<u>Developing fuels – Revision pack</u>

Use this pack in conjunction with the textbook to ensure that you are aware of the learning objectives for each chapter. In addition to these questions, use the extra support sheets and questions that are provided in the worksheets on the Frog website.

Q1:

The search for alternatives to fuels made from crude oil is becoming more important. 'Biofuels' such as ethanol and biodiesel are now readily available.

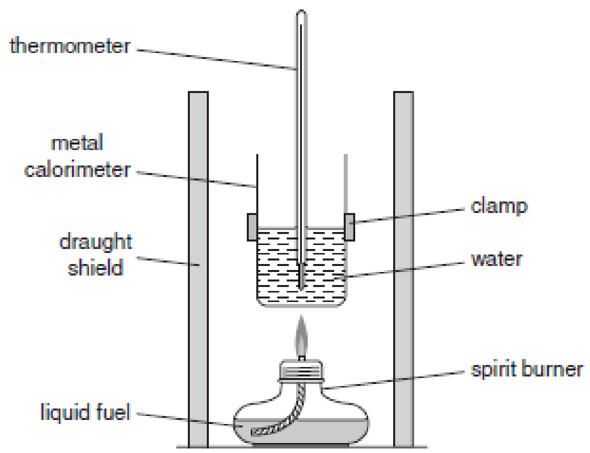
(a) Suggest **two** benefits associated with using 'biofuels'.

....

....

.... **[2]**

A student determined the enthalpy change of combustion of ethanol using the apparatus shown below.



The student's results are shown below.

mass of calorimeter	= 120 g
mass of water in calorimeter	= 100 g
mass of spirit burner at start	= 43.56 g
mass of spirit burner at end	= 42.36 g
initial temperature of water	= 20 °C
final temperature of water	= 45 °C

(i) Calculate the energy transferred to the water.

Specific heat capacity of water = $4.18\,J\,g^{-1}\,K^{-1}$.

energy transferred = ... J **[2]**

(ii) Use your answer to **(i)** to work out the enthalpy change of combustion of ethanol, in $kJ\,mol^{-1}$.

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

M_r (ethanol) = 46.0.

enthalpy change of combustion of ethanol = ... $kJ\,mol^{-1}$ **[4]**

A data book shows that when one mole of ethanol burns under standard conditions, 1370 kJ are produced.

Suggest **two** reasons why this value is very different from the student's experimental result.

....

....

.... **[2]**

List the bonds that are broken and made when ethanol burns.

[3]

Use the ideas of bond making and bond breaking to explain why the combustion of ethanol gives out energy.

....

....

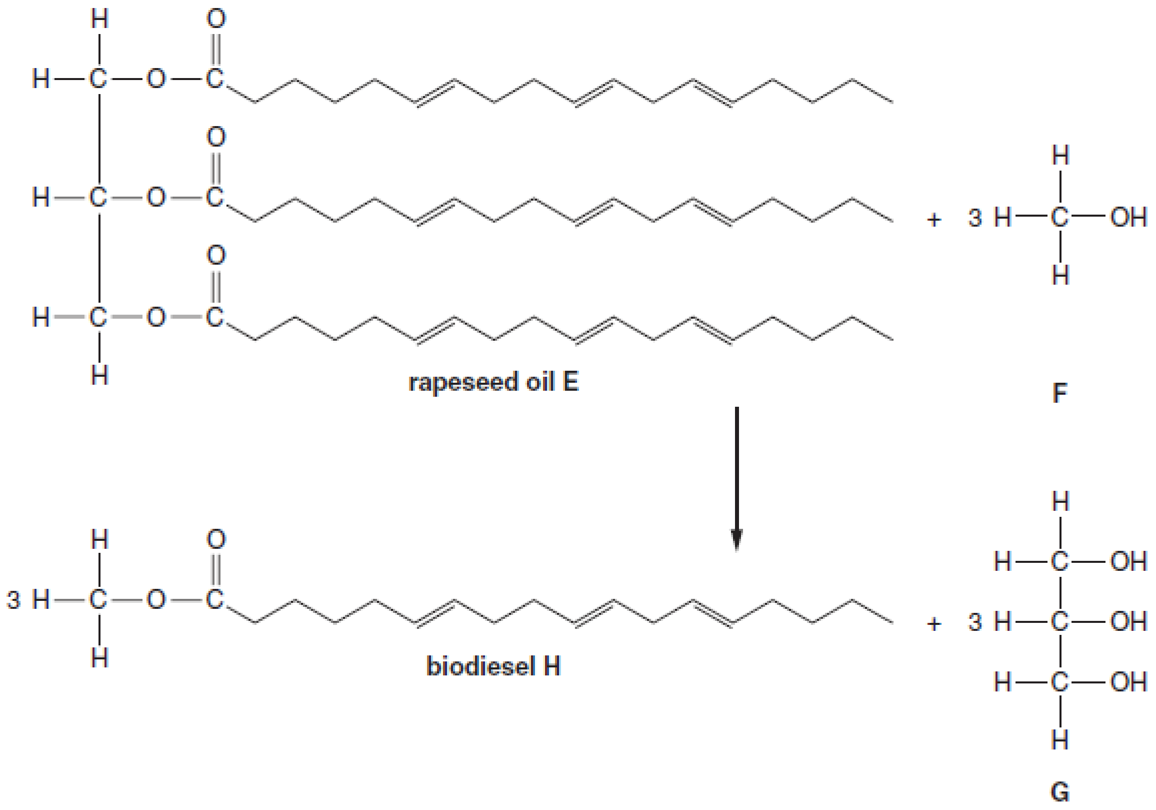
....

....

.... **[2]**

Q2:

4 A fuel made from rapeseed oil can be used to replace diesel in cars. The following reaction scheme shows how this 'biodiesel' can be made from rapeseed oil.



You are **not** expected to know all of the functional groups in these structures.

Answer the following questions based on the reaction scheme opposite.

(i) Give the letter or letters of the structure(s) that contain alcohol groups.

.... **[2]**

(ii) Structure **E** contains hydrocarbon chains. Draw a circle around **one** hydrocarbon chain. **[1]**

(iii) What **type** of formula has been used to represent this hydrocarbon chain?

.... **[1]**

(iv) What is the molecular formula of **G**?

.... **[1]**

Cars that run on biodiesel produce oxides of nitrogen. Nitrogen and oxygen react under the high temperatures in the combustion chamber.

(i) Where does the nitrogen come from?

.... [1]

(ii) Write a balanced equation for the reaction between nitrogen and oxygen to produce nitrogen monoxide. Include state symbols.

.... [2]

(iii) Suggest why high temperatures are needed for this reaction to take place.

....

.... [1]

Q3:

Cracking is another process that can be used to improve the performance of hydrocarbon fuels.

Explain what happens in cracking reactions and what **types** of molecules are produced.

....

....

....

.... [3]

Techniques have now been found to convert GVL into a fuel that can be used on its own, without blending.

One component of the fuel is hydrocarbon **A** with the following skeletal formula.

Give the molecular formula of hydrocarbon **A**.

.... [1]

Techniques have now been found to convert GVL into a fuel that can be used on its own, without blending.

One component of the fuel is hydrocarbon **A** with the following skeletal formula.

hydrocarbon A

The energy density of a fuel is the amount of energy, in kJ, released when 1.0 kg of the fuel is burned.

The enthalpy change of combustion of hydrocarbon **A** is –5300 kJ mol^{-1}.

Calculate its energy density.

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

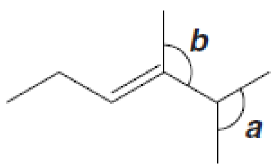
energy density = ... kJ per kg **[3]**

Techniques have now been found to convert GVL into a fuel that can be used on its own, without blending.

One component of the fuel is hydrocarbon **A** with the following skeletal formula.

hydrocarbon A

One isomer of hydrocarbon **A** is shown below, where ***a*** and ***b*** represent bond angles.



isomer of hydrocarbon A

Suggest a value for bond angle ***b*** and explain your answer.

....

....

....

....

Would you expect the value of bond angle ***a*** to be greater, smaller or the same as the value of bond angle ***b***?

Explain your answer.

....

....

....

.... **[2]**

A student designs an experiment to measure the energy transferred when hydrocarbon **A** and one of its isomers are burned separately in air.

The student burns the liquid isomers in order to heat up water in copper cans. Care is taken to keep the heating conditions the same for the two liquids.

(i) The student's results table for hydrocarbon **A** is shown below.

Use the data in the table to calculate the energy transferred to the water.

Starting temperature of water / °C	**Final temperature of water / °C**	**Volume of water used / cm^3**
22.0	47.0	200

specific heat capacity of water = $4.18\,J\,g^{-1}\,K^{-1}$

energy transferred to water = ... J **[1]**

The student knows the M_r of hydrocarbon **A**.

What further information does the student require to calculate the enthalpy change of combustion of hydrocarbon **A**?

....

.... **[1]**

The enthalpy changes of combustion of hydrocarbon **A** and its isomer are approximately the same.

Suggest why the enthalpy changes of combustion are approximately the same.

....

....

....

.... **[2]**

The student's calculated values for the enthalpy changes of combustion were very much lower in magnitude than the data book values.

The main reason for this was heat loss to the surroundings.

Suggest **one** other possible reason for the low values.

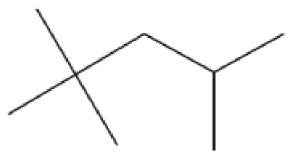
Assume that the student carries out the experiment carefully and calculates the enthalpy changes correctly.

....

.... **[1]**

Q4:

Octane is a component of petrol and the 'octane number' of a petrol is a measure of the tendency of the petrol to auto-ignite. The structure of an **isomer** of octane is given below.



(a) **(i)** What **type** of formula is represented by the structure above?

.... **[1]**

(ii) Give the systematic name of this isomer of octane.

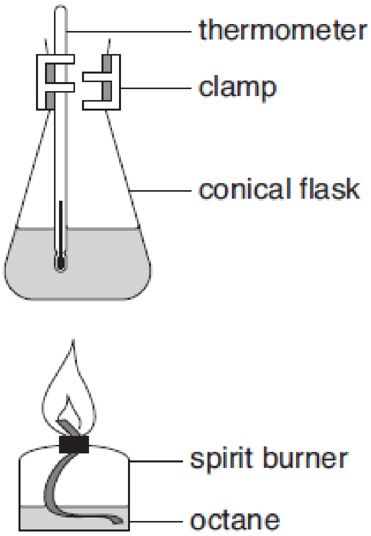
.... **[2]**

(iii) Branched chain hydrocarbons are useful in petrol because they have a low tendency to auto-ignite.

Name another structural feature of hydrocarbon molecules that also results in a lower tendency of the fuel to auto-ignite.

.... **[1]**

A value for the enthalpy change of combustion of octane can be obtained from a simple experiment using the following apparatus.



Describe how you could use this apparatus to obtain data from which you could calculate a value for the enthalpy change of combustion of octane. You should also explain how you would use your experimental results to calculate this value.

....

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.... **[5]**

Results obtained using this apparatus give a much less negative value for the enthalpy change of combustion of octane than the data book value.

Suggest **two** limitations in the practical procedure which would result in a less negative value for the enthalpy change of combustion of octane than the data book value.

....

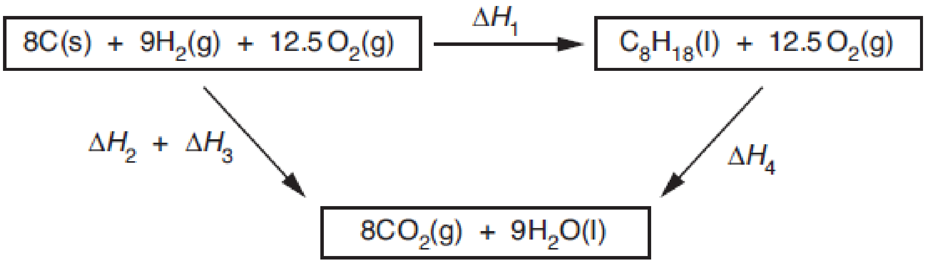
....

....

.... **[2]**

ΔH_f values can be calculated for hydrocarbons using enthalpy changes of combustion in an enthalpy cycle.

The enthalpy cycle below can be used to calculate the standard enthalpy change of formation of octane.



State the enthalpy changes represented by ΔH_1, ΔH_2, ΔH_3, and ΔH_4.

ΔH_1 = ...

....

ΔH_2 = ...

....

ΔH_3 = ...

....

ΔH_4 = ...

.... **[4]**

You are given the following values:

$$\Delta H_2 + \Delta H_3 = -5718\,\text{kJ mol}^{-1}; \quad \Delta H_4 = -5470\,\text{kJ mol}^{-1};$$

Calculate a value for ΔH_1.

ΔH_1 = ... kJ mol^{-1} **[1]**

Q5:

In 1860, Michael Faraday gave a series of lectures in London entitled 'The Chemical History of a Candle'. Paraffin wax was, and still is, one of the materials used to make candles.

(a) Paraffin wax is a mixture of aliphatic hydrocarbons with more than 20 carbon atoms per molecule. Hydrocarbons of this length can be obtained from crude oil.

(i) Explain the term *aliphatic*.

....

.... **[1]**

What is the name of the process used to separate hydrocarbons of different chain lengths from crude oil?

.... **[1]**

Paraffin wax can be represented by the formula $C_{25}H_{52}$.

Balance **equation 3.1** to represent the complete combustion of $C_{25}H_{52}$.

$$C_{25}H_{52} + \ldots\ldots O_2 \rightarrow 25CO_2 + 26H_2O$$ **equation 3.1** **[1]**

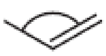
Oil refineries sometimes 'crack' paraffin waxes to produce more useful products.

The products formed from the cracking process always include an unsaturated compound such as the one shown in the diagram below.

(i) What is the molecular formula of the unsaturated molecule shown above?

.... **[1]**

Suggest a value for the bond angle shown in the structure below and explain your value.



Bond angle .... °

....

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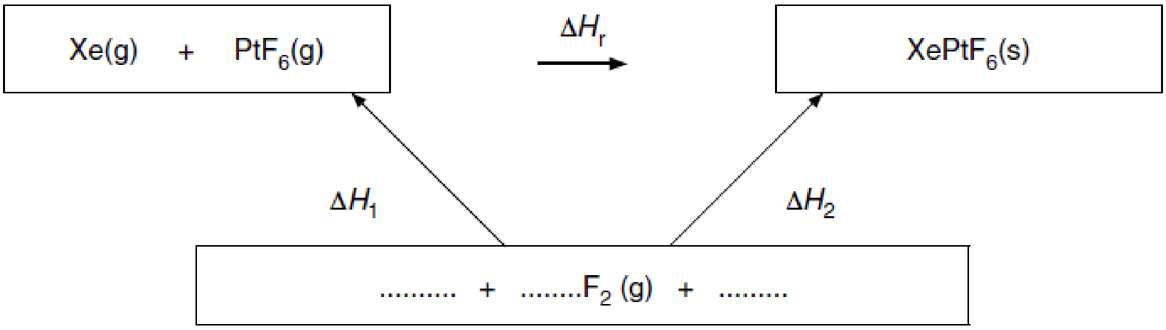
....

....

.... **[4]**

Q6:

A value for the enthalpy change for Bartlett's reaction can be calculated using the enthalpy cycle below.



ΔH_1 and ΔH_2 are the enthalpy changes of formation of PtF_6 and $XePtF_6$. Complete the enthalpy cycle by filling in the gaps in the box on page 6. **[2]**

Use Hess' law to write an expression relating the enthalpy change of reaction, ΔH_r, to ΔH_1 and ΔH_2.

.... **[1]**

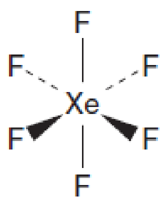
Explain why you would expect ΔH_r to be exothermic.

....

.... **[1]**

Bartlett's work soon led to several other noble gas compounds being prepared, including the gas xenon hexafluoride, XeF_6.

The diagram below is a representation of the shape of this molecule.



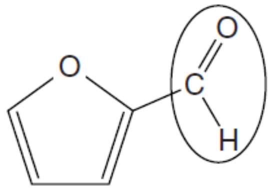
Explain the significance of the dotted lines and wedges in this diagram.

....

.... **[2]**

Q7:

One ‘second generation’ biofuel is furfural. Its structure is shown below. The circled group of atoms is the aldehyde functional group.



furfural

(i) In addition to the aldehyde group, name **two** other functional groups in furfural.

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

The molecular formula of furfural is $C_5H_4O_2$.

Write an equation for the complete combustion of furfural in excess oxygen.

[2]

A student tried to measure the enthalpy change of combustion of furfural, which he knew to be $C_5H_4O_2$. He burnt the liquid fuel in a spirit burner and used the burning fuel to heat up water in a copper calorimeter.

The student measured the mass of furfural burnt and the temperature rise of the water.

Give **three** other pieces of information the student needed in order to calculate the enthalpy change of combustion of furfural.

....

....

....

.... **[3]**

The student also calculated a value for the enthalpy change of combustion, ΔH_c, of furfural using average bond enthalpies.

The results calculated by the student for the balanced equation are shown below.

To break all bonds in the reactants, enthalpy change = 7521 kJ

To make all bonds in the products, enthalpy change = 9906 kJ

Use these results to calculate a value for the enthalpy change of combustion of furfural.

enthalpy change of combustion, ΔH_c = ... $kJ\,mol^{-1}$ **[1]**

The value obtained for the enthalpy change of combustion of furfural using average bond enthalpies is very different from the value the student obtained by the experimental method described in **(c)(i)**.

Suggest **three** reasons for this difference, apart from heat losses.

....

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.... **[3]**

Q8:

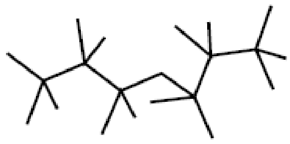
Engine lubricating oils are produced from crude oil by several different refining processes.

One lubricating oil contains the four hydrocarbons listed below.

Compound A $C_{22}H_{44}$

Compound B $CH_3(CH_2)_{17}C(CH_3)_3$

Compound C $CH_3(CH_2)_{20}CH_3$

Compound D 

(i) Name the **type** of structural formula represented in compound **D**.

.... **[1]**

(ii) Give the molecular formula of compound **D**.

.... **[1]**

(iii) Give the letter of the compound in the above list that could be a cycloalkane.

.... **[1]**

(iv) Give the letters of **two** compounds in the above list that are structural isomers of each other.

.... **[1]**

(v) Give the letter of **one** compound in the above list that is a non-cyclic, unbranched, saturated hydrocarbon.

.... **[1]**

Cracking is used to produce hydrocarbons suitable for use in lubricating oils.

(i) Give **two** ways in which molecules formed by the cracking of a straight chain alkane molecule differ from the original molecule.

....

....

....

.... **[2]**

Q9:

Calculations using average bond enthalpies give the following data.

	enthalpy change/kJ mol^{-1}
to break all bonds in the reactants	17578
energy released when new bonds are formed	23524

Use this data to calculate a value for the overall enthalpy change for **equation 4.1**.
Include the sign with your answer.

overall enthalpy change = ... kJ mol^{-1} **[2]**

The data book value for the enthalpy change of combustion of liquid limonene is slightly different from the value calculated above.

Suggest **two** reasons why this is the case.

....

....

....

.... **[2]**

One advantage is that butan-1-ol has a higher energy density (energy per kilogram of fuel).

Calculate the energy density of butan-1-ol in kJ kg^{-1}.

Standard enthalpy change of combustion of butan-1-ol, ΔH°_{c} = –2676 kJ mol^{-1}

M_r butan-1-ol = 74

energy density = ... kJ kg^{-1} **[2]**

Explain why many reactions are exothermic, using ideas of bond making and bond breaking.

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.... [3]

Q10:

Olympic torches have used a variety of fuels since the first Olympic games in 776 B.C. Propane gas was the fuel chosen for the Beijing Olympics in 2008.

Balance the equation for the complete combustion of propane, C_3H_8.

$$C_3H_8 \quad + \quad ......O_2 \quad \rightarrow \quad ......CO_2 \quad + \quad ......H_2O$$

[1]

Calculate a value for the enthalpy change of combustion of propane from the average bond enthalpy data below.

bond	average bond enthalpy / kJ mol^{-1}
C–C	+347
C–H	+413
O=O	+498
C=O	+805
O–H	+464

ΔH_c propane = ...kJ mol^{-1} [3]

The strong smell of cut onions is the result of volatile sulfur compounds getting into the atmosphere. One of these compounds also makes you cry. Its structure is given in **Fig. 3.1** with two bond angles indicated by '**a**' and '**b**'.

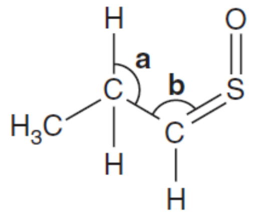

Fig. 3.1

What is the molecular formula of the compound shown in **Fig 3.1**?

.... **[1]**

The bond angle indicated by '**a**' in **Fig. 3.1** is 109° whereas '**b**' is about 120°.

Explain these bond angles.

....

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.... **[4]**

Millions of tyres are used and disposed of every year.

Fires involving tyres are a serious problem, as toxic chemicals are released into the atmosphere.

Some of the chemicals released when tyres burn include benzene and buta-1,3-diene.

(i) Name the group of hydrocarbons of which benzene is a member.

.... **[1]**

The skeletal formula of buta-1,3-diene is shown below.

Draw the **full** structural formula for buta-1,3-diene.

[1]

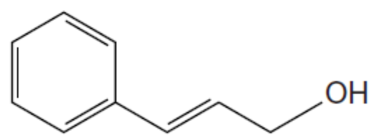
Pyrolysis (heating in the absence of oxygen) is another method of dealing with waste tyres. Pyrolysis yields useful products such as alkenes and high molecular mass alkanes.

Name the term used to describe alkenes, that refers to their molecules containing fewer hydrogen atoms than alkanes.

.... **[1]**

Unusual household lighting systems such as 'lava lamps' have become popular in recent years. These lamps contain two immiscible liquids of slightly differing densities. When switched on, the heat of the bulb causes one of the liquids to rise up and then fall in a bubble through the other liquid.

The immiscible liquids in one type of lava lamp are organic compound **X** and brine (sodium chloride solution). A structure of compound **X** is shown below.



compound X

Name **two** functional groups, apart from the benzene ring, found in compound **X**.

.... **[2]**

The structure of compound **X** is shown above as a skeletal formula.

Give the molecular formula of compound **X**.

.... **[1]**

Another substance that can be used in lava lamps is 'paraffin wax'. Paraffin wax is a mixture of long chain alkanes.

Paraffin wax is obtained from crude oil.

Name the process used to separate different hydrocarbons from crude oil.

.... **[1]**

An essential component of Avgas is a product of oil refining called 'alkylate'. Alkylate consists mainly of 'isopentane' and 'isooctane'.

(i) The systematic name for isopentane is methylbutane.

Draw the **full** structural formula of methylbutane.

[1]

C_8H_{18} has many structural isomers, one of which is octane.

Explain the term *structural isomer* and draw **skeletal** formulae in the boxes for **two** other structural isomers of C_8H_{18}.

Structural isomer ....

....

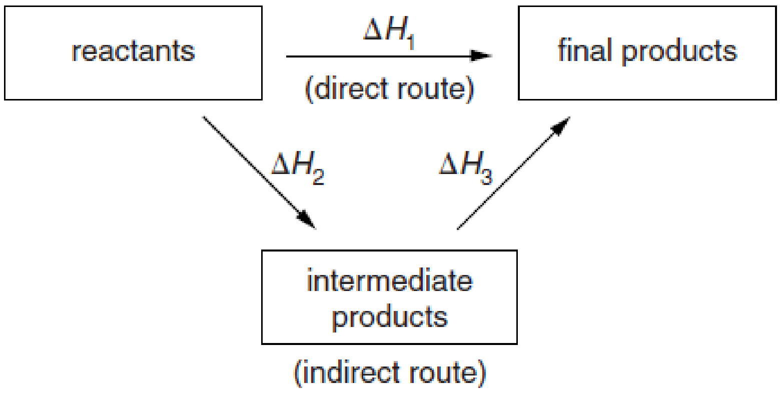
....

[3]

It is sometimes impossible to measure an enthalpy change directly. However, an enthalpy change can usually be measured indirectly using an enthalpy cycle based on Hess' law.

Use the enthalpy cycle below to write an equation relating ΔH_1 to ΔH_2 and ΔH_3.

Use this cycle to explain your understanding of Hess' law.



equation ....

explanation of Hess' law ....

....

....

....

.... **[3]**

Precious metals such as rhodium are used as heterogeneous catalysts in catalytic converters.

A simple model of heterogeneous catalysis describes four main stages in the process.

List the four stages, in order, below.

Your answer should include the appropriate technical terms, spelled correctly.

Stage 1 ....

....

Stage 2 ....

....

Stage 3 ....

....

Stage 4 ....

.... **[4]**

In an oil refinery, the production of hydrocarbon fuels requires the use of heterogeneous catalysts.

Explain the term *catalyst*.

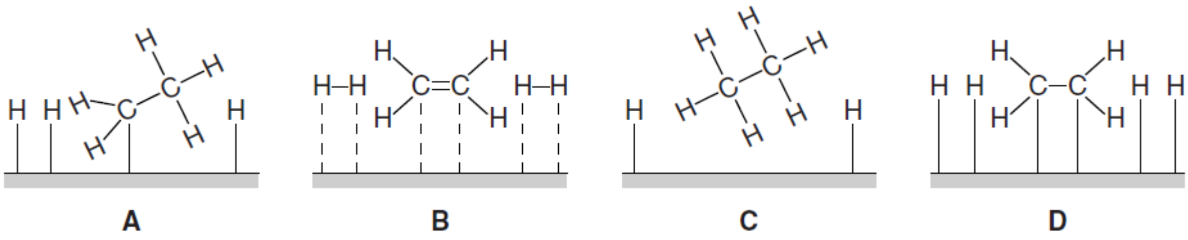
....

.... **[1]**

(ii) In heterogeneous catalysis there are four essential stages. One example is the reaction of ethene with hydrogen. This reaction is shown below with the stages represented by diagrams **A**, **B**, **C** and **D**.

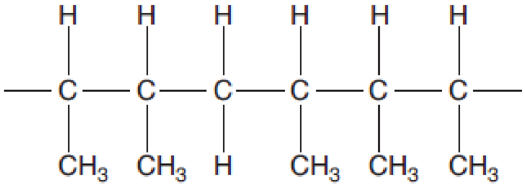
The diagrams are **not** in the correct order.

Using the letters, place the stages shown in the diagrams in the correct order.



stage 1 .... stage 2 .... stage 3 .... stage 4 .... **[2]**

Co-polymers have a variety of uses. The diagram below shows a section of **co-polymer A**, which is produced from but-2-ene and another alkene monomer.



co-polymer A

Name the **type** of polymerisation that produces **co-polymer A**.

.... [1]

Give the name and full structural formula of the other alkene monomer that is reacted with but-2-ene to produce **co-polymer A**.

Name: ....

Full structural formula:

[2]

The monomers used to make **co-polymer A** are both alkenes. Describe a simple chemical test for an alkene.

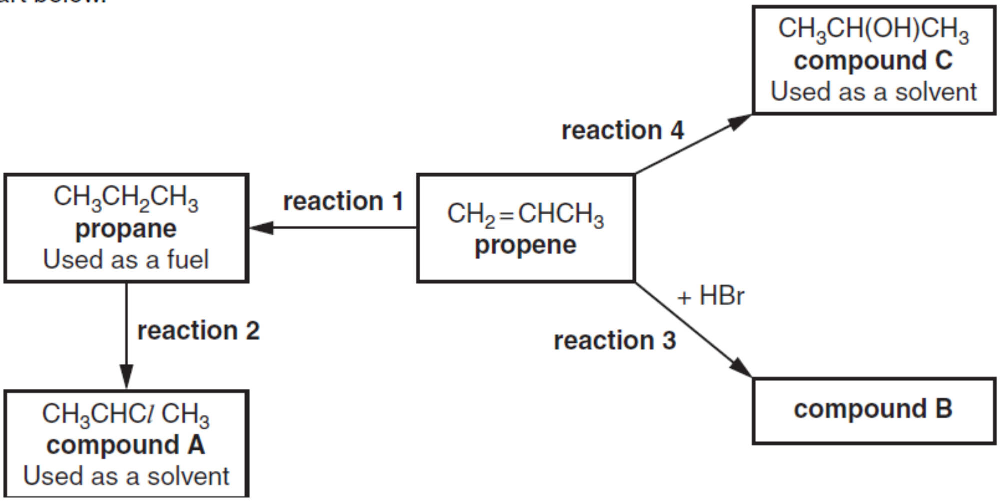
aqueous reagent used.

.... [1]

colour change seen during the test.

from .... to .... [2]

Propene can be converted into a wide range of chemicals, some of which are shown in the flow chart below.



Name the homologous series that includes propene.

.... **[1]**

Suggest a source for the propene used in industrial processes.

.... **[1]**

It is possible to test propene, to show it is unsaturated, by reacting it with bromine water. Give the colour change of the bromine water during this test.

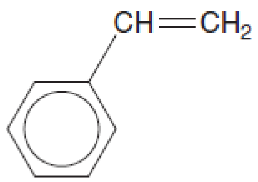
from .... to ....**[1]**

Underline **two** words that describe the mechanism of both **reaction 3** and **reaction 4**.

addition **electrophilic** **elimination**

nucleophilic **radical** **substitution** **[2]**

The poly(phenylethene) monomer has the structure shown below.

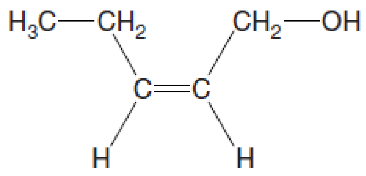


phenylethene

Draw the structure of the repeating unit of poly(phenylethene).

[1]

'Violet oil' is sometimes used in aromatherapy treatments for its mild pain-killing properties. The oil has a strong 'leafy' odour due partly to the presence of compound **A**.



compound A

Name the functional groups present in compound **A**.

....

.... **[2]**

Give the molecular formula of compound **A**.

.... **[1]**

A student reacts compound **A** with bromine water.

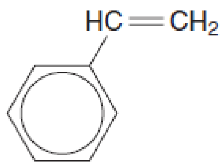
Describe the colour change the student would **see** when this reaction takes place.

from .... to .... **[2]**

Underline **two** words from the list below that best describe the mechanism for this reaction.

addition **electrophilic** **nucleophilic** **radical** **substitution** **[2]**

Poly(phenylethene), commonly known as polystyrene, is used to make packaging. The monomer from which it is produced, phenylethene, is a product of the petrochemical industry.



phenylethene

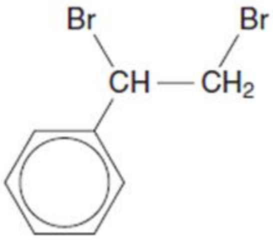
Name the **type** of polymerisation that occurs when polystyrene is made from phenylethene.

.... **[1]**

Draw the structure of the repeating unit that forms.

[1]

When this reaction is done in the laboratory, any unreacted phenylethene can be detected by adding a solution of bromine to the reaction mixture. The reaction produces **compound A**.



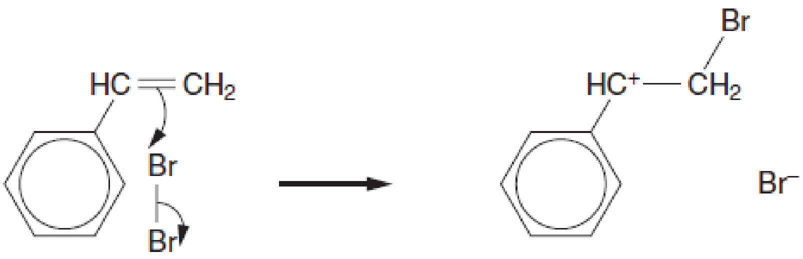
compound A

What colour change would you see when the phenylethene reacts with bromine?

....

.... **[2]**

The first step in the mechanism for this reaction is shown below.



intermediate 1

What name is given to the **type** of organic intermediate, such as **intermediate 1**, formed in the reaction?

.... **[1]**