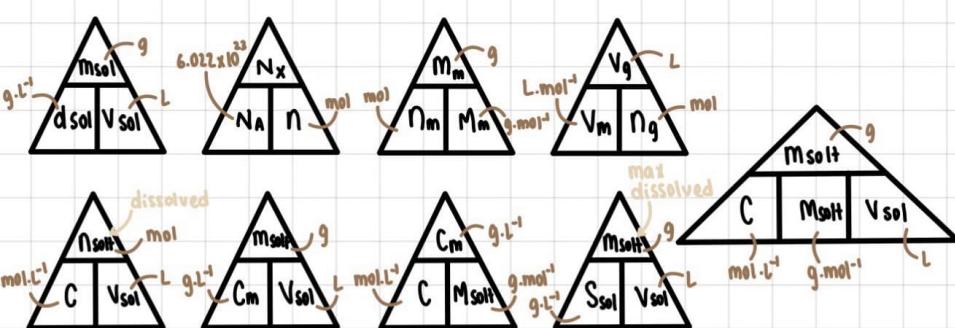


# chemistry

## basic rules



$$\begin{aligned} \% \text{ Msolute} &= \frac{\text{Msolute}}{\text{Msolution}} \times 100 \\ \% \text{ Vsolute} &= \frac{\text{Vsolute}}{\text{Vsolution}} \times 100 \\ \% \text{ yield} &= \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 \\ \% \text{ purity} &= \frac{\text{Msolute}}{\text{Mimpure}} \times 100 \\ \% \text{ cl} &= \frac{n(\text{reactant})_{\text{reacted}}}{n(\text{reactant})_{\text{initial}}} \times 100 \end{aligned}$$

## conversion

|                 |                  |                |
|-----------------|------------------|----------------|
| $\text{mg}$     | $\times 10^{-3}$ | $\text{g}$     |
| $\text{Kg}$     | $\times 10^3$    | $\text{g}$     |
| $\text{mL}$     | $\times 10^{-3}$ | $\text{L}$     |
| $\text{mmol}$   | $\times 10^{-3}$ | $\text{mol}$   |
| $\text{kg/L}$   | $\times 10^3$    | $\text{g/L}$   |
| $\text{g/mL}$   | $\times 10^3$    | $\text{g/L}$   |
| $\text{mol/L}$  | $\times 10^3$    | $\text{mol/L}$ |
| $\text{mmol/L}$ | $\times 10^{-3}$ | $\text{mol/L}$ |

## PREPARATION OF SOLUTION

- Preparation of a Solution Starting from a Solid State:

- Objective: Prepare a solution of a volume  $V$  and concentration  $C$ , by dissolving the solute of molar mass  $M$ .  $\text{Msolute} = ?$

$$\text{Msolute} = \text{Nsolute} \times \text{Msolute} = C \times \text{Vsolute} \times \text{Msolute}$$

### Materials:

- \* digital balance      \* watch glass      \* funnel
- \* volumetric flask      \* spatula      \* wash bottle containing distilled water

### Procedure:

1. Place a watch glass on a sensitive digital balance.
2. Weigh using a spatula  $m$  of the solid.
3. Transfer the solid to a volumetric flask  $V$  using a funnel.
4. Rinse the watch glass and funnel.
5. Stopper the flask and shake to dissolve the solute.
6. Continue adding distilled water to reach the line mark and shake to homogenize.

solid

liquid



- Preparation of a Solution Starting from a Liquid State:

- Objective: Prepare a solution of volume  $V$  and concentration  $C$ , by dissolving the solute of molar mass  $M$ .  $\text{Vsolute} = ?$

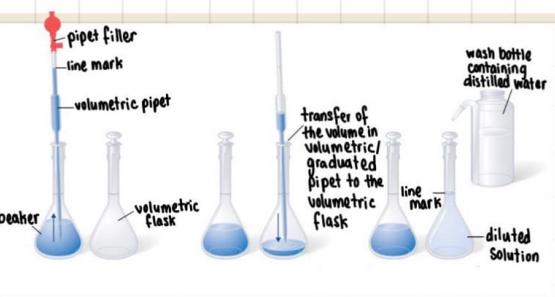
$$\text{Vsolute} = \frac{\text{Msolute}}{\text{dsolute}} = \frac{\text{Nsolute} \times \text{Msolute}}{\text{dsolute}} = \frac{C \times \text{Vsolution} \times \text{Msolute}}{\text{dsolute}}$$

### Materials:

- \* beaker      \* volumetric/graduated pipet      \* wash bottle containing distilled water
- \* volumetric flask      \* pipet filler      \* volume of solution

### Procedure:

1. Pour a sample of the liquid in a beaker (to avoid contamination).
2. Withdraw  $V$  using a volumetric/graduated pipet with the aid of a pipet filler.
3. Transfer  $V$  to the volumetric flask  $V_{\text{solute}}$ .
4. Add distilled water to reach the line mark.
5. Shake to homogenize.



## Diluting a Solution of Known Concentration:

- Objective: Prepare a solution of volume  $V$  and concentration  $C$ , by diluting a solution of concentration  $C_0$ .  $V_0 = ?$

$$N(\text{solute})_0 = N(\text{solute}) \quad \text{Nsolute diluted is conserved}$$

$$C_0 V_0 = C V \rightarrow V_0 = \frac{V \times C}{C_0}$$

$$DF = \frac{C_0}{C} = \frac{V}{V_0} \rightarrow V_0 = \frac{V}{DF}$$

### Materials:

- \* beaker *(holds a sample)*
- \* volumetric/graduated pipet
- \* wash bottle containing distilled water
- \* volumetric flask *(to be diluted)*
- \* pipet filler
- volume to be diluted*

### Procedure: diluted volume

1. Pour a sample of the liquid in a beaker (to avoid contamination).
2. Withdraw  $V_0$  using a volumetric/graduated pipet with the aid of a pipet filler.
3. Transfer  $V_0$  to the volumetric flask *Vsolution*. *diluted*
4. Add distilled water to reach the line mark.
5. Shake to homogenize.

## Diluting a Solution from a Commercial Solution:

- Objective: Prepare a solution of volume  $V$  and concentration  $C$ , by diluting a commercial solution of given density  $d$ , molar mass  $M$  and percentage by mass  $\%m$ .  $C_0 = ?$   $V_0 = ?$

$$\%m \text{ solute} = \frac{M_{\text{solute}} \times 100}{M_{\text{solution}}} = \frac{N_{\text{solute}} \times M_{\text{solute}}}{d_{\text{solution}} \times V_{\text{solution}}} \times 100 = \frac{C_0 \times M_{\text{solute}}}{d_{\text{solution}}} \times 100$$

$$\rightarrow C_0 = \frac{\%m \times d_{\text{solution}}}{M_{\text{solute}} \times 100}$$

$$N(\text{solute})_0 = N(\text{solute}) \quad \text{Nsolute diluted is conserved}$$

$$C_0 V_0 = C V \rightarrow V_0 = \frac{V \times C}{C_0}$$

$$DF = \frac{C_0}{C} = \frac{V}{V_0} \rightarrow V_0 = \frac{V}{DF}$$

### Materials:

- \* beaker *(holds a sample)*
- \* volumetric/graduated pipet
- \* wash bottle containing distilled water
- \* volumetric flask
- \* pipet filler
- volume to be diluted*

### Procedure: diluted volume

1. Pour a sample of the liquid in a beaker (to avoid contamination).
2. Withdraw  $V_0$  using a volumetric/graduated pipet with the aid of a pipet filler.
3. Transfer  $V_0$  to the volumetric flask *Vsolution*. *diluted*
4. Add distilled water to reach the line mark.
5. Shake to homogenize.

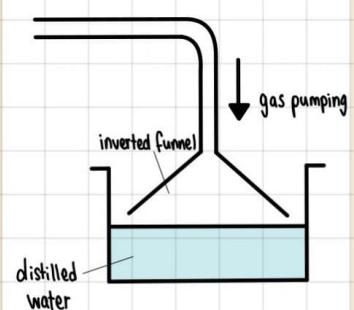
## Preparing a Solution Starting from a Gaseous State:

- Objective: Prepare a solution of volume  $V$  and concentration  $C$ , by dissolving the solute at pressure condition  $V_m$ .  $V_{\text{solute}} = ?$

$$V_{\text{solute}} = N_{\text{solute}} \times V_m = C \times V_{\text{solution}} \times V_m$$

### Procedure:

- \* Pump the gas into distilled water using inverted funnel arrangement.



# Chemical Kinetics

is a branch of chemistry that studies the progress of slow reactions.



## Rate of Formation of Products:

### Average rate of formation:

$$\bar{r}(B) = \frac{\Delta n(B)}{\Delta t} = \frac{n_2 - n_1}{t_2 - t_1}$$

\* Slope of secant between two time intervals  $t_1$  and  $t_2$ .

### Instantaneous rate of formation:

$$r_{\text{inst}}(B) = \lim_{\Delta t \rightarrow 0} \frac{\Delta n(B)}{\Delta t} = \frac{dn(B)}{dt}$$

\* Slope of tangent at instant  $t$ .

### Initial rate of formation:

$$r_{\text{form}}(B) = \frac{dn(B)}{dt} \Big|_{t=0}$$

\* Slope of tangent at instant  $t=0$ .

## Rate of Disappearance of Reactants:

### Average rate of disappearance:

$$\bar{r}(A) = \frac{-\Delta n(A)}{\Delta t} = \frac{n_2 - n_1}{t_2 - t_1}$$

\* Negative slope of secant between two time intervals  $t_1$  and  $t_2$ .

### Instantaneous rate of disappearance:

$$r_{\text{inst}}(A) = \lim_{\Delta t \rightarrow 0} \frac{-\Delta n(A)}{\Delta t} = \frac{-dn(A)}{dt}$$

\* Negative slope of tangent at instant  $t$ .

### Initial rate of disappearance:

$$r_{\text{dis}}(A) = \frac{dn(A)}{dt} \Big|_{t=0}$$

## Rate:

- Rate of formation and disappearance decreases with time.

- Rate is represented graphically.

- Rate is always positive.

- Units of rate: mol.time<sup>-1</sup>, mmol.time<sup>-1</sup>, mol.L<sup>-1</sup>.time<sup>-1</sup>, mmol.L<sup>-1</sup>.time<sup>-1</sup>...

- Rates are related stoichiometrically:

$$\frac{r(A)_t}{a} = \frac{r(B)_t}{b}$$

## Half-life Time ( $t_{1/2}$ ):

- For the product: it is the time needed for half the maximum amount of the product to be formed at  $t=\infty$ .

$$* n(B)_{t=1/2} = \frac{n(B)_{\infty}}{2}$$

- For the limiting reactant: it is the time needed for half the initial amount of the limiting reactant to disappear.

$$* n(A)_{t=1/2} = \frac{n(A)_0}{2}$$

- For the reactant in excess:

$$* n(C)_{\text{remained at } t=1/2} = n(C)_0 - n(C)_{\text{reacted at } t=1/2}$$

$$= n(C)_0 - \frac{n(C)_0}{a}/2$$

at  $t=1/2$ :

$$n(C)_{\text{reacted at } t=1/2} = n(C)_{\text{reacted at } t=1/2}$$

$$\Rightarrow n(C)_{\text{reacted at } t=1/2} = \frac{n(C)_0}{a}/2$$

## Kinetic Factors:

- It is a factor affecting the rate of a chemical reaction.

- Some kinetic factors: temperature - initial concentration - catalyst - concentration of the catalyst - surface area of contact of reactants - light ...

## Catalyst:

- It can be in the solid form or in the ionic form (solution).

### Properties of a catalyst:

\* activity: lesser amount, greater activity.

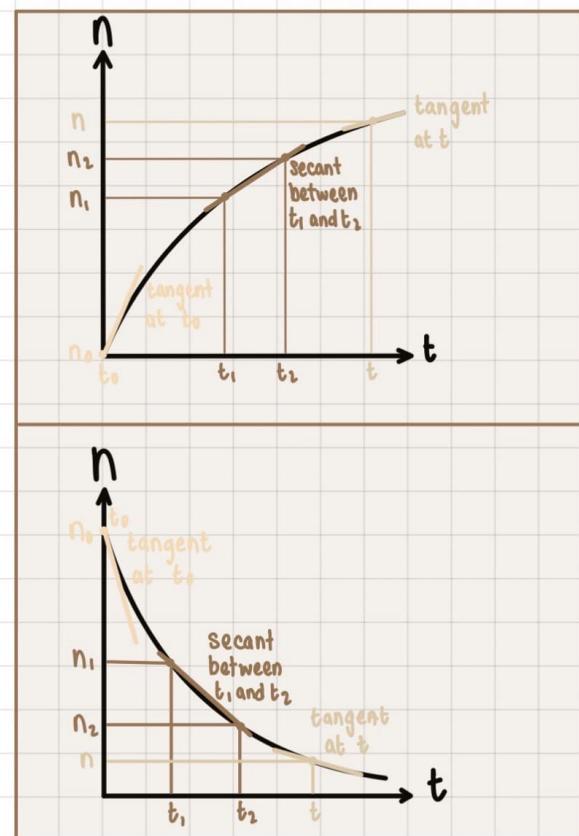
\* selectivity: each reaction has its own catalyst and changing the catalyst might change the products.

\* specific: for each reaction there is a catalyst.

\* interferes in the reaction without being chemically changed.

in excess

limiting



. ice water bath blocks the reaction

(for titration)

. the kinetic factor would be temperature, if distilled water is added initial concentration is a kinetic factor too.

- . Compare the initial concentration of reactants in beaker.
  - State the equal ones and the different ones.
- . Interpret the formation of a color in each beaker.
  - the only colored species will appear.
- . Compare the intensity of the color instant t in each beaker. Interpret the results.
  - compare the intensity in each beaker at same beaker at same t.
  - where did the color come from.
  - Compare the number of mole in each beaker of same V at t.
  - Compare the concentration in each beaker at same t.
- . Compare the rate in each beaker.
  - compare the concentration in each beaker at same t.
  - compare the rate in each beaker at same instant t.
- . Specify the kinetic factor involved.
  - State the variables and the conditions of each.
  - Compare the variable.
  - Conclude the kinetic factor.
- . What do you conclude?
  - as the given kinetic factor (state it) increase, the rate increases (or vice versa).
- . Will the color intensity be the same at the end of the reaction in each beaker.
  - the limiting reactant is responsible for any change.
- . Compare the half-life time of each experiment.
  - State the kinetic factor.
  - as the given kinetic factor increases the rate increases (or vice versa).
- . Draw the shape of the curves.
  - State the kinetic factor.
  - as the given kinetic factor increases the rate increases (or vice versa).
  - compare n or C in each beaker at same t.
  - draw the curves.
- . Associate each curve to its corresponding experiment.
  - State the kinetic factor.
  - as the given kinetic factor increases the rate increases (or vice versa).
  - compare the slope of tangent at each curve at same t.
  - slope of tangent represents the rate.
  - compare the rate in each beaker at same t .
  - associate the curves.

- . Compare the rate at  $t_1$  and  $t_2$ .
- draw tangents at  $t_1$  and  $t_2$ .
- rate is represented by the slope of tangent drawn at each  $t$ .
- Compare the slopes of the tangents drawn at  $t_1$  and  $t_2$ .
- Compare the rates at  $t_1$  and  $t_2$ .

### . Determine the half-life time.

- give the definition of half-life time
- give the relation.
- represent  $t_{1/2}$  graphically.
- $t_{1/2} = ?$

### . Determine the rate of the reaction.

- rates are related stoichiometrically.
- find the rate of the reaction by the relation.

# Chemical Equilibrium

. Complete Reaction:  $aA + bB \rightarrow cC + dD$

- It is a reaction that reaches an end where at least one reactant is totally consumed.

. Law of Mass Action:

-  $K_c$  is the equilibrium constant with respect to the concentration.

- Every reaction has a  $K_c$  at equilibrium state at a given temperature and regardless of the initial state.

$$K_c = \frac{[C]^c \times [D]^d}{[A]^a \times [B]^b}$$

Formed at equilibrium  
remained at equilibrium

. Esterification:

- It is the process of combining an alcohol ( $ROH$ ) and a carboxylic acid ( $RCOOH$ ) to form ester ( $RCOOR$ ) and water ( $H_2O$ ).

- This reaction is:

\* reversible

\* very slow

\* athermic (temperature doesn't affect its  $K_c$  because it doesn't absorb heat)



. Hydrolysis:

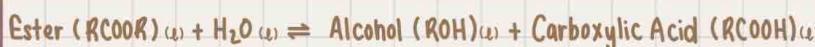
- It is the process of combining ester ( $RCOOR$ ) and water ( $H_2O$ ) to form alcohol ( $ROH$ ) and carboxylic acid ( $RCOOH$ ).

- This reaction is:

\* reversible

\* very slow

\* ?



. How to check if a reaction is at equilibrium?

- The reaction quotient ( $Q$ ) must be calculated.

\* It is between the amount of products and the amount of reactants in a reaction.

$$Q = \frac{[C]^c \times [D]^d}{[A]^a \times [B]^b}$$

- If  $Q = K_c$

⇒ the system is at equilibrium

- If  $Q \neq K_c$

⇒ the system is not at equilibrium

$Q < K_c$        $Q > K_c$

Q must increase to reach equilibrium

Reactants / Products  $\nearrow [R] \gg [P]$

the system moves forward

Q must decrease to reach equilibrium

Reactants / Products  $\searrow [P] \gg [R]$

the system moves backward

. Catalyst and Temperature in Reversible Reactions:

- Kinetic factors that increase the rate of forward and backward to reach equilibrium faster with no effect on the composition.

- Changing the temperature can be applicable only in esterification since it is resistant to heat (athermic).

. Degree of Composition ( $\alpha$ ):

- In reversible reactions, it is specific for each reaction and  $\alpha < 1$ .

- In irreversible reactions,  $\alpha = 1$ .

$$\alpha = \frac{N(\text{Reactant}) \text{ reacted}}{N(\text{Reactant}) \text{ initial}}$$

. Incomplete Reaction:  $aA + bB \rightleftharpoons cC + dD$

- It is a reaction where no reactant is totally consumed and it goes in both directions.

. Yield:

$$\% \text{ Yield} = \frac{N(\text{Product}) \text{ actual}}{N(\text{Product}) \text{ theoretical}} \times 100$$

determined at equilibrium

the reaction is considered complete (use limiting)

# ACIDS AND BASES

## Arrhenius Definition:

- Acid: is a chemical species that liberates an  $H^+$  freely in water.
- Base: is a chemical species that liberates an  $HO^-$  in water.

## Acid and Base Reaction:

- Acid form:  $HA + H_2O \rightarrow H_3O^+ + A^-$
- Base B form:  $B + H_2O \rightarrow BH^+ + HO^-$
- Base B<sup>-</sup> form:  $B^- + H_2O \rightarrow BH + HO^-$

## pH in Aqueous Solution:

- If  $[H_3O^+] \uparrow$  pH ↘
- If  $[H_3O^+] \downarrow$  pH ↗

$$pH = -\log [H_3O^+]$$

$$[H_3O^+] = 10^{-pH}$$

## pH Measurement:

- By pH indicator paper.
- By pH meter which has a sensitive electrode (must be calibrated before each use).

## Auto-ionization of Water:

- Water molecules undergo self-ionization to produce  $H_3O^+$  and  $HO^-$ .
- ↳  $2H_2O \rightleftharpoons H_3O^+ + HO^-$
- At  $25^\circ C$   $K_w = 10^{-14}$ .
- $K_w$  remains constant at constant temperature.

$$K_w = [H_3O^+][HO^-] = 10^{-14} = 10^{-pK_w}$$

$$pK_w = -\log K_w = 14$$

## pH Range of Aqueous Solutions (at $25^\circ C$ ):

### In neutral medium:

$$\star [H_3O^+] = [HO^-] = 10^{-7} \text{ mol L}^{-1}$$

$$\hookrightarrow pH = \frac{pK_w}{2} = 7$$

### In acidic medium:

$$\star [H_3O^+] > [HO^-] \quad (\text{dissolving acid in water}).$$

$$\hookrightarrow pH < \frac{pK_w}{2} \quad pH < 7$$

### In basic medium:

$$\star [HO^-] > [H_3O^+] \quad (\text{dissolving base in water}).$$

$$\hookrightarrow pH > \frac{pK_w}{2} \quad pH > 7$$

## Strong Acid:

- It is the acid that dissociates completely in water.



- If  $C_a = [H_3O^+] = 10^{-pH}$

- If  $pH_{\text{solution}} = -\log C_a$

➡ the acid is a strong acid.

## Strong Base:

- It is the base that dissociates completely in water.



- If  $C_b = [HO^-]$

- If  $pH = pK_w + \log [HO^-]$

➡ the base is a strong base.

## Bronsted-Lowery Theory:

- Acid: is a chemical species that donates a proton in water.  $H_3O^+$  produced.
- Base: is a chemical species that captures a proton in water.  $HO^-$  produced.



$$pK_w = pH + pHO$$

$$pH = pK_w - pHO$$

$$pH = pK_w - (-\log [HO^-])$$

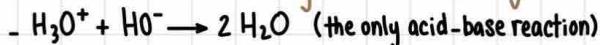
$$pH = pK_w + \log [HO^-]$$

## Degree of Dissociation:

- Strong acids and strong bases dissociate completely in water.

$$\alpha = \frac{n_{\text{reacted}}}{n_{\text{initial}}} = \frac{n(H_3O^+)_\text{formed}}{n(\text{acid})_\text{initial}} = \frac{n(OH^-)_\text{formed}}{n(\text{base})_\text{initial}} = 1$$

## Relation Between Strong Acid and Strong Base:



- The characteristics of the strong acid-strong base reaction:

- \* complete 99.9% (autoionization takes place but in a small amount compared to this reaction)
  - \* fast
  - \* spontaneous
  - \* unique
  - \* exothermic (controlled with monitoring the concentrations)
- These characteristics allow us to carry out titration.

## pH-metric Study of the Strong Acid-Strong Base Reaction:

**Materials:** pH meter - graduated burette - volumetric pipet - pipet filler - beaker - magnet bar - magnetic stirrer - distilled water.

### Procedure: *case of titrating an acid*

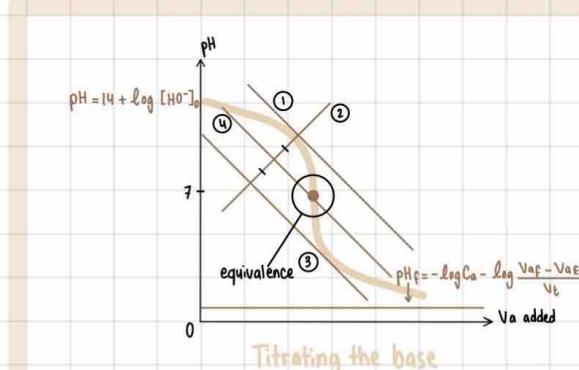
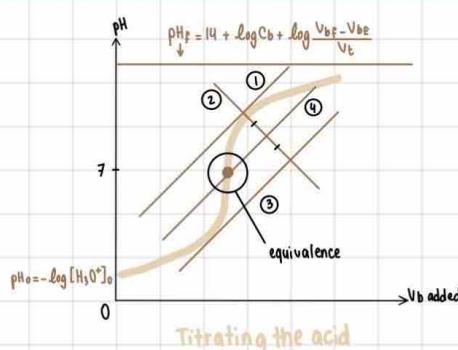
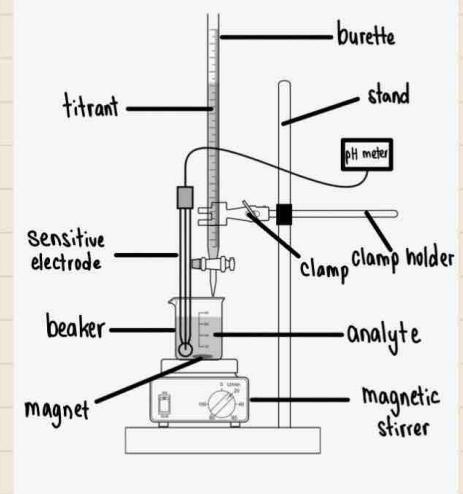
- 1- calibrate pH-meter.
- 2- fill the burette with base solution of concentration  $C_b$ .
- 3- using a  $V_a$  volumetric pipet, by the aid of a pipet filler, take  $V_a$  of the acid solution into the beaker containing magnetic bar and place it on the magnetic stirrer.
- 4- immerse the sensitive electrode of the pH meter in the beaker, if the bulb is not totally immersed, add distilled water to the beaker.
- 5- start adding gradually the base solution of concentration  $C_b$  from the burette and record the pH of the solution in the beaker after each addition with continuous stirring.

### Procedure: *case of titrating a base*

- 1- calibrate pH-meter.
- 2- fill the burette with acid solution of concentration  $C_a$ .
- 3- using a  $V_b$  volumetric pipet, by the aid of a pipet filler, take  $V_b$  of the base solution into the beaker containing magnetic bar and place it on the magnetic stirrer.
- 4- immerse the sensitive electrode of the pH meter in the beaker, if the bulb is not totally immersed, add distilled water to the beaker.
- 5- start adding gradually the acid solution of concentration  $C_a$  from the burette and record the pH of the solution in the beaker after each addition with continuous stirring.

### Equivalence point:

- \* It is reached when the reactant introduced in the beaker reacts totally with the reactant added from the burette according to their stoichiometric proportions.
- \* pH at equivalence in strong acid-strong base titration is  $pH_E = 7$ .



## The Effect of Addition of Distilled Water Initially:

- Distilled water is not used to dilute the solution but to:

\* immerse the sensitive bulb of the pH meter for precise and accurate reading.

\* provide efficient mixing after each addition.

- Conserved:

\*  $\text{N}(\text{H}_3\text{O}^+)$  initially in beaker or  $\text{N}(\text{HO}^-)$  initially in beaker.

\*  $\text{pH}_E = 7$  (at equivalence no acid no base character is present).

$$\star \text{V}_E \left( \frac{\text{N}(\text{H}_3\text{O}^+)_0}{C_b} \right) \stackrel{?}{=} \frac{\text{N}(\text{HO}^-)_0}{C_a}$$

- Not conserved:

$$\star [\text{H}_3\text{O}^+]_0 = \frac{\text{N}(\text{H}_3\text{O}^+)}{V_t} \text{ or } [\text{HO}^-]_0 = \frac{\text{N}(\text{HO}^-)}{V_t}$$

$$\star \text{pH}_0 > [\text{H}_3\text{O}^+]_0 \stackrel{?}{=} [\text{HO}^-]_0$$

$$\star \text{pH}_0 > -\log C_a$$

## Titrating the Acid:

### At equivalence ( $\text{V}_{BE}$ ):

\*  $\text{N}(\text{H}_3\text{O}^+)$  in  $\text{V}_a = \text{N}(\text{HO}^-)$  in  $\text{V}_{BE}$

$$C_a V_a = C_b V_{BE}$$

\*  $\text{pH}_E = 7$  (since strong acid-strong base)

\* Using chemical species at equivalence:

$\text{H}_2\text{O}$  (neutral solvent)

$\text{Na}^+, \text{Cl}^-$  no acid no base character

### Before equivalence ( $\text{V}_b = 0$ ):

#### No distilled water added:

$$\star \text{pH}_0 = -\log [\text{H}_3\text{O}^+]_0 = -\log C_a$$

#### Distilled water added:

$$\star \text{pH}_0 > -\log C_a$$

$$\star [\text{H}_3\text{O}^+]_0 = \frac{\text{N}(\text{H}_3\text{O}^+)_0}{V_t}$$

### Before equivalence ( $\text{V}_b < \text{V}_{BE}$ ):

$$\star \text{N}(\text{H}_3\text{O}^+) \text{ remained} = \text{N}(\text{H}_3\text{O}^+)_0 - \text{N}(\text{HO}^-) \text{ in } \text{V}_b$$

$$= C_a V_a - C_b V_b$$

$$= C_b V_{BE} - C_b V_b$$

$$= C_b (\text{V}_{BE} - \text{V}_b)$$

$$\star [\text{H}_3\text{O}^+] = \frac{\text{N}(\text{H}_3\text{O}^+) \text{ remained}}{V_t} = \frac{C_b (\text{V}_{BE} - \text{V}_b)}{V_t}$$

$$\star \text{pH} = -\log [\text{H}_3\text{O}^+] = -\log \left( C_b \frac{(\text{V}_{BE} - \text{V}_b)}{V_t} \right) = -\log C_b - \log \frac{\text{V}_{BE} - \text{V}_b}{V_t}$$

### After equivalence ( $\text{V}_b > \text{V}_{BE}$ ):

$$\star \text{N}(\text{HO}^-) \text{ remained} = \text{N}(\text{HO}^-) \text{ in } \text{V}_b - \text{N}(\text{H}_3\text{O}^+) \text{ in } \text{V}_b$$

$$= C_b V_b - C_a V_a$$

$$= C_b V_b - C_b V_{BE}$$

$$= C_b (\text{V}_b - \text{V}_{BE})$$

$$\star [\text{HO}^-] = \frac{\text{N}(\text{HO}^-) \text{ remained}}{V_t} = \frac{C_b (\text{V}_b - \text{V}_{BE})}{V_t}$$

$$\star \text{pH} = 14 + \log [\text{HO}^-] = 14 + \log \left( C_b \frac{(\text{V}_b - \text{V}_{BE})}{V_t} \right) = 14 + \log C_b + \log \frac{\text{V}_b - \text{V}_{BE}}{V_t}$$

## Titrating the Base:

### At equivalence ( $\text{V}_{AE}$ ):

\*  $\text{N}(\text{HO}^-)$  in  $\text{V}_b = \text{N}(\text{H}_3\text{O}^+)$  in  $\text{V}_{AE}$

$$C_b V_b = C_a V_{AE}$$

\*  $\text{pH}_E = 7$  (since strong acid-strong base)

\* Using chemical species at equivalence:

$\text{H}_2\text{O}$  (neutral solvent)

$\text{Na}^+, \text{Cl}^-$  no acid no base character

### Before equivalence ( $\text{V}_a = 0$ ):

#### No distilled water added:

$$\star \text{pH}_0 = 14 + \log [\text{HO}^-]_0 = 14 + \log C_b$$

#### Distilled water added:

$$\star \text{pH}_0 > 14 + \log C_b$$

$$\star [\text{HO}^-]_0 = \frac{\text{N}(\text{HO}^-)_0}{V_t}$$

### Before equivalence

$$\star \text{N}(\text{HO}^-) \text{ remained} = \text{N}(\text{HO}^-)_0 - \text{N}(\text{H}_3\text{O}^+) \text{ in } \text{V}_a$$

$$= C_b V_b - C_a V_a$$

$$= C_a V_{AE} - C_a V_a$$

$$= C_a (\text{V}_{AE} - \text{V}_a)$$

$$\star [\text{HO}^-] = \frac{\text{N}(\text{HO}^-) \text{ remained}}{V_t} = \frac{C_a (\text{V}_{AE} - \text{V}_a)}{V_t}$$

$$\star \text{pH} = 14 + \log [\text{HO}^-] = 14 + \log \left( C_a \frac{(\text{V}_{AE} - \text{V}_a)}{V_t} \right) = 14 + \log C_a - \log \frac{\text{V}_{AE} - \text{V}_a}{V_t}$$

### After equivalence ( $\text{V}_a > \text{V}_{AE}$ ):

$$\star \text{N}(\text{H}_3\text{O}^+) \text{ remained} = \text{N}(\text{H}_3\text{O}^+) \text{ in } \text{V}_a - \text{N}(\text{HO}^-) \text{ in } \text{V}_a$$

$$= C_a V_a - C_b V_b$$

$$= C_a V_a - C_a V_{AE}$$

$$= C_a (\text{V}_a - \text{V}_{AE})$$

$$\star [\text{H}_3\text{O}^+] = \frac{\text{N}(\text{H}_3\text{O}^+) \text{ remained}}{V_t} = \frac{C_a (\text{V}_a - \text{V}_{AE})}{V_t}$$

$$\star \text{pH} = -\log [\text{H}_3\text{O}^+] = -\log \left( C_a \frac{(\text{V}_a - \text{V}_{AE})}{V_t} \right) = -\log C_a - \log \frac{\text{V}_a - \text{V}_{AE}}{V_t}$$

# ORGANIC CHEMISTRY

## Organic Substances:

- They are substances containing mainly carbon (C) and other elements such as hydrogen (H) and oxygen (O).
- An organic sample of a known mass ( $m_A$ ) undergoes combustion to produce two gases:  $\text{CO}_2$  and  $\text{H}_2\text{O}$ .
- The mass of  $\text{CO}_2$  and the mass of  $\text{H}_2\text{O}$  are determined experimentally.
- To deduce  $\% \text{m}(\text{CO}_2)$  we use:
  - ★ potash (potassium hydroxide)
  - ★ Soda (sodium hydroxide)
- the change in mass  $\Delta m$  in the tube containing potash or soda corresponds to  $\% \text{m}(\text{CO}_2)$ .

- To deduce  $\% \text{m}(\text{H}_2\text{O})$  we use:

★ Sulfuric acid (dehydrating agent)

→ the change in mass  $\Delta m$  in the tube containing sulfuric acid corresponds to  $\% \text{m}(\text{H}_2\text{O})$ .

## Determination of $\% \text{m}_C$ , $\% \text{m}_H$ , $\% \text{m}_O$ :

### Determining $\% \text{m}_C$ :

↪ take a sample of the organic substance to make combustion.

$$n_C = n_{\text{CO}_2}$$

$$\frac{\% \text{m}_C}{\% \text{m}_C} = \frac{m_{\text{CO}_2}}{m_{\text{CO}_2}} \quad \text{experimentally determined}$$

$$\boxed{\% \text{m}_C = \frac{\% \text{m}_C \times \% \text{m}_{\text{CO}_2}}{\% \text{m}_{\text{CO}_2}} = \frac{12 \times \% \text{m}_{\text{CO}_2}}{44}}$$

$$\boxed{\% \text{m}_C = \frac{\% \text{m}_C}{m_{\text{sample}}} \times 100}$$

### Determining $\% \text{m}_H$ :

↪ take a sample of the organic substance to burn it.

$$n_H = 2n_{\text{H}_2\text{O}}$$

$$\frac{\% \text{m}_H}{\% \text{m}_H} = 2 \frac{\% \text{m}_{\text{H}_2\text{O}}}{\% \text{m}_{\text{H}_2\text{O}}}$$

$$\boxed{\% \text{m}_H = \frac{\% \text{m}_H \times \% \text{m}_{\text{H}_2\text{O}}}{\% \text{m}_{\text{H}_2\text{O}}} = \frac{2 \times \% \text{m}_{\text{H}_2\text{O}}}{18}}$$

$$\boxed{\% \text{m}_H = \frac{\% \text{m}_H}{m_{\text{sample}}} \times 100}$$

### Deducing $\% \text{m}_O$ :

↪ oxygen is present in a chemical compound if the sum of  $\% \text{m}_C$  and  $\% \text{m}_H < 80\%$ .

$$\boxed{\% \text{m}_O = 100 - (\% \text{m}_C + \% \text{m}_H)}$$

## Empirical and Molecular Formulas:

- Empirical formula isn't a real formula it is the simplest formula that shows the ratio of atoms in a compound.

↪ EF of alkenes:  $\text{CH}_2$  (ratio between C and H is 1:2)

- Molecular formula is a real formula is a real formula that shows the exact number of atoms in a compound.

↪ MF of alkenes:  $\text{C}_2\text{H}_4$ ,  $\text{C}_3\text{H}_6$ ...

## Condensed Structural Formula:

- It shows the arrangement of carbon atoms and specifically the type of bonds between carbon atoms in the C-chain and between C-atoms and functional groups in a molecule but not between carbon and hydrogen.

↪  $\text{CH}_3 = \text{CH}_2$ ,  $\text{CH}_3 - \text{O} - \text{CH}_2 - \text{CH}_3$ ,  $\text{CH}_3 - \text{CH}_2 - \text{OH}$ ...

## Determination of Empirical Formula:

- ↪ Starting from  $\% \text{m}$ :

| $\% \text{m}$  | C                                | H                               | O                                |
|--|----------------------------------|---------------------------------|----------------------------------|
| M element in 100g  | $\% \text{m}_C$                  | $\% \text{m}_H$                 | $\% \text{m}_O$                  |
| $n_{\text{atom}} = \frac{\% \text{m}_C}{12}$                           | $n_C = \frac{\% \text{m}_C}{12}$ | $n_H = \frac{\% \text{m}_H}{1}$ | $n_O = \frac{\% \text{m}_O}{16}$ |
| $\text{mole ratio} = \frac{n_{\text{atom}}}{\text{smallest whole no}}$ |                                  |                                 |                                  |

## Determination of Molecular Formula:

↳ Starting from empirical formula :

- Empirical formula:  $C_a H_b O_c$

- Molecular formula:  $(C_a H_b O_c)_n$

$$n = \frac{M_{\text{molecular formula (given)}}}{M_{\text{empirical formula}} (12a+b+16c)}$$

## Using Law of Definite Proportions:

∴ Element is fixed in a given mass of the organic sample.

- For compound  $C_x H_y O_z$

↳ take  $n = 1 \text{ mol} = \frac{Mcpd}{Mcpd}$  So  $Mcpd = Mcpd = 12x + y + 16z$

$$\star \% \text{ C} = \frac{Mc}{Mcpd} \times 100 = \frac{12x}{Mcpd} \times 100$$

$$\star \% \text{ H} = \frac{M_H}{Mcpd} \times 100 = \frac{y}{Mcpd} \times 100$$

$$\star \% \text{ O} = \frac{Mo}{Mcpd} \times 100 = \frac{16z}{Mcpd} \times 100$$

$$\frac{Mcpd}{100} = \frac{12x}{\% \text{ C}} = \frac{y}{\% \text{ H}} = \frac{16z}{\% \text{ O}}$$

|        |        |
|--------|--------|
| 1-meth | 6-hex  |
| 2-eth  | 7-hept |
| 3-prop | 8-oct  |
| 4-but  | 9-non  |
| 5-pent | 10-dec |

number-chain  
number, number-chain  
number-chain-number-chain

. Alkyl Group (R):  
- It is a functional group.  
- General formula:  $C_n H_{2n+1}$ .

## The Rules for Naming Organic Compounds:

1. Find the longest carbon chain holding the functional group (not alkyl).
2. Identify the functional group.
3. Number the carbon atoms in the longest chain so that the functional group has the lowest possible number.
4. Name the longest chain.
5. Identify the branches, their position and number and name them.

## Isomers:

- Isomers are compounds that share the same molecular formula but different structural formulas.

### Types of isomers:

\* skeletal isomers : differ in the main chain skeletal.

\* positional isomers : differ in the position of the functional group.

\* functional isomers : differ in the type of functional group.

### Alcohol (ROH):

- Alcohol is a type of organic compound containing hydroxyl group.
- Alcohol is a Saturated Open-chain (Non-Cyclic) Monoalcohol.

C-chain has Simple covalent bond containing one hydroxyl group

- General formula:  $C_nH_{2n+2}O$  or  $C_nH_{2n+1}-OH$  ( $n \geq 1$ )

- Systematic name of alcohol: Alkanol

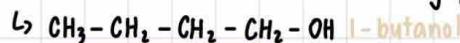
### Hydroxyl Group:

- It is a functional group.
- General formula:  $-OH$ .

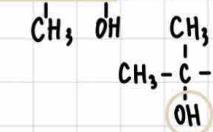
| A        | n | Molecular Formula | Possible Condensed Structural Formula   | Systematic Name   |
|----------|---|-------------------|---|---|
| L        | 1 | $C_1H_4O$         | $CH_3-OH$   | methanol  |
| O        | 2 | $C_2H_6O$         | $CH_3-CH_2-OH$  | ethanol   |
| O        | 3 | $C_3H_8O$         | $CH_3-CH_2-CH_2-OH$<br>$CH_3-CH(OH)-CH_3$   | 1-propanol<br>2-propanol  |
|          | 4 | $C_4H_{10}O$      | $CH_3-CH_2-CH_2-CH_2-OH$<br>$CH_3-CH_2-CH(OH)-CH_3$<br><br>$CH_3-CH(OH)-CH_2-CH_3$<br>$CH_3$<br>$CH_3-C(OH)-CH_3$<br>$CH_3$   | 1-butanol<br>2-butanol<br><br>2-methyl-1-propanol<br><br>2-methyl-2-propanol  |
|          | 5 | $C_5H_{12}O$      | $CH_3-CH_2-CH_2-CH_2-CH_2-OH$<br>$CH_3-CH_2-CH_2-CH(OH)-CH_3$<br><br>$CH_3-CH_2-CH(OH)-CH_2-CH_3$<br>$CH_3-CH_2-CH(OH)-CH_2-CH_3$<br>$CH_3$<br>$CH_3-C(OH)-CH_2-CH_3$<br>$CH_3$<br><br>$CH_3-CH(OH)-CH_2-CH_2-CH_3$<br>$CH_3$<br>$CH_3-C(OH)-CH_2-CH_2-CH_3$<br>$CH_3$<br><br>$CH_3-CH(OH)-CH_2-CH_2-CH_2-CH_3$<br>$CH_3$<br>$CH_3-C(OH)-CH_2-CH_2-CH_2-CH_3$<br>$CH_3$ | 1-pentanol<br><br>2-pentanol<br>3-pentanol<br><br>2-methyl-1-butanol<br><br>2-methyl-2-butanol<br><br>3-methyl-1-butanol<br>3-methyl-2-butanol<br><br>2,2-dimethyl-1-propanol |
| examples | 7 | $C_7H_{16}O$      | $CH_3-C(CH_3)_2-CH(OH)-CH_2-CH_3$<br><br>$CH_3-CH_2-CH(OH)-CH_2-CH_2-CH_2-CH_2-CH_3$  | 2,2-dimethyl-3-pentanol<br><br>2-ethyl-1-pentanol   |

## Isomerism in Alcohols:

- Alcohols admit skeletal isomers starting from  $n \geq 4$ .



- Alcohols admit positional isomers starting from  $n \geq 3$ .



- Alcohols admit functional isomers with ether group starting from  $n \geq 2$ .



## Classes of Alcohol:

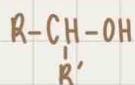
- Primary alcohol:

\* the carbon bearing the hydroxyl group is bonded to two hydrogen atoms and one alkyl group.



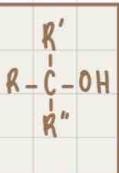
- Secondary alcohol:

\* the carbon bearing the hydroxyl group is bonded to one hydrogen atom and two alkyl groups.



- Tertiary alcohol:

\* the carbon bearing the hydroxyl group is bonded to three alkyl groups and no hydrogen atoms.



## Physical Properties of Alcohol:

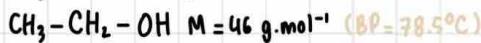
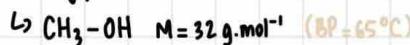
- Alcohols have high boiling points compared to other organic compounds and very soluble in water.

- A hydrogen bond forms intermolecular bonding between the second row elements (Hydrogen, Oxygen...). So, the high boiling points of alcohols is due to the presence of intermolecular force between alcohol molecules similar to that in water molecules, this force is known as hydrogen bonding.

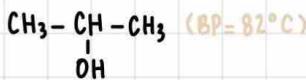
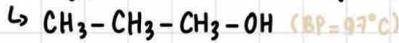
- The structure of alcohol and this force makes alcohols have close properties as water.

$\hookrightarrow$  Similarity in: boiling points, solubility and presence of hydrogen bonding.

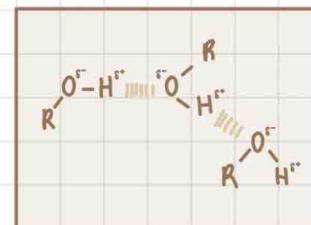
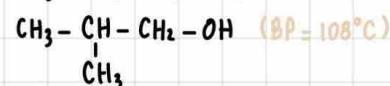
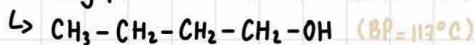
- Boiling point increases as molar mass increases.



- Boiling point decreases as the hydroxyl group moves to the center.



- Boiling point decreases as branches increases.



### Aldehyde ( $\text{RCHO}$ ) and Ketone ( $\text{RCOR}$ ):

- Aldehyde is a type of organic compound containing carbonyl group.
- Aldehyde is a Saturated Open-chain (Non-Cyclic) Molecule.
- General formula of aldehyde:  $\text{C}_n\text{H}_{2n}\text{O}$  ( $n \geq 1$ )
- Systematic name of aldehyde: Alkanal
- Ketone is a type of organic Compound containing carbonyl group.
- Ketone is a Saturated Open-chain (Non-Cyclic) Molecule.
- General formula of ketone:  $\text{C}_n\text{H}_{2n}\text{O}$  ( $n > 3$ )
- Systematic name of ketone: Alkanone

### Carbonyl Group:

- It is a functional group.
- General formula:  $-\text{C}=\text{O}-$

| A<br>L<br>E<br>Y<br>D<br>E<br>3.<br>K<br>E<br>T<br>O<br>N<br>E | n<br>1<br>2<br>3<br><br>4<br><br>5 | Molecular Formula<br>$\text{CH}_4\text{O}$<br>$\text{C}_2\text{H}_4\text{O}$<br>$\text{C}_3\text{H}_6\text{O}$<br><br>$\text{C}_4\text{H}_8\text{O}$<br><br>$\text{C}_5\text{H}_{10}\text{O}$ | Possible Condensed Structural Formula<br>$\text{H}-\overset{\text{O}}{\underset{\text{H}}{\text{C}}}-\text{H}$<br>$\text{CH}_3-\overset{\text{O}}{\underset{\text{H}}{\text{C}}}-\text{H}$<br>$\begin{array}{c} \text{CH}_3-\text{CH}_2-\overset{\text{O}}{\underset{\text{CH}_3}{\text{C}}}-\text{H} \\ \text{CH}_3-\overset{\text{O}}{\underset{\text{CH}_3}{\text{C}}}-\text{CH}_3 \end{array}$<br>$\begin{array}{c} \text{CH}_3-\text{CH}_2-\text{CH}_2-\overset{\text{O}}{\underset{\text{CH}_3}{\text{C}}}-\text{H} \\ \text{CH}_3-\overset{\text{O}}{\underset{\text{CH}_3}{\text{C}}}-\text{CH}_2-\text{CH}_3 \\ \text{CH}_3-\overset{\text{O}}{\underset{\text{CH}_3}{\text{C}}}-\text{H} \end{array}$<br>$\begin{array}{c} \text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}_2-\overset{\text{O}}{\underset{\text{CH}_3}{\text{C}}}-\text{H} \\ \text{CH}_3-\text{CH}_2-\overset{\text{O}}{\underset{\text{CH}_3}{\text{C}}}-\text{H} \\ \text{CH}_3 \\ \text{CH}_3-\text{CH}-\overset{\text{O}}{\underset{\text{CH}_3}{\text{C}}}-\text{H} \\ \text{CH}_3 \\ \text{CH}_3-\overset{\text{O}}{\underset{\text{CH}_3}{\text{C}}}-\text{C}-\text{H} \\ \text{CH}_3 \\ \text{CH}_3-\text{CH}_2-\overset{\text{O}}{\underset{\text{CH}_3}{\text{C}}}-\text{CH}_3 \\ \text{CH}_3-\text{CH}_2-\overset{\text{O}}{\underset{\text{CH}_3}{\text{C}}}-\text{CH}_2-\text{CH}_3 \\ \text{CH}_3-\overset{\text{O}}{\underset{\text{CH}_3}{\text{C}}}-\text{CH}-\overset{\text{O}}{\underset{\text{CH}_3}{\text{C}}}-\text{CH}_3 \end{array}$ | Systematic Name<br>methanal<br>ethanal<br>propanal<br>propanone<br>butanal<br>butanone<br>2-methylpropanal<br>pentanal<br>2-methylbutanal<br>3-methylbutanal<br>2,2-dimethylpropanal<br>2-pentanone<br>3-pentanone<br>3-methylbutanone |
|--|------------------------------------|---|---|--|
|  |                                    |   |   |  |
|  |                                    |   |   |  |
|  |                                    |   |   |  |
|  |                                    |   |   |  |
|  |                                    |   |   |  |

### Isomerism in Aldehydes and Ketones:

- Aldehydes admit skeletal isomers starting from  $n \geq 4$ .



- Aldehydes don't admit positional isomers (no numbering in aldehydes).

- Ketones admit skeletal isomers starting from  $n \geq 5$ .



- Ketones admit positional isomers starting from  $n \geq 5$ .



- Aldehydes admit functional isomers with ketones from  $n \geq 3$ .



. Aldehydes undergo mild oxidation due to the presence of a hydrogen atom bonded to the carbonyl group.

. Ketones don't undergo mild oxidation.

### Identification Test of Aldehydes and Ketones:

- Identify the presence of carbonyl group which is shared between aldehydes and ketones (common test).

- Identify the presence of either an aldehyde or a ketone.

| Identification Chemical Test   | Experimental Result                         | Organic Compound Identified                         |
|--|---|---|
| Saturated solution of sodium bisulfite ( $\text{NaHSO}_3$ )<br>$\hookrightarrow$ colorless                 | White Precipitate                           | Contains carbonyl group (either aldehyde or ketone) |
| 2,4DNPH<br>$\hookrightarrow$ yellow orange in color  | Yellow Orange Precipitate                   | Contains carbonyl group (either aldehyde or ketone) |
| Fehling solution ( $\text{Cu}^{2+}/\text{Cu}^+$ ) requires heat<br>$\hookrightarrow$ blue in color         | Brick Red Precipitate                       | Aldehyde  |
|  | Remains Blue                                | Ketone  |
| Tollen's reagent ( $\text{Ag}(\text{NH}_3)_2^+$<br>$\hookrightarrow$ colorless                             | Silver Mirrors on the Wall of the Test Tube | Aldehyde  |
|  | Remains Colorless                           | Ketone  |
| Shiff's reagent ( $\text{C}_{20}\text{H}_{20}\text{N}_3 \cdot \text{HCl}$ )<br>$\hookrightarrow$ colorless | Pink Solution                               | Aldehyde  |
|  | Remains Colorless                           | Ketone  |
| Potassium permanganate ( $\text{K}^+ + \text{MnO}_4^-$ )<br>$\hookrightarrow$ purple in color              | Decolorization                              | Aldehyde  |
|  | No Change in Color                          | Ketone  |
| Potassium dichromate ( $2\text{K}^+ + \text{Cr}_2\text{O}_7^{2-}$ )<br>$\hookrightarrow$ orange in color   | Decolorization                              | Aldehyde  |
|  | No Change in Color                          | Ketone  |

### Carboxylic Acid ( $\text{RCOOH}$ ) and Ester ( $\text{RCOOR}'$ ):

- Carboxylic acid is a type of organic compound containing carboxyl group.
- Carboxylic acid is a Saturated Open-chain (Non-cyclic) Molecule.
- General formula of carboxylic acid:  $\text{C}_n\text{H}_{2n}\text{O}_2$  ( $n \geq 1$ )
- Systematic name: Alkanoic Acid
- Ester is a type of organic compound containing Carboxyl group.
- Ester is a Saturated Open-chain (Non-cyclic) Molecule.
- General formula of ester:  $\text{C}_n\text{H}_{2n}\text{O}_2$  ( $n \geq 2$ )
- Systematic name of ester: Alkyl Alcanoate

### Carboxyl Group:

- It is a functional group.
- General formula:  $-\text{C}(=\text{O})\text{OH}$

| C<br>A<br>R<br><br>X<br>Y<br><br>L<br>I<br>C<br>A | n | Molecular Formula                   | Possible Condensed Structural Formula  | Systematic Name   |
|---|---|-------------------------------------|--|---|
| A<br>B<br>O                                       | 1 | $\text{CH}_3\text{O}_2$             | $\text{H}-\text{C}(=\text{O})\text{OH}$  | methanoic acid  |
| X<br>Y  | 2 | $\text{C}_2\text{H}_4\text{O}_2$    | $\text{CH}_3-\text{C}(=\text{O})\text{OH}$   | ethanoic acid   |
| L<br>I<br>C<br>A                                  | 3 | $\text{C}_3\text{H}_6\text{O}_2$    | $\text{CH}_3-\text{CH}_2-\text{C}(=\text{O})\text{OH}$   | propanoic acid  |
| C<br>I<br>D                                       | 4 | $\text{C}_4\text{H}_8\text{O}_2$    | $\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{C}(=\text{O})\text{OH}$<br>$\text{CH}_3-\text{CH}-\text{C}(=\text{O})\text{OH}$<br> <br>$\text{CH}_3$   | butanoic acid<br>2-methyl propanoic acid  |
| E<br>S<br>T                                       | 5 | $\text{C}_5\text{H}_{10}\text{O}_2$ | $\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{C}(=\text{O})\text{OH}$<br>$\text{CH}_3-\text{CH}_2-\text{CH}-\text{C}(=\text{O})\text{OH}$<br> <br>$\text{CH}_3$<br>$\text{CH}_3-\text{CH}_2-\text{CH}-\text{C}(=\text{O})\text{OH}$<br> <br>$\text{CH}_3$<br>$\text{CH}_3-\text{C}(=\text{O})-\text{C}-\text{OH}$<br> <br>$\text{CH}_3$ | pentanoic acid<br>2-methylbutanoic acid<br>3-methylbutanoic acid<br>2,2-dimethyl propanoic acid |
| E<br>R  | 2 | $\text{C}_2\text{H}_4\text{O}_2$    | $\text{H}-\text{C}(=\text{O})\text{O}-\text{CH}_3$   | methyl methanoate   |
| E   | 3 | $\text{C}_3\text{H}_6\text{O}_2$    | $\text{CH}_3-\text{C}(=\text{O})\text{O}-\text{CH}_3$<br>$\text{H}-\text{C}(=\text{O})\text{O}-\text{CH}_2-\text{CH}_3$  | methyl ethanoate<br>ethyl methanoate  |
|   | 4 | $\text{C}_4\text{H}_8\text{O}_2$    | $\text{CH}_3-\text{CH}_2-\text{C}(=\text{O})\text{O}-\text{CH}_3$<br>$\text{CH}_3-\text{C}(=\text{O})\text{O}-\text{CH}_2-\text{CH}_3$<br>$\text{H}-\text{C}(=\text{O})\text{O}-\text{CH}_2-\text{CH}_2-\text{CH}_3$<br>$\text{H}-\text{C}(=\text{O})-\text{O}-\text{CH}-\text{CH}_3$<br> <br>$\text{CH}_3$                                      | methyl propanoate<br>ethyl ethanoate<br>propyl methanoate<br>1-methylethyl methanoate           |
| G   | 6 | $\text{C}_6\text{H}_{12}\text{O}_2$ | $\text{CH}_3-\text{C}(=\text{O})\text{O}-\text{CH}_2-\text{CH}-\text{CH}_3$<br> <br>$\text{CH}_3$  | 2-methyl propyl ethanoate   |
|   | 7 | $\text{C}_7\text{H}_{14}\text{O}_2$ | $\text{CH}_3-\text{CH}_2-\text{C}(=\text{O})\text{O}-\text{C}-\text{CH}_3$<br> <br>$\text{CH}_3$<br>$\text{CH}_3-\text{CH}-\text{C}(=\text{O})\text{O}-\text{CH}-\text{CH}_3$<br> <br>$\text{CH}_3$<br> <br>$\text{CH}_3$  | 2,2-dimethyl propyl propanoate<br>2-methylethyl 2-methylpropanoate                              |

## Isomerism in Carboxylic Acid and Ester:

- Carboxylic acids admit skeletal isomers starting from  $n \geq 4$ .



- Carboxylic acids don't admit positional isomers (no numbering in carboxylic acids).

- Esters admit skeletal isomers starting from  $n \geq 4$ .



- Esters don't admit positional isomers (no numbering in esters).

- Carboxylic acids admit functional isomers with esters starting from  $n \geq 2$ .

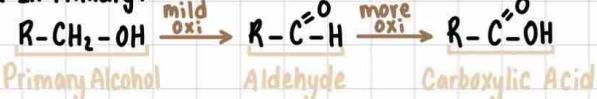


## Chemical Reactions of Alcohols:

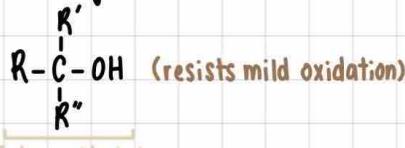
- They are reactions that distinguish between primary, secondary and tertiary alcohols.

- Mild oxidation takes place on the carbon atom holding the hydroxyl group without breaking the carbon chain.

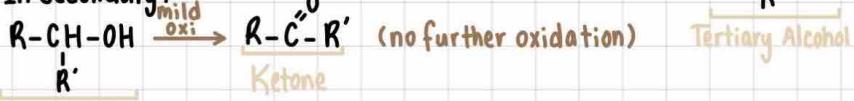
\* In Primary:



\* In Tertiary:



\* In Secondary:



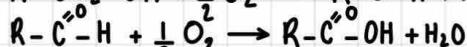
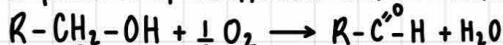
## Secondary Alcohol

### Mild Oxidation:

- Catalytic Oxidation: in the presence of  $\text{O}_2$  and catalyst Cu.

\* In Primary:

. In presence of insufficient (limited) amount of  $\text{O}_2$ :



→ The 2 reactions take place simultaneously.

The mixture obtained contains alcohol (remained), aldehyde (formed) and carboxylic acid (formed) in different percentages.

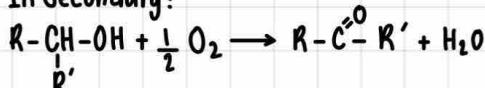
. In presence of sufficient (excess) amount of  $\text{O}_2$ :



→ The aldehyde is transformed to carboxylic acid due to the excess of  $\text{O}_2$ .

The mixture obtained contains alcohol (if remained) and carboxylic acid (formed).

\* In Secondary:



→ The alcohol is transformed to ketone only in the presence of insufficient or sufficient amount of  $\text{O}_2$ .

The mixture obtained contains alcohol (if remained) and ketone (formed).

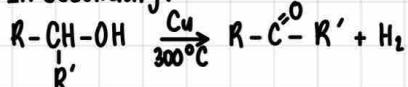
- Catalytic Dehydrogenation: removing hydrogen in absence of  $\text{O}_2$  and in the presence of catalyst Cu at  $T = 300^\circ\text{C}$ .

\* In Primary:



→ Can't undergo further dehydrogenation to produce carboxylic acid, it can be produced by different type of mild oxidation.

\* In Secondary:

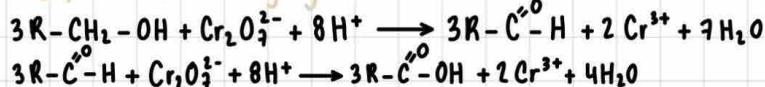


## - Using Strong Oxidizing Agents ( $\text{Cr}_2\text{O}_7^{2-}$ & $\text{MnO}_4^-$ ):

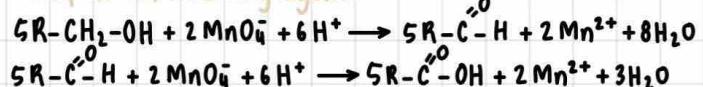
### \* In Primary:

- . In presence of insufficient (limited) amount of oxidizing agent:

$\text{Cr}_2\text{O}_7^{2-}$  as an oxidizing agent:



$\text{MnO}_4^-$  as an oxidizing agent:



- . In presence of sufficient (excess) amount of oxidizing agent:

$\text{Cr}_2\text{O}_7^{2-}$  as an oxidizing agent:



$\text{MnO}_4^-$  as an oxidizing agent:

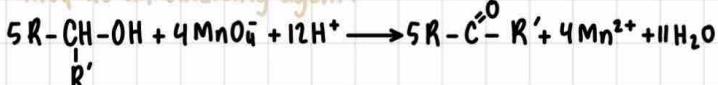


### \* In Secondary:

$\text{Cr}_2\text{O}_7^{2-}$  as an oxidizing agent:

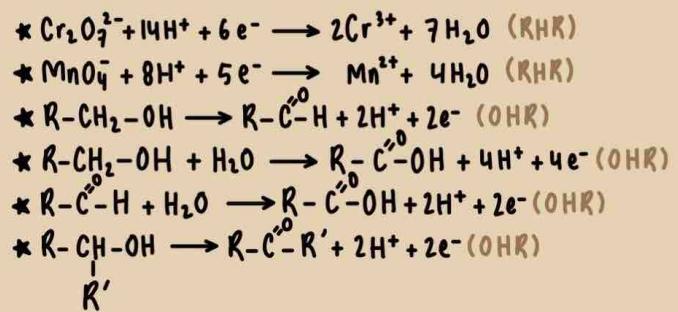


$\text{MnO}_4^-$  as an oxidizing agent:



RHR: sum of e<sup>-</sup> in reactants - sum of e<sup>-</sup> in products = e<sup>-</sup> in reactants

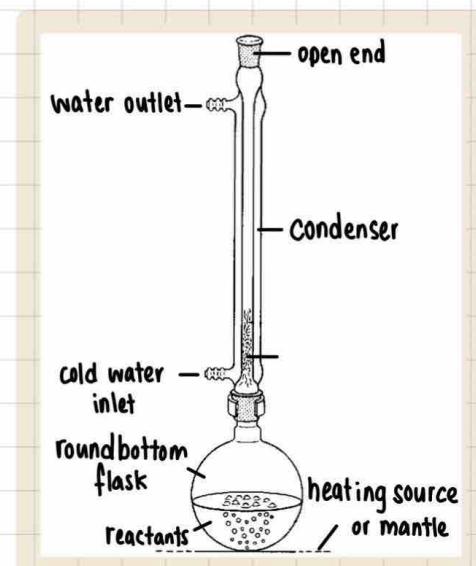
OHR: sum of e<sup>-</sup> in products - sum of e<sup>-</sup> in reactants = e<sup>-</sup> in products





### Reflux Heating:

- Esterification requires heat since it is a slow reaction, but heating can't take place in open flask otherwise the contents used (alcohol carboxylic acid reacted and ester formed) vaporize.
- Esterification takes place by heating under reflux, since heat is a kinetic factor. The vapors condense back to the reaction mixture so that the reactants remain in contact with each other with no loss to produce efficient yield.



- \* Cold water goes to the bottom of the condenser.
- \* There must not be a stopper on the opening of the condenser.
- \* Cold water cools the vapor produced back into liquid form.