Electrolysis, Electrode Potentials & Cells

Question Paper 1

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Electrochemistry
Sub-Topic	Electrolysis, Electrode Potentials & Cells
Paper Type	Theory
Booklet	Question Paper 1

Time Allowed:	**76 minutes**
Score:	**/63**
Percentage:	**/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 (a) (i) State how the melting point and density of iron compare to those of calcium.

melting point of iron: ....

density of iron: ....

(ii) Explain why these differences occur.

melting point: ....

....

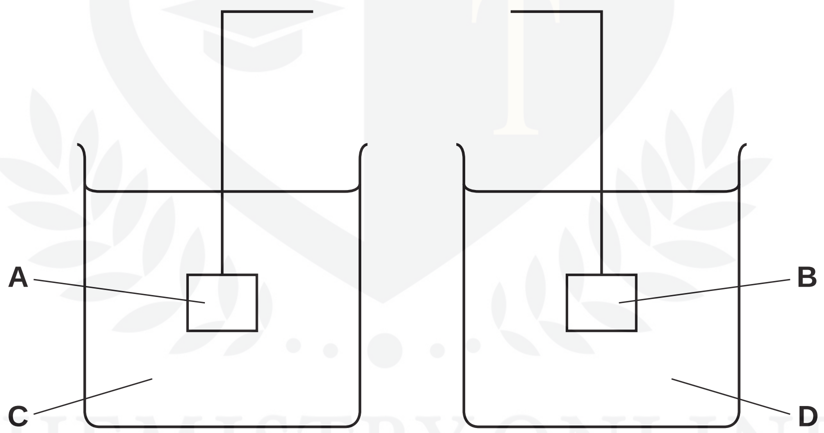
density: ....

....

[4]

(b) The following diagram shows the apparatus used to measure the standard electrode potential, $E^\ominus$, of a cell composed of a Cu(II) / Cu electrode and an Fe(II) / Fe electrode.

(i) Finish the diagram by adding components to show the complete circuit. Label the components you add.



(ii) In the spaces below, identify or describe what the four letters **A**-**D** represent.

A ....

B ....

C ....

D ....

(iii) Use the *Data Booklet* to calculate the $E^\ominus$ for this cell.

....

(iv) Predict how the size of the overall cell potential would change, if at all, as the concentration of solution **C** is increased.
Explain your reasoning.

....

....

....

[8]

(c) The iron(II) complex *ferrous bisglycinate hydrochloride* is sometimes prescribed, in capsule form, to treat iron deficiency or anaemia.
A capsule containing 500 mg of this iron(II) complex was dissolved in dilute H_2SO_4 and titrated with 0.0200 mol dm^{-3} $KMnO_4$.
18.1 cm^3 of $KMnO_4$ solution were required to reach the end point.

The equation for the titration reaction is as follows.

$$5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$$

(i) Describe how you would recognise the end point of this titration.

....

(ii) Calculate

- the number of moles of Fe^{2+} in the capsule,

- the mass of iron in the capsule,

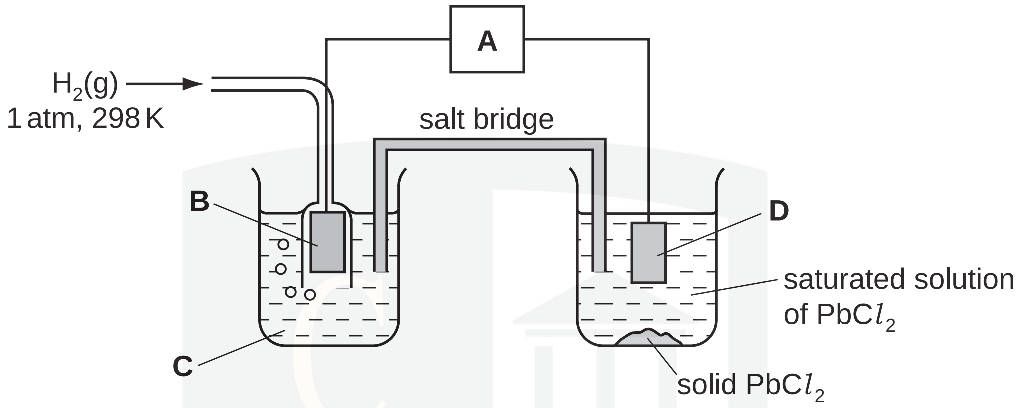
- the molar mass of the iron(II) complex, assuming 1 mol of the complex contains 1 mol of iron.

[4]

[Total: 16]

2 Lead(II) chloride, $PbCl_2$, can be used in the manufacture of some types of coloured glass.

$PbCl_2$ is only sparingly soluble in water. The $[Pb^{2+}]$ in a saturated solution of $PbCl_2$ can be estimated by measuring the cell potential, E_{cell}, of the following cell.



(a) In the spaces below, identify what the four letters **A**-**D** in the above diagram represent.

A .... **B** ....

C .... **D** ....

[4]

(b) In a saturated solution of $PbCl_2$, $[PbCl_2(aq)] = 3.5 \times 10^{-2}\,mol\,dm^{-3}$.

(i) The $E^{\ominus}$ for the Pb^{2+}/Pb electrode is –0.13 V. Predict the potential of the right-hand electrode in the diagram above. Indicate this by placing a tick in the appropriate box in the table below.

electrode potential / V	place **one tick only** in this column
–0.17	
–0.13	
–0.09	
0.00	

Explain your answer.

....

....

(ii) Write an expression for the solubility product, K_{sp}, of $PbCl_2$.

....

(iii) Calculate the value of K_{sp}, including units.

K_{sp} = ... units ....

[5]

(c) The behaviours of $PbCl_2$ and $SnCl_2$ towards reducing agents are similar, but their behaviours towards oxidising agents are very different.

(i) Illustrate this comparison by quoting and comparing relevant $E^{\ominus}$ values for the two metals and their ions. Explain what the relative $E^{\ominus}$ values mean in terms of the ease of oxidation or reduction of these compounds.

....

....

....

....

....

....

(ii) Writing a balanced molecular or ionic equation in each case, suggest a reagent to carry out each of the following reactions.

the reduction of $PbCl_2$

....

the oxidation of $SnCl_2$

....

[5]

(d) Write an equation to represent the lattice energy of $PbCl_2$. Show state symbols.

....

(ii) Use the following data, together with appropriate data from the *Data Booklet*, to calculate a value for the lattice energy of $PbCl_2$.

electron affinity of chlorine	=	$-349\ kJ\ mol^{-1}$
enthalpy change of atomisation of lead	=	$+195\ kJ\ mol^{-1}$
enthalpy change of formation of $PbCl_2(s)$	=	$-359\ kJ\ mol^{-1}$

lattice energy = ... $kJ\ mol^{-1}$

(iii) How might the lattice energy of $PbCl_2$ compare to that of $PbBr_2$? Explain your answer.

....

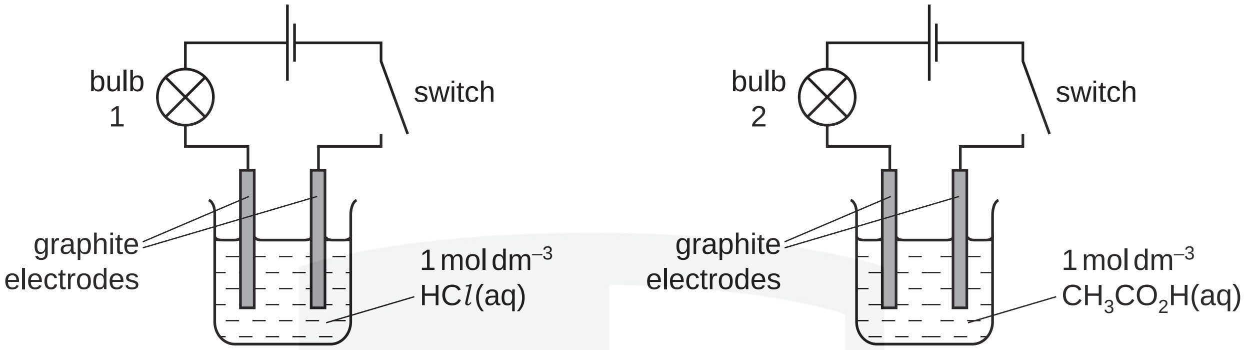
....

....

[6]

[Total: 20]

3 (a) The following circuits were set up using aqueous hydrochloric and aqueous ethanoic acids as electrolytes. Assume that the two circuits were identical apart from the electrolyte.



When the switches were closed, bulb 1 was brighter than bulb 2. Explain why.

....

....

....

.... [2]

(b) State what is meant by a *buffer solution*.

....

....

(ii) Outline how a buffer solution can be prepared from ethanoic acid and a named base.

....

....

[4]

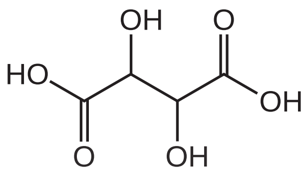
(c) Amino acids such as alanine, $CH_3CH(NH_2)CO_2H$, can act as a buffer solution.
Construct **two** equations to illustrate this.

equation 1

equation 2

[2]

(d) Tartaric acid is present in many plants.



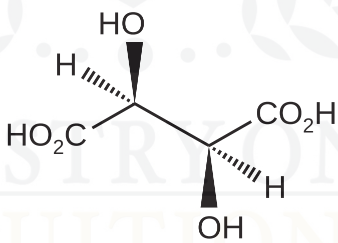
tartaric acid

(i) Tartaric acid has two dissociation constants, K_1 and K_2, for which the pK_a values are 2.99 and 4.40.
Suggest equations showing the two dissociations that give rise to these pK_a values.

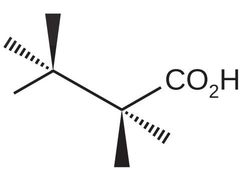
pK_a 2.99

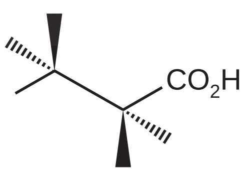
pK_a 4.40

(ii) One stereoisomer of tartaric acid is shown.



Complete the diagrams showing two other stereoisomers of tartaric acid.





[4]

[Total: 12]

4 **(a)** What is meant by the term *standard electrode potential*, SEP?

....

....
[2]

(b) Draw a fully labelled diagram of the apparatus you could use to measure the SEP of the Fe^{3+}/Fe^{2+} electrode.

[5]

(c) The reaction between Fe^{3+} ions and I^- ions is an equilibrium reaction.

$$2Fe^{3+}(aq) + 2I^-(aq) \rightleftharpoons 2Fe^{2+}(aq) + I_2(aq)$$

(i) Use the *Data Booklet* to calculate the $E^{\ominus}_{cell}$ f

....

(ii) Hence state, with a reason, whether there will be more products or more reactants at equilibrium.

....

....

(iii) Write the expression for K_c for this reaction, and state its units.

K_c =

units ....

An experiment was carried out using solutions of Fe^{3+}(aq) and I^-(aq) of equal concentrations. 100 cm^3 of each solution were mixed together, and allowed to reach equilibrium.

The concentrations at equilibrium of Fe^{3+}(aq) and I_2(aq) were as follows.

$[Fe^{3+}(aq)] = 2.0 \times 10^{-4}$ mol dm^{-3}

$[I_2(aq)] = 1.0 \times 10^{-2}$ mol dm^{-3}

(iv) Use these data, together with the equation given in **(c)**, to calculate the concentrations of Fe^{2+}(aq) and I^-(aq) at equilibrium.

$[Fe^{2+}(aq)]$ = ... mol dm^{-3}

$[I^-(aq)]$ = ... mol dm^{-3}

(v) Calculate the K_c for this reaction.

K_c = ...

[8]

[Total: 15]