Water, Body Fluids and Aqueous Solutions

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Water is life itself!

- Water has major importance to all life forms
  - from the most simple to the most advanced
- The more water, the more biological diversity
- A large proportion of body weight is made up of water
  - This rate is about 57% of an adult human
  - This rate is about 75% of children
- Approx. 40 liters of water exists in a 70 kilograms adult

Body Fluids

- Expressing the amount of body fluids as a percentage of body weight is not true!
  - The percentage of water in the body decreases with increasing body fat
  - There is not much water in body fat
  - In adult women, fat makes up more of the body than men.

Composition of body fluids

- Intracellular fluid - the fluid inside the cell
  - In terms of matter concentrations in the cell fluid there is no significant differences between the various cell types
  - For this reason, a single name is referred to: “intracellular fluid”
  - Intracellular fluid has a “gel” form

Composition of body fluids

- Extracellular fluid - the fluid outside of the cell
  - Exist in different compartments of the body
  - The largest part of this fluid is "interstitial" fluid – intercellular fluid
  - More than 99% of interstitial fluid in the "gel" form
  - The remaining fluid is in liquid form (not gel) flows between the cells

Extracellular Fluid

- Other special fluids that make up the extracellular fluid
  - blood plasma
  - Cerebrospinal fluid – brain - spinal cord fluid
  - Intraocular fluid – the fluid inside the eye
  - Gastrointestinal canals, peritoneal cavity*, and the pericardial space**, intra-articular spaces etc.
    - Normally contain small quantities of liquid
    - in some special cases these spaces may be filled with large amount of fluid

* the serous membrane lining the walls of the abdominal and pelvic cavities
** is a double-walled sac containing the heart and the roots of the great vessels.

Physicochemical Properties of Water

Water

- serves as a medium for almost all cellular metabolic events
- has a special value among other liquids

Physicochemical Properties of Water

- Very high specific heat capacity (the second highest after ammonia)

  Specific heat capacity: The amount of heat needed to raise its temperature to a certain amount.

C: specific heat capacity

$$C = \frac{Q}{m\Delta T}$$

ΔT: temperature change

The specific heat of water is 1 calorie/gram °C = 4.186 joule/gram °C

  - Prevents the quick and large temperature changes
  - This property is important to regulate the temperature of the body (thermoregulation).

Specific Heats of Some Common Substances

Substance	Specific Heat [cal/(g · °C)]
Water (liquid)	1.00
Water (solid)	0.50
Water (gas)	0.47
Ethyl alcohol	0.54
Wood	0.42
Aluminum	0.21
Glass	0.12
Iron	0.11
Copper	0.09
Silver	0.06
Gold	0.03

http://witcombe.sbc.edu/water/chemistryproperties.html

Physicochemical Properties of Water

- The vaporization heat of water is higher than the other liquids
  - In order to maintain a constant body temperature this feature is important in evaporation of sweat from the body surface

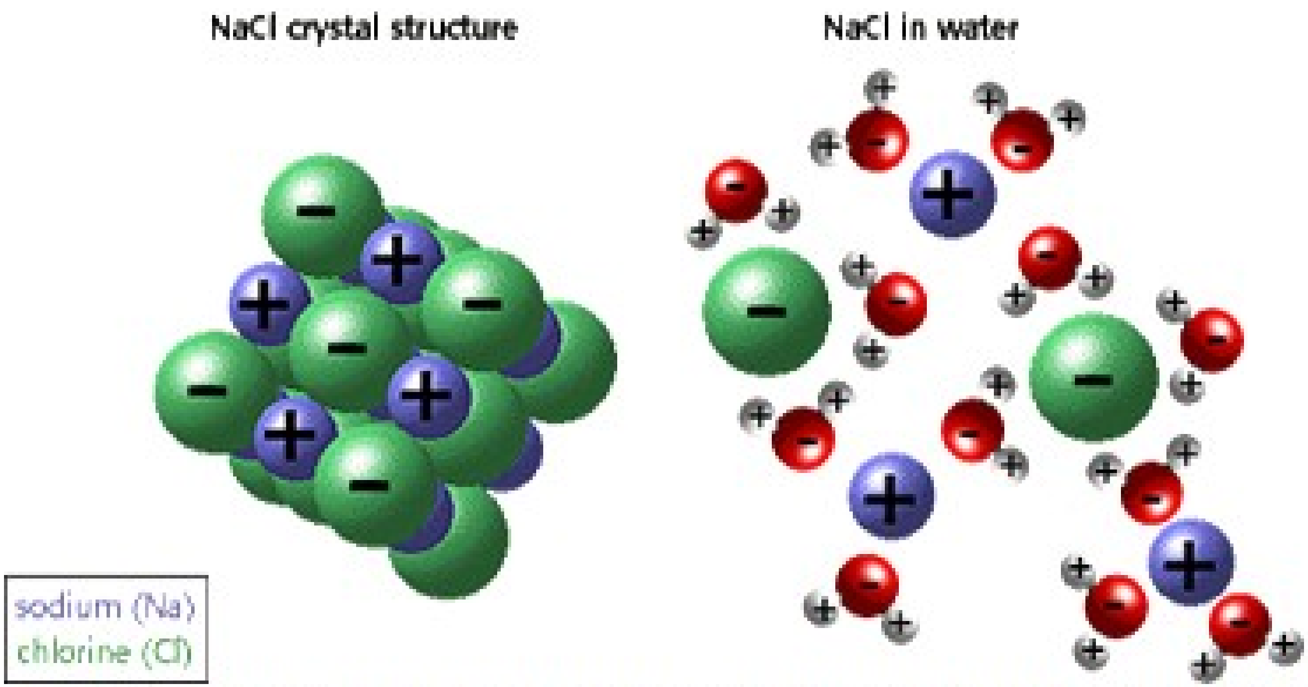
Physicochemical Properties of Water

- Ice is less dense than water
- Water is the only liquid whose density decreases while passing through solid state.
  - Ice floats on water enabling a good insulation for the deeper parts of water
  - Thus life goes on in the depths of water

Physicochemical Properties of Water

- Universal solvent: It is the solvent for the electrolytes and nutrients needed by the cells, and also the solvent to carry waste material away from the cells.
  - The best solvent is water for ionic compounds
  - most of the small organic molecules with polar groups such as -OH,-NH2,-COOH are water-soluble

Ion - Dipole Interactions



A molecular picture showing the ion-dipole interaction that helps a solid ionic crystal dissolve in water.

Electrostatic forces will arise between an ion and dipole molecule.

* Ions and polar molecules dissolve well in water.
  Water is a good solvent due to its polarity.

SOLUTIONS

- a **solution** is a homogeneous mixture of one or more solutes dissolved in a solvent.
  - The solution more or less takes on the characteristics of the solvent including its phase, and the solvent is commonly the major fraction of the mixture
- a **solute** is a substance dissolved in a solvent.
- The solvent does the dissolving.
- Solutions may be in gas, liquid and solid phases.

Solubility

- The **solubility** is the amount of the substance that will dissolve in a given amount of solvent.
- Solubility units are:
  - g/ml
  - g/l
  - mol/l

Solubility

- The solubility is high if the interaction between the solvent and solute is strong.
- Dissolution lasts until the system reaches an equilibrium:

$$\text{Solute} + \text{Solvent} \leftrightarrow \text{Solution}$$

- Saturated solution is the solution in which the maximum amount of solvent has been dissolved. Any more solute added will sit as crystals on the bottom of the container

Factors affecting solubility

- The solubility of a substance fundamentally depends on the used solvent as well as on temperature and pressure.
- Temperature
  - increasing the temperature increases solubility in **endothermic solutions** (absorb energy from the surroundings in the form of heat)
  - increasing the temperature would decrease the solubility in **exothermic solutions** ("gives out" energy in the form of heat)
    - Gas solubility in liquids is always reduced with the increased temperature

Factors affecting solubility

- Pressure
  - Of the solutions, including liquid and solid are not affected by pressure
  - Increasing pressure increases the solubility of gases in liquids

$$S_g = k\ P_g$$

P_g= partial gas pressure

k= solubility constant

Decompression sickness- DCS
divers' disease

- DCS is a dangerous and occasionally lethal condition caused by nitrogen bubbles that form in the blood and other tissues of scuba divers who surface too quickly.
- the partial pressure of blood gases increases when the divers dive into depths of water and much more than the normal amount of nitrogen dissolve in the blood.
- If a diver ascend rapidly from a dive, a sudden drop in the surrounding pressure will occur.
- The partial pressure of gas will drop and thereby solubility will drop
- Nitrogen bubbles will form in the blood and tissues
- Produce many symptoms, and their effects may vary from joint pain to paralysis and death

Electrolyte Solutions

- Substances that give ions when dissolved in water are called electrolytes.
- They can be divided into acids, bases and salts because they all give ions when dissolved in water.
- These solutions conduct electricity due to the mobility of the positive and negative ions, which are called cations and anions respectively.
- Strong electrolytes completely ionize when dissolved.
- NaCl, HNO_3, NaOH etc are strong electrolytes. An ionization can be represented by,

  NaCl(s) = Na+(aq) + Cl-(aq)

Colligative Properties of Solutions

- Colligative is a property that depends only on the number of molecules of a solute in a given solution, not the identity of the solute.
- These colligative properties are:
  - Vapor Pressure Depression
  - Boiling Point Elevation
  - Freezing Point Depression
  - Osmotic Pressure

Colligative Properties of Solutions:

Vapor Pressure Depression

- Vapor pressure, the pressure of the evaporated solvent, decreases as the concentration of nonvolatile solute particles increases.
- This fact is called Raoult's Law

$P_A = X_A P_A^o$

P_A is the vapor pressure of the solution

P_A^o is the vapor pressure of the *pure* solvent

X_A is the mole fraction of the solvent

- When the solvent is pure, and the mole fraction of the solvent is equal to 1, $P_A = P_A^o$.
- As the mole fraction of the solvent becomes smaller, the vapor pressure of the solvent escaping from the solution also becomes smaller.

Mole Fraction

- Mole fraction(x) is the amount of a constituent divided by the total amount of all constituents in a solution.

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$$x_i = \frac{moles\ of\ component\ i}{total\ moles\ of\ solution}$$

- For example, a solution composed of components A, B, C, …
  - The mole fraction of components A and B are;

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$$X_A = \frac{n_A}{n_A + n_B + n_C + \ldots}$$

$$X_B = \frac{n_B}{n_A + n_B + n_C + \ldots}$$

  - *The sum of the mole fractions for a solution will equal 1.*
  - XA + XB + XC + … = 1

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  - XA + XB + XC + … = 1

Colligative Properties of Solutions:

Boiling Point Elevation

- The boiling point of a substance is the temperature at which the vapor pressure of the liquid equals to the surrounding pressure.
- If the vapor pressure of the solvent is smaller than the vapor pressure of the pure solvent at any given temperature, the solution must be **heated to a higher temperature** in order to reach the surrounding pressure. And thus the boiling point is elevated.

$$\Delta T_{BP} = K_b\, m$$

ΔT_{BP} is the boiling point elevation

K_b is the *molal boiling point elevation constant* for the solvent

m is the molality of the solution

Colligative Properties of Solutions

Freezing Point Depression

- The presence of a solute lowers the freezing point of a solution relative to that of the pure solvent

$$\Delta T_f = K_f m$$

ΔT_f is the freezing point depression

K_f is called the freezing-point-depression constant

m is the molality of the solution

- Because the presence of a solute lowers the freezing point, many communities put salt on their roads after a snowfall, to keep the melted snow from refreezing.

Colligative Properties of Solutions

Osmotic Pressure

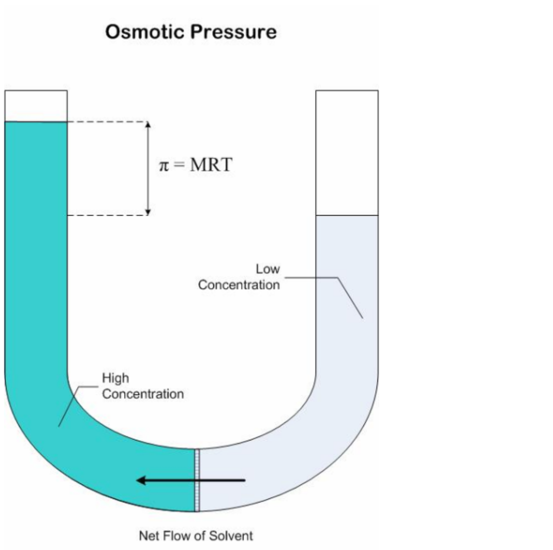
- Osmosis is the process whereby a solvent passes through a semipermeable membrane from one solution to another (or from a pure solvent into a solution).
- A semipermeable membrane is a barrier through which some substances may pass (e.g., the solvent particles), and other species may not (e.g., the solute particles).
- Osmosis tends to drive solvent molecules through the semipermeable membrane from the low solute concentrations to the high solute concentrations.
- **Osmotic pressure** is the pressure that must be applied on the high concentration side to stop osmosis.
- Osmotic pressure is defined by:

$$\pi = MRT$$

M is the molar concentration of solution

R is the molar gas constant

T is absolute temperature in K



Colligative Properties of Solutions

Osmotic Pressure

- Isotonic solutions have equal osmotic pressure.
  - an equal concentration exists in solutions
  - there is no flow between solutions

Osmotic Pressure- Example 1

- How much glucose ($C_6H_{12}O_6$) per liter should be used (in order to have a isotonic solution) to match the 7.7 atm at 25°C osmotic pressure of blood? (molar mass of glucose = 180g/mol)

- Find absolute temperature

  T = °C + 273 = 25 + 273 = **298 K**

  Find concentration of blood

  π= MRT π= 7.7 atm   R= 0.082 L·atm/mol·K   T= 298 K

  M = π / RT = 7.7 / 0.082 x 298

  = 0.31 mol/L

  Find amount of glucose per liter

  molar mass of glucose = 180 g/mol

  mass of glucose = 0.31 x 180

  mass of glucose = **55.8 g**

55.8 grams per liter of glucose should be used to match the 7.7 atm at 25°C osmotic pressure of blood.

Osmotic Pressure- Example 2

- How much NaCl should be used to have a isotonic saline solution which has the same osmotic pressure as blood in 7.7 atm at 25°C?

Find absolute temperature

T = °C + 273 = 25 + 273 = 298 K

Find concentration of blood

π= MRT π= 7.7 atm   R= 0.082 L·atm/mol·K   T= 298 K

M = π / RT = 7.7 / 0.082 x 298

M = 0.31 mol/L

Because NaCl dissolved well in water and decomposes into Na + and Cl-ions (a strong electrolyte)

Accordingly, it will be sufficient to obtain 0.155 M from each ions (0.31/2= 0.155)

0.155 M NaCl → 0.155 M Na^+ + 0.155 M Cl^-

Total ion concentration = 0.31 M

1 mol NaCl = 58.5 g

0.155 mol NaCl is : 0.155 x 58.5 = **9.06 g NaCl** should be used to match the 7.7 atm at 25°C osmotic pressure of blood.

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