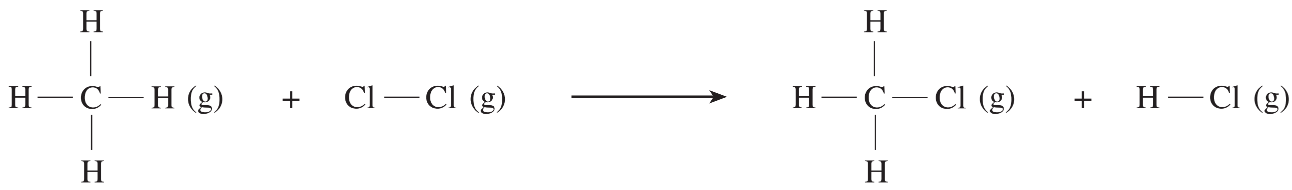
3. Chloromethane, CH_3Cl, is made by reacting methane, CH_4, with chlorine.



(i) The total enthalpy changes of formation from gaseous atoms (calculated from bond energies) of the species involved are shown in the table below.

Species	*Total enthalpy change of formation from gaseous atoms* / kJ mol^{-1}
CH_4	1652
Cl_2	243
CH_3Cl	1585
HCl	432

Use the values in the table to calculate the enthalpy change for the reaction above. [1]

....

....

.... kJ mol^{-1}

(ii) The atom economy of a reaction is given by the formula

$$\text{atom economy} = \frac{\text{theoretical mass of required product} \times 100}{\text{total mass of reactants used}} \%$$

Calculate the atom economy of the reaction above, where chloromethane, CH_3Cl, is the required product. [1]

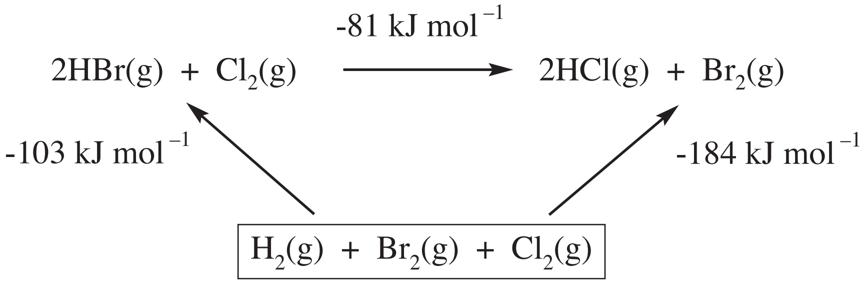
....

....

7. *(a)* The enthalpy change of formation of a compound is usually quoted per mole, at standard conditions. Define the term ***standard conditions***. [1]

....

(b) The energy cycle below shows the enthalpy changes that occur when hydrogen bromide reacts with chlorine.



(i) State Hess's Law. [1]

....

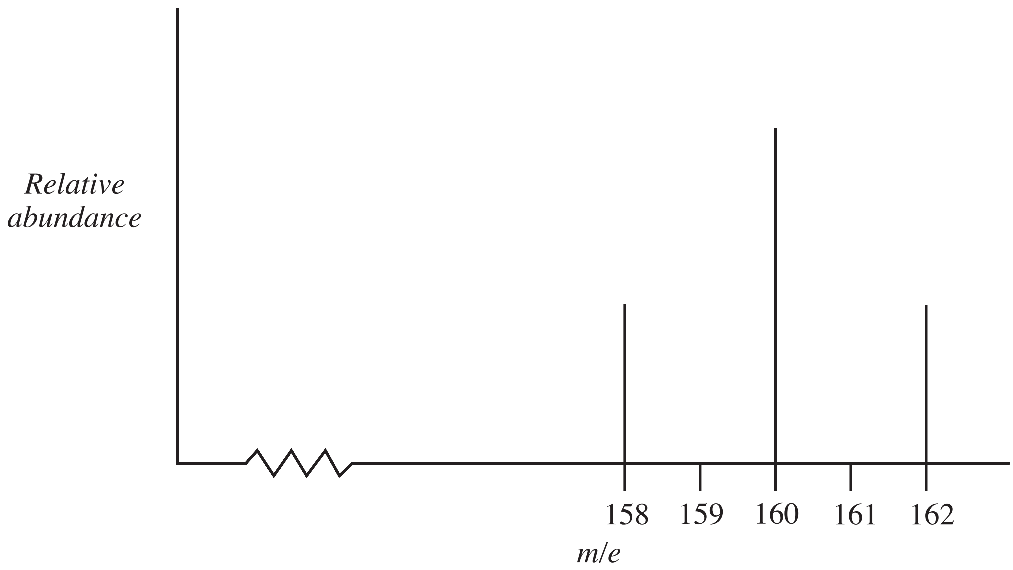
....

(ii) Show that the values in the energy cycle above obey the principle of the conservation of energy. [1]

....

....

(iii) The products of the reaction were examined using a mass spectrometer. The molecular ion peaks for Br_2^+ are shown in the diagram.



Use this information to

I. state the relative isotopic masses of the two bromine atoms, ^{x}Br, [1]

....

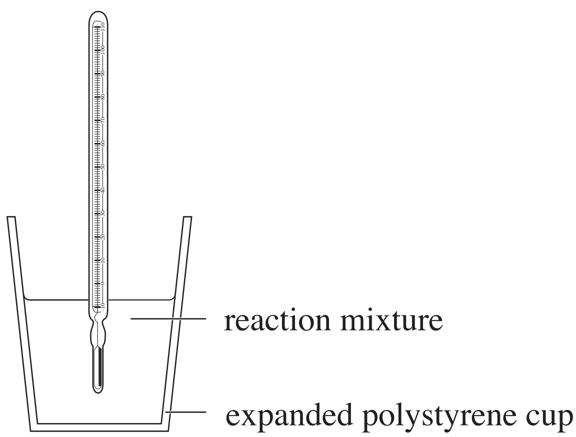
II. find the relative abundance of the two bromine isotopes, giving a reason for your answer. [2]

....

....

(c) Elfed carried out an experiment, using the simple apparatus shown below, to find the enthalpy change for the reaction between hydrobromic acid, HBr(aq), and aqueous sodium hydroxide.

$$HBr(aq) + NaOH(aq) \longrightarrow NaBr(aq) + H_2O(l)$$



Examiner only

He used 50·0 cm^3 of hydrobromic acid of concentration 2·00 mol dm^{-3} and 75·0 cm^3 of sodium hydroxide solution of concentration 2·00 mol dm^{-3}.

He measured the temperature before and after mixing.

Temperature of the solutions before mixing = 21·5 °C
Maximum temperature of the mixture = 32·1°C

He used the equation

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

where m is the total mass of the solutions used, n is the number of moles of hydrobromic acid used and ΔT is the temperature rise.

He assumed that c, the specific heat capacity of the mixture, had the value 4·2 J g^{-1} K^{-1}, and that 1cm^3 of each solution had a mass of 1g.

(i) Calculate the number of moles of hydrobromic acid used. [1]

....

....

(ii) Use your answer to (i) to calculate ΔH, the enthalpy change of reaction, in kJ mol^{-1}. [4]

....

....

.... kJ mol^{-1}

(iii) The accepted value for this reaction is –57·6 kJ mol^{-1}.
State why values obtained are often smaller than this value. [1]

....

....

(iv) Explain why the calculation used the number of moles of hydrobromic acid rather than the number of moles of sodium hydroxide. [1]

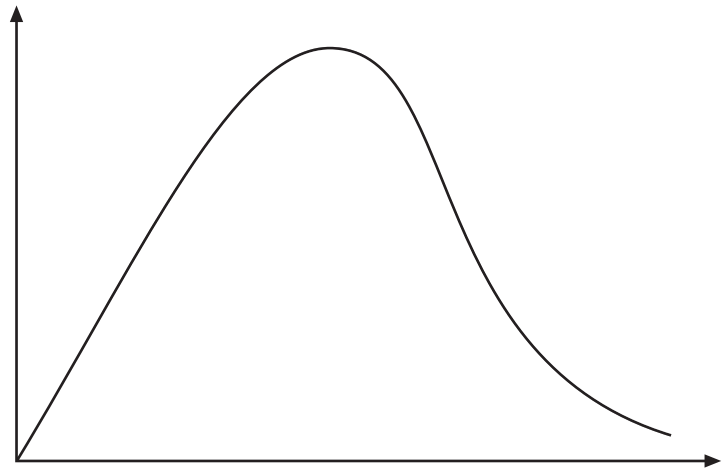
....

....

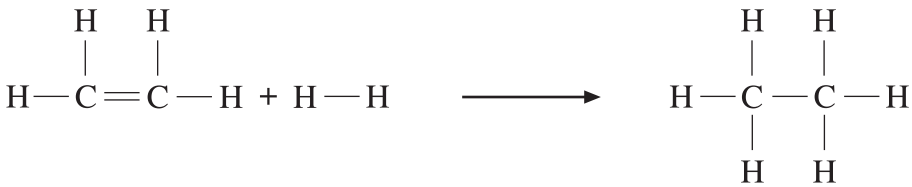
Total [13]

4. *(a)* The diagram below shows the distribution of molecular energies for a sample of ethene.

On the diagram, draw the distribution curve of molecular energies for the same sample of ethene at a higher temperature. [1]



(b) Ethene can be converted to ethane. The equation for the reaction is shown below.



Using the average bond enthalpy values listed below, calculate the enthalpy change, in kJ mol^{-1}, for the reaction. [2]

Bond	*Average bond enthalpy* / kJ mol^{-1}
C—C	348
C=C	612
C—H	412
H—H	436

....

....

....

Section A Total [10]

8. *(a)* In 1987, the United Nations published a report on sustainable development, which included the following statement:

"Sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs."

(i) In the UK, most electricity is generated in gas-fired power stations.
Give **two** reasons why the use of gas to generate electricity does not match the definition of sustainability. [2]

QWC [1]

....

....

....

....

(ii) Suggest **one** method of generating electricity which would be sustainable and outline how it works. [2]

....

....

....

....

(b) In some countries, ethanol is replacing petrol (octane) as a car fuel.

(i) When ethanol, C_2H_5OH, is burnt in air, the only products are carbon dioxide and water.

Balance the following equation for this reaction. [1]

$$C_2H_5OH + \ldots\ldots\ldots\ O_2 \longrightarrow \ldots\ldots\ldots\ CO_2 + \ldots\ldots\ldots\ H_2O$$

(ii) Use the standard enthalpy change of formation values given in the table to calculate the standard enthalpy change, $\Delta H^{\ominus}$, for the combustion of ethanol. [2]

Compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$C_2H_5OH(l)$	–278
$CO_2(g)$	–394
$H_2O(l)$	–286
$O_2(g)$	0

....

....

....

....

(iii) The standard enthalpy change of combustion for octane $\Delta H_c^{\ominus}(C_8H_{18})$ is –5512 kJ mol^{-1}.

Using this value and your answer to *(b)*(ii), show that octane gives more energy per gram of fuel burned than ethanol. [2]

....

....

....

....

(iv) Suggest a reason why ethanol is being used rather than petrol. [1]

....

....

Total [11]

Examiner only

9. *(a)* (i) Given the bond enthalpy values

Bond	*Bond enthalpy value* / kJ mol^{-1}
Cl – Cl	243
H – Cl	432
H – H	436

calculate the standard enthalpy change, $\Delta H^{\ominus}$, for the gaseous reaction

$$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$$ [2]

....

....

....

(ii) Using your answer to *(a)*(i) calculate the standard enthalpy change of formation, $\Delta H_f^{\ominus}$, for gaseous hydrogen chloride, HCl(g). [1]

....

....

(iii) State the standard conditions which apply to *standard* enthalpy changes. [2]

....

....

(iv) By reference to the bond enthalpy values in *(a)*(i), state which bond will break first in the reaction. [1]

....

....

Examiner only

(v) Typical energies associated with visible light are

Colour of light	*Typical energy* / kJ mol^{-1}
red	171
yellow	200
green	226
blue	254
violet	285

State and explain which colours of light will cause a mixture of hydrogen and chlorine to react. [3]

....

....

(vi) Explain why shining visible light has very little effect on the reverse reaction

$$2HCl(g) \longrightarrow H_2(g) + Cl_2(g)$$ [1]

....

....

Examiner only

(d) During World War II, ammonia was used as a fuel for running buses in Belgium. With the current problems associated with fossil fuels, interest in the use of ammonia as a fuel is being revived.
Some relevant standard enthalpy changes of formation, $\Delta H_f^{\ominus}$, are given in the table below.

Species	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
CH_4(g)	–74.8
CO_2(g)	–393.5
H_2O(g)	–241.8
N_2(g)	0
NH_3(g)	–46.1
O_2(g)	0

(i) Explain why N_2(g) and O_2(g) each have a value of zero for their standard enthalpy change of formation, $\Delta H_f^{\ominus}$. [1]

....

....

(ii) Use the $\Delta H_f^{\ominus}$ values given to calculate:

I the standard enthalpy change, $\Delta H^{\ominus}$, for the combustion of ammonia;

$$4NH_3(g) + 3O_2(g) \longrightarrow 2N_2(g) + 6H_2O(g)$$ [2]

....

....

....

II the standard enthalpy change, $\Delta H^{\ominus}$, for the combustion of methane (as an example of a fossil fuel).

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$$ [2]

....

....

....

Examiner only

(iii) State **one** advantage and **one** disadvantage of using ammonia as a fuel compared to using methane. [2]

Advantage of using ammonia ....

....

Disadvantage of using ammonia ....

....

Total [18]

Section B Total [70]

Examiner only

(c) A member of the public read in an article that the pH of an ammonium sulfate solution was 6. He asked you to explain what was meant by the pH scale.
What would be your reply? [2]

....

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....

....

(d) Ammonium nitrate, NH_4NO_3, is also used as a fertiliser. However, in the presence of certain impurities, it can explode very violently. This explosive reaction gives nitrogen, oxygen and steam.

$$NH_4NO_3(s) \longrightarrow N_2(g) + 2H_2O(g) + \tfrac{1}{2}O_2(g) \quad \Delta H = -296 \text{ kJ mol}^{-1}$$

M_r 80

Some years ago 400 tonnes (4×10^8 g) of ammonium nitrate, stored in a ship in a harbour, exploded, causing extensive damage.

Calculate the energy produced in this explosion, in kJ. [2]

....

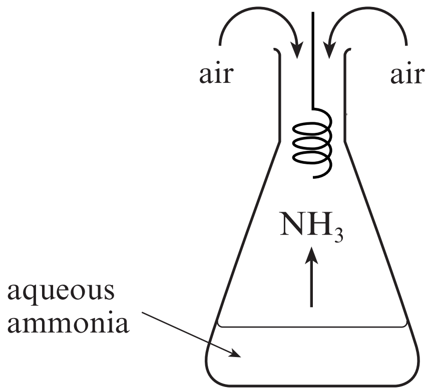
....

....

....

Examiner only

(e) Ammonia gas can be oxidised in air in the presence of a platinum catalyst. One method of showing this is to suspend a red-hot spiral of platinum wire in the neck of a flask containing ammonia gas and air. The platinum wire continues to glow red-hot as the ammonia is oxidised.



(i) Use the information given to explain how this experiment shows that the oxidation of ammonia is an exothermic reaction. [1]

....

....

....

(ii) The platinum wire is acting as a heterogeneous catalyst in this reaction.
Explain what is meant by the term 'heterogenous'. [1]

....

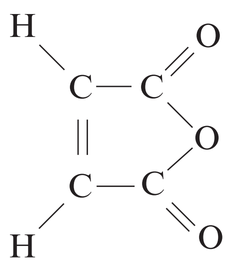
....

Total [14]

1091 01 07

Examiner only

9. *(a)* The compound maleic anhydride (Z-butenedioic anhydride) is an important compound that is used in the production of polyester resins.



maleic anhydride

(i) Three compounds, **L**, **M** and **N**, can be used to produce maleic anhydride in the presence of oxygen. The same conditions are used in each method.

Compound	% Yield of maleic anhydride	Other product(s)
L	75	H_2O and CO_2
M	65	H_2O
N	75	H_2O

I Using the **information in the table only** suggest which compound, **L**, **M** or **N**, should be used to produce maleic anhydride. Explain your reasoning. [2]

....

....

....

II Chemical manufacturers are interested in methods of production that have a minimum effect on the environment – 'Green Chemistry'.
Suggest **two** factors (not from information given in the table) that manufacturers should take into account when considering the production of maleic anhydride. [2]

1. ....

....

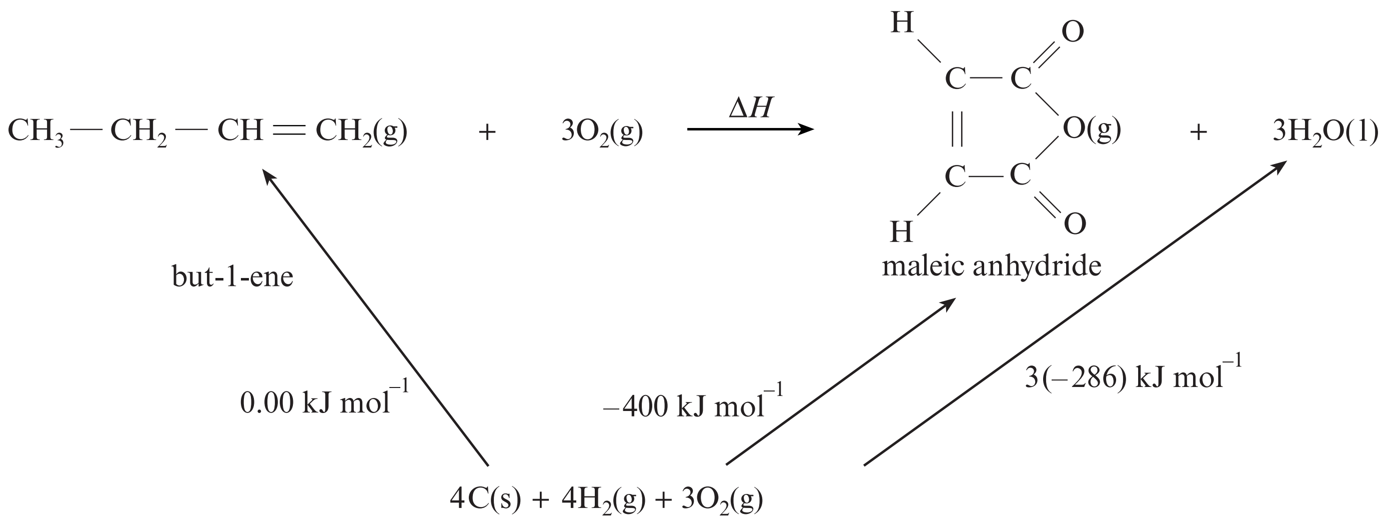
2. ....

....

Examiner only

(ii) One method of preparation of maleic anhydride is the oxidation of but-1-ene.

Use the energy cycle to calculate the enthalpy change, ΔH, for the production of maleic anhydride from but-1-ene. [2]



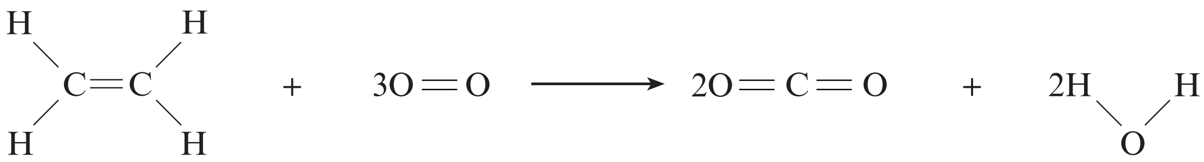
....

....

(b) In the complete oxidation of ethene, carbon dioxide and water are formed.

Use the bond energy values in the table to calculate the enthalpy change in the reaction given. [4]

Bond	Average bond energy / $kJ\ mol^{-1}$
C — H	412
C = C	612
O = O	496
C = O	743
O — H	463



ethene

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....

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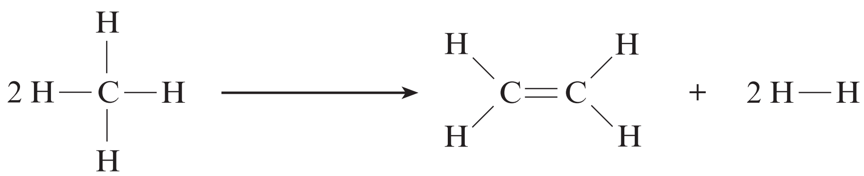
Examiner only

(c) Another way of producing hydrogen is from reforming natural gas.



Use the values in the table below to calculate the enthalpy change for the above reaction. [2]

Bond	Average bond enthalpy / $kJ\,mol^{-1}$
C ═ C	612
C — H	412
H — H	436

....

....

....

....

Total [11]

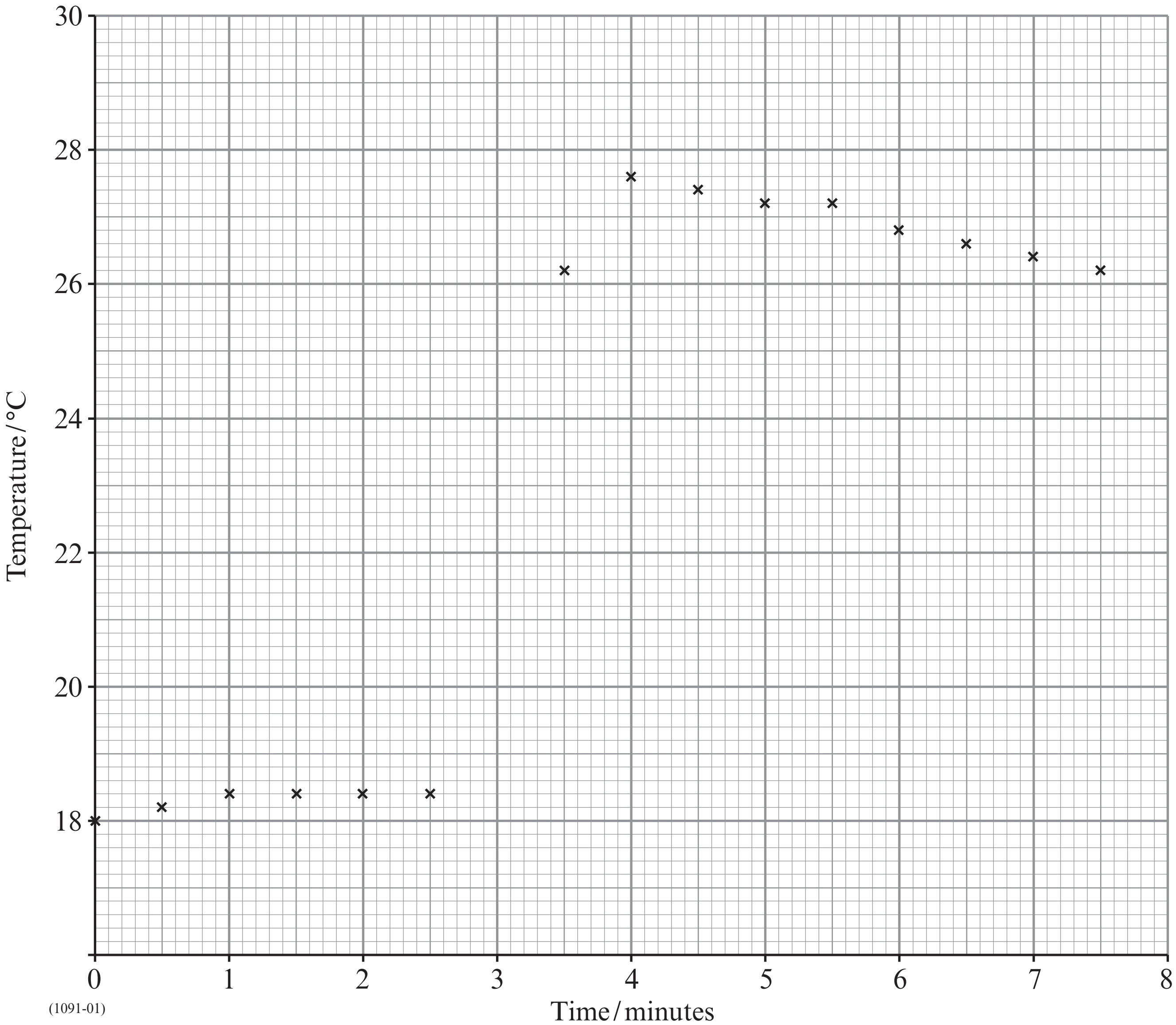
10. Lisa was asked to measure the molar enthalpy change for the reaction between magnesium and copper(II) sulfate solution.

$$Mg(s) \quad + \quad CuSO_4(aq) \longrightarrow MgSO_4(aq) \quad + \quad Cu(s)$$

She was told to use the following method.

- Weigh out about 0.90 g of powdered magnesium.
- Accurately measure 50.0 cm^3 of copper(II) sulfate solution of concentration 0.500 mol dm^{-3} into a polystyrene cup (placed in another polystyrene cup to provide insulation).
- Place a 0.2 °C graduated thermometer in the solution and measure its temperature every half-minute, stirring the solution before reading the temperature.
- At the third minute add 0.90 g of powdered magnesium, but do not record the temperature.
- Stir the mixture thoroughly, then record the temperature after three and a half minutes.
- Continue stirring and record the temperature at half-minute intervals for a further four minutes.

Lisa's results are shown on the graph below.



Examiner only

(a) Explain why the temperature of the copper(II) sulfate solution was measured for three minutes before adding the magnesium. [1]

....

....

(b) (i) Determine the maximum temperature **change** by drawing lines of best fit for both sets of points and extrapolating both lines to the third minute.

Temperature rise from the graph after extrapolation .... °C [2]

(ii) Explain why extrapolation gives a more accurate temperature change than using the maximum temperature recorded in the experiment. [1]

....

....

....

(c) Use the temperature rise from the graph to calculate the amount of 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]

....

....

(d) (i) Calculate the number of moles of magnesium in 0.90 g. [1]

....

....

(ii) Calculate the number of moles of copper(II) sulfate in 50.0 cm^3 of a 0.500 $mol\,dm^{-3}$ solution. [1]

....

....

(e) Calculate the molar enthalpy change for the reaction between magnesium and copper(II) sulfate solution. [2]

....

....

(f) Name a piece of apparatus that Lisa could use to accurately measure 50.0 cm^3 of the solution. [1]

....

Examiner only

(g) State why she did not need to accurately weigh the powdered magnesium. [1]

....

....

(h) Explain why it is better to use powdered magnesium rather than a strip of magnesium ribbon. [1]

....

....

(i) The data book value for this molar enthalpy change is $-93.1\,\text{kJ}\,\text{mol}^{-1}$.
Express the difference between Lisa's value and this value as a percentage of the data book value. [1]
(If you do not have an answer in *(e)* assume that the molar enthalpy change is $-65\,\text{kJ}\,\text{mol}^{-1}$, although this is **not** the correct answer.)

....

....

(j) State the **main** reason for Lisa's low value in this experiment and suggest **one** change that would improve her result. [2]

....

....

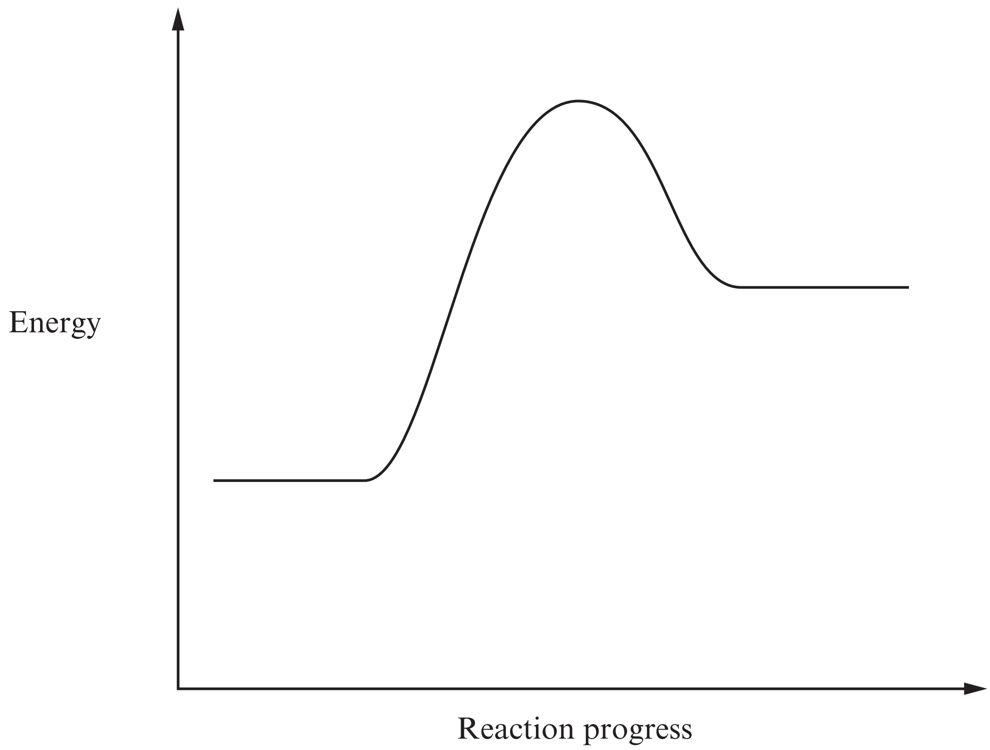
....

Total [15]

Section B Total [70]

Examiner only

5. Label clearly on the energy profile diagram below the forward (E_f) and reverse (E_b) activation energies and the enthalpy change (ΔH) for the reaction. [2]



6. An oxide of nitrogen has a relative molecular mass of 92 and contains 30.4 % of nitrogen and 69.6 % of oxygen, by mass.

Calculate

(a) the empirical formula, [1]

....

....

....

(b) the molecular formula of this oxide. [1]

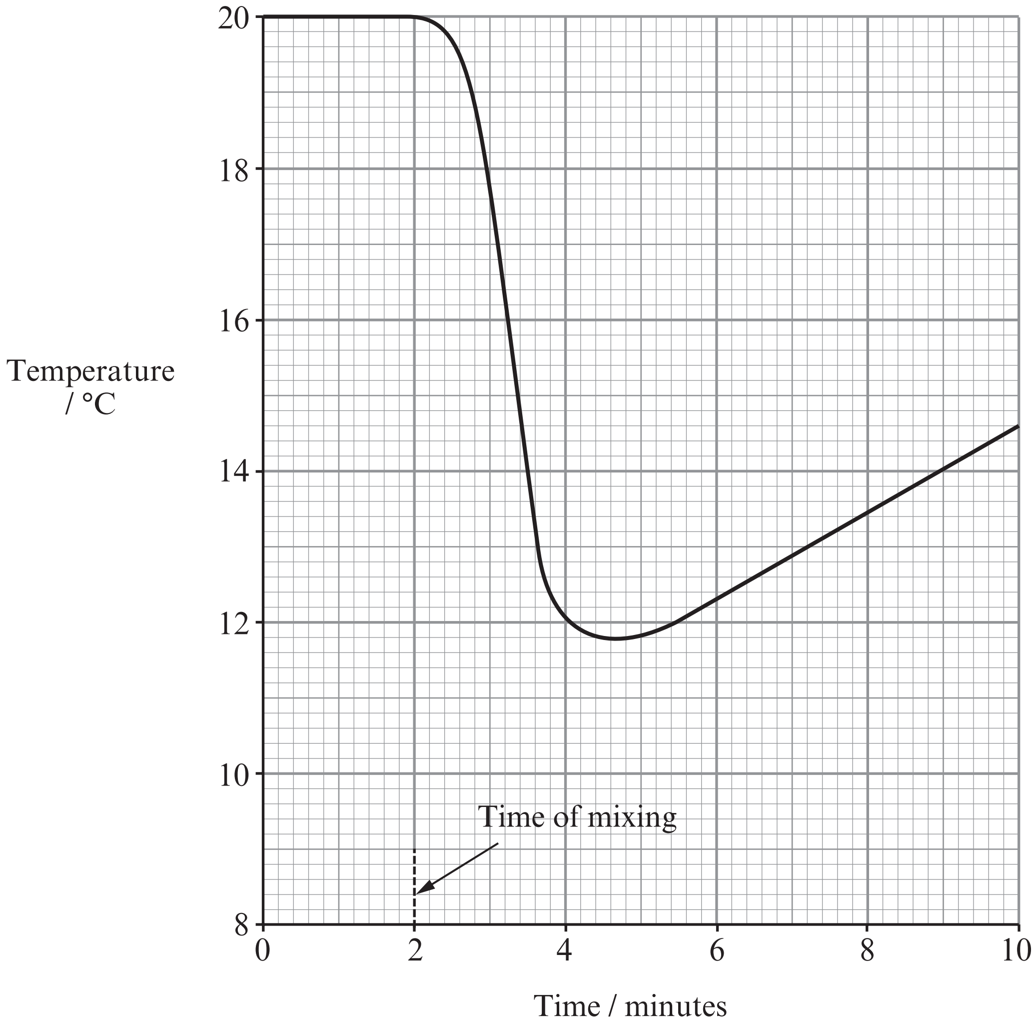
....

....

Section A Total [10]

11. The study of energy changes is important in chemistry and concerns most aspects of modern life such as the efficiency of fuels.

(a) The plot below resulted from an experiment to find the enthalpy change that occurs when sodium nitrate(V), $NaNO_3$, is dissolved in water.



Examiner only

(i) Describe how you could carry out such an experiment, using a diagram if you wish. [4]

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....

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(ii) Using the plot and drawing lines where necessary, find ΔT and thus calculate ΔH using the equation

$$\Delta H = \frac{-mc\Delta T}{n} \text{ Jmol}^{-1}$$

where the mass of water (m) was 50 g, the heat capacity (c) was 4.2 J g^{-1} K^{-1} and the amount of nitrate used (n) was 0.10 mol. [4]

....

....

ΔH = ... kJ mol^{-1}

(b) (i) State *Hess's Law*. [1]

....

....

(ii) Use this law to calculate the enthalpy change when sulfur trioxide and water react to form sulfuric acid.

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

The standard enthalpy changes of formation of the compounds ($\Delta H_f^{\ominus}$) are given in the following table.

Compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
H_2O	–286
SO_3	–395
H_2SO_4	–811

[2]

....

....

....

....

....

(c) State what is meant by the *average bond enthalpy* of an O—H bond and explain why the word *average* must be used. [2]

....

....

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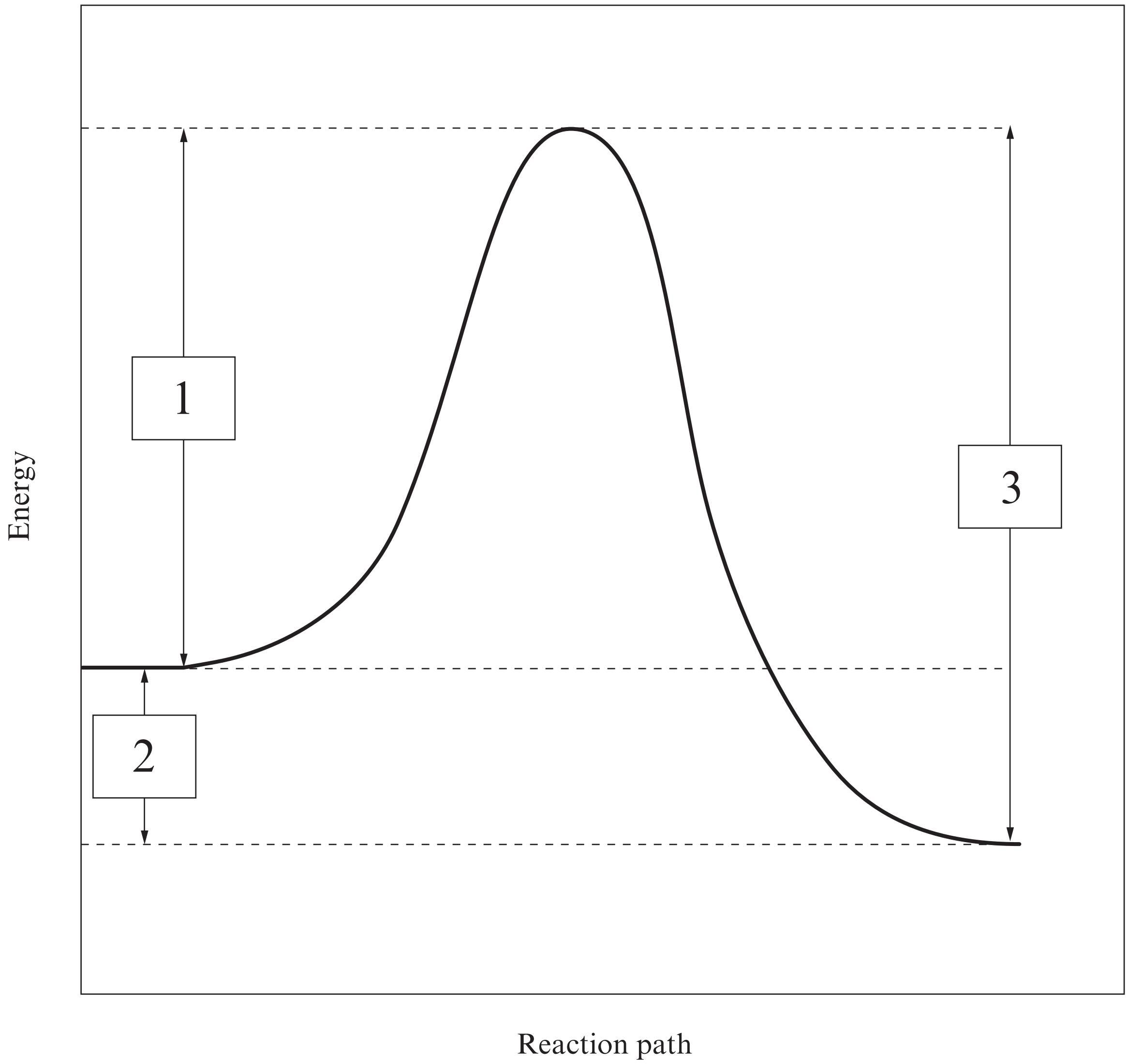
Examiner only

5. 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

.... [1]

Examiner only

SECTION B

Answer **all** *questions in the spaces provided.*

7. Hydrocarbons play an important role in our life today, both as fuels and as raw materials for the synthesis of a wide range of materials. Most hydrocarbons are isolated from crude oil, however there is increasing interest in alternative methods of obtaining these molecules.

(a) One route to the production of hydrocarbons is the Fischer-Tropsch process, which uses hydrogen and carbon monoxide as starting materials to produce a range of molecules. The equation below shows the production of pentane, C_5H_{12}, by this route.

$$11H_2(g) + 5CO(g) \longrightarrow C_5H_{12}(l) + 5H_2O(l) \qquad \Delta H^{\ominus} = -1049\,kJ\,mol^{-1}$$

The enthalpies of formation of some of these substances are given in the table below.

Substance	Standard enthalpy of formation, $\Delta H_f^{\ominus}$ / $kJ\,mol^{-1}$
Hydrogen, $H_2(g)$	0
Carbon monoxide, $CO(g)$	–111
Water, $H_2O(l)$	–286

(i) State the temperature and pressure used as standard conditions. Give units for each. [2]

Temperature .... *Pressure* ....

(ii) State why the standard enthalpy of formation for hydrogen gas is $0\,kJ\,mol^{-1}$. [1]

....

....

....

(iii) Use the values given to calculate the standard enthalpy of formation for pentane, $C_5H_{12}(l)$, in $kJ\,mol^{-1}$. [3]

....

....

....

....

Examiner only

10. 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 cm^3 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]

....

....

....

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

II. Describe, giving full practical details, how Callum should prepare the 250.0 cm^3 of copper(II) sulfate solution. [5]
QWC [1]

....

....

....

....

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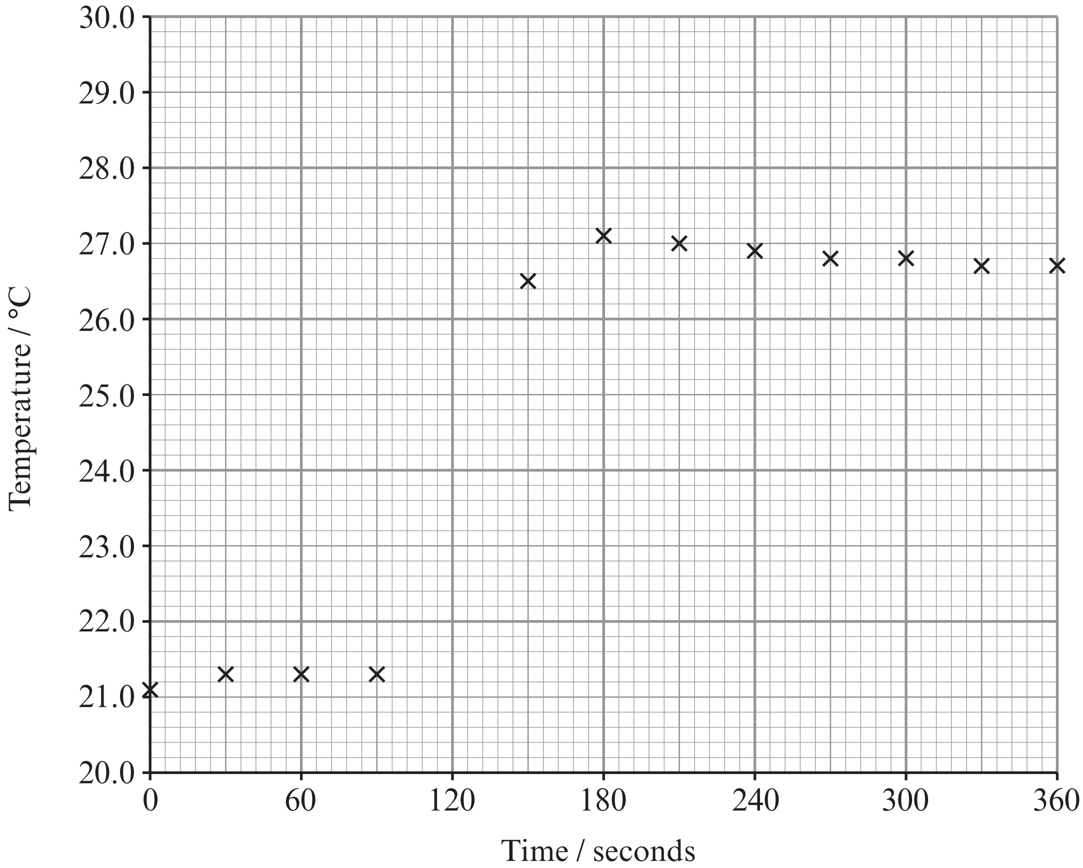
....

....

(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.



Examiner only

(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]

Total Section B [70]

Examiner only

9. Ethanol is an important industrial chemical and can be made by the direct hydration of ethene using a phosphoric acid catalyst.

$$CH_2{=}CH_2(g) \ + \ H_2O(g) \ \rightleftharpoons \ CH_3CH_2OH(g) \qquad \Delta H = -46\,kJ\,mol^{-1}$$

(a) State, giving your reasons, the general conditions of temperature and pressure required to give a high equilibrium yield of ethanol in this process. [4]
QWC [1]

....

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....

(b) Using the standard enthalpy change for the reaction above and the standard enthalpy changes of formation ($\Delta H_f^\ominus$) given in the table below, calculate the standard enthalpy change of formation of gaseous ethanol. [3]

Compound	$\Delta H_f^\ominus$ / kJ mol^{-1}
$CH_2{=}CH_2(g)$	52.3
$H_2O(g)$	–242

....

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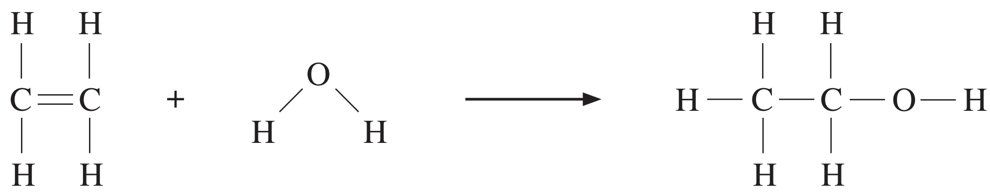
....

Examiner only

(c) Another way of calculating the enthalpy change of a reaction is by using average bond enthalpies. Use the values in the table below to calculate the enthalpy change for the direct hydration of ethene. [3]



Bond	Average bond enthalpy / kJ mol^{-1}
C—C	348
C=C	612
C—H	412
C—O	360
O—H	463

....

....

....

....

(d) (i) Give a reason why the calculated value in *(c)* is different to the actual value, –46 kJ mol^{-1}. [1]

....

....

(ii) Explain whether your answer to part (i) supports the use of average bond enthalpies to calculate the energy change for a reaction. [1]

....

....

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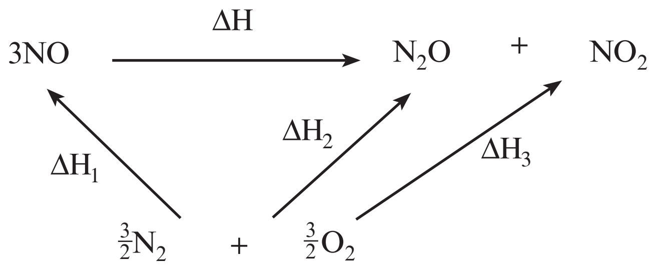
4. The energy cycle for a decomposition of nitrogen(II) oxide is shown below.



(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]

....

5. Carbon oxide sulfide, COS, is obtained by heating together carbon monoxide and gaseous sulfur.

$$2CO(g) + S_2(g) \rightleftharpoons 2COS(g)$$

State and explain any change that occurs when more carbon monoxide is added to the equilibrium mixture. [2]

....

....

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....

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9. *(a)* Nitrogen(I) oxide is a colourless gas that reacts with hydrogen to give nitrogen and water.

$$N_2O(g) + H_2(g) \longrightarrow N_2(g) + H_2O(l) \qquad \Delta H = -368\,kJ\,mol^{-1}$$

(i) State why the standard enthalpy of formation of both hydrogen and nitrogen gases is $0\,kJ\,mol^{-1}$. [1]

....

....

(ii) Calculate the standard enthalpy of formation of nitrogen(I) oxide in $kJ\,mol^{-1}$. (You should assume that the standard enthalpy of formation of water is $-286\,kJ\,mol^{-1}$) [2]

Standard enthalpy of formation = ... $kJ\,mol^{-1}$

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10. *(a)* Potassium hydroxide contains potassium ions, K^+.
Give the electron configuration of a potassium **atom** and use this to explain why most potassium compounds contain the potassium ion. [2]

....

....

....

(b) Michael was asked to make 250 cm^3 of a solution of potassium hydroxide and to record the maximum rise in temperature that occurred as it dissolved.
He measured 250 cm^3 of water in a glass beaker and then added 7.01 g (0.125 mol) of solid potassium hydroxide to this, with stirring.
He noticed that the temperature rose from 20.2 °C to a maximum of 25.0 °C.

(i) Calculate the molar enthalpy change of solution of potassium hydroxide by use of the formula

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

where m = mass of the solvent 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 solution
n = number of moles of the solute
ΔH = molar enthalpy change of solution

You should show the **units** in your answer. [3]

ΔH = ...

(ii) Michael's measurements produced a value for the enthalpy of solution of potassium hydroxide that was different to the literature value.

Use the information given to suggest and explain **two** factors that might produce a different result. [2]

1. ....

....

2. ....

....

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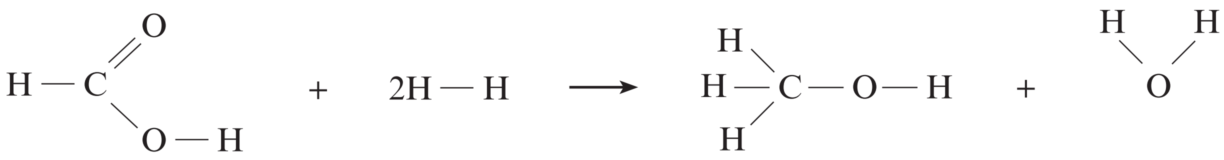
(b) Methanoic acid, HCOOH, can be reduced to methanol, CH_3OH, in a gas phase reaction, by using hydrogen in the presence of a solid ruthenium metal catalyst.

(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}

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SECTION B

Answer **all** *questions in the spaces provided.*

7. Jewels such as diamonds, rubies and emeralds are highly valued but are all closely related to much less precious materials.

(a) Emeralds are a form of the mineral beryl, with their green colour due to the impurities present.

A sample of beryl contains 10.04% aluminium, 53.58% oxygen and 31.35% silicon by mass, with beryllium making up the remainder. Its molecular formula is $Al_2Be_xSi_6O_{18}$. Find the percentage by mass of beryllium in the compound and hence calculate the value of x in this formula. [3]

x = ...

(b) The most common form of carbon is graphite, however the element also exists in the form of diamond.

We can calculate the standard enthalpy change of reaction for making diamond from graphite using Hess' Law.

Reaction	Standard enthalpy change of reaction / kJ mol^{-1}
$C(diamond) + O_2(g) \longrightarrow CO_2(g)$	–395.4
$C(graphite) + O_2(g) \longrightarrow CO_2(g)$	–393.5

(i) State Hess' Law. [1]

....

....

Examiner only

(ii) Use Hess' Law and the data in the table on page 4 to calculate the enthalpy change of the reaction below. [2]

$$C(graphite) \rightarrow C(diamond)$$

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

(iii) Kyran states that because diamond is an element, its enthalpy of formation under standard conditions must be zero.

State whether Kyran is correct and give a reason to support your answer. [1]

....

....

....

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(iv) Most diamonds used in jewellery come from natural sources, but it is possible to produce diamonds artificially although these are rarely of gemstone quality.

I One proposed use of artificial diamond is to protect medical implants. To cover a particular implant, a volume of 2.08 cm^3 of diamond is needed. Calculate the mass of diamond required. [1]

[Density of diamond under standard conditions = 3.51 g cm^{-3}]

Mass of diamond = ... g

II The process of producing diamond from graphite has a yield of 93%. Calculate the mass of graphite needed to make the diamond required. [2]

Mass of graphite = ... g

Total [10]

Examiner only

11. The combustion of fossil fuels provides much of the energy we use today. Nonane, C_9H_{20}, is one of the compounds present in the fuel kerosene.

(a) (i) The equation for the combustion of nonane is given below.

$$C_9H_{20}(l) + 14\,O_2(g) \longrightarrow 9\,CO_2(g) + 10H_2O(l)$$

Use the values given in the table to calculate the standard enthalpy of combustion of nonane. [3]

Substance	Standard enthalpy of formation, $\Delta H_f^{\ominus}$ / kJ mol^{-1}
$C_9H_{20}(l)$	–275
$O_2(g)$	0
$CO_2(g)$	–394
$H_2O(l)$	–286

Standard enthalpy of combustion = ... kJ mol^{-1}

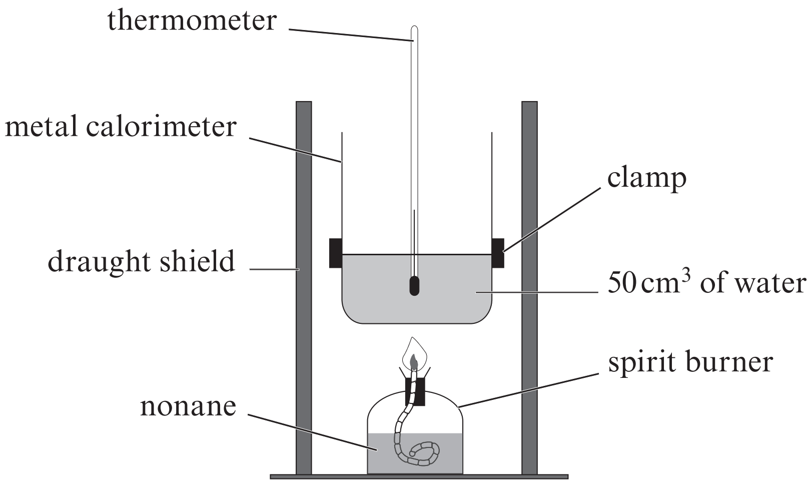
(ii) Standard enthalpy changes are measured under standard conditions. Give the standard conditions of temperature and pressure, including units for each. [2]

Temperature ....

Pressure ....

Examiner only

(b) Iwan wished to confirm the value he had calculated for the enthalpy of combustion of nonane, and he used the apparatus below.



(i) Iwan measured the mass of the spirit burner at the start and end of the experiment and found that 0.20 g of nonane had been burned. Calculate the number of moles of nonane present in 0.20 g. [2]

Number of moles = ... mol

(ii) During this experiment, the temperature of the water increased by 42.0 °C. Use the formula below to calculate the enthalpy change of combustion of nonane, in kJ mol^{-1}. [2]

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

m is the mass of water
c is the specific heat capacity of water which is 4.18 J °C^{-1}g^{-1}
ΔT is the temperature change in °C
n is the number of moles of nonane

ΔH = ... kJ mol^{-1}

QUESTION 11 CONTINUES ON PAGE 14

Examiner only

(iii) Give **one** reason why the experimental value that Iwan obtained differs from the theoretical value calculated in part *(a)*. [1]

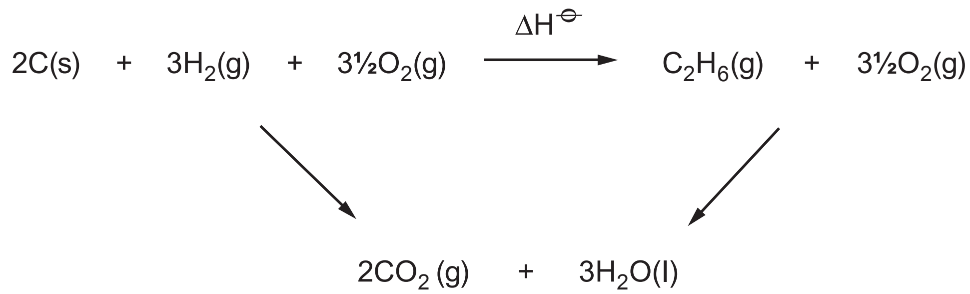
....

....

Total [10]

Examiner only

4. Study the following energy cycle.



Use the values in the table below to calculate the enthalpy change of reaction, ΔH⦵. [2]

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

ΔH⦵ = ... kJ mol^{-1}

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Examiner only

9. *(a)* State what is meant by the term *standard molar enthalpy change of formation*. [2]

....

....

....

(b) (i) Write an equation to represent the standard molar enthalpy change of formation, $\Delta H_f^{\ominus}$, of $H_2O(g)$. [1]

....

(ii) The standard molar enthalpy change of formation, $\Delta H_f^{\ominus}$, of $H_2O(g)$ is −242 kJ mol^{-1}. Using this value and the average bond enthalpies given in the table below, calculate the average bond enthalpy of the O—H bond in H_2O. [2]

Bond	Average bond enthalpy / kJ mol^{-1}
H—H	436
O═O	496

Average bond enthalpy of O—H *bond* = ... kJ mol^{-1}

(c) Hydrogen has been proposed as a possible alternative to petrol as a fuel for cars. One suggestion is to store the hydrogen in the car as solid magnesium hydride, MgH_2, and generate it as required by heating.

(i) I Give **one** advantage of using hydrogen in place of petrol as a fuel for cars. [1]

....

....

II Give **one** advantage of storing the fuel in the car in the form of magnesium hydride rather than hydrogen gas. [1]

....

....

Examiner only

(ii) One possible disadvantage of using magnesium hydride arises from its reaction with water.

$$MgH_2(s) + 2H_2O(l) \longrightarrow Mg(OH)_2(s) + 2H_2(g)$$

Suggest why magnesium hydride's reaction with water could be a problem. [1]

....

....

(iii) The fuel tank of one type of hydrogen-powered car holds 70 kg of magnesium hydride.
Calculate the volume of hydrogen gas, measured at room temperature and pressure, which would be produced if this amount of magnesium hydride reacted with water. [3]
[1 mol of gas molecules occupies 24 dm^3 at room temperature and pressure]

Volume of hydrogen gas = ... dm^3

(d) Methanol can be produced industrially by passing carbon monoxide and hydrogen over a catalyst at high temperatures and pressures.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -91 \text{ kJ mol}^{-1}$$

(i) State how the equilibrium yield of methanol is affected by an increase in temperature and in pressure. [1]

....

....

(ii) Explain your answer to part (i). [2]

....

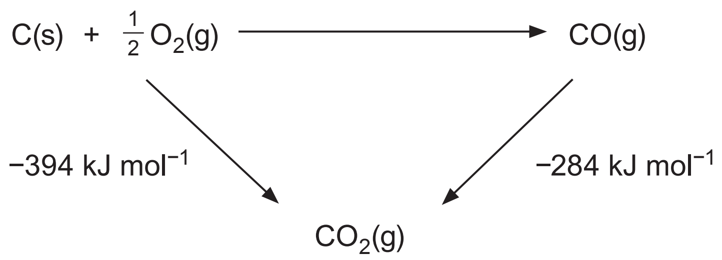
....

....

....

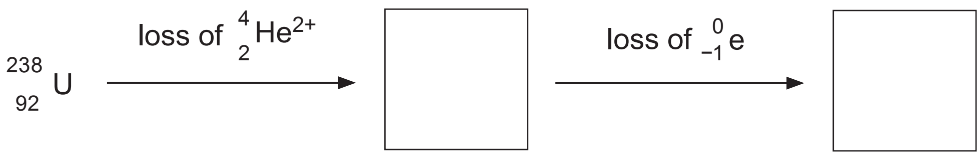
Examiner only

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



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

6. Complete the equation to show the two-stage process by which a radioactive isotope of uranium decays. [2]



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11. *(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]

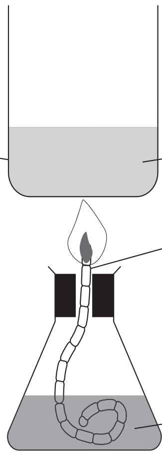
....

....

(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

Examiner only

(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]

ΔH_c *of ethanol* = ... kJ mol^{-1}
sign *value*

(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]

....

....

....

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(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]

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Total [17]

