Analysis of Practical Activities

Reading time: 5 minutes

Writing time: 55 minutes

Student's Name: _____

Teacher: _____

Structure of booklet

Section	Number of Questions	Number of questions to be answered	Marks
Short Answer	24	24	43
		Total:	**43**

Directions to students

Materials

- Students **are permitted** to bring into the examination room: pens/pencils, highlighters, erasers, sharpeners, rulers, and an approved scientific calculator.

- Students are **NOT permitted** to bring into the examination room: white out liquid/tape, phones or electronic devices, including smart watches.
- Students are provided with the following: Question and answer book of **10** pages and VCAA Data booklet.

The task

- Please ensure that you write your name and teacher's name on this booklet. This paper consists of short answer questions.

- There are a total of **43** marks available.

- Be sure to include states with all chemical equations.

- All numerical answers need to be quoted to the correct number of significant figures.

- All working out must be shown in the space provided.

Practical Experiments referred to in this assessment

Prac 1: Formation and combustion of biodiesel

Prac 2: Combustion of ethanol

Prac 3: Electrical calibration and use of a solution calorimeter

Prac 4: Formation of an electrochemical series

Prac 5: Demonstration of a hydrogen fuel cell

Consider Prac 1 when answering these questions: (2 marks)

1. *Identify the **dependent** variable in the combustion part of the investigation only. (1 mark)*

   _____*temperature change or heat of combustion* _____

2. *Other than wearing a lab coat and safety glasses, what other safety measure was taken during this experiment. (1 mark)*

Any one of the following but limited to.

- *Conduct the experiment in a well-ventilated area away from open flames and ignition sources. Use a fire-resistant surface and have a fire nearby.*
- *Perform the procedure in a well ventilate room to avoid build of CO and other pollutants due to incomplete combustion of fuel.*
- *Wear heat-resistant gloves, tongs or insulated holders to handle heated containers.*
- *Avoid biodiesel spillage and quickly clean up the slipper surface with sand or sawdust or a spill tray beneath the setup.*

3. What is a disadvantage of this fuel? (1 mark)
   - *When compared to petrodiesel it has a lower energy density*
   - *It competes with land for food crops.*

Consider Prac 2 when answering these questions: (8 marks)

A student conducted experiment 2 and obtained the following results:

Measurement	**Result**
Volume of water	150.0mL
Initial temperature of water	23.5°C
Initial mass of beaker and ethanol	148.23g
Final temperature of water	38.2°C
Final mass of beaker and ethanol	146.17g

4. Using the above results, calculate the heat of combustion of ethanol to the correct number of significant figures. *Density of water is 1.0g/ml.* (3 marks)
   Step 1 – Calculate the energy absorbed by the water
   => ΔT = 38.2 – 23.5 = 14.7 °C *---- 1 mark*
   => Energy(joules) = 4.18 X 150.0 X 14.7 = 9.22 kJ
   Step 2 – calculate the mol of ethanol used
   => (148.23 – 146.17) / 46 = 0.0448 *---- 1 mark*
   Step 3 – calculate the molar heat of combustion => 9.22 kJ/0.0448 = 2.0 X 10^2 kJ/mol (2 sig figs due to density of water 1.0 g/mL) *---- 1 mark*

5. Using your answer to Question 4, write a balanced thermochemical equation for the combustion of ethanol. (2 marks)

   $C_2H_6O(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ ΔH = - 200 kJ or -200kJ/mol
   ---- 1 mark balanced eqn -----1 mark correct ΔH with negative sign

6. Using your answer to question 4 and the knowledge that the heat of combustion of ethanol is 1360 kJ/mol, calculate the efficiency of this process. (1 mark)

   $(2.0 \times 10^2 / 1360) \times 100 = 15.\%$

7. One student conducted the experiment and obtained a result of 1555 kJ/mol. State what **mistake** the student may have made for this to occur? Explain how this has resulted in a higher result. (2 marks)

   The use of less than 150 mL of water in the beaker will results in a higher temperature change. ------ 1 mark
   Less water will heat up to a higher temperature with eh same amount of energy as that used to heat a greater volume of water. Hence the ΔT will be greater leading to a higher ΔH calculation. ----- 1 mark

Consider Prac 1 and 2 when answering these questions: (5 marks)

8. Given that the ethanol supplied was a pure substance, which experiment, given that they followed the same method for combustion, would have produced a more accurate result for the heat of combustion of each fuel? Explain your answer. (2 marks)

   A more accurate result for the heat of combustion would be obtained from the experiment using pure ethanol. ---- 1 mark

   This is because the biodiesel produced in the school lab may contain impurities, such as glycerol and water, from the production and purification process. These impurities could affect the combustion efficiency of the fuel, leading to variability in the measured heat of combustion. ---- 1 mark

9. Comment on the validity of these experiments. (2 marks)

   Invalid ---- 1 mark
   lack of insulation causes a great amount of heat loss which is not absorbed by the water and hence can not be measured. ---- mark

10. State an improvement that could be done to increase the accuracy of the experiments. (1 mark)

Any plausible suggestion that leads to an improvement eg.

- insulate the beaker with paper of Styrofoam .

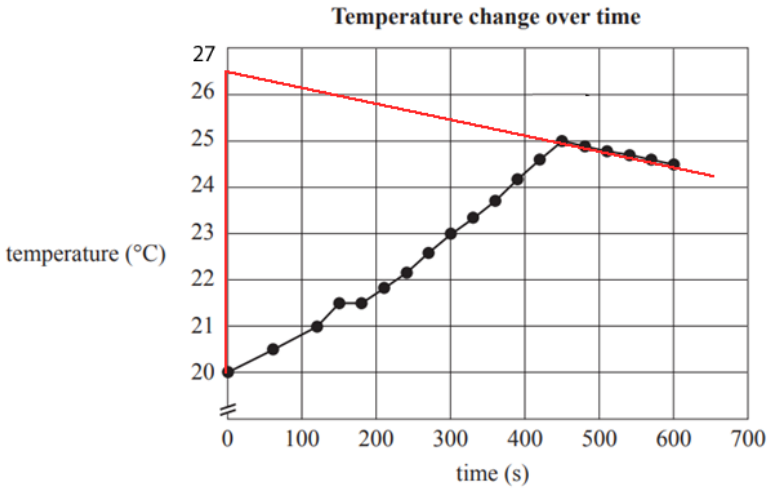
- place lid on the beaker

- place the bottom of the beaker closer to the flame to reduce heat loss via convection currents or use a draft shield.

- Using a larger volume of water to reduce evaporation, however, the volume should not so high as to reduce the temperature increase significantly. If this is an option given by the student then the adverse impact of a large volume of water should also be stated, eq. low ΔH

Consider Prac 3 when answering these questions: (12 marks)

Student A conducted electrical calibration of a calorimeter and produced the graph below from their results. They turned the heater on at 0 seconds and left on for 7 minutes.



11. Determine the calibration factor (in J $^{o}C^{-1}$) of the calorimeter given 100.0mL of water was used. (3 marks)

Step 1 – calculate the energy delivered

=> E = Vit = 5.8 X 1.6 X 7 X 60 = 3.9 kJ ---- 1 mark

Step 2 – Using the graph work out ΔT

=> 6.5 ^{o}C ---- 1 mark

Step 3 Calculate C_f

=> 3.9 kJ / 6.5 = 0.60 kJ/^{o}C ----- 1 mark

12. How would the calibration factor calculated in question 7 be affected if the heater was turned off after :

    i. 3 minutes. (2 marks)

    No impact on the C_f. ---- 1 mark

    A shorter time for current to run would deliver less energy and would raise the temperature accordingly by a smaller amount. Thus the relationship between temperature change and energy delivered is preserved. ----- 1 mark

    ii. 30 seconds. (2 marks)

    The C_f with 30 seconds is less accurate ----- 1 mark

    The group with a 0.3°C temperature change (30s) has unreadable data since their change is smaller than the graph's resolution, leading to an extremely high percentage uncertainty thus making the calibration factor less accurate when compared to the 6.5 ^oC change.

    --- 1 mark

    j. Name one systematic error related to the electrical calibration of the calorimeter. (1 mark)

    Any valid systematic error get the mark. For example:

    - *Heat escaping from the calorimeter due to poor insulation.*
    - *Resistance in the wires produces a current that is consistently less than detected by the ammeter.*
    - *Parallax error was applied consistently when reading the analogue dial of the voltmeter.*

In the second part of this experiment, Student A wanted to determine the change in enthalpy (ΔH) of the reaction between hydrochloric acid and magnesium. They added 100mL of 1.0M HCl and 0.2515g of magnesium into the calorimeter. The temperature of the calorimeter increased by 8.6°C.

k. Give a balanced chemical equation, states included.
$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

l. Determine which reagent is limiting. (2 marks)

Step 1 - find the mol of both reactants
=>n_{HCl} = 0.100 X 1.0 = 0.10
=>n_{Mg} = 0.2515 / 24.3 = 0.01035
Step 2 – divide by the coefficient in the balanced equation above
=> Mg = 0.01035 / 1 = 0.0135, HCl = 0.10 / 2= 0.050
Hence Mg is the limiting reactant.
---- 1 mark for correct reactant , 1 mark for any calculation justifying student's choice.

m. Calculate the volume of hydrogen gas produced at SLC. (2 marks)
0.01035 X 24.8 = 0.257 L ----- 1 mark correct volume + 1 mark correct sig figs

n. Calculate the experimental change in enthalpy (ΔH) for the reaction. (2 marks)
Energy given out per mol of Mg = (0.60 kJ/^oC X 8.6 ^oC) / 0.01035 = 5.0 X10^2 kJ
=> ΔH = - 5.0 X 10^2 kJ ----- 1 mark correct answer ---- 1 mark correct sig figs

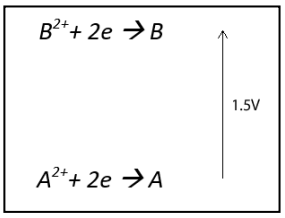
Consider Prac 4 when answering these questions: (4 marks)

A sample of student results from this experiment is given below:

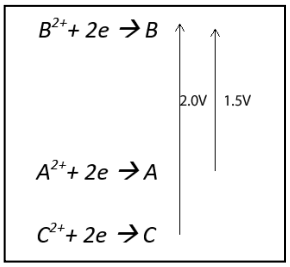
Cell	Negative terminal	Positive terminal	Cell Voltage
$A^{2+}/A \,||\, B^{2+}/B$	A	B	1.5V
$B^{2+}/B \,||\, C^{2+}/C$	C	B	2.0V
$D^{2+}/D \,||\, A^{2+}/A$	A	D	0.9V
$C^{2+}/C \,||\, A^{2+}/A$	C	A	0.5V
$D^{2+}/D \,||\, B^{2+}/B$	D	B	

o. Using the results above, write an electrochemical series (no voltages required). (3 marks)
Students should realise that the reductant reacts at the anode (negative terminal).
A negative gradient is created between the oxidant and the reductant in a spontaneous reaction.

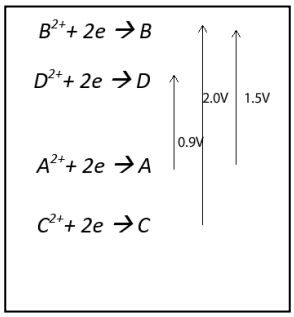
The cell ($A^{2+}/A \,||\, B^{2+}/B$) has A as the reductant hence a difference of 1.9 V between the reductant (A) and the oxidant (B^{2+})



The cell ($B^{2+}/B \,||\, C^{2+}/C$) has C as the reductant hence a difference of 2.0 V between the reductant (C) and the oxidant (B^{2+})



The cell ($D^{2+}/D \,||\, A^{2+}/A$) has A as the reductant hence a difference of 0.9 V between the reductant (A) and the oxidant (D^{2+}).



$B^{2+} + 2e \rightarrow B$

$D^{2+} + 2e \rightarrow D$
$A^{2+} + 2e \rightarrow A$
$C^{2+} + 2e \rightarrow C$

p. Determine the cell voltage for the $D^{2+}/D \,||\, B^{2+}/B$ cell using the results. (1 mark)
0.6 V

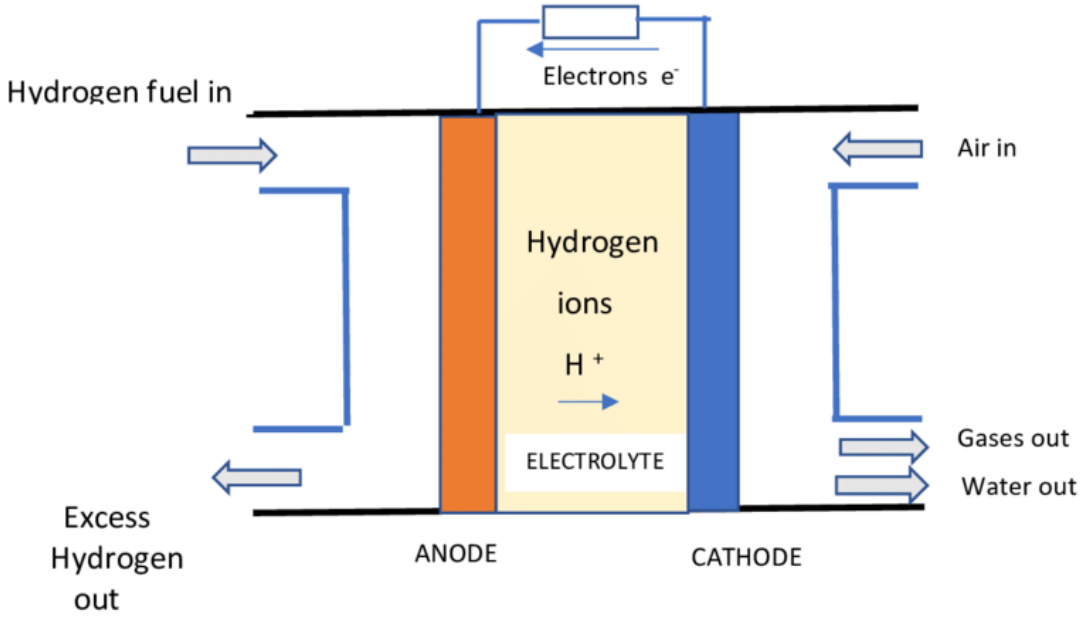
q. Explain why you were unable to assign E.M.F (E^{o}) values to the electrochemical series formed and compare to the standard electrochemical series. (1 mark)
Assuming these were conducted at SLC (25°C, 1 atm) no reference point was given. In a normal electrochemical series the hydrogen electrode is assigned a value of 0 and all other cells are measured relative to it.

Consider Prac 5 when you answer the following questions: (7 marks)

A hydrogen fuel cell was demonstrated to you in class, the half equations for the hydrogen fuel cell and a simplified diagram are given below.

$$H_2\,(g) \rightarrow 2H^+\,(aq) + 2e^-$$

$$O_2\,(g) + 4H^+\,(aq) + 4e^- \rightarrow 2H_2O\,(l)$$



r. Given that the hydrogen oxygen fuel cell is 57% efficient. Calculate the amount (in grams) of hydrogen required to produce 150MJ of usable energy, given the heat of combustion of hydrogen is 282kJ/mol. (2 marks)

Step 1 – calculate the amount of energy that needed to be supplied taking into account the 57% efficiency.

=> 150000kJ / 0.57 = 263.2 MJ ---- 1 mark

Step 2 calculate the mol of H_2

=> 263200 / 282 = 933.3

Step 3 Calculate the mass of H_2

=> 933.3 X 2.0 = 1.9 kg. ---- 1 mark

s. Another type of fuel cell can use **bioethanol** as a fuel with a **molten carbonate electrolyte.** Write the balanced half equations and overall equation for an acidic bioethanol-oxygen fuel cell. (3 marks)

a. Anode: *$C_2H_5OH(l) + 6CO_3^{2-}(l) \rightarrow 8CO_2\,(g) + 3H_2O(l) + 12e^-$*

b. Cathode: *$O_2(g) + 2CO_2(g)\ 4e^- \rightarrow 2CO_3^{2}\text{-}(l)$*

c. Overall: *$C_2H_6O(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$*

t. Would a biogas-oxygen **or** hydrogen/oxygen fuel cell be more environmentally friendly? Explain your answer. (2 marks)

Biogas is preferred ------- 1 mark

if the hydrogen is sourced from fossil fuels. ----- 1 mark

or

Hydrogen is preferred ---- 1 mark

if the hydrogen is sourced using renewable energy as biogas will still release CO_2 in to the atmosphere. ---- 1 mark

Consider Prac 1, 2, and 5 when answering these questions: (3 marks)

u. Assuming that all experiments were conducted on the same day, identify a controlled variable that was consistent across all of the investigations. (1 mark)

Any of the below.

temperature, air pressure, humidity or any other logical suggestion.

v. Which of the experiments would provide the most energy efficient way to obtain energy to drive a car? Explain your reasoning. (2 marks)

Fuel cell ---- 1 mark

Less energy transformations hence less energy loss. ---- 1 mark

Chemical → electrical

END OF SAC