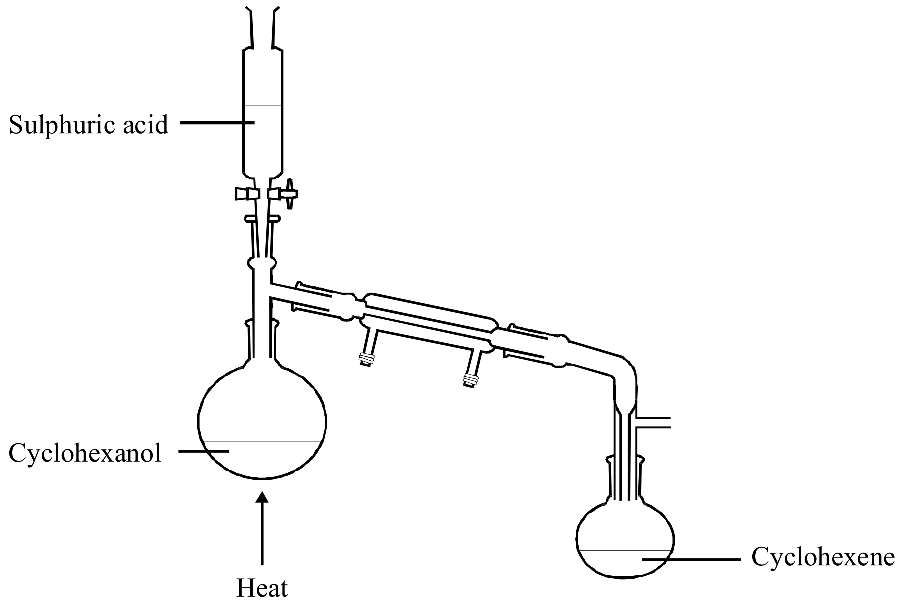
1. In an experiment to prepare cyclohexene, C_6H_{10}, concentrated sulphuric acid was added drop by drop to 6.00 g of cyclohexanol, $C_6H_{11}OH$, in the apparatus shown in the diagram below.



As the reaction took place cyclohexene distilled over into the collection flask and a black deposit of carbon formed in the reaction flask.

The equation for the main reaction is

$$C_6H_{11}OH(l) \rightarrow C_6H_{10}(l) + H_2O(l)$$

After purification 1.80 g of cyclohexene was collected.

(a) (i) Calculate the amount (number of moles) of cyclohexanol used in the experiment.

(2)

(ii) Calculate the mass of cyclohexene that would be formed if all of the cyclobexanol was converted into cyclohexene.

(2)

(iii) Calculate the percentage yield of cyclohexene.

(1)

(b) Explain the relevance of the boiling points of cyclohexanol (161°C) and cyclohexene (83.3°C) to the success of the preparation.

....

....

....

(2)

(c) Explain why the formation of carbon reduces the yield of cyclohexene.

....

....

(1)

(d) Using the information below, suggest what precautions should be taken when clearing up the apparatus after the preparation.

Sulphuric Acid H_2SO_4
(Concentrated)
Very corrosive, causes severe burns.
With water, heat is evolved.

(2)

(e) Suggest a reagent which could be used to test for the presence of the alkene double bond in cyclohexene. Give the expected result of the test.

Reagent..

Result..

(2)
(Total 12 marks)

2. Four of the structural isomers of $C_4H_{10}O$ are alcohols. One of these isomers is butan-2-ol.

(a) Draw the structural formulaE of two other alcohols with molecular formula $C_4H_{10}O$ and name each of these isomers.

Diagrams

Isomer 1 Isomer 2

Name of isomer 1 Name of isomer 2

....

(4)

(b) A sample of butan-2-ol, C_4H_9OH, was heated with a mixture of sulphuric acid and potassium dichromate (VI).

(i) State the colour change that would be observed during the reaction.

....

....

(1)

(ii) Give the name of the organic product formed, and name the type of reaction occurring.

....

....

(2)

(Total 7 marks)

3. In the preparation of the alcohol butan-2-ol, 13.7 g of 2-bromobutane was hydrolysed with 9.0 g of potassium hydroxide in aqueous solution. The following reaction occurred.

$$CH_3CHBrCH_2CH3 + KOH \rightarrow CH_3CHOHCH_2CH_3 + KBr$$

(a) Calculate the amount (number of moles) of each **reactant** in the above experiment, and use your answers to state which reactant was present in excess.

(4)

(b) Calculate the maximum possible mass of butan-2-ol which could be obtained in the above experiment.

(3)

(c) The reaction taking place can be classified as nucleophilic substitution. Explain the term **nucleophile** and identify the nucleophile in the reaction.

....

....

....

(2)

(d) The above experiment was repeated under identical conditions, except that 2-iodobutane was used in place of 2-bromobutane. State and explain the effect that this change would have on the rate of reaction.

....

....

....

(2)
(Total 11 marks)

4. 1-bromobutane (boiling, temperature 102 °C) may be prepared by the reaction shown in the equation below.

$$C_4H_9OH + NaBr + H_2SO_4 \rightarrow C_4H_9Br + NaHSO_4 + H_2O$$

The preparation is in three stages.

- Stage 1: The reagents are heated for about 45 minutes in the apparatus shown in **Diagram 1**.
- Stage II: Impure 1-bromobutane is extracted from the reaction mixture and transferred to the round bottomed flask in the apparatus shown in **Diagram 2**.
- Stage III: A sample of pure 1-bromobutane is obtained using the apparatus shown in **Diagram 2**. The sample is weighed and the yield calculated.

(a) Give the names of the practical techniques carried out in the apparatus shown in Diagrams I and 2.

Diagram 1

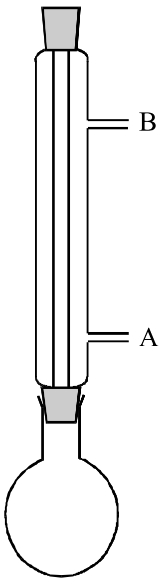


Diagram 2

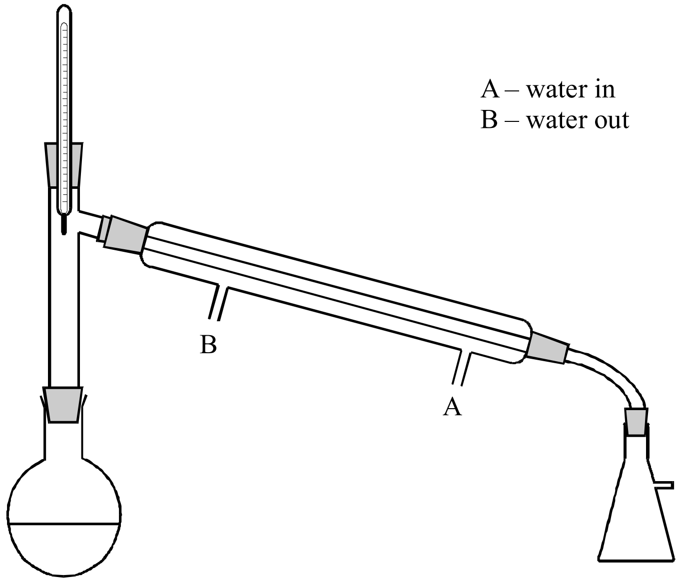


Diagram 1: ....

Diagram 2: ....

(2)

(b) (i) Explain why, in Stage I, the reactants are heated for such a long time.

....

....

(1)

(ii) Explain the purpose and arrangement of the condenser in **Diagram 1**.

....

....

....

....

(2)

(c) Briefly describe how you would use the apparatus shown in **Diagram 2** to give a sample of pure 1-bromobutane.

....

....

....

....

....

(3)

(d) A student preparing 1-bromobutane by this method calculated that the maximum yield in this preparation was 7.2 g. His actual yield was 3.1 g.

(i) Calculate the percentage yield.

(2)

(ii) Suggest **two** reasons why the actual yield was much lower than the maximum yield.

Reason 1: ....

....

Reason 2: ....

....

(2)

(Total 12 marks)

5. (a) A compound **Z** has the composition (by mass) of 68.2% C, 13.6% H and 18.2% O. It has a relative molecular mass of 88.

(i) Find the empirical formula of **Z**.

(3)

(ii) Deduce the molecular formula of **Z**.

(2)

(b) Compound **Z** is an alcohol, which can be tested for with phosphorus pentachloride,PCl_5.

(i) Using the symbol ROH to represent compound **Z**, write an equation to show how it reacts with PCl_5.

…………………………..…………………………………………………………..

(2)

(ii) What would you **see** as the test is performed?

…………………………………………………………………………………..

(1)

(c) (i) Draw a full structural formula for **Z** that is a branched-chain primary alcohol.

(2)

(ii) Draw the full structural formula of the compound that would be obtained if the primary alcohol in (c) (i) were to be oxidised so that the product distils over as it is formed.

(1)

(iii) Suggest a suitable oxidising mixture for the reaction in (c) (ii).

…………………………………………………………………………………..

(2)

(iv) State what type of organic compound would be formed if the reaction in (c) (ii) were heated under reflux.

…………………………………………………………………………………..

(1)

(d) If the alcohol **Z** is heated with concentrated sulphuric acid, a gas **Y** is produced. Gas **Y** reacts with bromine solution decolourising it.

(i) Draw the functional group present in **Y**.

(1)

(ii) Suggest a structure for a compound that could be produced from the reaction of bromine with **Y**.

(2)
(Total 17 marks)

6. (a) The reactivity of organic compounds is related to their bonding. Ethane reacts very slowly with bromine in the dark but rapidly in ultraviolet light; ethene reacts rapidly with bromine even in the dark.

(i) What type of reaction is the reaction of bromine with ethane?

…………….……………….……………………………………………………..

(1)

(ii) Explain the difference in the reactivity of ethane and ethene with bromine in terms of the types of covalent bonding found in these two compounds.

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

(4)

(b) Halogenoalkanes such as $CH_3CH_2CH_2Br$ react with potassium hydroxide solution in several ways depending on the conditions.

(i) Name the compound $CH_3CH_2CH_2Br$.

……………………………………………………………………………………..

(1)

(ii) Draw the structure of the compound obtained if $CH_3CH_2CH_2Br$ is reacted with KOH in ethanolic solution.

(1)

(iii) Draw the structure of the substance obtained if $CH_3CH_2CH_2Br$ is reacted with KOH in aqueous solution.

(1)

(iv) What is the role of the hydroxide ion in the reaction in (iii)?

……………………………………………………………………………………..

(1)

(v) $CH_3CH_2CH_2Cl$ reacts much more slowly with aqueous KOH than $CH_3CH_2CH_2Br$ does. Why is this?

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

(2)
(Total 11 marks)

7. 1-bromobutane (boiling temperature 102°C) maybe prepared from butan-l-ol (boiling temperature 117 °C).

$$C_4H_9OH + NaBr + H_2SO_4 \rightarrow C_4H_9Br + NaHSO_4 + H_2O$$

(a) The reagents are heated under reflux at 100 °C for about 45 minutes.
Draw a diagram of the apparatus that you would use for this procedure.

(4)

(b) Impure 1-bromobutane containing unreacted butan-l-ol can be extracted from the reaction mixture from (a).

(i) Give the name of the practical technique that you would use to obtain a pure sample of 1-bromobutane from the mixture with butan-l-ol.

…………………………………………………………………………………..

(1)

(ii) Explain the relevance of the boiling temperatures 1-bromobutane and butan-l-ol to the success of this technique.

…………………………………………………………………………………..

…………………………………………………………………………………..

…………………………………………………………………………………..

…………………………………………………………………………………..

(2)

(c) In a preparation of 1-bromobutane, 11.1 g of butan-l-ol gave 12.4 g of 1-bromobutane.

(i) Calculate the amount (number of moles) of butan-1-ol used in this preparation.

(2)

(ii) Calculate the mass of 1-bromobutane that would be formed if all the butan-l-ol was converted into 1-bromobutane.

(2)

(iii) Calculate the % yield in this preparation to an appropriate number of significant figures.

(1)

(iv) Suggest a reason why the yields in organic preparations seldom approach 100%.

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

(1)
(Total 13 marks)

8. This question is about the secondary alcohol, **X**, which has the molecular formula $C_4H_{10}O$.

(a) Draw the **displayed** formula of this secondary alcohol, **X**. Give its systematic name.

Name ....

(3)

(b) (i) Draw the **structural** formula of **Y**, a primary alcohol, which is an isomer of **X**.

(1)

(ii) If **X** and **Y** are heated with sodium dichromate and sulphuric acid, products with different functional groups are formed. Give the names of the products which could be formed.

Oxidation product of **X** ....

Oxidation products of **Y** ....

....

(3)

(c) (i) Draw a fully labelled diagram of the laboratory apparatus to show how the alcohol **Y** could be fully oxidised.

(3)

(ii) How would you separate the organic product of this reaction from the resulting mixture?

....

(1)

(d) (i) The secondary alcohol, **X**, can be dehydrated. Draw the structural formulae and give the names of TWO possible alkenes which could be formed.

(3)

(ii) If either of the alkenes is shaken with acidified potassium manganate(VII), what colour change would you **see**?

From .... to ....

(1)

(iii) What other reagent could you use to show that the products of the dehydration of **X** are alkenes?

....

(1)

(Total 16 marks)

9. Cracking is an important process in the petrochemical industry. Cracking the fraction of crude oil with a boiling **range** of 200–300 °C produces a number of useful alkanes and alkenes.

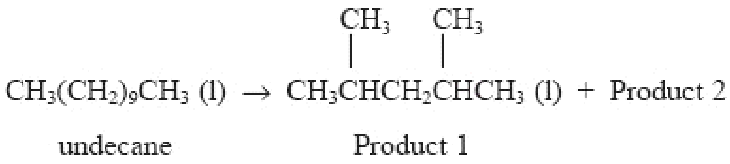
(a) Why does the original fraction of crude oil have a boiling **range** rather than a single boiling point?

....

....

(1)

(b) The following equation represents one possible reaction which might occur during cracking.



$$\underset{\text{undecane}}{CH_3(CH_2)_9CH_3\ (l)} \rightarrow \underset{\text{Product 1}}{CH_3\overset{\overset{CH_3}{|}}{C}HCH_2\overset{\overset{CH_3}{|}}{C}HCH_3\ (l)} + \text{Product 2}$$

(i) Give the name of Product 1.

....

(1)

(ii) Give the **molecular** formula of Product 1.

....

(1)

(iii) Product 1 of this reaction is used as a component of petrol. Suggest ONE reason why it is more suitable for this use than the original undecane.

....

....

(1)

(iv) State TWO necessary conditions used when cracking petroleum fractions.

....

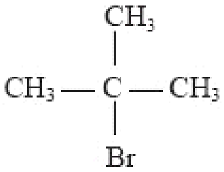
....

(2)

(v) Draw a labelled diagram showing suitable apparatus and materials for ‘cracking’ a liquid such as ‘light paraffin’ in the laboratory. You should indicate how a gaseous product of the reaction could be collected.

(4)

(c) There are several isomers of Product 2. One of them, an alkene, can be made from 2-bromo-2-methylpropane, which has the following formula:



$$CH_3-\underset{\displaystyle Br}{\overset{\displaystyle CH_3}{\underset{|}{\overset{|}{C}}}}-CH_3$$

(i) Draw the structural formula of the alkene produced.

(1)

(ii) Name the type of reaction involved in the conversion of 2-bromo-2-methylpropane to Product 2.

....

(1)

(iii) What reagent and conditions would be used to bring about this conversion?

Reagent ....

Conditions ....

(2)

(Total 14 marks)

10. (a) Halogenoalkanes react with many nucleophiles.

Define the term **nucleophile**.

....

....

....

(2)

(b) (i) Identify the reagent and conditions necessary for the conversion of iodoethane to ethylamine, $C_2H_5NH_2$.

Reagent:...

Conditions:............ ....

....

(3)

(ii) State why the rate of reaction would be slower if bromobutane were used in place of iodoethane, with all other conditions remaining the same.

....

....

(1)

(c) Iodoethane reacts with water to form ethanol and hydrogen iodide.

$$C_2H_5I + H_2O \rightarrow C_2H_5OH + HI \qquad \Delta H_f^{\ominus} = +36\ \text{kJ mol}^{-1}$$

Use some or all of the data below to calculate the C—I bond enthalpy.

Bond	Bond enthalpy / kJ mol^{-1}	Bond	Bond enthalpy / kJ mol^{-1}
C—H	413	H—I	298
C—C	347	C—O	358
H—O	464		

(3)

(d) Ethanol was heated under reflux with an excess of a mixture of potassium dichromate(VI) and dilute sulphuric acid. Draw the full structural formnula of the organic product.

(1)
(Total 10 marks)

11. (a) Cyclohexanol and hexan-1-ol are both alcohols containing 6 carbon atoms per molecule.

(i) Draw the **displayed** formula of each alcohol.

cyclohexanol hexan-1-ol

(2)

(ii) Explain why cyclohexanol and hexan-1-ol are **not** isomers.

....

....

(1)

(iii) State whether each of the two alcohols is a primary, secondary or tertiary alcohol.

Cyclohexanol ....

Hexan-1-ol ....

(2)

(iv) Hexan-1-ol was heated gently with a mixture of potassium dichromate and sulphuric acid. The product of the reaction was distilled off as it formed.

Give the structural formula of the product and name it.

Name ....

(2)

(v) The reaction in (iv) was repeated using cyclohexanol. The products which were distilled off from each of the two alcohols contain different functional groups.

State a test to distinguish between these functional groups and give the result in each case.

Test ....

....

Result with the product from hexan-1-ol ....

....

Result with the product from cyclohexanol ....

....

(3)

(b) Cyclohexanol can be converted to cyclohexene.

(i) What type of reaction is this?

....

(1)

(ii) Draw a fully labelled diagram of the laboratory apparatus, including the chemicals, which you would use to convert cyclohexanol into cyclohexene and collect the liquid cyclohexene which forms.

(4)

(iii) Describe how you would obtain a dry sample of cyclohexene from the liquid collected.

....

....

....

(2)

(Total 17 marks)

12. This question is concerned with alkenes including ethene and buta-1,3-diene, $CH_2 = CHCH = CH_2$.

(a) (i) The typical reactions of alkenes are addition reactions, for example their reactions with bromine.

Explain why the reaction of ethene with bromine is described as an addition reaction.

....

....

....

(1)

(ii) Why should this reaction be carried out in the absence of sunlight or ultra-violet radiation?

....

....

(1)

(iii) Explain how, in this reaction, the bromine molecule is able to act as an electrophile, even though it is normally non-polar.

(2)

(b) (i) When 1 mole of bromine molecules is added to 1 mole of buta-1,3-diene, the principal product is 1,4-dibromobut-2-ene, $CH_2BrCH = CHCH_2Br$, a compound which exists as two geometric isomers.

Draw the **displayed** formulae of both of these two isomers.

(2)

(ii) State why geometric isomerism is possible in 1,4-dibromobut-2-ene.
[You may find it helpful to refer to the formulae you have drawn above].

....

....

....

(1)

(c) It has been suggested that cyclohexene, another alkene, could be made by a reaction between ethene and buta-1,3-diene.

Using molecular formulae, the reaction could be represented by the equation

$$C_2H_4(g) \quad + \quad C_4H_6(g) \rightleftharpoons C_6H_{10}(l) \qquad \Delta H = -200 \text{ kJ mol}^{-1}$$

(i) Draw the **displayed** formula of cyclohexene.

(1)

(ii) Decide whether high or low temperature and pressure would give the higher proportion of cyclohexene at equilibrium. Justify your choice in each case.

Temperature ....

....

Pressure ....

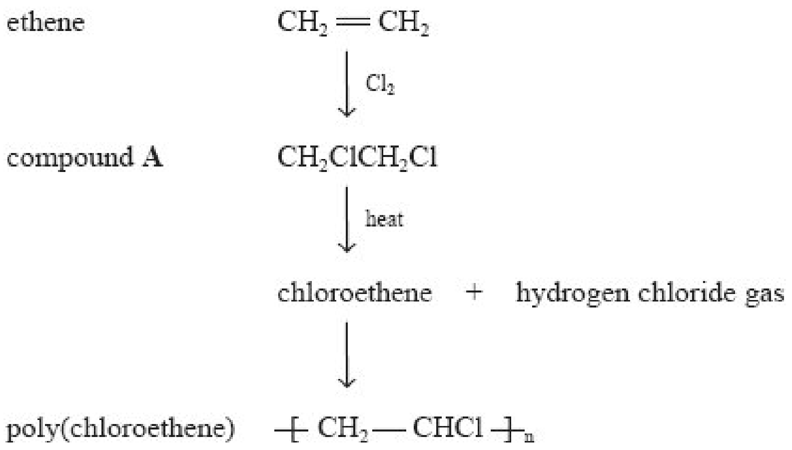
....

....

(2)

(Total 10 marks)

13. One of the most important industrial uses of chlorine is in the production of poly(chloroethene), usually called PVC. A sequence of reactions used to make PVC is set out below.



(a) (i) Name compound **A**.

.... **(1)**

(ii) Give the **structural** formula of chloroethene.

(1)

(iii) It is important that hydrogen chloride gas is not allowed to escape into the atmosphere.

Suggest a way in which its escape could be prevented.

....

.... **(1)**

(b) (i) Chloroethene is polymerised by a reaction involving free radicals. Explain what is meant by a **free radical**.

....

....

(1)

(ii) Give a necessary condition for the production of free radicals.

....

....

(1)

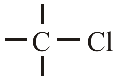
(c) (i) Ethane-1,2-diol, CH_2OHCH_2OH, is a useful compound which could be made from compound **A** using a nucleophilic substitution reaction.

Suggest a suitable nucleophile for this reaction.

....

(1)

(ii) The diagram below shows part of the formula of compound **A**. Use the diagram to show how your suggested nucleophile attacks **A**.



$$-\overset{|}{\underset{|}{C}}-Cl$$

(2)

(iii) What is the leaving group in this reaction?

....

(1)

(iv) Suggest a suitable chemical test you could use to confirm the identity of this leaving group.

You should state the reagent you would use and give the observation expected.

....

....

(2)
(Total 11 marks)

14. (a) State the meaning of the following terms:

(i) electrophile;

....

....

(1)

(ii) free radical;

....

....

(1)

(iii) nucleophile.

....

....

(1)

(b) Classify the following reactions:

(i) chloroethane with aqueous sodium hydroxide;

....

....

(2)

(ii) ethane with chlorine;

....

....

(2)

(iii) ethene with hydrogen bromide.

....

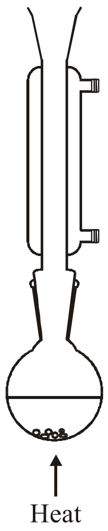
....

(2)

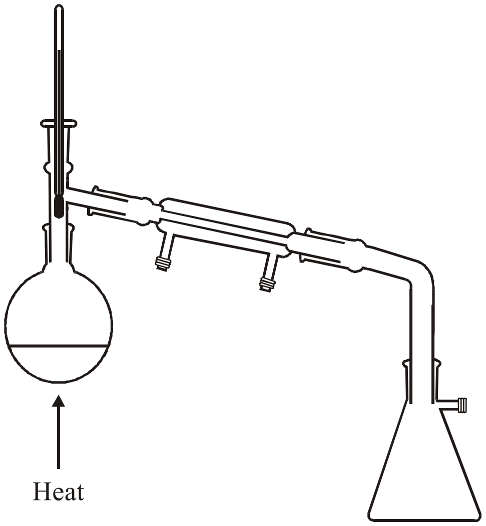
(Total 9 marks)

15. The alcohol 2-methylpropan-1-ol, $CH_3CH(CH_3)CH_2OH$, may be converted into a number of other organic compounds in reactions which are carried out using simple laboratory techniques. The apparatus shown below is used in two of these techniques.

Apparatus I



Apparatus II



The table below summarises two conversions of 2-methylpropan-1-ol.

Organic product of conversion	Reagents	Apparatus used in conversion
1-bromo-2-methylpropane $CH_3CH(CH_3)CH_2Br$	Sodium bromide + sulphuric acid	I and II
2-methylpropanal $CH_3CH(CH_3)CHO$	sodium dichromate(VI) + sulphuric acid	II

(a) Give the name of the practical technique carried out in each apparatus shown above.

Apparatus I ....

Apparatus II ....

(2)

(b) The conversion of 2-methylpropan-1-ol into 1-bromo-2-methylpropane is summarised below.

$$CH_3CH(CH_3)CH_2OH \xrightarrow{Na_2Br+H_2SO_4} CH_3CH(CH_3)CH_2Br$$

(i) Calculate the maximum mass of 1-bromo-2-methylpropane that would be formed from 3.70 g of 2-methylpropan-l-ol.

[Molar mass of 1-bromo-2-methylpropane = 137 g mol^{-1}; Molar mass of 2-methylpropan-1-ol = 74 g mol^{-1}]

(2)

(ii) In a conversion, the actual yield of 1-bromo-2-methylpropane is 4.60 g. Calculate the percentage yield in this conversion.

(1)

(iii) When carrying out the conversion, the reagents are heated in Apparatus I for one hour. What does this suggest about the reaction?

....

....

(1)

(iv) After one hour, the contents of the flask in Apparatus I are allowed to cool, then transferred to Apparatus II and heated until the pure product collects. How could Apparatus II be used to check the purity of the product?

....

....

(2)

(c) When 2-methylpropan-l-ol is heated with sodium dichromate(VI) and sulphuric acid in Apparatus II, it is converted to 2-methylpropanal.

(i) Describe the colour change observed in the reaction flask.

....

(1)

(ii) Explain why a different organic product forms if 2-methylpropan-1-ol is heated with sodium dichromate(VI) and sulphuric acid in Apparatus 1.

....

....

(2)

(iii) Explain how the use of Apparatus II avoids the formation of this different product.

....

(1)
(Total 12 marks)

16. An alcohol, **X**, has the molecular formula $C_4H_{10}O$.

(a) **X** reacts with sodium, forming bubbles of a colourless gas.

Write a balanced equation for the reaction.

(2)

(b) When **X** is heated under reflux with a mixture of sodium dichromate(VI) solution and concentrated sulphuric acid, a green solution forms.

(i) Give the formula of the **ion** responsible for the green colour of the solution.

....

(1)

(ii) Draw a labelled diagram of the apparatus used to reflux the mixture.

(3)

(iii) A colourless organic liquid, **Y**, is distilled from the green solution.

This liquid will **not** neutralise sodium carbonate solution, and it will **not** react with Benedict's solution.

Draw the **displayed** formula of **Y** and state its name.

Displayed formula

Name ....

(2)

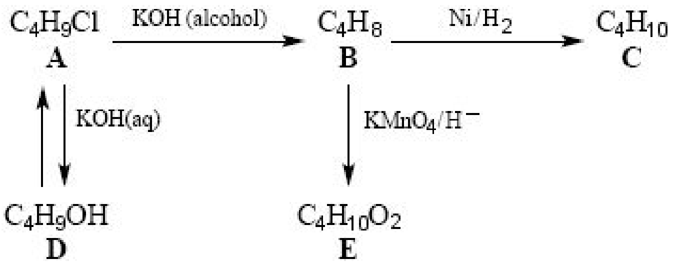
(iv) Deduce the **structural** formula of **X**.

....

(1)

(Total 9 marks)

17. The flow chart below shows some of the reactions of alcohols, alkanes, alkenes and halogenoalkanes.



(a) Compound **A**, C_4H_9Cl, is a tertiary halogenoalkane.

Draw the **displayed** formula for **A** and state its name.

Displayed formula

Name ....

(2)

(b) The halogenoalkane **A** can be formed from the alcohol **D**.

(i) What reagent could be used to bring about this reaction? ....

....

(1)

(ii) State the type and mechanism of this reaction.

Type ....

Mechanism ....

(2)

(c) When **A** is heated with concentrated, alcoholic potassium hydroxide, only one alkene, **B**, can be formed.

(i) Draw the **displayed** formula for **B** and state its name.

Displayed formula

Name ....

(2)

(ii) Can **B** exist as geometric isomers? Explain your answer.

....

....

....

(1)

(d) State the type of reaction in the conversion of

B to **C** ....

B to **E** ....

(2)

(e) Draw the **displayed** formula for **E**.

(1)
(Total 11 marks)

18. 2-bromopropane, $CH_3CHBrCH_3$, can react with hydroxide ions, OH^-, to produce either propan-2-ol, $CH_3CH(OH)CH_3$, or propene, $CH_2{=\!=}CHCH_3$, depending on the conditions of the reaction.

(i) Name the type of reaction, and give the required condition, for the conversion of 2-bromopropane into propan-2-ol.

Type of reaction ....

Condition ....

(2)

(ii) Name the type of reaction, and give the required conditions, for the conversion of 2-bromopropane into propene.

Type of reaction ....

Conditions ....

(3)
(Total 5 marks)

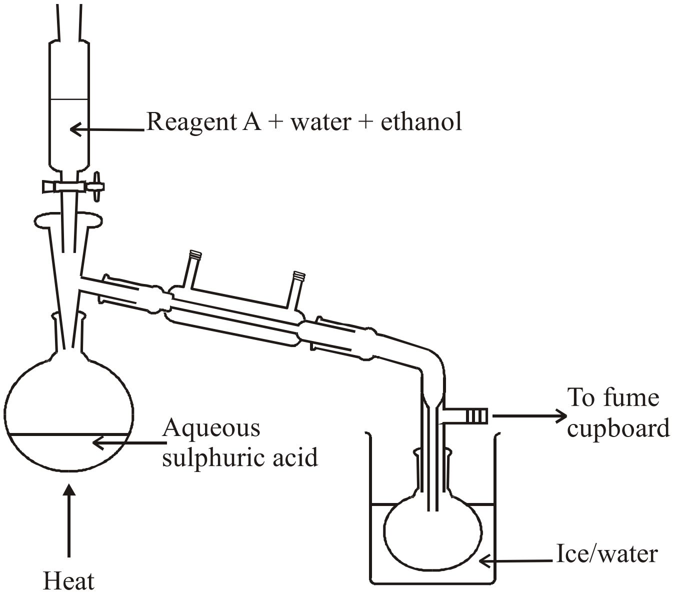
19. Ethanol is oxidised when it reacts with a mixture of reagent **A** and sulphuric acid. Using the distillation apparatus shown in the diagram, the reaction may be used to prepare an aqueous solution of ethanal. The reaction taking place is shown by the equation below, where [O] represents the oxidising agent.

$$CH_3CH_2OH + [O] \rightarrow CH_3CHO + H_2O$$

Data

Ethanal CH_3CHO

- volatile liquid, boiling temperature 21 °C
- miscible with water
- flammable
- irritant, harmful vapour
- molar mass 44 g mol^{-1}



(a) Give the name or formula of reagent **A**.

....

(1)

(b) The preparation is carried out by heating the flask until the aqueous sulphuric acid begins to boil, removing the heat source and then adding the mixture from the separating funnel slowly. The solution in the flask continues to boil.

(i) What conclusion can you make about the reaction in the flask based on the fact that the solution continues to boil after the heat source is removed?

....

(1)

(ii) Describe how the condenser converts hot vapour into liquid.

....

....

(1)

(iii) Suggest a reason for surrounding the collection flask with an ice/water mixture.

....

....

(1)

(iv) Suggest a reason for the tube leading to the fume cupboard.

....

....

(1)

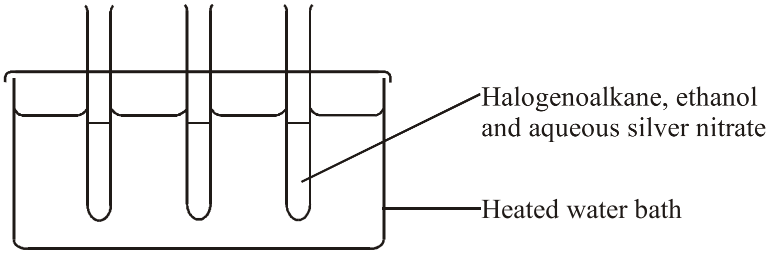
(c) Calculate the mass of ethanal that would be formed from 5.0 g of ethanol, assuming a 40 % yield.
[Molar mass of ethanol is 46 g mol^{-1}]

(2)
(Total 7 marks)

20. Halogenoalkanes can be hydrolysed on heating with aqueous silver nitrate.

The reaction forms a halide ion, X^-, which immediately reacts with aqueous silver nitrate to form a precipitate.

The rate of hydrolysis of halogenoalkanes can be compared by warming them with aqueous silver nitrate and ethanol in separate test tubes in a water bath as shown in the diagram below.



(a) (i) Suggest why ethanol is added to the test tubes.

....

(1)

(ii) Write an ionic equation to show the reaction between silver nitrate and a halide ion. Include state symbols in your equation.

....

(2)

(iii) Suggest ONE reason why a water bath is used rather than heating the test tubes directly over a Bunsen flame.

....

....

....

(1)

(b) Describe how you would carry out the experiment in such a way that you can show that the relative rate of hydrolysis of three halogenoalkanes is

2-iodobutane > 2-bromobutane > 2-chlorobutane

Include in your answer the observation you would make with each halogenoalkane and the relative times for hydrolysis to take place.

....

....

....

....

....

....

....

....

....

....

(5)
(Total 9 marks)

21. (a) Propan-1-ol can be dehydrated to produce propene gas.

(i) Draw the **displayed** formula of propan-1-ol.

(1)

(ii) One method used to dehydrate propan-1-ol uses a solid catalyst.

Draw a fully labelled diagram of the apparatus used to prepare and collect propene gas. Name the solid catalyst.

(4)

(b) Propan-1-ol reacts with sodium to produce an ionic compound and hydrogen gas.

(i) Name the ionic compound formed.

....

(1)

(ii) When carrying out this reaction, a student collected 48 cm^3 of hydrogen gas at room temperature and pressure. Calculate the number of moles of hydrogen molecules collected.
[Molar volume is 24 000 $cm^3 mol^{-1}$ at room temperature and pressure]

(1)

(c) Propan-1-ol can be partially oxidised to produce the aldehyde, propanal.
Some alcohols can be oxidised to produce ketones.

(i) Write the **structural** formula and give the name of the alcohol that can be oxidised to produce the ketone, propanone.

Formula ....

Name ....

(2)

(ii) Describe what you would expect to **see** if propanal and propanone were separately warmed with Benedict's solution.

Propanal

....

....

Propanone

....

....

(2)

(Total 11 marks)

(ii) Describe how the condenser converts hot vapour into liquid.

....

....

(1)

(iii) Suggest a reason for surrounding the collection flask with an ice/water mixture.

....

....

(1)

(iv) Suggest a reason for the tube leading to the fume cupboard.

....

....

(1)

(c) Calculate the mass of ethanal that would be formed from 5.0 g of ethanol, assuming a 40 % yield.
[Molar mass of ethanol is 46 g mol^{-1}]

(2)
(Total 7 marks)

22. The industrial processes involved in the production of poly(chloroethene) are summarised in the flow chart:

ethane → ethene → 1,2-dichloroethane → chloroethene → poly(chloroethene)

(a) (i) Ethane is converted to ethene by dehydrogenation.

Write a balanced equation, including state symbols, for this equilibrium reaction.

(1)

(ii) Explain why conditions of high pressure are less favourable for ethene production.

....

....

....

....

(2)

(b) Draw a labelled diagram of an ethene molecule, showing the electron density distribution in the σ and π bonds between the carbon atoms.

(2)

(c) Give a chemical test which would distinguish between ethane and ethene.

State the result of your test with ethene.

Test ....

Result ....

(2)

(d) 1,2-dichloroethane is formed from ethene by reaction with chlorine.

State the type and mechanism of this reaction.

Type ....

Mechanism ....

(2)

(Total 9 marks)

23. (a) (i) Write the structural formula of 2-iodobutane.

(1)

(ii) Identify a reagent and the condition necessary for the conversion of 2-iodobutane to butan-2-ol.

Reagent:.. ..

Condition:... .

(2)

(iii) The same reagent can be used to convert 2-iodobutane to an alkene. In what way are the conditions different for this reaction?

....

(1)

(iv) Draw the structures of the three isomers obtained in the reaction in (iii).

(3)

(b) The reaction in (a)(ii) takes place at a different rate when 2-bromobutane is used instead of 2-iodobutane.

Suggest and explain in what way the rate would be different.

....

....

....

....

(3)

(Total 10 marks)

24. 1-bromobutane can be prepared by the reaction of hydrogen bromide with butan-l-ol.

$$C_4H_9OH + HBr \rightarrow C_4H_9Br + H_2O$$

Sodium bromide and sulphuric acid are used to generate the hydrogen bromide in the reaction flask.

The stages in the preparation are listed below.

- Mix sodium bromide, 50% sulphuric acid and butan-1-ol, then heat the mixture under reflux for about 30 minutes.
- Rearrange the apparatus for distillation and distil off the impure 1-bromobutane.
- Transfer the impure 1-bromobutane to a separating funnel so that the 1-bromobutane may be separated from the aqueous layer and then washed.
- Add anhydrous calcium chloride to the 1-bromobutane and leave to stand. When the liquid becomes clear, filter off the calcium chloride.
- Carry out a final distillation to obtain pure 1-bromobutane.

Information on 1-bromobutane, C_4H_9Br

Density 1.3 g cm^{-3}
Boiling temperature 102 °C
Harmful by skin absorption
Immiscible with water.

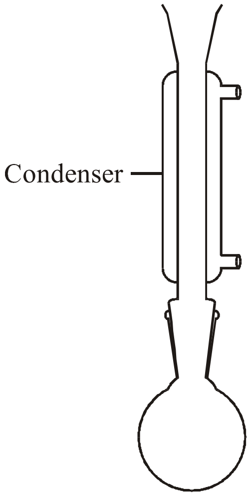
(a) (i) Calculate the maximum mass of 1-bromobutane that may be prepared from 4.0 g of butan-1-ol if all the other reagents are in excess.
[Molar masses: butan-l-ol = 74 g mol^{-1}, 1-bromobutane = 137 g mol^{-1}.]

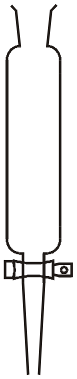
(1)

(ii) In a preparation, 5.9 g of 1-bromobutane is obtained from 4.0 9 of butan-1-ol. Calculate the percentage yield.

(1)

(b) The diagrams below show the reflux apparatus and the separating funnel used in the preparation.





(i) Explain the purpose of the vertical condenser in the reflux apparatus.

....

....

....

(2)

(ii) On the diagram of the separating funnel, draw and label two layers to show 1-bromobutane and water during the washing stage.

(1)

(iii) What is the purpose of adding anhydrous calcium chloride to the 1-bromobutane?

....

(1)

(iv) Draw a labelled diagram of the distillation apparatus that is used to obtain pure 1-bromobutane.

(4)

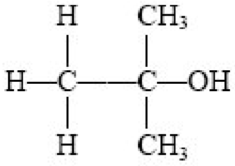
(c) Give ONE safety precaution (apart from wearing eye protection and a laboratory coat) that should be taken during the preparation. Give a reason for your choice.

....

....

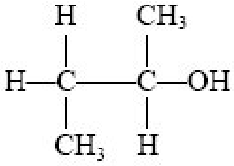
(1)
(Total 11 marks)

25. Five formulae of alcohols with the same molecular formula, $C_4H_{10}O$, are shown below.



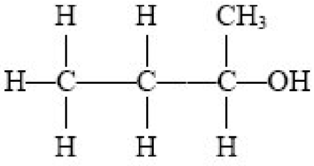
$CH_3-C(CH_3)_2-OH$

A



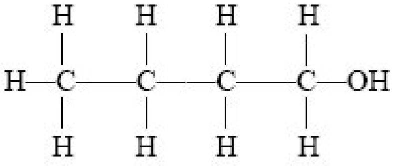
$CH_3-CH(CH_3)-OH$

B



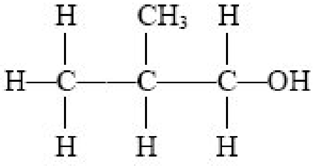
$CH_3-CH_2-CH(CH_3)-OH$

C



$CH_3-CH_2-CH_2-CH_2-OH$

D



$CH_3-CH(CH_3)-CH_2-OH$

E

(a) What is the name given to organic compounds with the same molecular formula, but different structural formulae?

....

(1)

(b) Which TWO of the formulae, **A** to **E**, represent the **same** alcohol?

....

(1)

(c) Which formula represents a **tertiary** alcohol?

....

(1)

(d) Name alcohol **A**.

....

(1)

(e) Which TWO of the alcohols, **A** to **E**, can be each readily oxidised to a carboxylic acid?

....

(2)

(f) All of the alcohols, **A** to **E**, can be dehydrated.

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

....

(1)

(ii) What functional group is formed when an alcohol is dehydrated?

....

(1)

(iii) Draw the **displayed** formula and give the name of the compound formed when alcohol **E** is dehydrated.

Displayed formula

Name ....

(2)
(Total 10 marks)

26. The table below shows some data for four organic compounds.

	Butane	Propan-1-ol	Propan-2-ol	Propanone
Structural formula	$CH_3CH_2CH_2CH_3$	$CH_3CH_2CH_2OH$	$CH_3CH(OH)CH_3$	CH_3COCH_3
Number of electrons per molecule	34	34	34	32
Boiling point/°C	–0.5	97.2	82.4	?

(a) The molecules of each compound contain a similar number of electrons. What type of intermolecular forces are likely to be similar in strength?

....

(1)

(b) Explain why propan-1-ol boils at a **higher** temperature than

(i) butane

....

....

(1)

(ii) propan-2-ol.

....

....

....

....

(2)
(Total 4 marks)

27. Read the passage below on **CHEMISTRY THAT WON'T LET YOU DOWN** straight through, and then more carefully, in order to answer the following questions.

CHEMISTRY THAT WON'T LET YOU DOWN

The current deodorant, antiperspirant and body spray market in the UK is estimated to be worth £447 million. This represents approximately 30% of the toiletries sector which makes up almost a third of the entire cosmetics market. So what is the story behind antiperspirants and deodorants?

Sweating plays a vital role in controlling the body's temperature. The evaporation of a watery fluid from sweat glands on the surface of skin has a cooling effect. During sweating, pheromones, chemicals that identify us through odour, are secreted. Sweat glands, of which there are two types, occur over most of the body surface. They are most abundant in the armpits, the groin, on the soles of the feet, the palms of the hands and the forehead. Eccrine glands, of which there are about two to four million over 99% of the body, are triggered by emotional, thermal and sensory stimuli. The sweat which they produce is virtually odourless and is essentially a dilute aqueous solution containing mainly sodium chloride and urea, and also other metabolic waste products, such as the lactates produced in muscles. Emotional stimuli also trigger the aprocrine glands, which are found only in the armpit and groin. Aprocrine glands produce small amounts of secretions rich in proteins and lipids, together with cholesterol and steroids. These fatty compounds are broken down by bacteria on the skin surface, mostly to low carbon chain (C_4–C_{10}) fatty acids, RCOOH, such as 3-methylhexanoic acid, which we recognise as body odour (BO).

Antiperspirants and deodorants share many of the same ingredients. However, each has its own distinct role and contains different active compounds.

Deodorants act solely to reduce BO by killing the odour-causing bacteria. The first deodorant, marketed in the US in 1888, was “Mum”, a zinc oxide based cream. Chemists soon discovered that other zinc-based compounds such as zinc peroxide were anti-bacterials and therefore also had deodorant potential. In the early 1960s Gillette introduced an aerosol deodorant, “Right Guard”, that contained essentially two antibacterial agents, zinc phenolsulphonate and hexachlorophene. While zinc phenolsulphonate remains one of the few zinc salts clinically accepted in deodorants, hexachlorophene was banned in the mid-1970s because of its toxicity. In today’s deodorants, ethanol is the principal antibacterial agent. Further antibacterial activity is derived from some of the added perfume oils, for example, the essential oils of sage and lemon, and additional antibacterial agents such as triclosan.

In contrast to deodorants, antiperspirants have a dual action, reducing both odour and wetness. Antiperspirants usually contain aluminium salts, which physically block the eccrine sweat glands. Aluminium salts are also antibacterial agents and therefore have a deodorising effect.

“Everyday”, launched in 1902, was the first branded antiperspirant. It was an aqueous solution of aluminium chloride which was dabbed onto the armpits with cotton wool. Unfortunately with a pH of about 2 the “Everyday” solution was so acidic that it irritated the skin and rotted clothes. Early attempts in 1921 to counteract the corrosive nature of this solution used borax and alum, but eventually urea became the agent of choice. These products were cold and wet to apply and slow drying. It was not until John H. Wallace, a Princeton chemist working for Carter Medicine, developed “Arrid Cream” in 1934, which used the less corrosive aluminium sulphate, that antiperspirant products began to have as much appeal as deodorants like “Mum”.

In 1947, two chemists, T. Gorett and M. G. deNavarre, used the more basic aluminium salts, known as aluminium chlorohydrates (ACH) with the general formula $Al2(OH)_mCl_n$, where $m + n = 6$, in antiperspirant formulations, with more success. These are still used extensively in antiperspirants today.

Deodorants and antiperspirants are sold in three different formulations: solutions, suspensions and emulsions. These are applied in several different ways: pump sprays developed from World War II insecticide sprays, roll-ons, an idea inspired by Ladislas and Georg Biro’s ballpoint pen, as well as sticks, aerosols and gels.

In the personal hygiene market cosmetic companies are continually trying to win over customers. Formulation chemists will continue to develop products that provide optimum performance, effective application and pleasant use.

[635 words]

Adapted from “Chemistry That Won’t Let You Down” by James Berressem, Education in Chemistry, July 2002.

(a) What does sweat, produced by the eccrine glands, contain?

(1)

(b) State THREE factors which stimulate the creation of sweat.

(1)

(c) Suggest the structural formula for 3-methylhexanoic acid.

(2)

(d) What was the main problem associated with the use of the earliest antiperspirants?

(1)

(e) Write the formula of the "ACH" antiperspirant in which m = 2.

(1)

(f) Suggest ONE advantage of applying an antiperspirant as a "roll-on", as opposed to using it in an aerosol.

(1)

You are NOT asked to summarise the whole passage, nor to include equations in your summary. At the end of your summary state the number of words you have used.

Credit will be given for answers written in good English, using complete sentences and with the correct use of technical words. Avoid copying long sections from the original text. Numbers count as one word, as do standard abbreviations, units and hyphenated words. Any title you give your passage does not count in your word total.

There are penalties for the use of words in excess of 100.

(Total 7 marks)

28. (a) There are two isomers of molecular formula C_3H_8O that are alcohols.

(i) Draw the full structural formulae of these isomers and name them.

Isomer 1 Isomer 2

Name Name

....

(4)

(ii) When heated under reflux with potassium dichromate(VI) in dilute sulphuric acid, one of the isomers can be oxidised to give a compound $C_3H_6O_2$. Draw the full structural formula of this compound, $C_3H_6O_2$. State the colour change you would see during this reaction.

Structural formula

Colour change

....

(2)

(b) (i) Both isomeric alcohols can be converted to bromoalkanes of molecular formula C_3H_7Br. Give the reagents needed for this change.

....

....

(1)

(ii) One of the bromoalkanes, **X**, reacts with potassium cyanide to produce a compound with molecular formula $CH_3CH(CN)CH_3$.

Identify **X**..

(1)

(iii) **X** reacts differently with potassium hydroxide in aqueous solution than in ethanolic solution.

Give the structural formula of the product formed when the reaction is carried out

in aqueous solution

in ethanol.

(2)

(Total 10 marks)

29. (a) The table below gives the boiling points of three organic compounds.

Compound	Boiling point /K
chloroethane	285
1-chloropropane	320
2-chloropropane	309

(i) Explain why 1-chloropropane has a higher boiling point than chloroethane.

....

....

....

....

(2)

(ii) Explain why 1-chloropropane has a higher boiling point than its isomer, 2-chloropropane.

....

....

....

(1)

(b) Both chloroethane and iodoethane react with aqueous potassium hydroxide solution to form ethanol. The hydroxide ions act as nucleophiles.

(i) What is a **nucleophile**?

....

....

....

(1)

(ii) Explain why iodoethane reacts faster than chloroethane with aqueous potassium hydroxide, under the same conditions.

....

....

(1)

(c) (i) Under what conditions does chloroethane react with potassium hydroxide to form ethene rather than ethanol?

....

....

(1)

(ii) Name the **type** of reaction in which ethene is formed from chloroethane.

....

(1)
(Total 7 marks)

30. This question is about laboratory techniques used in organic chemistry.

The hydrolysis of ethyl benzoate, $C_6H_5COOC_2H_5$, produces ethanol and sodium benzoate, C_6H_5COONa.

Reaction I $C_6H_5COOC_2H_5 + NaOH \rightarrow C_6H_5COONa + C_2H_5OH$

The sodium benzoate can be converted to benzoic acid, C_6H_5COOH, by the addition of dilute hydrochloric acid.

Reaction II $C_6H_5COONa + HCl \rightarrow C_6H_5COOH + NaCl$

Method

- Place 4.5 g of ethyl benzoate in a flask and add an excess of sodium hydroxide solution.
- Heat the mixture under reflux for fifteen minutes.
- Distil off the ethanol formed.
- Add hydrochloric acid to the sodium benzoate solution left in the flask.
- Allow the mixture to cool to room temperature.
- Filter off the solid benzoic acid.

Data	Ethyl benzoate	Benzoic acid	Ethanol
Molar mass /g mol^{-1}	150	122	46
Solubility in water	Insoluble	Soluble in hot water. Insoluble in cold water.	Soluble

(a) The reaction mixture was heated under reflux. Suggest why it was:

(i) heated

....

....

(1)

(ii) under reflux.

....

....

(1)

(b) Draw a labelled diagram to show the apparatus used for **heating under reflux.**

(4)

(c) (i) Suggest why hydrochloric acid is added in Reaction II.

....

....

(1)

(ii) Explain why the flask was cooled before filtering off the benzoic acid.

....

....

....

....

(1)

(d) (i) The benzoic acid produced weighed 2.93 g.

Calculate the percentage yield.

(3)

(ii) What would be the effect on the yield of benzoic acid if the mixture was **not** cooled thoroughly before filtering? Justify your answer.

....

....

....

(1)

(e) The presence of the —OH group in ethanol can be shown by testing the dried distillate with phosphorus pentachloride.

Why must the distillate be dry?

....

....

(1)
(Total 13 marks)

31. Butan-1-ol is a primary alcohol with the formula $CH_3CH_2CH_2CH_2OH$.

(a) Butan-1-ol can be converted into an aldehyde.

(i) What type of reaction is this?

....

(1)

(ii) Give the names or formulae of the TWO reagents you would mix with butan-1-ol to carry out this reaction.

....

....

(2)

(iii) What colour change would you see when the reaction occurs?

From .... to ....

(1)

(iv) Draw a labelled diagram showing the apparatus you would use to carry out this reaction and collect the product.

(2)

(v) Draw the **displayed** formula of the aldehyde that forms.

(1)

(vi) An isomer of butan-1-ol produces butanone if treated as in (ii).

How would you distinguish the aldehyde from butanone?
Name the reagent you would use and state your observation with each compound.

Reagent ....

Observation with aldehyde ....

Observation with butanone ....

(3)

(b) Draw the **displayed** formula of another **primary** alcohol which is an isomer of butan-1-ol, and name it.

Name ....

(2)

(Total 12 marks)

32. (a) Calculate the enthalpy change of atomisation, ΔH_{at}, in kJ mol^{-1}, for but-2-ene, $CH_3CH{=}CHCH_3$

$$CH_3CH{=}CHCH_3(g) \rightarrow 4C(g) + 8H(g)$$

Use the following average bond energies.

	Average bond energy /kJ mol^{-1}
C—C	+347
C═C	+612
C—H	+413

(3)

(b) The enthalpy changes of atomisation and the boiling points of some alkenes are shown below.

Alkene	ΔH_{at} /kJ mol^{-1}	Boiling point /°C
Ethene, C_2H_4	+2260	–103.6
Propene, C_3H_6	+3440	–47.3
But-1-ene, C_4H_8		–6.2
Pent-1-ene, C_5H_{10}	+5800	+30.0
Hex-1-ene, C_6H_{12}	+6990	+63.4

(i) On the grid below, plot values for the enthalpy change of atomisation (vertical axis) against the number of carbon atoms in the alkene molecule (horizontal axis).

(One page of graph paper should be provided).

(3)

(ii) Explain why these enthalpy changes rise regularly.

....

....

....

....

(2)

(iii) Use your graph to estimate the value of the enthalpy change of atomisation for but-1-ene.

.... kJ mol $^{-1}$

(1)

(c) (i) Which intermolecular force occurs between alkene molecules?

....

(1)

(ii) Explain why the boiling points increase from ethene to hex–1–ene.

....

....

....

....

....

(2)

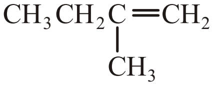
(iii) There are two boiling points for $CH_3CH{=}CHCH_3$, but only one for $CH_3CH_2CH{=}CH_2$. Why is this?

....

....

(1)

(iv) 2-methylbut-1-ene, , is an isomer of pent-l-ene.



$CH_3CH_2C(CH_3){=}CH_2$

Predict which of these isomers has the higher boiling point. Justify your answer.

....

....

....

....

(2)

(d) By considering the intermolecular forces in water, suggest why liquid alkenes do not mix with water.

....

....

....

....

(2)
(Total 17 marks)

33. Read the passage on **Halothane – the first designer anaesthetic** straight through, and then more carefully. Answer the following questions.

HALOTHANE – THE FIRST DESIGNER ANAESTHETIC

Various methods have been used since antiquity to lessen operative pain, including hypnosis, the use of narcotics prepared from marijuana, stupefying with alcohol or even knocking the patient unconscious with a blow to the jaw.

In 1818, Michael Faraday noted the ability of ether vapour to induce a profound lethargic state. Earlier, Humphry Davy had reported the results of his research on nitrogen(I) oxide, and claimed that it appeared capable of destroying physical pain, and might probably be used with advantage during surgical operations. But neither the application of ether nor of nitrogen(I) oxide was followed up at this time.

Three Americans are generally credited with the introduction of inhalation anaesthesia. In 1842, Dr Crawford Long used ether to render a patient unconscious while he removed a cyst from his neck. In 1844, dentist Horace Wells had one of his own teeth painlessly extracted while under nitrogen(I) oxide anaesthesia and in 1846, William Morton successfully used ether to anaesthetise a patient at his dental practice. The era of truly painless operations had begun. In 1847, James Simpson used chloroform ($CHCl_3$) as an anaesthetic for the first time, and for the remainder of the century chloroform, nitrogen(I) oxide and ether reigned supreme as anaesthetic agents.

The use of anaesthetics was not, however, without risk. When they were given in sufficiently large amounts to cause muscle relaxation, the doses were not far removed from those which caused breathing paralysis, and ether caused gastric irritation and post-operative vomiting. Chloroform in large, repeated doses, sometimes caused irreversible liver damage. In the early part of the last century, nitrogen(I) oxide was mainly used for quick operations such as tooth extraction, where its analgesic (pain-killing) action also came in useful. However, for any but the most trivial of operations, ether was the anaesthetic of first choice. That said, a significant number of operations ended in explosions – the flammable ether/air mixture would have been ignited by sparks from switches and other electrical apparatus, and sometimes static discharge from clothing. The search was on for an agent lacking all the undesirable chemical and physiological properties associated with ether and chloroform.

In 1928, Thomas Midgley came up with the first of the chlorofluoro compounds (CFCs), dichlorodifluoromethane, which he advocated for use as a heat transfer agent in refrigerators. Several research chemists coincidentally realized that CFCs, being non-flammable, non-toxic and volatile might well prove to be promising anaesthetics too. In the mid-1940s, pharmacologist Benjamin Robbins carried out extensive experiments on 46 potential CFC anaesthetics and concluded that:

- the majority of the CFCs produced anaesthesia;
- within a group of related compounds, potency increased with increasing boiling point;
- the introduction of a bromine atom increased the safety of an anaesthetic and its potency.

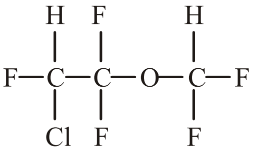
Subsequently, a research chemist, Charles Suckling, working in the ICI's laboratories at Widnes, was guided by three factors to help him choose potential anaesthetics. First was the inertness of fluorine in the C—F bond, especially in the CF_3 and CF_2 groups. The C—F group also conferred stability to adjacent C—Hal bonds. Thus compounds of the type CF_3CHalX_2 (X = H or Hal) should have high chemical stability and thus low toxicity. Second, the CFCs that had a C—H bond were safer than the totally halogenated alkanes. Chemists reasoned that the greater polar nature of the former species enabled them to interact electrostatically with 'brain molecules' and thus show anaesthetic effects at lower doses compared with the latter group. Finally, potential anaesthetics should be able to produce narcosis ("deep sleep") at the lowest concentrations possible.

Only one compound, halothane, $CF_3CHBrCl$, satisfied all these requirements.

The early 1950s, and the arrival of halothane on the clinical scene, marked the start of an exciting new era in anaesthesia. Whereas ether had several problems associated with its use, halothane was a potent inhalation agent with a smooth, pleasant induction for the patient. Although having no analgesic properties, when used in conjunction with intravenous painkillers and muscle relaxant drugs, halothane provided ideal conditions for a multitude of surgical operations, and rapidly became the agent of choice. But was it too good to be true?

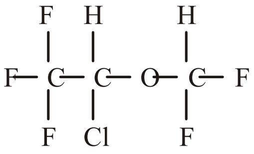
Despite its huge popularity and success in the 1960s, warning bells were beginning to ring about the role of halothane in post-operative liver dysfunction, especially after repeated exposure. In the face of increasing concern, it became evident that the concept of a ‘safe period’ between administrations should be questioned.

During the 1980s, the use and popularity of halothane began to wane, while the use of even safer and cheaper fluorinated agents, such as enflurane and isoflurane, increased. By the early 1990s halothane’s use had all but ceased, isoflurane having taken its place.



$$\begin{array}{ccccccccc} & & H & & F & & & & H & & \\ & & | & & | & & & & | & & \\ F & - & C & - & C & - & O & - & C & - & F \\ & & | & & | & & & & | & & \\ & & Cl & & F & & & & F & & \end{array}$$

enflurane



$$\begin{array}{ccccccccc} & & F & & H & & & & H & & \\ & & | & & | & & & & | & & \\ F & - & C & - & C & - & O & - & C & - & F \\ & & | & & | & & & & | & & \\ & & F & & Cl & & & & F & & \end{array}$$

isoflurane

[777 words]

Adapted from “Halothane - the first designer anaesthetic” by T. Dronsfield, M. Hill and J. Pring, Education in Chemistry, September 2002

(a) What is the formula of nitrogen(I) oxide?

....

(1)

(b) Explain the link between the search for good refrigerants and good anaesthetics.

....

....

....

(1)

(c) Explain why it was desirable to choose CFCs with CF_2 and CF_3 groups as potential anaesthetics.

....

....

....

(1)

(d) (i) Suggest why the molecule CF_3CH_2Cl is more polar than CF_3CCl_3.

....

....

....

(1)

(ii) According to the text, which of these two molecules is likely to be the safer to use as an anaesthetic? Justify your answer.

....

....

....

(1)

(e) Give the systematic name for halothane.

....

(1)

(f) Estimate the value of the COC bond angle in **enflurane**.

....

(1)

(Total 7 marks)

34. (a) A primary alcohol, a secondary alcohol and a tertiary alcohol are isomers with molecular formula C_4H_9OH. Each was heated under reflux with potassium dichromate(VI) in dilute sulphuric acid.

Complete the table below.

Structural type	Structural formula of the isomer	Structural formula for the compound (if any) formed by **complete** oxidation of the alcohol
primary		
secondary		
tertiary		

(6)

(b) Propan-1-ol, $CH_3CH_2CH_2OH$, can be converted to $CH_3CH_2CH_2I$ using red phosphorus and iodine.

(i) Name the compound $CH_3CH_2CH_2I$.

....

(1)

(ii) State the conditions needed to react propan-1-ol with red phosphorus and iodine.

....

....

(1)

(iii) This halogenation of propan-1-ol is brought about by an intermediate compound produced from the reaction between red phosphorus and iodine. Suggest the formula of this intermediate.

....

(1)

(c) $CH_3CH_2CH_2I$ will react with cyanide ions.

(i) State the conditions needed for this reaction.

....

....

(2)

(ii) Write the formula of the organic product.

....

(1)

(iii) Classify the type of reaction that has occurred.

....

(1)

(Total 13 marks)

35. This question is about the reactions of a compound **Z**, $CH_3CH(OH)CH_3$.

(a) Name compound **Z**.

....

(1)

(b) Explain, in terms of its structure, why **Z** is classified as a **secondary** alcohol.

....

....

(1)

(c) Write an equation for the complete combustion of **Z** using the **molecular** formula for **Z**. State symbols are **not** required.

(2)

(d) A small piece of freshly cut sodium was added to **Z**. Give TWO observations which would be made.

....

....

....

....

(2)

(e) A few drops of **Z** were put in a boiling tube with a mixture of sodium dichromate(VI) solution and dilute sulphuric acid and the mixture was warmed gently until a reaction occurred.

(i) What colour change would be observed?

From ....to ....

(1)

(ii) Draw the **displayed** formula of the organic product of this reaction and name it.

Name ....

(2)

(iii) A pure sample of the organic product was mixed with Benedict’s solution. State the colour of the mixture after it was warmed.

....

(1)

(f) A sample of **Z** was dehydrated using a **solid** dehydrating agent.

Draw a labelled diagram of the apparatus you would use to dehydrate **Z** and collect the gaseous product.

(3)
(Total 13 marks)

36. Two reactions of a chloroalkane, **X**, are shown below.

$$\text{Propanol-2-ol} \xleftarrow{\textbf{Reaction 1}} \text{Chloroalkane } \mathbf{X} \xleftarrow{\textbf{Reaction 2}} \underset{\text{propene}}{CH_2{=}CHCH_3}$$

(a) The chloroalkane **X** can be used to make propan-2-ol in **Reaction 1**.

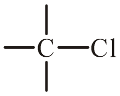
(i) Name and draw the **displayed** formula of the chloroalkane **X**.

Name ....

Displayed formula

(2)

(ii) **Reaction 1** is an example of nucleophilic substitution. The nucleophile is the hydroxide ion. Use the diagram below to show how it is able to attack the chloroalkane **X**.



(2)

(b) (i) What type of reaction is **Reaction 2**?

....

(1)

(ii) Give the reagent and conditions needed for this reaction.

Reagent ....

Conditions ....

....

(2)

(c) Propan-2-ol has a higher boiling point than both the chloroalkane **X** and propene.

(i) Name the strongest intermolecular force between propan-2-ol molecules.

....

(1)

(ii) Draw a diagram to show this force between two propan-2-ol molecules. Clearly mark and label the bond angle between the molecules.

(2)

(d) Propene, $CH_2{=}CHCH_3$, can be polymerised forming poly(propene).

(i) Draw a section of the poly(propene) polymer chain formed from two monomer units.

(2)

(ii) Explain, in terms of intermolecular forces, why poly(propene) is a solid at room temperature.

....

....

....

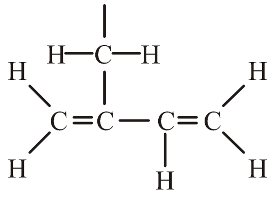
....

....

....

(2)
(Total 14 marks)

37. (a) The molecule isoprene has the displayed formula



(i) Give the systematic name of isoprene.

....

(2)

(ii) What colour change occurs when aqueous bromine solution is added to isoprene?

From .... to ....

(1)

(iii) State the type and mechanism of this reaction.

Type .... Mechanism ....

(2)

(iv) Suggest the displayed formula of the product formed when excess bromine reacts with isoprene in the dark.

(1)

(b) Compound **Q**, an isomer of isoprene, has the structural formula $CH_2=CHCH_2CH=CH_2$.

(i) Give the name of the intermolecular force present in both isomers.

....

(1)

(ii) Which isomer would you expect to have the higher boiling point? Justify your answer.

....

....

....

(2)
(Total 9 marks)

38. 1-bromobutane can be prepared in a laboratory by heating under reflux butan-1-ol, sodium bromide and 50 % sulphuric acid.

The apparatus is then arranged for distillation and a mixture of water and 1-bromobutane is distilled off. This mixture is collected in a separating funnel where two layers form. The denser 1-bromobutane is separated from the water and dried by adding solid anhydrous calcium chloride.

The 1-bromobutane is finally purified by distillation, collecting the fraction boiling between 101–103 °C.

(a) (i) Explain how the apparatus for **heating under reflux** works and suggest why it is necessary.

....

....

....

....

....

....

(3)

(ii) Draw a diagram of the apparatus used for the final **distillation**.

(3)

(b) Suggest ONE safety precaution that could be used when heating flammable liquids such as butan-1-ol.

....

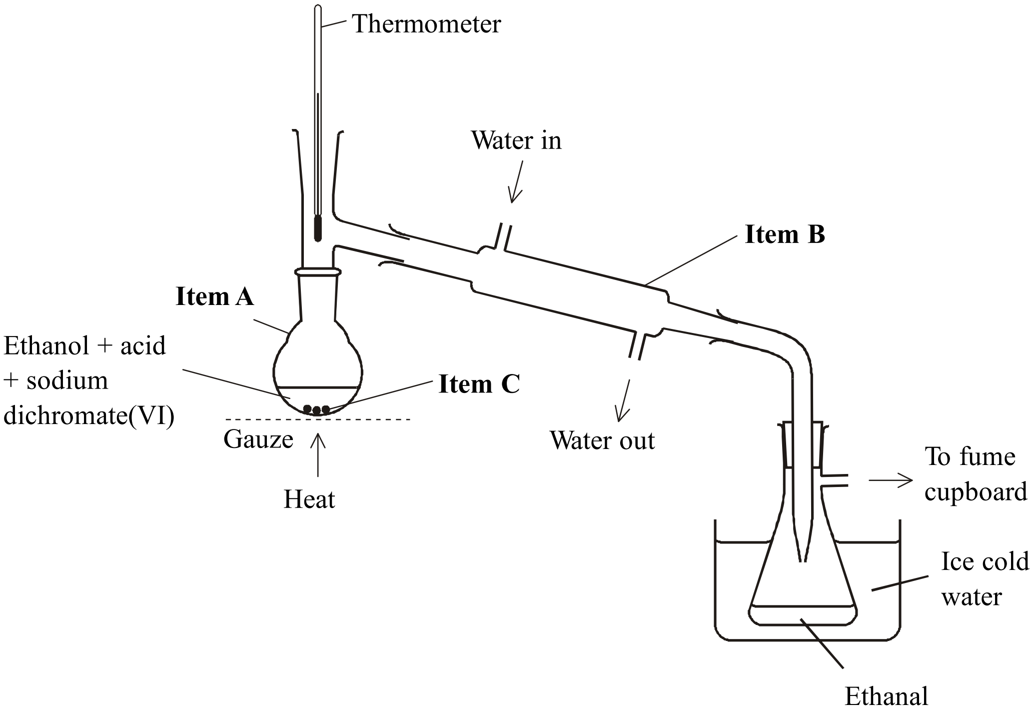
....

(1)

(Total 7 marks)

39. Ethanol, C_2H_5OH, can be converted into ethanal, CH_3CHO, if it is heated with an acid and sodium dichromate(VI) solution, provided that the ethanal is immediately distilled off.

A possible arrangement of apparatus for this experiment is shown below. However, it is incompletely labelled and the diagram contains some errors. You may assume that the apparatus is correctly clamped.



(a) What are the names of the three items labelled A, B and C?

A ....

B ....

C ....

(3)

(b) List **THREE** errors in this diagram.

....

....

....

....

....

....

....

....

....

(3)

(c) Which acid should be used?

....

(1)

(d) What type of reaction is the conversion of ethanol to ethanal? Justify your answer by considering their formulae.

....

....

....

(2)

(e) (i) What is the formula of the dichromate ion in sodium dichromate(VI) $Na_2Cr_2O_7$?

....

(1)

(ii) What colour change would you expect to see as the reaction proceeded?

Colour at start .... Colour at end . ...

(1)

(f) If the mixture is refluxed first before being distilled, what is the name and formula of the organic product?

Name ....

Formula ....

(2)

(Total 13 marks)

40. This question is about the chemistry of propane, C3H8.

Propane is sold for use as a fuel for camping stoves. On complete combustion it forms carbon dioxide and water.

(a) The enthalpy change of combustion of propane, ΔH_c, can be measured by burning a known mass of propane below a container of water and measuring the temperature rise of the water.

The heat capacity of the apparatus (the energy required to raise the temperature of the apparatus by 1 °C) is found by calibrating it with a fuel with known enthalpy change of combustion.

The results of an experiment are shown below.

Mass of propane burned	0.500 g
Temperature of water at start	21.0 °C
Final temperature of water	39.0 °C
Heat capacity of apparatus	1.35 kJ $°C^{-1}$

(i) Calculate the number of kilojoules of energy transferred when the 0.500 g sample of propane burns in this experiment.

(1)

(ii) Use your answer to (i) to calculate ΔH_c for propane in kJ mol^{-1}. Give your answer to **three significant figures**.

Use the Periodic Table as a source of data.

(2)

(iii) The *Book of data* gives the value of ΔH_c for propane as –2220 kJ mol^{-1}.

Calibrating the apparatus means that the answer you calculated in (ii) allows for errors due to heat loss.

Suggest the other main source of error which makes the experimental result different from the data book value.

....

....

(1)

(b) A value of ΔHc for propane can be calculated using mean bond energies and the Hess cycle below.

(i) Complete the Hess cycle, and use the mean bond energies to calculate ΔH_1. Hence calculate ΔH_c.

	Mean bond energies /kJ mol^{-1}
C=O	805
H–O	464

$$\begin{tikzcd}
C_3H_8(g) + \ldots\ldots\ldots\ldots O_2(g) \arrow[rr, "\Delta H_c"] \arrow[dr, "+6490\ \text{kJ mol}^{-1}"'] & & 3CO_2(g) + 4H_2O(g) \arrow[dl, "\Delta H_1 = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots"] \\
& 3C(g) + 8H(g) + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots &
\end{tikzcd}$$

ΔHc = ...

(3)

(ii) Give ONE reason why the value you calculated in (b)(i) also differs from the value for the heat of combustion of propane in the *Book of data*.

....

....

(1)

(c) When propane reacts with chlorine in the presence of ultraviolet light one of the products is 2-chloropropane.

(i) Name the mechanism and type of this reaction.

Mechanism ....

Type ....

(2)

(ii) In this reaction a small quantity of an alkane, C_6H_{14}, is produced.

Explain how this occurs. Include an equation in your answer.

....

....

....

(2)

(d) 2-Chloropropane and 2-iodopropane are both colourless liquids at room temperature. They can be distinguished by their reactions with aqueous silver nitrate.

(i) What would you see when the reaction is carried out with each halogenoalkane?

2-chloropropane ....

2-iodopropane ....

(2)

(ii) Write an ionic equation showing how silver ions react in the mixture made from 2-iodopropane and aqueous silver nitrate. Include state symbols in your answer.

(2)

(iii) Both 2-chloropropane and 2-iodopropane form the same organic product in the reaction with aqueous silver nitrate.

Name, or give the structural formula of, this organic product.

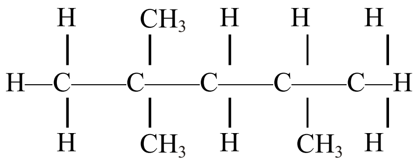
....

(1)

(Total 17 marks)

41. This question is about some of the chemicals used in car engines and their reactions.

(a) Compound **X**, shown below, is one component of petrol.



$CH_3C(CH_3)_2CH_2CH(CH_3)CH_3$

(i) Name **X**.

....

(1)

(ii) Give the **empirical** formula of **X**.

....

(1)

(iii) **X** can be made by cracking decane, $C_{10}H_{22}$.

Assuming only one other product forms in a cracking reaction, deduce the **molecular** formula of this other product.

(1)

(iv) What is the sign of the enthalpy change for the reaction in which decane is cracked? Give a reason for your answer.

....

....

....

(1)

(v) If the air supply in a car engine is poor, there is not enough air for carbon dioxide to be produced.

Use this information to suggest ONE possible equation for the combustion of **X** in this engine. Use the molecular formula of **X** in your equation.

(2)

(b) When air enters a car engine, as well as the fuel burning, nitrogen and oxygen can react to form nitrogen(II) oxide.

$$N2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad \Delta H = + 180 \text{ kJ mol}^{-1}$$

(i) What, if any, is the effect on the percentage of nitrogen(II) oxide in an equilibrium mixture of these three gases if the pressure and temperature are increased? Explain your answers.

Increase in pressure

....

....

....

Increase in temperature

....

....

....

(2)

(ii) In a car exhaust pipe, nitrogen(II) oxide passes over a catalytic converter. The following reaction occurs.

$$2NO(g) + 2CO(g) \rightarrow N_2(g) + 2CO_2(g) \qquad \Delta H = -746 \text{ kJ mol}^{-1}$$

Explain why this reaction speeds up when the car engine has been running for a few minutes.

....

....

(1)

(iii) A textbook says "The catalytic converter converts the gases coming out of the engine into less harmful ones".

State, with a reason, which of the four gases in the equation in (ii) you consider to be **least** harmful.

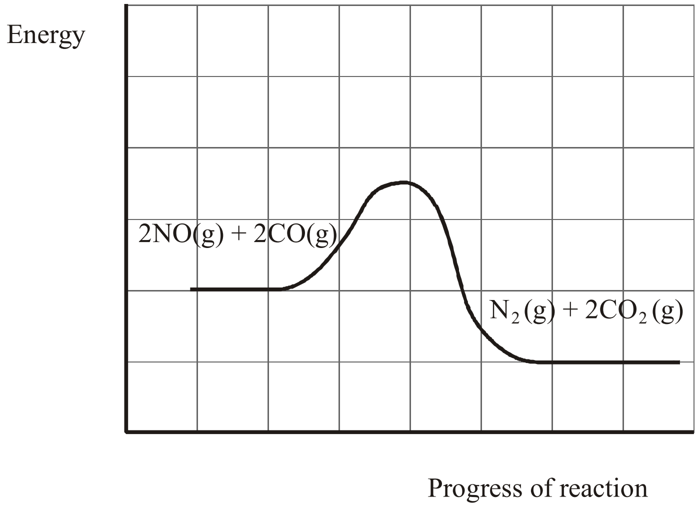
....

....

....

(1)

(iv) The diagram below shows the reaction profile for the change which occurs in the catalytic converter.



On the diagram, show the activation energy, E_A.

Add a line showing the reaction profile if no catalyst is present.

(2)
(Total 12 marks)

42. In an experiment to prepare iodoethane, solid moist red phosphorus is placed into a flask to which ethanol is added. The flask is then arranged as shown in **Apparatus I**.

20.0 g of powdered iodine is then added to the flask in small portions. Before each addition the condenser is removed, the iodine is added and the condenser is immediately replaced. At least two minutes must be allowed between additions of iodine.

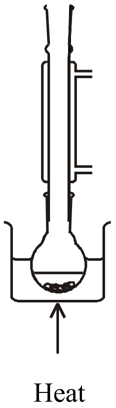
When all the iodine has been added, the flask is allowed to stand for about 10 minutes and is then heated for an hour in **Apparatus I**.

$$2P + 3I_2 \rightarrow 2PI_3$$

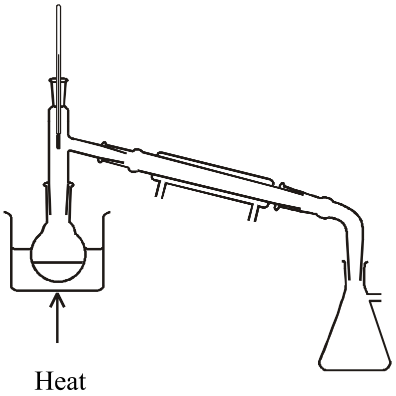
$$3CH_3CH_2OH + PI_3 \rightarrow 3CH_3CH_2I + H_3PO3$$

The iodoethane is then removed from the reaction mixture, purified and dried. A final purification is then carried out using **Apparatus II**. Iodoethane is collected over a narrow temperature range.

Apparatus I



Apparatus II



Data
Ethanol: colourless liquid, flammable, boiling temperature 78 °C
Iodoethane: colourless liquid, flammable, boiling temperature 72 °C

(a) (i) Give the name of the practical technique carried out in each apparatus shown above.

Apparatus I ....

Apparatus II ....

(2)

(ii) Explain why it is important that a stopper should **not** be placed in the top of the condenser in **Apparatus I**.

....

....

(1)

(b) (i) Suggest a reason why the iodine is added in small portions and over a period of time.

....

....

(1)

(ii) Give ONE reason why water baths are used in both **Apparatus I** and **Apparatus II**, rather than heating the flasks directly with a Bunsen flame.

....

....

....

(1)

(iii) Why is the reaction mixture in **Apparatus I** heated for such a long time after all the iodine has been added?

....

....

(1)

(iv) Suggest the readings on the thermometer in **Apparatus II** between which iodoethane should be collected.

From .... to ....°C

(1)

(c) (i) Calculate the amount (moles) of iodine molecules, I_2, in 20.0 g of iodine.

(1)

(ii) Calculate the maximum mass of iodoethane that would be formed from 20.0 g of iodine.

[molar mass iodoethane = 156 g mol^{-1}]

(2)

(iii) In such a preparation, the yield of iodoethane was 16.7 g. Calculate the percentage yield.

(1)
(Total 11 marks)

43. (a) Compound **A**, $CH_3CHBrCH_2CH_3$, can be converted into butan-2-ol by reaction with potassium hydroxide solution.

(i) Name compound **A**.

....

(1)

(ii) Write an equation for the conversion of compound **A** into butan-2-ol.

....

(1)

(iii) Identify the solvent required for this reaction.

....

(1)

(iv) Classify this reaction.

....

(1)

(b) Compound **A** can also be converted into a mixture of the structural isomers but-1-ene and but-2-ene by reaction with potassium hydroxide under different conditions.

(i) Write the **ionic** equation for the conversion of compound **A** into **either** but-1-ene **or** but-2-ene.

....

(1)

(ii) What is the solvent required for this reaction?

....

(1)

(iii) Classify this reaction.

....

(1)

(c) But-2-ene exists as two geometric isomers.

(i) Draw the structural formulae of these TWO geometric isomers.

(1)

(ii) Explain why but-2-ene exists as two geometric isomers.

....

....

....

....

....

(2)

(d) Both but-1-ene and but-2-ene react with hydrogen, in the presence of a suitable catalyst, to give the same product.

(i) Identify the catalyst.

....

(1)

(ii) Identify the product of this reaction.

....

(1)
(Total 12 marks)

44. Ethanol is a primary alcohol and can be oxidised if heated with an acidified solution of potassium dichromate(VI). Two possible organic oxidation products may be obtained.

(i) Draw the **full** structural formula, showing all bonds, of **both** oxidation products.

(2)

(ii) Give the name **and** structural formula of an alcohol that would **not** be oxidised by heating it with an acidified solution of potassium dichromate(VI).

(2)
(Total 4 marks)

45. 1-bromopropane may be prepared from propan-1-ol using the following method:

- Propan-1-ol, water and solid sodium bromide are mixed in a flask and 50 % sulphuric acid is added, a little at a time, with cooling.
- The mixture is heated under reflux and then distilled.
- The distillate is mixed with sodium carbonate solution in a separating funnel and the lower organic layer removed.
- Solid anhydrous calcium chloride is added to the organic layer, which is finally distilled. The distillate boiling in the range 70–72°C is collected.

The reaction may be represented by the following equation:

$$CH_3CH_2CH_2OH + HBr \rightarrow CH_3CH_2CH_2Br + H_2O$$

Hazard information about 1-bromopropane
- flammable
- harmful by skin absorption

(a) (i) Why is the mixture cooled while the sulphuric acid is added?

....

....

(1)

(ii) Draw a labelled diagram of the apparatus used for heating under reflux.

(3)

(iii) What property of 1-bromopropane allows it to be separated from the sodium carbonate solution using a separating funnel?

....
(1)

(iv) What is the purpose of the anhydrous calcium chloride?

....
(1)

(v) Suggest a safety precaution (other than the use of a fume cupboard, laboratory coat or safety goggles) that would be appropriate for this experiment.
Give a reason for your choice.

....

....

....
(2)

(b) (i) Calculate the theoretical maximum mass of 1-bromopropane that could be obtained from 7.55 g of propan-1-ol.

[Molar masses/g mol^{-1} : propan-1-ol 60.0, 1-bromopropane 123]
(2)

(ii) In the actual experiment 8.30 g of 1-bromopropane was obtained.
Calculate the percentage yield of the reaction.

(1)

(iii) Suggest a reason why the yield is less than 100 %.

....

....
(1)
(Total 12 marks)

46. This question is about the four halogenoalkanes:

E 1-chlorobutane, $CH_3CH_2CH_2CH_2Cl$
F 2-chloro-2-methylpropane, $CH_3CCl(CH_3)CH_3$

G 1-iodobutane, $CH_3CH_2CH_2CH_2I$
H 2-iodo-2-methylpropane, $CH_3CI(CH_3)CH_3$

(a) (i) Explain why 1-iodobutane has a higher boiling point than 1-chlorobutane.

....

....

(2)

(ii) Which has the higher boiling point, 1-chlorobutane or 2-chloro-2-methylpropane? Justify your answer.

....

....

....

....

(2)

(iii) Which of the halogenoalkanes, **E**, **F**, **G** or **H**, has the highest boiling point?

Put a cross (☒) in the box of the correct answer. If you change your mind about the answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

E	☒
F	☒
G	☒
H	☒

(1)

(b) All four halogenoalkanes form precipitates when mixed with hot aqueous silver nitrate.

E 1-chlorobutane, $CH_3CH_2CH_2CH_2Cl$
F 2-chloro-2-methylpropane, $CH_3CCl(CH_3)CH_3$
G 1-iodobutane, $CH_3CH_2CH_2CH_2I$
H 2-iodo-2-methylpropane, $CH_3CI(CH_3)CH_3$

(i) Which of these halogenoalkanes would react most rapidly?

Put a cross (☒) in the box of the correct answer. If you change your mind about the answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

E	☒
F	☒
G	☒
H	☒

(1)

(ii) Which of these halogenoalkanes would take the longest time to react? Justify your answer.

....

....

....

(2)

(iii) Name the functional group present in the organic product formed when halogenoalkanes react with the water in hot aqueous silver nitrate.

....

(1)

(iv) Write an ionic equation to represent the part of the reaction which forms the precipitate, using **X** to represent the halogen. Include state symbols.

(1)

(c) (i) Under appropriate conditions, halogenoalkanes react with ammonia.

What are these conditions?

....

....

....

(2)

(ii) Complete the balanced equation for the reaction of 1-iodobutane with ammonia.

$CH_3CH_2CH_2CH_2I + 2NH_3 \rightarrow$

(2)

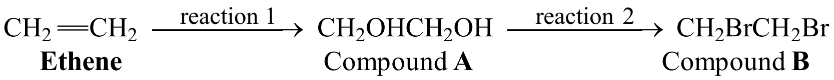
(iii) Name the organic product of the reaction in (c)(ii).

....

(1)

(Total 15 marks)

47. (a) Consider the following series of reactions.



$$\underset{\textbf{Ethene}}{CH_2{=}CH_2} \xrightarrow{\text{reaction 1}} \underset{\text{Compound }\textbf{A}}{CH_2OHCH_2OH} \xrightarrow{\text{reaction 2}} \underset{\text{Compound }\textbf{B}}{CH_2BrCH_2Br}$$

(i) Identify the reagent required for **reaction 1**.

....

(1)

(ii) Name compound **B**.

....

(1)

(iii) Identify the TWO reagents required for **reaction 2**.

....

....

(2)

(iv) Compound **A** can be oxidised by heating with an acidified solution of potassium dichromate(VI).

Give the colour change that would be observed and draw the full structural formulae of TWO possible oxidation products, showing all bonds.

Colour from .... **to** ....

Oxidation products

(3)

(v) Suggest the name **or** formula of a compound that would be obtained if compound **B** were reacted with ethanolic potassium hydroxide.

....

(1)

(b) (i) Compound **B** can be produced by reacting **ethane** with bromine in the presence of ultra-violet light.

Suggest why a good yield of compound **B** would **not** be obtained and identify another organic product that would be formed during the reaction.

....

....

....

....

....

....

(2)

(ii) Write an equation for the complete combustion of ethane.

....

(2)

(iii) Define the term **empirical formula**.

....

....

(1)

(iv) Give the empirical formula for ethane.

....

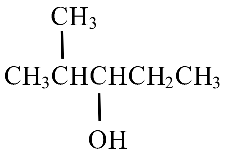
(1)

(v) Give the formula of an alkane, containing more than one carbon atom, whose molecular and empirical formulae are the same.

(1)
(Total 15 marks)

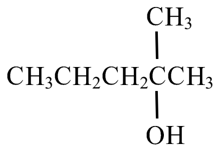
48. This question is about the alcohols labelled **A – F** and some of their reactions.

A



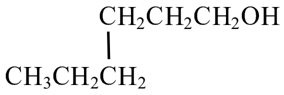
$CH_3\overset{CH_3}{C}H\underset{OH}{C}HCH_2CH_3$

B



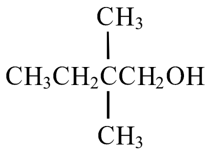
$CH_3CH_2CH_2\underset{OH}{\overset{CH_3}{C}}CH_3$

C



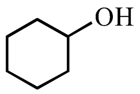
$\begin{array}{l} \qquad\qquad CH_2CH_2CH_2OH \\ \qquad\qquad | \\ CH_3CH_2CH_2 \end{array}$

D

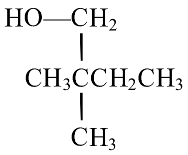


$CH_3CH_2\underset{CH_3}{\overset{CH_3}{C}}CH_2OH$

E



F



$CH_3\underset{CH_3}{\overset{HO-CH_2}{C}}CH_2CH_3$

(a) (i) Two of the formulae **A – F** represent the same compound. Identify them by letter and give the systematic name of this compound.

....

....

Systematic name ....

(2)

(ii) Select from **A – F** any tertiary alcohols. Explain how you would recognise a tertiary alcohol from its structure.

....

....

....

(2)

(iii) Five of the alcohols **A – F** are isomers. Explain what is meant by **isomers**.

....

....

....

(2)

(b) (i) Give the letters of **all** the alcohols that would form carboxylic acids when refluxed with acidified sodium dichromate(VI).

....

(1)

(ii) What type of reaction takes place during the formation of the carboxylic acids?

....

(1)

(iii) What colour change would you expect to accompany the reaction?

From .... to ....

(1)

(c) (i) Alcohol **E** can be converted to a liquid alkene in a reaction with concentrated phosphoric acid. Draw and label suitable apparatus to carry out this reaction and collect the alkene formed.

(3)

(ii) 15.0 g of alcohol **E** formed 9.84 g of the alkene cyclohexene, after purification. Calculate the percentage yield of the reaction.

[Relative molecular mass, M_r, of alcohol **E** = 100, M_r of cyclohexene = 82]

(2)
(Total 14 marks)

49. A halogenoalkane, **P**, has the molecular formula C_4H_9X, where X represents chlorine, bromine or iodine. **P** reacts with a hot aqueous solution of silver nitrate to form a yellow precipitate very quickly.

(a) (i) Give the **formula** of the yellow precipitate.

....

(1)

(ii) Write the ionic equation, including state symbols, for the formation of this yellow precipitate.

(1)

(b) (i) Write a balanced equation for the reaction of the halogenoalkane, **P**, with water.

(1)

(ii) State the type of reaction which has occurred in (b)(i).

....

(1)

(iii) What type of reagent is water in this reaction?

Explain why water can act in this way.

....

....

....

(2)

(c) The halogenoalkane, **P**, reacts with a hot concentrated solution of potassium hydroxide in ethanol very quickly, to form methylpropene.

(i) Draw a fully labelled diagram of the apparatus you would use to carry out this reaction and collect the methylpropene gas formed.

(3)

(ii) Deduce the displayed formula and the name of the halogenoalkane, **P**.

Name ....

(2)

(d) Explain why the halogenoalkane, **P**, reacts very quickly with water.

....

....

....

....

(2)

(e) (i) At high temperature and high pressure, in the presence of a suitable catalyst, methylpropene polymerises.

Draw a section showing **two** units of the polymer chain.

(1)

(ii) Explain why working at high pressure increases the yield of this equilibrium reaction.

....

....

(1)

(iii) In general, how does a catalyst increase the rate of a chemical reaction?

....

....

....

....

....

(2)
(Total 17 marks)

50. An organic compound is found to react with sodium metal and to react with acidified sodium dichromate(VI), but not to decolourise bromine water, nor to neutralise sodium carbonate solution. The liquid could be

A ethanol

B ethane

C ethanoic acid

D ethene

(Total 1 mark)

51. This question concerns the preparation of 1-bromobutane from butan-1-ol, 50% sulfuric acid and sodium bromide. The mixture was placed in a flask and heated under reflux for ten minutes.

	Boiling temperature / °C
1-bromobutane	100
butan-1-ol	118

(a) The reason that 50% sulfuric acid was used rather than concentrated sulfuric acid is because concentrated sulfuric acid

A would oxidise some of the bromide ions to bromine.

B would cause the reaction to go too fast.

C would react with the bromide ions to produce hydrogen bromide.

D is too hazardous a chemical.

(1)

(b) The reaction mixture was distilled. The impure distillate did **not** contain

A butan-1-ol

B 1-bromobutane

C sodium bromide

D hydrogen bromide

(1)

(c) The impure 1-bromobutane was washed with concentrated hydrochloric acid and shaken in a tap funnel with a base to remove acidic impurities. Which of the following would remove acidic impurities without reacting with the 1-bromobutane.

A calcium hydroxide solution

B sodium hydroxide solution

C calcium chloride solution

D sodium hydrogencarbonate solution

(1)

(d) The 1-bromobutane was washed with water, dried and distilled. Which of the following is the correct procedure?

A heat the liquid to 118 °C and collect the substance given off

B heat the liquid to 100 °C and collect the substance given off

C boil the liquid and collect the fraction that boils off between 116 and 120 °C

D boil the liquid and collect the fraction that boils off between 98 and 102 °C

(1)
(Total 4 marks)

52. Some absorptions by chemical bonds in the infrared spectrum are given below.

A O–H stretching in alcohols at 3750–3200 cm^{-1}

B C–H stretching in alkanes at 2962–2853 cm^{-1}

C C=O stretching in aldehydes at 1740–1725 cm^{-1}

D C=O stretching in ketones at 1700–1680 cm^{-1}

From A–D above, select which feature of the infrared spectrum would enable you to distinguish between the following compounds:

propanone, CH_3COCH_3, propanal, CH_3CH_2CHO

propan-1-ol, $CH_3CH_2CH_2OH$

(a) propanone from propanal and propan-1-ol

A

B

C

D

(1)

(b) propanal from propanone and propan-1-ol

A

B

C

D

(1)

(c) propan-1-ol from propanal and propanone

A

B

C

D

(1)
(Total 3 marks)

53. This question is about organic compounds with the molecular formula C_3H_8O.

(a) Draw the structural formulae of the two isomers with molecular formula C_3H_8O which are alcohols. Give the names of these alcohols.

	Alcohol 1	**Alcohol 2**
Structural formula		
Name	………………………….	…………………………

(4)

(b) Primary alcohols can be oxidised to carboxylic acids.

(i) Give the name and structural formula of the carboxylic acid formed when the primary alcohol C_3H_8O is fully oxidised.

Name ....

Structural formula

(2)

(ii) State the reagents used for this oxidation.

Reagent 1 ....

Reagent 2 ....

(2)
(Total 8 marks)

54. (a) This part of the question is about the hydrolysis of halogenoalkanes.

2 cm^3 of ethanol is added to each of three separate test-tubes.

Three drops of 1-chlorobutane are added to the first, three drops of 1-bromobutane to the second, and three drops of 1-iodobutane are added to the third test-tube.

2 cm^3 portions of hot aqueous silver nitrate solution are added to each test-tube.

A precipitate forms immediately in the third test-tube, slowly in the second testtube and extremely slowly in the first test-tube. In each reaction the precipitate is formed by silver ions, $Ag^+(aq)$, reacting with halide ions formed by hydrolysis of the halogenoalkane.

(i) Why was ethanol added to each test-tube?

....

(1)

(ii) The mechanism of this reaction is similar to that of the reaction between halogenoalkanes and aqueous hydroxide ions.

What feature of a water molecule enables it to act as a nucleophile in this reaction? Suggest the mechanism for the reaction between water and 1-iodobutane. (You may represent 1-iodobutane as RCH_2I).

Feature of water molecule

....

....

Mechanism

(4)

(iii) What is the colour of the precipitate in the third test-tube?

....

(1)

(iv) Name the precipitate which forms slowly in the **first** test-tube.

....

(1)

(v) Ammonia solution is added to the precipitate in the **first** test-tube. Describe what you would observe.

....

....

(1)

(vi) Suggest, why the rates of hydrolysis of the three halogenoalkanes are different, in terms of bonding and kinetics.

....

....

....

....

....

....

(3)

(b) One method of the manufacture of alcohols is to react steam with an alkene.
For example

$C_2H_4(g) + H_2O(g) \longrightarrow C_2H_5OH(l)$

Suggest TWO reasons why this method is preferred to the hydrolysis of halogenoalkanes.

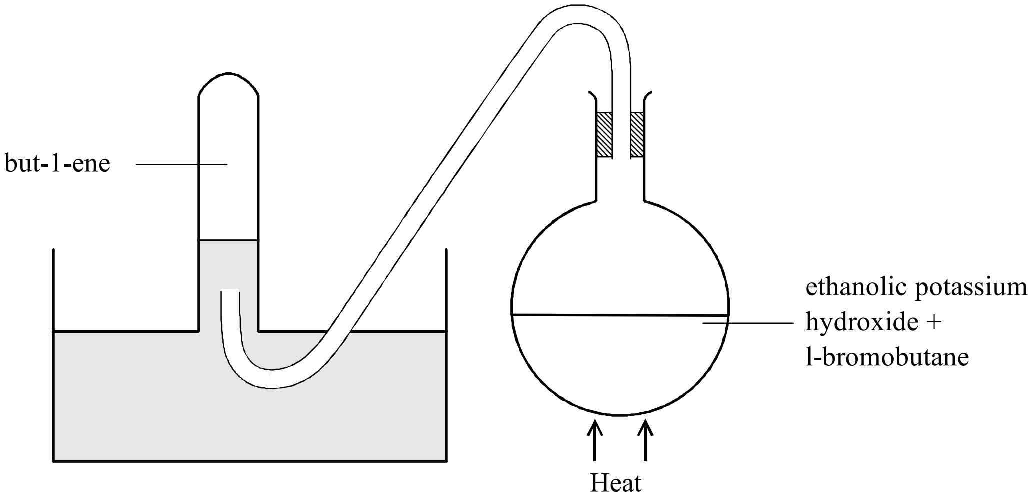
....

....

....

(2)

(c) 1-bromobutane reacts with an ethanolic solution of potassium hydroxide on heating to form but-1-ene. A diagram of the apparatus that could be used to carry out this reaction and to collect the gaseous but-1-ene is shown below.



(i) State the hazard when the heating is stopped.

....

....

(1)

(ii) How would you minimise the risk associated with this hazard?

....

....

(1)

(Total 15 marks)