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VCE Chemistry ¾
AOS 1 Revision I [1.11]
Workbook

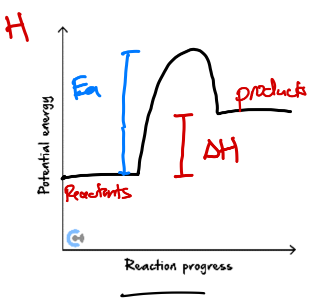
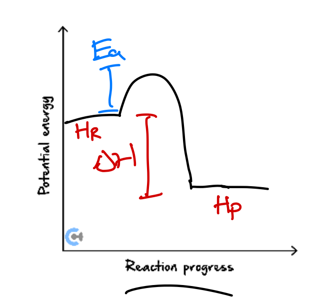
Outline:

Section A: [1.1] – Thermochemistry (18 Marks)

Sub-Section: Recap

Cheat Sheet

[1.1.1] – Identify delta H & E_a in endothermic/exothermic energy profile diagrams

Endothermic reactions	Exothermic reactions
[Absorb]/[Release] thermal energy.	[Absorb]/[Release] thermal energy.
Energy conversion: thermal → chem	Energy conversion: chem → thermal
Change in enthalpy (ΔH) sign is: [positive]/[negative]	Change in enthalpy (ΔH) sign is: [positive]/[negative]
	

- Energy profile diagram axis labels:
  - Vertical axis: enthalpy ($kJ\ mol^{-1}$ | kJ)
  - Horizontal axis: reaction progress

[1.1.2] – Identify differences between complete & incomplete combustion & write their thermochemical combustion equations

Complete combustion	Incomplete combustion
Produces $CO_2 + H_2O$	Produces $(CO \text{ or } C) + H_2O$
[More]/[Less] oxygen used overall.	[More]/[Less] oxygen used overall.

- Method of balancing: CHO
- State of fuels: never aqueous.
- Thermochemical equations include ΔH & states.
- The state of water in thermochemical equations is liquid when using the databook.

[1.1.3] – Apply changing equations to thermochemical equations & energy profile diagrams

- When reversing the equation, the:
  - ΔH: swap sign (+/−)
  - E_a:
- When multiplying the equation by some coefficient:
  - ΔH value: multiplied by same coefficients
  - ΔH units: $kJ\ mol^{-1}$ → kJ

Let's Walkthrough Together!

Question 1 (5 marks) **Walkthrough.**

CHO

Butane can be found in gas canisters for barbeques.

a. Write the thermochemical equation for the complete combustion of butane. (2 marks) **[1.1.2]**

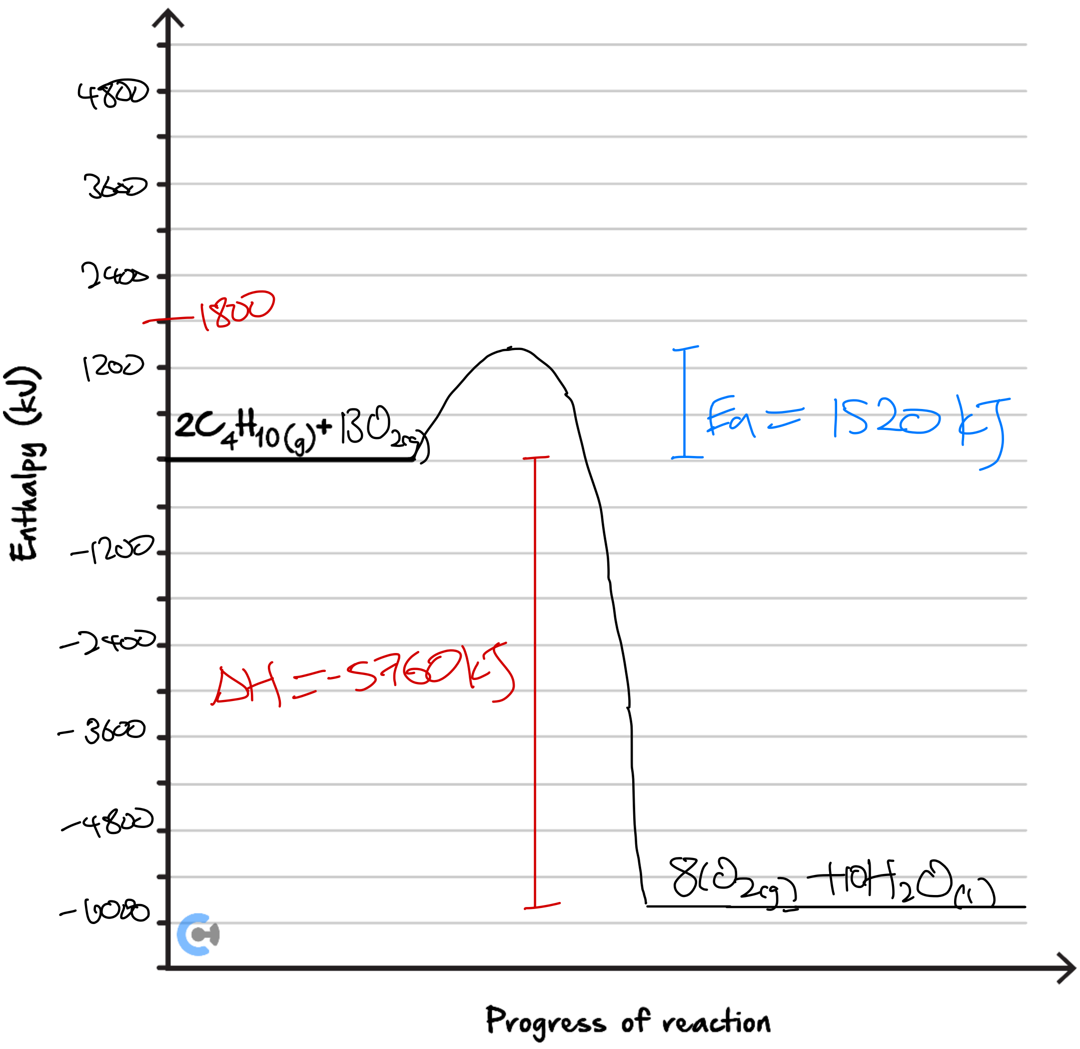
$C_4H_{10(g)} + \frac{13}{2}O_{2(g)} \rightarrow 4CO_{2(g)} + 5H_2O_{(l)}$ $\Delta H = -2880\ kJ\ mol^{-1}$

$2C_4H_{10(g)} + 13O_{2(g)} \rightarrow 8CO_2 + 10H_2O$ $\Delta H = -5760\ kJ$

It is known that the activation energy for the reaction is $760\ kJ\ mol^{-1}$ of butane completely combusted.

Ea = 1520

b. On the axes provided below, sketch the energy profile diagram for the complete combustion of two moles of butane. Indicate on the diagram the ΔH and the activation energy. (3 marks) **[1.1.1] [1.1.3]**



Sub-Section: Questions

INSTRUCTION: 11 Marks. 11 Minutes Writing.

Question 2 (3 marks)

a. Write the thermochemical equation for the complete combustion of ethanol. (2 marks) **[1.1.2]**

$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l) \quad \Delta H = -1370\ kJ\ mol^{-1}$

b. The thermochemical equation for the reaction between hydrogen gas and chlorine gas to form hydrogen chlorine gas is shown below:

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g) \qquad \Delta H = -185\ kJ\ mol^{-1}$$

Alternatively, hydrogen chlorine gas can decompose and produce hydrogen gas and chlorine gas. Write the balanced thermochemical equation for this reaction. (1 mark) **[1.1.3]**

$2HCl(g) \rightarrow H_2(g) + Cl_2(g) \quad \Delta H = +185\ kJ$

Question 3 (1 mark) **[1.1.1]**

In the combustion of methane, the activation energy corresponds to:

A. The energy required to convert products back into reactants.

B. The energy difference between reactants and products.

C. The energy needed to break the bonds in the reactants.

D. The total heat released in the reaction.

Question 4 (1 mark) **[1.1.1]**

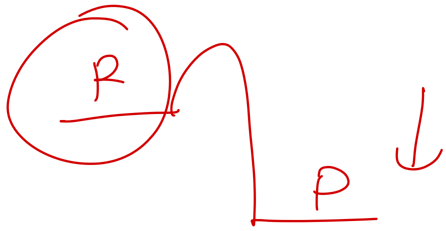
In the combustion of butane, what happens to the energy levels of reactants and products?

A. Products have higher energy than reactants.

B. Reactants and products have the same energy.

C. Reactants have higher energy than products.

D. Energy difference is zero as no energy is exchanged.



Question 5 (1 mark) **[1.1.2]**

Write the equation number for each of the equations which shows the incomplete combustion of methane.

- Equation 1: $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
- Equation 2: $2CH_4(g) + 3O_2(g) \rightarrow 2CO(g) + 4H_2O(l)$
- Equation 3: $CH_4(g) + O_2(g) \rightarrow C(s) + 2H_2O(l)$
- Equation 4: $2CH_4(g) + \frac{7}{2}O_2(g) \rightarrow CO_2(g) + CO(g) + 4H_2O(l)$

2, 3, 4
___

Space for Personal Notes

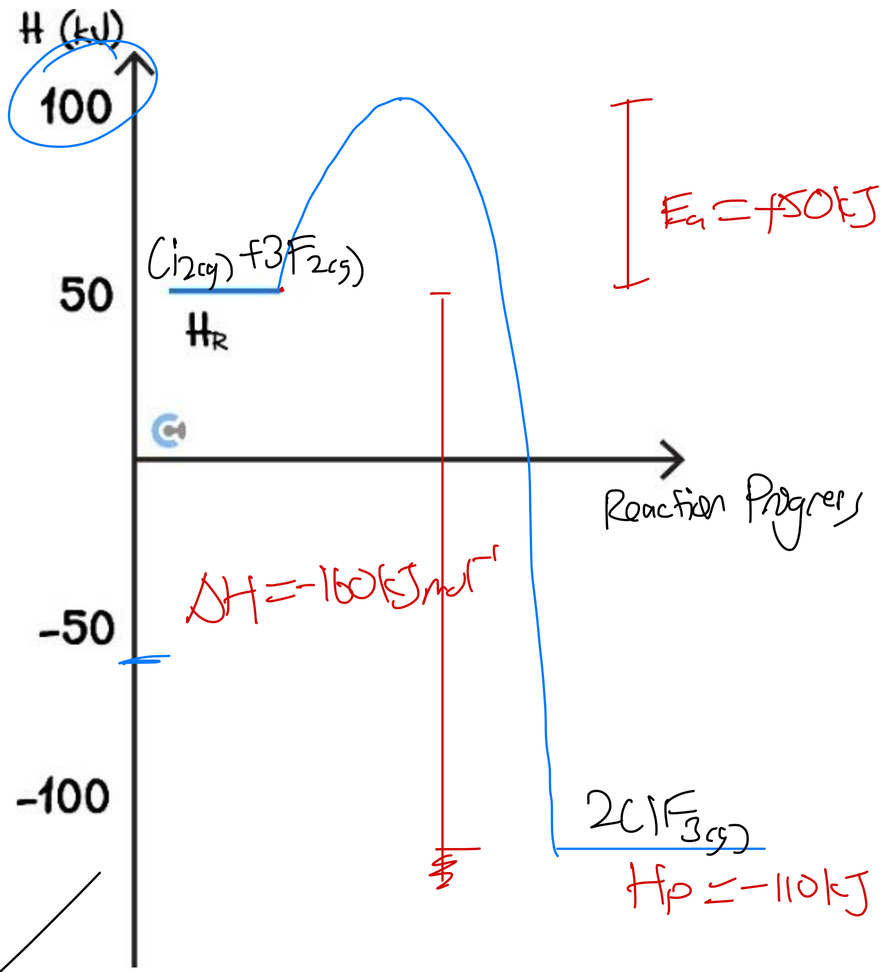
Question 6 (4 marks)

Chlorine trifluoride, ClF_3, is produced by reacting chlorine and fluorine gases according to the following:

$$Cl_2(g) + 3F_2(g) \rightarrow 2ClF_3(g) \qquad \Delta H = -160\ kJ\ mol^{-1}$$

The activation energy for the forward reaction is 50 $kJ\ mol^{-1}$.

a. Sketch an energy profile for the reaction on the axes below. Mark the enthalpy of the products (H_P), the change in enthalpy (ΔH) and the activation energy (E_a) of the reaction. (2 marks) **[1.1.1]**



b. For the reaction $4ClF_3(g) \rightarrow 2Cl_2(g) + 6F_2(g)$, determine: (2 marks) **[1.1.3]**

ΔH	E_a
$\Delta H = +320\ kJ$	$E_a = 420\ kJ$

Question 7 (1 mark) **[1.1.2]**

Ethanal (CH_3CHO) rapidly decomposes at 500°C according to the following equation:

$$CH_3CHO(g) \rightarrow CH_4(g) + CO(g)$$

The activation energy for the forward reaction is $190\ kJ\ mol^{-1}$. The activation energy for the reverse reaction is $210\ kJ\ mol^{-1}$.

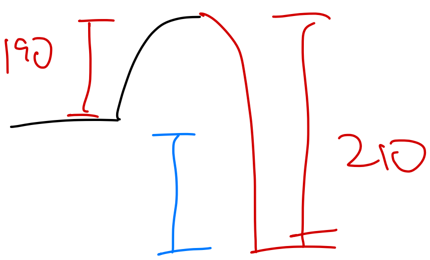
The enthalpy change (in $kJ\ mol^{-1}$) of the forward reaction is:

A. -400

B. -20

C. $+20$

D. $+400$



Check off any learning objectives that obtained full marks from the "Contour Check" booklet!

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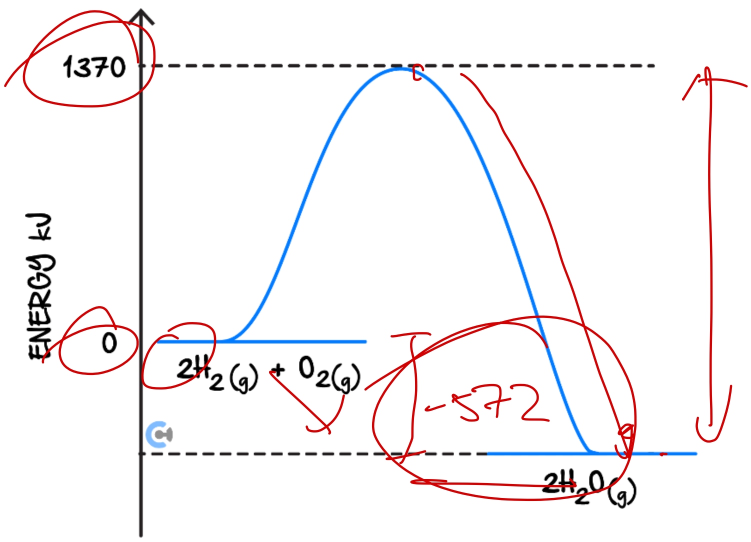
Sub-Section: Additional

Question 8 (1 mark) **[1.1.1]**

Shown below is some of the energy profile information for the reaction described by the equation:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$



When the bonds between oxygen and hydrogen atoms form in 2 *mol* H_2O molecules:

A. 1370 *kJ* of energy is absorbed.

B. 286 *kJ* of energy is released.

C. 572 *kJ* of energy is absorbed.

D. 1942 *kJ* of energy is released.

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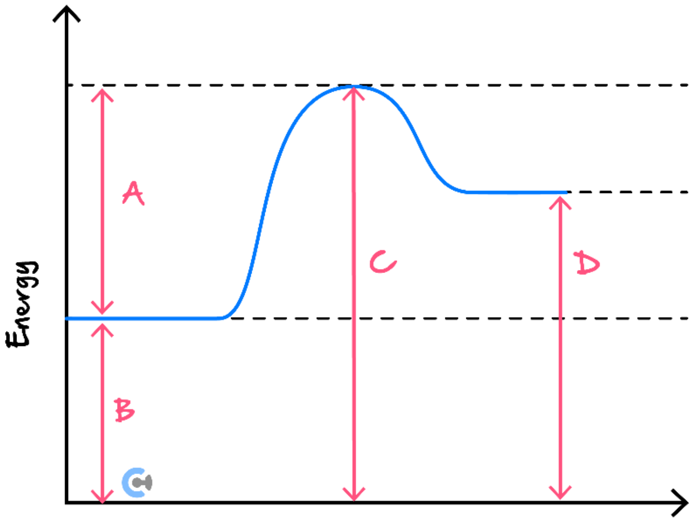
Question 9 (1 mark) **[1.1.3] [1.1.1]**

An energy profile for a reversible chemical reaction is represented below.



According to this profile, the activation energy of the reverse reaction is equal to:

A. D

B. C – B

C. A – B

D. C – D

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Section B: [1.2] - Energy Calculations (22 Marks)

Sub-Section: Recap

Cheat Sheet

[1.2.1] - Apply $q = \Delta H \times n$ to energy released

- To convert between mass and moles, $n = \frac{m}{M}$.
- To find energy released by a fuel, use the Data Book, and the formula $q = \Delta H \times n$.

[1.2.2] - Apply ΔH in kJ/mol, kJ/g and kJ/mL to energy calculations

- The heat of combustion ΔH value can be calculated in the following ways:

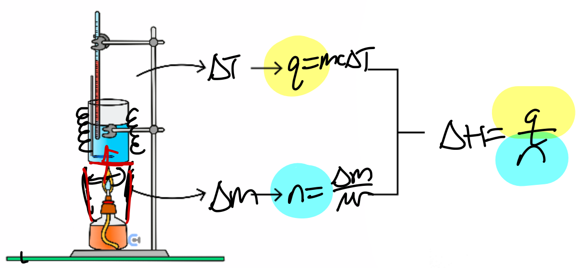
ΔH (kJ/mol)	ΔH (kJ/g)	ΔH (kJ/mL)
$\Delta H = \frac{q}{n}$	$\Delta H = \frac{q}{m}$	$\Delta H = \frac{q}{V}$

- Density used to convert between mass and volume: $d = \frac{m}{V}$

[1.2.3] - Apply $q = mc\Delta T$ to find energy absorbed

- To measure the energy absorbed by water, it can be calculated by $q = mc\Delta T$, whereby the specific heat capacity of water is $4.18\ J\ g^{-1}\ °C^{-1}$.

[1.2.4] - Calculate ΔH experimentally



[1.3.1] - Identify changes to minimise heat loss & calculate percentage efficiency

- Percentage Efficiency:

$$\% \, eff = \frac{\text{experimental}}{\text{theoretical}} \times 100\%$$

- When finding theoretical ΔH from experimental ΔH, [multiply]/[divide] by percentage efficiency.
- Systematic error links to [accuracy]/[precision] is how close to the value.
- Random error links to [accuracy]/[precision] which is how close to each other.
- To minimise heat loss:
  - bring flame closer
  - windshield / foil
  - insulate sides of beaker
  - Add lid

$$x = \frac{y}{z}$$

- Direct Proportionality: $x \propto y$
  - If x doubles, y ________________.
- Inverse Proportionality: $x \propto \frac{1}{z}$
  - If x doubles, z ________________.

Let's Walkthrough Together!

$d = \frac{m}{V}$

gas law $n = V/V_m$

Question 10 (3 marks) **[1.2.1] [1.2.2] Walkthrough.**

The density of octane is known to be $0.703\ g\ mL^{-1}$. A sample of $12.0\ L$ of octane is combusted at SLC.

Find the energy released in MJ.

$\Delta H = \frac{q}{n}$ $q = \Delta H \times n$

$m(C_8H_{18}) = dV = 0.703\ g/mL \times 12000\ mL = 8436\ g$

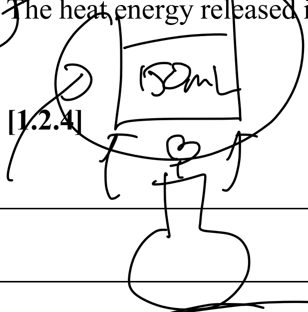
$n(C_8H_{18}) = \frac{m}{M} = \frac{8436}{8\times12+18} = 74\ mol$

$q = \Delta H \times n = 5470\ kJ/mol \times 74\ mol = 404780\ kJ$

$= 405\ MJ$

Question 11 (4 marks) **Walkthrough.**

A sample of ethanol in a spirit burner which initially weighs $198.30\ g$ undergoes complete combustion. After the combustion is complete, it is found that the spirit burner weighs $196.09\ g$. The heat energy released is used to heat $150\ mL$ of water at SLC. The temperature of the water rises to 89.60°C.



a. Calculate the experimental heat of combustion of ethanol in kJ/mol. (3 marks) [1.2.4]

$\Delta H = \frac{q}{n}$

$q = mc\Delta T = 150\ g \times 4.18 \times (89.6 - 25)$

$q = 40504\ J = 40.5\ kJ$

$198.3\ g \rightarrow 196.09\ g$

$\Delta m = 198.3 - 196.09 = 2.21\ g$

$n(C_2H_5OH) = \frac{m}{M} = \frac{2.21}{46} = 0.048\ mol$

$\Delta H = \frac{q}{n} = \frac{40.5\ kJ}{0.048\ mol} = -843\ kJ/mol$

b. Find the percentage efficiency. (1 mark) **[1.3.1]**

$\frac{843}{1370} \times 100\% = 61.5\%$

Space for Personal Notes

Sub-Section: Questions

INSTRUCTION: 13 Marks. 15 Minutes Writing.

Question 12 (1 mark) **[1.2.1]**

Calculate the amount of energy released when 1.39 *mol* of ethanol is combusted, providing your answer in *kJ*.

$q = \Delta H \times n = 1370\ kJ\ mol^{-1} \times 1.39\ mol = 1.90 \times 10^3\ kJ$

Question 13 (1 mark) **[1.2.1]**

Calculate the mass of glucose required to completely combust to produce 290 *kJ* of energy.

$\Delta H = \frac{q}{n}$ $n = \frac{q}{\Delta H} = \frac{290\ kJ}{2840\ kJ/mol} = 0.102\ mol$

$m(C_6H_{12}O_6) = n \times M = 0.102 \times 180 = 18.4\ g$

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Question 14 (3 marks)

Kerosene is extracted from crude oil from fractional distillation and can be combusted to release energy.

A sample of kerosene undergoes complete combustion at SLC to release 120 kJ of energy.

a. Find the volume, in mL, of kerosene that was combusted. (1 mark) **[1.2.2]**

$\Delta H = \frac{q}{V}$ $V = \frac{q}{\Delta H} = \frac{120\ kJ}{37\ kJ/mL} = 3.24\ mL$

$\approx 3.2\ mL$

1250 mL 25

b. The energy is used to heat up a 1.25 L sample of water at SLC. Find the final maximum temperature reached by the water. (2 marks) **[1.2.3]**

$q = mc\Delta T$ $\Delta T = \frac{q}{mc} = \frac{120 \times 10^3\ J}{1250\ g \times 4.18} = 23\ °C$

$T_f = 48.0\ °C$

Question 15 (3 marks) **[1.2.1] [1.2.2]**

$d = \frac{m}{V}$ $\Delta H = \frac{q}{n}$

The density of methanol is 0.791 g/mL. Find the volume of methanol required to release 40.2 kJ of energy.

$n = \frac{q}{\Delta H} = \frac{40.2\ kJ}{726} = 0.0554\ mol$

$m(CH_3OH) = n \times M = 0.0554 \times 32 = 1.77\ g$

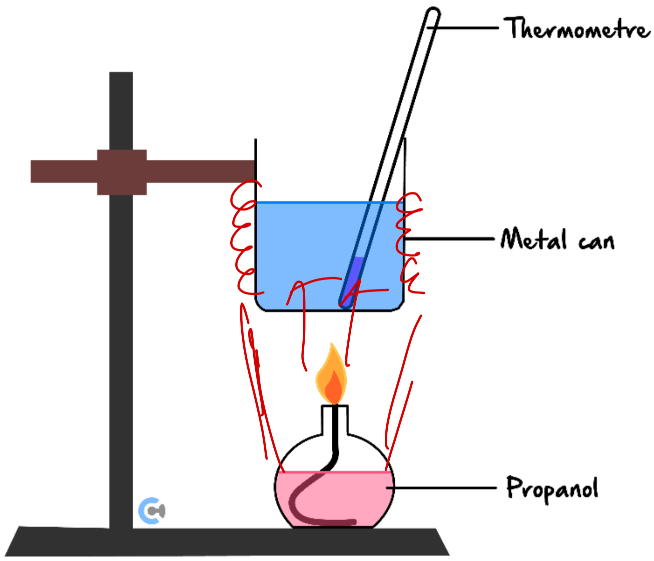
$V = \frac{m}{d} = \frac{1.77\ g}{0.791\ g/mL} = 2.24\ mL$

Space for Personal Notes

Question 16 (5 marks)

0.572 g of propanol (C_3H_7OH) undergoes complete combustion in a spirit burner. The heat energy released is used to heat 100 mL of water. The temperature of the water rises from 26.0°C to 49.8°C.

The setup used is shown below:



a. Calculate the experimental heat of combustion of propanol in $kJ\ mol^{-1}$. (3 marks) **[1.2.4]**

$\Delta H = \frac{q}{n}$ $q = mc\Delta T = 100 \times 4.18 \times (49.8 - 26)$

$= 9948\ J = 9.948\ kJ$

$n(C_3H_7OH) = \frac{m}{M} = \frac{0.572}{36+8+16} = 0.009533\ mol$

$\Delta H = \frac{q}{n} = \frac{9.948\ kJ}{0.009533\ mol} = 1043\ kJ/mol$

$= -1.04 \times 10^3\ kJ\ mol^{-1}$

b. The calculated heat of combustion in **part a.** is only 45.0% efficient.

i. Find the theoretical heat of combustion of the propanol. (1 mark) **[1.3.1]**

$-1043 \times \frac{100}{45} = 2319$ kJ mol^{-1}

$= -2.32 \times 10^3$ kJ mol^{-1}

ii. Which of the following changes to the experiment could be made in order to produce a more accurate result? (1 mark) **[1.3.1]**

I. Using a glass beaker in place of the metal can.
II. Loosely wrapping the assembled equipment in aluminium foil.
III. Placing a lid on the vessel containing the water.

A. I or II only

B. I or III only

C. II or III only

D. I, II or III

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Check off any learning objectives that obtained full marks from the "Contour Check" booklet!

Sub-Section: Additional

Question 17 (1 mark) **Additional Question.**

If 0.108 moles of a certain fuel are burnt and 30.5 kJ are released, what is the chemical formula of this fuel likely to be?

A. Methanol

B. Ethane

C. Hydrogen

D. Octane

Question 18 (1 mark) **Additional Question.**

The complete combustion of 0.12 mol of a particular fuel is found to require 0.42 mol of oxygen gas.

The fuel is likely to be:

A. Methane

B. Ethane

C. Ethanol

D. Butane

Space for Personal Notes

Section C: [1.3] - Gas Calculations & Stoichiometry (20 Marks)

Sub-Section: Recap

Cheat Sheet

[1.3.2] – Apply $n = V/V_m$ to calculate volumes of gas at SLC

- Gas Law at SLC Equation/Formula:

  $$n = \frac{V}{V_m}$$

- Molar Volume at SLC value: $24.8\ L/mol$

[1.3.3] – Apply m-m, m-v, v-v stoichiometry to calculation questions with equations

- Stoichiometry calculations are done using the coefficients as $\frac{unknown}{known}$.
- Mass-Volume stoichiometry steps:

  1. Find the moles of substance using: $n = \frac{m}{Mr}$.
  2. Find the moles of other substances using: stoichiometric ratios.
  3. Find the volume of other substances using: $V = n \times V_m$.

- Volume-Volume stoichiometry conditions:
  - Constant temperature.
  - Constant pressure.
  - Both substances are gas.

[1.3.4] – Identify limiting reagents

- Finding limiting reagents steps:

  1. Find amount (mol) of each reactant.
  2. Divide each reactant by stoichiometric ratio.
  3. Limiting reagent has less amount.

- When finding the amount of products formed, the amount (in moles) of the [limiting reagent]/[excess reagent] is used.
- Amount of excess reagent left over:

  $$n(\text{excess})_{\text{leftover}} = n(\text{excess})_{\text{initial}} - n(\text{excess})_{\text{reacted}}$$

Let's Walkthrough Together!

Question 19 (2 marks) **[1.3.2] [1.3.3] Walkthrough.**

When an acid is split on baking soda, the following reaction can occur:

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

Given that 10.0 *L* of carbon dioxide was observed to be formed, find the mass of hydrochloric acid which must have reacted.

$n(CO_2) = \frac{V}{V_m} = \frac{10}{24.8} = 0.403\,mol$

$n(HCl) = \frac{1}{2} n(CO_2) = \frac{1}{2} \times 0.403 = 0.2016\,mol$

$m(HCl) = n \times M = 0.2016 \times (1+35.5)$

$= 7.36\,g$

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Sub-Section: Questions

INSTRUCTION: 11 Marks. 12 Minutes Writing.

Question 20 (2 marks)

For the following two scenarios, assume everything occurs at SLC.

a. Find the mass (g) of 4.00 L of chlorine gas (Cl_2). (1 mark) **[1.3.2]**

$n(Cl_2) = \frac{V}{V_m} = \frac{4}{24.8} = 0.161\ mol$

$m(Cl_2) = n \times M_r = 0.161\ mol \times (35.5 \times 2)$

$= 11.45\ g$

b. Find the volume that 13.0 g of hydrogen gas occupies. (1 mark) **[1.3.2]**

f hydrogen gas occupies. (1 mark) [1.3.2]

$n(H_2) = \frac{m}{M} = \frac{13}{2} = 6.5\ mol$

$V(H_2) = n \times V_m = 161.2\ L$

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Question 21 (5 marks)

There is 16.5 g of hexane available in the following equation:

$$C_6H_{14}(l) + \frac{19}{2}O_2(g) \rightarrow 6CO_2(g) + 7H_2O(l)$$

a. Calculate the volume of carbon dioxide that would be evolved at SLC. (2 marks) **[1.3.2] [1.3.3]**

$n(C_6H_{14}) = \frac{m}{M} = \frac{16.5}{72+14} = 0.192 \text{ mol}$

$n(CO_2) = 6n(C_6H_{14}) = 1.15 \text{ mol}$

$V(CO_2) = n \times V_m = 1.15 \text{ mol} \times 24.8 \text{ L/mol} = 28.5 \text{ L}$

b. Calculate the volume of water vapour produced at SLC. (1 mark) **[1.3.3]**

$0\ L$

c. What is the mass of oxygen gas that reacts? (2 marks) **[1.3.3]**

$n(O_2) = \frac{19}{2} n(C_6H_{14}) = 0.192 \times \frac{19}{2} = 1.82 \text{ mol}$

$m(O_2) = n \times M_r = 1.82 \times 32 = 58.3 \text{ g}$

Space for Personal Notes

Question 22 (4 marks)

Ammonia can be produced by nitrogen gas and hydrogen gas during the Haber process. The reaction is shown below:

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

A sample of 250 mL of nitrogen gas is mixed with 600 mL of hydrogen gas at SLC.

a. Determine the excess reagent. (1 mark) **[1.3.4]**

Limiting reagent: Hydrogen gas
Excess reagent: Nitrogen gas

b. Assuming the reaction goes to completion, find the total volume of gases present after the reaction is completed and is returned to SLC. (3 marks) **[1.3.3] [1.3.4]**

$$V(NH_3) = \frac{2}{3}V(H_2) = 400\ mL$$

$$V(N_2)_{reacted} = \frac{1}{3}V(H_2) = 200\ mL$$

$$V(N_2)_{leftover} = V_i - V_r = 250\ mL - 200\ mL = 50\ mL$$

$$V(total) = V(NH_3) + V(N_2)_{leftover} = 400\ mL + 50\ mL = 450\ mL$$

Check off any learning objectives that obtained full marks from the "Contour Check" booklet!

Space for Personal Notes

Sub-Section: Additional

Question 23 (2 marks) **[1.2.1] [1.3.2]**

Find the amount of energy released when 34.6 L of butane (C_4H_{10}) is combusted at SLC.

$n(C_4H_{10}) = \frac{V}{V_m} = \frac{34.6}{24.8} = 1.395\ mol$

$q = \Delta H \times n = 2880\ kJ/mol \times 1.395\ mol$

$= 4018\ kJ$

Question 24 (5 marks)

The complete combustion equation for propane at SLC is shown below:

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

a. Calculate the energy released by the combustion of 0.750 mol of propane. (1 mark) **[1.2.1]**

$q = \Delta H \times n = 2220\ kJ/mol \times 0.75$

$= 1665\ kJ$

b. Calculate the volume of carbon dioxide, measured at SLC, produced for every 200 kJ of energy released. (2 marks) **[1.2.1] [1.3.2] [1.3.3]**

$n(C_3H_8) = \frac{q}{\Delta H} = \frac{200\ kJ}{2220\ kJ/mol} = 0.09009\ mol$

$n(CO_2) = 3n(C_3H_8) = 0.270\ mol$

$V(CO_2) = n \times V_m = 0.27 \times 24.8 = 6.70\ L$

c. Calculate the energy released when 2.50 g of water is produced. (2 marks) **[1.3.3]**

$$n(H_2O) = \frac{2.50}{18.0} = 0.14\ mol$$

$$n(C_3H_8) = \frac{1}{4}n(H_2O) = 0.035\ mol$$

Space for Personal Notes

Section D: [1.4] - Calorimetry (15 Marks)

Sub-Section: Recap

Cheat Sheet

[1.4.1] - Calculate the Calibration Factor via Electrical and Chemical Calibration ($CF = E/\Delta T$)

- Calorimeters are used to minimise heat loss.
- Heat is transferred directly to water.

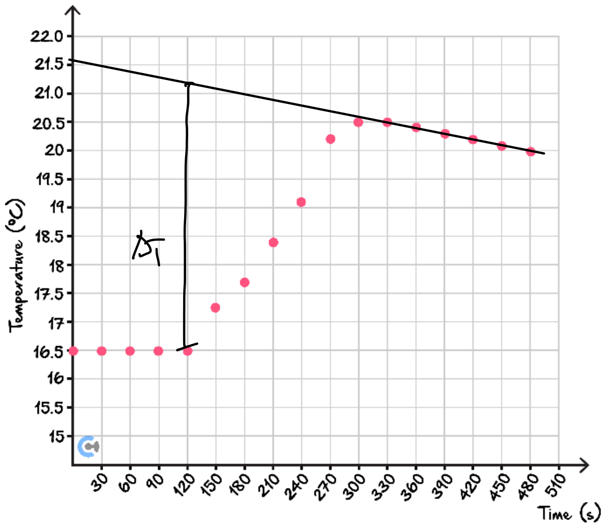
Electrical Calibration	Chemical Calibration
E=VIt	E=ΔH×n or ΔH×m

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

- Calorimetry Calculation Steps:
  1. Find energy (chemical/electrical) ($E = VIt$ or $E = \Delta H \times n$).
  2. Find CF (CF = E/ΔT).
  3. Use CF (E=CF×ΔT).
  4. ΔH= E/m.

[1.4.3] - Apply Temperature-Time Graphs to Calorimetry

- Find ΔT by extrapolating back.
- For the following temperature-time graph, the temperature change is as labelled:



- If the calorimeter has poor insulation, it has a [higher]/ [lower] calibration factor.

CF = E/ΔT

Let's Walkthrough Together!

Question 25 [1.4.1] [1.4.2] Walkthrough.

$\Delta H = \frac{q}{m}$

A solution calorimeter was calibrated by reacting 0.053 *mol* of nitric acid (HNO_3) $\Delta H = -21.30\ kJ/g$ at 20.00°C. The temperature of the water in the calorimeter increased to 23.50°C during the calibration.

This calorimeter was then used to determine the heat content of a sample of Doritos. 25.00 *g* of Doritos were reacted in the calorimeter and the temperature of the water in the calorimeter rose by 4.9°C. Calculate the energy content of the Doritos in $kJ\ g^{-1}$.

① $m(HNO_3) = n \times M = 0.053 \times (1+14+3\times16) = 3.34\ g$

$q = \Delta H \times m = 21.3\ kJ/g \times 3.34\ g = 71.1\ kJ$

② $CF = \frac{E}{\Delta T} = \frac{71.1\ kJ}{3.5°C} = 20.3\ kJ\ °C^{-1}$

$E = CF \times \Delta T = 20.3\ kJ\ °C^{-1} \times 4.9°C = 99.6\ kJ$

$\Delta H = \frac{E}{m} = \frac{99.6\ kJ}{25\ g} = 3.98\ kJ\ g^{-1}$

$= 4.0\ kJ\ g^{-1}$

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Sub-Section: Questions

INSTRUCTION: 9 Marks. 9 Minutes Writing.

Question 26 (1 mark) **[1.4.1]**

A bomb calorimeter was calibrated using a constant current of 3.40 A for 5.00 minutes. The voltage was 3.85 V. The temperature increased from 19.5°C to 22.1°C.

Find the calibration factor.

$CF = \frac{E}{\Delta T} = \frac{VIt}{\Delta T} = \frac{3.85 \times 3.4 \times 5 \times 60}{22.1 - 19.5} = 1510 \, J \, °C^{-1}$

$= 1.5 \, kJ \, °C^{-1}$

Question 27 (5 marks)

A strip of zinc weighing 25.0 g is added to excess copper (II) sulfate, which reacts according to the following reaction:

$$Cu(SO_4)_2(aq) + Zn(s) \rightarrow Zn(NO_3)_2(aq) + Cu(s) \quad \Delta H = -115 \, kJ \, mol^{-1}$$

The temperature of the system increases from 28.3°C to 35.7°C.

a. Find the calibration factor in $kJ \, °C^{-1}$. (2 marks) **[1.4.1]**

$n(Zn) = \frac{m}{M} = \frac{25}{65.4} = 0.383 \, mol$

$q = \Delta H \times n = 115 \times 0.383 = 44 \, kJ$

$CF = \frac{E}{\Delta T} = \frac{44 \, kJ}{(35.7 - 28.3)°C} = 5.94 \, kJ \, °C^{-1}$

$= 5.9 \, kJ \, °C^{-1}$

A sample of 30.4 g ammonium nitrate is then dissolved in the calibrated calorimeter according to the following equation:

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

When this occurs, the temperature decreases from 30.0°C to 28.1°C.

b. Using the calibration factor obtained in **part a.**, find the change in enthalpy of the dissolution of ammonium nitrate in water in $kJ\ mol^{-1}$. (3 marks) **[1.4.2]**

$E = CF \times \Delta T = 5.94\ kJ/°C \times (30 - 28.1)°C = 11.3\ kJ$

$n(NH_4NO_3) = \frac{m}{M} = \frac{30.4}{28+4+48} = 0.380\ mol$

$\Delta H = \frac{E}{n} = \frac{11.3\ kJ}{0.380\ mol} = 29.7\ kJ\ mol^{-1}$

$= +30\ kJ\ mol^{-1}$

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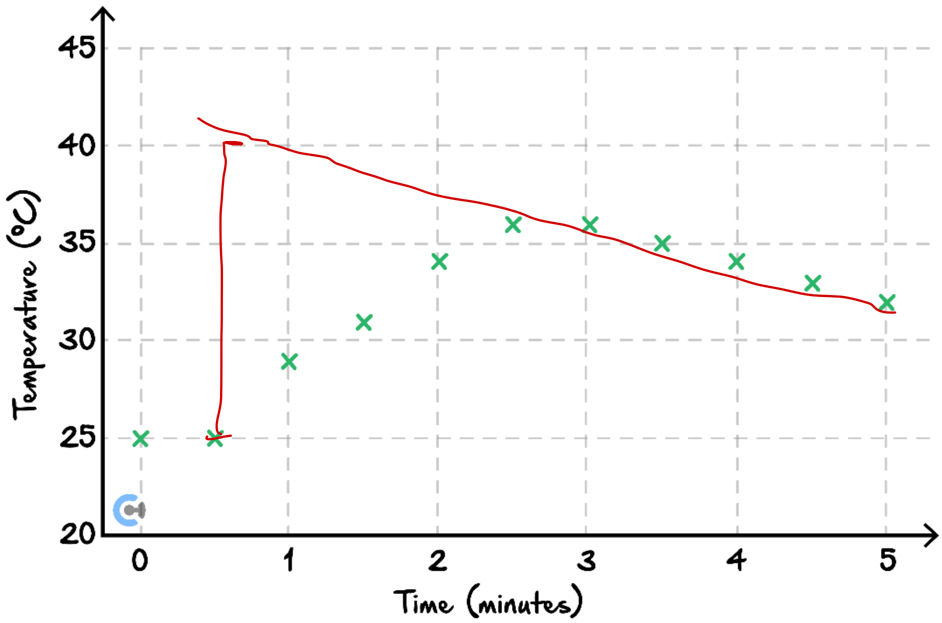
Question 28 (3 marks) **[1.4.3]**

To more accurately find the calibration factor of a calorimeter, Jayden plots the following temperature-time graph. He reacts some nitrogen dioxide (NO_2), which is known to have a change in enthalpy of $-15.29\ kJ/g$.



Find the calibration factor, if 2.00 mol of nitrogen dioxide is reacted.

$\Delta T = 15°C$ 93.8 $kJ\ °C^{-1}$

Check off any learning objectives that obtained full marks from the "Contour Check" booklet!

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Sub-Section: Additional

Question 29 (6 marks)

Sarah is investigating calorimeters and plays around with one having hydrogen gas.

a. The calorimeter is calibrated starting at SLC by passing 7.50 V at a current of 3.20 A for 2.30 minutes. The temperature rises to 32.0°C. Find the calibration factor. (1 mark) **[1.4.1]**

$$CF = \frac{E}{\Delta T} = \frac{VIt}{\Delta T} = \frac{7.5 \times 3.2 \times 2.3 \times 60}{32-25} = 473\ J/^\circ C$$

b. A sample of hydrogen gas (H_2) is completely combusted at SLC in the calorimeter, whereby the temperature is seen to increase to 47.0°C.

i. Find the mass of hydrogen gas which has been combusted. (2 marks) **[1.2.1]**

$$E = CF \times \Delta T = 473\ J/^\circ C \times (47-25) = 10409\ J = 10.409\ kJ$$

$$\Delta H = \frac{E}{n} \quad n = \frac{E}{\Delta H} = \frac{10.409\ kJ}{141\ kJ/g} = 0.074\ g$$

ii. Find the volume of hydrogen gas that was present in mL. (2 marks) **[1.3.2]**

$$n(H_2) = \frac{m}{M} = \frac{0.074\ g}{2} = 0.0369\ mol$$

$$V(H_2) = V_m \times n = 24.8\ L/mol \times 0.0369\ mol = 0.915\ L = 915\ mL$$

c. It turns out that as Sarah was in a rush, she misread the voltage in **part a.** during calibration, and when she did the calculations herself, she used a voltage of 1.50 V instead. Describe the effect this has on the volume of gas that she obtains compared to your answer in **part b. ii.** (1 mark) **[1.4.1]**

As the voltage is lower, the calibration factor is lower. This decreases the energy released by the hydrogen gas, which decreases the volume of gas obtained.

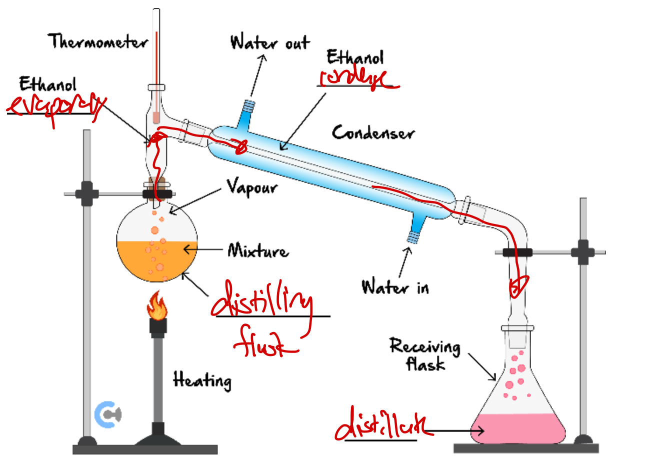
Section E: [1.5] - Fuels (25 Marks)

Sub-Section: Recap

Cheat Sheet

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

- Biogas: Comprised of CH_4 and $CO_2(g)$.
  - Formation: anaerobic respiration by bacteria of organic materials.
- Bioethanol: Comprised of C_2H_5OH.
  - Formation: fermentation of glucose with help of yeast.
  - Equation: $C_6H_{12}O_6(aq) \xrightarrow{yeast} 2C_2H_5OH_{(aq)} + 2CO_{2(g)}$
- Biodiesel: Comprised of FAME (fatty acid methyl ester).
  - Formation: transesterification reaction of plant/animal fats and oils.
- **Distillation Process**: Mixture is heated to target temp.
- **Target Temperature**: Temperature between two substance's boiling points.
- During the distillation of the ethanol and water mixture, [ethanol]/[water] evaporates first.



- **Purpose of Distillation**: increases efficiency upon combustion of ethanol as less water is present.

[1.5.2] - Identify & Explain Differences Between Fossil Fuels & Biofuels with Reference to Renewability, Heat of Combustion & Carbon Neutrality

- Renewable fuel can be replenished by natural processes within a relatively short period time.
- A fuel which already has some oxygens in the molecular formula is partially oxidise.
- This results in a [higher]/[lower] heat of combustion.
- Biogas, bioethanol and biodiesel are considered to be **carbon neutral** as the CO_2 released upon use is previously absorbed via photosynthesis.
- However, they are not 100% carbon-neutral due to transporting and farming.

[1.5.3] - Write Cellular Respiration & Photosynthesis Equations

- Cellular respiration is the process by which humans obtain energy.
- Cellular Respiration equation:

$$C_6H_{12}O_{6(aq)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(l)}$$

- Photosynthesis equation:

$$6CO_{2(g)} + 6H_2O_{(l)} \xrightarrow[chlorophyll]{sunlight} C_6H_{12}O_{6(aq)} + 6O_{2(g)}$$

1.5.4] - Calculate Energy Obtained from Foods & Compare the Energy Values Between Carbohydrates, Proteins, and Fats

- Energy obtained from foods can be calculated by the formula: $q = \Delta H \times m$
- Humans [can]/[cannot] obtain energy from cellulose. (fibre)
- Fats have the [highest]/[lowest] energy content of all food classes because it is [more]/[less] partially oxidised.

Sub-Section: Question Set A

INSTRUCTION: 9 Marks. 9 Minutes Writing.

Question 30 (1 mark) **[1.5.3]**

Write the balanced equation that shows how plants obtain glucose.

$6CO_2(g) + 6H_2O(l) \xrightarrow[\text{chlorophyll}]{\text{sunlight}} C_6H_{12}O_6(aq) + 6O_2(g)$

Question 31 (7 marks)

a. Compare the environmental impact of CH_4 obtained from landfills to the environmental impact of CH_4 obtained from natural gas, with reference to green chemistry principles. Use **Item 26** (**ii**) of the Data Book. (2 marks) **[1.5.1]**

Methane from landfills (biogas), is made from anaerobic breakdown of organic materials by bacteria. ∴ less environmental impact & relates to green chemistry principle 'Use of renewable feedstocks

On the other hand, methane from natural gas forms over millions of years ∴ non-renewable

b. Octane can also be compared to bioethanol.

i. State the process by which octane can be obtained from crude oil. (1 mark) **[1.5.1]**

fractional distillation

ii. Explain why bioethanol is considered to be 'carbon neutral' but octane from crude oil is not. (2 marks) **[1.5.2]**

Bioethanol is considered 'carbon neutral' as CO_2 released upon combustion is offset by CO_2 absorbed via photosynthesis. However, crude oil CO_2 was absorbed millions of years ago ∴ not carbon neutral.

iii. Compare the amount of energy released if an equal mass of bioethanol and octane is combusted. Explain the reasoning for this difference. (2 marks) **[1.5.2]**

Bioethanol is partially oxidised due to oxygen, which results in less energy released for the same mass combusted when compared to octane.

Question 32 (1 mark) **[1.5.4]**

The human body cannot obtain any energy from the polysaccharide cellulose. This is because:

A. Cellulose is not present in any of the foods we eat.

B. The gut cannot absorb the molecules produced from the digestion of cellulose.

C. The molecules produced from the digestion of cellulose are unable to be oxidised in human body cells.

D. The human body lacks the enzymes required to digest cellulose.

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Sub-Section: Question Set B

INSTRUCTION: 9 Marks. 9 Minutes Writing.

Question 33 (5 marks)

Biothanol and biodiesel are two biofuels that can be compared.

a. How they are formed is compared.

i. Explain how biodiesel is made. (1 mark) **[1.5.1]**

Transesterification of fats and oils from plants and animals.

ii. Explain how bioethanol is formed. Write any equation(s) that are relevant. (3 marks) **[1.5.1]**

Fermentation of glucose in the presence of yeast.

$C_6H_{12}O_6(aq) \xrightarrow{yeast} 2C_2H_5OH(aq) + 2CO_2(g)$.

Ethanol is then separated from water through distillation, where ethanol is evaporated and forms the distillate.

b. Which of the following statements accurately distinguishes between bioethanol and biodiesel based on their feedstock? (1 mark) **[1.5.1]**

A. Bioethanol is exclusively produced from animal fats, while biodiesel is produced from plant sugars.

B. Both bioethanol and biodiesel are primarily produced from fossil fuels.

C. Bioethanol is typically produced from plant sugars or starches, while biodiesel is made from vegetable oils or animal fats.

D. Bioethanol and biodiesel are both derived from natural gas.

Question 34 (1 mark) **[1.5.1]**

What is the primary advantage of using biogas over bioethanol and biodiesel?

A. Biogas production requires no water.

B. Biogas can be produced from a wide variety of organic wastes, including agricultural waste, manure, municipal waste, and plant material.

C. Biogas has a higher energy content per litre compared to bioethanol and biodiesel.

D. Biogas production is completely carbon neutral.

CH_4 – 60% ←
CO_2 – 40%

Question 35 (3 marks)

A food label contains the following data:

Food Type	Mass present (g) in one serving
Fats	1.50 g
Glucose	3.00 g
Protein	5.50 g
Cellulose	0.900 g
Oils	1.20 g

a. State and justify whether the majority of the energy contained in the food is from lipids (fats & oils), proteins or carbohydrates. (2 marks) **[1.5.4]**

q (fats & oils) =

q (protein) =

q (carbs) =

⇒ majority from lipids

b. Find the total amount of energy contained in one serving of the food. (1 mark) **[1.5.4]**

total energy = 241.4 kJ

Check off any learning objectives that obtained full marks from the "Contour Check" booklet!

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Sub-Section: Additional

Question 36 (7 marks)

a. Describe the production of bioethanol, including an equation to show how it is formed. (2 marks)

Bioethanol is formed via the fermentation of glucose in the presence of yeast.

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

b. Why is ethanol sourced from crude oil considered to be a fossil fuel, but ethanol sourced from bioethanol is considered a biofuel? (2 marks)

Crude oil is non-renewable as it takes millions of years to form, and thus is considered a fossil fuel.

Bioethanol can be produced by natural processes within a relatively short time and thus is considered a biofuel.

c.

i. How much energy would be produced by completely combusting the contents of a full 50.0 L biogas container at SLC given that 60.0% of the biogas is methane and the rest is carbon dioxide? (2 marks)

$$V(CH_4) = 0.6 \times 50 = 30\ L$$
$$n(CH_4) = V/Vm = 30/24.8 = 1.21\ mol.$$
$$E(CH_4) = \Delta H \times n = 1.21 \times 890 \times 1076.6\ kJ.$$

ii. If the composition were 70% methane: 30% CO_2, would the energy released upon combustion be greater, the same, or less than that in **part c. i.**? No calculations are required. (1 mark)

More

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