

# Electrochemistry

## Question Paper

<b>Level</b>	International A Level
<b>Subject</b>	Chemistry
<b>Exam Board</b>	Edexcel
<b>Topic</b>	Transition Metals & Organic Nitrogen Chemistry
<b>Sub Topic</b>	Electrochemistry
<b>Booklet</b>	Question Paper

**Time Allowed:** 64 minutes

**Score:** /53

**Percentage:** /100

**Grade Boundaries:**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 What is the relationship between the equilibrium constant,  $K$ , and  $E_{\text{cell}}^{\ominus}$  for a reaction?

- A  $K$  is directly proportional to  $\ln E_{\text{cell}}^{\ominus}$
- B  $K$  is directly proportional to  $E_{\text{cell}}^{\ominus}$
- C  $\ln K$  is inversely proportional to  $E_{\text{cell}}^{\ominus}$
- D  $\ln K$  is directly proportional to  $E_{\text{cell}}^{\ominus}$

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(Total for Question 1 = 1 mark)

2 Which of the following **cannot** disproportionate?

- A  $\text{I}_2$
- B  $\text{Cu}^+$
- C  $\text{H}_2\text{O}_2$
- D  $\text{MnO}_4^-$

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(Total for Question 2 = 1 mark)

3 The oxidation number of oxygen in hydrogen peroxide,  $\text{H}_2\text{O}_2$ , is

- A +2
- B 0
- C -1
- D -2

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(Total for Question 3 = 1 mark)

4 The  $E_{\text{cell}}$  for a reaction is +1.00 V. What can be deduced about this reaction?

- A At equilibrium there will be mainly reactants.
- B At equilibrium there will be mainly products.
- C At equilibrium there will be approximately equal amounts of reactants and products.
- D It is impossible to estimate the relative amounts of reactants and products at equilibrium because the  $E_{\text{cell}}$  was not measured under standard conditions.

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**(Total for Question 4 = 1 mark)**

5 In the hydrogen-oxygen fuel cell, oxygen is

- A oxidized at the negative electrode.
- B oxidized at the positive electrode.
- C reduced at the negative electrode.
- D reduced at the positive electrode.

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**(Total for Question 5 = 1 mark)**

6 Ammonia, butylamine and phenylamine are dissolved in separate samples of water to form solutions of the same concentration. The pH of each solution was measured.

The order of **increasing** pH will be

- A ammonia < butylamine < phenylamine
- B butylamine < ammonia < phenylamine
- C phenylamine < ammonia < butylamine
- D phenylamine < butylamine < ammonia

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**(Total for Question 6 = 1 mark)**

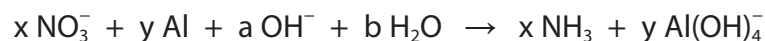
7 Manganese forms a complex with carbon monoxide, with the formula  $\text{Mn}_2(\text{CO})_{10}$ . The oxidation number of manganese in  $\text{Mn}_2(\text{CO})_{10}$  is

- A 0
- B +2
- C +5
- D +10

(Total for Question 7 = 1 mark)

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8 The reduction of nitrate(V) ions by aluminium in alkaline conditions may be represented by the equation below.



From the change in the oxidation numbers of nitrogen and aluminium, it can be deduced that the values of x and y are

- A  $x = 3$  and  $y = 2$
- B  $x = 2$  and  $y = 3$
- C  $x = 8$  and  $y = 3$
- D  $x = 3$  and  $y = 8$

(Total for Question 8 = 1 mark)

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9 In which of the following compounds is there an element with the same oxidation number as that of chromium in  $\text{K}_2\text{Cr}_2\text{O}_7$ ?

- A  $\text{Cl}_2\text{O}_7$
- B  $\text{Na}_3\text{Fe}(\text{CN})_6$
- C  $\text{K}_2\text{MnO}_4$
- D  $\text{CaTiF}_6$

(Total for Question 9 = 1 mark)

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10 Chlorine exists in oxidation states from  $-1$  to  $+7$ . For which of the following compounds is a reaction resulting in the disproportionation of chlorine **impossible**?

- A NaClO
- B NaClO<sub>2</sub>
- C NaClO<sub>3</sub>
- D NaClO<sub>4</sub>

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(Total for Question 10 = 1 mark)

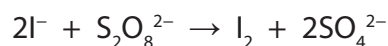
11 In an ethanol / oxygen fuel cell, the ethanol is

- A oxidized at the positive electrode.
- B oxidized at the negative electrode.
- C reduced at the positive electrode.
- D reduced at the negative electrode.

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(Total for Question 11 = 1 mark)

12 Iodide ions are oxidized by peroxodisulfate ions in aqueous solution:



This reaction is catalysed by Fe<sup>3+</sup> ions. The mechanism is most likely to involve

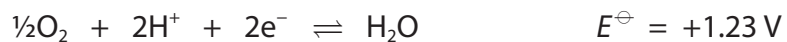
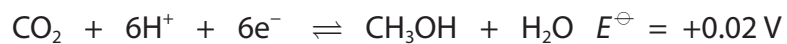
- A I<sup>-</sup> reducing Fe<sup>3+</sup> to an intermediate which is then oxidized by S<sub>2</sub>O<sub>8</sub><sup>2-</sup>.
- B I<sup>-</sup> oxidizing Fe<sup>3+</sup> to an intermediate which is then reduced by S<sub>2</sub>O<sub>8</sub><sup>2-</sup>.
- C S<sub>2</sub>O<sub>8</sub><sup>2-</sup> oxidizing Fe<sup>3+</sup> to an intermediate which is then reduced by I<sup>-</sup>.
- D S<sub>2</sub>O<sub>8</sub><sup>2-</sup> reducing Fe<sup>3+</sup> to an intermediate which is then oxidized by I<sup>-</sup>.

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(Total for Question 12 = 1 mark)

**13** Methanol fuel cells have significant advantages over hydrogen fuel cells.

The half equations for the methanol fuel cell are



- (a) Use your knowledge of the hydrogen electrode to draw a labelled diagram of the half cell that could be used to measure the oxygen electrode potential.

Include the conditions needed for the standard electrode potential to be measured.

**(3)**

- (b) Write the overall equation for the methanol fuel cell reaction.  
State symbols are not required.

**(1)**

(c) Calculate the emf of this methanol cell.

(1)

\*(d) Suggest **one** advantage and **one** disadvantage of a methanol fuel cell compared to a hydrogen fuel cell.

(2)

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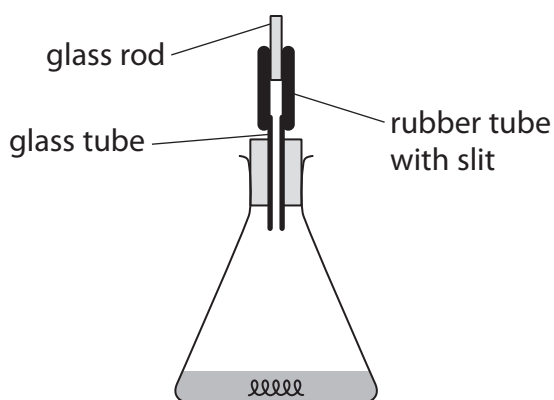
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**(Total for Question 13 = 7 marks)**

**14** Steel is the world's most important structural metal; it is strong and cheap but it corrodes rapidly if unprotected. In its simplest form, steel is an alloy of iron and carbon.

(a) The following method was used to determine the percentage of iron in a sample of wire. Exactly 1.25 g of the wire was placed in a conical flask and about 50 cm<sup>3</sup> of dilute sulfuric acid (an excess) was added. The flask was closed as shown in the diagram below.



When all of the iron in the wire had been converted to iron(II) sulfate, the contents of the flask were used to make 250.0 cm<sup>3</sup> of solution with distilled water.

25.00 cm<sup>3</sup> portions of this final solution were placed in a conical flask, acidified with an equal volume of dilute sulfuric acid and then titrated with a potassium manganate(VII) solution of concentration 0.0195 mol dm<sup>-3</sup>. The mean titre was 22.15 cm<sup>3</sup>.

(i) Write the equation for the reaction between iron and dilute sulfuric acid. Include state symbols in your answer.

(1)



(ii) Suggest why the conical flask was not left open, and how the labelled part of the apparatus shown in the diagram works.

(2)

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(iii) State the essential steps of the procedure for making up the reaction mixture to 250.0 cm<sup>3</sup> for use in the titration.

(3)

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(iv) Write the **ionic** equation for the titration reaction to show that 5 mol of iron(II) ions react with 1 mol of manganate(VII) ions. State symbols are not required.

(1)

(v) Calculate the percentage by mass of iron in the wire. Give your answer to **three** significant figures.

(4)

(vi) Describe the colour change at the end-point of the titration.

(1)

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(vii) One student who carried out this experiment forgot to acidify the mixture in the conical flask before the titration.

A brown precipitate formed before the end-point.

Identify the brown precipitate and explain how this error affects the titration value.

(3)

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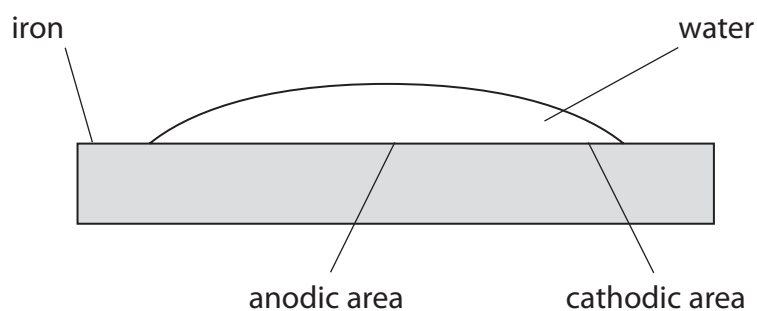
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(b) The rusting of iron is an electrochemical process. A piece of iron with a droplet of water on its surface operates as an electrochemical cell. In the first stage of corrosion, iron is oxidized to iron(II) ions in the anodic area and the electrons produced travel to the cathodic area where oxygen from the air is reduced.



- (i) From the information about standard electrode potentials on pages 14 and 15 of the Data Booklet, write the ionic half equations for the reactions taking place at the anodic area and at the cathodic area. State symbols are not required.

(2)

Anodic area

Cathodic area

- (ii) Calculate  $E_{\text{cell}}^{\ominus}$  for the overall reaction in (b)(i).

(1)

- (iii) By considering the rusting mechanism described in part (b), suggest why the presence of salt in the water droplet speeds up rusting.

(1)

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- (iv) The corrosion of oil pipelines made of steel is prevented by connecting the pipeline to magnesium blocks. Suggest how this method works.

(1)

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**(Total for Question 14 = 20 marks)**

- 15** Limestone is an important industrial raw material. The chemically important component of limestone is calcium carbonate and the proportion of this compound determines the quality of the material.

One method of determining the proportion of calcium carbonate in limestone involves dissolving the limestone in acid and precipitating the calcium ions as calcium ethanedioate. The precipitate is filtered and then re-dissolved in dilute sulfuric acid. The concentration of ethanedioate ions is determined by titration with a solution of potassium manganate(VII) of known concentration.

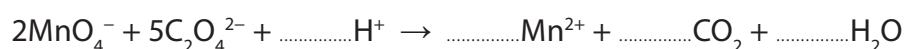
In one such determination, 1.77 g of limestone produced 250 cm<sup>3</sup> of calcium ethanedioate solution and 25.0 cm<sup>3</sup> samples of this solution were titrated at about 70 °C with potassium manganate(VII) solution of concentration 0.0205 mol dm<sup>-3</sup>. The mean titre was 24.55 cm<sup>3</sup>.

- (a) (i) State the appearance of the titration mixture at the end-point.

(1)

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- (ii) Complete the ionic equation for this titration.

(1)



- \*(iii) Calculate the percentage by mass of calcium carbonate in the limestone. Show your working and give your final answer to **three** significant figures.

(5)

- (b) (i) Before the calcium ethanedioate is re-dissolved, it is washed in deionized or distilled water. Explain why this step is necessary and the effect its omission would have on the titration.

(2)

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- (ii) The table below summarises the tolerances on the measuring apparatus used in this experiment.

Complete the table by calculating the percentage error for each piece of apparatus to **two** significant figures.

(2)

Apparatus	Value	Maximum total error on the stated value	Percentage error on the stated value
Balance	1.77 g	$\pm 0.01$ g	
Volumetric flask	250 cm <sup>3</sup>	$\pm 0.12$ cm <sup>3</sup>	
Pipette	25 cm <sup>3</sup>	$\pm 0.06$ cm <sup>3</sup>	
Burette	24.55 cm <sup>3</sup>	$\pm 0.10$ cm <sup>3</sup>	

(iii) Using the method in (a), it was found that 2.00 g of a **different** sample of limestone contained 0.015 mol of calcium carbonate.

Use the data from (b)(ii), and the fact that the solubility of calcium ethanedioate in water is  $0.0067 \text{ g dm}^{-3}$ , to calculate whether the fact that some calcium ethanedioate remains in solution has a significant effect on the accuracy of this **second** calcium carbonate determination. Assume that the combined volume of the filtrate and the washings is approximately  $500 \text{ cm}^3$ .

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**(Total for Question 15 = 14 marks)**