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CHEMISTRY
PHYSICAL CHEMISTRY

Level & Board	CIE (A-LEVEL)
TOPIC:	ELECTROCHEMISTRY
PAPER TYPE:	QUESTION PAPER - 1
TOTAL QUESTIONS	13
TOTAL MARKS	166

Electrochemistry

1)

(a) By means of a fully labelled diagram, describe how the standard electrode potential of the Fe^{3+}/Fe^{2+} system can be measured by using a standard hydrogen electrode.

[4]

(b) Hydrogen peroxide and an acidified solution of tin(II) ions react according to the following question.

$$H_2O_2(aq) + 2H^+(aq) + Sn_2^+(aq) \longrightarrow Sn_4^+(aq) + 2H_2O(l)$$

For this reaction

(i) calculate the changes in oxidation numbers that occur, and

(ii) use the data Booklet to calculate the $E^{\ominus}_{cell}$ of the reaction.

Hence predict whether the reaction is feasible in the left → right direction.

[2]

(c) For each of the following situations, use $E^{\ominus}$ data to predict what might happen when Solutions of the two reagents are mixed together. Write balanced equations for any reactions that occur.

(i) $Ag^+(aq) + Fe^{2+}(aq) \longrightarrow$

(ii) $V^{3+}(aq) + Cu^{2+}(aq) \longrightarrow$

[4]

I am Sorry !!!!!

2)

(a) Predict the products formed at the anode, and at the cathode, when the following liquids are electrolyzed using insert electrodes.

(i) NaBr(l)

(ii) NaBr(aq)

(iii) CuF_2(aq)

In each case explain your reasoning, using data from the Data Booklet.

[6]

3)

Zinc chloride is one of the most important compounds of zinc. It is used to dry cell batteries, as a flux for soldering and tinning, as a corrosion inhibitor in cooling lowers and in the manufacture of rayon.

(a) Draw a fully labelled diagram to show how you could use a standard hydrogen electrode to measure the standard electrode potential, $E^{\ominus}$, of zinc.

[6]

(b) The electrolysis of zince chloride can give different electrode products, depending on the conditions used.

Suggest the products formed at each electrode in the following cases. One space has been filled in for you.

Conditions	Product at anode	Product at cathode
$ZnCl_2$(1)	***chlorine***	
$ZnCl_2$ (concentrated aqueous)		
$ZnCl_2$ (dilute aqueous)		

[3]

(c) Use the following data, together with relevant data from the *Data Booklet*, to construct a Born – Haber cycle and calculate a value for the lattice energy of zince chloride.

Standard enthalpy change of formation of $ZnCl_2$	- 415 KJ mol^{-1}
Standard enthalpy change of atomization of Zn(s)	+ 131 mol^{-1}
Electron affinity per mole of chlorine atoms	-349 mol^{-1}

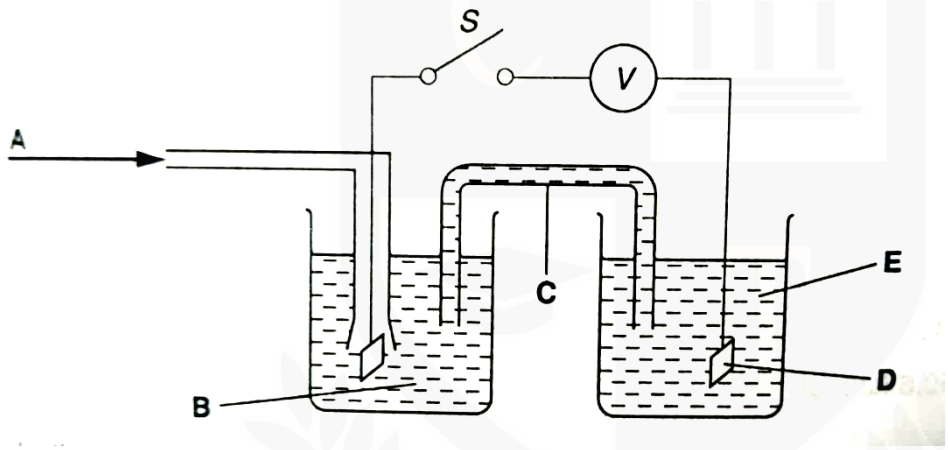
[3]

4)

Chloride gas and iron(ii) ins react together in aqueous solution as follows.

$$Cl^2 + 2Fe^{2+} \rightarrow 2Cl^- + 2Fe^{3+}$$

(a) The following diagram shows the apparatus needed to measure the $E^{\ominus}_{cell}$ for the above reaction.



(i) In the spaces below, identify what the five latters A – E the above diagram represent.

(ii) Use the Data Booklet to calculate the $E^{\ominus}_{cell}$ for this reaction, and hence decide which direction (left to right, or right to left) electrons would flow through the voltmeter V when switch S is closed

[7]

(b)iron (iii) chloride readily dissolves in water.

$$FeCl^3(s) \rightarrow Fe^{3+}(aq) + 3Cl^-(aq)$$

(i) Use the following data to calculate the standard enthalpy change for this process.

species	$E^{\ominus}_f$ /KJmol^{-1}
$FeCl^3(s)$	- 399.5
$Fe^{3+}(aq)$	- 48.5
$Cl^-(aq)$	- 167.2

(ii) A solution of iron(III) chloride is used to dissolve unwanted copper from printed circuit boards.

When a copper – coated printed circuit board is immersed in $FeCl_3(aq)$, the solution tums pale blue.

Suggest an equation for the reaction between copper and iron (III) chloride and use the Data Booklet to calculate the , $E^{\ominus}$ for the reaction.

[4]

5)

Chlorine gas is manufactured by the electrolysis of brine using a diaphragm cell.

(a) Write half – equations, including state symbols, for the reactions occurring at each of the electrodes of a diaphragm cell.

anode ……..

cathode ……

[2]

(b) In the diaphragm cell, the anode is made of titanium and the cathode is made of steel.

Suggest why steel is never used for the anode.

[1]

(c) One important product made in the diaphragm cell is formed in aqueous solution.

(i) What substance is produced in aqueous solution in the diaphragm cell?

(ii) Explain, why the aid of appropriate half – equation(s), how this compound is formed by electrolysis.

[3]

(d) Chlorine is very reactive and will form compounds by direct combination with many elements.

Describe what you would see when chlorine is passed over separate heated samples of sodium and phosphorus. In each case write an equation for the reaction.

[4]

(e) Magnesium chloride, $MgCl_2$, and silicon tetrachloride, $SiCl_4$, each dissolve in or react with water.

Suggest the approximate pH of the solution formed in each case.

$MgCl_2$ …….. SiCl4, ……..

Explain, with the aid of an equation, the difference between the two values.

[5]

6)

(a) Describe the observations you would make when concentrated sulfuric acid is added to separate portions of NaCl (s) and NaBr(s). write an equation for each reaction that occurs.

[4]

(b) By quoting relevant $E^{\ominus}$ data from the *Data Booklet*, explain how the observations you have described above relate to the relative oxidizing power of the elements.

[2]

(c) By referring to relevant $E^{\ominus}$ data choose a suitable reagent to convert Br_2 into Br^-. Write an equation and calculate the $E^{\ominus}$ for the reaction.

[3]

7)

Iron metal and its compounds are useful catalysts in certain reactions.

(a) Apart from its catalytic activity, state **two** properties of iron or its compounds that

(b) show that it is a transition element.

[2]

(c) You are provided with a solution of KMnO4 of known concentration in a burette. Outline how you could use this solution to find out the concentration of Fe^{2+}(aq) in a solution. You should include relevant equations for any reactions you describe.

[4]

(d) For each of the following equations, write the oxidation number of the element printed **in bold** undemeath its symbol, and balance the equation by adding appropriate numbers before each species.

(i) ..... $Mn O_4^-$ + ... SO_2 + ... H_2O → ..... Mn^{2+} + ... SO_4^{2-} + ... H^-

Oxidation numbers: ....

(ii) ..... $Cr_2 O_7^{2-}$ + ... NO_2 + ... H+ → .....Cr^{3+} ..... NO_3^{2-}+ ..... H_2O

oxidation numbers: ....

[6]

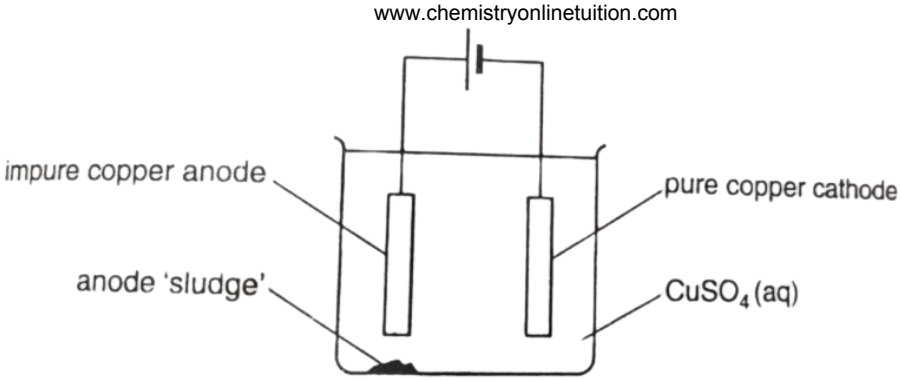
(d) Outline the role that Fe3+ ions play in catalyzing the reaction between iodide ions and Peroxydisulfate (VI) ions.

$$2I^- + S_2O_8^{2-} \longrightarrow I_2 + 2O_4^{2-}$$

[2]

8)

The electrolytic purification of copper can be carried out in an apparatus similar to the one shown below.



The impure copper anode contains small quantities of metallic nickel, zinc and silver, together with inert oxides and carbon resulting from the initial reduction of the copper ore with coke.

The copper goes into solution at the anode, but the silver remains as the metal and falls to the bottom as part of the anode 'sludge'. The zinc also dissolves.

(a) (i) Write a half equation including state symbols for the reaction of copper at the anode.

(ii) Use data from the *Data Booklet* to explain why silver remains as the metal.

(iii) Use data from the *Data Booklet* to predict what happens to the nickel at the anode.

(iv) Write a half equation including state symbols for the main reaction at the cathode.

(v) Use data from the Data Booklet to explain why zinc is not deposited on the cathode.

(vI) Suggest why the blue colour of the electrolyte slowly fades as the electrolysis proceeds.

[7]

(a) Most of the current passed through the cell is used to dissolve the copper at the anode and precipitate pure copper onto the cathode. However, a small proportion of it is 'wasted' in dissolving the impurities at the anode which then remain in solution.

When a current of 20.0 A was passed through the cell for 10.0 hours, it was found that 225 g of pure copper was deposited on the cathode.

(i) Calculate the following, using appropriate data from the *Data Booklet*.

- number of moles of copper produced at the cathode
- number of moles of electrons needed to produce this copper
- number of moles of electrons that passed through the cell

(ii) Hence calculate the percentage of the current through the cell that has been 'wasted' in dissolving the impurities at the anode.

[4]

(c) Nickel often occurs in along with iron. After the initial reduction of the ore with coke, a nickel – iron alloy is formed.

Use data from the Data Booklet to explain why nickel can be purified by a similar electrolysis technique to that used for copper, using an impure nickel anode, a pure nickel cathode, and nickel sulfate as the electrolyte.

Explain what would happen to the iron during this process.

[2]

9)

Chlorine is manufactured by electrolysis from brine, concentrated aqueous sodium chloride.

(i) Describe, with the aid of a fully labelled diagram, the industrial electrolysis of brine in a diaphragm cell. State what each electrode is made of and show clearly the inlet for the brine and the outlets for the products.

(ii) Write a half – equation, with state symbols, for the reaction at each electrode.

anode:

cathode:

(iii) Name the chemical that is produced in solution in this electrolytic process.

[7]

10)

(a) State the relationship between the Faraday constant, F, the charge on the electron, e, and the Avogadro number, L.

[1]

(b) If the charge on the electron, the A_r and the valency of copper are known. The value of the Avogadro number can be determined experimentally. This is done by passing a known current for a known time through a copper electrolysis cell, and weighing the mass of copper deposited into the cathode.

(i) Draw a diagram of suitable apparatus for carring out this experiment. Label the following: power supply (with + and – terminals); anode; cathode; and ammeter. Show the composition of the electrolyte.

The following are the results obtained from one such experiment.

Current passed through the cell = 0.500 A

Time current was passed through cell = 30.0 min

Initial mass of copper cathode = 52.243 g

Final mass of copper cathode = 52.542 g

(ii) Use these data and relevant information from the Data booklet to calculate a value of L to 3 significant figures.

[9]

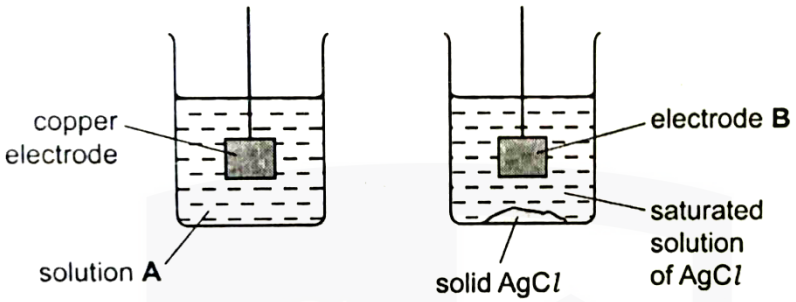
(c) Use relevant information from the Data Booklet to identify the substances formed at the anode and at the cathode when aqueous solutions of the following compounds are electrolyzed.

Compound	product at anode	product at cathode
AgF		
$FeSO_4$		
$MgBr_2$		

[5]

11)

(a) The diagram below shows an incomplete experimental set – up needed to measure the E_{cell} of a cell composed of the standard Cu^{2+} /Cu electrode and an Ag^{+}/Ag electrode.



(i) State the chemical composition of

Solution A,

Electrode B

(ii) Complete the diagram to show the whole experimental set – up.

[4]

(b) The above cell is not under standard conditions, because the $[Ag^{+}]$ in a saturated solution of AgCl is much less than 1.0 mol dm^{-3}. The $E_{electrode}$ is related to [Ag+] by the following equation.

Equation 1 $E_{electrode} = E^{\ominus}_{electode} + 0.06 \log[Ag^{+}]$

(i) Use the Data booklet to calculate the $E^{\ominus}_{cell}$ cell if the cell was operating under standard conditions.

In the above experiment, the E_{cell} was measurd at + 0.17V.

(ii) Calculate the value of $E_{electrode}$ for the Ag^{+}/Ag electrode in this experiment.

(iii) Use equation 1 to calculate $[Ag^{+}]$ in the saturated solution.

[3]

(c) (i) Write an expression for K_{sp} of silver sulfate, Ag_2SO_4, including units.

Using a similar experimental set – up to that illustrated opposite, it is found that $[Ag^{+}]$ in a saturated solution of Ag_2SO_4 is 1.6×10^{-2} mol dm^{-3}.

(ii) Calculate the value of K_{sp} of silver sulfate.

[3]

(d) Describe how the colours of the silver halides, and their relative solubilities in NH3(aq), can be used to distinguish between solutions of the halide ions Cl-, Br- and I-.

[4]

(e) Describe and explain the trend in the solubilites of the sulfates of the elements in Group II.

[4]

12)

(a) (i) With the aid of a fully – labelled diagram, describe the standard hydrogen electrode.

(ii) Use the *Data Booklet* to calculate the standard cell potential for the reaction between Cr^{2+} ions and $Cr_2O_7^{2-}$ ions I acid solution, and construct a balanced equation for the reaction.

(iii) Describe what you would see if blue solution of Cr2+ ions was added for an acidified solution of $Cr_2O_7^{2-}$ ions until reaction was complete.

[8]

(b) A buffer solution is to be made using 1.00 mol dm^{-3} ethanole acid, CH_3CO_2H, and 1.00 mol dm^{-3} sodium ethanoate, CH_3CO_2Na.

Calculate to the nearest 1 cm^3 the volumes of each solution that would be required to make 100 cm^3 of cm^3 the volumes of each solution that would be required to mae 100 cm^3 of a buffer solution with pH 5.50.

Clearly show all steps I your working.

$K_a(CH_3CO_2H) = 1.79\times 10^{-5}$ mol dm^{-3}

[4]

(c) write an equation to show the reaction of this buffer solution with each of the following.

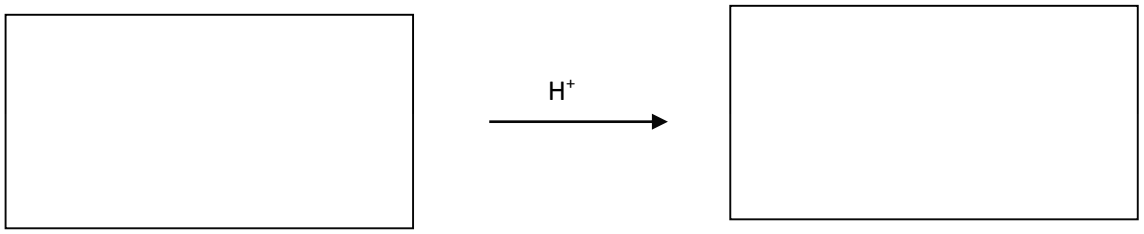
(i) added HCl,

(ii) added HCl,

(ii) added NaOH

[2]

(a) Choose one reaction in a organic chemistry that is catalyzed by an acid ad write the structural formula of the reactants and products in the boxes below.

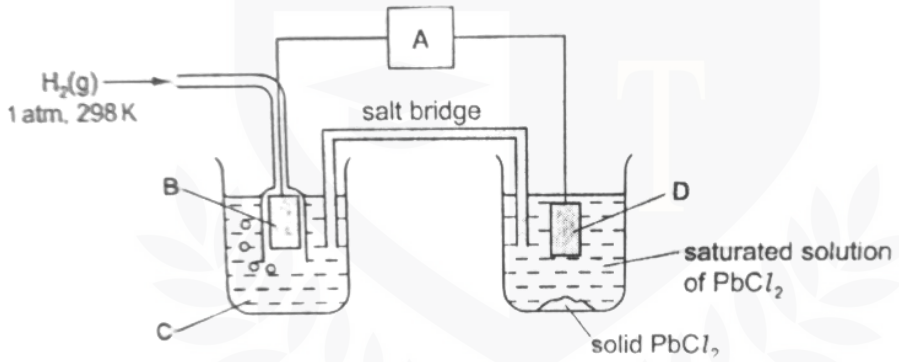


[3]

13)

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

$PhCl_2$ is only sparingly soluble in water. The [Pb2+] in a saturated solution of PbCl2 can be estimated by measuring the cell potential, E_{cell} of the following cell



(a) Identify what the four letters A – D in the above diagram represent.

[4]

(b) In a saturated solution of $[PhCl_2(aq)] = 3.5 \times 10^{-2}$ mol dm^{-3}.

(i) The $E^{\ominus}$ for the Pb^{2+} /Pb electrode is – 0.13V. 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.

[5]

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

(i) Illustrate this comparison by quoting and comparing relative $E^{\ominus}$ 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 aquation 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) (i) 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 atomization of lead = + 195 KJ mol^{-1}

Enthalpy change of formation of PbCl2(s) = - 359 KJ mol^{-1}

(iv) How might the lattice energy of PbCl2 compare to that of PbBr2? Explain your answer.

[6]

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