Electrolyte Solutions: Milliequivalents, Millimoles, and Milliosmoles

Lecture :5,6

Learning Objectives

Upon successful completion of this chapter, the student will be able to:

- Calculate the milliequivalent weight from an atomic or formula weight.
- Convert between milligrams and milliequivalents.
- Calculate problems involving milliequivalents.
- Calculate problems involving millimoles and milliosmoles.

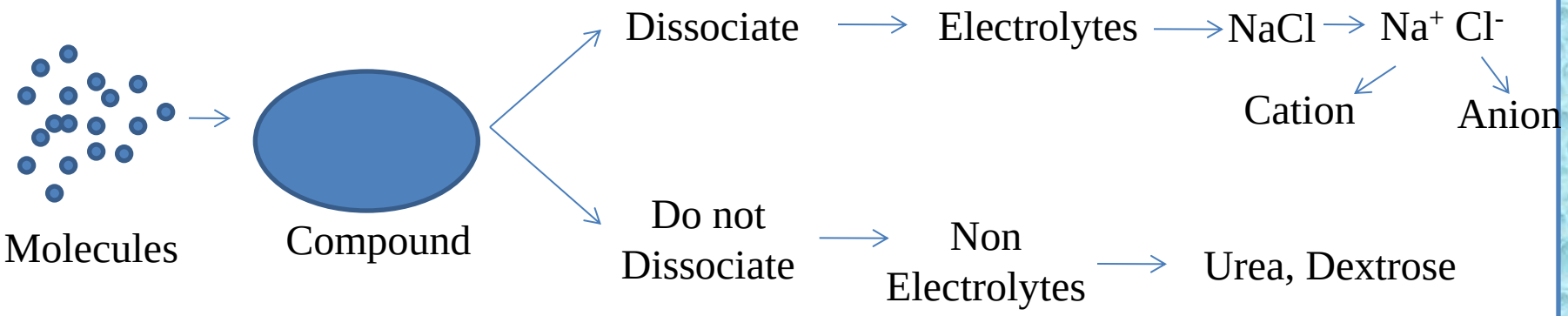
Introduction

Electrolytes vs. Non - electrolytes

- Compounds in solution are often referred to as either electrolytes or non – electrolytes
- Substances that do not dissociate are called non-electrolytes (urea, dextrose) – remain intact
- Those with varying degrees of dissociation are called electrolytes (NaCl)
- Electrolyte ions in blood plasma include cations (Na^+, K^+, Ca^{2+}, and Mg^{2+}) and anions (Cl^-, HCO_3^-, HPO_4^{2-}, SO_4^{2-})

Introduction

- Electrolytes in human body fluids play an important role in maintaining acid-base balance in body.
- Electrolytes help regulate metabolism in the body and control volume of water in the body.



Pharmaceutical Application

- Electrolyte preparations are employed to treat fluid and electrolyte imbalances in the body.
- Available as oral solutions, syrups, dry granules to be dissolved in water/juice, capsules, tablets and also intravenous infusions.

Milliequivalents

- A chemical unit used by pharmacists, physicians, manufacturers and clinicians across USA to express electrolyte concentration in solution.
- Internationally, molar concentrations (mmol/L or μmol/L) are employed.
- A mEq measures the chemical activity of an electrolyte in solution
- A mEq represents the total number of ionic charges in solution, and the valence (charge) of the ions.

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

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.

Milliequivalents

- The equivalent is formally defiened as the amount of a substancece which will either :
  - React with or supply one mole of hydrogen ions in an acid –base reaction, or
  - React with or supply one mole of electrons in a redox reaction

K^+

?

Cl^-

Cl^-

Cl^-

kCl

1Eq K^+ =1mol Cl^-

1mol Cl^- = Eq K^+

Ca^{2+}

?

Cl^-

Cl^-

Cl^-

CaCl2

1Eq Ca^{2+} =1/2 mol Cl^-

1mol Cl= 2 Eq Ca^{2+}

N^{3-}

?

H^+

H^+

H^+

NH3

1Eq N^{3-} = 1/3 mol H^+

1mol H^+ = 3 Eq N^{3-}

Calculations of Milliequivalents

Equivalent = mass of a given compound / Equivalent weight

Equivalent weight = molecular weight / valence

To convert milligrams (mg) to milliequivalents (mEq)

mEq = (mg x valence) / molecular weight

To convert mEq/mL to mg/mL

mg/mL = (mEq/ml x molecular weight) / valence

CALCULATIONS CAPSULE

Milliequivalents

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

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

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

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

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

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

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

- **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 molecular weight) / valence

  = 2 x 74.5 = 149 mg/mL, answer.

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

  Formula weight of $CaCl_2 \cdot 2H_2O$ = 147

  mg/mL = (mEq/mL x molecular weight) / valence

  = 4 x 147 / 2

  = 294 mg/ml = 0.294 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

100 mEq / 1000ml = x mEq /1ml

x= 0.1 mEq / ml

mg/mL = (mEq/mL x molecular weight) / valence

= 0.1 x 53.5 /1

= 5.35 mg / ml = 0.00535 g/ml

= 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

10 mg / 100 ml = x mg /1ml

x= 0.1 mg / ml

mg/mL = (mEq/mL x molecular weight) / valence

0.1 = (mEq/ ml x 39) / 1

mEq / ml = 0.00256 = 2.564 mEq / L

- **A solution contains 10 mg/100 mL of Ca ions. Express this concentration in terms ofmilliequivalents per liter?**

  Atomic weight of Ca 40

  Equivalent weight of Ca 40 / 2 = 20

  mEq/L = (mg / L x valance) / atomic weight

  = (100 mg / ml x 2) / 40

  = 5 mEq/L answer.

- **A magnesium (Mg) level in blood plasma is determined to be 2.5 mEq/L Express this concentration in terms of milligrams?**

  Atomic weight of Mg 24

  Equivalent weight of Mg 24 / 2 = 12

  mg / L = (mEq / L x molecular weight) / valence

  = (2.5 x 24) / 2

  = 30 mg / L answer.

- **How many milliequivalents of potassium chloride are represented in a 15 mL dose of a 10% (w/v) potassium chloride elixir?**

Molecular weight of KCl = 74.5

Equivalent weight of KCl = 74.5

10 g / 100 ml = x / 15 ml

x = 1.5 g = 1500 mg

mg = (mEq x molecular weight) / valence

mEq = (1500 x 1) / 74.5 = 20.13 mEq answer.

- How many milliequivalents of magnesium sulfate are represented in 1 g of anhydrous magnesium sulfate (MgSO4)?

Molecular weight of MgSO4 = 120

Equivalent weight of MgSO4 = 60

mg = (mEq x molecular weight) / valence

1000 mg = (mEq x 120) / 2

mEq = 2000 / 120 = 16.67 mEq answer.

- **How many milliequivalents of Na would be contained in a <u>30 mL</u> dose of the following solution?**

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

1- For Disodium hydrogen phosphate: Formula Na2HPO4.7H2O

Molecular weight = 268 and the equivalent weight =134

18/100 = x / 30 x = 5.4 g = 5400 mg

mEq = (mg x valance) / molecular weight

= (5400 x 2) / 268 = 40.29 mEq

2- For Sodium biphosphate : Formula NaH2PO4.H2O

Molecular weight = 138 and the equivalent weight =138

48/100 = x / 30 x = 14.4 g = 14400 mg

mEq = (mg x valance) / molecular weight

= (14400 x 1) / 138 = 104.35 mEq

40.29 + 104.35 = 144.64 mEq of Na would be contained in a **<u>30 mL</u>** dose of the solution

- **A person is to receive 2 mEq of sodium chloride per kilogram of body weight. If the person weighs 132 lb., how many milliliters of a 0.9% sterile solution of sodium chloride should be administered?**

Molecular weight of NaCl = 58.5

Equivalent weight of NaCl = 58.5

- 1 kg = 2.2 lb. Weight of person in kg = 132 lb / 2.2 lb = 60 kg

mg = (mEq x molecular weight) / valence

= (2 x 58.5) / 1 = 117 mg to be received per kg body wight

117 x 60 = 7020 mg = 7.02 g to be recived for this person

0.9 g	100 ml	
7.02 g	x ml	x = 780 ml answer .

To be Continued

with

Millimoles and Micromoles

Next Lecture

Thank you


THANK YOU

Millimoles and Micromoles

- A mole is the molecular weight of substance in grams.
- A millimole – one thousandth of a mole
- A micromole – One millionth of a mole
- SI expresses, electrolyte conc. in mmol/L
- For monovalent species, the numeric values of the mEq and mmol are identical

Osmolarity

- Osmotic pressure is important to biologic processes that involve the diffusion of solutes and the transfer of fluids through semi-permeable membranes
- Osmotic pressure is proportional to the total number of particles in a solution
- Unit of measurement is milliosmoles (mOsmol)

Osmolarity

- For non-electrolytes like dextrose, 1 mmol represents 1 mosmol
- However for electrolytes, the total number of particles in solution depends on the degree of dissociation of a substance.
- E.g. Assuming complete dissociation, 1 mmolNaCl represents 2 mOsmol (Na^+ + Cl^-) of total particles
- 1 mmol of $CaCl_2$ represents 3 mOsmol (Ca^{2+} + $2Cl^-$)
- 1 mmol of sodium citrate ($Na_3C_6H_5O_7$) represents 4 mOsmol ($3\ Na^+$ + $C_6H_5O_7^-$) of total particles

- The milliosmolar value of the complete solution is equal to the sum of milliosmolar values of individual ions.
- U.S. Pharmacopeia lists the following formula for calculation of ideal osmolar concentration:

$$\text{mOsmol/L} = \frac{\text{Wt. of substance (g/L)}}{\text{Mol. Wt (g/mol)}} \times \text{No. of Species} \times 1000$$

Osmolarity vs. Osmolality

- Osmolarity -- “Milliosmoles of solute per liter of solution”
- Osmolality – “Milliosmoles of solute per kilogram of solvent”
- For dilute aqueous solutions – both terms are nearly identical
- For more concentrated solutions – the two values are not identical
- Pharmacist should make distinction between Osmolarity and Osmolality


THANK YOU