Topic 8a – Carbonyl compounds
Revision Notes

1. Introduction

- Aldehydes and ketones are carbonyl compounds
- They contain the carbonyl group C=O
- The functional group in aldehydes is –CHO on the end of a chain e.g. ethanal CH_3CHO
- The functional group in ketones is C=O not at the end of a chain e.g. propanone CH_3COCH_3

2. AS Recap

- Primary alcohols are oxidised by acidified potassium dichromate. An aldehyde is produced first and this can be further oxidised to a carboxylic acid. To get the aldehyde, it must be distilled off as it is formed. To get the acid, heat under reflux.
- Secondary alcohols are oxidised to ketones by acidified $K_2Cr_2O_7$. Colour change is orange to green.
- The C=O bond in aldehydes, ketones, carboxylic acids and esters can be identified by infrared spectroscopy. It produces a large peak around 1700 cm^{-1}.

3. Reduction of Aldehydes and Ketones

Reduction, here, means addition of hydrogen.

a) Reduction using $NaBH_4$

A specific reducing agent for aldehydes and ketones is sodium borohydride, $NaBH_4$. In equations the reducing agent is represented by [H].

Aldehydes are reduced to primary alcohols by $NaBH_4$ e.g.

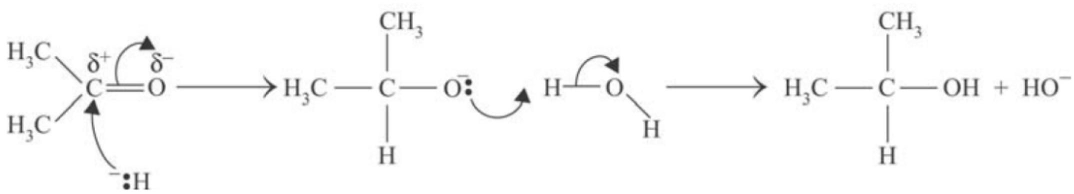
$$CH_3CHO + 2[H] \rightarrow CH_3CH_2OH$$

Ketones are reduced to secondary alcohols by $NaBH_4$ e.g.

$$CH_3COCH_3 + 2[H] \rightarrow CH_3CH(OH)CH_3$$

Other points to note about this reaction are:

- It is an addition reaction (there is only one product)
- The mechanism is called **nucleophilic addition**
- The nucleophile is H^- which is provided by $NaBH_4$



b) Comparison with hydrogen gas

$NaBH_4$ will reduce C=O double bonds but it will not reduce C=C double bonds

e.g. $CH_2=CH\text{-}CHO + 2[H] \rightarrow CH_2=CH\text{-}CH_2OH$

To reduce both C=O and C=C use H_2 with Ni catalyst

e.g. $CH_2=CH\text{-}CHO + 2H_2 \rightarrow CH_3CH_2CH_2OH$

4. Reaction with 2,4-dinitrophenylhydrazine (2,4-DNPH)

- Aldehydes and ketones react with 2,4-DNPH to give an orange precipitate (solid)
- This is used a test for the presence of an aldehyde or ketone
- The particular aldehyde or ketone can be identified by purifying (recrystallisation) the precipitate, measuring its melting point and comparing this with the melting points of known compounds (from a data book).

5. Reaction with Tollen's Reagent

- Tollen's reagent is ammoniacal silver nitrate.
- It is a mild oxidising agent that is used to distinguish between aldehydes and ketones. The compound to be tested is warmed with Tollen's reagent.
- Aldehydes are oxidised by Tollen's reagent which is reduced to silver metal

$CH_3CHO + [O] \rightarrow$	CH_3COOH	**Oxidation**
$Ag^+(aq) + e^- \rightarrow$	$Ag(s)$	**Reduction**
	silver mirror on inside of test tube	

- Ketones do not react with Tollen's reagent because they are not easily oxidised.

Topic 8b – Carboxylic acids and esters
Revision Notes

1. Carboxylic acids

- Carboxylic acids contain the functional group –COOH on the end of a chain.
- They are weak acids (H^+ donors). The acidic H is in the –COOH group e.g.

CH_3COOH $CH_3COO^- + H^+$ (note – reversible reaction so not →)

- They are soluble in water because they can hydrogen bond to water molecules

a) Reactions of carboxylic acids

As they are acids they will react with metals, carbonates and bases e.g.

$CH_3COOH + Na \rightarrow$ $CH_3COONa + ½H_2$ Fizzing seen
Ethanoic acid sodium ethanoate Sodium dissolves

$2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$ Fizzing seen
Carbonate
dissolves

$CH_3COOH + NaOH \rightarrow$ $CH_3COONa + H_2O$

2. Esters

- Esters contain the functional group –COOR on the end of a chain
- Making esters is called esterification
- Esters can be made in two ways: carboxylic acid + alcohol or acid anhydride + alcohol
- Esters are sweet smelling and are used as flavourings and perfumes in food.

a) Esterification of carboxylic acid with alcohol

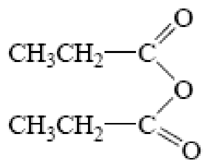
Carboxylic acids react with alcohols to make and ester and water e.g.

$CH_3COOH + C_2H_5OH$ $CH_3COOC_2H_5 + H_2O$
Ethanoic acid ethyl ethanoate

Conditions: Reflux with <u>concentrated</u> H_2SO_4 (acts as a catalyst)

b) Esterification of acid anhydride with alcohol

- Acid anhydrides can be thought of as 2 molecules of acid that have lost a molecule of water e.g. propanoic anhydride, $(CH_3CH_2CO)_2O$



$(CH_3CH_2CO)_2O$ + CH_3OH → $CH_3CH_2COOCH_3$ + CH_3CH_2COOH
Propanoic anhydride methyl propanoate propanoic acid

c) Acid hydrolysis of esters

- This is the reverse of esterification

$CH_3COOC_2H_5$ + H_2O CH_3COOH + C_2H_5OH
Ethyl ethanoate

- For acid hydrolysis, heat the ester with a dilute acid such as HCl

d) Alkaline hydrolysis

- This is similar to acid hydrolysis but produces the carboxylate salt of acid rather than acid itself. This is not reversible.

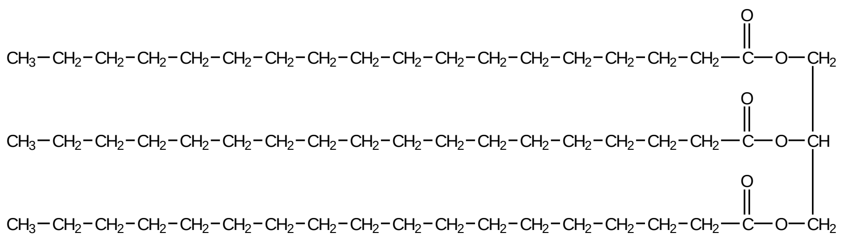
$CH_3COOC_2H_5$ + NaOH → CH_3COONa + C_2H_5OH
Ethyl ethanoate sodium ethanoate

- For alkaline hydrolysis, heat the ester with dilute NaOH.

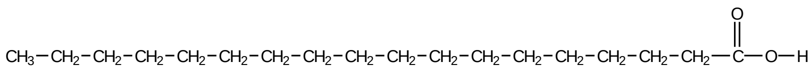
Topic 8c – Triglycerides, unsaturated and saturated fats
Revision Notes

1. Triglycerides

- Triglycerides are more commonly known as fats and oils
- A triglyceride is a tri-ester of glycerol and 3 fatty acids e.g.

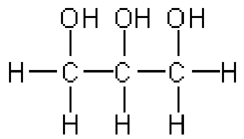


- A fatty acid is an unbranched, long chain carboxylic acid e.g. octadecanoic acid. The shorthand formula for a fatty acid shows the number of carbons and the number and position of any double bonds. Octadecanoic acid has 18 carbons and no double bonds so its shorthand formula is 18, 0



Source of these 2 diagrams - http://www.chemsheets.co.uk/

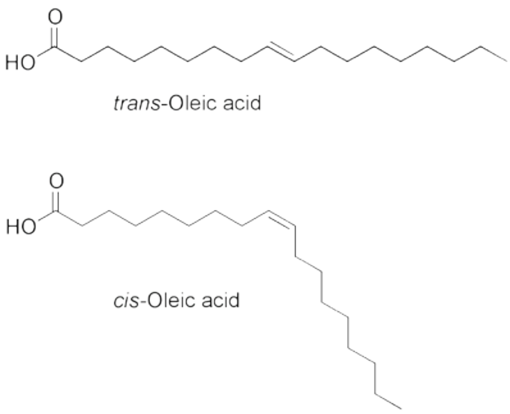
- Glycerol is propane-1,2,3-triol



- In a triglyceride the 3 fatty acids do not have to be the same

2. Saturated and unsaturated fats

- In a saturated fat there are no double bonds in the fatty acids from which the triglyceride was formed
- Unsaturated fats are formed from one or more fatty acids that contain a double bond
- The systematic name for oleic acid, shown below, is octadec-9-enoic acid which indicates that the double bond starts on carbon 9. The shorthand formula for this acid is 18, 1(9)
- Linoleic acid has 2 double bonds starting on carbons 9 and 12 so its systematic name is octadec-9,12-dienoic acid and the shorthand formula is 18, 2(9,12)

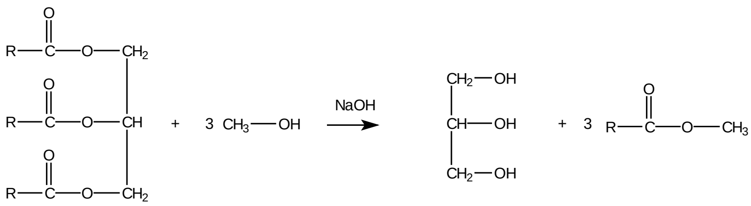


Source - http://en.wikipedia.org/wiki/File:Isomers_of_oleic_acid.png

- The presence of double bonds means that unsaturated fatty acids can have cis and trans isomers
- Note that trans fatty acids are less kinked than cis fatty acids
- The presence of trans fatty acids in the diet raises the level of LDL (‘bad’) cholesterol and reduces the level of HDL (‘good’) cholesterol. This increases the risk of coronary heart disease and strokes

3. **Biodiesel**

- Biodiesel consists of the esters of fatty acids
- Biodiesel can be made from cooking oil. The oil is mixed with methanol and potassium hydroxide is added as a catalyst



Source - http://www.chemsheets.co.uk/

- The use of biodiesel is increasing because of reduced greenhouse gas emissions, deforestation and pollution compared with petro-diesel (made from crude oil)