Video worksheet -primary, secondary and fuel cells.

1. A secondary, alkaline cell produces 1.5 V, but has a longer shelf life and maintains a constant voltage output during discharge than an acidic, primary cell. Its overall equation is shown below.

$$Zn(s)+2MnO_2(s) \longrightarrow ZnO(s)+Mn_2O_3(s)$$

a. Identify the oxidant. ______________ *$MnO_2(s)$*

b. Identify the reductant. ______________ *$Zn(s)$*

c. Give the balanced equation, states included, for the reaction taking place at the positive electrode.

$$MnO_2(s) \rightarrow Mn_2O_3(s)$$
$$2MnO_2(s) \rightarrow Mn_2O_3(s)$$
$$2MnO_2(s) \rightarrow Mn_2O_3(s) + H_2O(l)$$
$$2e^- + 2H^+(aq) + 2MnO_2(s) \rightarrow Mn_2O_3(s) + H_2O(l)$$
$$2e^- + 2H^+(aq) + 2OH^-(aq) + 2MnO_2(s) \rightarrow Mn_2O_3(s) + H_2O(l) + 2OH^-(aq)$$
$$2e^- + 2H_2O(l) + 2MnO_2(s) \rightarrow Mn_2O_3(s) + H_2O(l) + 2OH^-(aq)$$
$$2e^- + 2H_2O(l) + 2MnO_2(s) \rightarrow Mn_2O_3(s) + H_2O(l) + 2OH^-(aq)$$
$$2e^- + H_2O(l) + 2MnO_2(s) \rightarrow Mn_2O_3(s) + 2OH^-(aq)$$

Check to see if electrons appear as reactants , hence, a reduction reaction is written. This happens at the cathode(+)

d. As the cell is allowed to discharge for exactly 3.45 minutes it produces a current equivalent to 0.60 mol of electrons. What is the mass change, in grams, at the anode as the battery is discharging? Give your answer to the right number of significant figures.

Step 1 Reaction taking place at the anode during discharge.

=> $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

Step 2 Calculate the mol of zinc that reacts to produce 0.6 mol of electrons using the half equation at the anode.

=> for every two mol of electrons formed one mol of zinc metal is consumed.

=> hence for 0.6 mol of electrons 0.3 (0.6 X ½) mol of zinc is consumed at the anode.

Step 3 Find the mass of zinc lost.

=> mass = 0.30 X 65.4 = 20 grams

e. An attempt is made to recharge the battery. Give the balanced, half equation occurring the positive electrode of the battery when the recharger is connected. Included states.

$Mn_2O_3(s) + 2OH^-(aq) \rightarrow 2e^- + H_2O(l) + 2MnO_2(s)$

f. Give one condition of this cell that enables recharging to occur?

Products formed during discharge must maintain contact with the electrodes.

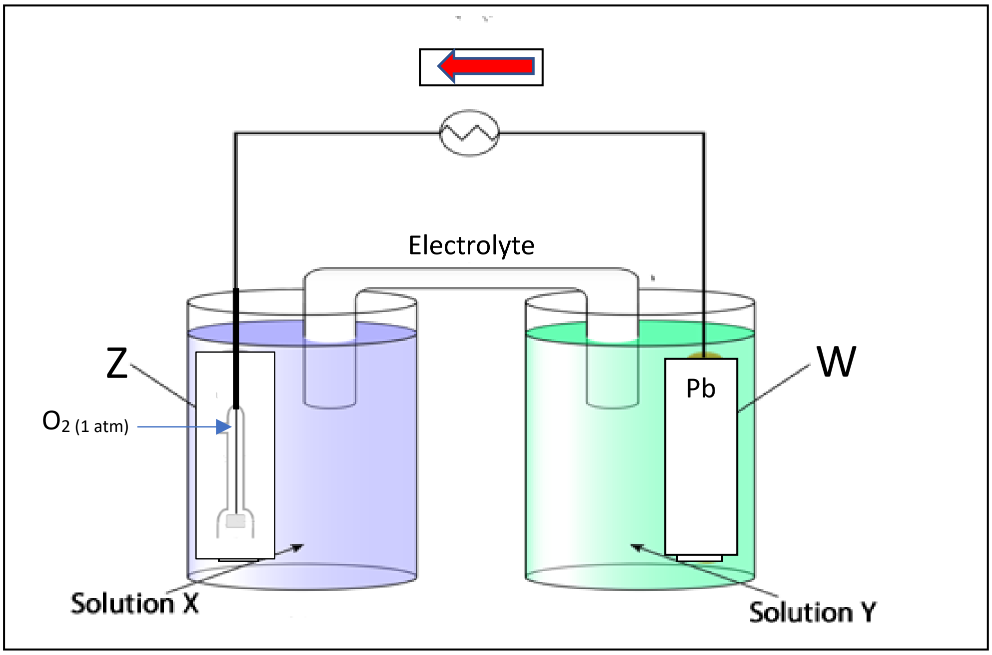
g. Argue for or against this comment. “Fuel cells and secondary cells can be recharged multiple times”

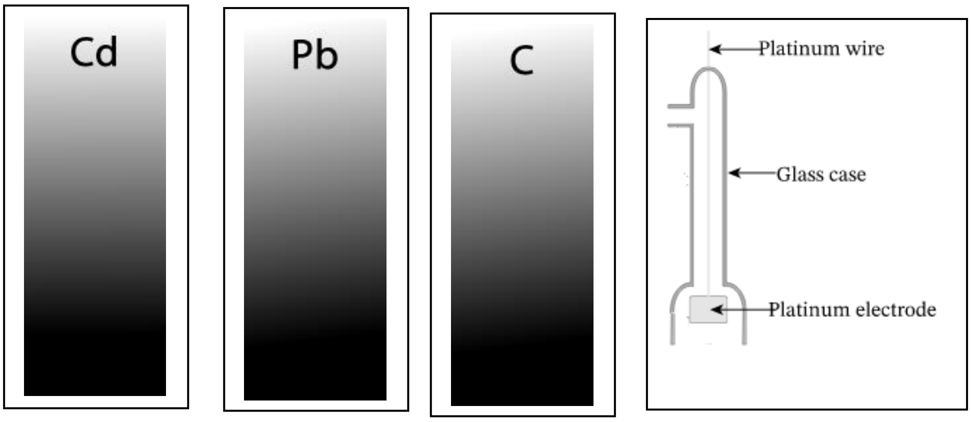
Secondary cells can be recharged, however fuel cells constantly remove products and constantly supply reactants. Since the fuel cell constantly replenishes its fuel recharging is not required and since the products are removed they are not available to take part in any recharge reactions.

h. State one disadvantage of using a fuel cell as opposed to a set of secondary cells.

Fuel cells are expensive as they operate at very high temperatures and use expensive catalyst electrodes. The high temperature limits the life-span of a fuel cell as secondary reactions take place which degrade the electrodes.

2. A galvanic cell is setup by a student to produce a theoretical output of 1.36 V at standard conditions.
Construct this galvanic cell using the template shown and select from the electrodes given below.





a. In the spaces labelled A and B draw and correctly label the electrodes used in each half cell.

b. Indicate the direction of electron flow by placing an arrow in the box provided.

c. Select an appropriate electrolyte. Justify your selection. *KNO_3 as K^+ is weak oxidant and NO_3^- is a weak reductant and so will not take part in any side reactions with the electrolytes in each half cell.*

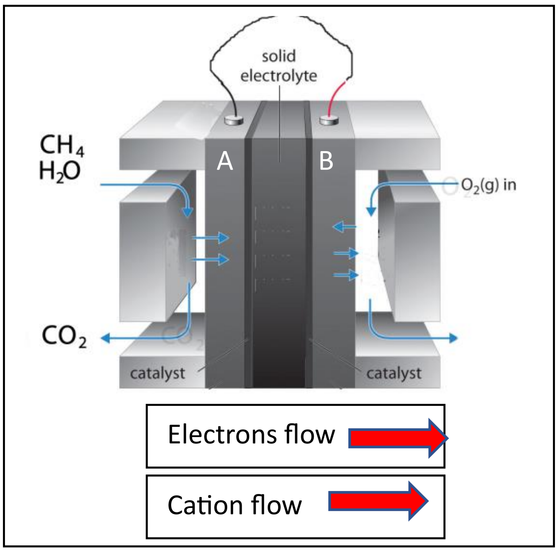
d. Choose appropriate solutions for X and Y, concentration needed.
Solution X ___*HCl__or any strong acid*__________ *Concentration __$[H^+] = 1M$*
Solution Y _____*$Pb(NO_3)_2$*___________ Concentration _____*1M*________

e. Give the reactants Z and W Z ____*O_2 in $H^+(aq)$*_____ , *W* ____*Pb(s)*_____

f. Give the half reaction occurring at the:
- anode *$Pb(s) \rightarrow Pb^{2+}(aq) + 2e^-$*
- cathode *$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$*

g. How will the cell function change if $Al(NO_3)_3$ is used as the electrolyte for the salt bridge?
Al^{3+} is a weak oxidant that will not spontaneously react with any species in the half cells. No change.

3. The PEMFC shown on the right operates on methane gas sourced from biogas.



a. Give the balanced reaction, states not required, occurring at each electrode:

- A ________________________________
  $CH_4 + H_2O \rightarrow CO_2 + 8H^+ + 8e$
- B ________________________________
  $O_2 + 4e + 4H^+ \rightarrow 2H_2O$.

b. Give the balanced equation, states not included, to the overall reaction taking place in the fuel cell.
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

c. In the boxes provided in the diagram on the right, label the following:
- direction of electron flow
- direction of cation flow

d. List three differences between the electrodes of this cell and the electrodes of a primary cell.

Fuel cell	Primary cell
Electrodes act as catalysts	*Electrodes do not act as catalysts*
Electrodes are not consumed in reactions	*Electrodes may be used up in reactions*
Separate the reactants from electrolyte	*Electrodes do not separate reactants from electrolytes in primary or secondary cells*
Porous electrodes to increase surface area	*Electrodes are not porous*
Expensive	*Relatively cheap*

e. List one similarity between the electrodes of the fuel cell and the primary cell.

Electrodes in both cells conduct electrons

h. An MCFC (molten carbonate fuel cell) operate at 800 °C and can also be used to burn methane. The combustion reaction in the MCFC is exactly the same as the combustion of methane in the PEMFC. Give the reaction taking place, states included, at the negative electrode if methane gas is burnt in an MCFC to produce electricity.

$CH_4(g) \rightarrow CO_2(g) + H_2Og)$

$CH_4(g) \rightarrow CO_2(g) + 2H_2Og)$ (balance for H)

$CH_4(g) + 4CO_3^{2-}(l) \rightarrow 5CO_2(g) + 2H_2Og)$ (balance for O by adding $CO_3^{2-}(l)$ to the side deficient in O)

$CH_4(g) + 4CO_3^{2-}(l) \rightarrow 5CO_2(g) + 2H_2Og)$ (Add CO_2 molecules to the right as the number of CO_3^{2-} was added to the left)

$CH_4(g) + 4CO_3^{2-}(l) \rightarrow 5CO_2(g) + 2H_2Og) + 8e^-$ (balance for charge)

f. Methane gas is also used as a fuel to drive an electric generator, shown on the right. Both the PEMFC and the generator have the same overall reaction taking place. Compare the efficiency of both the fuel cell and the generator in producing electrical energy from a given mass of methane gas. Justify your response.

Energy is lost, in the form of heat, every time one energy form is transformed into another.

Fuel cells undergo a one step energy transformation to provide electrical energy.

Chemical → electrical.

Generators have multiple steps and hence greater amount of heat energy is lost.

Chemical → heat → kinetic (steam) → mechanical (Spinning the generator) → electrical