# Analytical Chemistry

**References :**

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# Chapter one

## Introduction to Analytical Chemistry :

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.

### 1.1 Classifying Analytical Techniques

**A- Classical techniques**

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- Instrumental techniques**

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.

**1.2 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.

**1.3 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.).

**Atomic weight :** It is the mass of an atom of that element based on a mass of exactly 12 to the carbon isotope $C^{12}$.

**Molecular or Formula weight(M.wt**): It is the sum of the atomic weights of the elements that constitute a molecule of the substance.

**Examples :**

**M.wt of water ($H_2O$) =2x(1.008)+1x16=18.02 g/gmole**

**Note:** it is possible to express the molecular weights in any unit of mass for example M.wt of $H_2$=2.016 g/gmole ,Ib/Ib mole , ton /ton mole.

**the mole unit (n) :** the mole (or g.mole ) can be defined as the amount of the substance that contains number of molecules equal to that in exactly 12 gram of $C^{12}$ .Hence number of moles is computed as

**No .of moles =** $\frac{\boldsymbol{Mass\ in\ g}}{\boldsymbol{M.wt\ g/gmole}}$

the term of g.atom can be defined as the amount of an element that contain the same number of atoms equal to that of carbon atoms in exactly 12 gm of $C^{12}$ .Hence number of g.atoms is computed as

**No. of g.atoms =** $\frac{Mass\ of\ the\ element\ in\ g}{atomic\ weight}$

Note .Since we usually work in millimole,hence

**No. of mmol =** $\frac{\boldsymbol{Mass\ in\ mg}}{\boldsymbol{M.wt}}$

**Calculating the Amount of a Substance in Moles or Millimoles**

The two examples that follow illustrate how the number of moles or millimoles of a species can be determined from its mass in grams or from the mass of a chemically related species

Example 1: Calculate the number of moles in 500 mg of sodium tungstate ($Na_2WO_4$) ?

Solution:

M.wt. of $Na_2WO_4 = 2(22.99) + 183.85 + 4(16) = 293.83$ g/mol

$\therefore$ No. of moles $= \frac{500\ mg\ (\frac{1g}{1000 mg})}{293.83\ g/mol} = 0.0017\ mol = 1.7\ mmol.$

Example 2: Calculate the mass in mg of 0.25mmol of ferric oxide ($Fe_2O_3$)?

Solution:

Mwt of $Fe_2O_3$ = 159.69 mg/mmol

$\therefore$ mass = 0.25 mmole * 159.69 $\frac{mg}{mmol}$ = 39.9 mg

Example3:

(a) Calculate the number of moles of $K_2CO_3$ that contains 117.3g of potassium.

(b) Calculate the mass in grams of other elements in such compound.

Given that: atomic weight of K=39.1

Solution:

(a) g.atoms of K = $\frac{117.3}{39.1}$ = 3 g.atms

Each mole of $K_2CO_3$ contains 2g.atms of K

$\therefore$ No. of moles of $K_2CO_3$ = $\frac{3}{2}$ = 1.5 mol

(b) Mass of oxygen = g.atoms of oxygen * atomic wt.

= 1.5 * 3 * 16 = 72 g

Mass of carbon = g.atoms of carbon * atomic wt.

= 1.5 * 1 * 12 = 18g

**Example 5**

Find the number of moles and millimoles of benzoic acid (M = 122.1 g/mol) that are contained in 2.00 g of the pure acid.

**Solution**

If we use HBz to represent benzoic acid, we can write that 1 mole of HBz has a mass of 122.1 g. Therefore,

$$\text{Amount HBz} = n_{HBz} = 2\text{gHBz x}\frac{1\ mol\ HBz}{122.1gHBZ}$$

$$= 0.0164 \text{ mol HBz}$$

To obtain the number of millimoles, we divide by the millimolar mass (0.1221 g/mmol), that is,

$$\text{Amount HBz} = n_{HBz} = 2\text{gHBz x}\frac{1\ mol\ HBz}{0.1221gHBZ}$$

$$= 16.4 \text{ mmol HBz}$$

**Example 6**

What is the mass in grams of $Na^+$ (22.99 g/mol) in 25.0 g of $Na_2SO_4$ (142.0 g/mol)?

Solution

The chemical formula tells us that 1 mole of $Na_2SO_4$ contains 2 moles of Na+, that is,

$$\text{Amount } Na^+ = n_{Na+} = \text{mol } Na_2SO_4 \text{ x}\frac{2\ mol\ Na+}{\text{mol Na2SO4}}$$

To find the number of moles of $Na_2SO_4$, we proceed as in Example 1-1:

$$\text{Amount } Na_2SO_4 = n_{\ Na2SO4} = 25 \text{ g } Na_2SO_4 \text{ x}\frac{1\ mol\ \text{Na2SO4}}{142 \text{ g}}$$

$$= 0.176 \text{ mol}$$

$$\text{Amount Na+} = 2*0.176 = 0.352 \text{ mol}$$

$$\text{Mass } Na^+ = m_{Na+} = \text{mol } Na^+ \text{ x}\frac{22.99\ g}{\text{mol Na+}}$$

$$= 8.1\text{g}$$