Carbonyl Compounds

Question Paper 3

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Carbonyl Compounds
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 3

Time Allowed: **75 minutes**

Score: **/62**

Percentage: **/100**

Grade Boundaries:

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

1 Three organic compounds, **G**, **H**, and **J**, each have the empirical formula CH_2O.
The numbers of carbon atoms in their molecules are shown in the table.

compound	number of C atoms
G	1
H	2
J	3

In **H** and in **J**, the carbon atoms are bonded directly to one another.

G gives a silver mirror when treated with Tollens' reagent.

H and **J** each give a brisk effervescence with $Na_2CO_3(aq)$.

(a) Identify **G**.

……

[1]

(b) **(i)** What functional group is common to both **H** and **J**?

……

(ii) Identify **H**.

……

(iii) Identify **J**.

……

[3]

(c) When **J** is heated under reflux with acidified $K_2Cr_2O_7$, the product, **K**, gives a red-orange precipitate with 2,4-dinitrophenylhydrazine reagent.

Draw the structural formula of **K**, the compound formed from **J**.

[1]

(d) When **J** is warmed with concentrated sulfuric acid, a cyclic compound, **L**, is formed. **L** has the molecular formula $C_6H_8O_4$.

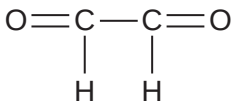
(i) Suggest a displayed formula for **L**.

(ii) What type of reaction occurs when **L** is formed from **J**?

…… [2]

[Total: 7]

2 Ethanedial (glyoxal) is used in the production of fabrics which have permanent creases.



ethanedial

Ethanedial undergoes many of the reactions of aldehydes.

(a) Ethanedial reacts with Tollens' reagent.

(i) What would you see if you carried out this reaction?

.....

(ii) What is the structural formula of the organic compound formed?

[2]

(b) Ethanedial reacts with hydrogen cyanide, HCN, to give compound **F**.

(i) What is the structural formula of **F**?

(ii) What type of reaction is this?

.....

(iii) What is the structural formula of the compound formed when **F** is heated with an aqueous mineral acid such as dilute sulphuric acid?

[3]

(c) Ethanedial can be oxidised and reduced.

(i) What is the structural formula of the organic compound formed when ethanedial is heated under reflux with an excess of acidified potassium dichromate(VI)?

(ii) What is the structural formula of the compound formed when ethanedial is reduced?

(iii) What reagent would be used for this reduction?

.....
[3]

(d) When ethanedial is reacted with NaOH and the product treated with a mineral acid such as dilute sulphuric acid, the following reaction sequence takes place.

I $CHOCHO + NaOH \rightarrow HOCH_2CO_2Na$

II $HOCH_2CO_2Na + H^+ \rightarrow HOCH_2CO_2H + Na^+$

What type of reaction is the overall change?

.....[1]

(e) An isomer of ethanedial exists which reacts with sodium metal to give hydrogen.

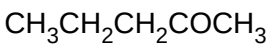
Suggest the displayed formula of this isomer.

[2]

[Total: 11]

3 Compounds **D** and **E** are both ketones.

D



E

(a) State which one of these compound reacts with alkaline aqueous iodine, and draw the structural formulae of the products formed during this reactions.

(i) compound (**D** or **E**) .....

(ii) products

..... [3]

(b) The reduction of **D** with $NaBH_4$ produces just one alcohol, but a similar reduction of **E** produces two isomers in equal amounts. Explain these observations, drawing structures where appropriate.

.....

.....

[3]

[Total: 6]

4 A compound, **A**, has the following composition by mass.

C, 66.7%; H, 11.1%; O, 22.2%.

It has an M_r of 72.

(a) Calculate the molecular formula of **A**.

[2]

(b) **A** reacts with 2,4-dinitrophenylhydrazine but not with Fehling's or Tollens' reagents.

(i) State what you would see when **A** reacts with the 2,4-dinitrophenylhydrazine reagent.

.....

(ii) State what functional group is present in **A**. .....

(iii) Identify **A** either by name or by its structural formula.

.....[3]

(c) **A** can be reduced to compound **B**.

For this reaction

(i) state a suitable reducing agent, ...

(ii) name the functional group in **B** (two words are required),

.....

(iii) give the structural formula of **B.**

[3]

[Total : 8]

5 Acetals are compounds formed when aldehydes are reacted with an alcohol and an acid catalyst. The reaction between ethanal and methanol was studied in the inert solvent dioxan.

$$\underset{\text{ethanal}}{CH_3CHO} + \underset{\text{methanol}}{2CH_3OH} \overset{H^+}{\rightleftharpoons} \underset{\text{acetal } \mathbf{A}}{CH_3CH(OCH_3)_2} + H_2O$$

(a) When the initial rate of this reaction was measured at various starting concentrations of the three reactants, the following results were obtained.

experiment number	$[CH_3CHO]$ / mol dm^{-3}	$[CH_3OH]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	relative rate
1	0.20	0.10	0.05	1.00
2	0.25	0.10	0.05	1.25
3	0.25	0.16	0.05	2.00
4	0.20	0.16	0.10	3.20

(i) Use the data in the table to determine the order with respect to each reactant.

order with respect to $[CH_3CHO]$ .....

order with respect to $[CH_3OH]$ .....

order with respect to $[H^+]$ .....

(ii) Use your results from part **(i)** to write the rate equation for the reaction.

.....

(iii) State the units of the rate constant in the rate equation .....

(iv) Calculate the relative rate of reaction for a mixture in which the starting concentrations of all three reactants are 0.20 mol dm^{-3}.

relative rate = ...

[6]

(b) The concentration of the acetal product was measured when experiment number 1 was allowed to reach equilibrium. The result is included in the following table.

	$[CH_3CHO]$ / mol dm^{-3}	$[CH_3OH]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	[acetal **A**] / mol dm^{-3}	$[H_2O]$ / mol dm^{-3}
at start	0.20	0.10	0.05	0.00	0.00
at equilibrium	(0.20–***x***)			***x***	
at equilibrium				0.025	

(i) Complete the second row of the table in terms of ***x***, the concentration of acetal **A** at equilibrium. You may wish to consult the chemical equation opposite.

(ii) Using the [acetal **A**] as given, 0.025 mol dm^{-3}, calculate the equilibrium concentrations of the other reactants and products and write them in the third row of the table.

(iii) Write the expression for the equilibrium constant for this reaction, K_c, stating its units.

K_c = ... units = ...

(iv) Use your values in the third row of the table to calculate the value of K_c.

K_c = ...
[9]

[Total: 15]

6 Lactic acid, 2-hydroxypropanoic acid, $CH_3CH(OH)CO_2H$, occurs in sour milk.

Glycollic acid, 2-hydroxyethanoic acid, $HOCH_2CO_2H$, occurs in sugar cane.

(a) Lactic acid may be synthesised from propene by the following sequence.

$$CH_3CH{=}CH_2 \xrightarrow{\text{step I}} CH_3CH(OH)CH_2OH \xrightarrow{\text{step II}} CH_3CH(OH)CO_2H$$

(i) What reagent(s) and condition(s) are used for step I?

reagent(s) .....

condition(s) .....

(ii) What type of reaction is step II?

.....

[3]

(b) Glycollic acid may be synthesised from ethanoic acid by the following sequence.

$$CH_3CO_2H \xrightarrow{\text{step III}} ClCH_2CO_2H \xrightarrow{\text{step IV}} HOCH_2CO_2H$$

(i) Suggest the reagent(s) and condition(s) that are used for step III.

reagent(s) .....

condition(s) .....

(ii) What reagents and conditions are used in step IV?

reagent(s) .....

condition(s) .....

[4]

(c) Lactic acid and glycollic acid react differently when heated under reflux with acidified dichromate(VI) ions.

Draw the structural formula of the organic product in **each** case.

product from lactic acid product from glycollic acid

[2]

(d) Lactic acid is chiral. Draw displayed formulae of the two optical isomers of lactic acid clearly showing their three-dimensional structures. Indicate with an asterisk (*) the chiral carbon atom in each.

[2]

Glycollic acid and lactic acid each give the reactions of an alcohol group and of a carboxylic acid group. Each compound will react with the other to give an ester.

(e) When one molecule of glycollic acid reacts with one molecule of lactic acid, it is possible to form two different esters.

Draw the structure of **each** of these esters.

[2]

Glycollic acid and lactic acid are reacted together to make the material for 'soluble stitches' (also known as 'soluble sutures') which are used in surgery.

In this material, many molecules of each acid have been reacted to form a long chain 'polyester' molecule which contains many ester groups.

This polyester is used in surgery to sew up wounds inside the body.

Over a period of time, the polyester undergoes a chemical reaction and breaks up to re-form the two individual hydroxy-acids.

(f) **(i)** This reaction occurs where the pH of the body is about pH5 to pH6. Suggest what type of chemical reaction causes the polyester material to break up.

.....

(ii) Suggest why the products of this reaction are soluble in water.

.....

.....

[2]

[Total: 15]