

# Electrolysis

## Question Paper 3

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Electrolysis- Equilibria
Booklet	Question Paper 3

**Time Allowed:** 59 minutes

**Score:** /49

**Percentage:** /100

**Grade Boundaries:**

1. (a) When aqueous barium chloride is added to a solution containing sulfate ions a white precipitate of barium sulfate is formed. This white precipitate is very sparingly soluble in water.

(i) Write the **ionic** equation, including state symbols, for the formation of the white precipitate.

..... [1]

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

[1]

(iii) Given that the value of  $K_{sp}$  for barium sulfate is  $1.08 \times 10^{-10}$  at 298K, calculate the concentration of sulfate ions in a saturated solution of barium sulfate. Give your answer to **three** significant figures.

.....  $\text{mol dm}^{-3}$  [2]

(iv) Regulations state that the maximum permitted level of sulfate ions in drinking water is  $250 \text{ mg dm}^{-3}$  ( $1 \text{ mg} = 1 \times 10^{-3} \text{ g}$ ).

$200 \text{ cm}^3$  of aqueous barium chloride solution was added to  $300 \text{ cm}^3$  of drinking water and a white precipitate formed. Assume that the sample of water contained the maximum permitted level of sulfate ions. Calculate the minimum concentration, in  $\text{mol dm}^{-3}$ , of barium chloride in the solution that was added to the sample of drinking water.

.....  $\text{mol dm}^{-3}$  [3]

- (b) The electrode potential of silver in contact with a solution of silver ions,  $\text{Ag}^+(\text{aq})$ , is impossible to measure directly but can be measured using a standard hydrogen electrode.

Using this method, the standard electrode potential of silver,  $E^\ominus$ , is found to be +0.80 V.

- (i) Complete the cell diagram for the cell used to measure the standard electrode potential of silver. State the concentration of  $\text{H}^+(\text{aq})$  used.

..... |  $\text{H}_2(\text{g})$  |  $2\text{H}^+(\text{aq})$  || .....

concentration of  $\text{H}^+(\text{aq}) = \dots\dots\dots \text{mol dm}^{-3}$  [3]

- (ii) When an excess of sodium chloride solution is added to the right-hand half-cell the silver ions will be precipitated as solid silver chloride,  $\text{AgCl}$ . Use Le Chatelier's principle to explain qualitatively how the cell emf will change as a result.

.....  
 .....  
 .....  
 ..... [2]

- (iii) At 298 K, the expression below can be used to calculate the concentration of silver ions in solution under non-standard conditions, from a measurement of the electrode potential.

$$E = E^\ominus - 0.030 \log \frac{1}{[\text{Ag}^+(\text{aq})]^2}$$

$E$  = electrode potential of silver under non-standard conditions

$E^\ominus$  = standard electrode potential of silver = +0.80 V

The addition of excess aqueous sodium chloride,  $\text{NaCl}(\text{aq})$ , to the right-hand half-cell results in a chloride ion concentration of  $2.1 \text{ mol dm}^{-3}$ .

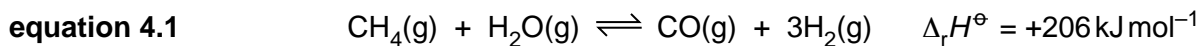
Given that  $K_{\text{sp}}$  for silver chloride,  $\text{AgCl}$ , is  $1.8 \times 10^{-10}$  at 298 K, calculate the value of  $E$ , in the cell shown in (b)(i), after the addition of the excess aqueous sodium chloride to the right-hand half-cell.

$E = \dots\dots\dots \text{V}$  [3]

[Total: 15]

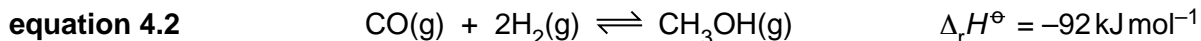
2. The use of methanol, CH<sub>3</sub>OH, in fuel cells is the subject of considerable research. A commercial production of methanol involves a two step process.

**Step 1** production of hydrogen gas



A temperature of 850 °C and pressure of 1500 kPa are used in this step.

**Step 2** reaction of hydrogen and carbon monoxide to form methanol



A temperature of 300 °C and pressure of 7500 kPa are used in this step, with a catalyst of ZnO/CrO<sub>3</sub>.

- (a) (i) Write an expression for the equilibrium constant,  $K_p$ , for the reaction in equation 4.2.

[1]

- (ii) After the reaction shown in equation 4.2 had reached equilibrium, a mixture of gases was extracted. It contained 38.0 g of hydrogen, 462 g of carbon monoxide and 7200 g of methanol.

Calculate the mole fraction of each gas in the mixture.

mole fraction of hydrogen = .....

mole fraction of carbon monoxide = .....

mole fraction of methanol = .....

[2]

- (iii) Use your values from (a)(ii) to calculate the value of the equilibrium constant,  $K_p$ , for the reaction shown in equation 4.2.

$K_p = \dots\dots\dots$  [2]

- (b) (i) Elevated temperatures are used in both steps, with the temperature used in step 1 being much higher than in step 2.

Explain why.

.....  
.....  
.....  
.....  
.....  
..... [3]

- (ii) Pressures higher than atmospheric are used in both steps, with the pressure used in step 2 being much higher than in step 1.

Explain why.

.....  
.....  
.....  
.....  
.....  
..... [3]

(c) In a direct methanol fuel cell, DMFC, methanol is oxidised at the anode.

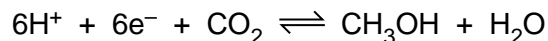
The protons produced migrate across the proton exchange membrane, PEM, to the cathode where oxygen is reduced to water.

The standard electrode potential of the oxygen cathode is +1.23V.

(i) Write the half-equation for the reduction of oxygen to water in acidic conditions at the cathode.

..... [1]

(ii) The electrode potential for



is +0.02V.

Write the overall equation for the reaction taking place in the DMFC and calculate the standard cell potential.

equation .....

standard cell potential = .....V [2]

(d) One method for the construction of a DMFC involves electroplating a layer of platinum onto the surface of the proton exchange membrane, PEM. The electrolyte for this process consists of a solution of tetraammineplatinum(II) chloride,  $\text{Pt}(\text{NH}_3)_4\text{Cl}_2$ , and the PEM is the cathode in the electrolytic cell.

(i) State the shape and bond angle of the tetraammineplatinum(II) ion,  $[\text{Pt}(\text{NH}_3)_4]^{2+}$ .

shape .....

bond angle ..... [1]

(ii) Suggest the half-equation for the cathode reaction that deposits platinum on the PEM.

..... [1]

(e) In one such preparation a PEM with a surface area of  $25\text{cm}^2$  was immersed in an electrolyte bath and a current of  $3.5 \times 10^{-3}\text{A cm}^{-2}$  was passed for 95 minutes.

Calculate the mass of platinum deposited onto the surface of the PEM.

[3]

[Total: 19]

3. (a) When aqueous barium chloride is added to a solution containing sulfate ions a white precipitate of barium sulfate is formed. This white precipitate is very sparingly soluble in water.

(i) Write the **ionic** equation, including state symbols, for the formation of the white precipitate.

..... [1]

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

[1]

(iii) Given that  $K_{sp}$  for barium sulfate is  $1.08 \times 10^{-10} \text{ mol}^2 \text{ dm}^{-6}$  at 298 K, calculate the concentration of sulfate ions in a saturated solution of barium sulfate. Give your answer to **three** significant figures.

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(b) The electrode potential of silver in contact with a solution of silver ions,  $\text{Ag}^+(\text{aq})$ , is impossible to measure directly but can be measured using a standard hydrogen electrode. Using this method the standard electrode potential of silver,  $E^\ominus$ , is found to be +0.80V.

(i) Complete the cell diagram in Fig. 2.1 for the cell used to measure the standard electrode potential of silver. State the concentration of  $\text{H}^+(\text{aq})$  used.

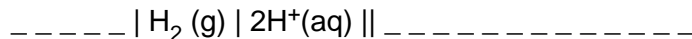


Fig. 2.1

concentration of  $\text{H}^+(\text{aq}) = \dots\dots\dots$  [3]

(ii) When an excess of aqueous sodium chloride is added to the right-hand half-cell the silver ions will be precipitated as solid silver chloride,  $\text{AgCl}$ . Use Le Chatelier's principle to explain qualitatively how the cell emf will change as a result.

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(iii) At 298K the expression below can be used to calculate the concentration of silver ions in solution under non-standard conditions, from a measurement of the electrode potential.

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$E = \dots\dots\dots$  V [3]