Polymers (Part 2) – Reactions of Functional Groups

Learning Outcomes

Students should be able to:

describe the chemistry of the following classes of compounds:

(i) alkanes (exemplified by ethane) as being generally unreactive except in terms of combustion and substitution by chlorine

(ii) alkenes (exemplified by ethene) in terms of combustion and addition reactions with bromine (in CCl_4) and hydrogen

(iii) halogenoalkanes (exemplified by bromoethane) in terms of substitution reaction to alcohols and elimination reactions to alkenes

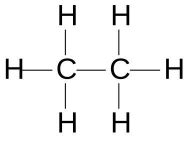
(iv) aldehydes (exemplified by ethanal) and ketones (exemplified by propanone) in terms of their reduction to primary and secondary alcohols respectively; and oxidation of aldehydes to carboxylic acids

(v) alcohols (exemplified by ethanol) in terms of combustion, oxidation to carboxylic acids and elimination to alkenes

(vi) carboxylic acids (exemplified by ethanoic acid) in terms of condensation with alcohols to form esters (in the presence of concentrated sulfuric acid), and amines (exemplified by ethylamine) to form amides (in the presence of dicyclohexylcarbodiimide, DCC)

(vii) esters (exemplified by ethyl ethanoate) and amides (exemplified by ethanamide) in terms of hydrolysis with acids and bases

Success Criteria:
- I can understand alkanes are generally unreactive except it undergoes
  - combustion reaction to form CO_2 and H_2O
  - substitution reaction by chlorine to form halogenoalkane



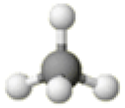
$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

ethane

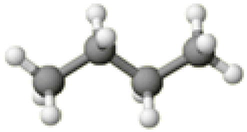
1 Alkanes

Alkanes are **saturated hydrocarbons**. (i.e. contains only C−H and C−C **single** bonds)

All the C atoms in alkanes forms 4 σ bonds, therefore every C atom has a **tetrahedral** shape.



methane
CH_4



butane
$CH_3CH_2CH_2CH_3$

They are generally unreactive, except in terms of combustion and substitution by chlorine or bromine. Reasons:
- They are non-polar molecules (Since C and H have very similar electronegativity).
- Since **C−C and C−H bonds** are **very strong**, large amount of energy is required to break the C−C and C−H bonds in order for reaction to occur.

1.1 Physical Properties

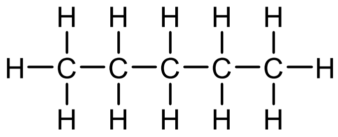
Since the electronegativity of C and H are similar (i.e. negligible electronegativity difference), C–H bond is non–polar, alkanes molecules are non–polar and are held together by weak instantaneous dipole–induced dipole attraction.

(a) Boiling and melting point

Boiling and melting points **increases** as number of carbon atoms in the alkane increases. This is because **incresing amount of energy** is required to overcome the **increasing strength of instantaneous dipole-induced dipole interaction** between molecules as the **size of electron cloud increases.**

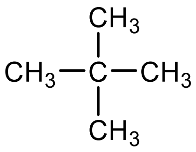
Straight–chain alkanes: C_1 to C_4 are **gases**,
C_5 to C_{17} are **liquids**,
C_{18} and above are **solids** at r.t.p.

Boiling points of branched alkanes are **lower** than the boiling point of the corresponding straight–chain alkanes. Due to **branching** of hydrocarbon chain, the molecules are **more spherical** and have **smaller surface area of contact** between molecules. Thus, there is **weaker instantaneous dipole–induced dipole attraction between the molecules**.



$$\begin{array}{ccccccccccccc} & & H & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & H & & \end{array}$$

pentane
(b.p. 36 °C)



$$\begin{array}{ccccc} & & CH_3 & & \\ & & | & & \\ CH_3 & - & C & - & CH_3 \\ & & | & & \\ & & CH_3 & & \end{array}$$

2,2-dimethylpropane
(b.p. 10 °C)

(b) Solubility

Alkanes are **insoluble in water** as the molecules **cannot form ion-dipole interaction nor hydrogen bonds with water molecues.** They **are soluble in organic solvents**.

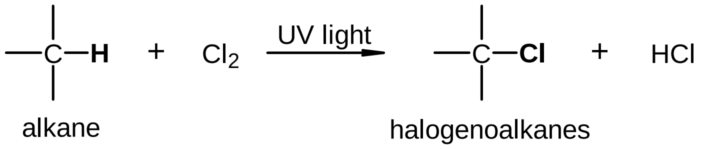
1.2 Combustion

In complete combustion, hydrocarbons burn in excess O_2 to form CO_2, H_2O and release heat.

$$C_xH_y\ (g) + \left(x + \frac{y}{4}\right) O_2\ (g) \longrightarrow x\ CO_2\ (g) + \frac{y}{2} H_2O\ (l)$$

E.g. $C_2H_6\ (g) + \frac{7}{2} O_2\ (g) \longrightarrow 2\ CO_2\ (g) + 3\ H_2O\ (l)$

1.3 Substitution reaction


$$-\overset{|}{\underset{|}{C}}-H + Cl_2 \xrightarrow{\text{UV light}} -\overset{|}{\underset{|}{C}}-Cl + HCl$$

Note:
R is used to represent an alkyl group.
e.g. methyl ($-CH_3$), ethyl ($-CH_2CH_3$)

Type of reaction	Substitution
Reagent and condition	Cl_2(g), UV light

$$R-H + Cl_2 \xrightarrow{\text{UV}} R-Cl + HCl$$

For example, when methane reacts with chlorine in the presence of UV light, one of H atoms of methane is substituted by a C*l* atom.

$$CH_4 + Cl_2 \xrightarrow{\text{UV}} CH_3Cl + HCl$$

CH_3Cl undergoes further substitution with chlorine to produce a **mixture of alkyl chlorides**:

$$CH_3Cl + Cl_2 \longrightarrow \mathbf{CH_2Cl_2} + HCl \quad \text{(disubstitution)}$$
$$CH_2Cl_2 + Cl_2 \longrightarrow \mathbf{CHCl_3} + HCl \quad \text{(trisubstitution)}$$
$$CHCl_3 + Cl_2 \longrightarrow \mathbf{CCl_4} + HCl \quad \text{(tetrasubstitution)}$$

*If **methane** is used in **excess**, Cl_2 limiting, the major product is $\mathbf{CH_3Cl}$ (chloromethane).*

*If $\mathbf{Cl_2}$ is used in **excess**, methane limiting, the major product is $\mathbf{CCl_4}$ (tetrachloromethane)*

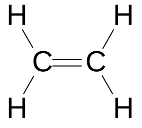
These substitutions take place very **rapidly** in the **presence of UV light**.

However, **no reaction** will take place in the **dark at room temperature**.

Success Criteria:
- I can understand alkene undergoes
    - combustion reaction to form CO_2 and H_2O
    - addition reactions with bromine (in CCl_4) to form dibromoalkane
    - reduction reactions with hydrogen to form alkane

2 Alkenes

Alkenes are **unsaturated** hydrocarbons because of the presence of **C=C double bond**. The C atom in C=C has a **trigonal planar** shape.



ethene

$CH_2=CHCH_2CH_3$	$CH_3CH=CHCH_3$	$CH_2=CHCH=CH_2$
but-1-ene	but-2-ene	buta-1,3-diene

2.1 Physical Properties

(a) Boiling and melting point

Alkenes, like all hydrocarbons, have relatively **low boiling and melting points** as the alkene molecules have **weak instantaneous-dipole induced-dipole interaction** between molecules.

Boiling and melting points **increases** as number of carbon atoms in the alkene increases. This is because **incresing amount of energy** is required to overcome the **increasing strength of instantaneous dipole-induced dipole interaction** between molecules as the **size of electron cloud increases.**

(b) Solubility

Alkenes are **insoluble in water** as the molecules **cannot form ion-dipole interaction nor hydrogen bonds with water molecues.** They **are soluble in organic solvents**.

2.2 Combustion

In complete combustion, hydrocarbons burn in excess O_2 to form CO_2, H_2O and release heat.

$$C_2H_4\,(g) + 3\,O_2\,(g) \longrightarrow 2\,CO_2\,(g) + 2\,H_2O\,(l)$$

2.3 Addition reaction

Unsaturated alkene undergoes **addition** reaction to form saturated compound.

Less energy is required to **break** the **π bond** in the C=C bond as the side-way overlap of atomic orbitals is less effective than head-on overlap in σ bond.

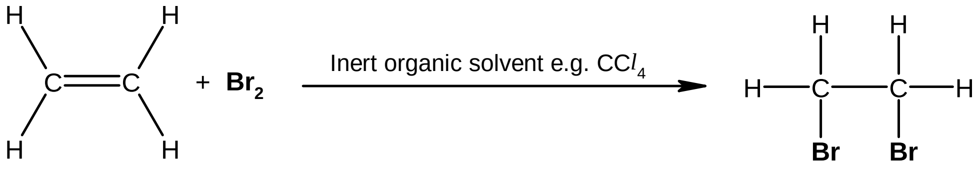
Type of Bond	C—C (σ)	C=C (σ + π)	π bond in C=C
Bond Energy/ kJ mol^{-1}	350	610	260

Hence, **alkenes** tend to undergo reactions that **involve** the **breaking** of the weaker **π bond** in the C=C bond, leaving the σ bond intact.

The π bond electrons are used to form two new σ bonds during **addition reaction** to form **one product**.

Video of reaction of alkene with Br_2

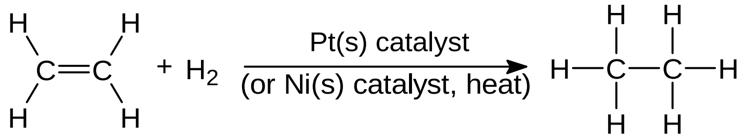
(a) **Addition** reaction With Br_2 *__(Distinguishing test for alkene)__*



Note:
Distinguishing tests are chemical reactions for specific functional group that gives a significant observation (e.g. change in colour, production of precipitate or gas)

Type of reaction	Addition
Reagent and condition	Br_2 in inert organic solvent (CCl_4)
__Observation__	Orange-red Br_2 decolourises.

(b) Catalytic **addition (reduction)** reaction With H_2



Alkenes are **reduced** to alkanes by the addition of hydrogen gas.

Type of reaction	Reduction
Reagent and condition	H_2(g), Pt(s) catalyst or H_2(g), Ni(s) catalyst, heat

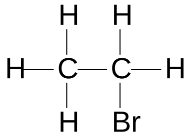
__Industrial use for addition of H_2 to alkene:__
Used in the food industry to make a large variety of manufactured goods, like spreads and shortenings, from unsaturated liquid oils.

Success Criteria:

- I can understand halogenoalkane undergoes
    - substitution reaction to form alcohol
    - elimination reactions to form alkene

3 Halogenoalkanes

Halogenoalkanes are **saturated** hydrocarbons with a C−**X** bond.
Where **X** is a halogen (Group 17 elements) e.g. Cl, Br, I.



bromoethane

$CH_3CHBrCH_3$	$CH_3CH_2CH_2CH_2Cl$	$CH_2BrCH_2CH_2Br$
2-bromopropane	1-chlorobutane	1,3-dibromopropane

3.1 Physical Properties

(a) Boiling and melting point

For the same alkyl chain, the **boiling point of RX increases** down Group 17.

RX	$CH_3\mathbf{Cl}$	$CH_3\mathbf{Br}$	$CH_3\mathbf{I}$
boiling point /K	249	277	316

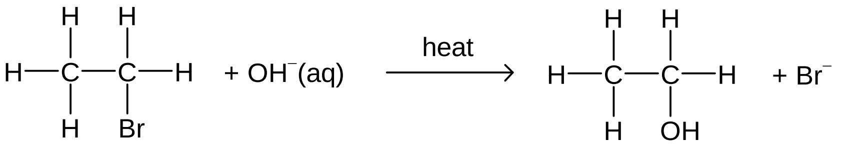
RX has a simple covalent structure. From RCl to RI, the **electron cloud size increases and is more easily polarised.** Thus, **more energy** is required to overcome the **stronger instantaneous dipole–induced dipole interactions between** RX **molecules**.

(b) Solubility

Halogenoalkanes are **insoluble in water** because they **cannot form hydrogen bonds nor ion–dipole interactions with H_2O molecules**. They are **soluble in organic solvents**.

3.2 Substitution reaction

Halogenoalkane (C−X) undergoes **substitution** reaction to form alcohol (C−OH).

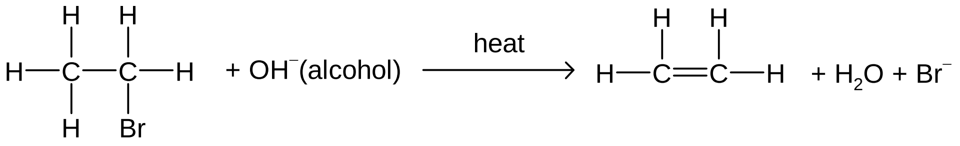


OH^- in aqueous medium, e.g. NaOH (aq), would favor substitution reaction.

Type of reaction	Substitution
Reagent and condition	NaOH(aq), heat or KOH(aq), heat

3.3 Elimination reaction

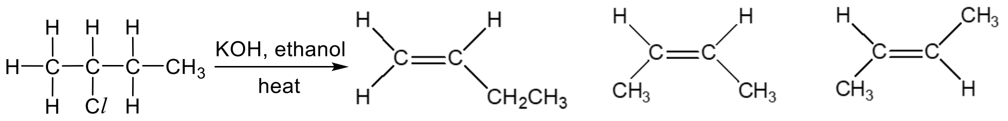
Halogenoalkane (C−X) undergoes **elimination** reaction (eliminate H and X from two adjacent C atoms) to form alkene (C=C).



OH^- in alcohol medium, e.g. NaOH in ethanol, would favor elimination reaction. H_2O and X^- are produced together with alkene.

Type of reaction	Elimination
Reagent and condition	NaOH(alcohol), heat or KOH(alcohol), heat

NOTE:
When group of atoms such as H & C*l* are **eliminated** from **different pairs of adjacent carbons**, a <u>mixture of alkene isomers is produced.</u>



Checkpoint 1

1 Pentane reacts with Cl_2(g) in presence of UV light to give three monochlorinated products.

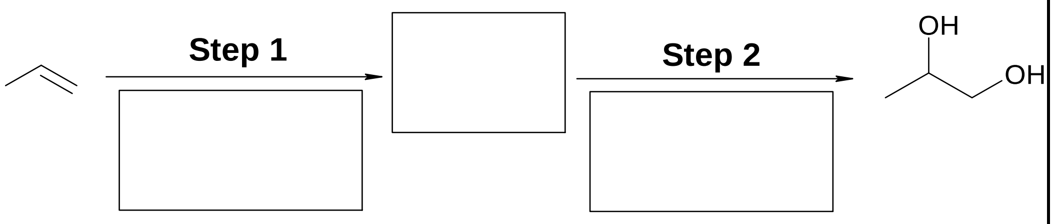
Draw the skeletal formula of the three compounds.

2 2-chloropentane reacts with hot ethanolic KOH to give three isomeric products with molecular formula of C_5H_{10}, containing a pair of cis-trans isomers.

Identify the type of reaction and deduce the structure of the three products.

3 Propene is converted to propan-1,2-diol in a **2-step** reaction sequence.

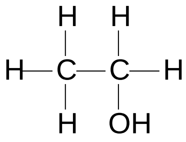
Fill in the reagents and conditions required for each step as well as the missing structure.



Success Criteria:

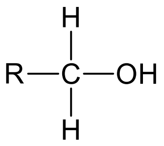
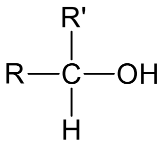
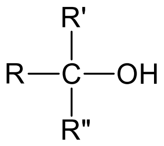
- I can understand alcohol undergoes
    - combustion reaction to form CO_2 and H_2O
    - elimination reaction to form alkene
- I can understand primary alcohol undergoes oxidation reaction to form carboxylic acids

4 Alcohols



ethanol
(primary alcohol)

Alcohols (where the **–OH bonded C** of alkyl chain) are classified as <u>primary (1°)</u>, <u>secondary (2°)</u> or <u>tertiary (3°)</u> depending on the number of alkyl (or aryl) groups attached to the carbon linked to the –OH group.

<u>Primary</u> alcohol	**<u>Secondary</u> alcohol**	**<u>Tertiary</u> alcohol**
		
$CH_3CH_2CH_2OH$	$CH_3CH(OH)CH_3$	$(CH_3)_3COH$
propan-1-ol	propan-2-ol	2-methylpropan-2-ol

4.1 Physical Properties

(a) Boiling and melting point

Boiling points of alcohols are **higher than** boiling points of alkanes of **comparable *M*r**.

More energy is needed to overcome the **stronger hydrogen bonds between the alcohol molecules** than the **weaker instantaneous dipole-induced dipole interactions between the alkane molecules**.

(b) Solubility

Alcohols are **soluble in water** due to the presence of the **–OH group** which can form **hydrogen bonds with water molecules**.

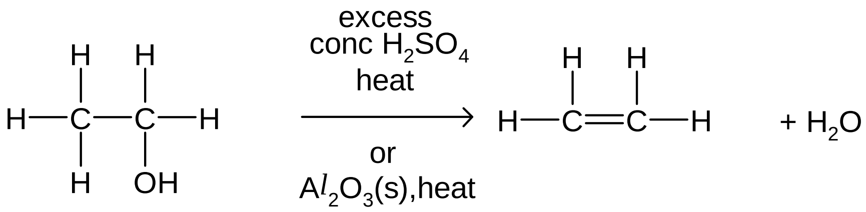
4.2 Combustion reaction

Alcohols burn in air (or excess oxygen) with a clear, hot flame to produce CO_2 & H_2O. They are called 'clean' fuels.

$$CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

4.3 Elimination reaction

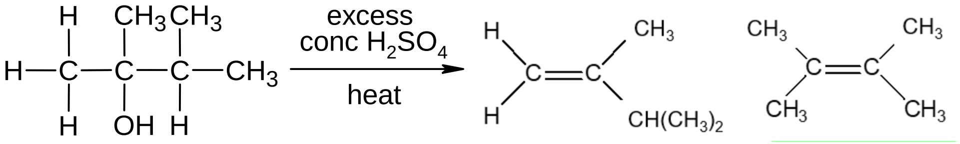
Alcohol (C−OH) undergoes **elimination** reaction (eliminate H and OH from two adjacent C atoms) to form alkene (C=C).



Hot, concentrated H_2SO_4 function as a dehydrating agent.

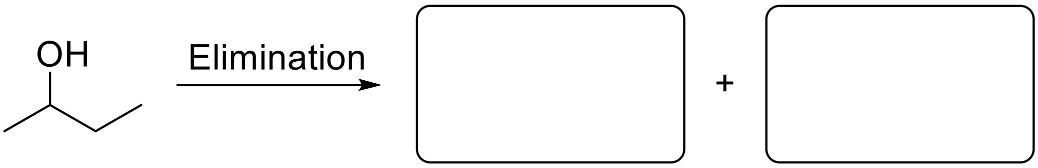
Type of reaction	Elimination
Reagent and condition	Excess concentrated H_2SO_4, heat or Al_2O_3(s), heat

NOTE:
When group of atoms such as H & OH are **eliminated** from **different pairs of adjacent carbons**, a mixture of alkene isomers is produced.

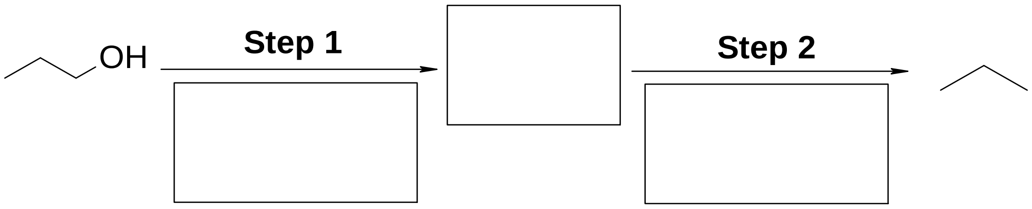


Checkpoint 2

1 Butan-2-ol undergo elimination to gives 2 different alkenes.
Draw the structures of the 2 alkenes.

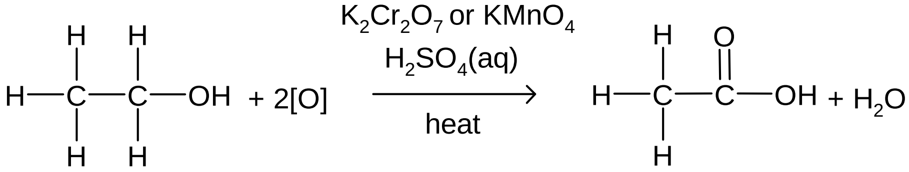


2 Propan-1-ol is converted to propane in a **2-step** reaction sequence. Fill in the reagents and conditions required for each step as well as the missing structure.



4.4 Oxidation reaction of primary (1°) alcohols

Primary alcohol (R−CH_2OH) undergoes **oxidation** reaction to form carboxylic acid (R−COOH).

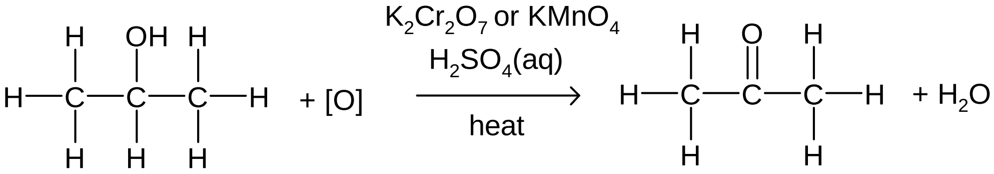


Hot, acidified $K_2Cr_2O_7$ and $KMnO_4$ function as oxidising agent.

Type of reaction	Oxidation
Reagent and condition	$K_2Cr_2O_7$, H_2SO_4(aq), heat or $KMnO_4$, H_2SO_4(aq), heat
Observation	Orange $Cr_2O_7^{2-}$ turns green or Purple MnO_4^- turns colourless

4.5 Oxidation reaction of secondary (2°) alcohols

Secondary alcohol undergoes **oxidation** reaction to form ketone.



Hot, acidified $K_2Cr_2O_7$ and $KMnO_4$ function as oxidising agent.

Type of reaction	Oxidation
Reagent and condition	$K_2Cr_2O_7$, H_2SO_4(aq), heat or $KMnO_4$, H_2SO_4(aq), heat
Observation	Orange $Cr_2O_7^{2-}$ turns green or Purple MnO_4^- turns colourless

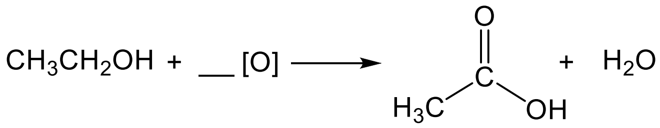
4.6 Tertiary (3°) alcohols are resistant to oxidation

Oxidation reactions can be used in distinguishing between 1° and 2° alcohols from 3° alcohols. Tertiary alcohol does not result in any change in colour of hot acidified $KMnO_4$ or $K_2Cr_2O_7$.

Checkpoint 3

1 Fill in the blanks provided. Indicate the reagent and condition required for the reaction and the observation of the reaction.

(a)



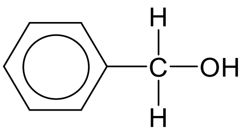
Reagent and Condition:

(b)

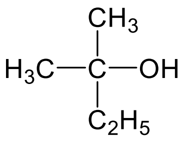
$CH_3CH(OH)CH_3 + [O] \longrightarrow$

2 Which alcohol does **not** result in a colour change when warmed with acidified potassium dichromate(VI)?

A

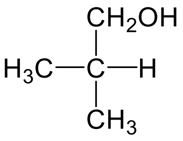


B



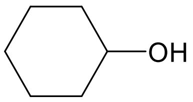
$H_3C-C(CH_3)(C_2H_5)-OH$

C



$H_3C-C(CH_2OH)(CH_3)-H$

D



3 Draw the structure of the alcohol with the molecular formula $C_5H_{12}O$ that is resistant to oxidation. Give the name of this alcohol.

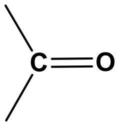
Success Criteria:

- I can understand aldehyde undergoes
    - reduction reaction to form primary alcohol
    - oxidation reaction to form carboxylic acid

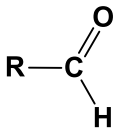
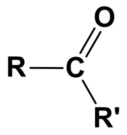
- I can understand ketone undergoes reduction reaction to form secondary alcohol

5 Aldehydes and ketones

Aldehydes and ketones contain the carbonyl functional group



Carbonyl functional group

Aldehyde (**RCHO**)	Ketone (**RCOR'**)
General Formula :  R can be **H, alkyl or aryl** group	**General Formula** :  R and R' can be **alkyl or aryl** group

CH_3CH_2CHO propanal	CH_3COCH_3 propanone	$CH_3CH_2COCH_2CH_3$ pentan-3-one

5.1 Physical Properties

(a) Boiling and melting point

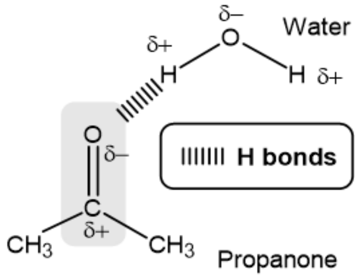
Compound	Structural formula	M_r	b.p. / °C	Intermolecular forces
Butane	$CH_3CH_2CH_2CH_3$	58	–0.5	id-id
Propanal	$CH_3CH_2\mathbf{CHO}$	58	49	pd-pd

Boiling points of carbonyl compounds are **higher** than the corresponding **alkanes or alkenes** of **similar** M_r. This is because **more energy** is needed to overcome the **stronger permanent dipole–permanent dipole attraction between molecules of carbonyl compounds** than the **weaker instantaneous dipole–induced dipole attraction between molecules of alkanes/ alkenes**.

(b) Solubility

Short chain aldehydes and ketones are **soluble in water** as the molecules **can form hydrogen bonding** with H_2O molecules.

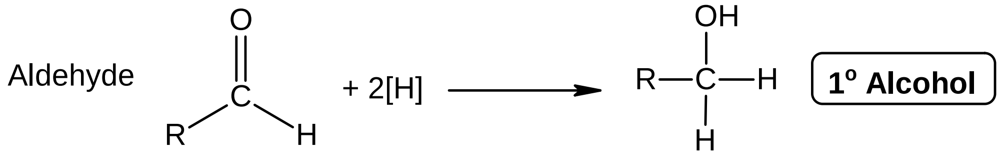
Solubility decreases as the carbon chain of aldehydes and ketones gets longer.

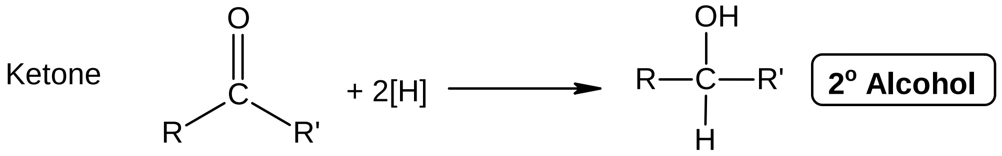


5.2 Reduction reaction

Ketones are reduced to secondary alcohols and aldehydes are reduced to primary alcohols by

- $LiAlH_4$ in dry ether
- $NaBH_4$ in ethanol
- H_2(g), Pt(s)
- H_2(g), Ni(s), heat





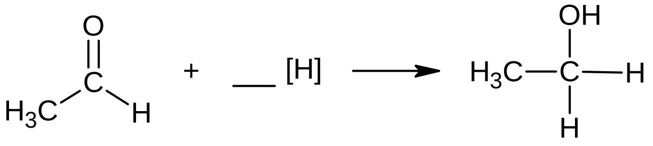
Type of reaction	Reduction
Reagent and condition	$LiAlH_4$ in dry ether or $NaBH_4$ in ethanol or H_2(g), Pt(s) or H_2(g), Ni(s), heat

Note:

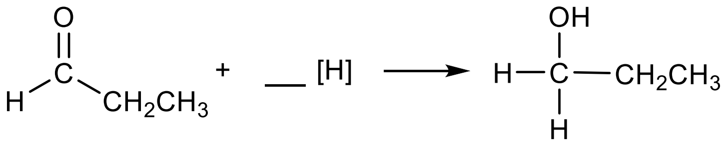
Recall that alkenes can undergo reduction with H_2 (g) in the presence of Pt(s) or Ni(s) catalyst to form alkanes. However, alkenes do not react with $LiAlH_4$ / $NaBH_4$.

Checkpoint 4

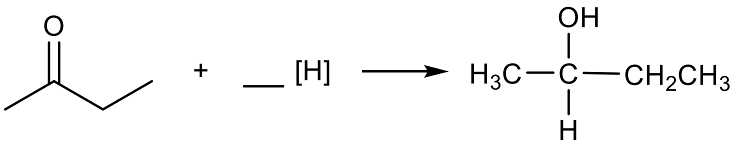
Fill in the blanks provided. Place a '✓' next to the reducing agent which allows the reduction to be carried out.



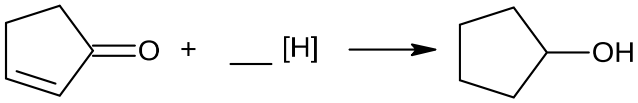
☐ LiA/H$_4$ in dry ether
☐ NaBH$_4$ in ethanol
☐ H_2/Pt



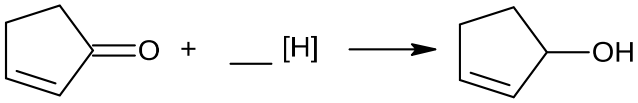
☐ LiA/H$_4$ in dry ether
☐ NaBH$_4$ in ethanol
☐ H_2/Pt



☐ LiA/H$_4$ in dry ether
☐ NaBH$_4$ in ethanol
☐ H_2/Pt



☐ LiA/H$_4$ in dry ether
☐ NaBH$_4$ in ethanol
☐ H_2/Pt

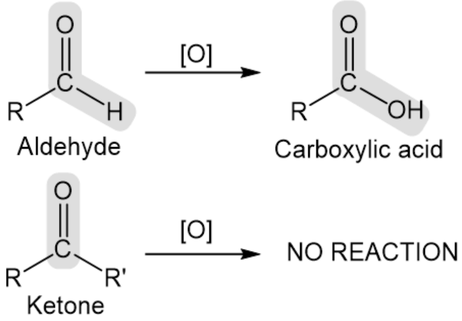


☐ LiA/H$_4$ in dry ether
☐ NaBH$_4$ in ethanol
☐ H_2/Pt

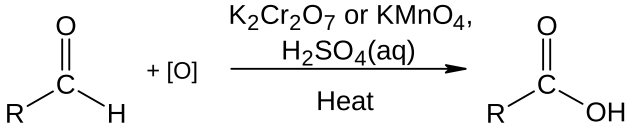
5.3 Oxidation reaction of aldehydes

The –CHO in aldehydes are easily oxidised.

Ketones are resistant to oxidation as they do not have a hydrogen atom directly attached to the carbonyl carbon.



Heating aldehyde with acidified $K_2Cr_2O_7$ or $KMnO_4$ produces carboxylic acid.

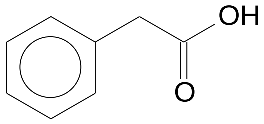


Type of reaction	Oxidation
Reagent and condition	$K_2Cr_2O_7$, H_2SO_4(aq), heat or $KMnO_4$, H_2SO_4(aq), heat
Observation	Orange $Cr_2O_7^{2-}$ turns green or Purple MnO_4^- turns colourless

Checkpoint 5

$CH_3CH_2CHO \xrightarrow[\text{heat}]{KMnO_4\text{, dil } H_2SO_4}$

C_8H_8O $\xrightarrow[\text{heat}]{K_2Cr_2O_7\text{, dil } H_2SO_4}$

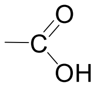


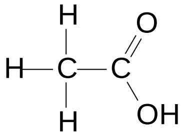
Success Criteria:

- I can understand carboxylic acid undergoes
    - condensation reaction with alcohols to form esters (in the presence of concentrated sulfuric acid),
    - condensation reaction with amines to form amides (in the presence of dicyclohexylcarbodiimide, DCC)

6 Carboxylic acids

Carboxylic acids are represented as RCO_2H where R is H or alkyl or aryl group.

The **carboxyl group**,  , is the distinguishing feature of a carboxylic acid.



Ethanoic acid

6.1 Physical Properties

(a) Boiling and melting point

Carboxylic acids have **higher boiling points** than alkanes of comparable M_r.

Condensed formula	Functional group	M_r	Boiling point / ^oC
CH_3CO_2H	Carboxylic acid	60	118
$CH_3CH_2CH_2CH_3$	Alkane	58	–0.5

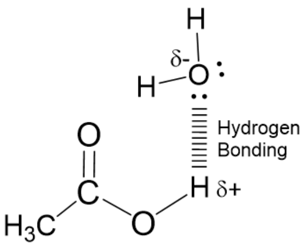
Both compounds have **simple molecular strcuture.**

Alkanes have lower boiling point as they require **least energy** to overcome the **weaker instantaneous dipole-induced dipole interaction** between alkane molecules.

Carboxylic acids have higher boiling point as **more energy** is needed to overcome the **stronger hydrogen bonds** between carboxylic acid moleucles.

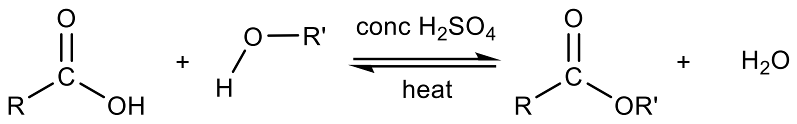
(b) Solubility

Carboxylic acids are **soluble in water** as the molecules **can form hydrogen bonding** with H_2O molecules.



6.2 Condensation reaction with alcohol to form ester

Carboxylic acids react reversibly with alcohols to produce esters and H_2O.

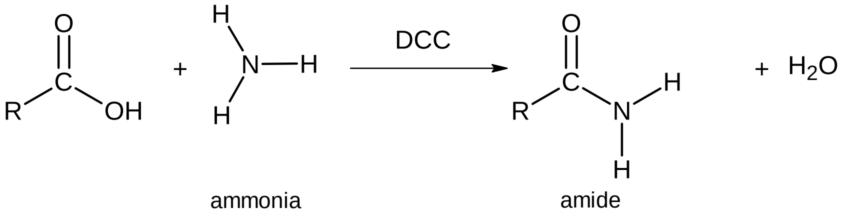


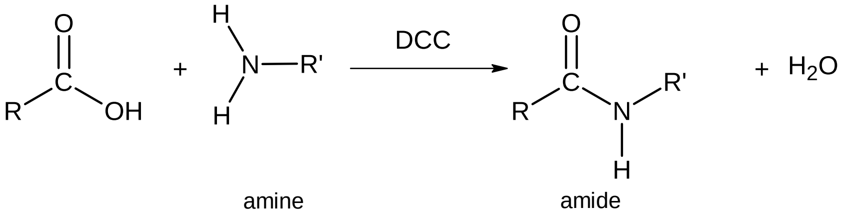
Type of reaction	Condensation
Reagent and condition	R−OH (alcohol), concentrated H_2SO_4, heat

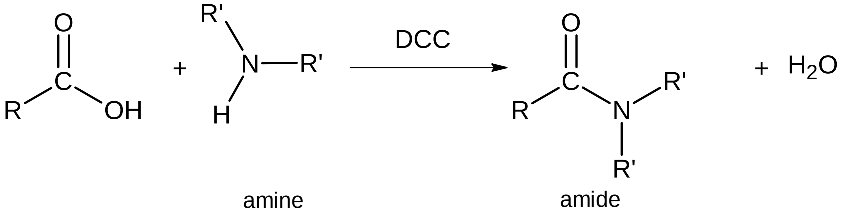
Some of the esters produced can undergo acidic hydrolysis to form back the carboxylic acid and alcohol.

6.3 Condensation reaction with ammonia/amine to form amide

Treatment of carboxylic acids with ammonia (NH_3) or amines, RNH_2 or R_2NH (C bonded to N via C−N single bond) in the presence of the dehydrating agent N,N'-dicyclohexylcarbodiimide (DCC) leads to the formation of amides.





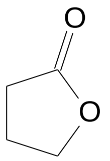


Type of reaction	Condensation
Reagent and condition	NH_3, DCC or R−NH_2 (amine), DCC or R_2NH (amine), DCC

Checkpoint 6

$CH_3CH_2COOH + CH_3OH \xrightarrow[\text{heat}]{\text{conc } H_2SO_4}$

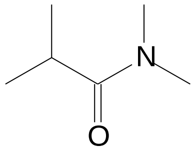
$C_4H_8O_3$ $\xrightarrow[\text{heat}]{\text{conc } H_2SO_4}$



$+ H_2O$

$CH_3COOH + NH_3 \xrightarrow{\text{DCC}}$

$\xrightarrow{\text{DCC}}$



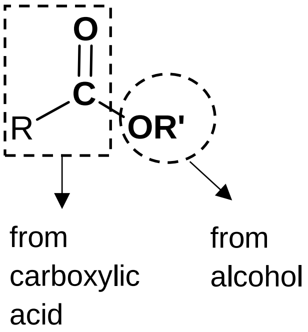
$+ H_2O$

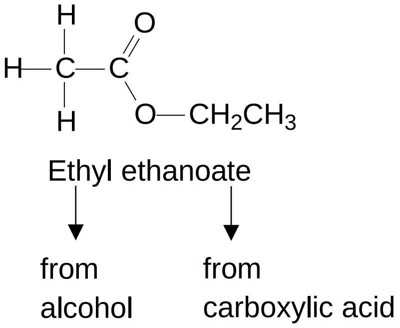
Success Criteria:

- I can understand ester undergoes
  - hydrolysis reaction with acid to form alcohol and carboxylic acid
  - hydrolysis reaction with base to form alcohol and carboxylate salt

7 Esters

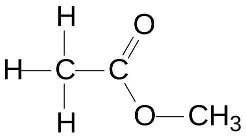
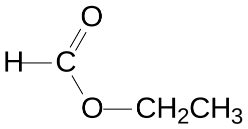
Ester is a derivative of carboxylic acid in which the H in −COOH group is replaced by a R group where R is an alkyl or aryl group. Esters are often identified by their strong sweet fruity smell.





Esters are named with the alkyl chain of the alcohol as substituent followed by the name of the parent chain from the carboxylic acid part of the ester, with the ending -oate.

Ethyl ethanoate contains 2 carbons from alcohol and 2 carbons from carboxylic acid.

 Methyl ethanoate	 Ethyl methanoate

Checkpoint 7

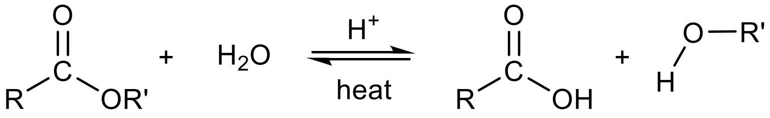
Draw the structure of the following esters.

Methyl propanoate	Ethyl propanoate

7.1 Hydrolysis reaction of ester with acids/bases

(a) Acid hydrolysis

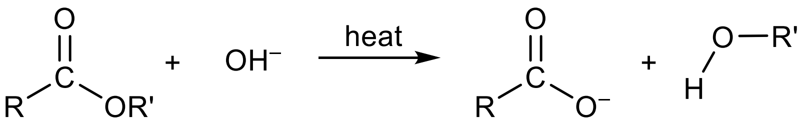
Ester undergoes hydrolysis with H^+(aq) to give carboxylic acid and alcohol.



Type of reaction	Hydrolysis
Reagent and condition	H_2SO_4(aq) / HC*l*(aq) / HNO_3(aq), heat

(b) Alkali hydrolysis

Ester undergoes hydrolysis with OH^-(aq) to give carboxylate ion ($RCOO^-$) and alcohol.



Type of reaction	Hydrolysis
Reagent and condition	NaOH(aq) / KOH(aq) , heat

In alkaline hydrolysis, the RCOOH formed undergoes further acid-base reaction to give $RCOO^-$.

Checkpoint 8

Write the balanced equation when propyl ethanoate reacts with

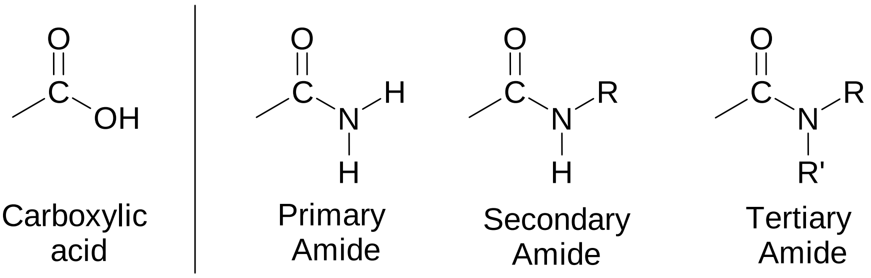
(i) H_2SO_4(aq), heat

(ii) NaOH(aq), heat

Success Criteria:
- I can understand amide undergoes
  - hydrolysis reaction with acid to form salt of amine/ammonium and carboxylic acid
  - hydrolysis reaction with base to form amine/ammonia and carboxylate salt

8 Amides

Amides are carboxylic acid derivatives in which the –OH group is substituted by the $–NH_2$.


Carboxylic acid

Primary Amide

Secondary Amide

Tertiary Amide

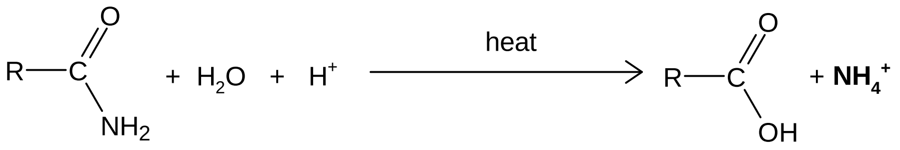
Amide is named from the parent carboxylic acid with the **–oic acid** ending changed to **–amide**.

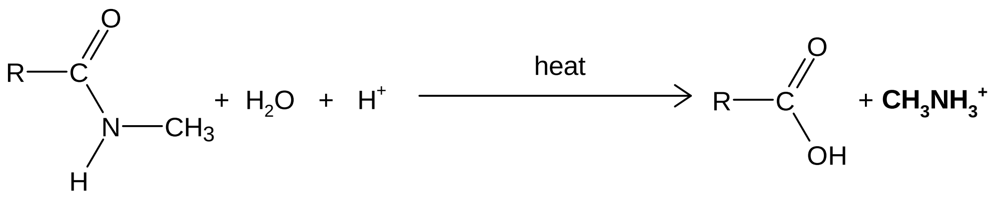
$CH_3CH_2CONH_2$	$CH_3CH_2CH_2CONH_2$
propanamide	butanamide

8.1 Hydrolysis reaction of amide with acids/bases

(a) Acid hydrolysis

Amide undergoes hydrolysis with $H^+(aq)$ to give carboxylic acid and ammonium/amine salt.



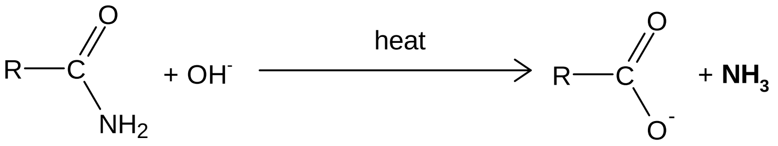


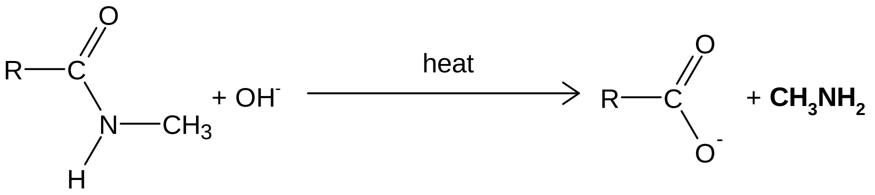
Type of reaction	Hydrolysis
Reagent and condition	$H_2SO_4(aq)$ / $HCl(aq)$ / $HNO_3(aq)$, heat

In acidic hydrolysis, the NH_3 / RNH_2 formed undergoes further acid-base reaction to give NH_4^+ / RNH_3^+.

(b) Alkali hydrolysis

Amide undergoes hydrolysis with OH^-(aq) to give carboxylate ion ($RCOO^-$) and ammonia / amine.



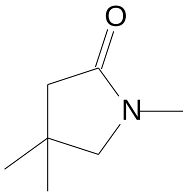


Type of reaction	Hydrolysis
Reagent and condition	NaOH(aq) / KOH(aq) , heat

In alkaline hydrolysis, the RCOOH formed undergoes further acid-base reaction to give $RCOO^-$.

Checkpoint 9

Draw the structure of the products formed when the amide **A** reacts with



Amide **A**

(i) H_2SO_4(aq), heat

(ii) NaOH(aq), heat

Polymers (Part 2) – Reactions of Functional Groups - Tutorial

Alkanes

1 **X** and **Y** have a molecular formula of C_4H_9Br. Both **X** and **Y** can be formed from butane by the following reaction.

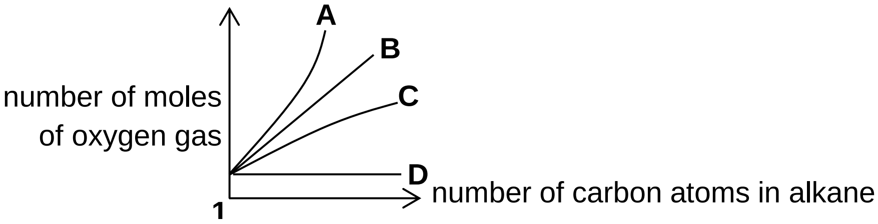
$$CH_3CH_2CH_2CH_3 \longrightarrow \mathbf{X} + \mathbf{Y}$$

(a) State the type of reaction undergone in the above reaction.

(b) Suggest reagents and conditions necessary for the above reaction.

(c) Suggest the structural formula of **X** and **Y**.

2 The complete combustion for alkane to produce carbon dioxide and water is an important exothermic reaction. Which line on the graph shows the relationship between the number of carbon atoms in the alkane and the number of moles of oxygen gas needed for complete combustion of the alkane?



Alkenes

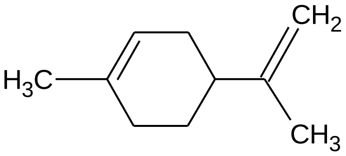
3 One of the four isomers of C_4H_8 is shown below:

Isomer **A** $CH_2=CHCH_2CH_3$

(a) Draw the other 3 isomers of C_4H_8.

(b) State which pair of isomers are *cis-trans* isomers.

4 Limonene occurs in oil of lemons and is used to flavour citrus drinks.



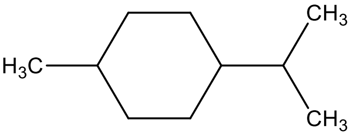
Limonene

Give the structural formulae of the organic products, when limonene reacts with

(a) H_2(g)

(b) Describe a simple chemical test by which you could distinguish the following pairs of compounds. State the observation for the test and write equation for the reaction.

Limonene and



Halogenoalkanes

5 The following reaction scheme shows the various reactions which bromopropane undergoes.

$$CH_3CH_2{=}CH_2 \xleftarrow{\textbf{I}} CH_3CH_2CH_2Br \xrightarrow{\textbf{II}} CH_3CH_2CH_2OH$$

(i) State the type of reactions for steps **I** and **II.**

(ii) State the reagent and condition for steps **I** and **II**.

Alcohol

6 **(i)** Suggest the structural formula of the **product** of the following reactions and ***balance the equations.***

(ii) State the ***type of reaction*** undergone in each case.

(a)

$$CH_3\,CH(OH)CH_2CH_3 \xrightarrow[\text{heat}]{\text{Excess conc. } H_2SO_4}$$

(b)

$$CH_3CH(CH_3)CH_2OH \xrightarrow[\text{heat under reflux}]{\text{acidified } K_2Cr_2O_7}$$

(c)

$$CH_3CH(CH_3)CH_2OH \xrightarrow{\text{excess } O_2}$$

7 Suggest the intermediates and products formed during the following reactions of 1-bromobutane.

- reaction with aqueous NaOH, heat, followed by acidified $KMnO_4$, heat under reflux.
- reaction with NaOH in ethanol, heat, followed by Br_2 in CCl_4.

Aldehyde and Ketone

8 Compound **X** has the following structure:

$$CH_3CH{=}CHCH_2CHO$$

(a) Name the functional groups present in **X**.

(b) Identify the type of stereoisomerism exhibited by **X** and draw diagrams to illustrate this isomerism exhibited.

(c) Draw the structural formula of the organic products formed when compound **X** reacts with the following reagents separately and state the type of reaction involved:

(i) acidfied $K_2Cr_2O_7$, heat under reflux

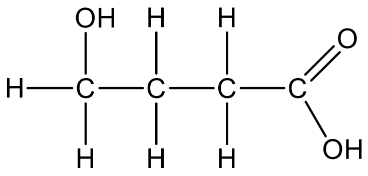
(ii) H_2, in the presence of catalyst, heat

(iii) $LiAlH_4$, dry ether

(iv) $NaBH_4$, methanol

Carboxylic Acid

9 Draw the structure of the organic product(s) that is likely to be formed when a compound, with the formula as given below, reacts, if at all, with the following reagents. State the type(s) of reaction undergone (if any) for each reagent used.



(a) aqueous NaOH

(b) $K_2Cr_2O_7$(aq), H_2SO_4 (aq), heat under reflux

(c) CH_3CH_2OH, a few drops of conc. H_2SO_4, heat under reflux

(d) CH_3NH_2, in the presence of DCC

Ester and Amide

10 There are four ester isomers with the molecular formula $C_4H_8O_2$.

(a) Give the structural formulae of all these isomers.

(b) For each of the isomer, state the carboxylic acid and alcohol from which the ester is formed.

11 Give the products for each of the following reactions.

(a) $CH_3CH_2CO_2CH_3$, HC*l*(aq), heat

(b) $CH_3CO_2CH_2CH_3$, NaOH(aq), heat

(c) $CH_3CH_2CONH_2$, HC*l*(aq), heat

(d) $CH_3CH_2CONHCH_3$, NaOH(aq), heat

12 Suggest the reagent and condition to form the following organic product from the given starting organic molecule.