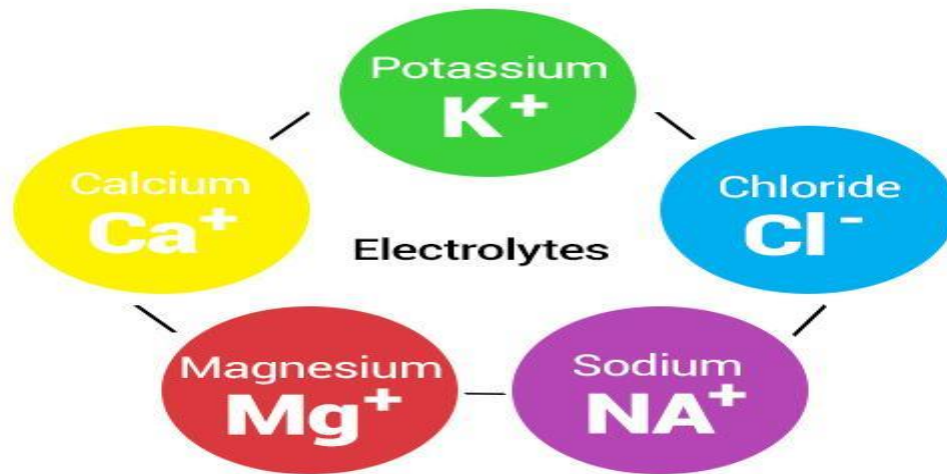


Electrolyte Solutions : milliequivalents, millimoles , milliosmoles

Chapter 12

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Nonelectrolytes: Substances that are not dissociated in solution example Urea and dextrose .

Electrolytes: substances with varying degrees of dissociation example sodium chloride.

Sodium chloride in solution provides Na^+ and Cl^- ions, which carry electric charges. If electrodes carrying a weak current are placed in the solution, the ions move in a direction opposite to the charges. Na^+ ions move to the negative electrode (cathode) and are called cations. Cl^- ions move to the positive electrode (anode) and are called anions.

Electrolytes in body fluids play an important role in maintaining the acid-base balance in the body. They play a part in controlling body water volumes and help to regulate body metabolism.

In clinical practice, they are provided in the form of oral solutions and syrups, as dry granules intended to be dissolved in water or juice to make an oral solution, as oral tablets and capsules and, when necessary, as intravenous infusions.

Milliequivalent (mEq): is now used almost exclusively in the United States by clinicians, physicians, pharmacists, and manufacturers to express the concentration of electrolytes in solution. This unit of measure is related to the total number of ionic charges in solution, and it takes note of the valence of the ions. In other words, it is a unit of measurement of the amount of chemical activity of an electrolyte.

For a given chemical compound, the milliequivalents of cation equals the milliequivalents of anion equals the milliequivalents of the chemical compound.

blood plasma contains 154 mEq of cations and an equal number of anions.

if we dissolve enough potassium chloride in water to give us 40 mEq of K^+ per liter, we also have exactly 40 mEq of Cl^- , but the solution will not contain the same weight of each ion.

A milliequivalent represents the amount, in milligrams, of a solute equal to 1/1000 of its gram equivalent weight, taking into account the valence of the ions.



CALCULATIONS CAPSULE

Milliequivalents

To convert milligrams (mg) to milliequivalents (mEq):

$$mEq = \frac{mg \times \text{Valence}}{\text{Atomic, formula, or molecular weight}}$$

To convert milliequivalents (mEq) to milligrams (mg):

$$mg = \frac{mEq \times \text{Atomic, formula, or molecular weight}}{\text{Valence}}$$

To convert milliequivalents per milliliter (mEq/mL) to milligrams per milliliter (mg/mL):

$$mg/mL = \frac{mEq/mL \times \text{Atomic, formula, or molecular weight}}{\text{Valence}}$$

$$^a \text{Equivalent weight} = \frac{\text{Atomic or formula weight}}{\text{Valence}}$$

$$\text{mEq} = 1/1000 \times \text{g eq wt}$$

TABLE 12.3 VALUES FOR SOME IMPORTANT IONS

ION	FORMULA	VALENCE	ATOMIC OR FORMULA WEIGHT	EQUIVALENT WEIGHT ^a
Aluminum	Al ⁺⁺⁺	3	27	9
Ammonium	NH ₄ ⁺	1	18	18
Calcium	Ca ⁺⁺	2	40	20
Ferric	Fe ⁺⁺⁺	3	56	18.7
Ferrous	Fe ⁺⁺	2	56	28
Lithium	Li ⁺	1	7	7
Magnesium	Mg ⁺⁺	2	24	12
Potassium	K ⁺	1	39	39
Sodium	Na ⁺	1	23	23
Acetate	C ₂ H ₃ O ₂ ⁻	1	59	59
Bicarbonate	HCO ₃ ⁻	1	61	61
Carbonate	CO ₃ ⁻⁻⁻	2	60	30
Chloride	Cl ⁻	1	35.5	35.5
Citrate	C ₆ H ₅ O ₇ ⁻⁻⁻	3	189	63
Gluconate	C ₆ H ₁₁ O ₇ ⁻	1	195	195
Lactate	C ₃ H ₅ O ₃ ⁻	1	89	89
Phosphate	H ₂ PO ₄ ⁻	1	97	97
	HPO ₄ ⁻	2	96	48
Sulfate	SO ₄ ⁻	2	96	48

^aAtomic or formula weights

What is the concentration, in milligrams per milliliter, of a solution containing 2 mEq of potassium chloride (KCl) per milliliter?

$$\text{Molecular weight of KCl} = 74.5$$

$$\text{Equivalent weight of KCl} = 74.5$$

$$1 \text{ mEq of KCl} = \frac{1}{1000} \times 74.5 \text{ g} = 0.0745 \text{ g} = 74.5 \text{ mg}$$

$$2 \text{ mEq of KCl} = 74.5 \text{ mg} \times 2 = 149 \text{ mg/mL, answer.}$$

Or, by using the preceding equation:

$$\begin{aligned} \text{mg/mL} &= \frac{2 \text{ (mEq/mL)} \times 74.5}{1} \\ &= 149 \text{ mg/mL, answer.} \end{aligned}$$

What is the concentration, in grams per milliliter, of a solution containing 4 mEq of calcium chloride ($\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$) per milliliter?

Recall that the equivalent weight of a binary compound may be found by dividing the formula weight by the *total valence* of the positive or negative radical.

$$\text{Formula weight of } \text{CaCl}_2 \cdot 2\text{H}_2\text{O} = 147$$

$$\text{Equivalent weight of } \text{CaCl}_2 \cdot 2\text{H}_2\text{O} = \frac{147}{2} = 73.5$$

$$1 \text{ mEq of } \text{CaCl}_2 \cdot 2\text{H}_2\text{O} = \frac{1}{1000} \times 73.5 \text{ g} = 0.0735 \text{ g}$$

$$4 \text{ mEq of } \text{CaCl}_2 \cdot 2\text{H}_2\text{O} = 0.0735 \text{ g} \times 4 = 0.294 \text{ g/mL, answer.}$$

Or, solving by dimensional analysis:

$$\frac{1 \text{ g } \text{CaCl}_2 \cdot 2\text{H}_2\text{O}}{1000 \text{ mg } \text{CaCl}_2 \cdot 2\text{H}_2\text{O}} \times \frac{147 \text{ mg}}{1 \text{ mmole}} \times \frac{1 \text{ mmole}}{2 \text{ mEq}} \times \frac{4 \text{ mEq}}{1 \text{ mL}} = 0.294 \text{ g/mL, answer.}$$

What is the percent (w/v) concentration of a solution containing 100 mEq of ammonium chloride per liter?

Molecular weight of NH_4Cl = 53.5

Equivalent weight of NH_4Cl = 53.5

1 mEq of NH_4Cl = $\frac{1}{1000} \times 53.5 = 0.0535$ g

100 mEq of NH_4Cl = $0.0535 \text{ g} \times 100 = 5.35 \text{ g/L}$ or

0.535 g per 100 mL, or 0.535%, *answer.*

A solution contains 10 mg/100 mL of K^+ ions. Express this concentration in terms of milliequivalents per liter.

Atomic weight of K^+ = 39

Equivalent weight of K^+ = 39

1 mEq of K^+ = $\frac{1}{1000} \times 39 \text{ g} = 0.039 \text{ g} = 39 \text{ mg}$

10 mg/100 mL of K^+ = 100 mg of K^+ per liter

$100 \text{ mg} \div 39 = 2.56 \text{ mEq/L}$, *answer.*

How many milliequivalents of magnesium sulfate are represented in 1 g of anhydrous magnesium sulfate (MgSO_4)?

Molecular weight of $\text{MgSO}_4 = 120$

Equivalent weight of $\text{MgSO}_4 = 60$

1 mEq of $\text{MgSO}_4 = \frac{1}{1000} \times 60 \text{ g} = 0.06 \text{ g} = 60 \text{ mg}$

1.0 g of $\text{MgSO}_4 = 1000 \text{ mg}$

$$\frac{60 \text{ (mg)}}{1000 \text{ (mg)}} = \frac{1 \text{ (mEq)}}{x \text{ (mEq)}}$$

$x = 16.7 \text{ mEq, answer.}$

How many milliequivalents of Na^+ would be contained in a 30-mL dose of the following solution?

Disodium hydrogen phosphate	18 g
Sodium biphosphate	48 g
Purified water ad	100 mL

Disodium hydrogen phosphate

$$\text{Formula} = \text{Na}_2\text{HPO}_4 \cdot 7\text{H}_2\text{O}$$

$$\text{Molecular weight} = 268 \text{ and the equivalent weight} = 134$$

$$\frac{18 \text{ (g)}}{x \text{ (g)}} = \frac{100 \text{ (mL)}}{30 \text{ (mL)}}$$

$$x = 5.4 \text{ g of disodium hydrogen phosphate per 30 mL}$$

$$1 \text{ mEq} = \frac{1}{1000} \times 134 \text{ g} = 0.134 \text{ g} = 134 \text{ mg}$$

$$\frac{134 \text{ (mg)}}{5400 \text{ (mg)}} = \frac{1 \text{ (mEq)}}{x \text{ (mEq)}}$$

$$x = 40.3 \text{ mEq of disodium hydrogen phosphate}$$

Because the milliequivalent value of Na^+ ion equals the milliequivalent value of disodium hydrogen phosphate, then

$$x = 40.3 \text{ mEq of } \text{Na}^+$$

Sodium biphosphate

$$\text{Formula} = \text{NaH}_2\text{PO}_4 \cdot \text{H}_2\text{O}$$

$$\text{Molecular weight} = 138 \text{ and the equivalent weight} = 138$$

$$\frac{48 \text{ (g)}}{x \text{ (g)}} = \frac{100 \text{ (mL)}}{30 \text{ (mL)}}$$

$$x = 14.4 \text{ g of sodium biphosphate per 30 mL}$$

$$1 \text{ mEq} = \frac{1}{1000} \times 138 \text{ g} = 0.138 \text{ g} = 138 \text{ mg}$$

$$\frac{138 \text{ (mg)}}{14,400 \text{ (mg)}} = \frac{1 \text{ (mEq)}}{x \text{ (mEq)}}$$

$$x = 104.3 \text{ mEq of sodium biphosphate}$$

$$\text{and also, } = 104.3 \text{ mEq of } \text{Na}^+$$

Adding the two milliequivalent values for $\text{Na}^+ = 40.3 \text{ mEq} + 104.3 \text{ mEq} = 144.6 \text{ mEq}$,

answer.

Millimoles and micromoles:

the SI expresses electrolyte concentrations in millimoles per liter (mmol/L).

A **mole** is the molecular weight of a substance in grams.

How many millimoles of monobasic sodium phosphate (m.w. 138) are present in 100 g of the substance?

$$\text{m.w.} = 138$$

$$1 \text{ mole} = 138 \text{ g}$$

$$\frac{1 \text{ (mole)}}{x \text{ (mole)}} = \frac{138 \text{ (g)}}{100 \text{ (g)}}$$

$$x = 0.725 \text{ moles} = 725 \text{ mmol, answer.}$$

Convert blood plasma levels of 0.5 $\mu\text{g/mL}$ and 2 $\mu\text{g/mL}$ of tobramycin (mw = 467.52) to $\mu\text{mol/L}$.¹

By dimensional analysis:

$$\frac{0.5 \mu\text{g}}{1 \text{ mL}} \times \frac{1 \mu\text{mol}}{467.52 \mu\text{g}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 1.07 \mu\text{mol/L}$$

and,

$$\frac{2 \mu\text{g}}{1 \text{ mL}} \times \frac{1 \mu\text{mol}}{467.52 \mu\text{g}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 4.28 \mu\text{mol/L, answers.}$$

طريقة اسهل للحل

$$1 \text{ mole} = 467.5 \text{ g} \quad 1 \text{ } \mu\text{mole} = 467.5 \text{ } \mu\text{g}$$

$$1 \text{ } \mu\text{mole}/X = 467.5 \text{ } \mu\text{g}/ 0.5 \text{ } \mu\text{g}$$

$$X = 0.00106952 \text{ } \mu\text{mole} / \text{ml} * 1000$$

$$= 1.069 \text{ } \mu\text{mole} / \text{L}$$

$$1 \text{ } \mu\text{mole}/X = 467.5 \text{ } \mu\text{g}/ 2 \text{ } \mu\text{g}$$

$$X = 0.00427 \text{ } \mu\text{mole} / \text{ml} * 1000$$

$$= 4.28 \text{ } \mu\text{mole} / \text{L}$$

osmolarity

Osmotic pressure is proportional to the total number of particles in solution. The unit used to measure osmotic concentration is the milliosmole (mOsmol). For dextrose, a nonelectrolyte, 1 mmol (1 formula weight in milligrams) represents 1 mOsmol. This relationship is not the same with electrolytes, however, because the total number of particles in solution depends on the degree of dissociation of the substance in question. Assuming complete dissociation, 1 mmol of NaCl represents 2 mOsmol ($\text{Na}^+ + \text{Cl}^-$) of total particles, 1 mmol of CaCl_2 represents 3 mOsmol ($\text{Ca}^{++} + 2\text{Cl}^-$) of total particles

$$\text{mOsmol/L} = \frac{\text{Weight of substance (g/L)}}{\text{Molecular weight (g)}} \times \text{Number of species} \times 1000$$

A distinction also should be made between the terms **osmolarity** and **osmolality**. Whereas **osmolarity** is the milliosmoles of solute per liter of solution.

osmolality is the milliosmoles of solute per kilogram of solvent.

For dilute aqueous solutions, osmolarity and osmolality are nearly identical.

Osmometers are commercially available for use in the laboratory to measure osmolality.

How many milliosmoles are represented in a liter of a 0.9% sodium chloride solution?

Osmotic concentration (in terms of milliosmoles) is a function of the total number of particles present. Assuming complete dissociation, 1 mmol of sodium chloride (NaCl) represents 2 mOsmol of total particles ($\text{Na}^+ + \text{Cl}^-$).

Formula weight of NaCl = 58.5

1 mmol of NaCl (58.5 mg) = 2 mOsmol

$1000 \times 0.009 = 9 \text{ g or } 9000 \text{ mg of NaCl per liter}$

$$\frac{58.5 \text{ (mg)}}{9000 \text{ (mg)}} = \frac{2 \text{ (mOsmol)}}{x \text{ (mOsmol)}}$$

$x = 307.7$, or 308 mOsmol, *answer*.

الطريقة الثانية للحل

$$\text{mOsmol/L} = \frac{\text{Weight of substance (g/L)}}{\text{Molecular weight (g)}} \times \text{Number of species} \times 1000$$

$$\begin{aligned} \text{mOsmol/L} &= \{(9\text{g/L}) / 58.5\} \times 2 \times 1000 \\ &= 307.7 \end{aligned}$$

Calculate the milliequivalents of sodium, potassium and chloride, the millimoles of anhydrous dextrose, and the osmolarity of the following parenteral fluid.

Dextrose, anhydrous	50 g
Sodium Chloride	4.5 g
Potassium Chloride	1.49 g
Water for Injection, ad	1000 mL

Molecular weight of NaCl = 58.5

Equivalent weight of NaCl = 58.5

$$1 \text{ mEq of NaCl} = \frac{1}{1000} \times 58.5 = 0.0585 \text{ g} = 58.5 \text{ mg}$$

$$4.5 \text{ g of NaCl} = 4500 \text{ mg}$$

$$\frac{58.5 \text{ mg}}{4500 \text{ mg}} = \frac{1 \text{ mEq}}{x \text{ mEq}}$$

$$x = 76.9 \text{ or } 77 \text{ mEq of Na}^+ \text{ and} \\ 76.9 \text{ or } 77 \text{ mEq of Cl}^-$$

Molecular weight of KCl = 74.5

Equivalent weight of KCl = 74.5

$$1 \text{ mEq of KCl} = \frac{1}{1000} \times 74.5 = 0.0745 \text{ g} = 74.5 \text{ mg}$$

$$1.49 \text{ g of KCl} = 1490 \text{ mg}$$

$$\frac{74.5 \text{ mg}}{1490} = \frac{1 \text{ mEq}}{x \text{ mEq}}$$

$$x = 20 \text{ mEq of K}^+ \text{ and} \\ 20 \text{ mEq of Cl}^-$$

$$\text{Total: Na}^+ = 77 \text{ mEq}$$

$$\text{K}^+ = 20 \text{ mEq}$$

$$\text{Cl}^- = 77 \text{ mEq} + 20 \text{ mEq} = 97 \text{ mEq, answers.}$$

Molecular weight of anhydrous dextrose = 180

1 mmol of anhydrous dextrose = 180 mg

50 g of anhydrous dextrose = 50,000 mg

$$\frac{180 \text{ mg}}{50,000 \text{ mg}} = \frac{1 \text{ mmol}}{x \text{ mmol}}$$

$x = 277.7$ or 278 mmol, *answer.*

Osmolarity:

Dextrose, anhyd.: $278 \text{ mmol} \times 1 \text{ particle per mmol} = 278 \text{ mOsmol}$

NaCl: $77 \text{ mEq} \times 2 \text{ particles per mEq (or mmol)} = 154 \text{ mOsmol}$

KCl: $20 \text{ mEq} \times 2 \text{ particles per mEq (or mmol)} = 40 \text{ mOsmol}$

Total = 472 mOsmol, *answer.*

