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Chapter 11

Isotonic and Buffer Solutions

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Electrolytes

- With electrolytes, the problem is not so simple. Because osmotic pressure depends more on the number than on the kind of particles, 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.

- If we assume that sodium chloride in weak solutions is about 80% dissociated, then every 100 molecules yields 180 particles or 1.8 times as many particles as are yielded by 100 molecules of a nonelectrolyte.

Electrolytes

- This dissociation factor, commonly symbolized by the letter *i*, must be included in the proportion when we seek to determine the strength of an isotonic solution of sodium chloride (m.w. 58.5):

$$\frac{1.86\ (^\circ C) \times 1.8}{0.52\ (^\circ C)} = \frac{58.5\ (g)}{x\ (g)}$$

$$x = 9.09\ g$$

- Hence, 9.09 g of sodium chloride in 1000 g of water should make a solution isotonic with blood or lacrimal fluid. In practice, a 0.90% w/v sodium chloride solution is considered isotonic with body fluids.

- Simple isotonic solutions may then be calculated by using this formula:

$$\frac{0.52 \times \text{molecular weight}}{1.86 \times \text{dissociation } (i)} = \text{g of solute per 1000 g of water}$$

- If the number of ions is known, we may use the following values, lacking better information:

Nonelectrolytes and substances of slight dissociation 1.0

Substances that dissociate into 2 ions: 1.8

Substances that dissociate into 3 ions: 2.6

Substances that dissociate into 4 ions: 3.4

Substances that dissociate into 5 ions: 4.2

EXAMPLE CALCULATIONS OF THE (*i*) FACTOR

- ***Zinc sulfate is a 2-ion electrolyte, dissociating 40% in a certain concentration. Calculate its dissociation (i) factor.***
- On the basis of 40% dissociation, 100 particles of zinc sulfate will yield:

40 zinc ions

40 sulfate ions

60 undissociated particles

or 140 particles

- Because 140 particles represent 1.4 times as many particles as were present before dissociation,
- the dissociation (*i*) factor is 1.4, *answer.*

Zinc chloride is a 3-ion electrolyte, dissociating 80% in a certain concentration. Calculate its dissociation (i) *factor.*

On the basis of 80% dissociation, 100 particles of zinc chloride will yield:

80 zinc ions
80 chloride ions
80 chloride ions
20 undissociated particles
or 260 particles

Because 260 particles represents 2.6 times as many particles as were present before dissociation, the dissociation (*i*) factor is 2.6, *answer.*

SODIUM CHLORIDE EQUIVALENT

- The **sodium chloride equivalent** of a chemical (***E***) is defined as the amount of sodium chloride (in grams or grains) that has the same osmotic pressure as that of 1 g of the chemical.

- The sodium chloride equivalent of a substance may be calculated as follows:

$$\frac{\text{Molecular weight of sodium chloride}}{i\text{ Factor of sodium chloride}} \times \frac{i\text{ factor of the substance}}{\text{Molecular weight of the substance}} = \text{Sodium chloride equivalent}$$

Papaverine hydrochloride (m.w. 376) *is a 2-ion electrolyte, dissociating 80% in a given concentration. Calculate its sodium chloride equivalent.*

Because papaverine hydrochloride is a 2-ion electrolyte, dissociating 80%, its *i* factor is 1.8.

$$\frac{58.5}{1.8} \times \frac{1.8}{376} = 0.156, \text{ or } 0.16, \textit{ answer.}$$

Calculate the sodium chloride equivalent for glycerin, a nonelectrolyte with a molecular weight of 92.[2]

Glycerin, *i* factor = 1.0

$$\frac{58.5}{1.8} \times \frac{1.0}{92} = 0.35, \textit{ answer.}$$

Calculate the sodium chloride equivalent for timolol maleate, which dissociates into two ions and has a molecular weight of 432.[2]

Timolol maleate, *i* factor = 1.8

$$\frac{58.5}{1.8} \times \frac{1.8}{432} = 0.14, \textit{ answer.}$$

THE PROCEDURE FOR THE *CALCULATION OF ISOTONIC SOLUTIONS WITH SODIUM CHLORIDE EQUIVALENTS* MAY BE OUTLINED AS FOLLOWS:

Step 1. Calculate the amount (in grams) of sodium chloride represented by the ingredients in the prescription. Multiply the amount (in grams) of each substance by its sodium chloride equivalent.

Step 2. Calculate the amount (in grams) of sodium chloride, alone, that would be contained in an isotonic solution of the volume specified in the prescription, namely, *the amount of sodium chloride in a 0.9% solution of the specified volume.* (Such a solution would contain 0.009 g/mL.)

Step 3. Subtract the amount of sodium chloride represented by the ingredients in the prescription (Step 1) from the amount of sodium chloride, alone, that would be represented in the specific volume of an isotonic solution (Step 2). The answer represents the amount (in grams) of sodium chloride to be added to make the solution isotonic.

Step 4. If an agent other than sodium chloride, such as boric acid, dextrose, or potassium nitrate, is to be used to make a solution isotonic, divide the amount of sodium chloride (Step 3) by the sodium chloride equivalent of the other substance.

EXAMPLE CALCULATIONS OF TONICIC AGENT REQUIRE

How many grams of sodium chloride should be used in compounding the following prescription?

℞	Pilocarpine Nitrate	0.3 g
	Sodium Chloride	q.s.
	Purified Water ad	30 mL
	Make isoton. sol.	
	Sig. For the eye.	

Step 1. 0.23×0.3 g = 0.069 g of sodium chloride represented by the pilocarpine nitrate

Step 2. 30×0.009 = 0.270 g of sodium chloride in 30 mL of an isotonic sodium chloride solution

Step 3. 0.270 g (from Step 2)
− 0.069 g (from Step 1)
0.201 g of sodium chloride to be used, *answer.*

How many grams of boric acid should be used in compounding the following prescription?

℞	Phenacaine Hydrochloride	1%
	Chlorobutanol	½%
	Boric Acid	q.s.
	Purified Water ad	60
	Make isoton. sol.	
	Sig. One drop in each eye.	

The prescription calls for 0.6 g of phenacaine hydrochloride and 0.3 g of chlorobutanol.

Step 1. 0.20×0.6 g $=$ 0.120 g of sodium chloride represented by phenacaine hydrochloride
0.24×0.3 g $=$ 0.072 g of sodium chloride represented by chlorobutanol
Total: 0.192 g of sodium chloride represented by both ingredients

Step 2. $60 \times 0.009 = 0.540$ g of sodium chloride in 60 mL of an isotonic sodium chloride solution

Step 3. 0.540 g (from Step 2)
− 0.192 g (from Step 1)
0.348 g of sodium chloride required to make the solution isotonic

But because the prescription calls for boric acid:

Step 4. 0.348 g ÷ 0.52 (sodium chloride equivalent of boric acid) = 0.669 g of boric acid to be used, *answer.*

How many grams of potassium nitrate could be used to make the following prescription isotonic?

℞	Sol. Silver Nitrate	60
	1:500 w/v	
	Make isoton. sol.	
	Sig. For eye use.	

The prescription contains 0.12 g of silver nitrate.

Step 1. 0.33 × 0.12 g = 0.04 g of sodium chloride represented by silver nitrate

Step 2. 60 × 0.009 = 0.54 g of sodium chloride in 60 mL of an isotonic sodium chloride solution

Step 3. 0.54 g (from step 2)

− 0.04 g (from step 1)

0.50 g of sodium chloride required to make solution isotonic

Because, in this solution, sodium chloride is incompatible with silver nitrate, the tonic agent of choice is potassium nitrate. Therefore,

Step 4. 0.50 g ÷ 0.58 (sodium chloride equivalent of potassium nitrate) = 0.86 g of potassium nitrate to be used, *answer.*

How many grams of sodium chloride should be used in compounding the following prescription?

℞	Ingredient X	0.5
	Sodium Chloride	q.s.
	Purified Water ad	50
	Make isoton. sol.	
	Sig. Eye drops.	

Let us assume that ingredient X is a new substance for which no sodium chloride equivalent is to be found in Table 11.1, and that its molecular weight is 295 and its *i* factor is 2.4. The sodium chloride equivalent of ingredient X may be calculated as follows:

$$\frac{58.5}{1.8} \times \frac{2.4}{295} = 0.26, \text{ the sodium chloride equivalent for ingredient X}$$

Then,

Step 1. 0.26×0.5 g $= 0.13$ g of sodium chloride represented by ingredient X

Step 2. $50 \times 0.009 = 0.45$ g of sodium chloride in 50 mL of an isotonic sodium chloride solution

Step 3. 0.45 g (from Step 2)
− 0.13 g (from Step 1)
0.32 g of sodium chloride to be used, *answer.*

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Thank You