Enthalpy changes – 2021/20 GCE AS Chemistry A

1. Nov/2021/Paper_H032/01/No.10

The equation for the complete combustion of propene, C_3H_6, is shown below.

$C_3H_6(g) + 4½O_2(g) \rightarrow 3CO_2(g) + 3H_2O(l)$

Standard enthalpy changes of formation, $\Delta_f H^{\ominus}$, are shown in the table.

Compound	$\Delta_f H^{\ominus}$ / kJ mol^{-1}
$C_3H_6(g)$	+20
$O_2(g)$	0
$CO_2(g)$	–394
$H_2O(l)$	–286

What is the standard enthalpy change of combustion of $C_3H_6(g)$, in kJ mol^{-1}?

A –2060

B –700

C +700

D +2060

Your answer ☐ **[1]**

2. Nov/2021/Paper_H032/01/No.22(a, c)

This question is about enthalpy changes.

Hydrogen, H_2, can be manufactured by the reaction of methane and steam.
This is a reversible reaction, as shown in **Equilibrium 22.1** below.

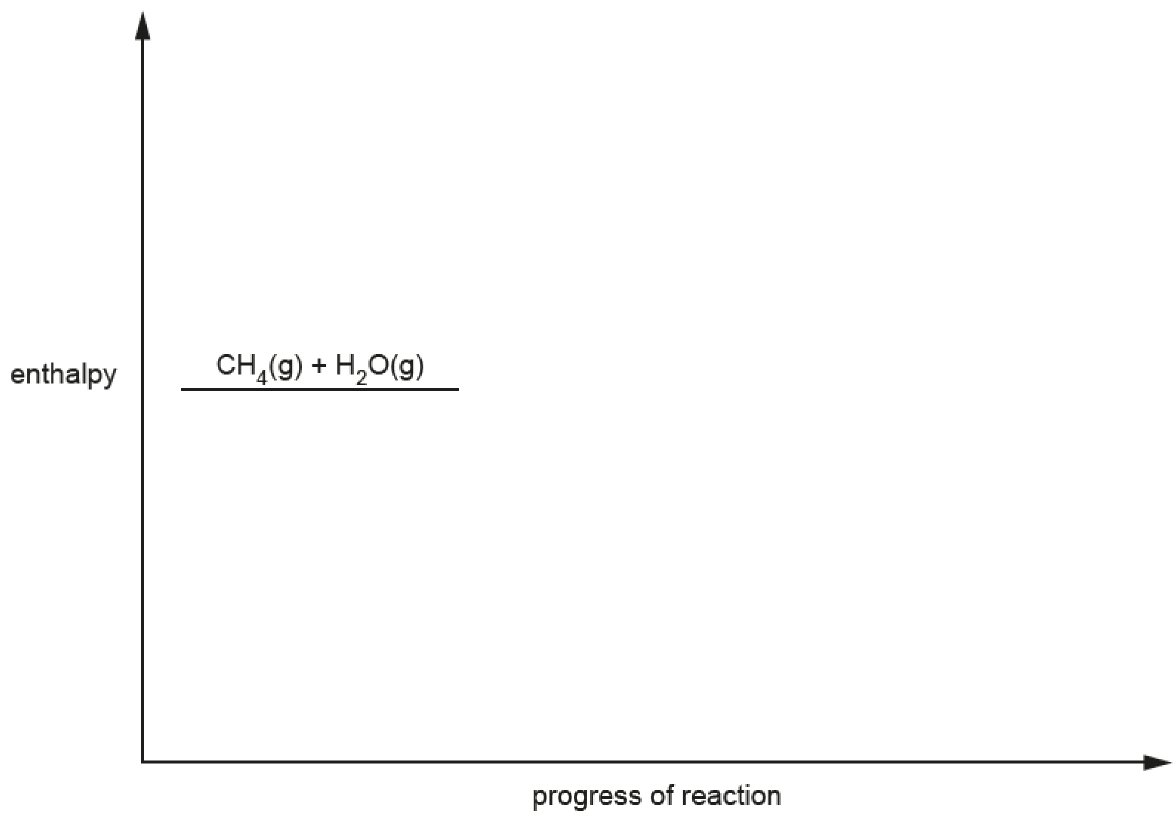
Equilibrium 22.1 $CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$ $\Delta H = +206\ kJ\ mol^{-1}$

(a) The rate of this reaction increases when a catalyst is present.

Complete the enthalpy profile diagram below.

On your diagram:

- label the activation energies, $\boldsymbol{E_a}$ (without catalyst) and $\boldsymbol{E_c}$ (with catalyst)
- label the enthalpy change of reaction, $\boldsymbol{\Delta H}$.



[3]

(c) The reaction for the production of hydrogen is repeated below.

$CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$ $\Delta H = +206\,kJ\,mol^{-1}$

Average bond enthalpies are shown in the table.

Bond	**Average bond enthalpy / $kJ\,mol^{-1}$**
C–H	413
O–H	464
C≡O	1077

Calculate the bond enthalpy of the H–H bond.

bond enthalpy = ... $kJ\,mol^{-1}$ **[3]**

3. Nov/2020/Paper_H032/01/No.11

Hydrogen and oxygen react as shown below.

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ $\Delta_r H = -486\,kJ\,mol^{-1}$

Bond enthalpies are shown in the table.

Bond	H–H	O=O
Bond enthalpy / $kJ\,mol^{-1}$	+436	+498

What is the bond enthalpy, in $kJ\,mol^{-1}$, for the O–H bond?

A +221

B +355

C +464

D +928

Your answer ☐ **[1]**

4. Nov/2020/Paper_H032/01/No.24(a)

This question is about making ammonia, NH_3.

(a) Ammonia is manufactured by reacting nitrogen with hydrogen:

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

Standard enthalpy changes of combustion, $\Delta_c H^\ominus$, are given in the table.

Substance	$\Delta_c H^\ominus$ / kJ mol^{-1}
$N_2(g)$	+180
$H_2(g)$	–286
$NH_3(g)$	–293

Calculate the standard enthalpy change of formation, $\Delta_f H^\ominus$, for $NH_3(g)$.

$\Delta_f H^\ominus$ for $NH_3(g)$ = ... kJ mol^{-1} **[3]**

5. Nov/2021/Paper_H032/02/No.4

A student carries out an investigation to find the enthalpy change for the decomposition of magnesium carbonate, ΔH_1 (**Reaction 1**).

Reaction 1 $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$ ΔH_1

This enthalpy change cannot be found directly. It can be determined indirectly from the enthalpy changes for the reactions below, which can be found by experiment.

Reaction 2 $MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$ ΔH_2

Reaction 3 $MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$ ΔH_3

The enthalpy cycle is shown in **Fig. 4.1**.

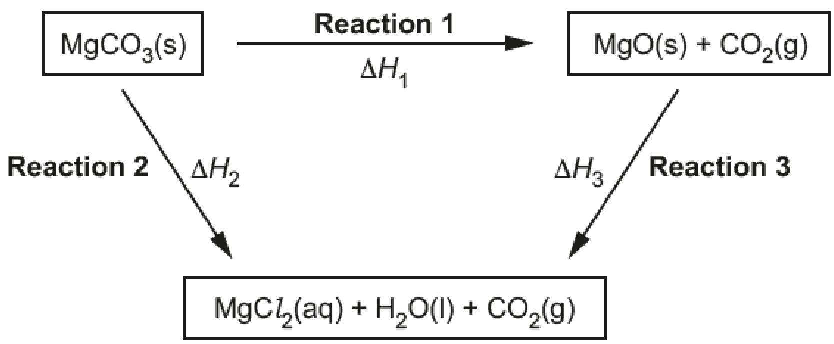


Fig. 4.1

Determination of ΔH_2 for Reaction 2

Student's method

- Weigh a 250 cm^3 polystyrene cup.
- Add about 100 cm^3 of 2.00 $mol\,dm^{-3}$ hydrochloric acid (an excess) to the polystyrene cup and record the initial temperature of the $HCl(aq)$.
- Add 4.215 g $MgCO_3$, stir the mixture, and record the final temperature.
- Weigh the polystyrene cup containing the final solution.

Results

Mass of polystyrene cup / g	21.415
Mass of polystyrene cup + final solution / g	124.425
Initial temperature of $HCl(aq)$ / °C	20.40
Final temperature of solution / °C	25.40

Determination of ΔH_3 for Reaction 3

The student uses the same method as for **Reaction 2** but with MgO in place of $MgCO_3$.

The student calculates ΔH_3 for **Reaction 3** as $-136.1\ kJ\,mol^{-1}$.

(a)* Use the student's results to calculate ΔH_2 for **Reaction 2** and determine the enthalpy change ΔH_1, in $kJ\,mol^{-1}$, for the decomposition of magnesium carbonate (**Reaction 1**), using the energy cycle in **Fig. 4.1**.

Assume the specific heat capacity, *c*, of the reaction mixture is the same as for water.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

Additional answer space if required.

....

....

....

....

.... **[6]**

6. Nov/2020/Paper_H032/02/No.2

Enthalpy changes of combustion can be determined directly by experiment.

(a) Explain the term **enthalpy change of combustion**, $\Delta_c H$.

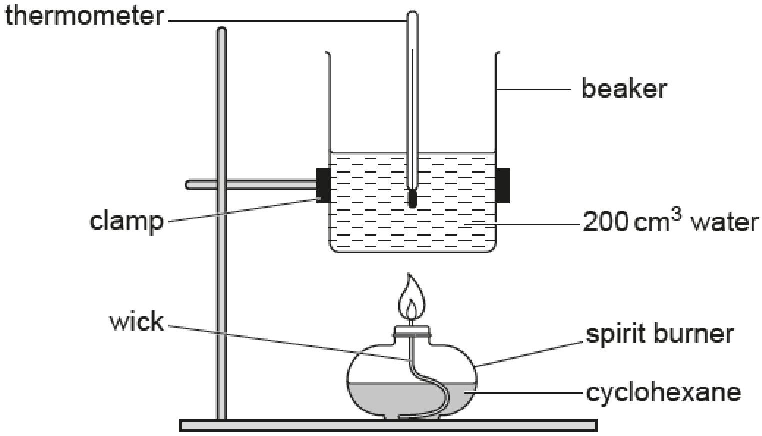
....

....

....

.... **[2]**

(b) A student carries out an experiment to determine the enthalpy change of combustion of cyclohexane, C_6H_{12}, using the apparatus shown in the diagram.



In the experiment, 0.525 g of cyclohexane are burnt, and the temperature of the 200 cm^3 of water changes from 21.0 °C to 41.0 °C.

Calculate the enthalpy change of combustion, $\Delta_c H$, of cyclohexane in $kJ\,mol^{-1}$.

Give your answer to **3** significant figures.

$\Delta_c H$ = ... $kJ\,mol^{-1}$ **[4]**

(c) The student finds that their experimental value for $\Delta_c H$ is less exothermic than the value in a data book.

The student evaluates the experimental results.

(i) The uncertainty in each thermometer reading is ±0.5 °C and the uncertainty in the measured volume of water is ±2 cm^3.

Determine whether the temperature **change** or the measured volume of water has the greater percentage uncertainty.

[2]

(ii) Suggest **two** reasons, apart from measurement uncertainties, why the experimental value for $\Delta_c H$ is less exothermic than the data book value.

Reason 1 ....

....

Reason 2 ....

....

[2]

(iii) In the experiment the water in the beaker was heated for 5 minutes. The student thought that the experiment could be improved by heating the water for 10 minutes.

Explain whether the accuracy in the student's calculated value for $\Delta_c H$ may or may **not** be improved by heating for longer.

....

....

....

....

.... **[2]**