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Chapter 4

Reactions in Aqueous Solutions

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4.4
Oxidation-reduction reactions

Reaction Types

(some simple patterns of chemical reactivity)

Precipitation reactions

Acid-base reactions

Oxidation-reduction (redox) reactions

- Combination reactions
- Decomposition reactions
- Combustion reactions
- Displacement reactions
- Disproportionation reactions

Only ...

- **C**ombination Reactions
- **D**ecomposition Reactions
- **C**ombustion Reactions

Combination Reactions

-In this type of reaction two or more substances combine to form one product.

$$A + B \longrightarrow C$$

-A combination reaction between a metal and a nonmetal produce ionic solid.

Sulfur burning in air to form sulfur dioxide

Sodium burning in chlorine to form sodium chloride

Aluminum reacting with bromine to form aluminum bromide

Examples:

$$2\ Mg_{(s)} + O_{2\,(g)} \longrightarrow 2\ MgO_{(s)}$$

$$C_{(s)} + O_{2\,(g)} \longrightarrow CO_{2\,(g)}$$

$$N_{2\,(g)} + 3\ H_{2\,(g)} \longrightarrow 2\ NH_{3\,(g)}$$

$$CaO_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2\,(s)}$$

$$C_3H_{6\,(g)} + Br_{2\,(l)} \longrightarrow C_3H_6Br_{2\,(l)}$$

Decomposition Reactions

-Decomposition reactions are the opposite of combination reactions; one substance breaks down into two or more substances.

$$A \longrightarrow B + C$$

-Many compounds undergo decomposition reactions when heated.

On heating, mercury(II) oxide (HgO) decomposes to form mercury and oxygen

Heating potassium chlorate ($KClO_3$) produces oxygen, which supports the combustion of the wood splint

Examples:

$$CaCO_{3\,(s)} \longrightarrow CaO_{(s)} + CO_{2\,(g)}$$

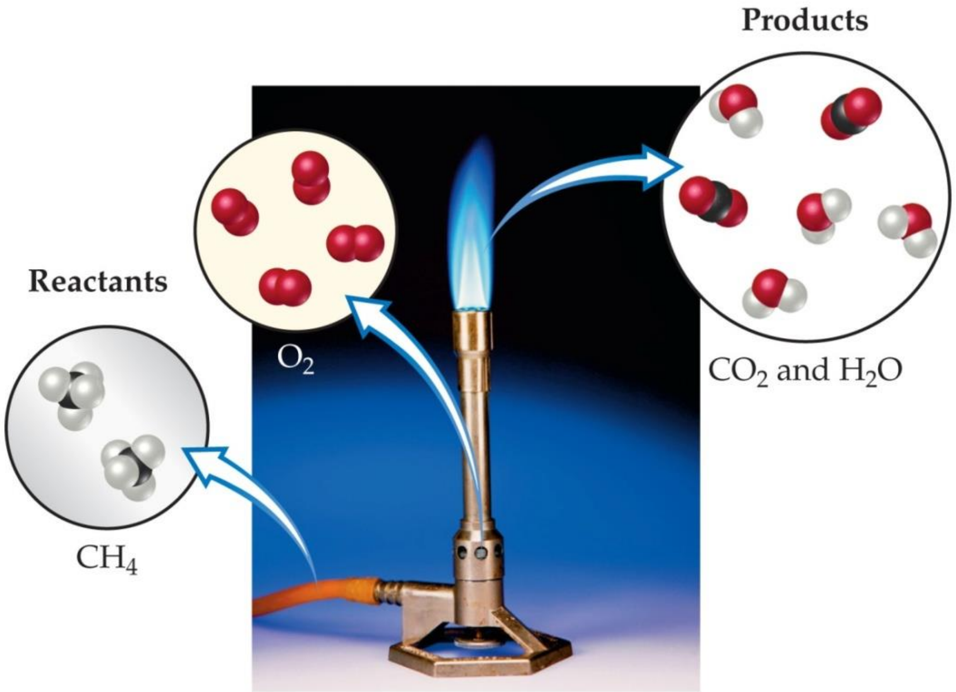
$$2\,KClO_{3\,(s)} \longrightarrow 2\,KCl_{(s)} + 3\,O_{2\,(g)}$$

$$Cu(OH)_{2\,(s)} \longrightarrow CuO_{(s)} + H_2O_{(l)}$$

$$PbCO_{3\,(s)} \longrightarrow PbO_{(s)} + CO_{2\,(g)}$$

$$2\,NaN_{3\,(s)} \longrightarrow 2\,Na_{(s)} + 3\,N_{2\,(g)}$$

Combustion Reactions



-A reaction in which a substance reacts with oxygen, usually with the release of heat and light to produce a flame.

-These are generally rapid reactions that produce a flame.

-Most often involve hydrocarbons reacting with oxygen in the air.

-Hydrocarbon compounds contain only Carbons (**C**) and Hydrogen (**H**).

Examples:

$CH_{4\,(g)} + 2\,O_{2\,(g)} \longrightarrow CO_{2\,(g)} + 2\,H_2O_{\,(g)}$

$C_3H_{8\,(g)} + 5\,O_{2\,(g)} \longrightarrow 3\,CO_{2\,(g)} + 4\,H_2O_{\,(g)}$

$C_2H_5OH_{\,(l)} + 3\,O_{2\,(g)} \rightarrow 2\,CO_{2\,(g)} + 3\,H_2O_{\,(g)}$

$S_{\,(s)} + O_{2\,(g)} \rightarrow SO_{2\,(g)}$

4.5
Concentration of solutions

The **concentration of a solution** is the amount of solute present in a given amount of solvent, or a given amount of solution.

The concentration of a solution can be expressed in many different ways.

Molarity (M), or **molar concentration,** which is the number of moles of solute per liter of solution.

$$\text{molarity} = \frac{\text{moles of solute}}{\text{liters of solution}}$$

$$M = \frac{n}{V}$$

where;
n: denotes the number of moles of solute
V: is the volume of the solution in liters.

A 1.46 molar glucose ($C_6H_{12}O_6$) solution, written as 1.46 *M* $C_6H_{12}O_6$; contains 1.46 moles of the solute ($C_6H_{12}O_6$) in 1 L of the solution.

Molarity refers only to the amount of solute originally dissolved in water and does not take into account any **subsequent processes**, such as the **dissociation** of a salt or the ionization of an acid.

Consider what happens when a sample of potassium chloride (KCl) is dissolved in enough water to make a 1 *M* solution:

$$KCl(s) \xrightarrow{H_2O} K^+(aq) + Cl^-(aq)$$

Because KCl is a **strong electrolyte**, it undergoes complete dissociation in solution. Thus, a 1 *M* KCl solution contains 1 mole of K^+ ions and 1 mole of Cl^- ions, and no KCl units are present.

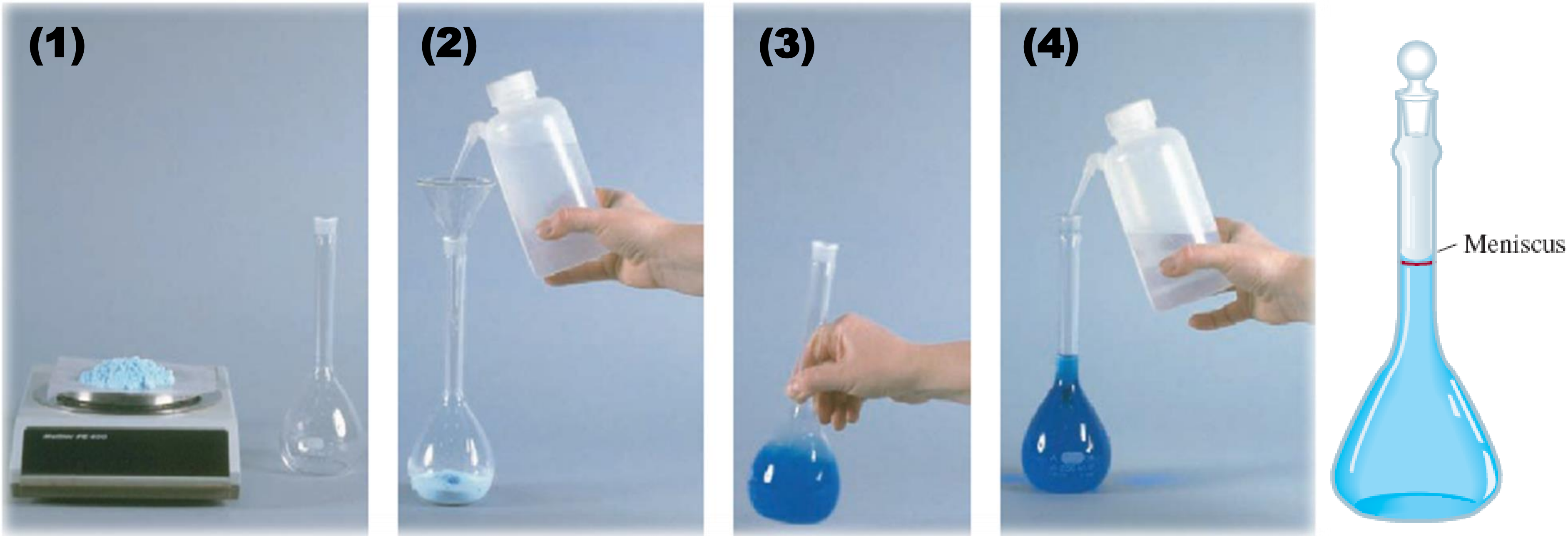
The concentrations of the ions can be expressed as $[K^+] = 1\ M$ and $[Cl^-] = 1\ M$.

Similarly, in a 1 *M* barium nitrate $[Ba(NO_3)_2]$ solution

$$Ba(NO_3)_2(s) \xrightarrow{H_2O} Ba^{2+}(aq) + 2NO_3^-(aq)$$

we have $[Ba^{2+}] = 1\ M$ and $[NO_3^-] = 2\ M$ and no $Ba(NO_3)_2$ units at all.

Preparing a Solution



Procedure for preparation of 250 mL of 1.00 M solution of $CuSO_4$ ($\mathcal{M}$=159.5 g/mol).

0.25 mole of $CuSO_4$ (39.9 g) is weighed out and placed in the volumetric flask. Water is added to dissolve the salt, and the resultant solution is diluted to a total volume of 0.250 L. The molarity of the solution is:

M = (0.250 mol $CuSO_4$) / (0.250 L soln) = 1.00 M

EXAMPLE

How many grams of potassium dichromate ($K_2Cr_2O_7$) are required to prepare a 250-mL solution whose concentration is 2.16 *M*?

moles of solute = molarity x V soln. (L)

$$\text{moles of } K_2Cr_2O_7 = \frac{2.16 \text{ mol } K_2Cr_2O_7}{1 \cancel{\text{L soln}}} \times 0.250 \cancel{\text{L soln}}$$
$$= 0.540 \text{ mol } K_2Cr_2O_7$$

The molar mass of $K_2Cr_2O_7$ is 294.2 g, so

$$\text{grams of } K_2Cr_2O_7 \text{ needed} = 0.540 \cancel{\text{mol } K_2Cr_2O_7} \times \frac{294.2 \text{ g } K_2Cr_2O_7}{1 \cancel{\text{mol } K_2Cr_2O_7}}$$
$$= 159 \text{ g } K_2Cr_2O_7$$

Practice Exercise

What is the molarity of an 85.0-mL ethanol (C_2H_5OH) solution containing 1.77 g of ethanol?

EXAMPLE

In a biochemical assay, a chemist needs to add 3.81 g of glucose to a reaction mixture. Calculate the volume in milliliters of a 2.53 *M* glucose solution she should use for the addition.

The molar mass of $C_6H_{12}O_6$ is 180.2 g, so

$$3.81\ \cancel{g\ C_6H_{12}O_6} \times \frac{1\ mol\ C_6H_{12}O_6}{180.2\ \cancel{g\ C_6H_{12}O_6}} = 2.114 \times 10^{-2}\ mol\ C_6H_{12}O_6$$

$$\begin{aligned} V &= \frac{n}{M} \\ &= \frac{2.114 \times 10^{-2}\ mol\ C_6H_{12}O_6}{2.53\ mol\ C_6H_{12}O_6/L\ soln} \times \frac{1000\ mL\ soln}{1\ L\ soln} \\ &= 8.36\ mL\ soln \end{aligned}$$

Practice Exercise

What volume (in milliliters) of a 0.315 *M* NaOH solution contains 6.22 g of NaOH?

Dilution of Solutions

Concentrated solutions are often stored in the laboratory for use as needed; "**stock**" solutions are frequently diluted before working with them.

Dilution is the procedure for preparing a less concentrated solution from a more concentrated one.

Two potassium permanganate ($KMnO_4$) solutions of different concentrations

moles of solute before dilution = moles of solute after dilution

$$M_i V_i = M_f V_f$$

moles of solute before dilution = moles of solute after dilution

where M_i and M_f are the initial and final concentrations of the solution in molarity and V_i and V_f are the initial and final volumes of the solution, respectively.

The units of V_i and V_f must be the same (mL or L) for the calculation to work.

$M_i > M_f$ and $V_f > V_i$

EXAMPLE

Describe how you would prepare 5.00 x 10^2 mL of a 1.75 *M* H_2SO_4 solution, starting with an 8.61 *M* stock solution of H_2SO_4.

$$M_i = 8.61\ M \qquad M_f = 1.75\ M$$
$$V_i = ? \qquad V_f = 5.00 \times 10^2\ \text{mL}$$

$$(8.61\ M)(V_i) = (1.75\ M)(5.00 \times 10^2\ \text{mL})$$
$$V_i = \frac{(1.75\ M)(5.00 \times 10^2\ \text{mL})}{8.61\ M}$$
$$= 102\ \text{mL}$$

Thus, we must dilute 102 mL of the 8.61 *M* H_2SO_4 solution with sufficient water to give a final volume of 5.00 x 10^2 mL in a 500-mL volumetric flask to obtain the desired concentration.

Practice Exercise

How would you prepare 2.00 x 10^2 mL of a 0.866 *M* NaOH solution, starting with a 5.07 *M* stock solution?


Thank You!