LECTURE – 1

Introduction to Analytical Chemistry

1.1 Types of analytical chemistry & their uses .
1.2 Classifying Analytical Techniques.
1.3 Quantitative Analysis Methods.
1.4 Applications of Analytical Chemistry.
1.5 Units For Expressing Concentration of Solutions.
1.6 P - Functions.
1.7 Stoichiometric Calculation.
1.8 Preparing Solutions.
1.9 Basic Tools and operations of Analytical Chemistry.

1.1 Types of analytical chemistry & their uses .

Everything is made of chemicals. Analytical chemistry determine what and how much. In other words analytical chemistry is concerned with the separation, identification, and determination of the relative amounts of the components making up a sample.

Analytical chemistry is concerned with the chemical characterization of matter and the answer to two important questions what is it (qualitative) and how much is it (quantitative).

Analytical chemistry answering for basic questions about a material sample:

· What?
· Where?
· How much?
· What arrangement, structure or form?

Qualitative analysis: An analysis in which we determine the identity of the constituent species (the elements and compounds) in a sample.

Quantitative analysis: An analysis in which we determine how much of a constituent species is present in a sample.

Analytes: Are the components of a sample that are to be determined.

1.2 Classifying Analytical Techniques

A- <u>Classical techniques</u>

Mass, volume, and charge are the most common signals for classical techniques, and the corresponding techniques are:

1- Gravimetric techniques.
2- Volumetric techniques.
3- Coulometeric techniques.

B- <u>Instrumental techniques</u>

1- Spectroscopic methods - measuring the interaction between the analyte and electromagnetic radiation (or the production of radiation by an analyte).
2- Electroanalytic methods - measure an electrical property (i.e., potential, current, resistance, amperes,etc.) chemically related to the amount of analyte.

1.3 Quantitative Analytical Methods

We compute the results of a typical quantitative analysis from two measurements.One is the mass or the volume of samole being analyzed. The second is the measurement of some quantity that is proportional to the amount of analyte in the sample such as mass, volume, intensity of light, or electrical charge. This second measurement usually completes the analysis, and we classify analytical methods according to the nature of this final measurement. Gravimetric methods determine the mass of analyte or some compound chemically related to it. In a volumetric method, the volume of a solution containing sufficient reagent to react completely with the analyte is measured. Electrochemical methods involve the measurement of such electrical properties as potential,current,resistance, and quantity of electrical charge. Spectroscopic methods are based on measurement of the interaction between electromagnetic radiation and analyte atoms or molecules or on the production of such radiation by analytes. Finally, a group of miscellaneous methods includes the measurement of such quantities as mass – to -charge ratio of molecules by mass spectrometry , rate of radioactive decay, heat of reaction,rate of reaction,simple thermal conductivity,optical activity,and refractive index.

1.4 Applications of Analytical Chemistry

Analytical chemistry used in many fields:

1, In *medicine*, analytical chemistry is the basis for clinical laboratory tests which help physicians diagnosis disease and chart progress in recovery.

2. In *industry*, analytical chemistry provides the means of testing raw materials and for assuring the quality of finished products whose chemical composition is critical.Many household products, fuels, paints,Pharmaceutical, etc. are analysed by the procedures developed by analytical chemists before being sold to the consumer.

3. *Environmental quality* is often evaluated by testing for suspected contaminants using the techniques of analytical chemistry.

4. The nutritional value of *food* is determined by chemical analysis for major components such as protein and carbohydrates and trace components such as vitamins and minerals. Indeed, even the calories in a food are often calculated from the chemical analysis.

5. *Forensic analysis* - analysis related to criminology; DNA finger printing, finger print detection; blood analysis.

6. *Bioanalytical chemistry and analysis* - detection and/or analysis of biological components (i.e., proteins, DNA, RNA, carbohydrates, metabolites, etc.).

7. in pharmacy sciences:

· Pharmaceutical chemistry.
· Pharmaceutical industry (quality control).
· Analytical toxicology is concerned with the detection, identification and measurement of drugs and other foreign compounds (and their metabolites in biological and related specimens.
· Natural products detection, isolation, and structural determination.

Many chemists,biochemists, and medicinal chemists devote much time in the

laboratory gathering quantitative information about systems that are important and interesting to them. The central role of analytical chemistry in this enterprise and many others is illustrated in Figure 1-1. All branches of chemistry draw on the ideas and techniques of analytical chemistry. Analytical chemistry has a similar sunction with respect to the many other scientific fields listed in the diagram. Chemistry is often called the central science ; its top center position and the central position of analytical chemistry in the figure emphasize this importance.The interdisciplinary nature of chemical analysis makes it a vital tool in medical, industrial, government, and academic laboratories throughout the world.

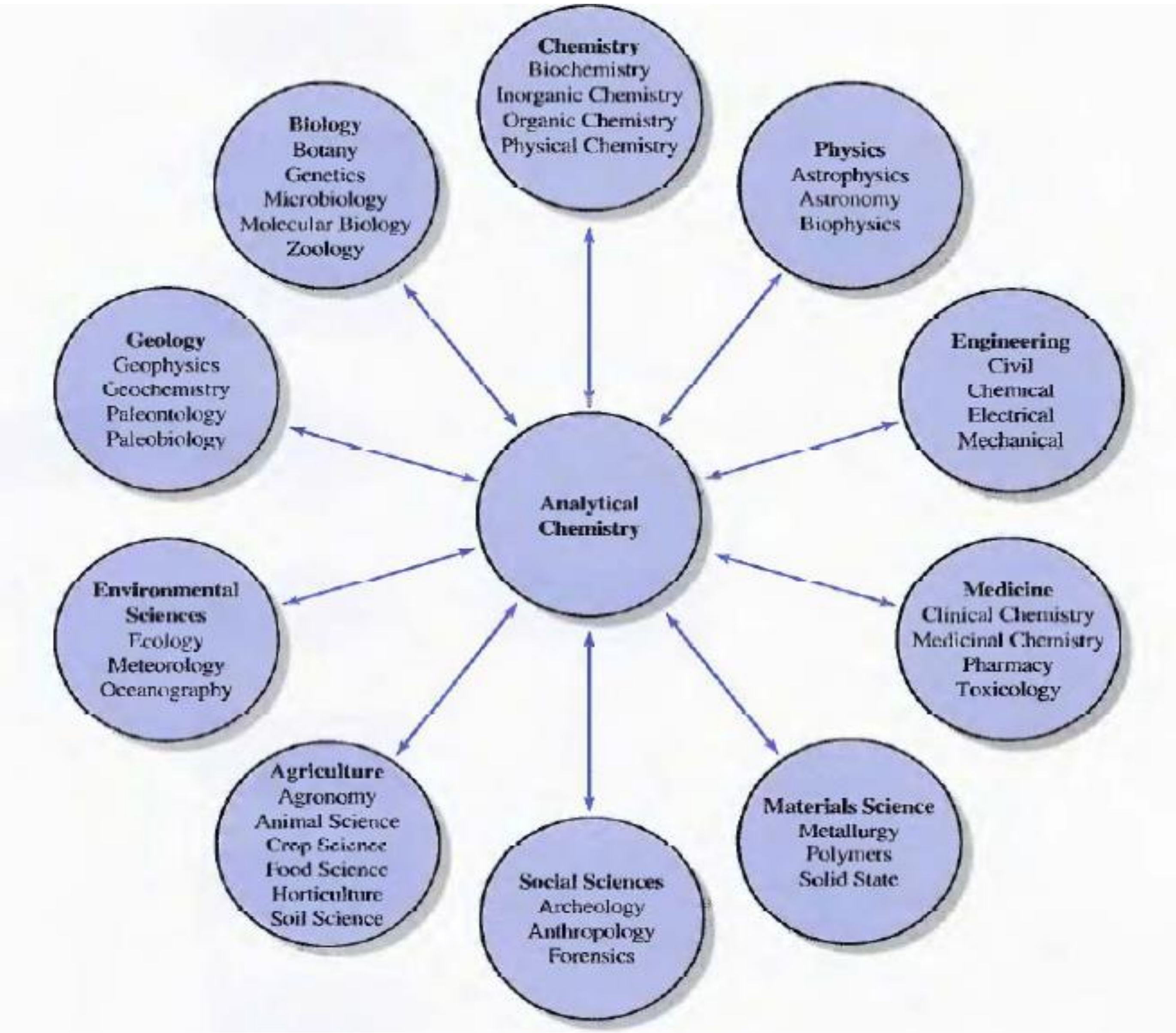

Figure 1-1 The relationship between analytical chemistry, other branches of chemistry, and the other sciences. The central location of analytical chemistry in the diagram signifies its importance and the breadth of its interactions with many other disciplines.

1.5 Units For Expressing Concentration Of Solutions

Concentration is a general measurement unit stating the amount of solute present in a known amount of solution

$$\text{Concentration} = \frac{\text{amount of solute}}{\text{amount of solution}} \qquad \textbf{2.1}$$

Although the terms "solute" and "solution" are often associated with liquid samples, they can be extended to gas-phase and solid-phase samples as well. The actual units for reporting concentration depend on how the amounts of solute and solution are measured. Table 2.4 lists the most common units of concentration.

1.5.1 Molarity and Formality

Both molarity and formality express concentration as moles of solute per liter of solution. There is, however, a subtle difference between molarity and formality. **Molarity** is the concentration of a particular chemical species in solution. **Formality,** on the other hand, 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,

Table 1.1 Common Units For Reporting Concentration

Name	Units[a]	Symbol
molarity	$\frac{\text{moles solute}}{\text{liters solution}}$	M
formality	$\frac{\text{number FWs solute}}{\text{liters solution}}$	F
normality	$\frac{\text{number EWs solute}}{\text{liters solution}}$	N
molality	$\frac{\text{moles solute}}{\text{kg solvent}}$	*m*
weight %	$\frac{\text{g solute}}{\text{100 g solution}}$	% w/w
volume %	$\frac{\text{mL solute}}{\text{100 mL solution}}$	% v/v
weight-to-volume %	$\frac{\text{g solute}}{\text{100 mL solution}}$	% w/v
parts per million	$\frac{\text{g solute}}{10^6\ \text{g solution}}$	ppm
parts per billion	$\frac{\text{g solute}}{10^9\ \text{g solution}}$	ppb

[a]FW = formula weight; EW = equivalent weight.

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. The rigorous definition of molarity, for better or worse, is largely ignored in the current literature, as it is in this text. When we state that a solution is 0.1 M NaCl we understand it to consist of Na^+ and Cl^- ions. The unit of formality is used only when it provides a clearer description of solution chemistry.

Molar concentrations are used so frequently that a symbolic notation is often used to simplify its expression in equations and writing. The use of square brackets around a species indicates that we are referring to that species' molar concentration. Thus, $[Na^+]$ is read as the "molar concentration of sodium ions."

1.5.2 Normality

Normality is an older unit of concentration that, although once commonly used, is frequently ignored in today's laboratories. Normality is still used in some handbooks of analytical methods, and, for this reason, it is helpful to understand its meaning. For example, normality is the concentration unit used in *Standard Methods for the Examination of Water and Wastewater*,[1] a commonly used source of analytical methods for environmental laboratories.

Normality makes use of the chemical equivalent, which is the amount of one chemical species reacting stoichiometrically with another chemical species. Note that this definition makes an equivalent, and thus normality, a function of the chemical reaction in which the species participates. Although a solution of H_2SO_4 has a fixed molarity, its normality depends on how it reacts.

The number of **equivalents,** n, is based on a reaction unit, which is that part of a chemical species involved in a reaction. In a precipitation reaction, for example, the reaction unit is the charge of the cation or anion involved in the reaction; thus for the reaction

$$Pb^{2+}(aq) + 2I^-(aq) \rightleftharpoons PbI_2(s)$$

$n = 2$ for Pb^{2+} and $n = 1$ for I^-. In an acid–base reaction, the reaction unit is the number of H^+ ions donated by an acid or accepted by a base. For the reaction between sulfuric acid and ammonia

$$H_2SO_4(aq) + 2NH_3(aq) \rightleftharpoons 2NH_4^+(aq) + SO_4^{2-}(aq)$$

we find that $n = 2$ for H_2SO_4 and $n = 1$ for NH_3. For a complexation reaction, the reaction unit is the number of electron pairs that can be accepted by the metal or donated by the ligand. In the reaction between Ag^+ and NH_3

$$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+(aq)$$

the value of n for Ag^+ is 2 and that for NH_3 is 1. Finally, in an oxidation–reduction reaction the reaction unit is the number of electrons released by the reducing agent or accepted by the oxidizing agent; thus, for the reaction

$$2Fe^{3+}(aq) + Sn^{2+}(aq) \rightleftharpoons Sn^{4+}(aq) + 2Fe^{2+}(aq)$$

$n = 1$ for Fe^{3+} and $n = 2$ for Sn^{2+}. Clearly, determining the number of equivalents for a chemical species requires an understanding of how it reacts.

Normality is the number of **equivalent weights** (EW) per unit volume and, like formality, is independent of speciation. An equivalent weight is defined as the ratio of a chemical species' **formula weight** (FW) to the number of its equivalents

$$EW = \frac{FW}{n}$$

Consequently, the following simple relationship exists between normality and molarity.

$$N = n \times M$$

Example 2.1 illustrates the relationship among chemical reactivity, equivalent weight, and normality.

Example 1.1

- Calculate the equivalent weight and normality for a solution of 6.0 M H_3PO_4 given the following reactions:

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

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

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

SOLUTION

For phosphoric acid, the number of equivalents is the number of H^+ ions donated to the base. For the reactions in (a), (b), and (c) the number of equivalents are 3, 2, and 1, respectively. Thus, the calculated equivalent weights and normalities are

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

1.5.3 Molality

Molality is used in thermodynamic calculations where a temperature independent unit of concentration is needed. Molarity, formality and normality are based on the volume of solution in which the solute is dissolved. Since density is a temperature dependent property a solution's volume, and thus its molar, formal and normal concentrations, will change as a function of its temperature. By using the solvent's mass in place of its volume, the resulting concentration becomes independent of temperature.