University Chemistry I

Chemistry 120, Section A

Chapter 4

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Solutions

Solution- homogenous mixture of two or more pure substances; composition can be varied.

One or more *solutes* are dissolved in a *solvent*.

Solute- substance dissolved in a solvent, present in smaller amount.

Solvent- substance present in greater amount, contains dissolved solute.

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Aqueous Solutions

- Water is the solvent
- NB: Only One Solvent

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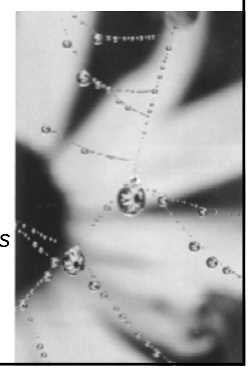
Important Properties of Water

- Bent or angular shape
- O-H bonds are polar covalent
- polar
- high *surface tension*

- stores much energy in *h-bonds*
- excellent solvent



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A Solute

dissolves in water (or other “solvent”)

changes phase (if different from the solvent)

is present in lesser amount (if the same phase as the solvent)

4-5

A Solvent

retains its phase (if different from the solute)

is present in greater amount (if the same phase as the solute)

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Solubility is Favored By:

- Strong solvent-solute interactions
- Weak solvent-solvent interactions
- Weak solute-solute interactions

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Solubility

- "like dissolves like"
- Ionic compounds are harder to remember
- Insoluble if water can't pull the atoms apart
- We will know a short list (subsequent slide)

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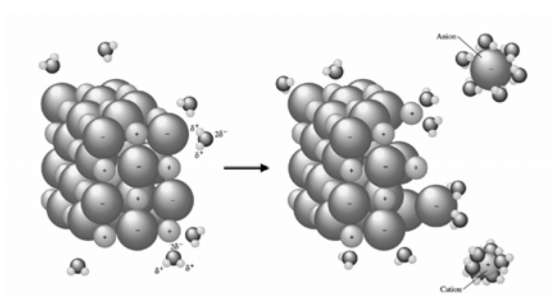
The Solution Process – Forces Are Important

Fig. 4.2 Zumdahl and Zumdahl, 6th Ed.



Hydration occurs when salts dissolve in water.

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Dissociation

Dissociate- acids and bases and other soluble compounds break apart into ions when placed in water.

$CaCl_2 \rightarrow Ca^{2+} + 2\,Cl^-$

$HCl + H_2O \rightarrow H_2O + H^+ + Cl^-$ Eqn. I

$HCl + H_2O \rightarrow H_3O^+ + Cl^-$ Eqn. II

Eqn. I and Eqn. II mean the same thing

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Solubility in Water

See Table 4.2 Chang, 9th Ed.

1. Group IA element-containing compounds are soluble.
2. Ammonium, nitrate, and acetate-containing compounds are soluble.
3. Compounds containing halogens are soluble - except Ag, Hg, and Pb.
4. Compounds containing sulfate are soluble -except Ag, Hg, and Pb, and Ca, Sr, Ba.
5. Hydroxides tend to be *insoluble* - except IA, Ca, Ba and Sr are soluble. And ammonium.
6. Sulfides (S^{2-}), carbonates (CO_3^{2-}), chromates (CrO_4^{2-}), and phosphates (PO_4^{3-}) tend to be insoluble - except IA and ammonium.

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Electrolytes

- Strong - conduct current efficiently
  - NaCl, HNO_3
  - 100% Na^+, Cl^-; 0% NaCl
- Weak - conduct only a small current
  - vinegar, tap water
  - 2% H^+, OAc^-; 98% HOAc
- Non - no current flows
  - pure water, sugar solution
  - 100% $C_6H_{12}O_6$; 0% H^+, $C_6H_{11}O_6^-$

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Strong and Weak Acids

Strong acids- dissociate completely to produce H^+ in solution

Hydrochloric, nitric and sulfuric acid

Weak acids- dissociate to a slight extent to give H^+ in solution

"all the rest" like acetic and formic acid

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Strong *vs*. Weak Acids and Ka Values

Acid	Formula	Ka
hydrochloric acid	HCl	∞
nitric acid	HNO_3	∞
sulfuric acid	H_2SO_4*	∞
phosphoric acid	H_3PO_4	7.5×10^{-3}
phosphoric acid	H_2PO_4	6.2×10^{-8}
phosphoric acid	HPO_4	4.8×10^{-13}
acetic acid	$HC_2H_3O_2$	1.8×10^{-5}

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Strong and Weak Bases

Strong bases- react completely with water to give OH^- ions.

sodium hydroxide

anything hydroxide (as long as it is soluble)

Weak bases- react only slightly with water to give OH^- ions.

ammonia

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Concentrations of Solutions

- We need a way to accurately describe *how much* solute is dissolved in a solvent
- Several possible units
  - Molarity
  - Normality
  - Percent solution
  - ppm
  - others

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Molarity

Molarity (*M*) = moles of solute per volume of solution in liters:

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

$$3\ M\ \text{HCl} = \frac{\text{6 moles of HCl}}{\text{2 liters of solution}}$$

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Practice Molarity Problems

What is the molarity of a solution composed of 2.85 mol solute in 0.500 L distilled water?

What is the molarity of a solution composed of 25.852 g NaCl dissolved in distilled water to a final volume of 1.000 L?

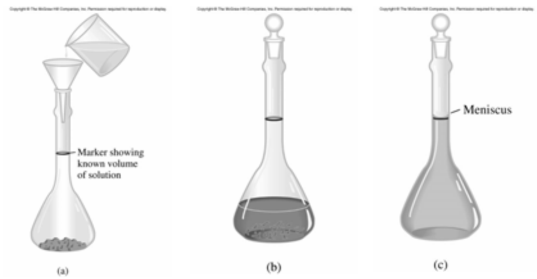
What is the molarity of a solution composed of 25.852 g NaCl dissolved in distilled water to a final volume of in 750 mL?

How many grams NaCl are in 0.15 L of 3.2 M NaCl?

What is the concentration, in molarity, of a 2.50 mg/mL solution of Cu^{2+}?

Preparing Solutions

Fig. 4.18 Chang, 9th Ed.



1. Weigh out the amount of solute needed
2. Dissolve in a portion of water
3. Dilute to final volume and MIX!

Common Terms of Solution Concentration

Stock Solution - routinely used solutions prepared in concentrated form.

Concentrated Solution - *relatively* large ratio of solute to solvent. (5.0 *M* NaCl or 12 M HCl)

Dilute solution - *relatively* small ratio of solute to solvent. (0.01 *M* NaCl or 6 M HCl)

Dilution in Solutions

$$(C_I)(V_I) = (C_F)(V_F)$$

What is the final concentration of HCl if 53.0 mL concentrated (11.6 M) is diluted to 1.00 L?

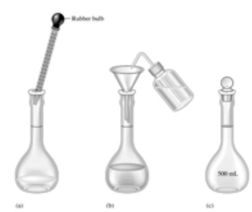
What volume of 11.6 M HCl would you dilute to 1.0 L if you wanted a solution of 4.5 M?

$$(N_A)(V_A) = (N_B)(V_B) \text{ or } (M_A)(V_A) = (M_B)(V_B)$$

If I titrate 200.0 mL of NaOH to neutrality with 24.96 mL of 1.00 M HCl, what is the concentration of the NaOH?

Procedure for the Dilution of Stock Solutions

Fig. 4.12 Zumdahl and Zumdahl, 6th Ed.



(a) A measuring pipet is used to transfer 28.7mL of 17.4 *M* acetic acid solution to a volumetric flask.

(b) Water is added to the flask to the calibration mark.

(c)MIX!

(d) The resulting solution is 1.00 *M* acetic acid.

Interconverting Concentrations

Concentration of Select Acids and Bases
Common Commercial Strengths

	Molecular weight	Moles per liter	Grams per liter	Percent by weight	Specific gravity
acetic acid, glacial	60.05	17.4	1045	99.5	1.05
acetic acid	60.05	6.27	376	36	1.045
Hydrochloric acid	36.5	11.6	424	36	1.18
		2.9	105	10	1.05
hypophosphorous acid	66.0	9.45	625	50	1.25
		5.14	339	30	1.13
		1.57	104	10	1.04
sodium hydroxide	40.0	19.1	763	50	1.53
		2.75	111	10	1.11

Types of Solution Reactions

Precipitation reactions

$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

Acid-base reactions

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

Oxidation-reduction reactions

$Fe_2O_3(s) + Al(s) \rightarrow Fe(l) + Al_2O_3(s)$

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Describing Reactions in Solution

1. Molecular equation (reactants and products as compounds)
   $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$
2. Complete ionic equation (all strong electrolytes shown as ions)
   $Ag^+ + NO_3^- + Na^+ + Cl^- \rightarrow AgCl\downarrow + Na^+ + NO_3^-$
3. Net ionic equation (show only components that actually react)
   $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(ppt)$
   Na^+ and NO_3^- are *spectator ions*.

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Sample Test Question

- Write the molecular equation for the reaction of hydrochloric acid with potassium hydroxide.
- Write the total ionic equation for the reaction of hydrochloric acid with potassium hydroxide.
- Write the net ionic equation for the reaction of hydrochloric acid with potassium hydroxide.

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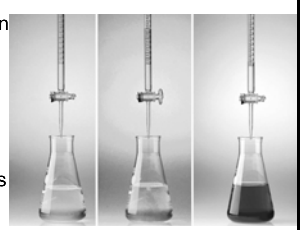
Key Titration Terms

Titrant- solution of known concentration used in titration

Analyte- substance being analyzed

Equivalence point- enough titrant added to react *exactly* with the analyte

Endpoint- the indicator changes color so you can tell the equivalence point has been reached.



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Sample Test Question

- How many milliliters of 0.25 M NaOH are required to reach the equivalence point with 250 g HCN?

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Oxidation-Reduction (Redox) Reactions

- Mnemonic devices
  - OIL RIG
  - Leo the tiger says gerr ?sp?
  - Others?
- In order to know whether redox rxn, must examine *oxidation state*

Oxidation state- charge that develops as an atom loses or gains e^-

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Rules for Assigning Oxidation States

1. Oxidation state of an atom in an *elemental state* = 0
2. Oxidation state of monatomic ion = charge (periodic table prediction)
3. Oxygen = -2 in covalent compounds (except in peroxides where it = -1)
4. H = +1 in covalent compounds
5. Fluorine = -1 in compounds
6. Sum of oxidation states = 0 in compounds
7. Sum of oxidation states = charge of the ion in polyatomic ion

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Sample Test Question

- Identify the oxidation state of all atoms in the following species
  - Al
  - NaCl
  - CH_4
  - CO_2
  - NO_3^-
  - Fe_2O_3
- #4.49

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Balancing by Half-Reaction Method

1. Write separate reduction, oxidation reactions.
2. For each half-reaction:
   Balance elements (except H, O)
   Balance O using H_2O
   Balance H using H^+
   Balance charge using electrons
3. If necessary, multiply by integer to equalize electron count.
4. Add half-reactions.
5. Check that elements and charges are balanced.

Discussion

Discussion Session 4.33 Chang

- (Complete and) Balance the following equations and write the corresponding ionic and net ionic equations (if appropriate)

$H_3PO_4(aq) + Ba(OH)_2(aq) \rightarrow ?$

$HBr(aq) + NH_3 \rightarrow ?$

Discussion

Discussion Section

- 4.85: 18.68 mL KOH needed to neutralize 0.4218 g *KHP*. ?M KOH? KHP eq. wt (right) 204.22
- 4.87b: ?mL? 1.420 M NaOH reqd titrate 25.00 mL 4.500 M H_2SO_4

Discussion

Discussion Session 4.43 Chang

- For the complete redox reactions given here, (i) break down each reaction into its half reactions; (ii) identify the *oxidizing reagent*; (iii) identify the *reducing agent*

$2Sr + O_2 \rightarrow 2SrO$

Oxidizing agent- REACTANT that causes oxidation. Always contains the element that is reduced.

Reducing agent- REACTANT that causes reduction. Always contains the element that is oxidized.

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STQ

- Balance the following redox reaction, which occurs in acidic solution.

$Fe^{2+} + Cr_2O_7^{2-} \rightarrow Fe^{3+}\ Cr^{3+}$

repeat

Balancing by Half-Reaction Method

1. Write separate reduction, oxidation reactions.
2. For each half-reaction:
   - Balance elements (except H, O)
   - Balance O using H_2O
   - Balance H using H^+
   - Balance charge using electrons
3. If necessary, multiply by integer to equalize electron count.
4. Add half-reactions.
5. Check that elements and charges are balanced.

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Half-Reaction Method - Balancing in Base

1. Balance as in acid.
2. Add $OH^–$ that equals H^+ ions (both sides!)
3. Form water by combining H^+, $OH^–$
4. Check elements and charges for balance.

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STQ

- Balance the following redox reaction, which occurs in basic solution.

$$MnO_4^– + I^– \rightarrow MnO_2 + I_2$$

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Activity Series — Exp 05

- If one mixes copper sulfate (a blue solution) and zinc (a chunk of grey metal), one observes over time the blue disappears and is replaced by a reddish-brown solid:

$$CuSO_4 + Zn \rightarrow ZnSO_4 + Cu$$

- However, if one mixes a copper penny with zinc sulfate, the solution will remain colorless and Abe will still be recognizable and honest (unlike misogynic Bill):

$$ZnSO_4 + Cu \rightarrow NR$$

- Observations like these lead to the *activity series*

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The *Activity Series*

See Fig. 4.16 Chang 9th Ed.

activity series- the results of many displacement reactions are portrayed in tabular form
AKA electrochemical series
Upper-left corner = strongest reducing agent
Lower-right corner = strongest oxidizing agent
Note: Always shown as the oxidation half-reaction.
The most important thing about the activity series is the ability to predict whether a reaction will occur:

- A reaction will occur if any *metal* in the series will react with any *metal compound* beneath it