IB · DP · Chemistry

2 hours 15 questions

Structured Questions: Paper 2

19.1 Electrochemical Cells

Easy (5 questions)	/55
Medium (5 questions)	/52
Hard (5 questions)	/36
Total Marks	**/143**

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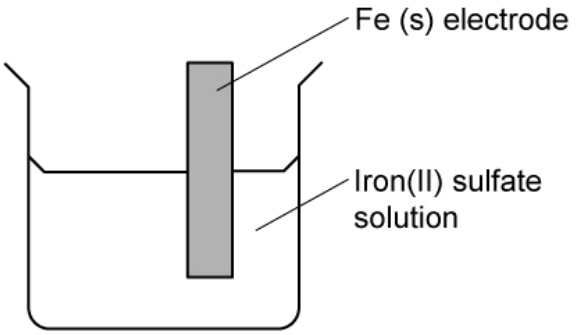
Easy Questions

1 (a) The image below shows a half cell that can be used to calculate the standard electrode potential of the Fe^{2+} / Fe reaction.



State the half equation, including state symbols, that represents this half cell.

[1]

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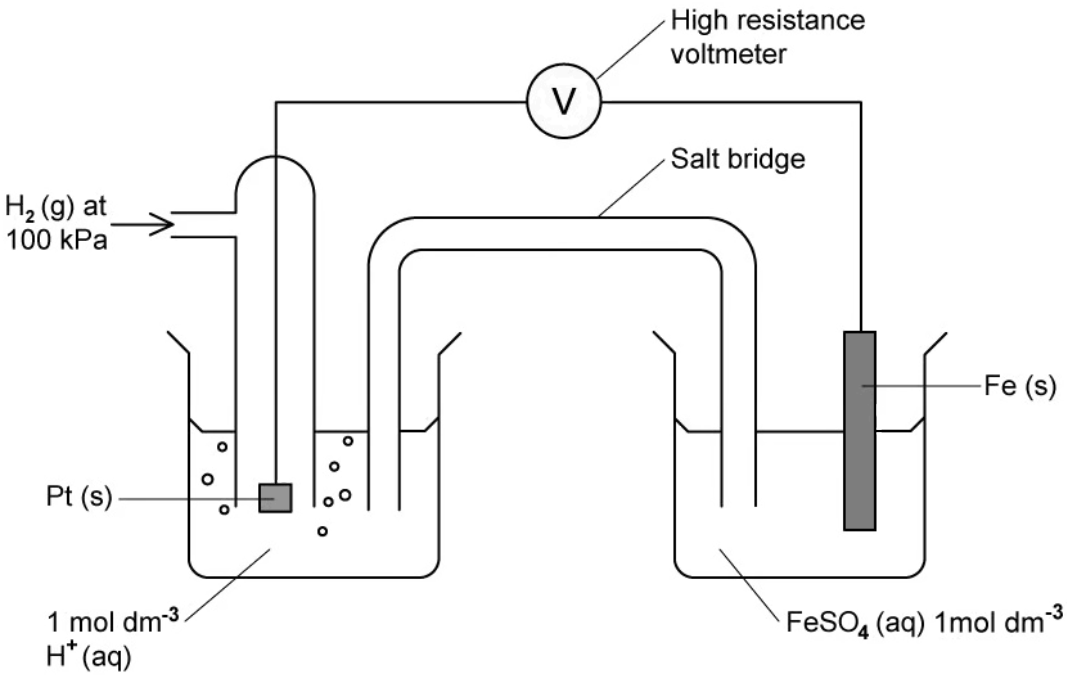
(1 mark)

(b) The electrochemical cell that is used to measure the standard electrode potential of the Fe^{2+} / Fe electrode is shown below.



State the cell representation for the electrochemical cell set up using the standard hydrogen electrode and the Fe^{2+} / Fe electrode.

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(3 marks)

(c) Explain why platinum is used as the electrode for the standard hydrogen electrode.

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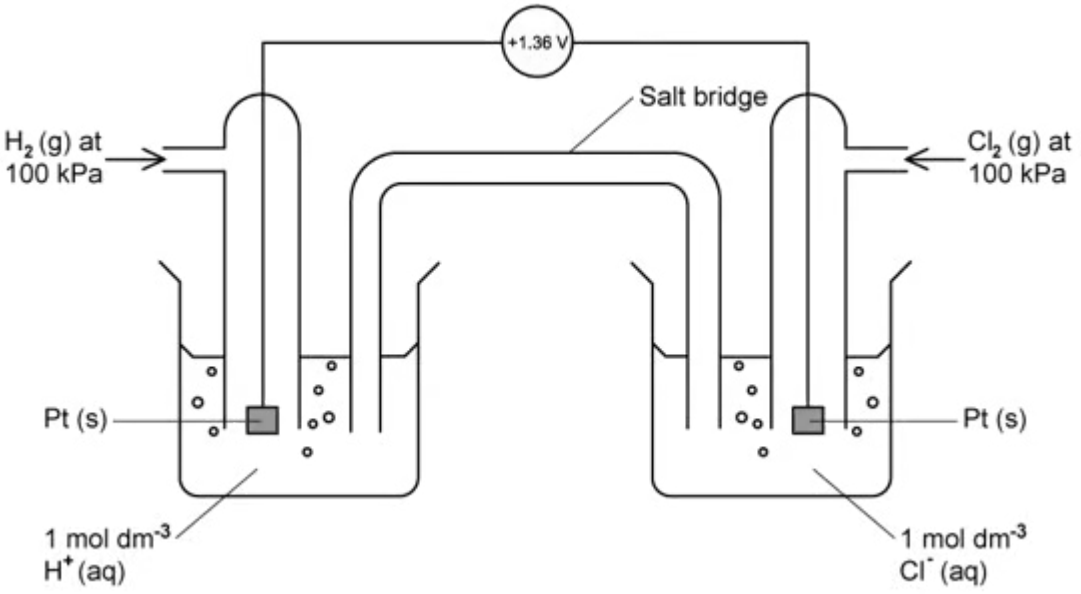
(2 marks)

(d) The image shows the electrochemical cell used to measure the standard electrode potential, $E^{\ominus}$, for the Cl_2 / Cl^- half cell.



i) Write the conventional cell representation for this electrochemical cell.

[3]

ii) Determine the standard electrode potential, $E^{\ominus}$, for the Cl_2 / Cl^- half cell.

[1]

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(4 marks)

2 (a) State the equation that is required to determine the electromotive force (EMF).

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(1 mark)

(b) Use section 24 of the data booklet to calculate the electromotive force, in volts, of the following cells.

i) $Zn\,(s) \mid Zn^{2+}\,(aq) \mid\mid Cu^{2+}\,(aq) \mid Cu\,(s)$

[1]

ii) $Mg\,(s) \mid Mg^{2+}\,(aq) \mid\mid Ag^{+}\,(aq) \mid Ag\,(s)$

[1]

iii) $Pt\,(s) \mid Fe^{2+}\,(aq)\,, Fe^{3+}\,(aq) \mid\mid Cl_2\,(g), 2Cl^{-}\,(aq) \mid Pt\,(s)$

[1]

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(3 marks)

(c) A voltaic cell is constructed using the Ag / Ag^{+} half cell and Pb / Pb^{2+}. Use section 24 of the data booklet to state the following. Include state symbols in your equations.

Half equation for the Ag / Ag^{+} half cell

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[1]

Half equation for the Pb / Pb^{2+} half cell

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[1]

Overall equation for the voltaic cell

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[2]

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(4 marks)

(d) Use section 24 of the data booklet to determine the electromotive force of the voltaic cell outlined in part c).

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(1 mark)

3 (a) Use section 24 of the data booklet to answer the following questions about the electrolysis of **dilute** sodium chloride solution using inert electrodes.

i) State the equations to generate the ions present in solution.

[2]

ii) Predict the product at the anode.

[2]

iii) Predict the product at the cathode.

[2]

(6 marks)

(b) Use section 24 of the data booklet to predict the products at the anode and cathode for the electrolysis of copper sulfate with inert electrodes.

i) State the equations to generate the ions present in solution.

[2]

ii) Predict the product at the anode.

[2]

iii) Predict the product at the cathode.

[2]

(6 marks)

(c) Use your answer to part b) to write an overall equation for the electrolysis of copper sulfate using inert electrodes.

(3 marks)

(d) The inert electrodes for the electrolysis of copper sulfate are replaced by copper electrodes. State the half equations that occur at the anode and cathode that occur with copper electrodes.

(2 marks)

4 (a) State the equation which can be used to determine charge in coulombs, C.

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(1 mark)

(b) During the electrolysis of silver nitrate a current of 0.10 amps is run for ten minutes. Use section 2 and 6 of the data booklet to determine the following.

i) The number of coulombs.

[1]

ii) The number of Faradays.

[1]

iii) The half equation for the formation of silver metal from silver ions.

[1]

iv) The amount of silver, in moles.

[1]

v) The mass of silver, in grams, deposited after ten minutes.

[1]

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(5 marks)

(c) A solution of copper sulfate, $CuSO_4$ (aq), is electrolysed for 20 mins at a current of 1.50 A. Use sections 2 and 6 of the data booklet to determine the following.

i) The number of coulombs.

[1]

ii) The number of Faradays.

[1]

iii) The half equation for the formation of copper metal from copper ions.

[1]

iv) The amount of copper, in moles.

[1]

v) The mass of copper, in grams, deposited after ten minutes.

[1]

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(5 marks)

(d) A student sets up apparatus to electroplate a metal spoon with copper. The student chose to use copper as the anode and the spoon as the cathode. Is the student correct to do so?

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(1 mark)

5 (a) State the value above which the value for the standard electrode potential, E^{θ}_{cell} value , indicates a reaction is spontaneous.

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(1 mark)

(b) The spontaneous reaction between zinc and copper in a voltaic cell is shown below

$$Ni\ (s) + Cu^{2+}\ (aq) \rightarrow Ni^{2+}\ (aq) + Cu\ (s) \qquad E^{\theta}_{cell} = +0.60\ V$$

Use sections 1 and 2 of the data booklet to determine the free energy change, ΔG^{θ}, for the reaction in kJ mol^{-1}.

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(2 marks)

(c) Use section 24 of the data booklet to determine if the reaction shown is spontaneous at standard conditions

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

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(4 marks)

Medium Questions

1 (a) Some standard electrode potential data are shown in **Table 1** which you will need to answer the following questions.

Table 1

Half-equation	E^{θ} / V
$Cu^{2+}(aq) + 2e^{-} \rightleftharpoons Cu(s)$	+0.34
$Ni^{2+}(aq) + 2e^{-} \rightleftharpoons Ni(s)$	-0.25
$Fe^{3+}(aq) + e^{-} \rightleftharpoons Fe^{2+}(aq)$	+0.77
$Sn^{2+}(aq) + 2e^{-} \rightleftharpoons Sn(s)$	−0.14
$Fe^{2+}(aq) + 2e^{-} \rightleftharpoons Fe(s)$	−0.44

Deduce the species from **Table 1** that is the weakest oxidising agent. Explain your choice.

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(2 marks)

(b) Give the conventional representation of the cell that is used to measure the standard electrode potential of copper/copper(II) ions as shown in **Table 1** in part (a).

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(2 marks)

(c) A voltaic cell is made from nickel in a solution of nickel(II) chloride and copper in a solution of copper(II) sulfate.

Calculate the EMF of this cell using the values given in **Table 1** in part (a).

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(1 mark)

(d) Two half-cells, involving species in **Table 1**, are connected together to give a cell with an EMF = +0.30 V.

i) Determine which two half equations produce this EMF using the data from **Table 1** and write the overall equation for the reaction

ii) Suggest the half-equation for the reaction that occurs at the positive electrode(cathode).

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(3 marks)

2 (a) Aqueous copper(II) sulfate can be electrolysed using passive or active electrodes. Passive electrodes can be made of platinum and active electrodes from copper.

Draw a labelled diagram of an electrolytic cell for this process using platinum electrodes and identify in which direction electrons flow.

(2 marks)

(b) Write the half equations taking place at each electrode in part a), including state symbols, and state what is seen at each electrode.

(4 marks)

(c) Write the half equations taking place at each electrode when using copper electrodes, including state symbols, and state what is seen at each electrode.

(4 marks)

(d) State what happens to the colour and acidity of the electrolyte when using platinum and copper electrodes in the electrolysis of aqueous copper(II) sulfate.

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(4 marks)

3 (a) Iron(II) bromide can be electrolysed in the liquid state. Describe two ways in which the current is conducted in an electrolytic cell.

(2 marks)

(b) A current of 2.00 A flows for 20 minutes in a cell containing molten iron(II) bromide.

Write the half reaction equations at the electrodes and determine the mass of iron and bromine produced.

(4 marks)

(c) If iron(III) bromide was used in place of iron(II) bromide in part b) determine the differences in the mass of iron and bromine produced.

(2 marks)

(d) State and explain the products of electrolysing dilute iron(II) bromide.

(4 marks)

4 (a) State the conditions under which the EMF of a redox reaction will be spontaneous.

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(1 mark)

(b) Using Sections 1 & 24 of the Data Booklet, calculate ΔG for the following reaction and state whether the reaction is spontaneous under standard conditions.

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

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(3 marks)

(c) Suggest, with a reason, how a non-spontaneous reaction could be made spontaneous.

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(2 marks)

(d) Using **Table 2**, predict and write overall equations for all the spontaneous reactions.

Table 2

Half-equation	E^{θ} / V
$Ag^{+}(aq) + e^{-} \rightleftharpoons Ag(s)$	+0.80
$\frac{1}{2} I_2(aq) + e^{-} \rightleftharpoons I^{-}(aq)$	+0.54
$Sn^{2+}(aq) + 2e^{-} \rightleftharpoons Sn(s)$	−0.14

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(3 marks)

5 (a) Metals coatings on other metals can be achieved using electroplating. Three beakers containing solutions of $Sn(NO_3)_4$, $Co_2(SO_4)_3$, $Pb(NO_3)_2$, were set up as electrolytic cells and used to electroplate the metals. The same amount of current was passed through the cells for the same length of time.

State and explain in which cell would the greatest amount of metal be produced and identify the electrode where the metals are deposited.

(4 marks)

(b) Apart from current and time, identify two factors that influence the amount of cobalt deposited in the $Co_2(SO_4)_3$ cell.

(2 marks)

(c) State **two** reasons why electroplating of metals is carried out.

(2 marks)

(d) A nickel teaspoon is electroplated with silver using sodium argentocyanide. Predict the mass changes at each electrode.

(1 mark)

Hard Questions

1 (a) Use section 24 of the data booklet to draw the electrochemical cell for the feasible reaction of Ag / Ag^{+} and Al / Al^{3+}. Write the conventional representation, including state symbols, for this cell.

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(3 marks)

(b) Write the conventional representation, including state symbols, for this cell.

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(1 mark)

(c) Explain why the salt bridge connecting the silver and aluminum electrodes cannot be made with potassium chloride solution.

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(2 marks)

(d) The silver half cell is replaced with a magnesium half cell. Deduce the reading on the voltmeter.

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(2 marks)

2 (a) Use section 24 of the data booklet and the information below to determine if the following reaction is feasible at 298 K.

$$2KMnO_4\,(aq) + 5H_2O_2\,(aq) + 6HCl\,(aq) \rightarrow 2MnCl_2\,(aq) + 8H_2O\,(l) + 5O_2\,(g) + 2KCl\,(aq)$$

$$O_2\,(g) + 2H^+ + 2\,e^- \rightleftharpoons H_2O_2 \quad E^\theta = 0.68\ V$$

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(2 marks)

(b) The reaction of copper oxide and sulfuric acid is shown below. Use section 24 of the data booklet to explain why the reaction is thermodynamically feasible.

$$CuO\,(aq) + H_2SO_4\,(aq) \rightarrow CuSO_4\,(aq) + H_2O\,(l)$$

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(2 marks)

(c) Suggest a reason why the reaction does not occur despite being thermodynamically feasible.

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(1 mark)

3 (a) A student set up a electrolytic cell using a concentrated sodium chloride solution using a current of 6 amps.

State the half-equations occurring at the electrodes during the electrolysis of the concentrated aqueous solution of sodium chloride.

Cathode .....

Anode .....

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(2 marks)

(b) Use section 2 of the data booklet to determine the time, in minutes, to produce 2.00 dm^3 of gas at the **anode** at standard temperature and pressure. State your answer to 2 significant figures.

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(3 marks)

(c) The student changed the electrolyte to a very dilute sodium chloride solution. State what change would occur at the anode and give the half equation for the process.

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(2 marks)

(d) In a different electrolysis experiment, copper sulfate solution was electrolysed using graphite electrodes. Using section 24 of the data booklet explain how the products at the anode and cathode are produced.

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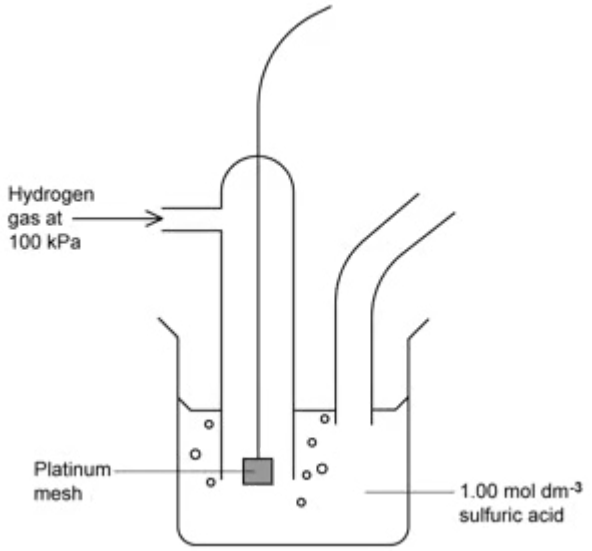
(3 marks)

4 (a) Explain why the following does not represent the standard hydrogen electrode.



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(2 marks)

(b) The standard electrode potential for Zn^{2+} (aq) + $2e^-$ → Zn (s) is –0.76 V. State the meaning of the minus sign in the value of –0.76 V.

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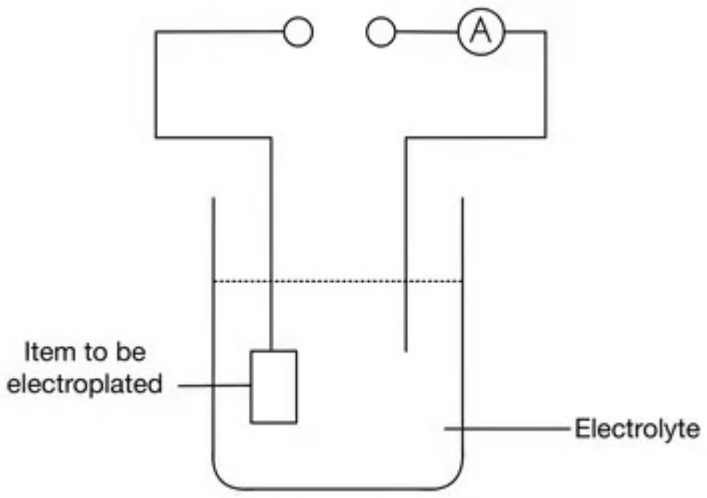
(1 mark)

(c) Zinc coating on metals serves as physical protection which prevents rust from affecting the underlying metal surface. This is achieved by electroplating.



i) Suggest a suitable solution to act as the electrolyte during zinc electroplating.

[1]

ii) Complete the diagram by labelling the polarity of the power source by using a + and - sign.

[1]

(2 marks)

(d) Use sections 2 and 6 of the data booklet to determine the length of time, in hours, a 0.1 A current required to deposit 1.0 g of zinc on the item to be electroplated. State your answer to 2 significant figures.

(3 marks)

5 (a) Using section 24 of the data booklet deduce the full equation for the $Cr_2O_7^{2-}$ (aq) / Cr^{3+} (aq) and Br_2 (l) / Br^- (aq) cell.

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(1 mark)

(b) Determine the value for $E^{\ominus}$cell value for the cell outlined in part a).

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(1 mark)

(c) Use your answer to part b) and sections 1 and 2 of the data booklet to determine whether the reaction in part a) reaction is spontaneous.

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(1 mark)

(d) An electrochemical cell has a free energy change of -14.475 kJ mol^{-1}. Use the information in the table to determine the cell representation of the electrochemical cell.

Electrode half-equation	$E^{\ominus}$ / V
Ag^+ (aq) + e^- ⇌ Ag (s)	+0.80
Li^+ (aq) + e^- ⇌ Li (s)	-3.04
ClO_2 (aq) + e^- ⇌ ClO_2^- (aq)	+0.95
H_2O (l) + e^- ⇌ ½H_2 (g) + OH^- (aq)	-0.83
Fe^{3+} (aq) + e^- ⇌ Fe^{2+} (aq)	+0.77

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(2 marks)