

Normal Saline Is Six Percent Too Concentrated by Particle Count, but Nearly Equal to Plasma Once the Osmotic Coefficient Is Included

— osmotic pressure is set not by the number of dissolved particles itself but by their power to move water, and at the same osmolarity a solute that crosses the membrane moves no water out of cells — the separator is whether solutes are counted as particles or by their power to move water without crossing the membrane — [Paper 922]

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Abstract

A 0.9 percent salt solution is used as a liquid with the same osmotic pressure as blood. This paper compares its osmolarity with a representative value for plasma when counted by dissolved particles and when multiplied by the osmotic coefficient, confirms the comparison by freezing-point depression, and sets it beside glucose and urea solutions of similar concentration. No new theorem or law is claimed. First, counted by particles, the salt solution is six percent more concentrated than plasma: 0.9 w/v percent NaCl is 0.153996 mol/L; counting two particles, sodium and chloride, gives **307.9924** mOsm/L, **1.062043** times plasma at 290 mOsm/kg (representative) (Section 2). Second, with the osmotic coefficient, they become nearly equal: multiplying by the osmotic coefficient of NaCl, 0.93 (representative), gives 286.4329 mOsm/L, **0.987700** times plasma (Section 2). Third, freezing-point depression tells the same: the plasma freezing-point depression of 0.54 K (representative) divided by 1.86 is 0.290323 Osm/kg, and the salt solution's depression is 0.572866 K by particle count and 0.532765 K with the osmotic coefficient (Section 3). Fourth, at the same osmolarity, a solute that crosses the membrane moves no water out of cells: 1.8 percent urea is 299.7203 mOsm/L, 0.973142 times the salt solution's particle count, and 5 percent glucose is 277.5372 mOsm/L, but counted as solutes that cross the membrane (or are taken up), the share that moves cell water is 0 (Section 4). Fifth, the separator is whether solutes are counted as particles or by their power to move water without crossing the membrane: particle count overcounts by six percent and includes solutes that cross the membrane. Counted by the power to move water, the salt solution is nearly equal to plasma and urea becomes 0 (Section 5). **Keywords:** normal saline, osmolarity, osmotic coefficient, freezing-point depression, isotonic, membrane-permeant solute.

Scope of this paper (scope note): No new theorem or law is claimed: osmolarity, the osmotic coefficient, the freezing-point depression formula, and the fact that solutes crossing a membrane create no tonicity are all standard. No medical use is discussed, which fluid to use when is not treated. The values are representative: the osmotic coefficient of NaCl 0.93, plasma osmolality 290 mOsm/kg, plasma freezing-point depression 0.54 K and the cryoscopic constant of water 1.86 K kg/mol are representative, and the osmotic coefficients of glucose and urea are taken as 1. Per litre and per kilogram are not distinguished: for dilute aqueous solutions the difference between mOsm/L and mOsm/kg is not included. Changes in cell volume are not computed: the rate of haemolysis, the rate of membrane permeation and the time for glucose uptake are not treated. Urea and glucose are counted under the assumption that they cross the membrane. Relation to earlier papers: Paper 472, in its scope note, treated solutions as ideal without activity coefficients; this paper sits in that seat of the osmotic coefficient (no earlier occupant). Paper 333 showed that the constant ratio of osmotic pressure to freezing-point depression follows from an assumption, not from a measurement. Here that ratio is used, and the effect of the osmotic coefficient is confirmed by freezing-point depression. What is added: comparing the osmolarity of the salt solution with plasma by particle count and with the osmotic coefficient, making the same comparison by freezing-point depression, setting urea and glucose of similar osmolarity side by side and counting that solutes crossing the membrane move no cell water, and placing the separator on “particle count, or the power to move water without crossing the membrane”.

1. Notation and the Question

Setting: for a solute of mass concentration w (g/L) and molar mass M that splits into i particles, the osmolarity by particle count, the osmolarity multiplied by the osmotic coefficient ϕ , and the freezing-point depression are:

$$c_{\text{particles}} = \frac{i w}{M}, \quad c_{\text{power}} = \phi c_{\text{particles}}, \quad \Delta T_f = K_f c$$

Only the share of solutes that do not cross the membrane moves water out of cells. The check counts three solutes: NaCl ($i = 2$), glucose ($i = 1$) and urea ($i = 1$).

Question: counting what makes a 0.9 percent salt solution equal to plasma?

2. Particle Count and the Osmotic Coefficient

Computation 2.1: 0.9 w/v percent NaCl.

counted as	osmolarity (mOsm/L)	ratio to plasma 290
particles ($i = 2$)	307.9924	1.062043
with osmotic coefficient 0.93	286.4329	0.987700

The molarity was 0.153996 mol/L.

Observation 2.2

counted by particles it is six percent more concentrated; with the osmotic coefficient, nearly equal. The osmotic coefficient of 0.93 expresses that the dissolved particles move water not in proportion to their number but at 0.93 of it: the salt solution is nearly equal to plasma when counted by that power, not by particles.

3. Confirming by Freezing-Point Depression

Computation 3.1: the plasma freezing-point depression of 0.54 K (representative) divided by $K_f = 1.86$ is 0.290323 Osm/kg, matching the representative plasma value of 290. The salt solution's depression is 0.572866 K by particle count and 0.532765 K with the osmotic coefficient.

Observation 3.2

by freezing-point depression too, the value with the osmotic coefficient is closer to plasma. The particle-count 0.572866 K exceeds plasma's 0.54 K, and the 0.532765 K with the osmotic coefficient falls slightly below: using the constant ratio of osmotic pressure to freezing-point depression, either measurement gives the same comparison.

4. Solutes That Cross the Membrane

Computation 4.1: three fluids of similar osmolarity (osmotic coefficient 1 for glucose and urea).

fluid	osmolarity (mOsm/L)	share not crossing the membrane
0.9 percent NaCl (with osmotic coefficient)	286.4329	286.4329
1.8 percent urea	299.7203	0
5 percent glucose	277.5372	0 (after uptake)

The osmolarity of urea was 0.973142 times the salt solution's particle count.

Observation 4.2

at the same osmolarity, a solute that crosses the membrane moves no water out of cells. Urea passes through until its concentration is the same on both sides of the membrane, so even with an osmolarity nearly equal to plasma no difference remains to draw water from cells: the salt solution keeps tonicity because sodium and chloride act as solutes that do not cross the membrane.

5. The Separator

Observation 5.1

the separator is whether solutes are counted as particles or by their power to move water without crossing the membrane. Particle count gives 307.9924 mOsm/L, six percent more, and counts even urea, which crosses the membrane, as 299.7203: counted by the power to move water, the salt solution is 286.4329 mOsm/L, 0.987700 times plasma, and urea becomes 0.

Observation 5.2

what is not said. Medical use, the rate of haemolysis, changes in cell volume and individual plasma values are not treated. What is shown is that whether the two are equal depends on what is counted: six percent more concentrated by particles, nearly equal by power.

6. Roll Call and Closing

1. $c_{\text{particles}} = iw/M$, $c_{\text{power}} = \phi c_{\text{particles}}$ (Section 1): two ways of counting.

2. particle count **307.9924** mOsm/L, ratio **1.062043** (Computation 2.1): **six percent more concentrated.**
3. with osmotic coefficient **286.4329**, ratio **0.987700** (Computation 2.1): **nearly equal.**
4. freezing-point depression **0.572866** and **0.532765** K (Computation 3.1): **plasma 0.54 K.**
5. urea **299.7203**, share moving cell water **0** (Computation 4.1): **a solute that crosses the membrane.**
6. particles, or power (Observation 5.1): **the separator; the scope note of Paper 472; Paper 333.**

Closing: Normal saline is six percent too concentrated by particle count, but nearly equal to plasma once the osmotic coefficient is included. By particle count the 0.9 percent salt solution was 307.9924 mOsm/L, 1.062043 times plasma: multiplied by the osmotic coefficient it was 286.4329 mOsm/L, 0.987700 times, and by freezing-point depression too the value with the osmotic coefficient was closer to plasma. Urea, of nearly the same osmolarity, crosses the membrane and moves no water out of cells: the separator is whether solutes are counted as particles or by their power to move water without crossing the membrane. Placed among the earlier papers: the osmotic coefficient was added to the osmotic pressure that Paper 472 set as ideal, and checked by freezing-point depression using the ratio of Paper 333. To be honest, which fluid should be used is not said. What must be counted for the two to be equal, and no further.

References

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