Republic of Iraq
Ministry of Higher Education & Scientific research
Al-Mustaqbal University
Science College
Medical physics Department

Analytical Chemistry

For

First Year Student

Lecture 9

By

Dr. Karrar M. Obaid

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Acid-Base Equilibria

Acid-base theories:-

1) <u>Arrhenius Theory (H^+ and OH^-):-</u>

Acid:-any substance that ionizes (partially or completely) in water to give hydrogen ion (which associate with the solvent to give hydronium ion H_3O^+):

$$HA + H_2O \leftrightarrow H_3O^+ + A^-$$

Base:-any substance that ionizes in water to give hydroxyl ions. Weak (partially ionized) to generally ionize as follows:-

$$B + H_2O \leftrightarrow BH^+ + OH^-$$

While strong bases such as metal hydroxides (e.g. NaOH) dissociate as

$$M(OH)n \leftrightarrow M^{n+} + nOH^-$$

This theory is obviously restricted to water as the solvent.

2) <u>Bronsted-Lowry Theory (taking and giving protons, H^+):-</u>

Acid:-any substance that can donate a proton.

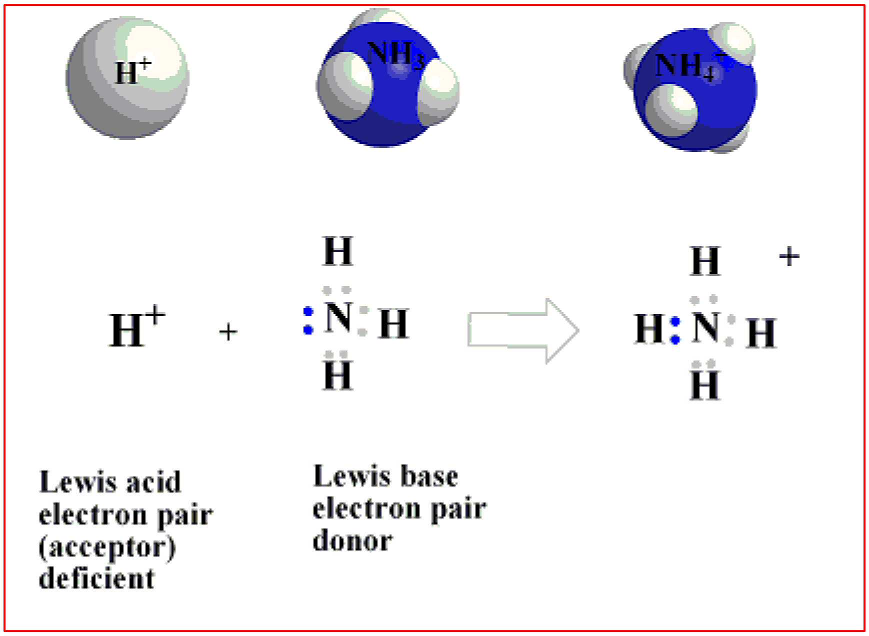
Base:-any substance that can accept a proton. Thus, we can write a half reaction:

$$\mathbf{Acid = H^+ + Base}$$

3) <u>Lewis Theory (taking and giving electrons):-</u>

Acid:-a substance that can accept an electron pair.

Base:-a substance that can donate an electron pair.



Strong acids: - H_2SO_4, $HClO_4$, HNO_3, HI and HCl .

Strong bases: - LiOH, KOH, NaOH and $Ca(OH)_2$.

<u>Oxides</u> are indeed fascinating compounds formed when elements react with oxygen. They play crucial roles in chemistry and are often stable due to their negative standard Gibbs free energy of formation (ΔG°f). Oxides of the first and second groups, as well as transition metals, tend to be particularly stable

Oxides are defined as compounds of diatomic oxygen with the other elements of the periodic table, except for noble gases.

Types of Oxides:

Oxides are classified into the following types:

1.Acidic Oxides: These oxides are formed when non-metallic elements (such as carbon, sulfur, and phosphorus) burn in oxygen gas. The resulting oxides dissolve in water to form acids, increasing the concentration of hydrogen ions. Their fundamental component is oxygen.

$$P_4O_{10}(s) + 6H_2O \longrightarrow 4H^+(aq) + 4\,H_2PO_4(aq)$$

They are non-metal oxides, such as:

- **Carbon dioxide (CO_2)** – Forms carbonic acid (H_2CO_3) in water.
- **Sulfur dioxide (SO_2) and Sulfur trioxide (SO_3)** – Form sulfurous acid (H_2SO_3) and sulfuric acid (H_2SO_4), respectively.
- **Phosphorus pentoxide (P_2O_5)** – Forms phosphoric acid (H_3PO_4) in water.
- **Nitrogen dioxide (NO_2)** – Forms nitric acid (HNO_3) and nitrous acid (HNO_2) in water.

$$H_2CO_3 \longrightarrow CO_2 + H_2O$$

$$SO_2 + H_2O \longrightarrow H_2SO_3$$

$$P_2O_5 + 3H_2O \longrightarrow 2H_3PO_4$$

And they react with alkalis to produce salt and water.

For example:

$$SO_2 + 2NaOH \rightarrow Na_2SO_3 + H_2O$$

$$CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$$

2. Basic Oxides:

These oxides are formed when certain metallic elements (such as sodium, potassium, and magnesium) burn in oxygen. The resulting oxides dissolve in water to form hydroxide ions (OH^-), which decrease the concentration of hydrogen ions in an aqueous solution, making the solution basic (alkaline).

MgO, Na_2O, K_2O, CuO

$$Na_2O+H_2O\rightarrow 2NaOH$$

$$MgO+H_2O\rightarrow Mg(OH)_2$$

These oxides react with acids to form salts and water, demonstrating their basic nature.

$$Na_2O + 2HCl \longrightarrow 2NaCl + H_2O$$

3.Amphoteric Oxides:

These oxides do not dissolve in water but can react with both strong acids and strong bases, forming salt and water in both cases. This dual behavior classifies them as amphoteric.

Examples of Amphoteric Oxides:

- Aluminum oxide (Al_2O_3)
- Zinc oxide (ZnO)
- Lead(II) oxide (PbO)

Reactions of Amphoteric Oxides:

1. With Acids (acting as a base):

$$Al_2O_3+6HCl\rightarrow 2AlCl_3+3H_2O$$

2.With Bases (acting as an acid)

$$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$$

Gradation of Acidic and Basic Properties in the Periodic Table

The acidic and basic nature of oxides varies systematically across the periodic table due to changes in **electronegativity** and **metallic character** of elements.

1. Across a Period (Left to Right):

- As we move from **left to right** in a period, elements transition from **metals** to **non-metals**.
- **Metal oxides** (on the left) are **basic**, while **non-metal oxides** (on the right) are **acidic**.
- **Amphoteric oxides** appear between metals and non-metals (mainly in transition metals and metalloids).

Example (Period 3):

- Sodium oxide (Na_2O) → **Strongly basic**
- Magnesium oxide (MgO) → **Moderately basic**
- Aluminum oxide (Al_2O_3) → **Amphoteric**
- Silicon dioxide (SiO_2) → **Weakly acidic**
- Phosphorus pentoxide (P_2O_5) → **Strongly acidic**
- Sulfur trioxide (SO_3) → **Strongly acidic**

2. Down a Group (Top to Bottom):

- As we move **down a group**, the **metallic character** increases, making oxides **more basic**.

- Non-metal oxides become less acidic as atomic size increases and electronegativity decreases.