Revision 6 – secondary cells, equilibrium, rates

1) An alkaline nickel cadmium battery is shown on the right.
When discharging the overall cell reaction is given below.

$Cd(s) + 2NiO(OH)(s) + 2H_2O(l) \rightarrow Cd(OH)_2(s) + 2Ni(OH)_2(s)$

a) Give the balanced chemical equation of the half reaction that occurs at the:

=> $Cd(s) \rightarrow Cd(OH)_2(s)$

=> $2H_2O(l) + Cd(s) \rightarrow Cd(OH)_2(s)$

=> $2H_2O(l) + Cd(s) \rightarrow Cd(OH)_2(s) + 2H^+(aq)$

=> $2H_2O(l) + Cd(s) \rightarrow Cd(OH)_2(s) + 2H^+(aq) + 2e$

Since it is an alkaline battery replace the H^+ by adding OH^- to both sides.

=> $2H_2O(l) + 2OH^-(aq) + Cd(s) \rightarrow Cd(OH)_2(s) + 2H^+(aq) + 2OH^-(aq) + 2e$

=> $2H_2O(l) + 2OH^-(aq) + Cd(s) \rightarrow Cd(OH)_2(s) + 2H_2O(l) + 2e$

Cancel the water from both sides

=> $2OH^-(aq) + Cd(s) \rightarrow Cd(OH)_2(s) + 2e$

- Anode *(-) $2OH^-(aq) + Cd(s) \rightarrow Cd(OH)_2(s) + 2e$*

=> $NiO(OH)(s) \rightarrow Ni(OH)_2(s)$

=> $H^+(aq) + NiO(OH)(s) \rightarrow Ni(OH)_2(s)$

=> $e + H^+(aq) + NiO(OH)(s) \rightarrow Ni(OH)_2(s)$

Since it is an alkaline battery replace the H^+ by adding OH^- to both sides

=> $e + H^+(aq) + OH^-(aq) + NiO(OH)(s) \rightarrow Ni(OH)_2(s) + OH^-(aq)$

=> $e + H_2O(l) + NiO(OH)(s) \rightarrow Ni(OH)_2(s) + OH^-(aq)$

- Cathode *(+) $e + H_2O(l) + NiO(OH)(s) \rightarrow Ni(OH)_2(s) + OH^-(aq)$*

b) The cell is recharged using a recharger that is 80.0% efficient. A current of 1.11 amps is applied for 2.560 hours.

i) Give the polarity and the balanced chemical equation to the half reaction occurring at the:

- anode *(+) $Ni(OH)_2(s) + OH^-(aq) \rightarrow NiO(OH)(s) + H_2O(l) + e$*
- cathode *(-) $Cd(OH)_2(s) + 2e \rightarrow 2OH^-(aq) + Cd(s)$*

b) What is the change in mass of the cathode after recharging?

Step 1 – Find the charge delivered

=> $Q = 1.11 \times 2.56 \times 60 \times 60 = 10230$ C

Step 2 – find 80% of this charge

=> $10230 \times 0.80 = 8184$ C

Step 3 – Find mole of electrons

=> 8184/96500 = 0.0848 mol

Step 4 - find the mole of $Cd(OH)_2$

=> 0.0848 / 2 = 0.0424 mol.

Step 5 - Find the mass loss of the cathode

Since the reaction at the cathode forms Cd from $Cd(OH)_2$ with the loss of 2 OH^- ions there will be an overall mass loss.

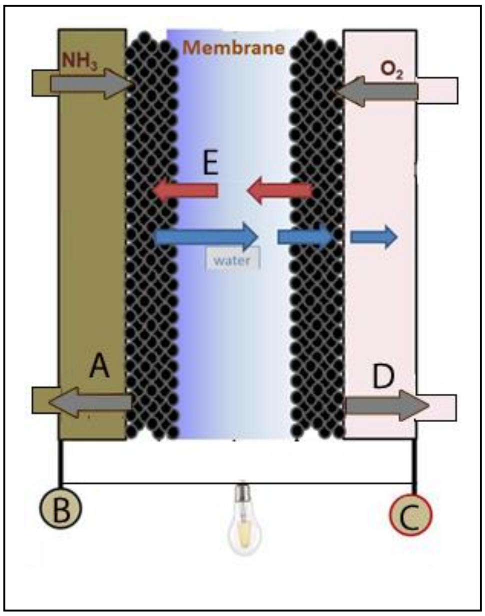
mole of OH^- lost = 0.0424 X 2 = 0.0848

mass of OH^- lost = 0.0848 X 17.0 = 1.44 gram loss.

2) An ammonia fuel cell is shown on the right. Ammonia is cheaper to store and transport than hydrogen. This fuel cell uses a hydroxide exchange membrane.

The overall cell reaction is given below.

$4NH_3(l) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(g)$ ΔH = -1290 kJ/mol



a) Give the balanced equations to the half reactions occurring at the:

anode *$2NH_3(g) + 6OH^-(aq) \rightarrow 6H_2O(l) + N_2(g) + 6e$*

cathode *$O_2(g) + 2H_2O(l) + 4e \rightarrow 4OH^-(aq)$*

b) Give one advantage of using ammonia over ethanol as the fuel. *No CO_2 is produced.*

c) Identify the following.

i. Polarity of electrode B *Negative*

ii. Polarity of electrode C *Positive*

iii. Exhaust gas A *N_2*

iv. Exhaust gas D *H_2O*

v. Ions labelled E *$OH^-(aq)$*

d) What volume, in litres, of N_2 gas is theoretically formed at S.L.C. if the fuel cell provides a steady 12.00 amps of electrical current over a period of 24.00 hours?

Step 1 Find the charge delivered by the cell.

=> Q = It = 12 X 24.00 X 60 X 60 000 = 1.037 X 10^6C

Step 2 Find the mol of electrons

=> 1.037 X 10^6 /96500 = 10.74 mol

Step 3 Find the mol of N_2 produced.

=> according to the stoichiometry for every 6 mol of electrons produced 1 mol of N_2 is produced

$2NH_3(g) + 6OH^-(aq) \rightarrow 6H_2O(l) + N_2(g) + 6e$

=> 10.74/6 = 1.791 mol of N_2 is produced.

Step 4 find the volume at S.L.C.

=> 1.791 X 24.8 = 44.4 litres.

e) If the fuel cell is 80.00% efficient in converting chemical energy into electrical energy what amount of ammonia , in grams, is required to deliver 0.5000 MJ of electrical energy?

Step 1 find the amount of energy that must be supplied in order for the cell to deliver 500.0 Kj of energy.

=> Let x be the amount of energy.

=> x X 0.8000 = 500.0 kJ

=> x = 625 Kj

Step 2 Find the mol of ammonia needed

=> apply the stoichiometry and let y be the required mol of ammonia

$4NH_3(l) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(g)$ ΔH = -1290 kJ/mol

=> 4 mol of NH_3 / 1290 kJ = y / 625 kJ

=> 4 x 625 kJ / 1290 = 1.94 mol

Step 3 find the mass of ammonia

=> 1.94 X 17.0 = 32.9 grams

f) If the amount of ammonia, calculated in e) above, is placed in a 30.0 L container at 30.00 °C what is the pressure, in kPa, exerted by the gas on the walls of the container?

PV = nRT

=>P =nRT/V = 0.969 X 8.31 X 303 /30.0

=> P = 81.3 kPa.

g) An external, 90.0 L, pressurised container of ammonia constantly feeds the fuel cell that is 80.0% efficient. Ammonia is kept in the cylinder at a pressure of 612.3 kPa and a temperature of 25.0 °C. Calculate the length, in hours, of operation of the fuel cell if it delivers a constant current of 12.0 amps?

Step 1 Calculate the mol of NH_3 present in the cylinder

=> $n = PV/RT$

=> $n = 612.3 \times 90.0 / (8.31 \times 298) = 22.25$ mol

Step 2 Calculate 80.0% of this amount, as only 80.0% of this will contribute to producing a current.

=> $22.25 \times 0.800 = 17.80$ mol

Step 3 Find the mol of electrons produced.

=> according to the stoichiometry

$2NH_3(g) + 6OH^-(aq) \rightarrow 6H_2O(l) + N_2(g) + 6e$

=> $n_e = 17.80 \times 3 = 53.41$ mol

Step 4 Find the charge that this represents

=> $Q = 53.41 \times 96500\ C = 5.154 \times 10^6\ C$

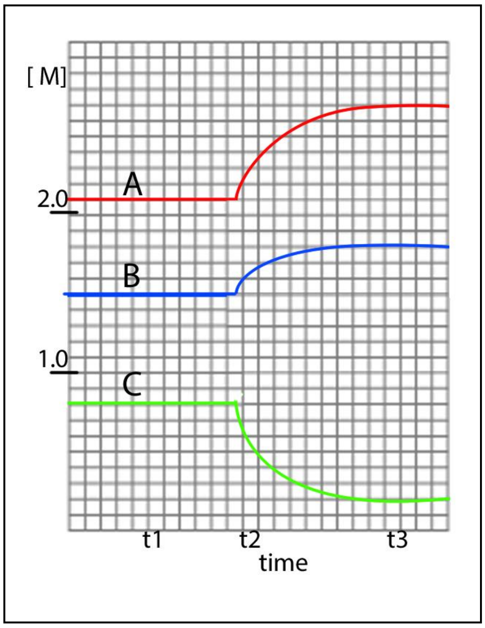
Step 5 Find the time in hours that this charge can be delivered using a current of 12.0A.

=> $Q = It$

=> $5.154 \times 10^6\ C = 12.0 \times t$

=> $t = 4.30 \times 10^5$ seconds

=> $t = 119$ hours



3) Consider the concentration versus time graph shown on the right of a reaction taking place in a closed vessel. At time t_2 the vessel is heated.

a) Give a possible balanced equation to the reaction taking place and indicate whether it is exothermic or endothermic.

$2C \rightleftharpoons 2A + B$ ΔH is positive

or

$2A + B \rightleftharpoons 2C$ ΔH is negative

b) Consider the reaction forming C. Describe how the yield and the rates of the forward and backward reactions change as a result of a temperature increase. Explain.

Looking at the graph as temperature is increased the amount of C decreases. The reaction drives in a net backward direction. This must be an exothermic reaction forming C. Therefore, the yield of C decreases but both the rates of the forward and backward reactions increase. Overall the backward reaction increases more than the forward reaction driving the system in a net backwards direction forming A and B.

c) Calculate the value of the equation quotient at t_1 using your answer to question a) above.

If this reaction was given $2C \rightleftharpoons 2A + B$ ΔH is positive then

$K = [2.1]^2 [1.5] / [0.80]^2 = 1.0 \times 10^1 M$

If this reaction was given $2A + B \rightleftharpoons 2C$ ΔH is positive then

$K = [0.80]^2 / [2.1]^2 [1.5] = 9.7 \times 10^{-2} M^-$

d) Explain how the equilibrium constant changes from t_1 to t_3.

If this reaction was given $2C \rightleftharpoons 2A + B$ *ΔH is positive then*

K_c at t_3 will be higher than at t_1

If this reaction was given $2A + B \rightleftharpoons 2C$ *ΔH is positive then*

K_c at t_3 will be lower than at t_1