

ISOTONICITY // Non-electrolytes

9/9/2010

VOCUBULARY TO KNOW

- ISOSMOTIC: two solutions that have the same osmotic pressure
- ISOTONIC: a solution possessing the same osmotic pressure as intracellular fluid → limited to solutions where cells neither swell nor shrink (also called “tonic”)
- HYPOTONIC: cause cells to swell
- HYPERTONIC: cause cells to crenate; can be used to draw fluids out of edematous tissues and into the administered solution
- This is an effect of a colligative property of solutions

COLLIGATIVE PROPERTIES change based only on the NUMBER of particles in solution:

1. Osmotic pressure
2. Freezing point depression (very easy to do, used to determine osmotic pressure)
3. Boiling point elevation
4. Vapor pressure lowering

NON-ELECTROLYTES: glucose (=dextrose), all sugars, urea

1g MW of *any* non-electrolyte dissolved in 1000g of water lowers the freezing point by **1.86°C**

How many molecules in 1g MW?

Avogadro's number = **6.023×10^{23} molecules** ← not the avocado number!

NEED TO MW:

Dextrose= 180amu

NaCl= 58.5amu (23+35.5)

Both **lachrymal fluid** and **blood serum** lower the freezing point by only 0.52°C (f.p. = -0.52°C)

For glucose:

$$180\text{g}/1.86^\circ\text{C} = X\text{g}/0.52^\circ\text{C}$$

$$X=50.3\text{g of dextrose/L}$$

$$\sim 50\text{g}/1000\text{ml} = 5\text{g}/100\text{ml} = 5\% \leftarrow \text{D5W}$$

D5W is isotonic (not necessary isosmotic)

NaCl 0.9% is both isotonic and isosmotic

Only for non-electrolytes:

$$1\text{g MW}/1.86^\circ\text{C} = X\text{g MW}/0.52^\circ\text{C}$$

$$X=0.27957\text{g MW} \rightarrow 0.280\text{M of any non-electrolyte will be isotonic with RBCs}$$

This is the nice thing about non-electrolytes since they don't carry any charge

$$0.280\text{M} = 280\text{mM} = 280\text{mOsm}$$

By definition, 1mM = 1mOsm

Another non-electrolyte: **UREA**

MW=60amu

$$60\text{g}/1.86^\circ\text{C} = X\text{g}/0.52^\circ\text{C}$$

$$X = 16.77\text{g} \rightarrow 16.8\text{g/L} = 16.8\text{g}/1000\text{ml} = 1.68\text{g}/100\text{ml} = 1.68\%$$

Sounds a lot less than dextrose because it weighs 1/3

But this urea solution has the same number of particles as that of dextrose

For dextrose, we need a 5% solution to be isotonic but for urea we only need 1.68% solution to be isotonic

GENERAL RULE

For ALL non-electrolytes (no exceptions, ladies & gentlemen), 0.280M solution will be 280mM or 280 mOsm in concentration

Only charged particles have **mEq** (therefore, non-electrolytes will not have mEq)

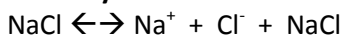
SOLUTION	mM	mEq	mOsm
D5W	280	-	280
D10W	560	-	560

ISOTONICITY // Electrolytes

9/16/2010

Because osmotic pressure depends only on the *number* of particles (and not the kind), substances that dissociate have a tonic effect that increases with the degree of dissociation; the greater the dissociation, the smaller the quantity required to produce any given osmotic pressure.

Electrolytes dissociate



$$100\# \quad 80 \quad + \quad 80 \quad + \quad 20 \quad = \quad 180$$

100 molecules \rightarrow 180 particles or 1.8x

Na=23amu, Cl=35.5amu \rightarrow **NaCl=58.5amu**

$$\frac{58.5\text{gNaCl}}{(1.86^\circ\text{C})(1.86^\circ\text{C})} = \frac{\text{XgNaCl}}{0.52^\circ\text{C}} \quad \frac{58.5\text{g}}{3.348} = \frac{\text{Xg}}{0.52^\circ\text{C}} \quad \text{x} = \frac{58.5\text{g} \times 0.52^\circ\text{C}}{3.348^\circ\text{C}} \quad \text{x} = 9.086\text{g/L} = \mathbf{0.9\%}$$

Therefore,

$$\frac{(\text{g MW of an electrolyte})(0.52^\circ\text{C})}{(1.86^\circ\text{C})(\text{Ionization constant})} = \text{Xg/L needed to make an isotonic solution}$$

Ionization constant, *i*

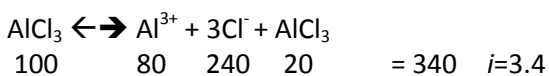
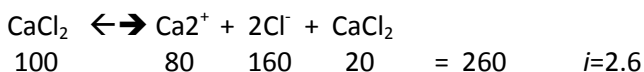
For all non-electrolytes, e.g. dextrose, the $i=1$

For electrolytes that do NOT dissociate well, e.g. boric acid H_3BO_4 , $i=1$

For electrolytes that dissociate into 2 particles, e.g. NaCl, $i= 1.8$

For electrolytes that dissociate into 3 particles, e.g. CaCl_2 , $i=2.6$

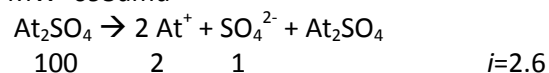
For electrolytes that dissociate into 4 particles, e.g. AlCl_3 , $i=3.4$



Prepare a 1% (w/v) atropine sulfate and make isotonic with NaCl

$$1\% \text{At}_2\text{SO}_4 = 1\text{g}/100\text{ml}$$

MW=695amu



RULE:

The quantity of 2 substances that are tonic equivalents are proportional to the MW of each multiplied by the *i* value of the other.

$$695 \times 1.8 = \frac{1g \text{ At}_2\text{SO}_4}{58.5 \times 2.6} \times \text{Xg NaCl}$$

$$58.5 \times 2.6 \quad \text{Xg NaCl}$$

How many grams of NaCl the At_2SO_4 is equivalent to

$$\frac{1251}{152.1} = \frac{1}{x} \quad 152.1 = 1251x \quad x = 0.12g \text{ NaCl}$$

$$152.1 \quad x$$

1g of At_2SO_4 behaves as if it is 0.12g NaCl in water (because it doesn't dissociate as well)

How many grams of NaCl are in 100ml of N.S.?

$$0.9\% = 0.9g/100ml$$

But I want to make it isotonic with atropine drug + NaCl

$$0.9g - 0.12g \text{ "At}_2\text{SO}_4" = 0.78g \text{ NaCl needed}$$

Look at pg. 161 at Table 11.1 "**Sodium Chloride Equivalents (E values)**" for other drugs

Another way to do it:

1g At_2SO_4 + DDW + qs ad to 100ml with N.S.

$$0.9\% - \frac{0.9g \text{ NaCl}}{100ml} = \frac{0.78g \text{ NaCl}}{x} \quad 78 = 0.9x \quad x = 86.67ml \quad 100ml - 86.67ml = 13.33ml \text{ DDW}$$

Dissolve 1g of atropine sulfate in 13.33ml DDW and then qs ad to 100ml with N.S. to make an isotonic solution

MILLIEQUIVALENTS

Denotes amount of chemical activity of an electrolyte

You may run into: EqWt (g MW of compounds) and mEqWt (mg MW of compounds)

We usually only deal with mEq (not Eq)

DEFINITION of mEq

$$\text{mEq Wt} = \frac{\text{milliMW}}{\text{Total + or - charge}}$$

$$\text{mEq Wt} = \text{mMW}$$

$$\text{NaCl mEq Wt} = 58.5\text{mg}/1 \text{ charge (amu} \rightarrow \text{mg)}$$

$$\text{KCl mEq Wt} = 74.5\text{mg}/1 \text{ charge} \quad \text{K}=39, \text{Cl}=35.5 \rightarrow \text{KCl}=74.5$$

$$\text{CaCl}_2 \text{ mMW} \quad \text{Ca}=40, \text{Cl}=35.5 \rightarrow \text{CaCl}_2=111.0\text{amu anhydrous}$$

$$\text{CaCl}_2 = \text{mEq Wt} = \frac{111\text{mg}}{2 \text{ charges}} = 55.5\text{mg/mEq}$$

mEq Wt will always be equal to or less than mMW

If it is less than, it will be by the factor of the charge

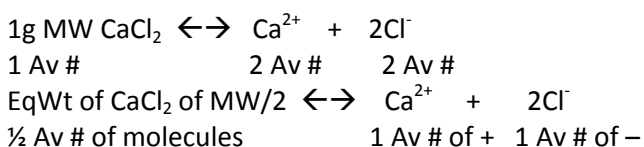
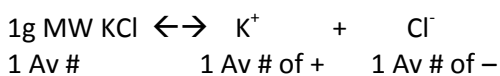


CHART FILLING

9/20/2010 + 9/23/2010

OSMOLARITY: of serum is 275-295 mOsm/L ←***

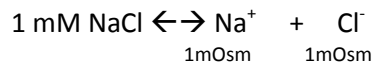
OSMOLALITY: of serum is 275-295 mOsm/kg ←eh

For non-electrolytes: 1mM = 1 mOsm

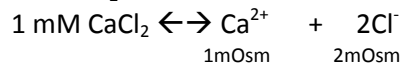
For electrolytes, the total number of particles depends on the degree of dissociation of the solute in question

If we assume 100% dissociation

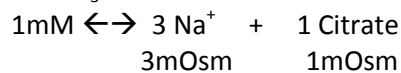
For NaCl



For CaCl₂



For Na₃Citrate



Osmolarity goes up much faster in electrolytes

How many mOsm are in D5W (non-electrolyte)?

$$5\% = 5\text{g}/100\text{ml} = 50\text{g}/1000\text{ml} \times 1\text{Osm}/180\text{g}(1\text{mol}) = 0.277 \text{ Osm/L}$$

$$0.277\text{Osm/L} \times 1000\text{mOsm/Osm} = 280 \text{ mOsm/L}$$

$$\frac{50\text{g}}{\text{L}} = \frac{50000\text{mg}}{\text{L}} \times \frac{1 \text{ mOsm}}{180\text{mg}} = \frac{277.7 \text{ mOsm}}{\text{L}} = \frac{280 \text{ mOsm}}{\text{L}}$$

1 liter of 0.9% NaCl = N.S.

$$0.9\% = 0.9\text{g}/100\text{ml} = 9\text{g}/1000\text{ml}$$

NaCl = 58.5 amu

How many mEq of NaCl/L?

$$9\text{g} = 9000 \text{ mg/L} \times \text{mEq}/58.5\text{mg} = 154 \text{ mEq/L}$$

mEq Wt = mMW / (total+/total-)

How many mOsm of NaCl/L?

If we assumed 100% dissociation:

$$\frac{9000\text{mg}}{\text{L}} \times \frac{\text{mM}}{58.5\text{mg}} \times \frac{2 \text{ mOsm}}{\text{mM}} = 307.7 \text{ mOsm/L}$$

If we assume 80% dissociation:

$$\frac{9000\text{mg}}{\text{L}} \times \frac{\text{mM}}{58.5\text{mg}} \times \frac{1.8 \text{ mOsm}}{\text{mM}} = 277 \text{ mOsm/L}$$

→ which is close enough to 308, so we are allowed to **assume 100%**

Isotonic = 280 – 310 mOsm/L

Hypotonic < 280 mOsm/L

Hypertonic > 310 mOsm/L

Direct relationship between

mM and mOsm

mM and mEq

No charge → No mEq

mMW > mEq

mEq is charge, mOsm is # of particles

You can't calculate mOsm/L without being given the volume

SOLUTION	mM	mEq	mOsm	mOsm/L
1L D5W	280	-	280	280
1L D10W	560	-	560	560
½ L D5W	140	-	140	280
N.S.	154	154	308	308
NaCl	1	1	2	-
KCl	1	1	2	-
CaCl ₂	1	2	3	-
Ratios	15	30	45	-
Mg ²⁺ SO ₄ ²⁻	1	2	2	-
Ca ₃ ²⁺ (citrate) ₂ ³⁻	1	6	5	-
½L D5W + ½L N.S. (=1L solution)	140+77 =217	0+77 =77	140+154 =294	294 Isotonic
SVP (1:1:2) 40mEq KCl/20ml	40	40	80	4000 Hypertonic!
Take SVP and add to LVP 40mEq KCl/20ml + 1L D5W	280+40 =320	0+40 =40	280+80 =360	352
1L D5W/N.S. Hypertonic because smaller volume	280+154 =434	0+154 =154	280+308 =588	588
Add 15ml KCl (40mEq/20ml) 1:1:2	+30 =464	+30 =184	+60 =648	638.4
1L D10W/0.2% N.S.	560+38.5 =598.5	0+38.5 =38.5	560+77 =637	637
Add MgSO ₄ – 20mEq 10mEq/30ml	+10 =608.5	+20 =58.5	+20 =657	632
Add Ca(Glu) ₂ – 30mEq (30mEq/20ml)	+15 =623.5	+30 =88.5	+45 =702	662
NS 0.9%	154	154	308	308
½ NS 0.45%	77	77	154	154 Hypo
¼ NS 0.2%	38.5	38.5	77	77 Hypo
MgSO ₄ 10mEq/20ml	5	10	10	500 Hyper
Ca ₃ (citrate) ₂	10	60	50	-
MgSO ₄	17.5	35	35	-
KCl	10	10	20	-

Add isotonic to isotonic = ALWAYS isotonic

Hypertonic + isotonic = hypertonic

Hypotonic + isotonic = hypotonic

Hypotonic + hypertonic = who knows

Decision to go **central vs. peripheral** under the risk of causing phlebitis:

600 mOsm is the borderline ← depends on how long

(some say 800 mOsm)