Topic 19.1A Electrochemical Cells

Past Exam Questions (Paper 1, 2)

1. *[1 mark]*

Which are necessary conditions for the standard hydrogen electrode to have an E^{Θ} of exactly zero?

I. Temperature = 298 K

II. $[H^{+}] = 1\, mol\, dm^{-3}$

III. $[H_2] = 1\, mol\, dm^{-3}$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

2. *[1 mark]*

Consider these standard electrode potentials.

$$Mg^{2+}(aq) + 2e^{-} \rightleftharpoons Mg(s)\ E^{\Theta} = -\ 2.36\, V$$

$$Zn^{2+}(aq) + 2e^{-} \rightleftharpoons Zn(s)\ E^{\Theta} = -\ 0.76\, V$$

What is the cell potential for the voltaic cell produced when the two half-cells are connected?

A. −1.60 V

B. +1.60 V

C. −3.12 V

D. +3.12 V

3. *[1 mark]*

What is the cell potential, in V, for the reaction that occurs when the following two half-cells are connected?

$$Fe^{2+}(aq) + 2e^{-} \rightleftharpoons Fe(s)\ E^{\ominus} = -\ 0.44\ V$$

$$Cr_2O_7^{2-}(aq) + 14H^{+}(aq) + 6e^{-} \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)\ E^{\ominus} = +\ 1.33\ V$$

A. +0.01

B. +0.89

C. +1.77

D. +2.65

4. *[1 mark]*

A voltaic cell is made by connecting two half-cells represented by the half-equations below.

$$Mn^{2+}(aq) + 2e^{-} \rightarrow Mn(s)\ E^{\ominus} = -\ 1.19\ V$$

$$Pb^{2+}(aq) + 2e^{-} \rightarrow Pb(s)\ E^{\ominus} = -\ 0.13\ V$$

Which statement is correct about this voltaic cell?

A. Mn is oxidized and the voltage of the cell is 1.06 V.

B. Pb is oxidized and the voltage of the cell is 1.06 V.

C. Mn is oxidized and the voltage of the cell is 1.32 V.

D. Pb is oxidized and the voltage of the cell is 1.32 V.

5. *[1 mark]*

The standard electrode potentials for two metals are given below.

$$Al^{3+}(aq) + 3e^{-} \rightleftharpoons Al(s)\ E^{\ominus} = -\ 1.66\ V$$

$$Ni^{2+}(aq) + 2e^{-} \rightleftharpoons Ni(s)\ E^{\ominus} = -\ 0.23\ V$$

What is the equation and cell potential for the spontaneous reaction that occurs?

$A.\ 2Al^{3+}(aq) + 3Ni(s) \rightarrow 2Al(s) + 3Ni^{2+}(aq)\ E^{\ominus} = 1.89\ V$

$B.\ 2Al(s) + 3Ni^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Ni(s)\ E^{\ominus} = 1.89\ V$

$C.\ 2Al^{3+}(aq) + 3Ni(s) \rightarrow 2Al(s) + 3Ni^{2+}(aq)\ E^{\ominus} = 1.43\ V$

$D.\ 2Al(s) + 3Ni^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Ni(s)\ E^{\ominus} = 1.43\ V$

6. *[1 mark]*

Consider the following standard electrode potentials:

$$Sn^{4+}(aq) + 2e^{-} \rightleftharpoons Sn^{2+}(aq)\ E^{\ominus} = +\ 0.13\ V$$

$$Pb^{2+}(aq) + 2e^{-} \rightleftharpoons Pb(s)\ E^{\ominus} = -\ 0.13\ V$$

What is the value of the cell potential, in V, for the spontaneous reaction that occurs when the two half-cells are connected together?

A. $-\ 0.26$

B. 0.00

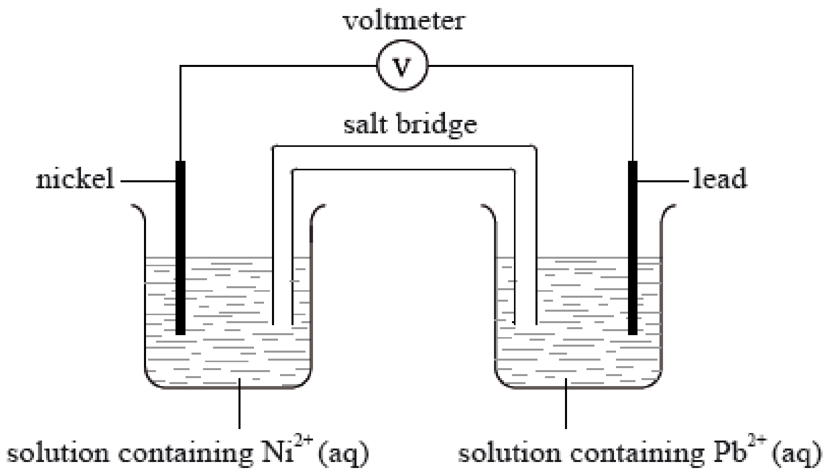
C. $+\ 0.13$

D. $+\ 0.26$

7. *[1 mark]*

The overall reaction in the voltaic cell below is:

$$Ni(s) + Pb^{2+}(aq) \rightarrow Ni^{2+}(aq) + Pb(s)$$



Which statement is correct for the nickel half-cell?

A. Nickel is the positive electrode (cathode) and is reduced.

B. Nickel is the negative electrode (anode) and is reduced.

C. Nickel is the positive electrode (cathode) and is oxidized.

D. Nickel is the negative electrode (anode) and is oxidized.

8. *[1 mark]*

The standard electrode potentials of some half-reactions are given below.

$$Sn^{4+}(aq) + 2e^{-} \rightleftharpoons Sn^{2+}(aq) \quad E^{\Theta} = +0.15\ V$$

$$\frac{1}{2}I_2(s) + e^{-} \rightleftharpoons I^{-}(aq) \quad E^{\Theta} = +0.54\ V$$

$$Fe^{3+}(aq) + e^{-} \rightleftharpoons Fe^{2+}(aq) \quad E^{\Theta} = +0.77\ V$$

Which of the following reactions will occur spontaneously?

A. Iodine reduces Fe^{3+} to Fe^{2+}

B. Iodine reduces Sn^{4+} to Sn^{2+}

C. Iodine oxidizes Fe^{2+} to Fe^{3+}

D. Iodine oxidizes Sn^{2+} to Sn^{4+}

9. *[1 mark]*

Consider the following standard electrode potentials.

$Sn^{2+}(aq) + 2e^{-} \rightleftharpoons Sn(s) \quad E^{\Theta} = -\ 0.14\ V$

$H^{+}(aq) + e^{-} \rightleftharpoons \frac{1}{2}H_2(g) \quad E^{\Theta} = 0.00\ V$

$Fe^{3+}(aq) + e^{-} \rightleftharpoons Fe^{2+}(aq) \quad E^{\Theta} = +\ 0.77\ V$

Which species will reduce H^{+}(aq) to H_2(g) under standard conditions?

A. Fe^{2+}(aq)

B. Sn^{2+}(aq)

C. Sn(s)

D. Fe^{3+}(aq)

10. *[1 mark]*

The overall equation of a voltaic cell is:

$$Ni(s) + 2Ag^{+}(aq) \rightleftharpoons Ni^{2+}(aq) + 2Ag(s) \qquad E^{\Theta} = 1.06\ V$$

The standard electrode potential for $Ni^{2+}(aq) + 2e^{-} \rightleftharpoons Ni(s)$, is $-\ 0.26\ V$. What is the standard electrode potential for the silver half-cell, $Ag^{+}(aq) + e^{-} \rightleftharpoons Ag(s)$, in V?

A. $-\ 1.32$

B. $-\ 0.80$

C. $+\ 0.80$

D. $+\ 1.32$

11. *[1 mark]*

Which components are used to make the standard hydrogen electrode?

A. $H_2(g),\ H^+(aq),\ Pt(s)$

B. $H_2(g),\ H^+(aq),\ Ni(s)$

C. $H_2(g),\ HO^-(aq),\ Pt(s)$

D. $H_2(g),\ HO^-(aq),\ Ni(s)$

12. *[1 mark]*

What is the cell potential, in V, of the reaction below?

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

$\frac{1}{2}S_4O_6^{2-}(aq) + e^- \rightleftharpoons S_2O_3^{2-}(aq) \quad E^\Theta = +\ 0.09\ V$

$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq) \quad E^\Theta = +\ 0.54\ V$

A. $+\ 0.63$

B. $+\ 0.45$

C. $-\ 0.45$

D. $-\ 0.63$

13. *[1 mark]*

Two half-cells are connected via a salt bridge to make a voltaic cell. Which statement about this cell is correct?

A. Oxidation occurs at the positive electrode (cathode).

B. It is also known as an electrolytic cell.

C. Ions flow through the salt bridge.

D. It requires a power supply to operate.

14. *[1 mark]*

Consider the standard electrode potentials:

$$Fe^{2+}(aq) + 2e^{-} \rightleftharpoons Fe(s)\ E^{\Theta} = -\ 0.45\ V$$

$$\frac{1}{2}Cl_2(g) + e^{-} \rightleftharpoons Cl^{-}(aq)\ E^{\Theta} = \ +\ 1.36\ V$$

What is the standard cell potential, in V, for the reaction?

$$Cl_2(g) + Fe(s) \rightarrow 2Cl^{-}(aq) + Fe^{2+}(aq)$$

A. $+\ 0.91$

B. $+\ 1.81$

C. $+\ 2.27$

D. $+\ 3.17$

15. *[1 mark]*

The standard electrode potentials for three reactions involving copper and copper ions are:

$Cu^{2+}(aq) + e^{-} \rightleftharpoons Cu^{+}(aq)\ E^{\Theta} = +\ 0.15\ V$

$Cu^{2+}(aq) + 2e^{-} \rightleftharpoons Cu(s)\ E^{\Theta} = +\ 0.34\ V$

$Cu^{+}(aq) + e^{-} \rightleftharpoons Cu(s)\ E^{\Theta} = +\ 0.52\ V$

Which statement is correct?

A. Cu^{2+} ions are a better oxidizing agent than Cu^{+} ions.

B. Copper metal is a better reducing agent than Cu^{+} ions.

C. Cu^{+} ions will spontaneously form copper metal and Cu^{2+} ions in solution.

D. Copper metal can be spontaneously oxidized by Cu^{2+} ions to form Cu^{+} ions.

16a. *[2 marks]*

Outline **two** differences between an electrolytic cell and a voltaic cell.

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16b. *[2 marks]*

Consider the following half-cell reactions and their standard electrode potentials.

$$Ni^{2+}(aq) + 2e^{-} \rightleftharpoons Ni(s)\ E^{\Theta} = -\ 0.26\ V$$

$$Al^{3+}(aq) + 3e^{-} \rightleftharpoons Al(s)\ E^{\Theta} = -\ 1.66\ V$$

Deduce a balanced equation for the overall reaction which will occur spontaneously when these two half-cells are connected.

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16c. *[1 mark]*

Determine the cell potential when the two half-cells are connected.

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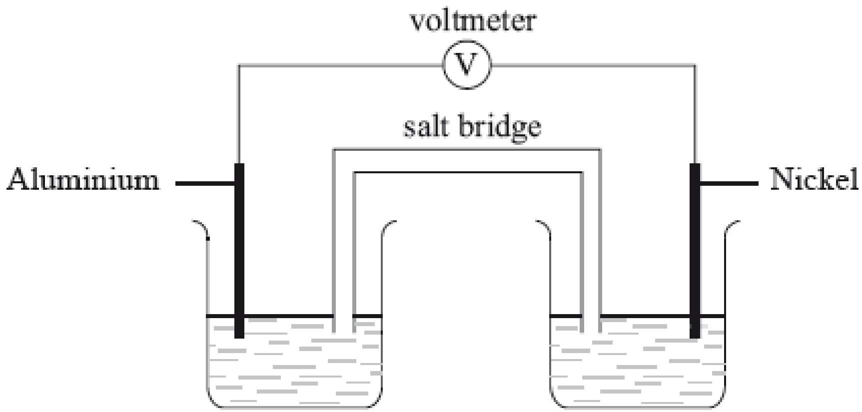
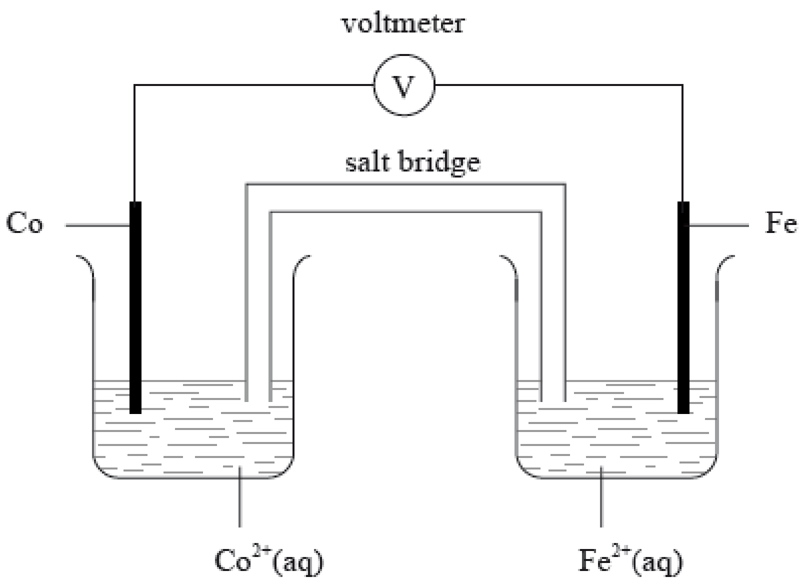
16d. *[4 marks]*

On the cell diagram below, label the negative electrode (anode), the positive electrode (cathode) and the directions of the movement of electrons and ion flow.



17a. *[3 marks]*

An electrochemical cell is made from an iron half-cell connected to a cobalt half-cell:



The standard electrode potential for $Fe^{2+}(aq) + 2e^{-} \rightleftharpoons Fe(s)$ is −0.45 V. The total cell potential obtained when the cell is operating under standard conditions is 0.17 V. Cobalt is produced during the spontaneous reaction.

Define the term *standard electrode potential* and state the meaning of the minus sign in the value of −0.45 V.

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17b. *[1 mark]*

Calculate the value for the standard electrode potential for the cobalt half-cell.

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17c. *[1 mark]*

Deduce which species acts as the oxidizing agent when the cell is operating.

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17d. *[2 marks]*

Deduce the equation for the spontaneous reaction taking place when the iron half-cell is connected instead to an aluminium half-cell.

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17e. *[2 marks]*

Explain the function of the salt bridge in an electrochemical cell.

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18a. *[3 marks]*

The standard electrode potentials for three other electrode systems are given below.

	$E^\ominus$ / V
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$Cd^{2+}(aq) + 2e^- \rightleftharpoons Cd(s)$	−0.40

The standard electrode potentials for three other electrode systems are given below.

	$E^\ominus$ / V
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$Cd^{2+}(aq) + 2e^- \rightleftharpoons Cd(s)$	−0.40

(i) Identify which species in the table above is the best reducing agent.

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(ii) Deduce the equation for the overall reaction with the greatest cell potential.

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18b. *[4 marks]*

These values were obtained using a standard hydrogen electrode. Describe the materials and conditions used in the standard hydrogen electrode. (A suitably labelled diagram is acceptable).

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19a. *[1 mark]*

Chromium is a typical transition metal with many uses.

Distinguish between the terms *oxidation* and *reduction* in terms of oxidation numbers.

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19b. *[2 marks]*

State the names of Cr_2O_3 and CrO_3.

Cr_2O_3:

CrO_3:

19c. *[1 mark]*

Define the term *oxidizing agent*.

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19d. *[3 marks]*

$Cr_2O_7^{2-}(aq)$ and $I^-(aq)$ ions react together in the **presence of acid** to form $Cr^{3+}(aq)$ and $IO_3^-(aq)$ ions. Deduce the balanced chemical equation for this redox reaction and identify the species that acts as the oxidizing agent.

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19e. *[5 marks]*

A voltaic cell is constructed as follows. One half-cell contains a platinum electrode in a solution containing $K_2Cr_2O_7$ and H_2SO_4. The other half-cell contains an iron electrode in a solution containing Fe^{2+} ions. The two electrodes are connected to a voltmeter and the two solutions by a salt bridge.

Draw a diagram of the voltaic cell, labelling the positive and negative electrodes (cathode and anode) and showing the direction of movement of the electrons and ions. Deduce an equation for the reaction occurring in each of the half-cells, and the equation for the overall cell reaction.

19f. *[1 mark]*

Define the term *standard electrode potential*.

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19g. *[1 mark]*

Calculate the cell potential, in V, under standard conditions, using information from Table 14 of the Data Booklet.

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19h. *[2 marks]*

State **two** characteristic properties of transition elements.

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19i. *[2 marks]*

State the type of bond formed by a ligand and identify the feature that enables it to form this bond.

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19j. *[3 marks]*

Explain why the complex $[Cr(H_2O)_6]^{3+}$ is coloured.

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19k. *[1 mark]*

Draw an orbital box diagram (arrow-in-box notation) showing the electrons in the 4s and 3d sub-levels in chromium metal.

19l. *[3 marks]*

Chromium is often used in electroplating. State what is used as the positive electrode (anode), the negative electrode (cathode) and the electrolyte in the chromium electroplating process.

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20a. *[2 marks]*

The standard electrode potential for a half-cell made from iron metal in a solution of iron(II) ions, $Fe^{2+}(aq)$, has the value $-\ 0.45\ V$.

Define *standard electrode potential*.

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20b. *[1 mark]*

Explain the significance of the minus sign in $-\ 0.45\ V$.

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20c. *[1 mark]*

Consider the following table of standard electrode potentials.

	$E^{\ominus}$ / V
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	−0.45
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	−0.14
$H^+(aq) + e^- \rightleftharpoons \frac{1}{2}H_2(g)$	0.00
$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$	+0.15
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
$\frac{1}{2}Br_2(l) + e^- \rightleftharpoons Br^-(aq)$	+1.07

From the list above:

State the species which is the strongest oxidizing agent.

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20d. *[1 mark]*

Deduce which species can reduce $Sn^{4+}(aq)$ to $Sn^{2+}(aq)$ but will not reduce $Sn^{2+}(aq)$ to Sn(s) under standard conditions.

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20e. *[1 mark]*

Deduce which species can reduce $Sn^{2+}(aq)$ to Sn(s) under standard conditions.

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20f. *[5 marks]*

Draw a labelled diagram of a voltaic cell made from an Fe (s) / $Fe^{2+}(aq)$ half-cell connected to an Ag(s) / $Ag^{+}(aq)$ half-cell operating under standard conditions. In your diagram identify the positive electrode (cathode), the negative electrode (anode) and the direction of electron flow in the external circuit.

20g. *[2 marks]*

Deduce the equation for the chemical reaction occurring when the cell in part (c) (i) is operating under standard conditions and calculate the voltage produced by the cell.

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20h. *[1 mark]*

An acidified solution of potassium dichromate is often used as an oxidizing agent in organic chemistry. During the oxidation reaction of ethanol to ethanal the dichromate ion is reduced to chromium(III) ions according to the following **unbalanced** half-equation.

$$Cr_2O_7^{2-}(aq) + H^+(aq) + e^- \rightarrow Cr^{3+}(aq) + H_2O(l)$$

Describe the colour change that will be observed in the reaction.

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20i. *[1 mark]*

Deduce the oxidation number of chromium in $Cr_2O_7^{2-}$.

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20j. *[1 mark]*

State the balanced half-equation for the reduction of dichromate ions to chromium(III) ions.

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20k. *[3 marks]*

Deduce the half-equation for the oxidation of ethanol to ethanal and hence the overall redox equation for the oxidation of ethanol to ethanal by acidified dichromate ions.

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20l. *[1 mark]*

Explain why it is necessary to carry out the reaction under acidic conditions.

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20m. *[1 mark]*

Identify the organic product formed if excess potassium dichromate is used and the reaction is carried out under reflux.

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20n. *[2 marks]*

Sodium metal can be obtained by the electrolysis of molten sodium chloride.

Explain why it is very difficult to obtain sodium from sodium chloride by any other method.

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20o. *[2 marks]*

Explain why an aqueous solution of sodium chloride cannot be used to obtain sodium metal by electrolysis.

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21a. *[1 mark]*

In acidic solution, ions containing titanium can react according to the half-equation below.

$$TiO^{2+}(aq) + 2H^{+}(aq) + e^{-} \rightleftharpoons Ti^{3+}(aq) + H_2O(l) \quad E^{\Theta} = -0.06\,V$$

Define the term *standard electrode potential*, E^{Θ}.

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21b. *[2 marks]*

State the initial and final oxidation numbers of titanium and hence deduce whether it is oxidized or reduced in this change.

Initial oxidation number	Final oxidation number	Oxidized / reduced

21c. *[2 marks]*

Considering the above equilibrium, predict, giving a reason, how adding more acid would affect the strength of the TiO^{2+} ion as an oxidizing agent.

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21d. *[3 marks]*

In the two experiments below, predict whether a reaction would occur and deduce an equation for any reaction that takes place. Refer to Table 14 of the Data Booklet if necessary.

KI(aq) is added to a solution containing $Ti^{3+}(aq)$ ions:

Zn (s) is added to a solution containing $TiO^{2+}(aq)$ and $H^{+}(aq)$ ions:

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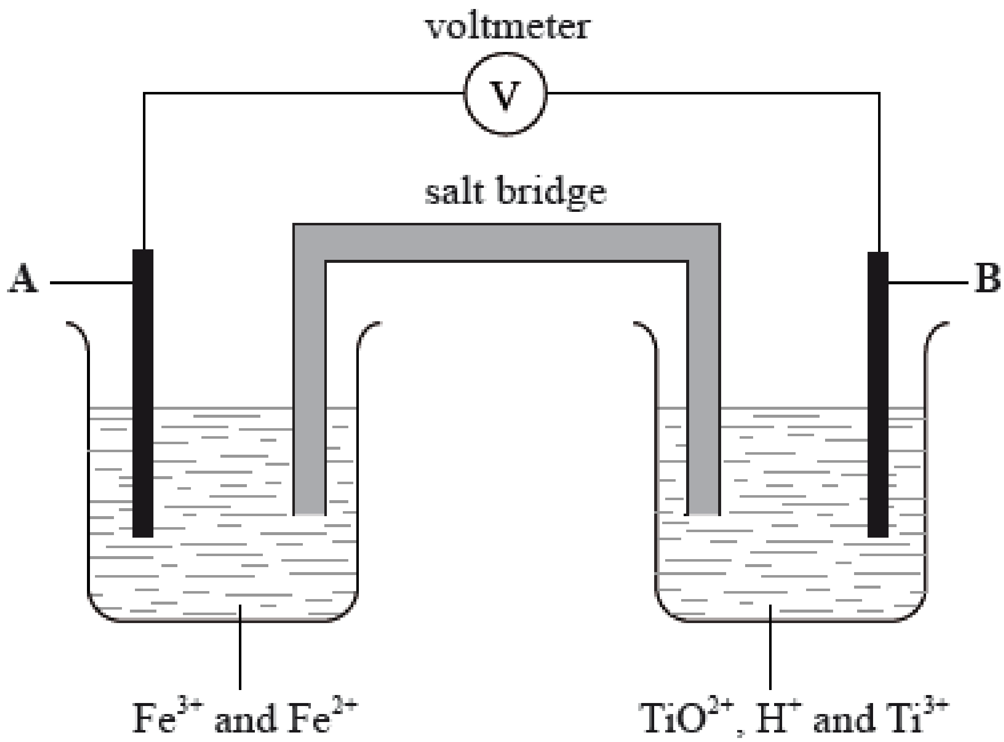
21e. *[2 marks]*

In the diagram below, **A** and **B** are inert electrodes and, in the aqueous solutions, all ions have a concentration of 1 $mol\,dm^{-3}$.



Using Table 14 of the Data Booklet, state the balanced half-equation for the reaction that occurs at electrode **A** and whether it involves oxidation or reduction.

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21f. *[1 mark]*

Calculate the cell potential in V.

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21g. *[1 mark]*

On the diagram above label with an arrow

• the direction of electron flow in the wire

• the direction in which the positive ions flow in the salt bridge.

22a. *[1 mark]*

Ethanedioic acid (oxalic acid), $(COOH)_2$, reacts with acidified potassium permanganate solution, $KMnO_4$, according to the following equation.

$$5(COOH)_2(aq) + 2MnO_4^-(aq) + 6H^+(aq) \rightarrow 10CO_2(g) + 2Mn^{2+}(aq) + 8H_2O(l)$$

The reaction is a redox reaction.

Deduce the half-equation involving ethanedioic acid.

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22b. *[2 marks]*

The standard electrode potential for the half-equation involving ethanedioic acid is $E^{\Theta} =- 0.49V$. Using Table 14 of the Data Booklet, calculate the standard electrode potential for the equation on page 10.

22c. *[1 mark]*

Explain the sign of the calculated standard electrode potential.

23a. *[1 mark]*

Define *oxidation* in terms of oxidation number.

23b. *[2 marks]*

Deduce the balanced chemical equation for the redox reaction of copper, Cu(s), with nitrate ions, $NO^{3-}(aq)$, **in acid**, to produce copper(II) ions, $Cu^{2+}(aq)$, and nitrogen(IV) oxide, $NO_2(g)$.

23c. *[1 mark]*

Deduce the oxidizing and reducing agents in this reaction.

Oxidizing agent:

Reducing agent:

23d. *[3 marks]*

A voltaic cell was set up, using the standard hydrogen electrode as a reference electrode and a standard $Cu^{2+}(aq)/Cu(s)$ electrode.

Describe the standard hydrogen electrode including a fully labelled diagram.

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23e. *[1 mark]*

Define the term *standard electrode potential*, E^{Θ}.

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23f. *[2 marks]*

Deduce a balanced chemical equation, including state symbols, for the overall reaction which will occur spontaneously when the two half-cells are connected.

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23g. *[1 mark]*

Another voltaic cell was set up, using a $Sn^{2+}(aq)/Sn(s)$ half-cell and a $Cu^{2+}(aq)/Cu(s)$ half-cell under standard conditions.

Using Table 14 of the Data Booklet, calculate the cell potential, E^{Θ}_{cell}, in V, when the two half-cells are connected.

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23h. *[1 mark]*

Water in a beaker at a pressure of 1.01×10^{5} Pa and a temperature of 298 K will not spontaneously decompose. However, decomposition of water can be induced by means of electrolysis.

State why dilute sulfuric acid needs to be added in order for the current to flow in the electrolytic cell.

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23i. *[1 mark]*

State why copper electrodes cannot be used in the electrolysis of water. Suggest instead suitable **metallic** electrodes for this electrolysis process.

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23j. *[2 marks]*

Deduce the half-equations for the reactions occurring at the positive electrode (anode) and the negative electrode (cathode).

Positive electrode (anode):

Negative electrode (cathode):

23k. *[1 mark]*

Deduce the overall cell reaction, including state symbols.

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23l. *[2 marks]*

Draw a fully labelled diagram of the electrolytic cell, showing the positive electrode (anode) and the negative electrode (cathode).

23m. *[1 mark]*

Comment on what is observed at both electrodes.

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