Al-Mustaqbal University
Department of Medical Laboratory Techniques
Subject: - General Chemistry (1) (2023-2024)
lecture (6)
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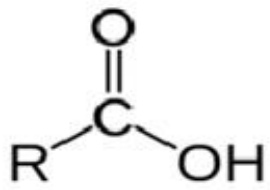
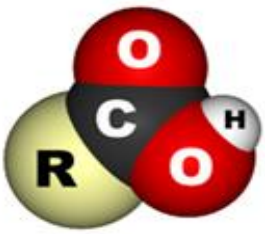
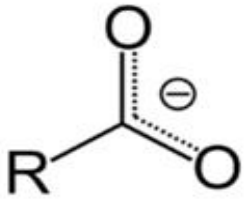
Carboxylic acid

A carboxylic acid is an organic compound that contains a carboxyl group (C(=O)OH). The general formula of a carboxylic acid is R–COOH, with R referring to the rest of the molecule. Carboxylic acids occur widely. Important examples include the amino acids and acetic acid. Deprotonation of a carboxyl group gives a carboxylate anion.



Structure of a carboxylic acid





Structure of a Carboxylate Anion

Nomenclature of Carboxylic Acids :-

The guidelines that must be followed in the IUPAC nomenclature of carboxylic acids are listed below.

1-The suffix (e) in the name of the corresponding alkane is replaced with (oic acid).

2-When the aliphatic chain contains only one carboxyl group, the carboxylic carbon is always numbered one. For example, CH_3COOH is named as ethanoic acid.

3-When the aliphatic chain contains more than one carboxyl group, the total number of carbon atoms is counted and the number of carboxyl groups is represented by Greek numeral prefixes such as (di-, tri- , etc).

4-A carboxylic acid is named by adding these prefixes and suffixes to the parent alkyl chain. Arabic numerals are used for indicating the positions of the carboxyl group.

5-The name "carboxylic acid" assigned for a carboxyl substituent on a carbon chain. An example of such nomenclature is the name 2-carboxyfuran for the compound 2-Furoic acid$C_5H_4O_3$, 5-Mmethyl-3-heptenoic acid.

Formic acid	Methanoic acid	HCOOH	CH_2O_2
Acetic acid	Ethanoic acid	CH_3COOH	$C_2H_4O_2$
Propionic acid	Propanoic acid	CH_3CH_2COOH	$C_3H_6O_2$
Butyric acid	Butanoic acid	$CH_3(CH_2)_2COOH$	$C_4H_8O_2$
Valeric acid	Pentanoic acid	$CH_3(CH_2)_3COOH$	$C_5H_{10}O_2$
Caproic acid	Hexanoic acid	$CH_3(CH_2)_4COOH$	$C_6H_{12}O_2$
Enanthic acid	Heptanoic acid	$CH_3(CH_2)_5COOH$	$C_7H_{14}O_2$
Caprylic acid	Octanoic acid	$CH_3(CH_2)_6COOH$	$C_8H_{16}O_2$
Pelargonic acid	Nonanoic acid	$CH_3(CH_2)_7COOH$	$C_9H_{18}O_2$
Capric acid	Decanoic acid	$CH_3(CH_2)_8COOH$	$C_{10}H_{20}O_2$
Undecylic acid	Undecanoic acid	$CH_3(CH_2)_9COOH$	$C_{11}H_{22}O_2$
Lauric acid	Dodecanoic acid	$CH_3(CH_2)_{10}COOH$	$C_{12}H_{24}O_2$
Myristic acid	Tetradecanoic acid	$CH_3(CH_2)_{12}COOH$	$C_{14}H_{28}O_2$
Palmitic acid	Hexadecanoic acid	$CH_3(CH_2)_{14}COOH$	$C_{16}H_{32}O_2$

Margaric acid	**Heptadecanoic acid**	**$CH_3(CH_2)_{15}COOH$**	**$C_{17}H_{34}O_2$**
Stearic acid	**Octadecanoic acid**	**$CH_3(CH_2)_{16}COOH$**	**$C_{18}H_{36}O_2$**

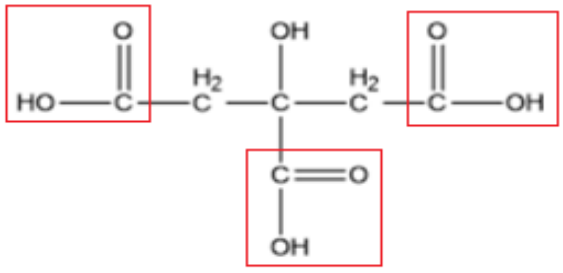
Classification of Carboxylic :-

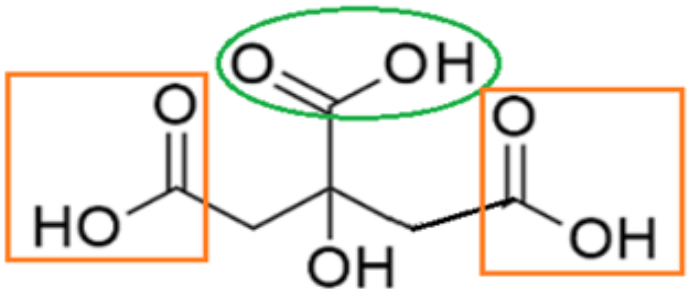
a- Carboxylic acids are classified according to the number of carboxylic groups as:-

1-Monocarboxylic acid, Example :-Ethanoic acid (acetic acid) CH_3COOH

2-Dicarboxylic acids containing two carboxyl groups, examples: Oxalic (Ethanedioic) acid $HO_2C\text{-}CO_2H$. Butanedioic acid $HO_2C\text{-}CH_2CH_2\text{-}CO_2H$

3-Tricarboxylic acid

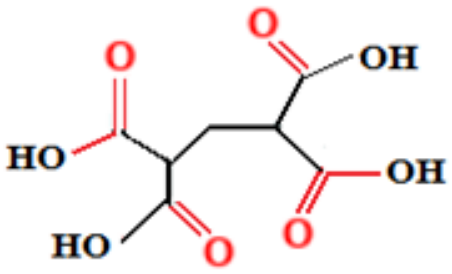




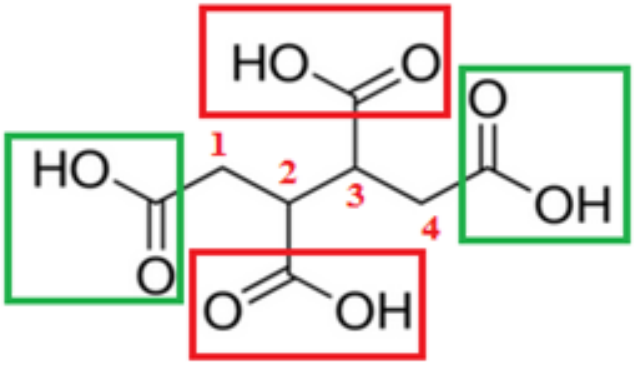
Citric acid

4- Tetracarboxylic acid.

1,1,3,3-Propanetetracarboxylic acid



1,1,3,3-Propanetetracarboxylic acid



1,2,3,4-Butanetetracarboxylic acid

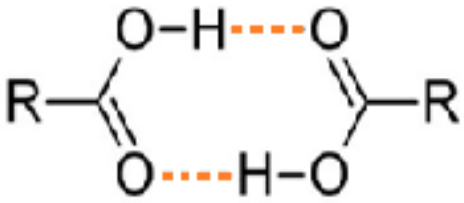
b- Carboxylic acids are classified according to the nature and composition of the bonds:

1-Fatty acids medium to long-chain saturated and unsaturated monocarboxylic acids, with even number of carbons, examples: docosahexaenoic acid($C_{22}H_{32}O_2$)
CH_3CH_2CH=CHCH_2CH=CH-CH_2 CH=CH CH_2-CH=CHCH_2CH=CHCH_2CH= CHCH_2CH_2COOH.

2-Unsaturated monocarboxylic acids acrylic acid (2-propenoic acid) CH_2=CHCOOH, used in polymer synthesis
3- Amino acids the building-blocks of proteins .
4- Aromatic carboxylic acids containing at least one aromatic ring, examples: benzoic acid C_6H_5COOH .

Physical Properties of Carboxylic Acids: -

- **Carboxylic acid molecules are polar due to the presence of two electronegative oxygen atoms.**
- **They also participate in hydrogen bonding due to the presence of the carbonyl group (C=O) and the hydroxyl group.**
- **When placed in nonpolar solvents, these compounds form dimers via hydrogen bonding between the hydroxyl group of one carboxylic acid and the carbonyl group of the other.**



- **The solubility of compounds containing the carboxyl functional group in water depends on the size of the compound. The smaller the compound (the shorter the R group), the higher the solubility.**
- **The boiling point of a carboxylic acid is generally higher than that of water.**
- **They generally have a strong sour smell. However, their esters have pleasant odors and are therefore used in perfumes.**
- **These compounds have the ability to donate protons and are therefore Bronsted-Lowry acids.**
- **Acidity :- Carboxylic acids are typically weak acids, meaning that they only partially dissociate into H_3O^+ cations and $RCOO^-$ anions in neutral aqueous solution.**

Preparation of Carboxylic Acids :-

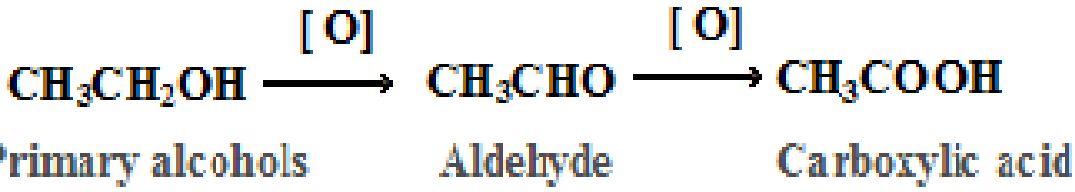
1-Hydrolysis of ester using water or dilute acid :-

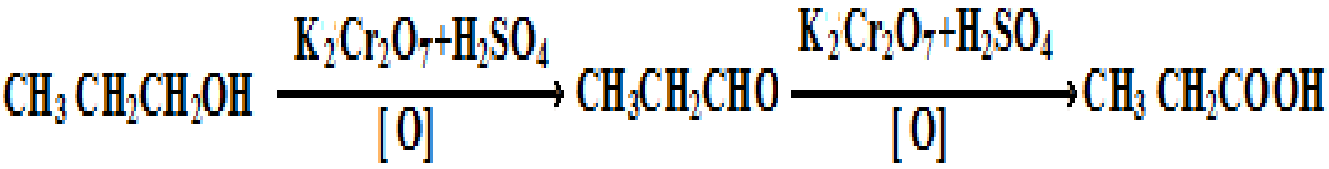
The reaction with pure water is so slow that it is never used. The reaction is catalysed by dilute acid, and so the ester is heated under reflux with a dilute acid like dilute hydrochloric acid or dilute sulphuric acid .Here simple examples of hydrolysis using an acid catalyst. First, hydrolysing ethyl ethanoate:

Methyl Propanoate Propanoic acid Methanol

2-Oxidation of Primary Alcohols and Aldehydes :-

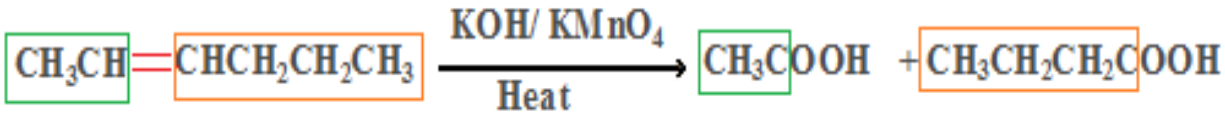
Primary alcohols on oxidation give aldehydes, the reaction does not stop here and the oxidation(by $K_2Cr_2O_7$ or $KMnO_4$) continues to give carboxylic acids as final product.

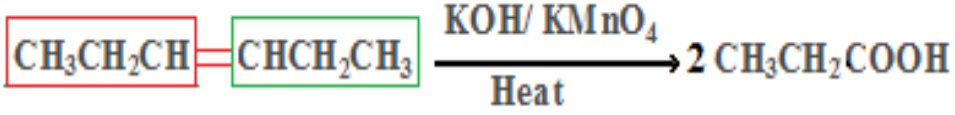




3-Oxidation of Alkenes :-

Strong oxidation of alkenes results in formation of carboxylic acids. Alkenes can be oxidized to carboxylic acids with hot alkaline $KMnO_4$

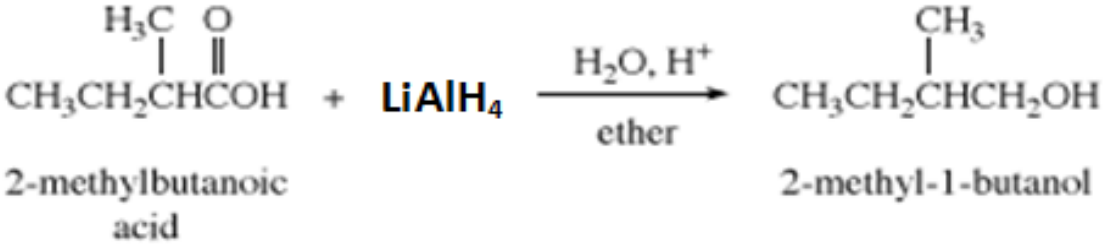




Reactions of carboxylic acids :-

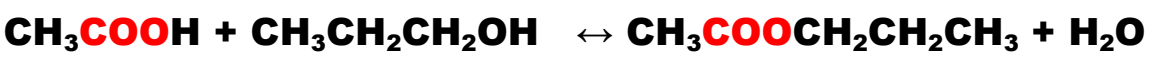
1-Reduction of carboxylic acids :-

Although carboxylic acids are more difficult to reduce than aldehydes and ketones, there are several agents that accomplish this reduction, the most important being lithium aluminum hydride ($LiAlH_4$) and borane (BH_3).



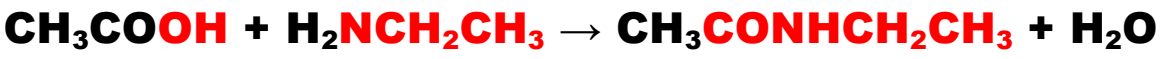
2-Esterification :-

Carboxylic acidsreact with alcohol by condensation reaction is an unfavorable equilibrium, promoted by using non-aqueous solvent and a dehydrating agent such as sulfuric acid (non-nucleophilic), catalyzing the reaction).



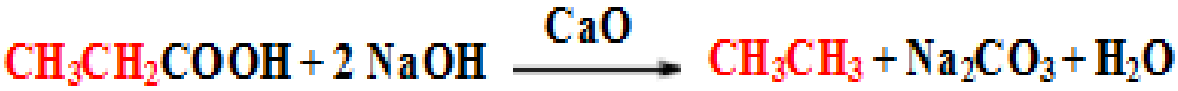
3-Amides Formation :-

The amide is formed by reaction of an acid (an electrophile) with an amine compound (a nucleophile), releasing water.



4-Acid Decarboxylation :-

On heating with sodalime (NaOH/CaO solid mix) carboxylic acids lose their –COOH group and produce a small alkane plus sodium carbonate:



Note how a carbon is lost from the main chain. The product of the reaction may be easier to identify than the original acid, helping us to find the structure.