

12-1

Solutions

Table 12.1 Chang, 9th Ed.

Solution- uniform mixture of two or more pure substances, whose composition can be varied.

There are many types of solutions:

Component 1	Component 2	State of Resulting Solution	Examples
Gas	Gas	Gas	Air
Gas	Liquid	Liquid	Soda water (CO ₂ in water)
Gas	Solid	Solid	H ₂ gas in palladium
Liquid	Liquid	Liquid	Ethanol in water
Solid	Liquid	Liquid	NaCl in water
Solid	Solid	Solid	Brass (Cu/Zn), solder (Sn/Pb)

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Concentrations of Solutions

- We need a way to accurately describe how much solute is dissolved in a solvent
- Previously dealt with molarity (M), which is most commonly used, but there are others we need to learn now
- BTW, remember *solute* and *solvent*; *dilute* and *stock*; *etc.*, previously discussed

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Mass Percent solution

$$\text{Mass Percent} = \frac{\text{mass solute}}{\text{mass solution}} \times 100\%$$

What is the mass percent solution if 12.5 g NaCl is added to 100.0 mL water?

11.1% (w/w)

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Mol Fraction

$$\text{mol fxn}_A = \chi_A = \frac{n_a}{n_a + n_b}$$

What is the mol fraction of sodium chloride if 12.5 g NaCl is added to 100.0 g water?

Note no units

$$\chi_{\text{NaCl}} = 0.0581$$

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Molality

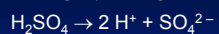
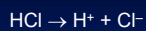
$$m = \frac{\text{mol}}{\text{kg solvent}}$$

What is the molality if 12.5 g NaCl is added to 100.0 mL water?

$$2.14 \text{ m}$$

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Normality



There are two *equivalents* of H per molecule of H_2SO_4

$$\text{Normality} = \frac{\text{equivalents of solute}}{\text{liters of solution}}$$

If molarity known, Normality = $M \times X$, where X is number ions of interest

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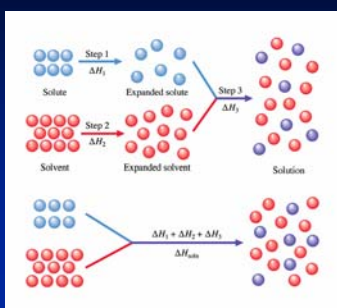
Rule of Thumb for Solubility

- “like dissolves like”:
- Polar solutes dissolve in polar solvents
- Nonpolar solutes dissolve in nonpolar solvents
- Polar solutes do not dissolve in nonpolar solvents
- Nonpolar solutes do not dissolve in polar solvents

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ΔH Solution

Fig. 11.1 Zumdahl and Zumdahl, 6th Ed.
See Fig. 12.2 Chang, 9th Ed.



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ΔH Solution

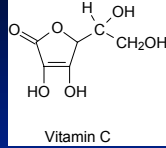
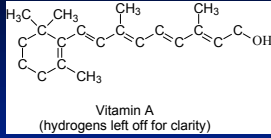
Table 11.3 Zumdahl and Zumdahl, 6th Ed.

TABLE 11.3 The Energy Terms for Various Types of Solutes and Solvents

	ΔH_1	ΔH_2	ΔH_3	ΔH_{soln}	Outcome
Polar solvent, polar solute	Large	Large	Large, negative	Small	Solution forms
Polar solvent, nonpolar solute	Small	Large	Small	Large, positive	No solution forms
Nonpolar solvent, nonpolar solute	Small	Small	Small	Small	Solution forms
Nonpolar solvent, polar solute	Large	Small	Small	Large, positive	No solution forms

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Solubility as a Function of Structure



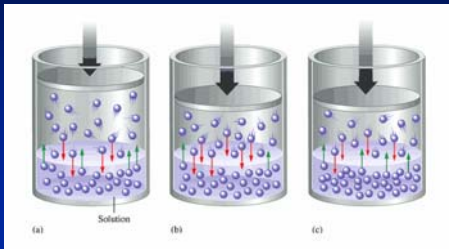
- Fat soluble vs. water soluble vitamins
 - Polar bear liver is deadly to humans
 - “expensive urine is all you get from taking vitamins”

12-11

Solubility of Gas in Liquid

Fig. 11.5 Zumdahl and Zumdahl, 6th Ed.
See Fig. 12.6 Chang, 9th Ed.

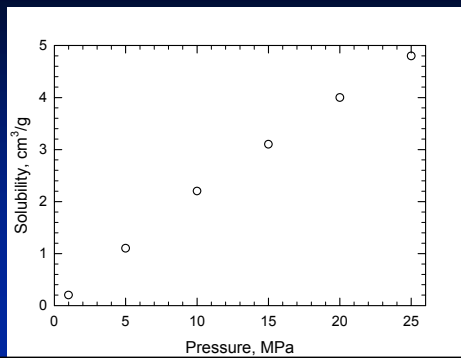
- Affected by pressure and temperature



12-12

Solubility of Air in Water (Henry's Law)

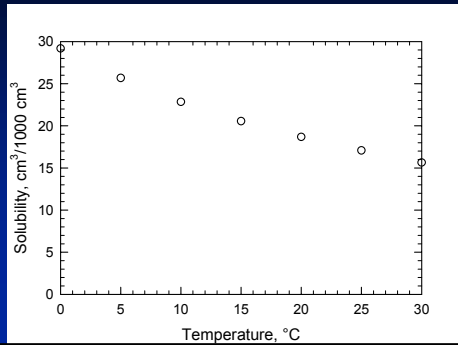
Data: ?



12-13

Solubility of Air in Water

Data: Lange's Handbook of Chemistry

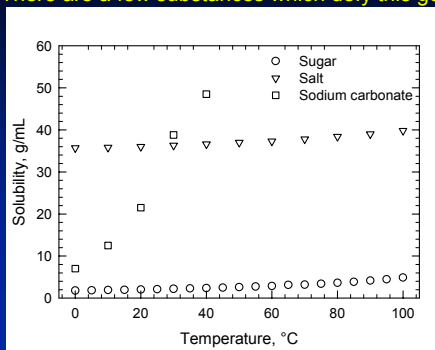


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Solubility as a Function of Temperature

Data: Lange's Handbook of Chemistry

Note: There are a few substances which defy this generality



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Vapor Pressure (Again)

Fig. 11.10 Zumdahl and Zumdahl, 6th Ed.

The presence of solute(s) changes the behavior of a solvent

Vapor pressure is one property that is affected

$$Vp, soln < Vp, solvent$$



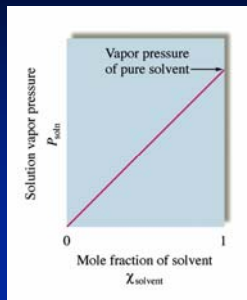
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Raoult's Law

Fig. 11.11 Zumdahl and Zumdahl, 6th Ed

$$P_{\text{soln}} = \chi_{\text{H}_2\text{O}} P_{\text{H}_2\text{O}}^{\circ}$$

- P° for water is 23.76 torr at 25 °C
- ?What is the vapor pressure if 25.0 g sucrose added to 1.0 L water?



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This Example

Fig. 11.12 Zumdahl and Zumdahl, 6th Ed.

- Used sucrose:
 - Does dissolve
 - Does not *dissociate*
 - NaCl would be different
 - Can, and often do, have multiple solutes
- Volatile solutes:
 $V_{p,\text{soln}} > V_{p,\text{solvent}}$
(note typo on slide printout of last year)



12-18

Nonideal solutions

- Remember nonideal gases? What made them not ideal?
 - ▶ Intermolecular forces of attraction ◀
- Raoult's Law is not going to be obeyed ideally by everything because of intermolecular forces of attraction
- Remember Dalton's Law of partial pressures?

$$P_{\text{total}} = \chi_A P_A^{\circ} + \chi_B P_B^{\circ} + \dots + \chi_n P_n^{\circ}$$

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Colligative Properties

Colligative properties- changes in the behavior of a solvent based on containing a solute

The changes depend only on the number of solute **particles** present in a solution, not on the identity of the solute.

Four colligative properties:

- Decreased melting point
- Increased boiling point
- Increased osmotic pressure
- (decreased) Vapor pressure

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Colligative Properties-mp

Table 12.2 Chang, 9th Ed.

For water, 1 mol particles/kg water lowers mp by 1.86 °C

$$K_f = \frac{1.86^\circ\text{C kg}}{\text{mol}}$$

TABLE 12.2

Molal Boiling-Point Elevation and Freezing-Point Depression Constants of Several Common Liquids

Solvent	Normal Freezing Point (°C)*	K_f (°C/m)	Normal Boiling Point (°C)*	K_b (°C/m)
Water	0	1.86	100	0.52
Benzene	5.5	5.12	80.1	2.53
Ethanol	-117.3	1.99	78.4	1.22
Acetic acid	16.6	3.90	117.9	2.93
Cyclohexane	6.6	20.0	80.7	2.79

*Measured at 1 atm.

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Practice Problems: Freezing Point Depression

How much would the melting point decrease if 113 g $\text{CH}_3\text{CH}_2\text{OH}$ were dissolved in 1750 mL water?

How much would the melting point decrease if 36 g CaCl_2 were dissolved in 432 mL water?

The melting point of 1.00 kg of water changes by 3.26 °C when 25.0 g of a *covalent* compound is added. What is the molar mass of the compound?

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van't Hoff Factor, i

- relationship between moles solute dissolved and moles particles in solution

$$i = \frac{\text{moles particles in solution}}{\text{moles particles in solution}}$$

- reason for this being important is experimental measurements: for example, NaCl = 1.87

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Colligative Properties-bp Elevation Including Sample Problems

For water, 1 mol particles/kg water raises bp by 0.51 °C

$$\left(K_{\text{c}} = \frac{0.51^{\circ}\text{C kg}}{\text{mol}} \right)$$

How much would the boiling point increase if 3.25 mol CH_3Cl were dissolved in 251 g water?

How much would the boiling point increase if 27.5 g NaCl were dissolved in 657 mL water?

The melting point of 1.00 kg of water changes by 1.036 °C when 250.0 g of an unknown compound is added. What are the possible molar masses of the compound?

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Colligative Properties-Osmotic Pressure

Osmosis is movement of water through a *semipermeable membrane*

Dialysis is an important application of this concept

$$\Pi V = nRT$$

or

$$\Pi = MRT$$

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Isotonic

See Fig. 12.13 Chang 9th Ed.

- Isotonic- same ionic strength, but not the same solution
- Hypertonic- surroundings higher ionic strength
- Hypotonic- surroundings lower ionic strength



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Practice Problems: Colligative Properties

The melting point of 1.00 kg of water changes by 1.86 °C when 75.0 g of an ionic compound (molar mass 300.0 g/mol) is added. How many ions does this molecule dissociate into?

12-27

Colloids

Fig. 7-13 Blei and Odian, GOB 1st Ed.

Colloids- solutions in which the solutes are large enough that light is scattered.

Na^+ is 1.53×10^{-10} m

Milk, a typical colloid, has proteins such as casein, which is about 1.41×10^{-7} m in diameter

This causes light scattering- the *Tyndall effect*

The casein is soluble, so colloids do not settle out



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Suspensions

An example of a suspension is muddy water.
Light is not just scattered, but stopped.
The "mud" is insoluble, so over time it settles out.
