Introduction to Clinical Biochemistry

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Units, Concentrations, Solutions & Dilutions

Molarity

- Molarity" is a concentration term.
- It refers to the number of moles of a substance per liter of solution.
- It you recall, a "mole" is the quantity of substance that contains 6.02×10^{23} (Avogadro's number) items.
- You may also recall that the atomic or formula weight of a substance, in grams, contains 1 mole (6.02×10^{23} units) of that substance.
- For example, the atomic weight of oxygen gas (O_2) is 32. Therefore, 1 mole of O_2 weighs 32 g and contains 6.02×10^{23} O_2 molecules.
- NaCl provides another example. 1 mole of NaCl weighs approximately 58.4 g (Na atomic wt. = 23, Cl atomic weight = 35.4) and, you guessed it, contains 6.02×10^{23} atoms of *both* Na and Cl.

- The atomic or formula (for substances which don't exist as molecules) weight of a substance can also be easily used to determine how many moles of a substance are contained in a given quantity.
- For example, if we have 25 g of NaCl on hand, we can calculate the number of moles by dividing this amount by the formula weight of NaCl:
- *Number of moles* = $\frac{\textit{given weight in grams}}{\textit{weight of one mole}} = \frac{25\ g\ NaCl}{58.4\ g\ per\ mole} = 0.43\ moles\ NaCl$ (1)

- It is relatively easy to extrapolate calculations for the number of moles of substance into the concentration term “molarity”.
- To calculate the molarity of a solution, simply divide the number of moles of substance it contains (solute) by the volume of the solution, in liters. Using our NaCl example, a 1 molar (M) solution of NaCl contains:

$$\frac{1 \textit{ mole NaCl}}{\textit{liter solution}}$$

Unit reviews

milligram	10^{-3} g	0.001 g
microgram	10^{-6} g	0.000001 g
nanogram	10^{-9} g	0.000000001 g
picogram	10^{-12} g	0.000000000001 g
milliliter	10^{-3} liter	0.001 L
microliter	10^{-6} liter	0.000001 L

Solutions and Dilutions

- A solution contains one chemical dissolved in another liquid.
- When chemicals are in the form of liquids, they can be either pure liquids or solutions.
- A pure liquid would be something like absolute ethanol; it contains nothing but molecules of ethanol.
- When dealing with solutions, the chemical in the *smaller quantity* is the **solute**.
- The liquid it is dissolved in is the **solvent**.
- When you calculate the amount of solute dissolved in the solvent, you have determined the concentration.

- Concentrations are used to describe the relative amount of solute in a solution.
- It is important to be able to distinguish values that are concentrations from those that are not, which we will call amounts.
- If we put 1 gram of salt in a beaker that it is an amount. If we bring the volume up to 1 liter with water then we have a 1 g/L solution, which is described using values for concentration. If we have 1 millimole (mmol) of salt in a beaker that is an amount. If we bring the volume up to 1L with water then we have a 1mM (millimolar) solution, which is also described using values for concentration.

% Solutions

- Solutions based on percent are the easiest to calculate, because they do not depend on knowledge of the molecular weight.
- **%w/v** means **percent weight to volume** and has units of grams/100 ml. Therefore a 1% w/v solution has 1 g of solute in a total of 100 ml of solution.
- **%v/v** means **percent volume to volume** and has units of mL/ 100 ml. Therefore a 1% v/v solution of ethanol has 1 ml of pure ethanol in 100 ml of total solution.

Blood Components

- Normally, 7-8% of human body weight is from blood.
- In adults, this amounts to 4.5-6 quarts of blood.
- This essential fluid carries out the critical functions of transporting oxygen and nutrients to our cells and getting rid of carbon dioxide, ammonia, and other waste products.
- In addition, it plays a vital role in our immune system and in maintaining a relatively constant body temperature.
- Blood is a highly specialized tissue composed of more than 4,000 different kinds of components.
- Four of the most important ones are red cells, white cells, platelets, and plasma. All humans produce these blood components; there are no populational or regional differences.

Red Cells

- Red cells, or **erythrocytes** , are relatively large microscopic cells without nuclei.
- In this latter trait, they are similar to the primitive prokaryotic cells of bacteria.
- Red cells normally make up 40-50% of the total blood volume.
- They transport oxygen from the lungs to all of the living tissues of the body and carry away carbon dioxide.

- The red cells are produced continuously in our bone marrow from stem cells at a rate of about 2-3 million cells per second.
- **Hemoglobin** is the gas transporting protein molecule that makes up 95% of a red cell.
- Each red cell has about 270,000,000 iron-rich hemoglobin molecules.
- People who are anemic generally have a deficiency in red cells, and subsequently feel fatigued due to a shortage of oxygen.
- The red color of blood is primarily due to oxygenated red cells.
- Human fetal hemoglobin molecules differ from those produced by adults in the number of amino acid chains.
- Fetal hemoglobin has three chains, while adults produce only two.
- As a consequence, fetal hemoglobin molecules attract and transport relatively more oxygen to the cells of the body.

White Cells

- White cells, or **leukocytes** , exist in variable numbers and types but make up a very small part of blood's volume--normally only about 1% in healthy people.
- Leukocytes are not limited to blood. They occur elsewhere in the body as well, most notably in the spleen, liver, and lymph glands.
- Most are produced in our bone marrow from the same kind of stem cells that produce red blood cells.
- Others are produced in the thymus gland, which is at the base of the neck. Some white cells (called lymphocytes) are the first responders for our immune system. They seek out, identify, and bind to alien protein on bacteria, viruses, and fungi so that they can be removed.

White Cells

- Other white cells (called granulocytes and macrophages) then arrive to surround and destroy the alien cells.
- They also have the function of getting rid of dead or dying blood cells as well as foreign matter such as dust and asbestos.
- Red cells remain viable for only about 4 months before they are removed from the blood and their components recycled in the spleen.
- Individual white cells usually only last 18-36 hours before they also are removed, though some types live as much as a year.

Platelets

- Platelets , or **thrombocytes** , are cell fragments without nuclei that work with blood clotting chemicals at the site of wounds.
- They do this by adhering to the walls of blood vessels, thereby plugging the rupture in the vascular wall.
- They also can release coagulating chemicals which cause clots to form in the blood that can plug up narrowed blood vessels.
- Thirteen different blood clotting factors, in addition to platelets, need to interact for clotting to occur. They do so in a cascading manner, one factor triggering another. Hemophiliacs lack the ability to produce either blood factor 8 or 9.

Platelets

- Platelets are not equally effective in clotting blood throughout the entire day. The body's circadian rhythm system (its internal biological clock) causes the peak of platelet activation in the morning. This is one of the main reasons that strokes and heart attacks are more common in the morning.
- Recent research has shown that platelets also help fight infections by releasing proteins that kill invading bacteria and some other microorganisms.
- In addition, platelets stimulate the immune system. Individual platelets are about 1/3 the size of red cells.
- They have a lifespan of 9-10 days. Like the red and white blood cells, platelets are produced in bone marrow from stem cells.

Plasma

- Plasma is the relatively clear, yellow tinted water (92+%), sugar, fat, protein and salt solution which carries the red cells, white cells, and platelets.
- Normally, 55% of our blood's volume is made up of plasma.
- As the heart pumps blood to cells throughout the body, plasma brings nourishment to them and removes the waste products of metabolism.
- Plasma also contains blood clotting factors, sugars, lipids, vitamins, minerals, hormones, enzymes, antibodies, and other proteins.
- It is likely that plasma contains some of every protein produced by the body--approximately 500 have been identified in human plasma so far.

References

- Clinical Biochemistry (Fundamentals of Biomedical Science), Editor: Nessar Ahmed
- Handbook of Clinical Biochemistry, 2nd Edition, R. Swaminathan