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

Lecture 2

Lecturer Anas Tarik Nafei

Millimoles and Micromoles

Electrolyte concentrations expressed in millimoles per liter (mmol/L) in representing the combining power of a chemical species.

A ***mole*** is the (molecular weight of a substance in grams). A ***millimole*** is one thousandth of a mole (molecular weight of a substance in milligrams) and a ***micromole*** is one millionth of a mole (molecular weight of a substance in micrograms).

Mole = wt. (g) / m.wt.

Millimole = wt. (mg) / m.wt.

Micromole = wt. (µg) / m.wt.

Important notes:

1- Millimolar conversions do not take into account the valence of an electrolyte as do milliequivalent conversions.

For monovalent species, the **numeric values of the milliequivalent and millimole are identical**.

2- Similar to milliequivalents, **the millimoles of the compound are equal to the millimoles of the cation, which are equal to the millimoles of the anion**, but this does not hold true for the actual weights of the ions.

Example calculations of Millimoles and Micromoles

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

m.wt. = 138

100 g = 100000 mg

mmol = wt.(mg) / m.wt.

mmol = 100000/ 138 = 724.64 mmol ≈ 725 mmol

or

According to the definition each 1 mole = 138 g

1 mole	138 g	X= 0.725 moles = 725 mmol
X mole	100 g	

2) What is the weight, in milligrams, of 5 mmol of potassium phosphate dibasic?

m.wt. of K_2HPO_4 = [2 x 39 (K^+) + 96 (HPO_4^{2-}) = 174

mmol = wt. (mg) / m.wt.

5 = wt.(mg) / 174

wt. (mg) = 870 mg

3) Convert blood plasma levels range of 0.5 microgram/mL and 2 microgram /mL for tobramycin (m.w. = 467.52) to micromole /L?

Micromole = wt. (µg) / m.wt.

Micromole = 0.5 µg / 467.52 = 0.0010695

0.0010695 mcmol / x = 1 mL / 1000 mL = 1.07 mcmol / L

Micromole = 2µg / 467.52 = 0.0042778

0.0042778 mcmol / x mcmol = 1mL / 1000mL = 4.28 mcmol / L

Range = 1.07 – 4.28 mcmol / L

(4) If lactated Ringer's injection contains 20 mg of calcium chloride dihydrate ($CaCl_2 \cdot 2H_2O$) in each 100 mL, calculate the millimoles of calcium present in 1 L of lactated Ringer's injection.

m.wt. of $CaCl_2 \cdot 2H_2O$ = 40 (Ca^{2+}) + [2x 35.5 (Cl^-)] + [2 x 18 (H_2O)] = 147

1 L = 1000 mL

Millimole = wt. (mg) / m.wt.

mmol = 20 / 147 = 0.136

0.136 mmol	100 mL	= 1.36 mmol / L of $CaCl_2 \cdot 2H_2O$
X mmol	1000 mL	= 1.36 mmol / L of Ca^{2+}

(5) *If lactated Ringer's injection contains 20 mg of calcium chloride dihydrate* ($CaCl_2 \cdot 2H_2O$) in each 100 mL. *How many micromoles of calcium are present in each milliliter of lactated Ringer's injection?*

m.wt. of $CaCl_2 \cdot 2H_2O$ = 40 (Ca^{2+}) + [2x 35.5 (Cl^{-})] + [2 x 18 (H_2O)] = 147

Microgram = 20 mg X 1000 = 20000 µg / 100 mL

Micromole = wt. (µg) / m.wt.

mcmol = 20000 / 147 = 136

136 mcmol	100 mL
X mcmol	1 mL

= 1.36 mcmol / mL of $CaCl_2 \cdot 2H_2O$

= 1.36 mcmol / mL of Ca^{2+}

(6) A patient is receiving a slow intravenous infusion containing 40 mEq of potassium chloride in 1000 mL of fluid. If, after 12 hours, 720 mL of infusion had been in used, how many millimoles of potassium chloride were administered?

M.wt. of KCl = 39 (K^{+}) + 35.5 (Cl^{-}) = 74.5   Valence = 1

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

mg = 40 x 74.5 / 1 = 2980 mg / 1000 mL of KCl received by patient

2980 mg	1000 mL	= 2145.6 mg of KCl after 12 hours
X mg	720 mL	

Millimole = wt. (mg) / m.wt.

mmol = 2145.6 / 74.5 = 28.8 mmol of KCl were administered

(7) A medication order calls for 1.8 g of potassium chloride in 60 mL of solution. How many millimoles of KCl are contained in each milliliter?

M.wt. of KCl = 39 (K^{+}) + 35.5 (Cl^{-}) = 74.5

Mg = 1.8 gm x 1000 = 1800 mg

1800 mg	60 mL	= 30 mg of KCl
X mg	1 mL	

Millimole = wt. (mg) / m.wt.

mmol = 30 / 74.5 = 0.403 mmol / mL of KCl

(8) Calculate the concentrations in mmol/L for each of the following infusion solutions: (a) 5% NaCl, (b) 3% NaCl, (c) 0.9% NaCl (NSS), (d) 0.45% NaCl (half -NSS), and (e) 0.2% NaCl.

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

A) mg = 5 gm x 1000 = 5000 mg

5000 mg 100 mL = 50000 mg / L

X mg 1000 mL

Millimole = wt. (mg) / m.wt.

mmol = 50000 / 58.5 = 854.7 mmol / L

B) same as branch A: 30000 mg / L

mmol = 30000 / 58.5 = 512.82 mmol / L

C) same as branch A: 9000 mg / L

mmol = 9000 / 58.5 = 153.85 mmol / L

D) same as branch A: 4500 mg / L

mmol = 4500 / 58.5 = 76.92 mmol / L

E) same as branch A: 2000 mg / L

mmol = 2000 / 58.5 = 34.19 mmol / L

Osmolarity

Osmotic pressure is important to biologic processes that involve the diffusion of solutes or the transfer of fluids through semipermeable membranes.

Ex: solutions that provide intravenous (I.V.) replenishment of fluid, nutrients, or electrolytes, and the osmotic diuretic mannitol are required to state the osmolar concentration.

whether the solution is hypoosmotic, isoosmotic, or hyperosmotic with regard to biologic fluids and membranes.

Osmotic pressure is proportional to the *total number* of particles (molecules or ions) in solution.

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

For **nonelectrolyte** (dextrose), 1 mmol (1 formula weight in milligrams) represents 1 mOsmol.

While **electrolytes** (the total number of particles in solution depends on the degree of dissociation of the substance in question).

Ex: Assuming complete dissociation, 1 mmol of NaCl represents 2 mOsmol ($Na^+ + Cl^-$) of total particles, 1 mmol of $CaCl_2$ represents 3 mOsmol ($Ca^{++} + 2Cl^-$) of total particles, and 1 mmol of sodium citrate ($Na_3C_6H_5O_7$) represents 4 mOsmol ($3Na^+ + C_6H_5O_7^-$) of total particles.

<u>The milliosmolar value of *separate* ions of an electrolyte</u> may be obtained by [dividing the concentration, in milligrams per liter, of the ion by its atomic weight].

<u>The milliosmolar value of the *whole* electrolyte in solution</u> is equal to the sum of the milliosmolar values of the separate ions.

Osmotic concentration = mOsmol

mOsmol = mmole (mole x 1000) x Number of species

mOsmol= {Weight (mg) / Molecular weight } x Number of species

Osmolarity = no. of mOsmol / L of solution

mOsmol/L = (concentration of substance [g/L] / Molecular weight [g]) x Number of species x 1000

A distinction also should be made between the terms *osmolarity* and *osmolality*:

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.

Note: 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.

Example calculations of Milliosmoles

1) A solution contains 10% of anhydrous dextrose in water for injection. How many milliosmoles per liter are represented by this concentration?

Molecular weight of anhydrous dextrose = 180

Dextrose does not dissociate, therefore (no. of species)= 1

10 g	100 mL	= 100 g/L
X	1000 mL	

mOsmol/L = (Weight of substance (g/L) / Molecular weight g) x Number of species x 1000

mOsmol/L = (100 / 180) x 1 x 1000 = 555.56 mOsmol/L

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

Atomic weight of K^+ = 39

156 mg x 1000 = 0.156 g

0.156g	100 ml	= 1.56g
X	1000 ml	

mOsmol/L = (Weight of substance (g/L) / Molecular weight g) x Number of species x 1000

mOsmol/L = (1.56/39) x 1 x1000 = 40

3) Calculate the number of milliosmoles corresponding to 0.386g of NaCl (m.wt. 58.5)?

Wt = 0.386 g x 1000 = 386 mg

No. of species = 2 (Na^{+} + Cl^{-})

mOsmol= {Weight (mg) / Molecular weight } x Number of species

mOsmol = 386mg / 58.5 x 2 = 13.2 mOsmol

4) Calculate the osmolarity of 15 mOsm. Dissolved in enough water to make a total volume 100 ml?

Osmolarity = no. of mOsmol / L of solution

Osmolarity = 15 mOsmol / 0.1 L = 150 mOsmol / L

5) A pharmacist added 25ml of 7.5% solution of magnesium acetate (m.wt. 142) to a patient's infusion solution. How many mOsmol of magnesium acetate did the patient receive?

No. of species of magnesium acetate = $Mg^{+} + 2\ (C_2H_3O_2)$ = 3parts

7.5 g	100 ml	= 1.875g = 1875 mg
x	25 ml	

mOsmol= {Weight (mg) / Molecular weight } x Number of species

mOsmol = 1875mg / 142 x 3 = 39.6 mOsmol

6) Calculate the osmolarity of a 3% hypertonic sodium chloride solution. Assume complete dissociation.

M.wt. of NaCl = 58.5

No. of species = 2 ($Na^{+} + Cl^{-}$)

3 g	100 mL	= 30 g/L
X g	1000 mL	

Osmolarity = mOsmol/L = (Weight of substance (g/L) / Molecular weight g) x Number of species x 1000

mOsmol/L = (30 / 58.5) x 2 x 1000 = 1025.64 mOsmol/L

7) Calcium chloride dihydrate injection is a 10% solution of $CaCl_2.2H_2O$*. How many milliosmoles are present in a 10-mL vial? Assume complete dissociation.*

M.wt. of $CaCl_2.\ 2H_2O$ = 40 (Ca^+) + [2 X 35.5 (Cl^-)] + [2 x 18 (H_2O)] = 147

No. of species = 3 (Ca^+ and 2 Cl^-)

10 g	100 ml	
x g	1000 ml	= 100 g/L

mOsmol/L = (Weight of substance (g/L) / Molecular weight g) x Number of species x 1000

mOsmol/L = (100/ 147) x 3 x 1000 = 2040.81 mOsmol/L

2040.81 mOsmol	1000 mL	
x mOsmol	10 mL	= 20.408 mOsmol in 10 mL vial

8) If a pharmacist wished to prepare 100 mL of a solution containing 50 mOsmol of calcium chloride, how many grams of calcium chloride would be needed? Assume complete dissociation.

M.wt. of $CaCl_2$ = 40 (Ca^+) + [2 X 35.5 (Cl^-)] = 111

No. of species = 3 (Ca^+ and 2 Cl^-)

50 mOsmol   100 mL

X   1000 mL   = 500 mOsmol / L

mOsmol/L = (Weight of substance (g/L) / Molecular weight g) x Number of species x 1000

$$500 = \left[\frac{\text{weight of substance (g/L)}}{111}\right] \times 3 \times 1000$$

Weight of substance = (500 x 111) / 3000 = 18.5 g/L

18.5 g   1000 mL

x   100 mL   = 1.85 g of $CaCl_2$

9) What is the osmolarity of a solution containing 5% dextrose and 0.45% sodium chloride (D5 $^1/_2$ NS)? Assume complete dissociation.

Molecular weight of dextrose = 180
Dextrose does not dissociate, therefore (no. of species)= 1

$\frac{5\ g}{100\ mL} \times \frac{x}{1000\ mL}$ = 50 g/L

mOsmol/L = (Weight of substance (g/L) / Molecular weight g) x Number of species x 1000
mOsmol/L = (50 / 180) x 1 x 1000 = 277.78 mOsmol/L

M.wt. of NaCl = 58.5
No. of species = 2 ($Na^+ + Cl^-$)

$\frac{0.45\ g}{100\ mL} \times \frac{x}{1000\ mL}$ = 4.5 g/L

mOsmol/L = (Weight of substance (g/L) / Molecular weight g) x Number of species x 1000
mOsmol/L = (4.5 / 58.5) x 2 x 1000 = 153.85 mOsmol/L

Total = 277.78 + 153.85 = 431.62 mOsmol/L

10) PLASMA-LYTE 56 contains 32 mg of magnesium acetate tetrahydrate, 128 mg of potassium acetate, and 234 mg of sodium chloride in each 100 mL of solution. What is the osmolarity of this solution? Assume complete dissociation.

M. wt. of $Mg(C_2H_3O_2)_2$ = 24 (Mg^+) + [2 x 59 ($C_2H_3O_2^-$)] + [4 x 18 (H_2O)] = 214

No. of species = 3(Mg^{2+} +2 $C_2H_3O_2^-$)

32 mg 100 mL

x 1000 mL

= 320 mg/L = 0.32 g/L

mOsmol/L = (Weight of substance (g/L) / Molecular weight g) x Number of species x 1000

mosmol/L = 0.32 / 214 x 3 x 1000 = 4.49 mOsmol/L

M. wt. of potassium acetate ($KC_2H_3O_2$)= 39 (K^+) + [59 ($C_2H_3O_2^-$)] = 98

No. of species = 2(K^+ + $C_2H_3O_2^-$)

128 mg 100 mL

x 1000 mL

= 1280 mg/L = 1.28 g/L

mOsmol/L = (Weight of substance (g/L) / Molecular weight g) x Number of species x 1000

mosmol/L = 1.28 / 98 x 2 x 1000 = 26.12 mOsmol/L

M.wt. of NaCl = 58.5

No. of species = 2 ($Na^+ + Cl^-$)

234 mg	100 mL	= 2340 mg/L = 2.34 g/L
x	1000 mL	

mOsmol/L = (Weight of substance (g/L) / Molecular weight g) x Number of species x 1000

mOsmol/L = (2.34 / 58.5) x 2 x 1000 = 80 mOsmol/L

Total = 4.49 + 26.12 + 80 = 110.61 mOsmol/L

11) Calculate the milliequivalents of sodium, potassium, and chloride, the millimoles of anhydrous dextrose, and the osmolarity of the following parenteral fluid. Assume complete dissociation.

Dextrose, anhydrous	50 g
Sodium chloride	4.5 g
Potassium chloride	1.49 g
Water for injection, ad	1000 mL

Sodium Chloride

mEq = 4500 x 1/ 58.5 = 76.92 mEq NaCl = 76.92 mEq of Na^+ and 76.92 mEq of Cl^-

mOsmol/L = (Weight of substance (g/L) / Molecular weight g) x Number of species x 1000

mOsmol/L = (4.5 / 58.5) x 2 x 1000 = 153.85 mOsmol/L

Potassium Chloride

mEq = 1490 x 1/ 74.5 = 20 mEq KCl = 20 mEq of K^+ and 20 mEq of Cl^-

mOsmol/L = (Weight of substance (g/L) / Molecular weight g) x Number of species x 1000

mOsmol/L = (1.49 / 74.5) x 2 x 1000 = 40 mOsmol/L

Dextrose:

Millimole= 50000 / 180 = 277.78 mmol

mOsmol/L = (Weight of substance (g/L) / Molecular weight g) x Number of species x 1000

mOsmol/L = (50 / 1800) x 1 x 1000 = 277.8 mOsmol/L

76.92 mEq of Na^+; 20 mEq of K^+; 76.92 mEq of Cl^- and 20 mEq of Cl^- = 96.92 mEq of Cl^-

Osmolarity = 153.85 mOsmol/L + 40 mOsmol/L + 277.8 mOsmol/L = 471.62 mOsmol/L

Thank you!