



Please write clearly in block capitals.

Centre number

--	--	--	--	--

Candidate number

--	--	--	--

Surname

Forename(s)

Candidate signature

A-level CHEMISTRY

Paper 2 Organic and Physical Chemistry

Monday 19 June 2017

Morning

Time allowed: 2 hours

Materials

For this paper you must have:

- the Periodic Table/Data Booklet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this booklet. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 105.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
TOTAL	



J U N 1 7 7 4 0 5 2 0 1

IB/M/Jun17/E6

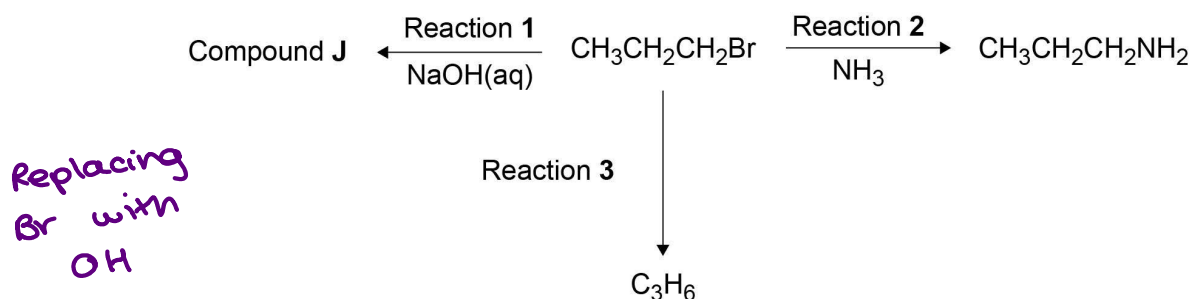
7405/2

Answer **all** questions in the spaces provided

0 1

Figure 1 shows some compounds made from a halogenoalkane.

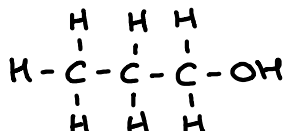
Figure 1



0 1 . 1

Draw the displayed formula of **compound J**.

[1 mark]



0 1 . 2

Name the **mechanism** for Reaction 2 and give an **essential condition** used to ensure that **CH₃CH₂CH₂NH₂** is the **major product**.

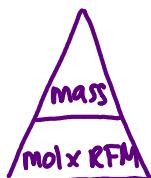
[2 marks]

Name of mechanism nucleophilic substitutionCondition Excess NH₃ (ensures 1° product produced)

0 1 . 3

Calculate the **mass**, in grams, of **CH₃CH₂CH₂NH₂** produced from **25.2 g** of **CH₃CH₂CH₂Br** in Reaction 2 assuming a **75.0% yield**.Give your answer to the **appropriate number of significant figures**.

[3 marks]



$$\begin{aligned} M_r \text{ of } \text{CH}_3\text{CH}_2\text{CH}_2\text{Br} &= 12 + 3 + 12 + 2 + 12 + 2 + \\ &77.9 = 122.9 \text{ g mol}^{-1} \end{aligned}$$

$$\frac{25.2}{122.9} = 0.205 \text{ mol} \quad \text{As assuming 75\% yield}$$

$$0.205 \times 0.75 = 0.154 \text{ mol}$$

$$0.154 \times 59 = 9.07 \text{ g}$$

→ Mr of CH₃CH₂CH₂NH₂

$$12 + 3 + 12 + 2 + 12 + 2 + 14 + 2 = 59$$

Mass 9.07 g

0 1 . 4

When Reaction 2 is carried out under different conditions, a compound with molecular formula $C_9H_{21}N$ is produced.

Draw the skeletal formula of the compound.

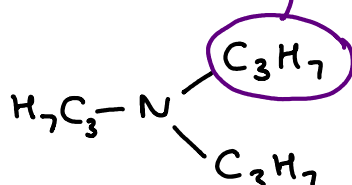
Identify the functional group in the compound including its classification.

[2 marks]

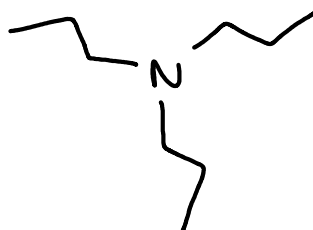
Propyl
groups

Skeletal formula

Structural



Skeletal



Functional group including classification tertiary amine

0 1 . 5

Identify the reagent and conditions used in Reaction 3.

[1 mark]

NaOH and Ethanolic

0 1 . 6

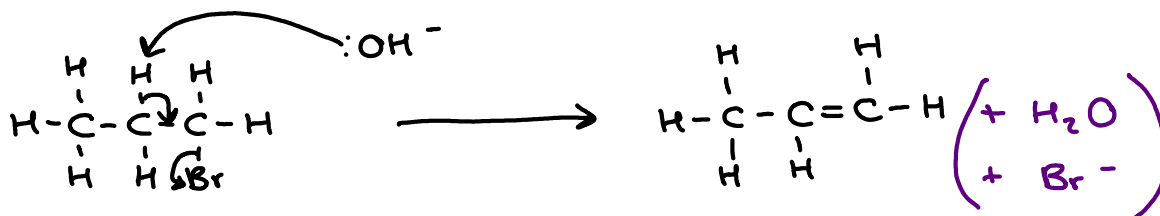
Name and outline a mechanism for Reaction 3.

[4 marks]

Elimination
as
alkene
produced

Name of mechanism Elimination

Mechanism



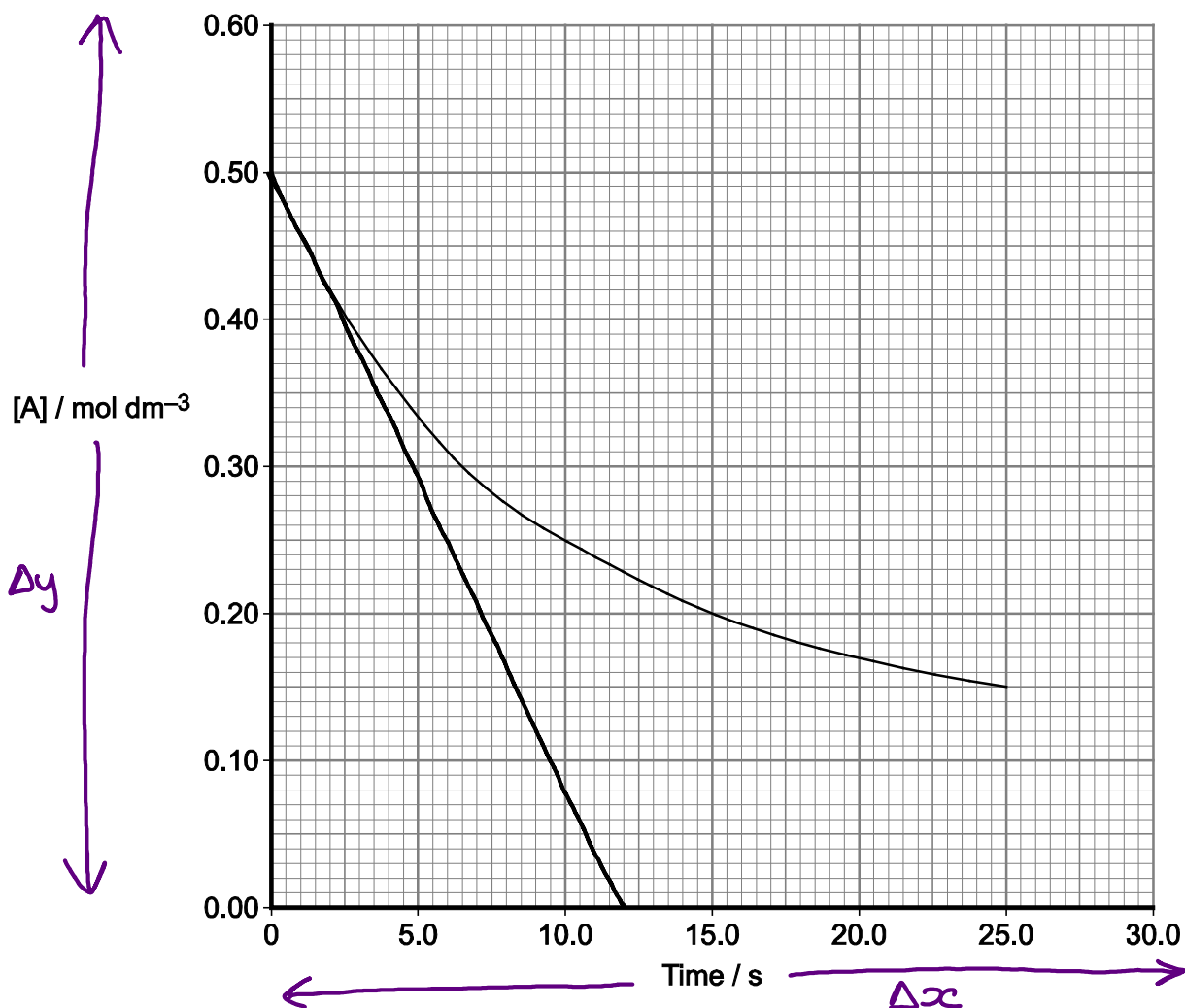
0 2

The rate equation for the reaction between compounds A and B is

$$\text{rate} = k[\text{A}]^2[\text{B}]$$

Figure 2 shows how, in an experiment, the concentration of A changes with time, t , in this reaction.

Figure 2



0 2 . 1

Draw a tangent to the curve at $t = 0$

[1 mark]

0 2 . 2

Use this tangent to deduce the initial rate of the reaction.

Tangent $\Rightarrow$ Gradient = Rate of Reaction [1 mark]

$$\frac{\Delta y}{\Delta x} = \frac{0.5}{12} = 0.416$$

Initial rate 0.416 mol dm⁻³s⁻¹



0 2 . 3

The experiment was repeated at the same temperature and with the same initial concentration of B but with a different initial concentration of A. The new initial rate was 1.7 times greater than in the original experiment.

Calculate the new initial concentration of A.

[2 marks]

$$\text{Rate} = k[A]^2[B]$$

$$\text{Rate} = k[A]^2[B] \text{ (Reaction 1)}$$

$$\text{Rate} = k[A]^2[B] \text{ (Reaction 2)}$$

$$1.7 = \frac{k[A]^2[B]}{k[0.5]^2[B]} = \frac{[A]^2}{[0.5]^2}$$

$$[A]^2 = 1.7 \times [0.5]^2 = 0.425$$

$$[A] = 0.65$$

Initial concentration of A 0.65 mol dm⁻³

4

Turn over for the next question



0 3

A series of experiments is carried out with compounds **C** and **D**. Using the data obtained, the rate equation for the reaction between the two compounds is deduced to be

$$\text{rate} = k[\text{C}][\text{D}]$$

In one experiment at 25 °C, the initial rate of reaction is $3.1 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$ when the initial concentration of **C** is 0.48 mol dm^{-3} and the initial concentration of **D** is 0.23 mol dm^{-3}

0 3

. 1

Calculate a value for the rate constant at this temperature and give its units.

[3 marks]

$$\text{Rate} = k[\text{C}][\text{D}]$$

$$3.1 \times 10^{-3} = k[0.48][0.23]$$

$$k = \frac{3.1 \times 10^{-3}}{[0.48][0.23]} = 2.8 \times 10^{-2}$$

$$\text{Units: } \frac{\cancel{\text{mol dm}^{-3}} \text{ s}^{-1}}{\cancel{\text{mol dm}^{-3}} \text{ mol dm}^{-3}} = \frac{\text{s}^{-1}}{\text{mol dm}^{-3}} = \text{mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$$

when we flip the
indices if +ve becomes
-ve and vice versa

Rate constant 2.8×10^{-2} Units $\text{mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$



0 3 . 2

An equation that relates the rate constant, k , to the activation energy, E_a , and the temperature, T , is

Arrhenius
Equation

$$\ln k = \frac{-E_a}{RT} + \ln A$$

Use this equation and your answer from Question 3.1 to calculate a value, in kJ mol^{-1} , for the activation energy of this reaction at 25°C .

For this reaction $\ln A = 16.9$

The gas constant $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

$$273 + 25 = 298 \text{ K}$$

→ Convert into
kelvin as
units = $\text{J K}^{-1} \text{ mol}^{-1}$

(If you were unable to complete Question 3.1 you should use the value of 3.2×10^{-3} for the rate constant. This is not the correct value.)

[4 marks]

our value is 2.8×10^{-2}

$$\ln k = \frac{-E_a}{RT} + \ln A$$

$$\ln(2.8 \times 10^{-2}) = \frac{-E_a}{8.31 \times 298} + 16.9 \quad \rightarrow -16.9 \text{ from both sides}$$

$$-3.5727 - 16.9 = \frac{-E_a}{2476.38}$$

store full answer on calculator don't round

$$-20.4727 \times 2476.38 = -E_a$$

$$-50,716 \text{ J mol}^{-1} = -E_a$$

$$50.716 \text{ kJ mol}^{-1} = E_a$$

$$51 \text{ kJ mol}^{-1} = E_a$$

Activation energy 51 kJ mol^{-1}



0 5

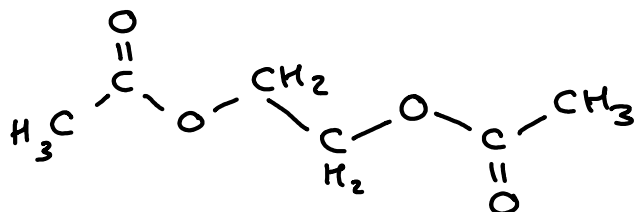
Ethanoic acid and ethane-1,2-diol react together to form the diester ($\text{C}_6\text{H}_{10}\text{O}_4$) as shown.



0 5 . 1

Draw a structural formula for the diester $\text{C}_6\text{H}_{10}\text{O}_4$

[1 mark]



0 5 . 2

A small amount of catalyst was added to a mixture of 0.470 mol of ethanoic acid and 0.205 mol of ethane-1,2-diol.

The mixture was left to reach equilibrium at a constant temperature.

Complete **Table 1**.

Table 1

Same molar
ratio so change
is the same

Amount in the mixture / mol				
	CH_3COOH	$\text{HOCH}_2\text{CH}_2\text{OH}$	$\text{C}_6\text{H}_{10}\text{O}_4$	H_2O
At the start	0.470	0.205	0	0
At equilibrium	0.180	0.06	0.145	0.290

[3 marks]

Space for working

$$0.470 - 0.180 = 0.290 \text{ mol}$$

$$\frac{0.290}{2} = 0.145 \text{ mol}$$

$$0.205 - 0.145 = 0.06 \text{ mol}$$



0 5 . 3

Write an expression for the equilibrium constant, K_c , for the reaction.

The total volume of the mixture does not need to be measured to allow a correct value for K_c to be calculated.

Justify this statement.

Expression

$$K_c = \frac{[\text{ester}] \times [\text{H}_2\text{O}]^2}{[\text{CH}_3\text{COOH}]^2 \times [\text{HOCH}_2\text{CH}_2\text{OH}]}$$

[2 marks]

Justification volume cancels out OR equal
number of moles on each side.

0 5 . 4

A different mixture of ethanoic acid, ethane-1,2-diol and water was prepared and left to reach equilibrium at a different temperature from the experiment in Question 5.2

The amounts present in the new equilibrium mixture are shown in Table 2.

Table 2

Amount in the mixture / mol				
	CH ₃ COOH	HOCH ₂ CH ₂ OH	C ₆ H ₁₀ O ₄	H ₂ O
At new equilibrium	To be calculated	0.264	0.802	1.15

The value of K_c was 6.45 at this different temperature.

Use this value and the data in Table 2 to calculate the amount, in mol, of ethanoic acid present in the new equilibrium mixture.

Give your answer to the appropriate number of significant figures.

[3 marks]

$$6.45 = \frac{(0.802 \times 10^{-1}/V)(1.15/V)^2}{[\text{CH}_3\text{COOH}]^2 (2.64 \times 10^{-1}/V)}$$

As volume cancels out ...

$$\frac{0.802 \times 1.15^2}{6.45 \times 0.264} = [\text{CH}_3\text{COOH}]^2 \text{ (mol)}$$

$$\sqrt{\frac{0.802 \times 1.15^2}{6.45 \times 0.264}} = \sqrt{0.623} = 0.789 \text{ mol}$$

Amount of ethanoic acid 0.789 mol



0 6 . 4

An amide link is also formed when an acyl chloride reacts with a primary amine.

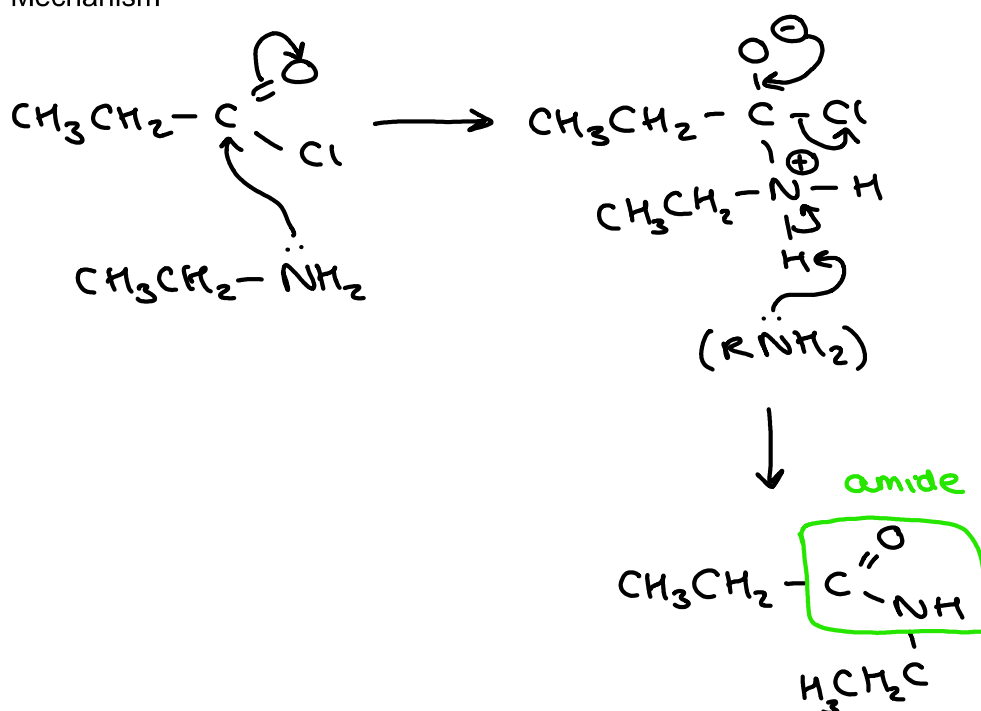
Name and outline a mechanism for the reaction between $\text{CH}_3\text{CH}_2\text{COCl}$ and $\text{CH}_3\text{CH}_2\text{NH}_2$

Give the IUPAC name of the organic product.

[6 marks]

Name of mechanism nucleophilic addition - Elimination

Mechanism



IUPAC name of organic product N-ethylpropanamide

10

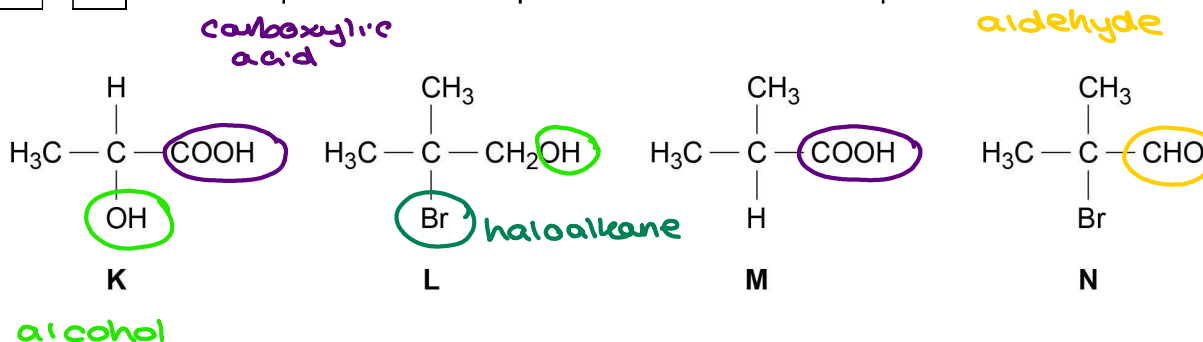


0 7

Test-tube reactions can be used to identify the functional groups in organic molecules.

0 7 . 1

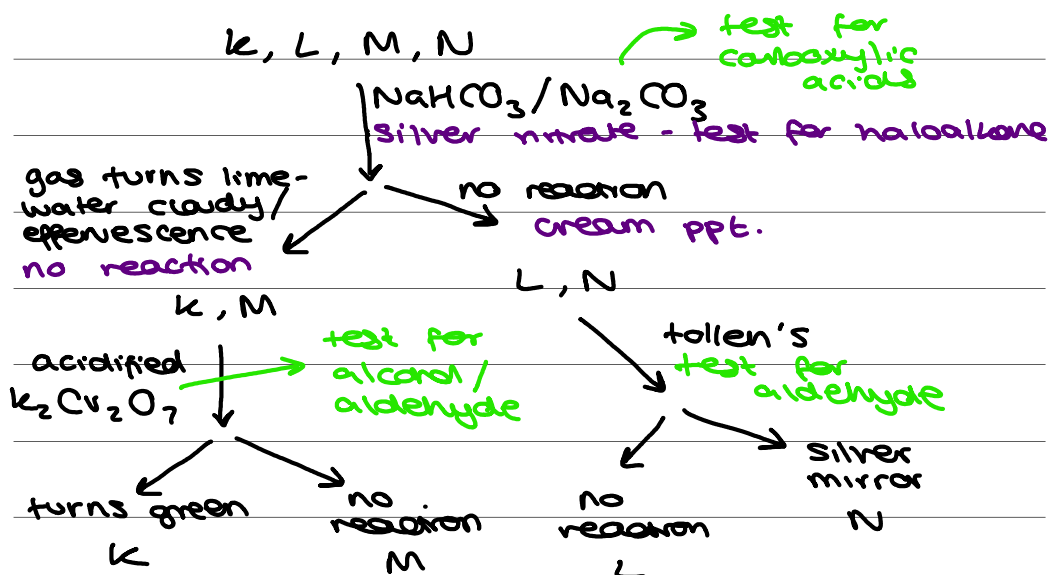
You are provided with samples of each of the four compounds.



Describe how you could distinguish between all four compounds using the minimum number of tests on each compound.

You should describe what would be observed in each test.

[6 marks]



0 8

This question is about nitrobenzenes.

0 8 . 1

Nitrobenzene reacts when heated with a mixture of concentrated nitric acid and concentrated sulfuric acid to form a mixture of three isomeric dinitrobenzenes.

Write an equation for the reaction of concentrated nitric acid with concentrated sulfuric acid to form the species that reacts with nitrobenzene.

[1 mark]

electrophile



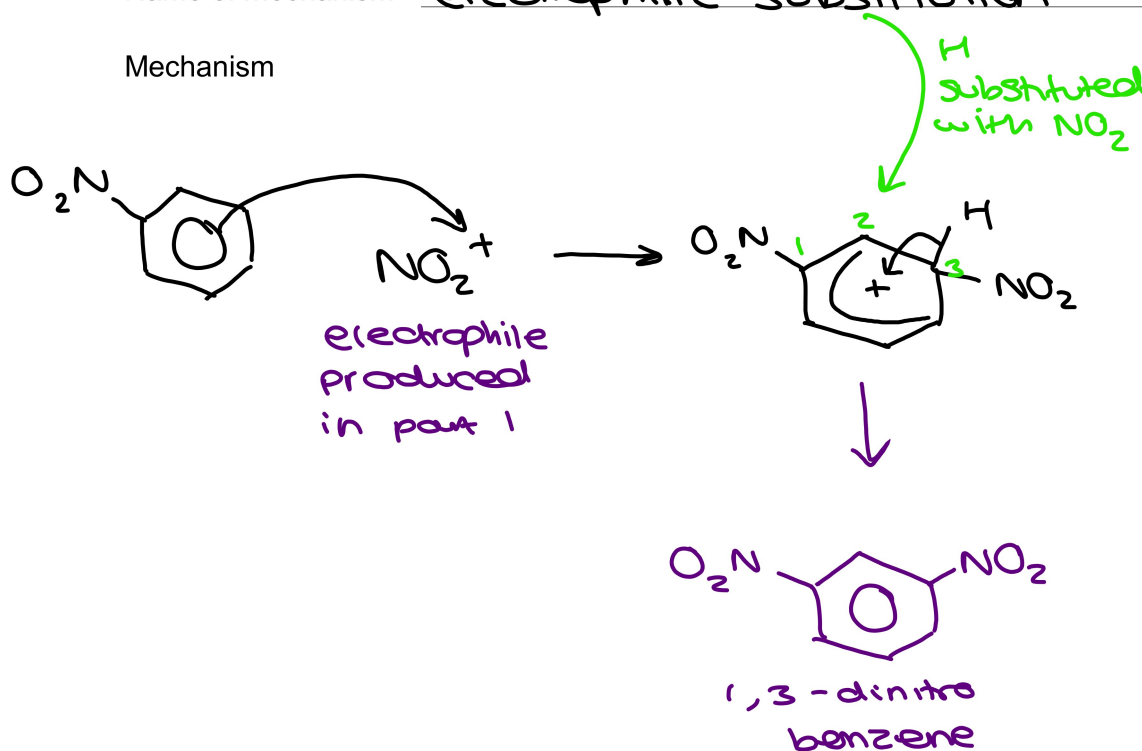
0 8 . 2

Name and outline a mechanism for the reaction of this species with nitrobenzene to form 1,3-dinitrobenzene.

[4 marks]

Name of mechanism electrophilic substitution

Mechanism

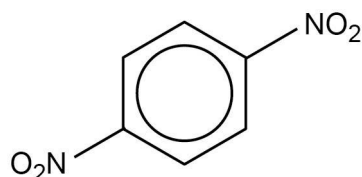
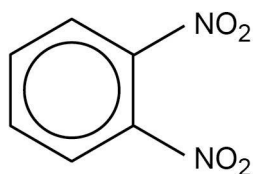


Turn over for the next question



0 8 . 3

The dinitrobenzenes shown were investigated by thin layer chromatography (TLC).

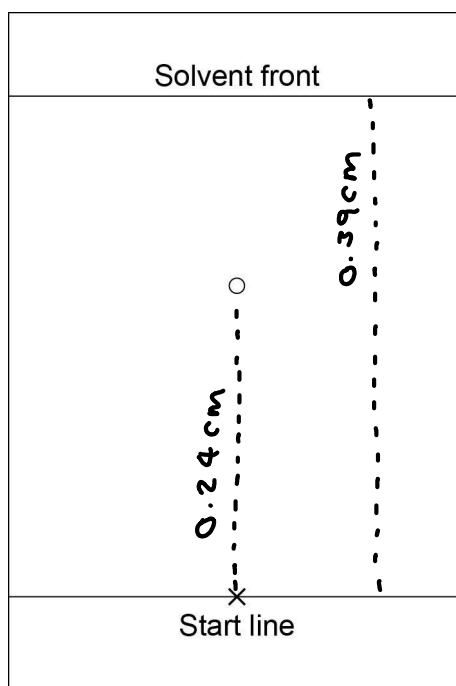


In an experiment, carried out in a fume cupboard, a concentrated solution of pure 1,4-dinitrobenzene was spotted on a TLC plate coated with a solid that contains polar bonds. Hexane was used as the solvent in a beaker with a lid.

The start line, drawn in pencil, the final position of the spot and the final solvent front are shown on the chromatogram in **Figure 3**

$$R_f = \frac{\text{distance moved by sample}}{\text{solvent front}}$$

Figure 3



Use the chromatogram in **Figure 3** to deduce the R_f value of 1,4-dinitrobenzene in this experiment.

Tick (✓) **one** box.

A 0.41

☐

B 0.46

☐

C 0.52

☐

D 0.62

☒

[1 mark]

$$\frac{0.24}{0.39} = 0.62$$



08 . 4

State in general terms what determines the distance travelled by a spot in TLC. [1 mark]

Solubility in moving phase and
retention by Stationary phase.

08 . 5

To obtain the chromatogram, the TLC plate was held by the edges and placed in the solvent in the beaker in the fume cupboard. The lid was then replaced on the beaker.

Give one other practical requirement when placing the plate in the beaker.

[1 mark]

Solvent depth must be below the
Start line.

08 . 6

A second TLC experiment was carried out using 1,2-dinitrobenzene and 1,4-dinitrobenzene. An identical plate to that in Question 8.3 was used under the same conditions with the same solvent. In this experiment, the R_f value of 1,4-dinitrobenzene was found to be greater than that of 1,2-dinitrobenzene.

Deduce the relative polarities of the 1,2-dinitrobenzene and 1,4-dinitrobenzene and explain why 1,4-dinitrobenzene has the greater R_f value.

[2 marks]

Relative polarities

↳ distance
travelled by sample is
greater

1,2-dinitrobenzene is more polar

Explanation

1,4-dinitrobenzene is less attracted
to Stationary phase.



0 8 . 7

A third TLC experiment was carried out using 1,2-dinitrobenzene. An identical plate to that in Question 8.3 was used under the same conditions, but the solvent used contained a mixture of hexane and ethyl ethanoate.

A student stated that the R_f value of 1,2-dinitrobenzene in this third experiment would be greater than that of 1,2-dinitrobenzene in the experiment in Question 8.6

Is the student correct? Justify your answer.

[2 marks]

Solvent more polar so the polar isomer is more attracted to the solvent.



so sample will move further up / distance travelled by sample will be greater.

12



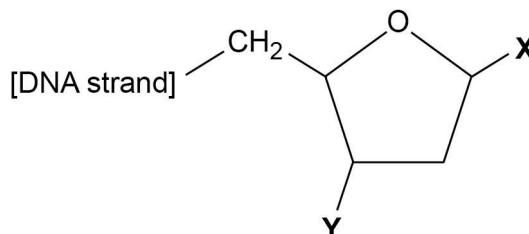
0 9

Use the Data Booklet to help you answer these questions.

DNA exists as two strands of nucleotides in the form of a double helix with hydrogen bonding between the two strands.

0 9 . 1

A deoxyribose molecule in a strand of DNA is shown.

Name the types of group attached to 2-deoxyribose at positions **X** and **Y**.**[2 marks]**X baseY phosphate group

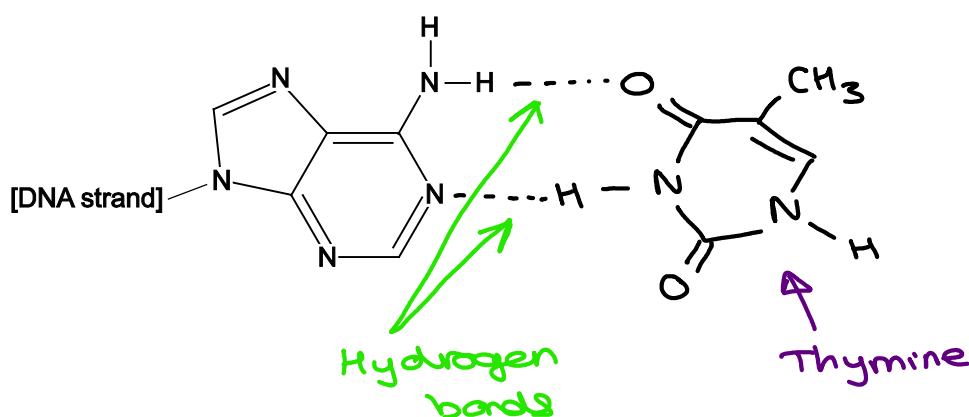
0 9 . 2

In the DNA double helix, adenine is linked by hydrogen bonds to a molecule in the other strand of DNA.

Complete the diagram below to show the **other molecule** and the **hydrogen bonds** between it and **adenine**.

[2 marks]

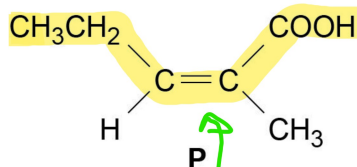
DNA pairs AT, GC



1 0

This question is about six isomers of $C_6H_{10}O_2$

1 0 . 1

Give the full IUPAC name of isomer **P**.largest carbon
chain
pent ...

P

alkene

[1 mark]

Z - 2 - methylpent - 2 - enoic acid

1 0 . 2

A sample of **P** was mixed with an excess of oxygen and the mixture ignited. After cooling to the original temperature, the **total volume of gas** remaining was **335 cm³**

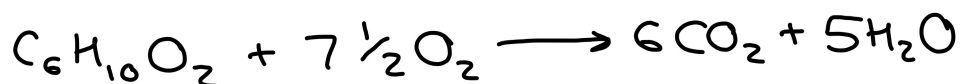
When this gas mixture was passed through aqueous sodium hydroxide, the carbon dioxide reacted and the **volume of gas decreased to 155 cm³**

Both gas volumes were measured at **25 °C** and **105 kPa**

Write an **equation for the combustion of P** in an excess of oxygen and calculate the **mass, in mg, of P** used.

The gas constant **$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$**

[5 marks]



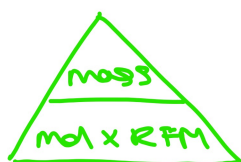
$$\text{Volume of } CO_2: 335 - 155 = 180 \text{ cm}^3$$

$$PV = nRT \longrightarrow n = PV/RT$$

$$\begin{aligned} \text{moles of } CO_2: & \frac{105000 \text{ Pa} \times (180 \times 10^{-6}) \text{ m}^3}{8.31 \text{ J K}^{-1} \text{ mol}^{-1} \times (273 + 25) \text{ K}} \\ & = 7.632 \times 10^{-3} \text{ mol} \end{aligned}$$

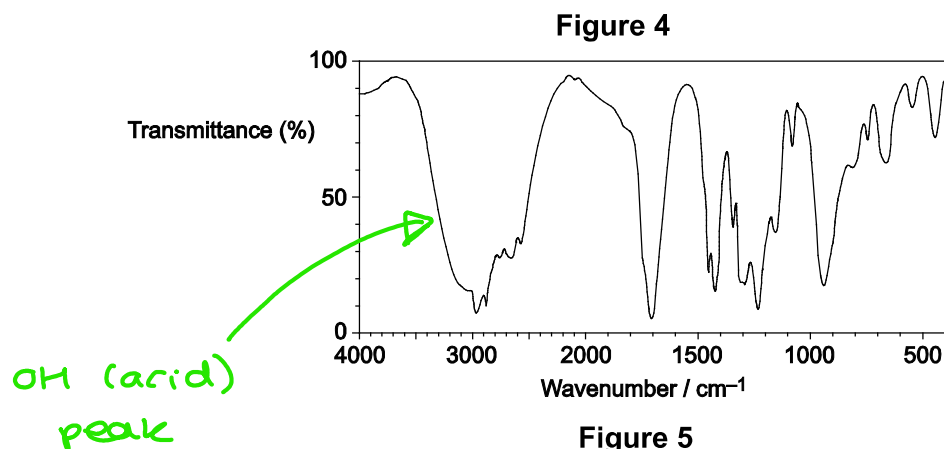
$$\text{moles of P: } 7.632 \times 10^{-3} \div 6 = 1.272 \times 10^{-3} \text{ mol}$$

$$\begin{aligned} \text{mass of P: } & 1.272 \times 10^{-3} \times ((6 \times 12) + 10 + (16 \times 2)) \\ & = 145 \text{ mg} \longrightarrow 0.145 \text{ g} \end{aligned}$$

Mass of **P** used 145 mg

1 0 . 3

Isomer **Q** ($C_6H_{10}O_2$) is a cyclic compound. The infrared spectrum of **Q** is shown in **Figure 4** and the ^{13}C NMR spectrum of **Q** is shown in **Figure 5**.

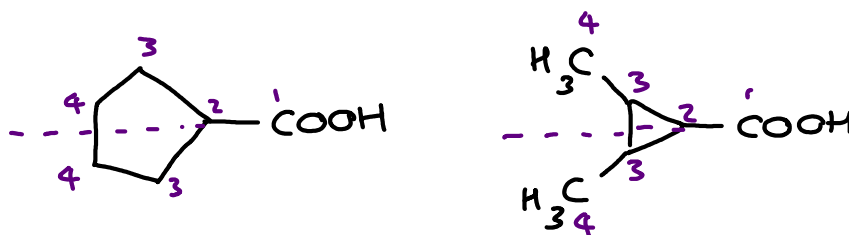


Use these spectra and Tables **A** and **C** in the Data Booklet to deduce the structure of **Q**.

In your answer, state one piece of evidence you have used from each spectrum.

[3 marks]

Structure of **Q**.



Evidence from **Figure 4**

OH (acid) peak 2500 - 3000 cm^{-1}

present

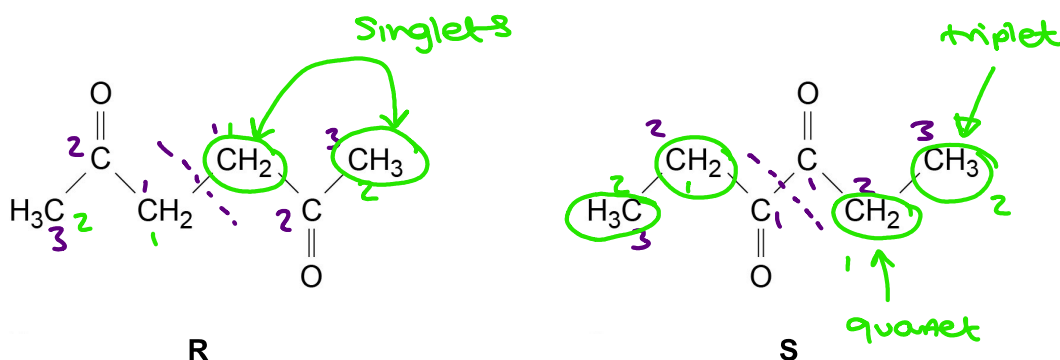
Evidence from **Figure 5**

^{13}C NMR has 4 peaks so 4

environments



1 0 . 4

Isomers **R** and **S** are shown.

Although the ¹³C spectra of **R** and **S** both show the same number of peaks, the spectra can be used to distinguish between the isomers.

Justify this statement using Table **C** from the Data Booklet.

Give the number of peaks for each isomer.

[3 marks]

Justification

- R has 4C next to C=O
- S has 2C next to C=O
- In the range $\delta = 20-50$ R has 2 peaks and S only has one.

Number of peaks 3



1	0
---	---

 .

5

Although the ^1H spectra of **R** and **S** both show the same number of peaks, the spectra can be used to distinguish between the isomers.

Justify this statement using the splitting patterns of the peaks.

Give the number of peaks for each isomer.

[3 marks]

Justification

- R both Singlets
- S has a triplet and a quartet

Number of peaks 2

Question 10 continues on the next page



1 0

6

The action of heat on 5-hydroxyhexanoic acid can lead to two different products.

On gentle heating, 5-hydroxyhexanoic acid loses water to form a cyclic compound, **T** ($C_6H_{10}O_2$).

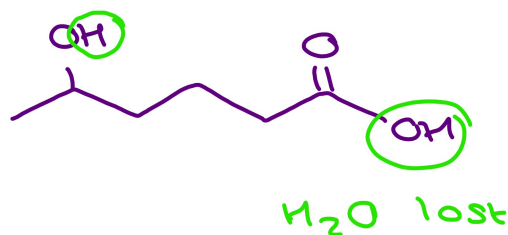
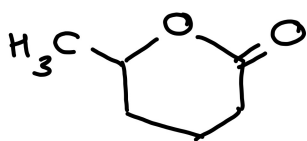
Under different conditions, 5-hydroxyhexanoic acid forms a polyester.

Draw the structure of **T**.

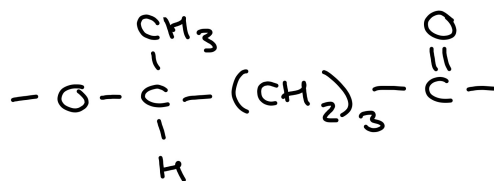
Draw the repeating unit of the polyester and name the type of polymerisation.

[3 marks]

Structure of **T**



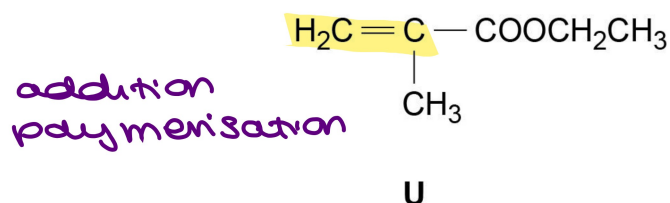
Repeating unit of polyester



Type of polymerisation Condensation



1 0 . 7

Isomer **U** is shown.

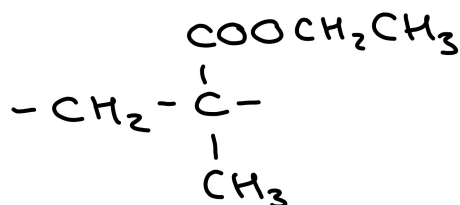
The polymer formed by **U** and the polymer formed by 5-hydroxyhexanoic acid in Question 10.6 both contain ester groups that can be hydrolysed.

Draw the repeating unit of the polymer formed by **U**.

Justify the statement that, although both polymer structures contain ester groups, the polymer formed by **U** is not biodegradable.

[3 marks]

Repeating unit of polymer formed by **U**.



Justification

• Strong non-polar C-C bonds cannot be attacked by nucleophiles/hydrolysed.

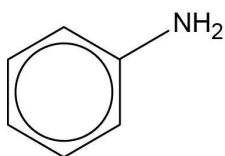
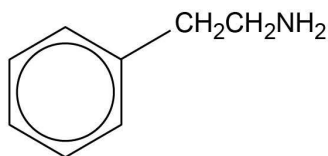
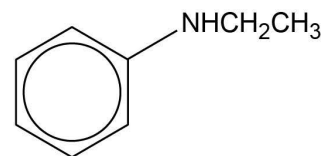
Turn over for the next question

Turn over ►



1 1

This question is about the three amines, **E**, **F** and **G**.

**E****F****G**

1 1 . 1

Amines **E**, **F** and **G** are weak bases.

Explain the difference in base strength of the three amines and give the order of increasing base strength.

[6 marks]

Strength depends on availability of lone pair on N

E: N lone pair is delocalised into the ring so is less available to donate/accept H^+

F or **G**: electrons pushed to N, +I inductive effect so more available to donate/accept H^+

Base strength order: $E < G < F$



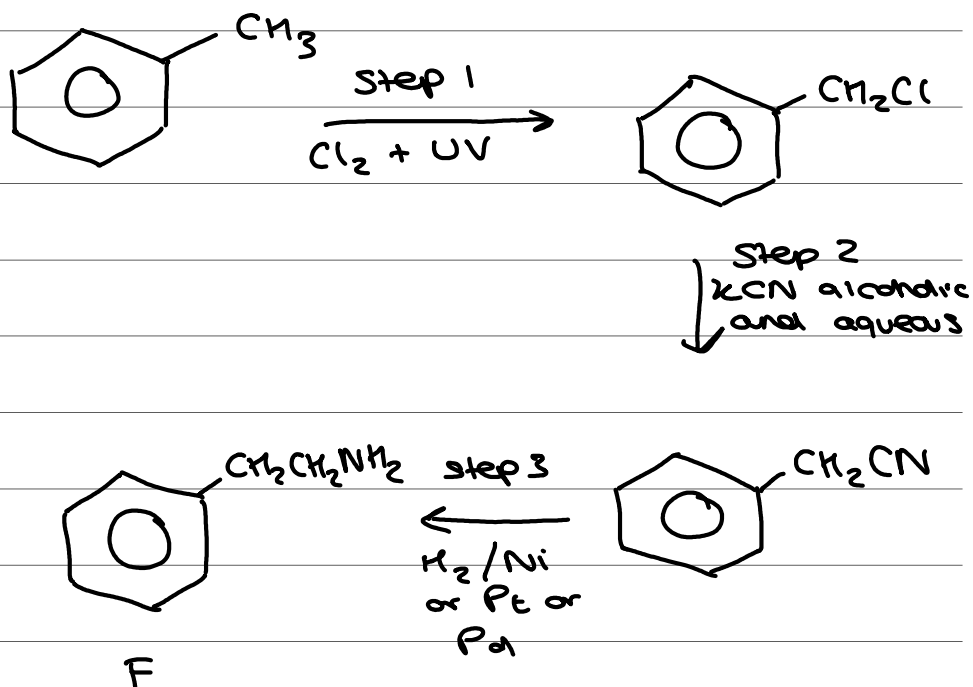
1 1 . 2

Amine **F** can be prepared in a three-step synthesis starting from methylbenzene.

Suggest the structures of the two intermediate compounds.

For each step, give reagents and conditions only. Equations and mechanisms are **not** required.

[5 marks]



END OF QUESTIONS



There are no questions printed on this page

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**

Copyright Information

For confidentiality purposes, from the November 2015 examination series, acknowledgements of third party copyright material will be published in a separate booklet rather than including them on the examination paper or support materials. This booklet is published after each examination series and is available for free download from www.aqa.org.uk after the live examination series.

Permission to reproduce all copyright material has been applied for. In some cases, efforts to contact copyright-holders may have been unsuccessful and AQA will be happy to rectify any omissions of acknowledgements. If you have any queries please contact the Copyright Team, AQA, Stag Hill House, Guildford, GU2 7XJ.

Copyright © 2017 AQA and its licensors. All rights reserved.

