Analytical chemistry

First Stage/ College of Education for pure science/Department of Chemistry

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Lecture 1

Introduction

Chemistry

Is a science concerned with the study of matter, including its composition, structure, physical properties, reactivity, changes occur to it and emitted or absorbed energies accompany these changes.

There are many approaches to studying chemistry, but, according to the type of materials and the purpose of their studies, we traditionally divide it into five fields: organic, inorganic, physical, biochemical, and analytical. Other branches are theoretical chemistry, quantum chemistry, nuclear chemistry etc.

Analytical Chemistry

Is a measurement science deals with the study on the identification of materials composition and the determination of the amount of each component presented by an expression of concentration directly or indirectly (after separation). Analytical chemistry helped in understanding the natural phenomena through providing the knowledge about quantitative relations of the phenomena. It develops chemistry science and other sciences since most of the laws based on the quantitative analysis.

Analytical chemistry consists of:

1- 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).

2- 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:

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

B- 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).

C- 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). (4th 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

$NaCl_{(s)}+H_2O_{(l)} \rightarrow$ Salt Solution.

Types of Solution:

Concentrated solution: has a large amount of solute.

Dilute solution: has a small amount of solute.

Classification of solutions according to amount of solute:

(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).

Classification of solution based on solute particle size:

تصنيف المحاليل تبعاً لحجم جزيئات المذاب في المحلول

(1)***True solution:*** A homogeneous mixture of two or more substances in which substance (solute) has a particle size less than 1nm 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.

Lecture 2

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.

Step one: Choosing a method أختيار الطريقة

The essential first step in any quantitative analysis is the selection of a method that should be suitable to the nature of the sample, number of samples and accuracy required. The selected method is usually represents a compromise between the accuracy required and the time and money available for the analysis. In addition, some samples like archaeological or forensic samples need a nondestructive method to keep the samples without destruction.

Step 2: Sampling أختيار العينات أو النماذج

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.

أختيار النموذج خطوة مهمة وحرجة ، اذ يجب أن يكون النموذج متجانس ويمثل المادة واذا كانت كمية المادة كبيرة يمكن إعداد عدة نماذج وسحقها وخلطها لأخذ 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 نقاط اساسيه يجب ان تؤخذ بعين الأعتبار لتهيئه النموذج لعمليه التحليل:

أولا: يجب ان يحضر نموذج متجانس من العينة باستخدام عملية الطحن والسحق والمزج.

ثانيا: اختيار مذيب مناسب.

ثالثاً: تقليل حجم حبيبات العينه.

رابعاً: تحويل العينة الى طور او صيغه تمكن الكاشف من مهاجمة او الارتباط مع العينه

خامساً: توخي الحذر وتجنب اي تداخلات قد تؤثر على عمليه التقدير وبالتالي تؤدي الى تلوث العينه.

Step four: Procurement of the measured wanted quantity of the sample قياس كمية من النموذج

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 أخذ وزن معين جاف من العينه إذا كان نموذج التحليل صلباً أما إذا كان نموذج التحليل سائلاً فيجب أخذ حجم معين من العينه لإجراء عمليه التحليل.

Step five: Dissolution of the measured sample إذابة النموذج المقاس

Most analyses are performed on solutions of the sample made with a suitable solvent. Ideally, the solvent should dissolve the entire sample, including the analyte, rapidly and completely and should not interfere in the analysis. Water is a magic solvent for almost all the inorganic materials and some of the organic materials. Organic materials require organic solvents like alcohols, carbontetrachloride and chloroform. Fusion is used for melting samples which do not dissolve in common solvents.

معظم التحاليل تؤدي لمحاليل النماذج المذابة في مذيب مناسب والذي يعمل على إذابة النموذج تماماً وبوقت قصير وبدون أن يتداخل مع المادة المراد قياسها. يعتبر الماء المذيب المثالي أو السحري لمعظم المواد اللاعضوية وبعض المواد العضوية أما بقية المواد العضوية فتحتاج الى مذيبات عضوية مثل الكحولات، رابع كلوريد الكاربون والكلوروفورم. الانصهار يستخدم لصهر العينات التي لاتذوب في المذيبات الشائعة.

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.

لقياس النموذج بدون أي تداخل بسبب وجود المكونات الأخرى، يتم أستخدام الفصل الكيميائي وكذلك المواد الماسكة لتجنب حدوث التداخل أثناء القياس.

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 بقياس المادة أو المكون قيد الدراسة بإستخدام وسيلة مناسبة مثل الترسيب، تكوين اللون، التسحيح......الى آخره.

Step eight: Calculation and data analysis 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.

Parameters	Meaning
Concentration	تركيز
Expression	تعبير
Gram equivalent	المكافئ الغرامي
Density	الكثافة
Specific gravity	الوزن النوعي
Dillution	تخفيف
Solution	محلول
Solute	مذاب
Solvent	مذيب
Salt	ملح
Molarity	مولارية
Formality	فورمالية

Normality	عيارية
Reducing agent	عامل مختزل
Oxidizing agent	عامل مؤكسد
Acid	حامض
Base	قاعدة
Units	وحدات
Microgram ($\mu g = 10^{-6}$ gm)	مايكروغرام
Nanogram ($ng = 10^{-9}$ gm)	نانوغرام
mg	ملغرام
gm	غرام
Kg	كيلوغرام (كغم)
Percent	نسبة مئوية
aqueous	مائي
Organic solvent	مذيب عضوي
Molecular weight	الوزن الجزيئي
Molecular formula	الصيغة الجزيئية
Equivalent weight	الوزن المكافئ
Defined	يعرف
ppm	جزء لكل مليون
ppb	جزء لكل بليون
Substitution	تعويض
per	لكل
Milliliter (ml)	مللتر
Liter (L)	لتر

Method of expression of concentration

1. Weight of solute in a certain volume of solvent or solution

وزن المذاب في حجم معين من المذيب أو المحلول.

Normality (N)

Number of gram equivalent of the solute 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 المذاب في لتر واحد من المحلول مقسوم على الوزن المكافئ

The units are eq./L

For solid material

$$N = Wt \times 1000 \,/\, Eq.wt \times V(ml)$$

For liquid material

$$N = D \text{ or } Sp.gr \times \% \times 10 \,/\, Eq.wt$$

Density (D) = كثافة السائل
Specific gravity (Sp.gr) = الوزن النوعي
Equivalent (Eq.wt) = الوزن المكافئ
Weight (wt) = وزن المذاب بالغرام

Dilution Equation

Conc. Dil.

$$N_1 \times V_1 = N_2 \times V_2$$

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 = 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

$$M = Wt \times 1000 / M.wt \times V(ml)$$

Liquid material

$$M = d \text{ or } sp.gr \times \% \times 10 / M.wt$$

Dilution equation

Conc. Dil.

$$M_1 \times V_1 = M_2 \times V_2$$

Calculation of equivalent weight:

Molecular weight = Σ Atomic weight × no. of Atoms

1-Acids:

$$eq.wt\ (acid) = \frac{M.wt}{no.of\ ionized\ hydrogen\ atoms(H+)}$$

Ex: Calculate the equivalent weight for hydrochloric and sulphuric acid.

For HCl:

$$eq.wt\ (acid) = \frac{M.wt}{no.of\ ionized\ hydrogen\ atoms(H+)}$$

$$eq.wt = \frac{(1+35.5)\ g/mole}{1}$$

$$= 36.5\ g/eq$$

For H_2SO_4:

$$eq.wt = \frac{[(2\times1)+(1\times32)+(4\times16)]g/mole}{2}$$

$$= 49\ g/eq$$

2- Bases:

$$eq.wt\ (base) = \frac{M.wt}{no.of\ ionized\ hydroxide\ groups\ (OH^-)}$$

Ex: Calculate the equivalent weight for sodium hydroxide and aluminum hydroxide (Atomic weight: H = 1,O=16, Na=23, Al=27).

For NaOH:

$$eq.wt\ (base) = \frac{M.wt}{no.of\ ionized\ hydroxide\ groups\ (OH^-)}$$

$$= \frac{(23+1+16)g/mole}{1} = 40g/eq$$

For $Al(OH)_3$:

$$= \frac{[27+(3\times1)+(3\times16)]g/mole}{3} = 26\ g/eq$$

3- Salts:

$$\text{eq.wt (Salt)} = \frac{\text{M.wt}}{\text{no.of cations} \times \textit{oxidation number of cations}}$$

Ex: Calculate the equivalent weight for calcium chloride and ferric sulphate (Atomic weight: Ca= 40,Cl=35.5, S=32, Fe=56, H=1, O=16).

For $CaCl_2$

$$\text{eq.wt} = \frac{\text{M.wt}}{\text{no.of cations} \times \textit{oxidation number of cations}}$$

$$= \frac{(40+(2\times35.5)g/mole}{2\times1} = 55.5\ g/eq$$

For $Fe_2(SO_4)_3$

$$= \frac{[(2\times56)+(3\times32)+(12\times16)]\ g/mole}{3\times2} = 66.667\ g/eq$$

4- Oxidizing and Reducing agents:

$$\text{eq.wt (Oxidizing agent)} = \frac{\text{M.wt}}{\text{no.of gained electrons}}$$

$$\text{eq.wt (Reducing agent)} = \frac{\text{M.wt}}{\text{no.of lost electrons}}$$

Ex: Calculate the equivalent weight for potassium permanganate (Atomic weight: K= 39, Mn= 55, O=16).

$$\text{eq.wt } (KMnO_4) = \frac{\text{M.wt}}{\text{no.of gained electrons}}$$

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

$$= \frac{[39+55+(4\times16)]\ g/mole}{5} = 31.6\ g/eq$$

التكافؤ	الرمز الكيميائي	اسم المجموعة الذرية	
ثنائي	CO_3^{2-}	كربونات	Carbonates
أحادي	HCO_3^{-1}	بيكربونات	Hydrogen Carbonates
أحادي	NO_2^{-1}	نتريت	Nitrites
ثنائي	SO_3^{-2}	كبريتيت	Sulphites
ثنائي	$S_2O_3^{-2}$	ثايوكبريتات	Thiosulphates
أحادي	NO_3^{-1}	نترات	Nitrates
ثنائي	SO_4^{-2}	كبريتات	Sulphates
ثلاثي	PO_4^{3-}	فوسفات	Phosphates
ثنائي	$B_4H_7^{-2}$	بورات	Borates
أحادي	NH_4^{+1}	امونيوم	Amonium
أحادي	OH^{-1}	هيدروكسيل	Hydroxyl
أحادي	CN^{-1}	سيانيد	Cyanide
أحادي	SCN^{-1}	ثايوسينات	Thiocyanate
أحادي	$CH_3CO_2^{-1}$	اسيتات	Acetates

تكافؤه	الرمز الكيمياني	اسم الأيون	
ثنائي	S^{-2}	كبريتيد	Sulphide
أحادي	Cl^{-1}	كلوريد	Chloride
أحادي	Br^{-1}	بروميد	Bromide
أحادي	I^{-1}	ايوديد	Iodide
أحادي	Ag^{+1}	فضة	Silver
ثنائي	Pb^{2+}	الرصاص	Lead
أحادي	Hg_2^{+1}	الزئبقوز	Mercurous
ثنائي	Cu^{+2}	النحاسيك	Copper
ثنائي	Ca^{2+}	الكادميوم	Cadmium
ثلاثي	Bi^{+3}	بزموث	Bismuth
ثنائي	Hg^{+2}	زئبقيك	Mercuric
ثنائي	Fe^{+2}	الحديدوز	Iron (II)
ثلاثي	Fe^{+3}	الحديديك	Iron (III)
ثلاثي	Cr^{+3}	كروم	Chromium
ثلاثي	Al^{+3}	المنيوم	Aluminum
أحادي	Mn^{+2}	منغنيز	Manganese
ثنائي	Zn^{+2}	زنك	Zinc
ثنائي	Co^{+2}	كوبلت	Cobalt
ثنائي	Ni^{+2}	نيكل	Nickel
ثنائي	Ca^{+2}	كالسيوم	Calcium
ثنائي	Ba^{+2}	باريوم	Barium
أحادي	K^{+1}	بوتاسيوم	Potassium
ثنائي	Mg^{+2}	مغنيسيوم	Magnesium
أحادي	Na^{+1}	صوديوم	Sodium
أحادي	H^{+1}	هيدروجين	Hydrogen
ثنائي	O^{-2}	اوكسجين	Oxygen

Lecture 3

Ex.1: How many milligrams are in 0.250 mmole Ferric oxide.

Solution:

wt (mg)=mmole×M.wt (mg /mmol) =0.250 mmole ×159.7mg/mmol =39.9 mg

Ex.2: Solution was prepared by dissolving 1.26 g of silver nitrate in a 250 ml volumetric flask and diluted to the mark. Calculate the molarity of the silver nitrate solution. How many millimoles of silver nitrate were dissolved.

Solution:

$$M = \frac{wt.(gram)\ x\ \ 1000}{M.wt\ x\ V(ml)}$$

$$M = \frac{1.26\,g\ x\ \ 1000}{169.9\ g/mol\ x\ 250\ ml}$$

M= 0.0297 mol/L

Millimoles=M (mmol/mL)×V(ml) = 0.0297 (mmol/mL)×250 mL= 7.42 mmole

Ex.3: How many grams of sodium sulphate should be weight out to prepare 500 ml of a 0.10 M solution.

$$M = \frac{wt.(g)\ x\ \ 1000}{M.wt\ x\ V(ml)}$$

$$0.1 = \frac{wt.(g)\ x\ 1000}{142\ g/mol\ x\ 500\ ml}$$

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

Ex. 4: Prepare 250 ml of 0.2M hydrochloric acid if you know the percentage of acid is 32 and the Specific graffiti is 1.14.

$$M = \frac{Sp.gr \times \% \times 10}{M.wt}$$

$$M = \frac{1.14 \times 32 \times 10}{36.5}$$

M = 9.996 mol/L (مولارية الحامض المركز)

Conc. Dil.

$$M_1 \times V_1 = M_2 \times V_2$$

$$9.996 \times V_1 = 0.2 \times 250$$

V1= 5.00 ml take out this volume and complete it to 250 ml by D.W

[يؤخذ هذا الحجم ويكمل الى 250 مللتر بالماء المقطر(حد العلامة)].

Ex.5: Prepare 500 ml of 0.23M of $BaCl_2.2H_2O$ (Barium chloride)

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

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

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

$$0.23 = \frac{Wt. \times 1000}{244.3 \times 500}$$

Wt. = 28.0945gm were dissolved in D.W and diluted to 500 ml.

Ex.6: How many grams are contained in 500 ml of 0.2 M sodium carbonate

M.wt of Na_2CO_3 =106 g/ mol

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

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

Wt = 10.6 gm are present in this solution.

Ex.7: Calculate the concentration of potassium ion in gram per liter after mixing 100 ml of 0.25 M KCl and 200 ml of 0.1M K_2SO_4 .

Solution:

no. of mmol (K^+) = mmol (KCl) + 2 mmol (K_2SO_4)

= (M × V) KCl + (M × V) K_2SO_4

$= (0.25 \times 100)\ KCl + 2(0.1 \times 200)\ K_2SO_4$

$= 25 + 40 = 65$ mmol of K^+ in 300 ml

wt. = mmole × M.wt. = 65×39.1

$= 2541.5$ mg $= 2.5415$ gm in 300 ml   mg = 10^{-3} gm

Conc . = 2.5415 gm ×1000 ml /300 ml = 8.4716 g/ L

Homework:

1- Prepare 500 of 0.5 N sulphuric acid. If you know the percentage of acid is 96% and the Specific graffiti is 1.9.

2- Calculate the molarity (M) of solution result from dissolving 20g of sodium phosphate in 2.0 L of solution .

3- Calculate the normality of the solutions containing the following: (a) 5.3 g/L sodium carbonate (when the CO_3^{2-} reacts with two protons). (b) 5.267 g/L potassium dichromate (the Cr is reduced to Cr^{3+}) .

4- What volume of the 0.25 M of potassium dichromate solution must be diluted to prepare 500 ml of 0.1M solution?

5- prepare 500 ml of 0.01M solution of Na^+ from solid sodium carbonate.

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

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

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

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

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

or   Normality = Molarity x Basicity

or   Normality = Molarity x Acidity

EX. **Calculate the equivalent weight and normality for a solution of 6.0 M phosphoric acid (H_3PO_4) giving the following reactions.**

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

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

$$H_3PO_4(aq) + F^-(aq) \rightleftharpoons H_2PO_4^-(aq) + HF(aq)$$

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

FORMALITY——INSTEAD OF MOLARITY

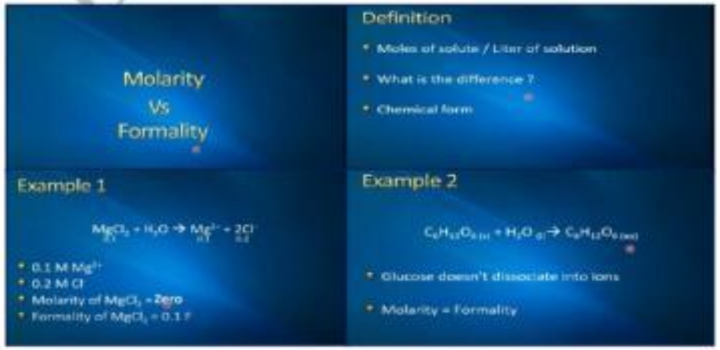
Formality: number of formula weight in liter of solution, is a substance's total concentration in solution without regard to its specific chemical form. There is no difference between a substance's molarity and formality if it dissolves without dissociating into ions. The molar concentration of a solution 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 1L 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 0.1F because it represents the total amount of NaCl in solution.

الفورمالية (Formality): يعرف المحلول الفورمالي لمادة بأنه ذلك المحلول الذي يحتوي على وزن صيغة كيميائية من تلك المادة في لتر من المحلول.

وغالباً ما تكون المولارية والفورمالية متماثلة خصوصاً عندما يكون المركب من النوع التساهمي الأصرة اذ يوجد في المحلول على شكل جزيئات.

$$F = \frac{wt \times 1000}{F.wt \times Vml}$$

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



Abstract

Formality is a measure of the concentration of a solute in a solution, expressed in terms of the formal concentration of the solute. It is denoted by the symbol "F". In the context of chemistry, formality is defined as the number of formula weights of a substance per liter of solution. The formula weight is the sum of the of the atomic weights of each atom in the empirical formula of the substance.

The formula for formality is given by:

F= n /V , Where: n is the number of moles of the solute

V is the volume of the solution in liters.

It is important to note that formality is used instead of molarity when dealing with ionic compounds that can dissociate in solution, as it gives a more accurate measure of the concentration of the solute.

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

$$F = \frac{wt \times 1000}{F.wt \times V(ml)}$$

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

Example: Exactly 4.57 grams of $BaCl_2 . 2H_2O$ were dissolved in Water and diluted to 250 ml. Calculate the formal Concentration of barium chloride and Cl^- in this solution?

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

$$F = \frac{wt \times 1000}{F.wt \times Vml}$$

$$F = \frac{4.57 \times 1000}{244 \times 250}$$

$$= 0.0749 \text{ FW/L or (F)}$$

$BaCl_2 \longrightarrow 2Ba^{+2} + 2Cl^-$

0.0749 F $\qquad$ 0.0749 F×2= 0.149 F Cl^-

Molality (m): **is defined as the number of moles of solute per kilogram of solvent.**

المولالية: هو عدد مولات المذاب في 1كغم (1000غرام) من المذيب

Ex. What is molal concentration of the sodium hydroxide solution obtained by dissolving 4 grams of sodium hydroxide in 500 grams of water ?.

no of moles = wt/M.wt

= 4/40

= 0.1 mole

Molality = no. moles of solute/ 1000 grams of solvent

$$= 0.1 \times \frac{1000}{500}$$

= 0.2 mole/Kg

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:

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

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

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

Ex.: How many gram of sugar was found in 1 L of solution have

(w/v%) = 5

(W/V)= 5% → wt. = 5 /100 × V ml = 5/100 ×1000

wt. = 50 g

Ex: How many grams of NaCl was founded in 500 ml of solution has w/v % = 0.859

% (w/v) = wt/Vml× 100

$0.859 = \frac{wt}{500} \times 100$

wt= 4.295 gm

Ex : Calculate the(W/W%) for the solution prepared by dissolving 5 g of silver nitrate in 100 ml of water.

Assumed density of water equal 1 g/ml.

wt. solvent = d × v = 1 x100 = 100 g

wt. solution = 100 + 5 = 105 g

% w/w = 5 /105 × 100 = 4.76 % for $AgNO_3$

Ex: Calculate the (V/V%) for solution prepared by mixing 125 ml of methyl alcohol with 500 ml of water.

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

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

Part per (thousand, million, billion)

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

ppt$= \frac{weight\ (gram)}{volume\ (mL)} \times 10^3$

ppm$= \frac{weight\ (gram)}{volume\ (mL)} \times 10^6$

ppb$= \frac{weight\ (gram)}{volume\ (ml)} \times 10^9$

Ex : 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

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

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

NaCl (g) $= \frac{Na+\,g \times M.wt\ .of\ NaCl}{At\ .wt\ .of\ Na+}$

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

Chemical equilibrium الاتزان الكيميائي

Chemical reactions divided into:

1- Irreversible reaction: **التفاعلات غير العكسية**

A chemical reaction in which entire amount of the reactants is converted into products, it can be started from the reactant side only (i.e. only, the forward reaction takes place) and represented by a normal arrow ($\longrightarrow$) so that the reactants are completely consumed in the reaction, such as:

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

هي التفاعلات التي يحدث فيها استهلاك تام لتراكيز المواد المتفاعلة وتحويلها الى نواتج وتجري في اتجاه واحد ويمكن تمثيلها بسهم واحد في معادلة التفاعل يبدأ من المواد المتفاعلة كما في المثال أعلاه.

2- Reversible reaction

Is a reaction where the reactants form products, which react together to give the reactants back, it can be started from either side (i.e. the forward and backward reactions are in equilibrium) and represented by an equilibrium arrow ($\longleftrightarrow$) so that the reaction is never complete, such as:

$$CH_3COOH + NaOH \longleftrightarrow CH_3COONa + H_2O$$

هي التفاعلات التي لايحدث فيها استهلاك تام لتراكيز المواد المتفاعلة حيث ان نواتج التفاعل تتفاعل مع بعضها لتكون المتفاعلات مرة أخرى. هذه التفاعلات تجري في أتجاهين ويمكن تمثيلها بسهم التوازن في معادلة التفاعل كما في المثال اعلاه.

Law of chemical equilibrium قانون الاتزان الكيميائي

Most of the reactions that are useful for chemical analysis proceed rapidly to a state of chemical equilibrium in which reactants and products exist in constant ratios. The knowledge of this ratio permits the chemists to decide whether the reaction is suitable for chemical analysis or not.

Equilibrium constant expressions are algebraic equations that relate to the concentrations of reactants or products in a chemical reaction to one another in means of numerical quantity called equilibrium constant.

Lecture 5

تنتقل معظم التفاعلات المفيدة للتحليل الكيميائي بسرعة إلى حالة من التوازن الكيميائي حيث توجد المواد المتفاعلة والناتجة بنسب ثابتة. المعرفة بهذه النسب يسمح للكيميائيين القرار فيما اذا كان التفاعل مناسب للتحليل الكيميائي أم لا. يعبر عن الاتزان الكيميائي بمعادلات جبرية تتعلق بتراكيز المتفاعلات أو النواتج في تفاعل ما بوسائل كمية عددية تسمى ثابت الاتزان.

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

$$\text{Rate } \alpha \quad \{A\}^a \quad \{B\}^b$$

$$\text{Rate of f} = K_f [A]^a \times [B]^b$$

Where K_f is a constant known as the velocity coefficient

a and b are number of moles for A and B respectively.

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

$$\text{Rate of b} = K_b [C]^C \times [D]^d$$

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

$$\text{or} \quad = \frac{Kf}{Kb} = K_{eq}$$

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

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

Lecture 5

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

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

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

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 المولاري للنواتج مقسومًا على ناتج التركيز المولاري للمواد المتفاعلة. كل تركيز يتم رفعه إلى قوة مساوية لعدد مولات تلك المادة التي تشارك في التفاعل يكون ثابتًا.

Equilibrium constant Keq: The equilibrium constant expression is the ratio of concentrations of a reaction at equilibrium. At constant temperature in an equilibrium reaction, the mole numbers of the products are written as exponents and multiplied. The mole numbers of the reactants are also written as exponents and multiplied. The equilibrium constant is found by the ratio of those.

ثابت الاتزان Keq: يمثل حاصل ضرب التراكيز المولارية للمواد الناتجة عند حالة الاتزان مقسوماً على حاصل ضرب التراكيز المولارية للمواد المتفاعلة عند حالة الاتزان كل منها مرفوع لأس عدد مولاتها في معادلة التفاعل الموزونة وهي قيمة ثابتة عند ثبوت درجة الحرارة.

Types of Chemical Equilibrium

There are two types of chemical equilibrium:

- **Homogeneous Equilibrium**
- **Heterogeneous Equilibrium**

Homogeneous Chemical Equilibrium

In this type, the reactants and the products of chemical equilibrium are all in the same phase. Homogeneous equilibrium can be further divided into two types: Reactions in which the number of molecules of the products is equal to the number of molecules of the reactants. For example,

- $H_2 (g) + I_2 (g) \rightleftharpoons 2HI (g)$
- $N_2 (g) + O_2 (g) \rightleftharpoons 2NO (g)$

Reactions in which the number of molecules of the products is not equal to the total number of reactant molecules. For example,

- $2SO_2 (g) + O_2 (g) \rightleftharpoons 2SO_3 (g)$
- $COCl_2 (g) \rightleftharpoons CO (g) + Cl_2 (g)$

Heterogeneous Chemical Equilibrium

In this type, the reactants and the products of chemical equilibrium are present in different phases. A few examples of heterogeneous equilibrium are listed below.

- $CO_2 (g) + C (s) \rightleftharpoons 2CO (g)$
- $CaCO_3 (s) \rightleftharpoons CaO (s) + CO_2 (g)$

Thus, the different types of chemical equilibrium are based on the phase of the reactants and products.

Factors Affecting the Reaction Equilibrium العوامل التي تؤثر على الاتزان الكيميائي

1. Change in Temperature:

The effect of temperature on chemical equilibrium depends upon the sign of ΔH of the reaction and follows Le-Chatelier's Principle.

- As temperature increases the equilibrium constant of an exothermic reaction decreases.
- In an endothermic reaction the equilibrium constant increases with an increase in temperature.

Along with the equilibrium constant, the rate of reaction is also affected by the change in temperature. As per Le Chatelier's principle, the equilibrium shifts towards the reactant side when the temperature increases in case of exothermic reactions, for endothermic reactions the equilibrium shifts towards the product side with an increase in temperature.

Exothermic Reactions $\Delta H = (-)$ negative التفاعلات الباعثة للحرارة

Endothermic Reactions $\Delta H = (+)$ positive التفاعلات الماصة للحرارة

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 ثابت الاتزان على تراكيز المواد المتفاعلة والناتجة حسب قانون لي - شاتليه ولذلك يمكن التنبؤ باتجاه التفاعل

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

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 لي - شاتليه

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 اي 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 توجه 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	

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

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

$$0.3 = X^2 / (0.2 - x)(0.5 - x)$$

X with number is very small value so can be neglected

X = 0.173 M or Mole/L

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

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

$X^2 = 3x\ 10^{-7}$ -------- $X = \sqrt{3x\ 10^{-7}}$

$X = [A] = [B] = 5.5 \times 10^{-4}$ M

Example: in a chemical reaction, the rate constant for the backward reaction is 7.5×10^{-4} and the equilibrium constant is 1.5. What are the rate constant for forward reaction.

Answer: Equilibrium constant for a reaction.
Kc=rate of backward reaction/ rate of forward reaction= R_f/R_b

Therefore $1.5 = \frac{\text{rate of forward reaction}}{7.5\times10-4}$

Rate of forward reaction = $1.5\times7.5\times10^{-4} = 1.125\times10^{-3}$

Example: Write the appropriate equilibrium constant expression Kc for the following reaction:

$$2CO(g)+O_2(g) \rightleftharpoons 2CO_2(g)$$

Answer: Equilibrium constant; Kc for the given equation;

$2CO+O_2 \rightleftharpoons 2CO_2$ can be written as:

$Kc=[CO]^2/[O_2]\,[CO_2]^2$

Example:Find Keq for the following reaction at 100 C°

$2NO_2 \longleftrightarrow N_2O_4$

g g

Given the following concentrations at equilibrium

$[NO_2]$=0.019M , $[N_2O_4]$= 0.004M

Solution:

Since the reactivity of materials is given in the term of molar concentration then Kc is the same as Keq

$Kc=\frac{[N2O4]}{[NO2]2}$ $Kc=\frac{[0.004]}{[0.019]2}$

Kc= 11.08