Carboxylic Acids & Derivatives

Question Paper 3

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Carboxylic Acids & Derivatives
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 3

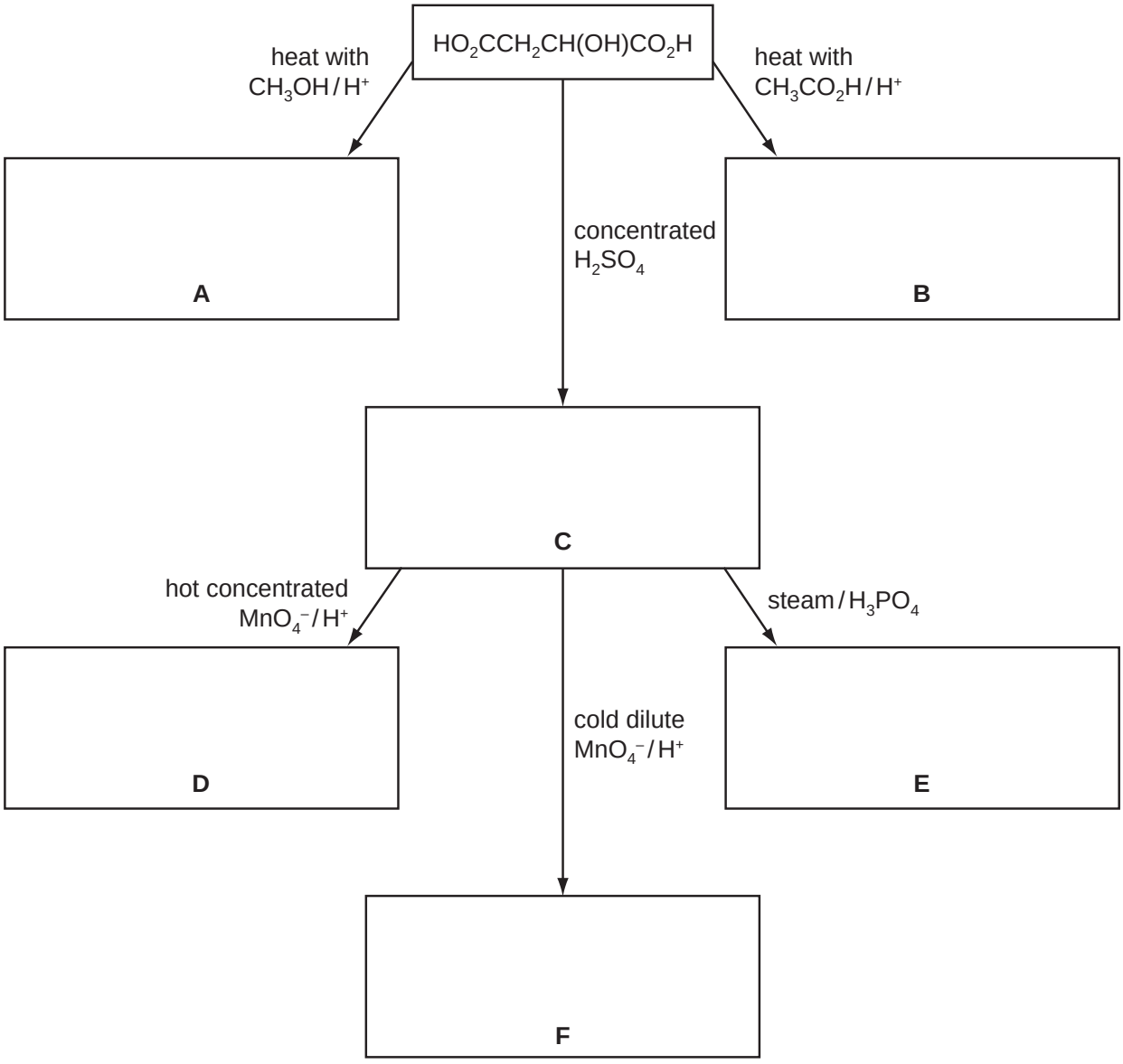
Time Allowed:	**66 minutes**
Score:	**/55**
Percentage:	**/100**

Grade Boundaries:

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

1 Food additives are substances added to food to preserve theflavourortoimproveitstaste and appearance.
European Union legislation requires most additives used in foods to be labelled clearly in the list of ingredients, either by name or by an 'E number'. E296 is malic acid which occurs in unripe fruit.
Malic acid has the structural formula $HO_2CCH_2CH(OH)CO_2H$.

(a) Some reactions of malic acid are shown below.
In the boxes below, give the **structural** formulae of organic compounds **A** to **F**.



[6]

(b) What *type of reaction* is **each** of the following conversions?

malic acid into **C** .....

C into **D** .....

C into **E** ..... [3]

(c) Suggest **one** major commercial use of compounds such as **A** or **B**.

..... [1]

(d) Malic acid is chiral.
Draw fully displayed formulae of the two optical isomers of malic acid.
Indicate with an asterisk (*) the chiral carbon atom.

(ii) Compound **C** also shows stereoisomerism.
Draw the skeletal formulae of **each** of the stereoisomers of **C**. Label **each** isomer.

[6]

(e) The food additive E330 is another organic compound which occurs naturally in fruit.
E330 has the following composition by mass: C, 37.5%; H, 4.17%; O, 58.3%.
Calculate the empirical formula of E330.

[3]

[Total: 19]

2 Methanoic acid, HCO_2H, was formerly known as formic acid because it is present in the sting of ants and the Latin name for ant is *formica*. It was first isolated in 1671 by John Ray who collected a large number of dead ants and extracted the acid from them by distillation.

In this question, you should give all numerical answers to two significant figures.

At room temperature, pure methanoic acid is a liquid which is completely soluble in water.

When we are stung by a 'typical' ant a solution of methanoic acid, **A**, is injected into our skin.

Solution **A** contains 50% by volume of pure methanoic acid.

A 'typical' ant contains $7.5 \times 10^{-6}\,dm^3$ of solution **A**.

(a) (i) Calculate the volume, in cm^3, of solution **A** in one ant.

volume = ... cm^3

(ii) Use your answer to **(i)** to calculate the volume, in cm^3, of pure methanoic acid in one ant.

volume = ... cm^3

(iii) Use your answer to **(ii)** to calculate how many ants would have to be distilled to produce $1\,dm^3$ of pure methanoic acid.

number = ...

[3]

When we are stung by an ant, the amount of solution **A** injected is 80% of the total amount of solution **A** present in one ant.

The density of pure methanoic acid is $1.2\,g\,cm^{-3}$.

(b) (i) Calculate the volume, in cm^3, of **pure** methanoic acid injected in one ant sting.

volume = ... cm^3

(ii) Use your answer to **(i)** to calculate the mass of methanoic acid present in one ant sting.

mass = ... g
[3]

Bees also sting us by using methanoic acid. One simple treatment for ant or bee stings is to use sodium hydrogencarbonate, $NaHCO_3$.

(c) Construct a balanced equation for the reaction between methanoic acid and sodium hydrogencarbonate.

.....

(ii) In a typical bee sting, the mass of methanoic acid injected is $5.4 \times 10^{-3}\,g$. Calculate the mass of $NaHCO_3$ needed to neutralise one bee sting.

mass = ... g
[3]

[Total: 9]

3 Fermentation of sugars by bacteria or moulds produces many different organic compounds.

One compound present in fermented molasses is 2-ethyl-3-methylbutanoic acid which gives a distinctive aroma to rum.

$(CH_3)_2CHCH(C_2H_5)CO_2H$

2-ethyl-3-methylbutanoic acid

(a) What is the molecular formula of 2-ethyl-3-methylbutanoic acid?

(ii) How many chiral carbon atoms are present in a molecule of 2-ethyl-3-methylbutanoic acid? If none write 'none'.

.....

[2]

A sample of 2-ethyl-3-methylbutanoic acid may be prepared in a school or college laboratory by the oxidation of 2-ethyl-3-methylbutan-1-ol, $(CH_3)_2CHCH(C_2H_5)CH_2OH$.

(b) State the reagent(s) that would be used for this oxidation.
Describe what colour change would be seen.

reagent(s) .....

colour change from ..... to .....

This reaction is carried out by heating the reacting chemicals together.

(ii) What could be the main organic impurity present in the sample of the acid?

Explain your answer.

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.....

.....

(iii) State whether a distillation apparatus or a reflux apparatus should be used.

Explain your answer.

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.....

.....

[6]

(c) A structural isomer of 2-ethyl-3-methylbutan-1-ol is 2-ethyl-3-methylbutan-2-ol, $(CH_3)_2CHC(OH)(C_2H_5)CH_3$.

What colour change would be seen if this were heated with the reagents you have given in **(b)(i)**?
Explain your answer as clearly as you can.

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.....

..... [3]

An isomer of 2-ethyl-3-methylbutanoic acid which is an ethyl ester is a very strong smelling compound which is found in some wines.

(d) This ethyl ester contains a branched hydrocarbon chain and is chiral.

Draw the displayed formula of this ethyl ester.

Identify the chiral carbon atom with an asterisk (*).

[3]

[Total: 14]

4 Isomerism occurs in many organic compounds. The two main forms of isomerism are structural isomerism and stereoisomerism. Many organic compounds that occur naturally have molecules that can show stereoisomerism, that is *cis-trans* or optical isomerism.

(a) (i) Explain what is meant by *structural isomerism*.

.....

.....

(ii) State **two** different features of molecules that can give rise to **stereoisomerism**.

.....

.....

[3]

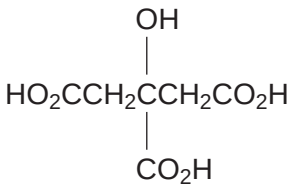
Unripe fruit often contains polycarboxylic acids, that is acids with more than one carboxylic acid group in their molecule.

One of these acids is commonly known as tartaric acid, $HO_2CCH(OH)CH(OH)CO_2H$.

(b) Give the structural formula of the organic compound produced when tartaric acid is reacted with an excess of $NaHCO_3$.

[1]

Another acid present in unripe fruit is citric acid,



(c) Does citric acid show optical isomerism? Explain your answer.

.....

.....

..... [1]

A third polycarboxylic acid present in unripe fruit is a colourless crystalline solid, **W**, which has the following composition by mass: C, 35.8%; H, 4.5%; O, 59.7%.

(d) (i) Show by calculation that the empirical formula of **W** is $C_4H_6O_5$.

(ii) The M_r of **W** is 134. Use this value to determine the molecular formula of **W**.

[3]

A sample of **W** of mass 1.97 g was dissolved in water and the resulting solution titrated with 1.00 mol dm^{-3} NaOH. 29.4 cm^3 were required for complete neutralisation.

(e) (i) Use these data to deduce the number of carboxylic acid groups present in one molecule of **W**.

(ii) Suggest the displayed formula of **W**.

[5]

[Total: 13]