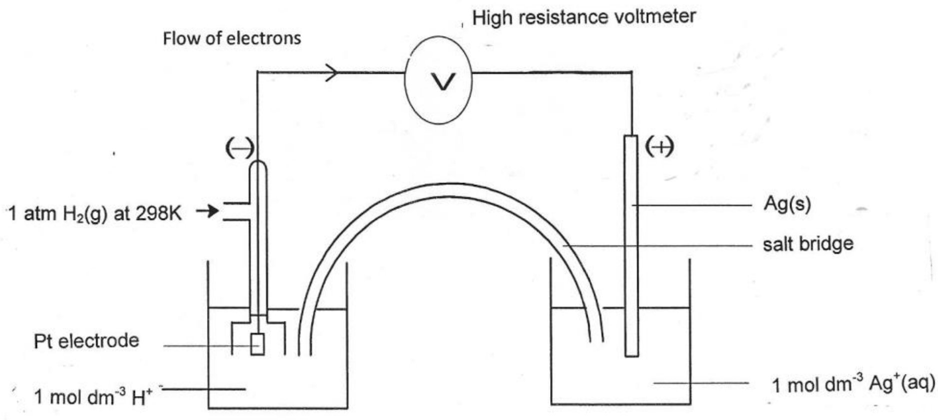
<u>Chemistry Olympiad 2015</u>
<u>Tutorial Worksheet</u>

[ACJC Prelims 2014/P3/2(b),(c)]

1 (a) (i) Draw a fully labelled diagram of the electrochemical cell you would use to determine the standard electrode potential of the $Ag^+(aq)$ I $Ag(s)$ electrode system and show the direction of electron flow .



(ii) When aqueous sodium chloride is added to the $Ag^+(aq)$I$Ag(s)$ electrode system in the above electrochemical cell in **(b)(i)**, explain qualitatively how the E_{cell} will change as a result.

(iii) At 298K, the equation below relates the concentration of silver ions in solution with the electrode potential under non-standard conditions.

$E = E^{\theta} + 0.060 \lg [Ag^+(aq)]$ where

E= electrode potential of silver under non-standard conditions
E^{θ} = standard electrode potential of silver

The addition of excess aqueous sodium chloride, $NaCl(aq)$, to the $Ag^+(aq)$ /$Ag(s)$ half-cell results in a chloride ion concentration of 2.1 mol dm^{-3}.

Using the K_{sp} of $AgCl$ given below, calculate the value of E, the electode potential of the $Ag^+(aq)$I$Ag(s)$ electrode system, after the addition of excess aqueous sodium chloride to the $Ag^+(aq)$I$Ag(s)$ half-cell.

K_{sp} of $AgCl = [Ag^+][Cl^-] = 2.00 \times 10^{-10}$ $mol^2\,dm^{-6}$

(b) Silver-oxide primary batteries account for over 20% of all primary battery sales in Japan. It is available in small sizes as button cells and are used in watches, cameras, heart pacemakers and hearing aids due to its very steady output.

A silver-oxide battery uses silver oxide as the positive electrode and zinc as the negative electrode and an alkaline electrolyte such as sodium hydroxide. The chemical reaction that takes place inside the battery is as follows:

$Zn + Ag_2O \rightarrow ZnO + 2Ag \qquad E_{cell} = +1.60\ V$

(i) Write the two half-equations that occur at the anode and cathode respectively.

(ii) Suggest a reason why this button battery is often used as stated in the question.

[10]

2 **(a)** A student is attempting to perform an experiment to determine the E^θ of two unknown half-cells, **M^+/M** and **N^{2+}/N**. The student will be using a Cu_{2+}/Cu half-cell for the experiment.

(i) Give the procedures to construct the Cu^{2+}/Cu half-cell. A strip of copper metal, a bottle of $CuSO_4.5H_2O$ and standard laboratory equipment are provided.

(ii) The student attempted to determine the E^θ of the two unknown half-cells by connecting them in different combinations.

First the Cu^{2+}/Cu half-cell was connected with the **M^+/M** half-cell. Next the **M^+/M** half-cell was connected to the **N^{2+}/N** half-cell. The voltmeter read +0.46 V and +1.56 V for the two measurements respectively. For the two measurements, the mass of the copper metal and metal **N** decreased.

Suggest the identity of **M** and **N**.

(iii) What would be the reading on the voltmeter if the Cu^{2+}/Cu half-cell was connected with the **N^{2+}/N** half-cell?

(b) **(i)** In order for the E^θ_{cell} value for the Cu^{2+}/Cu, **M^+/M** cell to be measured accurately, the student measured the voltage the moment the circuit was closed.

Explain why is there a need to measure the voltage at the instant of closing the circuit.

(ii) The Gibbs free energy of the Cu^{2+}/Cu, **M^+/M** cell can be calculated with the following equation:

$\Delta G = -nFE$

where,
ΔG = Gibbs free energy, J
n = number of moles of electrons transferred
F = Faraday's constant, 96500 C mol^{-1}

Calculate the ΔG of the Cu^{2+}/Cu, **M^+/M** cell.

(iii) During the measurement of the E^θ_{cell} value of Cu^{2+}/Cu, **M^+/M** cell, the student accidentally poured some sodium hydroxide into the Cu^{2+}/Cu half-cell.

With the aid of an equation, explain how will the E^θ_{cell} value of Cu^{2+}/Cu, **M^+/M** cell be affected.

[14]

[PJC Prelims 2013/P2/3(c)]

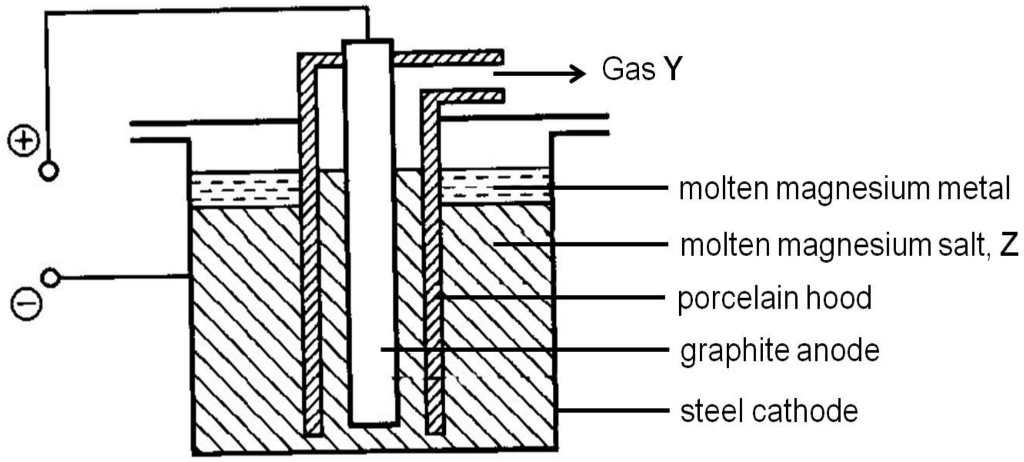
3 Anodising is the process to increase the thickness of the oxide layer on the surface of metal artefacts so as to increase the resistance of the metal to corrosion and to allow the application of dyes.

An aluminium mobile phone casing with a surface area of 200 cm^2 is to be anodised. Given that the density of Al_2O_3 is 4.0 g cm^{-3}, calculate the total quantity (in coulombs) of electricity that will be required to increase the thickness of the oxide layer on the casing by 0.2 mm.

[4]

[PJC Prelims 2014/P2/2, modified]

4 Magnesium metal can be manufactured by the electrolysis of molten magnesium salt, **Z** using the setup shown below. During the electrolysis process, 0.912 g of unknown gas **Y** was produced which occupied 500 cm^3 volume at 200 °C and 1 atm.



(a) **(i)** Determine the M_r of gas **Y** and hence identify it.

(ii) Explain why you would expect the behaviour of gas **Y** to be less ideal at low temperature.

(iii) Write ion-electron equations for the reaction occurring at the cathode and anode.

(iv) Given that the electrolysis took place for 40 minutes, calculate the current used for the process.

(v) Using relevant $E^\ominus$ data from the *Data Booklet*, explain why magnesium metal cannot be obtained by the electrolysis of aqueous magnesium salt.

(vi) During the electrolysis process, the space above the molten magnesium is filled with nitrogen gas. Explain why air may not be used.

[9]

5 **(a)** A current of 3 A was passed into 2 cells, containing aqueous copper(II) sulfate and dilute Na*Cl*(aq), connected in series for 25 minutes.

(i) Draw a diagram for the electrolytic process.

(ii) Calculate the mass of copper produced.

(iii) In the beginning of the electrolysis, a colourless gas was produced at the anode. After some time, the gas produced turned yellowish.

With the aid of equations, explain the observations as fully as you can.

(iv) When the sodium chloride solution was stirred after the formation of the yellowish gas, a reaction occurred.

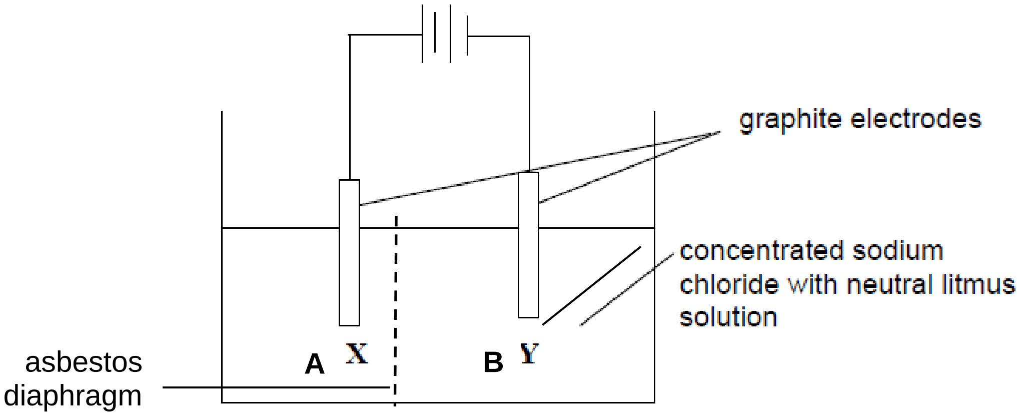
Give the equation for the reaction that occurred.

[10]

[SRJC Prelims 2014/P2/2, modified]

6 Sodium and chlorine are two common elements on Earth. Elemental chlorine is commercially produced from brine, also known as concentrated sodium chloride, by electrolysis.

The electrolysis of brine solution containing neutral litmus solution is carried out in the following apparatus using graphite electrodes. The colour changes of the litmus solutions around regions **A** and **B** were observed during the process.



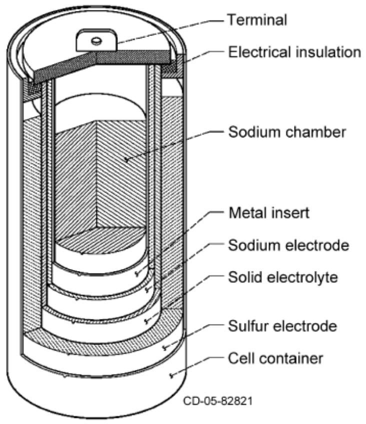
(a) **(i)** With the aid of the *Data Booklet*, account for the colours changes observed around regions **A** and **B**. Include balanced equations where appropriate.

Region	**Colour of litmus solution**	**Reason**
X	Litmus solution first turned red, and then turned colourless	
Y	Litmus solution turned blue	

(ii) The asbestos diaphragm is a porous material that prevents the products from electrolysis from mixing.

Write an equation to illustrate the reaction that will occur at room temperature when the diaphragm was removed after the electrolysis.

(b) Molten sodium salts are used in batteries to run industrial plants due to its high energy density and efficiency.



Sodium sulfur battery schematic

A typical sodium sulfur battery is as shown above. During the discharge phase, molten elemental sodium at the core serves as the anode. The sodium ions produced at the anode then migrates to the sulfur electrode. The discharge process of one such cell producing 2.00 V is represented as follows:

$$2Na + 4S \rightarrow Na_2S_4$$

(i) Using the information above, write the equation to represent the reaction taking place at the sulfur cathode.

(ii) With reference to the *Data Booklet*, determine a value for the E^θ of the reaction at the cathode. State any assumptions you make.

(iii) Using your answer in **(ii)**, suggest a replacement half-cell for sodium metal to generate a higher voltage reading than 2.00 V.

(iv) Suggest one precaution to take in storing the sodium-sulfur battery.

[10]

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