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

VCE Chemistry ¾
Thermochemistry [1.1]
Homework Solutions

Homework Outline:

Section A: Compulsory Questions (37 Marks)

Sub-Section: [1.1.1] Identify ΔH and E_a in endothermic/exothermic energy profile diagrams

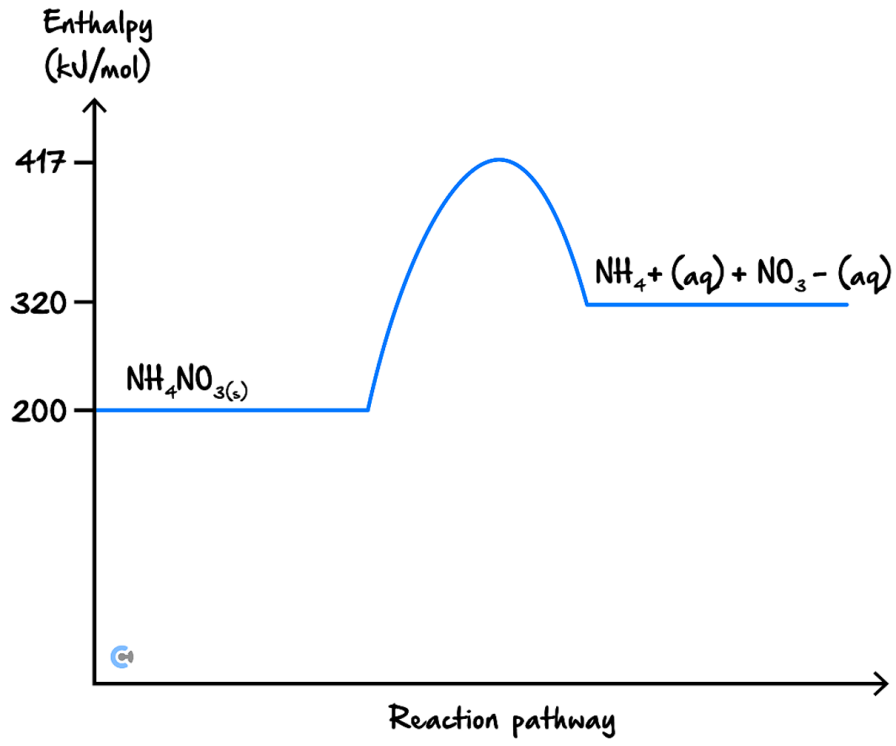
Question 1 (2 marks)

Consider the following energy profile diagrams.

Ammonium nitrate ($NH_4NO_3(s)$) can undergo dissociation in the following reaction:

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

The energy profile diagram for the reaction is shown below:



a. Determine the ΔH value of the dissociation of $NH_4NO_3(s)$. (1 mark)

$+120\ kJ\ mol^{-1}$

b. Find the activation energy of this reaction. (1 mark)

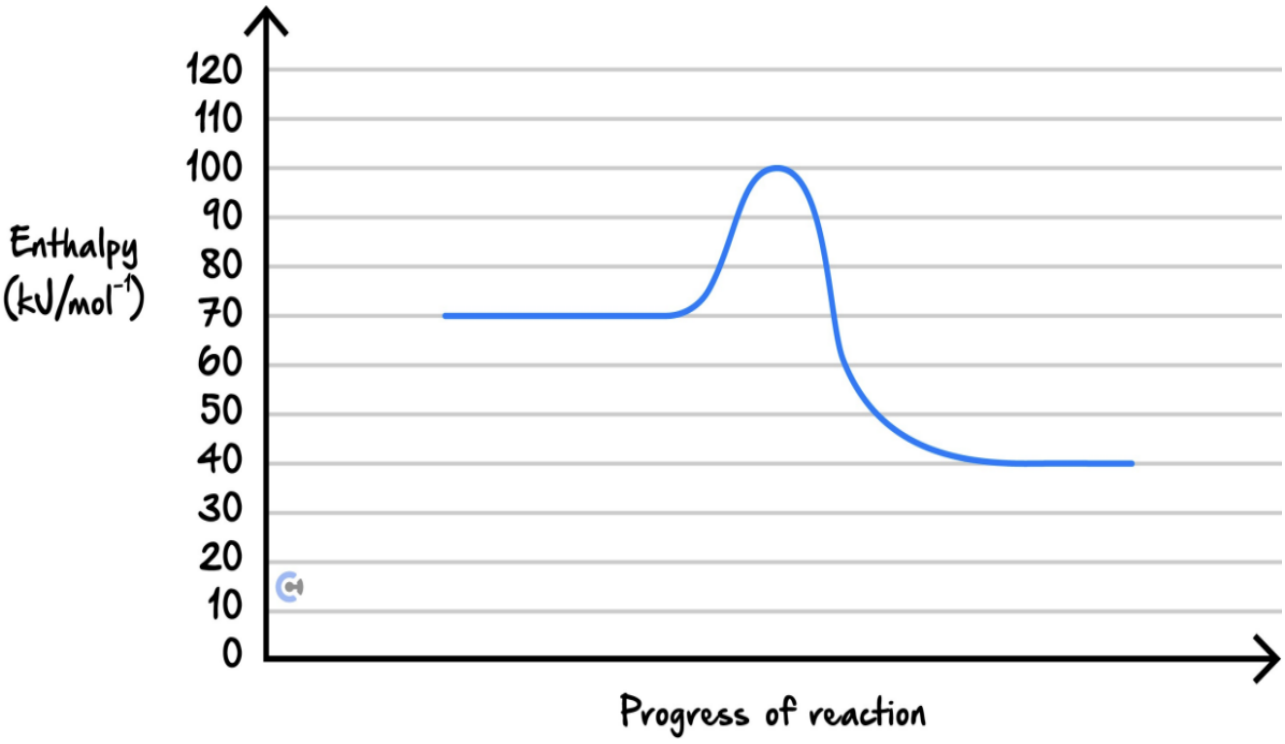
$217\ kJ\ mol^{-1}$

Question 2 (2 marks)

The chemical equation for a variation of the Haber process has been shown below:

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \qquad \Delta H = -30\ kJ$$

The following energy profile is created based on experimental observations.



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

Exothermic

b. Hence, determine whether the energy profile represents the forward or backward reaction. (1 mark)

Forward reaction

Space for Personal Notes

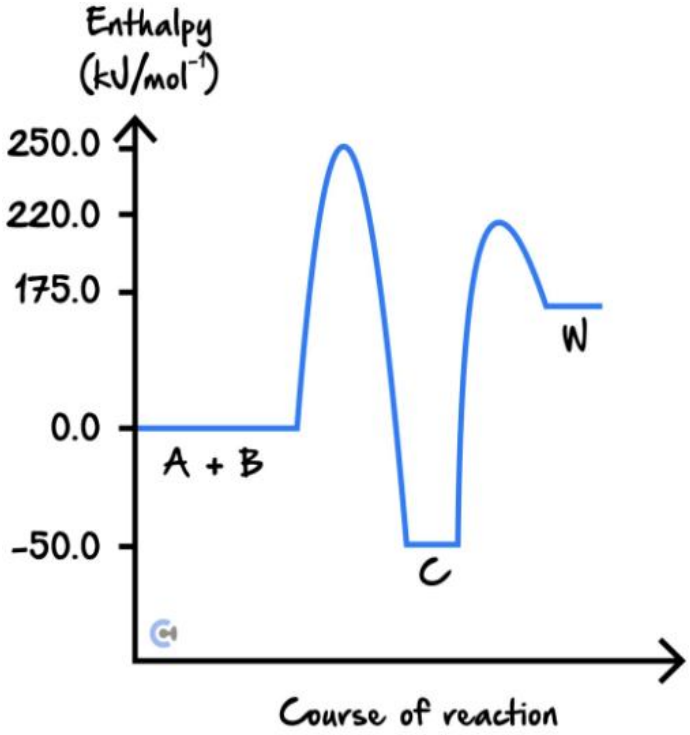
Question 3 (6 marks)

Compound W is produced in industry via a two-step process. The two reactions involved in the production of W are shown below.

$$A(aq) + B(aq) \rightarrow C(aq)$$

$$2C(aq) \rightarrow 2W(aq)$$

The energy profile diagram of the entire process is shown below.



a. State the activation energy required for the second reaction to occur. (1 mark)

$270\ kJ\ mol^{-1}$

b. Determine the overall enthalpy of the reaction. (1 mark)

$+175\ kJ\ mol^{-1}$

c. Hence, state and justify whether the overall reaction is exothermic or endothermic. (2 marks)

Endothermic (1).
The chemical energy of the products is greater than the chemical energy of the reactants (2).

d. Explain whether the production of W(aq) will happen in nature by itself. Justify your response. (2 marks)

It will not occur naturally as there is a high activation energy for the production of C. Therefore a large amount of energy must be inputted for the reaction to take place.

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 reaction:

a. The complete combustion of butane gas (C_4H_{10}). (1 mark)

$$C_4H_{10}(g) + \frac{13}{2}O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l) \qquad \Delta H = -2880\ kJ/mol$$

b. The incomplete combustion of propane gas (C_3H_8), forming carbon monoxide by-product, where $1500\ kJ\ mol^{-1}$ of energy is released. (1 mark)

$$C_3H_8(g) + \frac{7}{2}O_2 \rightarrow 3CO(g) + 4H_2O \qquad \Delta H = -1500\ kJ/mol$$

Question 5 (3 marks)

Liquid hexane is combusted under an open Bunsen burner flame in a fume hood. Emma accidentally leaves the Bunsen burner airhole closed.

a. Emma notices black soot accumulating along the circumference of the beaker containing hexane liquid. Explain the cause for this observation. (2 marks)

By closing the airhole, less oxygen reaches the fuel (1).
Therefore, incomplete combustion takes place, resulting in carbon byproduct (soot like substance) (2).

b. **Hence**, write a balanced equation for the incomplete combustion of liquid hexane occuring in Emma's bunsen burner. (1 mark)

$$2C_6H_{14}(l) + 7O_2(g) \rightarrow 12C(s) + 14H_2O(g)$$

Question 6 (3 marks)

Noah combusts $C_{19}H_{38}O_2(l)$ under a Bunsen burner flame.

a. Write a balanced chemical equation for the incomplete combustion of $C_{19}H_{38}O_2(l)$, whereby the only carbon-containing products are carbon (C). (1 mark)

$$C_{19}H_{38}O_2(l) + \frac{17}{2}O_2(g) \rightarrow 19C(s) + 19H_2O(g)$$

b. Hence or otherwise, explain whether the complete or incomplete combustion reaction will have a greater change in enthalpy. (2 marks)

Complete combustion will have a greater change in enthalpy. In complete combustion, the fuel is completely oxidised, and therefore all bonds have released energy. Whereas in incomplete combustion, the fuel is partially oxidised, and not all bonds have released energy.

Space for Personal Notes

Sub-Section: [1.1.3] Apply changing equations to thermochemical equations energy profile diagrams

Question 7 (3 marks)

Consider the following thermochemical equations.

Calcium carbonate can undergo decomposition under the following reaction:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g) \qquad \Delta H = +177.8\ kJ\ mol^{-1}$$

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

$$2CaCO_3(s) \rightarrow 2CaO(s) + 2CO_2(g)$$

$+355.6\ kJ$

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

$$\frac{1}{2}CaCO_3(s) \rightarrow \frac{1}{2}CaO(s) + \frac{1}{2}CO_2(g)$$

$+88.9\ kJ$

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

$$3CaO(s) + 3CO_2(g) \rightarrow 3CaCO_3(s)$$

$-533.4\ kJ$

Space for Personal Notes

Question 8 (3 marks)

The following reaction occurs in a beaker.

$$6C(s) + 3H_2(g) \rightarrow C_6H_6(g) \qquad \Delta H = +49\ kJ$$

During experimentation, the following reaction is obtained:

$$\frac{3}{2}C_6H_6(g) \rightarrow \frac{9}{2}H_2(g) + 9C(s)$$

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

Exothermic

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

$-73.5\ kJ$

c. State **two** experimental observations that will be observed in the beaker during the reaction. (1 mark)

Bubbling in the beaker.
Beaker gets warmer.

Space for Personal Notes

Question 9 (3 marks)

Hydrofluoric acid has applications in the pharmaceutical industry. It can be produced through the reaction shown below:

$$H_2(g) + F_2(g) \rightarrow 2HF(g) \qquad \Delta H = +130.9\ kJ\ mol^{-1}$$

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

$$4HF(g) \rightarrow 2H_2(g) + 2F_2(g)$$

$-261.8\ kJ$

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

$$\frac{1}{2}H_2(g) + \frac{1}{2}F_2(g) \rightarrow xHF(g)$$

$+65.5\ kJ$
$x = 1$

Space for Personal Notes

Sub-Section: The Final Boss

Question 10 (10 marks)

The following reactions represent butane-1,2-diol ($C_4H_{10}O_2$) and are associated with energy profile diagrams.

Reaction 1:

$$2C_4H_{10}O_2(l) + 11O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g) \;\; \Delta H = -2025\ kJ/mol$$

Reaction 2:

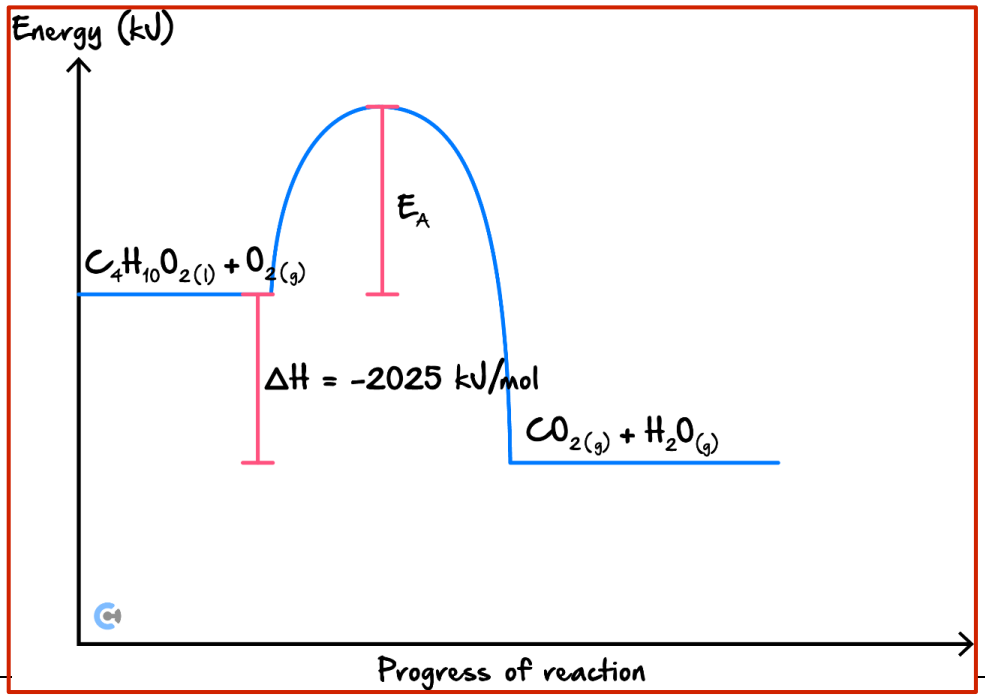
$$C_4H_{10}O_2(l) + \frac{9}{2}O_2(g) \rightarrow 2CO(g) + 2CO_2(g) + H_2O(l) \;\; \Delta H = -1200\ kJ/mol$$

a. Explain which reaction, complete or incomplete, releases more energy and why this is the case based on the provided ΔH values. (2 marks)

Complete combustion (Reaction 1) releases more energy, as indicated by its ΔH value of $-2025\ kJ/mol$, compared to the incomplete combustion (Reaction 2) which has a ΔH of $-1200\ kJ/mol$ (1).

This means that more energy is released when butane-1,2-diol undergoes complete oxidation, fully converting to carbon dioxide and water, whereas incomplete combustion produces less energy due to partial oxidation (2).

b. Draw and label an energy profile diagram for Reaction 1. Include labels for the activation energy (kJ), enthalpy change (ΔH), reactants, and products. (2 marks)



c. With reference to activation energy, explain why incomplete combustion might occur more easily than complete combustion under certain conditions. (2 marks)

Incomplete combustion may have a lower activation energy than complete combustion of butane-1,2-diol (1).

This means that despite less energy being produced, reaction 2 is able to occur more easily than reaction 1 (2).

d. Describe the effect of changing the ratio of oxygen in the combustion of butane-1,2-diol, and how this relates to whether complete or incomplete combustion occurs. (2 marks)

If the amount of oxygen is reduced below the stoichiometric ratio required for complete combustion, incomplete combustion will occur (1).

This is because there is insufficient oxygen to fully oxidise butane-1,2-diol to carbon dioxide and water. Instead, carbon monoxide or carbon (soot) may form, resulting in incomplete combustion and reduced energy output (2)

e. Consider the thermochemical equation for the decomposition of calcium carbonate:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g) \;\; \Delta H = +178\ kJ/mol$$

If the equation is doubled, what happens to the value of ΔH, and how would this be reflected in an energy profile diagram? (2 marks)

In the energy profile diagram, the difference in energy between the reactants and products would be greater, showing a larger enthalpy change (ΔH). However, the activation energy (kJ) would remain unchanged.

Space for Personal Notes

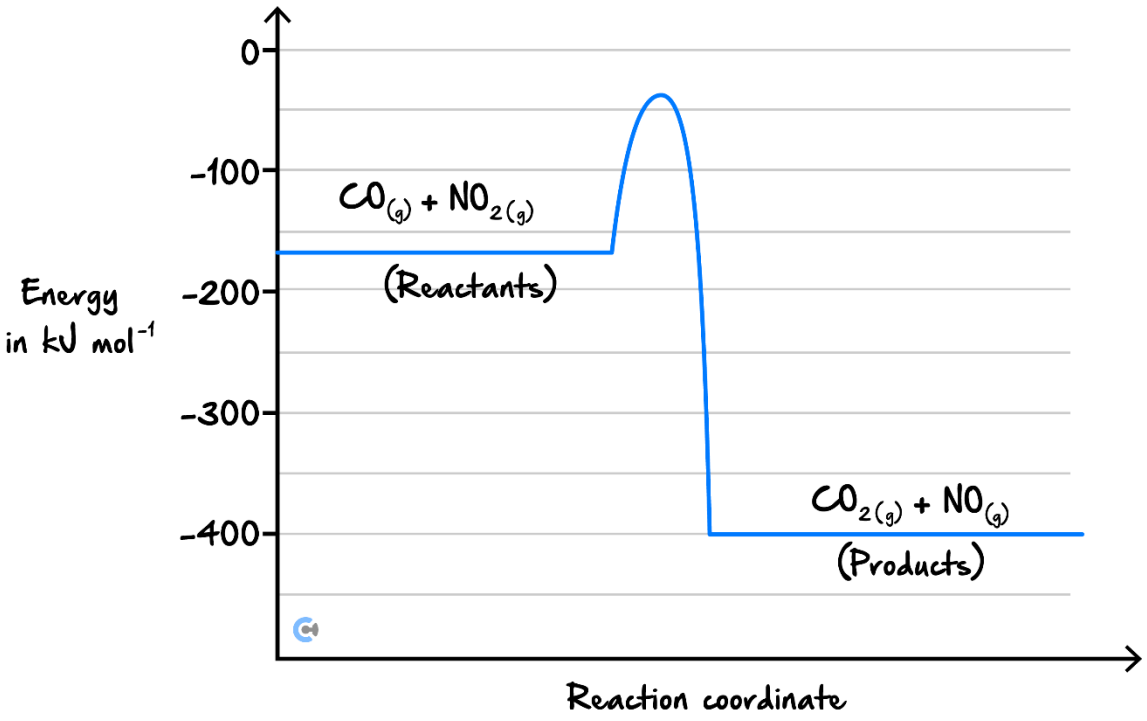
Section B: Supplementary Questions (44 Marks)

Sub-Section: [1.1.1] Identify ΔH and E_a in endothermic/exothermic energy profile diagrams

Question 11 (3 marks)

Consider the following energy profile diagrams.

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)

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

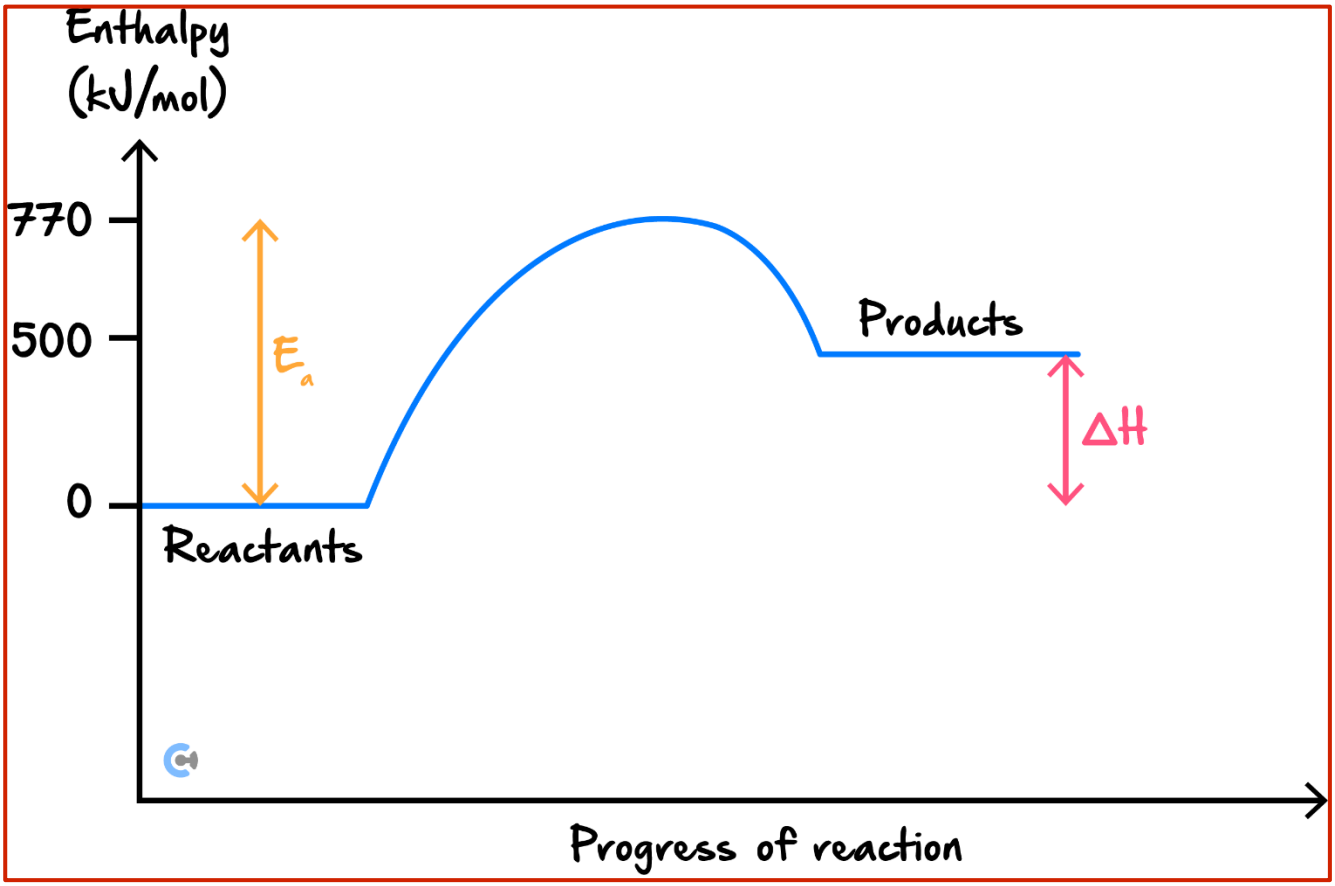
c. Calculate the ΔH value for this reaction. (1 mark)

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

Question 12 (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)



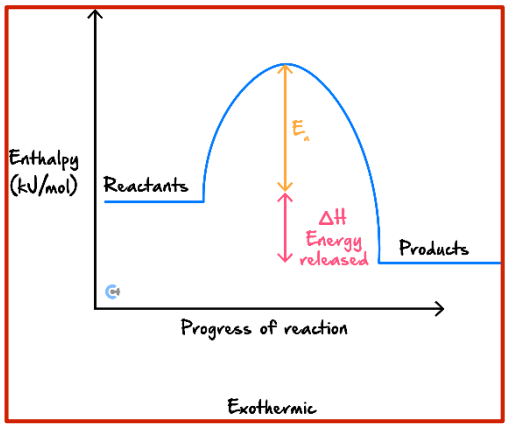
b. Label the activation energy and change in enthalpy on the energy diagram drawn in **part b.i.** (1 mark)

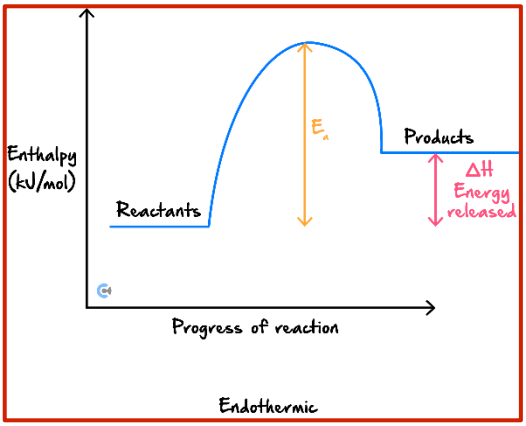
c. State whether the reaction is exothermic or endothermic. (1 mark)

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 13 (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 14 (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)

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

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

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

Space for Personal Notes

Question 15 (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 16 (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 17 (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 18 (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 19 (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)

$$3\text{Mg(s)} + \frac{3}{2}\text{O}_2\text{(g)} \rightarrow 3\text{MgO(s)}$$

$\Delta\text{H} = -1806\ kJ/mol$

Question 20 (3 marks)

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

$$\text{Fe}_2\text{O}_3\text{(s)} + 2\text{Al(s)} \rightarrow 2\text{Fe(l)} + \text{Al}_2\text{O}_3\text{(s)} \qquad \Delta H = -850\ kJ\ mol^{-1}$$

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

$$4\text{Fe(l)} + 2\text{Al}_2\text{O}_3\text{(s)} \rightarrow 2\text{Fe}_2\text{O}_3\text{(s)} + 4\text{Al(s)}$$

$+1700\ kJ/mol$

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

$$\frac{1}{6}\text{Fe(l)} + \frac{1}{12}\text{Al}_2\text{O}_3\text{(s)} \rightarrow \frac{1}{12}\text{Fe}_2\text{O}_3\text{(s)} + x\text{Al(s)}$$

$+70.83\ kJ/mol$

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

Space for Personal Notes

Question 21 (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)

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

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)

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

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

CONTOUREDUCATION

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