Revision for SAC 1 Experimental comparisons and fuels.

Show all working out in the space provided

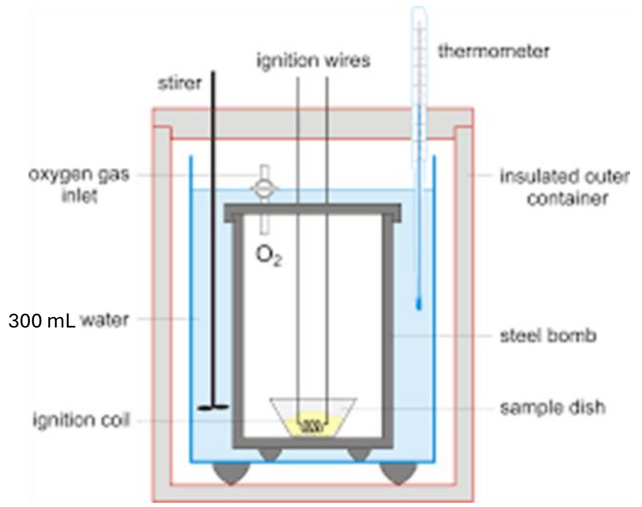

Figure 1 – bomb calorimeter

Apparatus used:

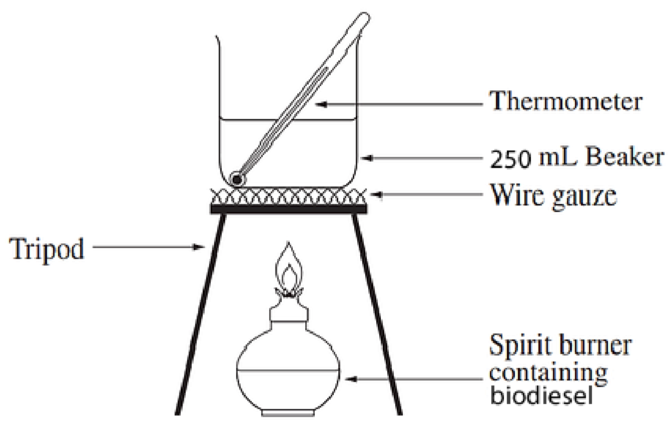

Figure 2 – experimental setup for the energy content of biodiesel

1. The energy content of a **pure** sample of biodiesel was investigated using two different methods as shown in fig. 1 and fig. 2, above.

a. The bomb calorimeter was calibrated via chemical means using the combustion of 1.600 grams of methanol as measured by an electronic balance. The temperature of the water increased from 19.0 °C to 46.0 °C.

i. Write a balanced thermochemical equation for the complete combustion of methanol at SLC.

$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$ $\Delta H = -1452$ kJ mol^{-1} or kJ

1-----mark balanced

1-----mark correct states

1-----mark correct enthalpy included and sign

ii. Calculate the amount of energy delivered by the combustion of 1.600 grams of methanol. *2 marks*

Mol of methanol = 1.600 / 32.0 = 0.0500 mol 1-----mark

=> 1452/2 = energy / 0.0500

=> 36.3 kJ 1----mark correct answer with an energy unit.

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

2 marks

CF = energy / ΔT 1-----mark correct formula

=> 36.3kJ/27.0 °C = 1.34 kJ°C^{-} 1-----mark correct value

b. Accurately calculate the energy content, in kJ/g, if the 2.534 grams of biodiesel, combusted in the bomb calorimeter, if the temperature of the water increased by 65 .0 °C *2 marks*

1.34 X 65.0 = 87.1 kJ 1-----mark

87.1 kJ / 2.534 = 34.4 kJ/g 1-----mark

c. Compare the energy content of the biodiesel, calculated in question b. above with the literature value in your 2026 Data Book. Give a clear explanation of a possible error by the operators of the bomb calorimeter that would account for the discrepancy.

Literature biodiesel is 37kJ/g
This is slightly lower than the literature value *1-----mark*

Possible
- impurities that may have reduced the available energy released.
- incomplete combustion, which would lower the energy output and hence the ΔT

- the volume of water may have being a factor. Less water was used than 300 mL in the calorimeter giving a higher ΔT which leads to a lower CF
1-----mark awarded only if the explanation clarifies how the ΔT and CF are impacted by the error.

e. Figure 2. Shows the setup used to calculate the energy content of the biodiesel in the classroom. Heating took place for 2 minutes after which the temperature was immediately recorded. This time 1.534 grams of the biodiesel was combusted using a spirit burner to increase the temperature of 200 grams of water by 75.0 °C.

i. Calculate the energy content of the biodiesel in kJ/g *2 marks*

$q = 200 \times 4.18 \times 75.0$ *1-----mark correct formula*
$= 62\ 700\ J$
$= 62.7\ kJ$ */1.534 = 40.9 kJ/g* *1-----mark correct answer*

ii. Comment on the accuracy of your answer to question i, above and give a detailed explanation as to what may have caused the discrepancy. *2 marks*

Low accuracy. *1-----mark*
1-----mark for any error that would lead to a higher value and an explanation as to how .
eg Thermometer was placed over the flame and heat had little time to dissipate. Thus recording a higher value than what would have been recorded had the water been stirred to evenly spread the heat throughout the water.

iii. What is assumed when calculating the energy content of biodiesel using the apparatus in fig 2?

All energy released is absorbed by the water. 1-----mark

iv. Which method fig 1 or fig 2 provides results with the greatest validity? Give a clear and detailed explanation.

The bomb calorimeter will produce results with a greater validity 1-----mark

Not only is it well insulated preventing heat loss to the environment 1-----mark
but also uses a calibration factor which takes into account the energy absorbed by the calorimeter and its many parts as well as energy that is lost to the environment. 1-----mark

2. Consider the food label in fig. 3 below.

MAGICAL MANGO - ORIGINAL

NUTRITION INFORMATION
Servings per package: 1
Serving size: 610 mL

	Avg Quantity per Serving
Protein	6.9g
Fat, total	4.4g
- saturated	3.0g
Carbohydrate	91.9g
- sugars	81.2g
Sodium	154mg

Figure 3 Food label for a fruit drink

Given that the density of a fruit juice is 1.035 g/mL answer the following questions.

a. What is the mass in grams of an average serve? *2 marks*

mass = density X volume 1-----mark

1.035 X 610 = 631g 1-----mark

b. What is the energy content of an average serve of fruit juice, available to the consumer, if an average serve contains 8 grams of fibre?

3 marks

Protein = 17 X 6.9 = 117.3

Fats = 37 X 4.4 =162.8

Carbohydrate = 16 X (91.9 – 8) = 1342.4

Total = 1623 kJ

1-----mark for correct calculation of each food group

1-----mark for correct total

1-----mark for taking into account fibre.

3. The same bomb calorimeter, as shown in fig. 1 above, was used to find the ΔH for the complete combustion of ethene (C_2H_4) in atmospheric oxygen (O_2)

A pure sample of 0.560 grams of ethene was placed in the bomb calorimeter and bunt at SLC. The temperature of the water increased by 21.1 °C.

a. Calculate the energy released in this combustion reaction in kJ

2 marks

$Energy = 1.34 \times 21.1$ 1-----mrak

$Energy = 28.3\ kJ$ *1-----mark*

b. Calculate the molar heat of combustion of ethene. *2 marks*

mol of ethene = 0.560 /28.0 = 0.0200

28.3 kJ / 0.0200 =

$\Delta H = -1415\ kJ\ mol^{-1}$

Molar heat of combustion = $-1.42 \times 10^{3}\ kJ\ mol^{-1}$

c. Write a balanced thermochemical equation for the combustion of ethene in pure oxygen gas at SLC.

$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)\ \Delta H = -1.42 \times 10^{3}\ kJ\ mol^{-1}$

1-----mark balanced

1-----mark states

1-----mark correct ΔH with sign

d. A camping stove burns 56.00 grams of ethene to boil 3.00 L of water originally at 5.00 °C. Calculate the energy efficiency of the stove.

Step 1 Find the total energy released

Molar mass of C_2H_4 = 28.0 g mol^{-1}

$$n = \frac{56.00}{28.0} = 2.00\ mol$$

Molar heat of combustion = 1.42 X 10^3 kJ mol$^-$

Total energy released:

$2.00 \times 1415 = 2830\ kJ$ *1-----mark*

Find the energy absorbed by the water (useful energy)

Volume of water = 3.00 L

Mass = 3000 g

Specific heat capacity of water:

$$c = 4.18\ J\ g^{-1}{}^{\circ}C^{-1}$$

Temperature change $\Delta T = 100 - 5 = 95^{\circ}C$

$$q = mc\Delta T$$
$$q = 3000 \times 4.18 \times 95$$
$$q = 1.19 \times 10^6\ J$$
$$= 1191\ kJ$$

1----mark correct amount of energy absorbed by water

Efficiency

$$= \frac{1191}{2830} \times 100$$
$$= 42.1\%$$

1-----mark correct formula

1------mark correct answer

4. Gaseous butane reacts with atmospheric oxygen in a complete combustion reaction at SLC according to the reaction below.

$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$ ΔH = -5760 kJ/mol or kJ

4.80 litres of butane is mixed with 40.00 litres of oxygen gas and ignited.

a. After the reaction is complete, which reactant is in excess and by how much, in mol. *4 marks*

$n(C_4H_{10})$ = 4.80 / 24.8 = 0.194 mol
$n(O_2)$ = 40.00 / 24.8 = 1.61 mol 1----mark

Find the limiting (divide mol by coefficient in the balanced equation)
C_4H_{10} = 0.194 / 2 = 0.097
O_2 = 1.61 / 13 = 0.12 1----mark oxygen is in excess
Calculate the amount of oxygen needed for 0.194 mol of butane
0.194 X 13/2 = 1.26 mol reacted 1-----mark
hence
1.61 – 1.26 = 0.35 mol of O_2 remains. 1-----mark

b. What is the total volume of gas remaining after the reaction is complete? *3 marks*

$Step\ 1 - n(CO_2\ formed) = 0.194 \times 8/2 = 0.776\ mol$ *1-----mark*

Step 2 - $V = n \times 24.8$
volume of CO_2 $= 0.776 \times 24.8 = 19.2\ L\ CO_2$ *1-----mark*

Step 3 Add the volume of the excess O_2:

$0.35\ mol \times 24.8 = 8.68\ L\ O_2$ *1-----mark*
$V_{total} = 19.2 + 8.68 = 27.9\ L$

c. Calculate the amount of energy, in kJ, given out by the reaction as heat. *2 marks*

Step 1: ΔH per mole of butane

$\Delta H = \frac{5760}{2} = 2880\ kJ\ mol^{-1}$ 1-----mark

Step 2: Energy for 0.194 mol butane = 0.194 X 2880 = 558 kJ 1-----mark