

Topic 10: Organic Chemistry (HL) Practice

1. Which molecule has a chiral centre?

- A. $\text{CH}_3\text{CH}=\text{CHCHO}$
- B. $(\text{CH}_3)_2\text{C}=\text{CHCH}_2\text{OH}$
- C. $\text{CH}_3\text{OCH}_2\text{CH}_3$
- D. $\text{CH}_3\text{CHOHCH}_2\text{CH}_3$

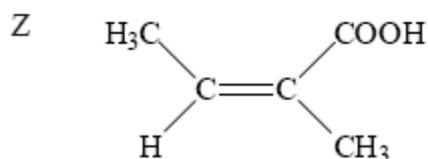
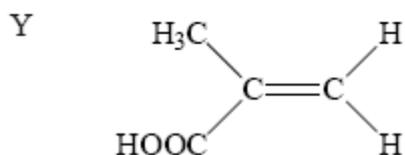
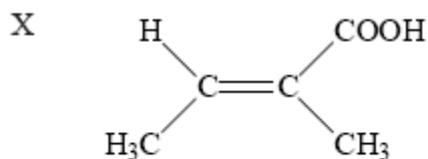
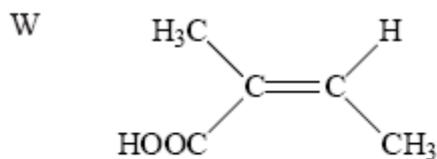
(Total 1 mark)

2. The compounds $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ and $\text{HOOCCH}_2\text{COOH}$ react to form a polymer. What is the structure of the repeating unit of the polymer?

- A. $\text{-(HNCH}_2\text{CONHCH}_2\text{CH}_2\text{NHCO)-}$
- B. $\text{-(HNCH}_2\text{CH}_2\text{NHCOCH}_2\text{CO)-}$
- C. $\text{-(OCCH}_2\text{CONHCH}_2\text{NHCO)-}$
- D. $\text{-(HNCH}_2\text{CH}_2\text{NHCOCH}_2\text{NH)-}$

(Total 1 mark)

3. Which two molecules are cis-trans isomers of each other?



- A. X and Z
- B. X and Y
- C. W and Y
- D. W and Z

(Total 1 mark)

4. What is the correct order of reaction types in the following sequence?



	I	II	III
A.	substitution	oxidation	condensation
B.	addition	substitution	condensation
C.	oxidation	substitution	condensation
D.	substitution	oxidation	substitution

(Total 1 mark)

5. Deduce an equation for the reaction between propanoic acid and methanol. Identify the catalyst and state the name of the organic compound, **X**, formed.

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(Total 4 marks)

6. 2-chloro-3-methylbutane reacts with sodium hydroxide via an S_N2 mechanism. Explain the mechanism by using curly arrows to represent the movement of electron pairs.

(Total 4 marks)

7. 1-chlorobutane can be converted to a pentylamine via a two stage process. Deduce equations for each step of this conversion including any catalyst required **and** name the organic product produced at **each** stage.

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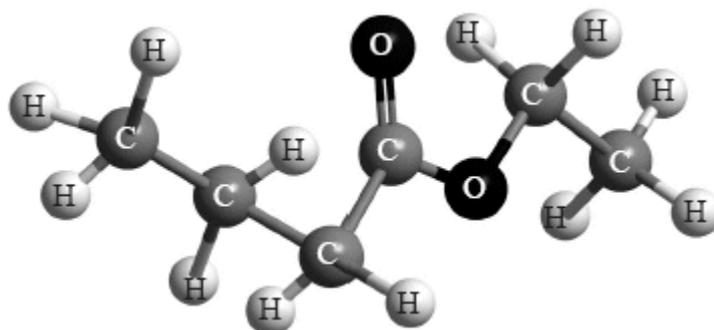
(Total 5 marks)

8. Propanitrile can be prepared by reacting bromoethane with potassium cyanide. Which statement is **not** correct about the reaction between bromoethane and potassium cyanide?

- A. The reaction is bi-molecular.
- B. The reaction follows the S_N2 mechanism.
- C. Homolytic fission occurs between the carbon-bromine bond in bromoethane.
- D. The cyanide ion, $:CN^-$, acts as a nucleophile.

(Total 1 mark)

9. Which reactants could be used to form the compound below?

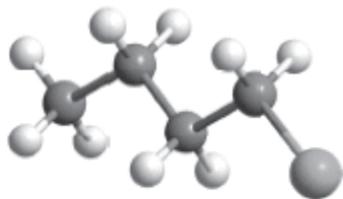


- A. Butanoic acid and ethanol
- B. Propanoic acid and ethanol
- C. Ethanoic acid and propan-1-ol
- D. Ethanoic acid and butan-1-ol

(Total 1 mark)

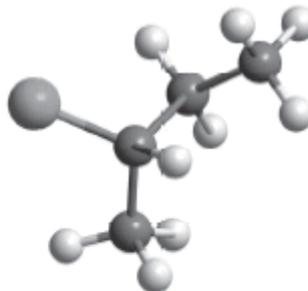
10. Which compound is optically active?

A.



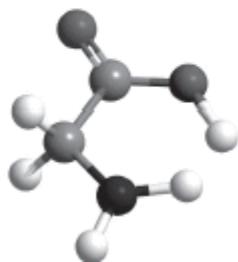
1-chlorobutane

B.



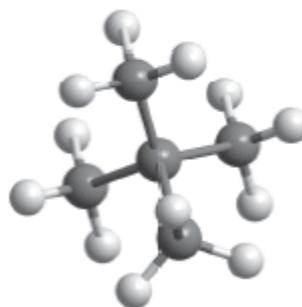
2-chlorobutane

C.



2-aminoethanoic acid

D.



2,2-dimethylpropane

(Total 1 mark)

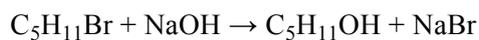
11. There are several structural isomers with the molecular formula C₅H₁₁Br.

- (a) Deduce the name of **one** of the isomers which can exist as enantiomers and draw three-dimensional representations of its **two** enantiomers.

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(3)

- (b) All the isomers react when warmed with a dilute aqueous solution of sodium hydroxide according to the equation below.



- (i) The reaction with 1-bromopentane proceeds by an $\text{S}_{\text{N}}2$ mechanism. Describe this mechanism using structural formulas and curly arrows to represent the movement of electron pairs.

(3)

- (ii) The reaction with 2-bromo-2-methylbutane proceeds by an $\text{S}_{\text{N}}1$ mechanism. Describe this mechanism using structural formulas and curly arrows to represent the movement of electron pairs.

(3)

- (iii) Explain why 1-bromopentane reacts by an S_N2 mechanism whereas 2-bromo-2-methylbutane reacts by an S_N1 mechanism.

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(3)

- (iv) Explain whether the boiling point of 1-bromopentane will be higher, lower or the same as that of 2-bromo-2-methylbutane.

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(3)

- (v) The product $C_5H_{11}OH$ formed from the reaction with 1-bromopentane is warmed with ethanoic acid in the presence of a few drops of concentrated sulfuric acid. State the name of the type of reaction taking place and the structural formula of the organic product.

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(2)

- (c) If the conditions of the reaction in (b) are changed so that a hot solution of sodium hydroxide in ethanol is used then a different reaction occurs. The reaction with 2-bromo-2-methylbutane gives **two** different organic products. State the type of reaction taking place and suggest the identity (name or structure) of these **two** products. Explain whether or not they can exist as geometrical isomers.

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(4)
(Total 21 marks)

12. Dihalogenoalkanes can react with warm dilute potassium hydroxide solution to form diols. These diols can react with dicarboxylic acids.

- (i) Deduce the equation for the reaction of benzene-1,4-dicarboxylic acid with the diol formed from 1,5-dibromopentane.

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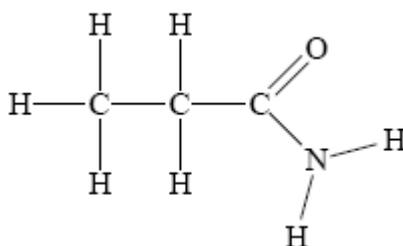
(3)

- (ii) Outline the economic importance of the reaction of diols with dicarboxylic acids.

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(1)
(Total 4 marks)

13. What is the IUPAC name of $\text{CH}_3\text{CH}_2\text{CONH}_2$?



- A. Aminopropanal
B. Ethanamide
C. Propylamine
D. Propanamide

(Total 1 mark)

14. What is the main organic product formed from the reaction of $\text{CH}_3\text{CH}_2\text{OH}$ with $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ in the presence of an acid catalyst?

- A. Ethyl butanoate
B. Butyl ethanoate
C. Ethyl propanoate
D. Propyl ethanoate

(Total 1 mark)

15. What are some uses of esters?

- I. Flavouring agents
 - II. Perfumes
 - III. Solvents
- A. I and II only
 - B. I and III only
 - C. II and III only
 - D. I, II and III

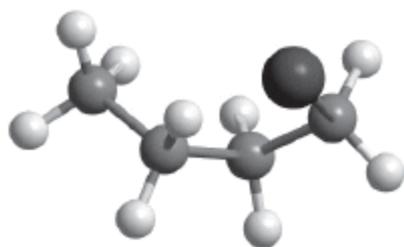
(Total 1 mark)

16. How many isomers can exist for a compound with the molecular formula $C_2H_2Cl_2$?

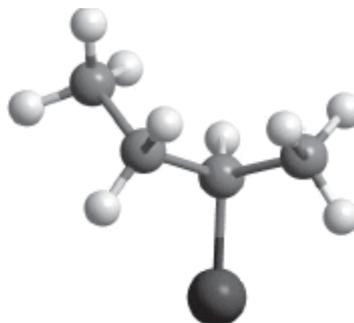
- A. 1
- B. 2
- C. 3
- D. 4

(Total 1 mark)

17. (a) Below are **four structural** isomers with molecular formula C_4H_9Br . State the name of each of the isomers **A**, **B**, **C** and **D**.



A



B

Key:



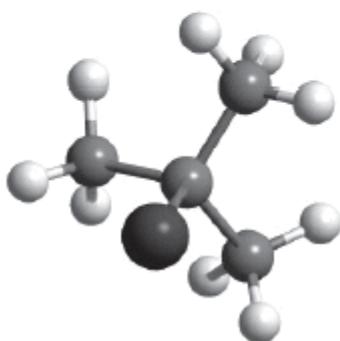
Bromine



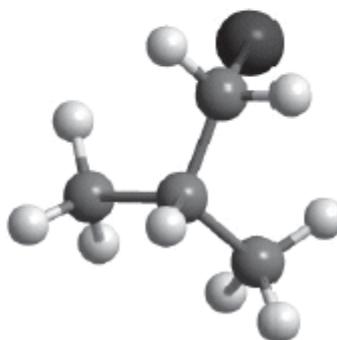
Carbon



Hydrogen



C



D

(4)

- (b) (i) Identify the isomer(s) which will react with aqueous sodium hydroxide almost exclusively by an S_N1 mechanism. State the meaning of the symbols in the term S_N1 mechanism.

(2)

- (ii) Using the formula RBr to represent a bromoalkane, state an equation for the rate determining step of this S_N1 reaction.

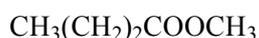
(1)

- (iii) Identify one isomer that will react with aqueous sodium hydroxide almost exclusively by an S_N2 mechanism. Draw the mechanism for this reaction using curly arrows to represent the movement of electron pairs. Include the structural formulas of the transition state and the organic product.

(4)

- (c) State and explain how the rates of the reactions in parts (b) (i) and (b) (iii) are affected when the concentration of the sodium hydroxide is doubled. (2)
- (d) State and explain how the rate of reaction of 1-bromobutane with sodium hydroxide compares with that of 1-chlorobutane with sodium hydroxide. (2)
- (e) Identify the isomer of C_4H_9Br that can exist as stereoisomers. Outline how a polarimeter will distinguish between the isomers, and how their physical and chemical properties compare. (5)
- (f) (i) State the type of reaction that occurs when isomer **B**, $CH_3CHBrCH_2CH_3$, reacts with a hot alcoholic solution of sodium hydroxide. (1)
- (ii) Explain how the reaction in part (f) (i) occurs by drawing the mechanism, using curly arrows to represent the movement of electron pairs and identify the two possible organic products. (4)
- (Total 25 marks)**

18. What is the IUPAC name for the following compound?



- A. Methyl butanoate
B. Butyl ethanoate
C. Butyl methanoate
D. Methyl propanoate

(Total 1 mark)

19. What is the product of the following reaction?



- A. $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$
- B. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$
- C. $\text{CH}_3\text{CH}_2\text{NH}_2$
- D. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$

(Total 1 mark)

20. How many chiral carbon atoms are present in a molecule of 2,3-dibromobutane?

- A. 1
- B. 2
- C. 3
- D. 4

(Total 1 mark)

21. Existence of isomers leads to diversity of organic compounds.

(a) Describe what is meant by the term *stereoisomers*.

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(2)

(b) 1,3-dichlorocyclobutane exists as geometrical isomers, a form of stereoisomers.

(i) Draw and name the **two** geometrical isomers of 1,3-dichlorocyclobutane.

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(2)

(ii) Identify the isomer with the **higher** boiling point and explain your reasoning.

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(3)

(Total 7 marks)

22. Halogenoalkanes undergo two major types of reaction leading to the formation of different organic compounds.

(i) 1-bromopropane can be converted to 1-butylamine (butan-1-amine) in **two** stages. Draw the structural formulas of 1-bromopropane and 1-butylamine (butan-1-amine).

(1)

- (ii) Deduce a reaction pathway for the **two**-stage conversion of 1-bromopropane to 1-butylamine (butan-1-amine). Your answer should include an equation for each stage of the reaction **and** the reaction conditions for the second stage.

(4)

(Total 5 marks)

23. (i) Describe the elimination of HBr from bromoethane. Your answer should include the reagents, conditions and equation for the reaction.

(3)

- (ii) Explain the mechanism for the elimination of HBr from bromoethane.

(5)

(Total 8 marks)

24. By which reactants and type of reaction can ethylamine (aminoethane) be produced?

	Reactants	Type of reaction
A.	$\text{CH}_3\text{Br} + \text{NH}_3$	Nucleophilic substitution
B.	$\text{CH}_3\text{CH}_2\text{Br} + \text{NH}_3$	Reduction
C.	$\text{CH}_3\text{CN} + \text{H}_2$	Nucleophilic substitution
D.	$\text{CH}_3\text{CN} + \text{H}_2$	Reduction

(Total 1 mark)

25. Which compound is an amide?

- A. $\text{CH}_3\text{COOCH}_3$
B. CH_3CONH_2
C. CH_3NH_2
D. $\text{CH}_2(\text{NH}_2)\text{COOH}$

(Total 1 mark)

26. Which process can produce a polyester?
- Addition polymerization of a dicarboxylic acid
 - Condensation polymerization of a diol and a dicarboxylic acid
 - Addition polymerization of a diol and dicarboxylic acid
 - Condensation polymerization of a dicarboxylic acid

(Total 1 mark)

27. Which statement about stereoisomers is correct?
- 1,2-dichloroethane has two geometrical isomers.
 - 1,2-dichloroethane has two optical isomers.
 - 1,2-dichloroethene has two geometrical isomers.
 - 1,2-dichloroethene has two optical isomers.

(Total 1 mark)

28. (a) There are four structural isomers with the molecular formula C_4H_9Br . One of these structural isomers exists as two optical isomers. Draw diagrams to represent the three-dimensional structures of the two optical isomers.

(2)

- (b) All the isomers can be hydrolysed with aqueous sodium hydroxide solution. When the reaction of one of these isomers, **X**, was investigated the following kinetic data were obtained.

Experiment	Initial [X] / mol dm^{-3}	Initial $[\text{OH}^-]$ / mol dm^{-3}	Initial rate of reaction / $\text{mol dm}^{-3} \text{ min}^{-1}$
1	2.0×10^{-2}	2.0×10^{-2}	4.0×10^{-3}
2	2.0×10^{-2}	4.0×10^{-2}	4.0×10^{-3}
3	4.0×10^{-2}	4.0×10^{-2}	8.0×10^{-3}

- (i) Deduce the rate expression for the reaction.

(3)

- (ii) Determine the value of the rate constant for the reaction and state its units.

(2)

(iii) State the name of isomer **X** and explain your choice.

(2)

(iv) State equations for the steps that take place in the mechanism of this reaction and state which of the steps is slow and which is fast.

(2)

(Total 11 marks)

29. Identify the functional group present in $\text{HCOCH}_2\text{CH}_3$.

- A. Ester
- B. Ketone
- C. Aldehyde
- D. Alcohol

(Total 1 mark)

30. What is the IUPAC name for $\text{HCOOCH}_2\text{CH}_2\text{CH}_3$?

- A. Butanoic acid
- B. Butanal
- C. Methyl propanoate
- D. Propyl methanoate

(Total 1 mark)

31. Which statements about substitution reactions are correct?

- I. The reaction between sodium hydroxide and 1-chloropentane predominantly follows an S_N2 mechanism.
- II. The reaction between sodium hydroxide and 2-chloro-2-methylbutane predominantly follows an S_N2 mechanism.
- III. The reaction of sodium hydroxide with 1-chloropentane occurs at a slower rate than with 1-bromopentane.

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

(Total 1 mark)

32. What is the organic product of the reaction between methylamine and ethanoic acid?

- A. CH_3COONH_4
- B. $CH_3NHCOCH_3$
- C. $CH_3COCH_2NH_2$
- D. $CH_3CH_2CONH_2$

(Total 1 mark)

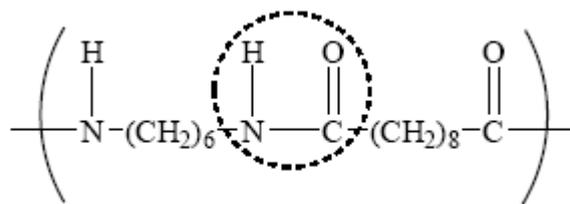
33. Which compound can exist as stereoisomers?

- A. CH_3CH_2CHO
- B. $CH_3CH_2COCH_3$
- C. $CH_3CH(CH_3)_2$
- D. $CH_3CH_2CHOHCH_3$

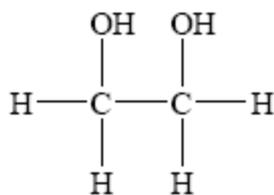
(Total 1 mark)

34. (a) But-1-ene and 1-aminobutane (1-butylamine) can both be prepared from 1-bromobutane.
- (i) State the equation (using structural formulas) and the necessary reagents and conditions for the preparation of but-1-ene from 1-bromobutane. (3)
- (ii) Identify the type of reaction and explain the mechanism for the preparation of but-1-ene from 1-bromobutane using curly arrows to represent the movement of electron pairs. (3)
- (iii) State the equation (using structural formulas) for the preparation of 1-aminobutane from 1-bromobutane. State the necessary reagents and conditions of the reaction. (3)
- (iv) Explain the mechanism for the preparation of 1-aminobutane from 1-bromobutane using curly arrows to represent the movement of electron pairs. (4)
- (b) 2-bromobutane and 2-bromo-2-methylpropane are two isomers of 1-bromobutane.
- (i) Draw the structures of the two mirror images of the isomer that can exhibit optical isomerism. (2)
- (ii) Describe how the two optical isomers can be distinguished practically using plane-polarized light. (2)
- (iii) Explain why the mechanism of the reaction will be different if 1-bromobutane is replaced by 2-bromo-2-methylpropane to form 2-amino-2-methylpropane in the reaction in part (a)(iv). (3)
- (Total 20 marks)**

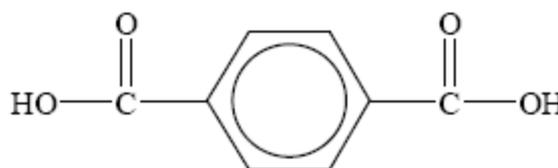
35. One form of nylon has the repeating unit:



- (i) Identify the circled functional group. (1)
- (ii) Deduce the structures of the two monomers used to make this form of nylon. (2)
- (iii) Nylon is a condensation polymer. Another condensation polymer can be formed by reacting ethane-1,2-diol with benzene-1,4-dicarboxylic acid.



ethane-1,2-diol



benzene-1,4-dicarboxylic acid

Deduce the equation for this reaction using n moles of each reactant.

(2)
(Total 5 marks)

36. What is the organic product of the reaction between $\text{CH}_3\text{CH}_2\text{NH}_2$ and $\text{CH}_3\text{CH}_2\text{COOH}$?

- A. $\text{CH}_3\text{CH}_2\text{NHCOCH}_2\text{CH}_3$
- B. $\text{CH}_3\text{CH}_2\text{CH}_2\text{NHCOCH}_3$
- C. $\text{CH}_3\text{CH}_2\text{NHCOCH}_3$
- D. $\text{CH}_3\text{NHCOCH}_3$

(Total 1 mark)

37. What is the IUPAC name of the compound $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_3$?

- A. Ethyl ethanoate
- B. Propyl ethanoate
- C. Ethyl propanoate
- D. Pentyl propanoate

(Total 1 mark)

38. Which statement is correct about the enantiomers of a chiral compound?

- A. Their physical properties are different.
- B. All their chemical reactions are identical.
- C. A racemic mixture will rotate the plane of polarized light.
- D. They will rotate the plane of polarized light in opposite directions.

(Total 1 mark)

39. Deduce a two-step synthesis for each of the following conversions. For each step, state the structural formulas of all reactants and products and state the conditions used in the reactions.

(i) Ethanol to ethyl ethanoate.

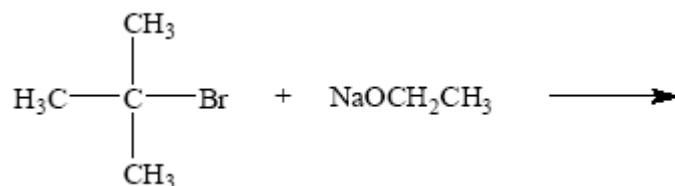
(2)

(ii) Propene to propanone.

(2)

(Total 4 marks)

40. The reagents used in an elimination reaction are shown below.



Explain the mechanism of this reaction using curly arrows to represent the movement of electron pairs.

(Total 3 marks)

41. (i) Describe geometrical isomerism.

(1)

(ii) Draw the geometrical isomers of but-2-ene.

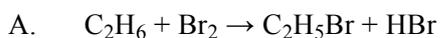
(2)

(iii) Draw the two enantiomers of butan-2-ol.

(2)

(Total 5 marks)

42. Which reaction occurs via a free-radical mechanism?



(Total 1 mark)

43. Which compound could rotate the plane of polarization of polarized light?

- A. $(\text{CH}_3)_2\text{CHCH}_2\text{Cl}$
- B. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Cl}$
- C. $\text{CH}_3\text{CH}_2\text{CHClCH}_3$
- D. $(\text{CH}_3)_3\text{CCl}$

(Total 1 mark)

44. What is the name of the ester formed when $\text{CH}_3\text{CH}_2\text{COOH}$ and CH_3OH react together?

- A. Ethyl methanoate
- B. Methyl ethanoate
- C. Propyl methanoate
- D. Methyl propanoate

(Total 1 mark)

45. Which formula represents a polyamide?

- A. $\text{-(CH}_2\text{-CHCl)-}_n$
- B. $\text{-(NH-(CH}_2\text{)}_6\text{-NH-CO-(CH}_2\text{)}_4\text{-CO)-}_n$
- C. $\text{-(CF}_2\text{-CF}_2\text{)-}_n$
- D. $\text{-(O-(CH}_2\text{)}_2\text{-O-CO-}\text{-CO)-}_n$

(Total 1 mark)

46. The compound $\text{C}_4\text{H}_7\text{Cl}$ can exhibit stereoisomerism.

- (i) Draw the structural formulas of the **two** geometrical isomers of 1-chloro-but-2-ene.

(2)

(ii) Explain why 1-chloro-but-2-ene shows geometrical isomerism. (1)

(iii) Draw the structural formula of **one** isomer of C_4H_7Cl that shows optical isomerism and identify the chiral carbon atom with an asterisk (*). (2)
(Total 5 marks)

47. The compound but-2-ene-1,4-dioic acid forms two geometrical isomers which have different physical and chemical properties.

(i) Explain the difference in the melting points of the two isomers. (3)

(ii) Outline how the two isomers behave differently when gently heated. (1)
(Total 4 marks)

48. The reaction between bromoethane, CH_3CH_2Br , and potassium cyanide is an example of a nucleophilic substitution reaction.

(i) State whether this reaction is S_N1 or S_N2 . (1)

(ii) Explain the mechanism of the reaction using curly arrows to represent the movement of electron pairs. (4)

(iii) The organic product obtained in part (ii) can be reduced to form an amine. State an equation for the reaction, naming the catalyst involved. (2)
(Total 7 marks)

49. Bromoethane reacts with potassium hydroxide to undergo mainly a substitution reaction or an elimination reaction depending on the reaction conditions used.

(i) State an equation and the reaction conditions used to control the products formed in each case.

(4)

(ii) Explain the mechanism of the elimination reaction using curly arrows to represent the movement of electron pairs.

(4)

(iii) Under certain conditions, the major product obtained in the elimination reaction can undergo polymerization. Identify the type of polymerization this major product undergoes.

(1)

(Total 9 marks)

50. What is the product of the following reaction?



A. $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$

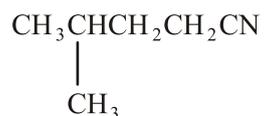
B. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$

C. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$

D. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$

(Total 1 mark)

51. What is the correct IUPAC name for the following compound?



- A. 4-methylbutanenitrile
- B. 4-methylpentanenitrile
- C. 2-methylbutanenitrile
- D. 2-methylpentanenitrile

(Total 1 mark)

52. What is the organic product of the reaction between ethanol and ethanoic acid in the presence of sulfuric acid?

- A. CH_3CHO
- B. $\text{CH}_3\text{COOCH}_3$
- C. $\text{CH}_3\text{CH}_2\text{COOCH}_3$
- D. $\text{CH}_3\text{COOCH}_2\text{CH}_3$

(Total 1 mark)

53. Which compound can exist as optical isomers?

- A. $\text{H}_2\text{NCH}_2\text{COOH}$
- B. H_3CCONH_2
- C. H_3CCHBrI
- D. HCOOCH_3

(Total 1 mark)

54. The molecular formula, $C_3H_4Cl_2$ represents several isomeric compounds. Some isomers are cyclic and some are unsaturated.

- (a) Draw the structures of two cyclic compounds that are structural isomers and state the names of both isomers.

(2)

- (b) Two of the non-cyclic compounds have geometrical isomers. Draw the structures of these compounds and their geometrical isomers.

(2)

(Total 4 marks)

55. The compound, 2-bromobutane, $CH_3CHBrCH_2CH_3$, can react with sodium hydroxide to form compounds **F**, **G** and **H**.

Compound **F**, $C_4H_{10}O$, exists as a pair of optical isomers. Compounds **G** and **H**, C_4H_8 , are structural isomers, and compound **H** exists as a pair of geometrical isomers.

- (i) Draw the structures of the two optical isomers of **F**.

(2)

- (ii) Outline the use of a polarimeter in distinguishing between the optical isomers.

(2)

- (iii) Draw diagrams to show the shapes of the two geometrical isomers of **H**.

(2)

- (iv) Draw the mechanism, using curly arrows to represent the movement of electron pairs, to show the formation of **G**.

(3)

(Total 9 marks)

56. A compound, **J**, has the molecular formula $C_2H_4O_2$ and is obtained from a reaction between methanoic acid and methanol. Write an equation for this reaction and state the name of compound **J**.

(Total 3 marks)