Beatty Secondary School
Science Department (Chemistry Unit)
Chemistry 6092

Name: _____ ( ) Date: _____

Class: 4E___

TOPIC: ELECTROCHEMISTRY (WORKSHEET 2) – ELECTROLYSIS OF AQUEOUS & CONCENTRATION SOLUTIONS

Learning Objectives:

(a) Apply the idea of selective discharge based on

- (i) cations: linked to the reactivity series
- (ii) anions: halides, hydroxides and sulfates [e.g. aqueous copper(II) sulfate and dilute sodium chloride solution (as essentially the electrolysis of water)]
- (iii) concentration effects (as in the electrolysis of concentrated and dilute aqueous sodium chloride)

(In all cases above, **inert** electrodes are used.)

(b) Predict the likely products of the electrolysis of an aqueous electrolyte, given relevant information.

(c) Construct ionic equations for the reactions occurring at the electrodes during the electrolysis, given relevant information.

Multiple-Choice Questions

1 Rubidium is above sodium in the reactivity series. What is formed when concentrated rubidium chloride is electrolysed?

	cathode (−)	anode (+)
A	chlorine	hydrogen
B	hydrogen	rubidium
C	hydrogen	chlorine
D	rubidium	chlorine

(**C**)

2 A solid deposit of element **R** is formed at the cathode(−ve) when an aqueous solution containing ions of **R** is electrolysed. Which statement about element **R** must be correct?

A **R** forms negative ions.
B **R** ions gain electrons at the cathode.
C **R** ions lose electrons at the cathode.
D **R** is above hydrogen in the reactivity series. (**B**)

3 Dilute sulfuric acid is electrolysed using inert electrodes. Which equation represents the reaction at the anode (+ve)?

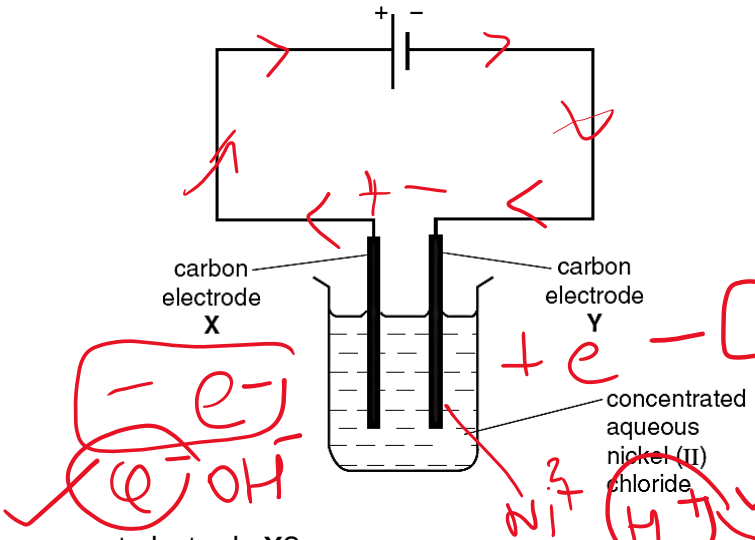
A $O_2^{2-} \rightarrow O_2 + 2e^-$ **B** $2H^+ + 2e^- \rightarrow H_2$
C $4OH^- \rightarrow 2H_2O + O_2 + 4e^-$ **D** $SO_4^{2-} \rightarrow SO_2 + O_2 + 2e^-$ (**C**)

4 In which line in the table is **all** the information correct?

	reaction at electrode	electrode	product
A	$2X^- \rightarrow X_2 + 2e^-$	cathode	metal
B	$X^+ + e^- \rightarrow X$	anode	metal
C	$2X^- \rightarrow X_2 + 2e^-$	anode	non-metal
D	$X^+ + e^- \rightarrow X$	cathode	non-metal

(**C**)

5 Apparatus is set up as shown in the diagram.



What occurs at electrode **X**?

A Chloride ions are oxidised. **B** Chloride ions are reduced.
C Nickel ions are oxidised. **D** Nickel ions are reduced. (**A**)

6 Which statement about the electrolysis of concentrated aqueous sodium chloride using inert electrodes is correct?

A Chlorine is released at the cathode.
B Oxygen is released at the cathode.
C Sodium is released at the cathode.
D The pH of the electrolyte increases. (**D**)

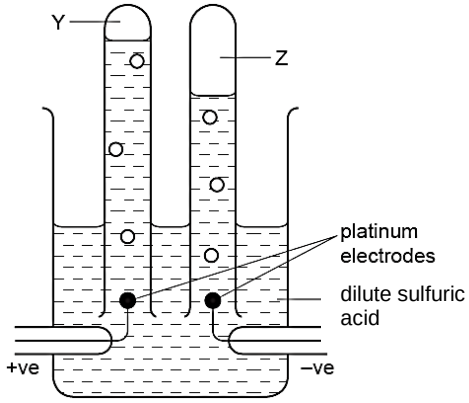
7 Four different conditions under which sodium chloride is electrolysed using inert electrodes are listed.

1 concentrated aqueous sodium chloride
2 dilute aqueous sodium chloride
3 molten sodium chloride
4 solid sodium chloride

Under which conditions is a green gas formed?

A 1 and 2 **B** 1 and 3
C 3 and 4 **D** 3 only (**B**)

8 The diagram shows the electrolysis of dilute sulfuric acid.

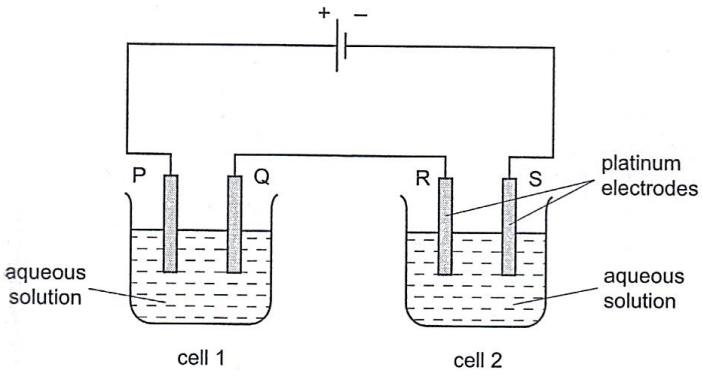


Which gas collects at Y and at Z?

	Y	Z
A	hydrogen	oxygen
B	oxygen	hydrogen
C	hydrogen	sulfur dioxide
D	sulfur dioxide	hydrogen

(**B**)

9 The circuit shown below is set up and an electric current is passed through the four cells.



If the increase in mass of Q is greater than the increase of mass of S in the same time, which statement must be true?

A The cation of the solution in cell 1 is different from the cation of the solution in cell 2.
B The current flowing in cell 1 is greater than the current flowing in cell 2.
C The cation in cell 1 is the same as in cell 2 but the solution in cell 1 is more concentrated than in cell 2.
D The loss of mass of electrode P is less than the loss of mass of electrode R.(**A**)

10 In an electrolysis experiment, the same amount of charge deposited 16 g of copper and 6 g of titanium. What was the charge on the titanium ion?

A 1+ **B** 2+
C 3+ **D** 4+ (**D**)

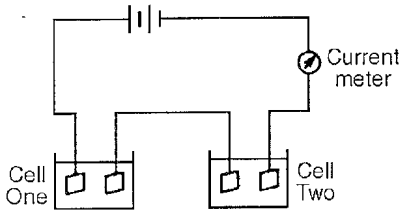
Structured Questions

11 Complete the table below by:

(a) writing the formulae of the ions present in the **aqueous solutions**,
(b) identifying the ions that will be discharged at the anode and the cathode during electrolysis, assuming that graphite electrodes are used,
(c) writing the ionic equation for the reaction at each electrode.

solutions / electrolyte	formulae of ions present in the solution	ions discharged at the **anode** and the equation	ions discharged at the **cathode** and the equation
dilute nitric acid	H^+, NO_3^-, OH^-	OH^- ions $4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$	H^+ ions $2H^+(aq) + 2e^- \rightarrow H_2(g)$
aqueous zinc sulfate	Zn^{2+}, H^+, SO_4^{2-}, OH^-	OH^- ions $4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$	H^+ ions $2H^+(aq) + 2e^- \rightarrow H_2(g)$
aqueous potassium hydroxide	K^+, H^+, OH^-	OH^- ions $4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$	H^+ ions $2H^+(aq) + 2e^- \rightarrow H_2(g)$
aqueous silver nitrate	Ag^+, H^+, NO_3^-, OH^-	OH^- ions $4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$	Ag^+ ions $Ag^+(aq) + e^- \rightarrow Ag(s)$
concentrated aqueous calcium chloride	Ca^{2+}, H^+, Cl^-, OH^-	Cl^- ions $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$	H^+ ions $2H^+(aq) + 2e^- \rightarrow H_2(g)$
concentrated aqueous lithium sulfate	Li^+, H^+, SO_4^{2-}, OH^-	OH^- ions $4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$	H^+ ions $2H^+(aq) + 2e^- \rightarrow H_2(g)$

12 Cell One has platinum electrodes dipping into dilute sulfuric acid. Cell Two has platinum electrodes dipping into copper(II) sulfate solution.



(a) Complete the table below.

		name of products	equation for the reaction
Cell One	Positive electrode	**oxygen gas, water**	$4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$
	Negative electrode	**hydrogen gas**	$2H^+(aq) + 2e^- \rightarrow H_2(g)$
Cell Two	Positive electrode	**oxygen gas, water**	$4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$
	Negative electrode	**copper metal**	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

(b) Describe what you would **observe** at each electrode of Cell Two.

Effervescence is observed at the positive electrode due to oxygen gas. A layer of reddish-brown metal deposit can be observed at the surface of the negative electrode.

(c) Describe changes expected to the solution in Cell Two after some time.

Solution in Cell Two turns from blue to colourless / blue solution fades away due to the discharge of copper(II) ions. The solution becomes more acidic / decreases in pH value due to the higher net concentration of hydrogen ions that are not discharged.

(d) Give brief reasons for your answers for the following questions. What change, if any, would you expect to see in the reading of the current meter if, in separate experiments:

(i) the solution in Cell Two were replaced by a solution of sugar,

No current would be registered. Sugar solution does not have mobile electrons or mobile ions to function as charge carriers to conduct electricity.

(ii) a few drops of barium hydroxide solution were added to the solution in Cell One?

The reading on current will decrease. Barium hydroxide will react with dilute sulfuric acid to form an insoluble salt, barium sulfate. Thus, the concentration of mobile ions will decrease, resulting in the decrease in electrical conductivity detected by current.

13 An electric current was passed through dilute sulfuric acid using platinum electrodes.

(a) Give the formulae of all of the ions present in dilute sulfuric acid.

H^+ ions, OH^- ions and SO_4^{2-} ions

(b) Give the ionic equations for the reactions occurring at the **two** electrodes in this electrolysis.

positive electrode: **$4OH^- (aq) \rightarrow 2H_2O (l) + O_2 (g) + 4e^-$**

negative electrode: **$2H^+ (aq) + 2e^- \rightarrow H_2 (g)$**

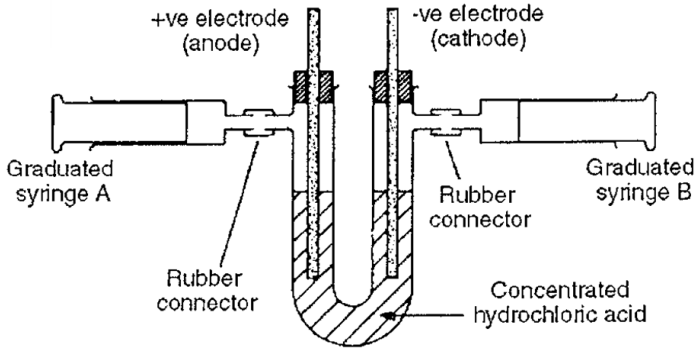
(c) Hence, explain why the volume of hydrogen formed is twice the volume of oxygen formed.

For every 4 moles of electrons involved in the reaction, 2 moles of hydrogen gas and 1 mole of oxygen gas is liberated, hence the volume of hydrogen is twice of oxygen.

(d) Oxygen is slightly soluble in water. Explain how the solubility of oxygen affects the ratio of hydrogen to oxygen collected?

The volume of oxygen collected would be lower than expected. Hence, the ratio of hydrogen to oxygen would be higher than expected.

14 The apparatus shown was used to investigate the electrolysis of concentrated hydrochloric acid. The volume of hydrogen collected was 72 cm^3 and the volume of chlorine collected was 60 cm^3.



(a) **Name** the ions present in concentrated hydrochloric acid.

hydrogen ions, chloride ions, hydroxide ions

(b) Name the gas collected in syringe A. Describe one chemical test for this gas.

Chlorine gas. Test the gas with a piece of moist blue litmus paper. If the gas produced turn moist blue litmus paper red and then bleaches it, chlorine is present.

(c) Explain why the electrodes are made of carbon and not of a metal such as iron.

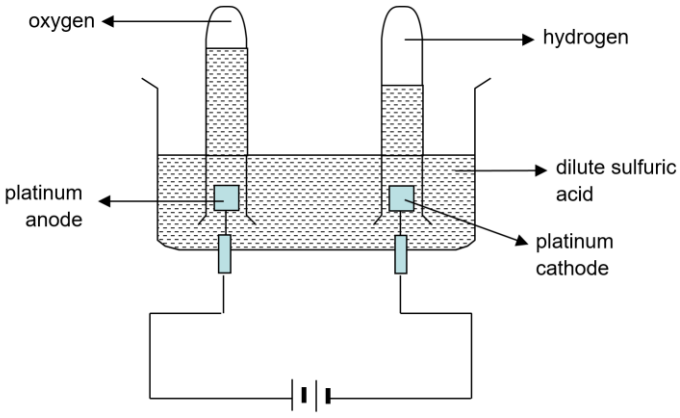
Electrodes made of carbon are inert and prevent reactions from occurring between the electrodes and the products of electrolysis / electrolyte. Iron is a reactive electrode and may take part in the reactions.

(d) Explain why the volume of chlorine collected is less than the volume of hydrogen.

Chlorine is soluble in water and would dissolve in the solution of hydrochloric acid, resulting in the loss of volume of chlorine gas collected.

(e) The experiment was repeated using dilute sulfuric acid and platinum electrodes, instead of concentrated hydrochloric acid and carbon electrodes.

(i) Draw a diagram to show the electrolysis can be carried so that the gases produced can be collected.

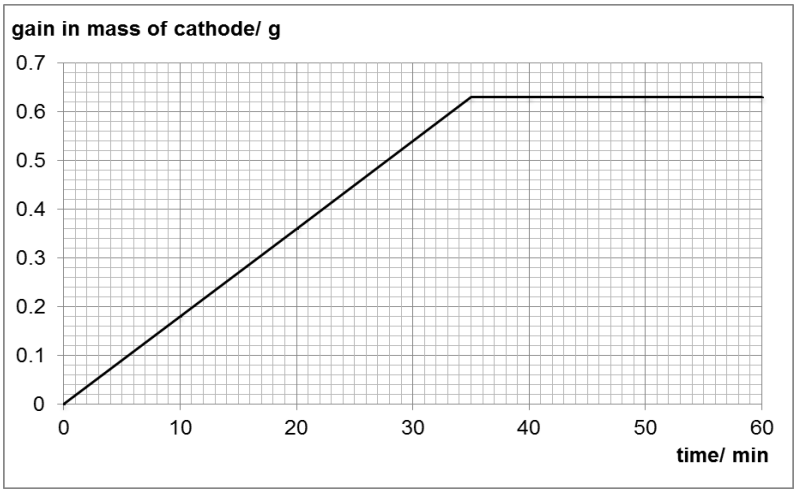


(ii) What products are set free at the both electrodes?

positive electrode: **oxygen gas and water**

negative electrode: **hydrogen gas**

15 An experiment is carried out to electrolyse 2 dm^3 of aqueous copper(II) sulfate solution using platinum electrodes. A current of 1 ampere was passed. The graph of gain in mass of cathode against time is plotted.



(a) Give the formulae of all the ions found in the electrolyte.

H^+ ions, OH^- ions, Cu^{2+} ions and SO_4^{2-} ions

(b) Construct ionic equations for the reactions that take place at both electrodes.

positive electrode: **$4OH^-$ (aq) $\rightarrow$ $2H_2O$ (*l*) + O_2 (g) + $4e^-$**

negative electrode: **Cu^{2+} (aq) + $2e^-$ $\rightarrow$ Cu (s)**

(c) The electrolyte initially contained 2.5g of copper(II) sulfate crystals ($CuSO_4.5H_2O$).

(i) Calculate the initial concentration, in mol/dm^3, of the copper(II) sulfate solution.

no of mol of $CuSO_4.5H_2O$ $= \frac{2.5}{64+32+64+5\times18}$

$= \underline{0.0100 \text{ mol}}$

concentration $= \frac{0.01}{2}$

$= \underline{0.00500 \text{ mol/dm}^3}$

(ii) Using the graph given, calculate the concentration, in mol/dm^3, of copper(II) sulfate solution after the electrolysis ran for 10 minutes.

no of mol of Cu $= \frac{0.18}{64}$

$= 0.0028125 \text{ mol}$

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$$

no of Cu^{2+} left behind $= 0.01 - 0.0028125$

$= 0.0071875 \text{ mol}$

$$CuSO_4.5H_2O \rightarrow Cu^{2+}(aq) + SO_4^{2-}(aq) + 5H_2O(l)$$

concentration $= \frac{0.0071875}{2}$

$= \underline{0.00359 \text{ mol/dm}^3}$

(iii) If the electrodes were replaced by copper electrodes, state the concentration, in mol/dm^3, of copper(II) sulfate solution after the electrolysis ran for 10 minutes.

$\underline{0.00500 \text{ mol/dm}^3}$

(d) State the pH and colour **changes** of the electrolyte after the electrolysis has been running for 40 minutes. Explain your reasoning.

The pH will be less than 7 and the blue colour fades / turns colourless. During electrolysis, Cu^{2+} ions gets preferentially discharged, hence the blue colour of the solution fades away due to the removal of Cu^{2+} ions.

As the ions remain in the electrolyte consists of H^+ and SO_4^{2-}, the presence of H^+ / increase in the net concentration of H^+ ions / concentration of H^+ ions greater than OH^- ions causes the pH to decrease.