Carboxylic Acids & Derivatives

Question Paper 6

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Carboxylic Acids & Derivatives
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 6

Time Allowed: **78 minutes**

Score: **/65**

Percentage: **/100**

Grade Boundaries:

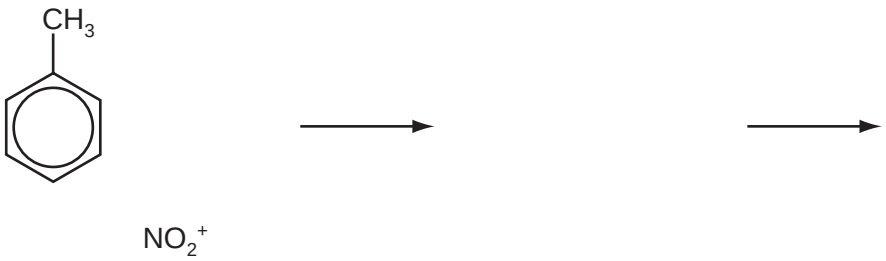
A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 **(a)** Methylbenzene undergoes electrophilic substitution with nitronium ions, NO_2^+.
Nitronium ions are generated by the reaction between concentrated sulfuric acid and concentrated nitric acid.

(i) Construct an equation for the formation of nitronium ions, NO_2^+, by this method.

.....

(ii) Complete the scheme to show the mechanism for this reaction. Use curly arrows to show the movement of electron pairs.



[4]

(b) Describe and explain the relative acidities of chloroethanoic acid and ethanoic acid.

.....

.....

.....

(ii) Describe and explain the relative acidities of phenol and ethanol.

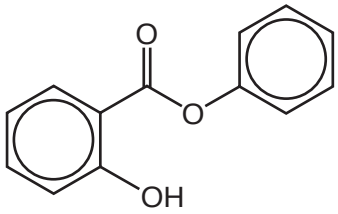
.....

.....

.....

[3]

(c) Phenyl 2-hydroxybenzoate is an antiseptic.



phenyl 2-hydroxybenzoate

Complete the following table about the reactions of phenyl 2-hydroxybenzoate with the three reagents.

reagent	structure of product(s)		type of reaction
Na			
excess $Br_2(aq)$			
excess hot NaOH(aq)			

[6]

[Total: 13]

2 Ethanoic acid can be reacted with alcohols to form esters, an equilibrium mixture being formed.

$$CH_3CO_2H + ROH \rightleftharpoons CH_3CO_2R + H_2O$$

The reaction is usually carried out in the presence of an acid catalyst.

(a) Write an expression for the equilibrium constant, K_c, for this reaction, clearly stating the units.

K_c =

units ..... [2]

In an experiment to determine K_c a student placed together in a conical flask 0.10 mol of ethanoic acid, 0.10 mol of an alcohol ROH, and 0.005 mol of hydrogen chloride catalyst.
The flask was sealed and kept at 25 °C for seven days.
After this time, the student titrated all of the contents of the flask with 2.00 mol dm^{-3} NaOH using phenolphthalein indicator.
At the end-point, 22.5 cm^3 of NaOH had been used.

(b) **(i)** Calculate the amount, in moles, of NaOH used in the titration.

(ii) What amount, in moles, of this NaOH reacted with the hydrogen chloride?

(iii) Write a balanced equation for the reaction between ethanoic acid and NaOH.

(iv) Hence calculate the amount, in moles, of NaOH that reacted with the ethanoic acid.

[4]

(c) **(i)** Use your results from **(b)** to calculate the amount, in moles, of ethanoic acid present at equilibrium. Hence complete the table below.

	CH_3CO_2H	ROH	CH_3CO_2R	H_2O
initial amount / mol	0.10	0.10	0	0
equilibrium amount / mol				

(ii) Use your results to calculate a value for K_c for this reaction.

[3]

(d) Esters are hydrolysed by sodium hydroxide. During the titration, sodium hydroxide reacts with ethanoic acid and the hydrogen chloride, but not with the ester.

Suggest a reason for this.

.....

..... [1]

(e) What would be the effect, if any, on the amount of ester present if all of the water were removed from the flask and the flask kept for a further week at 25 °C?

Explain your answer.

.....

.....

..... [2]

[Total: 12]

3 An organic compound, **E**, has the following composition by mass:
C, 48.7%; H, 8.1%; O, 43.2%.

(a) Calculate the empirical formula of **E**.

[2]

(b) When vaporised in a suitable apparatus, 0.130 g of **E** occupied a volume of 58.0 cm^3 at 127 °C and 1.00 × 10^5 $N\,m^{-2}$.

(i) Use the expression $pV = \frac{mRT}{M_r}$ to calculate M_r of **E**,

where *m* is the mass of **E**.

(ii) Hence calculate the molecular formula of **E**.

[4]

(c) Compound **F**, is an ester with the molecular formula $C_4H_8O_2$.

F is one of four isomers, **S**, **T**, **U**, and **V**, that are all esters.

In the boxes below, the structural formula of **S** is given.

Draw the structural formulae of the other **three** isomers of **F** that are esters.

$HCO_2CH(CH_3)_2$ **S**	**T**	**U**	**V**

[3]

(d) When the ester **F** is hydrolysed, an alcohol **G** is produced.

(i) What reagent can be used to hydrolyse an ester to an alcohol?

.....

(ii) What other type of organic compound is produced at the same time?

.....

[2]

(e) On mild oxidation, the alcohol **G** gives a compound **H** which forms a silver mirror with Tollens' reagent.

(i) What functional group does the reaction with Tollens' reagent show to be present in compound **H**? Give the name of this group.

.....

(ii) What type of alcohol is **G**?

.....

(iii) What could be the structural formula of the alcohol **G**?

[3]

(f) **(i)** Which of the four isomers, **S**, **T**, **U**, or **V**, could **not** be **F**?

.....

(ii) Explain your answer.

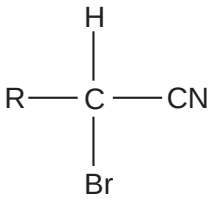
.....

.....

[2]

[Total: 16]

4 Compound **G**, in which R– represents the rest of the molecule, was made for use as a tear gas in World War 2.



compound **G**

Compound **G** was made by the following sequence of reactions.

$$R\text{–}CH_3 \xrightarrow{\text{stage I}} R\text{–}CH_2Cl \xrightarrow{\text{stage II}} R\text{–}CH_2CN \xrightarrow{\text{stage III}} R\text{–}CHBrCN$$

(a) **(i)** For stage I **and** for stage II, state the reagent(s) and condition(s) used to carry out **each** change.

stage I reagent(s) .....

condition(s) .....

stage II reagent(s) .....

condition(s) .....

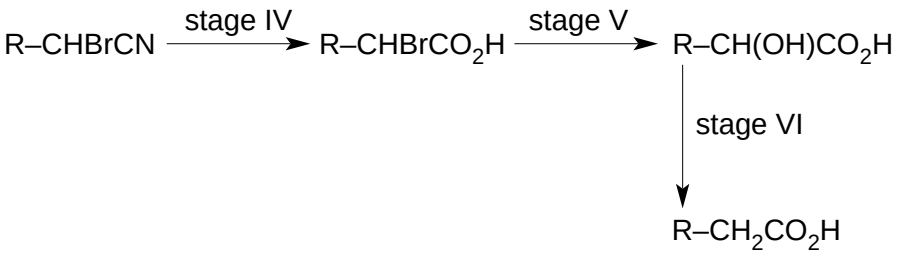
(ii) Suggest the reagent(s) and condition(s) necessary to carry out stage III.

reagent(s) .....

condition(s) .....

[6]

Compound **G** was not actually used in World War 2 and stocks of it had to be destroyed safely. The following sequence of reactions was used in this process.



(b) For stage IV **and** for stage V state the reagent(s) and condition(s) necessary to bring about **each** reaction.

stage IV reagent(s) .....

condition(s) .....

stage V reagent(s) .....

condition(s) ..... [4]

(c) The full sequence of stages I to VI involves some compounds which contain chiral centres.

(i) Explain what is meant by the term *chiral centre*.

.....

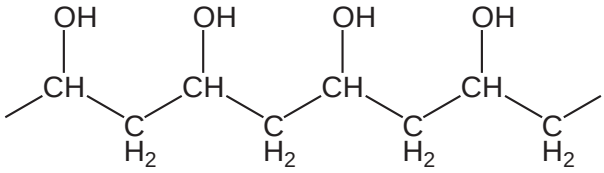
.....

(ii) Draw displayed formulae for the isomers of **one** compound in the full sequence of stages I to VI which you consider to be chiral.

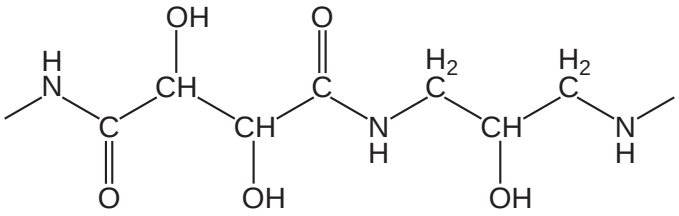
[3]

[Total: 13]

5 Hydrophilic polymers find important uses in the manufacture of contact lenses and wound dressings. Their chemical structures allow them to bond with water molecules, which keeps them soft and flexible. Sections of two hydrophilic polymers are shown below.



H



J

(a) What type of polymerisation has produced

(i) polymer **H**? .....

(ii) polymer **J**? .....

[2]

(b) What type of attractions might occur between these polymers and molecules of water?

..... [1]

(c) Chains of polymer **H** can be 'cross-linked', i.e. joined together, by reaction with a small bifunctional molecule.

(i) Which one of the following molecules would be most suitable for such cross-linking?

(place a tick in one box only)

$HOCH_2CH_2OH$	☐
$H_2NCH_2CH_2NH_2$	☐
$HOCH_2CH_2CO_2H$	☐
$HO_2CCH_2CH_2CO_2H$	☐
$H_2NCH_2CH_2CO_2H$	☐

(ii) What type of bond would be formed during the cross-linking?

.....

[2]

(d) **(i)** Suggest the reagents and conditions needed to hydrolyse polymer **J** into its monomers.

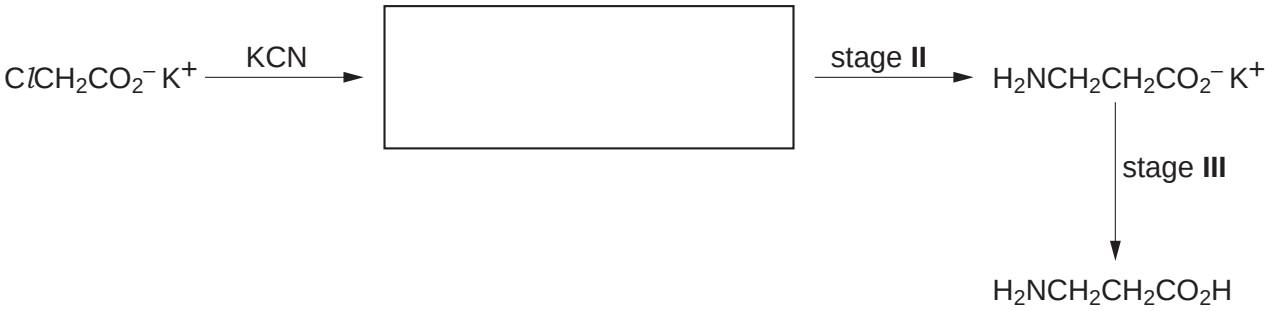
.....

(ii) Draw the structural formulae of the two products of this hydrolysis reaction.

.....

[3]

(e) The last compound in the list in **(c)(i)** above is 3-aminopropanoic acid. This can be made from potassium chloroethanoate by the following 3-stage route.



(i) In the box above write the structure of the intermediate in this route.

(ii) Suggest reagents and conditions for

stage **II** .....

stage **III** .....

[3]

[Total: 11]