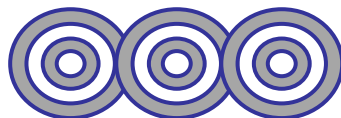




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Chapter 4

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



Sulfur burning in air to form sulfur dioxide

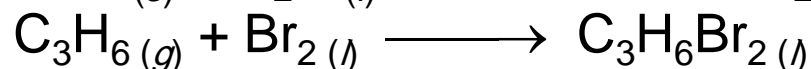
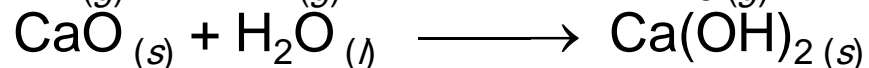
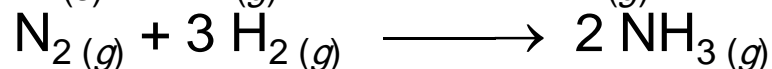
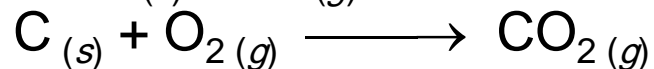
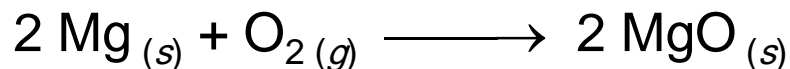


Sodium burning in chlorine to form sodium chloride



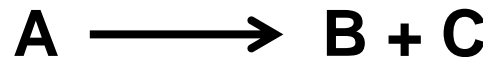
Aluminum reacting with bromine to form aluminum bromide

Examples:



Decomposition Reactions

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



-Many compounds undergo decomposition reactions when heated.

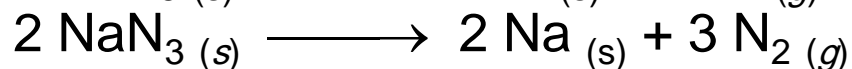
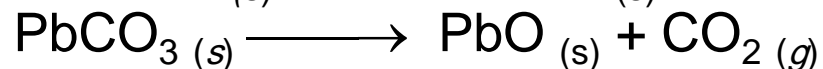
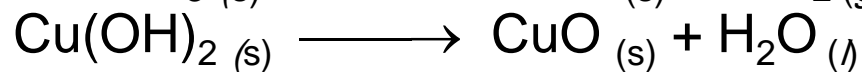
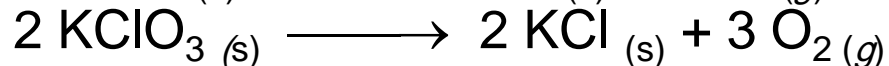
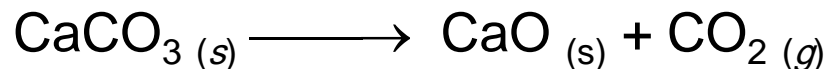


On heating, mercury(II) oxide (HgO) decomposes to form mercury and oxygen

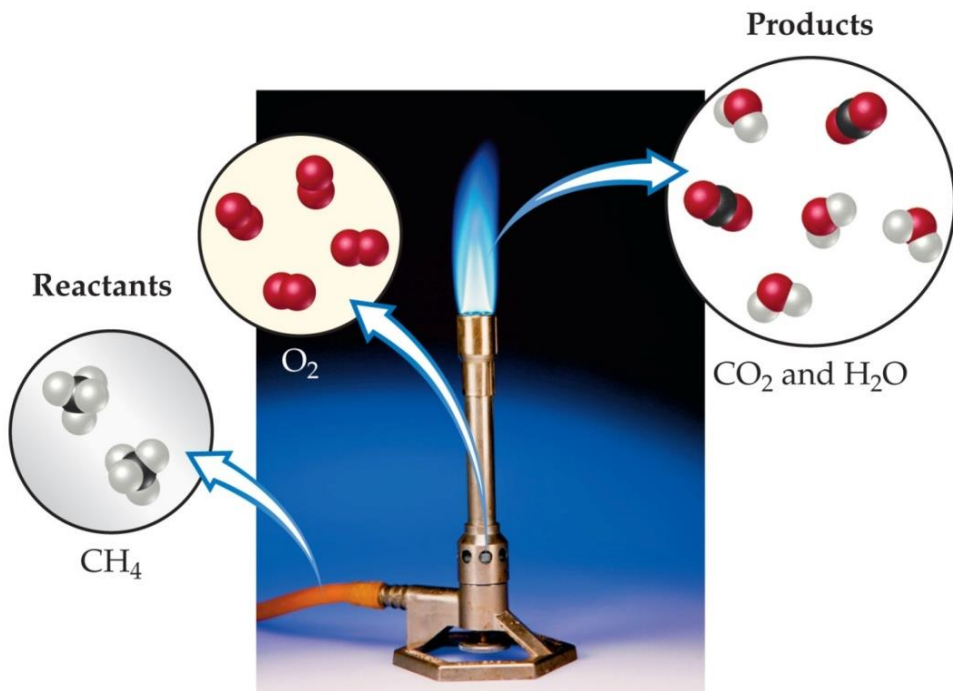


Heating potassium chlorate (KClO₃) produces oxygen, which supports the combustion of the wood splint

Examples:



Combustion Reactions



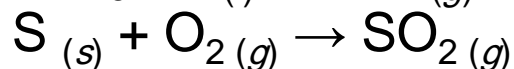
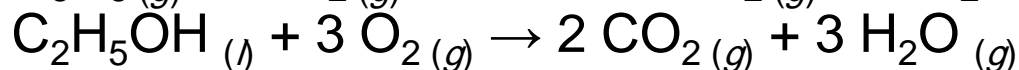
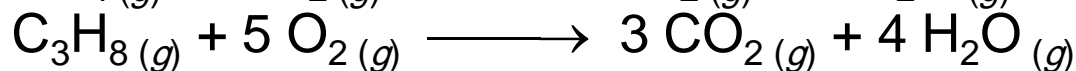
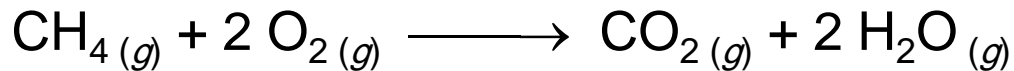
-A reaction in which a substance reacts with oxygen, usually with the release of heat and light to produce a flame.

-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:



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;

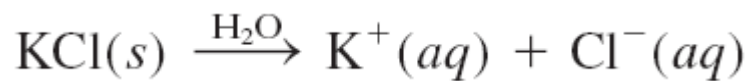
n: denotes the number of moles of solute

V: is the volume of the solution in liters.

A 1.46 molar glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) solution, written as 1.46 $M\text{C}_6\text{H}_{12}\text{O}_6$; contains 1.46 moles of the solute ($\text{C}_6\text{H}_{12}\text{O}_6$) 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:



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(NO₃)₂] solution



we have [Ba²⁺] = 1 *M* and [NO₃⁻] = 2 *M* and no Ba(NO₃)₂ units at all.

Preparing a Solution

(1)



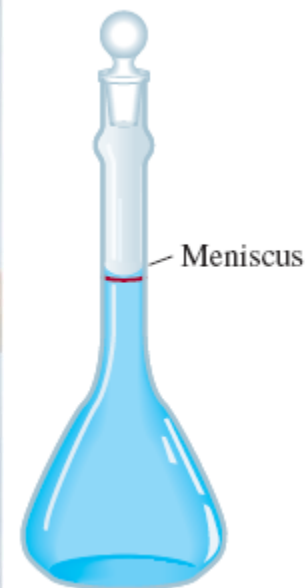
(2)



(3)



(4)



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:

$$M = (0.250 \text{ mol CuSO}_4) / (0.250 \text{ L soln}) = 1.00 \text{ M}$$

EXAMPLE

How many grams of potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) are required to prepare a 250-mL solution whose concentration is 2.16 M ?

moles of solute = molarity \times V soln. (L)

$$\begin{aligned}\text{moles of } \text{K}_2\text{Cr}_2\text{O}_7 &= \frac{2.16 \text{ mol } \text{K}_2\text{Cr}_2\text{O}_7}{1 \text{ L soln}} \times 0.250 \text{ L soln} \\ &= 0.540 \text{ mol } \text{K}_2\text{Cr}_2\text{O}_7\end{aligned}$$

The molar mass of $\text{K}_2\text{Cr}_2\text{O}_7$ is 294.2 g, so

$$\begin{aligned}\text{grams of } \text{K}_2\text{Cr}_2\text{O}_7 \text{ needed} &= 0.540 \text{ mol } \text{K}_2\text{Cr}_2\text{O}_7 \times \frac{294.2 \text{ g } \text{K}_2\text{Cr}_2\text{O}_7}{1 \text{ mol } \text{K}_2\text{Cr}_2\text{O}_7} \\ &= 159 \text{ g } \text{K}_2\text{Cr}_2\text{O}_7\end{aligned}$$

Practice Exercise

What is the molarity of an 85.0-mL ethanol ($\text{C}_2\text{H}_5\text{OH}$) 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

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

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

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

$$\begin{array}{ccc} M_i V_i & = & M_f V_f \\ \text{moles of solute} & & \text{moles of solute} \\ \text{before dilution} & & \text{after dilution} \end{array}$$

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 5.00×10^2 mL of a $1.75 \text{ M H}_2\text{SO}_4$ solution, starting with an 8.61 M stock solution of H_2SO_4 .

$$\begin{array}{ll} M_i = 8.61 \text{ M} & M_f = 1.75 \text{ M} \\ V_i = ? & V_f = 5.00 \times 10^2 \text{ mL} \end{array}$$

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

Thus, we must dilute 102 mL of the $8.61 \text{ M H}_2\text{SO}_4$ solution with sufficient water to give a final volume of 5.00×10^2 mL in a 500-mL volumetric flask to obtain the desired concentration.

Practice Exercise

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

