Carboxylic Acid and derivatives

(Past Year Topical Questions 2010-2015)

May/June 2010 (21)/Q5

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]

May/June 2010 (22)/Q4

(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]

+6018 – 375 2833

(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]

May/June 2010 (23)

5 Lactic acid, 2-hydroxypropanoic acid, $CH_3CH(OH)CO_2H$, occurs naturally in sour milk and in our muscles when we take hard exercise.
Lactic acid is chiral and shows stereoisomerism.

(a) Draw fully displayed structures of the two optical isomers of lactic acid.
Indicate with an asterisk (*) the chiral carbon atom in the lactic acid molecule.

[3]

(b) Lactic acid may be synthesised from ethanol by the following route.

$$CH_3CH_2OH \xrightarrow{\text{step 1}} CH_3CHO \xrightarrow{\text{step 2}} CH_3CH(OH)CN \xrightarrow{\text{step 3}} CH_3CH(OH)CO_2H$$

Give the reagent(s) and essential condition(s) for **each** step.

	reagent(s)	condition(s)
step 1		
step 2		
step 3		

[6]

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During exercise, lactic acid is produced in our muscles from pyruvic acid, CH_3COCO_2H. This reaction occurs in the presence of the enzyme lactic acid dehydrogenase.

(c) (i) What type of chemical compound is the enzyme lactic acid dehydrogenase?

.....

(ii) How would you detect a small quantity of pyruvic acid in a sample of lactic acid?

State the reagent(s) you would use and what would be seen in your test.

reagent(s) .....

observation .....

(iii) How would you detect a small quantity of lactic acid in a sample of pyruvic acid?

State the reagent(s) you would use and what would be seen in your test.

reagent(s) .....

observation .....

(iv) What chemical reagent would be used to convert pyruvic acid into lactic acid?

$$CH_3COCO_2H \rightarrow CH_3CH(OH)CO_2H$$

.....

[6]

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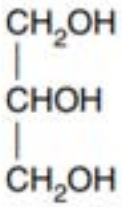
May/June 2011(22)

5 Although there are many different types of food eaten around the world, animal fats and/or vegetable oils are commonly used in cooking.

Animal fats and vegetable oils are usually glyceryl esters, that is esters of glycerol, propane-1,2,3-triol.



Many animal fats contain esters of stearic acid, $CH_3(CH_2)_{16}CO_2H$.

Vegetable oils often contain esters of oleic acid, $CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H$.

(a) Draw the structural formula of the glyceryl ester formed when one molecule of glycerol is completely esterified with stearic acid.

[1]

(b) What reagent(s) would you use, in a school or college laboratory, to obtain a small sample of oleic acid, $C_{17}H_{33}CO_2H$, from the glyceryl ester present in a vegetable oil?

.....

[1]

Oleic acid is the *cis* isomer and elaidic acid the *trans* isomer of

$$CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H.$$

(c) By using this formula, draw the structural formula of elaidic acid, clearly showing the stereochemistry.

[1]

Oleic and elaidic acids are examples of mono-unsaturated acids.
Many vegetable oils contain esters of polyunsaturated fatty acids. Such oils are often hydrogenated to form esters containing saturated or mono-unsaturated fatty acids.

(d) (i) Suggest the meaning of the term *polyunsaturated fatty acid*.

.....

.....

(ii) What reagent and condition(s) are used for the hydrogenation of an unsaturated fatty acid?

reagent .....

condition(s) ..... [3]

Oct/Nov 2011 (23)

5 Each of the three organic compounds, **V**, **W**, and **X**, has the empirical formula CH_2O. The number of carbon atoms in each of their molecules is shown in the table.

compound	number of C atoms
V	1
W	2
X	3

V gives a brick red precipitate when warmed with Fehling's reagent; **W** and **X** do not.

W is a fruity smelling liquid.

In **X**, the carbon atoms are bonded directly to one another.

X gives an effervescence when shaken with $Na_2CO_3(aq)$; **V** and **W** do not.

(b) (i) What functional group is present in **W**?

.....

(ii) Give the structural formula of **W**.

[2]

(d) When **X** is warmed with a little concentrated sulfuric acid, a small amount of a cyclic compound, **Z**, is formed.

Z has the molecular formula $C_6H_8O_4$.

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

(ii) What type of reaction occurs when **Z** is formed from **X**?

.....

[2]

May/June 2012 (21)

5 Organic compounds which contain oxygen may contain alcohol, aldehyde, carboxylic acid, ester or ketone functional groups. The functional groups may be identified by their reactions with specific reagents.

Compound **X** has the empirical formula CH_2O and M_r of 90.

(a) There is no reaction when **X** is treated with $NaHCO_3$.

What functional group does this test show to be **not** present in **X**?

.....

[1]

(b) When 0.600 g of **X** is reacted with an excess of Na, 160 cm^3 of H_2, measured at room temperature and pressure, is produced.

(i) What functional group does this reaction show to be present in **X**?

.....

(ii) Use the data to calculate the amount, in moles, of hydrogen **atoms** produced from 0.600 g of **X**.

(iii) Hence, show that each molecule of **X** contains **two** of the functional groups you have given in **(i)**.

[4]

(c) When **X** is warmed with Fehling's reagent, a brick red precipitate is formed. Treatment of **X** with 2,4-dinitrophenylhydrazine reagent produces an orange solid.

(i) What functional group do these reactions show to be present in **X**? Draw the displayed formula of this functional group.

(ii) Use your answers to **(b)(i)**, **(b)(ii)** and **(c)(i)** to deduce the structural formula of **X**.

(iii) What is the structural formula of the organic product of the reaction of **X** with Fehling's reagent?

[3]

(d) Compound **X** can be both oxidised and reduced.

(i) Give the structural formula of the compound formed when **X** is reacted with $NaBH_4$ under suitable conditions.

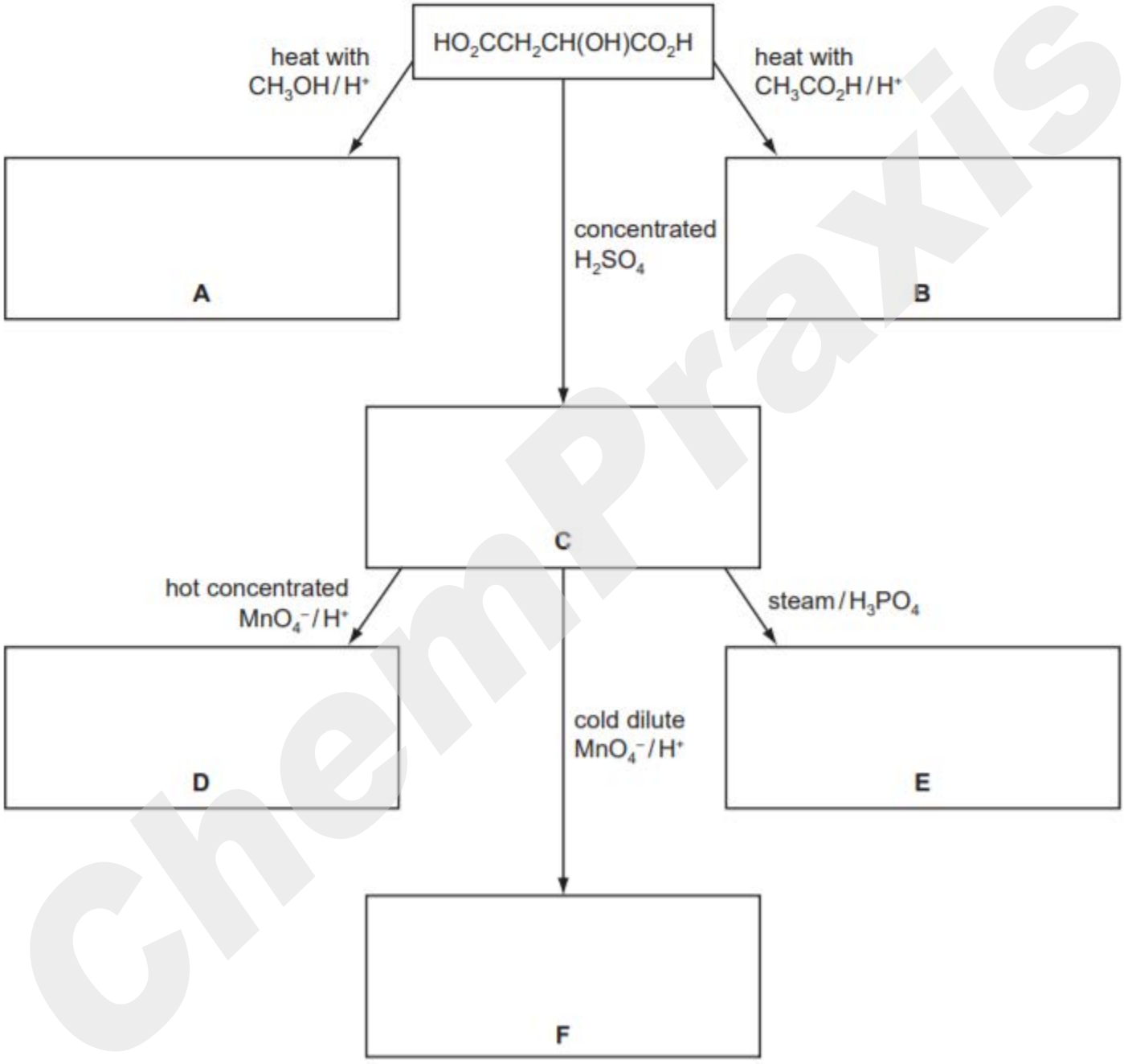
(ii) Give the structural formula of the compound formed when X is heated under reflux with acidified $K_2Cr_2O_7$.

[2]

May/June 2012 (22)

3 Food additives are substances added to food to preserve the flavour or to improve its taste 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]

4 Oxygen-containing organic compounds may contain a number of different functional groups including alcohol, aldehyde, carboxylic acid, ester or ketone functional groups. These functional groups may be identified by their reactions with specific reagents.

(a) On treating compounds containing each of these functional groups with the reagents below, only five reactions occur. Complete the table by placing a tick (✓) in each box where you believe a reaction will occur. You should place **no more** than five ticks in the table.

reagent	alcohol R_2CHOH	aldehyde RCHO	carboxylic acid RCO_2H	ester RCO_2R'	ketone RCOR'
$NaHCO_3$					
Na					
$Cr_2O_7^{2-}/H^+$					

[5]

May/June 2012 (23)

5 Many naturally occurring organic compounds contain oxygen. Such compounds may contain alcohol, aldehyde, carboxylic acid, ester or ketone functional groups. These functional groups may be identified by their reactions with specific reagents.

Compound **F** is a white solid which has the molecular formula $C_3H_6O_3$.

Compound **F** is soluble in water. Addition of $NaHCO_3$ to this solution produces a colourless gas, **G**, which turns lime water milky.

(a) (i) What is the identity of the gas **G**?

.....

(ii) What functional group does this test show to be present in F?

.....

[2]

(b) When **F** is heated with concentrated sulfuric acid, a colourless liquid **H** is produced. When cold dilute acidified $KMnO_4$ is shaken with **H**, the solution becomes colourless.

(i) What *type of reaction* occurs when **H** is formed from **F**?

.....

(ii) Use your answers to **(a)**(ii) and **(b)(i)** to deduce the structural formula of the colourless liquid **H**.

[4]

(c) Compound **F** will react with sodium.

Calculate the volume of H_2, measured at room temperature and pressure, which will be produced when 0.600 g of **F** is reacted with an excess of Na.

[4]

(d) There are two structural isomers of **F** that give the reactions described in **(a)** and **(b)**.

(i) Suggest two structural formulae for these isomers.

J	K

(ii) Isomers **J** and **K** can both be oxidised.
What will be produced when **each** of the isomers **J** and **K** is heated under reflux with acidified $K_2Cr_2O_7$?

product from **J**	product from **K**

[2]

Oct/Nov 2012 (21)

4 Many organic compounds, including alcohols, carbonyl compounds, carboxylic acids and esters, contain oxygen.

(a) The table below lists some oxygen-containing organic compounds and some common laboratory reagents.

(i) Complete the table as fully as you can.
If you think no reaction occurs, write 'no reaction' in the box for the structural formula(e).

reaction	organic compound	reagent	structural formula(e) of organic product(s)
A	$(CH_3)_3COH$	$Cr_2O_7^{2-}/H^+$ heat under reflux	
B	CH_3CH_2CHO	Fehling's reagent warm	
C	$HCO_2CH(CH_3)_2$	NaOH(aq) warm	
D	$CH_2{=}CHCHO$	$NaBH_4$	
E	$(CH_3)_3COH$	$NaBH_4$	
F	$CH_3CH_2COCH_3$	MnO_4^-/H^+ heat under reflux	

(ii) During some of the reactions in **(i)** a colour change occurs.
Complete the table below for any such reactions, stating the letter of the reaction and what the colour change is.

reaction	colour at the beginning of the reaction	colour at the end of the reaction

[10]

Oct/Nov 2012 (23)

4 Many organic compounds, including alcohols, carbonyl compounds, carboxylic acids and esters, contain oxygen.

(a) The table below lists some oxygen-containing organic compounds and some common laboratory reagents.

(i) Complete the table as fully as you can.
If you think no reaction occurs, write 'no reaction' in the box for the structural formula(e).

reaction	organic compound	reagent	structural formula(e) of organic product(s)
A	$CH_3CH(OH)CH_3$	$NaBH_4$	
B	CH_3COCH_3	Tollens' reagent warm	
C	$CH_3CO_2CH(CH_3)_2$	KOH(aq) warm	
D	$(CH_3)_3COH$	$Cr_2O_7^{2-}/H^+$ heat under reflux	
E	CH_3COCH_3	$NaBH_4$	
F	$(CH_3)_3COH$	PCl_5	
G	$CH_3CH{=}CHCH_2OH$	MnO_4^-/H^+ heat under reflux	

(ii) During some of the reactions in **(i)** a colour change occurs.
Complete the table below for any such reactions, stating the letter of the reaction and what the colour change is.

reaction	colour at the beginning of the reaction	colour at the end of the reaction

[12]

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May/June 2013 (22)

5 A student reacted together an alcohol and a carboxylic acid under appropriate conditions to produce an ester.
A sweet smelling organic liquid, **Q**, with the empirical formula C_2H_4O was produced.
The M_r of **Q** was found by experiment to be 87.5.

(a) What is the molecular formula of **Q**?

..... [1]

(b) In the boxes below, draw the structural formulae of **four** isomers with this formula that are esters.

W	**X**
Y	**Z**

[4]

(ii) Which of your structures, **W**, **X**, **Y** or **Z**, represents the ester, **Q**?

.....

[2]

(e) Which, if any, of your esters, **W**, **X**, **Y** or **Z**, is chiral?

.....

..... [1]

Oct/Nov 2013 (21)

4 Compound **R** is a weak diprotic (dibasic) acid which is very soluble in water.

(b) Three possible structures for **R** are shown below.

S	T	U
$HO_2CCH{=}CHCO_2H$	$HO_2CCH(OH)CH_2CO_2H$	$HO_2CCH(OH)CH(OH)CO_2H$

(i) Calculate the M_r of each of these acids.

M_r of **S** = ... M_r of **T** = ... M_r of **U** = ...

(ii) Deduce which of the structures, **S**, **T** or **U**, correctly represents the structure of the acid, R.

R is represented by .....

[2]

It is possible to convert **S**, **T**, or **U** into one another.

(c) State the reagent(s) and essential conditions that would be used for the following conversions.

S into **T**

.....

S into **U**

.....

T into **S**

..... [5]

(d) Give the structural formula of the organic product formed in **each** of the following reactions.

T reacting with an excess of Na

U reacting with an excess of Na_2CO_3

[2]

(e) The acid **S** shows stereoisomerism. Draw structures to show this isomerism. Label each isomer.

[2]

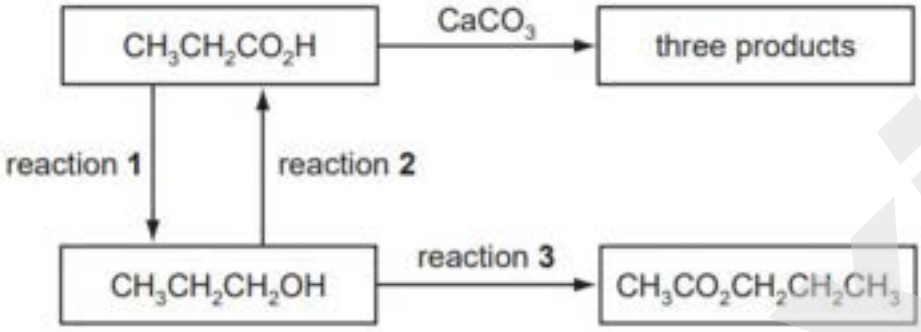
(f) When one of the isomers of **S** is heated at 110 °C in the absence of air, a cyclic compound **V**, with molecular formula $C_4H_2O_3$, is formed.
The other isomer of **S** does not react at this temperature.

Suggest the displayed formula of **V**.

[2]

Oct/Nov 2014 (21)

4 A series of reactions based on propanoic acid is shown.



(a) Write an equation for reaction **1**, using [H] to represent the reducing agent.

.....[2]

(b) **(i)** What type of reaction is reaction **2**?

.....[1]

(ii) Suggest a suitable reagent and conditions for reaction **2**.

.....[2]

(c) Write an equation for the reaction of propanoic acid with calcium carbonate, $CaCO_3$.

.....[2]

(d) **(i)** Suggest a suitable reagent and conditions for reaction **3**.

.....

.....[2]

(ii) Identify the **other** product of reaction **3**.

.....[1]