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 "tonicic")
- 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:
180g/1.86°C = Xg/0.52°C
X=50.3g of dextrose/L
~50g/1000ml = 5g/100mg = 5% ←D5W
D5W is isotonic (not necessary isosmotic)
NaCl 0.9% is both isotonic and isosmotic

Only for non-electrolytes:
1g MW/1.86°C = Xg MW/0.52°C
X=0.27957g MW → 0.280M of any non-electrolyte will be isotonic with RBCs
This is the nice thing about non-electrolytes since they don't carry any charge

0.280M = 280mM = 280mOsm
By definition, 1mM = 1mOsm

Another non-electrolyte: **UREA**
MW=60amu
60g/1.86°C = Xg/0.52°C
X = 16.77g → 16.8g/L = 16.8g/1000ml = 1.68g/100ml = 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
$NaCl \leftrightarrow Na^{+} + Cl^{-} + NaCl$
100# 80 + 80 + 20 = 180
100 molecules → 180 particles or 1.8x

Na=23amu, Cl=35.5amu → **NaCl=58.5amu**

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

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

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

$CaCl_2 \leftrightarrow Ca2^{+} + 2Cl^{-} + CaCl_2$
100 80 160 20 = 260 *i*=2.6

$AlCl_3 \leftrightarrow Al^{3+} + 3Cl^{-} + AlCl_3$
100 80 240 20 = 340 *i*=3.4

Prepare a 1% (w/v) atropine sulfate and make isotonic with NaCl
1% At_2SO_4 = 1g/100ml
MW=695amu
$At_2SO_4 \rightarrow 2\ At^{+} + SO_4^{2-} + At_2SO_4$
100 2 1 *i*=2.6

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

$\frac{695 \times 1.8}{58.5 \times 2.6} = \frac{1g\ At_2SO_4}{Xg\ NaCl}$

How many grams of NaCl the At_2SO_4 is equivalent to

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

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 "At_2SO_4" = 0.78g 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% - $\frac{0.9g\ NaCl}{100ml} = \frac{0.78g\ NaCl}{x}$ 78=0.9x x=86.67ml 100ml-86.67ml=13.33ml 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

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

mEq Wt = mMW

NaCl mEq Wt = 58.5mg/1 charge (amu → mg)

KCl mEq Wt = 74.5mg/1 charge K=39, Cl=35.5 → KCl=74.5

$CaCl_2$ mMW Ca=40, Cl=35.5 → $CaCl_2$=111.0amu anhydrous

$CaCl_2$ = mEq Wt = $\frac{111mg}{2\ charges}$ = 55.5mg/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

1g MW KCl ←→ K^+ + Cl^-

1 Av # 1 Av # of + 1 Av # of –

1g MW $CaCl_2$ ←→ Ca^{2+} + $2Cl^-$

1 Av # 2 Av # 2 Av #

EqWt of $CaCl_2$ of MW/2 ←→ Ca^{2+} + $2Cl^-$

½ Av # of molecules 1 Av # of + 1 Av # of –

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
1 mM NaCl ↔ Na^+ (1mOsm) + Cl^- (1mOsm)

For $CaCl_2$
1 mM $CaCl_2$ ↔ Ca^{2+} (1mOsm) + $2Cl^-$ (2mOsm)

For Na_3Citrate
1mM ↔ 3 Na^+ (3mOsm) + 1 Citrate (1mOsm)

Osmolarity goes up much faster in electrolytes

How many mOsm are in D5W (non-electrolyte)?
5% = 5g/100ml = 50g/1000ml x 1Osm/180g(1mol) = 0.277 Osm/L
0.277Osm/L x 1000mOsm/Osm = 280 mOsm/L

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

1 liter of 0.9% NaCl = N.S.
0.9% = 0.9g/100ml = 9g/1000ml
NaCl = 58.5 amu

How many mEq of NaCl/L?
9g = 9000 mg/L x mEq/58.5mg = 154 mEq/L

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

How many mOsm of NaCl/L?
If we assumed 100% dissociation:

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

If we assume 80% dissociation:

$\frac{9000mg}{L} \times \frac{mM}{58.5mg} \times \frac{1.8\ mOsm}{mM} = 277\ mOsm/L$ → 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
IL D5W/N.S. Hypertonic because smaller volume Add 15ml KCl (40mEq/20ml) 1:1:2	280+154 =434 +30 =464	0+154 =154 +30 =184	280+308 =588 +60 =648	588 638.4
1L D10W/0.2% N.S. Add $MgSO_4$ – 20mEq 10mEq/30ml Add $Ca(Glu)_2$ – 30mEq (30mEq/20ml)	560+38.5 =598.5 +10 =608.5 +15 =623.5	0+38.5 =38.5 +20 =58.5 +30 =88.5	560+77 =637 +20 =657 +45 =702	637 632 662
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)