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1 $HCOOH$ - Methanoic acid
$HOOCCH_2CH_2COOH$ - Pentan-1,5-dioic acid
$CH_3CH_2CH_2COOH$ - Butanoic acid
HO_2C-CO_2H - Ethanedioic acid
$CH_3(CH_2)_4COOH$ - Hexanoic acid
$CH_3CH=CHCH_2CH_2COOH$ - Hex-4-enoic acid

2 Physical properties of Carboxylic acid
(i) Physical appearances: All simple alphatic carboxylic acid to C_{10} are in liquid state at room temperature. Most other carboxylic acids are in solid state at room temperature although anhydrous carboxylic acid (acetic acid) also known as glacial ethanoic acid freezes to an ice-like solid below the room temperature.

ii Boiling point: Boiling point increases with increasing relative molecular mass. Aromatic carboxylic acids are crystalline solids and have higher melting points than their aliphatic counterparts of comparable relative molecular mass.

iii Solubility: Lower molecular mass carboxylic acids with up to four carbon atom in their molecules are solubie in water. This largely due to their ability to form hydrogen bonds with water molecules. The water solubility of the acids decreases as the relative molecular mass increases because the structure becomes relatively more hydrocarbon in nature and hence covalent. All carboxylic acids are soluble in organic solvents.

3 Two industrial preperations of carboxylic acids:
i From carbon(ii) oxide: Methanoic acid (formic acid) is manufactured by adding carbon(ii) oxide under pressure to hot aqueous solution of sodium hydroxide. The free carboxylic acid is liberated by careful reation with tetraoxosulphate(vi) acid (H_2SO_4)

$CO + NaOH \longrightarrow HCOONa + H_2SO_4 \longrightarrow HCOOH + NaHSO_4$

(ii) From petroleum: Liquid phase air oxidation of C_5-C_7 alkanes, obtainable from petroleum at high temperature and pressure will give C_5-C_7 carboxylic acids with methanoic, propanoic and butanedioic acids as by-products.

C_5-C_7 $\xrightarrow{O_2/\text{High temperature and Pressure}}$ C_5-C_7 carboxylic acids

4 Explanation of the synthetic preparation of carboxylic acid

i Oxidation of primary alcohols and aldehydes: It can be used to prepare carboxylic acids using the usual oxidizing agents ~~(i.e $K_2Cr_2O_7$ or $KMnO_4$)~~ (i.e $K_2Cr_2O_7$ or $KMnO_4$) in acidic solution.

$$RCH_2OH \xrightarrow[K_2Cr_2O_7 \text{ or } KMnO_4]{[O] \text{ excess acid/ } KMnO_4} RCHO \xrightarrow{[O]} RCOOH$$

ii. Carbonation of Grignard reagent: Aliphatic carboxylic acids are obtained by bubbling carbon(IV) oxide into the grignard reagent and then hydrolyzed with dilute acid.

$$RMgBr + CO_2 \longrightarrow RCOOMgBr \xrightarrow{H_2O/\text{dilute acid}} RCOOH + MgBrOH$$

R may be 1°, 2°, 3° aliphatic alkyl or aryl radical

In the preparation of benzoic acid, the reagent is added to solid carbon(IV) oxide (dry ice) which also serves as coolant to the reaction mixture

$$C_6H_5MgBr + CO_2 \longrightarrow C_6H_5COOMgBr \xrightarrow{H_2O/H^+} C_6H_5COOH + MgBrOH$$

iii. Hydrolysis of nitriles (cyanides) or esters

$$RCN + 2H_2O \xrightarrow{H^+} RCOOH + NH_4^+$$

(R = alkyl or aryl radical)

$$RCOOR' \xrightarrow{H_2O/H^+ \text{ reflux}} RCOOH + R'OH$$

$$C_6H_5CH_2CN + 2H_2O \xrightarrow{H^+} C_6H_5CH_2COOH + NH_4^+$$

$$CH_3CH_2COOCH_3 \xrightarrow{H_2O/H^+ \text{ reflux}} CH_3CH_2COOH + CH_3OH$$

5 Outline the reduction, decarboxylation and esterification of carboxylic acid with their chemical equations

i Reduction:

$$4RCOOH + 3LiAlH_4 \xrightarrow{(C_2H_5)_2O} (RCH_2O)_4AlLi + 2LiAlO_2 + 4H_2$$

$$(RCH_2O)_4AlLi \xrightarrow{4H_2O} 4RCH_2OH + Al(OH)_3 + LiOH$$

$$CH_3CH_2CH_2COOH \xrightarrow{LiAlH_4} CH_3CH_2CH_2CH_2OH$$

Butanoic acid → Butanol

ii Decarboxylation: They are two derivative of decarboxylation which are:

Thermal decarboxylation

~~$CH_3CH_2CH_2COONa + NaOH \xrightarrow{Fuse} CH_3(CH_2)_2CH_3 + CO_2$ cano~~

$$CH_3CH_2CH_2COONa + NaOH \xrightarrow{Fuse} CH_3CH_2CH_3 + Na_2CO_3$$

Kolbe synthesis (Involvement of electrolysis)

$$2CH_3CH_2COONa + 2H_2O \xrightarrow{\text{electrolysis/aq. } CH_3OH} CH_3(CH_2)_2CH_3 + (CO_2 \text{ cano de}) + 2NaOH + H_2 \text{ (cathode)}$$

ii: Esterification

$$CH_3CH_2CH_2COOH + CH_3CH_2CH_2OH \xleftrightarrow{H^+} CH_3CH_2CH_2COOCH_2CH_2CH_3 + H_2O$$