Ongoing revision 2 Unit 3 – Fuels, enthalpy, electrolysis

1. Electrolysis of water is used to produce H_2 gas which is pumped into a 300 litre vessel at 24.0 ^oC. This vessel is connected to a proton exchange membrane fuel cell (PEMFC) to generate electrical energy.
   a. The pressure needed for the efficient production of electrical energy is 180 kPa short.
      i. What mass, in kg, of hydrogen gas is needed to get to the correct operating pressure ?

      ii. The electrolytic cell used to generate the hydrogen gas has an operating current of 2.24 amps. Calculate the time, in hours, taken to produce the required amount of hydrogen gas in order to achieve the operating gas pressure.

   b. The hydrogen gas produced from the electrolysis of water is labelled "Green Hydrogen". This hydrogen, however, is turned into ammonia via the reaction, shown below, known as the "Haber-Bosch process".

$$3H_2(g) + N_2(g) \rightarrow 2NH_3(g)$$

   This reaction occurs at a temperature around 500^oC.
   i. Discuss with reference to intermolecular bonding why it is more economically viable to transport hydrogen in the form of liquid ammonia than as pure liquid hydrogen.

   ii. Argue against the use of the term "Green Hydrogen"

   iii. Given that hydrogen and ammonia gases are kept in separate sealed 300 L vessels, under the same conditions of temperature and pressure suggest a reason why more hydrogen can be transported in the form of ammonia rather than in pure hydrogen. Use a calculation to justify your reasoning.

2. Another electrolytic cell, shown in diagram 1, consumes a charge of 8.00 X 10^4 C in 8.00 minutes.

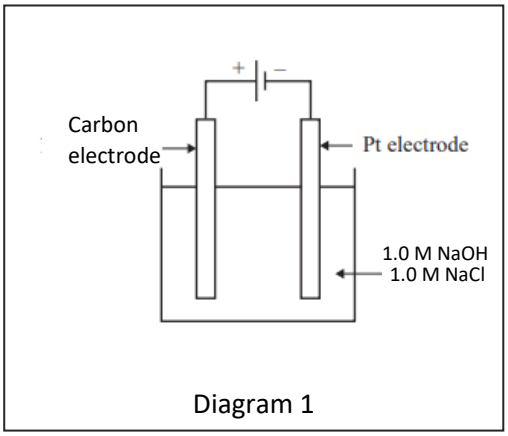


Diagram 1

i. Calculate the mol of electrons consumed.

ii. Give the gaseous products that occur at each electrode and justify your choice by writing the half equations for the reactions occurring at the:

- Anode
- Cathode

iii. Discuss the changes in pH that occur:

- at the anode.
- at the cathode.
- in the electrolyte.

iv. Calculate the mass of gaseous product formed at the anode. Give the answer to the right number of significant figures.

v. The efficiency of the cell in producing electrical energy is given by the expression on the right.

$$\frac{\text{Actual mass of product at the anode}}{\text{Theoretical mass of product at the anode}} \times 100$$

Calculate the efficiency of the cell if 5.40 grams of gas is produced at the anode.

vi. The cell's design has an inherent safety hazard. Explain what this hazard may be with reference to the products that are formed at each electrode and redesign the **electrodes** only to deal with the safety hazard identified. Use the space provided in the box on the right to draw an appropriate solution.

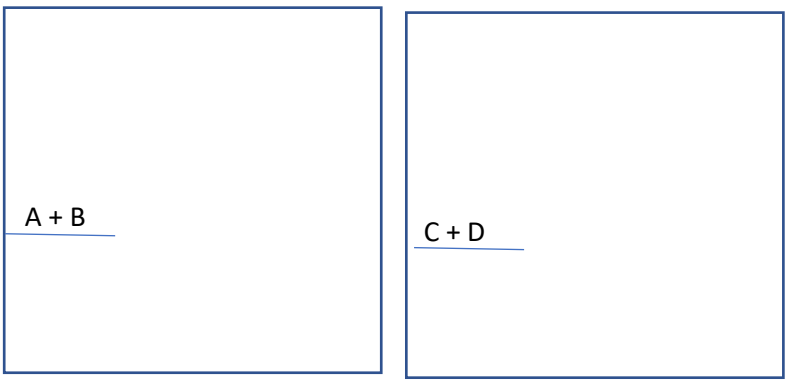
3. Propene (C_3H_6) gas undergoes complete combustion in atmospheric oxygen at SLC.
   a. Given that 4.20 grams of propene releases enough heat energy to increase the temperature of 2.00 kg of water by 24.6 °C:
      i. find the molar heat of combustion of propene.

      ii. write a balanced thermochemical equation for the complete combustion of propene.

      iii. calculate the minimum volume, in litres, of oxygen required to completely combust 4.20 grams of propene at SLC.

      iv. Calculate the volume, in litres, of gaseous product formed if 102.9 kJ of energy is released during the complete combustion of propene in atmospheric oxygen.

   b. During the following reaction A(g) + B(g) → C(g) + D(g) 200kJ of energy is required to break bonds while 150 kJ of energy is released during bond formation. Given the total chemical energy of the reactants (A and B) is 40 kJ complete the two energy profiles shown below. Drawings do not have to be to scale. In each clearly label and give the value of the:
      i. ΔH
      ii. Activation energy
      iii. Energy content of the products



   c. Which one of the following two reactions occurs at the faster rate? Justify your answer with reference to the energy profiles drawn in question b. above.
      i. A(g) + B(g) → C(g) + D(g)
      ii. C(g) + D(g) → A(g) + B(g)