Chapter 8. Solutions

Introduction to Inorganic Chemistry
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Contact me trough phone or e-mail if you have questions
Online Tests on Following days
March 24, 2017: Test 1 (Chapters 1-3)
April 10, 2017 : Test 2 (Chapters 4-5)
April 28, 2017: Test 3 (Chapters 6,7 &8)
May 12, 2017 : Test 4 (Chapters 9, 10 &11)
May 15, 2017: Make Up Exam: Chapters 1-11)

.

Chapter 8

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Section 8.1

Characteristics of Solutions

What is a "Solution"?

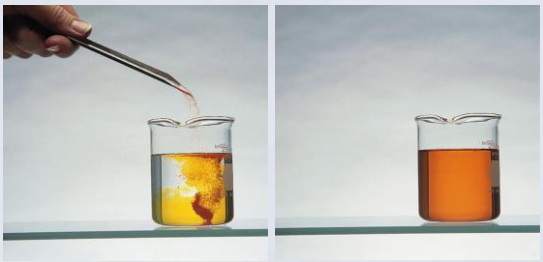
- A **homogeneous mixture** of two or more substances with each substance retaining its own chemical identity.
- Components of a solution
  - **Solute** – component of a solution that is present in a lesser amount relative to that of the solvent; substance being dissolved.

    Solute could be a gas, liquid or solid
  - **Solvent** – component of a solution that is present in the greatest amount; liquid water.

Section 8.1

Characteristics of Solutions

Colored Crystals (Solute-$K_2Cr_2O_7$) Mixed with Water (Solvent)



Section 8.1

Characteristics of Solutions

General Properties of a Solution

- Contains 2 or more components.
- Has variable composition.
- Properties change as the ratio of solute to solvent is changed.
- Dissolved solutes are present as individual particles (molecules, atoms, or ions).
- Solutes remain uniformly distributed and will not settle out with time.
- Solute generally can be separated from the solvent by physical means such as evaporation.

Section 8.2

Solubility

- The maximum amount (g) of solute that will dissolve in a given amount of solvent (100 g) under a given set of conditions at certain temperature.

Section 8.2

Solubility

Effect of Temperature on Solubility

- Most solids become more soluble in water with increasing temperature.

Table 8.1 Solubilities of Various Compounds in Water at 0°C, 50°C, and 100°C

	Solubility (g solute/100 g H_2O)		
Solute	0°C	50°C	100°C
lead(II) bromide ($PbBr_2$)	0.455	1.94	4.75
silver sulfate (Ag_2SO_4)	0.573	1.08	1.41
copper(II) sulfate ($CuSO_4$)	14.3	33.3	75.4
sodium chloride (NaCl)	35.7	37.0	39.8
silver nitrate ($AgNO_3$)	122	455	952
cesium chloride (CsCl)	161.4	218.5	270.5

Section 8.2

Solubility

Effect of Temperature on Solubility compared to gases

- In contrast, gas solubility in water decrease with increasing temperature.

Eg. Solubility of sugar ($C_{12}H_{22}O_{11}$) increases.

Eg. Solubility of CO_2 in water decreases.

Section 8.2

Solubility

Effect of Pressure on Solubility

- Pressure has little effect on the solubility of solids and liquids in water.
- Pressure has major effect on the solubility of gases in water.
- Eg. Solubility of CO_2 in water increases with pressure.

Section 8.2

Solubility

Henry's Law (for gas solubility in a liquid)

- The amount of gas that will dissolve in a liquid (P) at a given temperature is directly proportional to the partial pressure (P_x) of the gas above the liquid.

$$S = K_h P_x$$

K_h = Henry's constant for the system

- As the pressure of a gas above the liquid increases, the solubility of the gas increases.
- Eg. CO_2 in water (carbonated water)

Section 8.2

Solubility

Unsaturated Solution

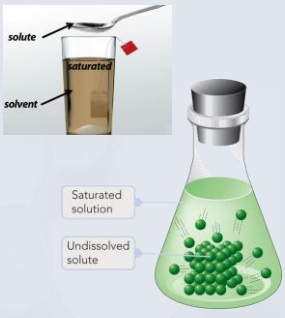
- A solution that contains less than the maximum amount of solute that can be dissolved under the conditions at which the solution exists.
- Most solutions we encounter fall into this category.

Section 8.2

Solubility

Saturated Solution

- A stable solution that contains the maximum amount of solute that can be dissolved under the conditions at which the solution exists.



Section 8.2

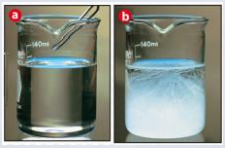
Solubility

Supersaturated Solution

a) An unstable solution that temporarily contains more dissolved solute than that present in a saturated solution.

b) Will produce crystals rapidly, often in a dramatic manner, if it is slightly disturbed or if it is "seeded" with a tiny crystal of solute.

a) adding more solute by heating A saturated solution Then let the temperature reach Normal and adding a seed crystal



Section 8.2

Solubility

Concentrated and Dilute Solutions

- Concentrated Solution – a solution that contains a large amount of solute relative to the amount that could dissolve.
- Dilute Solution – a solution that contains a small amount of solute relative to the amount that could dissolve.

Section 8.2

Solubility

Concentrated and Dilute Solutions

Section 8.2

Solubility

Aqueous and Nonaqueous Solutions

- Aqueous Solution – a solution in which water is the solvent.
- Nonaqueous Solution – a solution in which a substance other than water is the solvent.

E.g. Ethanol (C_2H_5OH)

Section 8.3

Solution Formation

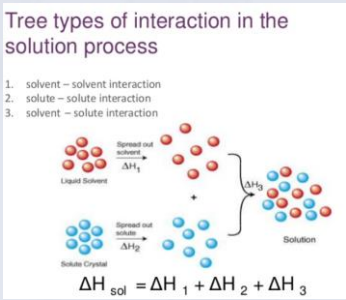
For a Solute to Dissolve in a Solvent

- Two types of interparticle (molecules or ions) attractions must be overcome:
  - Attractions between solute particles (solute-solute attractions).
  - Attractions between solvent particles (solvent-solvent attractions).
- New type of interaction forms:
  - Attraction between solute and solvent particles (solute-solvent attractions.)

Section 8.3

Solution Formation

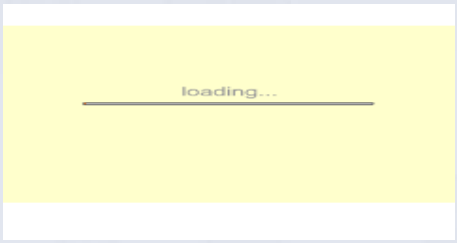
For a Solute to Dissolve in a Solvent



Section 8.3

Solution Formation

Dissolution of a Solid in a Liquid



https://www.youtube.com/watch?v=7PHhBBg-6X0
To play movie you must be in Slide Show Mode
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Mac Users: CLICK HERE

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Section 8.3

Solution Formation

Factors Affecting the Rate of Solution Formation with solids

1. The state of subdivision (particle size) of the solute.
2. The degree of agitation during solution preparation.
3. The temperature of the solution components.

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Section 8.4

Solubility Rules

- In general, it is found that the greater the difference in solute-solvent polarity (polar vs. non-polar), the less soluble is the solute.
- Substances of like polarity (similar either polar or non-polar) tend to be more soluble in each other than substances that differ in polarity.
  - "Like dissolves like" (for most covalent compounds)
  - Use Solubility Guidelines for ionic compounds in water.

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Section 8.4

Solubility Rules

Solubility Guidelines for Ionic Compounds in Water

Table 8.2 Solubility Guidelines for Ionic Compounds in Water

Soluble Compounds	Important Exceptions
Compounds containing the following ions are soluble with exceptions as noted.	
Group IA (Li^+, Na^+, K^+, etc.)	none
ammonium (NH_4^+)	none
acetate ($C_2H_3O_2^-$)	none
nitrate (NO_3^-)	none
chloride (Cl^-), bromide (Br^-), and iodide (I^-)	Ag^+, Pb^{2+}, Hg_2^{2+}
sulfate (SO_4^{2-})	Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}
Insoluble Compounds*	**Important Exceptions**
Compounds containing the following ions are insoluble with exceptions as noted.	
carbonate (CO_3^{2-})	Group IA and NH_4^+
phosphate (PO_4^{3-})	Group IA and NH_4^+
sulfide (S^{2-})	Groups IA and IIA and NH_4^+
hydroxide (OH^-)	Group IA and Ca^{2+}, Sr^{2+}, Ba^{2+}

*All ionic compounds, even the least soluble ones, dissolve to some slight extent in water. Thus the "insoluble" classification really means ionic compounds that have very limited solubility in water.

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Section 8.4

Solubility Rules

Concept Check

Which of the following ions form compounds with Pb^{2+} that are generally soluble in water?

a) S^{2-}
b) Cl^-
c) NO_3^-
d) SO_4^{2-}
e) Na^+

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Section 8.4

Solubility Rules

Concept Check

Which of the following ions form compounds with Pb^{2+} that are generally soluble in water?

a) S^{2-}
b) Cl^-
c) NO_3^-
d) SO_4^{2-}
e) Na^+

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Section 8.5

Solution Concentration Units

Concentration

- The amount of solute present in a specified amount of solution.
- Two Methods of Expressing Concentration:
  - Percent Concentration
  - Molarity

Section 8.5

Solution Concentration Units

Percent Concentration

- Three different ways of representing percent concentration:
  - Percent by Mass
  - Percent by Volume
  - Mass-Volume Percent

Section 8.5

Solution Concentration Units

Percent by Mass

$$\text{Percent by mass} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100$$

Mass of solution = mass of solute + mass of solvent

Section 8.5

Solution Concentration Units

Exercise

What is the percent-by-mass concentration of glucose in a solution made my dissolving 5.5 g of glucose in 78.2 g of water?

Section 8.5

Solution Concentration Units

Exercise

What is the percent-by-mass concentration of glucose in a solution made my dissolving 5.5 g of glucose in 78.2 g of water?

6.6%

$$\frac{5.5}{78.2 + 5.5} \times 100 = 6.6$$

Section 8.5

Solution Concentration Units

Percent by Volume

$$\text{Percent by volume} = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100$$

Exercise

Calculate the volume percent of solute in 30.0 mL of methyl alcohol in enough water to give 435 mL of solution.

Exercise

Calculate the volume percent of solute in 30.0 mL of methyl alcohol in enough water to give 435 mL of solution.

6.90%

$$\frac{30.0}{435} \times 100 = 6.90$$

Mass-Volume Percent

$$\text{Mass - volume percent} = \frac{\text{mass of solute (g)}}{\text{volume of solution (mL)}} \times 100$$

Conversion Factors Obtained From Percent Concentration Units

Table 8.3 Conversion Factors Obtained from Percent Concentration Units

Percent Concentration	Meaning in Words	Conversion Factors
15%(m/m) NaCl solution	There are 15 g of NaCl in 100 g of solution.	$\frac{15\text{ g NaCl}}{100\text{ g solution}}$ and $\frac{100\text{ g solution}}{15\text{ g NaCl}}$
6%(v/v) methanol solution	There are 6 mL of methanol in 100 mL of solution.	$\frac{6\text{ mL methanol}}{100\text{ mL solution}}$ and $\frac{100\text{ mL solution}}{6\text{ mL methanol}}$
25%(m/v) sucrose solution	There are 25 g of sucrose in 100 mL of solution.	$\frac{25\text{ g sucrose}}{100\text{ mL solution}}$ and $\frac{100\text{ mL solution}}{25\text{ g sucrose}}$

Molarity

- Moles of solute in a solution divided by the liters of solution.

$$\text{Molarity (M)} = \frac{\text{moles of solute}}{\text{liters of solution}}$$

Exercise

You have 1.00 mol of sugar in 125.0 mL of solution. Calculate the concentration in units of molarity.

Section 8.5

Solution Concentration Units

Exercise

You have 1.00 mol of sugar in 125.0 mL of solution. Calculate the concentration in units of molarity.

8.00 M

$$\frac{1.00\ \text{mol}}{0.125\ \text{L}} \times 100 = 8.00\ \text{M}$$

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Section 8.5

Solution Concentration Units

Exercise

You have a 10.0 M sugar solution. What volume of this solution do you need to have 2.00 mol of sugar?

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Section 8.5

Solution Concentration Units

Exercise

You have a 10.0 M sugar solution. What volume of this solution do you need to have 2.00 mol of sugar?

0.200 L

$$10.0\ \text{M} = \frac{10.0\ \text{mol}}{1.00\ \text{L}}$$

$$2.00\ \text{mol of sugar} \times \frac{1.00\ \text{L}}{10.0\ \text{mol}} = 0.200\ \text{L}$$

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Section 8.5

Solution Concentration Units

Exercise

Consider separate solutions of NaOH and KCl made by dissolving 100.0 g of each solute in 250.0 mL of solution. Calculate the concentration of each solution.

$$100\ \text{g NaOH} \times \left(\frac{1\ \text{mol NaOH}}{40.01\ \text{g NaOH}}\right) \times \left(\frac{1}{0.250\ \text{L}}\right) = 10.0\ \text{M}$$

$$100\ \text{g KCl} \times \left(\frac{1\ \text{mol KCl}}{74.55\ \text{g KCl}}\right) \times \left(\frac{1}{0.250\ \text{L}}\right) = 5.37\ \text{M}$$

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Section 8.5

Solution Concentration Units

Exercise

Consider separate solutions of NaOH and KCl made by dissolving 100.0 g of each solute in 250.0 mL of solution. Calculate the concentration of each solution.

10.0 M NaOH

5.37 M KCl

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Section 8.6

Dilution

- The process in which more solvent is added to a solution in order to lower its concentration.
- Dilution with water does not alter the numbers of moles of solute present.
- Moles of solute before dilution = moles of solute after dilution

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Section 8.6

Dilution

Dilution Calculations

$$C_s \times V_s = C_d \times V_d$$

(s = stock solution)

(d = diluted solution)

Section 8.6

Dilution

Concept Check

A 0.50 *M* solution of sodium chloride sits on a lab bench. Which of the following would decrease the concentration of the salt solution?

a) Add water to the solution.
b) Pour some of the solution down the sink drain.
c) Add more sodium chloride to the solution.
d) Let the solution sit out in the open air for a couple of days.
e) At least two of the above would decrease the concentration of the salt solution.

Section 8.6

Dilution

Concept Check

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e) At least two of the above would decrease the concentration of the salt solution.

Section 8.6

Dilution

Exercise

What is the minimum volume of a 2.00 *M* NaOH solution needed to make 150.0 mL of a 0.800 *M* NaOH solution?

$C_s \times V_s = C_d \times V_d$

$C_s = 2.00\ M$ NaOH

V_s = ?

$V_d = 150.0$ mL

$C_d = 0.800\ M$ NaOH

$V_s = \frac{0.800 \times 150.0}{2.00} = 60.0$ mL

Section 8.6

Dilution

Exercise

What is the minimum volume of a 2.00 *M* NaOH solution needed to make 150.0 mL of a 0.800 *M* NaOH solution?

60.0 mL

Section 8.7

Colloidal Dispersions and Suspensions

Colloidal Dispersion

- A homogeneous mixture that contains dispersed particles that are intermediate in size between those of a true solution and those of an ordinary heterogeneous mixture.
  - Dispersed phase (like the solute)
  - Dispersing medium (like the solvent (water))
  - E.g. Milk

Section 8.7

Colloidal Dispersions and Suspensions

Tyndall Effect

- The light-scattering phenomenon that causes the path of a beam of visible light through a colloidal dispersion to be observable.
  - When we shine a beam of light through a true solution, we cannot see the track of the light.
  - A beam of light passing through a colloidal dispersion can be observed because the light is scattered by the dispersed phase.

Section 8.7

Colloidal Dispersions and Suspensions

Yellow Solution (true) vs. Colloidal Dispersion in Red

Section 8.7

Colloidal Dispersions and Suspensions

Suspension

- A heterogeneous mixture that contains dispersed particles that are heavy enough that they settle out under the influence of gravity.

Section 8.7

Colloidal Dispersions and Suspensions

Property Comparison for Solutions, Colloidal Dispersions, and Suspensions

Table 8.4 Property Comparison for Solutions, Colloidal Dispersions, and Suspensions

Property	Solution	Colloidal Dispersion	Suspension
type of mixture	homogeneous	homogeneous	heterogeneous
type of particles	atoms, ions, and small molecules	groups of small particles or individual larger molecules	very large particles, which are often visible
effect of light	transparent	scatters light (Tyndall effect)	not transparent
settling properties	particles do not settle	particles do not settle	particles settle rapidly
filtration properties	particles cannot be filtered out	particles cannot be filtered out	particles can be filtered out

Section 8.8

Colligative Properties of Solutions

Colligative Property

A physical property of a solution that depends only on the number of solute particles (molecules or ions concentration) present in a given quantity of solvent and not on their chemical identities.

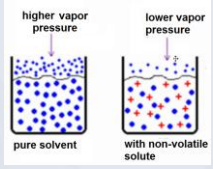
a) Vapor-pressure lowering
b) Boiling-point elevation
c) Freezing-point depression
d) Osmotic pressure

Section 8.8

Colligative Properties of Solutions

Vapor-Pressure Lowering

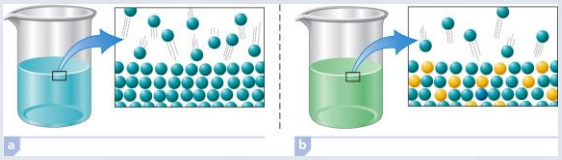
- Adding a nonvolatile solute to a solvent *lowers* the vapor pressure of the resulting solution below that of the pure solvent at the same temperature.



Section 8.8

Colligative Properties of Solutions

Vapor-Pressure Lowering

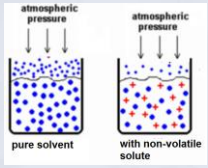


Section 8.8

Colligative Properties of Solutions

Boiling-Point Elevation

Adding a nonvolatile solute to a solvent *raises* the boiling point of the resulting solution above that of the pure solvent.

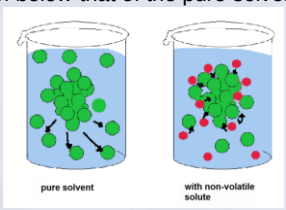


Section 8.8

Colligative Properties of Solutions

Freezing-Point Depression

- Adding a nonvolatile solute to a solvent *lowers* the freezing point of the resulting solution below that of the pure solvent.



Section 8.9

Osmosis and Osmotic Pressure

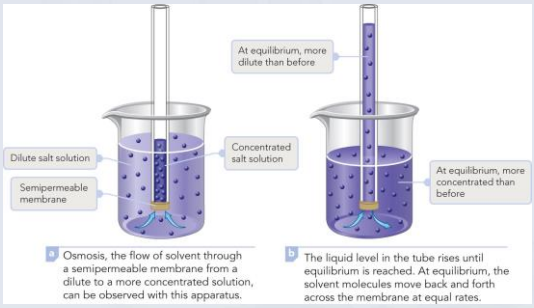
Osmosis

- The passage of a solvent through a semipermeable membrane separating a dilute solution (or pure solvent) from a more concentrated solution.
  - Semi-permeable membrane – a membrane that allows certain types of molecules (water) to pass through it but prohibits the passage of other types of molecules (sugar).

Section 8.9

Osmosis and Osmotic Pressure

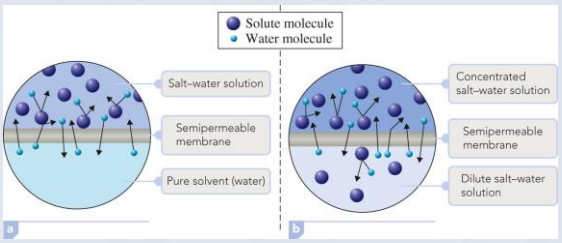
Osmosis



Section 8.9

Osmosis and Osmotic Pressure

Semi-Permeable Membrane



Section 8.9

Osmosis and Osmotic Pressure

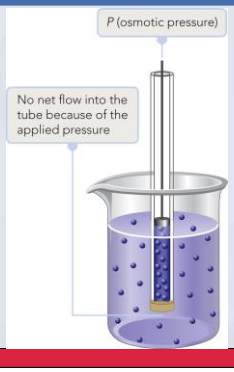
Osmotic Pressure

- The pressure that must be applied to prevent the net flow of solvent through a semipermeable membrane from a solution of lower solute concentration to a solution of higher solute concentration.

Section 8.9

Osmosis and Osmotic Pressure

Osmotic Pressure



Section 8.9

Osmosis and Osmotic Pressure

Osmolarity

Used to compare the osmotic pressures of solutions.

Osmolarity = Molarity × *i*

i is the number of particles produced from the dissociation of one formula unit of solute.

E.g. 1 M NaCl aqueous solution (*i* = 2)

Osmolarity = 1X 2 = 2 M

Section 8.9

Osmosis and Osmotic Pressure

Exercise

What is the osmolarity of a 3 M NaCl solution?

Section 8.9

Osmosis and Osmotic Pressure

Exercise

What is the osmolarity of a 3 M NaCl solution?

6 osmol

Section 8.9

Osmosis and Osmotic Pressure

Hypotonic Solution

- A solution with a lower osmotic pressure than that within cells.

Section 8.9

Osmosis and Osmotic Pressure

Hypotonic Solution: Hemolysis Occurs in Pure Water

a Hemolysis occurs in pure water (a hypotonic solution)

Section 8.9

Osmosis and Osmotic Pressure

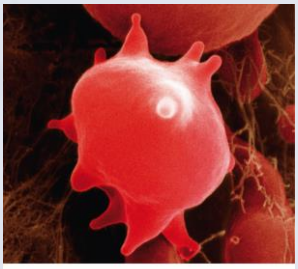
Osmolality of solutions

- Cell plasma have 0.23 mol/L
- It is most commonly used as a sterile 9 g of salt per liter (0.93 % m/L) (~0.23 M) solution, known as normal saline.
- 43 g of glucose per liter (0.5 % m/L) (~0.23 M) solution.

Section 8.9

Osmosis and Osmotic Pressure

Hypertonic Solution: Crenation Occurs in NaCl



b Crenation occurs in concentrated sodium chloride solution (a hypertonic solution)

Section 8.9

Osmosis and Osmotic Pressure

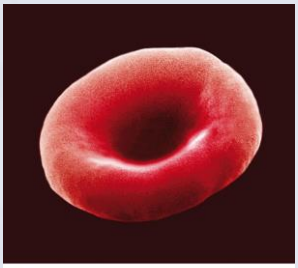
Isotonic Solution

- A solution with an osmotic pressure that is equal to that within cells.

Section 8.9

Osmosis and Osmotic Pressure

Isotonic Solution: Cells Neither Swell Nor Shrink in Saline Soln



c Cells neither swell nor shrink in physiological saline solution (an isotonic solution)

Section 8.9

Osmosis and Osmotic Pressure

Characteristics of Hypotonic, Hypertonic, and Isotonic Solutions

Table 8.5 Characteristics of Hypotonic, Hypertonic, and Isotonic Solutions

	Type of Solution		
	Hypotonic	Hypertonic	Isotonic
osmolarity relative to body fluids	less than	greater than	equal
osmotic pressure relative to body fluids	less than	greater than	equal
osmotic effect on cells	net flow of water into cells	net flow of water out of cells	equal water flow into and out of cells

