

18.1 CARBOXYLIC ACIDS

Learning outcomes

Candidates should be able to:

- recall the reactions by which carboxylic acids can be produced:
 - oxidation of primary alcohols and aldehydes with acidified $\text{K}_2\text{Cr}_2\text{O}_7$ or acidified KMnO_4 and refluxing
 - hydrolysis of nitriles with dilute acid or dilute alkali followed by acidification
 - hydrolysis of esters with dilute acid or dilute alkali and heat followed by acidification
- describe:
 - the redox reaction with reactive metals to produce a salt and $\text{H}_2(\text{g})$
 - the neutralisation reaction with alkalis to produce a salt and $\text{H}_2\text{O}(\text{l})$
 - the acid-base reaction with carbonates to produce a salt and $\text{H}_2\text{O}(\text{l})$ and $\text{CO}_2(\text{g})$
 - esterification with alcohols with concentrated H_2SO_4 as catalyst
 - reduction by LiAlH_4 to form a primary alcohol

Introduction

- Fig. 4.3 shows a synthesis starting from T, a different isomer of R and S.

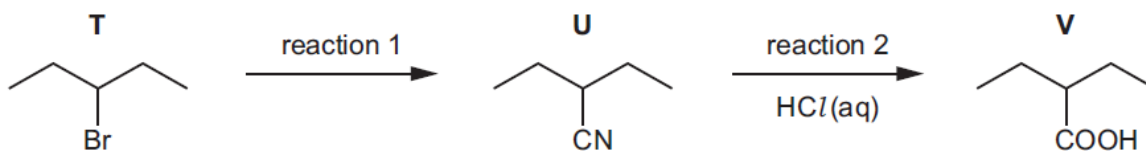


Fig. 4.3

- Identify the reagent and conditions for reaction 1.

..... [1]

- Reaction 2 is a hydrolysis reaction.
Construct an equation for reaction 2.

$(\text{C}_2\text{H}_5)_2\text{CHCN}$ [1]

- V reacts with propan-2-ol in the presence of a catalytic amount of H_2SO_4 to form organic compound W. Complete Table 4.1 to give details of this reaction. [3]

Table 4.1

	reaction of V with propan-2-ol
type of reaction	
functional group formed	
molecular formula of organic product W	

- An organic molecule W contains 3 carbon atoms. It requires 4.5 molecules of oxygen for complete combustion. What could W be?

A propane

B propanoic acid

C propanone

D propan-1-ol

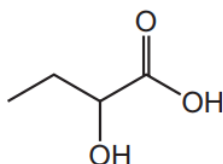
2. A carboxylic acid, P, has no chain isomers. It reacts with an alcohol, Q, that has only one positional isomer. What could be the ester formed from a reaction between P and Q?
- A butyl propanoate
- B ethyl butanoate
- C pentyl ethanoate
- D propyl pentanoate
3. In the general formula of which class of compound is the ratio of hydrogen atoms to carbon atoms the highest?
- A alcohols B aldehydes C carboxylic acids D halogenoalkanes

Preparations

Oxidation of primary alcohols and aldehydes (studied in the properties of alcohol)

2. Two students try to prepare 2-hydroxybutanoic acid in the laboratory.

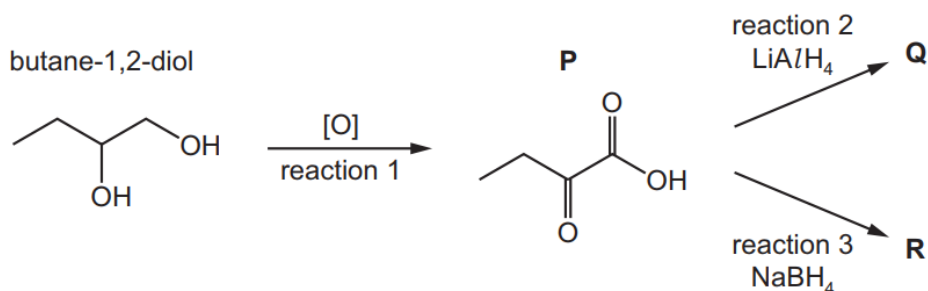
2-hydroxybutanoic acid



Both students oxidise butane-1,2-diol to form **P** in reaction 1.

One student then reduces **P** using LiAlH_4 . **Q** is formed.

The other student reduces **P** using NaBH_4 . **R** is formed.



- (i) State the reagents and conditions required for reaction 1.

.....

..... [2]

(ii) Only one of the students successfully prepares 2-hydroxybutanoic acid.

Identify which of **Q** or **R** is 2-hydroxybutanoic acid and explain the difference between reactions 2 and 3.

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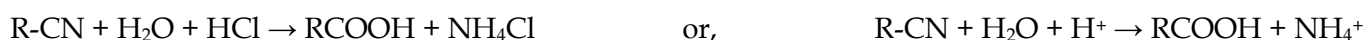
.....

..... [2]

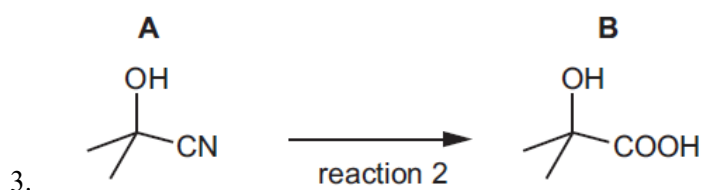
Hydrolysis of nitriles (with dilute acid or dilute alkali followed by acidification)

The nitrile group ($-\text{C}\equiv\text{N}$) can then be easily hydrolysed to a carboxylic acid.

When a nitrile is **refluxed** with dilute hydrochloric acid, hydrolysis occurs. The $-\text{C}\equiv\text{N}$ group at the end of the hydrocarbon chain **is converted to the $-\text{COOH}$ group**, forming a carboxylic acid:



You can also hydrolyse the nitrile group by refluxing with dilute alkali, such as sodium hydroxide solution. In this reaction a sodium salt of the carboxylic acid, $-\text{COO}^-\text{Na}^+$, is formed. Therefore, if you want to produce the carboxylic acid, $-\text{COOH}$, the products are treated with a strong acid, such as dilute sulfuric acid.



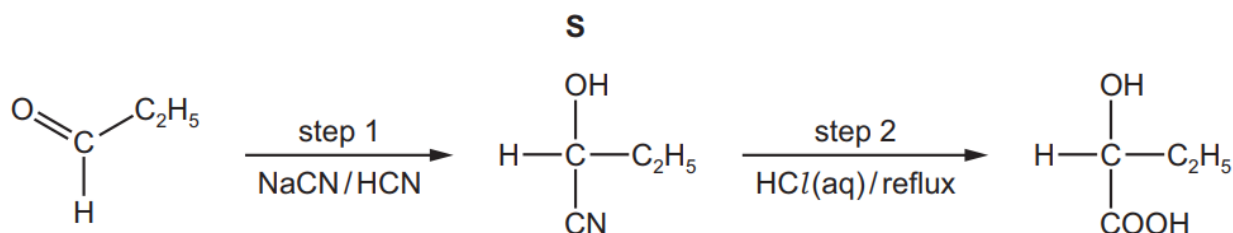
Suggest the reagents and conditions for reaction 2.

..... [1]

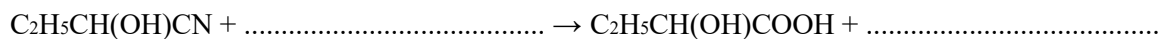
4. Draw the structure of the organic products formed in the following reactions.



5. A student prepares 2-hydroxybutanoic acid using Propanal as the starting material. In step 1 the student reacts Propanal with a mixture of NaCN and HCN.

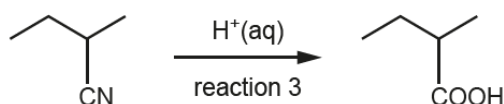


Complete the equation for the reaction in step 2, when **S** is heated under reflux with $\text{HCl}(\text{aq})$.



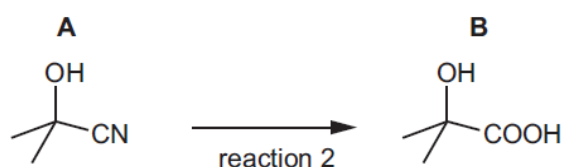
[1]

6. Complete the equation for reaction 3. R is represented as $\text{C}_4\text{H}_9\text{CN}$.

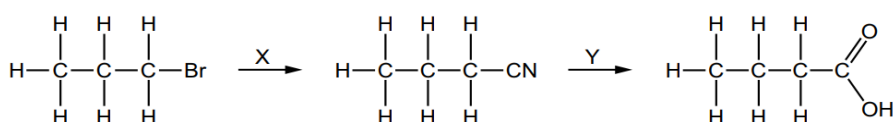


[1]

7. Suggest the reagents and conditions for reaction 2.



4. X and Y are the reagents required to convert 1-bromopropane into butanoic acid in the following reaction.



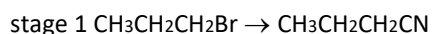
What are the correct identities of X and Y?

	X	Y
A	HCN	$\text{HCl}(\text{aq})$
B	KCN in $\text{C}_2\text{H}_5\text{OH}$	$\text{NaOH}(\text{aq})$
C	KCN in $\text{C}_2\text{H}_5\text{OH}$	$\text{HCl}(\text{aq})$
D	HCN	$\text{NaOH}(\text{aq})$

5. Propanoic acid can be made from bromoethane using a two-stage synthesis. Which pair of reagents is most suitable?

	reagent for stage 1	reagent for stage 2
A	hydrogen cyanide	aqueous sodium hydroxide
B	aqueous sodium hydroxide	excess acidified potassium dichromate(VI)
C	ethanolic sodium hydroxide	acidified potassium manganate(VII)
D	potassium cyanide	dilute hydrochloric acid

6. Butanoic acid can be made from 1-bromopropane in two stages.



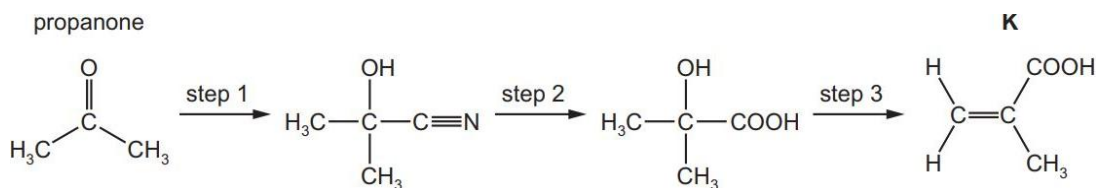
Which types of reaction are stage 1 and stage 2?

	stage 1	stage 2
A	electrophilic addition	hydrolysis
B	electrophilic addition	oxidation
C	nucleophilic substitution	hydrolysis
D	nucleophilic substitution	oxidation

7. Methylbut-2-ene reacts with HBr at room temperature to produce compound X as a major product. Compound X reacts with KCN in ethanol to produce compound Y. Compound Y is hydrolysed with acid to produce compound Z. What is compound Z?

- A** 2,2-dimethylbutanoic acid **B** 2,3-dimethylbutanoic acid
C 2-methylpentanoic acid **D** 3-methylpentanoic acid

8. **K** can be made from propanone in the three-step synthesis

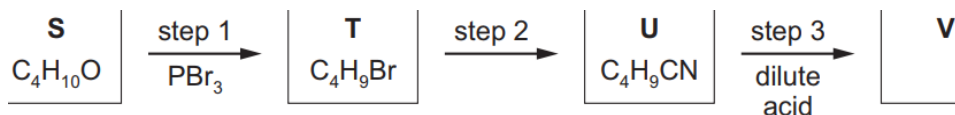


Complete the following table to identify the reagent(s) used and the type of reaction in each step.

[5]

step	reagent(s)	type of reaction
1		
2		
3	Al_2O_3	

9. **S** is converted to **V** in a three-step reaction sequence.



In step 1, the secondary alcohol **S** reacts with PBr_3 to produce **T**, which has molecular formula $\text{C}_4\text{H}_9\text{Br}$.

(i) Give the systematic name of **T**.

[1]

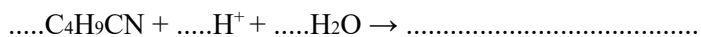
(ii) Name the type of reaction that occurs in step 1.

[1]

(iii) State the reagent(s) and conditions for step 2.

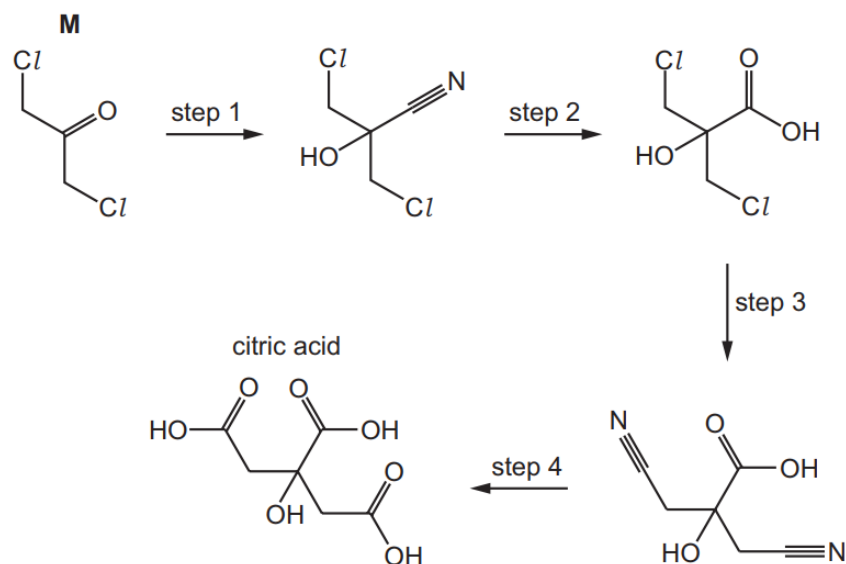
[2]

(iv) Step 3 involves heating $\text{C}_4\text{H}_9\text{CN}$ with dilute acid to form **V**.
Complete the equation for this reaction.



[2]

10. Citric acid can be made from **M** in a four-step reaction.



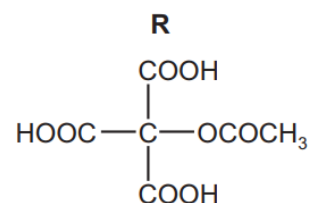
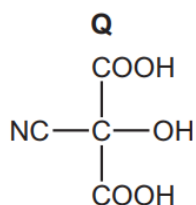
Complete the table for each step of the reaction sequence to identify:

- the reagents and conditions required
- the type of reaction.

[5]

step	reagent and conditions	type of reaction
1		
2	dilute sulfuric acid	
3		
4	dilute sulfuric acid	

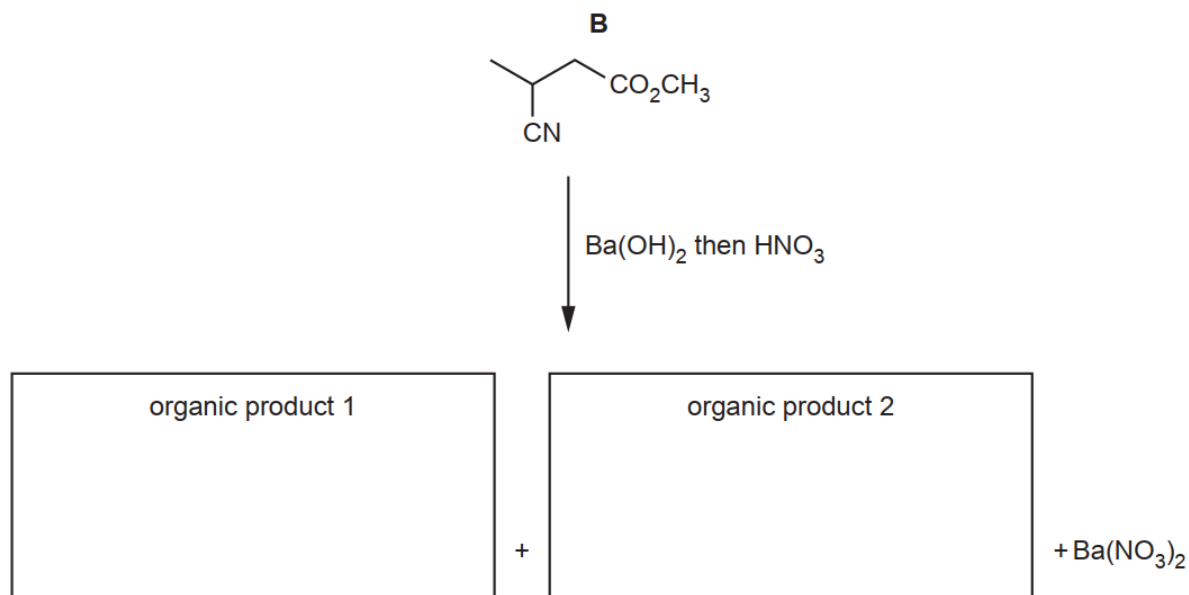
11. When **Q** is heated with excess aqueous ethanoic acid in the presence of a catalytic amount of sulfuric acid, two reactions take place to form compound **R**.



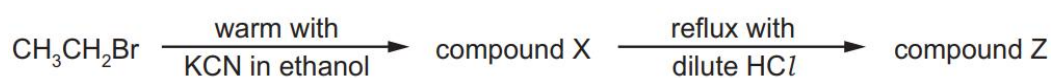
Identify the two types of reaction that occur.

[2]

12. $\text{Ba}(\text{OH})_2$ is used to hydrolyse organic compounds.
 Fig. 2.2 shows the reaction of **B** with $\text{Ba}(\text{OH})_2$, followed by acidification.
 Draw the structures of the organic products of the process shown in Fig. 2.2.



8. Compound Z is formed by the reaction scheme shown.



What is the formula of compound Z?

- A** $\text{CH}_3\text{CH}_2\text{Cl}$
B $\text{CH}_3\text{CH}_2\text{CN}$
C CH_3COOH
D $\text{CH}_3\text{CH}_2\text{COOH}$

9. The product of the reaction between propanone and hydrogen cyanide is hydrolysed under acidic conditions. What is the formula of the final product?

- A** $\text{CH}_3\text{CH(OH)COOH}$ **B** $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ **C** $(\text{CH}_3)_2\text{CHCONH}_2$ **D** $(\text{CH}_3)_2\text{C(OH)COOH}$

10. Chloroethane can be used to make sodium propanoate.
 chloroethane $\rightarrow$ intermediate Q $\rightarrow$ sodium propanoate

Intermediate Q is hydrolysed with boiling aqueous NaOH to give sodium propanoate.
 Which reagent would produce intermediate Q from chloroethane?

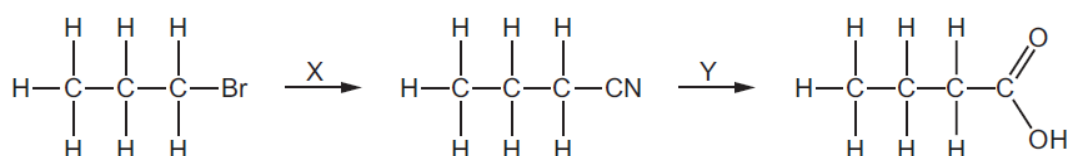
- A** concentrated ammonia solution
B dilute sulfuric acid

- C hydrogen cyanide in water
- D potassium cyanide in ethanol

11. Compound Y is treated with a single reagent under suitable conditions. 2-methylbutanoic acid is produced. What could compound Y be?

- A pentan-2-one
- B 2-methylbutan-2-ol
- C 2-methylbutanenitrile
- D methylpropanenitrile

12. X and Y are the reagents required to convert 1-bromopropane into butanoic acid.



What are the correct identities of reagents X and Y?

	X	Y
A	NH ₃	HCl(aq)
B	KCN in C ₂ H ₅ OH	NaOH(aq)
C	KCN in C ₂ H ₅ OH	HCl(aq)
D	HCN	NaOH(aq)

13. A student converts 1-iodopropane, C₃H₇I, into butanoic acid, C₃H₇CO₂H, by a two-stage chemical synthesis. In the first of the two stages, which reagent is reacted with 1-iodopropane?

- A aqueous sodium hydroxide
- B ethanolic ammonia
- C ethanolic potassium cyanide
- D ethanolic sodium hydroxide

14. Which compound can be used to make propanoic acid by treatment with a single reagent?

- A CH₂=CHCH₂CH₃
- B CH₃CH₂CH₂CN
- C CH₃CH(OH)CN
- D CH₃CH(OH)CH₃

15. A student converts 1-iodopropane, C₃H₇I, into butanoic acid, C₃H₇CO₂H, by a two-stage chemical synthesis.

In the **first** of the two stages, which reagent is reacted with 1-iodopropane?

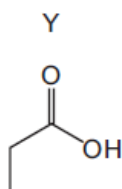
- A aqueous sodium hydroxide
- B ethanolic ammonia
- C ethanolic potassium cyanide
- D ethanolic sodium hydroxide

16. Which reaction will form propanoic acid?

- A acidic hydrolysis of propyl ethanoate
- B alkaline hydrolysis of ethyl propanoate
- C acidic hydrolysis of propanenitrile
- D acidic hydrolysis of ethanenitrile

Hydrolysis of esters (studied in the preparation of alcohols)

17. Which compounds can be used to make Y in a single-step reaction?



- 1 propanenitrile
- 2 ethanenitrile
- 3 propyl ethanoate
- 4 ethyl propanoate

- A 1 and 3 B 1 and 4 C 2 and 3 D 2 and 4

18. Which method could produce butanoic acid?

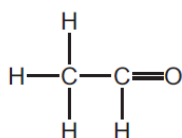
A an acid–base reaction involving $\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{Na}$

B the hydrolysis of $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CN}$

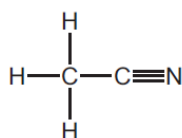
C the acidic hydrolysis of $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CH}_3$

D the oxidation of $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$

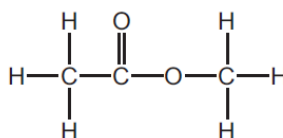
19. The structures of three organic compounds are shown.



1



2



3

Which compounds produce ethanoic acid when heated with HCl (aq)?

A 1, 2 and 3

B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

20. Three mixtures are heated under reflux.

Which mixtures will produce sodium propanoate as one product?

1 $\text{CH}_3\text{CH}_2\text{CHO} + \text{NaBH}_4(\text{aq})$

2 $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + \text{Na}(\text{s})$

3 $\text{CH}_3\text{CH}_2\text{CN} + \text{NaOH}(\text{aq})$

A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 3 only

21. Which compound is a product of the hydrolysis of $\text{CH}_3\text{CO}_2\text{CH}_2\text{C}_2\text{H}_5$ using aqueous sodium hydroxide?

A $\text{CH}_3\text{CO}_2^-\text{Na}^+$

B $\text{CH}_3\text{CO}_2\text{H}$

C $\text{C}_2\text{H}_5\text{CH}_2\text{O}^-\text{Na}^+$

D $\text{C}_2\text{H}_5\text{CH}_2\text{CO}_2^-\text{Na}^+$

22. Which organic starting material could be used in a single reaction to produce propanoic acid?

A ethanenitrile

B propan-2-ol

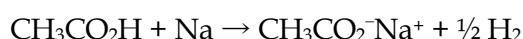
C propanal

D propyl ethanoate

Properties

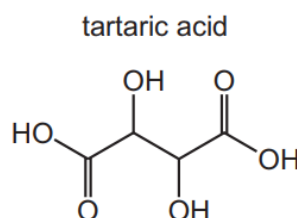
Action of reactive metals

Ethanoic acid reacts with sodium metal in a redox reaction, liberating hydrogen gas (compare with alcohols):



They also react in a similar way with other reactive metals, such as calcium and magnesium.

23. The structure of tartaric acid is shown



Which statements about tartaric acid are correct?

1 A molecule of tartaric acid has more than one chiral centre.

2 The molecular formula of tartaric acid is $\text{C}_4\text{H}_4\text{O}_6$.

3 One molecule of tartaric acid produces four hydrogen ions in aqueous solution.

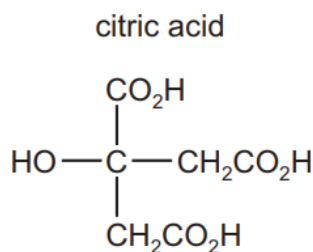
A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 1 only

24. How many moles of hydrogen, H_2 , are evolved when an excess of sodium metal is added to one mole of citric acid?



A 0.5

B 1.5

C 2

D 4

25. Which reaction is a redox reaction?

A ethanenitrile heated under reflux with dilute hydrochloric acid

B ethanoic acid reacted with aqueous sodium hydroxide

C ethanoic acid reacted with sodium

D ethyl ethanoate heated under reflux with dilute hydrochloric acid

26. Butanoic acid is prepared from 1-bromopropane.

This synthesis requires a sequence of two reactions.

Which compound is prepared in the first stage of the synthesis?

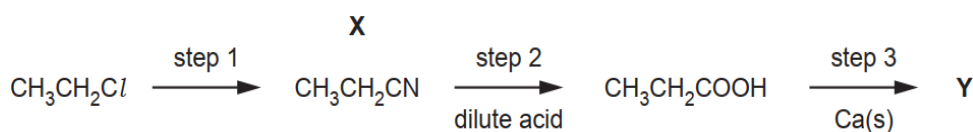
A 1-aminopropane

B propan-1-ol

C butanal

D butanenitrile

13. The following figure describes a sequence of reactions that can be used to produce a food additive, compound Y, from $\text{CH}_3\text{CH}_2\text{Cl}$.



(i) State the reagent and conditions for step 1.

[1]

(ii) Give the systematic name of X.

[1]

(iii) Identify the type of reaction that occurs when dilute acid is added to X in step 2.

[1]

(iv) In step 3, Y and a gas are produced.

Construct an equation for step 3.

[2]

27. An aqueous solution contains 4.00 g of a carboxylic acid, Q. When this solution reacts with an excess of magnesium, 380 cm³ of gas is produced, measured at s.t.p.
What is the relative formula mass of Q?

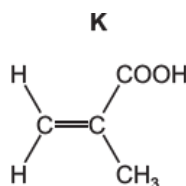
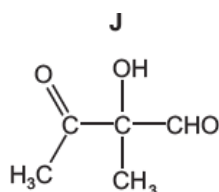
A 59

B 118

C 126

D 236

14. Compounds **J** and **K** are found in plant oils.

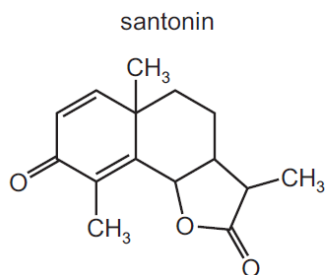


Complete Table 4.1 to state what you would **observe** when **J** reacts with the reagents listed.

[3]

Reagent	Observation with J
2,4-dinitrophenylhydrazine (2,4-DNPH)	
Tollens' reagent	
sodium metal	

28. The structure of santonin is shown.



Santonin is first treated with warm dilute H₂SO₄. The product of this reaction is treated with cold dilute acidified KMnO₄. A final product, Q, is obtained.

How many atoms of hydrogen in each molecule of product Q will react with sodium metal?

A 2

B 4

C 5

D 6

29. Ethanedioic acid has the formula HO₂CCO₂H.
What is the formula of aluminium ethanedioate?

A Al C₂O₄

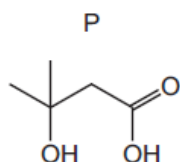
B Al (C₂O₄)₃

C Al₂C₂O₄

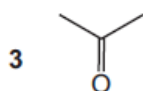
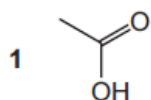
D Al₂(C₂O₄)₃

30. An excess of P reacts with Q, in the presence of concentrated sulfuric acid, to form R.

Effervescence is seen when a piece of sodium is added to pure R.
The structure of P is shown.



Which organic compounds could be compound Q?



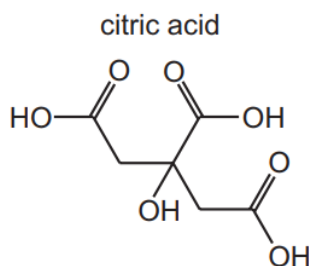
A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 1 only

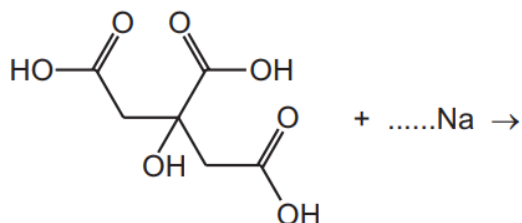
15. Compound X contains the same functional groups as citric acid.



The table describes some of the similarities and differences between citric acid and compound X.

	citric acid	X
chiral centre	no	yes
reaction with Na	fizzing	fizzing
reaction with $\text{H}^+/\text{Cr}_2\text{O}_7^{2-}$	remains orange	orange to green

- (i) Complete the equation to show the reaction of excess sodium with citric acid. Show the skeletal structure of the product.

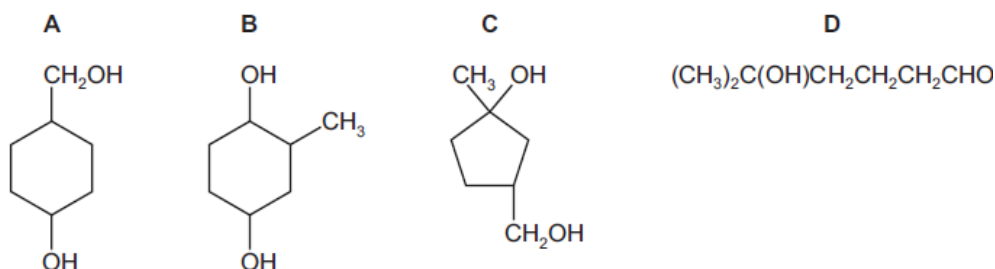


[3]

- (b) (i) Use the information in the table to deduce the skeletal formula of X, $\text{C}_3\text{H}_6\text{O}_3$. Draw the skeletal formula of X in the box. Label the chiral centre of compound X with an asterisk (*). [2]

(ii) Explain why compound **X** reacts with acidified $\text{Cr}_2\text{O}_7^{2-}$ but citric acid does not. [2]

31. Heating compound **X**, $\text{C}_7\text{H}_{14}\text{O}_2$, under reflux with an excess of acidified potassium dichromate(VI) produces compound **Y**.
Compound **Y** produces hydrogen gas with sodium metal and forms orange crystals with 2,4-DNPH reagent.
What could **X** be?



32. But-2-ene reacts with cold dilute acidified KMnO_4 to give product **X**.
But-2-ene reacts with an excess of hot concentrated acidified KMnO_4 to give product **Y**.
Which statement about **X** and **Y** is correct?

- A** Only one of **X** and **Y** reacts with 2,4-dinitrophenylhydrazine.
B **X** and **Y** both react with sodium hydroxide.
C **X** and **Y** both react with sodium metal.
D **Y** reacts with LiAlH_4 to give **X**.

33. A sample of propanoic acid of mass 3.70 g reacts with an excess of magnesium.
A second sample of propanoic acid of mass 3.70 g reacts with an excess of sodium.
Both reactions go to completion forming a gas.
Which row is correct?

	volume of gas formed with magnesium at s.t.p. / cm^3	volume of gas formed with sodium at s.t.p. / cm^3
A	560	560
B	560	1120
C	1120	560
D	1120	1120

34. In four separate reactions, **W**, **X**, **Y** and **Z**, 1 mol of an organic compound reacts with an excess of a reagent.

	organic compound	reagent
W	$(\text{CH}_2\text{COOH})_2$	Na
X	$\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{COOH}$	Na_2CO_3
Y	$\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{COOH}$	NaOH
Z	$\text{CH}(\text{OH})(\text{COOH})\text{CH}_2\text{COOH}$	Na

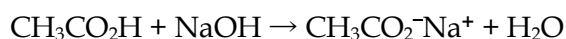
The volume of any gas produced is collected and measured. All gas volumes are measured at the same temperature and pressure.

What is the order of the reactions from greatest total volume of gas collected to least total volume of gas collected?

	Greatest volume least volume			
A	W	Y	Z	X
B	W	Z	Y	X
C	Z	W	X	Y
D	Z	X	W	Y

Neutralization with alkali

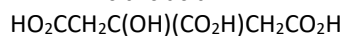
Unlike alcohols, carboxylic acids form salts with alkalis:



Salts are often much more soluble in water than the carboxylic acids from which they are derived.

35. Citric acid is found in lemon juice.

citric acid



Which volume of 0.40 mol dm^{-3} sodium hydroxide solution is required to neutralise a solution containing 0.0050 mol of citric acid?

A 12.5 cm^3

B 25.0 cm^3

C 37.5 cm^3

D 50.0 cm^3

Reaction with carbonates

Like the usual inorganic acids, but unlike alcohols, carboxylic acids react with carbonates, liberating carbon dioxide gas:

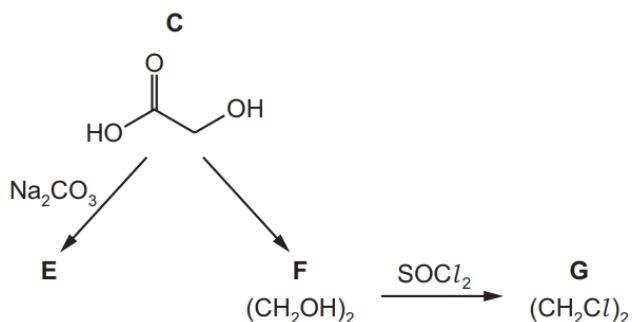


A similar reaction occurs with sodium hydrogen carbonate:



16. Describe a chemical test and observation which confirms the presence of a carboxyl functional group. [2]

17. Some other reactions of **C** are shown.



(i) Draw the structure of **E**. [1]

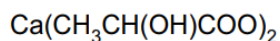
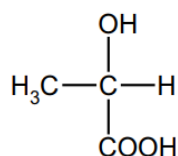
(ii) Suggest why NaBH_4 is not a suitable reagent to make **F**, $(\text{CH}_2\text{OH})_2$, from **C**. Explain your answer. [1]

(iii) Construct an equation for the reaction of $(\text{CH}_2\text{OH})_2$ with SOCl_2 to form **G**, $(\text{CH}_2\text{Cl})_2$. [1]

18. Calcium carbonate reacts with 2-hydroxypropanoic acid to form product **Y**.

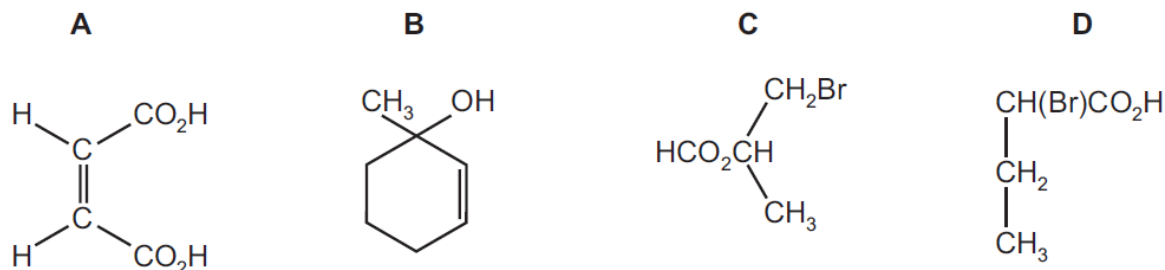
2-hydroxypropanoic acid

Y



Identify the **two** other products of the reaction of 2-hydroxypropanoic acid with calcium carbonate. [1]

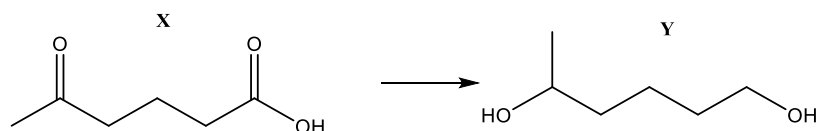
36. Which compound is chiral and reacts with Na_2CO_3 to give CO_2 ?



37. Propanoic acid is treated with reagent X at room temperature. The organic product of the reaction is sodium propanoate. No gas is produced during the reaction. What could be reagent X?



19. Y is formed from X in a single-step reaction, as shown in figure



Complete Table 5.2 with the expected observations that occur when the reagents shown are added to separate solutions of **X** and **Y**. Do **not** refer to temperature changes in your answer. [3]

reagent	observation on addition to X	observation on addition to Y
aqueous sodium carbonate		
2,4-dinitrophenylhydrazine (2,4-DNPH reagent)		
alkaline aqueous iodine		

20. Q contains the elements carbon, hydrogen and oxygen only. It is a saturated molecule with no branching in its carbon backbone.

Q contains only one functional group.

The relative molecular mass of Q is 88.

No effervescence is seen when Na_2CO_3 is added to Q.

Effervescence is seen when sodium is added to Q.

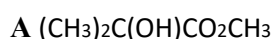
Q reacts with alkaline $\text{I}_2(\text{aq})$ to form a yellow precipitate.

Draw the structure of Q in the box.

[2]

38. Compound X, $\text{C}_5\text{H}_{10}\text{O}_3$, has one chiral carbon atom per molecule. Compound X produces bubbles with Na but **not** with Na_2CO_3 .

Which formula could represent compound X?



- B** $\text{HOCH}_2\text{CH}(\text{CH}_3)\text{CO}_2\text{CH}_3$
C $\text{CH}_3\text{CH}_2\text{C}(\text{CH}_3)(\text{OH})\text{CO}_2\text{H}$
D $\text{CH}_3\text{CH}(\text{OH})\text{CH}(\text{CH}_3)\text{CO}_2\text{H}$

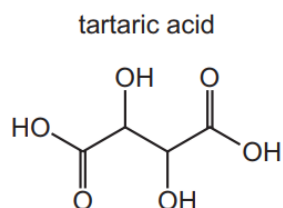
21. Propene is separated from the mixture and heated in air in the presence of a catalyst. Propene is oxidised to **X**, which contains two functional groups.

(i) Effervescence is seen when $\text{Na}_2\text{CO}_3(\text{aq})$ is added to **X**.

Identify the functional group present in **X** which is responsible for this observation.

[1]

39. The structure of tartaric acid is shown.



Four moles of substance **X** react with one mole of tartaric acid.

What could be substance **X**?

- A** sodium
B sodium carbonate
C sodium hydrogencarbonate
D sodium hydroxide

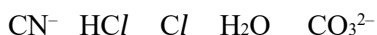
40. Two 1 g samples of **Y** are reacted separately and completely with sodium and with sodium carbonate. The volumes of the gases produced are collected and measured.

relative volumes of gases		
	with Na	with Na_2CO_3
Y	2	1

What could **Y** be?

- A** $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{OH}$
B $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}$
C $\text{CH}_3\text{COCH}_2\text{OH}$
D $\text{CH}_3\text{COCO}_2\text{H}$

22. Below is a list of species which can react with organic compounds.



From the list, identify a species which can be used to distinguish between solutions of propanoic acid and propan-1-ol. Describe any relevant observations.

[2]

41. Organic compound **Z** has an alcohol group and a carboxylic acid group.

Compound **Z** reacts with magnesium carbonate to make a salt with a relative formula mass of 230.3.

Compound Z does **not** react with acidified potassium manganate(VII).
What could be the identity of compound Z?

- A 2-hydroxy-2-methylbutanoic acid
- B 2-hydroxy-2-methylpropanoic acid
- C 3-hydroxy-2-methylbutanoic acid
- D 3-hydroxy-2-methylpropanoic acid

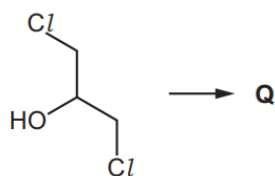
42. An organic compound, T, does **not** fizz when aqueous sodium carbonate is added to it.
Compound T contains 27.6% by mass of oxygen.
What could be the identity of T?

- 1 propanal
- 2 ethyl butanoate
- 3 3-methylpentanoic acid

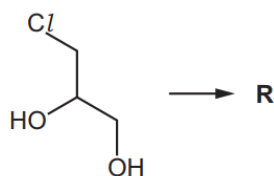
- A 1, 2 and 3 B 1 and 2 only C 2 and 3 only D 1 only

23. Separate samples of 1,3-dichloropropan-2-ol and 3-chloropropane-1,2-diol are heated with excess acidified $\text{Cr}_2\text{O}_7^{2-}$ until there is no further reaction.
In each reaction, a different organic product, **Q** or **R**, is made.

1,3-dichloropropan-2-ol



3-chloropropane-1,2-diol



Q and R are tested separately with 2,4-dinitrophenylhydrazine solution, 2,4-DNPH, and sodium carbonate solution, $\text{Na}_2\text{CO}_3(\text{aq})$.

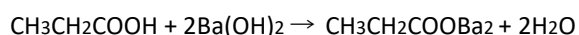
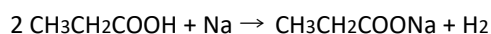
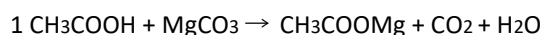
Complete the table to give any relevant observations.

If no reaction occurs, write 'no visible change'.

[4]

reagent	observation with Q	observation with R
2,4-DNPH		
$\text{Na}_2\text{CO}_3(\text{aq})$		

43. Three equations are shown.



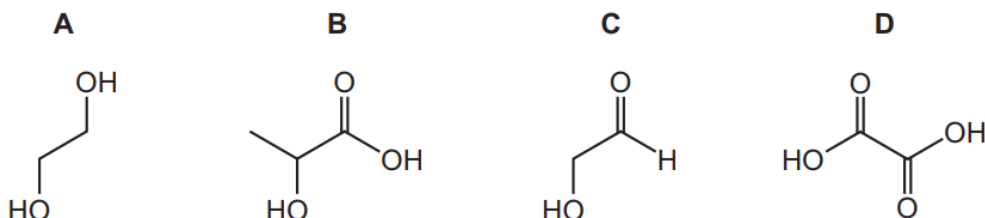
Which of the equations are correct?

- A 1, 2 and 3 B 1 and 2 only C 2 only D 3 only

44. P is a compound that burns in an excess of oxygen to give carbon dioxide and water only.
2.20 g of P contains 1.20 g of carbon and 0.20 g of hydrogen.
When P is added to a solution of sodium carbonate, bubbles of gas are seen.
What is P?

- A** CH_3CHO
B $\text{CH}_3\text{CO}_2\text{H}$
C $\text{CH}_3\text{COCH}_2\text{CH}_2\text{OH}$
D $\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$

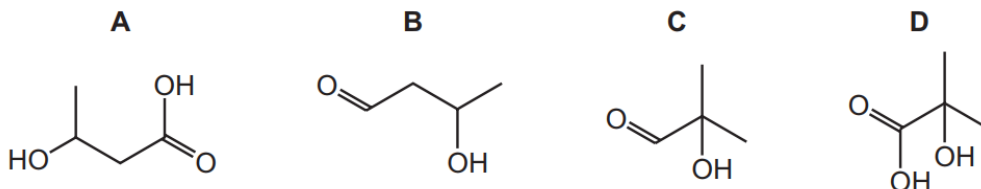
45. 1 mole of each of the following four compounds is reacted separately with:
- an excess of sodium
 - an excess of sodium carbonate.
- Which compound produces the same volume of gas with each of the **two** reagents?



46. X is an organic compound containing the elements carbon, hydrogen and oxygen only. The table shows the observations made from three chemical tests carried out on X.

reagent added	observation
Na(s)	effervescence
$\text{Na}_2\text{CO}_3(\text{s})$	effervescence
hot $\text{H}^+/\text{Cr}_2\text{O}_7^{2-}(\text{aq})$	remains orange

What is a possible structure of X?



47. The table shows the reagents and products of three reactions.

	Reagents	products
1	ethanoic acid + Na_2CO_3	$\text{CH}_3\text{CO}_2\text{Na} + \text{H}_2\text{O} + \text{CO}_2$
2	ethanoic acid + Mg	$(\text{CH}_3\text{CO}_2)_2\text{Mg} + \text{H}_2\text{O}$
3	ethanoic acid + CH_3OH	$\text{CH}_3\text{CO}_2\text{CH}_3 + \text{H}_2\text{O}$

Which rows are correct?

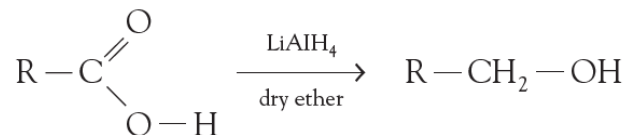
- A 1, 2 and 3 B 1 and 2 only C 1 and 3 only D 2 and 3 only

48. In four separate reactions, W, X, Y and Z, 1 mol of an organic compound reacts with an excess of a reagent.

	organic compound	reagent
W	$(\text{CH}_2\text{COOH})_2$	Na
X	$\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{COOH}$	Na_2CO_3
Y	$\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{COOH}$	NaOH
Z	$\text{CH}(\text{OH})(\text{COOH})\text{CH}_2\text{COOH}$	Na

Reduction by LiAlH₄

Carboxylic acids can be reduced to alcohols by reacting with lithium tetrahydridoaluminate(III) (lithium aluminium hydride), LiAlH₄, in dry ether.



The reaction requires the powerful reducing agent LiAlH₄; neither NaBH₄ nor H₂ + Ni are strong enough to reduce carboxylic acids.

49. Tartaric acid, HOOCCH(OH)CH(OH)COOH, is found in many plants.

A sample of tartaric acid reacts with an excess of LiAlH₄ to form the organic product J.

What happens when NaOH(aq) is added to separate samples of tartaric acid and J?

- A Both tartaric acid and J react.
- B Only tartaric acid reacts.
- C Only J reacts.
- D Neither tartaric acid nor J react.

50. Which statement is correct?

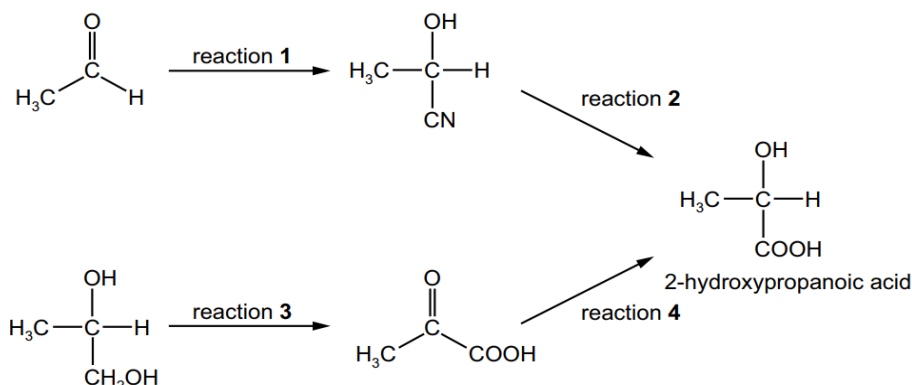
- A C₃H₇COOH can be used to form propyl propanoate in a single reaction.
- B The empirical formula of C₃H₇COOH is the same as its molecular formula.
- C Each of C₃H₇OH and C₃H₇COOH reacts separately with NaBH₄.
- D Each of C₃H₇OH and C₃H₇COOH reacts separately with sodium metal.

51. Propanoic acid can be used to make propene by a two-stage synthesis.

Which row shows suitable reagents for this synthesis?

	reagent for second stage	reagent for first stage
A	conc. H ₂ SO ₄	LiAlH ₄
B	NaOH in ethanol	LiAlH ₄
C	conc. H ₂ SO ₄	NaBH ₄
D	NaOH in ethanol	NaBH ₄

24. Two possible methods of making 2-hydroxypropanoic acid are shown in the following figure.



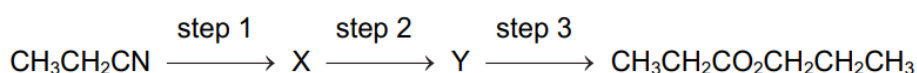
- (i) State suitable reagents and conditions for reactions **1** and **3**. [4]
- (ii) Deduce the type of reaction that occurs in reaction **2**. [1]
- (iii) The reagent for reaction **4** is NaBH_4 .
Identify the role of NaBH_4 in this reaction. [1]

52. Propyl propanoate can be synthesised in three steps using propanenitrile as the only organic starting material.

In step 1, the nitrile is converted into compound X.

In step 2, compound X is converted into compound Y.

In step 3, compound Y is reacted with more of compound X to give propyl propanoate.



Which reagents are suitable for carrying out step 1 and step 2?

	step 1	step 2
A	HCl(aq)	conc. H_2SO_4
B	HCl(aq)	LiAlH_4
C	NaOH(aq)	conc. H_2SO_4
D	NaOH(aq)	NaBH_4

25. Aqueous bromine reacts with methanoic acid to form hydrogen bromide and carbon dioxide gas.
 $\text{Br}_2(\text{aq}) + \text{HCO}_2\text{H}(\text{aq}) \rightarrow 2\text{HBr}(\text{aq}) + \text{CO}_2(\text{g})$

Suggest one change you would observe, ignoring temperature changes, when bromine reacts with methanoic acid. [1]

26. Fig. 5.2 shows how butan-1-ol can be made from 1-bromopropane in three steps.



- (i) In step **2**, butanenitrile is heated with HCl(aq) . A hydrolysis reaction occurs.
Construct an equation for the reaction in step **2**. [1]
- (ii) Step **3** is a reduction reaction.
Construct an equation for the reduction reaction in step **3**. Use $[\text{H}]$ to represent one atom of hydrogen from the reducing agent. [1]
- (iii) State the identity of a suitable reducing agent in step **3**. [1]

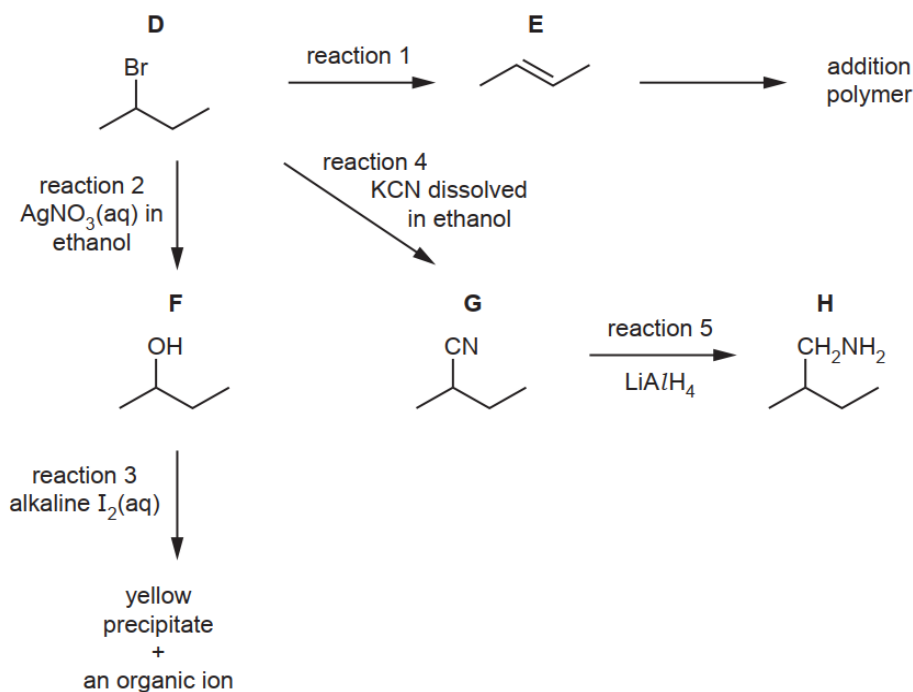
27. Z is a molecule which contains the elements carbon, hydrogen and oxygen only.

Z contains only alkene and carboxyl functional groups.

(a) Complete Table 6.1 by describing the observations that occur when two different reagents are added to separate samples of Z(aq) . [2]

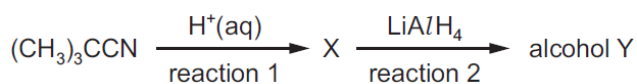
reagent added to Z(aq)	observation
Br ₂ (aq)	
Na ₂ CO ₃ (s)	

28. Fig. 4.1 shows some reactions of compound **D**, 2-bromobutane.



- State the reagent and conditions used to form **E** in reaction 1.
- State the type of reaction that occurs in reaction 4.
- Predict what is observed in reaction 2.
- Reaction 5 is similar to the reaction of LiAlH₄ with carboxylic acids to form alcohols. Suggest the role of LiAlH₄ in reaction 5. [1]

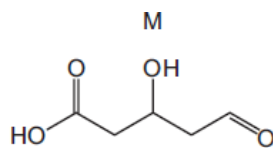
53. (CH₃)₃CCN reacts to form alcohol Y via the reaction sequence shown.



Which row names the molecule X and the class of alcohol Y?

	name of molecule X	class of alcohol Y
A	2,2-dimethylbutanoic acid	primary
B	3,3-dimethylbutanoic acid	tertiary
C	dimethylpropanoic acid	primary
D	dimethylpropanoic acid	tertiary

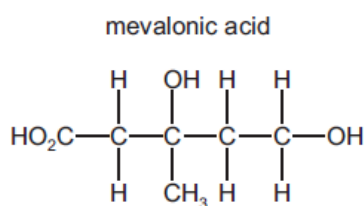
54. The skeletal formula of M is shown.
M is reacted with an excess of LiAlH_4 . Dilute acid is then added.



What is the molecular formula of the final organic product?

- A** $\text{C}_5\text{H}_6\text{O}_5$ **B** $\text{C}_5\text{H}_{10}\text{O}_4$ **C** $\text{C}_5\text{H}_{10}\text{O}_3$ **D** $\text{C}_5\text{H}_{12}\text{O}_3$

55. The diagram shows the structural formula of mevalonic acid.



Which reagent and conditions will react with mevalonic acid to produce an organic compound **without** a chiral carbon atom?

- A** heat under reflux with $\text{CH}_3\text{OH} / \text{H}^+$
B heat under reflux with $\text{Cr}_2\text{O}_7^{2-} / \text{H}^+$
C Na at room temperature
D PCl_5 at room temperature

56. Three colourless liquids with the following formulae are contained in separate unlabelled bottles.
 $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$ $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}$ $\text{CH}_3\text{COCO}_2\text{H}$

Which two tests, carried out on separate samples of each liquid, will successfully identify each liquid?

	test 1	test 2
A	NaHCO_3	2,4-DNPH reagent
B	NaHCO_3	Tollens' reagent
C	warm acidified dichromate	2,4-DNPH reagent
D	warm acidified dichromate	Tollens' reagent

57. Three colourless liquids with the following formulae are contained in separate unlabelled bottles.
 $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$ $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}$ $\text{CH}_3\text{COCO}_2\text{H}$

Which two tests, carried out on separate samples of each liquid, will successfully identify each liquid?

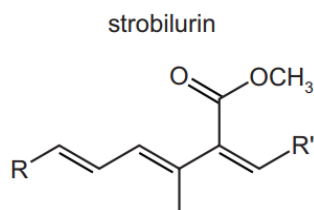
	test 1	test 2
A	NaHCO_3	2,4-DNPH reagent
B	NaHCO_3	Tollens' reagent
C	warm acidified dichromate	2,4-DNPH reagent
D	warm acidified dichromate	Tollens' reagent

58. Which pair of reagents react together in a redox reaction?

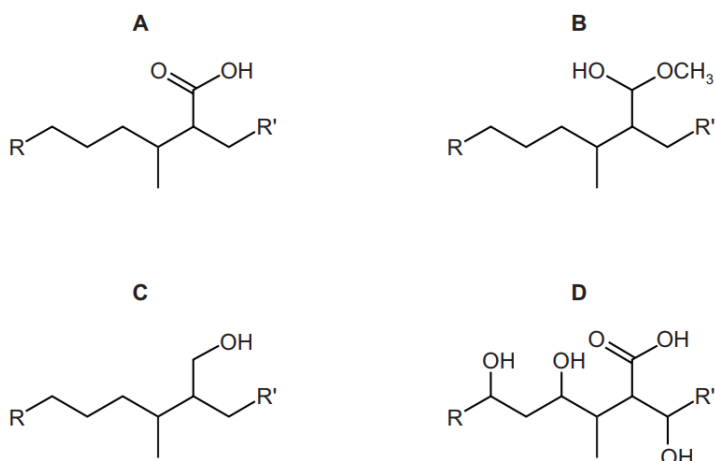
- A** $\text{CH}_3\text{CHCH}_2 + \text{Br}_2$
B $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + \text{concentrated H}_3\text{PO}_4$

- C** $\text{CH}_3\text{COCH}_3 + \text{HCN}$
D $\text{HCO}_2\text{C}_2\text{H}_5 + \text{dilute H}_2\text{SO}_4$

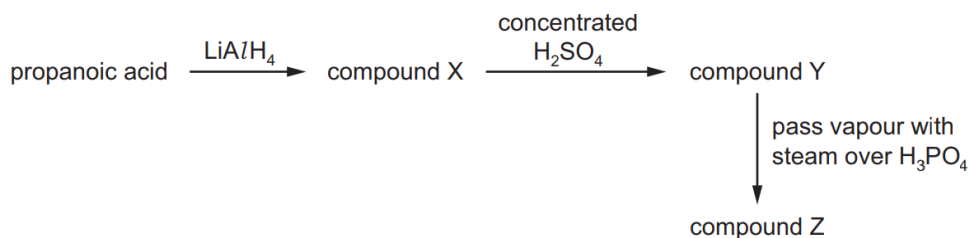
59. Part of the structure of strobilurin is shown. R and R' are inert groups.



Strobilurin is warmed with aqueous sulfuric acid producing compound X. Compound X is then treated with hydrogen in the presence of a nickel catalyst producing compound Y.
 What could be the structure of compound Y?



60. A sequence of reactions takes place. The major product is compound Z.



What is compound Z?

- A** propanone
B propene
C propan-1-ol
D propan-2-ol

61. P is a carboxylic acid with molecular formula $\text{C}_5\text{H}_{10}\text{O}_2$.
 Carboxylic acid P reacts with an excess of LiAlH_4 to form compound Q.
 Which pairs of molecules could be carboxylic acid P and compound Q?

	carboxylic acid P	compound Q
1	$\text{CH}_3(\text{CH}_2)_3\text{COOH}$	$\text{CH}_3(\text{CH}_2)_3\text{OH}$
2	$\text{CH}_3(\text{CH}_2)_3\text{COOH}$	$\text{CH}_3(\text{CH}_2)_3\text{CHO}$
3	$(\text{CH}_3)_3\text{CCOOH}$	$(\text{CH}_3)_3\text{CCH}_2\text{OH}$

- A 1 and 2 B 1 and 3 C 2 and 3 D 3 only

29. Below is a list of species which can react with organic compounds.

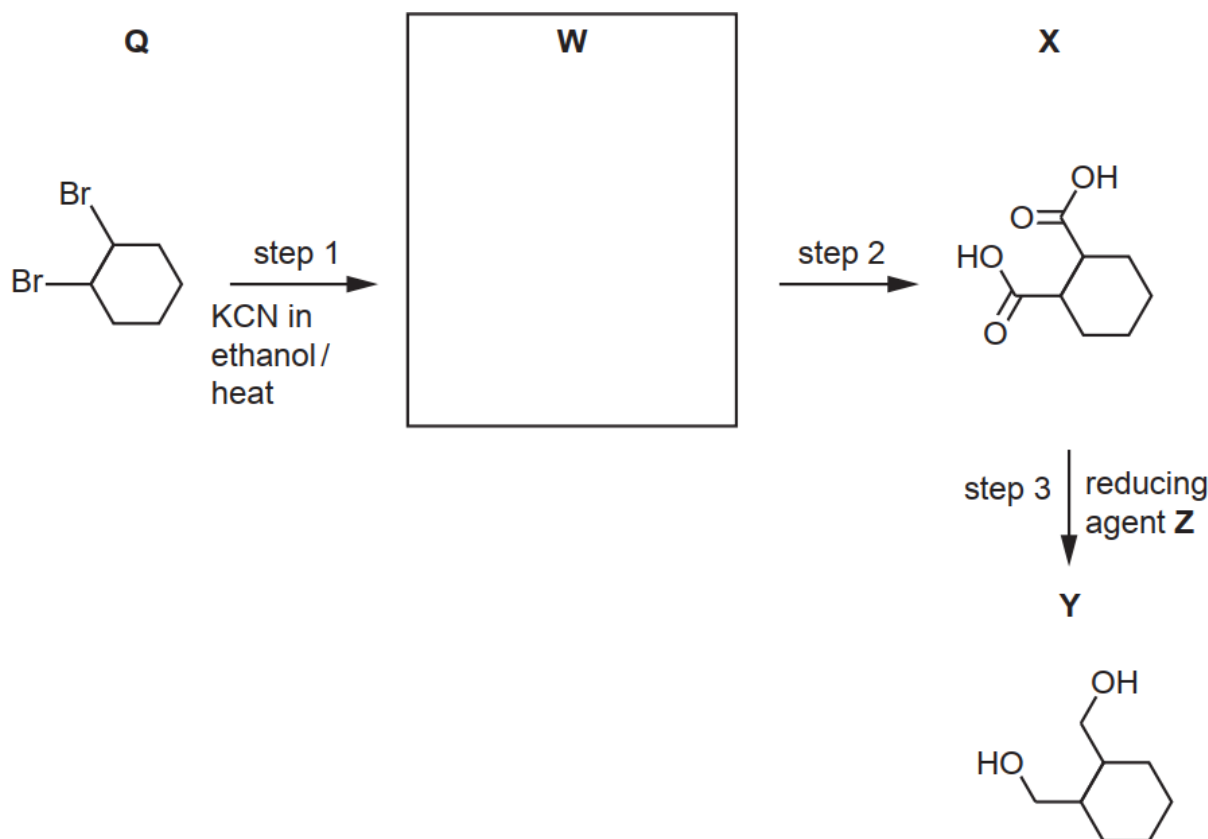


From the list, identify a species which can be used to distinguish between solutions of propanoic acid and propan-1-ol. Describe any relevant observations.

.....

 [2]

30. **Y** is made from **Q** in a three-step reaction.



[1]

(i) Draw the structure of **W** in the box in Fig. 5.4.

[1]

(ii) In step 2, **W** is heated with HCl(aq) to produce **X** and an inorganic product. Identify the formula of the inorganic product.

..... [1]

(iii) In step 3, **X** reacts with reducing agent **Z** to produce **Y**.

Complete the equation for the reaction of **X** with **Z**.

Use a molecular formula to represent the organic product.

Use $[\text{H}]$ to represent one atom of hydrogen from **Z**.

..... $\text{C}_8\text{H}_{12}\text{O}_4$ + $[\text{H}]$ [1]

(iv) Identify **Z**.

..... [1]

62. Which substance reacts with ethanoic acid to give the organic product with the highest M_r ?
- A lithium aluminium hydride
 - B magnesium
 - C potassium carbonate
 - D propan-2-ol
63. But-2-ene reacts with cold dilute acidified $KMnO_4$ to give product X.
But-2-ene reacts with an excess of hot concentrated acidified $KMnO_4$ to give product Y.
Which statement about X and Y is correct?
- A Only one of X and Y reacts with 2,4-dinitrophenylhydrazine.
 - B X and Y both react with sodium hydroxide.
 - C X and Y both react with sodium metal.
 - D Y reacts with $LiAlH_4$ to give X.
64. The M_r of compound X is 88.
Compound X is heated under reflux with an excess of acidified potassium dichromate(VI) to produce compound Y.
Compound Y reacts with compound X under suitable conditions to produce compound Z. The M_r of compound Z is 172.
What is compound X?
- A $CH_3CH_2CHOHCH_2CH_3$
 - B $(CH_3)_2COHCH_2CH_3$
 - C $(CH_3)_2CHCHOHCH_3$
 - D $(CH_3)_3CCH_2OH$

***This is not a complete note. It is to guide you. It is recommended to study the prescribed textbooks along with this material. ***