**10 continued.**

**(c) The amount of dissolved oxygen in a sample of river water was found using the process outlined.**

- **excess alkaline manganese(II) sulfate,  $\text{MnSO}_4$ , was added to a  $150\text{ cm}^3$  sample of river water**
- **the  $\text{Mn}^{2+}$  ions reacted with the dissolved oxygen forming a precipitate of manganese(IV) oxide hydroxide**



- **the precipitate was then dissolved using excess sulfuric acid, forming  $\text{Mn}^{4+}(\text{aq})$  ions**



- **excess potassium iodide solution was then added, forming iodine**

**(continued on the next page)**

**Turn over**

**10(c) continued.**



- the liberated iodine was then titrated with sodium thiosulfate solution,  $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ , of concentration  $0.00518 \text{ mol dm}^{-3}$



- the mean volume of the titre of  $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$  was  $34.20 \text{ cm}^3$ .

**(continued on the next page)**

**10(c) continued.**

- (i) Calculate the concentration of dissolved oxygen in the sample of river water, in  $\text{g dm}^{-3}$ .  
(5 marks)**

**Answer space continues on the next page.**



**10(c)(i) continued.**

**(continued on the next page)**

**Turn over**

**10(c) continued.**

- (ii) The concentration of oxygen in water is often expressed in parts per million (ppm), where 1 ppm equals 1 g of solute dissolved in  $1 \times 10^6$  g of solvent.**

**Calculate the concentration of the oxygen in the sample of river water in ppm. Assume the density of the river water is  $1.00 \text{ g cm}^{-3}$ .  
(1 mark)**

**Answer space continues on the next page.**

**10(c)(ii) continued.**

**(continued on the next page)**

**Turn over**

**10 continued.**

**(d) Look at the table for Question 10(d) in the Diagram Booklet. Some data is shown for electrode systems involving the  $\text{Mn}^{3+}(\text{aq})$  ion.**

**Explain why  $\text{Mn}^{3+}$  ions are unstable in aqueous solution.**

**Include an equation and the type of reaction that occurs.**

**(4 marks)**

**Answer space continues on the next page.**

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**Turn over**

**10(d) continued.**

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**(Total for Question 10 = 15 marks)**

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**TOTAL FOR PAPER = 90 MARKS**  
**END OF PAPER**