CONTOUREDUCATION

Website: contoureducation.com.au | Phone: 1800 888 300
Email: hello@contoureducation.com.au

VCE Chemistry ¾
AOS 1 Revision I [1.11]
Contour Check Solutions

Contour Checklist

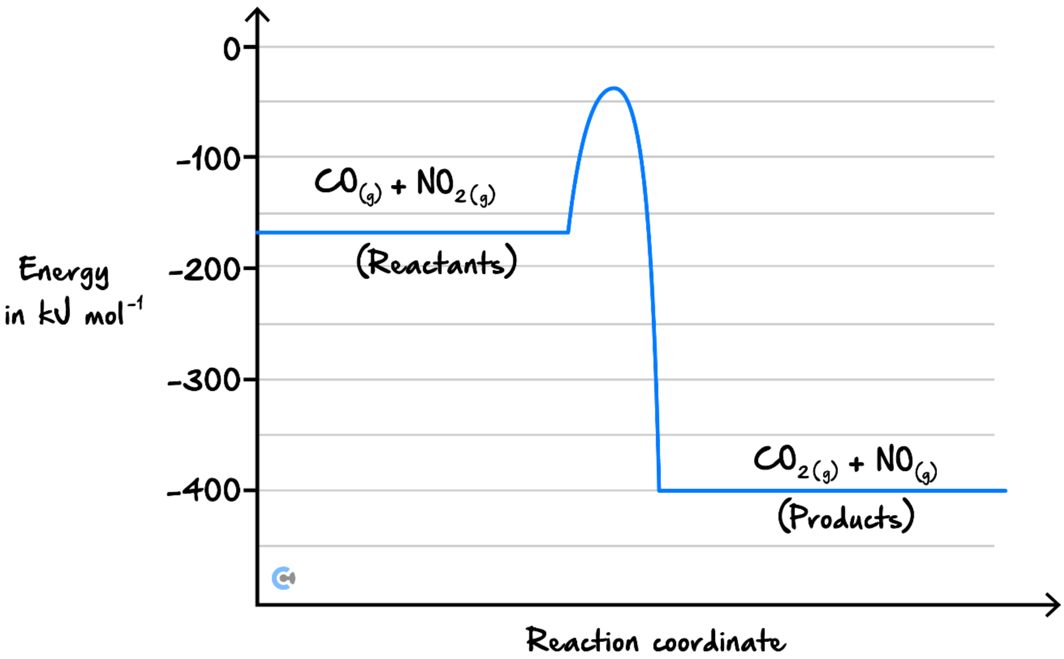
Section A: [1.1] - Thermochemistry (Checkpoints) (44 Marks)

Sub-Section: [1.1.1] Identify ΔH and E_a in Endothermic/Exothermic Energy Profile Diagrams

Question 1 (3 marks)

Consider the following energy profile diagram.

A student observes the following energy profile diagram below.



a. State whether the reaction is endothermic or exothermic. (1 mark)

Exothermic

b. State the activation energy (kJ) required for the reaction to occur. (1 mark)

$(170 - 40) = 130\ kJ\ mol^{-1}$

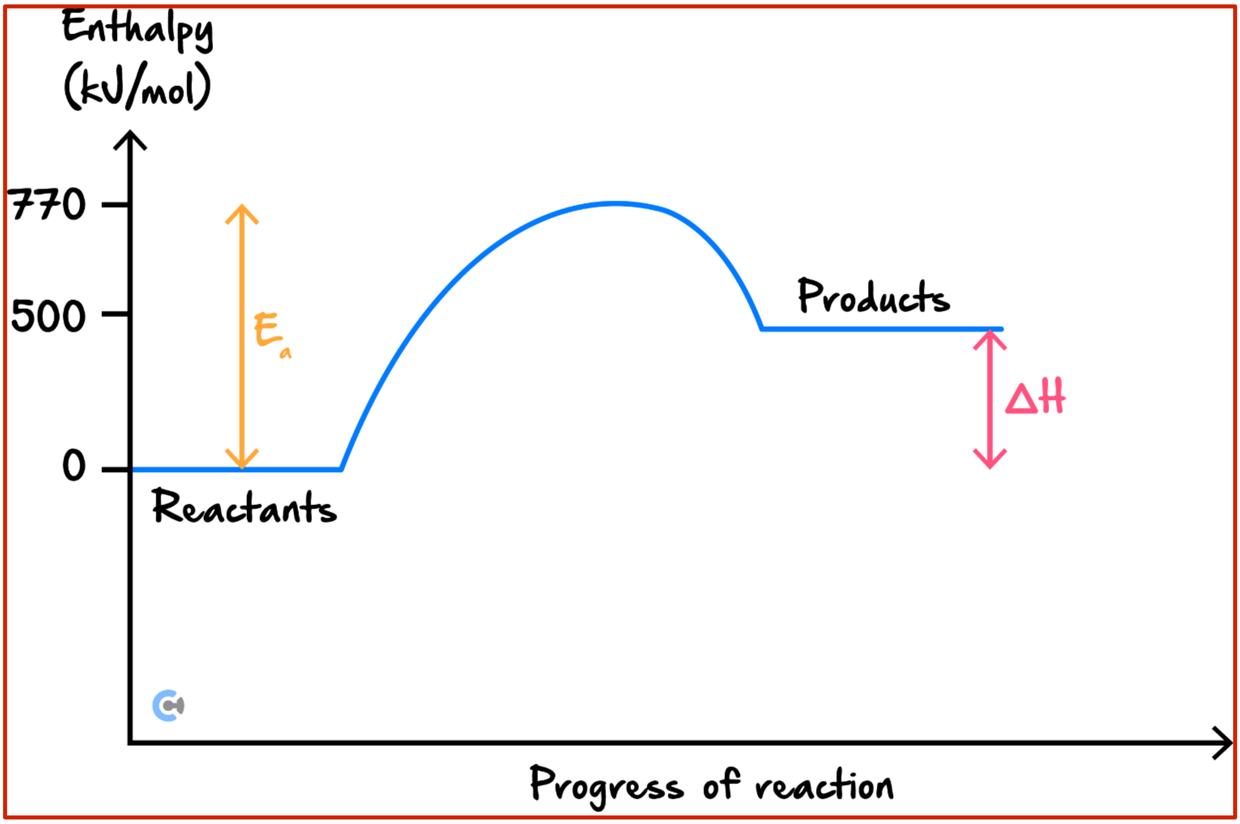
c. Calculate the ΔH value for this reaction. (1 mark)

$-230\ kJ\ mol^{-1}$

Question 2 (6 marks)

An upcoming scientist is exploring a new reaction. She notices that the energy required to break the bonds in the reactants and form the product is equal to $770\ kJ\ mol^{-1}$. Secondly, she finds that the amount of energy absorbed has a magnitude of $500\ kJ\ mol^{-1}$. Additionally, she notices the temperature of the test tube drops when this reaction occurs.

a. Draw an energy diagram showing the enthalpy of reactants and products. (2 marks)



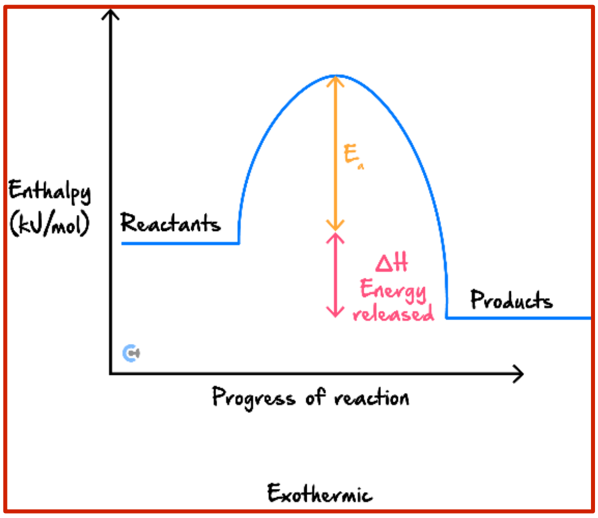
b. Label the activation energy and change in enthalpy on the energy diagram drawn in **part b.i.** (1 mark)

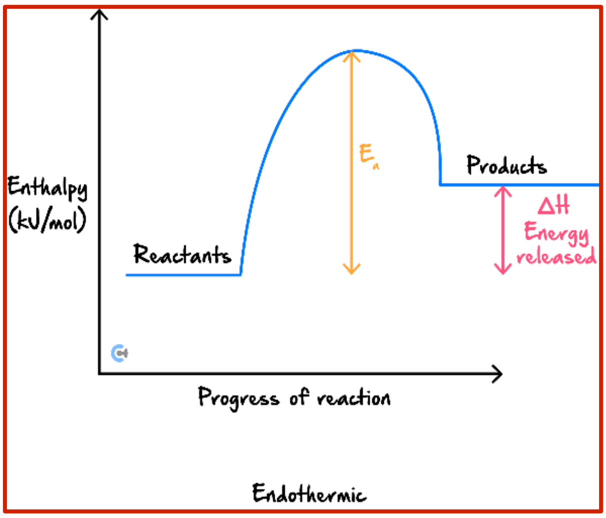
c. State whether the reaction is exothermic or endothermic. (1 mark)

Endothermic

d. Alex claims that an exothermic reaction will always have an activation energy that is always bigger in magnitude than the ΔH value, whereas James says this is only true for endothermic reactions. Determine who is correct. (**Hint**: Draw both out.) (2 marks)

James is correct.





Space for Personal Notes

Question 3 (4 marks)

Kevin bruises his leg playing soccer and uses an instant ice pack to help with the inflammation. He is told that when you activate the ice pack (by snapping it), it activates a chemical reaction. The ice pack is ready to use within 30-60 seconds.

a. State the type of chemical reaction (endothermic or exothermic) occurring when the ice pack is snapped. (1 mark)

Endothermic

b. Kevin is told that the following chemical reaction is occurring in the icepack:

$$NH_4NO_3(s) + H_2O(l) \rightarrow NH_4^+(aq) + NO_3^-(aq)$$

He is told that the ΔH value is 25.7 kJ/mol, but cannot remember if the value should be positive or negative.

State whether the value should be positive or negative. (1 mark)

Positive

c. Explain the purpose of snapping the ice pack. (2 marks)

Provides kinetic energy which causes the particles inside the icepack to vibrate (1). This acts as an activation energy, allowing for the reaction to start (2).

Space for Personal Notes

Sub-Section: [1.1.2] Identify Differences Between Complete and Incomplete Combustion & Write their Thermochemical Combustion Equations

Question 4 (2 marks)

Consider the following substances which have been combusted.

Write balanced thermochemical chemical equations for the following reactions:

a. The complete combustion of methane gas (CH_4). (1 mark)

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \quad \Delta H = -890\ kJ/mol$$

b. The incomplete combustion of hexane liquid (C_6H_{14}), forming carbon byproduct, where $2220\ kJ\ mol^{-1}$ of energy is released. (1 mark)

$$2C_6H_{14}(l) + 7O_2(g) \rightarrow 12C(s) + 14H_2O(g) \quad \Delta H = -2200\ kJ/mol$$

Space for Personal Notes

Question 5 (4 marks)

An experiment is conducted where methanol is combusted in a low-oxygen environment.

a. State the type of reaction that will occur.

Incomplete combustion

b. Write a balanced chemical equation for the reaction occurring, given that no carbon monoxide is detected in the experiment. (1 mark)

$$2CH_3OH(l) + O_2(g) \rightarrow 2C(s) + 4H_2O(g)$$

c. James explains that incomplete combustion is more efficient than complete combustion, as less energy is required to obtain products. Evaluate this statement. (3 marks)

James is incorrect (1).

For the same amount of energy input, in an incomplete reaction as oxygen is the limiting reagent, all of the fuel cannot be combusted, meaning its stored chemical energy cannot be released, where in a complete combustion the fuel is completely combusted (2).

Hence, complete combustion is more efficient (3).

Space for Personal Notes

Question 6 (3 marks)

An experiment was conducted where $C_{20}H_{40}O_2$ was combusted, where the fuel was the excess reagent.

Following the combustion, the experimenter noticed a thick black coating along the beaker which contained the fuel. No other carbon by-products were produced.

a. Write a balanced chemical equation for the reaction. (1 mark)

$C_{20}H_{40}O_2(l) + 9O_2(g) \rightarrow 20C(s) + 20H_2O(g)$

b. State what likely caused the black residue on the beaker. (1 mark)

Caused by the production of carbon soot matter along the beaker.

c. Predict whether the reaction was exothermic or endothermic. (1 mark)

Exothermic

Question 7 (7 marks)

A complete combustion reaction occurs with ethanol, over an open Bunsen burner flame.

a. Write a thermochemical equation for the reaction occurring. (1 mark)

$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l) \quad \Delta H = -1370\ kJ/mol$

b. In another experiment, the Bunsen burner hole is closed partially, causing the flame to change from blue to orange. The ethanol sample is then combusted under the open flame.

i. Explain why the colour change of the flame occurred. (2 marks)

Oxygen supply is restricted when the hole is partially closed (1).

This causes the flame to change colour from blue to orange (2).

ii. Write a balanced chemical equation for the reaction occurring, given that carbon monoxide and carbon soot are produced. (1 mark)

$2C_2H_5OH(l) + 3O_2(g) \rightarrow 2C(s) + 2CO(g) + 6H_2O(g)$

iii. State which reactant is reacting in excess. (1 mark)

Ethanol

c. Predict and justify whether the ΔH value for this reaction will be greater or less than that of **part a.** (2 marks)

Less (1).
Incomplete combustion reactions are less energy efficient than complete combustion reactions, meaning that less energy is released (2).

Space for Personal Notes

Sub-Section: [1.1.3] Apply Changing Equations to Thermochemical Equations & Energy Profile Diagrams

Question 8 (3 marks)

Consider the following thermochemical equations.

A reaction occurs, as shown in the following chemical equation:

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g) \qquad \Delta H = +129\ kJ\ mol^{-1}$$

a. Calculate the ΔH for the reaction represented by the equation: (1 mark)

$$NaHCO_3(s) \rightarrow \frac{1}{2}Na_2CO_3(s) + \frac{1}{2}H_2O(g) + \frac{1}{2}CO_2(g)$$

$+64.5\ kJ\ mol^{-1}$

b. Calculate the ΔH for the reaction represented by the equation: (1 mark)

$$4NaHCO_3(s) \rightarrow 2Na_2CO_3(s) + 2H_2O(g) + 2CO_2(g)$$

$258\ kJ\ mol^{-1}$

c. Calculate the ΔH for the reaction represented by the equation: (1 mark)

$$3H_2O(g) + 3CO_2(g) + 2Na_2CO_3(s) \rightarrow 6NaHCO_3(s)$$

$-387\ kJ\ mol^{-1}$

Question 9 (2 marks)

A reaction occurs, as shown in the following chemical equation:

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s) \qquad \Delta H = -1204\ kJ/mol$$

a. Calculate the ΔH for the reaction represented by the equation: (1 mark)

$$4Mg(s) + 2O_2(g) \rightarrow 4MgO(s)$$

$-2408\ kJ/mol$

b. Calculate the ΔH for the reaction represented by the equation: (1 mark)

$$3Mg(s) + \frac{3}{2}O_2(g) \rightarrow 3MgO(s)$$

$\Delta H = -1806\ kJ/mol$

Question 10 (3 marks)

Iron (III) oxide has applications in the pharmaceutical industry. It can be produced through the reaction shown below:

$$Fe_2O_3(s) + 2Al(s) \rightarrow 2Fe(l) + Al_2O_3(s) \qquad \Delta H = -850\ kJ\ mol^{-1}$$

a. Calculate the ΔH for the reaction represented by the equation: (1 mark)

$$4Fe(l) + 2Al_2O_3(s) \rightarrow 2Fe_2O_3(s) + 4Al(s)$$

$+1700\ kJ/mol$

b. Calculate the ΔH for the reaction represented by the equation, and find the value of the coefficient 'x'. (2 marks)

$$\frac{1}{6}Fe(l) + \frac{1}{12}Al_2O_3(s) \rightarrow \frac{1}{12}Fe_2O_3(s) + xAl(s)$$

$+70.83\ kJ/mol$

$x = \frac{1}{6}$

Space for Personal Notes

Question 11 (7 marks)

Anna is combusting a sample of $C_5H_{11}OH(l)$ over a Bunsen burner flame. If combusted completely, for every mole of pentanol, $3256\ kJ$ of energy is released.

a. Given that a complete combustion reaction occurs, write a balanced chemical equation for the reaction. (1 mark)

$$2C_5H_{12}O(l) + 15O_2(g) \rightarrow 10CO_2(g) + 12H_2O(g) \quad \Delta H \approx -3256\ kJ/mol$$

b. State whether the reaction is exothermic or endothermic. Justify your response. (2 marks)

Exothermic (1).
Energy is being released in the reaction (2).

c. Anna is trying to determine the chemical equation from the following ΔH values.

i. $\Delta H = +3256\ kJ/mol$. (1 mark)

$$10CO_2(g) + 12H_2O(g) \rightarrow 2C_5H_{12}O(l) + 15O_2(g) \quad \Delta H = +3256\ kJ/mol$$

ii. $\Delta H = -6512\ kJ/mol$. (1 mark)

$$4C_5H_{12}O(l) + 30O_2(g) \rightarrow 20CO_2(g) + 24H_2O(g)$$

iii. $\Delta H = -2170.67\ kJ/mol$. (2 marks)

$$\frac{1}{3}C_5H_{12}O(l) + 10O_2(g) \rightarrow \frac{20}{3}CO_2(g) + 8H_2O(g)$$

Space for Personal Notes

Section B: [1.2] - Energy Calculations & ΔH (Checkpoints) (39 Marks)

Sub-Section [1.2.1]: Apply $\Delta H = q \times n$ to find Energy Released

Question 12 (2 marks)

a. How much energy (in kilojoules) is released when 3.50 moles of hydrogen is combusted completely? (1 mark)

$$\text{Energy released} = 3.50\,\text{moles} \times (-286\,\text{kJ/mol}) = -1001.0\,\text{kJ}$$

b. A sample contains 1.25 moles of carbon (graphite). How much energy (in kilojoules) is released when the carbon is combusted? (1 mark)

$493\ kJ$

Question 13 (2 marks)

Calculate the energy released when 10.0 grams of glucose ($C_6H_{12}O_6$) are combusted.

1. **Moles of glucose:**

$$\text{Moles of glucose} = \frac{\text{Mass of glucose}}{\text{Molar mass of glucose}} = \frac{10.0\,\text{g}}{180.0\,\text{g/mol}} = 0.05556\,\text{mol}$$

2. **Energy released:**

$$\text{Energy released} = \text{Moles of glucose} \times \Delta H_{\text{combustion}} = 0.05556\,\text{mol} \times (-2840\,\text{kJ/mol}) = -157.78\,\text{kJ}$$

Space for Personal Notes

Question 14 (3 marks)

A sample contains 12.0 g of butane and 8.0 g of hydrogen gas. Calculate the total energy released when both are combusted.

1. **Moles of butane:**

$$\text{Moles of butane} = \frac{\text{Mass of butane}}{\text{Molar mass of butane}} = \frac{12.0\,\text{g}}{58.0\,\text{g/mol}} = 0.2069\,\text{mol}$$

2. **Energy released by butane:**

$$\text{Energy released (butane)} = \text{Moles of butane} \times \Delta H_{\text{combustion}} = 0.2069\,\text{mol} \times (-2880\,\text{kJ/mol}) = -595.86\,\text{kJ}$$

3. **Moles of hydrogen:**

$$\text{Moles of hydrogen} = \frac{\text{Mass of hydrogen}}{\text{Molar mass of hydrogen}} = \frac{8.0\,\text{g}}{2.0\,\text{g/mol}} = 4.0\,\text{mol}$$

4. **Energy released by hydrogen:**

$$\text{Energy released (hydrogen)} = \text{Moles of hydrogen} \times \Delta H_{\text{combustion}} = 4.0\,\text{mol} \times (-286\,\text{kJ/mol}) = -1144.0\,\text{kJ}$$

5. **Total energy released:**

$$\text{Total energy released} = \text{Energy released (butane)} + \text{Energy released (hydrogen)} = -595.86\,\text{kJ} + (-1144.0\,\text{kJ}) = -1739.86\,\text{kJ}$$

Question 15 (4 marks)

A 50/50 by-mass fuel mixture of ethanol and methane is combusted completely. If the total mass of the mixture is 20.0 g, calculate the total energy released.

1. **Mass of each fuel:**
Since the mixture is 50/50 by mass, each fuel contributes half the total mass:

$$\text{Mass of ethanol} = \text{Mass of methane} = \frac{20.0\,\text{g}}{2} = 10.0\,\text{g}$$

2. **Moles of ethanol:**

$$\text{Moles of ethanol} = \frac{\text{Mass of ethanol}}{\text{Molar mass of ethanol}} = \frac{10.0\,\text{g}}{46.0\,\text{g/mol}} = 0.2174\,\text{mol}$$

3. **Energy released by ethanol:**

$$\text{Energy released (ethanol)} = \text{Moles of ethanol} \times \Delta H_{\text{combustion (ethanol)}} = 0.2174\,\text{mol} \times (-1370\,\text{kJ/mol}) = -297.83\,\text{kJ}$$

4. **Moles of methane:**

$$\text{Moles of methane} = \frac{\text{Mass of methane}}{\text{Molar mass of methane}} = \frac{10.0\,\text{g}}{16.0\,\text{g/mol}} = 0.625\,\text{mol}$$

5. **Energy released by methane:**

$$\text{Energy released (methane)} = \text{Moles of methane} \times \Delta H_{\text{combustion (methane)}} = 0.625\,\text{mol} \times (-890\,\text{kJ/mol}) = -556.25\,\text{kJ}$$

6. **Total energy released:**

$$\text{Total energy released} = \text{Energy released (ethanol)} + \text{Energy released (methane)} = -297.83\,\text{kJ} + (-556.25\,\text{kJ}) = -854.08\,\text{kJ}$$

Space for Personal Notes

Sub-Section [1.2.2]: Apply ΔH in kJ/mol, kJ/g, and kJ/mL to Energy Calculations

Question 16 (1 mark)

A generator burns 15.0 mL of petrol to produce energy. Calculate the total energy released during this process.

510 kJ

Question 5 (4 marks)

a. The density of butan-1-ol is 0.745 g/mL, calculate the amount of energy that will be released by 1.50 L of butan-1-ol given its molar heat of combustion is 37.8 kJ/g. (2 marks)

$m(C_4H_9OH) = 1500\,mL \times 0.745\,g/mL = 1117.5\,g$

$q(C_4H_9OH) = 37.8\,kJ/g \times 1117.5\,g = 4.22 \times 10^4\,kJ$

b. A mixture of 3.00 g of ethane and 2.00 g of carbon is combusted. Calculate the total energy released in kJ. (2 marks)

4. **Total Energy Released by Ethane and Carbon (Intermediate Question 4):**
   - Energy released by ethane: $-156.0\,kJ$
   - Energy released by carbon: $-65.67\,kJ$
   - **Total energy released:**

$$-221.67\,kJ$$

Space for Personal Notes

Question 6 (3 marks)

The density of octane is 0.703 g/mL under SLC.

a. Calculate the amount of energy released by a canister containing 20.0 L of octane when it undergoes complete combustion. (1 mark)

$m(C_8H_{18}) = d \times V = 0.703\ g/mL \times 20000\ mL = 14060\ g$

$q(C_8H_{18}) = \Delta H \times m = 47.9\ kJ/g \times 14060\ g = 6.73 \times 10^5\ kJ$

b. Determine the volume of octane required to release 1.5 kJ of energy. (2 marks)

$n(C_8H_{18}) = \frac{q}{\Delta H} = \frac{1.5\ kJ}{5460\ kJ/mol} = 2.74 \times 10^{-4}\ mol$

$V(C_8H_{18}) = n \times V_m = 2.74 \times 10^{-4}\ mol \times 24.8 = 6.81 \times 10^{-3}\ L$

Question 17 (3 marks)

A ship uses 50.0 kg of kerosene during a trip.

a. Calculate the total energy released from combusting the kerosene in megajoules. (1 mark)

$q(H_2) = \Delta H \times m = 46 \times 50000 = 23000\ MJ$

b. Calculate the volume, in litres, of kerosene used during the trip. (2 marks)

$50000\ g \times \frac{46}{37} = 62.2\ L$

Space for Personal Notes

Sub-Section [1.2.3]: Apply $q = mcAT$ to Find Energy Absorbed

Question 18 (1 mark)

Calculate the amount of heat energy, in kJ, required to heat up a kettle containing 1.5 L of water from 25°C to 100°C.

$q = mc\Delta T = 1500 \times 0.997 \times 4.18 \times (100 - 25)$

$= 468839.25\ J$

$\approx 468.8\ kJ$

$= 4.7 \times 10^2\ kJ$

Question 19 (1 mark)

If 21.7 kJ of energy was inputted to a pot of water to increase the temperature from 14.0°C to 44.4°C, find the volume of water which was present.

$m = \frac{q}{c\Delta T} = \frac{21700}{4.18 \times (44.4 - 14)} = 170.769g$

$= 171g$

Question 20 (3 marks)

A sample of water with a volume of 500 mL at SLC absorbs 20.9 kJ of energy. Find the final temperature of the water.

$$q = mc\Delta T$$

$$\Delta T = \frac{q}{mc}$$

$$\Delta T = \frac{20,900}{500 \times 4.18}$$

$$\Delta T = \frac{20,900}{2090} = 10.0^\circ C$$

$$T_{\text{final}} = T_{\text{initial}} + \Delta T$$

$$T_{\text{final}} = 25 + 10 = 35.0^\circ C$$

Sub-Section [1.2.4]: Calculate ΔH Experimentally

Question 21 (3 marks)

A particular spirit burner contained a sample of an unknown fuel. It is used to heat up a beaker containing 150 mL of water. The following data was obtained:

- The initial mass of the spirit burner: 100 mL
- The final mass of the spirit burner: 98.5 mL
- The initial temperature of water: 25℃
- The final temperature of water: 37℃

a. Calculate the volume of the unknown fuel that underwent combustion. (1 mark)

100 − 98.5 = 1.5 mL

b. Determine the amount of energy absorbed by the water, in kJ. (1 mark)

$q = mc\Delta T = (150 \times 4.18 \times (37-25))$

$= 7524 J$

$= 7.52 kJ$

c. Calculate the heat of combustion of the unknown fuel in $kJ\ mol^{-1}$. (1 mark)

$n = \frac{V}{V_m} = \frac{0.0015}{24.8} = 6.05 \times 10^{-5} mol$

$\Delta H = \frac{q}{n} = \frac{7.52 kJ}{6.05 \times 10^{-5}} = 124330 kJ/mol$

$= 1.24 \times 10^{5} kJ/mol$

Space for Personal Notes

Question 22 (4 marks)

A burner containing ethanol (C_2H_5OH) is used to heat 200.0 g of water. The water temperature rises from 20.0°C to 45.0°C. The initial mass of the burner and ethanol is 120.50 g, and the final mass is 119.75 g. Calculate the experimental heat of combustion of ethanol in kJ/mol.

$$q = mc\Delta T$$

$$q = 200.0 \times 4.18 \times 25.0 = 20,900 \text{ J}$$

$$\text{Mass burned} = 120.50 - 119.75 = 0.75 \text{ g}$$

$$\Delta H = \frac{q}{\text{mass burned}} \times \text{molar mass}$$

$$\Delta H = \frac{20,900}{0.75} \times 46.07$$

$$\Delta H = 1283.82 \text{ kJ/mol}$$

Space for Personal Notes

Question 23 (5 marks)

A student uses ethanol (C_2H_5OH) to heat 300.0 g of water. The water's temperature increases from 22.0°C to 52.0°C. The initial volume of ethanol is 25.0 mL, and the final volume is 22.5 mL. The density of ethanol is 0.789 g/mL.

Calculate the experimental heat of combustion of ethanol in kJ/mol.

Step-by-Step Calculation:

Step 1: Calculate the heat absorbed by the water

$$q = mc\Delta T$$

$$q = 300.0 \times 4.18 \times 30.0 = 37,620\ \text{J}$$

Step 2: Calculate the volume of ethanol burned

$$\text{Volume burned} = 25.0 - 22.5 = 2.5\ \text{mL}$$

Step 3: Convert the volume of ethanol burned to mass

$$\text{Mass burned} = \text{Volume burned} \times \text{Density}$$

$$\text{Mass burned} = 2.5 \times 0.789 = 1.9725\ \text{g}$$

Step 4: Calculate the experimental heat of combustion

$$\Delta H = \frac{q}{\text{mass burned}} \times \text{molar mass}$$

$$\Delta H = \frac{37,620}{1.9725} \times 46.07$$

$$\Delta H = 878.66\ \text{kJ/mol}$$

Space for Persona

Section C: [1.3] - Gas Calculations & Stoichiometry (Checkpoints) (69 Marks)

Sub-Section [1.3.1]: Identify Changes to Minimise Heat Loss & Calculate Percentage Efficiency

Question 24 (2 marks)

An experiment involves a butane canister containing 5.00 g of butane.

a. Assuming excess oxygen, what is the amount of energy released in kJ if the molar heat of the combustion of butane is $-2880\ kJ\ mol^{-1}$? (1 mark)

$5/12 \times 4 + 12 = 0.0833$ moles
$0.0833 \times 2880 = 239.904\ kJ$

b. Later 2.00 g of ethanol was combusted, given that the molar heat of combustion of ethanol is $-1370\ kJ\ mol^{-1}$, calculate the amount of energy released during its combustion. (1 mark)

$2.00/46 = 0.0434$ moles
$0.0434 \times 1370 = 59.57\ kJ$

Question 25 (3 marks)

A sample of propanol in a spirit burner initially weighs 95.80 g. After complete combustion, the spirit burner weighs 93.45 g. The heat energy released is used to heat 400 mL of water at SLC. The temperature of the water rises from 22.00°C to 48.50°C.

Calculate the heat of combustion of propanol in $kJ\ mol^{-1}$.

$95.80 - 93.45 = 2.35\ g/36 + 8 + 16 =$ 0.039167 moles

$q = 400 \times 4.18 \times (48.50 - 22) = 44308\ J = 44.308\ kJ$

$44.308/0.039167 = 1131.258\ kJ\ mol^{-1}$

Question 26 (3 marks)

A sample of ethanol in a spirit burner initially weighs 60.00 g. After complete combustion, the spirit burner weighs 50.50 g. The heat energy released is used to heat 500 mL of water at SLC. The temperature of the water rises from 25.00°C to 60.00°C.

Calculate the heat of combustion of ethanol in $kJ\ mol^{-1}$ and state its energy efficiency.

$60 - 50.50 = 9.50/46 = 0.2065$ moles

$q = 500 \times (60 - 25) \times 4.18 = 73.150\ kJ$

$73.150/0.2065$ moles $= 354.23\ kJ\ mol^{-1}$

$354.23/1370 \times 100 = 25.86\%$

Question 27 (6 marks)

In the pharmaceutical industry, there is a particular compound that is highly desired. Its production involves a two-step process, whereby an intermediate product ($C_{15}H_{22}O$) is first produced, and then converted into the final product ($C_{30}H_{40}O_4$). The final product is produced via the following reaction:

$$2C_{15}H_{22}O + 2O_2 \rightarrow C_{30}H_{40}O_4 + 2H_2O$$

a. Given 10.0 mol of $C_{15}H_{22}O$ is reacted, calculate the final amount in grams of $C_{30}H_{40}O_4$ produced. (2 marks)

$n(C_{30}H_{40}O_4) = n(C_{15}H_{22}O) \times ½ = 5\ mol$
$5 \times (12 \times 30 + 40 + 16 \times 4) = 2320\ g = 2.32\ kg$

b. In practice, both reactions are 75% efficient.

i. Hence, calculate the amount of mol of $C_{30}H_{40}O_4$ that will be produced given 10.0 mol of $C_{15}H_{22}O$ is reacted. (2 marks)

$n(C_{30}H_{40}O_4) = n(C_{15}H_{22}O) \times ½ = 5\,mol = 5 \times 0.75 = 3.75$ moles

ii. Using your response to the previous question, explain whether in practice the final mol, or the final mass of $C_{30}H_{40}O_4$ will be affected. (2 marks)

Mass and mol will be decreased by 25%, multiples of each other and will be affected in the same way.

Space for Personal Notes

Sub-Section [1.3.2]: Apply $n = V/V_m$ to Calculate Volumes of Gas at SLC

Question 28 (2 marks)

For the following scenario, assume everything occurs at SLC.

a. Find the amount, in mol, of 6.00 L of ammonia gas, NH_3. (1 mark)

$6/24.8 = 0.2419$ moles

b. Find the volume that 10.00 g of sulphur dioxide occupies. (1 mark)

$10/32.1 + 32 = 0.156$ moles $\times 24.8 = 3.869\ L$

Question 29 (3 marks)

A sample of 20.5 g of propane is being investigated.

a. Determine the volume that propane will occupy at SLC. (1 mark)

$n(C_3H_8) = \frac{20.5}{36+8} = 0.466$ moles $\rightarrow 0.466 \times 24.8 = 11.6\ L$

b. Another sample of oxygen gas weighing 96.0 g is also added to the propane. Determine the volume that the mixture of both gases will occupy at SLC. (2 marks)

$n(O_2) = \frac{96}{32} = 3.00$ moles $\rightarrow 3 + 0.466 = 3.466$ moles $\rightarrow 3.466 \times 24.8 = 86.0\ L$

Space for Personal Notes

Question 30 (4 marks)

A gas canister containing 30.0 L of methane is used in a portable stove.

a. Calculate the amount of energy that will be released given the entire gas canister undergoes complete combustion at SLC. (2 marks)

$30/24.8 = 1.2096 \text{ moles} \times 890 = 1076.61\ kJ$

b. The same 30.0 L canister is filled half with liquid methane that has a density of 0.415 $g\ L^{-1}$. The other half of the canister is filled with gaseous methane. Calculate the potential amount of energy, if all the liquid and gas methane underwent combustion. (2 marks)

$15 \times 0.415 = 6.225\ g$ of methane $\rightarrow 6.225/16 = 0.389$ moles
$0.389 \times 890 = 346.26\ kJ$
$15/24.8 = 0.6048 \text{ moles} \times 890 = 538.31\ kJ$
Total $= 538.31 + 346.26 = 884.57\ kJ$

Question 31 (6 marks)

Ammonia gas (NH_3) is a versatile compound used as a fertiliser in agriculture, a key ingredient in nitric acid production, and a refrigerant. Its applications extend to pharmaceutical synthesis and cleaning agents. Despite its pungent odour and toxicity, ammonia gas plays a key role in agriculture, industry, and various industrial processes.

a. Calculate the volume that a sample of 20.0 g of ammonia gas (NH_3) will occupy at SLC. (1 mark)

$20/17 = 1.176 \text{ moles} \times 24.8 = 29.18\ L$

b. Determine the volume that 15.70 mol of ammonia gas will occupy at SLC. (1 mark)

$15.70 \times 24.8 = 389.36\ L$

c. Now, consider the reaction involving ammonia that occurs at SLC:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

i. If there was 12.50 L of ammonia that reacts, calculate the total mass of products made. (3 marks)

$N(C_{30}H_{40}O_4) = n(C_{15}H_{22}O) \times ½ = 5\, mol = 5 \times 0.75 = 3.75$ moles

ii. What type of data would you need if the reaction was not at SLC to convert from volume to moles? (1 mark)

Mass and mol will be decreased by 25%, multiples of each other, and will be affected in the same way.

Space for Personal Notes

Sub-Section [1.3.3]: Apply $m - m, m - v, v - v$ Stoichiometry to Calculation Questions with Equations

Question 32 (3 marks)

Hydrogen gas reacts with nitrogen gas to produce ammonia, as represented by the equation:

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

If 12.0 L of hydrogen gas reacts completely with nitrogen gas at SLC:

a. What volume of nitrogen gas is required? (1 mark)

$12.0/24.8 = 0.4838$ moles $\times 1/3 = 0.161$ moles of nitrogen gas
$0.161 \times 24.8 = 4\ L$

b. What volume of ammonia is produced? (2 marks)

$0.4838 \times 2/3 = 0.3225$ moles produced
$0.3225 \times 24.8 = 7.99 = 8.00\ L$

Question 33 (3 marks)

The decomposition of potassium chlorate produces oxygen gas:

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

a. How many moles of oxygen gas are produced when 5.00 g of potassium chlorate decomposes? (2 marks)

$5/39.1 + 35.5 + 48 = 0.04078$ moles of potassium chlorate
$0.04078 \times 3/2 = 0.06117$ moles of oxygen gas

b. Calculate the total volume of oxygen gas produced at SLC. (1 mark)

$0.6117 \times 24.8 = 1.517\ L$

Question 34 (5 marks)

Methane reacts with chlorine gas to produce dichloromethane and hydrochloric acid according to the following equation:

$$CH_4(g) + 2Cl_2(g) \rightarrow CH_2Cl_2(g) + 2HCl(g)$$

a. If 2.50 g of methane reacts, what is the mass of chlorine gas required? (2 marks)

$2.50/16 = 0.15625 \times 2 = 0.3125$ moles of chlorine gas $\times\ 35.5 \times 2 = 22.19\ g$

b. Calculate the total volume of gases produced in the reaction if the reaction occurs at SLC. (2 marks)

$0.15625 \times 1 = 0.15625$

$0.15625 \times 2 = 0.3125$

Total moles $= 0.46875 \times 24.8 = 11.625\ L$

c. Determine the total number of molecules of hydrochloric acid produced. (1 mark)

$0.15625 \times 2 = 0.3125$ moles of hydrochloric acid $\times\ 6.02 \times 1023 =$
1.88×1023 molecules of HCl

Space for Personal Notes

Question 35 (7 marks)

Ethene combusts in oxygen to produce carbon dioxide and water: Two experiments were completed using this reaction:

$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$$

a. The first experiment used 4.50 g of ethene.

i. If the ethene is combusted completely, determine the moles of oxygen gas required. (2 marks)

$4.50/28 = 0.1607$ moles of ethene
$0.1607 \times 3 = 0.482$ moles of oxygen gas

ii. Calculate the total volume of reactants consumed at SLC. (2 marks)

$0.482 \times 24.8 = 11.957\ L$
$0.1607 \times 24.8 = 3.99\ L$
$\text{Total} = 11.957 + 3.99 = 15.95\ L$

iii. What volume of carbon dioxide is produced at SLC? (1 marks)

$0.1607 \times 2 = 0.3214 \times 24.8 = 7.97\ L$

b. The second experiment used 4.50 L of ethene.

Now, determine the volume of carbon dioxide gas produced at SLC. (2 marks)

$4.50/24.8 = 0.18145$ moles
$0.18145 \times 2 = 0.3629 \times 24.8 = 9\ L$

Space for Personal Notes

Sub-Section [1.3.4]: Identify Limiting Reagents

Question 36 (2 marks)

Hydrochloric acid reacts with sodium carbonate according to the following equation:

$$2HCl(aq) + Na_2CO_3(s) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

A reaction is set up using 7.30 g of sodium carbonate and 1.0 L of 0.05 M hydrochloric acid.

Determine the excess and limiting reagent.

$\frac{7.30}{46+12+36} = 0.077659$ moles of sodium carbonate

$0.05 \times 1 \times \frac{1}{2} = 0.025$ moles of hydrochloric acid (1:1 ratio)

Sodium carbonate is in excess and hydrochloric acid is limiting.

Question 37 (5 marks)

Propane undergoes complete combustion according to the following equation:

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

8.8 g of propane reacts with 25.0 L of oxygen gas at SLC.

a. Find the limiting reagent. (2 marks)

$\frac{8.8}{44} = 0.2$ moles of propane

$\frac{25.0}{24.8} \times \frac{1}{5} = 0.2016...$ moles of oxygen gas

Oxygen is in excess and propane is limiting.

b. Calculate the mass of carbon dioxide produced. (1 mark)

$0.20 \times 3 = 0.60$ moles $\times 44 = 26.40\ g$

c. Calculate the mass of the excess reagent left over. (2 marks)

$0.20 \times 5 = 1.00$ moles
$1.008 - 1.00 = 0.008$ moles leftover$\rightarrow$ $0.008 \times 32 = 0.256\ g$ leftover

Question 38 (7 marks)

Zinc reacts with hydrochloric acid according to the following equation:

$$Zn(s) + 2HCl(q) \rightarrow ZnCl_2(aq) + H_2(g)$$

A reaction is carried out by mixing 6.50 g of zinc with 120.0 mL of 2.0 M hydrochloric acid.

a. Determine the limiting reagent. (2 marks)

$6.50/65.4 = 0.099$ moles
$0.120 \times 2 = 0.240$ moles/2 $0. = 0.120$ (1: 1 ratio)
Zn is limiting reagent.

b. Calculate the total volume of gases produced in the reaction if the reaction occurs at SLC. (2 marks)

$0.099 \times 65.4 + 35.5 + 35.5 = 13.56\ g$

c. Determine the total volume of hydrogen gas produced. (1 mark)

0.099 moles $\times 24.8 = 2.46\ L$

d. Calculate the mass of the excess reagent left over. (2 marks)

$0.099 \times 2 = 0.19877$ moles of HCl reacted
$0.240 - 0.19877 = 0.0412$ moles leftover $\times 36.5 = 1.50\ g$ leftover

Question 39 (8 marks)

Given the following reaction:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

A sample of 8.00 L of methane is mixed with 20.0 L of oxygen gas at SLC.

a. Identify the excess and limiting reagents. (3 marks)

$8/24.8 = 0.3225$ moles of methane
$20/24.8 = 0.8065$ moles of oxygen gas$/2 = 0.403$ moles (1: 1 ratio)
Oxygen gas is the excess reagent and methane is the limiting reagent.

b. Calculate the mass, in g, of excess reagent left unreacted. (2 marks)

$0.3225 \times 2 = 0.645$ moles oxygen gas reacted.
$0.8065 - 0.645 = 0.1615$ moles leftover $\times 32 = 5.17\ g$ leftover.

c. Determine the total volume of carbon dioxide gas produced at SLC. (1 mark)

$0.3225 \times 24.8 = 7.998\ L \rightarrow 8\ L$

d. Suppose the reaction occurs with the prescribed amounts, then what is the total volume of gas left over at the end, assuming that the water is completely converted to gas at the end? (2 marks)

Leftover oxygen gas $= 0.1615 \times 24.8 = 4.0052\ L$
CO_2 gas $= 8\ L$
Water vapour $= 0.3225 \times 2 = 0.645 \times 24.8 = 15.996 = 16\ L$
Total gas $= 4 + 8 + 16 = 28\ L$

Space for Personal Notes

Section D: [1.4] - Calorimetry (Checkpoints) (56 Marks)

Sub-Section [1.4.1]: Calculate Calibration Factor via Electrical & Chemical Calibration $\left(CF = \frac{E}{\Delta T}\right)$

Question 40 (2 marks)

Jamie passes 410 J of electrical energy through a solution calorimeter. The temperature rise of the solution is recorded as 1.8°C.

a. Determine the calibration factor for the calorimeter in $J/°C$. (1 mark)

$CF = \frac{E}{\Delta T}$

$CF = \frac{410}{1.8}$

$= 227.78\ J/°C \approx 2.3 \times 10^2\ J/°C$

b. Convert this calibration factor into $kJ/°C$. (1 mark)

$\frac{227.78}{1000}$

$= 0.23\ kJ/°C$

Space for Personal Notes

Question 41 (3 marks)

Angela is experimenting with a solution calorimeter containing 250 mL of water. She applies 3.50 mA of current through the instrument for 1.50 hours, whilst the voltage remains at 1.50 V. Interestingly, she finds that the temperature of the water changes from 24.2°C to 24.5°C. Calculate the calibration factor of the calorimeter in $kJ/°C$.

$E = VIt$

$= 1.5 \times 3.5 \times 10^{-3} \times 1.5 \times 60 \times 60$

$= 28.35\ J$

$\approx 0.02835\ kJ$

$\therefore CF = \frac{E}{\Delta T}$

$CF = \frac{0.02835}{24.5 - 24.2}$

$= 0.0945$

$\approx 9.45 \times 10^{-2}\ kJ/°C$

Question 42 (3 marks)

A solution calorimeter is calibrated using 120.0 mL of 1.00 M H_2SO_4 mixed with excess KOH at an initial temperature of 26.0°C. The reaction is as follows:

$$H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l) \quad \Delta H = -114.0\ kJ/mol$$

The final temperature of the calorimeter is 35.0°C. Calculate the calorimeter's calibration factor in $J/°C$.

$n(H_2SO_4) = 0.12 \times 1$

$= 0.12\ mol$

$\therefore E = 114 \times 0.12$

$= 13.68\ kJ$

$\therefore CF = \frac{13.68 \times 10^3}{35 - 26}$

$= 1.52 \times 10^3\ J/°C$

Space for Personal Notes

Question 43 (10 marks)

A calorimeter containing 200 mL of water is calibrated using both electrical and chemical methods.

A current of 3.00 A flows through the calorimeter for 5.00 minutes at a voltage of 4.50 V. There is an increase of 8.15°C in the temperature.

a. Calculate the energy transferred into the calorimeter. (1 mark)

$E = 3.00 \times 4.50 \times 300 = 4.05\ kJ$

b. Calculate the electrical calibration factor. (2 marks)

$CF = \frac{4.05}{8.15}$

$= 0.4969\ J/°C$

$\approx 0.497\ kJ/°C$

Next, 50.0 mL of 1.00 M H_2SO_4 is reacted with 50.0 mL of 3.00 M KOH in the calorimeter.

The reaction is:

$$H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l) \quad \Delta H = -56.0\ kJ/mol$$

The temperature rises from 25.0°C to 33.5°C.

c. Calculate the chemical calibration factor. (3 marks)

$n(H_2SO_4) = 1 \times 0.05 = 0.05\ mol$

$n(KOH) = 3 \times 0.05 = 0.15\ mol$

$n(H_2SO_4) : n(KOH) = 1 : 2$

$\therefore$ $n(H_2SO_4)$ is the limiting reactant.

$\therefore E = 0.05 \times 56 = 2.8\ kJ$

$\therefore CF = \frac{2.8}{33.5 - 25} = 0.329\ kJ/°C$

d. Compare the electrical and chemical calibration factors and make a conclusion on which calibration method is more efficient. (2 marks)

The electrical calibration method is more efficient than the chemical method (1). This is because the calibration value of the electrical method is higher, meaning that to change the temperature in the calorimeter by 1°C, less energy is required than using chemical calibration (2), making it more efficient.

e. Combine the calibration results from both methods to calculate an average calibration factor for the calorimeter in $kJ/°C$. (2 marks)

$$CF_{(average)} = \frac{0.329 + 0.427}{2} = 0.378\ kJ/°C$$

Space for Personal Notes

Sub-Section [1.4.2]: Apply Calibration Factor to Find Energy Released ($E = CF \times \Delta T$)

Question 44 (3 marks)

A calorimeter has a known calibration factor of 51.5 $J/°C$. Calculate the energy released, in J, in the following cases:

a. If the temperature change is 3.0°C. (1 mark)

$CF = \frac{E}{\Delta T}$

$E = 51.5 \times 3$
$= 1.55 \times 10^2 J$

b. If the temperature change is 7.0°C. (1 mark)

$CF = \frac{E}{\Delta T}$

$E = 51.5 \times 7$
$= 3.61 \times 10^2 J$

c. If the temperature increases from 45.5°C to 53.0°C. (1 mark)

$CF = \frac{E}{\Delta T}$

$E = 51.5 \times (53 - 45.5)$
$= 3.86 \times 10^2 J$

Space for Personal Notes

Question 45 (3 marks)

Liam uses a calorimeter with a calibration factor of 40.5 $J/°C$ and fills it with 250.0 mL of an unknown solution. During an experiment, when a piece of steak is placed into the calorimeter, the temperature rises from 30.0°C to 43.5°C.

a. Calculate the energy released by the steak in kJ. (2 marks)

$CF = \frac{E}{\Delta T}$

$\therefore E = 40.5 \times (43.5 - 30)$

$= 546.75\ J$

$\approx 0.547\ kJ$

b. Given that the steak weighs 20.0 g, compute its energy content in kJ/g. (1 mark)

$E.C = \frac{0.54675}{20}$

$= 0.0273\ kJ/g$

$\approx 2.73 \times 10^{-2}\ kJ/g$

Question 46 (4 marks)

A solution calorimeter was calibrated by applying a current of 6.00 A for 10.00 minutes at a voltage of 12.00 V. During calibration, the water's temperature increased from 20.5°C to 30.0°C. This calorimeter was later used to determine the heat content of a sample of cereal. A 4.00 g cereal sample caused the temperature to increase by 14.0°C. Calculate the energy content of the cereal in kJ/g.

Callibration:

$E = VIt$

$= 12 \times 6 \times 10 \times 60$

$= 43200\ J$

$\therefore CF = \frac{43.2}{30 - 20.5}$

$= 4.547\ kJ/°C$

Cereal:

$E = 14 \times 4.547$

$= 63.66\ kJ$

$\therefore E.C = \frac{63.66}{4}$

$= 15.9\ kJ/g$

Question 47 (7 marks)

A complex calorimeter has a calibration factor of 45.0 $J/°C$. The calorimeter has two compartments: a water and an unknown aqueous solution compartment. During an experiment:

- A 300 mL aqueous solution experiences a temperature increase from 23.0°C to 42.0°C when a 12.0 g sample of fuel is burned.
- At the same time, a 150 mL water compartment in the calorimeter increases in temperature by 3.50°C.
- The calorimeter itself has a heat capacity of 200.0 $J/°C$ and its temperature also rises from 23.0°C to 42.0°C.

a. Calculate the total energy released by the fuel. (4 marks)

Heat absorbed by Solution:

CF = 45.0 J/°C

∴ $E = 45.0 \times (42 - 23)$

$= 855.0\ J$

$= 0.855\ kJ$

Heat absorbed by water:

$q = mc\Delta T$

$q = 150 \times 4.18 \times 3.5$

$= 2.195\ kJ$

Heat absorbed by Calorimeter:

$E = 200 \times 19$

$= 3800\ J$

$= 3.8\ kJ$

∴ Total energy

$= 0.855 + 3.8 + 2.195$

$= 6.85\ kJ$

b. Determine the energy content of the fuel in kJ/g. (1 mark)

$\frac{6.85}{12} = 0.571\ kJ/g$

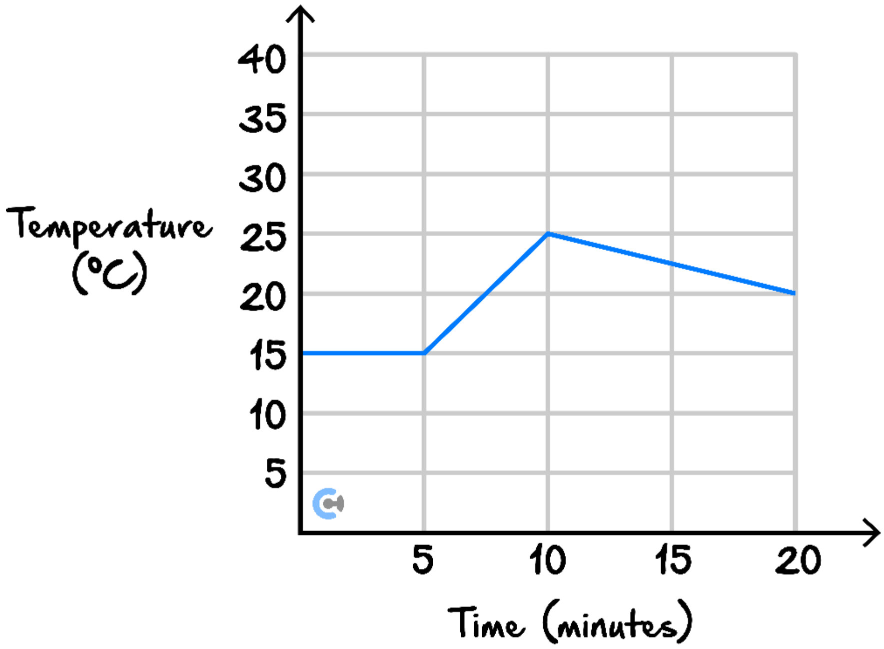
c. Sally, when analysing the calorimeter, notices that the temperature of the solution is not evenly distributed. She notices that closer to the centre, the solution is quite warm but cooler towards the peripheries. Suggest and justify an improvement that could be made to the calorimeter. (2 marks)

A stirrer (1).
This will help to disperse the thermal energy throughout the solution (2).

Sub-Section [1.4.3]: Apply Temperature-Time Graphs to Calorimetry

Question 48 (2 marks)

Alex is experimenting with a calorimeter. It is turned on at 5 minutes and switched off at 10 minutes.



a. From the graph, determine the temperature change in the calorimeter when it is turned on. (1 mark)

10°C

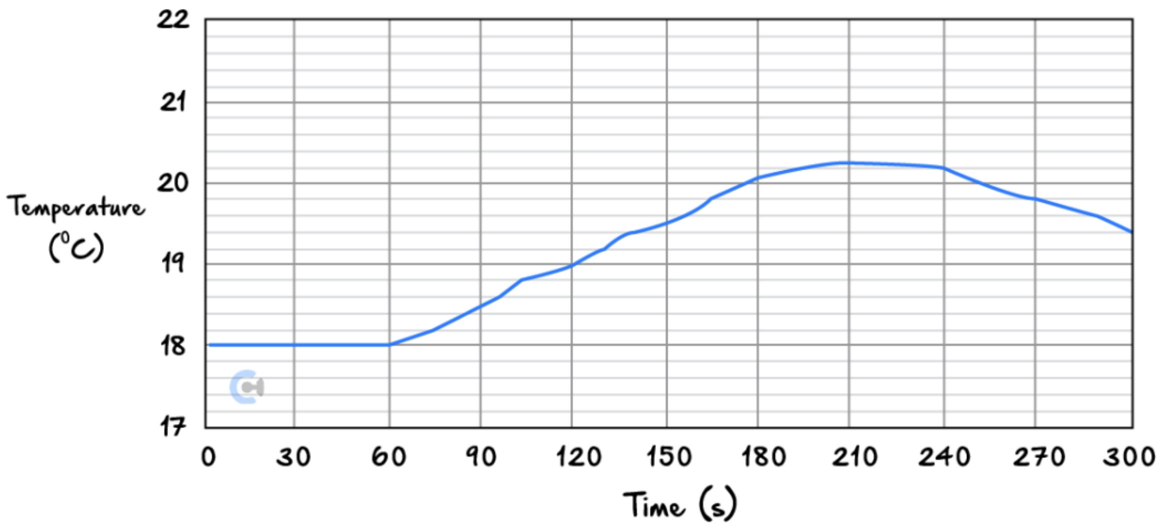
b. If 180 J of energy is released during calibration, calculate the calorimeter's calibration factor. (1 mark)

$$CF = \frac{180}{10} = 18\ J/°C$$

Space for Personal Notes

Question 49 (3 marks)

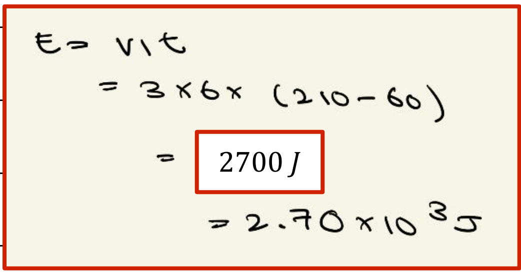
A calorimeter is calibrated with a current of 3.00 A and a voltage of 6.00 V. The heater operates from $t = 60.0$ seconds.



a. Predict when the heater in the calorimeter is turned off.

At roughly 210 seconds.

b. Determine the energy released during the calibration process. (2 marks)



c. Using the graph, compute the temperature change during calibration.

$20.25 - 18 = 2.25°C$

d. Calculate the calorimeter's calibration factor in $kJ/°C$. (1 mark)

$CF = \frac{2.7}{2.25}$

$\rightarrow 1.20 \, kJ/°C$

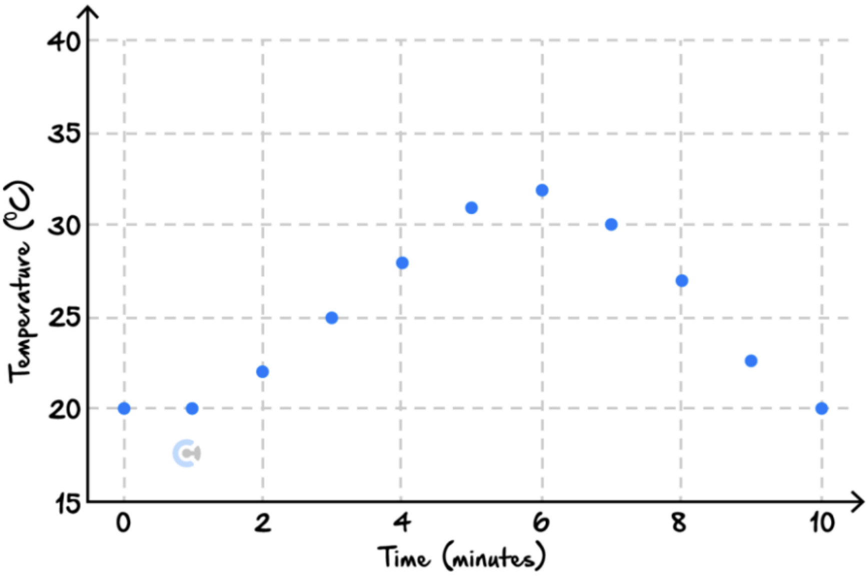
Space for Personal Notes

Question 50 (7 marks)

A 5.00 g sample of glucose is dissolved in water and reacts with oxygen in a calorimeter containing 200 mL of water at an initial temperature of 24°C. The reaction is as follows:

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l) \qquad \Delta H = -2800\ kJ/mol$$

The temperature-time graph for this reaction is provided:



When the reaction is completed, the temperature of the calorimeter is 45°C.

a. Determine the calibration factor for this calorimeter in $kJ/°C$. (3 marks)

$n(C_6H_{12}O_6) = \frac{5}{180}$

$= 0.02778\ mol$

$\therefore E = 0.02778 \times 2800$

$= 77.78\ kJ$

$\therefore CF = \frac{77.78}{45 - 24}$

$= 3.7\ kJ/°C$

b. Emma claims that "*Based on the graph, it is evident that the calorimeter is poorly designed to conserve energy*." Evaluate this claim. (2 marks)

Emma is right (1). There is a drop in the temperature of the solution after the calorimeter is switched off, indicating that heat is being lost to the environment. This suggests that the device is poorly designed to conserve energy (2).

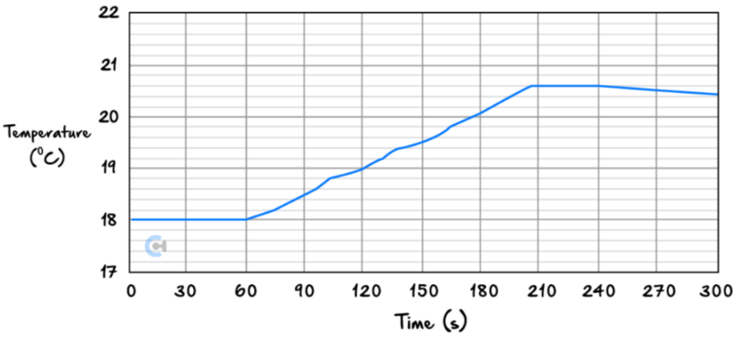
c. Suggest 2 ways in which the design of the calorimeter could be improved. (2 marks)

- Better insulation around the sides of the calorimeter.
- Ensuring a lid is present at the opening of the calorimeter, and that this lid is properly sealed.

Space for Personal Notes

Question 51 (9 marks)

A bomb calorimeter is calibrated by passing a current of 3.50 A at a voltage of 6.20 V for 150 seconds.



a. From the temperature-time graph provided, determine the calorimeter's calibration factor in $kJ/°C$. (3 marks)

$E = VIt$

$= 3.5 \times 6.2 \times 150$

$= 3255\ J$

$\therefore CF = \frac{E}{\Delta T}$

$= \frac{3255}{20.6 - 18}$

$= 1251.92\ J/°C$

$= 1.25\ kJ/°C$

The calorimeter is then used to analyse the combustion of a 2.00 g sample of fuel, which increases the calorimeter's temperature by 15.5°C. During this combustion, it is noted that:

- A separate 100 mL water compartment outside the calorimeter absorbs 4.00 kJ of heat.
- The calorimeter itself has a heat capacity of 200 $J/°C$, which also absorbs heat during combustion.

b. Calculate the total energy released by the fuel. (3 marks)

Calorimeter:

$E = CF \times \Delta T$

$= 1.25 \times 15.5$

$= 19.375\ kJ$

Water Heat:

$E = 4\ kJ$

Calorimeter structure:

$E = 0.2 \times 15.5$

$= 3.10\ kJ$

Total energy:

$E_T = 3.1 + 19.375 + 4$

$= 26.475\ kJ$

$\approx 26.5\ kJ$

c. Calculate the energy content of the fuel in kJ/g. (1 mark)

$\therefore E.C = \frac{26.475}{2}$

$= 13.2375\ kJ/g$

$\approx 13.2\ kJ/g$

d. Explain whether this calorimeter has good or poor insulation. (2 marks)

Yes, the calorimeter has good insultation (1).
There is a minimal drop in the temperature of the solution after the calorimeter is switched off, indicating that minimal heat is being lost to the environment. This suggests that the insulation is good (2).

Space for Personal Notes

Section E: [1.5] - Fuels (Checkpoints) (64 Marks)

Sub-Section [1.5.1]: Explain the Production of Biofuels (Biogas, Bioethanol & Biodiesel)

Question 52 (4 marks)

a. Describe one method through which biogas production helps reduce greenhouse gas emissions. (2 marks)

Biogas production captures methane (a potent greenhouse gas) released during organic waste decomposition. Instead of being emitted directly into the atmosphere, methane is combusted as a fuel, producing carbon dioxide which traps less heat.

b. State how the breakdown of glucose by yeast results in a usable fuel source. (2 marks)

Yeast ferments glucose under anaerobic conditions, converting it into ethanol and carbon dioxide via the reaction:

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

Ethanol is then distilled and used as a renewable biofuel.

Question 53 (4 marks)

a. Discuss why anaerobic digestion is more sustainable than landfill decomposition for waste management. (2 marks)

Anaerobic digestion prevents uncontrolled methane release from landfills by capturing the gas in a controlled environment, where it can be used as biogas. (1) It also reduces landfill volume and produces nutrient-rich digestate for use as fertiliser. (2)

b. Propose how agricultural residues could be converted into bioethanol and explain the advantage of this approach. (2 marks)

Agricultural residues (e.g., corn stalks, wheat straw) can be broken down into simple sugars using enzymes. (1) These sugars are then fermented by yeast to produce bioethanol. This approach reduces waste, adds value to residues, and does not compete directly with food crops. (2)

Question 54 (5 marks)

a. Explain why glycerol is produced during the synthesis of biodiesel and suggest one industrial use for this byproduct. (2 marks)

Glycerol is produced as a byproduct during the transesterification of triglycerides (fats/oils) with methanol. (1) It can be used in the pharmaceutical industry for making soaps, cosmetics, and moisturisers. (2)

b. Compare the feedstocks for producing biogas, bioethanol, and biodiesel, and evaluate which feedstock has the least environmental impact. (3 marks)

- Biogas: Organic waste (e.g., food scraps, animal manure).
- Bioethanol: Sugar-rich crops (e.g., sugarcane, corn).
- Biodiesel: Vegetable oils or animal fats.

Biogas feedstocks have the least environmental impact as they use waste materials, avoiding the land-use and deforestation issues associated with crop-based biofuels.

Space for Personal Notes

Question 55 (7 marks)

Evelyn is experimenting with methane.

a. She is interested in the methods to source methane. Her friend suggests using crude oil as a source of methane. State another 3 non-renewable methods of obtaining methane. (2 marks)

In gas deposits

Coal steam gas

Shale gas

b. Deciding on crude oil, Evelyn is unsure of how to obtain methane from crude oil. State the process used in this separation and how it works. (3 marks)

The process used to obtain methane from crude oil is fractional distillation. (1) Crude oil is heated, and its components separate based on their boiling points through a temperature gradient in a fractioning column. (2) Methane, being a lighter hydrocarbon with a very low boiling point, is collected in the fraction containing the gases at the top of the distillation column. (3)

c. State and explain an alternative renewable method of obtaining methane gas. (2 marks)

Through biogas in land fill deposits (1).

Biogas is produced via the anaerobic breakdown of waste/organic materials by bacteria. Bacteria feasts (yum) on the organic compounds within the waste, digesting it, and turning it into methane/. This methane is sucked up and forms our biogas.

Space for Personal Notes

Sub-Section [1.5.2]: Identify & Explain Differences Between Fossil Fuels & Biofuels with Reference to Renewability

Question 56 (4 marks)

a. Define "renewable fuel" and explain why firewood from a sustainably managed forest fits this definition. (2 marks)

A renewable fuel can be replenished naturally within a short timeframe. (1) Firewood from a sustainably managed forest qualifies because trees are replanted at a rate equal to or faster than their harvest. (2)

b. Name two fossil fuels and explain why their rate of consumption exceeds their natural replenishment rate. (2 marks)

Examples: Coal and natural gas. (1) These fuels form over millions of years from organic matter under heat and pressure, far slower than their consumption rate. (2)

Question 57 (4 marks)

a. Justify why bioethanol derived from sugarcane is often labelled "carbon neutral", referencing photosynthesis and combustion. (2 marks)

Sugarcane absorbs CO_2 from the atmosphere during photosynthesis. (1) When bioethanol is combusted, the same amount of CO_2 is released back into the atmosphere, achieving a balance. (2)

b. Discuss how the heat of combustion differs between fossil fuels and biofuels, considering the molecular composition of each. (2 marks)

Fossil fuels (e.g., hydrocarbons like octane) are fully reduced, containing no oxygen in their structure, which allows for high energy release during combustion. (1) Biofuels (e.g., ethanol) are partially oxidised, containing oxygen, which reduces their energy density. (2)

Question 58 (4 marks)

a. Contrast the carbon emission profiles of burning natural gas versus biogas. (2 marks)

Burning natural gas releases carbon that has been sequestered for millions of years, increasing atmospheric CO_2 levels. (1) Biogas combustion, however, recycles contemporary carbon, maintaining a balance in the carbon cycle. (2)

b. List two factors during biofuel production that compromise its carbon neutrality and suggest solutions to mitigate these effects. (2 marks)

- Farming machinery emissions: Use electric or renewable-energy-powered equipment.
- Fertiliser production emissions: Adopt organic or low-emission fertilisers.

Space for Personal Notes

Question 59 (6 marks)

a. Compare and justify the rate of replenishment of biofuels and fossil fuels. State the relationship between a renewable resource and its rate of replenishment. (4 marks)

The rate of replenishment for biofuels is much faster than for fossil fuels. (1) Biofuels are derived from recently living organisms, such as plants, which can grow and be harvested within a few months to years. (2) In contrast, fossil fuels form from the decomposition of ancient organic matter under high pressure and temperature over millions of years. (3)

This difference impacts their classification because biofuels can be replenished within a human timescale, making them renewable. Fossil fuels, on the other hand, cannot be replaced at the rate they are consumed, classifying them as non-renewable resources. (4)

b. Fossil fuels and biofuels both release CO_2 when burned. Despite this, why are biofuels considered more environmentally friendly in terms of CO_2 emissions? (2 marks)

Although both fossil fuels and biofuels release CO_2 when burned, biofuels are considered more environmentally friendly because the CO_2 released during combustion is offset by the CO_2 absorbed by plants during their growth. (1)
In contrast, fossil fuels release CO_2 that has been stored underground for millions of years, adding a significant amount of new CO_2 to the atmosphere (2).

Space for Personal Notes

Sub-Section [1.5.3]: Write Cellular Respiration & Photosynthesis Equations

Question 60 (1 mark)

State how sunlight can be absorbed in photosynthesis.

Chlorophyll pigment (1).

Question 61 (2 marks)

Angela is talking with her classmates and overhears that "in cellular respiration, energy is absorbed." Evaluate this statement.

Angela's classmate is incorrect (1). In cellular respiration, energy is released for use in the body (2).

Question 62 (5 marks)

During photosynthesis, plants undergo the following reaction:

$$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g) \qquad \Delta H = +3000\ kJ$$

a. If **$75.0\ L$ of carbon dioxide** is absorbed, what is the mass of glucose produced during photosynthesis? (3 marks)

$n(CO_2) = \frac{V}{V_m} = \frac{75}{24.8} = 3.024\ mol$

$\therefore n(CO_2) : n(C_6H_{12}O_6) = 6 : 1$

$\therefore n(C_6H_{12}O_6) = \frac{3.024}{6}$

$= 0.504\ mol$

$\therefore m(C_6H_{12}O_6) = 180 \times 0.504$

$= 90.7g$

b. How much energy is absorbed during this process? (2 marks)

$n(C_6H_{12}O_6) = 0.504$

$\therefore E = \Delta H \times n$

$= 3000 \times$ 0.54 mol

$=$ 1512 kJ

$\approx 1.51 \times 10^3$ kJ

Question 63 (7 marks)

a. Write the balanced chemical equations for aerobic respiration and fermentation in yeast and explain the key differences between the two processes. (3 marks)

Aerobic Respiration: $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$

Fermentation (in yeast): $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

In aerobic respiration, oxygen is required, and more energy is produced. In fermentation, oxygen is not required, and the energy yield is lower.

b. If 4 moles of glucose undergo fermentation in yeast, calculate:

i. The moles of ethanol (C_2H_5OH) produced. (1 mark)

From the equation, 1 mole of glucose produces 2 moles of ethanol.
For 4 moles of glucose: $4 \times 2 = 8$ moles of ethanol.

ii. The moles of carbon dioxide produced. (1 mark)

From the equation, 1 mole of glucose produces 2 moles of CO_2.
For 4 moles of glucose: $4 \times 2 = 8$ moles of CO_2.

c. Compare and justify the energy output of aerobic respiration and fermentation. (2 marks)

- **Aerobic respiration** is more efficient because it produces more ATP per mole of glucose.
- **Fermentation** is less efficient because it does not fully break down glucose, releasing less energy.

Space for Personal Notes

Sub-Section [1.5.4]: Calculate Energy Obtained from Foods

Question 64 (2 marks)

Fill in the table below.

Food	**Heat of combustion (kJg^{-1})**
Fats and oils	37
Protein	17
Carbohydrate	16

Question 65 (2 marks)

Julian is looking at food labels and notices that kJ/g rather than kJ/mol to describe the heat of combustion of foods. Justify this observation.

Food contains a mixture of macromolecules (1). Each macromolecule will have a different energy level, meaning that the overall energy content of the food cannot be expressed in mole. (2)

Space for Personal Notes

Question 66 (3 marks)

Emma is investigating the effect of ingestion of fibres such as cellulose in the body. State and justify what happens to cellulose during digestion.

Cellulose will pass through the digestive system and be excreted (1). Cellulose is a complex carbohydrate made of long chains of glucose molecules connected by β-1,4-glycosidic bonds (2). Humans lack the enzyme cellulase required to break these bonds, making it indigestible (3).

Question 67 (4 marks)

The label on a packet of some biscuits, which has a serving size of $\mathbf{60.0\ g}$, has the following composition:

- **Protein**: 8.25 g
- **Fats**: 2.10 g
- **Carbohydrates – sugars and starches**: 42.0 g
- **Carbohydrates – cellulose fibre**: 4.65 g

a. Calculate the total possible energy available to the body per gram of biscuit. (3 marks)

$q(\text{protein}) = 8.25 \times 17 = 140.25\ kJ$

$q(\text{fats}) = 37 \times 2.1 = 77.7\ kJ$

$q(\text{carbs}) = 16 \times 42 = 672\ kJ$

$q(\text{total}) = 140.25 + 77.7 + 672$

$= 889.95$

$\approx 889.95\ kJ$

b. A sample of biscuit is combusted in a calorimeter to determine its energy value. The result obtained indicates that the energy content of the biscuit is $\mathbf{19\ kJ/g}$. Explain why there is a difference between this answer and the value obtained in **part a.** (1 mark)

Cellulose can be combusted producing additional energy (1).

Space for Personal Notes

Section F: [1.1 - 1.5] - Overall (VCAA Qs) (63 Marks)

Question 68 (1 mark)

Inspired from VCAA Chemistry Exam 2022
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2022/2022chem-w.pdf

A fuel undergoes combustion to heat water.

Which of the following descriptions of the energy and enthalpy of combustion, ΔH, of the reaction is correct?

	Energy	ΔH
A.	Absorbed by the water	Negative
B.		
C.		
D.	Released by the water	Positive

2	A	**65**	20	13	2	Combustion is an exothermic reaction, indicated by $\Delta H < 0$. The energy released during combustion of the fuel is absorbed by the water. While some energy would be released by the water as it cools down, after heating or due to poor insulation, that can only be after the energy released during combustion has been absorbed by the water.

Question 69 (1 mark)

Inspired from VCAA Chemistry Exam 2023
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2023/2023chemistry-w.pdf

Consider the following statements about fossil fuels and biofuels.

I. The production of biofuels does not damage the environment.
II. Combustion of both biofuels and fossil fuels generates greenhouse gases.
III. Biofuels and fossil fuels are both renewable as they are produced from plants.

Which of the statements above is correct?

A. I only

B. II only

C. I and II only

D. I and III only

7.	B	6	**73**	21	1	Biofuel production potentially does damage the environment by degrading land used to grow food and through emissions from fuels used in production and transport. Both biofuel and fossil fuels do generate greenhouse gases – $CO_2(g)$ and/or $H_2O(g)$. Biofuels are renewable but fossil fuels, while traceable back to plants, take millions of years to form and are not considered renewable.

Space for Personal Notes

Question 70 (1 mark)

Inspired from VCAA Mathematics Exam 2013
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2013/2013chem-w.pdf

Which of the following alternatives lists only renewable energy resources?

A. Coal, diesel, ethanol

B. Coal, crude oil, uranium

Solution Pending

C. Ethanol, methane, diesel

D. Crude oil, natural gas, ethanol

Question 71 (1 mark)

Inspired from VCAA Mathematics Exam 2023
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2023/NHT/2023chem-nht-w.pdf

Bioethanol is a fuel produced by:

A. Fermentation.

B. Anaerobic digestion.

C. Transesterification of fats.

D. A substitution reaction of ethene.

Space for Personal Notes

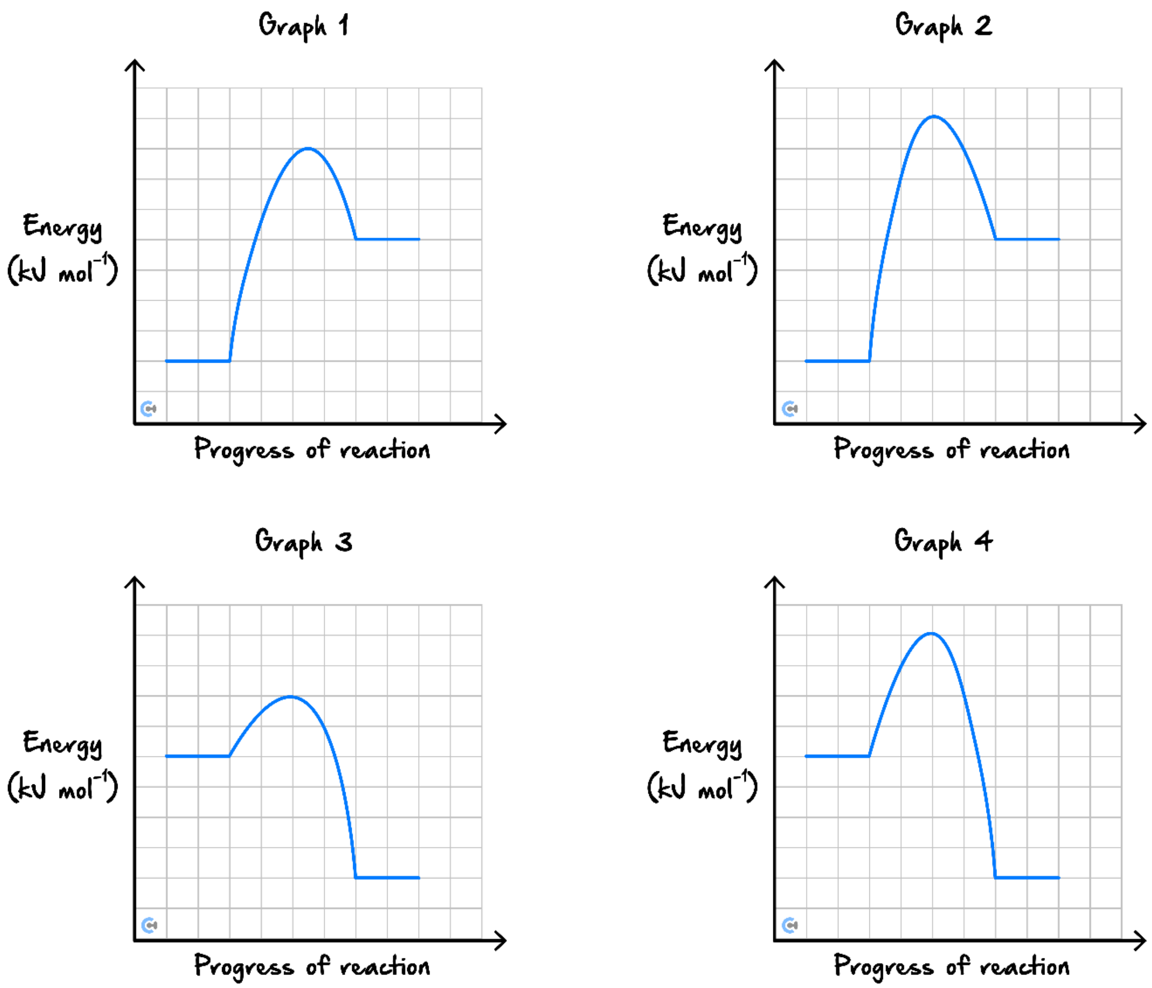
Question 72 (1 mark)

Inspired from VCAA Mathematics Exam 2022
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2022/2022chem-w.pdf

The graphs shown below are energy profiles for the following reaction.

$$A + B \leftrightharpoons C \qquad \Delta H < 0$$

The graphs represent the forward reaction, with and without a catalyst, and the reverse reaction, with and without a catalyst. All graphs are drawn to the same scale.



Which energy profile represents the reverse reaction without a catalyst?

A. Graph 1

B. Graph 2

C. Graph 3

D. Graph 4

Question	Correct answer	% A	% B	% C	% D	Comments
11	B	13	63	7	17	Since the forward reaction is exothermic, the products are at lower energy than the reactants – Graphs 3 and 4. It follows that the reverse reaction is endothermic, so the products are at higher energy than the reactants – Graphs 1 and 2. The presence of a catalyst lowers activation energy – Graphs 1 and 3. The profile for the reverse reaction without a catalyst is Graph 2.

Question 73 (1 mark)

Inspired from VCAA Mathematics Exam 2023
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2023/2023chemistry-w.pdf

Lignite is a type of brown coal. When lignite is completely combusted in a power station, 19.0 MJ/tonne of energy is released. The efficiency of the power station is 39%.

What mass of lignite is required to produce 42.0 MJ of usable energy in the power station?

A. 0.862 tonnes

B. 1.16 tonnes

C. 2.21 tonnes

D. 5.67 tonnes

17.	D	9	10	24	**57**	Since the power station is only 39% efficient, 42 MJ usable energy is only 39% of the total energy released by the lignite undergoing combustion. 42 MJ = 0.39 x total energy released from lignite. Total energy = 42 / 0.39 = 107.7 MJ *m*(lignite required) = 107.7 MJ / 19.0 MJ $tonne^{-1}$ = 5.67 tonne

Question 74 (1 mark)

Inspired from VCAA Chemistry Exam 2023
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2023/2023chemistry-w.pdf

Consider the following statements about coal seam gas and petroleum gas.

I. Coal seam gas and petroleum gas are both mixtures.
II. Coal seam gas and petroleum gas both combust to produce carbon dioxide.
III. Coal seam gas and petroleum gas are both fossil fuels.

Which of the above statements is correct?

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

9.	D	5	3	38	**54**	The main component of coal seam gas is a mixture of methane – 88 to 98% – with small amounts of other hydrocarbons. Petroleum gas, associated with crude oil, is also a mixture of lighter hydrocarbons. Both coal seam gas and petroleum gas are fossil fuels and produce CO_2 on combustion.

Space for Personal Notes

Use the following information to answer the two questions that follow.

Inspired from VCAA Chemistry Exam 2023
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2023/2023chemistry-w.pdf

A student investigated the viscosity of several biofuels.

The flow rate of each biofuel through a narrow glass tube was measured. The results are presented in the tables below.

Table 1: Flow rate ($mL\ min^{-1}$) of biodiesels produced using sodium hydroxide, NaOH (aq), catalyst

		Alcohol used in biodiesel production with NaOH catalyst	
		Methanol	**Ethanol**
Oil used in biodiesel production	Sunflower oil	4.8	4.4
	Canola oil	5.1	4.7

Table 2: Flow rate ($mL\ min^{-1}$) of biodiesels produced using potassium hydroxide, KOH (aq), catalyst

		Alcohol used in biodiesel production with KOH catalyst	
		Methanol	**Ethanol**
Oil used in biodiesel production	Sunflower oil	4.9	4.4
	Canola oil	4.8	4.6

Question 75 (1 mark)

How many independent variables are there in this investigation?

A. 1

B. 3

C. 4

D. 6

Solution Pending

Question 76 (1 mark)

Select the most valid conclusion that can be drawn from the stude

A. Biodiesels made from sunflower oil have a higher viscosity th

B. Biodiesels made from methanol have a lower viscosity than b

C. Biodiesels are unsuitable for use in cold climates because the

D. Biodiesels made using NaOH (aq) catalyst have a lower visc catalyst.

27.	B	17	**45**	19	18	The lower the flow rate of a biodiesel, the higher the viscosity; the higher the flow rate, the lower the viscosity. Using NaOH(aq) as a catalyst: The viscosity of canola oil is lower than the viscosity of sunflower oil for both methanol and ethanol. However, the viscosities of both sunflower oil and canola oil are lower when made from methanol, since the flow rates are higher than the flow rates using ethanol. Using KOH(aq) as a catalyst: Methanol: viscosity of canola oil is higher than the viscosity of sunflower oil Ethanol: viscosity of canola oil is lower than the viscosity of sunflower oil. Again, the viscosities of both sunflower oil and canola oil are lower when made from methanol since the flow rates are higher than the flow rates using ethanol. Biodiesels made from methanol have a higher flow rate, and hence a lower viscosity, than biodiesels made from ethanol. The relative suitability of biodiesels and petrodiesel in cold climates cannot be deduced from the results presented. The flow rate of the biodiesel made from sunflower oil and methanol is lower when NaOH is used (4.8) than it is when KOH is used (4.9). In this instance the viscosity of the biodiesel is higher when NaOH(aq) is used than when KOH(aq) is used.

Question 77 (1 mark)

Inspired from VCAA Chemistry Exam 2017
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2017/2017chem-w.pdf

A Year 12 Chemistry assignment requires students to quantitatively and qualitatively compare fossil fuels and biofuels.

Which one of the following investigations would be most appropriate for this comparison?

A. Use a bomb calorimeter to determine the heat of combustion for both fossil fuels and biofuels.

B. Interview car owners to determine what petrol price would make them consider using biofuels.

C. Produce biodiesel from vegetable oil and compare the viscosity of the biodiesel produced with that of a range of fossil fuels.

D. Find reliable information about the environmental impacts of producing fossil fuels and biofuels, and the amount of carbon dioxide produced per litre from the combustion of these fuels.

Question	% A	% B	% C	% D	% No Answer	Comments
19	17	1	11	71	0	It was necessary to select the option that would provide both quantitative and qualitative information.

Space for Personal No

Use the following information to answer the two questions that follow.

Inspired from VCAA Chemistry Exam 2017
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2017/2017chem-w.pdf

Four identical vehicle models, 1, 2, 3 and 4, were tested for fuel efficiency using LPG, petrol (unleaded, 91 octane), E10 (petrol with 10% ethanol added) and petrodiesel. Carbon dioxide, CO_2, emissions per litre of fuel burnt were also determined. The following table summarises the results.

Vehicle Model	**Fuel**	**Fuel consumption ($L/100\ km$)**	**CO_2 produced ($g\ CO_2/L$ of fuel)**
1	LPG	19.7	1665
2	Petrol	14.5	2392
3	E10	14.2	2304
4	Petrodiesel	9.2	2640

Question 78 (1 mark)

Using the information in the table above, which one of the following statements about petrodiesel is correct?

A. It has the highest energy content.

B. It has the poorest fuel efficiency.

C. It is a renewable energy source.

D. It has the lowest CO_2 emissions when burnt.

Question 79 (1 mark)

The use of which vehicle has the smallest impact on the environment, in terms of the grams of CO_2 produced per 100 km?

A. Vehicle Model 1

B. Vehicle Model 2

C. Vehicle Model 3

D. Vehicle Model 4

Question	% A	% B	% C	% D	% No Answer	Comments
13	78	16	3	3	0	
14	47	3	5	44	0	Impact on environment, i.e. $m(CO_2)$ produced per 100 km = fuel consumption (L/100 km) × $m(CO_2)$ per L of fuel The large number of students who selected option A overlooked the 100 km specification in the question.

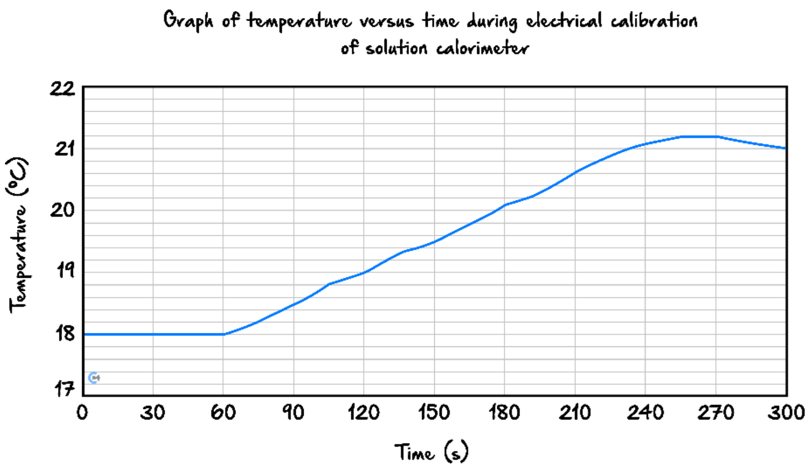
Space for Personal Notes

Use the following information to answer the two questions that follow.

Inspired from VCAA Chemistry Exam 2020
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2020/2020chem-w.pdf

A solution calorimeter containing 350 mL of water was set up. The calorimeter was calibrated electrically and the graph of the results is shown below.

Graph of temperature versus time during electrical calibration of solution calorimeter



The calorimeter was calibrated using a current of 2.7 A, starting at 60 s. The current was applied for 180 s and the applied voltage was 5.4 V.

Question 80 (1 mark)

What is the calibration factor for this calorimeter?

A. $125\ J\ °C^{-1}$

B. $820\ J\ °C^{-1}$

C. $847\ J\ °C^{-1}$

D. $875\ J\ °C^{-1}$

Solution Pending

Question 81 (1 mark)

The calibration factor of a bomb calorimeter was determined by connecting the calorimeter to a power supply. The calibration was done using 100 mL of water, 6.5 V and a current of 3.6 A for 4.0 minutes. The temperature of the water increased by 0.48°C during the calibration.

4.20 g of sucrose underwent complete combustion in the bomb calorimeter. The temperature of the 100 mL of water increased from 19.6°C to 25.8°C.

$$M(C_{12}H_{22}O_{11}) = 342\ g\ mol^{-1}$$

The experimental heat of combustion of pure sucrose, in joules per gram, is:

A. 5.9×10^6

B. 7.3×10^4

C. 1.7×10^4

D. 1.2×10^4

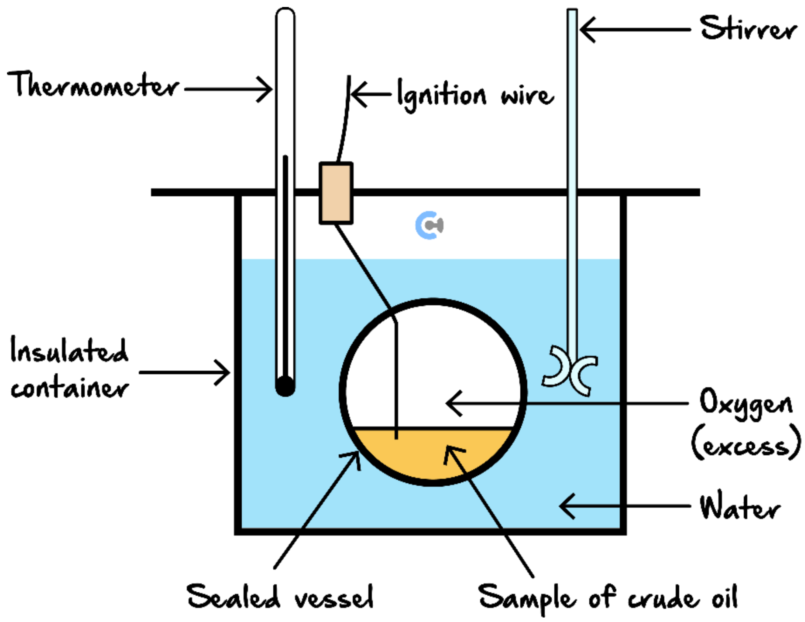
Qu.	%A	%B	%C	%D	% N/A	
26	14	22	51	12	2	Calorimeter constant = E / ΔT = VIt / ΔT = 6.5 × 3.6 × 4.0 × 60 / 0.48 = 1.17×10^4 J °C^{-1} Energy released by 4.20 g sucrose = 1.17×10^4 J °C^{-1} × 6.2 °C = 7.25×10^4 J Energy per gram of sucrose = 7.25×10^4 / 4.20 = 1.7×10^4 J g^{-1} Students who selected C had completed the first two steps accurately but did not proceed to divide by the mass of sucrose even though the unit 'joules per gram' was stated in the question.

Space for Personal Notes

Question 82 (1 mark)

Inspired from VCAA Chemistry Exam 2017
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2017/2017chem-w.pdf

The heat of combustion of a sample of crude oil is to be determined using a bomb calorimeter. All of the students in a class are given the same method to follow. The apparatus used by the students is shown below.



For this experiment, the students could maximise:

A. Precision by using a digital thermometer ± 0.2°C.

B. Validity by calculating the heat of combustion per mole.

C. Accuracy by taking samples from three different sources.

D. Uncertainty by having all students closely follow the same experimental procedure.

Question	% A	% B	% C	% D	% No Answer	Comments
23	49	18	28	5	0	Consider the options: • Option A – correct, since this removes the error inherent in reading a thermometer • Option B – incorrect, energy per mole is inappropriate because crude oil is a mixture • Option C – incorrect, accuracy is dependent on technique, not the oil source. Also, different sources may have significantly different compositions • Option D – incorrect, the uncertainty may be directly linked to the procedure followed

Space for Personal Notes

Question 83 (9 marks)

Inspired from VCAA Chemistry Exam 2023
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2023/2023chemistry-w.pdf#page=18

a. Propane is used as a fuel for barbeques.

i. Calculate the amount of energy released when 140.0 g of propane is completely combusted. (1 mark)

Question 3ai.

Marks	0	1	Average
%	0.3	0.7	0.7

Heat of combustion is 50.5 kJ g^{-1}

Therefore $50.5 \times 140 = 7.07 \times 10^3$ kJ (7.06×10^3 kJ was also a valid response).

Incorrect units such as kJ g^{-1} were commonly seen but could not be awarded marks.

ii. Write a thermochem ... marks)

Marks	0	1	2	Average
%	0.2	0.3	0.5	1.3

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ $\Delta H = -2220$ kJ mol^{-1} or -2220 kJ

Either kJ mol^{-1} or kJ were accepted as viable units for ΔH.

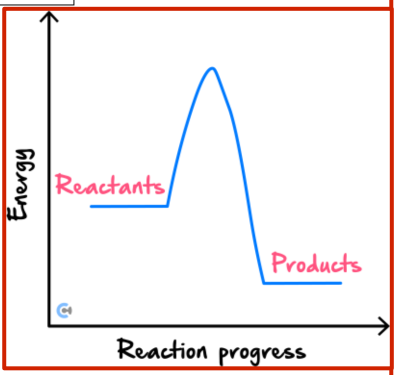
The first mark was awarded for a correctly balanced chemical equation with correct states.

The second mark was awarded for the correct ΔH value with correct units.

This question was well done, although some students were still attempting to use $\Delta H = -50.5$ kJ g^{-1}, which is not applicable for a thermochemical equation. Since the question explicitly stated at SLC, the states had to be (g) for propane and (l) for water, and this also was not always recognised.

iii. Sketch the energy profile for the complete combustion of propane on the axes provided below. (1 mark)

Marks	0	1	Average
%	0.2	0.8	0.8



The mark was awarded for the correct exothermic profile being shown.

iv. State how the energy profile for the **incomplete** combustion of propane would differ from the diagram you drew in **part a. iii.** Justify your answer. (2 marks)

Marks	0	1	2	Average
%	0.6	0.4	0.1	0.5

The first mark was awarded for recognising that the products of incomplete combustion needed to have a higher energy than shown for the complete combustion (but still below the reactants).

The second mark was awarded when the student identified this as being due to the incomplete oxidation of the reactants, which is the reason for less energy being released.

Students commonly tried to explain the reason for the energy difference as being due to the 'incomplete combustion' rather than incomplete oxidation, but as this term was already stated in the stem of the question, this was not an acceptable approach.

b. An equation for the complete combustion of ethanol, C_2H_5OH, is shown below.

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

96.0 g of ethanol completely combusts and the CO_2 produced is collected.

Calculate the volume of a tank required to store the captured CO_2 at 25.0°C and 100.0 kPa. (3 marks)

Marks	0	1	2	3	Average
%	0.1	0.1	0.2	0.6	2.3

The first mark was awarded for the correct calculation of n(ethanol) = 96.0/46.0 = 2.09 mol

The second mark was awarded for the correct calculation of n(CO_2) = 2 × 2.09 = 4.17 mol

The third mark was awarded for the correct calculation of the volume with units.

$$V(CO_2) = n \times V_m = 4.17\ mol \times 24.8 \frac{L}{mol} = 103\ L$$

Space for Personal Notes

Question 84 (10 marks)

Inspired from VCAA Chemistry Exam 2012
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2012/2012chem2-w.pdf#page=20

Methanol, CH_3OH, undergoes combustion according to the equation:

$$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$$

In an experiment to determine its suitability as a fuel, a sample of methanol underwent complete oxidation in a bomb calorimeter.

The calorimeter was first calibrated by passing a current through an electric heater placed in the water surrounding the reaction vessel. A potential of 5.25 Volts was applied for 3.00 minutes. The measured current was 1.50 Amperes and the temperature of the water and reaction vessel increased by 0.593°C.

a.

i. Determine the calibration constant, in $kJ\ °C^{-1}$, for the calorimeter and its contents. (2 marks)

Question 6ai.

Marks	0	1	2	Average
%	11	22	67	1.6

$E = VIt$
$= 5.25 \times 1.50 \times 3.00 \times 60$
$= 1.42 \times 10^3$ J

Calorimeter constant $= E \div \Delta T$
$= 1.42 \times 10^3 \div 0.593$
$= 2.39 \times 10^3\ J\ °C^{-1}$
$= 2.39\ (kJ\ °C^{-1})$

One mark was awarded for accurately calculating the energy, and the second mark for accurately calculating the calorimeter constant (calibration factor), in kJ $°C^{-1}$, from the energy.

The most common error was not converting the energy from joules to kilojoules, or assuming that the unit of electrical energy in the *VIt* calculation was joules.

A student then used this calorimeter to determine the molar heat of the combustion of methanol.

0.934 g of methanol was placed in the reaction vessel and excess oxygen was added. An electric ignition heater provided the energy required to initiate the combustion reaction. On this occasion, the temperature of the water increased by 8.63°C.

ii. Use this experimental data to determine the value of ΔH for the combustion of methanol given by the following equation.

$$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$$

Include appropriate

Marks	0	1	2	3	4	5	Average
%	16	10	11	21	28	15	2.8

$n(CH_3OH)$ reacting $= 0.934 \div 32.0$
$= 0.0292$ mol

Energy released by methanol $= CC \times \Delta T$
$= 2.39 \times 8.63$
$= 20.6$ kJ

Energy from 1 mol $CH_3OH = 20.6 \div 0.0292$
$= 706$ kJ

$\Delta H = -2 \times -706$ kJ mol^{-1}
$= -1.41 \times 10^3$ kJ mol^{-1} (-1.41×10^6 J mol^{-1})

One mark each was awarded for

- accurately calculating $n(CH_3OH)$
- accurately calculating the energy released using the calorimeter constant from part ai.
- accurately calculating the energy for 2 mol of CH_3OH
- including the negative sign and giving the answer to three significant figures
- correct units on ΔH.

This question was generally well handled; however, some common errors included

- using the molar enthalpy of combustion from the Data Book, rather than the temperature change during combustion and the calibration constant, to calculate the energy released by the methanol
- not determining the energy for 2 mol CH_3OH
- inconsistent significant figures and/or units.

b. The value of ΔH, calculated using the enthalpy of combustion provided in the data book, is different from the value of ΔH calculated from the experimental data provided in **part a. ii.**

Provide a reason for this difference. (1 mark)

Question 6b.

Marks	0	1	Average
%	66	34	0.4

The calculated energy released in combustion is lower due to loss of heat/energy to the surroundings during combustion.

The better responses indicated that a lower temperature change during combustion due to loss of heat would lead to a lower calculated energy released.

Students should avoid stating learned responses that are not relevant in this context; for example, as the question states that 'methanol underwent complete combustion', responses such as 'incomplete combustion' were not appropriate.

Statements such as 'the Data Book gives the energy for one mole of methanol' indicated that some students were comparing the ΔH for the reaction with the molar enthalpy of combustion from the Data Book rather than with 'the value of ΔH, calculated using the enthalpy of combustion provided in the Data Book'.

Statements such as 'the conditions of the experiment may not have been the same as those used to determine the values in the Data Book' were not accepted because there was no indication of why or how this would **reduce** the calculated energy released.

Methanol is suitable for use in a micro fuel cell that is used to power laptop computers and similar small electrical items. The methanol is oxidised to carbon dioxide and water. The half-equation for the anode reaction is:

$$CH_3OH(l) + H_2O(l) \rightarrow 6H^+(aq) + CO_2(g) + 6e^-$$

c.

i. Write a balanced half-equation for the cathode reaction. (1 mark)

Question 6ci.

Marks	0	1	Average
%	54	46	0.5

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

Given that students would have been well exposed to the half-equation for the reduction of oxygen in fuel cells, performance on this question was expected to be stronger. Students should know that reduction occurs at the cathode. The acidic electrolyte was implied in the given half-equation for oxidation.

ii. A finely divided platinum/ruthenium catalyst is used in this cell.

Give a reason why it is important to have a catalyst that will significantly reduce the activation energy for the cell reaction. (1 mark)

Question 6cii.

Marks	0	1	Average
%	83	17	0.2

Either of

- a fast rate of reaction is necessary for efficient current flow/instantaneous current in the computer
- since the computer is being used at room temperature, the catalyst will increase the reaction rate to an acceptable level in the fuel cell.

Some logical indication of the 'benefit/advantage' of a faster reaction rate in the context of the laptop computer was required. Most students simply explained, often very well, why or how a catalyst reduces the activation reaction and increases reaction rate, but did not give any explanation of why it is important to have a catalyst in the context of laptop computers.

Some responses suggested that the presence of the catalyst would increase the voltage of the cell. Just as catalysts do not affect ΔH values or the values of equilibrium constants, they also do not affect the voltage generated in a fuel cell. Some students provided good responses in terms of power generated.

Space for Personal Notes

Question 85 (5 marks)

Inspired from VCAA Chemistry Exam 2022
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2022/2022chem-w.pdf#page=21

Researchers have identified pathways that will enable the production of the biofuel 2-methylpropan-1-ol from proteins. 2-methylpropan-1-ol can be used in petrol engines. 2-methylpropan-1-ol has a heat of combustion of 36.1 $kJ\ g^{-1}$.

a. Compare the energy content of octane and 2-methylpropan-1-ol. Explain the difference. (2 marks)

Marks	0	1	2	Average
%	14	76	10	1.0

One mark was awarded for stating that the energy content of octane (47.9 kJ g^{-1}) was higher than the energy content of 2-methylpropan-1-ol (36.1 kJ g^{-1}).

The second mark was awarded for recognising that 2-methylpropan-1-ol contains oxygen and is therefore already partially oxidised.

A significant number of students incorrectly tried to claim that the longer carbon chain of octane delivered a greater energy per gram. This is contrary to what is shown in the Data Book, where longer carbon chains clearly show a decrease in the heat of combustion values.

b. A small fuel burner containing 2.36 g of 2-methylpropan-1-ol was placed directly underneath a beaker containing 500.0 g of water at standard laboratory conditions (SLC).

Calculate the maximum temperature that the water could reach if the contents of the fuel burner underwent complete combustion. (3 marks)

Marks	0	1	2	3	Average
%	31	11	17	41	1.7

The first mark was awarded for the correct calculation of the energy released.

Energy released = 2.36 × 36.1 = 85.2 kJ

The second mark awarded for the correct calculation of ΔT.

E = mcΔT, therefore ΔT = E / mc

= 85.2 x 103 / (500 × 4.18)

= 40.8 °C

The third mark was awarded for the correct calculation of the final temperature.

Max. Temp = 25.0 + 40.8

= 65.8 / 66 °C (339 K)

Consequential marks were awarded when students were able to show clear calculations.

Space for Pe

Question 86 (6 marks)

Inspired from VCAA Chemistry Exam 2022
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2022/2022chem-w.pdf

Corn makes up a large proportion of people's diet in some parts of the world.

Air-popped popcorn is made from whole corn kernels. The nutrition content of a particular type of air-popped popcorn is provided in Table 1.

Table 1

	Average Quantity per 100 *g*
Protein	10.7 *g*
Fat	5.0 *g*
Carbohydrates	78.7 *g*

a. Using the information provided in Table 1, calculate the energy content of air-popped popcorn in kilojoules per gram. (2 marks)

Question 6a.

Marks	0	1	2	Average
%	11	27	61	1.5

One mark was awarded for the correct calculation of the energy released per 100 g.

Energy = 10.7 x 17 + 5.0 x 37 + 78.7 x 16

= 181.9 + 185.0 + 1259.2

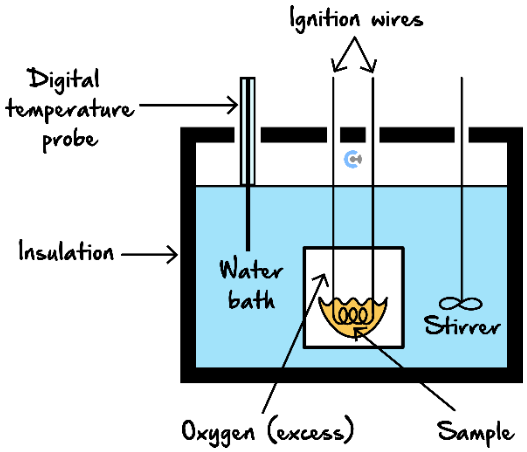
= 1.63×10^3 kJ

The second mark was awarded for the correct calculation of energy per gram.

Energy per gram = $1.63 \times 10^3 / 100$

= 16.3 (kJ g^{-1})

The energy content of food can be determined experimentally using a bomb calorimeter similar to the one shown in the diagram below.



A 1.50 g sample of air-popped popcorn is placed in the bomb calorimeter. The initial temperature of the water is 22.2°C and the final temperature is 25.7°C. Assume that the air-popped popcorn is fully combusted. The calibration factor for the bomb calorimeter is 6.54 kJ °C^{-1}.

b. Using the calibration factor provided, calculate the energy released by the air-popped popcorn in kilojoules per gram. (2 marks)

Marks	0	1	2	Average
%	28	21	51	1.2

ΔT = 3.5°C

One mark was awarded for the correct calculation of energy present in a 1.50 g sample.

Energy = CF x ΔT

= 6.54 x 3.5

= 22.9 kJ

The second mark was awarded for the correct calculation of energy released per gram.

Energy per gram = 22.9 / 1.50

= 15.3 (kJ g^{-1})

c. Assume that the calorimeter was accurately calibrated so that heat loss from the calorimeter was accounted for in the calibration factor.

State **two** factors that may contribute to a difference in the energy content that was calculated using the methods in **part a.** and **part b**. (2 marks)

Marks	0	1	2	Average
%	81	18	1	0.2

The two marks available for this question could have been obtained from any two of the following choices that clearly showed why the value for 6a. was higher than 6b.

- Nutrition label based on average quantities. Popcorn is not a homogeneous substance. Sample used in the bomb calorimeter could actually be less energy dense.
- The popcorn may contain water that reduces the amount of combustible material and therefore lowers the calculation of the energy released per g.
- Only one sample of popcorn was analysed using the bomb calorimeter. Need to analyse multiple samples to determine the reliability of the results. Possible that the average result of the multiple samples would be closer to the calculation in 6a.
- Mass lost during transfer from balance.
- If more water was present in the calorimeter than when it was calibrated, then a lower temperature change would occur and produce less of a temperature rise when popcorn is burnt.

Responses that were not accepted were ones in which students stated that 'heat was lost from the calorimeter' or 'poor insulation'. Given that the question stem clearly indicated that the calorimeter was 'accurately calibrated', this means that students could not use these simplistic approaches to address this question.

Consequential marks were awarded when students were able to show clear reasoning if their calculated values in 6a. and 6b. showed the opposite trend.

Question 87 (6 marks)

Inspired from VCAA Chemistry Exam 2020
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2020/2020chem-w.pdf

Methane gas, CH_4, can be captured from the breakdown of waste in landfills. CH_4 is also a primary component of natural gas. CH_4 can be used to produce energy through combustion.

a. Write the equation for the incomplete combustion of CH_4 to produce carbon monoxide, CO. (1 mark)

Marks	0	1	Average
%	25	75	0.8

$2CH_4(g) + 3O_2(g) \rightarrow 2CO(g) + 4H_2O(l)$ or

b. A Bunsen burner is use … 0.485 g of CH_4 raises the tempera …

Calculate the percentag …)

Marks	0	1	2	3	Average
%	20	19	17	45	1.9

Energy from CH_4 = 0.485 g x 55.6 kJ g^{-1} = 27.0 kJ

Energy absorbed by water = 4.18 J g^{-1} K^{-1} x 350.0 x (32.3 – 20.0)
= 1.80x10^4 J
= 18.0 kJ

Energy lost to environment = 27.0 – 18.0 = 9.0 kJ

% energy lost = (9.0 / 27.0) x 100 = 33.3 %

One mark was awarded for calculating the energy from CH_4.

One mark was awarded for calculating the energy absorbed by water.

One mark was awarded for working out the percentage of energy loss.

This question was generally handled well, although some students incorrectly converted the mass of water using the density value of 0.997 g ml^{-1}.

Students also used a wide variety of approaches such as calculating the expected temperature of the water rise of 18.3°C and then producing the energy lost via (18.5 – 12.3) / 18.5 yielding the 34% energy loss. A number of students did not access the Data Booklet and so were unable to establish the energy generated from the methane.

c. Compare the environmental impact of CH_4 obtained from landfills to the environmental impact of CH_4 obtained from natural gas. (2 marks)

Marks	0	1	2	Average
%	37	44	19	0.8

Similarity – methane from both sources

- Both produce atmospheric carbon dioxide through combustion.
- Methane from both sources contains small amounts of nitrogen and sulfur; combustion of natural gas leads to the formation of acidic oxides such as SO_x and NO_x.

Difference – landfill versus natural gas

- Methane from landfill can be produced renewably, whereas methane from natural gas releases stored carbon.
- Methane from landfill is more carbon neutral, methane from natural gas increases atmospheric CO_2 levels.
- Obtaining methane from natural gas via fracking causes additional significant environmental damage, whereas when obtaining methane from a landfill the damage has already been done in the formation of the landfill.
- Landfill gases contain less methane and release more CO_2 (for the same amount of energy generated), natural gas contains more methane and releases comparatively less CO_2.
- Methane captured from landfill and used as a source on energy may have a positive impact as it is a more potent greenhouse gas than CO_2.
- CH_4 from landfill is more easily collected compared to fracking/sourcing methane from fossil fuels.

Two marks were awarded for any two valid comparison points.

Students often made two very good statements, but more frequently than not these did not compare the environmental impact between the two sources. The key word 'compare' in the question means that a direct comparison is required to obtain full marks.

Space for Personal

Question 88 (8 marks)

Inspired from VCAA Chemistry Exam 2011
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2011chem2-w.pdf#page=14

A solution calorimeter was calibrated by passing an electric current through the heating coil at a potential difference of 5.10 volts. This caused the water in the calorimeter to increase in temperature by 9.50°C. The calibration factor for this calorimeter was previously determined to be 0.354 kJ °C^{-1}.

a. Use the calibration factor to determine the electrical charge, in coulombs, that passed through the heating coil. (2 marks)

Marks	0	1	2	Average
%	21	42	37	1.2

E added to calorimeter $= CF \times \Delta H$
$= 0.354 \times 9.50$
$= 3.36$ kJ

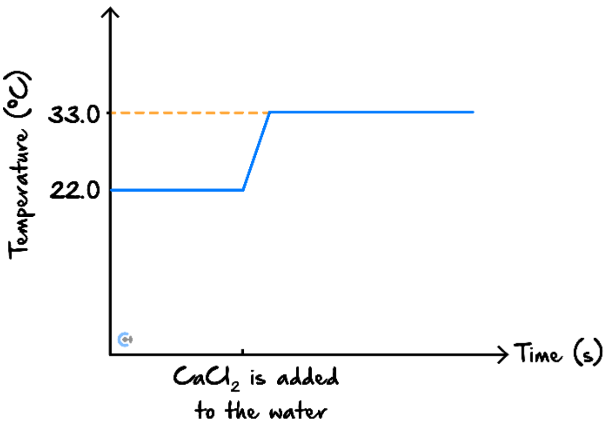
Electrical energy $E = VIt$, and electric charge $Q = It$. Therefore, $E = QV$ so
$Q = E/V$
$= 3.36 \times 10^3$ (J)/5.10
$= 659$ (C)

The most common answer to this question was 0.659. This indicated that most students did not recall that in the relationship $Q = E/V$, electrical energy is in joules and did not convert kJ to J. A significant number of students divided the temperature change by the calibration factor or vice versa.

This calorimeter is then used to determine the enthalpy change for the dissolution of one mol of anhydrous calcium chloride, $CaCl_2$, in water.

$$CaCl_2(s) \rightarrow CaCl_2(aq)$$

6.038 g of solid anhydrous calcium chloride, $CaCl_2$, was added to the water. The mixture was stirred until all the solids had dissolved. The temperature was monitored before and after the addition of the calcium chloride. The results are shown in the graph below.



b.

i. Is this reaction exothermic or endothermic? Explain your answer. (2 marks)

3bi.

Marks	0	1	2	Average
%	20	10	70	1.5

Exothermic – temperature of the water increased, indicating that energy was released

Overall performance on this question was quite strong. Students who received only one mark generally did not refer to the increase in temperature. Those who did not receive any marks generally considered, incorrectly, that the data was consistent with an endothermic reaction.

ii. Use the calibration factor to calculate the enthalpy change for the dissolution of 1.00 mol of $CaCl_2(s)$. The molar mass of $CaCl_2 = 111.1\ g\ mol^{-1}$. (4 marks)

3bii.

Marks	0	1	2	3	4	Average
%	32	13	15	20	20	1.9

$\Delta T = 33.0 - 22.0 = 11.0$ °C

Common errors included:

- using the energy value calculated in part a. or multiplying the calibration factor by 9.50, the temperature rather than the temperature change deduced from the graph provided
- not calculating the n($CaCl_2$) using the supplied data (6.038 g)
- not providing the 'sign' for ΔH
- not giving the final answer to three significant figures and leaving out or providing incorrect units.

There was evidence that some students struggled to assimilate the data provided in part bi.

Question 89 (4 marks)

Inspired from VCAA Chemistry Exam 2019
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2019/2019chem-w.pdf#page=40

Climate change has been identified as a threat to the environment. Fossil fuels are recognised as a significant contributor to the rise in carbon dioxide levels in the atmosphere. The replacement of fossil fuels as an energy source represents a challenge and has been the focus of research for a number of years. However, there are different opinions/views about the suitability of using a biofuel, such as biodiesel, as a replacement for fossil fuels. Some extracts representing different viewpoints are shown in the box below.

1. 'Biofuels are fuels that are produced from biological sources such as trees, plants or microorganisms. They are carbon neutral because they do not result in fossil carbon being released into the atmosphere.'
2. 'All good solutions are needed in the energy transition required to achieve Europe's climate goals - and sustainable biofuels are critical to transport decarbonisation.'
3. 'Many scientists view biofuels as inherently carbon-neutral: they assume the carbon dioxide (CO_2) plants absorb from the air as they grow completely offsets, or "neutralises," the CO_2 emitted when fuels made from plants burn.'
4. '..... our analysis affirms that, as a cure for climate change, biofuels are "worse than the disease."'
5. '…. although some forms of bioenergy can play a helpful role, dedicating land specifically for generating bioenergy is unwise.'

Sources: 'Carbon NeutralEarth, <www.carbonneutralearth.com/biofuels.php>; 2Sejersgård Fanø, quoted in Erin Voegele, 'EU reaches deal on REDII, sets new goals for renewables', Biodiesel Magazine, 15 June 2018, <www.biodieselmagazine.com>; 3 & 4John DeCicco, 'Biofuels turn out to be a climate mistake - here's why', The Conversation, 5 October 2016, <http://theconversation.com/au>; Andrew Steer and Craig Hanson, 'Biofuels are not a green alternative to fossil fuels', The Guardian, 30 January 2015, www.theguardian.com/au

Using the chemistry t … and the sustainability of using …

Marks	0	1	2	3	4	Average
%	20	15	28	26	12	2

Valid discussion points included:

Carbon

- For:
  - CO_2 is absorbed/used by the crops/plants (used to produce the biodiesel)
  - more carbon neutral as biodiesel produces less new CO_2 than other fuels
- Against:
  - use of petroleum diesel (or other fuels) to produce biodiesel – a large amount of energy is required to produce biodiesel fuel from soy crops, as energy is needed for sowing, fertilising, harvesting, transporting and processing crops
  - clearing land for crops by burning trees releases CO_2 and destroys habitats
  - there is less photosynthesis when land is cleared
  - burning biomass directly emits a bit more carbon dioxide than fossil fuels for the same amount of generated energy

Sustainability of using biodiesel as a fuel

- For:
  - plants can be produced/grown in a short period of time
  - can be made from waste vegetable oils, animal fats, or restaurant grease
  - releases fewer toxic chemicals if spilled or released to the environment/many by-products are biodegradable
  - biodiesel produces less soot (particulate matter)/carbon monoxide/unburned hydrocarbons/sulfur dioxide
  - crops (that produce oil) can be grown in many places
  - can use second-generation technologies to convert material such as crop residues into bioenergy and avoid competition for land

- Against:
  - some regions are not suitable for oil producing crops
  - uses crops/land that could be used for food/food production
  - the excess use of fertilisers can result in soil erosion and land pollution
  - nitrous oxide released from fertilisers could have a greater (300 times more) global warming effect than carbon dioxide
  - the use of water to produce more crops can put pressure on local water resources

Using biodiesel as a fuel for transport

- For:
  - produces less toxic pollutants and greenhouse gases than petroleum diesel
  - reduces dependence on foreign oil reserves as it is domestically produced
  - can be used in any diesel engine with little or no modification to the engine or the fuel system
  - higher flashpoint, which makes it less combustible and therefore safer to handle, store and transport
  - the lubricating property of the biodiesel may lengthen the lifetime of engines
- Against:
  - higher viscosity/not suitable for use in low temperatures
  - biodiesel fuel is more expensive than petroleum diesel fuel.

Two marks were awarded for at least two valid points for, two valid points against, or one valid point for and one valid point against carbon neutrality related to biodiesel. The same was awarded for sustainability related to biodiesel.

OR

One mark for at least one valid point (for or against) regarding sustainability related to biodiesel.

One mark for at least one valid point (for or against) regarding carbon neutrality related to biodiesel.

One mark for at least one valid point (for or against) use of biodiesel as a fuel.

One mark for a second valid point (for or against) one of carbon neutrality, sustainability, use as a fuel.

Sixty-five per cent of students obtained two or more marks, although many did not fully explain why biofuels were carbon neutral or renewable. Some who tried to incorporate the media statements did so without really making headway in explanation. There was evidence that time pressure affected some students.

Space for Pe

CONTOUR EDUCATION

Website: contoureducation.com.au | **Phone:** 1800 888 300 | **Email:** hello@contoureducation.com.au

VCE Chemistry ¾

Free 1-on-1 Support

Be Sure to Make The Most of These (Free) Services!

- Experienced Contour tutors (45+ raw scores, 99+ ATARs).
- For fully enrolled Contour students with up-to-date fees.
- After school weekdays and all-day weekends.

1-on-1 Video Consults	Text-Based Support
➤ Book via bit.ly/contour-chemistry-consult-2025 (or QR code below). ➤ One active booking at a time (must attend before booking the next).	➤ Message +61 440 137 304 with questions. ➤ Save the contact as “Contour Chemistry”.

Booking Link for Consults
bit.ly/contour-chemistry-consult-2025

Number for Text-Based Support
+61 440 137 304