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(1) Give the IUPAC names of the following compounds.
(a) $HCOOH$ = methanoic acid
(b) $HOOCCH_2CH_2CH_2COOH$ - petan-1,5-dioic acid
(c) $CH_3CH_2CH_2COOH$ = Butanoic acid
(d) HO_2C-CO_2H = Ethanedioic acid
(e) $CH_3(CH_2)_4COOH$ = Hex-4ene dioic acid
(f) $CH_3CH=CHCH_2CH_2COOH$ = Hexanoic acid

(2) Discuss briefly the physical properties of carboxylic acids under the following headings.
(i) Physical appearance: All simple aliphatic carboxylic acids up to C_{10} are liquids at room temperature. Most other carboxylic acids are solid 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 points: 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 atoms in their molecules are soluble in water, this largely due to their ability to form hydrogen bonds with water molecules. The water solubility of the acid 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.

(c) Write two industrial preparations of carboxylic acids from ethanol

Ethanoic acid is obtained commercially by the liquid phase air-oxidation of 5% solution of ethanol to ethanoic acid using manganese (II) ethanoate catalyst. Ethanal itself is obtained from ethylene.

$H_2C=CH_2 \xrightarrow{dil\ H_2SO_4/HgSO_4} CH_3CHO \xrightarrow{O_2/(CH_3COO)_2Mn} CH_3COOH$

(ii) 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 addition with tetraoxosulphate (VI) acid (H_2SO_4)

$CO + NaOH \rightarrow HCOONa \xrightarrow{H_2SO_4} HCOOH + NaHSO_4$

(d) With equations and brief explanation discuss the synthetic preparation of carboxylic acid

There are lots of ways to prepare the carboxylic acid synthetically, but I will state two briefly with the respective equations.

(1) Oxidations of primary alcohols and aldehydes

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

$RCH_2OH \xrightarrow[KMnO_4]{[O],\ excess\ acid} RCHO \xrightarrow{[O]} RCOOH$

(2) Hydrolysis of nitriles (Cyanides) or esters

$RCN + 2H_2O + H^+ \rightarrow RCOOH + NH_4^+$

(R = alkyl or aryl radical)

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

$C_6H_5CH_2CN + 2H_2O + H^+ \rightarrow C_6H_5CH_2COOH + NH_4^+$

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

Methanoic acid is common with the groups of

With chemical equations only outline the reduction decarboxylation and esterification of carboxylic acid

Reduction to primary alcohol.

Carboxylic acids are very difficult to reduce by catalytic hydrogenation or dissolving metals by lithium tetrahydridoaluminate (III) and diborane from intermediate compounds with the acids which liberate the alcohol on hydrolysis.

$4RCOOH + 3LiAlH_4 \rightarrow (RCH_2O)_4AlH + 2LiAlO_2 + 6H_2$

$4RCH_2OH + Al(OH)_3 + LiOH$

$CH_3CH_2CH_2COOH \xrightarrow{LiAlH_4} CH_3CH_2CH_2CH_2OH$

Butanoic acid — Butanol

Decarboxylation

— This allows removal of the carboxyl group from the acid to give a hydrocarbon or its derivative.

Thermal decarboxylation

Carboxylic acids with a strong electron attracting group e.g. —COOH, CN, NO_2, C=O decarboxylate readily on heating to 100-150°C while esters decarboxylate when their salts are heated with soda lime.

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

Kolbe synthesis

$2CH_3CH_2COONa + 2H_2O \xrightarrow{electrolysis} 2NaOH + H_2$ at cathode

Esterification

In the presence of strong acid catalyst, carboxylic acids react with alcohols to form esters

$CH_3CH_2CH_2COOH + CH_3CH_2CH_2OH \rightleftharpoons CH_3CH_2CH_2COOCH_2CH_2CH_3 + H_2O$