General Chemistry

CHEM 101

(3+1+0)

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Chapter 4

Reactions in Aqueous Solutions

- A ***solution*** is a homogenous mixture of 2 or more substances
- The ***solute*** is(are) the substance(s) present in the smaller amount(s)
- The ***solvent*** is the substance present in the larger amount

Solution	Solvent	Solute
Soft drink (*l*)	H_2O	Sugar, CO_2
Air (*g*)	N_2	O_2, Ar, CH_4


aqueous solutions of $KMnO_4$

Precipitation Reactions

precipitate ↓

$Pb(NO_3)_2\ (aq) + 2NaI\ (aq) \longrightarrow PbI_2\ (s) + 2NaNO_3\ (aq)$

molecular equation

$Pb^{2+} + \cancel{2NO_3^-} + \cancel{2Na^+} + 2I^- \longrightarrow PbI_2\ (s) + \cancel{2Na^+} + \cancel{2NO_3^-}$

ionic equation

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

net ionic equation

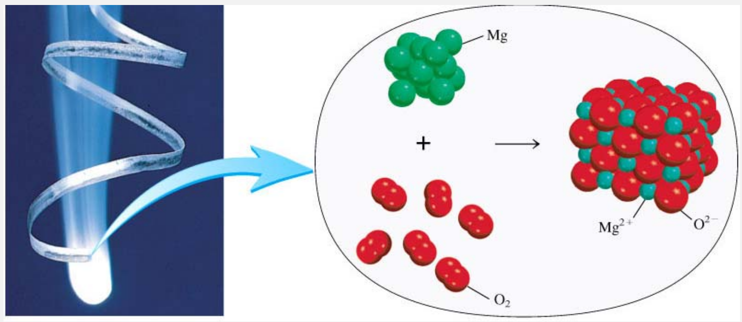
Neutralization Reaction

acid + base ⟶ salt + water

$HCl\ (aq) + NaOH\ (aq) \longrightarrow NaCl\ (aq) + H_2O$

Oxidation-Reduction Reactions

(electron transfer reactions)



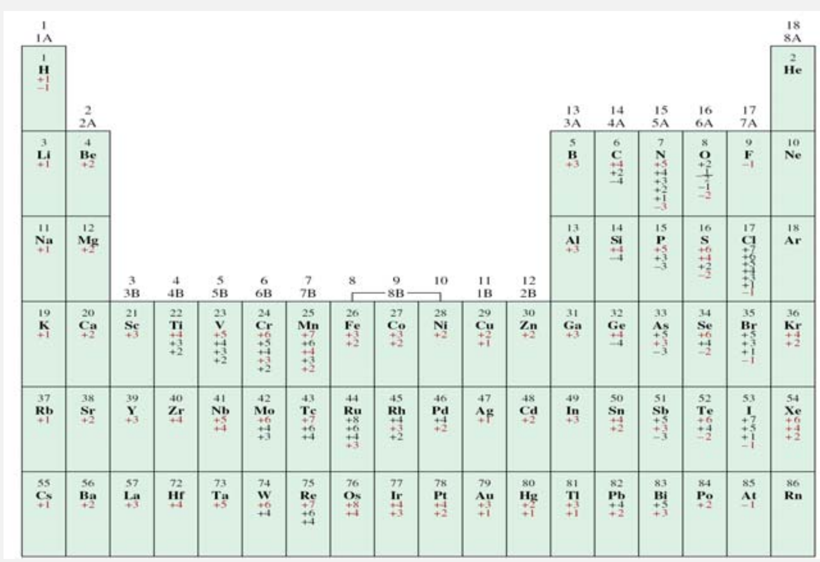
$2Mg \longrightarrow 2Mg^{2+} + 4e^-$ **Oxidation** half-reaction (lose e^-)

$O_2 + 4e^- \longrightarrow 2O^{2-}$ **Reduction** half-reaction (gain e^-)

$$2Mg + O_2 + \cancel{4e^-} \longrightarrow 2Mg^{2+} + 2O^{2-} + \cancel{4e^-}$$

$$2Mg + O_2 \longrightarrow 2MgO$$

The Oxidation Numbers of Elements in their Compounds



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Types of Oxidation-Reduction Reactions

1. Combination Reactions

A ***combination reaction*** is a *reaction in which two or more substances combine to form a single product*.

$$A + B \longrightarrow C$$

$$\overset{0}{2Al} + \overset{0}{3Br_2} \longrightarrow 2\overset{+3\ -1}{AlBr_3}$$

Types of Oxidation-Reduction Reactions

2. Decomposition Reactions

- *Decomposition reactions are the opposite of combination reactions*.
- A ***decomposition reaction*** is the *breakdown of a compound into two or more components.*

$$C \longrightarrow A + B$$

$$2\overset{+1\ +5\ -2}{KClO_3} \longrightarrow 2\overset{+1\ -1}{KCl} + 3\overset{0}{O_2}$$

Types of Oxidation-Reduction Reactions

3. Combustion Reactions

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

$$A + O_2 \longrightarrow B$$

$$\overset{0}{S} + \overset{0}{O_2} \longrightarrow \overset{+4}{S}\overset{-2}{O_2}$$

$$2\overset{0}{Mg} + \overset{0}{O_2} \longrightarrow 2\overset{+2}{Mg}\overset{-2}{O}$$

Concentration of solution

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

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

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

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

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

Concentration of solution

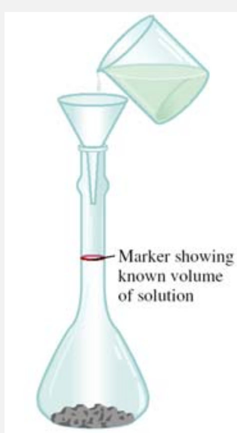
What mass of KI is required to make 500. mL of a 2.80 *M* KI solution?

$$\text{volume of KI solution} \xrightarrow{M\ \text{KI}} \text{moles KI} \xrightarrow{\mathcal{M}\ \text{KI}} \text{grams KI}$$

$$500.\ \text{mL} \times \frac{1\ \text{L}}{1000\ \text{mL}} \times \frac{2.80\ \text{mol KI}}{1\ \text{L soln}} \times \frac{166\ \text{g KI}}{1\ \text{mol KI}} = 232\ \text{g KI}$$

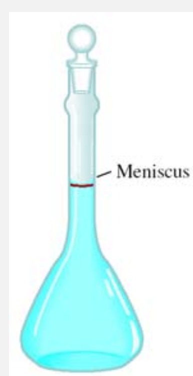
Concentration of solution

Preparing a Solution of Known Concentration



The solute is accurately weighed and transferred to a volumetric flask through a funnel.

Water is added to the flask, which is carefully swirled to dissolve the solid.



After all the solid has dissolved, more water is added slowly to bring the level of solution exactly to the volume mark.

Concentration of solution

EXAMPLE 4.6

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

Strategy How many moles of $K_2Cr_2O_7$ does a 1-L (or 1000 mL) 2.16 *M* $K_2Cr_2O_7$ solution contain? A 250-mL solution? How would you convert moles to grams?

Solution The first step is to determine the number of moles of $K_2Cr_2O_7$ in 250 mL or 0.250 L of a 2.16 *M* solution. Rearranging Equation (4.1) gives

$$\text{moles of solute} = \text{molarity} \times \text{L soln}$$

Thus,

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

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

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

Check As a ball-park estimate, the mass should be given by [molarity (mol/L) × volume (L) × molar mass (g/mol)] or [2 mol/L × 0.25 L × 300 g/mol] = 150 g. So the answer is reasonable.

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

Concentration of solution

EXAMPLE 4.7

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.

Strategy We must first determine the number of moles contained in 3.81 g of glucose and then use Equation (4.2) to calculate the volume.

Solution From the molar mass of glucose, we write

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

Next, we calculate the volume of the solution that contains 2.114×10^{-2} mole of the solute. Rearranging Equation (4.2) gives

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

Check One liter of the solution contains 2.53 moles of $C_6H_{12}O_6$. Therefore, the number of moles in 8.36 mL or 8.36×10^{-3} L is (2.53 mol × 8.36×10^{-3}) or 2.12×10^{-2} mol. The small difference is due to the different ways of rounding off.

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