Aldehyde, Ketones and Carboxylic Acids:

Aldehyde and Ketones

Preparation of Aldehydes

a. Oxidation of primary alcohols

b. Oxidation of methyl benzenes

c. Reimer - Tiemann synthesis of phenolic aldehydes

The electrophile is the dichlorocarbene, CCl_2 , formation of carbene is an example of α -elimination. $\overline{O}H + HCCl_3 \xrightarrow{-HCl} CCl_2$

d. Reduction of acid chlorides

COCI or RCOCI
$$\xrightarrow{H_2}$$
 RCHO + HCI
Poisoned with quinoline-S (trace)
Rosenmund's reaction

e. Stephen's Method

$$R -- C \equiv N \xrightarrow{1. SnCl_2} RCHO$$

H₂O (Hydrolysis of intermediate) RCH = NH to RCHO and NH₃

Preparation of Ketones:

a) Oxidation of Secondary alcohols:

b) Friedel - Crafts acylation

c) Acylation of Alkenes

This is Markovnikov addition initiated by $R - \overset{\bullet}{C} = \overset{\bullet}{O}$;, an acylium cation.

d) With Organometallics

e) By heating the calcium salt of any monocarboxylic acid other than formic acid

$$(RCO_2)_2Ca + \Delta \rightarrow R_2CO + CaCO_3$$

f) Acetoacetic ester synthesis of ketones

$$\begin{array}{c} \text{CH}_3\text{COCH}_2\text{COOC}_2\text{H}_5 \xrightarrow{\text{NaOEt}} \text{CH}_3\text{CO\overline{C}HCO}_2\text{CH}_2\text{CH}_3 \xrightarrow{\text{R-X}} \text{CH}_3 -- \text{C} -- \text{CHCO}_2\text{CH}_2\text{CH}_3 \\ \text{Acetoacetic ester} & \text{O} & \text{R} \\ \\ \xrightarrow{\text{OH}^-} \text{CH}_3\text{COCHCO}_2^- \longrightarrow \text{CH}_3 -- \text{CO} \longrightarrow \text{CH} -- \text{CO}_2\text{H} \longrightarrow \text{CH}_3\text{COCH}_2\text{R} \\ \text{R} & \text{R} \end{array}$$

g) Ring Ketones from Dicarboxylic acids and their Derivaties:

$$CO_2H$$
 $CH_2)_n$
 CO_2H
 CO_2H
 CO_2H
 CO_2H
 $CO_3 + H_2CO_3 + H$

h) Synthesis of Ketones and Aldehydes Using 1,3-Dithianes:

Reactions of Aldehydes and Ketones:

a) Aldol condensation

Aldehydes and ketones having alpha hydrogen atom:

(Since it contains two functional groups aldehydes and alcohol)

Aldol easily undergoes dehydration

b) Cannizzaro reaction:

Aldehydes and ketones having no alpha hydrogen atom:

When two carbonyl groups are present within a molecule, think of intramolecular reaction. OH^- will attack more positively charged carbon. In this case, it is right >c=0 group.

$$H_5C_6$$
 H_5C_6
 H

c) Formation of Keto Esters

Esters having a-hydrogen on treatment with a strong base e.g. C₂H₅ONa. Undergo self condensation to produce b-keto esters. This reaction is Claisen Condensation.

$$2CH_3COOC_2H_5 \xrightarrow{1. C_2H_5ONa} CH_3COCH_2COOC_2H_5$$

d) Reformatsky Reaction

This is the reaction of a-haloester, usually an a-bromoester with an aldehyde or ketone in the presence of Zinc metal to produce b-hydroxyester.

$$R_{2}C = O + BrCH_{2}COOC_{2}H_{5} \xrightarrow{1. Zn} R = C - CH_{2}COOC_{2}H_{5}$$

$$R$$

e) Pinacol-pinacolone Rearrangement

The acid catalysed rearrangement of 1,2 diols (Vicinal diols) to aldehydes or ketones with the elimination of water is known as pinacol pinacolone rearrangement.

a) Wittig-Ylide Reaction

Aldehydes and Ketones react with phosphorus Ylides to yield alkenes and triphenyl phosphine oxide. An Ylide is a neutral molecule having a negative carbon adjacent to a positive hetero atom. Phosphorus ylides are also called phosphoranes.

Preparation of Ylides

$$(C_6H_5)_3P^{\bullet}$$
 + C_H X $(H_5C_6)_3\overset{\dagger}{P}$ H_5 R_2 R_2 R_3 R_4 R_5 $R_$

Reaction of Ylide with >C=O

d) Baeyer-Villiger Oxidation

$$\begin{array}{ccc}
O & O & & O \\
R - C - R' & \xrightarrow{CF_3COOH} & R - C - OR' \\
O & O & O \\
R - C - H & \xrightarrow{CF_3COOH} & R - C - OH
\end{array}$$

Above things happens in BVO (Bayer Villiger oxidation). Reagents are either per acetic acid or perbenzoic acid or pertrifluoroacetic acid or permonosulphuric acid.

e) Addition of cyanide

$$\begin{array}{c|c} O & CH_3 \\ \parallel \\ CH_3 - C - CH_3 + NaCN \xrightarrow{H_2SO_4} CH_3 - C - CN \xrightarrow{H_2O_2/H_2SO_4} \\ OH & CH_3 - C - CO_2H \\ OH & CH_3$$

f) Addition of bisulfite:

	H_2N-G	Product	
H ₂ NOH	Hydroxylamine	> C = N $-$ OH	Oxime
H_2N-NH_2	Hydrazine	$> C = N - NH_2$	Hydrazone
$H_2N-NH-C_6H_5$	Phenylhydrazine	$> C = N - NHC_6H_5$	Phenylhydrazone
H ₂ N - NH - CO - NH ₂	Semicarbazide	> C = N - NHCONH ₂	Semicarbazone
NHNH ₂ NO ₂	2, 4-Dinitrophenyl hydrazine	NH - N = C NO ₂ NO ₂	2, 4- dinitrophenylhydrazo ne (bright orange or yellow precipitate used for identifying aldehydes and ketones

g) Addition of derivative of ammonia

$$\begin{array}{c} C + H_2N - G \rightarrow \\ | \\ O \\ \end{array}$$

$$\begin{array}{c} C - NH - G \\ OH \\ \end{array}$$

$$\begin{array}{c} C = N - G + H_2O \\ \hline \text{U sed for identification} \\ \end{array}$$

h) Addition of Alcohols; Acetal Formation

In H_3O^+ , RCHO is regenerated because acetals undergo acid catalyzed cleavage much more easily than do ethers. Since acetals are stable in neutral or basic media, they are used to protect the – CH = O group.

i) Addition of Water

$$\begin{array}{c} R \\ C = O + H_2O \\ R \end{array} \qquad \begin{array}{c} R \\ OH \\ R \end{array} \qquad \begin{array}{c} K = \frac{[hydrateO][H]}{[ketone][H]} \end{array}$$

j) Addition of Ammonia:

$$\begin{array}{c} R \\ H \end{array} \longrightarrow \begin{array}{c} R \\ C = O + NH_3 \longrightarrow \\ H \end{array} \longrightarrow \begin{array}{c} R \\ H \end{array} \longrightarrow \begin{array}{c} OH \\ NH_2 \end{array}$$

k) Tischenko reaction:

All aldehydes can be made to undergo the Cannizzaro reaction by treatment with *aluminium ethoxide*. Under these conditions the acids and alcohols are combined as the ester, and the reaction is then known as the

Tischenko reaction; eg, acetaldehyde gives ethyl acetate, and propionaldehyde gives propyl propionate.

Oxidation of Aldehydes and Ketones

a)

R CH = O/Ar CH = O
$$\xrightarrow{\text{KMnO}_4 \text{ or } K_2\text{Cr}_2\text{O}_7/\text{H}^+}$$
 R -- CO₂H/ArCO₂H

b) Tollen's Reagent

A specific oxidant for RCHO is [Ag(NH3)2]+

$$R - C - H + [Ag(NH_3)_2]^+ \longrightarrow RCOOH$$

Tollen's test chiefly used for the detection of aldehydes.

Tollen's reagent doesnot attack carbon-carbon double bonds.

c) Strong Oxidants: Ketones resist mild oxidation, but with strong oxidants at high temperature they undergo cleavage of C – C bonds on either sides of the carbonyl group.

$$\begin{array}{c|c} R-CH_2-C-CH_2R & \xrightarrow{\text{oxidation} \\ \text{O} & \text{(drastiq)} \end{array} } & RCO_2H+R'CH_2CO_2H+RCH_2CO_2H+R'CO_2 \\ & & \text{From cleavage of bond (a)} \end{array}$$

d) Haloform Reaction

CH₃COR are readily oxidised by NaOI (NaOH + I₂) to iodoform, CHI₃, and RCO₂Na

Example:

$$\begin{array}{c} C_2H_5 \longrightarrow C \longrightarrow CH_3 + NaOH + I_2 \longrightarrow C_2H_5CO_2^- Na^+ + CHI_3 \\ O & \text{lodoform yellow;} \\ & \text{mp 119}^\circ \end{array}$$

Reduction:

a) Reduction to alcohols

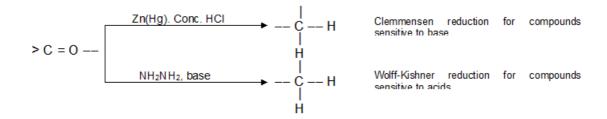
$$-- C = O --$$

$$LiAlH_4 \text{ or NaBH}_4;$$

$$+ C -- OF$$

Aldehydes → 1° alcohols; Ketones → 2°alcohols

b) Reduction to hydrocarbons



Carboxylic Acids:

Carboxylic Acids	Common Names
нсоон	Formic acid
CH ₃ COOH	Acetic acid
CH ₃ -CH ₂ -COOH	Propionic acid
CH ₃ (CH ₂)COOH	Butyric acid
CH ₃ (CH ₂) ₃ COOH	Valeric acid
CH ₃ (CH ₂) ₁₄ COOH	Palmitic acid
CH ₃ (CH ₂) ₁₆ COOH	Stearic Acid

Physical Properties of Carboxylic Acids

- The first three acids are colourless, pungent smelling liquids.
- First four members are miscible in water due the intermolecular hydrogen bonding whereas higher members are miscible in non polar solvents like ether.
- Benzene or ethanol but immiscible in water due to the increase in the size of lyophobic alkyl chain.
- The b.p. of carboxylic acids are higher than alcohols because carboxylic acids exist as dimers due to the presence of intermolecular H-bonding
- Increase in the number of Halogen atoms on a-position increases the acidity, eg.
 CCl₃COOH > CHCl₂COOH > CICH₂COOH > CH₃COOH
- Increase in the distance of Halogen from COOH decreases the acidity e.g
 CH₃ CH₂ CH(CI) COOH > CH₃ CH(CI) CH₂ COOH > CH₂ CH₂ CH₂ COOH
- Increase in the electro negativity of halogen increases the acidity.
 FCH₂COOH > BrCH₂COOH > ICH₂COOH

Methods of Preparations of Carboxylic Acids

a. Oxidation of Aldehydes & Ketones

$$R - CH_{2}OH \xrightarrow{K_{2}Cr_{2}O_{7} + H_{2}SO_{4}} RCHO \xrightarrow{K_{2}Cr_{2}O_{7} + H_{2}SO_{4}} RCOOH$$

$$R - CHO \xrightarrow{1. Ag_{2}O \text{ or } Ag(NH_{3})_{2}^{+}} RCO_{2}H$$

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b. Oxidation of Alkanes:

$$RCH = CHR' \xrightarrow{1. \text{ KMnO}_4, \text{ OH}^-} RCO_2H + R'CO_2H$$

c. Hydrolysis of Nitriles (Cyanides)

$$R - C \equiv N \xrightarrow{Acid hydrolysis} R.COOH + NH_3$$

 $d. \quad Carbonation \, of \, Grignard \, Reagents$

$$R - X + Mg \xrightarrow{Diethyl \ ether} RMgX \xrightarrow{CO_2} RCO_2MgX \xrightarrow{H_3O^+} RCO_2H$$

$$or \ Ar - Br + Mg \xrightarrow{Diethyl \ ether} ArMgBr \xrightarrow{CO_2} ArCO_2MgBr \xrightarrow{H_3O^+} ArCO_2H$$

e. Koch Reaction:

An olefin is heated with carbon monoxide and steam under pressure at 300-400° in the presence of a catalyst, e.g. phosphoric acid.

$$CH_2 = CH_2 + CO + H_2O \xrightarrow{H_3PO_4 \atop \text{steam 300-400'C}} CH_3 - CH_2 - COOH$$

f. Heating Gem Dicarboxylic Acids:

Heating Gem Dicarboxylic Acids:

$$COOH$$
 CH_2
 $COOH$
 $COOH$
 $COOH$
 $COOH$
 $COOH$
 $COOH$
 $COOH$
 $COOH$

Chemical Reactions of Carboxylic Acids

a. Salt formation:

2CH₃COOH + 2Na
$$\rightarrow$$
 2CH3COO-Na⁺ + H₂

$$CH_3COOH + NaOH \rightarrow CH3COO-Na^+ + H_2O$$

$$CH_3COOH + NaHCO_3 \rightarrow CH3COO-Na^+ + H_2O + CO_2$$

b. Conversion into Acid Chlorides:

Benzoic acid

Benzoyl chloride

$$R-C$$
 O
+ PCI_5
heat
 $R-C$
 O
+ $HCI + POCI_3$

c. Conversion into Esters (Esterification)

$$R - C + R'OH \xrightarrow{H^{\uparrow}} R - C + H_2O$$

$$OH OR'$$
Acid

d. Conversion into Amides

e. Conversion into Anhydrides $2CH_3COOH \xrightarrow{P_2O_5} (CH_3CO)_2O + H_2O$

f. Reduction:

$$4R-COOH + 3LiA1H_4 \longrightarrow 4H_2 + 2LiA1O_2 + (RCH_2O)_4 A1Li \xrightarrow{H_2O} RCH_2OH$$

g. Halogenation:

$$\mathsf{CH}_3 - \mathsf{COOH} \xrightarrow{\quad \mathsf{Cl}_2, \mathsf{P} \quad} \mathsf{CI} - \mathsf{CH}_2 - \mathsf{COOH} \xrightarrow{\quad \mathsf{Cl}_2, \mathsf{P} \quad} \mathsf{Cl}_2 \mathsf{CH} - \mathsf{COOH} \xrightarrow{\quad \mathsf{Cl}_2, \; \mathsf{P} \quad} \mathsf{Cl}_3 \mathsf{CCOOH}$$

Esters

a) Transesterification:

$$\begin{array}{c} O \\ || \\ CH_2 = CH - C - OCH_3 + CH_3CH_2 - CH_2 - OH \\ & \text{Methyl acrylate} \\ & \text{(bp 81°C)} \\ \end{array}$$

$$\begin{array}{c} \text{N-butylalcohol} \\ \text{(bp 117°C)} \\ \text{O} \\ & \text{V} \\ \\ \\ \text{CH}_3OH + CH_2 = CH - C - O - CH_2 - CH_2 - CH_2 - CH_3 \\ \\ \text{Methanol} \\ \\ \text{(bp 65°C)} \\ \end{array}$$

b) Hydrolysis:

c) Reduction:

$$\begin{array}{c} \text{CH}_3 - (\text{CH}_2)_{10} - \text{COOCH}_3 \xrightarrow[150^{\circ} \text{ High pressure}]{\text{Hz}, CuO, CuCr_2O_4} \\ \text{Methyl laurate} \end{array} \\ \begin{array}{c} \text{CH}_3 (\text{CH}_2)_{10} \text{ CH}_2\text{OH} + \text{CH}_3\text{OH} \\ \text{Lauryl alcohol} \end{array}$$

$$\begin{array}{c} \mathrm{CH_3-(CH_2)_{14}-COOC_2H_5} \xrightarrow{\quad \mathrm{LiAIH_4} \quad } \xrightarrow{\quad \mathrm{H^+} \quad } \mathrm{CH_3-(CH_2)_{14}-CH_2-OH} \\ &\quad \mathrm{Ethyl \ palmitate} \end{array}$$

Acid Chlorides:

a) Acetylation

$$\begin{array}{c} \text{CH}_3\text{COCI} + \text{HOH} \longrightarrow \text{CH}_3\text{COOH} + \text{HCI} \\ \text{CH}_3\text{COCI} + \text{HOC}_2\text{H}_5 \longrightarrow \text{CH}_3\text{COOC}_2\text{H}_5 + \text{HCI} \\ \text{Acetyl chloride} \qquad \qquad \text{Ethyl acetate} \\ \text{CH}_3\text{COCI} + \text{H}_2\text{NC}_6\text{H}_5 \longrightarrow \text{C}_6\text{H}_5\text{NHCOCH}_3 + \text{HCI} \\ \text{Aniline} \qquad \qquad \text{Acetanilide} \\ \text{OH} \\ \text{COOH} \\ \text{Salicylic acid} \qquad \qquad \text{Acetyl Salicylic acid} \\ \text{(Aspirin)} \\ \end{array}$$

b) Reaction with Olefins:

$$\begin{array}{c} \text{CH}_3 \\ \mid \\ \text{CH}_3 - \text{C} = \text{CH}_2 + \text{CH}_3 \text{COCI} \xrightarrow{\text{znCl}_2} \text{CH}_3 - \text{C} - \text{CH}_2 \text{COCH}_3 \xrightarrow{\text{heat}} \\ \mid \\ \text{CI} \\ \text{CH}_3 - \text{C} = \text{CH} - \text{COCH}_3 + \text{HCI} \\ \mid \\ \text{CH}_3 \end{array}$$

c) Conversion of Acid Chlorides into Acid Derivatives:

COOH

COCI

COOC₃H₇

PCl₅

heat

NO₂

NO₂

NO₂

NO₂

3-5, Dinitrobenzoic acid

3-5, Dinitrobenzoyl
chloride

3-5, Dinitrobenzoyl
chloride

3, 5 - dinitrobenzoate

Aqueous NaOH

Phenyl benzoate

RCOCl + R' COONa

$$R = C - O - C - R' + NaCl$$

Acid anhydride

Amides

a. Hydrolysis:

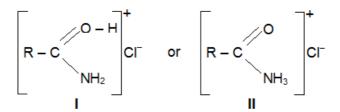
$$R - C \xrightarrow{H^{+}} R - C \xrightarrow{NH_{2}} \oplus \xrightarrow{H_{2}O} R - C - OH_{2} \xrightarrow{NH_{2}} \oplus R -$$

b. Acidic Character of Amides:

 $2 RCONH_2 + HgO \rightarrow (RCONH)_2 Hg + H_2O$

c. Basic Character of Amides:

Amides are very feebly basic and form unstable salts with strong inorganic acids. e.g. $RCONH_2HCI$. The structure of these salts may be I or II



d. Reduction:

RCONH
$$_2$$
 + 4H $\xrightarrow{\text{Na /C}_2\text{H}_5\text{OH}}$ R - CH $_2$ - NH $_2$ + H $_2\text{O}$

e. Reaction with Phosphorus Pentaoxide:

$$R$$
-CONH2 + $P_2O_5 \rightarrow R$ -CN

f. Reaction with Nitrous Acid:

$$RCONH_2 + HNO_2 \rightarrow RCO_2H + N_2 + H_2O$$