1 Glucose, $C_6H_{12}O_6$, can be completely combusted to give carbon dioxide and water.

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

(a) In the body, the conversion of glucose into carbon dioxide and water takes place in a number of stages catalysed by enzymes.

What name is given to this oxidation process in the body?

..... **[1]**

(b) A student carries out an experiment to determine the enthalpy change of combustion of glucose.

In the experiment, 0.831 g of glucose is burned. The energy released is used to heat 100 cm^3 of water from 23.7 °C to 41.0 °C.

(i) Calculate the energy released, in kJ, during combustion of 0.831 g glucose.

The specific heat capacity of water = 4.18 $J\,g^{-1}\,K^{-1}$.
Density of water = 1.00 $g\,cm^{-3}$.

energy = …….. kJ **[2]**

(ii) Calculate the amount, in moles, of glucose that is burned.

amount = …….. mol **[2]**

(iii) Calculate the enthalpy change of combustion of glucose.
Give your answer to **three** significant figures.

ΔH_c = …….. kJ mol^{-1} **[2]**

(c) The standard enthalpy change of combustion of glucose can also be determined indirectly.

Calculate the standard enthalpy change of combustion of glucose using the standard enthalpy changes of formation below.

substance	$\Delta H_f^{\ominus}$ **/ kJ mol^{-1}**
$C_6H_{12}O_6(s)$	–1250
$CO_2(g)$	–394
$H_2O(l)$	–286

$$C_6H_{12}O_6(s) + 6O_2(g) \longrightarrow 6CO_2(g) + 6H_2O(l)$$

answer = ... kJ mol^{-1} **[3]**

(d) Suggest **two** reasons why standard enthalpy changes of combustion determined experimentally are less exothermic than the calculated theoretical values.

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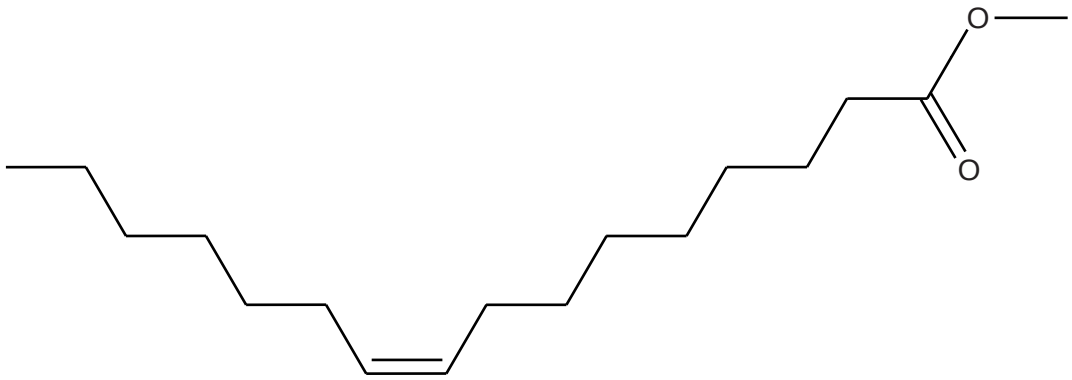
..... **[2]**

[Total: 12]

2 Compound **I** is found in biodiesel. It has the skeletal formula shown below.



(a) Name the **two** functional groups that are present in a molecule of **I**.

.....

..... **[2]**

(b) Why is compound **I** unsaturated?

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..... **[1]**

(c) A sample of compound **I** is shaken with aqueous bromine.

What colour change would you see?

from ..... to ..... **[1]**

(d) Compound **J** is a stereoisomer of compound **I**.

(i) What is meant by the term *stereoisomers*?

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..... **[1]**

(ii) Draw or describe how the structure of **J** differs from that of **I**.

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..... **[1]**

(e) A student determined the enthalpy change of combustion for compound **I**.

In her experiment, 1.34 g of compound **I** was used to heat 50.0 g of water.

The temperature of the water changed from 20.2 °C to 54.0 °C.

(i) What is meant by the term *enthalpy change of combustion*, ΔH_c?

.....

.....

..... **[2]**

(ii) Calculate the energy released, in kJ, in the student's experiment.

The specific heat capacity of water is 4.18 J g^{-1} K^{-1}.

energy = ... kJ **[2]**

(iii) The molecular formula of compound **I** is $C_{17}H_{32}O_2$.

Calculate the amount, in moles, of compound **I** used by the student.

amount = ... mol **[2]**

(iv) Calculate the enthalpy change of combustion of compound **I**.

ΔH_c = ... kJ mol^{-1} **[3]**

(v) The student noticed that compound **I** burnt with a yellow flame and produced black smoke.

Suggest an explanation for these observations.

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..... **[1]**

(f) Some scientists believe that we should use more biofuels such as biodiesel and bioethanol.

Bioethanol is made by the fermentation of plant sugars such as glucose.

Write the equation for the fermentation of glucose to make ethanol and state **two** essential conditions for this fermentation.

equation

.....

essential conditions

.....

..... **[3]**

[Total: 19]

3 The alkanes are an homologous series of hydrocarbons.
The table shows information about some straight chain alkanes.

alkane	molecular formula	boiling point / °C
methane	CH_4	–164
ethane	C_2H_6	–89
propane	C_3H_8	–42
butane	C_4H_{10}	–1

(a) (i) What is meant by an *homologous series*?

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..... **[1]**

(ii) Explain why the boiling points increase down the alkane homologous series.

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..... **[2]**

(b) Alkynes are another homologous series of hydrocarbons.
The table gives the molecular formulae of the first five straight chain alkynes.

alkyne	molecular formula
ethyne	C_2H_2
propyne	C_3H_4
but-1-yne	C_4H_6
	C_5H_8
hex-1-yne	C_6H_{10}

(i) Suggest the name of a straight chain alkyne with the molecular formula C_5H_8.

..... **[1]**

(ii) Deduce the general formula for an alkyne.

..... **[1]**

(iii) The alkynes contain the C≡C functional group.

Suggest the displayed formula for propyne.

[1]

(iv) Hex-1-yne has many cyclic structural isomers.

Draw the skeletal structure of one of these cyclic structural isomers.

[1]

(c) Ethyne is commonly called acetylene.
It is used in an oxy-acetylene flame which is hot enough to cut through steel.

Ethyne completely combusts as shown in the equation below.

Calculate the enthalpy change of combustion of ethyne using the average bond enthalpies in the table below.

bond	average bond enthalpy / kJ mol^{-1}
C–H	+415
C≡C	+837
O=O	+498
C=O	+805
O–H	+464

enthalpy change of combustion = …… kJ mol^{-1} **[3]**

(d) Ethyne is formed when water reacts with calcium carbide, CaC_2.

$$CaC_2(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(s) + C_2H_2(g)$$

The standard enthalpy change of this reaction can be determined indirectly using standard enthalpy changes of formation.

(i) What is meant by the term *standard enthalpy change of formation*, $\Delta H_f^{\ominus}$?
You should state the standard conditions in your answer.

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..... **[3]**

(ii) Standard enthalpy changes of formation are shown in the table below.

substance	**standard enthalpy change of formation, $\Delta H_f^{\ominus}$ / kJ mol^{-1}**
$CaC_2(s)$	–60
$H_2O(l)$	–286
$Ca(OH)_2(s)$	–987
$C_2H_2(g)$	+227

Calculate the standard enthalpy change of the reaction:

$$CaC_2(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(s) + C_2H_2(g)$$

standard enthalpy change of reaction = ... kJ mol^{-1} **[3]**

(e) A factory makes ethyne gas from calcium carbide, CaC_2.
One of the waste products is calcium hydroxide.

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$$

Each day 1.00×10^6 grams of calcium carbide are used and 3.60×10^5 dm^3 of ethyne gas, measured at room temperature and pressure, is manufactured.

(i) Calculate the atom economy for this process using the relative formula masses in the table below.

compound	**relative formula mass**
CaC_2	64.1
H_2O	18.0
$Ca(OH)_2$	74.1
C_2H_2	26.0

atom economy = …….. % **[2]**

(ii) Calculate the amount, in moles, of CaC_2 used each day.

amount of CaC_2 = ……mol **[1]**

(iii) Calculate the amount, in moles, of C_2H_2 made each day.

amount of C_2H_2 = ……mol **[1]**

(iv) Calculate the percentage yield of C_2H_2.

percentage yield = …… % **[1]**

(v) Comment on the percentage yield and the atom economy of this process in terms of sustainability.

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..... **[2]**

[Total: 23]

4 Dilute aqueous hydrogen peroxide, $H_2O_2(aq)$, is used to sterilise contact lenses.

(a) Dilute $H_2O_2(aq)$ slowly decomposes at room temperature to produce oxygen and water.

The decomposition of $H_2O_2(aq)$ can be made faster by:

- increasing the concentration of the $H_2O_2(aq)$,
- adding a small amount of manganese(IV) oxide catalyst,
- heating the solution to 60 °C.

(i) Construct the equation for the decomposition of H_2O_2.

..... **[1]**

(ii) Explain why increasing the concentration of $H_2O_2(aq)$ increases the rate of decomposition.

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..... **[2]**

(iii) Explain how the catalyst can increase the rate of decomposition of $H_2O_2(aq)$.

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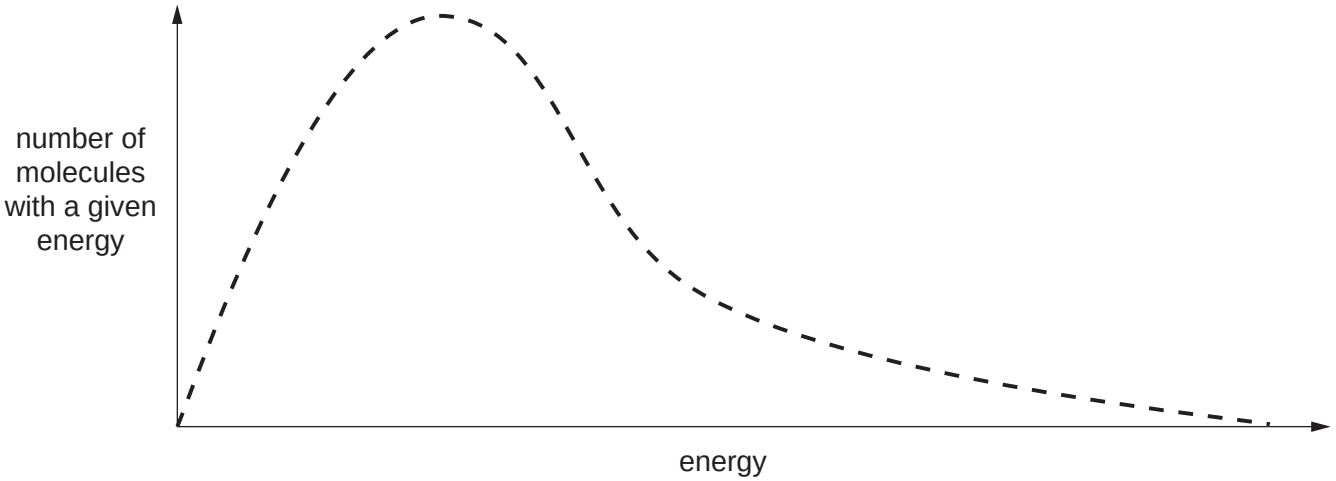
..... **[2]**

(iv) Explain why increasing the temperature of $H_2O_2(aq)$ increases the rate of decomposition.

As part of your answer, you should add a second curve and any necessary labels to the Boltzmann distribution of molecular kinetic energies shown below.



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..... **[3]**

(b) (i) In the past, hydrogen peroxide was manufactured by reacting barium peroxide, BaO_2, with ice-cold dilute sulfuric acid.

$$BaO_2(s) + H_2SO_4(aq) \longrightarrow BaSO_4(s) + H_2O_2(aq)$$

This method required the disposal of poisonous barium compounds.

Calculate the atom economy for this manufacture of hydrogen peroxide from BaO_2.
Use the table of relative formula masses given below.

compound	**relative formula mass**
BaO_2	169.3
H_2SO_4	98.1
$BaSO_4$	233.4
H_2O_2	34.0

atom economy = ... % **[2]**

(ii) Nowadays, hydrogen peroxide is manufactured using hydrogen gas, oxygen from the air and a substance called anthraquinone.

stage 1 H_2 + anthraquinone $\rightarrow$ anthraquinol

stage 2 O_2 + anthraquinol $\rightarrow$ H_2O_2 + anthraquinone

Compare the manufacture of H_2O_2 from hydrogen and oxygen with the manufacture from barium peroxide described in **b(i)**.

Explain the advantages of the manufacture of H_2O_2 from hydrogen and oxygen.

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..... **[3]**

(c) Some reactions of H_2O_2 are exothermic.

Use ideas about the enthalpy changes that take place during bond breaking and bond making to explain why some reactions are exothermic.

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..... **[2]**

[Total: 15]