

PROSPERITY ACADEMY

AS CHEMISTRY 9701

Crash Course

RUHAB IQBAL

CARBONYLS

COMPLETE NOTES



0331 - 2863334

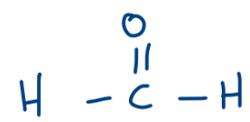


**ruhab.prosperityacademics
@gmail.com**

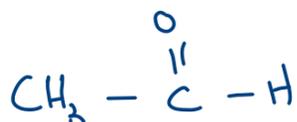


Carbonyls:- Organic compounds containing C=O bond.

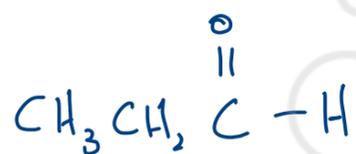
→ Aldehydes:- $\begin{array}{l} R \\ | \\ C=O \\ | \\ H \end{array}$ - H will always be hydrogen - R can be anything (alkyl, aryl, H etc)



methanal
HCHO



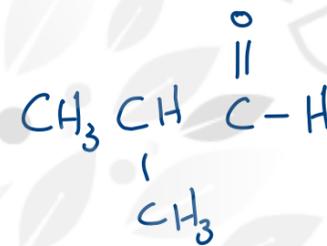
ethanal
CH₃CHO



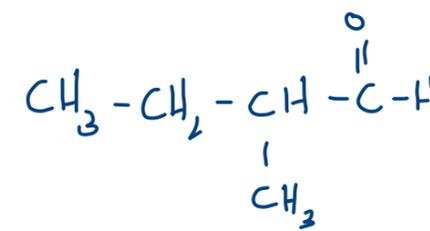
propanal
CH₃CH₂CHO



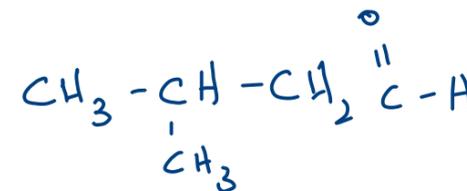
butanal
CH₃CH₂CH₂CHO



2-methyl propanal
CH₃CH(CH₃)CHO

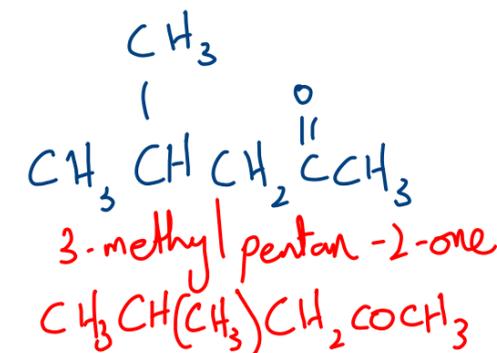
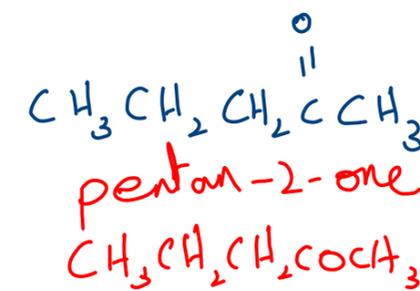
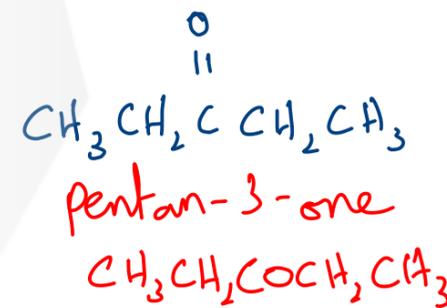
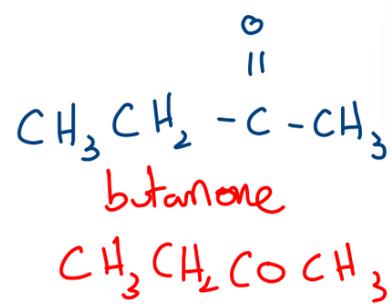
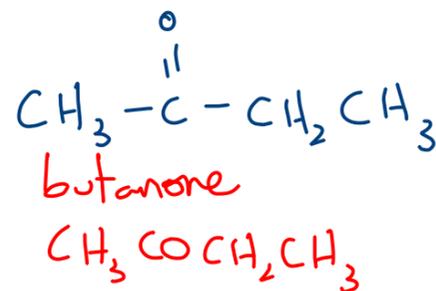
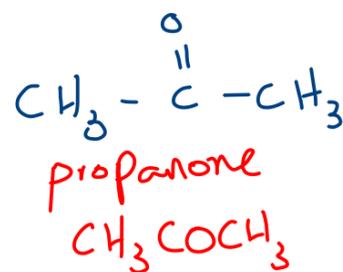


2-methyl butanal
CH₃CH₂CH(CH₃)CHO



3-methyl butanal
CH₃CH(CH₃)CH₂CHO

→ Ketones:- $\begin{array}{l} R \\ | \\ C=O \\ | \\ R' \end{array}$ - R and R' can be anything except for hydrogen (alkyl, aryl)



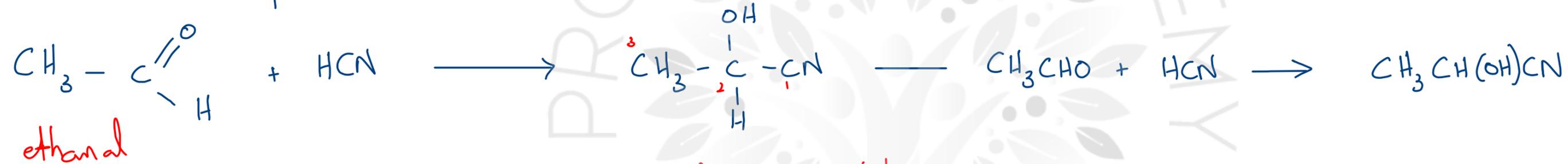
Physical properties:-

- low solubility in water as they have only temporary and permanent dipoles
- lower boiling points than alcohols as they do not have hydrogen bonding

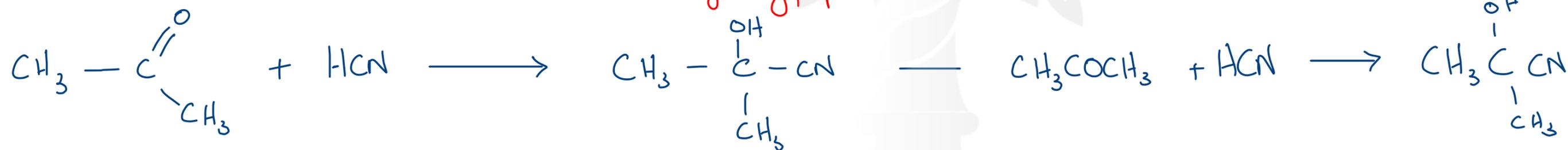
Chemical properties:- Carbonyls undergo the following reactions:-

1) Addition of HCN \longrightarrow HCN in NaCN or KCN

Mechanism:- Nucleophilic addition

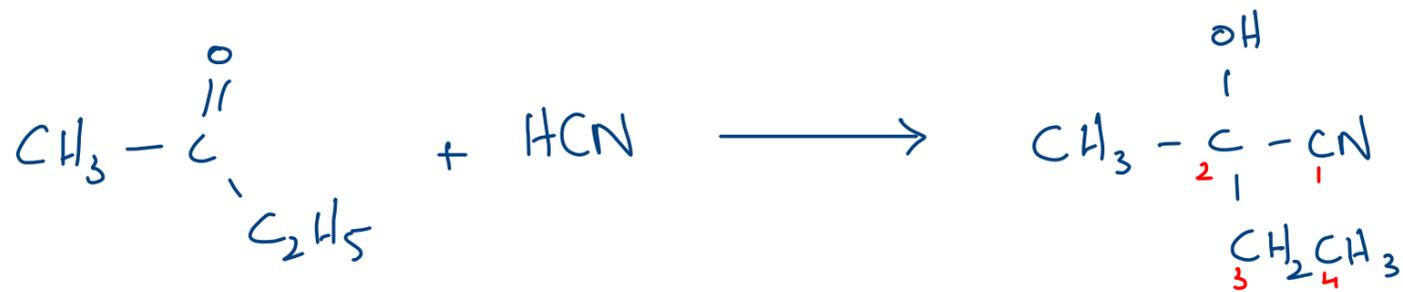


2-hydroxypropanenitrile



propanone

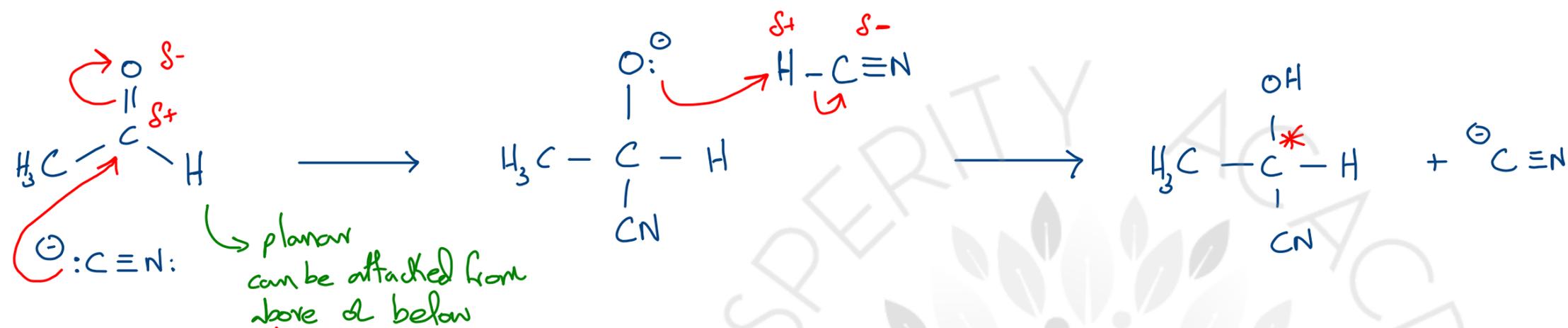
2-hydroxy-2-methylpropanenitrile



butanone

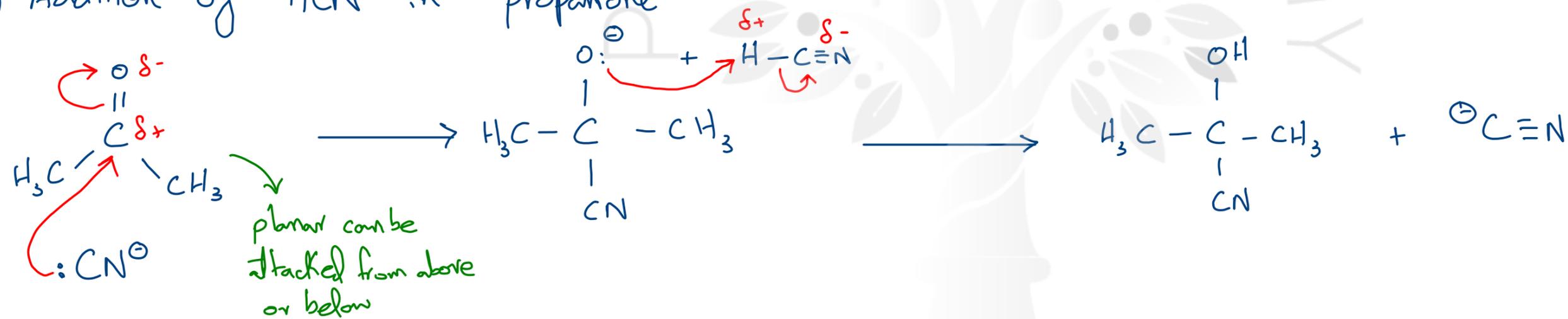
2-hydroxy-2-methylbutanenitrile

Mechanism: - 1) Addition of HCN in ethanal



- CN^\ominus ions catalyse the reaction
- A racemic mixture is obtained - 2 optical isomers

2) Addition of HCN in propanone



Importance of this reaction:-

- Carbon chain lengthens \rightarrow CN can be hydrolysed to COOH
- OH group gives all reactions of alcohols

2) Reduction of Aldehydes and Ketones :-

- Aldehydes are reduced to primary alcohols
- Ketones are reduced to secondary alcohols

Reagents :-

- 1) LiAlH_4 dissolved in dried ether
- 2) NaBH_4
- 3) H_2 + Nickel catalyst + 200°C (heat)



3) Oxidation of aldehydes and Ketones :-

- Aldehydes oxidise to carboxylic acids
- Ketones NEVER oxidise

Reagents

Observation with aldehyde

observation with ketone

- 1) Acidified $\text{K}_2\text{Cr}_2\text{O}_7$
- 2) Tollen's reagent
- 3) Fehling's reagent

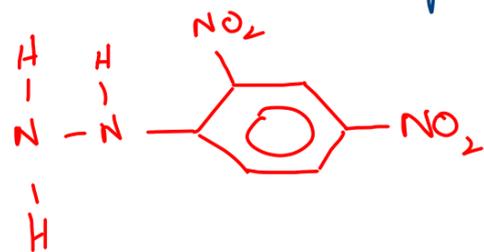
solution turns from orange to green
silver/grey ppt
brick red ppt

—
—
—

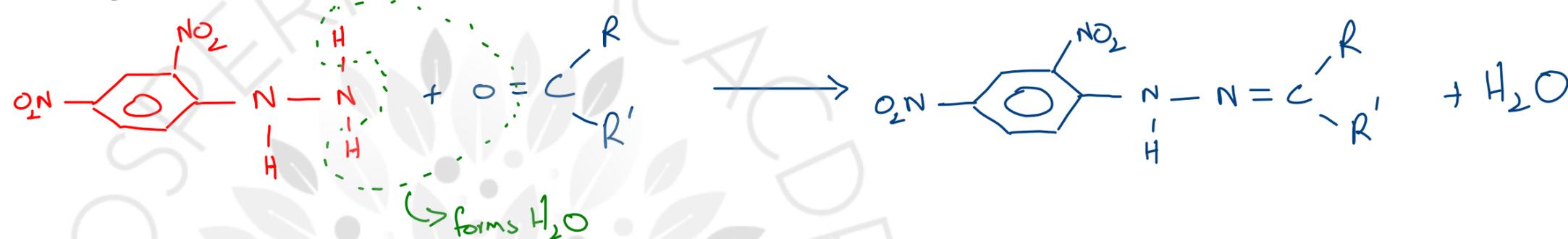
4) Reaction with 2,4-DNPH (dinitrophenylhydrazine):- Test for aldehydes and ketones

- Both aldehydes and ketones give a yellow ppt with 2,4-DNPH

2,4-dinitrophenyl hydrazine



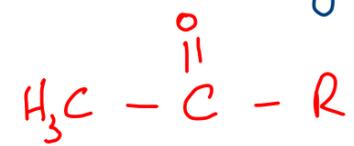
Reaction:-



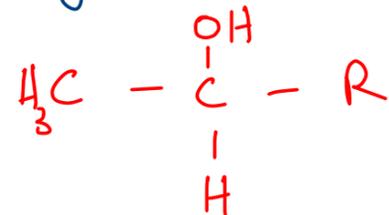
condensation reaction:- When 2 large molecules combine releasing a small molecule such as H_2O .

5) Triiodomethane / Iodoform reaction:- $I_2(aq) + NaOH(aq)$ (Alkaline aqueous iodine)

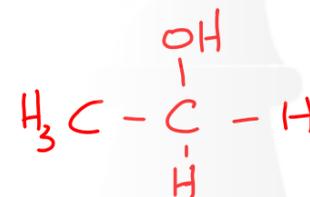
- Gives a yellow ppt of CHI_3 (triiodomethane/iodoform) with methyl ketones and secondary methyl alcohols



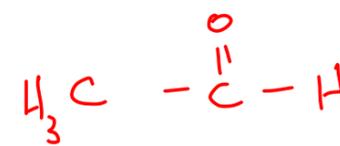
methyl ketone



secondary methyl alcohol



ethanol



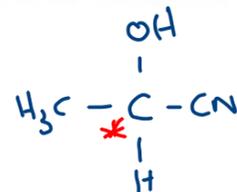
ethanal

also give reactions



1 Which compound on reaction with hydrogen cyanide produces a compound with a chiral centre?

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



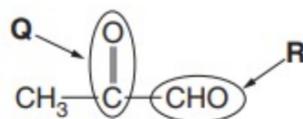
4 Ethanal may be converted into a three-carbon acid in a two-step process.

Which compound is the intermediate?

- A $\text{CH}_3\text{CO}_2\text{H}$ B CH_3CN C $\text{CH}_3\text{CH}_2\text{CN}$ **D** $\text{CH}_3\text{CH}(\text{OH})\text{CN}$



5 Burnt sugar has a characteristic smell caused partly by the following compound. It has two functional groups indicated by Q and R.



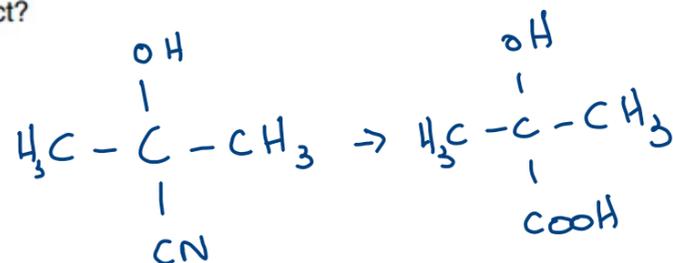
When this compound is tested in a laboratory with 2,4-dinitrophenylhydrazine and Fehling's reagent, which functional groups are responsible for positive tests?

	2,4-dinitrophenylhydrazine	Fehling's reagent
A	Q and R ✓	Q and R
B	R only	Q and R
C	Q and R ✓	R only ✓
D	Q only	R only

6 The product of the reaction between propanone and hydrogen cyanide is hydrolysed under acidic conditions.

What is the formula of the final product?

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

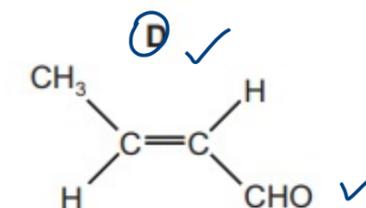
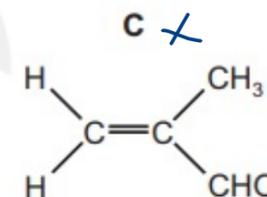
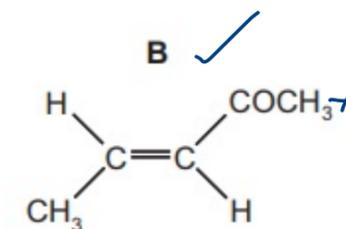
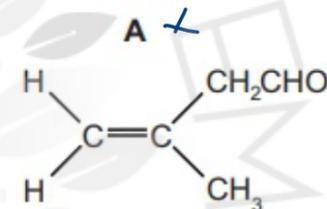


8 For which pair of compounds can the members be distinguished by means of Tollens' test (the use of a solution containing $\text{Ag}(\text{NH}_3)_2^+$)?

- A** CH_3CHO and CH_3COCH_3 ✓
 B CH_3COCH_3 and $\text{C}_2\text{H}_5\text{COCH}_3$
 C CH_3COCH_3 and $\text{CH}_3\text{CO}_2\text{CH}_3$
 D $\text{CH}_3\text{CO}_2\text{H}$ and $\text{CH}_3\text{CO}_2\text{CH}_3$

9 Compound P displays *cis-trans* isomerism and gives a red-brown precipitate with Fehling's solution.

What is P?



primary alcohol / 2° alcohol / aldehyde

10 Compound X changes the colour of acidified sodium dichromate(VI) from orange to green. 1 mol of X reacts with 2 mol of $\text{HCN}(\text{g})$.

↳ aldehyde / ketone

What could X be?

- A $\text{CH}_3\overset{\text{ket}}{\text{CO}}\text{CH}_2\overset{\text{ket}}{\text{CO}}\text{CH}_3$
 B $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$ aldehyde
 C $\text{H}_2\text{C}=\text{CHCH}_2\text{CHO}$ aldehyde
D $\text{OHCCH}_2\text{CH}_2\text{CHO}$

26 Hept-4-enal is present in cow's milk.

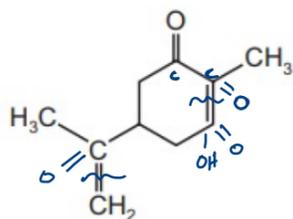
$$\text{CH}_3\text{CH}_2\overset{\text{H}}{\underset{|}{\text{C}}}\overset{\text{H}}{\underset{|}{\text{C}}}\text{CH}_2\text{CH}_2\text{CHO}$$

hept-4-enal

What is formed when hept-4-enal is reduced with **either** hydrogen and a nickel catalyst **or** sodium borohydride?

- A with H_2/Ni $\text{CH}_3(\text{CH}_2)_5\text{CH}_2\text{OH}$ ✓
 B with H_2/Ni $\text{CH}_3(\text{CH}_2)_5\text{CH}_3$ ✗
 C with NaBH_4 $\text{CH}_3(\text{CH}_2)_5\text{CH}_2\text{OH}$ ✗
 D with NaBH_4 $\text{CH}_3(\text{CH}_2)_5\text{CHO}$ ✗

30 Carvone gives the characteristic flavour to caraway and spearmint.



carvone

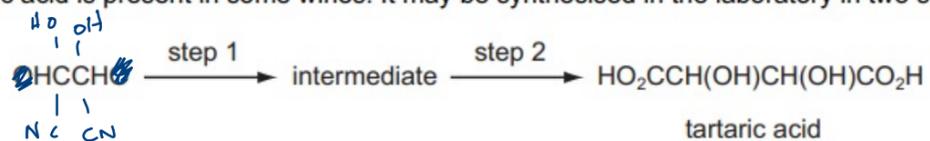
Prolonged heating of carvone with hot concentrated acidified potassium manganate(VII) produces carbon dioxide and a compound **X**.

X contains nine carbon atoms and reacts with 2,4-dinitrophenylhydrazine reagent.

What is the maximum number of molecules of 2,4-dinitrophenylhydrazine that will react with one molecule of **X**?

- A 1 B 2 C 3 D 4

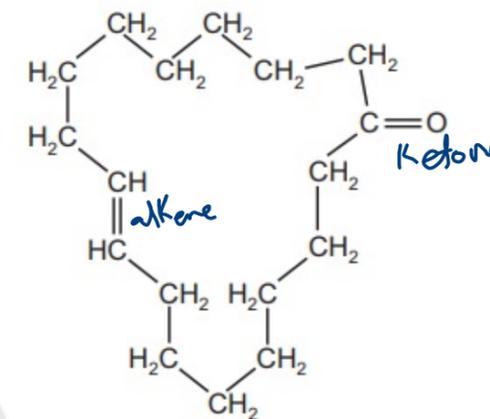
36 Tartaric acid is present in some wines. It may be synthesised in the laboratory in two steps.



Which reagents could be used for this synthesis?

	step 1	step 2
A	$\text{HCl}(\text{aq})$	$\text{HCN}(\text{g})$
<input checked="" type="radio"/> B	$\text{HCN}, \text{NaCN}(\text{aq}/\text{alcoholic})$	$\text{H}_2\text{SO}_4(\text{aq})$
C	$\text{H}_2\text{SO}_4(\text{aq})$	$\text{K}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4(\text{aq})$
D	$\text{KCN}(\text{aq}/\text{alcoholic})$	$\text{K}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4(\text{aq})$

33 The naturally-occurring molecule civetone is found in a gland of the African civet cat and has been used in perfumery.



civetone

With which reagent will civetone **not** react?

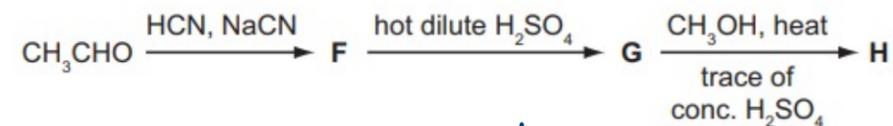
- A 2,4-dinitrophenylhydrazine reagent ✓
 B Fehling's reagent ✗
 C hydrogen bromide ✓
 D sodium tetrahydridoborate(III) (sodium borohydride) ✓

42 A compound **Y** is treated with warm acidified potassium dichromate(VI). The resulting organic product gives an orange precipitate with 2,4-dinitrophenylhydrazine reagent but does not give a silver mirror with Tollens' reagent.

What is **Y**?

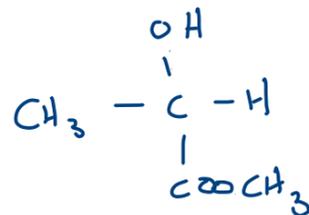
- A butan-1-ol → aldehyde
 B butan-2-ol ✓
 C butanal → carboxylic acid
 D 2-methylpropan-2-ol 3° alcohol

47 In a sequence of reactions, ethanal is converted into a compound **H**.

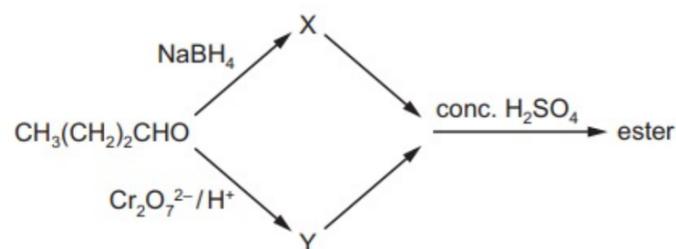


What could **H** be?

- A $\text{CH}_3\text{CH}_2\text{COOCH}_3$ ✗
 B $\text{CH}_3\text{CH}(\text{OH})\text{COOCH}_3$ ✓
 C $\text{CH}_3\text{CH}(\text{OH})\text{OCOCH}_3$ ✗
 D $\text{CH}_3\text{CH}(\text{OCH}_3)\text{COOH}$ ✗

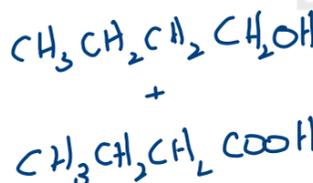


64 An ester with an aroma of pineapples can be synthesized in the laboratory from butanal using this reaction scheme.



What is the structural formula of the **ester**?

- A $\text{CH}_3(\text{CH}_2)_2\text{CO}_2(\text{CH}_2)_2\text{CH}_3$
 B $\text{CH}_3(\text{CH}_2)_2\text{CO}_2(\text{CH}_2)_3\text{CH}_3$ ✓
 C $\text{CH}_3(\text{CH}_2)_3\text{CO}_2(\text{CH}_2)_2\text{CH}_3$
 D $\text{CH}_3(\text{CH}_2)_3\text{CO}_2(\text{CH}_2)_3\text{CH}_3$

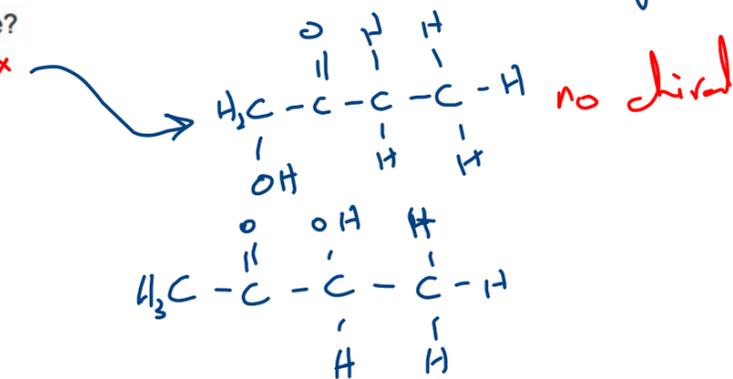


92 Compound **G**

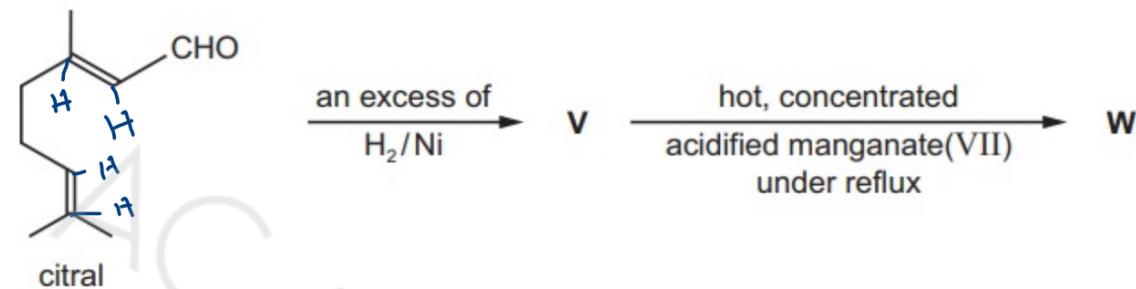
- has a chiral centre,
- gives a positive result with alkaline aqueous iodine,
- does not give a silver mirror with Tollens' reagent. → not aldehyde

What could compound **G** be?

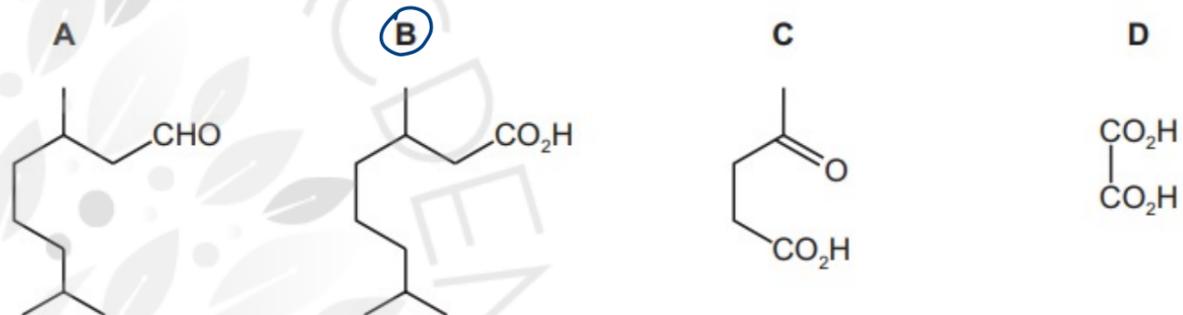
- A 1-hydroxybutan-2-one ✗
 B 2-hydroxybutanal ✗
 C 3-hydroxybutanal ✗
 D 3-hydroxybutan-2-one ✓



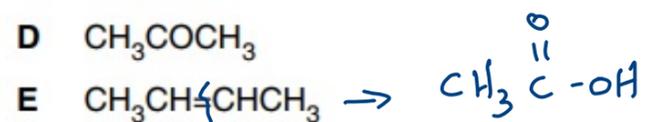
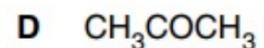
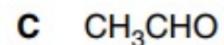
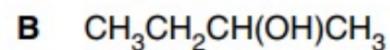
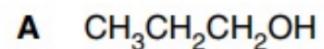
80 Citral is found in lemongrass oil. It can react to give compound **W**.



What could compound **W** be?



1 Samples of the following compounds were labelled **A** to **E** as shown.



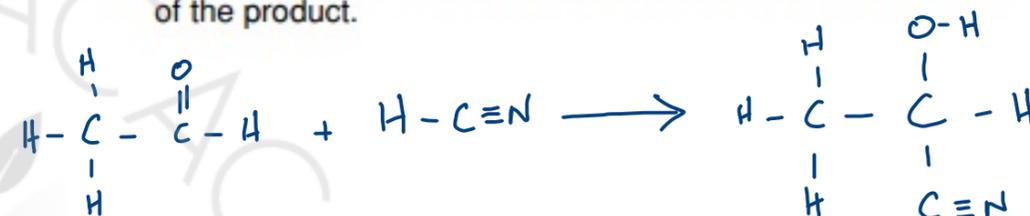
Complete the table below by inserting the letter (or letters) of the compounds that correspond to each test.

reagent	observation	letter(s)
acidified potassium dichromate(VI)	green colour obtained on boiling	A, B, C
acidified potassium manganate(VII)	ethanoic acid obtained on boiling	C, E
hydrogen in the presence of a platinum catalyst	hydrogen absorbed	C, D, E
Fehling's reagent	brown-red precipitate obtained on boiling	C
2,4-dinitrophenylhydrazine	orange precipitate	C, D
bromine in an inert solvent	solution decolourised	E

3 2-Hydroxypropanoic acid (lactic acid), $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}$, can be prepared in a two-stage synthesis from ethanal, CH_3CHO .

(a) In the first stage, ethanal reacts with hydrogen cyanide, HCN, in the presence of an NaCN catalyst to produce a cyanohydrin.

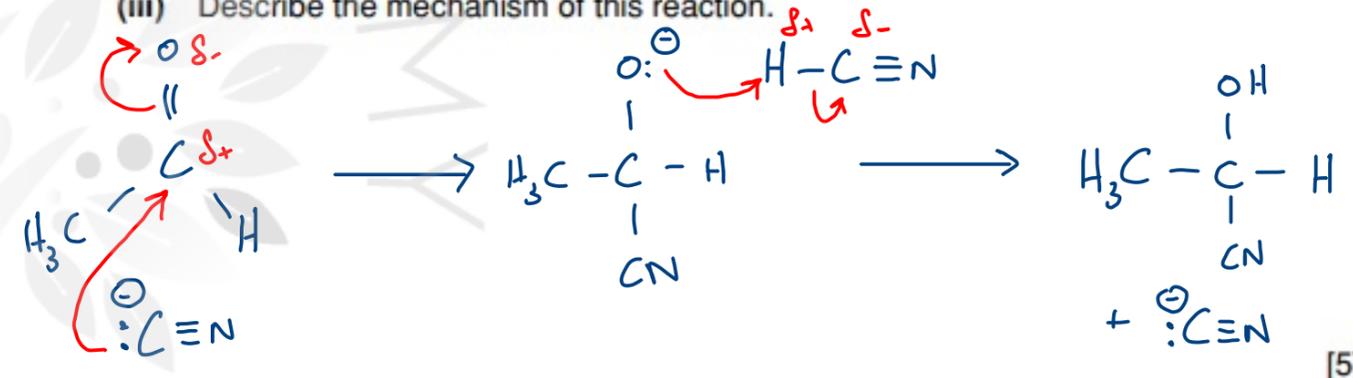
(i) Write an equation for the reaction of ethanal and HCN, giving the displayed formula of the product.



(ii) State what type of reaction this is.

Nucleophilic addition

(iii) Describe the mechanism of this reaction.



[5]

(b) In the second stage, the product from (a) is converted into lactic acid.

(i) Write the equation for this stage.



(ii) State what type of reaction this is.

hydrolysis

[2]

4 A student obtained the following results when analysing an organic compound, H.

test		observation
test 1	relative molecular mass	72
test 2	% composition by mass	C, 66.7%; H, 11.1%; O, 22.2%
test 3	reactions with Br ₂ (aq)	Br ₂ decolourised
test 4	reaction with Na(s)	H ₂ (g) evolved
test 5	reaction with warm Cr ₂ O ₇ ²⁻ /H ⁺	green colour observed

↳ 1° alcohol / 2° alcohol / aldehyde

The student allowed test 5 to go to completion and then investigated the product of test 5 with the following result.

1° Alcohol → aldehyde + CO₂H 2° alcohol → Ketone aldehyde → CO₂H

test 6	reaction with 2,4-dinitrophenylhydrazine	no reaction
--------	--	-------------

(a) Calculate the molecular formula of H.

$$n = \frac{66.7}{12} : \frac{11.1}{1} : \frac{22.2}{16}$$

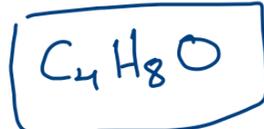
$$= (5.5583 : 11.1 : 1.3875) \div 1.3875$$

$$4 : 8 : 1$$

Emp formula = C₄H₈O

$$n = \frac{72}{12(4) + 8 + 16}$$

$$n = 1$$



Ans

[2]

(b) What can be deduced about the nature of H by the following tests?

- (i) test 3 it contains alkene functional group
- (ii) test 4 contains either alcohol or carboxylic acid

[2]

(c) (i) What functional group would have given a positive result in test 6?

carbonyl

(ii) What functional group is shown to be present in H by tests 5 and 6?

primary alcohol

[2]

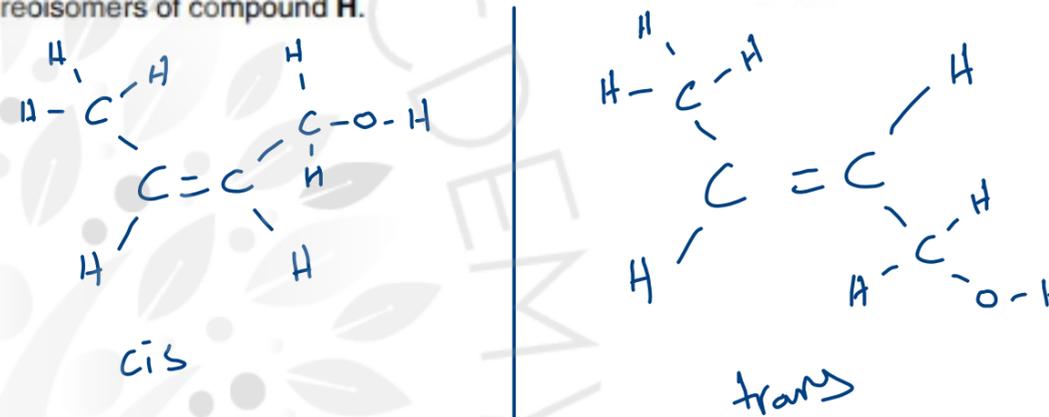
(d) On testing a sample of H, the student found that it was not chiral.

H did, however, show *cis-trans* isomerism.

How does *cis-trans* isomerism arise in an organic molecule?

It arises when a C=C bond is present and each carbon has different groups attached to it. The π bond prevents rotation so therefore isomers exist. [2]

(e) Use all of the information above to draw labelled, displayed formulae of the stereoisomers of compound H.



[2]

5 Compound **Z**, an organic compound with **three** functional groups, has the molecular formula $C_4H_6O_2$. The functional groups can be confirmed by the following tests.

(a) Test for the first functional group.

Z decolourises aqueous bromine.

What functional group is shown to be present in **Z** by this test?

..... alkene [1]

(b) Tests for the second functional group.

Z reacts with sodium to give hydrogen and a solid compound of formula $C_4H_5O_2Na$.

When **Z** is heated with ethanoic acid and a few drops of concentrated sulphuric acid, a sweet smelling liquid of molecular formula $C_6H_8O_3$ is formed.

What functional group is shown to be present in **Z** by these tests?

..... alcohol [1]

(c) Tests for the third functional group.

A few drops of **Z** form a yellow/orange precipitate when added to 2,4-dinitrophenylhydrazine reagent.

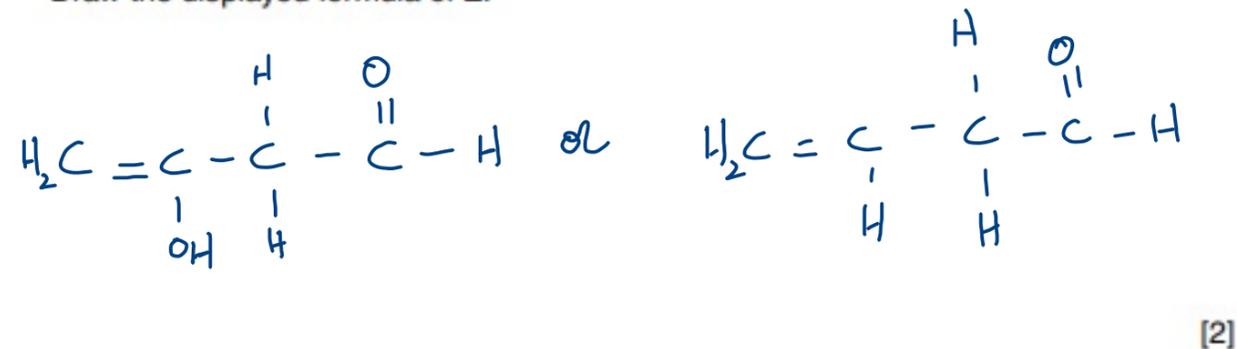
When a few drops of **Z** are warmed with Tollens' reagent, a silver mirror is formed.

What functional group is shown to be present in **Z** by these tests?

..... aldehyde [1]

(d) **Z** does **not** show *cis-trans* isomerism.

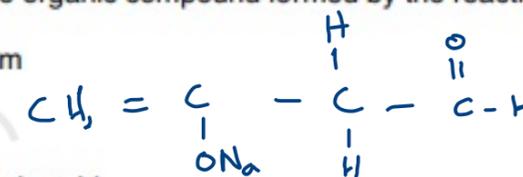
Draw the displayed formula of **Z**.



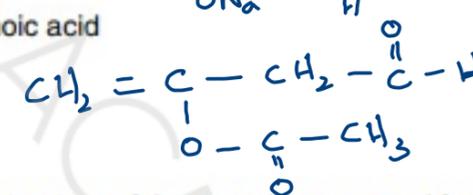
In parts (e) and (f) you may use R- to represent the part of the molecule that does not react.

(e) What is the organic compound formed by the reactions of **Z** in **each** of the tests in (b)?

with sodium



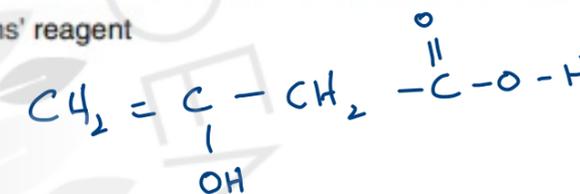
with ethanoic acid



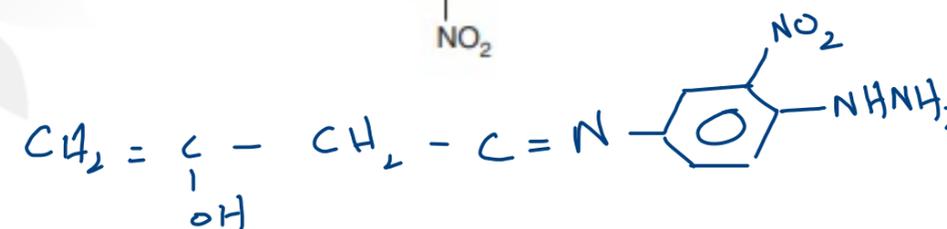
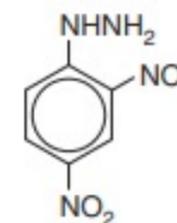
[2]

(f) Draw the structure of the organic compound formed by **Z** in **each** of the tests in (c).

with Tollens' reagent



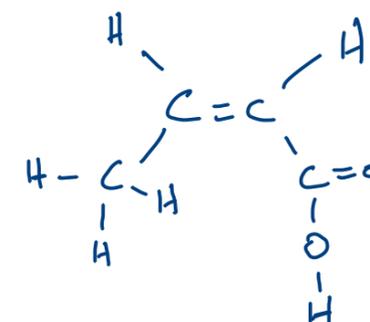
with 2,4-dinitrophenylhydrazine,



[2]

(g) But-2-enoic acid is an isomer of **Z** which shows *cis-trans* isomerism.

Draw a displayed formula of the *cis* isomer of this acid.



[2]

6 Commercial paint and varnish removers contain a mixture of dichloromethane, CH_2Cl_2 , and methanol, CH_3OH .

(a) What would be observed when the following reactions are carried out? In each case, give the name or formula of the reaction product which is responsible for the observation you have made.

(i) CH_2Cl_2 is reacted with $\text{NaOH}(\text{aq})$ and $\text{AgNO}_3(\text{aq})$ and the mixture left to stand.

observation white precipitate forms

product responsible AgCl

(ii) CH_3OH is mixed with PCl_5 .

observation steamy fumes

product responsible HCl

(iii) CH_3OH is reacted with sodium.

observation effervescence

product responsible H_2 gas

[6]

(b) When CH_2Cl_2 is heated under reflux with an excess of $\text{NaOH}(\text{aq})$, a compound **W** is formed.

W has the following composition by mass: C, 40.0%; H, 6.7%; O, 53.3%.

Use this information and the *Data Booklet* to show that the empirical formula of **W** is CH_2O .

$$n = \frac{\text{C}}{12} \quad \frac{\text{H}}{1} \quad \frac{\text{O}}{16}$$

$$= \frac{40}{12} \quad \frac{6.7}{1} \quad \frac{53.3}{16}$$

$$= (3.333 : 6.7 : 3.331) \div 3.331$$

$$= 1 : 2 : 1$$

Emp formula = CH_2O

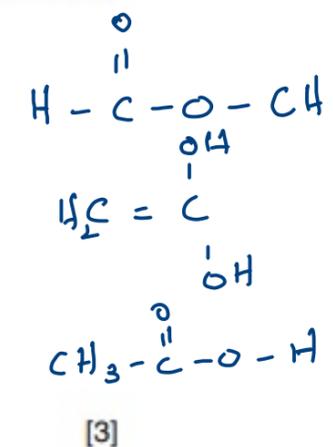
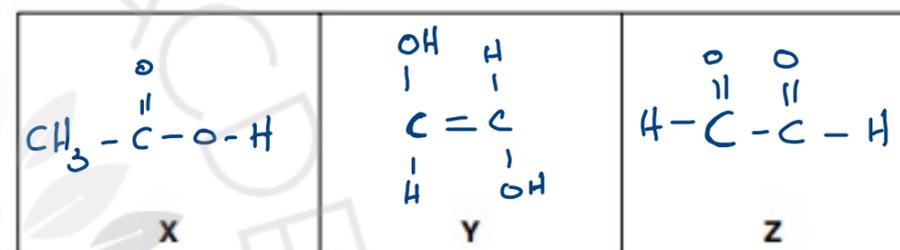
[2]

(c) Compounds with the empirical formula CH_2O can have the molecular formula $\text{C}_2\text{H}_4\text{O}_2$.

Two possible structural formulae for compounds with molecular formula $\text{C}_2\text{H}_4\text{O}_2$ are HCO_2CH_3 and $\text{H}_2\text{C}=\text{C}(\text{OH})_2$.

In the boxes below, draw displayed formulae for **three further** structural isomers with the molecular formula $\text{C}_2\text{H}_4\text{O}_2$.

Do **not** attempt to draw any structures containing rings or O-O bonds.



(d) Identify which of your compounds, **X**, **Y**, or **Z**, will react with the following reagents.

In **each** case, state what you would observe.

(i) solid NaHCO_3

compound X

observation effervescence of CO_2 gas

(ii) Tollens' reagent

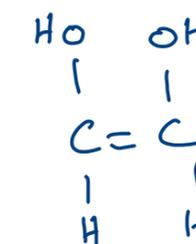
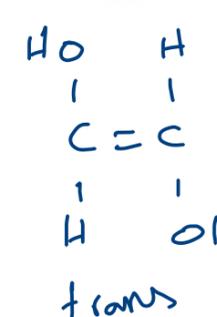
compound Z

observation silver precipitate

[4]

(e) One of the three compounds, **X**, **Y**, or **Z**, shows stereoisomerism.

Draw displayed, labelled structures of the stereoisomers of this compound.



[2]

5 The two compounds **V** and **W** are isomers with the molecular formula C_4H_8O , and show the following properties and reactions.

- Both compounds react with sodium metal, and both decolourise bromine water.
- Compound **V** forms a yellow precipitate with alkaline aqueous iodine, whereas compound **W** does not.
- When reacted with cold $KMnO_4(aq)$, both **V** and **W** produce the same neutral compound **X**, $C_4H_{10}O_3$.
- Both **V** and **W** exist as pairs of stereoisomers.

(a) Suggest which functional groups are responsible for the reactions with

(i) sodium,

Alcohol

(ii) bromine water,

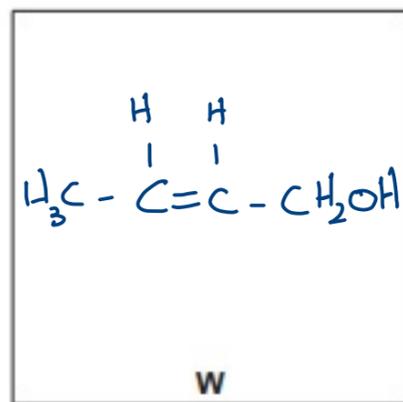
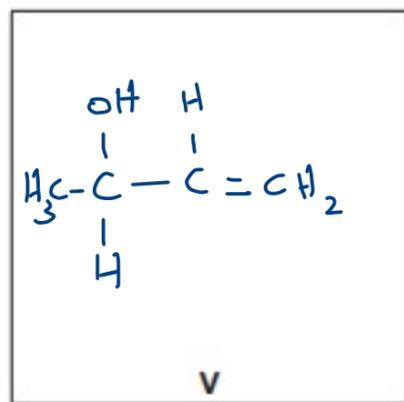
Alkene

(iii) alkaline aqueous iodine.

methyl ketone or secondary methyl alcohol

[3]

(b) Suggest structures for **V** and **W**.

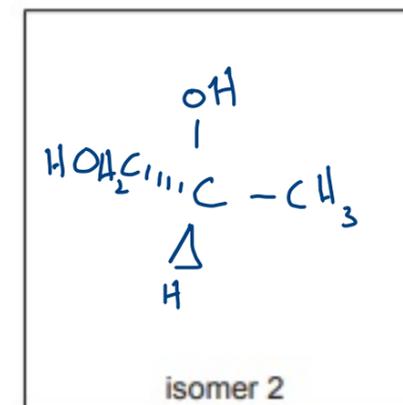
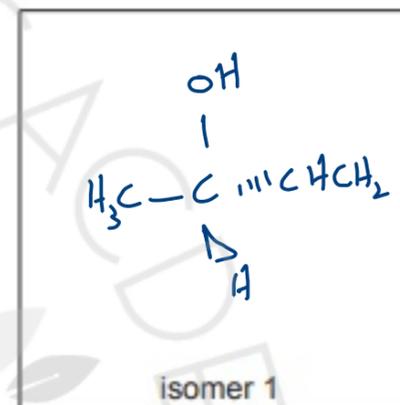


[2]

(c) State the type of stereoisomerism shown by compound **V** and draw the structures of the stereoisomers.

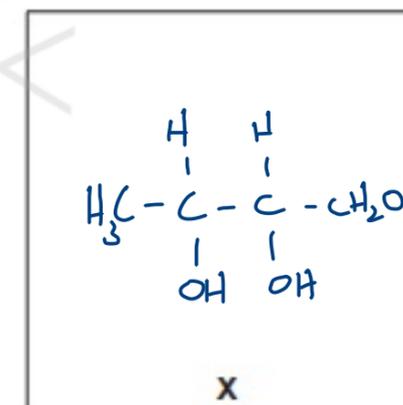
type of stereoisomerism *optical*

structures of stereoisomers



[2]

(d) Suggest the structure of the neutral compound **X**.



[1]