WJEC Chemistry A-level

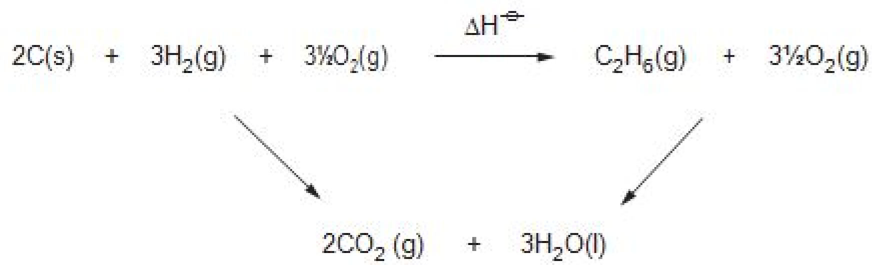
3.6: Enthalpy changes for solids and solutions

Practice Questions

Wales Specification

1.

Study the following energy cycle.



Use the values in the table below to calculate the enthalpy change of reaction, $\Delta H^{\ominus}$. [2]

Substance	Enthalpy change of combustion, $\Delta H_c^{\ominus}$ / kJ mol^{-1}
carbon	−394
hydrogen	−286
ethane	−1560

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

(Total 2)

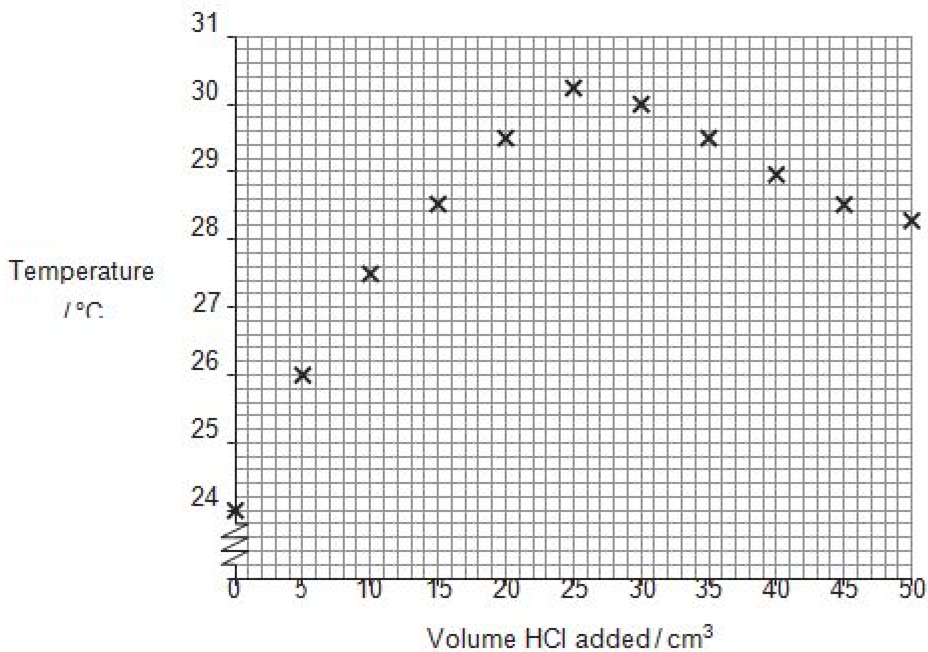
2. Zac was asked to measure the molar enthalpy change of neutralisation of sodium hydroxide by hydrochloric acid.

$$NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

He was told to use the following method:

- Measure 25.0 cm^3 of sodium hydroxide solution of concentration 0.970 mol dm^{-3} into a polystyrene cup.
- Measure the temperature of the solution.
- Place the hydrochloric acid solution into a suitable container and measure the temperature of the solution.
- When the temperatures of both solutions are equal add 5.00 cm^3 of hydrochloric acid to the sodium hydroxide and stir.
- Measure the temperature of the mixture.
- Keep adding 5.00 cm^3 portions of hydrochloric acid, until 50.0 cm^3 have been added, stirring and measuring the temperature each time.

Zac's results are shown on the graph below.



(a) Suggest why it is important that the hydrochloric acid and the sodium hydroxide are at the same temperature.

[1]

(b) By drawing lines of best fit for both sets of points determine:

(i) the maximum temperature **change** [2]

Maximum temperature rise from the graph = ... °C

(ii) the volume of acid required to neutralise the sodium hydroxide. [1]

Volume of acid = ... cm^3

(c) Use your value from part *(b)*(ii) to calculate the concentration, in mol dm^{-3}, of the hydrochloric acid solution. [2]

Concentration = ... mol dm^{-3}

(d) Use **both** values from part *(b)* to calculate the heat given out during **this** experiment.

[Assume that the density of the solution is 1.00 g cm^{-3} and that its specific heat capacity is 4.18 J K^{-1} g^{-1}] [1]

Heat given out = ... J

(e) Calculate the molar enthalpy change, ΔH, for the reaction between sodium hydroxide and hydrochloric acid. [2]

ΔH = ... kJ mol^{-1}

(g) Explain why the temperature falls on continuing to add hydrochloric acid **after** the maximum temperature has been reached.

[2]

(h) The data book value for this molar enthalpy change of neutralisation is more exothermic than Zac's value

State the **main** reason for the difference between the values and suggest **one** change that would improve his result.

[2]

(Total 14)

3. (a) An aqueous solution of methanoic acid can be used to dissolve 'lime scale' in kettles. The concentration of a methanoic acid solution used for this purpose can be found by a titration using sodium hydroxide solution. For this purpose a 25.0 cm^3 sample of aqueous methanoic acid was diluted to 250 cm^3.

(i)State the name of the piece of apparatus used to

I measure out 25.0 cm^3 of aqueous methanoic acid,

[1]

II contain exactly 250 cm^3 of the diluted solution.

[1]

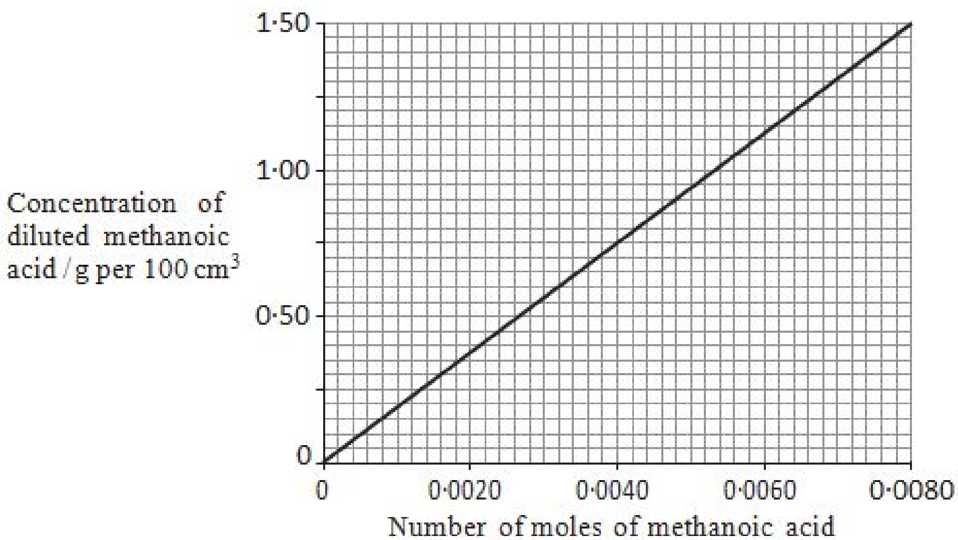
(ii) A 25.0 cm³ sample of the diluted methanoic acid was titrated with sodium hydroxide solution of concentration 0.200 mol dm⁻³. A volume of 32.00 cm³ was needed to react with all the methanoic acid present.

Calculate the number of moles of sodium hydroxide used.

[1]

Moles of sodium hydroxide = **......................................**mol

(iii) Methanoic acid and sodium hydroxide react together in a 1:1 molar ratio. Use the graph below and your result from (ii) to find the concentration of methanoic acid present in the diluted solution in g per 100 cm^3 of solution. [1]



Concentration = ... g per 100 cm^3

(iv) State the concentration of the original methanoic acid in g per 100 cm^3 solution. [1]

Original concentration = ... g per 100 cm^3

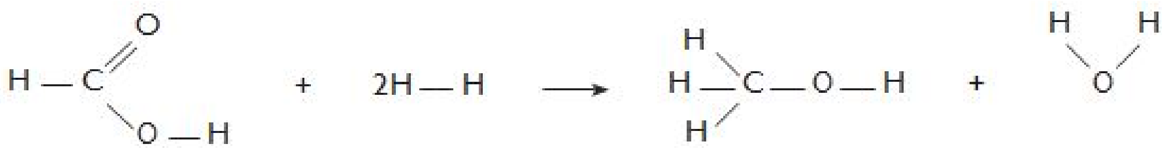
(b) Methanoic acid, HCOOH, can be reduced to methanol, CH_3OH, in a gas phase reaction, by using hydrogen in the presence of a solid ruthenium metal catalyst.

(i) Ruthenium is acting as a heterogeneous catalyst.
State the meaning of the word *heterogeneous*. [1]

....

....

(ii) The equation for the reduction of methanoic acid is shown below.



Use the table of bond enthalpies to find the enthalpy change for this reaction. [3]

Bond	Average bond enthalpy / $kJ\,mol^{-1}$
C—H	412
C—O	360
C=O	743
H—H	436
O—H	463

Enthalpy change = ... $kJ\,mol^{-1}$

(c) The relative molecular mass of methanoic acid is 46.02.

State why this quantity does not have units. [1]

(d) Methanoic acid reacts with propan-1-ol to give 1-propyl methanoate.

$$HCOOH + CH_3CH_2CH_2OH \rightleftharpoons \underset{\text{1-propyl methanoate}}{HCOOCH_2CH_2CH_3} + H_2O$$

(i) This reaction eventually reaches dynamic equilibrium.
State what is meant by *dynamic equilibrium*. [1]

(ii) Give the empirical formula of 1-propyl methanoate. [1]

Empirical formula ....

Total [12]

4. *(a)* Ethanol, C_2H_5OH, is a liquid at room temperature. It is being increasingly used as a fuel.

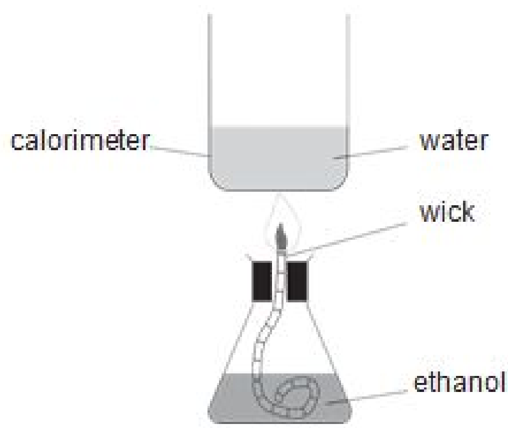
(i) Write the equation that represents the standard molar enthalpy change of formation (ΔH_f) of ethanol. [1]

(ii) Suggest why this enthalpy change cannot be measured directly. [1]

(b) Enthalpy changes of combustion can often be measured directly. The equation for the reaction which represents the enthalpy change of combustion (ΔH_c) of ethanol is as follows.

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

A student used the apparatus below to determine the enthalpy change of combustion of ethanol.



The student obtained the following results.

Mass of spirit burner + ethanol at start	= 72.27 g
Mass of spirit burner + ethanol after combustion	= 71.46 g
Temperature of water at start	= 21.5 °C
Temperature of water after combustion	= 75.5 °C
Volume of water in calorimeter	= 100 cm^3

The energy released in the experiment can be calculated using the formula

energy released = $mc\Delta T$

where
m = mass of the water in grams (assume 1 cm^3 has a mass of 1 g)
c = 4.2 J g^{-1} °C^{-1}
ΔT = change in temperature of the water

(i) Calculate the energy released in the experiment

[1]

Energy released = ... J

(ii) The enthalpy change of combustion of ethanol is defined as the energy change per mol of ethanol burned.

Use your answer to (i) to calculate the enthalpy change of combustion of ethanol.

Give your answer in kJ mol^{-1} and correct to **3 significant figures**. Include the sign.

[3]

(c) Another student did not carry out an experiment to find ΔH_c of ethanol. He looked up the literature value on a respected internet site.

How would you expect the numerical values obtained by the two students to differ? Explain your answer.

You may assume that both values were found under the same conditions of temperature and pressure.

[2]

(d) The students then used the apparatus from (b) to find the enthalpy change of combustion of higher relative molecular mass alcohols. They found that as the number of carbon atoms increased the value of the enthalpy change of combustion became more negative.

(i) Write the equation for the reaction which represents the enthalpy change of combustion of propanol, C_3H_7OH. [1]

(ii) In terms of bond strengths, explain why enthalpy changes of combustion are negative

[1]

(iii) Explain why the enthalpy change of combustion of propanol is more negative than that of ethanol

[1]

(e)Recent research has been carried out to find economic and environmentally friendly uses for waste straw and wood chippings.

The process of gasification involves the material being partly combusted at a temperature of about 700 °C to give a mixture consisting mainly of hydrogen and carbon monoxide but also some carbon dioxide.

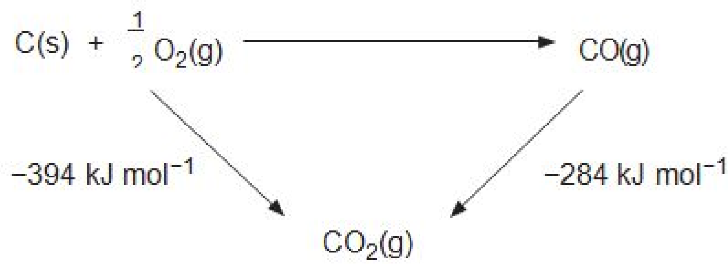
Another approach has been to use enzyme catalysed reactions to change the waste material into glucose and then to ethanol.

Comment on the economic and environmental factors involved in both of these processes.

[4] QWC [2]

(Total 17)

5. Use the energy cycle to calculate the enthalpy change of formation of carbon monoxide. [1]



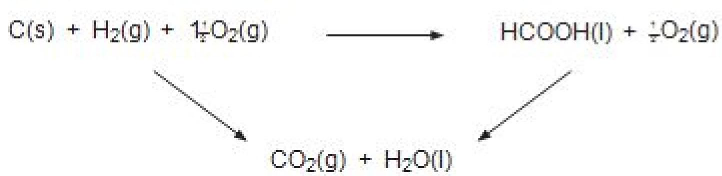
Enthalpy change of formation = ... kJ mol^{-1}

(Total 1)

6. Methanoic acid is the simplest carboxylic acid and occurs naturally, most notably in ant venom. It has a molar mass of 46.02 g mol^{-1}.

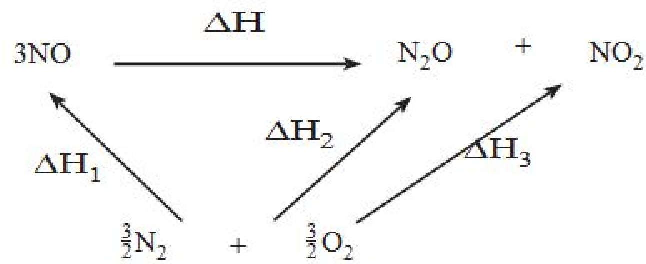
(a) State what is meant by *molar mass*. [1]

(b) Use the values in the table below to calculate the enthalpy change of formation for methanoic acid. [1]



Substance	Enthalpy change of combustion, $\Delta H_c^\ominus$ / kJ mol^{-1}
C	−394
H_2	−286
HCOOH	−263

7. The energy cycle for a decomposition of nitrogen(II) oxide is shown below.



(a) Complete the equation to show ΔH in terms of ΔH_1, ΔH_2 and ΔH_3. [1]

ΔH = ...

(b) Write the chemical equation for the standard molar enthalpy change of formation of gaseous nitrogen(II) oxide, NO. [1]

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8. Callum and Carys wish to measure the enthalpy change of the reaction of aqueous copper(II) sulfate with zinc powder. The reaction that occurs is:

$$CuSO_4(aq) + Zn(s) \longrightarrow ZnSO_4(aq) + Cu(s)$$

(a) Callum prepares copper(II) sulfate solution from hydrated copper(II) sulfate, $CuSO_4.5H_2O$.

(i) Calculate the relative molecular mass of hydrated copper(II) sulfate, $CuSO_4.5H_2O$. [1]

....

....

(ii) Callum measures a mass of hydrated copper(II) sulfate and uses this to make exactly 250.0 cm³ of copper(II) sulfate solution of concentration 0.250 mol dm⁻³.

I. Calculate the mass of hydrated copper(II) sulfate required to prepare this solution. [2]

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....

....

Mass of hydrated copper(II) sulfate = ... g

II. Describe, giving full practical details, how Callum should prepare the 250.0 cm³ of copper(II) sulfate solution. [5]

QWC [1]

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....

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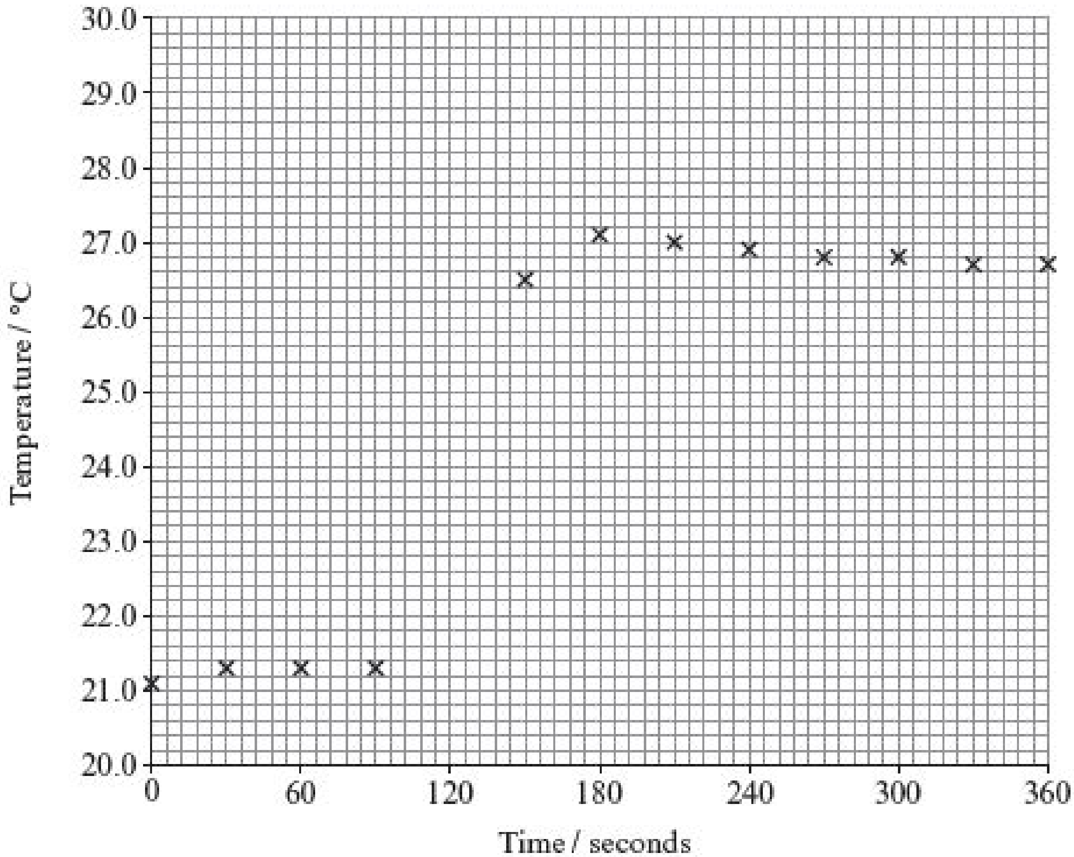
(b) In order to measure the enthalpy change, Carys carried out the reaction between zinc powder and their copper(II) sulfate solution in an insulated vessel. She measured the temperature in the vessel at 30 second intervals, before, during and after the reaction. The zinc powder was added to the copper(II) sulfate solution at 120 seconds. The temperatures recorded were plotted on the graph below.



(i) Explain why zinc powder is used in this experiment rather than pieces of zinc metal. [2]

....

....

(ii) Draw lines to complete the graph, and use these to find the maximum temperature change.

Maximum temperature change .... °C [2]

(iii) In this experiment, Carys used 50.00 cm^3 of the copper(II) sulfate solution prepared by Callum and added 0.400 g of zinc powder.

I. Calculate the number of moles of copper(II) sulfate present in this solution. [1]

....

....

II. The sample of zinc metal used contained 6.12×10^{-3} moles. State why this value, rather than the number of moles of copper(II) sulfate, is used to calculate the enthalpy change of the reaction. [1]

....

....

III. The enthalpy change can be calculated using the expression below.

$$\Delta H = -\frac{mc\Delta T}{n}$$

Where: m is the mass of the copper(II) sulfate solution (50 g)
ΔT is the change in temperature in °C
n is the number of moles of zinc
c is the specific heat capacity of the solution which equals 4.18 J g^{-1}°C^{-1}

Calculate the enthalpy change for the reaction in kJ mol^{-1}. [2]

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....

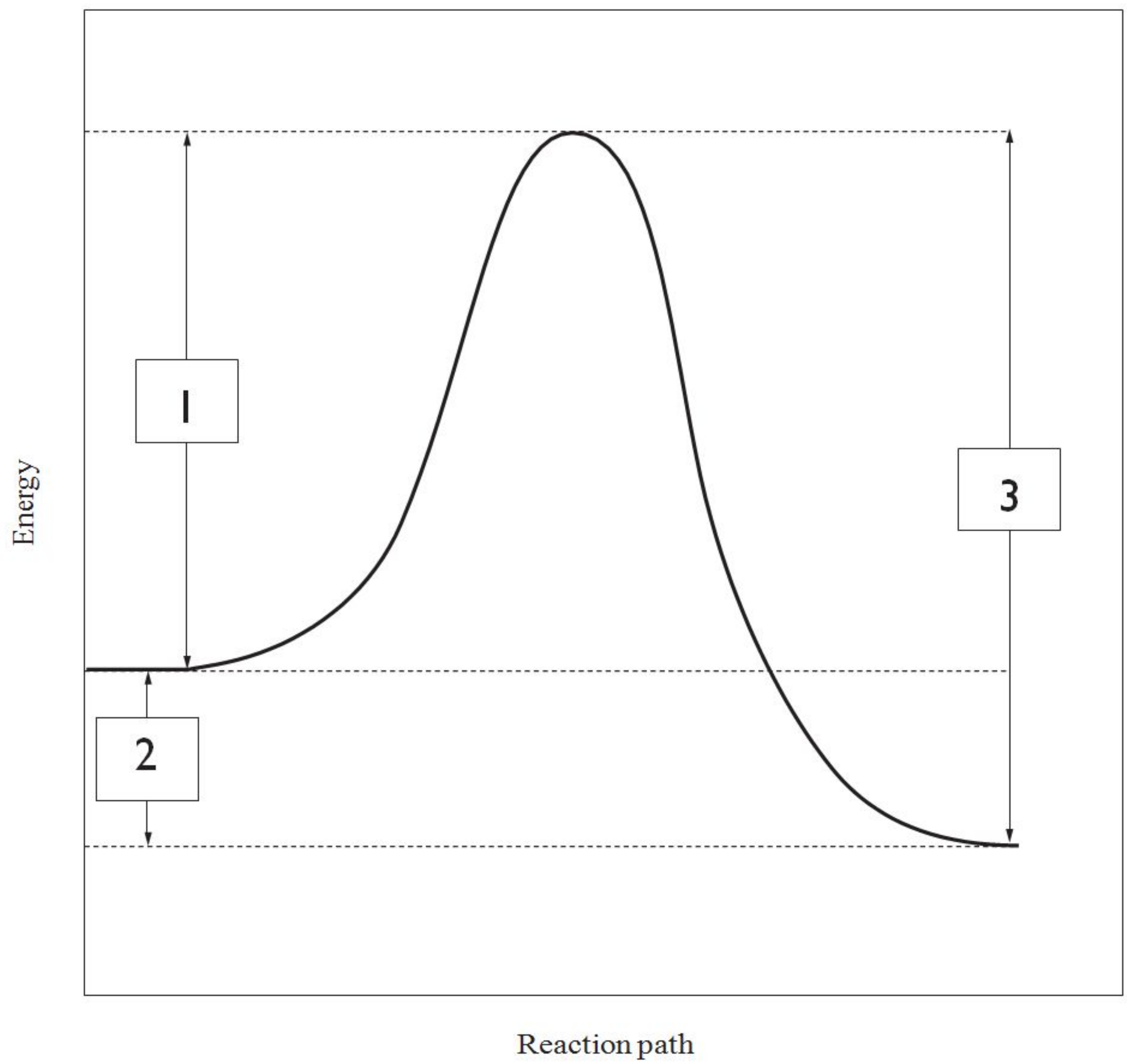
IV. Give a reason why the sign of the enthalpy value calculated is different from the sign of the temperature change measured. [1]

....

....

Total [18]

9. The diagram below shows the reaction profile for a chemical reaction. Three energy differences are marked on it with arrows labelled 1, 2 and 3.



Select which of the following correctly assigns the three energy differences.

	Activation energy of forward reaction	Activation energy of reverse reaction	Enthalpy change of reaction
A	1	3	2
B	2	1	3
C	2	3	1
D	3	2	1

....

(Total 1)