Analytical Chemistry

Lecture No. 1/ Year 1

Dr. Omar Abdulhay Al-Taee

Department of Chemistry

College of Education for Pure Science

Mosul University/Iraq

Analytical Chemistry: Analytical chemistry studies and uses instruments and methods used to separate, identify and quantify matter. In practice, separation, identification or quantification may constitute the entire analysis or be combined with another method.

Qualitative analysis identifies analyte, while quantitative analysis determines the numerical amount or concentration. Analytical chemistry is the science of obtaining, processing, and communicating information about the composition and structure of matter. Analytical chemistry involves the analysis of matter to determine its composition and the quantity of each kind of matter that is present.

Analytical chemists detect traces of toxic chemicals in water and air. They also develop methods to analyze human body fluids for drugs, poisons, and levels of medication.

يسعى العلم إلى تحسين وسائل قياس التركيب الكيميائي للمواد الطبيعية والاصطناعية باستخدام تقنيات لتحديد المواد التي قد تكون موجودة في المادة ولتحديد الكميات الدقيقة للمادة المحددة. تتضمن الكيمياء التحليلية تحليل المادة لتحديد تكوينها وكمية كل نوع من المواد الموجودة. يكتشف الكيميائيون التحليليون آثار المواد الكيميائية السامة في الماء والهواء. كما أنهم يطورون طرقًا لتحليل سوائل جسم الإنسان للأدوية والسموم ومستويات الأدوية.

Analytical chemistry consists of: ***تشمل الكيمياء التحليلية ماياتي***

(A) Qualitative analysis which deals with the identification of elements, ions, or compounds present in a sample (tells us what chemicals are present in a sample).

(B) Quantitative analysis which is dealing with the determination of how much of one or more constituents is present (tells how much amounts of chemicals are present in a sample). Quantitative analysis can be divided into three branches:

(1) Volumetric analysis (Titrimetric analysis): The analyte reacts with a measured volume of reagent of known concentration, in a process called titration. **(1st grade)**

(2) Gravimetric analysis: usually involves the selective separation of the analyte by precipitation, followed by the very non-selective measurement of mass (of the precipitate). **(2nd grade)**

(3) Instrumental analysis: They are based on the measurement of a physical property of the sample, for example, an electrical property or the absorption of electromagnetic radiation. Examples are spectrophotometry (ultraviolet, visible, or infrared), fluorimetry, atomic spectroscopy (absorption, emission), mass spectrometry, nuclear magnetic resonance spectrometry (NMR), X-ray spectroscopy (absorption, fluorescence) **(3^{th} grade)**.

Solutions.

Solution: Homogeneous mixture of two or more substance produce from dissolved (disappeared) solute particle (ions, atoms, molecules) (lesser amount) between solvent particle (larger amount).

Solute (lesser amount) + Solvent (larger amount) □ Solution

NaCl (s)+H_2O (l) → Salt Solution.

Types of Solution:

- Concentrated Solution: has a large amount of solute.
- Dilute Solution: has a small amount of solute.

Solute	**Solvent**		
	Gas	Liquid	Solid
Gas	$O_{2(g)}$ in $N_{2(g)}$, Air	$CO_{2(g)}$ in $H_2O_{(l)}$, Soda	$H_{2(g)}$ in $Pd_{(s)}$, H_2 catalyst
Liquid	Perfume	$Alcohol_{(l)}$ in $H_2O_{(l)}$, Martini	$Hg_{(l)}$ in $Ag_{(s)}$, Dental filling
Solid	Dust air, Smoke industry	$NaCl_{(s)}$ in $H_2O_{(l)}$, salt water, saline sol.	$Zn_{(s)}$ in $Cu_{(s)}$, Brass alloy

Classification of solutions according to amount of solute: **تصنيف المحاليل تبعا لكمية المذاب في المحلول**

(1) Unsaturated solutions: if the amount of solute dissolved is less than the solubility limit, or if the amount of solute is less than capacity of solvent.

(2) Saturated solutions: is one in which no more solute can dissolve in a given amount of solvent at a given temperature, or if the amount of solute equal to capacity of solvent.

(3) Super saturated solutions: solution that contains a dissolved amount of solute that exceeds the normal solubility limit (saturated solution). Or a solution contains a larger amount of solute than capacity of solvent at high temperature.

Classification of solution based on solute particle size*:*

تصنيف المحاليل تبعا لحجم جزيئات المذيب في المحلول

(1) True solution: A homogeneous mixture of two or more substances in which substance (solute) has a particle size less than 1 nm dissolved in solvent. Particles of true solution cannot be filtered through filter paper and are not visible to naked eye (NaCl in water).

(2) Suspension solution: heterogeneous mixtures which settles on standing and its components can be separated by filtrating (Amoxicillin or Ampicillin), particle of solute visible to naked eye.

(3) Colloidal solution: homogeneous mixture which does not settle nor are their components filterable, solute particle visible with electron microscope (milk).

(4) Standard solution: It is a reagent of known concentration that is used to carry out a titrimetric analysis.

The properties of standard solution are

1. Sufficiently stable under the lab condition.
2. React rapidly with the analyte so that the time required to complete the analysis is minimized.
3. React completely with the analyte so that satisfactory end point is realized.
4. Undergo a selective reaction with the analyte
5. The reaction with the analyte can be described by a balanced equation.

References:

(1) "Analytical Chemistry" by Gary D. Christian, 6th Edition, 2004, John Wiley and Sons, Inc.

(2) "Fundamental of Analytical Chemistry" by Doglas A.Skooge, Donald M.West and James Holler, 8th Edition, 2004.

(3) “An Introduction to Analytical Chemistry” by Doglas A. Skooge & Donald M.West, 4th Edition, 1986.

(4) الاساسيات النظرية للكيمياء التحليلية اللاعضويه التحليل الكمي الوزني و الحجمي تأليف د.هادي كاظم عوض واخرون، 1986.

(5) التحليل الحجمي والوصفي تاليف د. ثابت الغبشة ود. مؤيد العباجي. 1989

Analytical Chemistry

Lecture No. 2/ Year 1

Dr. Omar Abdulhay Al-Taee

Department of Chemistry

College of Education for Pure Science

Mosul University/Iraq

Steps of chemical analysis:

There are general steps for any analysis process a modification in this step depends on nature, size and complexity of the sample, the accuracy required and availability of reagent chemicals equipment and apparatus.

Q) How many steps you need to do the chemical analysis?

Step one: Choice of the method

the selected method should be suitable to the nature of the sample number of the sample and accuracy required some samples like archaeology or forensic sample need and a nondestructive method to keep the sample without destruction.

تعتمد هذه الطريقة على طبيعة النموذج وعدد النماذج ودرجة الدقة في التحليل حيث ان بعض النماذج الأثرية والجريمة (عند فك شفرة الجرائم) تحتاج طرائق التحليل لا اتلافيه اي ممكن ان نحافظ على النموذج كما هو

Step two: Sampling

Sampling is very important criteria, the sample should represent the material homogenized. If the material is big many samples could be selected, crashed and mixed for homogenization.

النمذجة خطوه مهمه وحرجة بحيث يجب ان يكون النموذج متجانس ويمثل الماده وإذا كانت كمية المادة كبيره يمكن اعداد عده نماذج وسحقها وخلطها لا اخذ نموذج يمثل المادة.

Step three: Preparing of the laboratory sample

The laboratory sample should be treated carefully and there are some required point should be taken to prepare the sample

1. Producing a homogenized sample by crashing, grinding and mixing.
2. Choosing proper solvent.
3. Decreasing the size of the material sample granules.
4. Turning the sample into a phase and formula can be attacked by reagent
5. Care should be taken to avoid any interference or any other factors can be affecting the estimation such as contamination.

نموذج التحليل يجب ان يعامل بدقه وهناك قواعد او نقاط اساسيه يجب ان تؤخذ بعين الاعتبار لتهيئه النموذج لعمليه التحليل اولا النقاط هي يجب ان يحضر نموذج متجانس من العينة باستخدام عمليه طحن والسحق والمزج. ثانيا تقليص حجم حبيبات العينه. تحويل العينة الى طور او صيغه تمكن الكاشف من مهاجمة او اختيار مذيب يناسب العين. الارتباط مع العينه. توخي الحذر وتجنب اي تداخلات قد تؤثر على عمليه التقدير وبالتالي تؤدي الى تلوث العينه

Step four: Procurement of the measured of the measured wanted quantity of the sample

If the sample is solid, a certain weight of the dried homogenized sample should be taken using calibrated balance but if the sample is liquid a certain volume should be taken.

يتم اخذ وزن معين جاف من العينه إذا كان نموذج التحليل صلبا اما إذا كان نموذج التحليل سائلا فيجب اخذ حجم معين من العينه لأجراء عمليه التحليل

Step five: Dissolution of the measured sample

A suitable solvent is selected to dissolve the sample completely within a short time, the solvent should not interfere in the analysis. Water is a magic solvent for almost the inorganic materials. Some organic materials require organic solvents such as alcohol, carbon tetrachloride and chloroform. Like dissolves like

يتم اذابه النموذج تماما في وقت قصير ويشترط لا يتداخل المذيب في عمليه التحليل ولذلك يعتبر الماء من أفضل المذيبات التي تذيب المواد اللاعضويه بينما بعض المركبات العضويه تحتاج الى مذيب عضوي كالكحول او رابع كلوريد الكربون او الكلوروفورم تبعا للقاعده المذيب يذيب شبيهه.

Step Six: Separation of the interferences

To measure the sample freely from the interferences by other components, certain steps should be taken such as separation or using masking agent to get rid of from the interferences compound.

لأجراء عمليه تحليل خاليه من المتداخلات هناك عده خطوات يجب اتخاذها ضمان عمليه التقدير وهي عمليه الفصل او اضافه عامل كليتي او مخلبي لغرض مسك العناصر المركبات الغير مرغوب بها

Step Seven: Completion of the analysis

This step concern with the measurement of the substance or component under consideration precisely using a suitable method such as precipitation or colour formation titration etc.

تهتم هذه الخطوة باستخدام وسيلة مناسبة لأغراض عملية التحليل الترسيب او تكون لون واستخدامه بالقياس اوعمليه تسحيح الى اخره

Step eight: Calculation and data analysis اجراء عملية الحسابات وتحليل النتائج

From the numeric obtained result, the final result can be calculated using the weight of the analysed sample. The final result could be evaluated by statistical analysis.

Concentration	تركيز	microgram μg $=10^{-6}$ gm	مايكروغرام
expression	تعبير		
gram equivalent	المكافئ الغرامي	ninogram ng $=10^{-9}$ gm	نانوغرام
dencity	الكثافة	mg	ملغرام
specific gravity	الوزن النوعي	gm	غرام
dillution	تخفيف	Kg	كيلوغرام
solution	محلول	percent	نسبة مئوية
solute	مذاب	aqueous	مائي
solvent	مذيب	organic solvent	مذيب عضوي
salt	ملح	molecular weight	الوزن الجزيئي
molarity	مولارية	molecular formula	الصيغة الجزيئية
Formality	فورمالية	equivalent weight	وزن مكافئ
normality	عيارية	defined	يعرف
reducing agent	عامل مختزل	ppm	جزء لكل مليون
oxidizing agent	عامل مؤكسد	ppb	جزء لكل بليون
		substitution	تعويض
acid	حامض	per	لكل
base	قاعدة	ml	ملليلتر
units	وحدات	L	Liter . لتر

Method of expression of concentration

1. Weight of salt in certain volume of solvent or solution وزن المذاب في حجم معين من المذيب او المحلول

Normality (N)

Number of gram equivalent of the salt in one letter of the solution
عدد المكافئات الغرامية في لتر واحد من المحلول
N= number of gram equivalent of the solute /one liter of solution……..(1)
Number of gm equivalents = grams of solutes / gm equivalent weight of solute….(2)

By substitution of equation 2 in 1
N= grams of solute per one liter of solution / gm equivalent weight of solute
العيارية = عدد غرامات الملح في ليتر واحد من المحلول مقسم على الوزن المكافئ
The units are g-eq./L

For solid material
N=Wet /eq. wt x1000 / V (ml)

For liquid material

N= d or sp.gr x% x1000/eq. wt
D= كثافة السائل
sp.gr = الوزن النوعي
eq. wt = الوزن المكافئ
Wet= وزن المذاب بالغرام

Dilution Equation
N1 x V1 =N2 x V2
N1 x V1= هما عيارية وحجم الحامض المخفف
N2 x V2 = عيارية وحجم الحامض المخفف

Molarity (M)

The number of molecular weight of the solute (gm) or numbers of moles of solute in one liter of solution and this solution can be called molaric solution.
المولارية هي عدد مولات المذاب في لتر واحد من المحلول

Molarity (M) = No.of moles of solute/gram molecular weight of solution

No.of moles of solute = No.of grams of solute / gram molecular weight of solute
عدد المولات = الوزن / الوزن الجزيئي للمذاب
M = grams of solute per liter of solution / grams molecular wight of solute
المولارية = عدد غرامات المذاب في لتر واحد من المحلول مقسوما على الوزن الجزيئي الغرامي للمذاب
For solid material
M=Wet x 1000/ M.wet x V (ml)

For Liquid material
M = d or sp.gr x % x1000/ M.wet
Dilution equation
M1 X V1 =M2 X V2

كيفية حساب الوزن المكافئ How to calculate the eq.wet
Molecular weight = Σ Atomic weight x No. of Atoms

Normal Standard Solutions (N)

- **Solution which contains gm equivalent weight /L of solution.**

Equivalent Weight

- Eq.Wt of acids = m.wt / no. of replaceable H^+
  Example Eq.Wt of HCl = m.wt / 1
  Eq.Wt of H_2SO_4 = m.wt / 2
- Eq.Wt of bases = m.wt / no. of replaceable OH^-
  Example Eq.Wt of NaOH = m.wt / 1
  Eq.Wt of $Ba(OH)_2$ = m.wt / 2
- **Eq. Wt For Salts** = m. wt/(number of cation or anion x its charge)
  Examples NaCl eq. wt = m.wt / 1
  $CaCl_2$ eq. wt = m.wt / 2

-N.B. Equal volumes of equal normalities contain equal number of molecules, that means equal normalities react 1 to 1 ratio.

Equivalent weight = (formula weight) / (e^- change)

Equivalents = g / eq. wt.   meq = mg / eq. Wt.

Normality (N) = eq / L = meq / ml

Reaction	eq. wt of reactant
$Fe^{2+} \rightarrow Fe^{3+} + e$	FW Fe ÷ 1
$KMnO_4 + 5e \rightarrow Mn^{2+}$	FW $KMnO_4$ ÷ 5
$Na_2S_2O_35H_2O \rightarrow ½\, S_4O_6^- + e$	FW $Na_2S_2O_35H_2O$ ÷ 1
$Cr_2O_7^{2-} + 6e \rightarrow 2\, Cr^{3+}$	FW $Cr_2O_7^{2-}$ ÷ 6

Analytical Chemistry

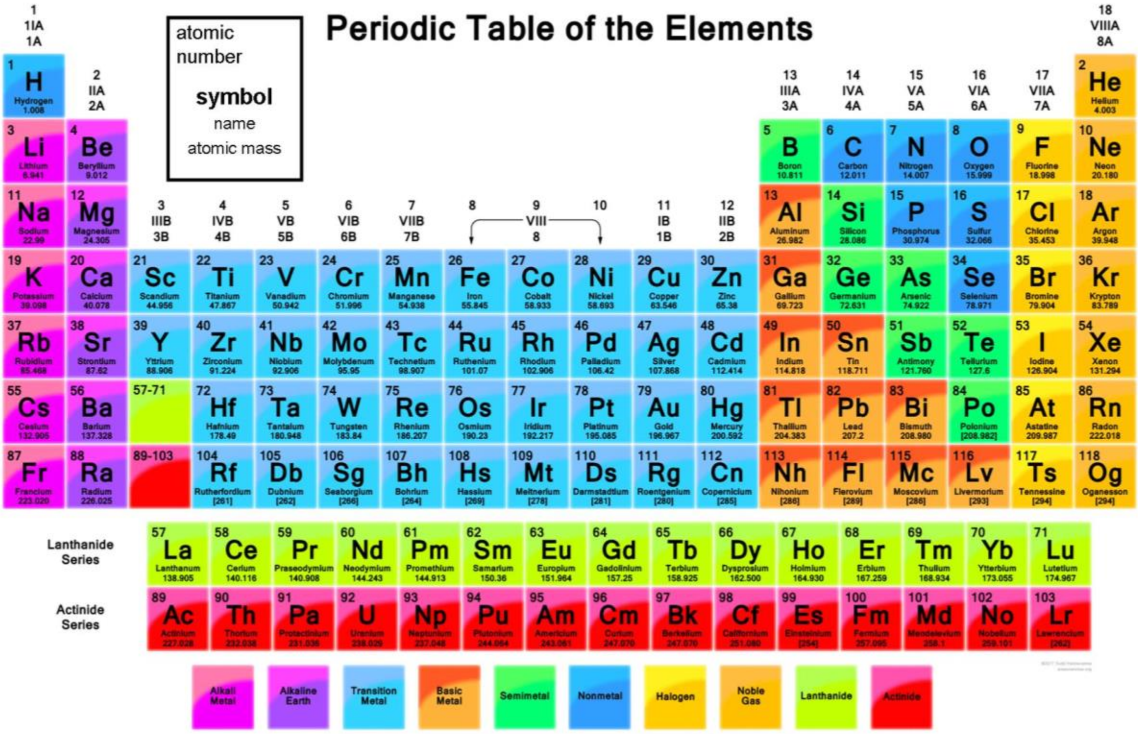
Lecture No. 3/ Year 1

Dr. Omar Abdulhay Al-Taee

Department of Chemistry

College of Education for Pure Science

Mosul University/Iraq



Anions	
Acetate (ethanoate)	CH_3COO^- or $C_2H_3O_2^-$
Acetylide	C_2^{2-}
Benzoate	$C_6H_5COO^-$ or $C_7H_5O_2^-$
Carbonate	CO_3^{2-}
Chromate	CrO_4^{2-}
Citrate	$C_6H_5O_7^{3-}$
Cyanide	CN^-
Hypochlorite	ClO^-
Chlorite	ClO_2^-
Chlorate	ClO_3^-
Perchlorate	ClO_4^-
Dichromate	$Cr_2O_7^{2-}$
Dihydrogen phosphate	$H_2PO_4^-$
Hydrogen carbonate (bicarbonate)	HCO_3^-
Hydrogen sulfate (bisulfate)	HSO_4^-
Hydrogen phosphate	HPO_4^{2-}
Hydroxide	OH^-
Nitrite	NO_2^-
Nitrate	NO_3^-
Peroxide	O_2^{2-}
Permanganate	MnO_4^-
Phosphate	PO_4^{3-}
Sulfite	SO_3^{2-}
Sulfate	SO_4^{2-}

TABLE 2.5 Common Anions

Charge	Formula	Name	Formula	Name
1−	H^-	Hydride ion	$C_2H_3O_2^-$	Acetate ion
	F^-	Fluoride ion	ClO_3^-	Chlorate ion
	Cl^-	Chloride ion	ClO_4^-	Perchlorate ion
	Br^-	Bromide ion	NO_3^-	Nitrate ion
	I^-	Iodide ion	MnO_4^-	Permanganate ion
	CN^-	Cyanide ion		
	OH^-	Hydroxide ion		
2−	O^{2-}	Oxide ion	CO_3^{2-}	Carbonate ion
	O_2^{2-}	Peroxide ion	CrO_4^{2-}	Chromate ion
	S^{2-}	Sulfide ion	$Cr_2O_7^{2-}$	Dichromate ion
			SO_4^{2-}	Sulfate ion
3−	N^{3-}	Nitride ion	PO_4^{3-}	Phosphate ion

Formula	Name	Formula	Name
Cation		**Singly charged anions (continued)**	
NH_4^+	Ammonium	NO_2^-	Nitrite
		NO_3^-	Nitrate
Singly charged anions			
$CH_3CO_2^-$	Acetate	**Doubly charged anions**	
CN^-	Cyanide	CO_3^{2-}	Carbonate
ClO^-	Hypochlorite	CrO_4^{2-}	Chromate
ClO_2^-	Chlorite	$Cr_2O_7^{2-}$	Dichromate
ClO_3^-	Chlorate	O_2^{2-}	Peroxide
ClO_4^-	Perchlorate	HPO_4^{2-}	Hydrogen phosphate
$H_2PO_4^-$	Dihydrogen phosphate	SO_3^{2-}	Sulfite
HCO_3^-	Hydrogen carbonate (or bicarbonate)	SO_4^{2-}	Sulfate
		$S_2O_3^{2-}$	Thiosulfate
HSO_4^-	Hydrogen sulfate (or bisulfate)		
		Triply charged anion	
OH^-	Hydroxide	PO_4^{3-}	Phosphate
MnO_4^-	Permanganate		

Ionic Chemical Formulas/PreAICE Chemistry

NAME:____ PERIOD_______

Directions: Using the Chemical Formulas program sheet, fill in the table below. Use subscripts & superscripts. Remember to use romam numerals to show the valence of the transition metals in the compound name.

METAL CATION (+)	CATION FORMULA	NONMETAL ANION (-)	ANION FORMULA	COMPOUND FORMULA	COMPOUND NAME
sodium	Na+1	hydroxide	OH-	NaOH	sodium hydroxide
magnesium	Mg+2	phosphate	PO4-3	Mg3(PO4)2	magnesium phosphate
calcium	Ca+2	chloride	Cl-	CaCl2	calcium chloride
gold(I)	Au+1	sulfite	SO3-2	Au2SO3	gold(I) sulfite
copper(II)	Cu+2	hydroxide	OH-	Cu(OH)2	copper(II) hydroxide
Iron(III)	Fe+3	telluride	Te-2	Fe2Te3	iron(III) telluride
magnesium	Mg+2	bromide	Br-1	MgBr2	magnesium bromide
manganese(II)	Mn+2	sulfide	S-2	MnS	manganese(II) sulfide
boron	B+3	oxide	O-2	B2O3	boron oxide
potassium	K+	nitrate	NO3-	KNO3	potassium nitrate
barium	Ba+2	bromide	Br-	BaBr2	barium bromide
strontium	Sr+2	sulfate	SO4-2	SrSO4	strontium sulfate
iron(III)	Fe+3	oxide	O-2	Fe2O3	iron(III) oxide
silver(I)	Ag+1	chloride	Cl-	AgCl	silver(I) chloride
aluminum	Al+3	carbonate	CO3-2	Al2(CO3)3	aluminum carbonate
gold(II)	Au+2	nitride	N-3	Au3N2	gold(II) nitride
cesium	Cs+1	phosphate	PO4-3	Cs3PO4	cesium phosphate
ammonium	NH4+	sulfide	S-2	(NH4)2S	ammonium sulfide
zinc(II)	Zn+2	nitrite	NO2-	Zn(NO2)2	zinc(II) nitrite
chromium(I)	Cr+1	nitride	N-3	Cr3N	chromium(I) nitride
mercury(II)	Hg+2	oxide	O-2	HgO	mercury(II) oxide
sodium	Na+	sulfite	SO3-2	Na2SO3	sodium sulfite
magnesium	Mg+2	oxide	O-2	MgO	magnesium oxide

Example (1): How many milligrams are in 0.250 mmole Fe_2O_3 (Ferric oxide).

Solution:

$$\text{wt (mg)} = \text{mmole} \times \text{M.wt (mgmmol)} = 0.250 \text{ mmole} \times 159.7 \text{mgmmol} = 39.9 \text{ mg}$$

Example (2): Solution was prepared by dissolving 1.26 g of $AgNO_3$ in a 250 mL volumetric flask and diluted to the mark. Calculate the molarity of the silver nitrate solution. How many millimoles of $AgNO_3$ were dissolved.

Solution:

$$M = \text{wt (g)} \times 1000 / \text{M.wt (gmol)} \times V(\text{mL})$$

$$M = 1.26 \text{ (g)} \times 1000 / 169.9 \text{ (gmol)} \times 250 \text{ (mL)} = 0.0297 \text{ mol/L}$$

$$\text{Millimoles} = M \text{ (mmolmL)} \times V \text{ (mL)} = 0.0297 \text{ (mmolmL)} \times 250 \text{ mL} = 7.42 \text{ mmole}$$

Example (3): How many grams per millilitre of NaCl are contained in a 0.250 M solution.

$$M = \text{wt (g)} \text{M.wt (gmol)} \times 1000 V \text{ (mL)}$$

$$0.250 \text{ M} = \text{wt (g)} 58.4 \text{ (gmol)} \times 10001 \text{ (mL)}, \text{ wt (g)} = 0.0146 \text{ gmL}$$

Example (4): How many grams of Na2SO4 should be weight out to prepare 500 mL of a 0.10 M solution.

$\mathbf{M}= \mathbf{wt}\ (\mathbf{g})\text{x } 1000/\ \mathbf{M.wt}\ (\mathbf{gmol}) \times \mathbf{V(mL)}$

$0.10\ \text{M}=\mathbf{wt}\ (\mathbf{g}) \times \mathbf{1000}\ (\mathbf{mL})\ /\ \mathbf{142}\ (\mathbf{gmol})\ \text{x}\ \mathbf{500}\ (\mathbf{mL})$

Wt=**7.1 g** **(**should be weight out to prepare 500 mL of a 0.10 M solution)

Example (5): Prepare 500 of 0.1 M HCl. If you know the percentage of acid is 37% and the Specific graffiti is 1.2.

M= $\boldsymbol{Sp.gr\ x\ \%\ x10 \div M.wt}$

M= 1.2 x 37x 10 /36.5 = 12.164 mol/L (هذه عيارية الحامض المركز)

M1x V1 = M2 x V2

12.164 x V1 = 1.2 x 500

V1= 49.325 take out this volume and complete it to 500 ml by D.W (يؤخذ هذا الحجم ويكمل الى حد العلامة 500 مليلتر بالماء المقطر)

Example (6): Calculate the number of grams in one mole of $CaSO_4 . 7H_2O$

Solution: One mole is the formula weight expressed in grams. The formula weight is Ca=40, 32, O=11x 16, H=14x1 = 262 g/mol

Example (7): Calculate the equivalent weight and normality for a solution of 6.0 M H_3PO_4 giving the following reactions

$$H_3PO_4\ (aq) + 3OH^-\ (aq) \rightleftharpoons PO_4^{-3}\ (aq) + 3H_2O\ (l)$$

$$H_3PO_4\ (aq) + 2NH_3\ (aq) \rightleftharpoons HPO_4^{-2}\ (aq) + 2NH_4^+(aq)$$

$$H_3PO_4\ (aq) + F^-\ (aq) \rightleftharpoons HPO_4^-\ (aq) + HF(aq)$$

(a) $EW = \frac{FW}{n} = \frac{97.994}{3} = 32.665 \qquad N = n \times M = 3 \times 6.0 = 18\ N$

(b) $EW = \frac{FW}{n} = \frac{97.994}{2} = 48.997 \qquad N = n \times M = 2 \times 6.0 = 12\ N$

(c) $EW = \frac{FW}{n} = \frac{97.994}{1} = 97.994 \qquad N = n \times M = 1 \times 6.0 = 6.0\ N$

Example (8): Calculate the molarity (M) of 100 ml of an aqueous solution contain 1.79 gm of NH3

احسب مولارية 100 ميللتر من محلول مائي يحتوي على 1.76 غم من الامونيا

$$M = \frac{wetx100}{\mathrm{M.wt\ xV(ml)}}$$

$$M = \frac{1.79x1000}{\mathrm{17.0\ x100}}$$

M= 1 Molar (Mole/L)

Example (9): Prepare 500 of 0.5 N sulphuric acid. If you know the percentage of acid is 96% and the Specific graffiti is 1.9.

Example (10): Prepare 250 of 0.1 M Nitric acid. If you know the percentage of acid is 69% and the Specific graffiti is 1.42.

Relation between Normality & Molarity

M = wt/ (mol wt * volume)
N = wt/ (eq wt * volume)

Eq wt = mol wt/ e transfer
Mol wt = Eq wt * e transfer

$$\text{Normality} = \frac{\text{wt}}{\text{(eq wt * volume)}}$$

$$\text{Normality} = \frac{\text{wt}}{\text{(mol wt/e transfer) * volume}}$$

$$\text{Normality} = \text{e transfer} * \frac{\text{wt}}{\text{mol wt * volume}}$$

Normality = e transfer * Molarity
N = e x M

Normality of 2 M H_2SO_4 is N = e x M = 2 x 2 = 4 N

Normality = Molarity x Molar mass/ Equivalent mass

OR Normality = Molarity x Basicity

OR Normality = Molarity x Acidity

Analytical Chemistry

Lecture No. 4/ Year 1

Dr. Omar Abdulhay Al-Taee

Department of Chemistry

College of Education for Pure Science

Mosul University/Iraq

Example (11): **Prepare 300 mL of 0.108 M of $BaCl_2 .2H_2O$?**

Ba = 137.32, Cl = 35.45, O = 16, H = 1

M. wt. of $BaCl_2 .2H_2O$ is =244.3 g/mol

$$M = \frac{wt.gram\ x\ \ 1000}{Mwt.\ x\ Vml}$$

$$0.108 = \frac{Wt.\ \ x\ 1000}{244.3\ x\ \ 300}$$

Wt. = 7.9153 grams were dissolved in water and diluted to 300 ml.

Example (12): **How many grams are contained in 500 ml of 0.2 M sodium carbonate**?

Mwt. Na_2CO_3 =106 g/ mol

$$\mathbf{M} = \frac{wt;gram\ x\ 1000}{MWt.\ x\ \ Vml} \quad ,$$

$$0.2 = \frac{Wt.\ \ x\ 1000}{106\ \ x\ \ 500}$$

Wt. = 10.6 grams are present in this solution

FORMALITY——INSTEAD OF MOLARITY

Formality: number of formula weight in liter of solution, is a substance's total concentration in solution without regard to its specific chemical form. There is no difference between a substance's molarity and formality if it dissolves without dissociating into ions. The molar concentration of a solution of glucose, for example, is the same as its formality. For substances that ionize in solution, such as NaCl, molarity and formality are different. For example, dissolving 0.1 mol of NaCl in 1 L of water gives a solution containing 0.1 mol of Na^+ and 0.1 mol of Cl^-. The molarity of NaCl, therefore, is zero since there is essentially no undissociated NaCl in solution. The solution instead, is 0.1 M in Na^+ and 0.1 M in Cl^-. The formality of NaCl, however, is 0.1 F because it represents the total amount of NaCl in solution.

الفورمالية هي عدد اوزان الصيغة الغرامي للمذاب في لتتر واحد من المحلول هو التركيز الكلي للمادة في المحلول بغض النظر عن شكلها الكيميائي المحدد

$$F= \frac{wt. \quad x \quad 1000}{gfwt. \quad x \quad Vml.}$$

F= No. Fw/ Liter of solution
F= gram of solute / one liter of solution x g.FW
Unit= g. FW/L

Example: 284 g of Na_2SO_4 has been dissolved in water (4 L). Calculate the formality if you know the atomic weight of Na= 23, S=32, O=16.

$$F = \frac{Wet\ x1000}{\text{gfw x V(mL)}}$$

$$F = \frac{284\ X\ 1000}{142\ X\ 4000} = 0.5 \text{ g.FW/L}$$

Molality (m): **The number of moles of solute per 1000 gm of solvent**
المولالية هو عدد مولات المذاب في 1000 غم من المذيب

Example: Exactly 4.57 grams of $BaCl_2 .2H_2O$ were dissolved in Water and diluted to 250 ml. What formal Concentration of barium chloride can get?

formal weight for $BaCl_2 .2H_2 O$ = 244

$$F= \frac{wt. \quad x \quad 1000}{gfwt. \quad x \quad Vml.} \quad , \quad F = \frac{4.57 \quad x \quad 1000}{244 \quad x \quad 250}$$

F = 0.0749

Percent Concentration (%)

Chemist can express concentration in terms of percentage (part in hundred) percent composition of a solution can be expressed in several ways. Three common methods are

Weight percentage (w/w) = $\frac{mass\ of\ solute}{mass\ of\ solution}$ x 100

Volume percent (V/V) = $\frac{volume\ of\ solute}{volume\ of\ solution} x\ 100$

Weight to volume percent (W/V) $= \frac{mass\ of\ solute}{volume\ \ of\ solution\ ml.}\ x\ 100$

Example: How many gram of sugar was found in 1 L of solution have w/v = 5 %?

% W.V = 5 → wt. = 5 /100 x V ml = 5/100 x1000
wt. = 50 g

Example: How many grams of NaCl was founded in 500 ml of solution has w/v % = 0.859?
% wt. V = 0.859 → wt.V= 0.859/100
wt. = 0.859/100 x Vml = 0.00859 x 500 = 4.295 g

Example: Calculate the w/w% for the solution prepared by dissolving 5 g of $AgNO_3$ in 100 ml of water.
Assumed density of water equal 1 g/ml.
wt. solvent = d x V = 1 x100 = 100 g
wt. solution = 100 + 5 = 105 g
% w/w = 5 /105 x 100 = 4.76 % for $AgNO_3$
Example: Calculate the V/V percentage for solution prepared by mixing 125 ml of methyl alcohol with 500 ml of water

$$(V/V)\ \% \quad = \quad \frac{V_{(solut)}}{V_{(solut)} + V_{(solvent)}} \quad \times \quad 100$$

$$= \quad \frac{125}{(125\ +\ \ 500)} \quad \times \quad 100\ =\ 20\ \%$$

Part per (thousand, million, billion)

For very dilute solutions, parts per million (ppm) is a convenient way to express concentration.

$$\textbf{ppt} = \frac{weight\ (gram\ )}{volume\ (ml.)} \text{X } 10^3$$

$$\textbf{ppm}= \frac{weight\ (gram)}{volume\ (ml.)} \text{X } 10^6$$

$$\textbf{ppb}= \frac{weight\ (gram)}{volume\ (ml.)} \text{X } 10^9$$

Example: How many grams of NaCl was needed to prepare 250 mL of solution contain 100 ppm Na^+ if you know At. wt. of Cl = 35.5, Na = 23?

$\textbf{ppm} = \frac{\textbf{mg}}{\textbf{L}}$ → 100 ppm = 100 mg/L = 0.1 g/L

Na^+ in 250 ml $= \frac{0.1 \times 250}{1000} = 0.025$ g

$$\text{NaCl (g)} = \frac{\textbf{Na+ g * M.wt .of NaCl}}{\textbf{At .wt .of Na+}}$$

$$\text{wt. NaCl (g)} = \frac{0.025 * 58.5}{23} = 0.0636 \text{ g NaCl}$$

Example: 155.3 g for aqueous solution sample contain 1.7 x10^{-4} g PO_4^{-2}. Calculate the concentration of PO_4^{-2} by ppm?

Assuming the density of water is 1.0g/ml, we can translate 155.3 g of water to be 155.3 mL of water!

$$ppm = \frac{Wt_{(solut)}}{Wt_{(solution)}} \times 10^6$$

$$= \frac{1.7 \times 10^{-4}}{155.3} \times 10^6 = 1.1\ ppm$$

Example: What is the concentration in parts per million of a 500 g sample of drinking water that contains 45 mg of lead?

Explanation:

PPM can be better understood in typical units of concentration!

PPM can also be represented as mg/L!

Assuming the density of water is 1.0g/ml, we can translate 500.0g of water to be 500.0mL of water!

Therefore,

Turning 500.0mL of water into L first;
500 mL·1 L1000 mL=0.5 L
For PPM, we want to keep our mass in mg, which was already supplied!
As such,
45 mg0.5 L=90 mg/L=90 ppm

Relation between ppm and Molarity:

$$ppm = M \times M.Wt \times 10^3$$

Homework:

1. How many mole and mmole of $CuSO_4$ are found in 250 ml solution contain 5 ppm?

Analytical Chemistry

Lecture No. 5/ Year 1

Dr. Omar Abdulhay Al-Taee

Department of Chemistry

College of Education for Pure Science

Mosul University/Iraq

The law of mass action

Law of chemical equilibrium قانون الاتزان الكيميائي

Most reaction which are useful for chemical analysis proceed rapidly to a state of chemical equilibrium in which reactants and products exist in constant and predictable ratios.

تنتقل معظم التفاعلات المفيدة للتحليل الكيميائي بسرعة إلى حالة من التوازن الكيميائي حيث توجد المواد المتفاعلة والمنتجات بنسب ثابتة ويمكن التنبؤ

The velocity of a chemical reaction is directly proportional to the product of the active masses of reacting substance.

تتناسب سرعة التفاعل الكيميائي طرديًا مع ناتج الكتل النشطة للمادة المتفاعلة

Let us consider first the simple reversible reaction at constant temperature

$$aA + bB \rightleftharpoons cC + dD$$

The velocity with which A & B react is proportional to their concentration.

تتناسب السرعة التي يتفاعل بها A & B مع تركيزهما.

Rate of forward reaction (f) سرعة التفاعل الامامي هي

Rate α $\{A\}^a$ $\{B\}^b$

Rate = $K_f [A]^a \times [B]^b$

Where K_f is a constant known as the velocity coefficient

A & b are number of moles for A & B respectively.

Similarly, the velocity with which the reverse reaction occurs is given by

Rate of b = $K_b [C]^C . [D]^d$

At equilibrium, the velocities of the reverse and forward reactions will be equal and therefore: عند التوازن فان سرعة التفاعل الامامي تساوي سرعة التفاعل الخلفي

Rate of f = Rate of b

Or $\frac{[C]\ [D]}{[A]\ [B]} = \frac{K}{K} = K_{eq}$

$$Keq = \frac{[C]\ [D]}{[A]\ [B]}$$

K_{eq} = is the equilibrium constant of the reaction at the given temperature

Some species dissociate stepwise, and an equilibrium constant can be written for each dissociation step, for example بعض الأنواع تتفكك تدريجيًا ، ويمكن كتابة ثابت التوازن لكل خطوة تفكك ، على سبيل المثال

$A_2B \rightleftharpoons AB + A$ $\quad K_1 = \frac{[A][AB]}{[A2B]}$

$AB \rightleftharpoons A + B$ $\quad K_2 = \frac{[A[B]}{[AB]}$

The overall dissociation process of the compound is sum of these two equation as follows

$$K_{eq} = [A]^2[B] / [A_2B]$$

By multiplying K_1 with K_2 together

$K_{eq} = K_1 \times K_2$

$$K_{eq} = \frac{[A][AB]}{[A2B]} \times \frac{[A][B]}{[AB]}$$

$$Keq = \frac{[A]^2\ [B]}{[A2B]}$$

The results may be expressed in words

When equilibrium is reached in reversible reaction at constant temperature the product of molar concentration of resultants divided by the product of molar concentration of the reactants. each concentration being raised to a power equal to the number of moles of that substance taking part in the reaction is constant.

عندما يتم الوصول إلى التوازن في تفاعل عكسي عند درجة حرارة ثابتة، يكون ناتج التركيز المولي للنواتج مقسومًا على ناتج التركيز المولي للمواد المتفاعلة. كل تركيز يتم رفعه إلى قوة مساوية لعدد مولات تلك المادة التي تشارك في التفاعل يكون ثابتًا.

Factor Affecting the Reaction Equilibrium بعض العوامل التي تؤثر على الاتزان الكيميائي

1- Temperature

Reactions are of two type

Exothermic Reactions ΔH = (-) negative التفاعلات الباعثة للحرارة

Endothermic Reactions ΔH = (+) positive التفاعلات الماصة للحرارة

$$CO + 2H_2O \rightleftharpoons CH_3OH \qquad \Delta H = -92\ kJ$$

The reaction is exothermic (to the left) and of course endothermic (to the right). Forward reaction is exothermic and backward reaction is endothermic, when temperature decreased the reaction proceed to left thus methanol concentration increased and (K) value increase also.

التفاعلات الماصة للحرارة يكون التفاعل الأمامي طاردًا للحرارة ويكون التفاعل الخلفي ماصًا للحرارة، وعندما تنخفض درجة الحرارة، يتقدم التفاعل لليسار وبالتالي يزداد تركيز الميثانول ويزيد (K) أيضًا.

2- Pressure

Pressure has the high effect on (K) value in gas phase reaction increasing the pressure will decrease the volume and directed the reaction to the direction which cause reduction in the system (reduction in the total number of molecules

$$\underset{gas}{N_2} + \underset{gas}{3H_2} \rightleftharpoons \underset{gas}{2NH_3}$$

الضغط له تأثير كبير على قيمة (K) في تفاعل الطور الغازي، حيث يؤدي زيادة الضغط إلى تقليل الحجم وتوجيه التفاعل إلى الاتجاه الذي يتسبب في انخفاض في النظام (انخفاض في العدد الإجمالي للجزيئات)

3- Concentration

K value depend on concentrations of the reactants and product using lechatle principle one can predict the direction of the reaction **تعتمد** قيمة () على تراكيز المواد المتفاعلة والناتجة حسب قانون ليه شاتليه ولذلك يمكن التنبؤ باتجاه التفاعل

$$3I^- + 2Fe \rightleftharpoons I^{-3} + 2Fe^{+2}$$

If one of the participant concentrations is changed then the system will search for equilibrium. Adding Fe^{+2} to the solution will direct the reaction to the left.

تعتمد قيمة ثابت الاتزان على تركيز المتفاعلات والنواتج وفي التفاعل أعلاه إضافة ايون الحديدوز يوجه التفاعل نحو اليسار وحسب قاعدة ليشاتليه

4- **Catalyst**

Catalyst can increase the velocity of the reactions and decrease the time required for reaching the equilibrium state but cannot change the (k) value.

العامل المساعد او المحفز يمكن ان يزيد من سرعة التفاعل للوصول الى حالة توازن ولكن ليس له أي تأثير على قيمة K

5- **Amount of solvent:**

When the volume of the solvent increase the reaction can be directed to the direction was the number of the of molecules is bigger.

زيادة كمية المذيب نوجه التفاعل باتجاه الجهة التي تحوي على أكبر عدد من الجزيئات

Le Chatelier's principle

When the system in equilibrium any changes in the values of the equilibrium factors lead to a deviation in the system in a way to decrease the effect of this change. These factors are temperature, pressure, concentration, amount of the solvent and common ion effect. When the system is subjected to such potential it directed the reaction toward the side decrees the effect of the potential.

عندما يكون النظام في حالة توازن فان تسليط جهد بتغيير في عوامل الاتزان كدرجة الحرارة، الضغط، التركيز، كمية المذيب، الخ. قد يوجه نظام التفاعل الى الاتجاه الذي يقلل من هذا التغيير او الجهد.

Example: The chemical A and B react as follows to produce C and D

$$A + B \rightleftharpoons C + D$$

If A= 0.2 mole, B= 0.5 mole, K= 0.3, Calculate the concentration of all substances

A	+	B	$\rightleftharpoons$	C	+	D	
0.2		0.5		0		0	at initial of reaction
0.2 – x		0.5 - x		x		x	

$$K = \frac{[C]\,[D]}{[A]\,[B]} ,$$

$$0.3 = \frac{(x)(x)}{(0.2-x)(0.5-x)}$$

$0.3 = X^2 / (0.2- x) (0.5 – x)$

X is very small so can be neglected

X = 0.173 M

Example: The chemical A and B react as follows to produce C and D, ionization constant (K) for this reaction is = 2×10^{16}, [A]= 0.2, [B]= 0.5 calculate the concentration for all substance.

Since the K value is very large number, the reaction of A with B is complete leaving only trace of A at equilibrium

$$A + B \longrightarrow C + D$$

X (0.5 + x) 0.2 –x 0.2 –x

$$K= \frac{[C][D]}{[A][B]} = \frac{(0.2-x)(0.2-x)}{(x)(0.3+x)}$$

$$2 \times 10^{16} = \frac{(0.2)(0.2)}{x\ (0.30)}$$

$X=6.7 \times 10^{-15}$ M usually analytically undetectable

Example: Calculate the equilibrium concentrations of A and B in a 0.1 M solution of a weak electrolyte AB with an equilibrium constant 3×10^{-6}.

Answer:

Both A and B are unknown concentration and equal to (X)

$$AB \rightleftharpoons A + B$$

0.1 - x x x

$$K_{eq} = \frac{[A][B]}{[AB]}$$

$$3 \times 10^{-6} = \frac{(x)(x)}{(0.1-x)}$$ تحذف قيمة x الموجودة في المقام

$$3 \times 10^{-6} = \frac{(x)(x)}{(0.1)}$$

X^2= 3x 10

X = $\sqrt[2]{3 \text{ x } 10 - 7}$

X = [A] = [B]= 5.5 x 10^{-4} M

Home work

1- Calculate the equilibrium concentrations of A and B in 0.10M solution of AB with equilibrium constant = 3 x 10^{-6}.

2- A and B react as follows

$$A + B \rightleftharpoons 2C$$

Assume 0.10 mol of A react with 0.20 mol of B in volume of 1000 mil. And equilibrium constant K_{eq} =1 x 10^{10}

Stoichiometric Calculations

In **chemistry** it is very important to understand the relationship between reactants and products in a reaction. **Stoichiometry** is exactly that. It is the quantitative relation between the number of moles (and therefore mass) of various products and reactants in a **chemical reaction**.

يتم تعريف Stoichiometric على أنها العلاقة الوزنية بين المواد المتفاعلة. يقدم هذا القسم استعراضًا موجزًا لقياس العناصر الكيميائية وتطبيقاتها في الحسابات الكيميائية.

A balanced chemical equation is a statement of the combining ratio. or stoichiometry, between reacting substances and their products. Thus, the equation هي وصف لنسب وتركيب المواد الداخلة والناتجة من التفاعل

$$2NaI + Pb(NO_3)_2 \rightleftharpoons PbI_2 + 2NaNO_3$$

2mole 1 mole 1mole 2mole

Indicates that 2 mol of aqueous sodium iodide combine with 1 mol of aqueous lead nitrate to produce 1 ml of solid lead iodide and 2 mol of aqueous sodium nitrate.

Example: What mass of $AgNO_3$ is needed to convert 2.33 g of Na_2CO_3 to Ag_2CO_3? What mass of Ag_2CO_3 formed?

Na_2CO_3 + $2AgNO_3$ $\rightleftharpoons$ Ag_2CO_3 + $2NaNO_3$

no. of mol of Na_2CO_3 = $\frac{\mathbf{2.33}}{\mathbf{106}}$

= 0. 02198 mol Na_2CO_3

$2AgNO_3$	Na_2CO_3
2 mol	1 mol
X	0.02198

X = $\frac{2 \quad x \quad 0.02198}{1}$ = 0.04396 mol of $AgNO_3$

Ag =107.86 , N= 14 , O = 16 0.

Mwt. Of $AgNO_3$ = 169. 86 g /mol

no. of mol = $\frac{wt.}{Mwt.}$,

0.04396 = $\frac{wt.}{169.9}$

Wt.= 7. 47 grams of $AgNO_3$ is needed to the reaction

Na_2CO_3	**Ag_2CO_3**
1 mol	**1 mol**
0.02198	**x**

No.of mol = $\frac{\boldsymbol{weight}}{\boldsymbol{Mwt.}}$

Mwt. Of Ag_2CO_3 =275.7

wt.= 0.02198 x 275.7

Wt. = 6.059 grams of Ag_2CO_3 produced

Example: What mass of Ag_2CO_3 is formed when 25 ml of 0.20 M $AgNO_3$ are mixing with 50 ml of 0.08 M Na_2CO_3?

$2AgNO_3$ + Na_2CO_3 $\longrightarrow$ Ag_2CO_3 +$2NaNO_3$

25 X 0.20 = 5 mmole of $AgNO_3$

$50 \times 0.08 = 4$ mmole of Na_2CO_3

Because each $CO_3^{=}$ ion react with two Ag^+

$4 \times 2 = 8$ mmole of Ag^+ the carbonate need

$2AgNO_3$ $\quad\quad$ Ag_2CO_3

2m mol $\quad\quad$ 1 m mol

5 $\quad\quad$ x

X = 5 x 1 / 2

X=2.5 mmole of Ag_2CO_3 is produce

mmole = wt. gram / Mwt.

mass of Ag_2CO_3= 0.0025 X 275.7

= 0.689 gram of Ag_2CO_3 is produce

Home work:

1) Calculate the mass of silver bromide produces upon mixing 25 ml of 0.066 M silver nitrate with 40 ml of 0.0397 M Potassium bromide? Atomic Weight, Ag = 107.8, N =14, O = 16, K= 39, Br=79.9

2) How many mil liters of 0.669 F $AgNO_3$ will be needed to convert 0.348 gram of Na_2CO_3 to Ag_2CO_3?