الحقيبة التعليمية

مادة الكيمياء التحليلية

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كيمياء حياتية سريرية

الفئة المستهدفة طلبة المرحلة الاولى لقسم تقنيات الصيدلة

الاهداف العامة للحقيبة التعليمية

1- تعريف الطالب بالمفاهيم الاساسية مثل التحليل الكمي والنوعي.

2 - التمييز بين انواع المحاليل ,التفرقة بين التحليل الوزني, الحجمي , الطيفي والكهروكيمياوي.

3 - اكتساب المهارات العملية.

4 - تفسير النتائج وتحليل البيانات.

5- التعرف على طرق التعبير عن التراكيز مثل المولارية والنورمالية والجزء بالمليون.

1st week

Analytical chemistry

What is analytical chemistry?

Analytical chemistry is the branch of chemistry that deals with separation, identification, and determination of components in a sample.

Classification of analytical chemistry:

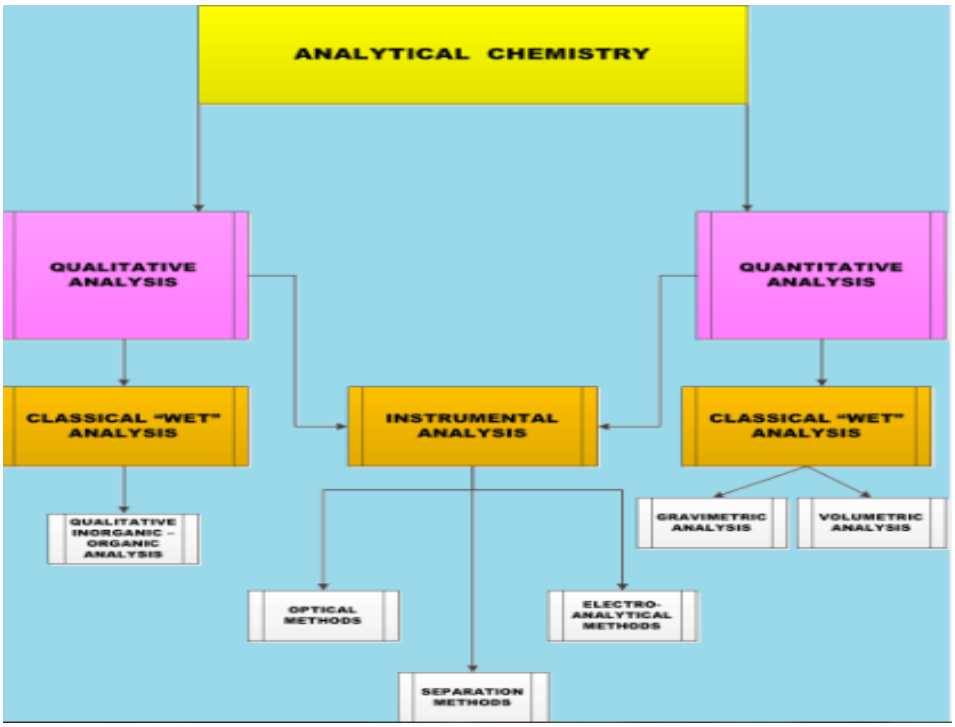
Analytical chemistry can be classified into two general analysis:

1- Qualitative analysis: an analysis in which we determine the identity of the constituents species in a sample.

2- Quantitative analysis: an analysis in which we determine how much of a constituents species are present in a sample. This analysis can be divided into three types:

a) Volumetric analysis: an analysis used to determine the concentration of an unknown substance by measuring the volume of a solution of known concentration that reacts with it.
b) Gravimetric analysis: this method determine the mass of analyte.
c) Instrumental analysis: this method uses instrument to measure physical and chemical properties of substance to determine their composition, structure, or concentration. This method consist of:
   i)Spectroscopic methods: involve studying the interaction between electromagnetic radiation and matter to analyze a sample's composition and structure. These methods rely on the principle that atoms and molecules absorb, emit, or scatter light in unique ways, creating characteristic spectra that can be used for identification and quantification.
   ii) Electro analytical methods: these methods involve measuring electrical properties like current, potential, or charge and relating them to the chemical composition and concentration of a substance (analyte).

iii)Separation methods: these methods involved the isolation of one component or more from mixture of component before further analyses, the common separation methods are filtration, distillation, chromatography and extraction.



2nd week

Solution

Definitions:

Solutions :are homogeneous mixture of two or more substances (solute/s)

Dispersed throughout another substance (solvent)

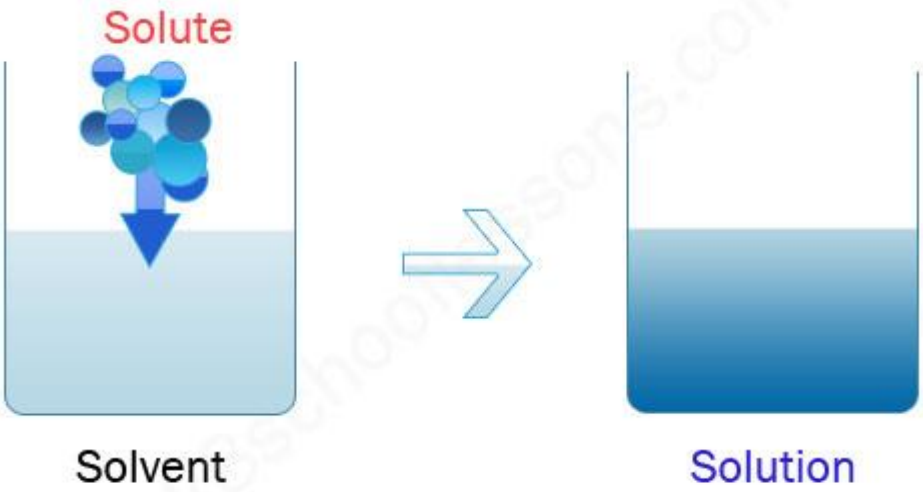
Solute : is the minor component of the solution (the part that gets dissolved)

Solvent: is the major component of a solution(the part that does the dissolving)

The solute does not have to be in the same physical state as the solvent, but the physical state of the solvent usually determines the state of solution.

As long as the solute and solvent combine to give a homogenous solution,

The solute is said to be soluble in the solvent. For example if we add a small amount of ethanol to water ;then the ethanol is the solute and the water is the solvent, if we add a smaller amount of water to a large amount of ethanol then the water could be the solute.



Types of solutions:

1-solution of solid in solid: Metal alloys are the solutions of solids in solids. For example brass is a solution of zinc in copper. Brass is prepared by mixing molting zinc with molten copper and coating their mixture.

2-solution of solid in liquid: this is the most common types of solution, sugar solution and salt solution are the solution of solids in liquids

a solution of iodine in alcohol called tincture of iodine "is also a solid in a liquid type of solution this is because it contains solid (iodine)dissolved in a liquid (alcohol)solution.

3-solution of liquid in liquid: vinegar is a solution of acetic acid (ethanoic acid)in water.

4-solution of gas in liquid: soda water is a solution of carbon dioxide gas in water.

5-solution of gas in gas: air is a solution of gases like oxygen ,argon, carbon dioxide and water vapor, etc., in nitrogen gas nitrogen is the solvent in air and all the other gases are solutes.

What is aqueous solutions?

They are solutions in which the solvent is water for example :vinegar , soda water.

Special properties of solutions

Viscosity

- Viscosity is a measure of a fluids resistance to flow
  The resistance caused by the frictional force that exists between liquid Layers.
- The viscosity of liquids decreased rapidly with an increase in temperature and the viscosity of gases increase with an increase in temperature thus upon heating liquids flow more easily;wearese gases
  Flow more slowly, also viscosity does not change as the amount of
  Matter changes, therefor it is an intensive property.

Diffusion

Is the process of movement of molecules under a concentration gradient, it is an important process occurring in all living beings, diffusion helps in the movement of substance in and out of the cells, the molecules moves from region of higher concentration to a region of lower concentration until the concentration become equal through. there are two main type of diffusion:

1-simple diffusion :a process in which the substance move through a semipermeable membrane or in a solution without any help from transport protein. for example, bacteria deliver small nutrients, water and oxygen into the cytoplasm through simple diffusion.

2- Facilitated diffusion: is a passive movement of molecules across the cell membrane from region of higher concentration to region of lower concentration by means a carrier molecules.

Osmosis

Osmosis is the movement of solvent molecules from the region of lower concentration to the region of high concentration through a semipermeable membrane .since water is solvent in every living being so osmosis define as

The diffusion of water across the selectively permeable membrane. for example plants take water and minerals from roots with help of osmosis.

Points must be note in osmosis

- The diffusion substance is water.
- The diffusion takes place through a semipermeable membrane.
- The diffusion will continue until the two solutions have the same concentration.
- Both osmosis and diffusion can occur at the same time, but not at the same rate.in general osmosis occurs more rapidly than diffusion.

Strength of solutions

1-Dilute and concentrated

- Dilute merely means that the solution contains a **small amount** of solute in relation to solvent.

- concentrated merely means that the solution contains a **large amount** of solute in relation to solvent.
  Note
- both dilute and concentrated terms don't use generally for medical application because they are relative terms.
- What is the relative terms means?
  A dilute sugar solution may contain 5gm of sugar per 100 ml of solution, whereas 5 gm (the same amount)of boric acid per 100 ml of solution will produced concentrated boric acid solution. That is ,the terms diluted and concentrated are relative terms usually having no quantitative meaning.

2- Saturated

Saturated solution defined as one that contains all the solute that is can hold under the given condition.

3-Unsaturated

An un saturated solution defined as one that contain less of solute than it could hold under normal condition.

4-Supersaturated

Supersaturated solution defined as one that contains excess of solute than it could hold under normal condition.

- In blood stream ,if the concentration of uric acid exceeds its solubility, the excess undissolved uric acid crystallizes. When these crystals accumulate in the great toe or in the earlobes, the condition called gout. If the uric acid crystallizes in the gallbladder, gallstones can be formed. Kidney stones may also be caused by crystallized uric acid.

Tonicity

Tonicity is the concentration of a solution as compared to another solution.

Concentration describes the amount of solutes dissolved by a solution.

Isotonic solution

- Isotonic means two solutions that have the same solute concentration.
- the normal salt concentration of the blood is approximately equal to 0.9 percent sodium chloride solution . the common name for 0.9 percent sodium chloride solution is physiologic saline solution. The
  Blood and physiologic saline solution are isotonic (they have the same salt concentration)
- A 5.5 percent glucose solution is also approximately isotonic with body fluids.
- Physiologic saline and 5.5 percent glucose solutions can be given intravenously to a patient without any effect on the red blood cells.

Hypotonic solution

- A hypotonic solution is one that contains a lower solute concentration than that of another solution.
- Distilled and tap water are hypotonic when compared with blood.

What happen when an RBC is placed in water (a hypotonic solution)?

The salt concentration in the RBC is higher than that of water. Therefore,

Osmosis will take place with the water diffusion into the RBC (from dilute to concentrated solution),the RBC thus enlarges until it bursts. this process of the bursting of RBC because of the hypotonic solution is called hemolysis. Thus a hypotonic solution is not usually used for transfusions.

Hypertonic solution

- a hypertonic solution is one that contains a higher solute concentration than that of another solution
- a 5% NaCl solution or a 10% glucose solution is an example of a hypertonic solution when compared with blood.

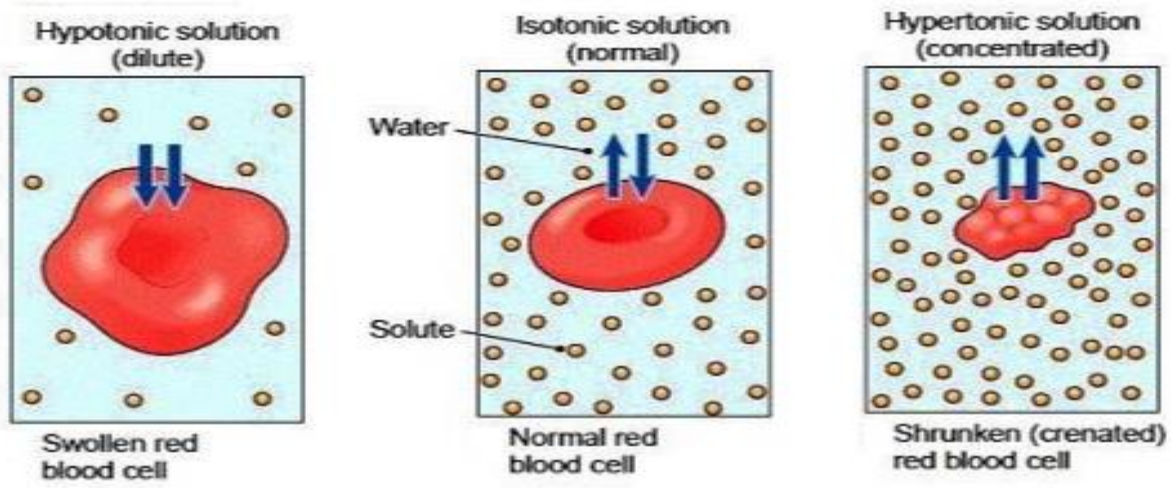
What happen when an RBC is placed in a hypertonic solution?

The salt concentration in the RBC is less than that in hypertonic solution.

Therefore osmosis will take place with the water diffusion out of the RBC (from dilute to concentrated).The RBC thus shrinks. This shrinking of RBC in a hypertonic solution is called crenation or plasmolysis.

Important note:

Usually only isotonic solutions may safety introduced into the blood stream. Hypotonic solutions may cause hemolysis and hypertonic may cause crenation.



Saline cathartics (also called osmotic laxative) act as hypertonic solution

Cathartics such as magnesium sulphate,milk of magnesia and magnesium citrate are absorbed from the large intestine slowly and incompletely. When

These substances are ingested, a hypertonic solution is produced in the large intestine and water will diffuse from the tissue spaces into the intestinal tract until the solution is gain isotonic with the body fluids. This additional water in the large intestine produces a watery stool that is easily evacuated.

3rd week

Reliability

Reliability in analytical chemistry refers to the consistency, accuracy, and reproducibility of analytical results. It ensures that the measurements and data obtained from an analytical method are trustworthy and can be repeated with the same outcome under the same conditions.

Accuracy:

The closeness of the measured value to the true or accepted value.

Precision (Reproducibility):

The closeness of repeated measurements to each other. High precision means little variation between results.

Specificity and Selectivity:

The ability of a method to measure the desired substance without interference from other components.

Sensitivity:

The ability of a method to detect small amounts or low concentrations of a substance.

Robustness:

The ability of a method to remain unaffected by small, deliberate changes in experimental conditions such as temperature or pH.

Repeatability and Reproducibility:

-Repeatability refers to consistent results under the same conditions, by the same operator and instrument.

-Reproducibility refers to consistent results under different conditions, such as different operators or instruments.

Importance of Reliability:

1-Ensures valid and trustworthy scientific conclusions.

2-Essential for quality control in industries like pharmaceuticals and food.

3-Necessary for regulatory compliance (e.g., FDA, ISO).

4-Builds confidence in research and decision-making based on analytical data.

Types of Errors in Analytical Chemistry

Understanding types of errors in analytical chemistry is essential for ensuring the accuracy and reliability of results. Errors are generally classified into three main types:

1. Systematic Errors:

These are predictable and consistent errors that affect the accuracy of results.

Causes:

-Improperly calibrated instruments.

-Incorrect analytical methods.

-Contaminated chemicals or environmental factors.

Characteristics:

-Can be detected and corrected.

-Cause all results to shift in the same direction (too high or too low).

Examples:

Using a pipette that delivers more than intended.

Reading a burette at the wrong angle.

2. Random Errors:

These are unpredictable fluctuations that affect the precision (repeatability) of results.

Causes:

-Environmental changes (air currents, temperature).

-Human limitations (difficulty in reading).

-Instrumental noise.

Characteristics:

-Cannot be completely eliminated.

-Vary in direction and magnitude.

-Can be minimized by repeating measurements.

Examples:

Slight variation in sample weighing each time.

Differences in color perception in visual analysis.

3. Gross Errors:

These are major mistakes due to human error or carelessness.

Causes:

-Misreading instruments.

-Recording data incorrectly.

-Using the wrong chemical or concentration.

Characteristics:

Lead to outlier or incorrect results.

Can be avoided with careful checking.

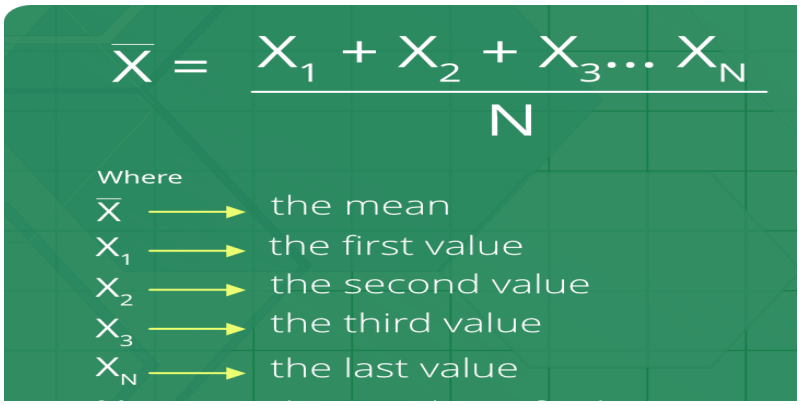
Examples:

Adding acid instead of base.

Writing 0.1 g instead of 1.0 g

The common Statistical analysis law

The average mean: is the sum of a collection of data divided by the number of it, the collection is often a set of results of an experiments or a set of survey.



The median: the median of a finite list of numbers can be found by arranging all observation from lowest value to highest value or vest versa and picking the middle one.

e.g. the median of {3,5,6,9,11} is 6

If there is an even numbers of observation, then there is no single middle value, the median is then usually defined to be the mean of the two middle values

e.g. the median of {3,5,7,9}is (5+7)/2 =6

The mode: is the value that appears most often (most repeated)in a set of data.

Standard deviation(SD):

Is a measure that is used to quantify the amount of variation or dispersion of a set of data values. A standard deviation close to(0) indicates that the data points tend to be very close to the mean, while a high standard deviation indicates that the data point are spread out over a wider range of values.

Population	Sample
$\sigma = \sqrt{\frac{\Sigma(x_i-\mu)^2}{n}}$	$S = \sqrt{\frac{\Sigma(x_i-\bar{x})^2}{n-1}}$
μ - Population Average xi - Individual Population Value n - Total Number of Population	x - Sample Average x_i - Individual Population Value n - Total Number of Sample

Relationship between the average mean and standard deviation

The average mean and the standard deviation of a set of data are usually written together, then a person can understand what the average number is and how widely other numbers in the group are spread out.

Coefficient of Variation (CV)

The coefficient of variation is a statistical measure that shows the ratio of the standard deviation to the mean, usually expressed as a percentage.

It is used to describe how much variability exists in relation to the average of the data set.

Formula:

CV = (Standard Deviation / Mean) × 100%

Purpose:

The CV is useful for comparing the precision of different sets of data, especially when the means are not the same.

-A lower CV indicates greater precision (less variation).

-It is commonly used in analytical chemistry, quality control, and biological experiments.

Example:

If the mean of your data is 10, and the standard deviation is 0.5:

CV = (0.5 / 10) × 100 = 5%

This means the variability in the data is 5% of the mean.

-In Analytical Chemistry:

CV helps to evaluate the repeatability of measurements.

-A CV of less than 5% is often considered acceptable for many laboratory methods, depending on the application.

Example(1) : a data set of{1,5,6,8,10,40,65,88} has its standard deviation is (30.75) and its average mean is (27.875) calculate the coefficient of variance.

30.78 / 27.875 × 100 = 110.4 %

Example (2): The following data is the fasting sugar levels of a diabetic patient (2.3, 2.5, 2.2, 2.6, 2.5) it has SD of 0.166 calculate the coefficient of variance of the data set, then discuss the precision of this method.

Answer:

Mean = (2.3 + 2.5 + 2.2 + 2.6 + 2.5) / 5

= 2.42

$$CV = \frac{SD}{mean} \times 100$$

$$CV = \frac{0.116}{2.42} \times 100$$

CV = 6.8 %

CV > 5% so this method is not presided or has low precision.

4th week

Concentration of solutions

Concentration = $\frac{amount\ of\ solute}{amount\ of\ solution}$

Expressing for concentrations as percent solutions

Percent solutions (the ratio parts of solute to one hundred part of solution)

These solution prepared by dissolving the solute in a small amount of solvent (water) and then diluted to the desired volume.

1- Mass percent(m/m %)

This is the mass of the solute divided by the mass of solution(mass of Solute plus mass of solvent) multiplied by 100

Example: determine the mass percent of a 100 gm salt solution which contains 20 gm Salt.

$\frac{20\ gm\ NaCl}{100\ gm\ solution} \times 100 = 20\%$ NaCl solution

2- Volume percent (v/v %)

v/v % = $\frac{volume\ of\ solute}{volume\ of\ solution} \times 100\ \%$

An example: 70 % v/v alcohol may be prepared by taking 70 ml of alcohol and adding sufficient water to obtain 100 ml of solution.

3- Mass to volume percent (m/v %)

m/v % = $\frac{mass\ of\ solute}{volume\ of\ solution} \times 100$

An example : 40 % (m/v) glucose solution means 40 gm of glucose dissolved in a small amount of solvent (water)and then diluted to 100 ml of a given solvent to give a 40 % solution.

What is the most common percent solution use in health laboratory?

Mass to volume percent (m/v or w/v)is the common use in health laboratory. It expresses the mass of solute in a given volume of solvent, usually water. A 10 percent glucose solution will contain 10 gm glucose per 100 ml of solution. A 0.9 percent saline solution will contain 0.9 gm sodium chloride per 100 ml of solution.

In clinical work involving dilute solutions, concentration are sometimes

Expressed in terms of **milligram percent (mg %)** which indicates the number of milligrams of solute per 100 ml of solution. Milligram percent referred to **as milligrams per deciliter (mg / dl).**

How to determine the molecular mass (M.m)?

Molecular mass is simply the sum of the atomic weights of its atoms.

How to determine the equivalent mass (eq.m) ?

- eq.m of acid

  It is equal to the M.m of that acid divided by the number of replaced hydrogen atoms

  Examples:

  Find the eq.m of the following acids (HCl, H_2SO_4, $H_2C_2O_4$, H_3PO_4)

  Solution:

  Eq.m of HCl = 36.5 / 1 = 36.5

  Eq.m of H_2SO_4 = 98 /2 = 49

  Eq.m of $H_2C_2O_4$ = 90 / 2 = 45

  Eq.m of H_3PO_4 = 98 / 3 = 33

- eq.m of base

  it is equal to the M.m of that base divided by the number of OH groups

  Example:

  Find the equivalent mass of the following bases (NaOH, $Ca(OH)_2$, $Al(OH)_3$)

Solution:

Eq.m of NaOH = 40/1 = 40

Eq.m of $Ca(OH)_2$ = 74/ 2 = 37

Eq.m of $Al(OH)_3$ = 78/3 = 26

- eq.m of salts

  it is equal to the M.m. of the salt divided by the number of metal atoms that are substitute with hydrogen in acid molecule, or the number of non-metal atoms that substituted with OH group.

  Example:

  Find the eq.m of the following salts (NaCl, $CaCl_2$, $Al(NO_3)_3$,CaC_2O_4)

  Solution

  Eq.m of NaCl = 58.5 /1 = 58.5

  Eq.m of $CaCl_2$ = 111 / 2 = 55.5

  Eq.m of $Al(NO_3)_3$ = 213 / 3 = 71

  Eq.m of CaC_2O_4 = 128 / 2 = 64

volumetric analysis

Definition of some terms:

Titration :also called titrimetry is the process of determining the concentration of a substance (titrand) in solution by adding to it a standard reagent of known concentration (titrant) in carefully measured amounts until a reaction is completed, as shown by color change.

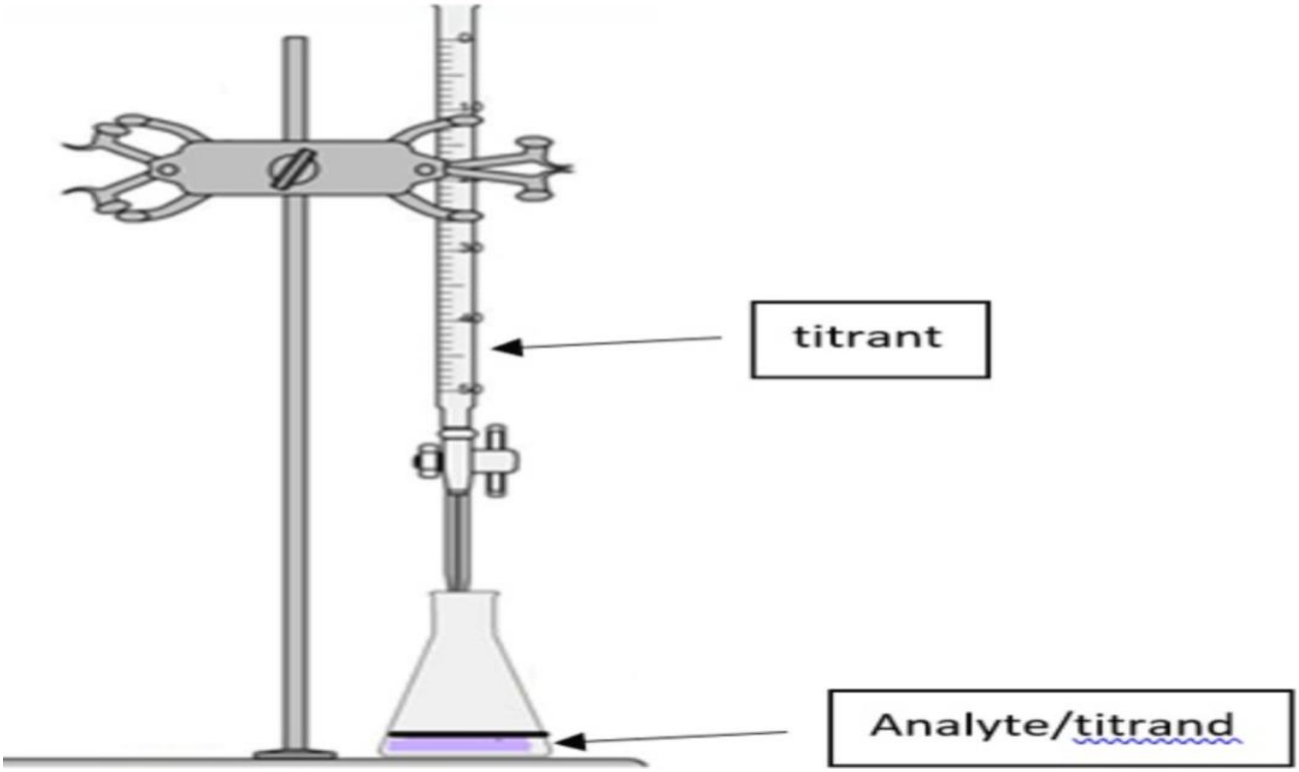
Equivalence point: is the theoretical completion of the titration reaction, it cannot be determined experimentally. It means the volume of added titrant at which the number of moles of titrant is equal to the number of moles of titrand.

End point is the point in a titration at which there is a sudden change in a physical property, such as indicator color. Used as a measure of the equivalence point.

Indicator: is a substance that changes color when the reaction is complete.

Titration error: is the difference between the observed end point and the true equivalence point in titration.

Analyte: An analyte is a specific substance or chemical constituents that is being analyzed or measured in a sample.



5th week

Expressing for concentration as molar and normal solutions

Molarity (molar concentration)

Molarity is the number of moles of solute in one liter of solution. It is routinely expressed in units of mole per liter (mol/L)or millimoles per

Milliliters (mmol/ml).

Molarity of a solution (M) = $\frac{no.\ of\ moles\ of\ solute}{no.of\ liters\ of\ solution}$

Moles = $\frac{m.(gm)}{Mm}$

M= $\frac{m.}{Mm \times v\ (liter)}$

Of course, we do not always work with solution volumes of exactly 1 L, so we convert the volume to ml units, the law of molarity become:

M= $\frac{m.}{Mm} \times \frac{1000}{v\ (ml)}$

m. = actual mass of solute in gram

Mm. = molecular mass of solute

V (ml) = volume of solution in ml

Examples:

Prepare 500 ml of 0.8M $CaCl_2$

M.m of $CaCl_2$ = 40 + (2 × 35.5) = 110

M = $\frac{m}{Mm} \times \frac{1000}{v\ (ml)}$

0.8 = $\frac{m}{110} \times \frac{1000}{500}$

m = 44 gm

weight out exactly 44 gm of calcium chloride ,then dissolve it in small amount water , finally complete the volume with distilled water up to 500 ml

Dilution of molar solution

In carrying out a dilution process, it is useful to remember that adding more

Solvent to a given amount of the stock solution changes (decrease) the concentration of the solution without changing the number of moles of solute resent in the solution.in other words,

Moles of solute before dilution = moles of solute after dilution

$M = \frac{n}{v\ (L)}$ so $n = M \times v\ (L)$, so $M_1 \times V_1 = M_2 \times V_2$

M_1,V_1 are the molarity and volume before dilution

M_2,V_2 are the molarity and volume after dilution

Normality (normal concentration)

Normality is expressed as the number of equivalent mass per liter

(eq/L)$Or\ milliequivalents\ per\ milliliter\ \ (meq/ml\ )$

$N = \frac{m}{eq.m} \times \frac{1000}{v\ (ml\ )}$

How to calculate the normality for liquid solutions?

Most acids which we use in the laboratory present as concentrated solutions

(not solid) and have known specific gravity and percentage.

Specific Gravity (Relative Density)

Definition:

Specific gravity is the ratio of the density of a substance to the density of water at a specific temperature, usually 4°C (where water has a density of 1.000 g/cm³).

-Specific gravity has no units.

$N = \frac{sp.gr \times \% \times 1000}{eq.m}$

sp.gr = specific gravity

% = percentage

Note : to calculate the molarity of liquid solutions we used the following law

$$M = \frac{sp.gr \times \% \times 1000}{M.m}$$

Example on normality:

Prepare 2 L of 1.5 N CaC_2O_4 ?

According to the previous calculation the equivalent mass of CaC_2O_4 is 64 so

$$1.5 = \frac{m}{64} \times \frac{1000}{2000}$$

m = 192 gm CaC_2O_4

So we take 192 gm of CaC_2O_4 then dissolved it in distilled water and dilute to a total 2 L .

6^{th} week

Parts per million (ppm)

It is a ratio of parts of solute to millions part of solution, and is usually applied for very dilute solution. One part per million is equivalent to **1 mg/L** that is , if a solution has a concentration of 40 mg/L its concentration may also be expressed as 40 ppm.

An examples:

1-What is the concentration, in part per million, of a solution in which 50 grams of aluminum oxide Al_2O_3 is dissolved in 500 ml of solution?

Solution:

ppm express as mg/ L so we must convert the mass unit to mg and the volume unit to liter

Mass in mg = 50 × 1000 = 50000 mg

Volume in L = 500 / 1000 = 0.5 L

$$ppm = \frac{50000}{0.5} = 100000 \text{ ppm}$$

2- What is the concentration in part per million, of a solution in which 480 grams of sodium chloride is dissolved in 4 liters of solution?

Solution:

480 ×1000 = 480000 mg

$ppm = \frac{480000}{4} = 120000$ ppm

one ppm like:

one inch in 16 miles

one second in 11.5 days

one minute in two years

Dilution

A dilution is the procedure for preparing a less concentrated solution from a more concentrated one (stock solution), with the concentration units remaining the same.

Dilution law: $C_c \times V_c = C_d \times V_d$

When C_c and V_c is the concentration and volume of more concentrated solution respectively and C_d , V_d is the concentration and volume of less concentrated solution.

Example :how many milliliters of 5 % NaCl solution must be used to prepare 100 ml of 2 % NaCl solution?

Solution:

$C_1 \times V_1 = C_2 \times V_2$

$0.05 \times V = 0.02 \times 100$

$V = 40$ ml

Exercises:

1- A patient is given 1000 ml 0.9 % NaCl intravenously. How many grams of NaCl did the patient receive?

2- Prepare 100 ml 0.9 % saline solution from 10 % saline solution.

3- What is the concentration of a solution in gram / liter when 80 grams of sodium chloride is dissolved in 2 liter?

4-What is the concentration, in part per million (ppm),of a solution in which 80 gm of potassium hydroxide is dissolved in 1 liter of solution?

5- What is the mass of water that must be used to dissolved 60 gm of NaCl to prepare 6% (m/m) solution ?

7^{th} week

Exercises:

1- How many grams of glucose ($C_6H_{12}O_6$) are present in 0.5 L of 2 M

Glucose solution ? (atomic mass you may require C = 12 H = 1 O = 16)

2- Calculate the molarity of a solution of 0.156 gm of $KClO_4$ in 250 ml of solution

(atomic mass you may require K = 39 , Cl = 35.5 , O = 16)

3- Make 500 ml of 0.1 molar solution of HCl from a 1 molar stock solution.

4-A blood sample contains 65 mg of testosterone ($C_{19}H_{28}O_2$) in 100 ml

What is the molarity of testosterone ?

(atomic mass you may require C = 12 H = 1 O = 16)

5- Determine the number of moles of solute present in 275 ml of 0.515 M $KClO_4$(atomic mass you may require K = 39 , Cl = 35.5 , O = 16)

6- 20 gm of $CaCO_3$ was used to create 2M solution, what is the volume of solution?

7- Determine the final volume, in milliliter of a 1.5 M HCl solution prepared from 20 ml Of 6M HCl solution.

Conversion of solutions

1-Conversion between mg / dL and mmol / L

You need here to convert deciliters to liters and mg to mmol. To proceed, you should multiply the mg/ dL by 10 since there are 10 deciliters per 1 liter. Then you should divide by molecular mass since

1 mmol is the molecular mass in mg.

Examples : the fasting blood sugar of diabetic patient is 126 mg/dL. What is its fasting blood sugar in mmol/ L (recall that the molecular mass of glucose is 180)

$$126 \text{ mg/dL} \times \frac{10}{180} = 7 \text{ mmol/ L}$$

When converting mmol/L to mg/dL. The reverse equation is applied.

Multiply by the molecular mass and divide by 10

Example: converts 1.8 mmol/L H_2SO_4 to mg/dL . (recall that the molecular mass of H_2SO_4 = 98

$$1.8 \text{ mmol/L} \times \frac{98}{10} = 17.6 \text{ mg/dL}$$

2- conversion between molarity and normality

When converting molarity to normality, one needs to mainly consider the valence as the molecular mass in grams is common in both. The

Simple equation is molarity × valence = normality

Example: converts 3 mol /L H_2SO_4 to normality in eq/L (remember the valence of H_2SO_4 is 2)

3× 2 = 6 N

Exercise:

1- prepare 100 ml of 0.2 N NaOH ?

(atomic mass you may require Na = 23, O = 16 , H = 1)

2- what volume of 14 N H_2SO_4 is needed to make 250 ml of 3.2 M H_2SO_4 solution?

8th week

Standard solution

Standard solution is the reagent of exactly known concentration that is used in titrimetric analysis. It classified into:

1- primary standard:a primary standard is prepared from solid compounds.

In order to be suitable for use as primary standard, a compound must:

- be ready available (and inexpensive)
- be very pure (analytical reagent grade, pure 99.9% pure)
- have a known formula (eg, degree of hydration must not change)
- be unaltered in air during weighing, that is, the compound must **not**
  a-absorb moisture from the air
  b- absorb carbon dioxide from the air
  c- be oxidized by air

- have a relatively large molar mass (to minimize errors during weighing)
- be soluble (in the solvent use, and under the condition use, to make the solution.
- Not toxic

Compound that meet or reach these criteria are very few, and only limited number of primary standard substance are available to the chemist.

an example of primary standard solution is potassium hydrogen phthalate,

$KH(C_8H_4O_4)$

2- secondary standard :

From the name itself it is obvious that this is a standard which comes second. That is the name is secondary.

A second standard is a chemical or reagent which has certain properties such as:

- It has less purity than primary standard
- Are somewhat hygroscopic (water absorption)

Substances like hydrochloric acid and sulfuric acid are not suitable for use as primary standard because the concentration of the commercially available concentrated acid is not known accurately.

Similarity, alkali hydroxide such as sodium hydroxide are unsuitable for use as primary standards because they absorb moisture and carbon dioxide from the atmosphere, however we can prepare a sodium hydroxide solution with an approximate concentration by weighing up some NaOH pellets and dissolving them in distilled water in a volumetric flask. This solution can then be titrated with a primary standard solution, such as potassium hydrogen phthalate in or der to determine the concentration of the basic solution more accurately. Because the accurate concentration of the base has been derived using a primary standard, the base is referred to as a secondary standard.

9th week

Classification of reaction in titrimetric analysis

The reaction employed in titrimetric analysis fall into four main classes:

1- Neutralization reaction, or acidimetry and alkalimetry, these include the titration of free bases with standard acid (**acidimetry**) , and the titration of free acids with a standard base (**alkalimetry**). This reactions involve the combination of hydrogen and hydroxide ions to form water.

2- precipitation reaction: these depend upon the combination of ions to form a simple precipitate as in the titration of silver ion with solution of chloride.

3-complex formation reaction: these depend upon the combination of ions, other than hydrogen or hydroxide ion, to form a soluble slightly dissociated ion or compound, as in the titration of a cyanide with silver nitrate.

4- oxidation –reduction reaction: under this heading are included all reactions involving change in oxidation number or transfer of electrons among the reactive substance.

The standard solutions are either oxidizing or reducing agents.

Neutralization reaction

Titration of strong acid against strong base

Neutralization titration are widely used to determine the amount of acids and base and to monitor the progress of reactions that produce or consume hydrogen ions. In addition, we investigate titration curve that are plot of pH

Vs. volume of titrant, and present several example of pH calculation.

Acid-base titration depend on the neutralization between an acid and a base when mixed in solution. In addition to the sample, an appropriate pH indicator is added to the

titration chamber, reflecting the pH range of the equivalent point. The acid-base indicator indicates the end point of the titration by changing the color. For example if the equivalent point is at pH of 8.4, then the phenolphthalein would be used.

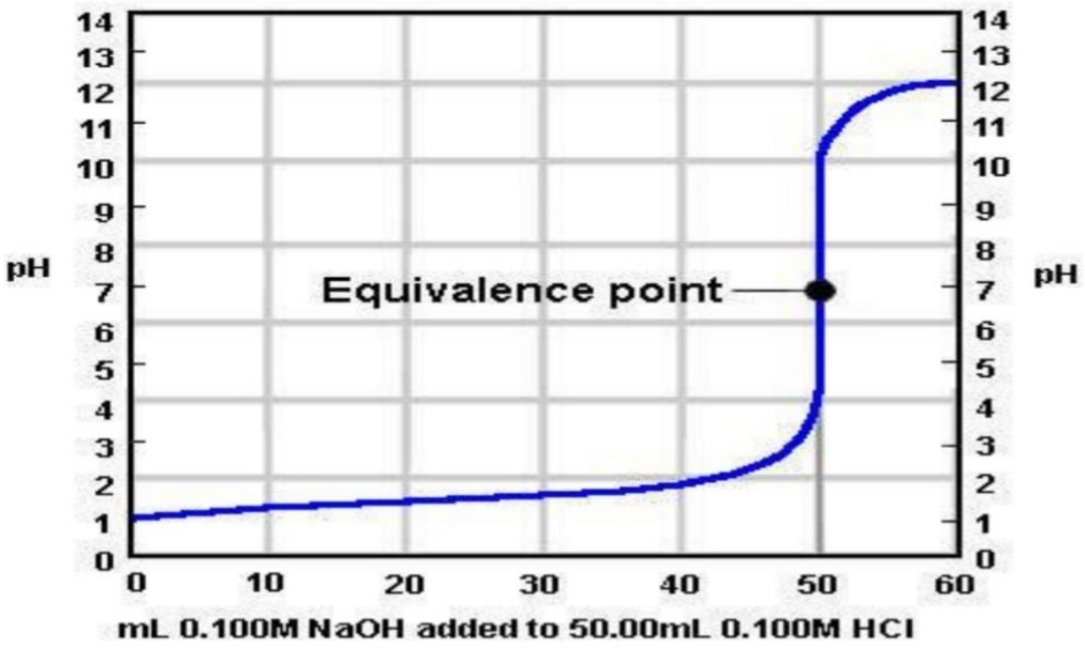
A solution and indicators for acid and base titration depend on a chemical reaction of the analyte with a standard reagent.

Acid base titration curves

A titration curve is a curve in the plane whose x-coordinates are the volume of titrant added since the beginning of the titration, and whose y-coordinate is the concentration of the analyte at the corresponding stage of the titration.

In acid base titration, the titration curve reflects the strength of the corresponding acid and base. For a strong acid and a strong base, the curve will be relatively smooth and very steep near the equivalence point.

Here is an example of titration curve, produced when a strong base is added to a strong acid. This curve shows how pH varies as 0.100M NaOH is added to 50 ml of 0.1 M HCl



For the calculation we use the formula:

$M_1 V_1 = M_2 V_2$

Where: M_1, V_1 = molarity and volume of acid

M_2, V_2 = molarity and volume of base

Example:

27.8 ml of 0.1 M HCl solutions reacts with 20 ml of NaOH solution. What is the concentration of of the NaOH solution?

Solution:

$27.8 \text{ ml} \times 0.1 \text{ M} = 20 \text{ ml} \times X$

$X = 0.139 \text{ M NaOH}$

Exercises:

A solution made from pure sodium hydroxide contained 2.74 gm in exactly 100 ml of water. Using phenolphthalein indicator, titration of 20 ml of this solution required 18.7 ml of a hydrochloric acid solution for complete neutralization.

a) calculate the molarity of sodium hydroxide solution.

b) calculate the molarity of hydrochloric acid neutralized.

c) What is the titrant in this procedure and what is the titrand?

10th week

The oxidation-reduction reaction

Oxidation: when a substance losses electrons, it is said to be oxidized. This result in an increase in its oxidation number.

Reduction: when a substance gains electrons, it is said to be reduced. This result in an decrease in its oxidation number.

The oxidation-reduction reaction also called redox. In this type of titration,

The chemical reaction takes place with a transfer of electrons in the reacting ions of aqueous solutions. The titration named after the reagent that is used in are as follows;

-permanganate titration

-dichromate titration

-Iodometric and Iodimetric titration

Permanganate titrations

In this titration, the potassium permanganate is used as an oxidizing agent.it maintained with the use of dilute sulphuric. here is the equation.

$$2KMnO_4 + 3H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 3H_2O + 5[O]$$

$$\text{Or } MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

Further, the solution remains colorless before the endpoint. The potassium permanganate is used to estimate oxalic acid, ferrous salts, hydrogen peroxide, oxalates and more. While the solution of potassium permanganate is always standardized before it used.

Dichromate titrations

These are titrations in which, potassium dichromate is used as an oxidizing agent in acidic medium. This medium is maintained acidic by the use of dilute sulphuric acid. The potential equation is:

$$K_2Cr_2O_7 + 4H_2SO_4 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 4H_2O + 3[O]$$

$$\text{Or } Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2\,Cr^{3+} + 7H_2O$$

The solution of potassium chromate can be directly used for titrations. It is mainly used for the estimation of ferrous salts and iodides.

Iodometric and Iodimetric titration

This titration involve oxidation-reduction reactions of iodine. Iodine can be very conveniently titrated with standard thiosulphate solution.

Iodimetry: Titration in which a standard iodine solution is used (direct titration).

$$\mathbf{I_2 + 2e^- \rightarrow 2I^-}$$

Iodometry:titration in which iodine liberated during chemical reaction is titrated (indirect titration)

$$\mathbf{2I^- - 2e^- \rightarrow I_2}$$

11th &12th weeks

Hydrogen ion concentration & pH

Reaction of water: it can be described by the following equilibrium reaction:

$$H_2O \leftrightarrow H^+ + OH^-$$

Use law of mass action to define the equilibrium point of the dissociation Reaction:

$$K_{eq} = \frac{[H^+][OH^-]}{[H_2O]}$$

K_{eq} for pure water determined experimentally to be 1.8×10^{-16} M at 25 °C

Concentration of pure H_2O = 55.5 M (weight of water in 1 liter (1000gm)

Divided by M.m of 18

$$[H^+][OH^-] = K_{eq}\,[H_2O]$$

$$[H^+][OH^-] = (1.8 \times 10^{-16})(55.5)$$

$$[H^+][OH^-] = 1 \times 10^{-14}\ \text{M}$$

Because according to the chemical equation for dissociation H^+ and OH^- Must have equal concentration in pure water. Then:

$$[H^+] = [OH^-] = \sqrt{1 \times 10^{-14} M} = 1 \times 10^{-7}\ \text{M}$$

- This is the basis of the pH scale
- These numbers are very small and difficult to work with, so in 1909 Soren Sorenson introduced the term pH to more conveniently express $[H^+]$.

pH defined1 as the negative logarithm of the hydrogen ion concentration:

pH = -log [H^+]

Also the same as log $\frac{1}{[H^+]}$

- " p " is an operator means to take the negative log of example:

  pOH = - log [OH^-]

- What is pH of pure water ?

  [H^+] = 1×10^{-7} , pH = - log (1×10^{-7}) = 7

- Back to water ionization:

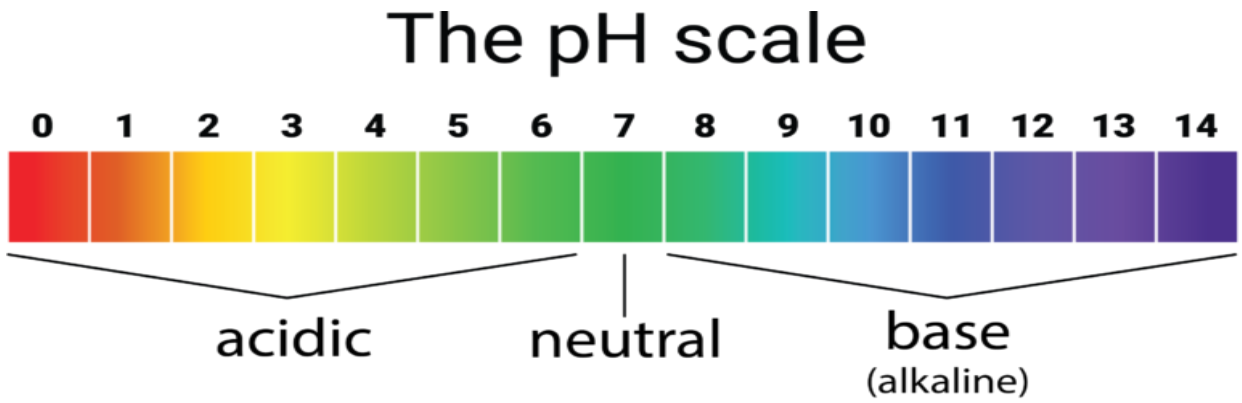
  [H^+][OH^-] = 1×10^{-14} M

- Take -log of both sides for convenience:

  - log (1×10^{-14} M) = - log [H^+] + - log [OH^-]

  14 = pH + pOH

- The pH scale ranges from 0 to 14



The following table show the pH of some fluids:

Pancreatic juice	**7.8 – 8**
Blood plasma	7.4
Seawater	7 – 7.5
Saliva	6.4 – 6.9
Muscle	6.1
Urine	5 – 8
Coffee	5
Acid rain	3.5
Lemon juice	2.3
Gastric juice	1.2 – 3

Calculation of pH for strong acid

Strong acids are completely ionized in solution, this can also be described as dissociating in the ions

$HA(aq) \rightarrow H^+(aq) + A^-(aq)$

Therefore, the concentration of hydrogen ions, H^+, is equal to the concentration of acid, HA

The list of strong acids and strong bases are provided below:

Example : what is the pH of 0.01M hydrochloric acid?

Answer:

$[HCl] = [H^+] = 0.01$ M

$PH = -\log [0.01] = 2$

Calculation of pH for strong base

Strong bases are completely ionized in solution, this can also be described as dissociating in the ions

$BOH\ (aq) \rightarrow B^{+}\ (aq) + OH^{-}\ (aq)$

Therefore, the concentration of hydroxide ions $[OH^{-}]$ is equal to the concentration of base [BOH]

Example:Calculate the pH of 0.15M sodium hydroxide.

Answer:

Sodium hydroxide is a strong base which ionizes as follows:

$NaOH\ (aq) \rightarrow Na^{+}\ (aq) + OH^{-}\ (aq)$

$[H^{+}]\ [OH^{-}] = 1\times 10^{-14}$

$[H^{+}]\ [0.15] = 1\times 10^{-14}$

$[H^{+}] = 6.66 \times 10^{-14}$

$pH = -\log 6.66 \times 10^{-14} = 13.17$

The list of strong acids and strong bases are provided below:

Strong acids	Strong bases
HCl	KOH
HBr	NaOH
HI	$Ba(OH)_2$
H_2SO_4	CsOH
HNO_3	$Sr(OH)_2$
$HClO_3$	$Ca(OH)_2$
$HClO_4$	LiOH
	RbOH

Calculation the PH of weak acid

Weak acids dissociate only slightly in aqueous solution.

Ka is the dissociation constant for a weak acid.

pKa = - log Ka

For a weak acid, $HA \rightleftharpoons H^+ + A^-$

At equilibrium $K_a = \frac{[H^+][A^-]}{[HA]}$

As position of equilibrium is considerably shifted to the left,

Assume, $[HA]_{initial} = [HA]_{equilibrium}$ and $[H^+]_{equilibrium} = [A^-]_{equilibrium}$

Then, $K_a = \frac{[H^+][H^+]}{[HA]} = \frac{[H^+]^2}{[HA]}$

$[H^+]^2 = [HA]K_a$

$[H^+] = \sqrt{[HA]K_a}$

pH $= -\log(\sqrt{[HA]K_a})$ where [HA]=initial concentration of weak acid HA

For weak base:

For a general weak base A- reacting with water according to the equation:

$$A^-(aq) + H_2O \rightleftharpoons OH^-(aq) + HA(aq)$$

the basicity constant is given by:

$$K_b = \frac{[OH^-(aq)]\,[HA(aq)]}{[A^-(aq)]}$$

If there is no other source of OH^- or HA, this can be written as:

$$K_b = \frac{[OH^-(aq)]^2}{[A^-(aq)]}$$

and thence the following expression for the $[OH^-]$ can be deduced:

$$[OH^-(aq)] = \sqrt{(K_b \times [A^-(aq)])}.$$

13th week

Buffer solution

Definition : solutions which resist changes in pH when small quantities of acid or base is added.

Types : Acidic buffer (pH < 7) weak acid + its Na or K salt

CH_3COOH CH_3COONa

Basic buffer (pH > 7) weak base + its chloride

NH_3 NH_4Cl

Biological uses : in biological system (saliva, stomach and blood) it is essential that the pH stay constant in order for any processes to work properly. Most enzymes work best at particular pH.

Blood

- The pH of blood is normally about 7.4
- If the pH varies by 0.5 it can lead to unconsciousness and coma.
- CO_2 produced by respiration can increase the acidity of blood by forming H^+ ions in aqueous solution.

$$CO_2 + H_2O \rightarrow H^+ + HCO_3^-$$

- The presence of hydrogen bicarbonate ions in blood removes excess H^+

$$H^+ + HCO_3^- \rightarrow H_2CO_3$$

Other uses: Many household and cosmetic products need to control their pH value:

- **Shampoo:** counteract the alkalinity of the soap and prevent irritation.
- **Baby lotion**: maintain a pH of about 6 to prevent bacteria multiplying.
- **Others**: washing powder and eye drops.

Buffer capacity

Buffer capacity is a measure of the efficiency of a buffer in resisting changes in pH.

Buffer capacity depends on:

1- The ratio of the salt to the acid or base. The buffer capacity is optimal when the ratio is 1 : 1,that is, when pH = pKa

2- The concentration of buffer: higher concentrations of the weak acid and conjugated base (or weak base and conjugated acid) lead to a greater buffer capacity.

Action of buffer solutions

Acidic buffer: it is essential to have a weak acid for equilibrium to be present so that ions can be removed and produced. The dissociation is small and there are few ions.

$$CH_3COOH \leftrightarrow H^+ + CH_3COO^-$$

Relative concentration high low low

A strong acid cannot be used as its fully dissociated and cannot removed H^+

$$HCl \rightarrow H^+ + Cl^-$$

Adding acid: any H^+ is removed by reacting with CH_3COO^- ions to form CH_3COOH via the equilibrium. Unfortunately, the concentration of CH_3COO^- is small and only a few H^+ can be " mopped up " a much large concentration of CH_3COO^- required.

To build up the concentration of CH_3COO^- ions, sodium ethanoate is added

Adding alkali: add OH^- .although it do not appear in the equation, it react with H^+

$$H^+ + OH^- \leftrightarrow H_2O$$

Removal of H^+ from the weak acid equilibrium means that, according to

Le-Chatelier's principle, more CH_3COOH dissociate to form ions to replace those being removed.

$$CH_3COOH \leftrightarrow H^+ + CH3COO^-$$

As the added OH^- ions remove H^+ from the weak acid system, the equilibrium moves to the right to produce more H^+ ions. Obviously, there must be a large concentration of un dissociated acid molecules to be available.

Summary:

For an acidic buffer solution one needs:

- Large [CH_3COOH] for dissociating into H^+ when alkali is added.
- Large [CH_3COO^-] for removing H^+ as its added.

This cannot exist if only acid is present so as a mixture of the acid and salt is used . the sodium salt provides the large CH_3COO^- concentration.

So one used a weak acid + its Na or K salt.

Alkaline buffer :similar but is based on the equilibrium surrounding a weak base.

$$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$$

Relative concentration	high	low	low

But one needs a large concentration of OH^- to react with any H^+ added. And a large concentration of NH_4^+ to react with any OH^- added.

There is enough NH_3 to act as source of OH^- but one needs to increase the concentration of ammonium ions by adding an ammonium salt.

Use ammonia (a weak base) + ammonium chloride (one of its salt)

Henderson – hasselbalch equation:

the pH of an acidic or basic buffer can be calculated by Henderson – hasselpalch equation.

For acidic buffer $pH = pKa + \log \frac{[salt]}{[acid]}$

For basic buffer $pOH = pKb + \log \frac{[salt]}{[base]}$

Knowing pH + pOH Can be calculated by application :

$$pH + pOH = 14$$

Example 1: calculate the pH of the buffer solution that is 0.15 M HF and 0.15 M F^-, Ka for HF is 6.8×10^{-4}

Solution:

$$pH = pKa + \log \frac{[\,salt\,]}{[\,acid\,]}$$

$$pH = - \log Ka + \log \frac{[F^-]}{[HF]}$$

$$pH = - \log (6.8 \times 10^{-4}) + \log \frac{0.15}{0.15}$$

$$= 3.17 + \log 1$$

$$= 3.17 + 0$$

$$= 3.17$$

Example 2 :calculate the pH for buffer solution composed from 0.01 M acetic acid (pKa = 4.76) and 0.02 M sodium acetate.

Solution:

$$pH = pKa + \log \frac{[\,salt\,]}{[\,acid\,]}$$

$$pH = 4.76 + \log \frac{0.02}{0.01}$$

$$pH = 4.76 + \log 2$$

$$pH = 4.76 + 0.3$$

$$pH = 5.06$$

Colorimetry analysis

A coulimetry is a technique used to determine the concentration of colored compounds in solution.

Principle of colorimetry

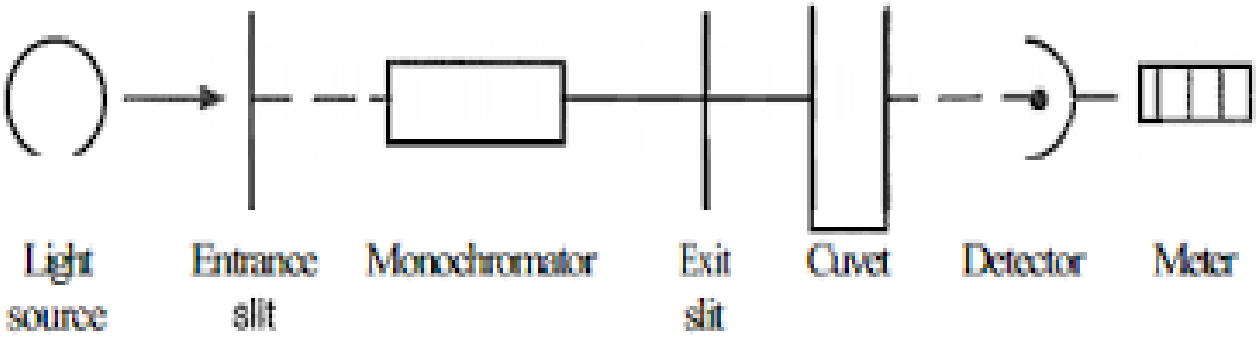
In general, a colorimetric procedure involves adding some type of chemical (or reagent) to a sample. The reagent then reacts with the substance we are trying to measure, causing a color change in the sample; the degree of color change due to the chemical reaction must be related to the concentration of the measured substance in the sample. The color change must be measured by specific instruments.

Spectrometer:-

Spectrometer is instrument used to measure the light transmitted by a solution to determine the concentration of light-absorbing substance in the solution.it also referred as, spectrophotometer, spectrographs, or spectral analyzer.

Principle of spectrophotometer:

When light of specific wavelength is allowed to pass through a colored solution some light is absorbed by the solution and the remaining is transmitted the transmitted light is allowed to fall on photocell. On excitation with light, the photocell generates a current. The amount of the current generation being proportional to the amount of light failing on the photocell. The current thus produced is measured by suitable device. On most spectrophotometers two scales are present,% T (transmittance) and Abs (absorbance).



Components of a spectrophotometer

Spectrophotometer has five essential parts:-

1- Light source:- This can vary in intensity, depending upon the type of instrument used. The widely light source used Tungsten-iodide lamp, deuterium-discharge lamp or mercury-arc lamp.

2- Monochromators:- Isolation of individual wavelengths of light is an important and necessary function of a monochromator.The major types of monochromator:-
a-Colored-glass filter.
b-The prism.
c-Diffraction gratings.

3- Sample cell(cuvet):-The sample cell mainly has square shape with uniform diameter to kept the light path constant in order to have absorbance proportional to concentration. Cuvet should be rinsed out immediately after use and placed in plastic-coated racks. It may be cleaned with mild detergent or soaked in a mixture of concentrated HCL, water and ethanol.

4- Photo detector:-The purpose of detector is to convert the transmitted radiant energy into an equivalent amount of electrical energy(current).

5- Readout:-are broadly classified as meters, recorders, or digital units. They all convert the electrical signal from the detector into usable form.

Note:

You must be avoid any errors due to dirty glassware, turbidity of solution or air bubbles as all these factors will seriously interfere with light absorption.

14th week

Beer lambert law:-

The beer-lambert law (or beer's law) is the linear relationship between absorbance and concentration

This law can be expressed mathematically as:

$A = KC\,t$ A:absorbance K:constant C:concentration of solution

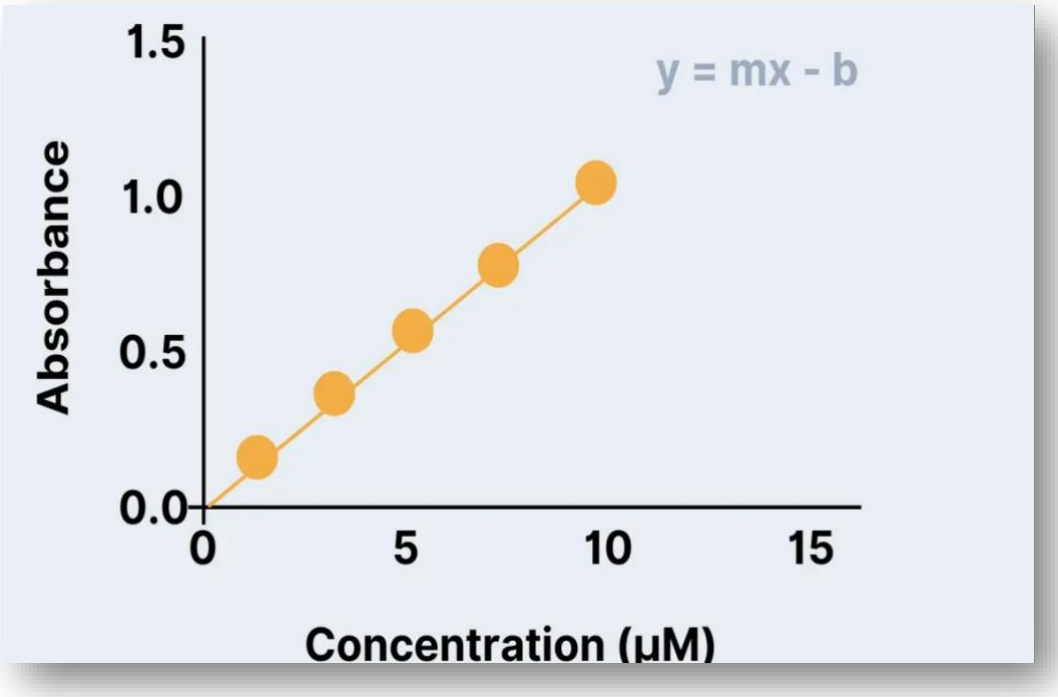
t:thickness of the solution or light path.

Calibration curve

A Clibration curve, also known as a standard curve is a graph that plots the absorbance of a series of solutions with known concentrations against their respective concentrations. This curve is based on the Beer- Lambert law. By measuring the absorbance of an unknown solution and comparing it to the calibration curve, one can determine the concentration of the unknown substance.

Ideally, a standard curve should pass through the origin (0.0), indicating that a solution with zero concentration should have zero absorbance. If the curve doesn't pass through the origin, it could indicate errors in preparing standards or other issues with the measurements.

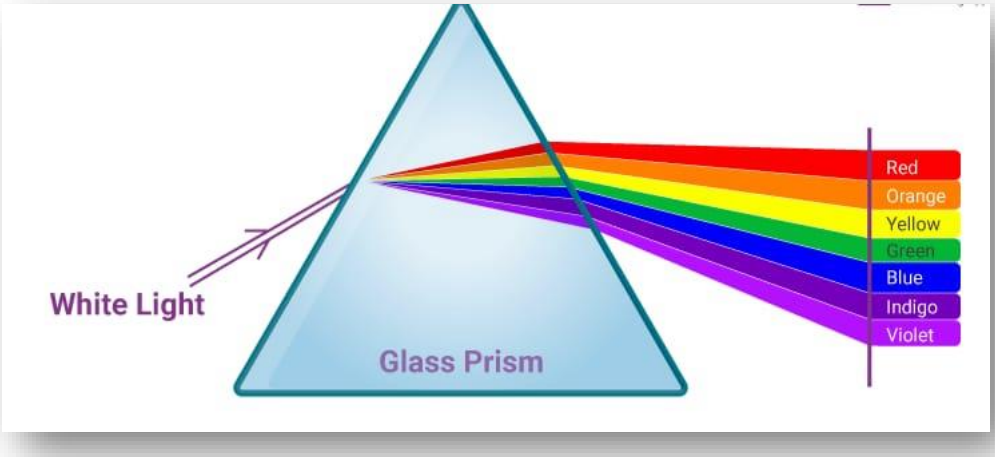
The standard curve should be linear over the relevant concentration range for accurate extrapolation.



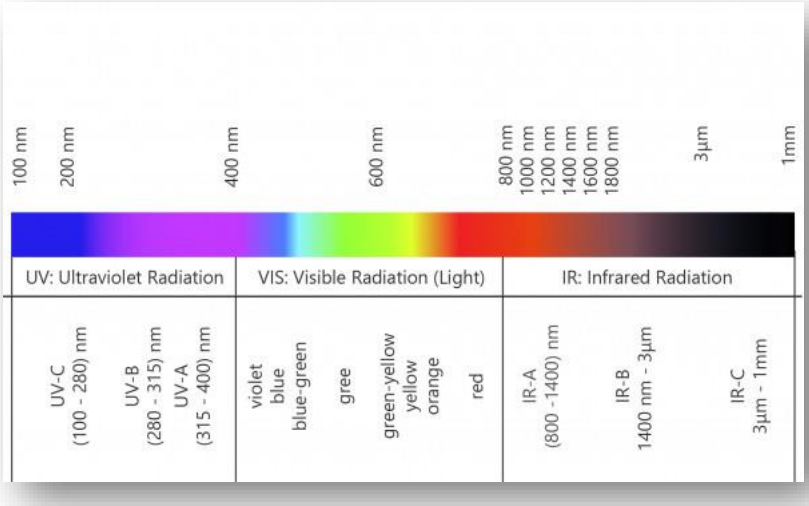
15th week

Fraction spectrum

A spectrum is a range of light or energy. When light passes through a prism, it splits into different colors. This shows the visible spectrum.



But light also includes invisible parts like ultraviolet (UV) and infrared (IR)



Spectrum usually means electromagnetic spectrum, which include all types of waves, not just visible light.

Types of spectra:

1-Continuous spectrum: shows a seamless range of colors or wavelengths.
For example: sunlight through prism.

2-Line spectrum (Emission spectrum): contains specific lines at certain wavelength. Each element has a unique line spectrum (like a finger print).
For example: Hydrogen emission spectrum.

3-Absorption spectrum: appears as a continuous spectrum with dark lines where light is Absorbed.

Electromagnetic spectrum includes:

Type	Wavelength range
Radio waves	> 1 meter
Microwaves	1 m – 1mm
Infrared (IR)	1 mm – 700 nm
Visible light	700 nm – 400 nm
UV Rays	400 nm – 10 nm
X-Rays	10 nm – 0.01 nm
Gamma Rays	< 0.01 nm

Application of spectrum in chemistry:

- Analyzing materials based on the light absorbed or emit.
- Identifying elements: each element has a unique spectral signature.
- Molecular structure; IR and UV spectroscopy give clues about bands and structure.