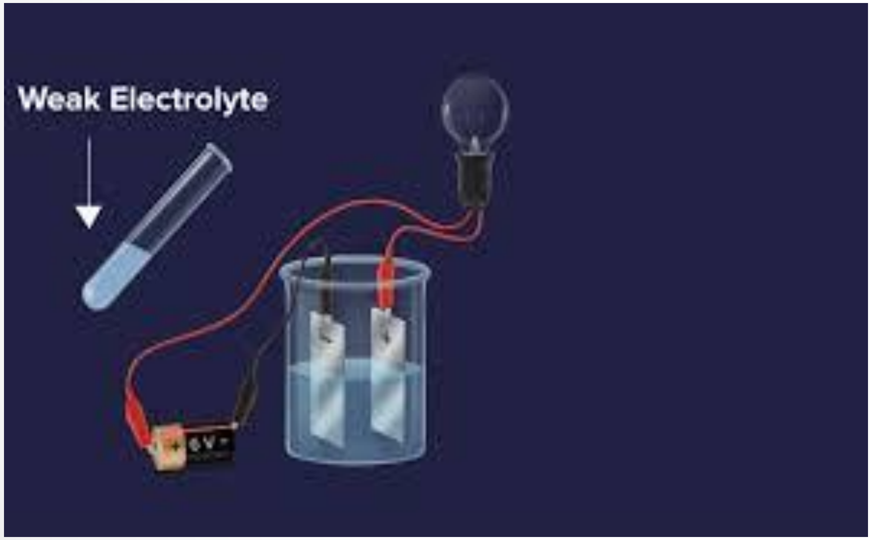
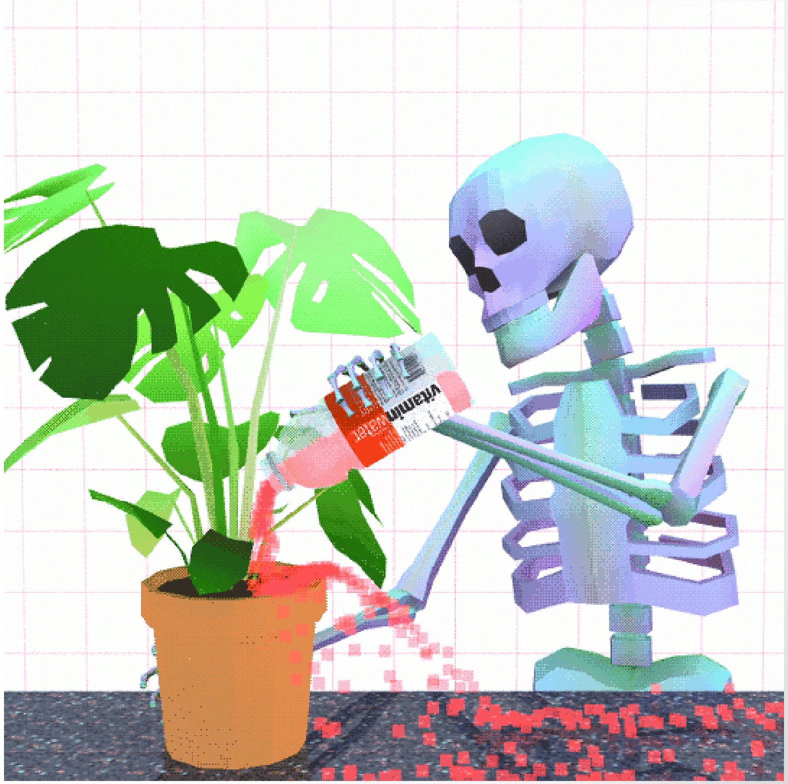
LECTURE 4:
Electrolyte Solutions : mEq, mmol, mOsmol





Mohamed Akl
Assistant Prof. of Pharmaceutics

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.

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.

Nonelectrolytes: Substances that are not dissociated in solution

example: Urea and dextrose in body water.

Electrolytes: substances with varying degrees of dissociation

example: sodium chloride in body fluids.

Electrolyte Solutions

Role of Electrolytes

- 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.

Applicable Dosage Forms

- Electrolyte preparations are used in the treatment of disturbances of the electrolyte and fluid balance in the body.
- 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
  - as intravenous infusions (when necessary,)

Milliequivalent (mEq):

Definition

- It is a chemical unit, used to express the concentration of electrolytes in solution. OR
- it is a unit of measurement of the amount of chemical activity of an electrolyte.

Uses:

- 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.

- mEq, mmol/L, and µmol/L → are used to express the concentration of electrolytes

Milliequivalent (mEq):

- The total concentration of cations always equals the total concentration of anions
- .Any number of milliequivalents of any cation as Na^+, K^+ always reacts with precisely the same number of milliequivalents of any anion as Cl^-, $HCO3^-$.
- For a given chemical compound, the mEq of cation equals the mEq of anion equals the mEq of the chemical compound.
- Under normal conditions, blood plasma contains 154 mEq of cations and an equal number of anions.
- Electrolytes in milliequivalents per liter (mEq/L)

Cation	mEq/L	Anions	mEq/L
Na^+	142	$HCO3^-$	24
K^+	5	Cl^-	105
Ca^{++}	5	$HPO4^{--}$	2
Mg^{++}	2	$SO4^{--}$	1
		Org. acids $^-$	6
		Proteinate $^-$	16

Milliequivalent (mEq):

- if we dissolve enough KCl 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 $\frac{1}{1000}$ of its gram equivalent weight, taking into account the valence of the ions.

$$\mathbf{mEq} = \frac{1}{1000} \times \mathbf{g}\ \text{Equivalent weight}$$

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

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

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

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

2. To convert (mEq/mL) to (mg/mL)

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

Milliequivalent (mEq):

1. What is the concentration, in milligrams per milliliter, of a solution containing 2 mEq of KCl / milliliter?

- Molecular weight of KCl = 74.5
- Equivalent weight of KCl = 74.51.

Answer

$$\textbf{mEq} = \frac{1}{1000} \times \textbf{g} \text{ Equivalent weight}$$

- 1 mEq of KCl = $\frac{1}{1000}$ × 74.5 g = 0.0745 g = 74.5 mg
- 2 mEq of KCl = 74.5 mg × 2 = 149 mg/mL.
- Or, by using the preceding equation:

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

$$\text{mg/mL} = \frac{2\ (\text{mEq/mL}) \times 74.5}{1} = 149 \text{ mg/mL}$$

Milliequivalent (mEq):

- 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
- Equivalent weight of $CaCl_2 \cdot 2H_2O$ = 147/2 = 73.51

Answer

$$\mathbf{mEq} = \frac{1}{1000} \times \mathbf{g}\ \text{Equivalent weight}$$

mEq of $CaCl_2 \cdot 2H_2O = \frac{1}{1000} \times 73.5\ g = 0.0735\ g$

4 mEq of $CaCl_2 \cdot 2H_2O = 0.0735 \times 4 = 0.294 g/mL$

Milliequivalent (mEq):

- 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

Answer

$$\textbf{mEq} = \frac{1}{1000} \times \textbf{g}\ \text{Equivalent weight}$$

1 mEq of NH_4Cl= 1/1000 × g 53.5 = 0.0535 g

100 mEq of NH_4Cl= 0.0535 g × 100 = 5.35 g/L or

0.535 g per 100 mL, or 0.535 %

Milliequivalent (mEq):

- 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

Answer

$$\mathbf{mEq} = \frac{1}{1000} \times \mathbf{g} \text{ Equivalent weight}$$

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

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

100 mg ÷ 39 = 2.56 mEq/L,.

Milliequivalent (mEq):

- A solution contains 10 mg/100 mL of Ca ions. Express this concentration in terms of milliequivalents per liter.
- Atomic weight of Ca = 40
- Equivalent weight of Ca = 40÷2 = 20

Answer

$$\mathbf{mEq} = \frac{1}{1000} \times \mathbf{g}\ \text{Equivalent weight}$$

$$1\ \text{mEq of Ca} = \frac{1}{1000} \times 20\ \text{g}\ \ 0.020\ \text{g} = 20\ \text{mg}$$

10 mg/100 mL of Ca 100 mg of Ca per liter

$$100\ \text{mg} \div\ 20 = 5\ \text{mEq/L},$$

Milliequivalent (mEq):

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

Answer

$$\mathbf{mEq} = \frac{1}{1000} \times \mathbf{g} \text{ Equivalent weight}$$

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

15-mL dose of 10% (w/v) elixir = 1.5 g or 1500 mg of KCl

74.5 (mg) $\rightarrow$ 1 (mEq)

1500 (mg) $\rightarrow$ x (mEq) so x = 20.1 mEq

Milliequivalent (mEq):

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

Answer

Each salt is considered separately in solving the problem.

- Disodium hydrogen phosphate
- Formula = $Na_2HPO_4.7H_2O$
- Molecular weight = 268 and the equivalent weight = 134

$$18\text{ g} \rightarrow 100\text{ ml}$$

$$X \rightarrow 30\text{ ml} \qquad \text{so } x = 5.4\text{ g}$$

$$\textbf{mEq} = \frac{1}{1000} \times \mathbf{134 = 0.0134\ g = 134\ mg}$$

$$134\text{ mg} \rightarrow 1\text{ mEq}$$

$$5400\text{ mg} \rightarrow x \qquad \text{so } x = 40.3\text{ mEq}$$

- Because the milliequivalent value of Na ion = the mEq value of disodium hydrogen phosphate, then x = 40.3 mEq of Na

Milliequivalent (mEq):

Answer

- Sodium biphosphate
- Formula = NaH2PO4.H2O
- Molecular weight = 138 and the equivalent weight = 138

48 g → 100 ml

X → 30 ml so x = 14.4 g

mEq = $\frac{1}{1000}$ × 138 = 0.138 g = 138 m

134 mg → 1 mEq

14400 mg → x so x = 104.3 mEq of sodium biphosphate

and also, 104.3 mEq of Na

- Adding the two milliequivalent values for

Na = 40.3 mEq + 104.3 mEq = 144.6 mEq,

Milliequivalent (mEq):

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

Answer

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

2 mEq of NaCl = 2 × 0.0585 g = 0.117 g

1 kg = 2.2 lb. So Weight of person in kg $= \frac{132\ lb}{2.2\ lb} = 60$ kg

- Because the person is to receive 2 mEq/kg,

→ then 2 mEq or 0.117 g × 60 = 7.02 g of NaCl needed

- because 0.9% sterile solution of NaCl contains 9 g of NaCl per liter,

→ Then

$$\frac{9\ g}{7.02\ g} = \frac{1000\ ml}{X\ ml} \quad \text{so } X = 780 \text{ ml}$$

Millimoles and Micromoles

- **A mole** is the molecular weight of a substance in grams.
- **A millimole** is one thousandth of a mole (10^{-3}).
- **A micromole** is one millionth of a mole (10^{-6}).

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

Answer

m.w. = 1381

1 mole = 138 g

$$1 \text{ (mole)} \rightarrow 138 \text{ g}$$

$$x \text{ (mole)} \rightarrow 100 \text{ g} \qquad x = 725 \text{ mmol}$$

How many milligrams would 1 mmol of monobasic sodium phosphate weigh?

Answer

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

$$1 \text{ mmol} = 0.138 \text{ g} \qquad = 138 \text{ mg}$$

Millimoles and Micromoles

What is the weight, in milligrams, of 1 mmol of HPO4 ?
Atomic weight of HPO4 = 95.981 mole of HPO4 = 95.981 g

Answer

I mole of HPO4 = $\frac{1}{1000}$ × **95.981 = 0.095981 g = 95.98 mg**

Convert blood plasma levels of 0.5µg/mL and 2 µg/mL of tobramycin (mw 467.52) toµmol/L.

Answer

By dimensional analysis:

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

Osmolarity

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.
- For more concentrated solutions, however, the two values may be quite dissimilar.
- **Osmometers** are commercially available for use in the laboratory to measure osmolality.
- Normal serum osmolality is within the range of 275 to 300 mOsmol/kg
- Abnormal blood osmolality that deviates from the normal range can occur in association with:
  - shock, trauma, burns,
  - water intoxication (overload),
  - electrolyte imbalance,
  - hyperglycemia, or renal failure

Osmolarity

- The unit used to measure osmotic concentration is the milliosmole (mOsmol).

$$\text{mOsmol} = \frac{weight\ of\ substanc\ (g/l)}{molecular\ weight\ (g)} \times \text{number of species} \times 1000$$

Remember that:

- Osmotic pressure is proportional to the total number of particles in solution
- **For a nonelectrolyte** as dextrose, 1 mmol (1 formula weight in milligrams) represents 1 mOsmol.
- **For electrolytes→** This relationship is not the same, however, because the total number of particles in solution depends on the degree of dissociation of the substance in question.

For example:

- Assuming complete dissociation, 1 mmol of NaCl represents 2 mOsmol ($Na^+ + Cl^-$) of total particles,
- 1 mmol of CaCl2 represents 3 mOsmol ($Ca^{++} + 2Cl^-$) of total particles

Osmolarity

A solution contains 5% of anhydrous dextrose in water for injection. How many milliosmoles per liter are represented by this concentration? Formula weight of anhydrous dextrose = 180

Answer

1 mmol of anhydrous dextrose (180 mg) = 1 mOsmol

5% solution contains 50 g or 50,000 mg/L

50,000 mg ÷180 = 278 mOsmol/L

A solution contains 156 mg of K ions per 100 mL. How many milliosmoles are represented in a liter of the solution?

Answer

Atomic weight of K 39

1 mmol of K (39 mg) = 1 mOsmol

156 mg of K per 100 mL = 1560 mg of K per liter

1560 mg ÷ 39 = 40 mOsmol,

Osmolarity

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

Answer

- 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 (Na^+ + Cl^-).
- Formula weight of NaCl = 58.5

1 mmol of NaCl (58.5 mg) = 2 mOsmol

1000 $\times$ 0.009 9 g or 9000 mg of NaCl per liter

58.5 (mg) $\rightarrow$ 2 mOsmol

9000 (mg) $\rightarrow$ x (mOsmol)

So x = 307.7, or 308 mOsmol,

Clinical Considerations of Water and Electrolyte Balance

- Reason for fluid and electrolyte therapy
    - to provide maintenance requirements
    - or to replace serious losses or deficits.
- Body losses of water and/or electrolytes can result from
    - vomiting, diarrhea, profuse sweating, fever,
    - Chronic renal failure,
    - diuretic therapy, surgery, and others
- The composition of body fluids generally is described with regard to body compartments:
    - intracellular (within cells),
    - intravascular (blood plasma), } extracellular fluid
    - interstitial (between cells in the tissue). } extracellular fluid
- Although all electrolytes and nonelectrolytes in body fluids contribute to osmotic activity, →
    - Na^+ and Cl^- exert the principal effect in extracellular fluid,
    - potassium and phosphate predominate in intracellular fluid.

Clinical Considerations of Water and Electrolyte Balance

Total Body water

- In adult males, water normally ranges between 55% and 65% of body weight depending on the proportion of body fat.
  - The greater the proportion of fat, the lesser the proportion of water.
- In adult women → about 10% less than those for men.
- Newborn infants have ~ 75% body water, which ↓ with growth and increases in body fat.
- Of the adult body's water content,
  - up to two thirds is intracellular
  - one third is extracellular.
- Generally, 1500 mL of water / m^2 of body surface area may be used to calculate the daily requirement for adults.
- On a weight basis, the average daily requirements of water intake for healthy individuals estimates
  - 32 mL/kg for adults
  - 100 to 150 mL/kg for infants

Clinical Considerations of Water and Electrolyte Balance

- cell membranes generally are freely permeable to water.
- the osmolality of the extracellular fluid (about 290 mOsm/kg water) is about equal to that of the intracellular fluid.

→ Therefore, the plasma osmolality is a convenient and accurate guide to intracellular osmolality and may be approximated by the formula

$$\text{Plasma osmolality} = 2\,([\text{Na}] + [\text{K}])\ \text{plasma} + \frac{[\text{BUN}]}{2.8} + \frac{[\text{Glucose}]}{1.8}$$

where:

- sodium (Na) and potassium (K) are in mEq/L,
- blood urea nitrogen (BUN) and glucose concentrations are in mg/100 mL , (mg/dL).

<u>This clinical calculations include</u>

1. The determination of body water requirement,
2. estimation of plasma osmolality,
3. calculation of the osmolality and milliequivalent content of physiologic electrolyte solutions.

Clinical Considerations of Water and Electrolyte Balance

Calculate the estimated daily water requirement for a healthy adult with a body surface area of 1.8 m^2.

Answer

Water Requirement 1500 mL/ m^2

1 $m^2 \rightarrow$ 1500 ml

1.8 $m^2 \rightarrow$ x ml   so x = 2700 ml

Estimate the plasma osmolality from the following data: sodium, 135 mEq/L; potassium, 4.5 mEq/L; blood urea nitrogen, 14 mg/dL; and glucose, 90 mg/dL.

Answer

$$\text{Plasma osmolality} = 2\,([Na] + [K])\,\text{plasma} + \frac{[BUN]}{2.8} + \frac{[Glucose]}{1.8}$$

$$\text{Plasma osmolality} = 2\,(135 + 4.5) + \frac{14}{2.8} + \frac{90}{1.8} = 289$$

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

R/ Dextrose, anhydrous 50 g — M.wt = 180

Sodium Chloride 4.5 g — M.wt = 58.5

Potassium Chloride 1.49 g — M.wt = 74.5

Water for Injection, ad 1000 mL

Answer

Equivalent weight of NaCl 58.5

1mEq of NaCl = $\frac{1}{1000} \times 58.5$

= 0.0585 g = 58.5 mg

4.5 g of NaCl = 4500 mg

58.5 mg → 1 mEq

4500 mg → X mEq

X = 76.9 Or 77 mEq of NaCl

77 mEq Na

77 mEq Cl

Equivalent weight of KCl= 74.5

1mEq of NaCl = $\frac{1}{1000} \times 74.5$

= 0.0745 g = 74.5 mg

1.49 g of NaCl = 1490 mg

74.5 mg → 1 mEq

1490 mg → X mEq

X = 20mEq of KCl

20 mEq K

20 mEq Cl

Total: Na 77 mEq ❁ K 20 mEq ❁ Cl (77+20) =97 mEq

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

R/ Dextrose, anhydrous 50 g — M.wt = 180

Sodium Chloride 4.5 g — M.wt = 58.5

Potassium Chloride 1.49 g — M.wt = 74.5

Water for Injection, ad 1000 mL

Answer

Equivalent weight of anhydrous dextrose = 180

1mEq of NaCl = $\frac{1}{1000} \times 180$ = = 0.0180 g = 180 mg

50 g of NaCl = 50000 mg

180 mg → 1 mEq

50000 mg → X mEq X = 277.7 Or 278 mEq

Osmolarity:

- Dextrose, anhyd.: 278 mmol × 1 particle per mmol = 278 mOsmol
- NaCl: 77 mEq × 2 particles per mEq (or mmol) = 154 mOsmol
- KCl: 20 mEq × 2 particles per mEq (or mmol) =40 mOsmol

Total = 472 mOsmol,

Questions ?