Lesson 6a Comparing Fuel cells with galvanic cells.

The table below seeks to summarise the differences and similarities between galvanic cells, such as primary and secondary cells, and fuel cells.

	Fuel cell	Galvanic cell (primary and secondary)
	Involve exothermic redox reactions	Involve exothermic redox reactions
Electrodes	Anode (-) Cathode (+)	Anode (-) Cathode (+)
	Anode is the site of oxidation	Anode is the site of oxidation
	Cathode is the site of reduction	Cathode is the site of reduction
	Electrodes: - act to conduct electrons - are not used up during discharge -separate reactants and electrolyte - catalyse the half-cell reactions - are porous	Electrodes: - act to conduct electrons - may be used up during discharge
Internal circuit	Electrolyte allows for migration of: - positive ions to the cathode - negative ions to the anode	Salt bridge allows for migration of: - positive ions to the cathode - negative ions to the anode
Reactants and products	Reactants are constantly supplied, hence the cell can operate indefinitely. In other words, chemical energy is not stored	Given amount of reactants are present in the primary or secondary cell and hence the cell has a limited life. In other words, chemical energy is stored. Secondary cells can be recharged.
	Products are constantly removed.	Products build up in the cell
Cost	Very expensive	Low cost
Voltage	Constant throughout the life of the cell	Drops off as the cell discharges.
Efficiency of energy conversion	Chemical to electrical up to 90% efficient, in some modern cells, but normally around 60%, as compared to coal fired which is 30%	Chemical to electrical up to 90% efficient as compared to coal fired which is 30%
Applications	Larger scale applications such as energy back-up systems and used as energy sources for electric motors in vehicles. Not yet capable of supplying base load power. Very quiet when compared to diesel electric generators.	Use in small appliances and as car batteries. Not suitable for larger continues use applications. Very quiet when compared to diesel electric generators.
Temperature of operation	Fuel cells generally operate at very high temperatures hence they are more expensive to run. They require expensive catalyst electrodes as well as containers that stand up to high corrosive electrolytes and temperatures.	Relatively low temperatures around 25°C is optimal. High temperatures cause side reactions that corrode electrodes and degrade reactants.

Fuel cells use electrodes that act as catalysts to speed up the rate of the half-cell reactions.

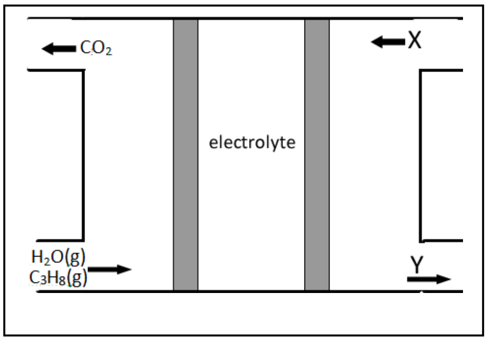
Most fuel cells use either hydrogen or methanol as their fuel, however, there are disadvantages with the use of these fuels. Expensive infrastructure needs to be developed to distribute and store liquid hydrogen. Adding to this draw back the manufacture of both hydrogen and methanol in commercial quantities requires natural gas (methane) in a process qual steam reformation. Steam reformation is a very expensive endothermic process that requires the burning of large quantities of natural gas to release the heat energy required for the steam reformation process. When using propane as a fuel, however, thess disadvantages are not present. Propane gas can be easily liquefied and stored.

1) A propane fuel cell has the overall unbalanced equation shown below.

   $C_3H_8(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$

   a) With reference to oxidation numbers suggest why this is or is not a redox reaction.

   b) A diagram of the fuel cell is shown on the right.



   i. Label the anode and cathode.

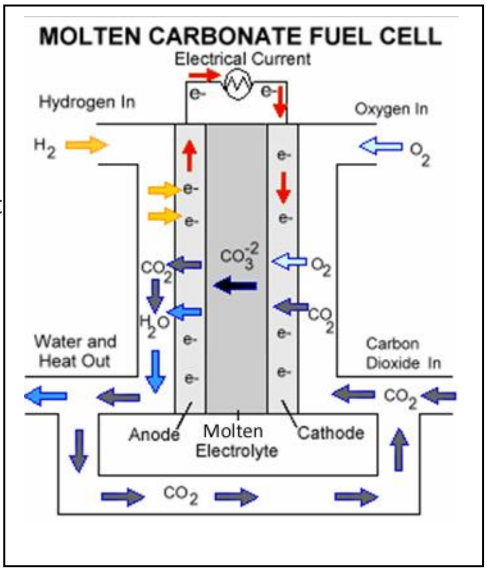
   ii. Give the balanced half-cell reaction, with states, that occurs at the :
   - anode
   - cathode

   iii. Identify “X”and “Y”

   iv. Indicate the direction of positive ion flow through the electrolyte.

   v. Use the two half equations in (ii.) above to derive a balanced overall equation.

2) Molten carbonate fuel cells (MCFCs) use a molten carbonate salt suspended in a porous ceramic matrix as the electrolyte. Salts commonly used include lithium carbonate, potassium carbonate and sodium carbonate. They operate at high temperature, around 650ºC and the benefit of this is that the rate of reaction at both electrodes is significantly increased. This eliminates the use of expensive catalysts to improve the rate of reaction.



a) Consider the hydrogen MCFC shown on the right. The two half-cell equations are shown below.

1 ------ $H_2(g) + CO_3^{-2}(l) \rightarrow H_2O(g) + CO_2(g) + 2e$

2 ------ $O_2(g) + 2CO_2(g) + 4e \rightarrow 2CO_3^{-2}(l)$

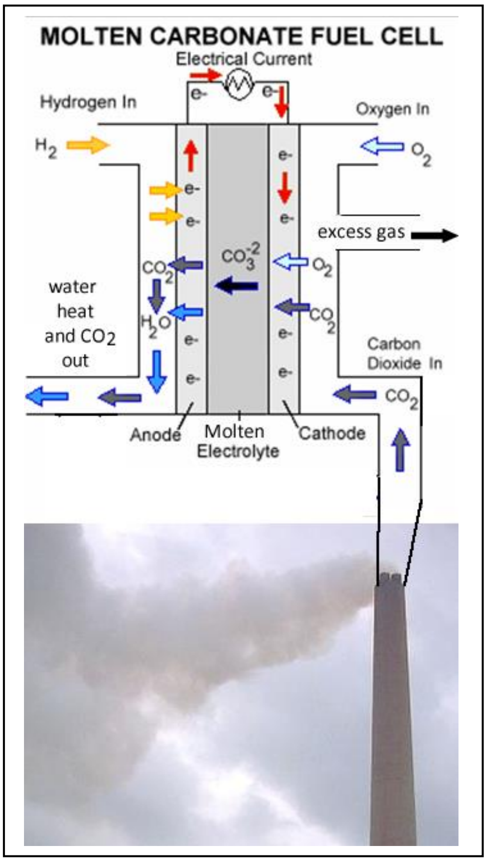
i. Write the balanced overall equation.

ii. What can you say about the net production of CO_2?

iii. How does the electrolyte change as the cell operates?

iv. What is the benefit of operating fuel cells at high temperatures?

b) Consider the image shown on the right. It is suggested that MCFCs can be used to capture CO_2 emitted from the chimney stacks of power stations and in the process add to the electrical output of the station.



i. Discuss the chemistry behind the CO_2 capture.

ii. Discuss the benefits to electrical output and the environmental impact.

3) Methanol is a liquid fuel that can be produced through fermentation. Direct methanol fuel cells use the electrochemical reactions below:

anode reaction $CH_3OH(g) + H_2O(g) \longrightarrow CO_2(g) + 6H^+ + 6e^-$

cathode reaction $3O_2(g) + 12H^+ + 12e^- \longrightarrow 6H_2O(g)$

a) Give the overall cell reaction.

b) Draw a diagram of a methanol fuel cell in the space on the right.

Label the following:

- Anode and cathode and their polarity
- A suitable electrolyte
- Direction of positive ion flow through the internal circuit.
- Inlet for each reactant
- Outlet for products
- Direction of electron flow through the external circuit.

c) An **Alkali** hydrogen fuel cell operates on compressed hydrogen and oxygen. It uses a solution of **potassium hydroxide** in water as its electrolyte. Efficiency is about 70%, and operating temperature is anywhere between 150 and 200 °C.

i. Write the balanced equations to the reactions occurring at the

- anode
- cathode

ii. What mass of oxygen gas needs to be pumped through the fuel cell to produce 233 mol of electrons flowing through the external circuit?