AS Chemistry

Raising Achievement Booklet

Each section contains 3 objectives. These objectives explore a variety of ways to revise and practice independent learning. Each section finishes with past paper questions, which will be checked during the Chemistry support sessions. You will then be given the mark scheme to correct your answers.

Topic	Date to be completed	Tick when completed	Checked by Teacher
Introduction to Organic Chemistry	02/09/24		
Alkanes	02/09/24		
Energetics	02/09/24		
Kinetics	02/09/24		

Introduction to organic

Objectives:

1. Use https://www.a-levelchemistry.co.uk/topic-7---introduction-to-organic-chemistry.html to create a revision resource using for key definitions and explanations. The revision resource can be flashcards, knowledge organisers or quizzes. It is important that the resources allow you to test your memory#

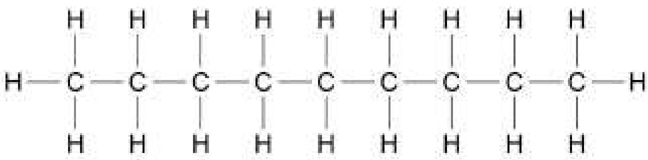
2. Complete the exercises '1. Formula and structure', '2. Nomenclature', '3. Isomerism' and '4. Alkanes and Crude oil' on https://www.a-levelchemistry.co.uk/topic-7---introduction-to-organic-chemistry.html and mark them using the mark scheme.

3. Complete the past paper questions

Q1.

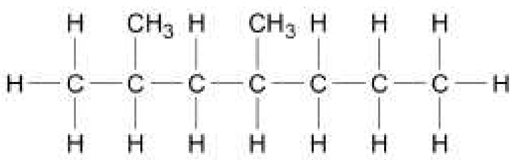
The alkanes nonane and 2,4-dimethylheptane are structural isomers with the molecular formula C_9H_{20}
They are found in crude oil and can be separated by fractional distillation.
Both can be used in fuels or cracked to form other products.

nonane



boiling point 151 °C

2,4-dimethylheptane



boiling point 134 °C

(a) State the general formula of an alkane containing n carbon atoms.
Deduce an expression for the relative molecular mass (M_r) of an alkane in terms of n.

General formula ____

Expression ____

(2)

(b) Explain why nonane has a higher boiling point than 2,4-dimethylheptane.

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(2)

(c) Give an equation for the complete combustion of nonane.

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(1)

(d) Nonane is often found in fuel for jet engines. Combustion in jet engines produces pollutants including nitrogen monoxide (NO).

Explain how this nitrogen monoxide is formed.

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(2)

(e) Nonane can be cracked to form large quantities of propene.

Name the type of cracking used.

____

(1)

(f) The main use of propene, formed from cracking, is to make poly(propene).

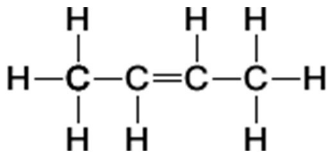
Draw the repeating unit of poly(propene).

(1)

(Total 9 marks)

Q2.

Compound **X** is shown below. It is a member of a homologous series of hydrocarbons.



(a) (i) Deduce the general formula of the homologous series that contains **X**.

____

(1)

(ii) Name a process used to obtain a sample of **X** from a mixture containing other members of the same homologous series.

____

(1)

(b) There are several isomers of **X**.

(i) Give the IUPAC name of the position isomer of **X**.

____

(1)

(ii) Draw the structure of a functional group isomer of **X**.

(1)

(c) At high temperatures, one molecule of $C_{15}H_{32}$ can be converted into two molecules of **X** and one molecule of another compound.

(i) Write an equation for this reaction.

____

(1)

(ii) State the name of the process used to obtain a high yield of **X** from $C_{15}H_{32}$
Give **one** reason why this process is used in industry.

Name ____

Reason ____

____

(2)

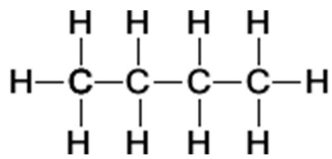
(iii) State why high temperatures are needed for this process.

____

____

(1)

(d) Compound **X** can be converted into compound **Y**.
Compound **Y** is shown below.



(i) Suggest the formula of a reagent that could be added to **X** in order to convert it into **Y**.

____

(1)

(ii) Give **one** use of **Y**.

____

(1)

(iii) Write an equation to show the reaction of **Y** in a limited supply of air to produce a solid and water only.

____

(1)

(iv) When a sample of **Y**, contaminated with CH_3SH, is burned completely in air, a toxic gas is formed.
Identify this toxic gas and suggest a compound that could be used to remove the toxic gas from the products of combustion.

Toxic gas ____

Compound used to remove toxic gas ______________________________

____

(2)

(v) Suggest the name of the process that occurs when the toxic gas in part (d)(iv) is removed.

____

(1)

(e) Explain why the boiling points of **X** and **Y** are similar.

____

____

(2)
(Total 16 marks)

Q3.

Pentane is a member of the alkane homologous series.

(a) Give the general formula for the homologous series of alkanes.

(1)

(b) One of the structural isomers of pentane is 2,2-dimethylpropane.

Draw the displayed formula of 2,2-dimethylpropane.

State the type of structural isomerism shown.

(2)

(c) A molecule of hydrocarbon **Y** can be thermally cracked to form one molecule of pentane and two molecules of ethene only.

Deduce the molecular formula of **Y**.

State why high temperatures are necessary for cracking reactions to occur.

Give **one** reason why thermal cracking reactions are carried out in industry.

(3)

(d) Write an equation for the incomplete combustion of pentane to form a solid pollutant.

Suggest why this solid pollutant is an environmental problem.

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(2)

(e) Pentane can react with chlorine as shown in the following equation.

$$C_5H_{12} + Cl_2 \rightarrow C_5H_{11}Cl + HCl$$

Calculate the percentage atom economy for the formation of $C_5H_{11}Cl$

Deduce how many straight-chain isomers of $C_5H_{11}Cl$ could be formed.

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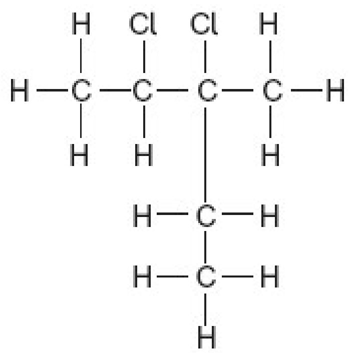
(3)

(f) Consider the following compound.



Name this compound.

Deduce the empirical formula of this compound.

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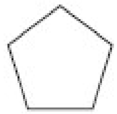
____

(2)

(Total 13 marks)

Q4.

The following table gives the names and structures of some structural isomers with the molecular formula C_5H_{10}.

	Name of isomer	**Structure**
Isomer **1**	pent-2-ene	$CH_3CH = CHCH_2CH_3$
Isomer **2**	cyclopentane	
Isomer **3**	3-methylbut-1-ene	$(CH_3)_2CHCH = CH_2$
Isomer **4**	2-methylbut-2-ene	$(CH_3)_2C = CHCH_3$
Isomer **5**	2-methylbut-1-ene	$H_2C = C(CH_3)CH_2CH_3$

(a) Isomer **1** exists as E and Z stereoisomers.

(i) State the meaning of the term **stereoisomers**.

(2)

(ii) Draw the structure of the E stereoisomer of Isomer **1**.

(1)

(b) A chemical test can be used to distinguish between separate samples of Isomer **1** and Isomer **2**.

Identify a suitable reagent for the test.
State what you would observe with Isomer **1** and with Isomer **2**.

Reagent ____

Observation with Isomer **1** ________________________________

____

Observation with Isomer **2** ________________________________

____

(3)

(c) Use **Table A** on the Data Sheet when answering this question.
Isomer **3** and Isomer **4** have similar structures.

(i) State the infrared absorption range that shows that Isomer **3** and Isomer **4** contain the same functional group.

____

____

(1)

(ii) State **one** way that the infrared spectrum of Isomer 3 is different from the infrared spectrum of Isomer **4**.

____

____

____

(1)

(d) Two alcohols are formed by the hydration of Isomer **4**.

Draw the **displayed formula** for the alcohol formed that is oxidised readily by acidified potassium dichromate(VI).

(1)

(e) Isomer **4** reacts with hydrogen bromide to give two structurally isomeric bromoalkanes.

(i) Name and outline a mechanism for the reaction of Isomer **4** with hydrogen bromide to give 2-bromo-2-methylbutane as the major product.

$$(CH_3)_2C = CHCH_3 + HBr \longrightarrow (CH_3)_2CBrCH_2CH_3$$

Name of mechanism ____

Mechanism

(5)

(ii) The minor product in this reaction mixture is 2-bromo-3-methylbutane.

Explain why this bromoalkane is formed as a minor product.

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(2)

(f) Name and outline a mechanism for the following reaction to form Isomer **5**.
State the role of the hydroxide ion in this reaction.

$(CH_3)_2CBrCH_2CH_3 + KOH \longrightarrow H_2C = C(CH_3)CH_2CH_3 + KBr + H_2O$

Name of mechanism ____

Mechanism

Role of hydroxide ion ____

(5)
(Total 21 marks)

Alkanes

Objectives:

1. Create revision resources using for key definitions and explanations.
2. Go to Senecalearning.com and complete the bonding assignment.
3. Complete the past paper questions

Q1.

Some oil-fired heaters use paraffin as a fuel.
One of the compounds in paraffin is the straight-chain alkane, dodecane ($C_{12}H_{26}$).

(a) Give the name of the substance from which paraffin is obtained.
State the name of the process used to obtain paraffin from this substance.

Substance ____

Process ____

(2)

(b) The combustion of dodecane produces several products.

Write an equation for the **incomplete** combustion of dodecane to produce gaseous products only.

____

(1)

(c) Oxides of nitrogen are also produced during the combustion of paraffin in air.

(i) Explain how these oxides of nitrogen are formed.

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(2)

(ii) Write an equation to show how nitrogen monoxide in the air is converted into nitrogen dioxide.

___

(1)

(iii) Nitric acid (HNO_3) contributes to acidity in rainwater.

Deduce an equation to show how nitrogen dioxide reacts with oxygen and water to form nitric acid.

___

(1)

(d) Dodecane ($C_{12}H_{26}$) can be cracked to form other compounds.

(i) Give the general formula for the homologous series that contains dodecane.

___

(1)

(ii) Write an equation for the cracking of one molecule of dodecane into equal amounts of two different molecules each containing the same number of carbon atoms.
State the empirical formula of the straight-chain alkane that is formed.
Name the catalyst used in this reaction.

Equation ___

Empirical formula of alkane ___

Catalyst ___

___

(3)

(iii) Explain why the melting point of dodecane is higher than the melting point of the straight-chain alkane produced by cracking dodecane.

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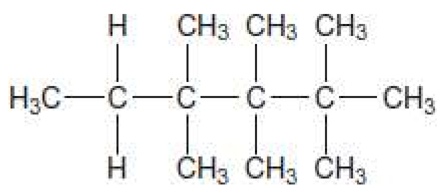
(2)

(e) Give the IUPAC name for the following compound and state the type of structural isomerism shown by this compound and dodecane.



IUPAC name ______________________________

Type of structural isomerism ______________________________

(2)

(f) Dodecane can be converted into halododecanes.

Deduce the formula of a substance that could be reacted with dodecane to produce 1-chlorododecane and hydrogen chloride only.

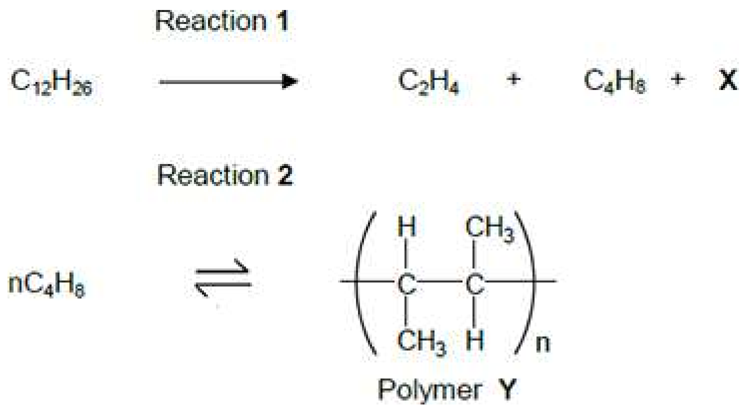
____

(1)

(Total 16 marks)

Q2.

Dodecane ($C_{12}H_{26}$) is a hydrocarbon found in the naphtha fraction of crude oil. Dodecane can be used as a starting material to produce a wide variety of useful products. The scheme below shows how one such product, polymer **Y**, can be produced from dodecane.



(a) Name the homologous series that both C_2H_4 and C_4H_8 belong to.
Draw a functional group isomer of C_4H_8 that does **not** belong to this homologous series.

Name ______________________________

Functional group isomer

(2)

(b) Identify compound **X**.

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(1)

(c) Name polymer **Y**.

____

(1)

(d) Reaction **1** is an example of thermal cracking and is carried out at a temperature of 750 °C.

State **one other** reaction condition needed.

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(1)

(e) Reaction **2** is exothermic. A typical compromise temperature of 200 °C is used industrially for this reaction.

Explain the effect of a change of temperature on both the position of equilibrium and the rate of reaction, and justify why a compromise temperature is used industrially.

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(6)

(Total 11 marks)

Q3.

This question is about the reactions of alkanes.

(a) Alkanes can be used as fuels.

Give an equation for the combustion of heptane (C_7H_{16}) in an excess of oxygen.

___

(1)

(b) Heptane can be obtained from the catalytic cracking of hexadecane ($C_{16}H_{34}$) at a high temperature.

Identify a suitable catalyst for this process.
Give **one** condition other than high temperature.
Give an equation for the catalytic cracking of one molecule of hexadecane to produce one molecule of heptane, one molecule of cyclohexane and one other product.

Catalyst ____

Condition ____

Equation ____

____

(3)

(c) Alkanes can be used in free-radical substitution reactions to produce halogenoalkanes.

Give equations for the propagation steps in the reaction of butane to form 2-chlorobutane.

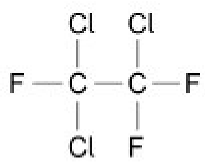
____

____

(2)

(d) Chlorofluorocarbons (CFCs) are a group of halogenoalkanes currently banned in many countries. They cannot be used as solvents or refrigerants because of their effect on the environment.

The structure of a CFC is shown.



Identify the radical produced from this CFC that is responsible for the depletion of ozone in the atmosphere.

Explain, with the aid of equations, why a single radical can cause the decomposition of many molecules of ozone.

Radical ____

Explanation ____

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(4)
(Total 10 marks)

Q4.

There are many uses of halogenated organic compounds despite environmental concerns.

(a) Bromotrifluoromethane is used in fire extinguishers in aircraft.
Bromotrifluoromethane is formed when trifluoromethane reacts with bromine.

$$CHF_3 + Br_2 \longrightarrow CBrF_3 + HBr$$

The reaction is a free-radical substitution reaction similar to the reaction of methane with chlorine.

(i) Write an equation for each of the following steps in the mechanism for the reaction of CHF_3 with Br_2

Initiation step

First propagation step

Second propagation step

A termination step

(4)

(ii) State **one** condition necessary for the initiation of this reaction.

(1)

(b) Bromine-containing and chlorine-containing organic compounds may have a role in the decomposition of ozone in the upper atmosphere.

(i) Draw an appropriate **displayed formula** in the space provided to complete the following equation to show how $CBrF_3$ may produce bromine atoms in the upper atmosphere.

$$CBrF_3 \longrightarrow \_\_\_\_\_\_ + Br^{\bullet}$$

(1)

(ii) In the upper atmosphere, it is more likely for $CBrF_3$ to produce bromine atoms than it is for $CClF_3$ to produce chlorine atoms.

Suggest **one** reason for this.

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(1)

(iii) Bromine atoms have a similar role to chlorine atoms in the decomposition of ozone.
The overall equation for the decomposition of ozone is

$$2O_3 \longrightarrow 3O_2$$

Write **two** equations to show how bromine atoms (Br•) act as a catalyst in the decomposition of ozone.

Explain how these two decomposition equations show that bromine atoms behave as a catalyst.

Equation 1

____

Equation 2

____

Explanation ____

____

____

(3)

(Total 10 marks)

Energetics

Objectives:

1. Make a revision resource
2. Test yourself with the revision resource for 1 hour and then create a mind map on the next page from memory.

3. Complete the past paper questions:

Q1.

This question is about energetics.

(a) Write an equation, including state symbols, for the reaction with an enthalpy change equal to the enthalpy of formation for iron(III) oxide.

____

(1)

(b) **Table 1** contains some standard enthalpy of formation data.

Table 1

	$CO(g)$	$Fe_2O_3(s)$
$\Delta_f H^\ominus$ / kJ mol^{-1}	−111	−822

$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(s) + 3CO_2(g)$ $\Delta H = -19$ kJ mol^{-1}

Use these data and the equation for the reaction of iron(III) oxide with carbon monoxide to calculate a value for the standard enthalpy of formation for carbon dioxide.

Show your working.

$\Delta_f H^\ominus$ ____________________ kJ mol^{-1}

(3)

(c) Some enthalpy data are given in **Table 2**.

Table 2

Process	**ΔH / kJ mol^{-1}**
$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$	−92
$N_2(g) \longrightarrow 2N(g)$	+944
$H_2(g) \longrightarrow 2H(g)$	+436

Use the data from **Table 2** to calculate the bond enthalpy for N−H in ammonia.

N−H bond enthalpy ____________________ kJ mol^{-1}

(3)

(d) Give one reason why the bond enthalpy that you calculated in part (c) is different from the mean bond enthalpy quoted in a data book (388 kJ mol^{-1}).

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(1)

(Total 8 marks)

Q2.

This question is about enthalpy changes.

(a) When ethanoic acid reacts with sodium hydroxide, the enthalpy change, ΔH, is –56.1 kJ mol^{-1}

$$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$$

Calculate the temperature rise when 25 cm^3 of 2.0 mol dm^{-3} aqueous ethanoic acid react with 25 cm^3 of 2.0 mol dm^{-3} aqueous sodium hydroxide.

Assume that both solutions have the same initial temperature, have a density of 1.0 g cm^{-3} and a specific heat capacity of 4.18 J K^{-1} g^{-1}

Temperature rise ____________________ °C

(4)

(b) A student recorded the temperature of aqueous ethanoic acid in a polystyrene cup for three minutes.

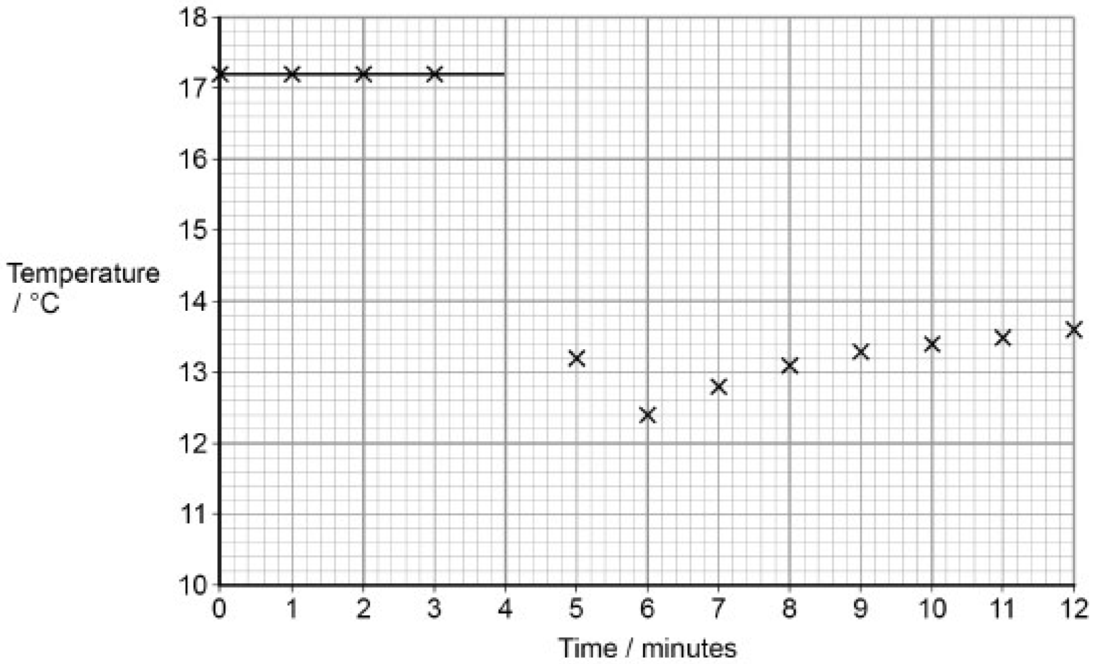
At the fourth minute, the student added sodium hydrogencarbonate.

The student stirred the mixture and carried on recording the temperature every minute for several minutes.

The student's measurements are shown in the graph.

A best-fit line showing the temperature before mixing has been drawn.

Draw an appropriate best-fit line on the graph and use it to find the temperature change at the time of mixing.



Temperature change at time of mixing ____________________ °C

(2)

(Total 6 marks)

Q3.

This question is about enthalpy changes.

(a) A student determined the enthalpy of combustion of cyclohexane (C_6H_{12}).

The student

- placed a pure sample of cyclohexane in a spirit burner
- placed the spirit burner under a beaker containing 50.0 g of water and ignited the cyclohexane
- extinguished the flame after a few minutes.

The results for the experiment are shown in **Table 1**.

Table 1

Initial temperature of the water / °C	19.1
Initial mass of spirit burner and cyclohexane / g	192.730
Final mass of spirit burner and cyclohexane / g	192.100

The student determined from this experiment that the enthalpy of combustion of cyclohexane is –1216 kJ mol^{-1}

Use the data to calculate the final temperature of the water in this experiment.

The specific heat capacity of water = 4.18 J K^{-1} g^{-1}
The relative molecular mass (M_r) of cyclohexane = 84.0

Final temperature of the water ________________________ °C

(4)

(b) A data book value for the enthalpy of combustion of cyclohexane is –3920 kJ mol^{-1}

The student concluded that the temperature rise recorded in the experiment was smaller than it should have been.

Suggest a practical reason for this.

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____

____

(1)

(c) **Table 2** gives some values of standard enthalpies of combustion ($\Delta_c H^\ominus$).

Table 2

Substance	C(s)	H_2(g)	C_6H_{12}(l)
Standard enthalpy of combustion, $\Delta_c H^\ominus$ / kJ mol^{-1}	−394	−286	−3920

Use the data in **Table 2** to calculate the enthalpy change for the reaction represented by this equation

$$6\,C(s) + 6\,H_2(g) \rightarrow C_6H_{12}(l)$$

Enthalpy change ________________________ kJ mol^{-1}

(3)

(Total 8 marks)

Q4.

When alkanes are burned in an excess of oxygen they produce carbon dioxide and water.

(a) Write an equation for the complete combustion of propane in oxygen.

____

(1)

(b) An expression can be derived using bond enthalpy data to estimate the enthalpy of combustion ($\Delta_c H$) of an alkane.

For an alkane with ***n*** carbon atoms: $\Delta_c H = -(496\boldsymbol{n} + 202)$ kJ mol^{-1}

The enthalpy of combustion of an alkane was calculated to be −6650 kJ mol^{-1} using this expression.

Deduce the molecular formula of this alkane.

Show your working.

Molecular formula of alkane ___________________________________

(2)

(c) Suggest **one** reason, other than the use of mean bond enthalpies, why a value for the enthalpy of combustion of a liquid alkane is different from the value obtained using the expression in part (b)

____

____

(1)

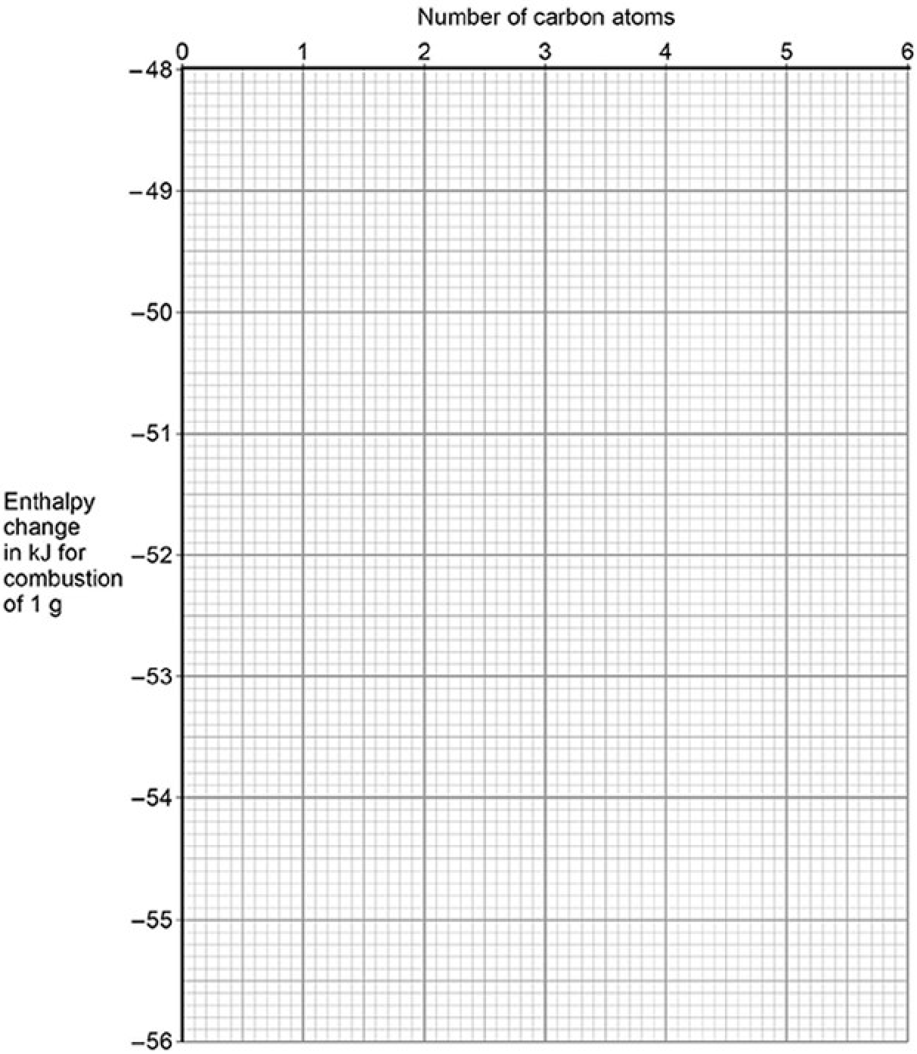
(d) Values of the enthalpy change for combustion of 1 g of some alkanes are shown in the table.

	methane	**ethane**	**propane**	**butane**	**pentane**
Enthalpy change in kJ for combustion of 1 g	−55.6	−52.0		−49.6	−48.7

Plot the enthalpy change for the combustion of 1 g against the number of carbon atoms in the alkanes in the table.

Draw a best fit line and use this to estimate the enthalpy change for combustion of 1 g of propane.

Write your answer in the table.



(3)

(e) Isooctane (2,2,4-trimethylpentane) is an important component of petrol used in cars.

When isooctane is burned, the enthalpy change is −47.8 kJ g^{-1}

Isooctane is a liquid at room temperature with a density of 0.692 g cm^{-3}

Calculate the heat energy released, in kJ, when 1.00 dm^3 of isooctane burns in excess oxygen.

Give your answer to the appropriate number of significant figures.

Heat energy released ______________________ kJ

(2)

(Total 9 marks)

Kinetics

Objectives:

1. Carry out your own revision and complete the past paper questions below:

Q1.

Sodium thiosulfate solution ($Na_2S_2O_3$) reacts slowly with dilute hydrochloric acid to form a precipitate. The rate of this reaction can be studied by measuring the time (*t*) that it takes for a small fixed amount of precipitate to form under different conditions. The fixed amount of precipitate is taken as the amount needed to obscure a cross on paper.

The equation for this reaction is shown below.

$$Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + S + SO_2 + H_2O$$

(a) Identify the insoluble product of this reaction which forms the precipitate.

____

(1)

(b) When this reaction takes place, the collision between the reacting particles requires an activation energy. State what is meant by the term *activation energy*.

____

____

(2)

(c) In terms of particles, explain why, at a fixed temperature, you might expect the rate of this reaction to double when the concentration of sodium thiosulfate is doubled and the concentration of hydrochloric acid remains the same.

____

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____

____

(2)

(d) (i) State what is meant by the term *rate of reaction*.

____

____

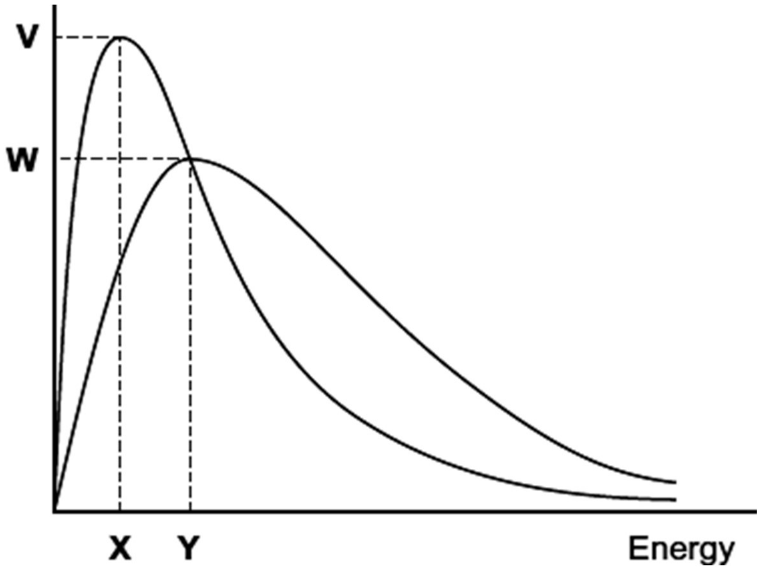
(1)

(ii) Consider the description of the way in which this experiment is carried out. Use your understanding of the term *rate of reaction* to explain why it is possible to use a simplified formula $\frac{1}{t}$ as a measure of the rate of **this** reaction.

(1)
(Total 7 marks)

Q2.

The diagram shows the Maxwell-Boltzmann distribution of molecular energies in a gas at two different temperatures.



(a) One of the axes is labelled. Complete the diagram by labelling the other axis.

(1)

(b) State the effect, if any, of a solid catalyst on the shape of either of these distributions.

(1)

(c) In the box, write the letter, **V**, **W**, **X** or **Y**, that represents the most probable energy of the molecules at the lower temperature.

(1)

(d) Explain what must happen for a reaction to occur between molecules of two different gases.

(2)

(e) Explain why a small increase in temperature has a large effect on the initial rate of a reaction.

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___

___

(1)
(Total 6 marks)

Q3.

The rate of a chemical reaction is influenced by the size of the activation energy. Catalysts are used to increase the rates of chemical reactions but are not used up in the reactions.

(a) Give the meaning of the term *activation energy*.

___

___

___

___

(2)

(b) Explain how a catalyst increases the rate of a reaction.

___

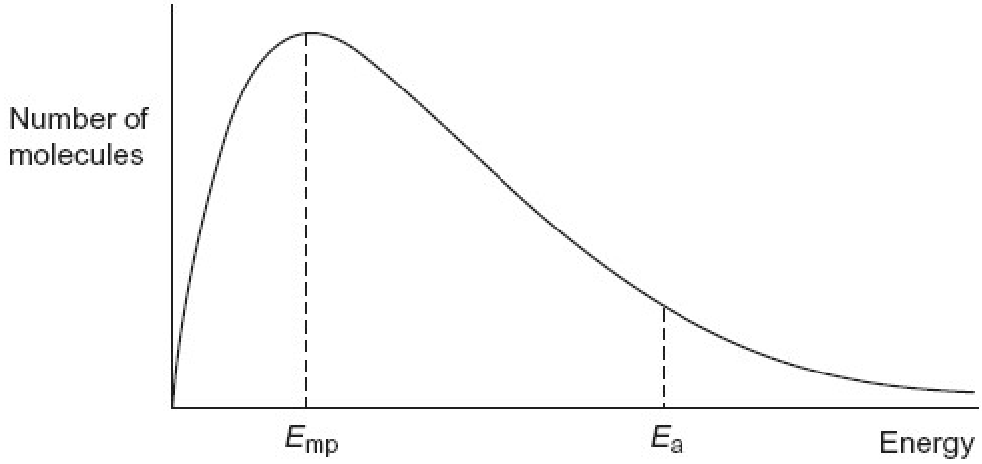
___

___

___

(2)

(c) The diagram below shows the Maxwell–Boltzmann distribution of molecular energies, at a constant temperature, in a gas at the start of a reaction.
On this diagram the most probable molecular energy at this temperature is shown by the symbol E_{mp}
The activation energy is shown by the symbol E_a



To answer the questions (c)(i) to (c)(iv), you should use the words **increases**, **decreases** or **stays the same**. You may use each of these answers once, more than once or not at all.

(i) State how, if at all, the value of the most probable energy (E_{mp}) changes as the total number of molecules is increased at constant temperature.

____

(1)

(ii) State how, if at all, the number of molecules with the most probable energy (E_{mp}) changes as the temperature is decreased without changing the total number of molecules.

____

(1)

(iii) State how, if at all, the number of molecules with energy greater than the activation energy (E_a) changes as the temperature is increased without c hanging the total number of molecules.

____

(1)

(iv) State how, if at all, the area under the molecular energy distribution curve changes as a catalyst is introduced without changing the temperature or the total number of molecules.

____

(1)

(d) For each of the following reactions, identify a catalyst and name the organic product of the reaction.

(i) The fermentation of an aqueous solution of glucose.

Catalyst ____

Name of organic product ______________________________________

____

(2)

(ii) The hydration of but-2-ene.

Catalyst ____

Name of organic product ________________________________

____

(2)
(Total 12 marks)

Q4.

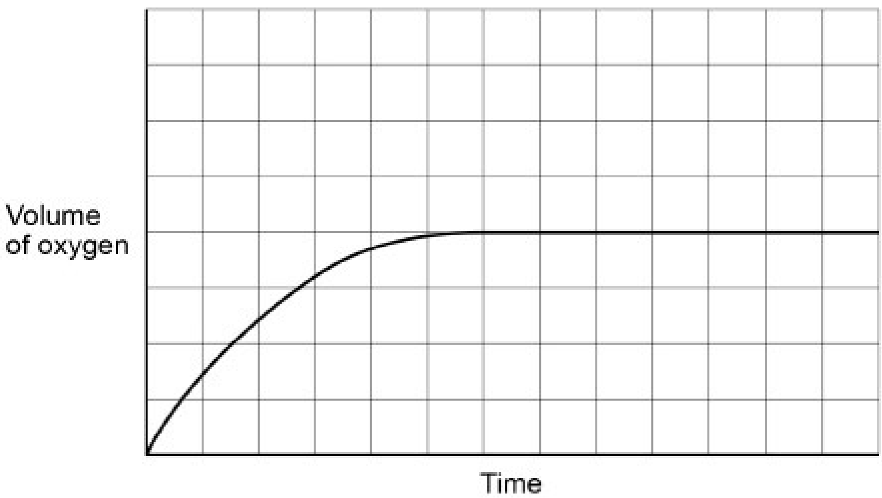
Hydrogen peroxide solution decomposes slowly to form water and oxygen.
The reaction is much faster in the presence of a manganese(IV) oxide catalyst.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

Three experiments, shown in the table, were carried out to investigate how the volume of oxygen produced varied over time under different conditions. The same mass of catalyst was used in each experiment.

Experiment	Concentration of $H_2O_2(aq)$ / mol dm^{-3}	Volume of $H_2O_2(aq)$ / cm^3	Temperature / °C	Catalyst
1	1.0	50	20	lumps
2	1.0	50	20	powder
3	0.5	50	20	lumps

The graph shows how the volume of oxygen collected varied with time in Experiment **1**.



(a) Explain, in general terms, how a catalyst increases the rate of a reaction.

____

____

____

(2)

(b) Draw **two** lines on the graph to show how the volume of oxygen collected varied with time in Experiments **2** and **3**.
Label each line with the experiment number.

(2)

(c) Explain, in terms of collision theory, the effect of increasing the concentration of hydrogen peroxide on the rate of reaction.

(2)
(Total 6 marks)

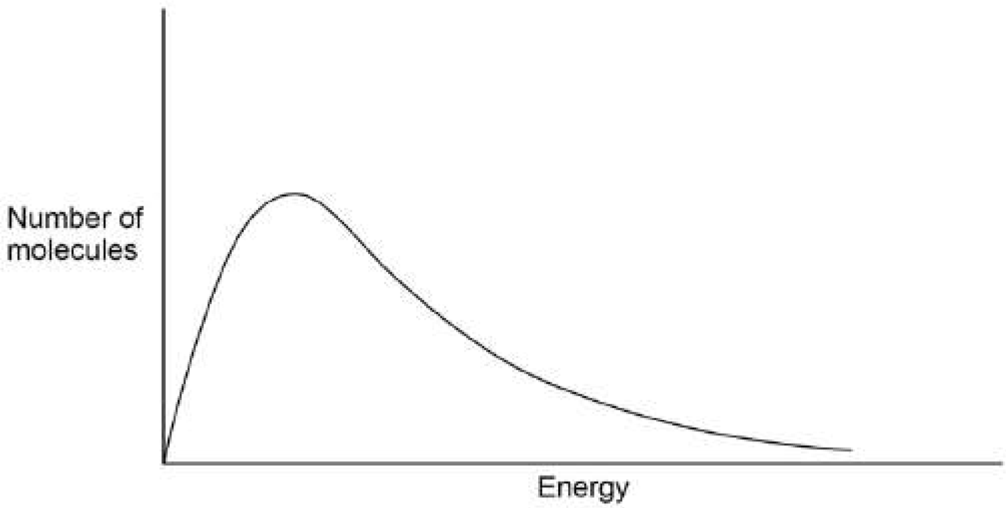
Q5.

Nitryl chloride reacts with nitrogen monoxide according to the equation:

$$ClNO_2(g) + NO(g) \longrightarrow NO_2(g) + ClNO(g)$$

The Maxwell–Boltzmann distribution curve in **Figure 1** shows the distribution of molecular energies in 1 mol of this gaseous reaction mixture (sample **1**) at 320 K.

Figure 1



(a) On the same axes, draw a curve for sample **1** at a lower temperature.

(2)

(b) Explain the effect that lowering the temperature would have on the rate of reaction.

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___

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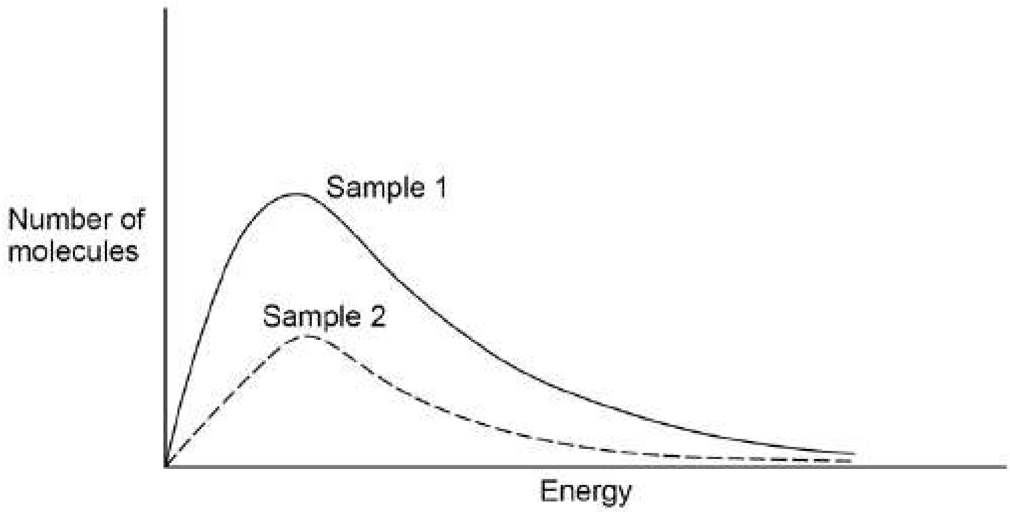
(2)

(c) A Maxwell–Boltzmann distribution curve was drawn for a second sample of the reaction mixture in the same reaction vessel. **Figure 2** shows the results.

Figure 2



Deduce the change that was made to the reaction conditions.

Explain the effect that this change has on the rate of reaction.

Change ___

___

Explanation ___

___

___

___

(3)
(Total 7 marks)