

1. (a) But-2-ene, $\text{CH}_3\text{CH}=\text{CHCH}_3$, exists as geometric isomers.

(i) Draw the geometric isomers of but-2-ene.

(2)

(ii) Explain how geometric isomerism arises.

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(1)

(b) (i) Draw the structural formula of a compound which is an isomer of but-2-ene but which does not show geometric isomerism.

(1)

(ii) Explain why the isomer drawn in (i) does not show geometric isomerism.

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(1)

(Total 5 marks)

2. (a) A sample of 2-bromobutane was heated with potassium hydroxide in ethanolic solution. A reaction occurred producing a mixture of but-1-ene and but-2-ene.

(i) Write an equation for the above reaction to show the production of **either** but-1-ene **or** but-2-ene.

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(1)

(ii) State the type of reaction taking place.

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(1)

(b) Some bromine solution was shaken with a sample of but-2-ene, and a reaction occurred.

(i) State what would be seen during this reaction.

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.....

(1)

(ii) Draw the structural formula of the product of this reaction, and name this product.

Diagram:

Name

(2)

(c) But-2-ene can exist as two stereoisomers.

(i) Draw the structural formula of the two stereoisomers of but-2-ene.

(2)

(ii) Explain why but-2-ene exists as two stereoisomers, and name this type of isomerism.

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(2)

(Total 9 marks)

3. (a) Ethene and propene are in the same homologous series. Explain the term **homologous series**.

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(3)

- (b) (i) Draw a representative length of the polymer chain of poly(propene).

(2)

- (ii) State, with a reason, the empirical formula of poly(propene).

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(3)

- (c) Poly(propene) does not have a sharp melting temperature, but softens over a range of temperature. Suggest why this is so.

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(1)

- (d) (i) Tetrafluoroethene, C_2F_4 , also forms a polymer. Suggest why this polymer is very inert.

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(1)

- (ii) Give one use for poly(tetrafluoroethene).

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(1)

- (e) Ethane and ethene both react with bromine. Ethane does not react at room temperature in the dark, whereas ethene does so extremely quickly. Explain in terms of the bonding in each molecule why this is so.

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(3)
 (Total 14 marks)

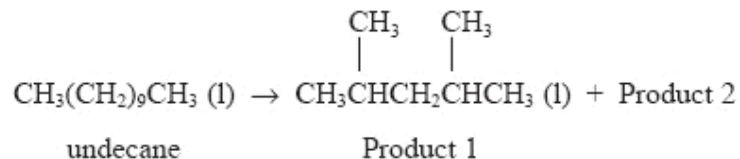
4. Cracking is an important process in the petrochemical industry. Cracking the fraction of crude oil with a boiling **range** of 200–300 °C produces a number of useful alkanes and alkenes.

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

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(1)

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



- (i) Give the name of Product 1.

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(1)

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

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(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.

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(1)

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

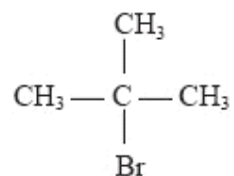
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(2)

- (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:



- (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.

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(1)

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

Reagent

Conditions

(2)

(Total 14 marks)

5. (a) Bromine reacts with both ethane and ethene.

- (i) Write the equations for the reactions below.

Ethane + bromine

.....

(1)

Ethene + bromine

.....

(1)

- (ii) Classify the two reactions in terms of the type of reaction occurring.

Ethane + bromine

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(2)

Ethene + bromine

.....

(2)

(b) Chloroethene (vinyl chloride), $\text{H}_2\text{C}=\text{CHCl}$, can be polymerised in a similar type of reaction to the polymerisation of ethene.

(i) Draw the full structural formula of the polymer poly(chloroethene), sufficient to make the structure of the polymer clear.

(1)

(ii) State **one** use of poly(chloroethene).

.....

(1)

(iii) State and explain **one** environmental problem arising from the disposal of poly(chloroethene).

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(2)

(Total 10 marks)

6. (a) Halogenoalkanes react with many nucleophiles.

Define the term **nucleophile**.

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.....

(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.

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(1)

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



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		

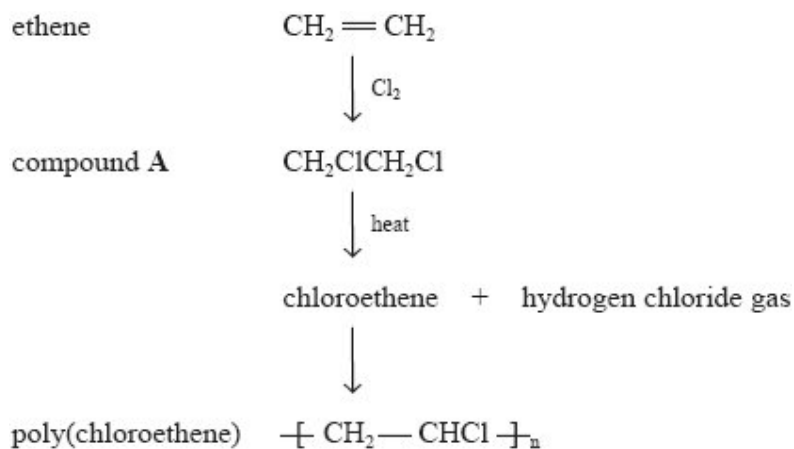
(3)

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

(1)

(Total 10 marks)

7. 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.

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(1)

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

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(1)

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

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(1)

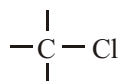
- (c) (i) Ethane-1,2-diol, $\text{CH}_2\text{OHCH}_2\text{OH}$, is a useful compound which could be made from compound **A** using a nucleophilic substitution reaction.

Suggest a suitable nucleophile for this reaction.

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(1)

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



(2)

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

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(1)

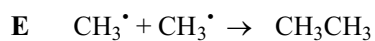
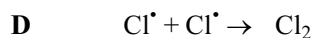
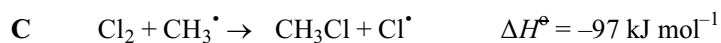
- (iv) Suggest a suitable chemical test you could use to confirm the identity of this leaving group.

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

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(2)
 (Total 11 marks)

8. The reaction between chlorine and methane, in the presence of ultraviolet light, involves the formation of free radicals and includes the following steps:



- (a) (i) What is meant by a **free radical**?

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(1)

- (ii) Draw a 'dot-and-cross' diagram, showing outer shell electrons only, for a chlorine free radical.

(1)

- (iii) What type of bond breaking occurs in step A?

.....

(1)

- (b) Which of the steps, A to F, are chain propagation steps?

.....

(1)

- (c) (i) Write the equation for the overall reaction between one mole of chlorine and one mole of methane molecules.

(1)

- (ii) Calculate the standard enthalpy change, ΔH^\ominus , for this reaction.

(2)

(d) (i) What is the value of ΔH^\ominus for step **D**? (1)

(ii) Would you expect step **E** to be exothermic or endothermic? Justify your answer.

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(1)

(e) The overall reaction was repeated using bromine gas instead of chlorine gas.

Would you expect step **A** for bromine to be more or less endothermic than step **A** for chlorine? Justify your answer.

.....

(2)

(Total 11 marks)

9. (a) Chlorine reacts with methane, CH_4 , to produce chloromethane.

(i) Write an equation for this reaction.

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(1)

(ii) State a necessary condition for this reaction.

.....

(1)

(b) Chlorine can react with but-2-ene to form an addition product.

(i) Draw the structural formulae of the two geometric isomers of but-2-ene.

Isomer 1

Isomer 2

(2)

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

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(2)

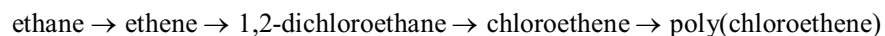
(iii) Name the addition product when chlorine reacts with but-2-ene.

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(1)

(Total 7 marks)

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



- (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.

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(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.

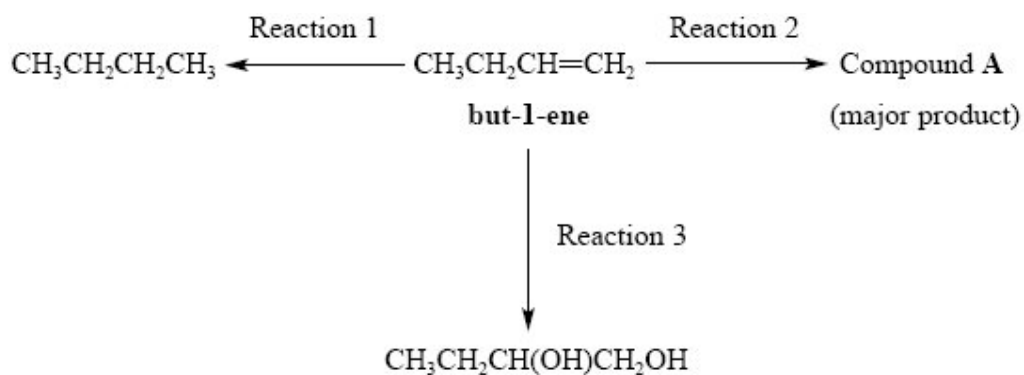
State the type and mechanism of this reaction.

Type

Mechanism

(2)
(Total 9 marks)

11. But-1-ene undergoes the following reactions:



- (a) State the reagent and conditions needed for **Reaction 1**.

Reagent

Conditions

(3)

- (b) (i) The reagent in **Reaction 2** is gaseous hydrogen bromide.

Draw the full structural formula of compound **A**.

(1)

- (ii) What type of reagent is hydrogen bromide in this reaction?

.....

(1)

- (c) Identify the reagent needed for **Reaction 3**.

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(1)

- (d) But-1-ene can be used to make an addition polymer.

Draw the repeating unit of the polymer.

(2)

(Total 8 marks)

12. Bromine reacts with both ethane, C_2H_6 , and ethene, C_2H_4 .

- (c) Explain, in terms of the bonding in the two hydrocarbons, why the reaction of bromine with ethene occurs so much more readily than that with ethane.

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(3)
(Total 8 marks)

13. (a) (i) Draw the structural formulae of the two geometric isomers of but-2-ene, C_4H_8 .

(2)

- (ii) Explain, in terms of structure and bonding, why but-2-ene exists as two geometric isomers whereas but-1-ene does not.

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(3)

(iii) Draw the structural formula of another isomer with formula C_4H_8 .

(1)

(b) Alkenes can be used to make polymers.

(i) Draw enough of the chain of poly(propene) to make its structure clear.

(2)

(ii) Explain why poly(alkenes) cause problems when they are disposed of in a landfill site.

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.....

(2)

(Total 10 marks)

14. (a) Name the homologous series to which the organic compound $CH_2=CHCH_3$ belongs.

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(1)

(b) Write the structural formula of a member of the series named in (a) which contains four carbon atoms.

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(1)

(Total 2 marks)

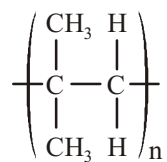
15. (i) Draw the **displayed** formula of propene, C₃H₆.

(1)

- (ii) Draw a 'dot and cross' diagram for propene. You should show outer shell electrons only.

(1)
(Total 2 mark)

16. An addition polymer has the structure shown below.



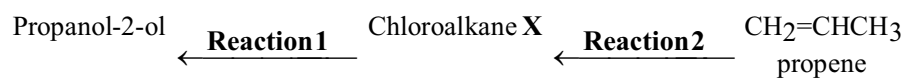
Give the structural formula and the name of the monomer from which this polymer is made.

Structural formula

Name

(Total 2 marks)

17. Two reactions of a chloroalkane, X, are shown below.



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

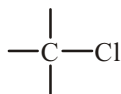
(i) Name and draw the **displayed** formula of the chloroalkane **X**.

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, $\text{CH}_2=\text{CHCH}_3$, 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.

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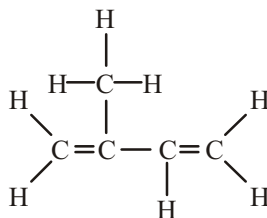
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(2)

(Total 14 marks)

18. (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
 $\text{CH}_2=\text{CHCH}_2\text{CH}=\text{CH}_2$.

(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.

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(2)
(Total 9 marks)

19. (a) Draw the **full** structural formulae, showing all bonds, of:

- (i) 2,4-dimethylpentane

(1)

- (ii) 2-bromopropan-2-ol

(1)

- (b) Pent-2-ene shows geometric isomerism.

Draw the structures of the two geometric isomers.

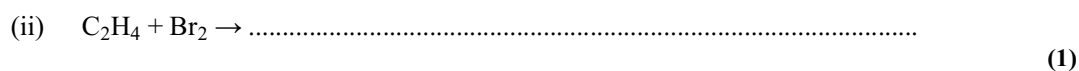
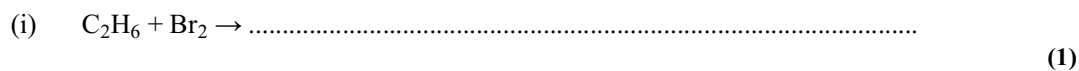
Isomer 1

Isomer 2

(2)
(Total 4 marks)

20. Bromine needs ultraviolet radiation to react with ethane, C_2H_6 , but reacts with ethene, C_2H_4 , in the dark.

- (a) Complete the equations.



- (b) (i) Identify and state the **type** of covalent bond in the hydrocarbon molecules that are broken during these two reactions.

Ethane

bond broken type

Ethene

bond broken type

(2)

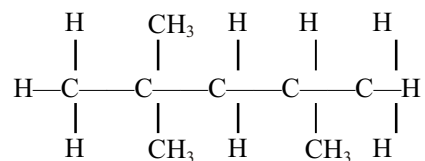
- (ii) Use your answer to (b)(i) to suggest why the reaction of bromine with **ethene** occurs more readily than with ethane in the dark.

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(1)
 (Total 5 marks)

21. 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.



- (i) Name **X**.

.....

(1)

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

.....

(1)

- (iii) **X** can be made by cracking decane, $\text{C}_{10}\text{H}_{22}$.

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.

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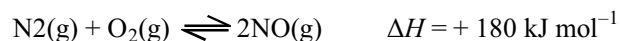
(1)

- (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.



- (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.



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

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(1)

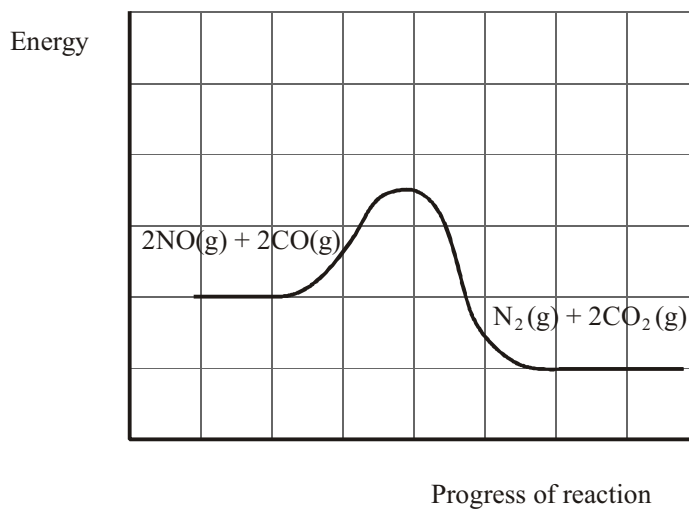
- (iii) A textbook says “The catalytic converter converts the gases coming out of the engine into less harmful ones”.

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

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.....
.....

(1)

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

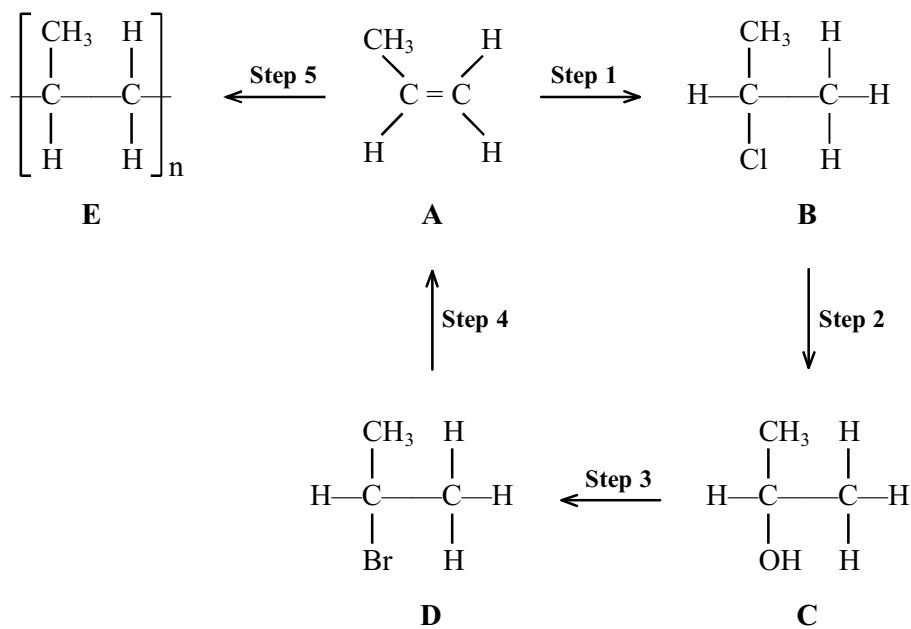


On the diagram, show the activation energy, E_A .

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

(2)
(Total 12 marks)

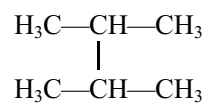
22. This question concerns the compounds and reactions shown in the following reaction scheme.



- (ii) Write an equation for the overall reaction to produce **B** in this way.

(1)

- (iii) Another possible product of this reaction has the following structural formula.



Name this compound

Suggest how this compound formed in the reaction mixture.

Name the type of step involved in its formation.

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(3)

(Total 13 marks)

23. A gaseous hydrocarbon, **W**, is a product formed in the cracking of eicosane, $C_{20}H_{42}$. **W** decolourises bromine, forming compound **X**.

When **X** is reacted with aqueous potassium hydroxide, compound **Y** is formed.

When a solution of **Y** is refluxed with an excess of acidified potassium dichromate(VI), compound **Z** is formed.

Compound **Z** contains carbon, hydrogen and oxygen only.

- (a) (i) On complete combustion, 0.10 g of **Z** produced 53 cm^3 of carbon dioxide and 0.020 g of water at room temperature and pressure.

Calculate the empirical formula of compound **Z**.

[Molar volume of a gas is $24\,000 \text{ cm}^3 \text{ mol}^{-1}$ at room temperature and pressure]

(3)

- (ii) The molar mass of **Z** is 90 g mol^{-1} . Find the molecular formula of **Z**.

(1)

- (iii) A solution made by dissolving 0.900 g of compound **Z** in water is titrated with sodium hydroxide solution. 20.0 cm³ of sodium hydroxide solution of concentration 1.00 mol dm⁻³ is required for complete neutralisation.

Deduce the structural formula of compound **Z**.

(2)

- (iv) Deduce the structural formulae of compounds **W**, **X**, and **Y**.

(3)

- (v) Suggest a balanced equation for the cracking of eicosane.

(1)

- (b) Compound **Y** can be made in one step from compound **W**.

State the reagents needed for this reaction.

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.....

(2)

(Total 12 marks)

24. (a) Compound **A**, $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$, can be converted into butan-2-ol by reaction with potassium hydroxide solution.

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

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(1)

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

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(1)

- (iii) Identify the solvent required for this reaction.

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(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.

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(1)

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

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(1)

(iii) Classify this reaction.

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(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.

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(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.

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(1)

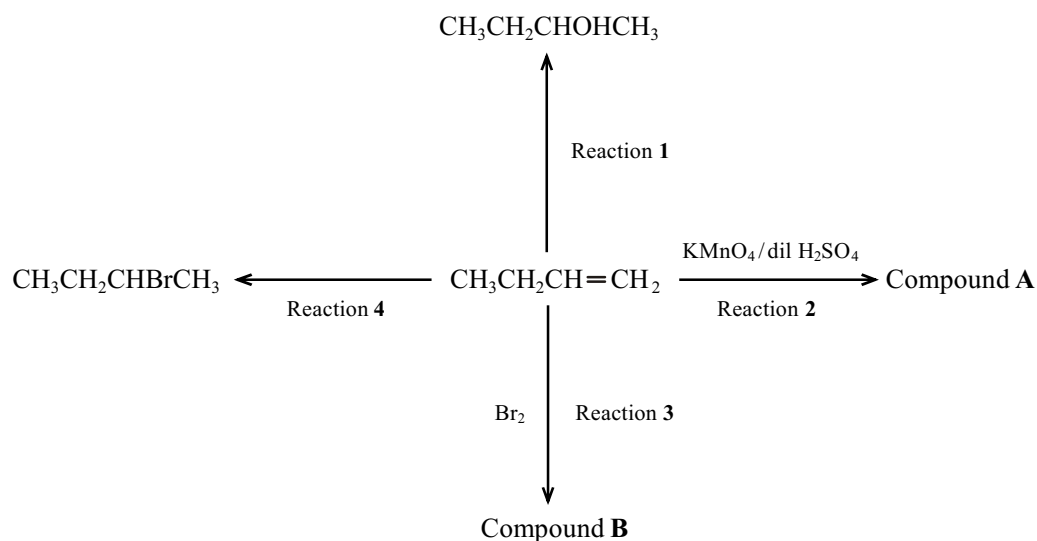
(ii) Identify the product of this reaction.

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(1)

(Total 12 marks)

25. (a) Four reactions of but-1-ene are summarised on the chart below.



(i) Give the TWO reagents you would use for Reaction 1 in the laboratory.

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(2)

(ii) Give the **name** of the product, Compound A, of Reaction 2.

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(1)

(iii) Give the **name** of the product, Compound B, of Reaction 3.

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(1)

(iv) Suggest the reagent needed for Reaction 4.

.....

(1)

(b) All four reactions are addition reactions. Explain what is meant by an **addition reaction**.

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.....

(1)

(c) (i) Explain what is meant by an **electrophile**.

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(1)

(ii) Give the formula of the attacking electrophile in Reaction 3.

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(1)

(d) (i) Select ONE reaction from 1–4 which involves oxidation of but-1-ene.

Reaction

(1)

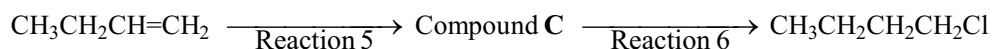
(ii) Explain what is meant by oxidation in this reaction.

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.....

(1)

(e) 1-chlorobutane can be made from but-1-ene in a two-step process. The but-1-ene is first reduced and then a chlorine atom is substituted for a hydrogen atom.



(i) Identify compound **C**.

.....

(1)

(ii) Name the reagent and catalyst required for Reaction **5**.

Reagent

Catalyst

(2)

(iii) Name the reagent and conditions for Reaction **6**.

Reagent

Conditions

(2)

(Total 15 marks)

26. (a) (i) State **TWO** features that members of a homologous series have in common.

.....

.....

.....

.....

(2)

(ii) Name the homologous series to which propene belongs.

.....

(1)

- (iii) Propene can be converted into a mixture of 2-chloropropane (as the major product) and 1-chloropropane.

Classify the reaction involved and identify the reagent required.

Classification

Reagent

(2)

- (b) Define the term **structural isomers**.

.....

.....

.....

.....

(2)

- (c) 1-chloropropane and 1-bromopropane both react with ammonia to give 1-propylamine.

State and explain, in terms of bonding and kinetics, which of 1-chloropropane and 1-bromopropane would react faster with ammonia.

.....

.....

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.....

.....

(3)

- (d) 1-chloropropene, $\text{CH}_3\text{CH}=\text{CHCl}$, can be polymerised to form poly(1-chloropropene).

Draw the repeat unit of poly(1-chloropropene).

(2)

- (e) Explain why 1-chloropropene exists as two different geometric isomers, but propene does not.

.....

.....

.....

.....

.....

(2)

(Total 14 marks)

27. This question is about four hydrocarbons with molecular formulae as shown.

- A** C_2H_2
- B** C_3H_6
- C** C_3H_8
- D** C_4H_{10}

(a) Which hydrocarbon has the same empirical formula as its molecular formula?

A

B

C

D

(1)

(b) Which has a molecular ion in the mass spectrum at mass/charge ratio = 58?

A

B

C

D

(1)

(c) Which is neither an alkane nor an alkene?

A

B

C

D

(1)

(d) Which could be 2-methylpropane?

A

B

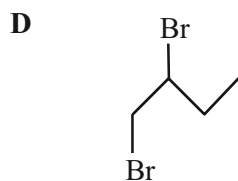
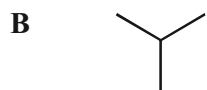
C

D

(1)

(Total 4 marks)

28. This question is about the following organic compounds with skeletal formulae as shown:



(a) Which compound could be made from one of the others in an addition reaction?

A

B

C

D

(1)

(b) Which compound has E-Z isomers?

A

B

C

D

(1)
(Total 2 marks)

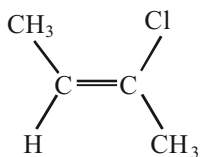
29. Chemists investigating the mechanism of the reaction of ethene and bromine thought that the first step was the addition of Br^+ . To test this, they reacted bromine with ethene in the presence of sodium chloride.

If their theory about the first step of the reaction was correct, which product might form as well as 1,2-dibromoethane?

- A $\text{CH}_2\text{BrCH}_2\text{Na}$
- B $\text{CH}_2\text{BrCH}_2\text{Cl}$
- C $\text{CH}_2\text{ClCH}_2\text{Cl}$
- D $\text{CH}_2\text{NaCH}_2\text{Na}$

(Total 1 mark)

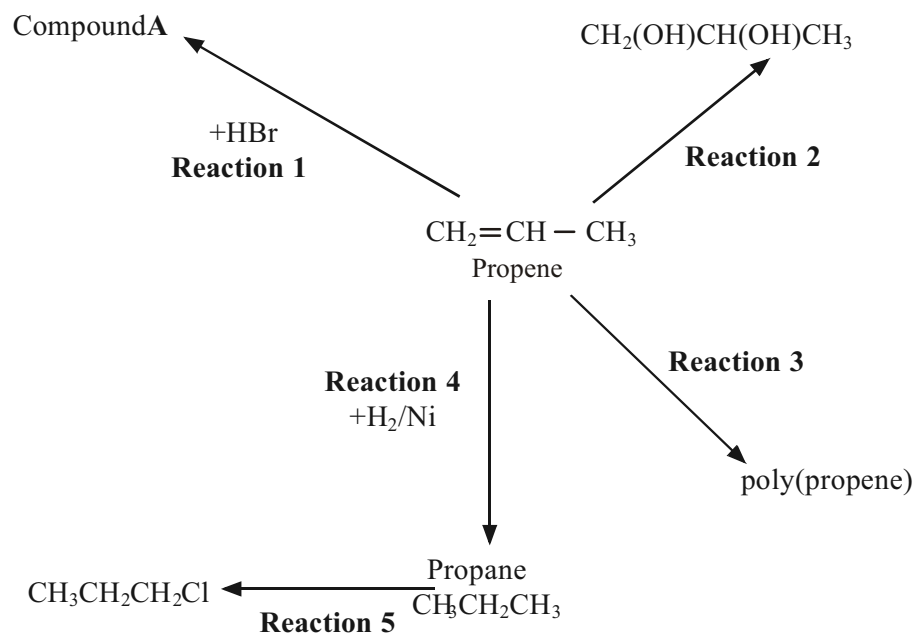
30. Which of the following is the correct name for the compound below?



- A Z-3-chlorobut-2-ene
- B E-3-chlorobut-2-ene
- C E-2-chlorobut-2-ene
- D Z-2-chlorobut-2-ene

(Total 1 mark)

31. Propene can be used to make other important chemical products. The processes involved can be summarised in the diagram:



- (a) (i) Give the mechanism for **Reaction 1**.

(3)

- (ii) Explain why compound **A** and **not** its structural isomer is the major product in **Reaction 1**.

.....

(1)

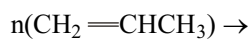
- (iii) Name compound **A** formed in **Reaction 1**.

Name (1)

- (b) What is added in **Reaction 2** to make the product $\text{CH}_2(\text{OH})\text{CH}(\text{OH})\text{CH}_3$?

..... (1)

- (c) Complete the balanced equation for the formation of poly(propene) in **Reaction 3** using **displayed** formulae.



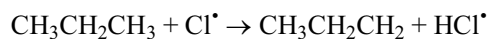
(2)

- (d) Poly(propene) fibres can be used to make fleece which is used at several horse racing courses to prevent the ground becoming frozen.

State **one** advantage of using poly(propene) instead of natural fibres of similar cost.

.....
 (1)

- (e) (i) One stage in the mechanism of **Reaction 5** is shown below.



What is this step?

..... (1)

- (ii) Give the name or formula of the trace product present in the final mixture which gives evidence for this mechanism.

.....

(1)

(Total 11 marks)