(Chapter 12)
Electrolyte Solutions: Milliequivalents, Millimoles, and Milliosmoles

Lecture 1

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Objectives:

Upon completing this chapter you will be able to:

1- Determine M.wt. of electrolyte from atomic or formula weight as well as valence and no. of ions upon dissociation

2- Calculate problems involving milliequivalents (used for electrolyte replacement)

3- Calculate problems involving millimoles and micromoles (used in pharmacy practice)

4- Calculate problems involving milliosmoles and osmolarity (used for IV infusion)

Electrolyte solutions

- The molecules of chemical compounds in solution may remain intact, or they may dissociate into particles known as ions, which carry an electric charge.
- Substances that are not dissociated in solution are called nonelectrolytes, and those with varying degrees of dissociation are called electrolytes.
- Urea and dextrose are examples of nonelectrolytes in body water; sodium chloride in body fluids is an example of an electrolyte. 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.
- Electrolyte ions in the blood plasma include the cations Na^+, K^+, Ca^{++}, and Mg^{++} and the anions Cl^-, HCO_3^-, HPO_4^{--}, SO_4^{--}, organic acids, and protein.
- **Electrolytes in body fluids play an important role in maintaining the acid-base balance in the body. They also play a part in controlling body water volumes and help to regulate body metabolism.**

Applicable Dosage Forms

- Electrolyte preparations are used in the treatment of disturbances of the electrolyte and fluid balance in the body.

- They are provided by the pharmacy in the form of oral solutions, syrups, tablets, capsules and, when necessary, as intravenous infusions.

Milliequivalents

- A ***chemical unit***, the ***milliequivalent (mEq),*** is now used in U.S.A. by clinicians, physicians, pharmacists, and manufacturers to express the concentration of electrolytes in solution.
- This unit of measure is **related to the total no. 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.

TABLE 12.1 BLOOD PLASMA ELECTROLYTES IN MILLIEQUIVALENTS PER LITER (mEq/L)

CATIONS	mEq/L	ANIONS	mEq/L
Na^{+}	142	HCO_3^{-}	24
K^{+}	5	Cl^{-}	105
Ca^{++}	5	HPO_4^{--}	2
Mg^{++}	2	SO_4^{--}	1
		Org. Ac.$^{-}$	6
		Proteinate^{-}	16
	154		154

- In the International System (SI), which is used in European countries and in many others throughout the world, molar concentrations [as milli-moles per liter (mmol/L) and micromoles per liter (μmol/L)] are used to express most clinical laboratory values, including those of electrolytes.

TABLE 12.2 USUAL REFERENCE RANGE OF BLOOD SERUM VALUES FOR SOME ELECTROLYTES[a]

CATION/ANION	mEq/L	SI UNITS (mmol/L)
Sodium	135–145	135–145
Potassium	3.5–5.5	3.5–5.5
Calcium	4.6–5.5	2.3–2.75
Magnesium	1.5–2.5	0.75–1.25
Chloride	96–106	96–106
Carbon Dioxide	24–30	24–30
Phosphorus	2.5–4.5	0.8–1.5

[a] Reference ranges may vary slightly between clinical laboratories based, in part, on the analytical methods and equipment used.

- <u>The total concentration of cations always equals the total concentration of anions.</u> Any number of milliequivalents of Na^+, K^+, or any cation always reacts with precisely the same number of milliequivalents of Cl^-, $HCO3^-$, or any anion.

<u>**Example:**</u> ***A chemical compound with milliequivalents of cation equals the milliequivalents of anion equals the milliequivalents of the chemical compound.***

Dissolving 40 mEq of potassium chloride in water results in a solution containing 40 mEq of K^+ per liter and 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.
- The milliequivalent expresses the chemical activity or combining power of a substance relative to the activity of 1 mg of hydrogen. Thus, based on the atomic weight and valence of the species, 1 mEq is represented by 1 mg of hydrogen, 20 mg of calcium, 23 mg of sodium, 35.5 mg of chlorine, 39 mg of potassium, and so forth.
- **Equivalent weight =** ***Atomic or formula weight / Valence***

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	$C_2H_3O_2^-$	1	59	59
Bicarbonate	HCO_3^-	1	61	61
Carbonate	CO_3^{--}	2	60	30
Chloride	Cl^-	1	35.5	35.5
Citrate	$C_6H_5O_7^{---}$	3	189	63
Gluconate	$C_6H_{11}O_7^-$	1	195	195
Lactate	$C_3H_5O_3^-$	1	89	89
Phosphate	$H_2PO_4^-$	1	97	97
	HPO_4^{--}	2	96	48
Sulfate	SO_4^{--}	2	96	48

[a] Equivalent weight $= \dfrac{\textit{Atomic or formula weight}}{\textit{Valence}}$

Example Calculations of Milliequivalents

- To convert the concentration of electrolytes in solution expressed as milliequivalents per unit volume to weight per unit volume and vice versa, use the following:

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

mEq = mg x Valence/ Atomic, formular, or molecular weight

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

mg = mEq x Atomic, formula, or molecular weight /Valence

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

mg/mL=mEq/mL x ***Atomic, formula, or molecular weight /Valence***

(1) *A physician prescribes 10 mEq of potassium chloride for a patient. How many milligrams of KCl would provide the prescribed quantity?*

Molecular weight of KCl = 39 (K^+) + 35.5 (Cl^-) = 74.5

Valence = 1

mg = mEq x Atomic, formula, or m.wt. / Valence

mg = 10 x 74.5 / 1 = 745 mg

(2) *If a patient is prescribed 300 mg of potassium chloride, what is the corresponding mEq?*

mEq = mg x Valence / Atomic, formular, or m.wt.

mEq = 300 x 1 / 74.5 = 4.03

(3) A physician prescribes 3 mEq/kg of NaCl to be administered to a 165-lb patient. How many milliliters of a half–normal saline solution (0.45% NaCl) should be administered?

1- M.wt. of Nacl = 23 (Na^{+}) + 35.5 (Cl^{-}) = 58.5

2- 1 kg 2.2 Ib
X 165 Ib
= 75 kg weight of patient

3- 3 mEq 1 kg
X 75 kg
= 225 mEq of NaCl given to patient

4- **Mg = mEq x Atomic, formula, or m.wt. /Valence**

Mg = 225 x 58.5 / 1 = 13164 mg = 13.16 gm of Nacl given to patient with 75 kg weight.

5- 0.45 gm 100 ml
13.16 gm x
= 2925 ml of 0.45% NaCl solution

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

- Molecular weight of KCl = 74.5

mg/mL=mEq/mL* x *Atomic, formula, or molecular weight /Valence

- mg/mL = 2 (mEq/mL) x 74.5 / 1 = 149 mg/mL.

5) What is the concentration, in grams per milliliter, of a solution containing 4 mEq of calcium chloride $(CaCl_2.2H_2O)$ per milliliter?

M.wt of $CaCl_2 \cdot 2H_2O$ = 40 (Ca^{2+}) + [2 x 35.5 (Cl^{-})] + [2 x18 (H_2O)] = 147

mg/mL=mEq/mL x **Atomic, formula, or molecular weight /Valence**

mg/ ml = 4 x 147/2 = 294 mg/ml = 0.294 g/ml

Note: The water of hydration molecules should be accounted for in the molecular weight but does not interfere in determination of valence.

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

mg/mL= mEq/mL x ***Atomic, formula, or molecular weight /Valence***

100 mEq / *x* = *1000ml* / *1ml* = *0.1 mEq/ml*

- Mg / ml = 0.1 mEq/ml x 53.5 / 1 = 5.35 mg / ml = 0.00535g/ml

0.00535g / X = 1ml / 100ml = 0.535 %

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

- Atomic weight of K =39

mg/mL= mEq/mL x ***Atomic, formula, or molecular weight /Valence***

Rearrange equation:

mEq/mL = mg/mL x Valence / Atomic, formula, or molecular weight

10mg x 100ml 1ml = 0.1 mg/ ml

- mEq/mL = 0.1 (mg/ml) x 1/ 39 = 0.00256 mEq/ml

0.00256 mEq x 1ml 1000ml = 2.56 mEq/L

8) A solution contains 10 mg/100 mL of Ca^{++} ions. Express this concentration in terms of milliequivalents per liter.

- Atomic weight of Ca^{++} = 40

mEq/mL = mg/mL x Valence / Atomic, formula, or molecular weight

$$\frac{10mg}{x} = \frac{100ml}{1ml} = 0.1\ mg/ml$$

- mEq/mL = 0.1mg/mL x 2 / 40 = 0.005mEq/mL

$$\frac{0.005mEq}{x} = \frac{1ml}{1000ml} = 5\ mEq/L$$

9) A magnesium (Mg^{2+}) level in blood plasma is determined to be 2.5 mEq/L. Express this concentration in terms of milligrams per liter.

- Atomic weight of Mg = 24

mg/mL=mEq/mL x ***Atomic, formula, or molecular weight /Valence***

$$\frac{2.5 \text{ mEq}}{1000\text{ml}} \times \frac{1\text{ml}}{} = 0.0025 \text{ mEq/mL}$$

- mg / ml = 0.0025 (mEq/ml) x 24 /2 = 0.03 mg / ml

$$\frac{0.03 \text{ mg}}{1 \text{ ml}} \times 1000\text{ml} = 30\text{mg/L}$$

10) An aluminum hydroxide gel suspension contains 320 mg of aluminum hydroxide in each teaspoonful dose. How many milliequivalents of aluminum would a patient receive each day if he is ingesting two teaspoonfuls of the suspension four times daily?

- Molecular weight of $Al(OH)_3$ = 27 (Al^{3+}) + [3 x 17 (OH^-)] = 78
- Valence = 3

320 mg	1 tsp	= 640 mg of $Al(OH)_3$ in 2 tsp
X	2 tsp	

640 mg X 4 = 2560 mg of $Al(OH)_3$ / day

mEq = mg x Valence / Atomic, formular, or m.wt.

mEq = 2560 X 3 / 78 = 98.46 mEq of $Al(OH)_3$ / day

= 98.46 mEq of Al^{3+} / day

(11) How many milliequivalents of magnesium are represented in an 8-mL dose of an injectable solution containing 50% w/v magnesium sulfate heptahydrate?

Molecular weight of $MgSO_4 . 7H_2O$ = 24 (Mg^{2+}) + 96 (SO_4^{2-}) + [7 x 18 (H_2O)] = 246.

Valence = 2

50 gm 100 ml

X 8 ml = 4 gm of $MgSO_4 . 7H_2O$

4 gm X 1000 = 4000 mg of $MgSO_4 . 7H_2O$

mEq = mg x Valence / Atomic, formular, or m.wt.

mEq = 4000 X 2 / 246 = 32.52 mEq of $MgSO_4 . 7H_2O$

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

Rx

Sodium phosphate, dibasic, heptahydrate		*18 g*
Sodium phosphate, monobasic, monohydrate		*48 g*
Purified water	*ad*	*100 mL*

Each salt is considered separately in solving the problem.

Sodium phosphate, dibasic, heptahydrate

Formula = $Na_2HPO_4.7H2O$ Molecular weight = 268 valence = 2

18 g 100 ml
X 30 ml

X = 5.4 g = 5400 mg of *Sodium phosphate, dibasic, heptahydrate* per 30 mL

mEq = 5400 x 2 / 268 = 40.3 mEq of *Sodium phosphate, dibasic, heptahydrate*

Because the milliequivalent value of Na^+ ion equals the milliequivalent value of *Sodium phosphate, dibasic, heptahydrate*, then: x = 40.3 mEq of Na^+

For Sodium phosphate, monobasic, monohydrate

Formula = $NaH_2PO_4.H2O$ Molecular weight = 138 valence = 1

48 g 100 ml
X 30 ml

X = 14.4g = 14400 mg of Sodium phosphate, monobasic, monohydrate per 30 mL

mEq = 14400 x 1 / 138 = 104.3

Adding the two milliequivalent values for Na^+ = 40.3 mEq + 104.3 mEq = 144.6 mEq

THANK YOU