This assessment covers the following.

- The three experiments undertaken in class:
  I. Synthesis of biofuel and the determination of energy content of the biofuel in kJ/g
  II. Molar heat of combustion of ethanol
  III. Electrical calibration of a calorimeter

i. Consider experiment I (synthesis of biodiesel). The apparatus and setup are shown below.

Materials:

- 150mL of oil **(oil is a slip hazard! Alert your teacher or lab tech if any is spilt on the ground!)**
- hotplate
- 100mL beaker
- 1.05g potassium hydroxide (KOH) **(caution potassium hydroxide is extremely caustic)**
- 250mL conical flask
- thermometer
- 30mL methanol **(caution methanol is flammable and toxic)**
- stirring rod
- 2 funnels
- retort stand
- 1 separating funnels

Figure 1 – biodiesel setup.

SAFETY: Lab coats, safety glasses and gloves must be worn at all times during this experiment! Extraction fans must also be used.

ii. Consider experiment II (Molar heat of combustion of ethanol). The apparatus and setup are shown below.

Materials

- Thermometer
- 250 mL beakers
- 100 mL of pure ethanol
- Weighing Balance
- Gauze mat
- Stopwatch

Procedure

Step 1 - Add 50 mL of distilled water to a 250 mL beaker.

Step 2 - Sit the beaker directly on a gauze mat on top of a tripod as shown in fig.1.

Step 3 - Record the temperature of the water.

Step 4 - Weigh the spirit burner with the ethanol.

Step 5 - Light the spirit burner and place under the beaker.

Step 6 - Record the temperature every minute for 5 minutes.

Step 7 – Extinguish the flame and reweigh the spirit burner and ethanol.

Step 8 - Continue to record the temperature every minute for another 5 minutes after the spirit burner has been extinguished.

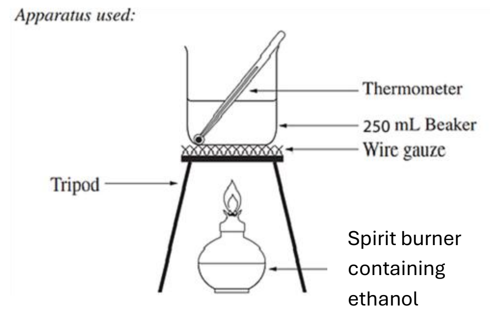


Figure 2. Setup for ethanol (kJ/mol)

Experiment -Calibration of a calorimeter

Purpose

To calibrate a calorimeter by measuring the increase in temperature that results from a measured input of electrical energy.

Keep electricity switched off until the apparatus is fully assembled.

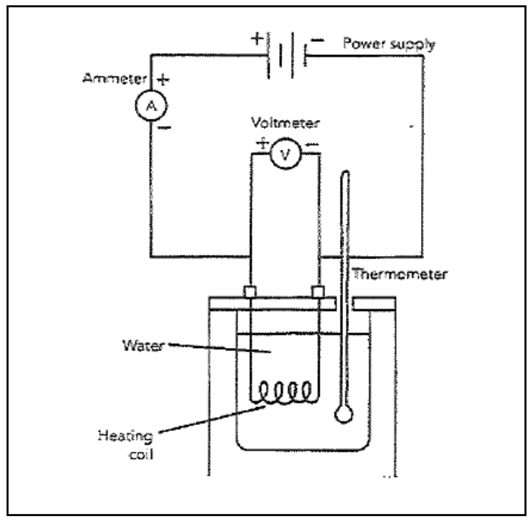
Duration 30 minutes

Materials

100 ml measuring cylinder calorimeter (with a code number for identification); DC power supply; 5 x wire leads; thermometer, -10 to 50°C; stopwatch; ammeter; voltmeter.

Procedure

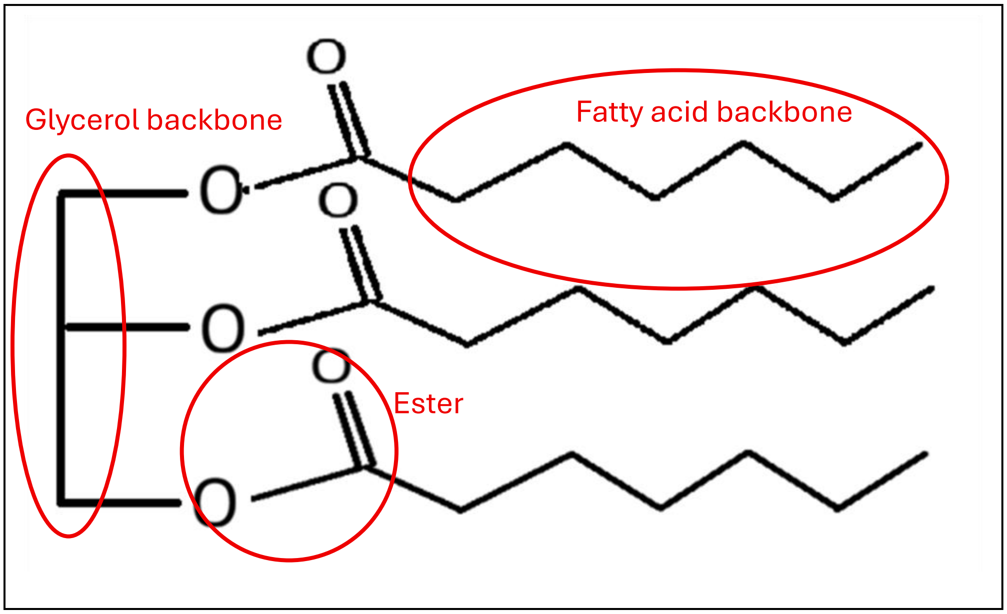
1	Record the code number of your calorimeter. You may need to use this calorimeter for future experiments once you have calibrated it.
2	Pour 100 ml of water into the calorimeter. Allow the temperature of the water to stabilise (around 2 - 3 mins) and record the temperature.
3	Now the temperature is steady, apply a measured voltage of approximately 6 V for exactly 3 minutes using the circuit shown. Stir continuously and record the temperature everv 30 seconds.
4	Record the potential difference (voltage) and current while the water is heating. After 3 minutes turn off the power supply. Continue to stir the water in the calorimeter and record its temperature every 30 seconds for a further 3 minutes.
5	Discard the water in the calorimeter and repeat steps 1-4 using a fresh supply of water.



1. The reaction below sums up the synthesis of biodiesel as it happened during experiment I (synthesis of biodiesel). Excess methanol is used to guarantee total reaction of the vegetable oil in the presence of alkaline catalyst (KOH).

$$\text{Vegetable oil} + \text{Methanol} \xrightarrow{KOH} \text{Methyl ester} + \text{"X"}$$

a. In the space below, draw the skeletal formula of a triglyceride formed from a fatty acid with the chemical formula $C_6H_{13}COOH$. *2 marks*



b. Using your drawing of the triglyceride drawn in the box above, clearly

- label and name the functional group present *2 marks*
- label the fatty acid carbon chain *1 mark*
- label the carbon chain represented by "X" *1 mark*

c. Consider the reaction shown above to produce biodiesel.

i. Identify the type of chemical reaction that occurs to produce biodiesel

__________________*Transesterification*__________________________*1 mark*

ii. Justify your answer to question i, above.

The triglyceride reacts with methanol, where the ester bonds are broken and reformed, replacing the glycerol group with a methyl group to form biodiesel and glycerol.

Figure 3 – Separating funnel containing the synthesised biodiesel

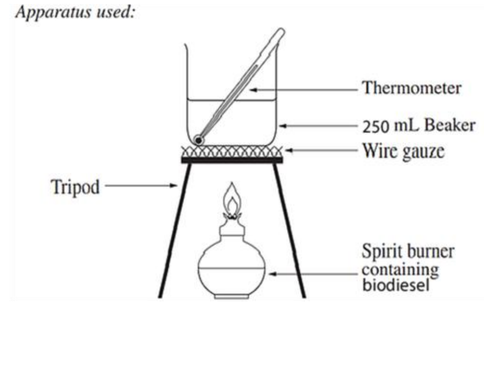
d. Consider the picture shown in fig. 3. It shows two layers forming as the biodiesel synthesised from vegetable oil is allowed to settle overnight. Identify two substances present in the lower layer after settling.

KOH and glycerol unreacted methanol can also be accepted. *2 marks*

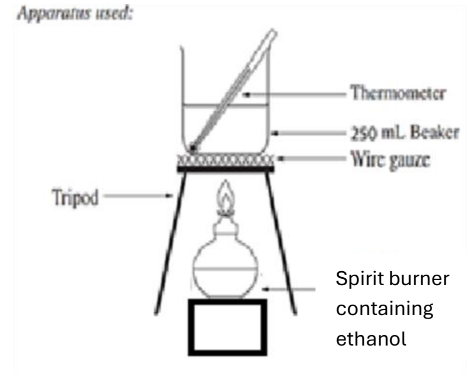
2. Consider the experiments i. and ii.

a. Explain the difference between the biodiesel and the ethanol fuels used, that determines why the energy content of biodiesel is measured in kJ/g but ethanol can be measured in both kJ/g and kJ/mol?

Biodiesel is a mixture of methyl esters *1-----mark*
As such it can not be given as energy per mol as it has no molecular formula.
1-----mark
Ethanol is pure substance whose molar mass is known *1-----mark*



Experiment i- the burning of biofuel



Experiment ii - the burning of ethanol

Figure 4. The two setups for biodiesel and ethanol in the determination of energy content of each fuel.

b. During the determination of the energy content of each fuel it was noticed that the wick of the spirit burner was placed in different positions for the biodiesel and for the ethanol, as shown in fig. 4, above.
Which experiment produced more valid results as a result of the change shown in Fig. 4? Explain your answer.
Experiment ii 1-----mark
The flame is closer to the beaker and less heat is lost through convection currents. This allows more energy to be absorbed by the water and hence is closer to the real amount of energy given off by the combustion reaction 1-----mark.

c. A student knowingly used 200 mL of water and factored this in to the calculations when working out the energy given off by the biodiesel instead of 250 mL, as shown in figure 4. Explain how this error would affect the calculated energy content (increase, decrease, or no change) and why.

No change 1-----mark

The lower mass of water is offset by the greater temperature the smaller volume of water will reach. 1-----mark

3. In both experiments i and ii, shown in question 2, above, the temperature of the water was measured over a ten minute time interval. The water was heated for 5 minutes and then allowed to cool for 5 minutes. The following results were achieved for each experiment.
In both experiments the original temperature of the water was 19.0 °C.

Time (min)	0 (°C)	1 (°C)	2 (°C)	3 (°C)	4 (°C)	5 (°C)	6 (°C)	7 (°C)	8 (°C)	9 (°C)	10 (°C)
Biodiesel	19.0	22.0	28.5	34.0	42.0	52.5	53.0	52.0	51.0	50.0	49.0
Ethanol	19.0	23.5	31.0	40.5	55.0	68.0	70.0	69.0	68.0	67.0	66.5

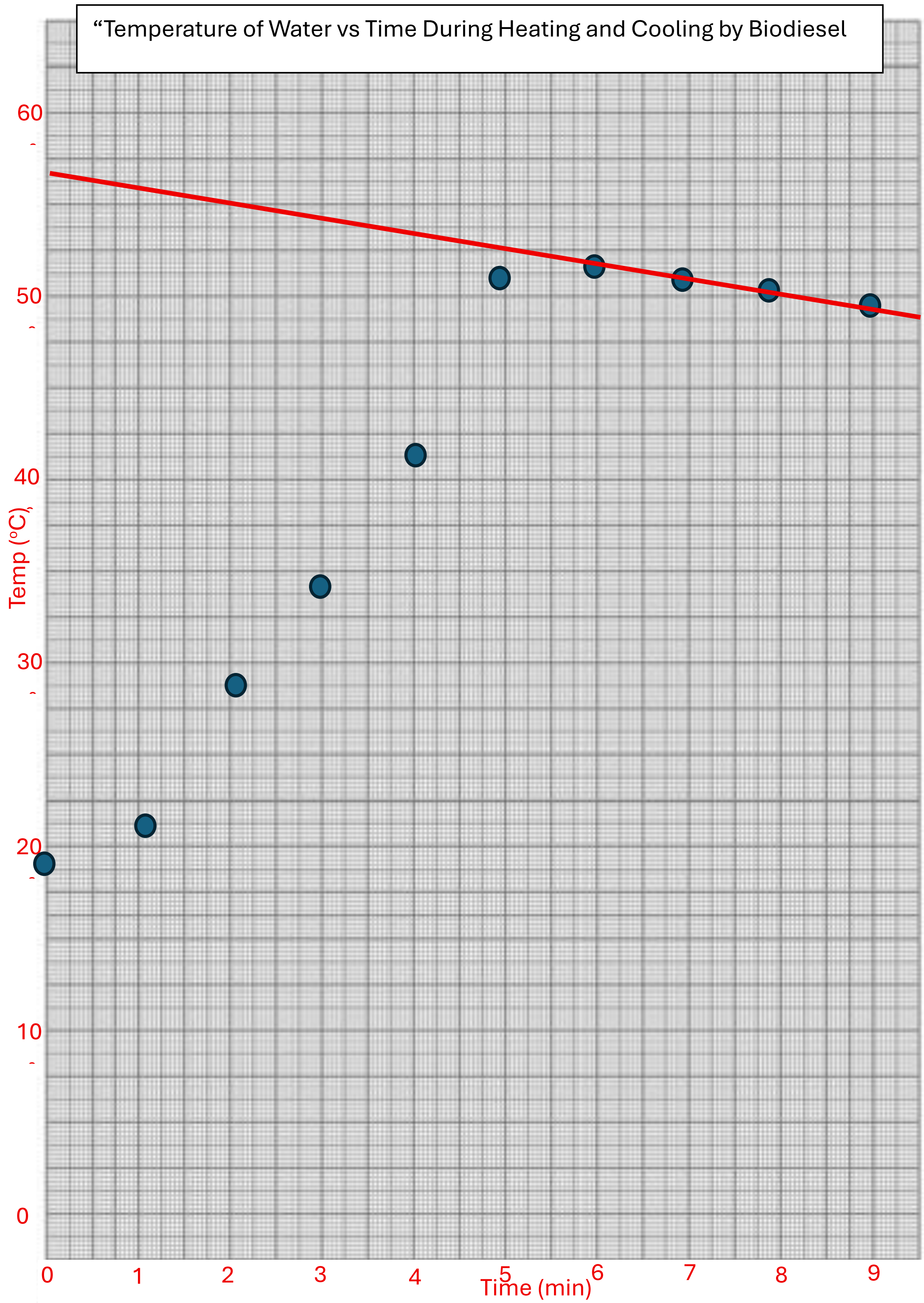
a. Use the graph paper provided, over the page, to plot a properly formatted graph of temperature vs time for the ***biodiesel*** only.
1 ----- mark for Heading (both IV and DV should be mentioned)
1----- mark for properly labelled and numbered Y axis
1 -----mark for properly labelled and numbered X axis
1----- mark for correct plotting of dtat
1-----mar correct line of best fit

b. Using your graph and an extrapolation method, determine the change in temperature (ΔT) of the water heated by the biodiesel. Clearly show on the graph how the ΔT was obtained. *2 marks*
1-----mark for correct extrapolation
1-----mark for correct ΔT approximately 38 °C

c. Given the mass loss of biodiesel in the spirit burner was recorded at 1.582 g, using a digital balance, calculate the energy content of biodiesel in kJ/kg. *3 marks*

Energy absorbed by the water = 4.18 X 250 X 38 = 39.7 Kj 1-----mark
limited by graph reading to 2 sig figs
1-----mark for correct value
1-----mark for correct units
Energy(kJ) per kg = 39.7 / 0.001582 = 2.5 X 10^4 kJ/kg 1-----mark

d. What two assumptions are made when calculating the energy output of both biodiesel and ethanol.
-All energy released is absorbed by the water 1-----mark
- fuel is pure 1-----mark


"Temperature of Water vs Time During Heating and Cooling by Biodiesel
Temp (ºC)
60
50
40
30
20
10
0
Time (min)
0
1
2
3
4
5
6
7
8
9

4. Consider the combustion of ethanol in experiment ii.
   a. Give the balanced **thermochemical** equation for the complete combustion of ethanol at SLC.
   Use theoretical values from the 2026 Data Book *3 marks*
   $C_2H_6O(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ $\Delta H = -1370$ kJ/mol or kJ
   1----- mark balanced eqn
   1-----mark correct states
   1-----mark correct ΔH (both in magnitude and sign and units)
   b. 0.460 grams of ethanol undergoes complete combustion at SLC. If all the energy released is absorbed by 80.0 g of water at 19 ^{0}C calculate the final temperature of the water. *3 marks*

   Find mol of ethanol = 0.460 /46.0 = 0.0100 mol
   Find the amount of energy released = 0.01000 X 1370 =13.70 kJ
   1-----mark
   Find the ΔT
   13700 (J) = 4.18 X 80.0 X ΔT
   ΔT = 41.0
   1-----mark

   Final temp
   19 + 41 = 60^{o}C (2 sig figs) 1-----mark correct value and sig figs
   Consequential marks were given

   c. Biodiesel and Bioethanol are often described as environmentally friendly, renewable and sustainable fuels.
      i. Using item 24 on page 24 of the 2026 data book, give one relevant United Nations Sustainability Development Goal that is achieved when using these fuels.
      Any one of the following
      Goal 7 – affordable and clean energy (justify clean energy)
      Goal 11 – sustainable cities and communities (justify sustainable)
      Goal 12-resposnible consumption and production(students must relate this to responsible production of the biomass to produce these fuels)
      Goal 13-climate action(justify hi the energy is clean or relative cleaner than fossil fuels)
      ii. Justify your answer to question i above.

A justification that shows that the biofuel is sustainable eq does not compete with food cropps and is renewable
1-----mark for renewable
1----mark for sustainable

iii. Using the thermochemical equation given as the answer to question 4a. above, as well as two other balanced chemical equations, justify ethanol being labelled as having minimal impact on climate change.

Students need to show net zero CO_2 output via the three equations
$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$ *-Photosynthesis*
1-----mark (photosynthesis correct equation states not necessary

$C_6H_{12}O_6(aq) \rightarrow 2C_2H_6O(l) + 2CO_2(g)$ *anaerobic fermentation*
1-----mark anaerobic fermentation state not necessary

$C_2H_6O(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ *combustion*

1-----mark for relating $6CO_2$ molecules consumed from the atmosphere via photosynthesis whilest 6 CO_2 molecules are put back, 4 via combustion of two mol of ethanol and 2 during the production of ethanol via fermentation. Students will gain the mark via a schematic as long as they show an understanding of the net 0 CO_2 impact.

d. The terms sustainable and renewable are often used incorrectly when it comes to biofuels.

i. Give a definition for each.

Renewable ______________________________

A biofuel is renewable if the biological source material (such as crops or plant biomass) can be replenished naturally within a relatively short time frame so that it never runs out.

Sustainable ______________________________

A biofuel is sustainable if it can be produced and used in a way that does not negatively impact future generations.

ii. Under what conditions are biofuels such as bioethanol and biodiesel renewable but not sustainable? Give one example

When they can be produced in a relatively small time frame but their production or use impacts future generations 1-----mark

Eg Bioethanol is renewable but its manufacture from corn starch or sugar can compete with fertile land that can be used for food crops 1-----mark.

5. Both experiments ii and iii used energy to heat a given volume of water.
   a. A diagram of experiment iii is shown in fig. 5 below. A student conducted experiment iii filling the solution calorimeter with 100 grams of distilled water.

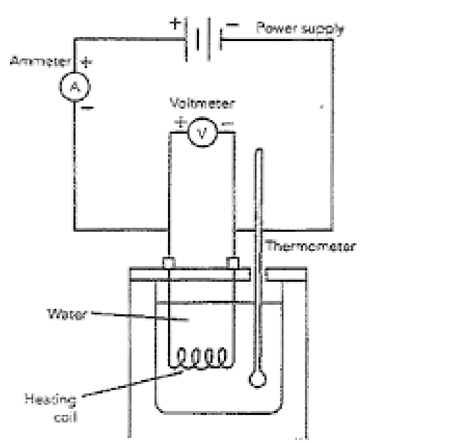


Figure 5. Electrical calibration of a solution calorimeter

A current of 2.750 amps at 6.00 volts was applied for 300 seconds to raise the temperature of the water by 2.88 °C.

i. Calculate the calibration factor (CF) of the calorimeter in kJ/°C.

Energy = Vit = 6.00 X 2.750 X 300 = 4950 J 1-----mark

CF = 4.95 / 2.88 = 1.72 kJ/°C 1 ----mark

ii. What is the energy efficiency of the calorimeter?

Efficiency = useful energy / total energy supplied X 100

=> useful energy = 4.18 X 100 X 2.88 = 1.203 kJ 1----- mark

%efficiency = (1.203 / 4.95) X 100 = 24.3% 1-----mark

b. The same calorimeter (with a known calorimeter constant, CF) was used by two students, Jack and Jill, to determine the enthalpy change (ΔH) of the neutralisation reaction shown below.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

A temperature change (ΔT) of 2.30 °C was recorded.
Jack calculated the energy change using q = 4.18 X mass(g) X ΔT
Jill calculated the energy change using q = CF X ΔT
Discuss which student's calculation would have the greatest validity and justify your answer.

Jack's calculations assume that all the energy released by the neutralization reaction is absorbed by the water. *1-----mark*

Jill's results are calculated using the calibration factor which takes into account the energy absorption of all parts of the calorimeter and also the energy that escapes into the environment. *1-----mark*
Jills results have greater validity

c. Describe a method by which a solution calorimeter can be calibrated without the use of electrical energy.

Energy can be delivered to the calorimeter via an exothermic reaction with a known ΔH. *1-----mark*

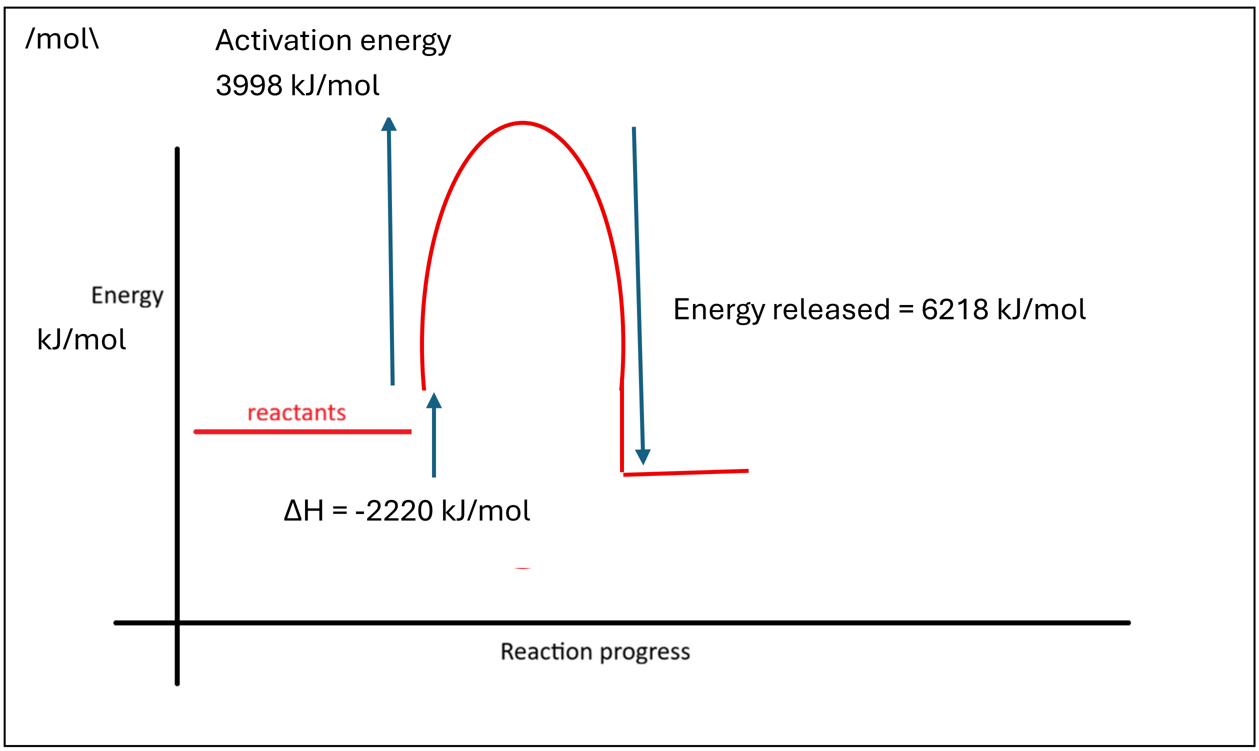
6. Consider the complete combustion of propane gas at SLC, shown below.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

Combustion of one mol of propane releases 2220 kJ of heat energy. Given that 3998 kJ/mol is required for bond breaking, draw an energy profile diagram for the combustion of propane in the space provided below.

Clearly label and give the magnitude of the:

- Activation energy *1 mark*
- Energy released during bond formation *1 mark*
- ΔH *1 mark*



7. The food label shown below is displayed on the packaging of a health bar.

Nutrition Information
Serving Size: 100 g

Nutrient	**Amount per 100**
Protein	8 g
Total Fat	12 g
– Saturated Fat	3 g
Carbohydrates	20 g
– Sugars	5 g
Dietary Fibre	4 g
Sodium	150 mg

Figure 6. Food label

a. Using item 11 page 12 of the 2026 Data Book, calculate the total energy, in kJ, available to the consumer if 50 grams of the health bar was consumed. *2 marks*

Protein 4g X 17 kJ/g = 68 kJ

Fat 6g X 37 = 222 kJ

Carbohydrates 8g X 16 = 128 kJ *Dietary fibre cannot be digested*

1----- mark

Total = 418 kJ *1-----mark*

b. A bomb calorimeter filled with 2.50×10^3 grams of water at 20.0 °C was used to burn 50 grams of the same health bar. The temperature of the water reached 66.0 °C.

i. Using the specific heat capacity of water, calculate the amount of energy absorbed by the water in the bomb calorimeter and compare it to the value calculated in question a. above. *2 marks*

Energy = 4.18 X 2500g X 46°C = 481 kJ *1-----mark*

It is greater than the energy available to a person consuming the bar. *1-----mark*

ii. Give a clear explanation for the discrepancy.

A bomb calorimeter burns the indigestible cellulose (fibre) hence it will release energy. A consumer, however cannot digest the cellulose to access the energy.

End of assessment.