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19/MHS01/269

1 The IUPAC names of the following compounds

- $HCOOH$ - methanoic acid
- $HOOCH_2CH_2CH_2COOH$ - Pentan-1,5-dioic acid
- $CH_3CH_2CH_2COOH$ - Butanoic acid
- $HO_2C-CO_2H$ - Ethanedioic acid
- $CH_3(CH_2)_4COOH$ - Hexanoic acid
- $CH_3CH=CHCH_2CH_2COOH$

2 Brief discussion of physical properties of carboxylic acid under the following headings.

- Physical Appearance: All simple aliphatic carboxylic acids up to $C_{10}$ are liquids at room temp. Most other carboxylic acids are solid at room temp. although anhydrous carboxylic acid also known as glacial ethanoic acid freezes to an ice-like solid below room temp.
- Boiling point: It increases with increasing RMM. Aromatic carboxylic acid are crystalline solids and have higher melting points than their aliphatic counterparts of comparable relative molecular mass.
- 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 acids decreases as the RMM increases because the structure becomes relatively more hydrocarbon in nature and hence covalent. All carboxylic acids are soluble in organic solvent.

3 Two industrial preparation of carboxylic acids

- From $CO_2$: methanoic acid is manufactured by adding $CO_2$ under pressure to hot aqueous solution of NaOH. The free carboxylic acid is liberated by careful reactions with $H_2SO_4$.

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

- From petroleum: liquid phase air oxidation of $C_4$-$C_7$ alkanes, obtainable from petroleum at high temp. and pressure will give $C_6$-$C_7$ carboxylic acids with methanoic, propanoic acids, butanoic acids as by-products. $C_6$-$C_7$ $\xrightarrow{O_2/\text{high temp \& pressure}}$ $C_6$-$C_7$ carboxylic acids

4. Synthesis of preparation of carboxylic acid.

- Oxidation of primary alkanols and aldehydes: Oxidation of primary alcohol is a common method for synthesis of carboxylic acids using the usual oxidizing agents in acidic solution.

$$RCH_2OH \xrightarrow{[O]} RCHO \xrightarrow{[O]} RCOOH$$

- Hydrolysis of Nitriles (cyanides) or Esters. All acid derivative can be hydrolized to yield carboxylic acids, the condition required range from mild to severe, depending on the compound involved. Nitriles undergo hydrolysis to form amides. The amides further undergo reaction in the presence of a catalyst which then to form carboxylic acids. The catalyst for this reaction is $H^+$ or $OH^-$

$$RCN + 2H_2O \xrightarrow{H^+} RCOOH + NH_4^+ \quad (R = \text{alkyl or aryl radical})$$

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

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

$$C_6H_5CH_2COOCH_3 \xrightarrow{H_2O/H^+} CH_3CH_2COOH + CH_3OH$$

- Carbonation of Grignard agent: The carboxylic acid formation is possible by Grignard reagent reaction. The reaction of Grignard reagents with crushed dry ice or solid $CO_2$ leads to the formation of salts of carboxylic acids. Further, the acidification of the salts of a carboxylic acid with mineral acids leads to the formation of corresponding carboxylic acids

$$C_6H_5MgBr + CO_2 \xrightarrow{(C_2H_5)_2O} C_6H_5COOMgBr \xrightarrow{H_2O/H^+} C_6H_5COOH + MgBrOH$$

5. Reduction: $4RCOOH + 3LiAlH_4 \xrightarrow{(C_2H_5)_2O} (RCH_2O)_4Al + 2LiAlO_2 + 4H_2$

$$\downarrow$$

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

Butanoic acid

$$CH_3CH_2CH_2COOH \xrightarrow{LiAlH_4} CH_3CH_2CH_2CH_2OH \text{ (Butanol)}$$

- Decarboxylation

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

Kolbe synthesis

$$2CH_3CH_2COONa + 2H_2O \xrightarrow{electrolysis} CH_3(CH_2)_2CH_3 + CO_2 + 2NaOH + H_2$$

Esterification

$$CH_3CH_2CH_2COOH + CH_3CH_2CH_2OH \xrightarrow{H^+} CH_3CH_2CH_2COOCH_2CH_2CH_3 + H_2O.$$