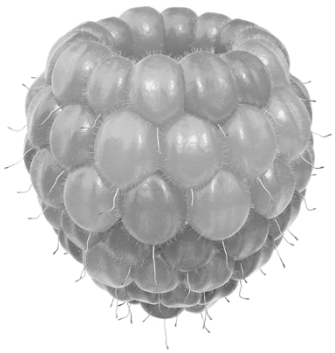
Question 1

8. (*a*) (*i*) Explain, with the aid of a diagram, the acidic nature of the carboxylic acid functional group.

(*ii*) Give an example of a reaction that demonstrates the acidic nature of ethanol.

(*iii*) Would you expect to observe a reaction when a drop of pure ethanol is added to damp solid sodium carbonate on a clock glass? Explain. (18)

(*b*) The pure ester **E** has a rum-like aroma and is partially responsible for the flavour of raspberries.



(*i*) Write a balanced chemical equation for the formation of **E** from methanoic acid and ethanol.

(*ii*) Give the systematic IUPAC name for **E**.

(*iii*) How many carbon atoms in a molecule of the ester **E** are in planar geometry?

(*iv*) Classify this esterification reaction as a redox reaction, an acid-base reaction or a substitution reaction.

(*v*) Another ester **F** has a glue-like smell and is a structural isomer of **E**. Identify **F**.

(*vi*) Identify the products of the base hydrolysis reaction between the ester methyl methanoate and an **NaOH** solution.

(*vii*) Explain why the boiling point of ethanoic acid (118 °C) is significantly higher than that of methyl methanoate (32 °C) although the two compounds have the same molecular formula $\mathbf{C_2H_4O_2}$. (32)

Question 2

(*b*) A few drops of oxidising reagent were added to a 0.5 cm^3 sample of ethanal (**CH_3CHO**) in a test-tube.

What was observed when the oxidising reagent used was

(*i*) warm dilute acidified **$KMnO_4$**,

(*ii*) Fehling's reagent, pre-heated to about 40 °C?

(*iii*) Identify the organic product of the oxidation of ethanal using these reagents.

(*iv*) Fehling's reagent is quite difficult to reduce.
Is ethanal very easy or very difficult to oxidise?

(*v*) Write a balanced half-equation to show the reduction of the **Cu^{2+}** ions of the Fehling's reagent in the test.

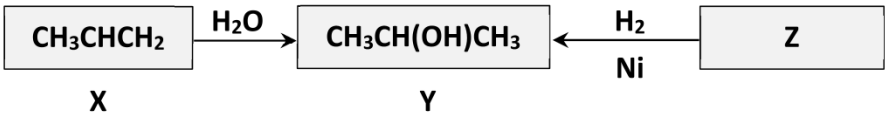
Ethanal is completely miscible with both of the aqueous oxidising reagents mentioned above.

(*vi*) Describe the polarity across the carbonyl group in ethanal.

(*vii*) Refer to the polarity across the carbonyl group to explain why ethanal is *very* soluble in water. (25)

Question 3

8. Study the reaction scheme below in which compound **Y** is produced by the reaction of compound **X** with water. **Y** is often called isopropyl alcohol and it is a component in many personal care products. **Y** can also be produced by the reduction of compound **Z**.



(*a*) (*i*) What is the systematic IUPAC name for **Y**?

(*ii*) Classify **Y** as a primary or a secondary alcohol. Justify your answer. (8)

(*b*) (*i*) Identify **Z**.

(*ii*) Draw an expanded molecular structure for **Y**, indicating clearly which of its bonds are formed when **Z** is reduced.

(*iii*) How does the geometry around the carbon atoms in **Z** change during this reduction reaction? (15)

(*c*) (*i*) What type of reaction is involved in the conversion of **X** to **Y**?

(*ii*) Identify another product of the reaction of **X** with water. (6)

(*d*) (*i*) Write a balanced equation for the reaction of **Y** with sodium.

(*ii*) What information does this reaction give about the –**OH** functional group in an alcohol? (9)

(*e*) Hand sanitizers with a high concentration of an alcohol are effective in destroying most bacteria and viruses on the skin. The ability of alcohols to form strong hydrogen bonds is involved in the mechanism of disrupting bacteria and virus protein.

(*i*) A hand sanitizer labelled 70% (*v*/*v*) isopropyl alcohol contains only water and **Y**. Express its concentration in terms of moles per litre of isopropyl alcohol**.** Take the density of isopropyl alcohol as 0.8 g cm^{-3}.

(*ii*) What is the most influential type of intermolecular force that occurs in **Z**? (12)

Question 4

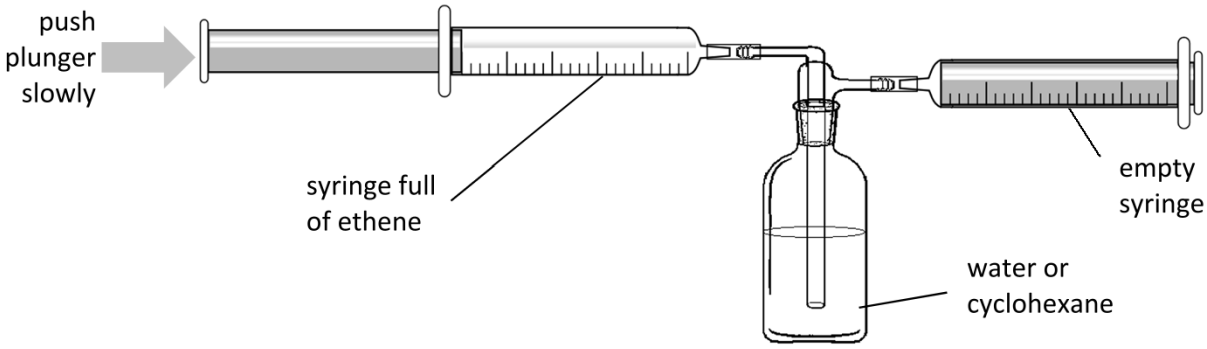
11. Answer any **two** of the parts (*a*), (*b*), (*c*) and (*d*). (2 × 25)

(*a*) More ethene is produced industrially than any other manufactured organic chemical.

(*i*) Give one major use for ethene.

(*ii*) Draw a labelled diagram of an arrangement of apparatus used to prepare and collect a small quantity of ethene in the school laboratory to examine its properties.

(*iii*) Draw the structure of an organic product of the reaction of ethene in a solution of bromine.

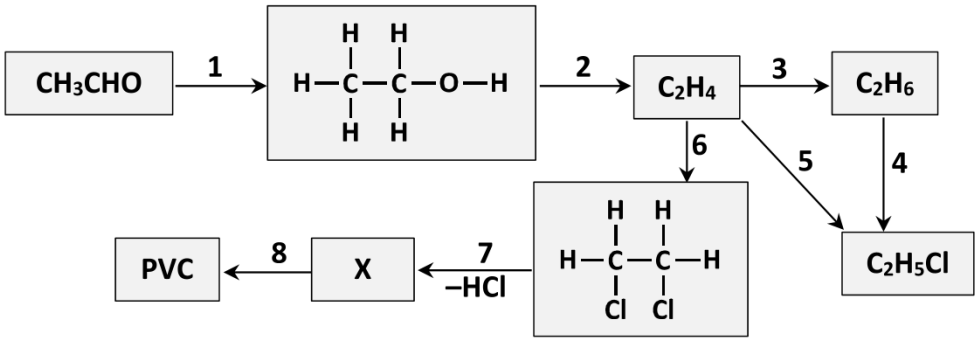


(*iv*) The diagram above shows an arrangement of apparatus used to compare the solubilities of ethene in water and in cyclohexane.

Explain how and why the solubility of ethene in water differs from its solubility in cyclohexane. (25)

Question 5

8. Study the reaction scheme and answer the questions below.



(*a*) Identify in the scheme (*i*) a substitution reaction, (*ii*) an addition reaction, (*iii*) an elimination reaction. (9)

(*b*) (*i*) What reagent and catalyst can be used in conversion **1**?

(*ii*) Copy the structure of ethanol and identify clearly the bonds formed during conversion **1**. (12)

(*c*) Identify an organic substance in the scheme that is highly soluble in water.

Justify your answer. (6)

(*d*) (*i*) Identify compound **X**.

(*ii*) How does the geometry around the carbon atoms change during conversion **7**?

(*iii*) Draw the structure of two repeating units of the polymer **PVC**. (12)

(*e*) Describe a mechanism, that involves ions, for conversion **6**. (11)

Question 6

(*b*) The percentage composition by mass of a pure, colourless liquid is 40.0% carbon, 6.67% hydrogen and 53.33% oxygen. The mass spectrum of the unknown substance was recorded and indicated that the relative molecular mass of the compound was 60. The infrared spectrum of the unknown substance was also recorded and indicated that there was a carbonyl group in the molecular structure of the compound.

(*i*) Find by calculation the empirical formula of the compound.

(*ii*) What molecular formula is suggested by the empirical formula and the mass spectrum result together? (15)

(*iii*) Give the systematic IUPAC names *or* draw the structures for two compounds with this molecular formula that contain a carbonyl group.

(*iv*) What conclusion can be reached if there was effervescence when a drop of the unknown liquid was added to a little damp, solid $\mathbf{Na_2CO_3}$ on a clock glass? (10)

Question 7

8. The table shows the boiling points of four primary alcohols and two secondary alcohols.

Alcohol	**Boiling point** (°C)
methanol	64.7
ethanol	78.4
propan-1-ol	97.2
propan-2-ol	82.4
butan-1-ol	117.5
butan-2-ol	99.1

(*a*) (*i*) What is a secondary alcohol?

(*ii*) On the same sheet of graph paper and using the same pair of axes, plot the boiling points of these alcohols against the number of carbon atoms present.

(*iii*) State and explain the trend in the boiling points of the four primary alcohols shown as their relative molecular masses increase.

(*iv*) Predict the approximate boiling point of the next alcohol in the same series as propan-2-ol and butan-2-ol. (23)

(*b*) Consider the oxidation of alcohols in which *no* carbon-carbon bonds are broken.

(*i*) Give the systematic IUPAC names for the two possible organic products of such an oxidation of butan-1-ol.

(*ii*) Draw the structure of the organic product when butan-2-ol is oxidised in this way.

(*iii*) Identify clearly which bonds in butan-2-ol are broken in this oxidation. (15)

(*c*) The ester formed from methanol and propanoic acid is found in many fruits.

(*i*) Draw the structure of this ester.

(*ii*) How many carbon atoms in a molecule of this ester are tetrahedrally bonded?

(*iii*) What are the products of the hydrolysis of this ester by **NaOH**? (12)

Question 8

(*a*) The mechanism for the substitution reaction between methane and chlorine in ultraviolet light involves free radicals.

(*i*) Explain the underlined term.

(*ii*) How are chlorine free radicals formed at the initiation stage of this reaction?

(*iii*) What name is given to the stage of the mechanism where a chain reaction is occurring?

Write balanced equations, using dots to label the free radicals, for the two reactions that repeat in the chain reaction to give chloromethane and hydrogen chloride.

(*iv*) Identify a hydrocarbon formed in the process.

Explain why only a trace quantity of this product is formed. (25)

Question 9

8. Consider compounds **A**, **B**, **C** and **D**, all of which have molecules of similar size and mass.

A	**B**	**C**	**D**
butane	**propan-1-ol**	**propanal**	**ethanoic acid**
$M_r = 58$	$M_r = 60$	$M_r = 58$	$M_r = 60$
b.p. = –1 to 1 °C	b.p. = 97 to 98 °C	b.p. = 46 to 50 °C	b.p. = 118 to 119 °C

(*a*) (*i*) Draw structures to show all the bonds in molecules of **B** and **C**.

(*ii*) Which one of the four compounds contains only one tetrahedrally bonded carbon atom in its molecules? (9)

(*b*) Propan-2-ol and **B** are structural isomers. **B** is a primary alcohol.

(*i*) Explain the underlined terms.

(*ii*) **C** and another compound **E** are structural isomers. Draw a structure for **E**.

(*iii*) Give the IUPAC name for **E**. (18)

(*c*) Explain clearly why

(*i*) the boiling point (b.p.) of propanal is much higher than that of butane,

(*ii*) the boiling point (b.p.) of ethanoic acid is higher than that of propan-1-ol. (12)

(*d*) What is the organic product of the reaction of **C** with acidified dilute **$KMnO_4$**? (6)

(*e*) Write a balanced equation for the reaction that occurs between sodium and **B**. (5)

Question 10

10. Answer any **two** of the parts (*a*), (*b*) and (*c*). (2 × 25)

(*a*) Describe how you could demonstrate that ethene readily undergoes an addition reaction with bromine water.

Would you expect benzene to readily undergo an addition reaction with bromine water? Explain your reasoning. (12)

Some of the electrons in a benzene molecule are delocalised.
Explain the underlined term.

How many electrons in a benzene molecule are

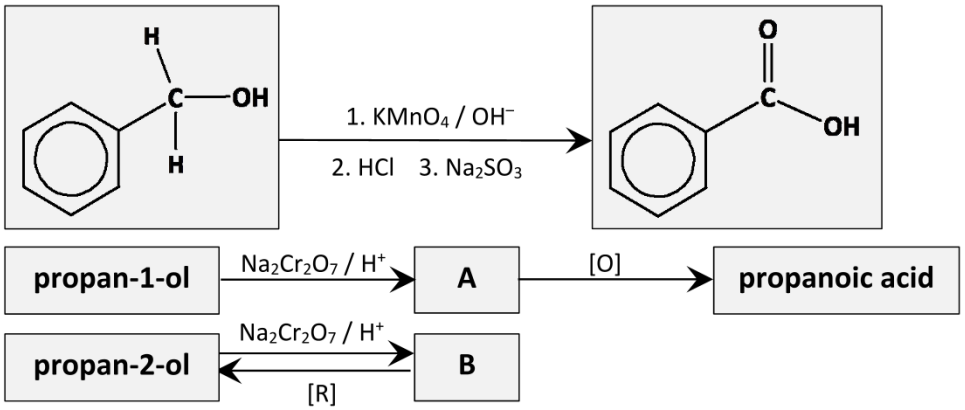
(*i*) delocalised,

(*ii*) involved in sigma bonds between carbon atoms?

What health hazard is associated with benzene? (13)

Question 11

8. The scheme below shows redox reactions of some organic compounds.



(*a*) What is the overall colour change that occurs in the reaction vessel as phenylmethanol is converted to benzoic acid under the conditions given in the scheme?

Explain this colour change by reference to the transition metal reagent used.

Copy the structures of phenylmethanol and benzoic acid into your answerbook and mark clearly the bond(s) involving carbon in this oxidation reaction

(*i*) that are broken in phenylmethanol,

(*ii*) that are formed in benzoic acid. (15)

(*b*) Give the IUPAC names for **A** and **B** and draw their structures. (12)

(*c*) Identify the reactant and a transition metal catalyst used to reduce **B** to propan-2-ol.(6)

(*d*) Oxidation of **B** is very difficult while **A** can be very readily oxidised with reagents that are weaker than those shown in the scheme.

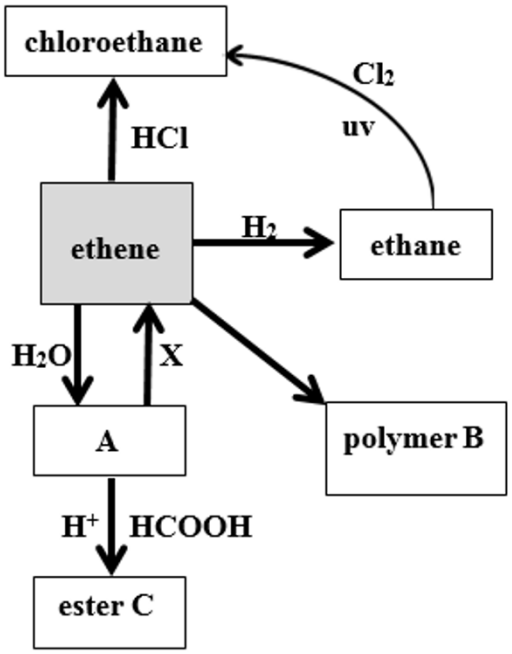
Suggest a weak oxidising reagent – a transition metal compound – that could be used to distinguish between a sample of **A** and a sample of **B**. (6)

(*e*) Name an ester that is a structural isomer of propanoic acid.

Identify the alcohol and the carboxylic acid used in the synthesis of this ester. (11)

Question 12

8. Consider the reaction scheme on the right.



(*a*) Name **A** and polymer **B**. (6)

(*b*) Identify substance **X** used in the conversion of **A** to ethene.

What organic reaction type is involved in this conversion?

How does the geometry around the carbon atoms change in this conversion? (9)

(*c*) What organic reaction type is involved in the conversion of ethane to chloroethane?

Describe in detail the mechanism for the reaction between ethane and chlorine in ultraviolet light to produce chloroethane.

Explain the effect of the presence of a little tetraethyllead, **$Pb(C_2H_5)_4$**, on this conversion. (21)

(*d*) Ester **C** is formed when **A** is heated with methanoic acid and a few drops of sulfuric acid acting as a catalyst.

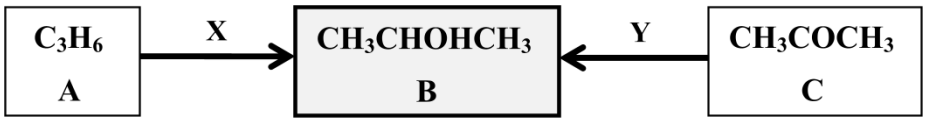
Name **C** and draw its structure.

In your drawing, circle the carbonyl group of the ester.

What name is given to the type of reaction that occurs between sodium hydroxide and **C**? (14)

Question 13

8. Study the reaction scheme below and answer the questions that follow.



(*a*) Give the IUPAC names for **A**, **B** and **C**. (8)

(*b*) Name the addition polymer formed from compound **A**. (3)

(*c*) Identify the bonds broken and the bonds formed in conversion **Y**. (9)

(*d*) An isomer of compound **B** can be synthesised from an aldehyde.
Name the isomer of compound **B** and the aldehyde and draw their full structural formulae.
How can the aldehyde be converted to the isomer of compound **B**? (18)

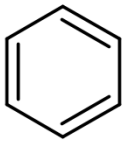
(*e*) The boiling points of compounds **A**, **B** and **C** are –48, 56 and 82 °C, but not necessarily in that order.
For each compound, identify its boiling point, justifying your answer in terms of intermolecular forces. (12)

Question 14

10. Answer any **two** of the parts (*a*), (*b*) and (*c*). (2 × 25)

(*a*) Distinguish between *saturated* and *unsaturated* hydrocarbons.
Describe how you would test a given hydrocarbon for unsaturation. (13)

In 1865 August Kekulé proposed the structure for benzene shown on the right.
How many pi-electrons are there in benzene?
Explain whether or not the Kekulé structure correctly describes
(*i*) the number,
(*ii*) the distribution, of the pi-electrons in benzene.
Give one piece of experimental evidence in support of your explanation to part (*ii*). (12)



Question 15

8. Answer the questions that follow with reference to hydrocarbons **A**, **B** and **C** below.

C_2H_2	C_2H_4	C_2H_6
A	**B**	**C**

(*a*) Give the IUPAC name and draw the structural formula of compound **B**. (5)

(*b*) Draw a labelled diagram to show how a sample of compound **A** can be prepared and collected in the school laboratory. (12)

(*c*) Describe a chemical test to distinguish between samples of compounds **B** and **C**. (9)

(*d*) Hydrocarbon **C** reacts with chlorine gas (Cl_2) in the presence of ultraviolet light.

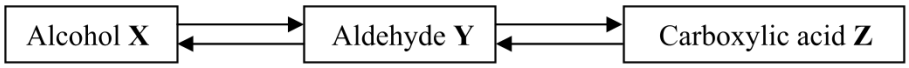
(*i*) Name the type of mechanism by which this reaction takes place.

(*ii*) Give a detailed description of the mechanism of this reaction.

(*iii*) Explain clearly how the occurrence of another hydrocarbon in the product mixture provides evidence for the mechanism. (24)

Question 16

(*a*) Study the reaction scheme below and answer the questions that follow with reference to the compounds **X**, **Y** and **Z**, each of which has two carbon atoms in its molecules.



(*i*) Give a major use for compound **Z**. (4)

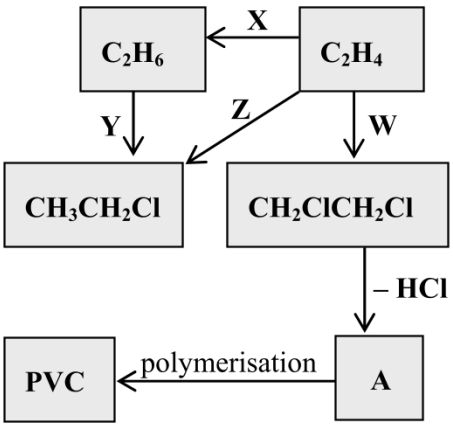
(*ii*) Draw the structure of aldehyde **Y** showing the bonding between the atoms. (6)

(*iii*) Draw the structural formula of the ester formed from compounds **X** and **Z**. Identify any carbon atom in this ester that is in planar geometry. (9)

(*iv*) How could aldehyde **Y** be reduced to alcohol **X**? (6)

Question 17

8. Study the reaction scheme and answer the questions that follow.



(*a*) Ethane and ethene belong to the homologous series of alkanes and alkenes, respectively.
Explain the underlined term.
What type of reaction was involved in conversion **X**?
How does the geometry around the carbon atoms change as a result of conversion **X**? (15)

(*b*) Identify the reagent required to bring about (*i*) conversion **Y**, (*ii*) conversion **Z**, (*iii*) conversion **W**. (9)

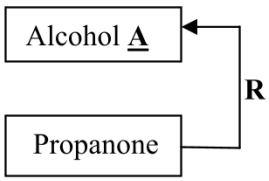
(*c*) Describe the mechanism of reaction **W**. (12)

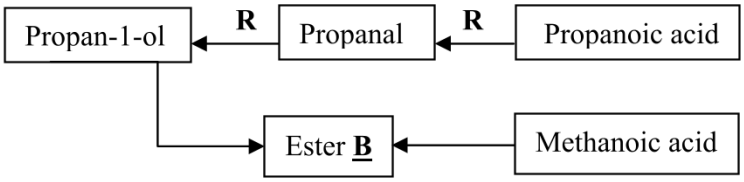
(*d*) Draw the structure of **A** and give its name. (9)

(*e*) Draw the structure of two repeating units of PVC. (5)

Question 18

8. Study the reaction scheme and answer the questions that follow.





(*a*) Give the systematic (IUPAC) name for (*i*) the alcohol **A**, (*ii*) the ester **B**. (8)

(*b*) Alcohol **A** and propan-1-ol are structural isomers. Explain the underlined term.
What is the structural difference between a primary alcohol and a secondary alcohol?
Identify another pair of structural isomers from the reaction scheme. (18)

(*c*) Identify a compound in the scheme whose carbon atoms are all in tetrahedral geometry. (3)

(*d*) Name the reagent and catalyst used to bring about the conversions labelled **R**. (6)

(*e*) Propanal is oxidised by Fehling's reagent. Describe how this reaction is carried out.
Why does propanone not react with Fehling's reagent? (12)

(*f*) Which compound in the scheme would you expect to have a fruity odour? (3)

Question 19

10. Answer any **two** of the parts (*a*), (*b*) and (*c*). (2 × 25)

(*a*) In general, alkenes are more reactive than alkanes. Alkenes undergo addition reactions and alkanes undergo substitution reactions.

(*i*) Account for the greater reactivity of alkenes compared to alkanes. (7)

(*ii*) Describe the mechanism of the addition of bromine (Br_2) to ethene.
State one piece of evidence to support the mechanism you have described. (18)

Question 20

8. Answer the questions below about methane (a saturated hydrocarbon), ethene (an unsaturated hydrocarbon) and benzene (an aromatic hydrocarbon).

(*a*) Describe the mechanism of the monochlorination of methane. (12)

State **three** pieces of experimental evidence for the mechanism you have given. Explain how each piece of evidence supports the mechanism you have described. (18)

(*b*) Ethene can be made by passing ethanol vapour over hot aluminium oxide.

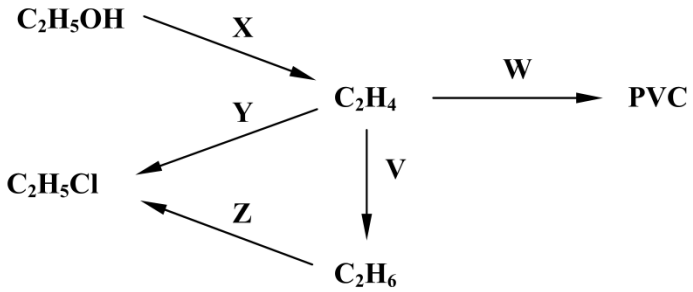
(*i*) Name the type of organic reaction involved in this conversion.

(*ii*) List the bonds broken and the bonds formed in this reaction. (12)

(*c*) Describe the bonding in benzene. (8)

Question 21

9. Study the reaction scheme and answer the questions that follow.



(*a*) Name the molecule in the scheme that contains no tetrahedral carbon atoms. (5)

(*b*) Identify (*i*) an addition reaction, (*ii*) a substitution reaction, in the scheme above. (6)

(*c*) Describe the mechanism of reaction **Y**. (12)

(*d*) State the reagent(s) and condition(s) required to bring about (*i*) conversion **V**, (*ii*) conversion **Z**. (12)

(*e*) Draw a labelled diagram to show how conversion **X** could be carried out in the school laboratory. (9)

(*f*) Conversion **W** involves a three-step synthesis. Draw the structures of the two organic intermediates in this synthesis. (6)

Question 22

8. Answer the questions below with reference to the compounds **A** – **D** in the table on the right.

A	C_2H_5OH
B	CH_3CHO
C	CH_3COOH
D	$CH_3COOC_2H_5$

(*a*) Give the IUPAC name for each of the compounds **A** – **D**. (12)

(*b*) Name the family (homologous series) of organic compounds to which compound **B** belongs. Name the aromatic compound, found in almond kernels, that has the same functional group as compound **B**. (9)

(*c*) Which of the compounds **A** – **D** is present in concentrations of about 40% (v/v) in whiskey? Which of the other compounds is formed as the primary metabolite of this compound in the human body? (6)

(*d*) Describe what is observed when a small amount of sodium carbonate is added to a test tube containing an aqueous solution of compound **C**. Write a balanced equation for the reaction. Name the flavouring agent that consists of an approximately one molar solution of compound **C**. Express the concentration of a one molar solution of **C** in terms of % (w/v). (15)

(*e*) Draw the full structural formula for compound **D** and clearly label each carbon atom that has tetrahedral geometry. (8)

Question 23

9. The alkenes are a homologous series of *unsaturated* hydrocarbons. Ethene (C_2H_4) is the first member of the series. Alkenes undergo addition reactions and polymerisation reactions.

(*a*) Draw a labelled diagram of an apparatus used to prepare ethene gas in the school laboratory. (8)

(*b*) Draw the structure of any one of the isomers of the third member of the alkene series. Indicate clearly which carbon atoms have planar bonding and which are bonded tetrahedrally. (12)

(*c*) Explain the term *unsaturated*. (6)

(*d*) The ionic addition mechanism for the reaction of ethene with bromine water involves the formation of an intermediate ionic species. Draw the structure of this species.

Give the names or structural formulas of the three products that would be formed if the bromine water used in the reaction contained sodium chloride.

How does the formation of these three products support the mechanism of ionic addition? (18)

(*e*) Name the polymer formed when ethene undergoes addition polymerisation.
Draw **two** repeating units of this polymer. (6)

Question 24

(*a*) Alcohols can be obtained by the reduction of aldehydes and ketones using hydrogen and a suitable catalyst.

(*i*) Name a suitable catalyst for these reduction reactions. (4)

(*ii*) Name the alcohol produced when propanal (**C_2H_5CHO**) is reduced. (3)

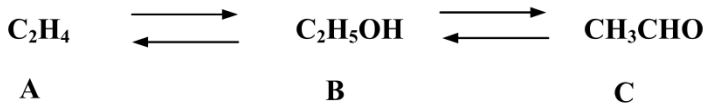
(*iii*) Draw the structure of the alcohol produced when propanone (**CH_3COCH_3**) is reduced. To which class (primary, secondary or tertiary) of alcohols does it belong? (6)

(*iv*) Which of the two compounds, propanal or propanone, would be oxidised by warm Fehling's solution? Give the name *and* structure of the organic product of the oxidation reaction. (9)

(*v*) Give **one** common use for propanone. (3)

Question 25

8. Study the reaction scheme and answer the questions which follow.



(*a*) Name the homologous series (*i*) to which **A** belongs, (*ii*) to which **C** belongs. (8)

(*b*) The conversion of **B** to **A** is an elimination reaction. What two features of elimination reactions are illustrated by this conversion? (6)

(*c*) Name the reagent and the catalyst required to convert **C** to **B**. (6)

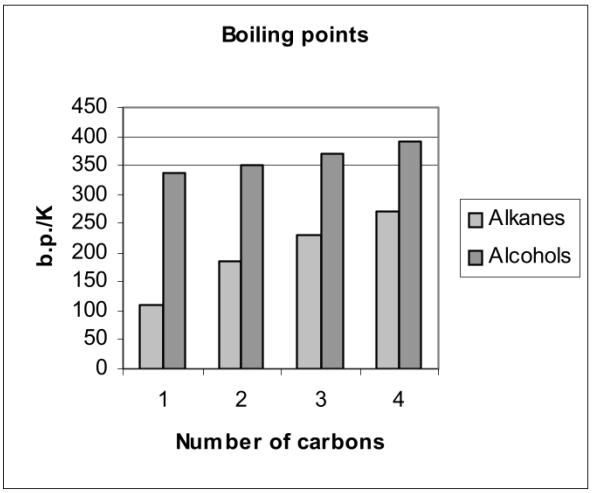
(*d*) Draw full structural formulas for **B** and **C**. Indicate any carbon atom in either structure that has planar geometry. List the bonds broken in **B** and the bond made in **C** in the synthesis of **C** from **B**. (18)

(*e*) After carrying out a laboratory conversion of **B** to **C**, how could you test the product to confirm the formation of **C**? (9)

(*f*) Compound **C** is formed as a metabolite of compound **B** in the human body. How does compound **B** come to be present in the body? (3)

Question 26

(*c*) The chart compares the boiling points of alkanes and primary alcohols containing from one to four carbon atoms.



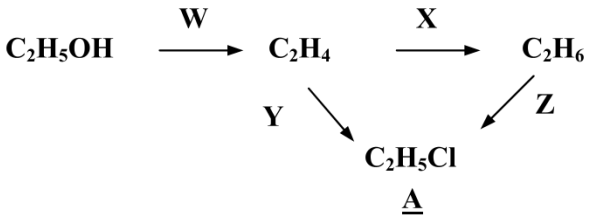
(*i*) Give **two** reasons why each of these alcohols has a higher boiling point than the corresponding alkane. (7)

(*ii*) Explain why the difference in boiling points between methane and methanol is 226.5 K while the difference in boiling points between butane and butanol is only 119 K. (6)

(*iii*) Describe, in general terms, the solubilities of methane, methanol, butane and butanol in water. (12)

Question 27

7. Examine the reaction scheme and answer the questions which follow.



(*a*) Name the compound labelled **A**. (5)

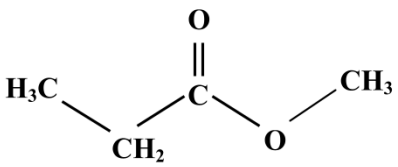
(*b*) For each of the conversions **W**, **X**, **Y** and **Z**, classify it as an *addition*, an *elimination* or a *substitution* reaction. (12)

(*c*) Describe with the aid of a labelled diagram how the conversion **W** may be carried out in a school laboratory and how a sample of the product may be collected. How would you test this product to show that it is unsaturated? (18)

(*d*) The conversion labelled **Z** is known to occur by a *free radical* mechanism.
State **three** clear pieces of experimental evidence which support this mechanism. (15)

Question 28

7. (*a*) Copy into your answer book the structure of the ester shown and indicate clearly on your diagram a carbon atom which is in planar geometry in the molecule, and also a carbon atom which is in tetrahedral geometry in the molecule. (8)



(*b*) Give the names of the alcohol and of the carboxylic acid from which the ester shown in the diagram is synthesised. What organic reaction type describes this esterification reaction? (15)

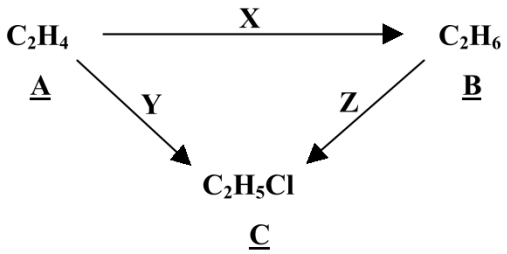
(*c*) The carboxylic acid you were asked to name in (*b*) may itself be synthesised in two steps from an alcohol.

(*i*) Identify the alcohol from which the carboxylic acid is derived.
(*ii*) Give the name and structure of the intermediate organic compound in this synthesis.
(*iii*) Identify the type of organic reaction involved in each step.
(*iv*) Identify the inorganic reagents which may be used in this synthesis. (21)

(*d*) State **two** common uses of esters. (6)

Question 29

6. Study the reaction scheme and answer the questions which follow.



(*a*) Which of the compounds **A**, **B** and **C** has no tetrahedrally bonded carbon atoms? Draw the structure of a molecule of this compound. (8)

(*b*) Classify the conversions **X**, **Y** and **Z** as *addition, substitution or elimination* reactions. (9)

(*c*) What reagent is used to convert **A** to **C**? (3)

(*d*) What reagent and what conditions are required for the conversion of **B** to **C**? (6)

(*e*) Describe the mechanism of the reaction for the conversion of **A** to **C**. (18)
State **one** piece of experimental evidence which supports the mechanism you have proposed. (6)

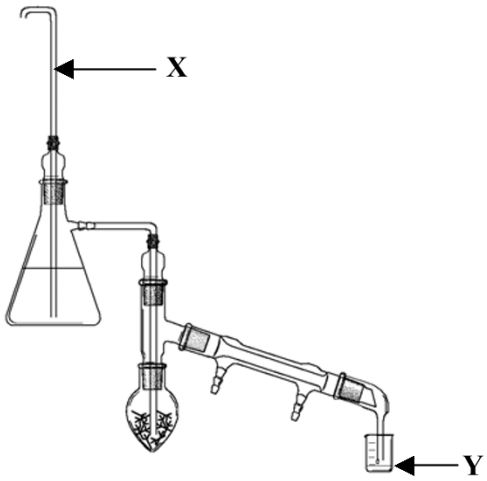
Question 30

9. (*a*) Draw the structure and state the IUPAC name for the aldehyde of the molecular formula $\mathbf{C_3H_6O}$. (8)

Draw the structure and give the name of another carbonyl compound that has the same molecular formula, $\mathbf{C_3H_6O}$. Give **one** use of this compound. (12)

Which of these two carbonyl compounds is easily oxidised to a carboxylic acid? Name that acid. (6)

(*b*) The diagram shows the arrangement of glassware for the extraction of clove oil from cloves by steam distillation.



(*i*) What is the purpose of the tube marked **X**? (6)

(*ii*) What is collected at **Y**? Describe its appearance. (12)

(*iii*) State **one** use of clove oil. (6)