Friday Worksheet **Name: …….**

Fuel cells worksheet 4

1) The reaction between hydrogen and oxygen was the basis of energy required for lift off during the Space Shuttle era. It was also the basis of electrical power generation in a number of fuel cells used in the Apollo Moon missions and are still used in Mars exploration vehicles today. The reaction is highly exothermic and is represented by the equation below.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \qquad \Delta H = -571.6 \text{ kJ mol}^{-1}$$

An alkaline electrolyte is used in a particular hydrogen/oxygen fuel cell.

a) Write a balanced half-equation for the reaction occurring at the

i. cathode

=> $O_2(g)$ => $H_2O(l)$

=> Balance for oxygens by adding water to the right

$O_2(g)$ => $2H_2O(l)$

=> Balance for hydrogen by adding H^+ to the left

$4H^+(aq) + O_2(g)$ => $2H_2O(l)$

=> balance for charge by adding es to the left

$4e + 4H^+(aq) + O_2(g)$ => $2H_2O(l)$

=> Replace the H^+ by adding OH^- to both sides

=> $4e + 4H^+(aq) + 4OH^-(aq) + O_2(g)$ => $2H_2O(l) + 4OH^-(aq)$

=> $4e + 4H_2O(l) + O_2(g)$ => $2H_2O(l) + 4OH^-(aq)$

=> cancel the waters

=> $4e + 2H_2O(l) + O_2(g)$ => $4OH^-(aq)$

ii. anode.

=> $H_2(g)$ => $H_2O(l)$

=> Balance for oxygens by adding water to the left

=> $H_2O(l) + H_2(g)$ => $H_2O(l)$

=> Balance for hydrogen by adding H^+ to the right

=> $H_2O(l) + H_2(g)$ => $H_2O(l) + 4H^+(aq)$

=> balance for charge by adding es to the right

=> $H_2O(l) + H_2(g)$ => $H_2O(l) + 2H^+(aq) + 2e$

=> Replace the H^+ by adding OH^- to both sides

=> $H_2O(l) + 2OH^-(aq) + H_2(g)$ => $H_2O(l) + 2H^+(aq) + 2OH^-(aq) + 2e$

=> $H_2O(l) + 2OH^-(aq) + H_2(g)$ => $3H_2O(l) + 2e$

=> cancel the waters

=> $2OH^-(aq) + H_2(g)$ => $2H_2O(l) + 2e$

b) Under standard conditions what is the maximum voltage 3 fuel cells connected in series can deliver?

Using the data booklet we can see that one fuel cell can deliver 2.06 V (1.23 - -0.83).
3 will deliver 6.18 volts.

$O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O$	+1.23
$2H_2O + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	−0.83

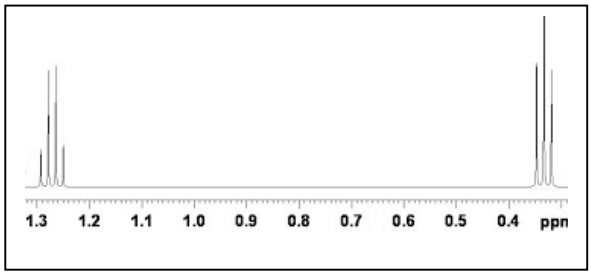
c) What amount of heat energy is produced when 2.14 L of O_2 gas is mixed with 3.14 L of H_2 at S.T.P.

Step 1 Find the limiting reactant.
=> Hydrogen is the limiting reactant.
Step 2 Find the mol of hydrogen
=> 3.14 / 22.4 = 0.141 mol
Step 3 find the amount of energy released.
=> 0.141 X 571.6 / 2 = 40.1 kJ

2) Much of the hydrogen used in fuel cells is produced from fossil fuels, such as methane, where the products are hydrogen and carbon monoxide gases. This process is known as steam reformation

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

i. An unknown fossil fuel is used in the process of steam reformation to generate hydrogen gas. The ^{1}HNMR of this compound is shown on the right.



- Using the n+1 rule identify the hydrocarbon.

Butane

- Write a balanced chemical equation for the steam reformation of this fuel.
  $C_4H_{10}(g) + 4H_2O(g) \Rightarrow 4CO(g) + 9H_2(g)$

ii. Explain why this fuel, in i. above, is not renewable but methane generated by biomass is a renewable.

Butane is a fossil fuel that must be collected from fossil fuel reserves produced over many millions of years. Hence it is not considered renewable as it cannot be generated in a relatively short period of time so that usage does not outstrip supply. Methane, however, can be regenerated in a short period of time through microbial action.