AQA A-Level Chemistry: Practice Paper 3

Focus: Organic

Difficulty: Hard

Time: 2 hours

Marks:

Section A (multiple choice): 15 marks (30 minutes)

Section B (standard questions): 75 marks (1 hour 30 minutes)

(Total 90 marks)

Grade Boundaries: (approximate)

A*: 72 (80%)

A: 63 (70%)

B: 54 (60%)

C: 45 (50%)

D: 36 (40%)

Main Topics Examined:

Haloalkanes, Alkenes, Organic Analysis, Mechanisms,

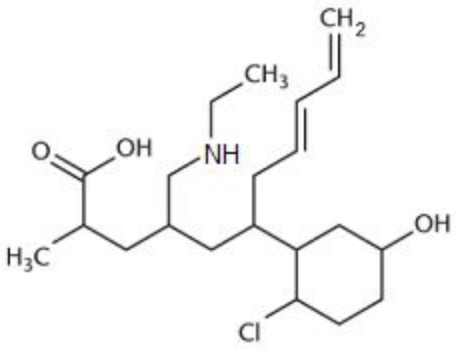
Organic Synthesis

Advice:

1. Read the questions carefully - look out for tricks.
2. Some questions are harder than the A-level standard.
3. Apply existing knowledge to unfamiliar questions.
4. Check the fully worked solutions for any questions you missed.

Section A: Multiple choice. You are advised to spend no more than **30 minutes** in Section A.

1. Consider the organic molecule below.



The IUPAC name of this molecule ends in what suffix?

O -ol
O -amide
O -enoic acid
O -anoic acid [1 mark]

2. A mixture of equal parts of hexane (boiling point 68 °C) and heptane (boiling point 98 °C) is distilled using a fractionating column.

The temperature of the liquid in the flask and the temperature at the top of the fractionating column are measured.

When the first drops of distillate are collected, the temperature in the flask is *X* °C and the temperature at the top of the column is *Y* °C.

What are the most likely values of *X* and *Y*?

O $X = 83, Y = 68$
O $X = 98, Y = 68$
O $X = 83, Y = 83$
O $X = 98, Y = 83$ [1 mark]

3. Which of these is **not** a condition for the fermentation of glucose into ethanol?

O The presence of yeast enzymes.
O Temperature controlled at 35 ^{o}C.
O Pressure controlled at slightly above atmospheric pressure.
O The absence of oxygen. [1 mark]

4. The IUPAC nomenclature for a molecule containing a ketone group is -one when it is the highest priority functional group, and oxo- when it is a side group.

The organic product formed when 3,4,5-trihydroxy-4-methylpentanal is refluxed with an excess of hot potassium dichromate solution in the presence of concentrated H_2SO_4 is named

O 2,3-dihydroxy-2-methylpentanedial
O 2-hydroxy-2-methyl-3-oxopentanedial
O 2,3-dioxopentanedioic acid
O 2-hydroxy-2-methyl-3-oxopentanedioic acid [1 mark]

5. Which of these reactions produces a racemic mixture?

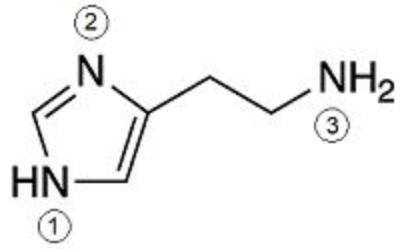
1 Heating but-2-ene with concentrated sulfuric acid
2 Hydrolysis of $CH_3CH_2C(CH_3)(OSO_2OH)CH_2CH_3$
3 Nickel-catalysed hydrogenation of 2,3-dimethylpent-2-ene

O **1** and **2** only
O **1** and **3** only
O **2** and **3** only
O **1**, **2** and **3** [1 mark]

6. Which of these amino acids is optically inactive?

O Lysine
O Alanine
O Glycine
O Serine [1 mark]

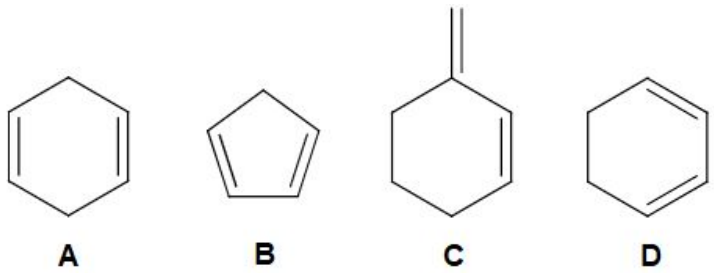
7. The structure of histamine is



When histamine is added to an acidic solution, the nitrogen atom(s) most likely to act as a Brønsted-Lowry base is/are

O **1** only
O **1** and **2** only
O **2** only
O **2** and **3** only [1 mark]

8. Use your knowledge of bonding in benzene to predict which of these compounds has the most exothermic enthalpy of hydrogenation.

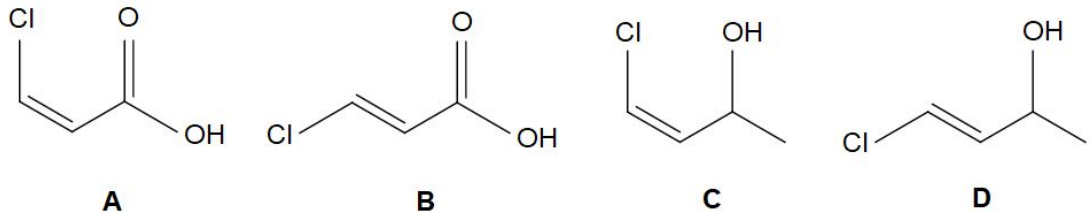


O A
O B
O C
O D [1 mark]

9. Which of these is not an isomer of the alkane $C_{10}H_{22}$?

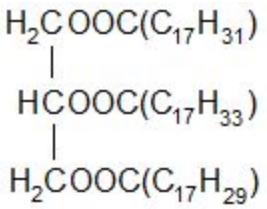
O 2,7-dimethyloctane
O 2,2,4-trimethylheptane
O 4-propylheptane
O 3,3-diethylpentane [1 mark]

10. The compound with the highest boiling point is



O A
O B
O C
O D [1 mark]

11. Consider the triglyceride ester **E** shown below.



E is hydrogenated at 150 °C under a nickel catalyst. How many hydrogen molecules must react per molecule of **E** to produce a saturated fat?

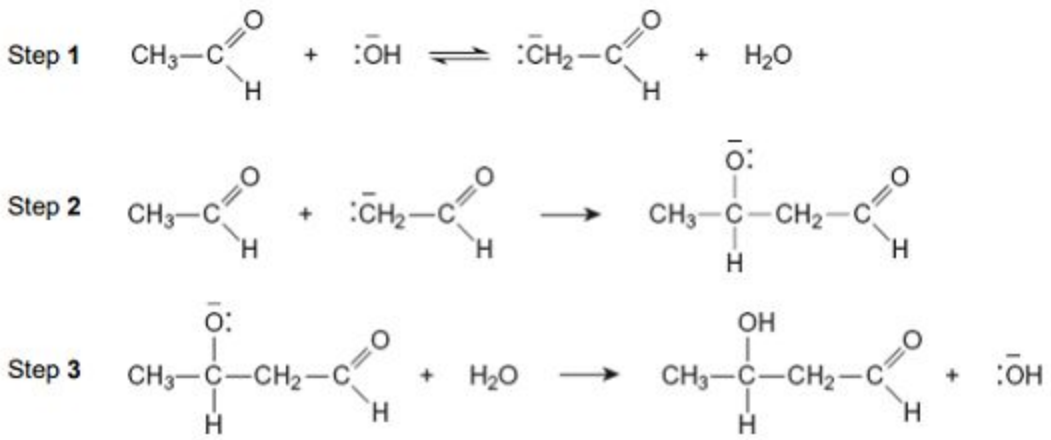
O 4
O 5
O 6
O 7 [1 mark]

12. The standard enthalpy change for the esterification of ethanoic acid and ethanol is -6 kJ mol^{-1}. The main reason why $\Delta H_r^{\ominus}$ is particularly small for this reaction is

O The same number of molecules are formed as were started with.
O The same number of bonds are formed as were broken.
O The same types of bonds are formed as were broken.
O The standard entropies of the molecules are similar. [1 mark]

13. The kinetics of the dimerisation of ethanal into 3-hydroxybutanal in the presence of dilute alkaline solution was studied and found to be first order with respect to both ethanal and hydroxide ions.

If the mechanism for the dimerisation is

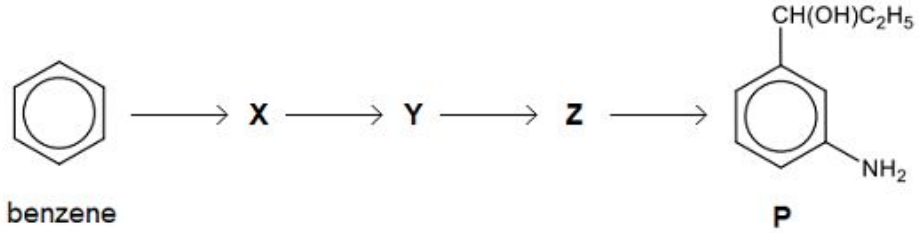


then which of the following statements is/are true?

1 The rate-determining step is Step **1**
2 Step **2** involves nucleophilic addition
3 In Step **3**, water acts as a base

O **1** and **2** only
O **2** and **3** only
O **1** and **3** only
O **1**, **2** and **3** [1 mark]

14. A reaction scheme to convert benzene to organic product **P** through three intermediate compounds **X**, **Y** and **Z** in four simple reactions is shown:



The most likely identities of the intermediate molecules are

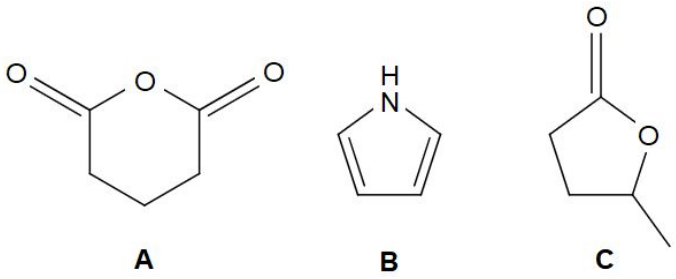
O **X**: benzoyl chloride, **Y**: *N*-propyl benzamide, **Z**: 3-aminophenol

O **X**: 3-phenylpropanoic acid, **Y**: phenylpropan-1-ol, **Z**: 1-(3-nitrophenyl)propan-1-ol

O **X**: nitrobenzene, **Y**: phenylamine, **Z**: 1-(3-aminophenyl)propan-1-one

O **X**: phenol, **Y**: 3-aminophenol, **Z**: propyl 3-aminobenzoate [1 mark]

15. Compounds **A**, **B** and **C** are as shown below.



Which of the following statements is/are true?

1 The reaction of **A** with **B** involves nucleophilic addition-elimination
2 Reduction of $(C_5H_4)CN$ with $LiAlH_4$ produces **B**
3 The acid-catalysed hydrolysis of **C** forms a single product

O **1** and **2** only
O **2** and **3** only
O **1** and **3** only
O **1**, **2** and **3** [1 mark]

Section B: Standard questions. You are advised to spend **most** of your time in Section B.

16. Tetrachloromethane (CCl_4) is an effective fire extinguisher but it is no longer used because of its toxicity and its role in the depletion of the ozone layer. In the upper atmosphere, a bond in CCl_4 breaks and reactive species are formed.

a. Identify the condition that causes a bond in CCl_4 to break in the upper atmosphere and deduce an equation for the formation of the reactive species.
[2 marks]

b. One of the reactive species formed from CCl_4 acts as a catalyst in the decomposition of ozone.

i) Write two equations to show how this species acts as a catalyst.
[2 marks]

ii) Write down the overall equation for the decomposition of ozone.
[1 mark]

c. A small amount of the freon CF_3Cl with a mass of 1.78×10^{-4} kg escaped from a refrigerator, into a room of volume 100 m^3.

Assuming that the freon is evenly distributed throughout the air in the room, calculate the number of freon molecules in a volume of 500 cm^3.
Give your answer to the appropriate number of significant figures.

(The Avogadro constant = 6.02×10^{23} mol^{-1}.) [4 marks]

d. The refrigerant R410A, used in air conditioners, is a mixture of two fluoroalkanes, pentafluoroethane and difluoromethane. The mechanism for the reaction of fluorine with either an alkane or a fluoroalkane is similar to that for the reaction of chlorine with methane.

i) Name the type of mechanism for the reaction of chlorine with methane. [1 mark]

ii) Write equations for the initiation, propagation and termination steps in the mechanism for the reaction of fluorine with fluoromethane to for difluoromethane. In the termination step, form 1,2-difluoroethane. [4 marks]

iii) Write an overall equation for the reaction of fluorine with ethane to form pentafluoroethane by this mechanism. [1 mark]

e. Nitrogen monoxide (NO) also catalyses the decomposition of ozone into oxygen. The sequence of reactions that occur when nitrogen monoxide catalyses the decomposition of ozone is shown.

Step **1**: $O_3 \rightarrow O + O_2$
Step **2**: $NO + O_3 \rightarrow NO_2 + O_2$
Step **3**:

Complete Step **3** in the above mechanism. [1 mark]

f. Bromine atoms have a similar role to chlorine atoms in the decomposition of ozone. Suggest and explain which of $CClF_3$ or $CBrF_3$, if released into the upper atmosphere, would form free halogen atoms more readily. [2 marks]

[Total marks for Q16: 18 marks]

17. Some alkenes can undergo dimerisation reactions at room temperature.

a. State what is meant by the term *dimerisation*. [2 marks]

b. 2-methylpropene dimerises in the presence of concentrated sulfuric acid catalyst to form two products, one of which is **X**, named 2,4,4-trimethylpent-1-ene.

i) Name the mechanism for the reaction of 2-methylpropene with concentrated sulfuric acid. [1 mark]

ii) Suggest and outline a mechanism for this dimerisation to form this particular product **X**. In each step, explain your reasoning to justify why each step might occur. [8 marks]

iii) Name the other dimer **Y** that could form as a product of this reaction.

[1 mark]

c. i) State the type of isomerism exhibited by **X** and **Y**.

[1 mark]

ii) When **X** and **Y** are hydrogenated in the presence of a nickel catalyst at 150 ^{o}C, the same product **Z** is formed in each case.

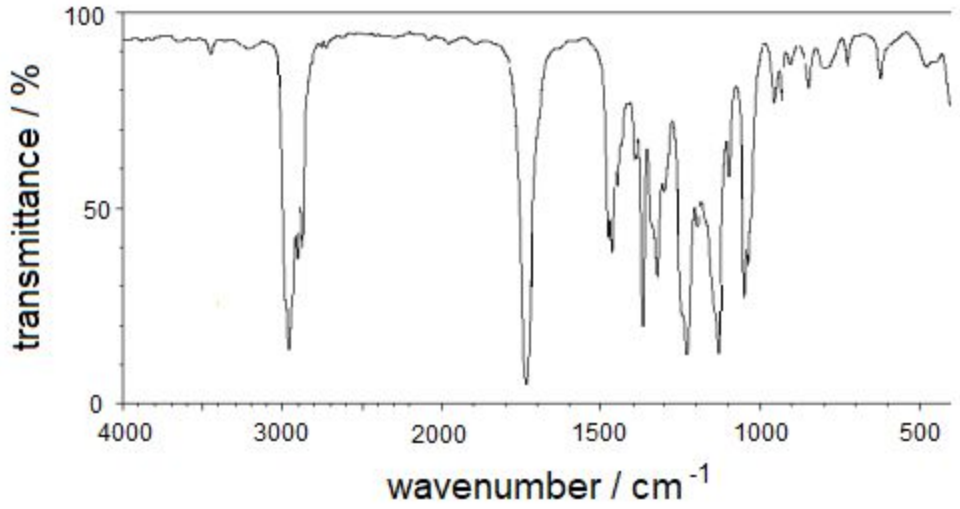
Draw the skeletal formula of **Z** and give a common use of this compound.

[2 marks]

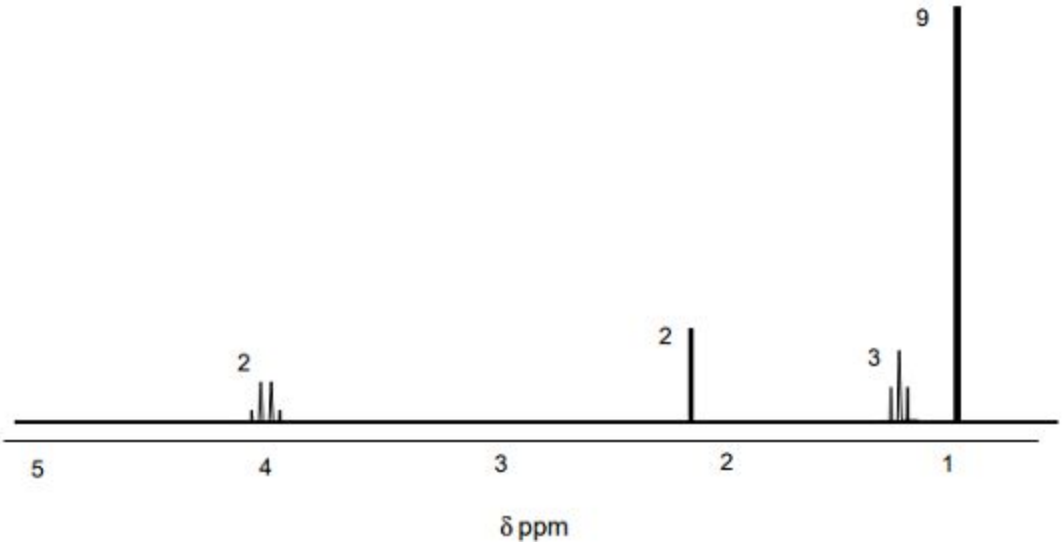
[Total for Q17: 14 marks]

18. A sample of an unknown chemical compound **A** has been obtained. A series of analytical techniques were performed to identify its structure:

- Mass spectrometry showed a molecular ion peak for **A** at *m*/*z* = 144.
- **A** is known to contain, by mass: 66.63% carbon, 11.18% hydrogen, 22.19% oxygen.
- The infrared (IR) spectrum of **A** is:



- The proton NMR (^{1}H-NMR) spectrum of **A** is:



Using the information given, deduce:

- The molecular formula of **A**
- The structure of **A**
- The IUPAC name of **A**

In your answer, you should show clearly how you deduce each part of the structure from the spectra provided. [9 marks]

[Total for Q18: 9 marks]

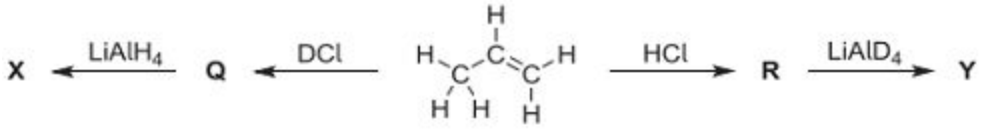
19. Lithium aluminium hydride is a useful compound in organic chemistry.

a. Lithium hydride reacts with aluminium chloride to form lithium aluminium hydride ($LiAlH_4$) and one other by-product.

Give a balanced chemical equation for the formation of lithium aluminium hydride from lithium hydride and aluminium chloride. [2 marks]

b. Lithium aluminium deuteride can be prepared if deuterium gas is used in place of normal hydrogen. Deuterium, often given the symbol D, is the non-radioactive isotope of hydrogen, i.e. D = ^2H. The formula for lithium aluminium deuteride can be written $LiAlD_4$. Both $LiAlH_4$ and $LiAlD_4$ are common reducing agents and the latter is useful for preparing deuterium-containing compounds.

Isomers of mono-deuterated propane, **X** and **Y**, may be prepared from propene according to the following scheme which also uses hydrogen chloride, HCl, and deuterium chloride, DCl. In the scheme, only the **major** organic compounds are shown; other by-products are not.



i) Deduce the structures of **Q**, **R**, **X** and **Y** formed in this scheme. [4 marks]

ii) Outline the mechanism for the formation of **Q** from propene. [3 marks]

c. 2,2-dideuterated propane may be prepared easily in two steps, from a mono-deuterated propene, **Z**. (The formula for **Z** is C_3H_5D.)

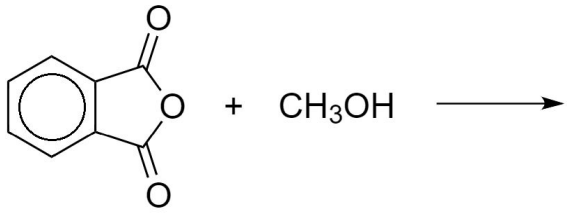
i) Draw the structures of all the alkenes with formula C_3H_5D. [4 marks]

ii) Give a synthesis, in the form of a reaction scheme, of 2,2-dideuterated propane starting from **Z**, showing reagents and intermediates in each step, using the displayed formula for **Z**. [5 marks]

[Total for Q19: 18 marks]

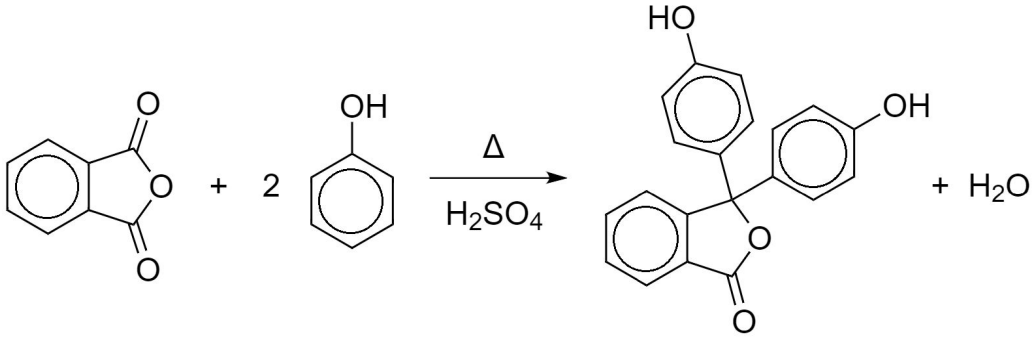
20. Phthalic anhydride is a common precursor to the indicator phenolphthalein.

a. i) Complete the following equation for the reaction of one molecule of benzene-1,2-dicarboxylic anhydride (phthalic anhydride) with one molecule of methanol by drawing the skeletal formula of the main product. [1 mark]

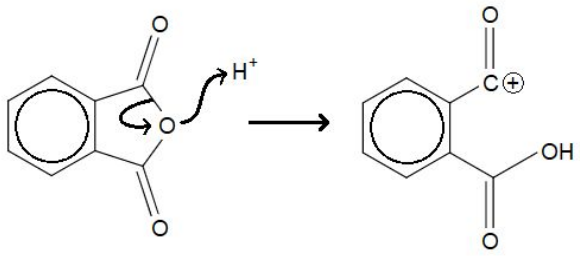


ii) Name and outline the mechanism for this reaction. [5 marks]

b. The phenolphthalein is synthesised by heating phthalic anhydride with phenol in the presence of concentrated sulfuric acid as shown in the following equation.



It is known that the first step of the mechanism for this conversion is



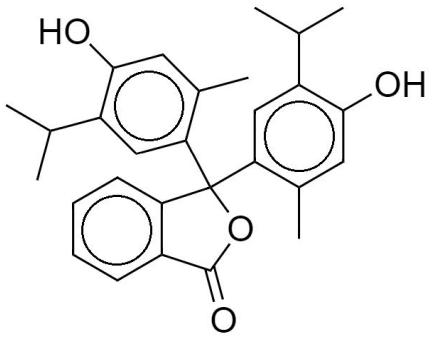
By considering carefully the reactions of the functional groups present and the products, suggest and outline the mechanism for this synthesis. In your answer, you should use skeletal formulae for benzene rings and displayed or structural formulae elsewhere.

(Represent the catalyst with H^+. You are advised to use the space below for planning and form your mechanism on the next page.) [9 marks]

(More space to answer Q20.b. Turn over for the next part of this question.)

c. Thymolphthalein is a similar indicator compound, also formed from phthalic anhydride and a phenol derivative in a similar reaction as phenolphthalein.

The structure of thymolphthalein is shown below.



Deduce the structure of the phenol derivative used to form thymolphthalein from phthalic anhydride. [1 mark]

[Total for Q20: 16 marks]

End of Questions

Question Sources

Q1:	MCAT Past Exam (Medical Chemistry)
Q2:	NSAA Past Paper (Chemistry)
Q7, 8:	AQA A-Level Chemistry Past Paper
Q16:	AQA A-Level Chemistry Past Paper
Q18:	AQA A-Level Chemistry Past Paper
Q19:	NSAA Past Paper (Chemistry)
Q20a:	AQA A-Level Chemistry Past Paper