

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	
<b>TOTAL</b>	



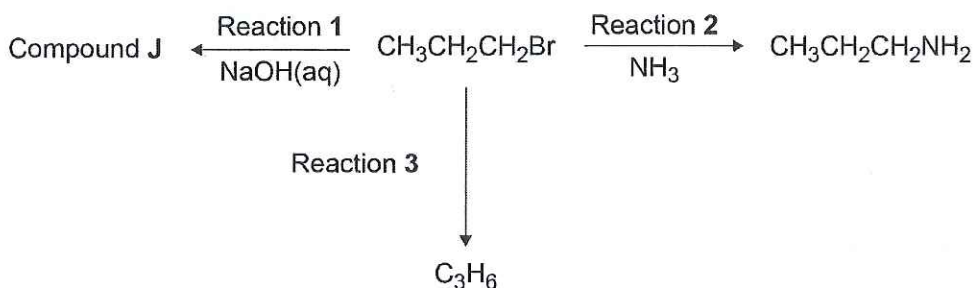
JUN177405201

IB/M/Jun17/E6

**7405/2**

Answer **all** questions in the spaces provided

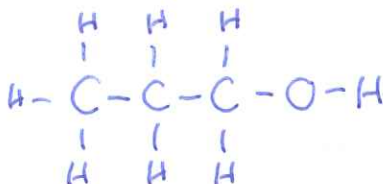
0 1

**Figure 1** shows some compounds made from a halogenoalkane.**Figure 1**

0 1 . 1

Draw the displayed formula of compound J.

[1 mark]



\* Don't forget the O-H bond.

0 1 . 2

Name the mechanism for Reaction 2 and give an essential condition used to ensure that  $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$  is the major product.

[2 marks]

Name of mechanism

Nucleophilic Substitution

Condition

Excess  $\text{NH}_3$ 

← without this you would get multiple substitutions.

0 1 . 3

Calculate the mass, in grams, of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$  produced from 25.2 g of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$  in Reaction 2 assuming a 75.0% yield.

Give your answer to the appropriate number of significant figures.

[3 marks]

$$\frac{25.2}{122.9} = 0.2075 \text{ moles}$$

$$0.2075 \times 59 = 12.24 \text{ g} \quad \times 75 = \frac{9.18 \text{ g}}{100}$$

\* odd - the markscheme says 9.07g using an initial mole of 0.205... however I do not get this.

Mass \_\_\_\_\_ 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]

Skeletal formula



the different conditions would be not having excess ammonia and allowing the formed amine ( $1^\circ$  or  $2^\circ$  etc.) to react with the haloalkane.

Functional group including classification

$3^\circ$  amine

0 1 . 5

Identify the reagent and conditions used in Reaction 3.

[1 mark]

\* Haloalkane  $\rightarrow$  alkene

NaOH in ethanolic conditions.

0 1 . 6

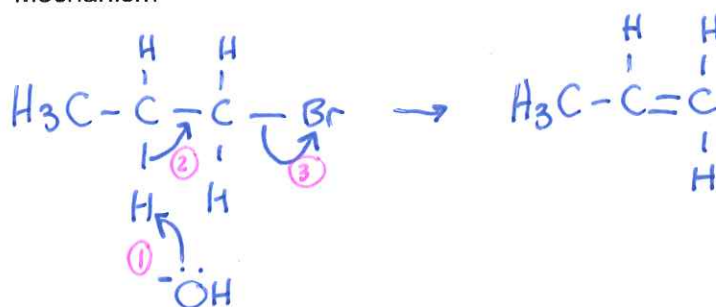
Name and outline a mechanism for Reaction 3.

[4 marks]

Name of mechanism

Elimination

Mechanism





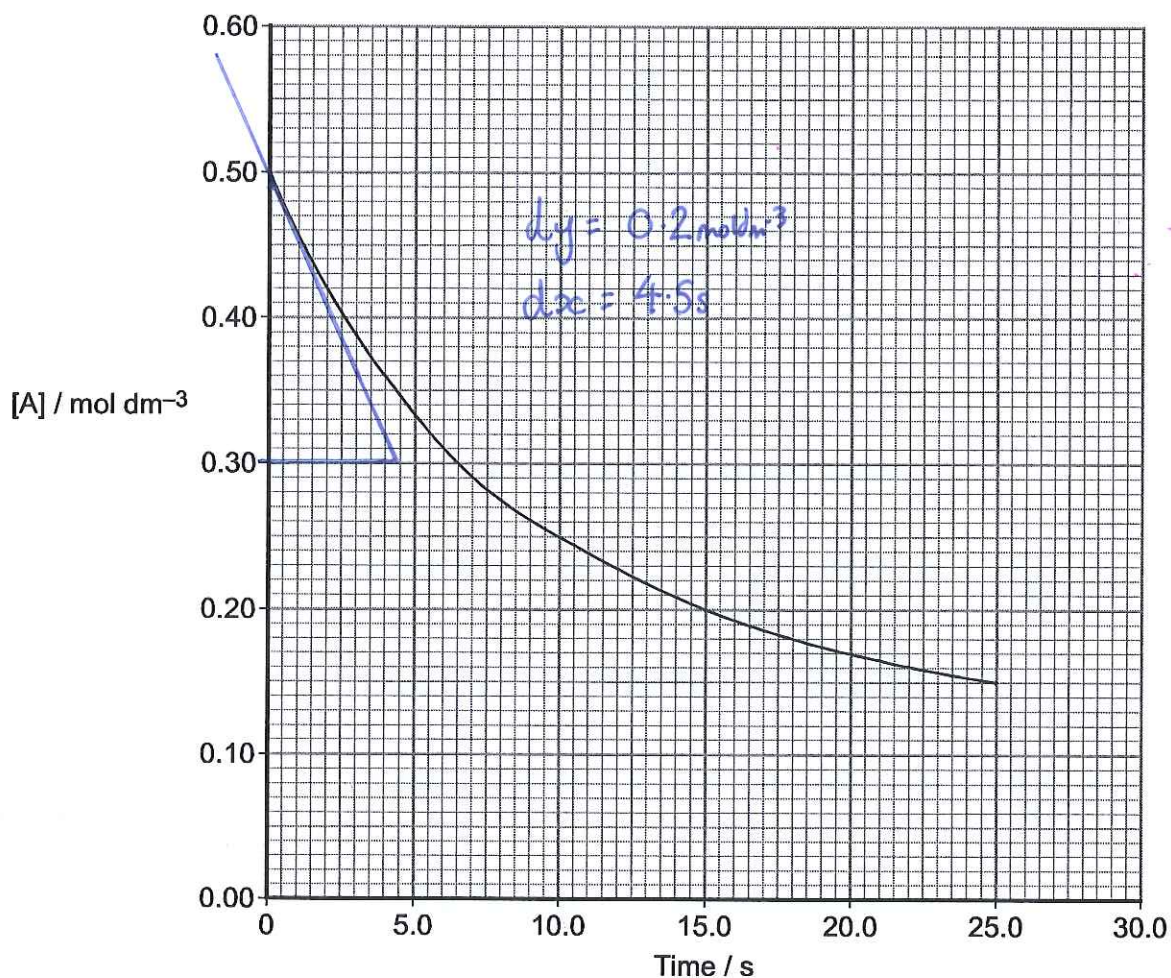
0 2

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.

[1 mark]

$$\frac{dy}{dx} = \text{rate} \quad \frac{0.2}{4.5} = \underline{\underline{0.044}}$$

Initial rate \_\_\_\_\_  $\text{mol dm}^{-3} \text{s}^{-1}$



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**.

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

$$\therefore [A] \text{ increases by } \sqrt{1.7}$$

$$\text{initial conc. was } 0.5 \text{ mol dm}^{-3} \text{ so } 0.5 \times \sqrt{1.7} = [A]$$

from the  
graph.

$$[A] = \underline{\underline{0.65 \text{ mol dm}^{-3}}}$$

← this comes from  
a partial re-arrangement  
of rate equation.

[2 marks]

Initial concentration of **A** \_\_\_\_\_ mol dm<sup>-3</sup>

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  $0.48 \text{ mol dm}^{-3}$  and the initial concentration of **D** is  $0.23 \text{ mol dm}^{-3}$

0 3

1

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

[3 marks]

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

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

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

$$k = 0.028 \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$$

$$\frac{\text{mol dm}^{-3} \text{ s}^{-1}}{\text{mol dm}^{-3} \times \text{mol dm}^{-3}}$$

Rate constant \_\_\_\_\_ Units \_\_\_\_\_



0 3 . 2

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

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

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

For this reaction  $\ln A = 16.9$

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

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

[4 marks]

$$\ln 0.028 = -3.58$$

$$E_a = R \times T \times (\ln A - \ln k)$$

*if you cannot rearrange  
to the correct form the  
must remember them.*

$$8.31 \times 298 \times (16.9 - -3.58) = E_a$$

*is now a (+).*

$$E_a = 50716 \text{ J mol}^{-1}$$

$$E_a = \underline{\underline{50.7 \text{ kJ mol}^{-1}}}$$

*÷ 1000 to give kJ*

Activation energy \_\_\_\_\_  $\text{kJ mol}^{-1}$





0 4

The aldehyde  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CHO}$  reacts with KCN followed by dilute acid to form a racemic mixture of the two stereoisomers of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}(\text{OH})\text{CN}$

0 4 . 1

Give the IUPAC name of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}(\text{OH})\text{CN}$

[1 mark]

\* Count from  
nitrile end.

2-hydroxyhexanenitrile

0 4 . 2

Describe how you would distinguish between separate samples of the two stereoisomers of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}(\text{OH})\text{CN}$

[2 marks]

Using plane polarised light, each enantiomer  
would rotate in opposite directions.

0 4 . 3

Explain why the reaction produces a racemic mixture.

[3 marks]

As the reactant contains a planar carbonyl  
group so the  $\text{:CN}^-$  can attack both above and  
below the plane with equal probability.





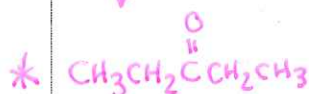
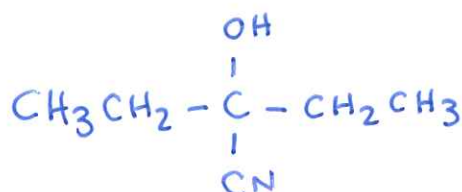
0 4 . 4

An isomer of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CHO}$  reacts with KCN followed by dilute acid to form a compound that does not show stereoisomerism.

Draw the structure of the compound formed and justify why it does not show stereoisomerism.

[2 marks]

Structure



Justification

The product does not contain a chiral carbon.

8

Turn over for the next question



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.

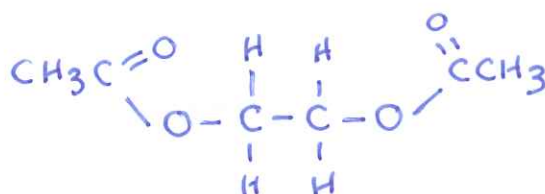


0 5

. 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

Amount in the mixture / mol				
	$\text{CH}_3\text{COOH}$	$\text{HOCH}_2\text{CH}_2\text{OH}$	$\text{C}_6\text{H}_{10}\text{O}_4$	$\text{H}_2\text{O}$
At the start	0.470	0.205	0	0
At equilibrium	0.180	0.06	0.145	0.29

$0.47 - 0.180$   
 $* = 0.29 = \text{H}_2\text{O as it is 2:2.}$

[3 marks]

Space for working

$\frac{0.29}{2} = 0.145 \text{ as it is 2:1}$

$* 0.205 - 0.145 = 0.06 \text{ as it is 2:1.}$



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.

[2 marks]

Expression

$$K_c = \frac{[C_6H_{10}O_4][H_2O]^2}{[CH_3COOH]^2[HOCH_2CH_2OH]}$$

Justification Same number of moles on both sides of the equation.

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 <sub>3</sub> COOH	HOCH <sub>2</sub> CH <sub>2</sub> OH	C <sub>6</sub> H <sub>10</sub> O <sub>4</sub>	H <sub>2</sub> 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]

$$6.45 = \frac{0.802 \times (1.15)^2}{(x)^2 \times 0.264}$$

↑  
3sf as it is the least you're given in the table.

$$\sqrt{\frac{0.802 \times (1.15)^2}{6.45 \times 0.264}} = x \quad x = \underline{\underline{0.789 \text{ mol}}}$$

Amount of ethanoic acid \_\_\_\_\_ mol



0 6

Use the Data Booklet to help you answer this question.

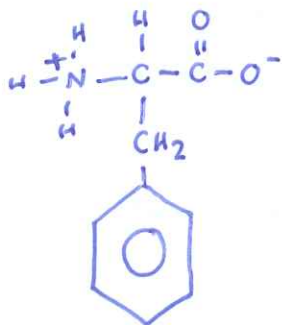
This question is about amino acids and peptide (amide) links.

0 6

. 1

Draw the structure of the zwitterion formed by phenylalanine.

[1 mark]

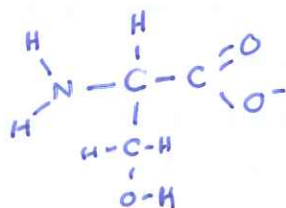


0 6

. 2

Draw the structure of serine at high pH.

[1 mark]



② high pH acid will protonate.

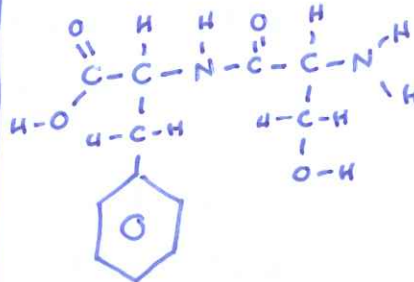
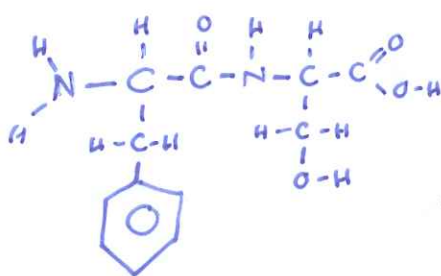
0 6

. 3

Draw the structures of both dipeptides formed when phenylalanine reacts with serine.

In each structure show all the atoms and bonds in the amide link.

[2 marks]

Look carefully they are  
totally different  
products!



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

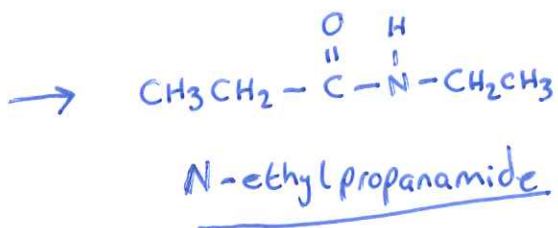
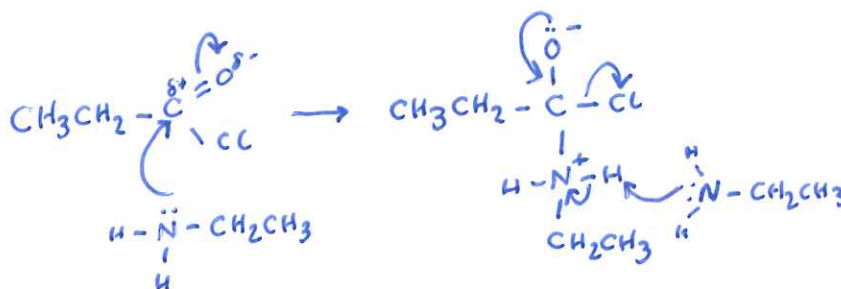
Give the IUPAC name of the organic product.

[6 marks]

Name of mechanism

(Nucleophilic) addition-elimination

Mechanism



\* N substituted amide formed - this means the nitrogen has been substituted and now has a chain on it.

IUPAC name of organic product

10

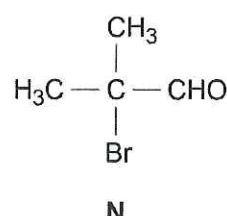
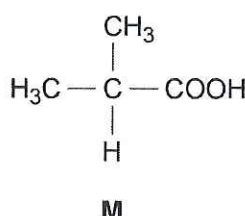
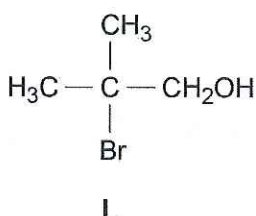
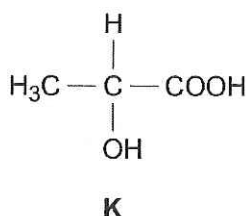


0 7

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]

for OH and  $-\text{C}(=\text{O})\text{H}$  → Test 1: Add acidified potassium dichromate to a sample of each. K, L and N would show a colour change of orange → green as they have been oxidised, M would not.

for  $\text{COOH}$  → Test 2: Add sodium carbonate to a sample of each. K and M would effervesce, the others would not.

for  $-\text{Br}$  → Test 3: Add silver nitrate solution to a sample of each (already mixed with sodium hydroxide, warmed and acidified with nitric acid). L and N would give cream ppt, K and M would not.

for  $-\text{C}(=\text{O})\text{H}$  → Test 4: Add Fehling's solution to a sample of each and a red ppt would be produced by N but not K, L or M.



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]



0 8 . 2

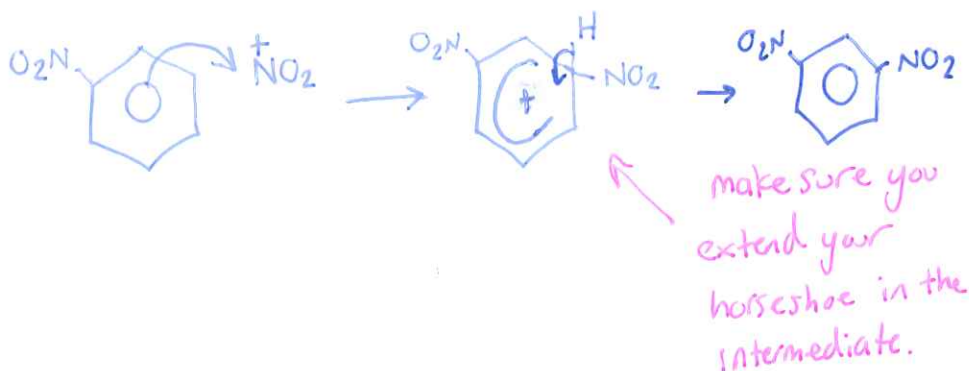
Name and outline a mechanism for the reaction of this species with nitrobenzene to form 1,3-dinitrobenzene.

[4 marks]

Name of mechanism

Electrophilic Substitution

Mechanism

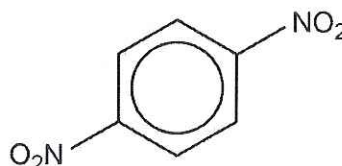
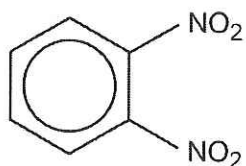


Turn over for the next question



0 8 . 3

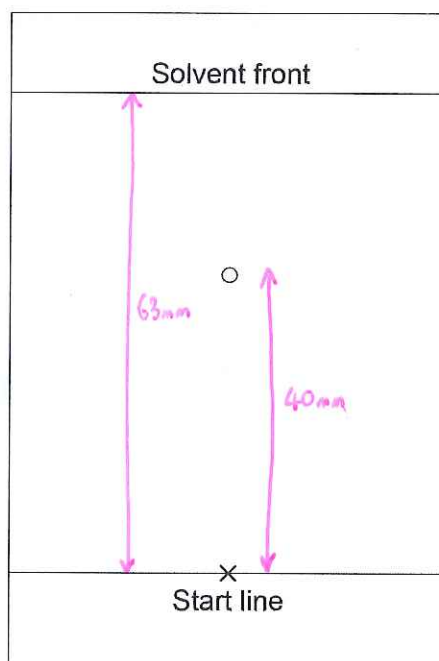
The dinitrobenzenes shown were investigated by thin layer chromatography (TLC).



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**

**Figure 3**



$$\frac{40}{63} = 0.63... \\ = D$$

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

Tick (✓) **one** box.

[1 mark]

A 0.41

☐

B 0.46

☐

C 0.52

☐

D 0.62

☒



0 8 . 4

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

Relative solubility/affinity for stationary and mobile phase.

0 8 . 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]

The solvent must be below the line on the plate.

0 8 . 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

1,2 is more polar.

Explanation

The more polar 1,2 is more attracted to the TLC plate and less soluble in the solvent.

converse  
accepted  
of course



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]

this solvent is polar  
compared to hexane and like  
dissolves like.

Yes. The solvent is now more polar. The more  
polar 1,2 is more soluble than the previous  
experiment.

12



0 9

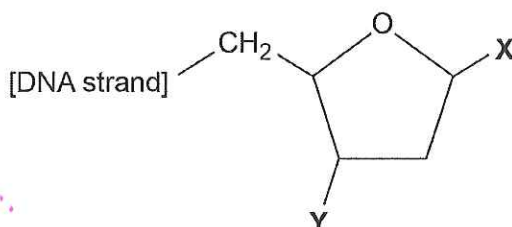
Use the Data Booklet to help you answer these questions.

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.



*Make sure you do not say sugar phosphate as they have drawn the sugar.*

Name the types of group attached to 2-deoxyribose at positions X and Y.

[2 marks]

X

Base

Y

Phosphate

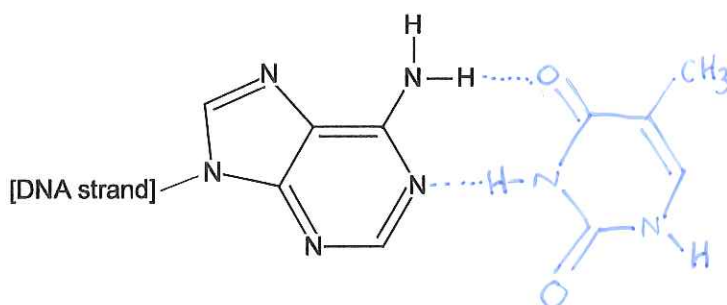
0 9

. 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]



*Thymine.  
You need to orient them to line up for hydrogen bonding.*

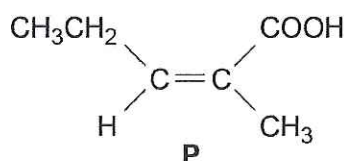


1 0

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

1 0

. 1

Give the full IUPAC name of isomer **P**.

[1 mark]

z-2-methylpent-2-en-1-oic 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  $335 \text{ cm}^3$

When this gas mixture was passed through aqueous sodium hydroxide, the carbon dioxide reacted and the volume of gas decreased to  $155 \text{ cm}^3$

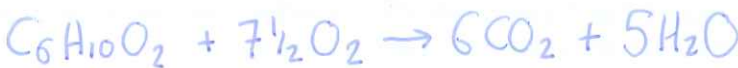
Both gas volumes were measured at  $25^\circ\text{C}$  and  $105 \text{ kPa}$

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]

What was reacted  
with the limewater.



$$335 - 155 = 180 \text{ cm}^3$$

$$\text{moles of } CO_2 = \frac{PV}{RT}$$

$$n = \frac{105000 \times (180 \times 10^{-6})}{8.31 \times 298}$$

$$n = 7.63 \times 10^{-3} \text{ moles}$$

$$CO_2 : C_6H_{10}O_2 \text{ ratio} = 6:1 \quad \text{from balanced equation.}$$

$$\therefore \frac{7.63 \times 10^{-3}}{6} = 1.272 \times 10^{-3} \text{ moles of } C_6H_{10}O_2$$

$$1.272 \times 10^{-3} \times 114 = 0.145 \text{ g} \times 1000 = 145 \text{ mg}$$

Don't forget  
this.

Mass of **P** used

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**.

CNMR  
not HNMR  
Be careful

Figure 4

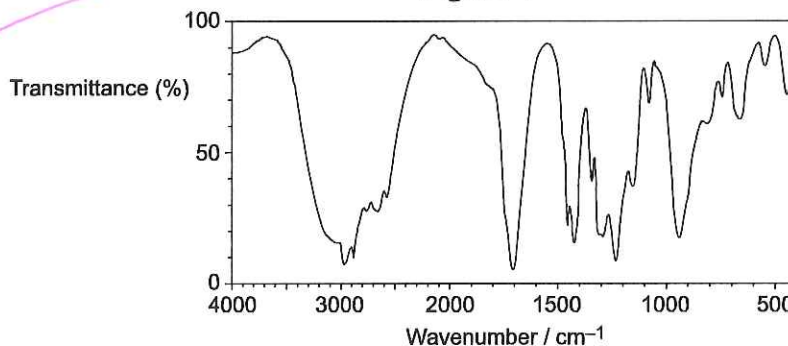
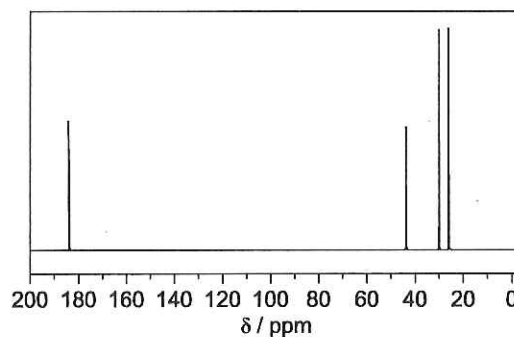


Figure 5

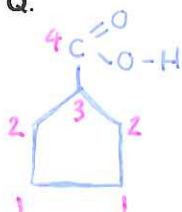


Use these spectra and Tables **A** and **C** in the Data Booklet to deduce the structure of **Q**.

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

[3 marks]

Structure of **Q**.



\* This has 4 environments.

Evidence from **Figure 4**

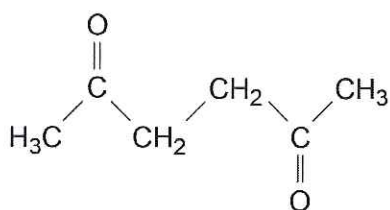
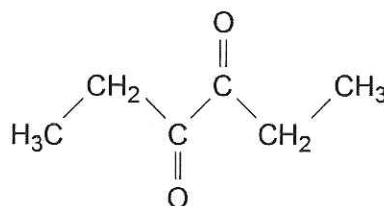
- \* Contains O-H acid group @ 2500-3000  $cm^{-1}$
- \* Contains C=O group @ 1700  $cm^{-1}$

Evidence from **Figure 5**

Contains 4 Carbon environments



1 0 . 4

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

Although the  $^{13}\text{C}$  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

*they would be more down field due to electronegative O in C=O meaning protons more easily flipped.*

S would have 2 carbons around 20-50ppm due to  $\text{R}-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}-\text{C}-$  but R has 4. R peaks would be more downfield due to this.

Number of peaks

Both R and S have 3 peaks.



1 0 . 5

Although the  $^1\text{H}$  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* peaks would both be singlets where as *S* would be a triplet and a quartet.

$\text{CH}_2$  @ 2.1-2.6

$\text{CH}_3$  @ 2.1-2.6

Number of peaks

*Both have two peaks.*

*↓ equivalent*

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.

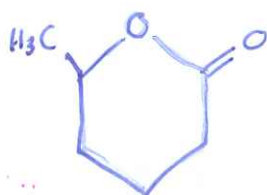
Draw the structure of **T**.

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

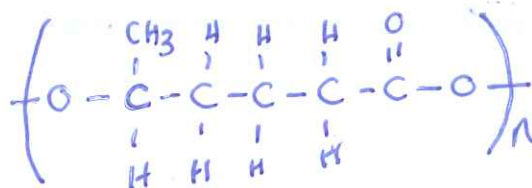
[3 marks]



Structure of **T**



Repeating unit of polyester



make sure it is the COOH and OH groups that polymerise.

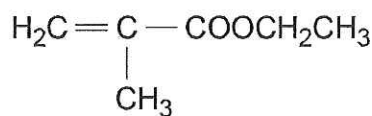
Type of polymerisation

Condensation





1 0 . 7

Isomer **U** is shown.**U**

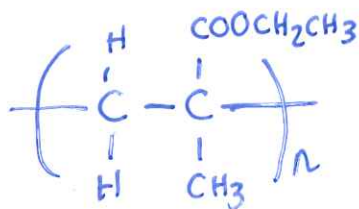
The polymer formed by **U** and the polymer formed by 5-hydroxyhexanoic acid in Question 10.6 both contain ester groups that can be hydrolysed.

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**.



\* Addition polymers  
tend to be non  
biodegradable.

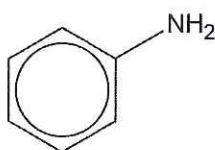
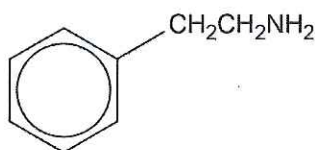
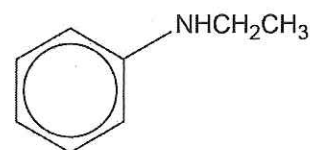
Justification

Contains strong C-C bonds in chain which is  
resistant to nucleophilic or acidic attack.

Turn over for the next question



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]

*Handwritten note:*  
 + NH<sub>2</sub> acts as a base as  
 it can donate its lone pair/  
 or accept H<sup>+</sup> to do this  
 it needs to be available

The strength of basicity is dependent on the availability of the lone pair on the nitrogen. **E** is the weakest base as the lone pair has been delocalised into the ring so less available. **G** is next strongest as the CH<sub>2</sub>CH<sub>3</sub> group is pushing so electron density onto N so more available than **E**, even though there is still some delocalisation into ring. **F** is the strongest as N is now further from ring, and CH<sub>2</sub>CH<sub>2</sub> electron density also donated to N somewhat making lone pair more available.



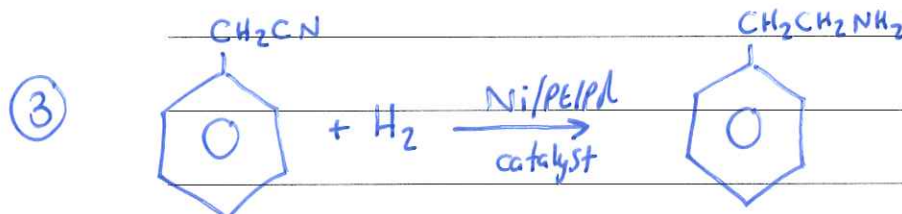
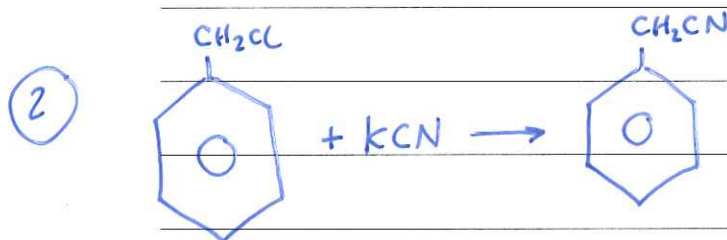
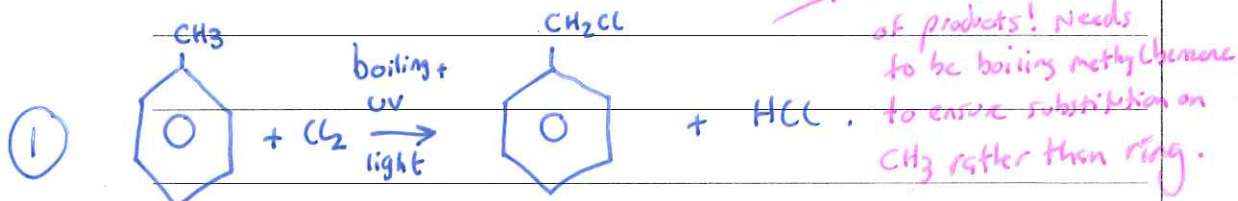
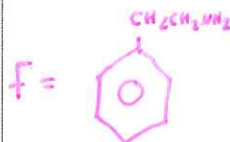
1 1 . 2

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](http://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.

