Cambridge AS & A Level

CHEMISTRY

Paper 2

Topical Past Paper Questions

+ Answer Scheme

2015 - 2021

PapaCambridge

Chapter 14

Hydrocarbons

14.1 Alkanes

99. 9701_m21_qp_22 Q: 2

Chlorine, Cl_2, is a reactive yellow-green gas. It is a strong oxidising agent.

(a) State how Cl_2 is used in water purification.

.....

..... [1]

(b) Chlorine has the highest first ionisation energy of the Period 3 elements Na to Cl.

(i) Construct an equation for the first ionisation energy of chlorine.

Include state symbols.

..... [1]

(ii) Explain the general increase in the first ionisation energies of the Period 3 elements.

.....

.....

.....

..... [2]

(c) The halide ions, X^- (where X = C*l*, Br, I), show clear trends in their physical and chemical properties.

(i) State and explain the relative thermal stabilities of the hydrogen halides, HX.

.....

.....

..... [2]

The halide ions react easily with concentrated H_2SO_4.

The main sulfur-containing product of each reaction is shown in the table.

halide ion	C*l*$^-$	Br$^-$	I$^-$
main sulfur-containing product of reaction with concentrated H_2SO_4	HSO_4^-	SO_2	H_2S
oxidation number of sulfur			

(ii) Complete the table to show the oxidation number of sulfur in each of the sulfur-containing products. [1]

(iii) Explain why different sulfur-containing products are produced when each of these halide ions reacts with concentrated H_2SO_4.

.....

..... [1]

(d) Cl_2 reacts with aqueous sodium hydroxide in a disproportionation reaction.

(i) State what is meant by *disproportionation*.

.....

..... [1]

(ii) Write an equation for the reaction of Cl_2 with cold aqueous sodium hydroxide.

..... [1]

(e) Aluminium reacts with chlorine to form aluminium chloride.

Aluminium chloride can exist as the gaseous molecule Al_2Cl_6(g). This molecule contains coordinate bonds.

(i) Draw a diagram that clearly shows all the types of bond present in Al_2Cl_6(g).

[2]

(ii) Describe what you would see when solid aluminium chloride reacts with water.

Name the type of reaction that occurs.

.....

.....

..... [2]

(f) 0.020 mol of element **Z** reacts with excess Cl_2 to form 0.020 mol of a liquid chloride.

The liquid chloride has formula **Z**Cl_n, where *n* is an integer.

ZCl_n reacts vigorously with water at room temperature to give an acidic solution and a white solid.

When excess $AgNO_3$(aq) is added to the solution, 11.54 g of AgCl(s) forms.

(i) Suggest the type of bonding and structure shown by **Z**Cl_n.

..... [1]

(ii) Calculate the value of *n* in **Z**Cl_n.

n = ... [2]

(g) Dichloromethane, CH_2Cl_2, is widely used as an organic solvent.

CH_2Cl_2 can be prepared by reacting CH_3Cl and Cl_2 at room temperature.

The reaction proceeds via several steps, as shown.

$$Cl_2 \xrightarrow{\text{initiation}} 2Cl^{\bullet}$$

$$Cl^{\bullet} + CH_3Cl \xrightarrow{\text{propagation 1}} HCl + {}^{\bullet}CH_2Cl$$

$$Cl_2 + {}^{\bullet}CH_2Cl \xrightarrow{\text{propagation 2}} \text{products}$$

$$Cl^{\bullet} + {}^{\bullet}CH_2Cl \xrightarrow{\text{final step}} CH_2Cl_2$$

(i) Give the name of the mechanism of this reaction.

..... [1]

(ii) State the essential condition required for the initiation step to take place.

..... [1]

(iii) Give the electronic configuration of $Cl^{\bullet}$.

$1s^2$ ..... [1]

(iv) Identify the products of the step labelled propagation 2.

..... [1]

(v) Name the type of reaction shown in the final step.

..... [1]

(vi) Suggest the identity of another organic molecule that is a product of the reaction of CH_3Cl and Cl_2 under the same conditions.

..... [1]

[Total: 23]

100. 9701_w19_qp_21 Q: 1

(a) Chlorine can be prepared using the following reaction.

$$MnO_2(s) + 4HCl(aq) \rightarrow MnCl_2(aq) + 2H_2O(l) + Cl_2(g)$$

(i) Explain why $MnO_2(s)$ is described as an oxidising agent in this reaction.

Refer to oxidation numbers in your answer.

.....

..... [1]

(ii) State what you would observe during this reaction.

..... [1]

(b) The halogens chlorine, bromine and iodine are all volatile elements.

State and explain the trend in volatility down Group 17.

.....

.....

..... [3]

(c) Chlorine undergoes disproportionation during many chemical reactions.

(i) Write an equation for the reaction of chlorine with cold aqueous sodium hydroxide, NaOH.

Explain why it is a disproportionation reaction.

equation .....

explanation .....

.....

[2]

(ii) One of the products of the reaction of chlorine with **hot** aqueous sodium hydroxide differs from those in **(c)(i)**.

Identify the compound that is formed in this reaction that is different from that formed in the reaction in **(c)(i)**.

..... [1]

(d) State and explain the use of chlorine in water purification.

.....

.....

..... [2]

(e) Under certain conditions, chlorine undergoes a free-radical substitution reaction with ethane.

(i) State the conditions required to initiate this reaction.

..... [1]

(ii) Write the overall equation for this free-radical substitution reaction.

..... [1]

[Total: 12]

101. 9701_w19_qp_21 Q: 3

Crude oil is a natural source of hydrocarbons that are used as fuels.

(a) Hydrocarbons with low relative molecular mass, M_r, are used as fuels in industry, in the home and for transport.

There is a high demand for the hydrocarbons with low M_r.

(i) Name the process by which long-chain hydrocarbons are broken down into shorter-chain hydrocarbons.

..... [1]

(ii) Give one reason why hydrocarbons with low M_r are suitable for use as fuels.

..... [1]

(iii) Incomplete combustion of hydrocarbons can release carbon monoxide, CO, into the atmosphere.

Write an equation for the formation of CO from the incomplete combustion of butene, C_4H_8.

..... [1]

(iv) Identify an analytical technique that can be used to monitor the levels of CO in the atmosphere.

Outline how this analytical technique may be used to monitor the levels of CO.

.....

.....

..... [2]

(b) Thiophene, $C_4H_4S(l)$, is an organic compound that is found as a contaminant in crude oil.

(i) Construct the equation for the complete combustion of thiophene, $C_4H_4S(l)$.

Include state symbols in your answer.

..... [2]

(ii) A student carries out an experiment to determine the enthalpy change of combustion of $C_4H_4S(l)$.

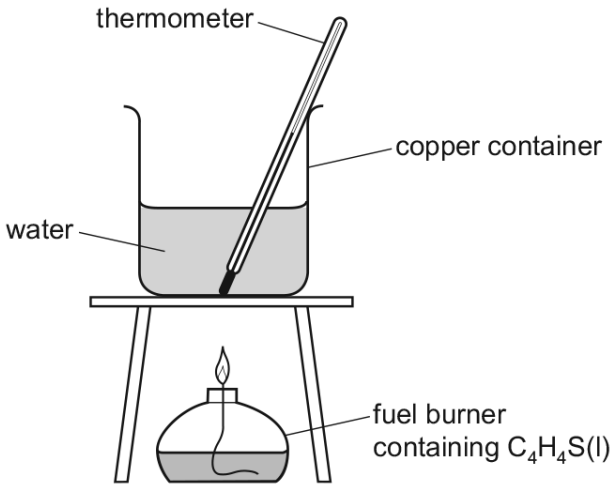
Explain the meaning of the term *enthalpy change of combustion*.

.....

.....

..... [2]

(iii) The student uses the following apparatus in the experiment.



mass of water in copper container / g	200
initial temperature of water / °C	18.5
highest temperature of water / °C	37.5

Calculate the heat energy released, in J, by the reaction.

Assume that 4.18 J of heat energy changes the temperature of 1.0 cm^3 of water by 1.0 °C.

Assume no heat is lost to the surroundings.

heat energy released = ... J
[2]

(iv) The student used 0.63 g of $C_4H_4S(l)$ in the experiment.

Calculate the enthalpy change of combustion of thiophene, $\Delta H_c(C_4H_4S(l))$. Include a sign in your answer.

$\Delta H_c(C_4H_4S(l))$ = ... $kJ\,mol^{-1}$
[2]

[Total: 13]

102. 9701_m18_qp_22 Q: 2

Carbon and silicon are elements in Group 14.

(a) C_{60} and diamond are allotropes of carbon.

(i) Describe the lattice structure of solid C_{60}.

.....

.....

.....

..... [2]

(ii) C_{60} sublimes (turns directly from solid to gas) at about 800 K. Diamond also sublimes but only above 3800 K.

Explain why C_{60} and diamond sublime at such different temperatures.

.....

.....

.....

.....

.....

.....

.....

..... [4]

(b) C_{60} forms hydrocarbons with similar chemical properties to those of alkenes. One such hydrocarbon is $C_{60}H_{18}$.

(i) State what is meant by the term *hydrocarbon*.

.....

..... [1]

(ii) Describe a test to indicate the presence of double bonds between carbon atoms in $C_{60}H_{18}$. Give the result of the test.

test .....

.....

result .....

.....

[2]

(c) 0.144 g of C_{60} was placed in a 100 cm^3 container of hydrogen gas at 20 °C and 1.00×10^5 Pa.

The container was heated to make the C_{60} and hydrogen gas react.

The reaction occurred as shown in the equation.

$$C_{60}(s) + xH_2(g) \rightarrow C_{60}H_{2x}(s)$$

After the reaction, the container was allowed to cool to 20 °C. The pressure decreased to 2.21×10^4 Pa. All of the C_{60} had reacted.

(i) Name the type of reaction that occurred.

..... [1]

(ii) Calculate the amount, in moles, of C_{60} that reacted.

amount of C_{60} = ... mol [1]

(iii) Calculate the amount, in moles, of hydrogen gas that reacted with the C_{60}.

amount of hydrogen gas = ... mol [2]

(iv) Use your answers from **(ii)** and **(iii)** to deduce the molecular formula of the hydrocarbon, $C_{60}H_{2x}$.

If you were unable to calculate the amount of hydrogen gas, assume that 0.00240 mol of hydrogen gas reacted. This is **not** the correct value for the amount of hydrogen gas that reacted.

molecular formula = ... [2]

(d) Silicon shows the same kind of bonding and structure as diamond.

(i) State the type of bonding and structure shown by silicon.

.....

.....

..... [2]

(ii) When silicon reacts with magnesium, Mg_2Si forms. Mg_2Si is thought to contain the Si^{4-} ion.

State the full electronic configuration of the Si^{4-} ion.

$1s^2$..... [1]

(iii) Solid Mg_2Si reacts with dilute hydrochloric acid to form gaseous SiH_4 and a solution of magnesium chloride.

Write an equation to show the reaction of solid Mg_2Si with dilute hydrochloric acid.

Include state symbols.

..... [2]

(iv) Predict the shape of the SiH_4 molecule.

..... [1]

(v) SiH_4 reacts spontaneously with oxygen to produce a white solid and a colourless liquid that turns anhydrous copper(II) sulfate blue. No other products are formed.

Write an equation for the reaction of SiH_4 with oxygen.

State symbols are **not** required.

..... [1]

[Total: 22]

103. 9701_s18_qp_21 Q: 2

Crude oil is a complex mixture of hydrocarbon molecules.

The hydrocarbon molecules in crude oil are separated by fractional distillation. Fractional distillation is used because the different hydrocarbon molecules in crude oil have different boiling points.

(a) Explain why the hydrocarbon molecules in crude oil have different boiling points.

.....

.....

.....

.....

.....

.....

..... [2]

(b) Some of the hydrocarbon molecules obtained from crude oil are processed further by cracking.

Suggest why some hydrocarbon molecules are processed further by cracking.

.....

.....

..... [1]

(c) Cracking one mole of dodecane, $C_{12}H_{26}$, produces two moles of ethene and one mole of another hydrocarbon molecule.

(i) Write the equation for this cracking reaction.

..... [1]

The ethene can be used in the production of poly(ethene).

(ii) Give the full name of the process used to produce poly(ethene) from ethene.

..... [1]

(iii) Give **two** reasons why poly(ethene) should be reused or recycled rather than just thrown away.

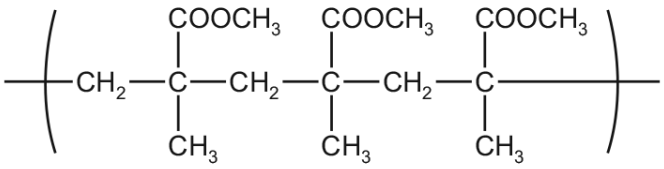
.....

.....

.....

..... [2]

(iv) Part of a polymer chain, produced by the same type of process as poly(ethene), is shown.



Give the **displayed** formula of the monomer used to produce this polymer.

[2]

[Total: 9]

104. 9701_s18_qp_22 Q: 3

Most vehicle fuels contain hydrocarbons obtained from crude oil.

(a) (i) State the name of the type of reaction that hydrocarbons undergo when being used as fuels.

..... [1]

(ii) Write an equation for the reaction of octane, C_8H_{18}, as a fuel, as in **(a)(i)**.

..... [2]

(b) The supply of material suitable for use as fuels directly from crude oil is **not** sufficient to meet demand. A process is carried out to make some of the larger hydrocarbon molecules more useful.

(i) Name this process.

..... [1]

As well as producing fuels, this process produces compounds suitable for use in the production of polymers. An example of such a compound is but-2-ene, $CH_3CH{=}CHCH_3$.

(ii) Draw the repeat unit of the polymer that is produced from but-2-ene.

[2]

(iii) Name the type of polymerisation that occurs during the production of the polymer in **(ii)**.

..... [1]

(c) Gases produced in internal combustion engines include carbon monoxide, oxides of nitrogen such as NO_2, and unburnt hydrocarbons.

These gases are removed from the exhaust before they can enter the atmosphere.

(i) State what is used to remove these gases from the exhaust.

..... [1]

(ii) Write **one** equation to show how both carbon monoxide, CO, and nitrogen dioxide, NO_2, are removed from the exhaust.

..... [1]

(iii) State the environmental consequence of allowing unburnt hydrocarbons to enter the atmosphere.

..... [1]

(d) Vehicle fuels are treated to remove sulfur. If sulfur is present in a fuel when it is burned, SO_2 is produced and may be released into the atmosphere where it can form acid rain.

(i) Acid rain can contribute to breathing difficulties.

Identify **two** other consequences of acid rain in the atmosphere.

.....

.....

.....

..... [2]

(ii) NO_2 is involved in the production of acid rain from SO_2.

Give **two** equations which describe how acid rain is formed by the action of NO_2 with SO_2.

.....

..... [2]

(iii) NO_2 is described as a catalyst during this process.

Explain, with the use of an appropriate equation, why NO_2 is described as a catalyst.

.....

..... [2]

[Total: 16]

105. 9701_s17_qp_23 Q: 1

Combustion data can be used to calculate the empirical formula, molecular formula and relative molecular mass of many organic compounds. Combustion data cannot distinguish between different structural isomers.

(a) Define the term *structural isomers*.

.....

.....

.....

..... [2]

(b) **P** is a hydrocarbon, C_xH_y. A gaseous sample of **P** occupied a volume of 25 cm^3 at 37 °C and 100 kPa.

The sample was completely burned in 200 cm^3 of oxygen (an excess).
The final volume, measured under the same conditions as the gaseous sample (so that the water produced is liquid and its volume can be ignored), was 150 cm^3.

Treating the remaining gaseous mixture with concentrated alkali, to absorb carbon dioxide, decreased the volume to 50 cm^3.

The equation for the complete combustion of **P** can be represented as shown.

$$C_xH_y + (x + \frac{y}{4})O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

(i) Use the data given to calculate the value of x.

x = ... [1]

(ii) Use the data given to calculate the value of $(x + \frac{y}{4})$.

$(x + \frac{y}{4})$ = ... [1]

If you were unable to calculate values in **(b)(i)** and **(b)(ii)** then use the data in this box for the remaining parts of this question. These are **not** the correct values.

$x = 6$ $\left(x + \frac{y}{4}\right) = 9$

(iii) Give the molecular formula and the empirical formula of **P**.

molecular formula of **P** .....

empirical formula of **P** .....

[2]

(iv) **P** is unbranched.

Give the skeletal formulae for two possible structures of **P** that are positional isomers of each other.

[2]

(v) Use the general gas equation to calculate the mass of **P** present in the original 25 cm^3 gaseous sample, which was measured at 37 °C and 100 kPa.

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

mass = ... g [3]

[Total: 11]

106. 9701_w15_qp_21 Q: 3

Heptane, C_7H_{16}, is an undesirable component of petrol as it burns explosively causing 'knocking' in an engine.

(a) There are nine structural isomers with the formula C_7H_{16}, only two of which contain chiral centres.

(i) Explain the meanings of the terms *structural isomers* and *chiral*.

structural isomers .....

.....

.....

chiral .....

.....

.....

[2]

(ii) Give the structures and names of the two structural isomers of C_7H_{16} which contain a chiral centre.

[4]

(b) **(i)** Write an equation for the complete combustion of heptane.

..... [1]

(ii) Write an equation for the incomplete combustion of heptane leading to the production of a solid pollutant.

..... [1]

(iii) Incomplete combustion can also lead to emission of unburnt hydrocarbons.

State one environmental consequence of this.

..... [1]

(c) The reaction of heptane with chlorine in the presence of UV light produces a wide variety of products.

Formation of the monochloroheptanes can be represented by the following equation.

$$C_7H_{16} + Cl_2 \rightarrow C_7H_{15}Cl + HCl$$

(i) Name the mechanism of the reaction between heptane and chlorine in the presence of UV light.

..... [1]

(ii) Describe this mechanism, using suitable equations and including the names of each stage in the process.

.....

.....

.....

.....

.....

.....

.....

.....

..... [5]

[Total: 15]

14.2 Alkenes

107. 9701_s21_qp_21 Q: 5

(a) Naphtha is a mixture which contains only hydrocarbon molecules.

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

.....

..... [1]

(ii) Name the raw material that is used to produce a sample of naphtha.

..... [1]

(b) Compound **V** is found in naphtha. It has a molecular formula $C_{10}H_{22}$.

When **V** is heated at high pressure in the absence of air, an equal number of moles of ethene, propene and **W** are made. **W** is a compound made of straight chain, saturated molecules.

(i) Name the process that describes this reaction.

..... [1]

(ii) Deduce the structure of **W**. Draw its structure below.

[1]

(c) Propene is separated from the mixture and heated in air in the presence of a catalyst. Propene is oxidised to **X**, which contains two functional groups.

(i) Effervescence is seen when Na_2CO_3(aq) is added to **X**.

Identify the functional group present in **X** which is responsible for this observation.

..... [1]

(ii) Identify a reagent which could be used to show that **X** contains a C=C. Include relevant observations.

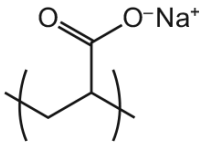
.....

..... [2]

(d) **X** reacts with another reagent to form **Y**.

Molecules of **Y** react together to form addition polymer **Z**. The diagram shows the repeat unit of polymer **Z**.

repeat unit of polymer **Z**



Draw the structural formula of monomer **Y**.

[1]

(e) Polymer **Z** is useful because it absorbs large amounts of water. However, there are problems associated with the disposal of products containing polymer **Z**.

Combustion is not an appropriate method to dispose of pure **Z** because the process releases harmful gases. Some of these gases contribute to the enhanced greenhouse effect.

(i) Identify a gas released during the combustion of **Z** which contributes to the enhanced greenhouse effect.

..... [1]

(ii) Identify another gas which could be produced during the combustion of pure **Z**. Describe a consequence, other than the enhanced greenhouse effect, of its release into the atmosphere.

gas .....

consequence .....

[1]

[Total: 10]

108. 9701_w21_qp_22 Q: 1

Hydrogen iodide, HI, is a colourless gas at room temperature.

(a) (i) Explain why HI has a higher boiling point than HC*l* and HBr.

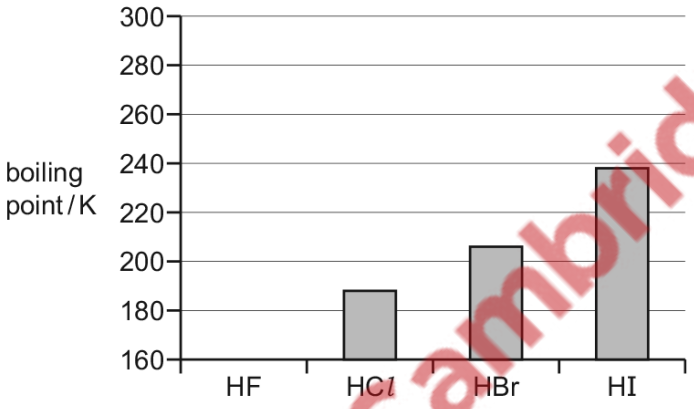
.....

.....

.....

..... [2]

(ii) The bar chart shows the boiling points of HC*l*, HBr and HI. The boiling point of HF is not shown.



Hydrogen bonds form between HF molecules.

Draw a bar on the bar chart to predict the boiling point of HF.

Explain your answer.

.....

..... [2]

(b) The standard enthalpy change of formation, $\Delta H_f^\ominus$, of HI(g) is +26.5 kJ mol^{-1}.

Define the term *standard enthalpy change of formation*.

.....

.....

..... [2]

(c) HI(g) can be formed by reacting $H_2(g)$ with $I_2(g)$. The reaction is reversible, and an equilibrium forms quickly at high temperatures.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(i) Construct an expression for the equilibrium constant, K_p, for the reaction of $H_2(g)$ and $I_2(g)$ to form HI(g).

K_p =

[1]

(ii) The equilibrium partial pressures of the gases at 200 °C are as follows.

$$p_{H_2(g)} = 895\,Pa$$
$$p_{I_2(g)} = 895\,Pa$$
$$p_{HI(g)} = 4800\,Pa$$

Calculate K_p for this reaction.

K_p = ... [1]

(iii) State how the value of K_p would change, if at all, if the reaction were carried out at 100 °C rather than 200 °C.

Explain your answer.

.....

.....

.....

..... [2]

(d) HI reacts with oxygen to form iodine and water.

(i) Construct an equation for the reaction of HI with oxygen.

..... [1]

(ii) Explain, with reference to oxidation numbers, why this reaction is a redox reaction.

.....

.....

.....

..... [2]

(e) HI(g) can also be formed by the reaction of $I_2(g)$ with hydrazine, $N_2H_4(g)$.

$$2I_2(g) + N_2H_4(g) \rightarrow 4HI(g) + N_2(g)$$

State the change in pressure that would occur when 2 mol $I_2(g)$ fully reacts with 1 mol $N_2H_4(g)$ in a sealed container at constant temperature. Explain your answer.

.....

.....

.....

..... [2]

(f) In the laboratory, HI(aq) can be formed in a two-step process.

step 1 $3I_2(s) + 2P(s) \rightarrow 2PI_3(s)$

step 2 $PI_3(s) + 3H_2O(l) \rightarrow H_3PO_3(aq) + 3HI(aq)$

(i) Draw a 'dot-and-cross' diagram of a PI_3 molecule.

[2]

(ii) Name the type of reaction in **step 2**.

..... [1]

(iii) $H_3PO_3(aq)$ and HI(aq) are both strong Brønsted–Lowry acids.

Give the meaning of the term *strong Brønsted–Lowry acid*.

.....

.....

..... [2]

(iv) Give the formula of the conjugate base of H_3PO_3.

..... [1]

(g) HI(g) reacts with propene, $CH_3CH{=}CH_2(g)$ to form a mixture of 1-iodopropane and 2-iodopropane.

(i) Identify which of 1-iodopropane and 2-iodopropane is the major product of this reaction.

Explain your answer.

.....

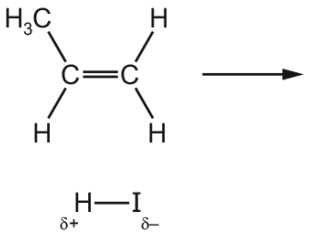
.....

.....

..... [2]

(ii) Complete the diagram to show the mechanism of the reaction between HI and $CH_3CH{=}CH_2$ that forms the major product identified in **(g)(i)**.

Include curly arrows, lone pairs of electrons and charges as necessary.



[3]

[Total: 26]

109. 9701_s20_qp_23 Q: 4

Hexane, C_6H_{14}, is a colourless liquid.
Two test-tubes contain equal amounts of hexane. 1 cm^3 of bromine, $Br_2(aq)$, is added to both test-tubes. One test-tube is kept in the dark and the other is exposed to sunlight.

The table describes the appearance of each test-tube after one hour.

test-tube conditions	observations
in the dark	no change, mixture remains orange
in sunlight	colour of mixture fades to pale yellow

(a) The test-tube in the dark is kept cool and is not exposed to ultraviolet light.

Explain the observations for the test-tube kept in the dark.

.....

..... [2]

(b) In sunlight, bromine reacts with hexane by a mechanism which occurs via a series of steps.

(i) State the name of the mechanism of the reaction that occurs.

..... [1]

(ii) Give an equation which shows a propagation step in this reaction in which hexane produces $\bullet C_6H_{13}$.

..... [1]

(iii) Give an equation which shows a propagation step in this reaction that produces 1-bromohexane.

..... [1]

(iv) Give an equation which shows a termination step in this reaction that produces 1-bromohexane.

..... [1]

(c) **A** and **B** are different straight chain alkenes with molecular formula, C_6H_{12}.

A does not show stereoisomerism.

A reacts with potassium manganate(VII) to form hexane-1,2-diol.

(i) Draw the structural formula of **A**.

[1]

(ii) State the conditions needed for this reaction of **A**.

..... [2]

(d) **B** reacts with hydrogen gas in the presence of a platinum catalyst to produce hexane.

(i) Name the type of reaction occurring.

..... [1]

(ii) In terms of σ and π bonds, describe any similarities and differences in the type of carbon-carbon bonds in **B** and the type of carbon-carbon bonds in hexane.

.....

.....

..... [2]

[Total: 12]

110. 9701_w20_qp_21 Q: 4

Iodine is used in many inorganic and organic reactions.

(a) (i) State and explain the trend in volatility of the halogens, from chlorine to iodine.

.....

.....

.....

..... [2]

(ii) Explain why HI is the **least** thermally stable of HC*l*, HBr and HI.

.....

..... [1]

(iii) The table shows the electronegativity values for hydrogen, fluorine and iodine.

element	electronegativity value
H	2.1
F	4.0
I	2.5

Explain, in terms of intermolecular forces, why HI has a lower boiling point than HF.

.....

.....

.....

..... [2]

(iv) Iodine reacts with hot concentrated aqueous sodium hydroxide in the same way as chlorine.

Write an equation for the reaction of iodine and hot aqueous sodium hydroxide.

..... [1]

(b) Iodoalkanes contain carbon-iodine bonds.

The simplest iodoalkane is CH_3I.

(i) CH_3I can be made from methanol, CH_3OH.

Identify a reagent that can convert CH_3OH to CH_3I.

..... [1]

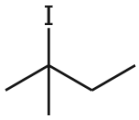
(ii) 1,2-diiodoethane, CH_2ICH_2I, can be made by bubbling ethene into liquid iodine.

Fully name the type of mechanism shown in this reaction.

..... [1]

(c) **J** reacts with NaOH, forming different products dependent on the conditions used.

J

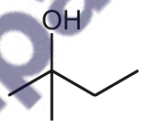


(i) Name **J**.

..... [1]

(ii) **J** reacts with NaOH(aq) to form **K**.

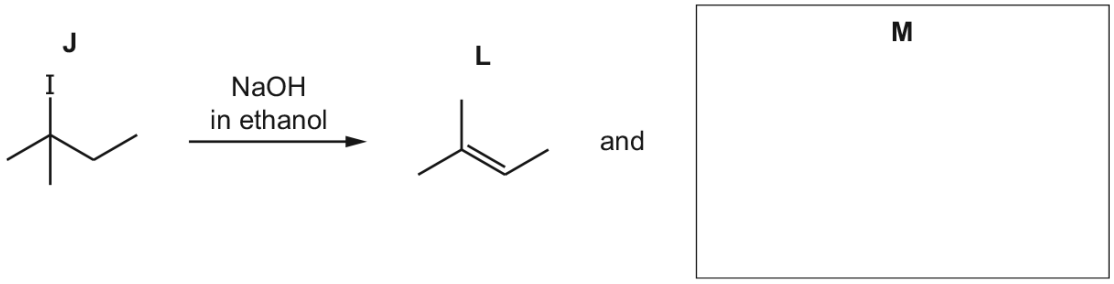
K



Fully name the mechanism of the reaction of **J** with NaOH(aq) to form **K**.

..... [1]

(iii) **J** reacts with NaOH dissolved in ethanol to form a mixture of two alkenes, **L** and **M**. Alkene **L** is shown.



In the box provided, draw the structure of **M**. [1]

(iv) Explain why **L** does **not** show geometrical (cis-trans) isomerism.

.....

.....

..... [1]

(v) **L** reacts with hot concentrated acidified $KMnO_4(aq)$ to form propanone and one other organic product.

Identify the other organic product.

..... [1]

(vi) Propanone reacts with excess alkaline aqueous iodine.

Complete and balance the equation for this reaction.

CH_3COCH_3 + ...I_2 + ...OH^- ⟶ .....CH_3COO^- + ...H_2O + ...I^- + ...
[2]

(vii) State **one** observation that can be made in the reaction in **(c)(vi)**.

..... [1]

[Total: 16]

111. 9701_m19_qp_22 Q: 1

Nitrogen, N_2, is the most abundant gas in the Earth's atmosphere and is very unreactive.

(a) State why N_2 is very unreactive.

..... [1]

(b) Magnesium and lithium both form nitrides with N_2. These compounds both contain the N^{3-} ion.

(i) Write an equation for the reaction of magnesium with N_2 to form magnesium nitride.

..... [1]

(ii) Solid lithium nitride, Li_3N, reacts with water according to the following equation.

$$Li_3N(s) + 3H_2O(l) \rightarrow 3LiOH(aq) + NH_3(aq)$$

State **one** observation you would make during this reaction.

..... [1]

(c) (i) State the industrial importance of ammonia.

..... [1]

(ii) One method of producing NH_3 is by heating ammonium chloride, NH_4Cl, with CaO.

$$2NH_4Cl + CaO \rightarrow 2NH_3 + CaCl_2 + H_2O$$

Explain why the reaction of NH_4Cl with CaO produces ammonia.

.....

.....

..... [2]

(d) Three oxides of nitrogen, NO, NO_2 and N_2O, can be formed under different conditions.

(i) Complete the table to give the oxidation numbers of nitrogen in NO and NO_2.

compound	NO	NO_2
oxidation number of N		

[1]

(ii) NO_2 can be formed by different chemical reactions.

Write equations for the formation of NO_2 by:

- the reaction of N_2 with O_2

.....

- the thermal decomposition of magnesium nitrate.

.....

[2]

(iii) Molecules of N_2O can be formed by the reaction between N_2 and O_2. The bond between the N and O atoms (N→O) is a co-ordinate (dative covalent) bond.

$$2N_2(g) + O_2(g) \rightarrow 2N{\equiv}N{\rightarrow}O(g)$$

The enthalpy change of reaction for this reaction is +82 kJ mol^{-1}.

Calculate the bond enthalpy, in kJ mol^{-1}, of the N→O bond.

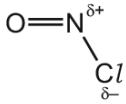
Use relevant data from the *Data Booklet* to answer this question.

bond enthalpy of the N→O bond = ... kJ mol^{-1}

[2]

(e) Nitrosyl chloride, NOCl, is a reactive gas that is sometimes formed when NO reacts with Cl_2.

nitrosyl chloride



NOCl is a strong electrophile and readily undergoes an addition reaction with alkenes.

Complete the diagram to show the mechanism of the electrophilic addition reaction of NOCl with ethene.

Include all necessary charges, lone pairs and curly arrows, and the structure of the organic intermediate.

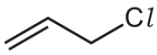
[2]

[Total: 13]

112. 9701_m19_qp_22 Q: 4

Allyl chloride is an important chemical used in the manufacture of plastics, pharmaceuticals and pesticides.

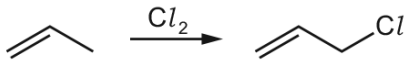
allyl chloride



(a) Give the systematic name of allyl chloride.

..... [1]

(b) Allyl chloride can be produced by many different methods. The most common method is chlorination of propene which proceeds via a free-radical substitution mechanism.



(i) The initiation step in this reaction is the formation of chlorine radicals ($Cl^{\bullet}$) from Cl_2 molecules.

State the conditions required to initiate this reaction.

..... [1]

(ii) The propenyl radical, $CH_2{=}CHCH_2^{\bullet}$, is formed in the first propagation step of the reaction.

Write an equation to show the formation of $CH_2{=}CHCH_2^{\bullet}$ in this propagation step.

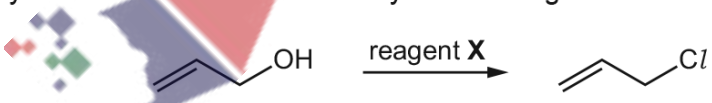
..... [1]

(iii) Explain why the free-radical substitution reaction gives a low yield of allyl chloride.

.....

..... [1]

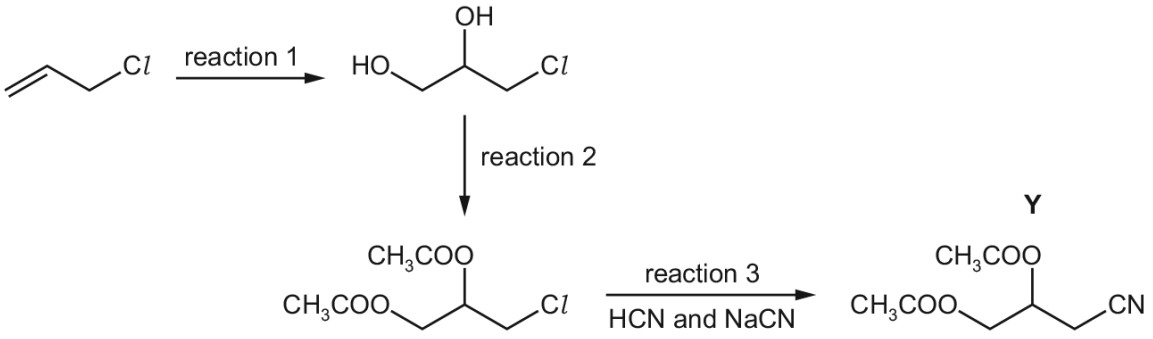
(iv) Allyl chloride can also be formed by the following substitution reaction.



Suggest the identity of reagent **X**.

..... [1]

(c) A series of reactions starting from allyl chloride is shown.



(i) Suggest a reagent that can be used in reaction 1.

..... [1]

(ii) In reaction 2, the organic product of reaction 1 is mixed with concentrated H_2SO_4 and an organic acid, and then heated under reflux.

State the role of the concentrated H_2SO_4. Identify the organic acid used.

role of the concentrated H_2SO_4 .....

identity of the organic acid .....

[2]

(iii) State the name of the mechanism that occurs in reaction 3.

..... [1]

(iv) The organic product of reaction 3 is **Y**.

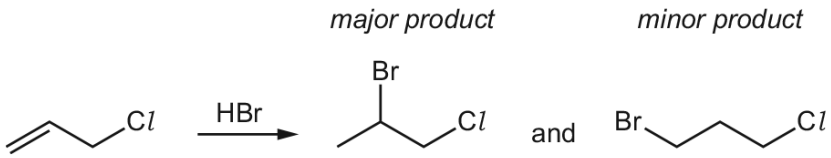
Y can be hydrolysed using excess aqueous H_2SO_4 to form **Z**.

The molecular formula of **Z** is $C_4H_8O_4$.

Draw the structure of **Z**.

[2]

(d) 2-bromo-1-chloropropane, $CH_3CHBrCH_2Cl$, is the major product of the reaction of allyl chloride with HBr.



Explain why 2-bromo-1-chloropropane is the major product of this reaction.

.....

.....

.....

..... [2]

[Total: 13]

113. 9701_s19_qp_22 Q: 4

There are many different types of aliphatic and aromatic hydrocarbons.

(a) Name a naturally occurring source of aliphatic and aromatic hydrocarbons and outline how different hydrocarbons are separated from this source.

name of source .....

outline of separation of hydrocarbons .....

.....

[2]

(b) When alkanes are heated to high temperatures, in the absence of air, the molecules can break into smaller molecules.

(i) Identify the type of reaction occurring.

..... [1]

(ii) Write an equation which describes the reaction occurring when heptane, C_7H_{16}, is heated in the absence of air, to form hexane, butane and ethene only.

..... [1]

(c) The equation for the complete combustion of ethene is shown.

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

Calculate the volume, in dm^3, of carbon dioxide formed in the complete combustion of 1.00 g of ethene at room temperature and pressure.

volume of CO_2 = ... dm^3 [3]

(d) The table compares the reactivity of alkanes and alkenes with chlorine.

	alkanes	alkenes
name of the type of reaction with chlorine	substitution	addition and substitution
name of the type of reacting species	free radical	electrophile and free radical

(i) During the first stage in the substitution reaction chlorine forms chlorine free radicals.

Explain what is meant by the term *free radical*.

..... [1]

(ii) Name and explain the type of bond breaking which occurs to form chlorine free radicals.

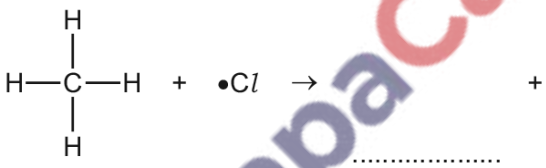
.....

..... [2]

(iii) Name the stage of the reaction mechanism which occurs when a methane molecule reacts with a chlorine free radical.

..... [1]

(iv) Complete the equation for the reaction which occurs when a methane molecule reacts with a chlorine free radical.



....

[1]

(v) Carbon atoms can form σ and π bonds within hydrocarbon molecules.

Explain the following statement with reference to σ and π bonds.

Alkenes react with electrophiles but alkanes do not.

.....

.....

.....

..... [2]

[Total: 14]

114. 9701_S15_qp_22 Q: 3

Ethane reacts with chlorine to form chloroethane.

$$C_2H_6(g) + Cl_2(g) \rightarrow C_2H_5Cl(g) + HCl(g)$$

(a) (i) Use bond energies from the *Data Booklet* to calculate the enthalpy change for this reaction. Include a sign in your answer.

enthalpy change = ... $kJ\,mol^{-1}$ [3]

(ii) State the conditions needed for this reaction to occur.

..... [1]

(iii) Use a series of equations to describe the mechanism of this reaction including the names of each stage and an indication of how butane can be produced as a minor by-product.

.....

.....

.....

.....

.....

..... [5]

(b) Chloroethane can be converted back into ethane by a two-stage process via an intermediate compound, **X**.

$$C_2H_5Cl \xrightarrow{\text{reaction 1}} \mathbf{X} \xrightarrow{\text{reaction 2}} C_2H_6$$

(i) Give the name of **X**.

..... [1]

(ii) Suggest the reagent and conditions needed for reaction 1.

..... [2]

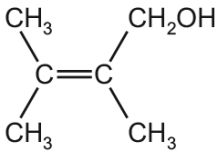
(iii) Suggest the reagent and conditions needed for reaction 2.

..... [1]

[Total: 13]

115. 9701_S15_qp_23 Q: 4

The structure of **H** is shown.



H

(a) **H** reacts with both cold, dilute, acidified potassium manganate(VII) and with hot, concentrated, acidified potassium manganate(VII).

(i) Give the structure of the organic product of the reaction of **H** with cold, dilute, acidified potassium manganate(VII).

[1]

(ii) Give the structures of the organic products of the reaction of **H** with hot, concentrated, acidified potassium manganate(VII).

[2]

(b) **(i)** Complete the reaction scheme to show the mechanism of the reaction of **H** with bromine to form **J**.

Include all necessary curly arrows, lone pairs and charges.

J

[3]

(ii) Explain the origin of the dipole on the bromine molecule.

.....

..... [1]

J is formed as an equimolar mixture of isomers.

(iii) State the type of isomerism shown by **J**.

..... [1]

(iv) Draw the structures of the two isomers of **J**.

[2]

[Total: 10]

14.3 Hydrocarbons as fuels

116. 9701_w18_qp_21 Q: 3

Trihalomethanes are organic molecules in which three of the hydrogen atoms of methane are replaced by halogen atoms, for example $CHCl_3$.

(a) $CHCl_3$ is a colourless liquid with a high vapour pressure.

(i) Explain what is meant by *high vapour pressure*.

.....

.....

.....

..... [2]

(ii) An important reaction of $CHCl_3(g)$ is the manufacture of $CHClF_2(g)$, using the following reversible reaction.

$$CHCl_3(g) + 2HF(g) \rightleftharpoons CHClF_2(g) + 2HCl(g)$$

Use the data to calculate the enthalpy change of reaction, ΔH_r, for the formation of $CHClF_2(g)$ as shown in the equation.

compound	enthalpy change of formation, ΔH_f / kJ mol^{-1}
$CHCl_3(g)$	–103.2
$CHClF_2(g)$	–482.2
HF(g)	–273.3
$HCl(g)$	–92.3

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

(iii) The reaction in **(ii)** is carried out using a heterogeneous catalyst.

Explain fully the meaning of the terms *heterogeneous* and *catalyst*.

heterogeneous .....

.....

.....

catalyst .....

.....

.....

..... [3]

(b) $CHCl F_2$ was used as an alternative to chlorofluorocarbons (CFCs). $CHCl F_2$ should no longer be used because it was found to contribute to the *enhanced greenhouse effect*.

(i) Give the meaning of the term *enhanced greenhouse effect*.

.....

..... [1]

(ii) Explain how $CHCl F_2(g)$ may contribute to this effect.

.....

.....

..... [2]

(iii) Suggest another environmental problem associated with the use of $CHCl F_2$.

..... [1]

(c) $CHClF_2$ is also used to produce the monomer tetrafluoroethene, C_2F_4.

This monomer can be used to produce poly(tetrafluoroethene), PTFE.

(i) State the type of polymerisation that occurs during the production of PTFE.

..... [1]

(ii) Draw the repeat unit of PTFE.

[1]

(iii) Suggest why PTFE is used as a coating for cooking pans.

.....

.....

.....

..... [1]

(iv) Waste disposal can cause litter problems.

State two **other** difficulties associated with the disposal of PTFE.

1 .....

.....

2 .....

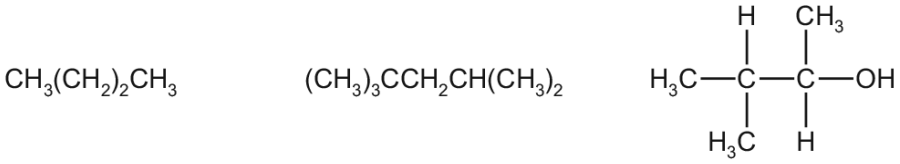
.....

[2]

[Total: 17]

117. 9701_m16_qp_22 Q: 4

The following compounds were all found to be components of a sample of petrol.



G **H** **J**

(a) (i) Give the **molecular** formula of compound **G**.

..... [1]

(ii) Give the **empirical** formula of compound **H**.

..... [1]

(iii) Draw the **skeletal** formula of compound **J**.

[1]

(b) Write an equation to represent the complete combustion of compound **H**.

..... [1]

(c) Fossil fuels are often contaminated with sulfur.

State and explain why supplies of fossil fuels that contain sulfur pose a problem to the environment.

.....

.....

..... [2]

(d) The boiling points of compounds **G**, **H** and **J** are shown below.

compound	**G**	**H**	**J**
boiling point / °C	0	99	112

Explain the differences in the boiling points of the three compounds.

.....

.....

.....

.....

.....

.....

..... [4]

(e) Compound **J** can be produced from 2-chloro-3-methylbutane, $C_5H_{11}Cl$.

Give the reagent(s) and conditions for this reaction.

..... [1]

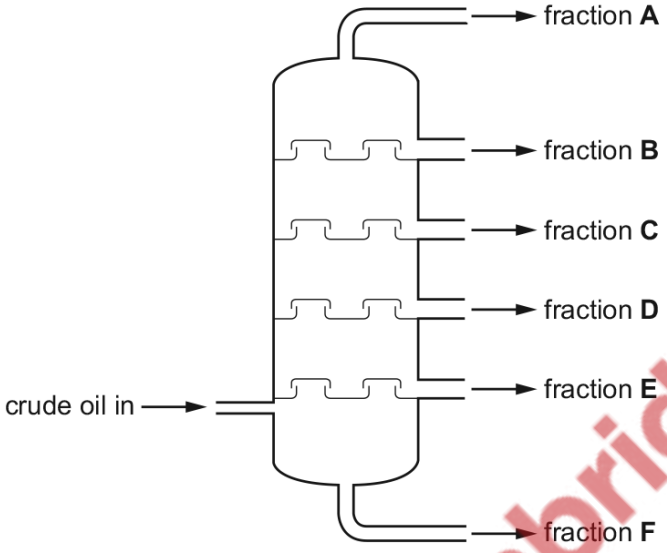
[Total: 11]

118. 9701_s16_qp_23 Q: 3

Crude oil is a mixture of hydrocarbons and provides many useful chemicals when processed.

Two of the stages involved in the processing of crude oil are fractional distillation and cracking.

(a) The diagram is a simplified representation of a fractional distillation column.



(i) What has to be done to the crude oil before it enters the column?

..... [1]

(ii) What trend in **structure** is there from fraction **A** to fraction **F**?

.....

..... [1]

(iii) State the trends in **two** properties of the fractions from **A** to **F**.

.....

.....

..... [2]

(b) The naphtha fraction from fractional distillation of crude oil is used as a starting material for cracking.

(i) Write an equation for the cracking of $C_{12}H_{26}$ to form the products ethene and one other hydrocarbon in a 2 : 1 mole ratio.

..... [1]

(ii) Suggest a use for each of the products from your equation in **(i)**. Explain what makes each product from **(i)** suitable for the use you suggest.

use of ethene .....

.....

explanation .....

.....

use of other product .....

.....

explanation .....

..... [4]

(c) Burning hydrocarbons can cause a number of environmental problems.

The products of internal combustion engines can include oxides of nitrogen and oxides of carbon.

Sulfur dioxide is a by-product of burning coal in power stations.

(i) Explain how and why oxides of nitrogen are produced in internal combustion engines.

.....

.....

..... [2]

(ii) Write an equation for the reaction between nitrogen monoxide and carbon monoxide in a catalytic converter.

..... [1]

(iii) Write equations to show the involvement of nitrogen monoxide in the formation of acid rain from atmospheric sulfur dioxide.

.....

.....

..... [3]

(iv) Describe two of the problems associated with acid rain.

.....

.....

..... [2]

[Total: 17]