Year 12 Redox (Electrolysis) Topic Test

Question 1 (9 marks)
Lithium-oxygen ($Li\text{-}O_2$) cells are currently being researched in hopes of utilising these cells in applications requiring large quantities of energy. Lithium ion in the presence of oxygen gas is converted to lithium peroxide, Li_2O_2, a white solid powder.

(a) Write both the oxidation and reduction half equations. No states are required. **2 marks**

(b) This cell is a rechargeable secondary cell. Explain what this means. **2 marks**

(c) Write the overall equation for the recharge equation. No states are required. **1 mark**

$Li–O_2$ cells are difficult to maintain. $Li–O_2$ batteries fail early because every component (the cathode, electrolyte, lithium metal, and discharge products) degrades during cycling. $Li–O_2$ cells rely on forming and decomposing solid Li_2O_2, which is chemically aggressive and can lead to cathode degradation.

(d) What material or substance must the anode and cathode be to allow this cell to operate. Explain your choice of material. **4 marks**

Question 2 (4 marks)
A 4M solution of $NaCl_{(aq)}$ is electrolysed using inert electrodes, a gas evolved at each of the electrodes.

(a) Write the half equation occurring at the positive electrode. **1 mark**

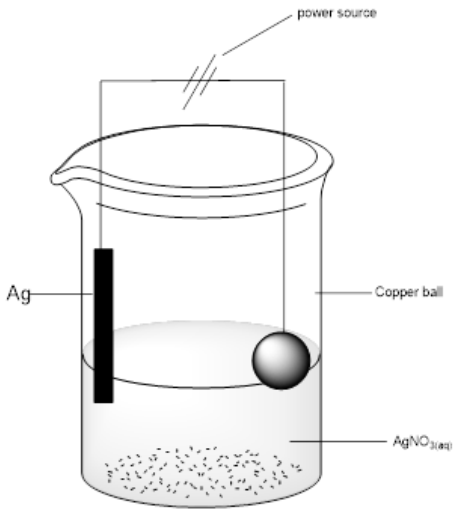
(b) Write the half equation occurring at the negative electrode. **1 mark**

(c) Explain your answer from part b. **2 marks**

Question 3 (9 marks)

Electroplating is a type of electrolysis that coats an object in a thin layer of metal using an electric current. Electroplating can be used for corrosion resistance, decorative purposes and improving the shelf life of some objects. One common application of electroplating is coating jewellery in silver.

In the illustration below, a small copper ball is to be plated in silver to be used in a jewellery piece. Silver metal is placed at the cathode, and the copper ball is placed at the anode. Both electrodes are immersed in a silver nitrate solution.



(a) Write the half equations occurring at both electrodes. **2 marks**

Cathode: _____

Anode: _____

(b) After 5 minutes, a layer of silver did not form on the copper ball. Suggest a reason why. **2 marks**

_____

_____

_____

(c) What preparation should be completed prior to electroplating the copper ball to ensure a smooth and even layer of silver forms around the surface? **2 marks**

_____

_____

_____

(d) A current of 3.4A passes through the external circuit. A mass of 3.65g of silver metal was plated onto the copper ball. Calculate the time, in minutes, taken to plate this amount if the electrochemical cell operated at 45% efficiency. **3 marks**

Question 4 (8 marks)

The Hall–Héroult process is the only industrial method used today to produce primary aluminium. The process works efficiently, reliably, and at a large scale. Aluminium oxide (Al_2O_3) has a melting point of 2072°C, far too high to electrolyse directly. So instead, alumina is dissolved in molten cryolite (Na_3AlF_6), which lowers the melting point to ~940–980°C.

Structure of the cell	
Component	Role
Carbon-lined steel pot	Cathode
Molten cryolite and alumina	Electrolyte
Carbon block	Anode
Molten aluminium layer	Collected at the bottom as product

The half equation occurring at the anode is shown below.

$$2O^{2-} + C \rightarrow CO_2 + 4e^-$$

(a) Write the balanced half equation occurring at the cathode. **2 marks**

(b) Explain why the carbon anodes must be replaced regularly in reference to the anode half equation provided. **2 marks**

(c) Why is it important from a green chemistry perspective to lower the melting point of aluminium oxide? **2 marks**

(d) Calculate the atom economy for this process. **2 marks**

Question 5 (16 marks)

Hydrogen gas is a promising fuel currently under research as an initiative to step towards a greener pathway for energy production. Currently hydrogen gas is produced using fossil fuel through a steam reforming process. a potential alternative is utilizing an electrochemical cell which carries out artificial photosynthesis to electrolyse water into hydrogen and oxygen gas. Sulfuric acid, H_2SO_4, is used as the electrolyte. Titanium dioxide and other titanium-based compounds used in artificial photosynthesis cells that can split water to produce hydrogen.

(a) Write the balanced half equation for the reaction occurring at the cathode. **1 mark**

(b) Write the balanced half equation for the reaction occurring at the anode. **1 mark**

(c) Discuss why this method of electrolysis is considered to mimic the process of photosynthesis. **2 marks**

(d) Hydrogen has exciting potential, but several limitations hold it back as a fuel. Suggest two reasons why. **2 marks**

(e) If 3.4L of water is used in the artificial photosynthesis electrochemical cell:

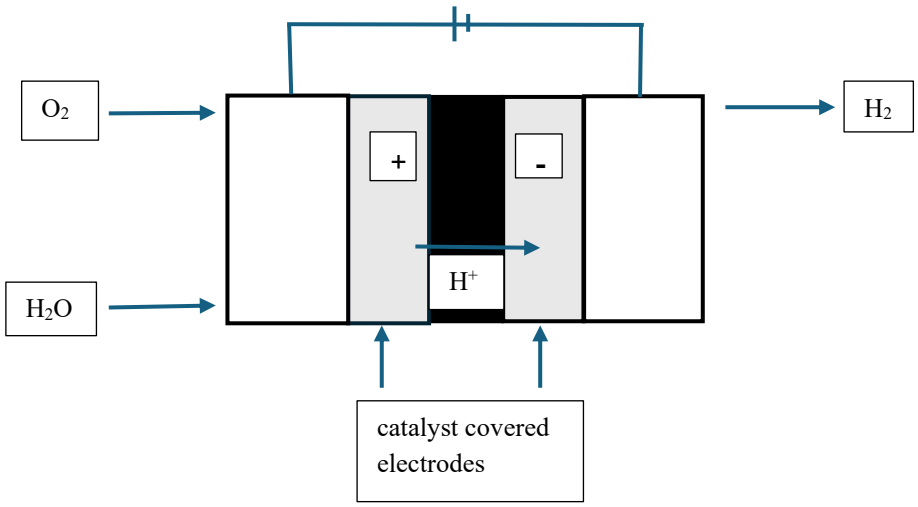
i. Calculate the volume of oxygen gas, in litres, that is produced under SLC. **4 marks**

ii. Calculate the current, in amps, used in the cell if the cell operated for 2 hours. **3 marks**

(f) Sodium chloride, NaCl, has been suggested to be used as the electrolyte in this artificial photosynthesis cell because it is a cheap and abundant industrial chemical. Suggest why it is not a suitable electrolyte for this particular cell. **3 marks**

Question 6 (9 marks)

Polymer electrolyte membrane (PEM) electrolysis is another process powered by either solar or wind energy to produce 'green' hydrogen from water. A schematic diagram is shown below.



(a) Other than the selectively permeable feature of the electrodes, suggest one other key role. **2 marks**

(b) PEM electrolysers rely on iridium and platinum to coat electrodes and gas diffusion layers as catalysts inside the cell, which are noble metals and are expensive and scarce. Discuss one reason as to whether the benefits of these catalysts outweigh their cost. **2 marks**

(c) This particular PEM cell operates at an efficiency of 81%. A volume of 2.3L of hydrogen gas was produced. The density of hydrogen gas is 0.0899g L^{-1}. The cell operated at a of current of 1.25A. How long, in hours, did the PEM cell run for? **5 marks**