Revision task 4

1) A 3.42 grams sample of a famous brand of brick cleaner was accurately weighed into a 250 mL volumetric flask and made to the mark with distilled water.
   A 25.00 mL aliquot was the taken from the volumetric flask and placed into a 100 mL conical flask with two drops of an appropriate indicator. This was then titrated against a 0.115 M Na_2CO_3 and an average titre of 15.32 mL was obtained.
   a) Write a balanced chemical equation of the reaction taking balance in the conical flask.

      $2HCl(aq) + Na_2CO_3(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$

   b) Calculate the amount of HCl in the conical flask.
      3.52×10^{-3} mol
   c) Calculate the amount of HCl in the volumetric flask and hence the 3.42 grams sample of brick cleaner.
      3.52×10^{-2} mol
   d) Calculate the concentration, in % w/w of HCl in the brick cleaner.

      37.6%w/w

   e) Calculate the concentration of the HCl in the brick cleaner in mol/Litre if the density of the brick cleaner is 1.24 g/mL.
      12.8M

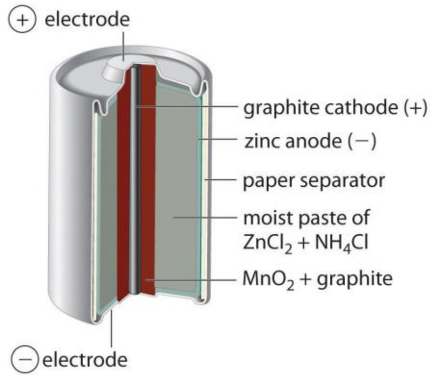
2) Pictured below is a Leclanché cell. The overall reaction taking place in this cell is

$2MnO_2(s) + 2NH_4Cl(aq) + Zn(s) \rightarrow Mn_2O_3(s) + Zn(NH_3)_2Cl_2(s) + H_2O(l)$

a) Which species is oxidised and which is reduced?

Zn is oxidised to Zn^{2+} and

Mn in MnO_2 is reduced form an oxidation state of 4+ to 3+ in Mn_2O_3



b) Write the equation to the half-reaction taking place at the cathode.

$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

c) Write the reaction occurring at the cathode

$2MnO_2(s) + 2H^+(aq) + 2e^- \rightarrow Mn_2O_3(s) + H_2O(l)$.

d) If the battery produces 1.50 volts find the E° value for the half-reaction taking place at the cathode at standard conditions,

$2MnO_2(s) + 2NH_4^+(aq) + 2e^- \rightarrow Mn_2O_3(s) + 2NH_3(aq) + H_2O(l)$.	**+0.74**
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	−0.76

e) Describe what happens to the pH of the surroundings at the anode during discharge. Explain why.

The pH will rise as the weak acid NH_4^+ is used up during discharge

f) An **alkaline battery** is essentially a Leclanché cell adapted to operate under ***alkaline***, or basic, conditions. It produces a more constant voltage output as it discharges than a Leclanché cell.

The overall reaction that occurs in an alkaline battery is

$Zn(s) + 2MnO_2(s) \rightarrow ZnO(s) + Mn_2O_3(s)$

a) Give the equation to the half-reaction that occurs at the negative terminal of the battery.

$Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$

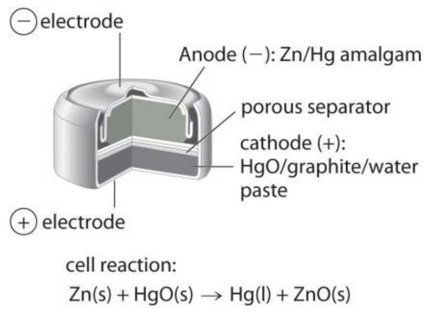
g) Give the equation to the half-reaction that occurs at the positive terminal of the battery.

$2MnO_2(s) + H_2O(l) + 2e^- \rightarrow Mn_2O_3(s) + 2OH^-(aq)$

h) Consider the alkaline button cell pictured on the right.

i. Give the equation to the half-reaction occurring at the anode *$Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$*

ii. Give the equation to the half-reaction occurring at the cathode. *$HgO(s) + H_2O(l) + 2e^- \rightarrow Hg(l) + 2OH^-(aq)$*



iii. Give one disadvantage when disposing of this cell.

Mercury contamination of the waste site.

3) A sustainable community is set up in a remote part of inland Australia. Corn crops are grown to derive glucose which is then fermented to produce ethanol.

a) Give the name of the process and a balanced equation for the synthesis of glucose by the plant.

Photosynthesis

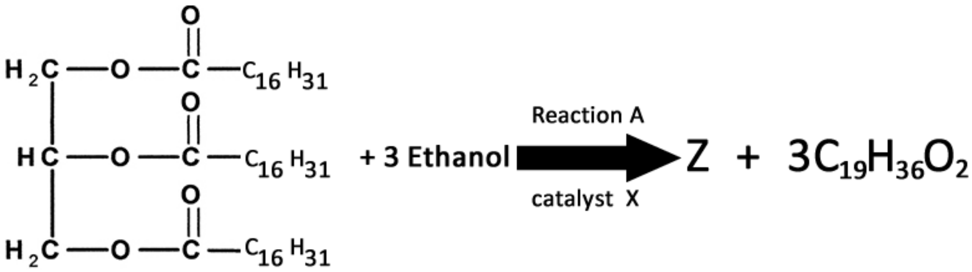
$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$

b) Give the name and a balanced equation for the production of ethanol via microbial action.

Fermentation

$C_6H_{12}O_6(aq) \rightarrow 2C_2H_6O(aq) + 2CO_2(g)$

c) Palm oil is also grown by the community and used in the formation of biodiesel as shown by the reaction pathway below.



Constituent of palm oil

i) Name a suitable substance for catalyst X

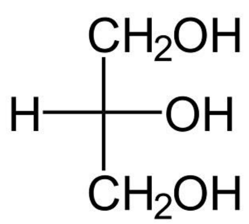
KOH or NaOH

ii) What type of reaction is reaction A?

Transesterification

iii) Draw the structural formula of substance Z in the box provided on the right.

Substance Z



iv) $C_{19}H_{36}O_2$ is then used in a process called steam reformation to produce hydrogen gas according to the equation below.

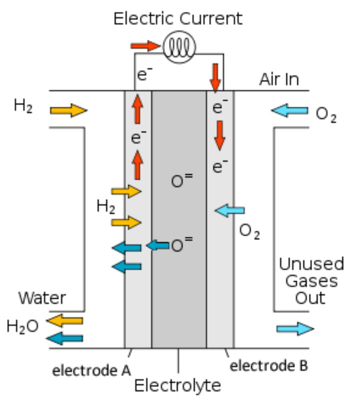
$C_{19}H_{36}O_2(g) + 17H_2O(g) \rightarrow 19CO(g) + 35H_2(g)$

This hydrogen is used to feed a **solid oxide fuel cell** shown on the right.

- Label the anode and cathode of the fuel cell.
- Write the equation to the half-reaction occurring at the:
  - Anode

    Electrode A ($H_2 \rightarrow 2H^+ + 2e$)
  - Cathode

    Electrode B ($O_2 + 4e \rightarrow 2O^{-2}$)



- At SLC 20.00 g per minute of $C_{19}H_{36}O_2$ is used every minute to form hydrogen gas.
    - Calculate the volume of hydrogen that is produced every minute.

      Step 1 calculate the amount in mol of $C_{19}H_{36}O_2$ per minute
      => 20.00 / 296 = 0.06757
      Step 2 calculate the amount in mol of H_2 gas
      => 35 X 0.06757 = 2.365 mol
      Step 3 Calculate the volume at SLC
      => 2.365 X 24.8 = 58.65 Litres = 58.7 L
    - If all the hydrogen formed is used to fuel the cell, calculate the current in Amps delivered by the battery, assuming it is 100% efficient. A current of *x* Amps means that *x* Coulombs of charge flows per second.

      Step 1 write the equation that occurs at the anode (states not required)
      => H_2 => $2H^+$ + 2e
      Step 2 calculate the charge delivered every minute
      => Q = 96,500 X mol of electrons
      => Q = 96,500 X 2 X 2.365 / 60 = 7.607 X 10^3 A
- Is hydrogen gas, obtained through steam reformation of biodiesel, a renewable fuel? Explain your answer.

  Yes. The source from which hydrogen is made, namely biodiesel, can be replenished quickly so that it never runs out.

d) The chemical engineers in the community were discussing the use of ethanol in the direct production of electrical power. Two options were proposed.

i. Use ethanol to run a piston, electric generator.
ii. Use ethanol in a fuel cell .

Discuss, with reference to efficiency, cost, and production of Green House gasses, the merits of each option.

Fuel cells are up to 60 % efficient in converting chemical energy into electrical energy whereas generators are up to 30% efficient. This means it requires less fuel than generators to deliver the same amount of current using a fuel cell and hence less Green House gasses produced.
Fuel cells are, however, very expensive and not yet able to deliver base load electrical power at a relatively low cost as is possible with generators.

e) Write the balanced chemical equation for the:

- combustion of liquid ethanol in oxygen gas

  $CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

- half-reaction occurring at the anode of the ethanol fuel cell

  $CH_3CH_2OH(l) + 3H_2O(l) \rightarrow 2CO_2(g) + 12H^+(aq) + 12e$

f) Calculate the electric current, in Amps, produced by an ethanol fuel cell that burns 20.0 grams of ethanol per minute and operates at 60.0% efficiency.

Step 1 write the oxidation equation

$CH_3CH_2OH(l) + 3H_2O(l) \rightarrow 2CO_2(g) + 12H^+(aq) + 12e$

Step 2 Calculate the mol of ethanol

=> 20.0 / 46.0 = 0.435 mol

Step 3 calculate the total mol of electrons produced every minute

=> 12 X 0.435 = 5.22 mol

Step 3 calculate the charge produced per minute

=> 5.22 X 96,500 = 5.04 X 10^5C

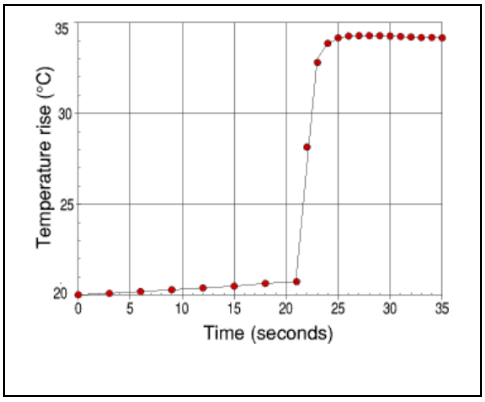
Step 4 calculate the charge produced per second

=> 5.04 X 10^5 / 60 = 8400 Amps

Step 5 Calculate 60.0%

=> 0.600 X 8400 = 5040 A

4) A bomb calorimeter, containing 50.0 mL of water at 20.6 °C was calibrated by passing a current of 6.11 A at 2.76 V for 2.50 minutes through the heating coil. The temperature was recorded periodically and the data recorded on a temperature vs time graph shown on the right.



a) Calculate the calibration(C_f) factor for the calorimeter.

Step 1 Calculate the energy delivered

=> E = VIt =2.76 X 6.11 X 2.50 X 60 = 2530J

Step 2 Calculate the ΔT. 34.0 – 20.6 = 13.4 °C

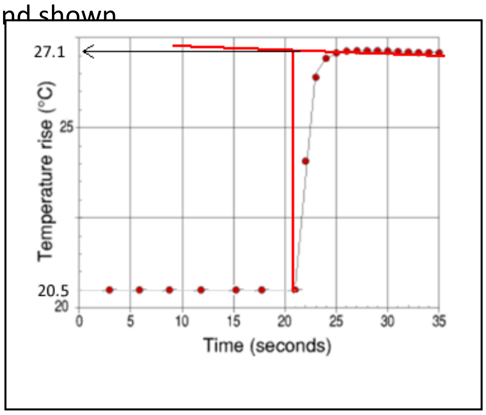
Step 3 Calculate C_f

=> 2530/13.4 = 189 J/°C

b) 0.0280 grams of liquid butane was placed in the bomb calorimeter with excess oxygen and ignited. The temperature was recorded and shown on the graph on the right.

i. Write a balanced chemical equation for the combustion of butane.

$2C_4H_{10}(l) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$



ii. Calculate the molar heat of combustion for butane

Step 1 – calculate the energy released

=> Energy (J) = C_f X ΔT = 189 X 6.6 = 1247 J

Step 2 calculate the mol of burtane

=> 0.0280 / 48.0 = 0.0005833 mol

Step 3 calculate the molar heat of combustion

=> 1247 / 0.0005833 = 2138kJ/mol

iii. Give the **ΔH** for the equation in i. above.

$2C_4H_{10}(l) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$ $\Delta H = -4276 kJ/mol$

c) Compare the molar heat of combustion of butane as calculated with the theoretical value. Explain any discrepancy.

The theoretical value for the heat of combustion is 2880 kJ/mol. The lower value is may be due to the poor insulation of the calorimeter allowing energy to escape to the surroundings.