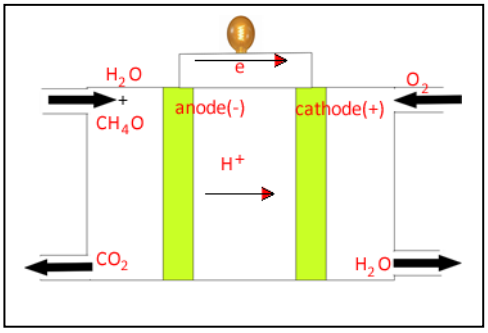
Friday worksheet 3 Fuel cells

1 A H_3PO_4 electrolyte fuel cell can be constructed that uses the following two half-reactions.

i $CO_2(g) + 6H^+(aq) + 6e– => CH_3OH(aq) + H_2O(l)$ $E^o = + 0.05$ V

ii $O_2(g) + 4H^+(aq) + 4e– => 2H_2O(l)$ $E^o = +1.23$ V

a) Draw a labelled fuel cell using the template on the right. Label the:
- anode and cathode
- polarity of the electrode
- direction of electrons
- direction of ions through the electrolyte

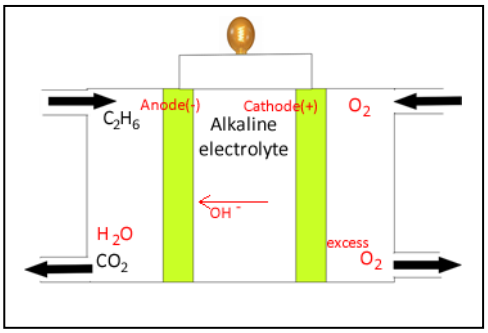


b) Identify the oxidant and reductant.
- oxidant *O_2*

- reductant *CH_3OH*

c) Which of the following is likely to occur at the **cathode**? Explain
- CH_3OH is used up *False The reaction taking place at the cathode is $O_2(g) + 4H^+(aq) + 4e– => 2H_2O(l)$*

- pH of the surrounding electrolyte decreases
False- pH of the surrounding electrolyte increase as H^+ ions are used according th the reaction below
$O_2(g) + 4H^+(aq) + 4e– => 2H_2O(l)$



- Water is formed
True- H_2O is formed
$O_2(g) + 4H^+(aq) + 4e– => 2H_2O(l)$
- Oxygen gas is used up.
False

d) Ethane is burnt in an alkaline electrolyte fuel cell.

i. Write the balanced reaction occurring a the
- cathode *– $O_2(g) + 4e + 2H_2O(l) \rightarrow 4OH^-(aq)$*
- anode *– $14OH^-(aq) + C_2H_6(g) \rightarrow 2CO_2(g) + 10H_2O(l) + 14e$*

ii. Label the remaining products and reactants

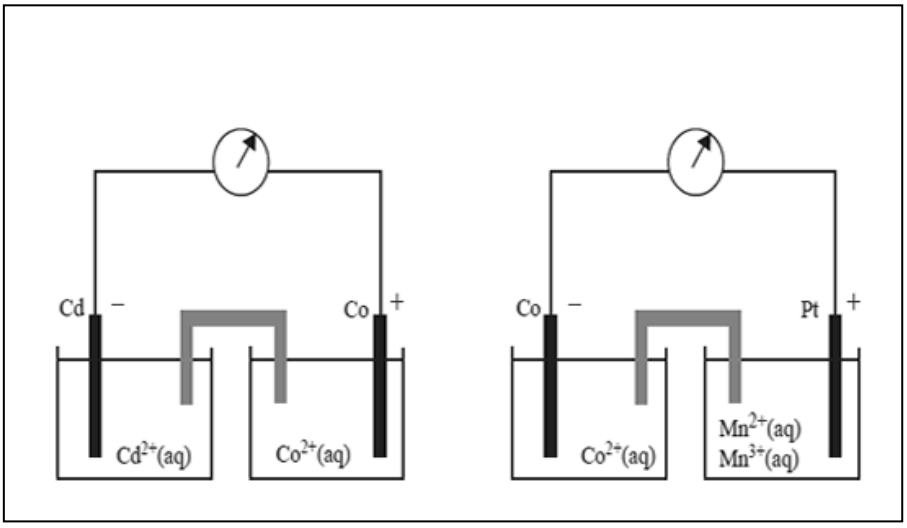
iii. Identify the ions travelling through the electrolyte and indicate their direction of travel.

iv. Which of the comments below is/are true about this alkaline fuel cell.
- All the chemical energy supplied is converted into electrical energy.
False no fuel cell is 100% efficient some waste heat is produced.
- The cell can be recharged using electrical energy from a power source.
False fuel cell cannot be reacharged as the reactants are constantly supplied and products removed.
- The pH of the electrolyte increases as the cell discharges
False -- pH does not change as the number of OH^- ions produced at the cathode are equal to the number used at the anode.

- cathode – $7O_2(g) + 28e + 14H_2O(l) \rightarrow 28OH^-(aq)$
- anode – $28OH^-(aq) + 2C_2H_6(g) \rightarrow 4CO_2(g) + 20H_2O(l) + 28e$

v. Calculate the energy efficiency of this cell when 20.0 grams of ethane produces 800 kJ of electrical energy at 25°C and 100 kPa pressure.

Step 1 from the data sheet obtain the heat of combustion of ethane per gram and find the total heat energy released.
=> 20.0 X 51.9 = 1038
Step 2 find the percentage efficiency
=> (800 /1038) X 100 = 77.1%



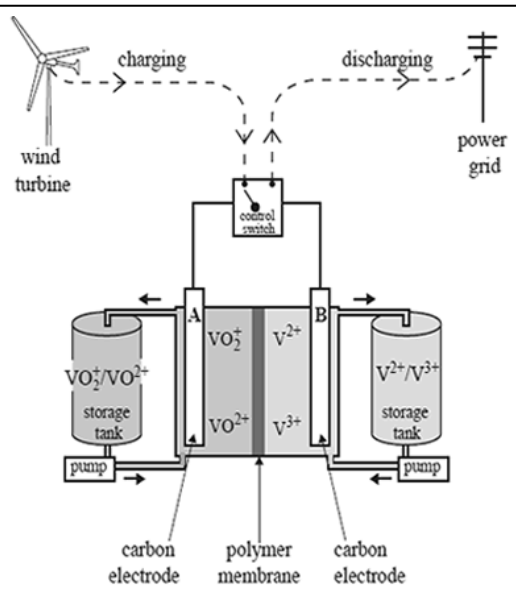
2) Consider the half cells shown above. Which one of the following reactions would not be expected to occur spontaneously? Explain

A. $Co^{2+}(aq) + Cd(s) \rightarrow Co(s) + Cd^{2+}(aq)$
B. $2Mn^{3+}(aq) + Co(s) \rightarrow 2Mn^{2<}+(aq) + Co^{2+}(aq)$
C. $2Mn^{3+}(aq) + Cd(s) \rightarrow 2Mn^{2+}(aq) + Cd^{2+}(aq)$
D. $2Mn^{2+}(aq) + Co^{2+}(aq) \rightarrow 2Mn^{3+}(aq) + Co(s)$

From the cells above we can write the relative positions of reductions reactions as they would appear on the electrochemical series

$Mn^{3+}(aq) + e \rightarrow Mn^{2+}(aq)$
$Co^{2+}9aq) + 2e \rightarrow Co(s)$
$Cd^{2+}(aq) + 2e \rightarrow Cd(s)$
Hence $2Mn^{2+}(aq) + Co^{2+}(aq) \rightarrow 2Mn^{3+}(aq) + Co(s)$ cannot occur spontaneously.

3) Consider the vanadium ion battery shown below.



The two relevant half-equations for the vanadium redox battery are

$$VO_2^+(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l) \qquad E^\circ = +1.004\ V$$

$$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq) \qquad E^\circ = -0.255\ V$$

This question is modified from the VCE 2009 paper.

a) Give the polarity of each electrode

B is the negative as it is the site of oxidation and hence the anode where the reaction $V^{2+}(aq) \rightarrow e + V^{3+}(aq)$ takes place.

b) Which vanadium-containing ion will have the highest concentration at the anode after the cell's first recharge and while it is still connected to the power source.

The anode during discharge hence becomes the cathode during recharge

$VO^{2+}(aq) + H_2O(l) \rightarrow VO_2^+(aq) + 2H^+(aq) + e$

VO^{2+} will have the highest concentration at the cathode.

c) Write a balanced overall equation to show why iron would be an unsuitable material to use as electrode B in the vanadium redox cell.

Iron is a stronger reductant than V^{2+} hence the following reaction will take place.

$2VO_2^+(aq) + 4H^+(aq) + Fe(s) \rightarrow 2VO^{2+}(aq) + 2H_2O(l) + Fe^{2+}(aq)$

d) Write a balanced overall equation to show if Zn metal is or is not appropriate for use as electrode B. Discuss if heat or electrical energy is the main output for this cell if Zn is used as electrode B.

$2VO_2^+(aq) + 4H^+(aq) + Zn(s) \rightarrow 2VO^{2+}(aq) + 2H_2O(l) + Zn^{2+}(aq)$

Heat producing

e) Discuss one major difference between a fuel cell and the vanadium ion battery.

Any of the following

Compared to the vanadium battery above fuel cells:

- use molecular reactants rather than ionic

- use electrodes that act as catalysts

- constantly supply reactants and maintain a steady voltage throughout their life

- products are constantly removed

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