THE INCREDIBLE MEDICAL SCHOOL
BASIC MEDICAL MATH

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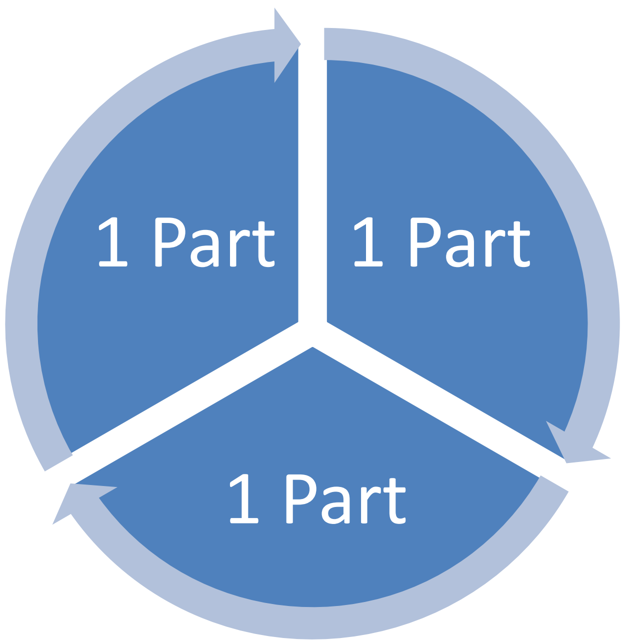
GENERAL MATH – FRACTIONS

A fraction is a part of a whole. It can be part of 1 as part of a circle, or part of a group as in part of a number of items. A fraction has a top number and a bottom number:

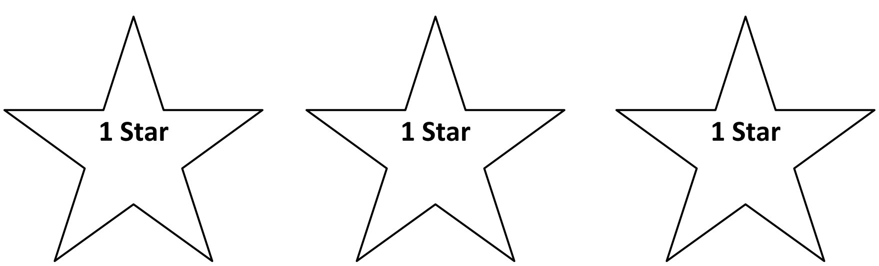
$$\frac{2}{3} \qquad \frac{\text{Numerator}}{\text{Denominator}}$$

The top number is the NUMERATOR. The bottom number is the DENOMINATOR

$\frac{2}{3}$ indicates that there are 3 total parts in the 1 item (such as a circle or space in a syringe) or in a group of items (such as number of stars on a page) AND we are referring to 2 parts of the item or group of items.



$\frac{2}{3}$ pronounced "two thirds" indicates 2 parts of the circle above or 2 stars from the group of 3 stars below



GENERAL MATH – DECIMALS

Decimals and fractions are both used to represent parts of a whole. Example:

$\frac{1}{2}$ is 1 part of whole containing 2 parts.

0.5 is the same as $\frac{5}{10}$ which reduces to $\frac{1}{2}$. So, 0.5 is $\frac{1}{2}$ of a whole, or $\frac{1}{2}$ of 1.

0.50 is the same as $\frac{50}{100}$ which reduces to $\frac{1}{2}$. So, 0.50 is also $\frac{1}{2}$ of a whole, or $\frac{1}{2}$ of 1.

Decimal Places:

1,000	100	10	1	**Decimal**	1/10	1/100	1/1,000
				.			
				.	**3**		
				.	**1**	**5**	
				.	**2**	**4**	**5**

You can think of decimals as fractions, using the above table:

$.3 = \frac{3}{10}$ $.15 = \frac{15}{100}$ $.245 = \frac{245}{1000}$

$\frac{7}{10} = .7$ $\frac{12}{100} = .12$ $\frac{231}{1000} = .231$

$.15 = \frac{15}{100} = \frac{3}{20}$ = 20√3.0 = .15 (√ is the dividing symbol)

$.2 = \frac{2}{10} = \frac{1}{5}$ = 5√1.0 = .2

ACID BASE

undissociated	equilibrium	dissociated		
HA	$\leftrightarrow$	H^+	+	A^-
weak acid	equilibrium	proton		conjugate base

These may be related by the following equation

$$K_a = \frac{[H^+]\,[A^-]}{[HA]}$$

K_a is the dissociation constant. The degree of proton dissociation.

WATER AS AN EXAMPLE

undissociated	equilibrium	dissociated		
H_2O	$\leftrightarrow$	H^+	+	OH^-
weak acid	equilibrium	proton		conjugate base

$$K = \frac{[H^+]\,[OH^-]}{[H_2O]}$$

k, the dissociation constant is 1.8×10^{-16}

We know that: One liter of water has 1,000 grams of water. The molecular weight (molar weight; atomic weight) of water is 18 grams. The concentration is expressed in moles/liter. Dividing 1,000 grams/liter by 18 grams equals a water concentration of 55.56 moles/liter.

In water, the concentration of H^+ and OH^- is very small, so the concentration of undissociated water is essentially unchanged. Assuming H_20 concentration doesn't change, the equation can also be written

$K_w = k\,[H_2O] = [H^+]\,[OH^-]$ (in our use, however, we will keep it simple: $K_w = [H^+]\,[OH^-]$

$K_w = (1.8 \times 10^{-16}) \times [55.56] = [10^{-7}] \times [10^{-7}]$

The concentration of hydrogen ions in water at 25 ^oC measured to be 10^{-7} moles/liter. The concentration of OH^- must be the same.

$K_w = [10^{-7}]\,[10^{-7}] = [10^{-14}]$

For acid base discussions, the hydrogen concentration is usually emphasized. S.P.L. Sorenson in the early 1900s, referred to the hydrogen concentration of 10^{-7} moles/liter as "7 puissance hydrogen".

Karl Hasselbalch expressed 10^{-7} moles/liter as the negative logarithm of hydrogen ion activity. As we shall see, this gives a number that is easier to deal with.

This number is known as **pH**. **p**= puissance or power or potential. **H** is hydrogen.

The pH is the measurement of concentration of hydrogen ions in a solution.
The pH is the negative logarithm of that concentration in moles/liter.

Let's look at how that number is simplified by use of the pH:

pH	1	2	6	7	8	9
$[H^+]$ moles/liter	10^{-0}	10^{-2}	10^{-6}	10^{-7}	10^{-8}	10^{-9}
$[H^+]$ moles/liter	1	.01	.000001	.0000001	.00000001	.000000001

acidic <<<<- **I** >>>>> basic/alkaline

larger number of H^+ <<<<- **I** >>>>> smaller number of H^+

For blood, the normal pH is about 7.4, which is $10^{-7.4}$ moles/liter

LOGARITHM

The logarithm of a number to a given base is the power or exponent to which the base must be raised to produce the number. This is the reason that logarithm was useful to produce a simple number to use for the concentration of hydrogen. The concentration of hydrogen is small and it is easier to say "a **pH** of **7"** than to say "$\mathbf{10^{-7}}$ moles/liter" or **0.0000007** moles/liter.
1,000 = base 10, exponent 3 = 10^3
log of 1,000 to base 10 = 3 because 10 X 10 X 10 = 1,000 (if not listed, assume base 10)
log of 1,000 = 3
log of 10^3 = 3
log of 10^5 = 5
log of 10^{-6} = **-**6 (a negative number)
-log of 10^{-6} = **6** **(a positive number)**
Using the negative logarithm of the negative number produces a positive number.

Here is the pH equation for blood:

$$pH = pK + \log \frac{[HCO_3^-]}{[H_2CO_3]}$$

This equation is reached by the following:

EQUIVALENTS / MILLIEQUIVALENTS

Important information is found in **The Periodic Table of the Elements**. Below is a sample of some of the elements in the periodic table. You can find complete tables on the internet.

1 **+1** **H** **Hydrogen** **1.00794**	**6** **-4** **C** **Carbon** **12.01**	**8** **-2** **O** **Oxygen** **16**
19 **+1** **K** **Potassium** **39.1**	**Atomic Number** **Valence** **Element Symbol** **Element Name** **Atomic Mass** ***KEY***	**12** **+2** **Mg** **Magnesium** **24.31**
11 **+1** **Na** **Sodium** **22.99**	**17** **-1** **Cl** **Chlorine** **35.45**	**20** **+2** **Ca** **Calcium** **40.08**

An electrolyte is a substance that dissociate into charged particles, called ions, with the capacity to conduct electricity.

Positive ions are called cations and include sodium (Na^{+}), potassium (K^{+}), calcium (Ca^{++}), and magnesium (Mg^{++}).

Negative ions are called anions and include chloride (Cl^{-}), bicarbonate (HCO_3^{-}), and phosphate ($HPO_4^{=}$).

Looking at our table, we observe some interesting facts with the valence:

The valences of our substances will add up to zero.
Na + Cl = NaCl = valence of sodium (+1) PLUS valence of chloride (-1) = zero.
Ca + Cl = $CaCl_2$ = valence of calcium (+2) PLUS valence of **two** chlorides (-1) and (-1) = zero

So what is this valency (valence)? It is the charge of the atom (ion). The combining capacity of an atom determined by the number of electrons it will add, lose, or share when it reacts with other atoms. You can think of it as the number of electrons which an atom generally bonds.

Therefore, one valence of sodium (Na) will bond with one valence of chloride (Cl), and one valence of calcium (Ca) will bond with two valences of chloride (Cl). This is **equal valence** or **equivalent** which is a measurement of quantity of the ions (charge). The previous can be repeated as one equivalent of sodium (Na) will bond with one equivalent of chloride (Cl), and one equivalent of calcium (Ca) will bond with two equivalents of chloride (Cl)

Now, how much is an equivalent (equal valence) of Na, or Cl, or Ca?

$$\textbf{Equivalent} = \frac{\textbf{moles}}{\textbf{valence}}$$ (ignore the valence positive or negative sign)

Mole is the gram molecule. The amount of chemical. The molecular weight. The atomic weight of an element in grams. Found on the periodic table! 1 mole of sodium is **23 <u>grams</u>**. Notice that the weight is in grams. As we shall see later, we can use milligrams (which is 1/1,000 of a gram) for atomic weight when referring to millimole (mM) which is 1/1,000 of a mole.

We now can determine that:
1 equivalent of sodium (Na) is equal to atomic weight of Na <u>23</u> (using grams) divided by the valence of Na, <u>1</u>, which is **23 grams.**
1 equivalent of calcium (Ca) is equal to atomic weight of Ca <u>40</u> (using grams) divided by the valence of Ca, <u>2</u>, which is **20 grams.**
1 equivalent of cloride (Cl) is equal to atomic weight of Cl <u>35.5</u> (using grams) divided by the valence of Cl, <u>1</u>, which is **35.5 grams.**

With most of these substances, we are dealing with small amounts. Instead of grams, we are usually using milligrams. That is why milliequivalents is better known. Just as 1 gram equals 1,000 milligrams, 1 equivalent equals 1,000 milliequivalent. This means that:
1 equivalent of sodium = 23 grams of sodium = 1 mole of sodium.
1 milliequivalent of sodium = 23 milligrams of sodium = 1 millimole of sodium.

NaCl contains one milliequivalent of sodium (Na) and one milliequivalent of chloride (Cl). $CaCl_2$ contains one milliequivalent of calcium (Ca) and one milliequivalent of chloride (Cl)

OSMOTIC PRESSURE

Osmotic pressure is equal to the total of all the ions in a solution. **Osmoles (Osm)** and **milliosmoles (mOsm)** is a measurement of osmotic pressure. **Osmolality** is the concentration of solutes in body fluids. Higher osmolality fluids have less water concentration than a lower osmolality fluid. Lower osmolality fluids have more water concentration than a higher osmolality fluid.

If you place two solutions next to each other with a membrane between them that will allow the water to move across the membrane, the water will move from the lower concentration solution (smaller number of ions per liter; lower osmotic pressure) into the higher concentration solution (larger number of ions per liter; higher osmotic pressure) resulting in both solutions reaching the same concentration (same number of ions per liter; same osmotic pressure).

Osmotic pressure is the hydrostatic pressure produced by a difference in concentration between solutions on the two sides of a surface such as a semipermeable membrane. It is the pressure which must be applied to a solution to prevent water from flowing in across the membrane.

With all the above put aside, we can simply say that, in the body, the osmotic pressure of the ECF (extracellular fluid) is equal to the total cation concentration which is 155 mEq/L. This is because Na = 142 mEq/L, K = 4.5 mEq/L, Ca = 3.0 mEq/L, Mg = 2.5 mEq/L. Total of 155 mEq/L.

Because Na is more than 90% of the total mEq/L (142 of the total 155), we can use Na as a close measurement of osmotic pressure in the ECF.

These salts dissociates in two ions. Remember the osmotic pressure is the total of all the ions in a solution. Therefore, the 155 mEq/L is multiplied by 2 to give a normal osmotic pressure of **310 mOsm/L**. Using Na as a close measurement, we get a normal osmotic pressure of 142 times 2 which equals **284 mOsm/L**. Just remember that this applies to normal individuals because other things can contribute to osmotic pressure.

Normal ECF osmolarity in humans is <u>310</u> mOsm/L

Normal ECF osmolality in humans is <u>275 to 290</u> mOsm/Kg

PERCENTAGES AND RATIOS

Percentage concentration is the number of grams of the substance in 100 mL solution.

5% dextrose = 5 Gm dextrose/100 mL solution.
0.9 % saline = 0.9 Gm NaCl / 100 ml solution

Ratios are expressed as X:Y
example: if X=1 and Y=10,000, the ratio is expressed as 1:10,000
This is read as "one to ten thousand".
1:10,000 epinephrine = 1 Gm epinephrine/10,000 mL solution.
also 1,000 mg/10,000 mL, 100 mg/1,000 mL, **10 mg/100 mL**, 1 mg/10 mL, 0.1 mg/1 mL.

Can 1:10,000 be expressed as a percent? Sure! Look at the 10 mg/ 100 mL. Looks familiar because it is the concentration used for percentage. We only have to change the 10 mg to grams. This is accomplished by diving it by 1,000 (as 1 Gm equals 1,000 mg). We could also move the decimal place three places to the left on the 10.0 mg/ 100mL. We also know which direction because the number has to get smaller moving from mg to Gm.
10 divided by 1,000 (or moving the decimal three places) equals 0.01 Gm
0.01 Gm / 100 mL equals 0.01 %

Another method is to not change the initial ratio from Gm to mg. The original ratio would remain 1:10,000 and 1 Gm/ 10,000 mL. We would now change the 10,000 to 100. Dividing both side by 100 will give us the result, but let's just continue to divide both sides by 10 until we get the 100 value we need.
1 Gm / 10,000 mL = 0.1 Gm / 1,000 mL = 0.01 Gm / 100 mL = 0.01 %

Let's check this value:
if our calculation of 0.01 Gm / 100 mL = 0.01% is correct, then it must follow that
0.1 Gm /100 mL = 0.1 %, and
1 Gm / 100 ml = 1 % (well, we know that is correct by definition).

Now, let's go the other way, from percentage to ratio. Express 5% as a ratio.
5 Gm / 100 mL (this is already a ratio). It is 5:100
We can use that and reduce it by dividing both by 5 to get 1:20
1:20 = 1 Gm in 20 mL solution.

BASIC MEDICAL MATH EXERCISES

You need to begin an epinephrine infusion at 30 mcg/hr.
You have available Epinephrine 1:1,000 and D5W 250mL.

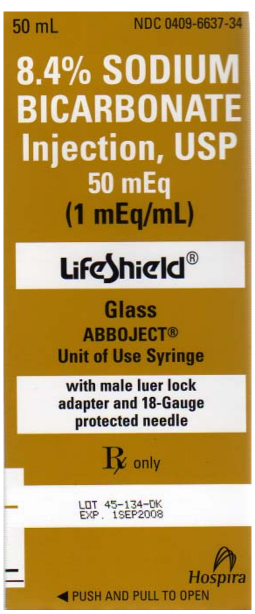
1:1,000 epinephrine has 1 Gm/1,000 mL = 1,000 mg/1,000 mL = 1mg/mL = **1,000 mcg/mL**
You decide to make the solution contain 15 mcg/mL (so the infusion will be 2 mL/hr)

15 mcg X 250 mL = 3,750 mcg to be added to the solution.

3,750 mcg = 3.75 mL of epinephrine 1:1,000.
Add 3.75 mL to 250 mL of D5W and begin the infusion at 2 mL/hr. Ideally, you would remove 3.75 mL of fluid from the D5W and replace it with 3.75 mL of the epinephrine.

In this problem, you need to know that 1:1,000 contains 1 Gm in 1,000 mL. From this you can get to the mg/mL and mcg/mL. You should know that 1 Gm equals 1,000 mg and that 1 mg equals 1,000 mcg. To have 15mcg/mL in 250mL, you would need 250 of the 15mcg (250X15). You could also have observed that 3,750 mcg equals 3.75 mg and since epinephrine 1:1,000 contains 1mg/mL, the amount of epinephrine needed would be 3.75mL.

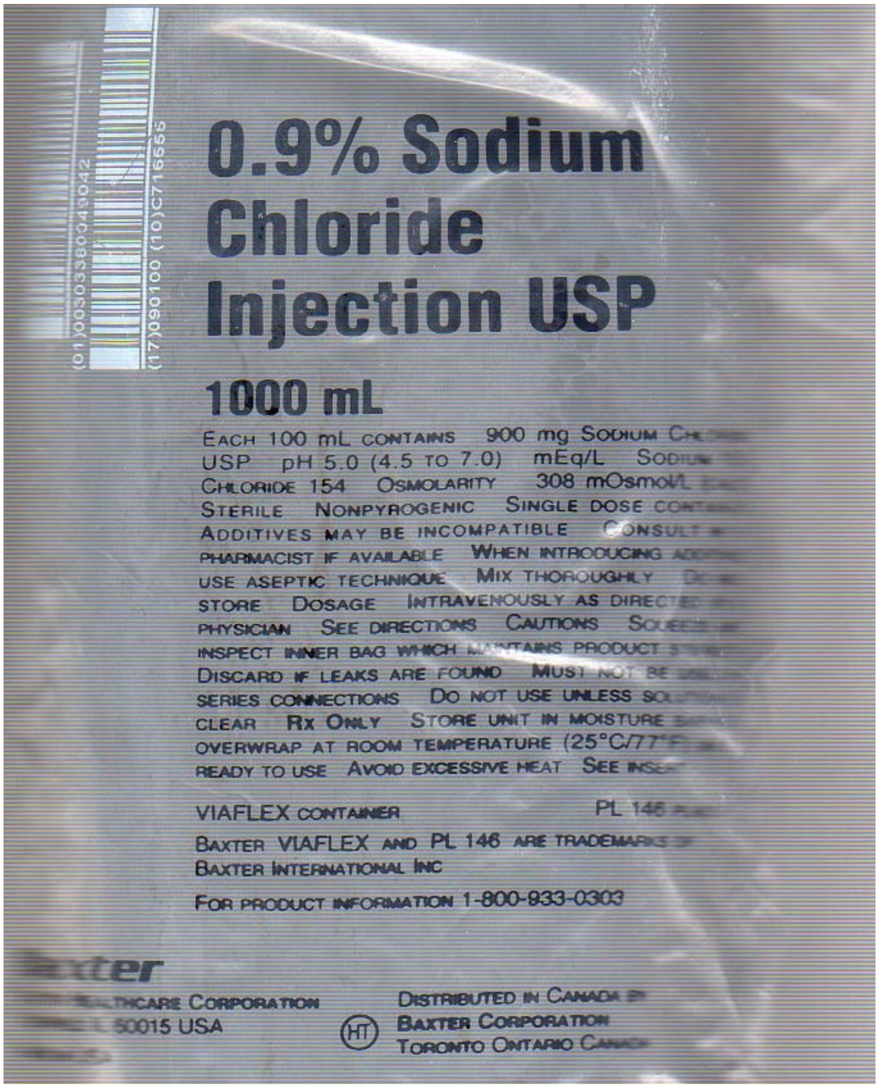
Relate the percentage, milliequivalent, milligrams, and osmolality of the following



8.4% Sodium Bicarbonate.
$NaHCO_3$. Molecular weight is **84mg = 1 mEq**
Na =23, H= 1, C=12, O=16X3=48
23+1+12+48 = 84
8.4% = 8.4Gm/100mL. = 8,400mg/100mL = **84mg/mL**
Therefore each mL contains 84mg which is **1mEq**
The total is 50mL which is a total of **50mEq** or 4,200mg or 4.2Gm

Osmolality is 2 X 50mEq = 100 mOsmol/50mL
multiply by 2 because $NaHCO_3$ dissociates to Na + HCO_3 (2 particles)

Alternatively, we could have multiplied 84mg/ml X 50 (the total volume) which equals 4,200mg. If we divided 4,200mg by 84 it would give us the total mEq of 50.



Here we have a 1 liter bag of IV fluid. It has 1000mL of 0.9% sodium chloride. The bag is labeled with the following information:

Each 100 mL contains 900 mg sodium chloride, 154 mEq sodium, 154 mEq chloride, and 308mOsmol/L

NaCl has a molecular weight of 58.5

Na=23,   Cl=35.5

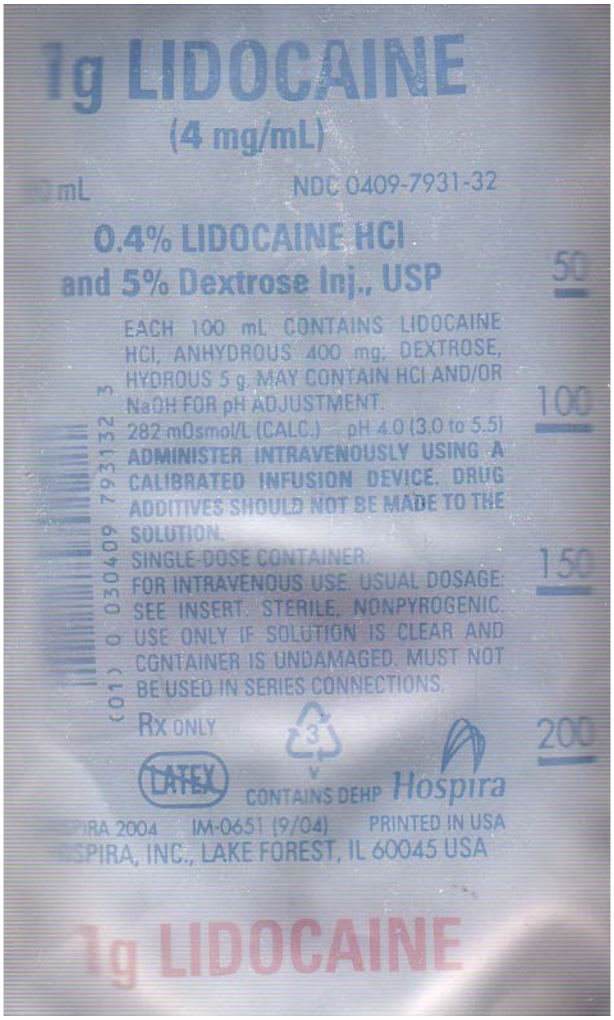
23+35.5= 58.5

0.9% sodium chloride = 0.9Gm/100mL = 900mg/100mL = 9,000mg/1,000mL.

9,000 divided by 58.5 = 153.8 mEq/L

Osmolality is 2 X 153.8mEq = 307.6 mOsmo/L.

Here we have a 250mL solution of 0.4% Lidocaine in 5% Dextrose. Much of the information is on the label, but we can determine it ourselves.



0.4% Lidocaine:

0.4Gm/100mL = 400 mg/100mL = 4 mg/mL.

250ml solution has: 250 X 4mg = 1,000mg = 1 Gm.

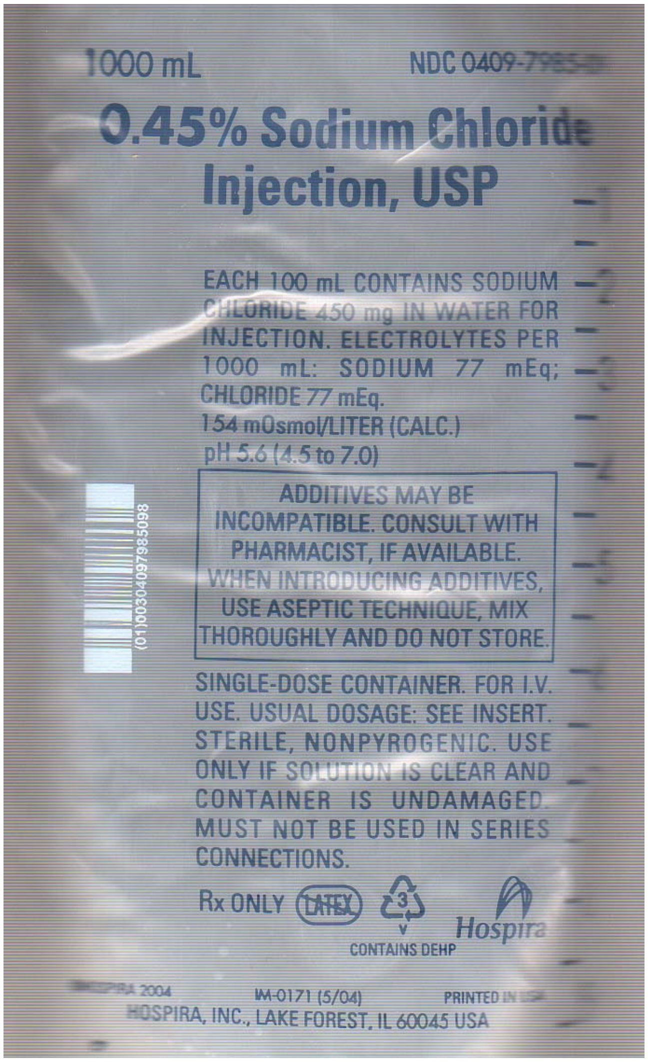
5% Dextrose:

5Gm/100mL = 5,000mg/100mL = 50mg/mL

250mL solution has: 250 X 50mg = 12,500mg.

12,500mg = 12.5 Gm

Below is 0.45% Sodium Chloride. It is also referred to as “half normal” saline. The osmolarity of 0.45% Sodium Chloride is approximately half the osmolarity of Sodium Chloride in blood, therefore the term “half normal”.



Determine the mg, mEq, and osmolarity of this solution:

0.45% = 0.45 Gm/100mL = 450 mg/ 100mL
450 mg/ 100mL = 4,500 mg/ 1,000mL
Molecular Weight: Na = **23**, Cl= **35.5**
23 (Na) + 35.5 (Cl) = **58.5**

$\frac{4500}{58.5}$ = **76.9 mEq/L**

Na (sodium) = 76.9 mEq/L = 76.9 mM (millimole)
Cl (chloride) = 76.9 mEq/L = 76.9 mM (millimole)

There is **450mg NaCl** in each 100mL
There is **4,500mg NaCl** in each 1,000mL
How many mg of Na and mg of Cl are in 1,000mL? We’ve determined that there are 76.9 mEq of sodium and 76.9 mEq of chloride in each liter. Multiplying the mEq times the molecular weight gives the total amount of mg in 1 liter.
Sodium 76.9 X 23 = 1, 768.7 mg/1,000mL.
Chloride 76.9 X 35.5 = 2,729.9 mg/1,000mL.
Adding these two numbers together gives the the total of **4,500mg** of NaCl in each liter. 1,768.7mg + 2,729.9mg = **4,498.6 mg**

Osmolarity is **76.9 mM** X 2 (because NaCl dissociates into 2 particles) = **153.8 mOsmol/Liter**.

153.8 mOsmol/Liter is about half human ECF. Therefore, the tem “half normal” saline.

RULE 3. You can exchange the numerator on one side of the equation with the denominator on the opposite of the equation

$$\mathbf{\frac{A}{B} = \frac{C}{D}} \quad \text{can be changed to} \quad \mathbf{\frac{D}{B} = \frac{C}{A}} \text{ OR } \mathbf{\frac{D}{C} = \frac{B}{A}} \text{ OR } \mathbf{\frac{A}{C} = \frac{B}{D}}$$

Let's prove that this works, A = 2, B = 6, C =4, D = 12

$$\mathbf{\frac{2}{6} = \frac{4}{12}}$$

Rule #1:

$$\frac{A \times D}{B} = \frac{C}{1} \quad \text{OR} \quad \frac{A}{1} = \frac{B \times C}{D} \quad \text{OR} \quad \frac{A \times D}{1} = \frac{B \times C}{1}$$

$$\frac{2 \times 12}{6} = \frac{4}{1} \quad \text{OR} \quad \frac{2}{1} = \frac{6 \times 4}{12} \quad \text{OR} \quad \frac{2 \times 12}{1} = \frac{6 \times 4}{1}$$

Rule #2:

$$\frac{B}{A} = \frac{D}{C}$$

$$\frac{6}{2} = \frac{12}{4}$$

Rule #3:

$$\frac{D}{B} = \frac{C}{A} \qquad \frac{D}{C} = \frac{B}{A} \qquad \frac{A}{C} = \frac{B}{D}$$

$$\frac{12}{6} = \frac{4}{2} \qquad \frac{12}{4} = \frac{6}{2} \qquad \frac{2}{4} = \frac{6}{12}$$

REFERENCES

Multiplication and Division with negative and positive numbers:
Multiplying or dividing two numbers with the same signs (both are positive numbers or both are negative numbers), the answer is a positive number.
Multiplying or dividing two numbers with the different signs (one number is a positive number and one number is a negative number), the answer is a negative number.

mOsm/mL for Selected IV Solutions:

SOLUTION	mOsm/mL
Dextrose 5%	0.25
Lactated Ringer's	0.28
Sodium Chloride 0.45%	0.154
Sodium Chloride 0.9%	0.31
Sodium Bicarbonate 8.4%	2.00
Sterile Water	0.00

mOsm/mL for Selected IV Additives:

ADDITIVE	mOsm/mL
Calcium Chloride	2.04
Calcium Gluconate	0.308
Magnesium Sulfate	4.06
Potassium Chloride	4.00
Sodium Bicarbonate 8.4%	2.00
Water	0.00

EQUATION H: Calculating cc/hr continuous infusion at known mCg/kg/min

$$\textbf{cc/hr} = \frac{\text{solution volume (cc) X 60 }_{\text{(min/hr)}}\text{ X infusion amount (mCg/kg/min) X Wt (kg)}}{\text{Amount of Drug in solution (mCg)}}$$

Dopamine 800 mg in 250 cc D5W. Infuse at 10 mCg/kg/min. Patient's weight is 70kg. (800mg = 800,000mCg)

$$\textbf{cc/hr} = \frac{\text{250 (cc) X 60 }_{\text{(min/hr)}}\text{ X 10 (mCg/kg/min) X 70 (kg)}}{\text{800000 (mCg)}} = \text{13.1 cc/hr}$$

EQUATION I: Calculating mCg/kg/min continuous infusion at known cc/hr

$$\textbf{mCg/kg/min} = \frac{\text{Amount of Drug in solution (mCg) X infusion rate (cc/hr)}}{\text{solution volume (cc) X 60 }_{\text{(min/hr)}}\text{ x Wt (kg)}}$$

Dopamine 800 mg in 250 cc D5W. Infuse at 13.1 cc/hr. Patient's weight is 70kg.

$$\textbf{mCg/kg/min} = \frac{\text{800000 (mCg) X 13.1 (cc/hr)}}{\text{250 (cc) X 60 }_{\text{(min/hr)}}\text{X 70 (kg)}} = \text{9.98 mCg/kg/min (rounded to 10)}$$

Converting pounds to kilograms

Multiply weight in pounds by 0.45:

110 pounds X 0.45 = 49.5 kg

Converting kilograms to pounds

Multiply weight in kilobrams by 2.2

50 kilograms X 2.2 = 110 pounds

1 kilogram = 2.2 pounds.

1 pound = 16 ounces.

Converting Celsius to fahrenheit

F = (1.8 X C)+ 32

Converting fahrenheit to celsius

$$C = \frac{F - 32}{1.8}$$

Approximate Equivalents

1 liter	1 quart / 32 ounces / 2 pints
500 milliliters	1 pint / 16 ounces / 2 cups
240 milliliters	1 cup / 8 ounces
30 milliliters	1 ounce
15 milliliters	1 tablespoon / 3 teaspoons
5 milliliters	1 teaspoon
1 milliliter	15 drops
0.0667 milliliters	1 drop
1 meter	39.372 inches / 3.281 feet
0.914 meters	3 feet / 1 yard
0.3048 meters	12 inches / 1 foot
2.54 centimeters	1 inch

THE END