**VOCABULARY 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 = \( 6.023 \times 10^{23} \) 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)

<table>
<thead>
<tr>
<th>SOLUTION</th>
<th>mM</th>
<th>mEq</th>
<th>mOsm</th>
</tr>
</thead>
<tbody>
<tr>
<td>D5W</td>
<td>280</td>
<td>-</td>
<td>280</td>
</tr>
<tr>
<td>D10W</td>
<td>560</td>
<td>-</td>
<td>560</td>
</tr>
</tbody>
</table>

ISOTONICITY // Electrolytes

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 <-> Na+ + Cl- + NaCl
100# 80 + 80 + 20 = 180
100 molecules -> 180 particles or 1.8x

Na = 23amu, Cl = 35.5amu -> NaCl = 58.5amu
\[
\frac{58.5 \text{g NaCl}}{(1.86^\circ \text{C})(1.86^\circ \text{C})} = \frac{x \text{g NaCl}}{0.52^\circ \text{C}}
\]
\[
\frac{58.5 \text{g}}{3.348} = \frac{x \text{g}}{0.52^\circ \text{C}}
\]
\[
x = 9.086 \text{g/L} = 0.9%
\]

Therefore,

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

Ionization constant, i

For all non-electrolytes, e.g. dextrose, the i=1
For electrolytes that do NOT dissociate well, e.g. boric acid H3BO4, i=1
For electrolytes that dissociate into 2 particles, e.g. NaCl, i = 1.8
For electrolytes that dissociate into 3 particles, e.g. CaCl2, i=2.6
For electrolytes that dissociate into 4 particles, e.g. AlCl3, i=3.4

CaCl2 <-> Ca2+ + 2Cl- + CaCl2
100 80 160 20 = 260 i=2.6

AlCl3 <-> Al3+ + 3Cl- + AlCl3
100 80 240 20 = 340 i=3.4

Prepare a 1% (w/v) atropine sulfate and make isotonic with NaCl
1% At2SO4 = 1g/100ml
MW=695amu
At2SO4 -> 2 At+ + SO42- + At2SO4
100 2 1 2
\[i=2.6\]

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.
How many grams of NaCl the $\text{At}_2\text{SO}_4$ is equivalent to

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

1g of $\text{At}_2\text{SO}_4$ 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 NaCl needed

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

Another way to do it:

1g $\text{At}_2\text{SO}_4$ + DDW + qs ad to 100ml with N.S.

0.9% - 0.9g NaCl = 0.78g NaCl

$$\frac{78}{0.9}x = 86.67 \text{ml}$$

100ml - 86.67ml = 13.3ml 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**

$$\text{mEq Wt} = \frac{\text{milliMW}}{\text{Total} \pm \text{charge}}$$

mEq Wt = mMWW

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

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

CaCl$_2$ mMWW Ca = 40, Cl = 35.5 $\rightarrow$ CaCl$_2$ = 111.0amu anhydrous

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

mEq Wt will always be equal to or less than mMWW

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

1g MW KCl $\leftrightarrow$ K$^+$ + Cl$^-$

1 Av # 1 Av # of + 1 Av # of –

1g MW CaCl$_2$ $\leftrightarrow$ Ca$^{2+}$ + 2Cl$^-$

1 Av # 2 Av # 2 Av #

EqWt of CaCl$_2$ of MW/2 $\leftrightarrow$ Ca$^{2+}$ + 2Cl$^-$

$\frac{1}{2}$ Av # of molecules 1 Av # of + 1 Av # of –
OSMOLARITY: of serum is 275-295 mOsm/L

OSMOLALITY: of serum is 275-295 mOsm/kg

For non-electrolytes: 1 mM = 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⁺ + Cl⁻
1 mOsm 1 mOsm

For CaCl₂:
1 mM CaCl₂ → Ca²⁺ + 2Cl⁻
1 mOsm 2 mOsm

For Na₃Citrate:
1 mM → 3 Na⁺ + 1 Citrate
3 mOsm 1 mOsm

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

50g = 50000mg x 1 mOsm/180mg = 277.7 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 = mM/MMW / (total+/total-)

How many mOsm of NaCl/L?
If we assumed 100% dissociation:
9000mg x mM x 2 mOsm = 307.7 mOsm/L
L 58.5mg mM

If we assume 80% dissociation:
9000mg x mM x 1.8 mOsm = 277 mOsm/L
L 58.5mg mM

→ 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

<table>
<thead>
<tr>
<th>SOLUTION</th>
<th>mM</th>
<th>mEq</th>
<th>mOsm</th>
<th>mOsm/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>1L D5W</td>
<td>280</td>
<td>-</td>
<td>280</td>
<td>280</td>
</tr>
<tr>
<td>1L D10W</td>
<td>560</td>
<td>-</td>
<td>560</td>
<td>560</td>
</tr>
<tr>
<td>½ L D5W</td>
<td>140</td>
<td>-</td>
<td>140</td>
<td>280</td>
</tr>
<tr>
<td>N.S.</td>
<td>154</td>
<td>154</td>
<td>308</td>
<td>308</td>
</tr>
<tr>
<td>NaCl</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>KCl</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>CaCl₂</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Ratios</td>
<td>15</td>
<td>30</td>
<td>45</td>
<td>-</td>
</tr>
<tr>
<td>Mg²⁺SO₄²⁻</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Ca₃²⁺(citrate)₃⁻</td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>½L D5W + ½ L N.S. (=1L solution)</td>
<td>140+77</td>
<td>0+77</td>
<td>140+154</td>
<td>294 Isotonic</td>
</tr>
<tr>
<td>SVP (1:1:2)</td>
<td>40</td>
<td>40</td>
<td>80</td>
<td>4000 Hypertonic</td>
</tr>
<tr>
<td>40mEq KCl/20ml</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Take SVP and add to LVP</td>
<td>280+40</td>
<td>0+40</td>
<td>280+80</td>
<td>352</td>
</tr>
<tr>
<td>=320</td>
<td>=40</td>
<td>=360</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IL D5W/N.S. Hypertonic because smaller volume Add 15ml KCl (40mEq/20ml) 1:1:2</td>
<td>280+154</td>
<td>0+154</td>
<td>380+308</td>
<td>588</td>
</tr>
<tr>
<td>=434</td>
<td>=154</td>
<td>=588</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+30</td>
<td>+30</td>
<td>+60</td>
<td>638.4</td>
<td></td>
</tr>
<tr>
<td>=464</td>
<td>=184</td>
<td>=648</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1L D10W/0.2% N.S. Add MgSO₄ – 20mEq 10mEq/30ml Add Ca(Glu)₂ – 30mEq (30mEq/20ml)</td>
<td>560+38.5</td>
<td>0+38.5</td>
<td>560+77</td>
<td>637</td>
</tr>
<tr>
<td>=598.5</td>
<td>=38.5</td>
<td>=637</td>
<td>637</td>
<td></td>
</tr>
<tr>
<td>+10</td>
<td>+20</td>
<td>+20</td>
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<tr>
<td>=608.5</td>
<td>=58.5</td>
<td>=657</td>
<td>632</td>
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</tr>
<tr>
<td>+15</td>
<td>+30</td>
<td>+45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>=623.5</td>
<td>=88.5</td>
<td>=702</td>
<td>662</td>
<td></td>
</tr>
<tr>
<td>NS 0.9%</td>
<td>154</td>
<td>154</td>
<td>308</td>
<td>308</td>
</tr>
<tr>
<td>½ NS 0.45%</td>
<td>77</td>
<td>77</td>
<td>154</td>
<td>154 Hypo</td>
</tr>
<tr>
<td>¼ NS 0.2%</td>
<td>38.5</td>
<td>38.5</td>
<td>77</td>
<td>77 Hypo</td>
</tr>
<tr>
<td>MgSO₄ 10mEq/20ml</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>500 Hyper</td>
</tr>
<tr>
<td>Ca₃(citrate)₂</td>
<td>10</td>
<td>60</td>
<td>50</td>
<td>-</td>
</tr>
<tr>
<td>MgSO₄ 17.5</td>
<td>35</td>
<td>35</td>
<td>500 Hyper</td>
<td></td>
</tr>
<tr>
<td>KCl</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>-</td>
</tr>
</tbody>
</table>

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)