A. Units, Amounts and Concentrations

Units and abbreviations

The common units, and their respective abbreviations, used in biomedical sciences are based on the International System of Measurements (SI units): grams (g), metres (m) etc. Often it is necessary to deal with large quantities e.g. 1500 g or, more commonly, very small quantities, e.g. 0.0000015 g. In such cases, such numbers are either expressed by use of powers of 10 (positive or negative) or by use of the appropriate prefix.

Thus: 1500 g = 1.5×10^{3} g = 1.5 kg (kilograms)

and 0.0000015 g = 1.5×10^{-6} g = 1.5 µg (micrograms)

Laboratory scientists most commonly use the prefix notation, particularly those that differ by a factor of 1000 in magnitude, so you should try to become familiar with them. Use of the prefixes can greatly simplify calculations, especially mental ones.

Note also that biomedical scientists normally express volumes and concentrations in terms of litres rather than in cubic measurements:

e.g. 1 litre, rather than 1 dm^3
1 millilitre (1 ml) rather than 1 cm^3

A concentration of 1 milligram per litre is also still commonly expressed in the form 1 mg/l rather than 1 $mg.l^{-1}$ or 1 $mg.dm^{-3}$.

The commonly used prefixes are:

Prefix	Name	Which modifies an amount by	Examples
m	milli	1/1000th, i.e. by 10^{-3}	mmol, mg, ml
µ	micro	1/1000 000th, i.e. by 10^{-6}	µmol, µg, µl
n	nano	by 10^{-9}	nmol, ng
p	pico	by 10^{-12}	pmol, pg
f	femto	by 10^{-15}	fmol, fg
k	kilo	by 1000 times, i.e. by10^{3}	kg
M	mega	by 10^{6}	MPa

The prefixes centi (10^{-2}) and deci (10^{-1}) are only commonly used in specific cases e.g. cm

Concentrations

The determination of the concentration of a substance in a biological fluid is central to many areas of medical and dental practice (e.g. electrolytes in serum or glucose in urine). It is important, therefore, that concentrations are expressed in clear unambiguous terms. There are several ways of doing this. The simplest is to express the concentration as the weight or mass of the substance per unit volume:

e.g. 10 g/l or 20 mg/ml or 2 µg/ml

Another way is to express the concentration of a solution or mixture in terms of per cent (%). This is a somewhat outdated method but you may still come across it, particularly if you read the older medical literature, so you should know what it means. Note that there are different types of % concentration:

% (v/v) (volume by volume)
% (w/v) (weight by volume)
% (w/w) (weight by weight)

- A 1% (v/v) concentration is obtained by diluting 1 volume of a substance into 100 volumes (total) of solution, e.g. 1 ml ethanol diluted with water to a final volume of 100 ml gives a 1% (v/v) ethanol solution.

- A 1% (w/v) concentration is obtained by dissolving 1 g of substance in a final volume of 100 ml solution, e.g. 1 g glucose dissolved in water to a final volume of 100 ml solution gives a 1% (w/v) glucose solution.

- A 1% (w/w) concentration is obtained by mixing 1 g of substance with something else in a total weight of 100 g, e.g. 1% (w/w) salt in sand.

Another old method of expressing concentration that you may still see (just look at the side of a tube of toothpaste) is "**parts per million (ppm)"**. One ppm is one part of anything in one million parts of total material, e.g. 1 g of compound X in a million g total, or 1 litre of Y in a million litres total.

Moles and molarity

By far the most important unit defining an **amount** of a biological substance is the **mole**, with the corresponding **concentration** being the **molarity**. As far as possible, the concentrations of specific compounds in serum, urine etc, are now expressed as molarities in clinical laboratories.

One mole of a substance is the molecular weight of that substance expressed in grams. Thus, the molecular weight of glucose is 180, so:

1 mole of glucose =	180 g
1 mmol glucose =	180 mg
1 µmol glucose =	180 µg
100 µmol glucose =	18,000 µg = 18 mg

Note the abbreviations: 1 mmol = 1 millimole; 2 mmol = 2 millimoles; 5 µmol = 5 micromoles.

Concentrations in molarities are given by expressing the number of moles of the substance present in a defined volume of solution:

A 1 molar (1 M) solution contains 1 mole per litre (1 mol/l)
a 1 millimolar (1 mM) solution contains 1 millimole per litre (1 mmol/l)

Note: **mol** and **moles** mean the same thing (an amount) and **moles/litre** (long winded but correct) is a concentration and can be expressed as **mol/l**, or **mol.l^{-1}**, or (best and simplest of all) — **M**. **Ensure you know the distinction between concentrations and amounts.**

So, if you dissolve 0.5 **mol** of a compound in one litre of solvent the concentration of the compound is 0.5 **mol/l**, or 0.5 **M.** 100ml of the solution contains 0.05 **mol.**

Prefix notation

The value of the prefix notation can now be seen as it allows rapid mental calculations to be performed (after much practice!). The following concentrations are all the same:

0.5 M, 0.5 mol/l, 0.5 mmol/ml, 0.5 µmol/µl, 0.5 pmol/pl

You see that by scaling both the units (amount and volume) in the concentration up or down by a factor of 1000, the value of the concentration remains the same. If you only scale one of the terms (amount or volume), then you can express the same concentration in yet more ways:

0.5 mol/l = 0.5 mmol/ml = 500 µmol/ml = 500,000 pmol/µl

Now, let's say you wanted to determine the amount of cholesterol in the blood of a newborn infant. You know it will be around 5 mM. The detection limit of the method you are going to use is about 20 nmol and you can only take 20 µl of blood. Will this be enough?

> 5 mM cholesterol contains 5 mmol/l, or 5 µmol/ml, or 5 nmol/µl.
>
> It is easy to see now that 20µl contains 100 nmol of cholesterol - **ENOUGH**.

Examples

· ***How many µmol are dissolved in 2 l of a 20 mM solution?***

20 mM = 20 mmol/l, so 2 l contain 40 mmol. 40 mmol = **40,000 µmol**.

· ***The molecular weight of NaCl is 58. How many mg are in 50 µmol of NaCl?***

1 mol of NaCl is 58 g, so 1 µmol is 58 µg, so 50 µmol is 2,900 µg = **2.9 mg**.

· ***What is the molarity of a 1% (w/v) solution of glucose? (molecular weight = 180)***

1% (w/v) contains 1 g in 100 ml and, therefore, 10 g in 1 litre.
A 1 M solution of glucose contains 180 g/l, so 10 g/l represents a molarity of 10/180 = **0.056 M** (or **56 mM**).

B. Dilutions

This is another source of great confusion. Most experiments require you to make dilutions of reagents, either before use or as a consequence of the actual assay. When you are asked to make a ten-fold dilution of a reagent, the objective is to produce a solution that has a reagent concentration one-tenth of the original. It follows that the molecules of reagent that occupied a volume of "x" before must now occupy a volume of "10x". This is obtained by adding to **one** volume of reagent to **nine** volumes of diluent (sometimes referred to as a "**1 plus 9**" dilution or, more commonly, a "**1 in 10**" dilution).

When a solution of known concentration is diluted, it is obvious that the concentration will fall. Less obvious is the amount by which it falls! Take a typical example:

A solution of a compound is maintained as a stock solution at 5 mM. What is the final concentration of the compond in which 0.15 ml of stock solution is mixed with 0.4 ml of buffer and 0.2 ml of water?

There are many ways to derive this answer. Here are a few different approaches — all equally acceptable. Take the one that seems most logical to you!

i. The final volume is 0.75 ml, therefore the concentration of the substrate will be 0.15/ 0.75 x 5 mM = **1 mM**

ii. 5 mM is 5 mmol/l, or 5 µmol/ml. Therefore 0.15 ml of stock solution contains 0.15 x 5 = 0.75 µmol. This is expanded into a volume of 0.75 ml and therefore there are now 0.75 µmol/0.75 ml, ***or*** 1 µmol/ml, ***or*** 1 mmol/l, ***or*** 1 **mM**

iii. The formula for a dilution is v1 x c1 = v2 x c2 (where c1 and c2 are the concentrations before and after dilution, and v1 and v2 are the volumes before and after dilution). Therefore, c2 = v1/v2 x c1, which works out to be c2 = 0.15 / 0.75 x 5 mM , i.e. **1 mM**

Note that the last and first are identical, except that the latter defines the problem as a formula. It may be valuable for dilutions when a solution of known concentration must be diluted to a new concentration. The formula will give the new volume, but remember that part of that volume will come from the sample before dilution! Method 2 seems tortuous with this example, but it suits some to work this way.

Lastly, remember to **think** about the answer — it's not unusual to see erroneous calculations giving serum concentrations of metabolites in the tens or hundreds of molar - try to imagine "10 M glucose" in the blood? (the molecular weight of glucose is 180 — imagine a cross between a Mars bar and black pudding!). You should always do rough calculations to ensure that your answers make biological (and logical!) sense.