Chapter 11
Reactions in Aqueous Solutions II: Calculations

Aqueous Acid-Base Reactions

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Calculations Involving Molarity

- If 100.0 mL of 1.00 M NaOH and 100.0 mL of 0.500 M H_2SO_4 solutions are mixed, what will the concentration of the resulting solution be?

- If 130.0 mL of 1.00 M KOH and 100.0 mL of 0.500 M H_2SO_4 solutions are mixed, what will be the concentration of KOH and K_2SO_4 in the resulting solution?

- What volume of 0.750 M NaOH solution would be required to completely neutralize 100 mL of 0.250 M H_3PO_4?

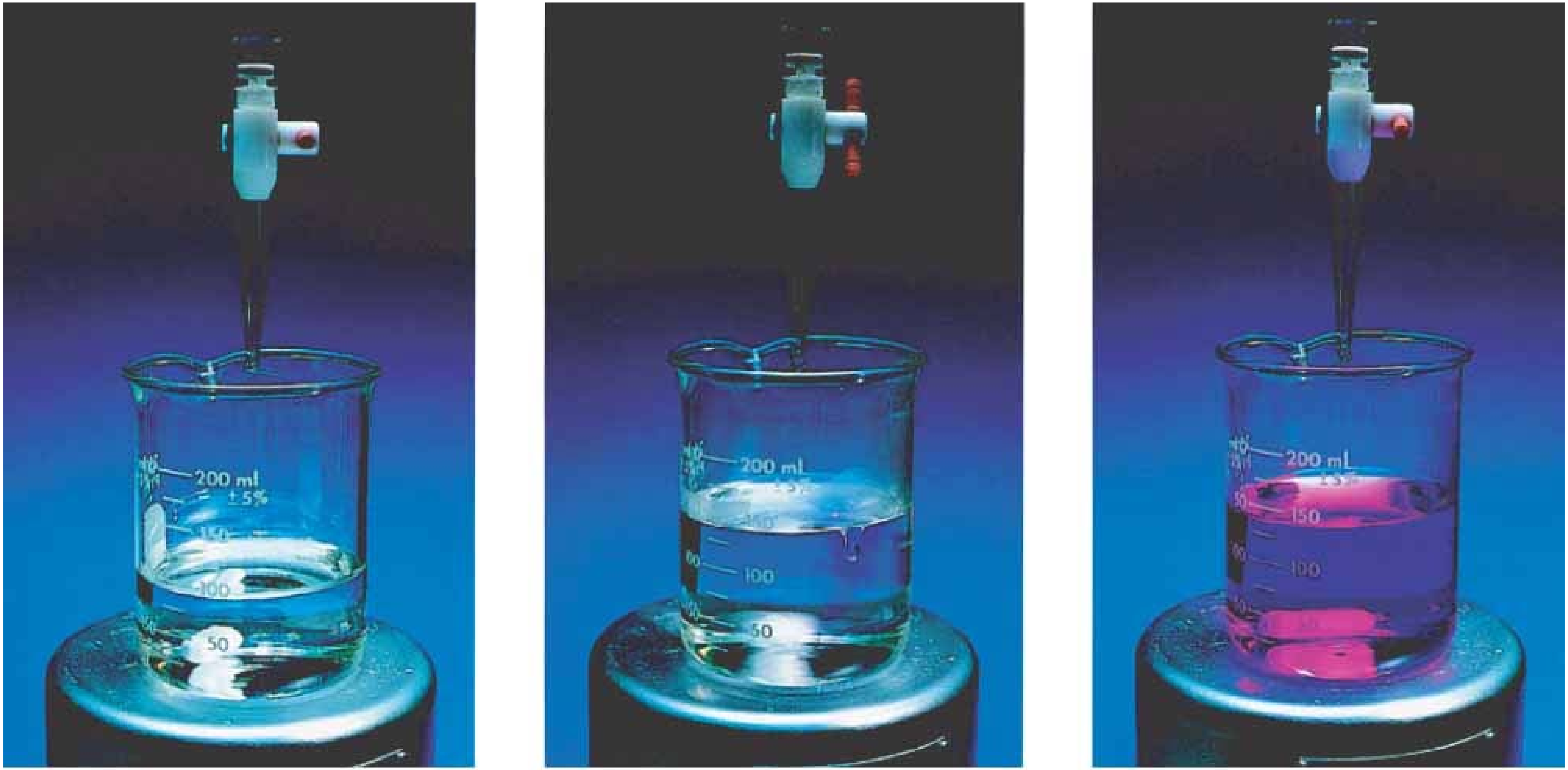
Titrations

- Acid-base Titration Terminology

1. Titration – A method of determining the concentration of one solution by reacting it with a solution of known concentration.
2. Primary standard – A chemical compound which can be used to accurately determine the concentration of another solution. Examples include KHP and sodium carbonate.
3. Standard solution – A solution whose concentration has been determined using a primary standard.
4. Standardization – The process in which the concentration of a solution is determined by accurately measuring the volume of the solution required to react with a known amount of a primary standard.

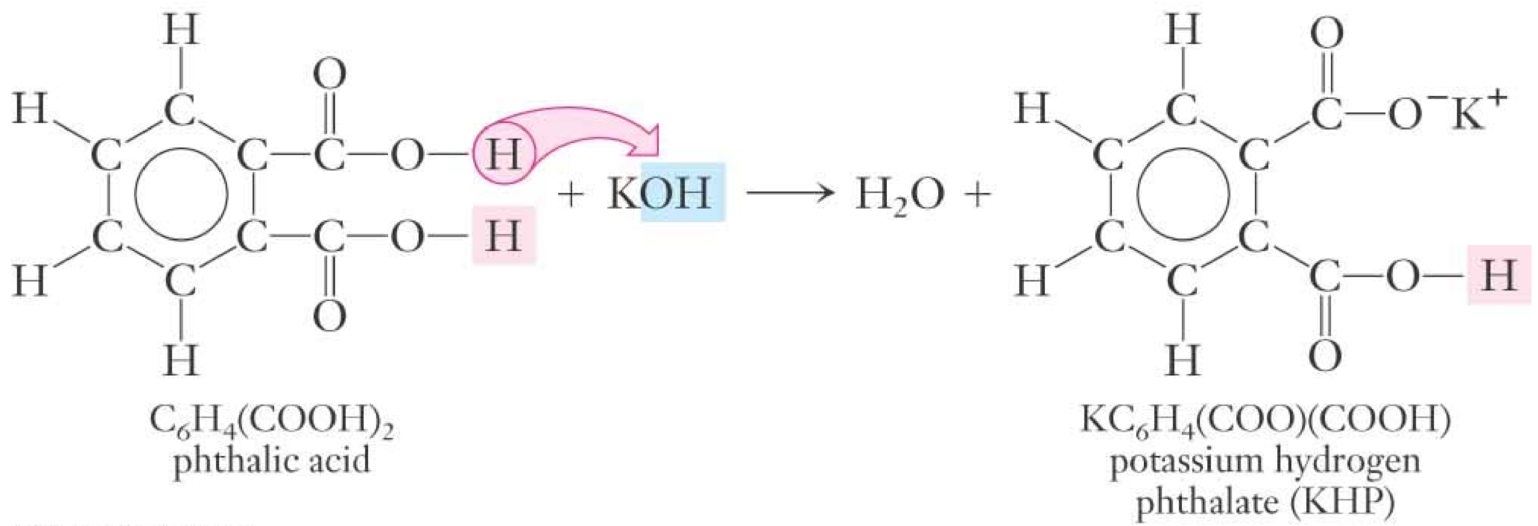
5. Indicator – A substance that exists in different forms with different colors depending on the concentration of the H^+ in solution. Examples are phenolphthalein and bromothymol blue.
6. Equivalence point – The point at which stoichiometrically equivalent amounts of the acid and base have reacted.
7. End point – The point at which the indicator changes color and the titration is stopped.

Titration



The Mole Method and Molarity

- Potassium hydrogen phthalate is a very good primary standard.
  - It is often given the acronym, KHP.
  - KHP has a molar mass of 204.2 g/mol.



- Calculate the molarity of a NaOH solution if 27.3 mL of it reacts with 0.4084 g of KHP.

$$NaOH + KHP \rightarrow NaKP + H_2O$$

- Calculate the molarity of a sulfuric acid solution if 23.2 mL of it reacts with 0.212 g of Na_2CO_3.

$$Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + CO_2 + H_2O$$

Equivalent Weights and Normality

- Normality is another method of expressing concentration.
  - Normality is defined as the number of equivalent weights of solute per liter of solution.

$$N = \frac{\#\ \text{eq solute}}{\text{L sol'n}} \quad \text{or} \quad N = \frac{\#\ \text{meq solute}}{\text{mL sol'n}}$$

- The equivalent weight of an acid is the mass in grams of the acid necessary to furnish Avogadro's number of H^+ ions.
- For monoprotic acids like HCl 1 mol = 1 eq
- For diprotic acids like H_2SO_4 1 mol = 2 eq
- For triprotic acids like H_3PO_4 1 mol = 3 eq

- Calculate the normality of a solution that contains 196 g of sulfuric acid in 1.500 x 10^3 mL of solution.

TABLE 11-1 *Equivalent Weights* of Some Acids and Bases*

Acids			Bases		
Symbolic representation		*One equivalent*	*Symbolic representation*		*One equivalent*
$\frac{HNO_3}{1}$	$= \frac{63.02 \text{ g}}{1}$	$= 63.02 \text{ g } HNO_3$	$\frac{NaOH}{1}$	$= \frac{40.00 \text{ g}}{1}$	$= 40.00 \text{ g } NaOH$
$\frac{CH_3COO\underline{H}}{1}$	$= \frac{60.03 \text{ g}}{1}$	$= 60.03 \text{ g } CH_3COO\underline{H}$	$\frac{NH_3}{1}$	$= \frac{17.04 \text{ g}}{1}$	$= 17.04 \text{ g } NH_3$
$\frac{K\underline{H}P}{1}$	$= \frac{204.2 \text{ g}}{1}$	$= 204.2 \text{ g } K\underline{H}P$	$\frac{Ca(OH)_2}{2}$	$= \frac{74.10 \text{ g}}{2}$	$= 37.05 \text{ g } Ca(OH)_2$
$\frac{H_2SO_4}{2}$	$= \frac{98.08 \text{ g}}{2}$	$= 49.04 \text{ g } H_2SO_4$	$\frac{Ba(OH)_2}{2}$	$= \frac{171.36 \text{ g}}{2}$	$= 85.68 \text{ g } Ba(OH)_2$

- Calculate the molarity and normality of a solution that contains 34.2 g of barium hydroxide in 8.00 liters of solution.

Equivalent Weights and Normality

- Since M x L = moles then
- N x L = number of equivalents or
  - N x mL = number of milliequivalents
- What volume of 6.00 M phosphoric acid solution is required to prepare 9.00 x 10^2 mL of 0.200 N phosphoric acid solution?

- What is the normality of a sulfuric acid solution if 31.3 mL of it reacts with 0.318 g of sodium carbonate?

- 30.0 mL of 0.0750 N nitric acid solution required 22.5 mL of calcium hydroxide solution for neutralization. Calculate the normality and the molarity of the calcium hydroxide solution.

$$2\ HNO_3 + Ca(OH)_2 \rightarrow Ca(NO_3)_2 + 2\ H_2O$$

Oxidation-Reduction Reactions
The Half-Reaction Method

- Half reaction method rules:

1. Write the unbalanced reaction.
2. Break the reaction into 2 half reactions:

One oxidation half-reaction and

One reduction half-reaction

Each reaction must have complete formulas for molecules and ions.

3. Mass balance each half reaction by adding appropriate stoichiometric coefficients. To balance H and O we can add:
   - H^+ or H_2O in acidic solutions.
   - OH^- or H_2O in basic solutions.

4. Charge balance the half reactions by adding appropriate numbers of electrons.
   - Electrons will be products in the oxidation half-reaction.
   - Electrons will be reactants in the reduction half-reaction.
5. Multiply each half reaction by a number to make the number of electrons in the oxidation half-reaction equal to the number of electrons reduction half-reaction.
6. Add the two half reactions.
7. Eliminate any common terms and reduce coefficients to smallest whole numbers.

	To balance O:		To balance H:
In Acidic Solution:	Add H_2O	and → then	Add H^+
In Basic Solution:	For *each* O needed, (1) add *two* OH^- to side needing O and (2) add *one* H_2O to other side	and → then	For *each* H needed, (1) add *one* H_2O to side needing H and (2) add *one* OH^- to other side

- Tin (II) ions are oxidized to tin (IV) by bromine. Use the half reaction method to write and balance the net ionic equation.

- Dichromate ions oxidize iron (II) ions to iron (III) ions and are reduced to chromium (III) ions in acidic solution. Write and balance the net ionic equation for the reaction.

- In basic solution hydrogen peroxide oxidizes chromite ions, $Cr(OH)_4^-$, to chromate ions, CrO_4^{2-}. The hydrogen peroxide is reduced to hydroxide ions. Write and balance the net ionic equation for this reaction.

- When chlorine is bubbled into basic solution, it forms hypochlorite ions and chloride ions. Write and balance the net ionic equation.
- This is a disproportionation redox reaction. The same species, in this case Cl_2, is both reduced and oxidized.

Stoichiometry of Redox Reactions

- What volume of 0.200 *M* $KMnO_4$ is required to oxidize 35.0 mL of 0.150 M HCl? The balanced reaction is:

$$2\,KMnO_4 + 16\,HCl \rightarrow 2\,KCl + 2\,MnCl_2 + 5\,Cl_2 + 8\,H_2O$$

- A volume of 40.0 mL of iron (II) sulfate is oxidized to iron (III) by 20.0 mL of 0.100 *M* potassium dichromate solution. What is the concentration of the iron (II) sulfate solution?

$$6\,Fe^{2+} + Cr_2O_7^{\;2-} + 14\,H^{+} \rightarrow 6\,Fe^{3+} + 2\,Cr^{3+} + 7\,H_2O$$

Chemistry is fun!