Q1.

This question is about silver nitrate.

(a) Define standard enthalpy of formation.

_____

_____

_____

_____

(2)

(b) Silver nitrate(V) is formed when silver nitrate(III) undergoes thermal decomposition.

$2\ AgNO_2(s) \longrightarrow Ag(s) + AgNO_3(s) + NO(g) \qquad \Delta H = +56.2\ kJ\ mol^{-1}$

The standard enthalpy of formation of $AgNO_3(s)$ is $-123.0\ kJ\ mol^{-1}$

The standard enthalpy of formation of $NO(g)$ is $+90.4\ kJ\ mol^{-1}$

Determine the standard enthalpy of formation of $AgNO_2(s)$

Standard enthalpy of formation _____ $kJ\ mol^{-1}$

(2)

(c) Suggest why the enthalpy change for the thermal decomposition of solid silver nitrate(III) is difficult to determine experimentally.

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_____

(1)

Silver nitrate(V) solution reacts with solid sodium chloride.

$$AgNO_3(aq) + NaCl(s) \longrightarrow AgCl(s) + NaNO_3(aq)$$

A student does an experiment to determine the enthalpy change for this reaction. The student follows this method:

1. Measure out 50 cm^3 of 0.10 mol dm^{-3} aqueous silver nitrate(V) using a clean, dry measuring cylinder.
2. Pour the silver nitrate(V) solution into a glass beaker.
3. Weigh out 2.00 g of solid sodium chloride (an excess) using a weighing boat and tip the solid into the silver nitrate(V) solution. Reweigh the weighing boat to determine the mass of sodium chloride added.
4. Add a lid to the beaker that has two small holes for a stirring rod and for a thermometer.
5. Stir the mixture with a plastic stirring rod whilst recording the temperature with a thermometer.
6. Record the maximum temperature reached.

(d) Identify **three** aspects of this method which could cause inaccurate results.

Describe how the student could improve these three aspects of the method to obtain more accurate results.

Inaccuracy 1 _____

Improvement 1 _____

_____

Inaccuracy 2 _____

Improvement 2 _____

_____

Inaccuracy 3 _____

Improvement 3 _____

_____

(6)

(Total 11 marks)

Q2.

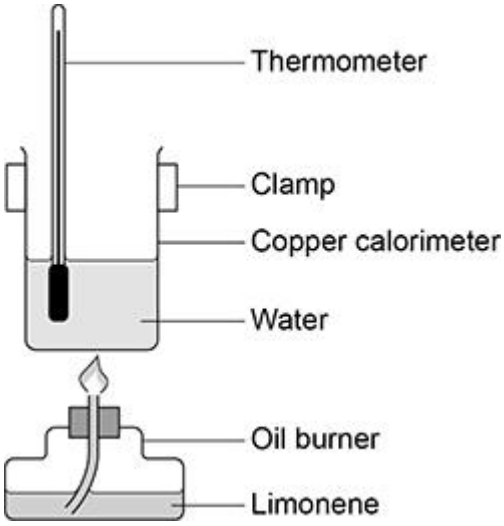
This question is about enthalpy of combustion.

(a) Limonene is found in the skin of citrus fruits.

The figure below shows a diagram of the apparatus used in an experiment to determine a value for the enthalpy of combustion of limonene.

When 1.31 g of limonene are burned, the temperature of the 60.0 g of water in the copper calorimeter increases by 52.1 °C

The specific heat capacity of water is 4.18 J K^{-1} g^{-1}



Calculate a value for the enthalpy of combustion, in kJ mol^{-1}, of limonene ($C_{10}H_{16}$).

Enthalpy of combustion _____ kJ mol^{-1}

(4)

(b) The table below shows values, obtained by different methods, for the enthalpy of combustion of a different liquid hydrocarbon.

	Method	Enthalpy of combustion / kJ mol^{-1}
1	Standard enthalpy of combustion $\Delta_c H^{\theta}298$	–4194
2	Value calculated from a calorimetry experiment	–1100
3	Value calculated using mean bond enthalpies	–3159

Suggest reasons for the differences between the values obtained by each of Methods **2** and **3**, and the value obtained by Method **1** in the table above.

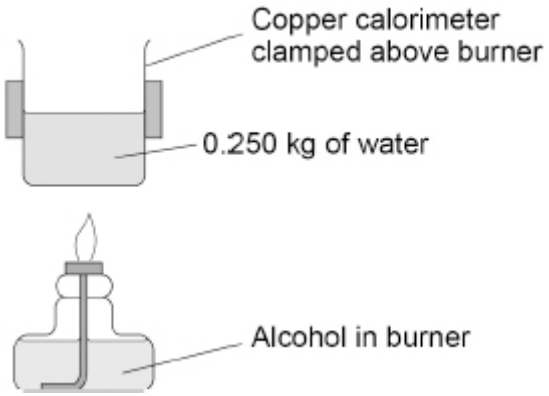
(5)

(Total 9 marks)

Q3.

A student is provided with a 0.0300 mol sample of an alcohol.
The student decides to identify the alcohol using an experiment to determine its enthalpy of combustion.

The figure below shows the apparatus used.



(a) The student finds that when all the alcohol is burned, the temperature of the water increases from 18.9 °C to 78.1 °C

Calculate the enthalpy of combustion, in kJ mol^{-1}, for the alcohol.
The specific heat capacity of water, c = 4.18 J g^{-1} K^{-1}

Enthalpy of combustion _____ kJ mol^{-1}

(3)

(b) **Table 1** shows the enthalpies of combustion of some alcohols.

Table 1

Alcohol	**Enthalpy of combustion / kJ mol^{-1}**
Ethanol	–1367
Propan-1-ol	–2021
Butan-1-ol	–2676

Explain how your answer to part (a) suggests that the alcohol is butan-1-ol.

(If you have been unable to obtain an answer for part (a), assume that the answer is –2120 kJ mol^{-1})

_____

_____

_____

_____

_____

_____

(2)

(c) The equation for the complete combustion of gaseous pentan-1-ol is shown.

$$CH_3(CH_2)_3CH_2OH(g) + 7\tfrac{1}{2}O_2(g) \rightarrow 5\ CO_2(g) + 6\ H_2O(g) \qquad \Delta H = -3388\ kJ\ mol^{-1}$$

Table 2 shows some bond enthalpy data.

Table 2

	C–H	C–O	O–H	C=O	O=O
Bond enthalpy / kJ mol^{-1}	412	360	463	805	496

Use data from **Table 2** to calculate a value for the mean C–C bond enthalpy in pentan-1-ol.

C–C bond enthalpy _____ kJ mol^{-1}

(3)

(d) The energy stored in fuels can be compared using energy density values measured in kJ dm^{-3}

Calculate the energy density of butan-1-ol.

enthalpy of combustion of butan-1-ol = –2676 kJ mol^{-1}
density of butan-1-ol = 0.810 kg dm^{-3}
relative molecular mass (M_r) of butan-1-ol = 74.0

Energy density _____ kJ dm^{-3}

(2)

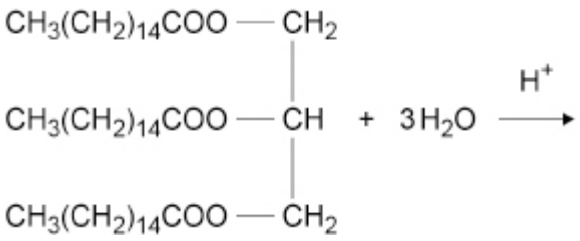
(Total 10 marks)

Q4.

This question is about biofuels.

Palmitic acid, $CH_3(CH_2)_{14}COOH$, can be made by hydrolysis of the triester in palm oil under acidic conditions.
Palmitic acid can be used as a biofuel.

(a) Complete the equation for the hydrolysis of the triester in palm oil under acidic conditions.



(2)

(b) Palmitic acid burns in air.

In a calorimetry experiment, combustion of 387 mg of palmitic acid increases the temperature of 0.150 kg of water from 23.9 °C to 37.5 °C

Calculate a value, in kJ mol^{-1}, for the enthalpy of combustion of palmitic acid in this experiment.
Give your answer to the appropriate number of significant figures.

The specific heat capacity of water is 4.18 J K^{-1} g^{-1}

Enthalpy of combustion _____ kJ mol^{-1}

(5)

(c) State how the value calculated in part (b) is likely to differ from data book values.

Give one reason, other than heat loss, for this difference.

Difference _____

Reason _____

_____

(2)

(d) A sample of a different biofuel, made from sewage sludge, is found to contain 37.08% carbon, 5.15% hydrogen and 24.72% oxygen by mass. The rest of the sample is sulfur.

Calculate the empirical formula of this biofuel.

Empirical formula _____

(3)

(e) Complete combustion of the biofuel made from sewage sludge produces the greenhouse gas carbon dioxide.

Suggest **one** other possible environmental problem with the complete combustion of this biofuel.

State the formula of the pollutant responsible for this problem.

Environmental problem _____

_____

Formula _____

(2)

(f) Ethanol is a biofuel that can be produced by the fermentation of glucose.

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

Glucose has the structural formula shown.

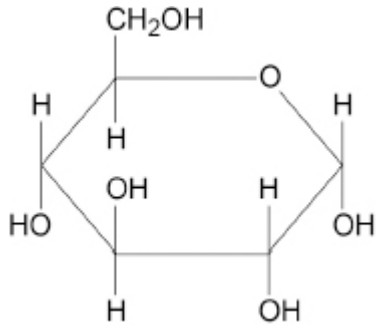


Table 1 shows some mean bond enthalpy values.

Table 1

	C–H	**C–C**	**C–O**	**C=O**	**O–H**
Mean bond enthalpy / kJ mol^{-1}	412	348	360	805	463

Use the equation and the data in **Table 1** to calculate an approximate value of ΔH for the fermentation of glucose. For this calculation you should assume that all the substances are in the gaseous state.

ΔH _____ kJ mol^{-1}

(3)

(g) The carbon dioxide produced from fermentation can be reacted with steam to make more ethanol.

The equation for this reaction is

$$2\ CO_2(g) + 3\ H_2O(g) \rightarrow C_2H_5OH(g) + 3\ O_2(g)$$

Table 2 shows some standard enthalpies of formation.

Table 2

	$CO_2(g)$	**$O_2(g)$**	**$C_2H_5OH(g)$**	**$H_2O(g)$**
$\Delta f H^{\ominus}$ / kJ mol^{-1}	–394	0	–235	–242

Use the data in **Table 2** to calculate a standard enthalpy change value for this reaction.

Standard enthalpy change _____ kJ mol^{-1}

(2)

(Total 19 marks)