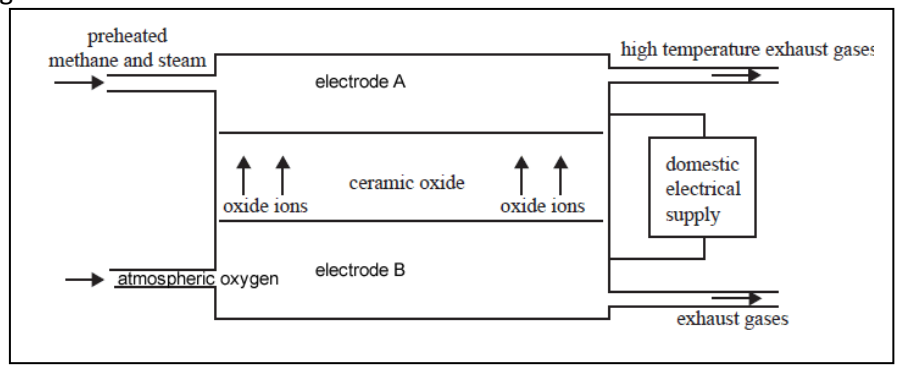
Redox reactions – Revision galvanic cells and fuel cells

Lesson 7

1) A fuel cell uses a solid oxide electrolyte to generate electrical energy, as shown in the diagram below.




Combustion of methane drives the fuel cell. One of the half equations is given below.

$$CH_4(g) + 4O^{-2}(g) \rightarrow CO_2(g) + 2H_2O(g) + 8e$$

a) At which electrode does the given half reaction, above, take place? _____
b) Give the other half equation _____
c) Give the overall equation _____
d) Label the anode and cathode
e) Label the direction of electron flow.
f) Although a fuel cell is a galvanic cell it differs markedly from other galvanic cells. Compare fuel cells with other galvanic cells by labelling the following statements as true or false
    i. Fuel cells can be recharged in a similar way to secondary cells. ____
    ii. Electrodes used in primary cells and secondary cells are similar to the electrodes used in fuel cells. ____
    iii. Fuel cells and all other galvanic cells transform chemical energy into electrical energy ____
    iv. Oxidation occurs at the anode of fuel cell, primary and secondary cells. ____
    v. Fuel cells deliver a constant voltage during their operation as compared to other galvanic cells which reduce in voltage as they discharge _____
    vi. The products of all galvanic cells, including fuel cells, must remain in contact with the electrodes so they can be recharged.
    vii. The anode in fuel cell is positive whereas the anode in other galvanic cell is negative ____
    viii. Electrodes in fuel cells act as catalysts for the oxidation and reduction reactions, whereas electrodes in other galvanic cells do not. ____
    ix. Fuel cells represent a cheap alternative to the supply of electrical energy ___

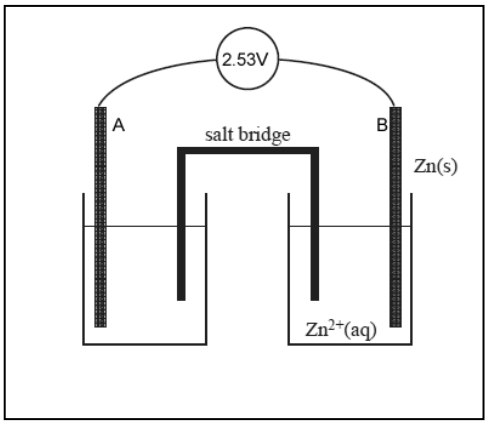
g) Assuming this fuel cell is 75.0% efficient in converting chemical energy into electrical energy and that methane is supplied at the rate of 44.50 litres per second at a pressure of 1 atm at 25°C, calculate the following, to the right number of significant figures.

i. Mol of $CH_4$ consumed every second.

ii. Total, theoretical, heat energy available from the combustion of methane, in kJ, every second.

iii. Electrical energy, in kJ, produced every second.

2) Consider the diagram of a galvanic cell shown on the right operating under standard conditions.




a) What is the half cell on the left composed of?

b) In which direction are electrons flowing?

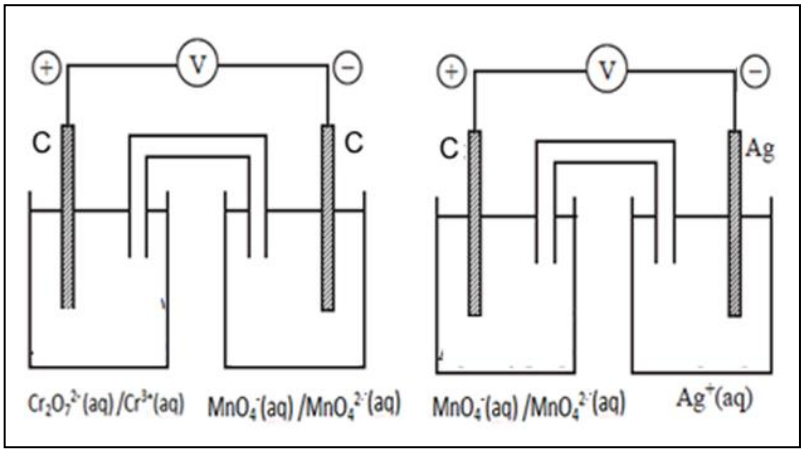
c) What is electrode A composed of?

d) What properties should electrode A have?

e) Identify the
- oxidant
- reductant

f) As the cell discharges label the following
- direction of cation flow
- direction of anion flow
- anode
- cathode
- polarity of electrodes.

3) Consider the two galvanic cell shown below




a) Place the following half equations in the order they would be found on an $E^o$ table.

$MnO_4^-(aq) + e^- \rightleftharpoons MnO_4^{2-}(aq)$ ----------$E^o$

$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$ ----------$E^o$

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7\,H_2O(l)$ ----------E

b) The lithium button cell, used to power watches and calculators, is a primary cell containing lithium metal. The lithium ion cell is a secondary cell that is used to power laptop computers.
a. What is the difference between a primary and secondary cell?

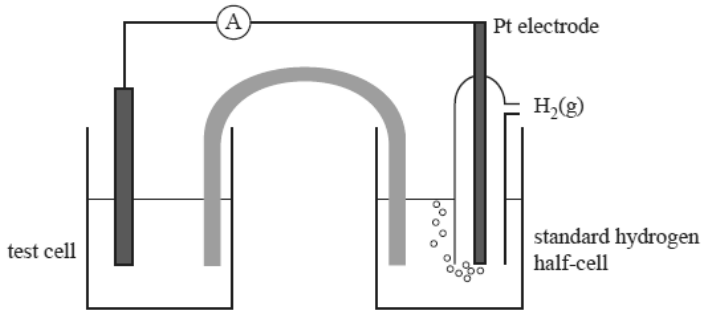
c) By referring to information provided in the Data Book, give one reason why lithium is used as a reactant in these galvanic cells.

d) Some early lithium metal batteries exploded when exposed to water. Explain why, using a balanced equation, including states, for the reaction between lithium metal and water. (assume all lithium products are water soluble)

4) In a problem-solving activity a student is given the following information regarding three half-equations. However, although the three numerical values of $E^0$ are correct, they have been incorrectly assigned to the three half-equations

| Half-equation | $E^0$ |
|---|---|
| $AgCl(s) + e \rightleftharpoons Ag(s) + Cl^-(aq)$ | –0.40 V |
| $Cd^{2+}(aq) + 2e \rightleftharpoons Cd(s)$ | –0.36 V |
| $PbSO_4(s) + 2e \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$ | +0.22 V |

The objective of this task is to correctly assign the $E^0$ values to the corresponding half-equation shown on the right. To do this, the student constructs standard half-cells for each of the above half-reactions. These half-cells are connected, one at a time, to a standard hydrogen half-cell as indicated in the diagram below.




The following observations were made either during or after the electrochemical cell discharged electricity for several minutes.

| Experiment | Half-cell reaction being investigated | Experimental notes |
|---|---|---|
| 1 | $AgCl(s) + e \rightleftharpoons Ag(s) + Cl^-(aq)$ | Electron flow was detected passing from the standard hydrogen half-cell to the half-cell containing the silver electrode. |
| 2 | $Cd^{2+}(aq) + 2e \rightleftharpoons Cd(s)$ | The mass of the cadmium electrode decreased. |
| 3 | $PbSO_4(s) + 2e \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$ | The pH of the solution in the standard hydrogen half-cell increased. |

a) The above information can only be used to assign one of the $E^0$ values to its corresponding half-equation. Identify this half-equation by placing the correct $E^0$ value next to its corresponding half-equation in the table on the right.

b) Explain why the other two $E^0$ values cannot be correctly assigned to their half-equations

| Half-equation | $E^0$ |
|---|---|
| $AgCl(s) + e \rightleftharpoons Ag(s) + Cl^-(aq)$ | |
| $Cd^{2+}(aq) + 2e \rightleftharpoons Cd(s)$ | |
| $PbSO_4(s) + 2e \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$ | |

c) Explain why the pH of the solution in the standard hydrogen half-cell increased in experiment 3.