Milliequivalents, Millimoles, and Milliosmoles

Electrolytes vs Nonelectrolytes

- Compounds in solution are often referred to as either electrolytes or nonelectrolytes
  - Electrolytes are compounds that in solution dissociate to varying degrees into “ions” which have an electrical charge
    - ♦ Examples: $NaCl$, KCl, $MgSO_4$
  - Nonelectrolytes are compounds which do not dissociate in solution
    - ♦ Examples: dextrose, urea

Cations versus Anions

- In solution ions move in a direction opposite their charge

- Cations: positively charged ions
  - When placed in a solution the ions move to the negative electrode (or the cathode)
  - Examples: Na^+, K^+, Ca^{++}, Mg^{++}

- Anions: negatively charged ions
  - When placed in solution the ions move towards the positive electrode (or the anode)
  - Examples: Cl^-, $HC0_3^-$,$S0_4^-$, $HP04^-$

Terminology

- Mole= Avogadro's number (6.023×10^{23}) of molecules
- Molecular Weight (MW)= weight in grams of one mole of compound
- Millimoles (mmole)= 1000 x moles
  - g/mole = mg/mmole
- Valence= amount of charge of an ion
- Equivalents (Eq)= number of univalent counter ions needed to react with each molecule of substance
  - HCl has 1 equivalent per mole in that one mole of H^+ reacts with one mole of Cl^-

Milliequivalent

- In the United States, the concentration of electrolytes in solution is expressed in terms of milliequivalents (mEq)
  - **EXCEPTION: Phosphorous is usually referred to in terms of mmoles**
  - Note: in Europe concentrations of electrolytes are often expressed in terms of millimoles per liter or micromoles per liter)

- Refers to the chemical activity of an electrolyte

- Is related to the total number of ionic charges in solution and considers the valence (charge) of each ion

- For a given chemical compound, the milliequivalents of cations equals that of anions
  - Example: a solution of NaCl will contain the same number of milliequivalents of Na^+ (the cation) as it will Cl^- (the anion).

- There is a trend to shift from using mEq to using mg of the given ion. Beware that this can be confusing! They are not EQUIVALENT!!! And mg of a given ion is not equivalent to mg of the compound. (i.e., mEq CaCl2 is not equal to mg CaCl2 which is not equal to mg Ca ion.

Milliequivalents

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

  Equivalent weight = formula weight divided by the total valence

$$\text{mEq} = \frac{\text{mg x valence}}{\text{atomic, molecular or formula weight}}$$

$$\text{mg} = \frac{\text{mEq x atomic, molecular or formula weight}}{\text{valence}}$$

$$\text{Equiv Weight (g)} = \frac{\text{atomic, molecular or formula weight}}{\text{valence}}$$

Calculations with Milliequivalents

- Converting millieqivalents to weight
- Converting weight to milliequivalents
- Converting mg% to mEq/L

Listing of Atomic Weights, Valences, and Equivalent Weights for Common Ions

	Atomic/Formula Weight	Valence	Equiv Wt (Atomic/valence)
Al^{+++}	27	3	9
NH_4^+	18	1	18
Ca^{++}	40	2	20
Fe^{+++}	56	3	18.7
Mg^{++}	24	2	12
K^+	39	1	39
Na^+	23	1	23
$C_2H_30_3^-$	59	1	59
$HC0_3^-$	61	1	61
$C0_3^{--}$	60	2	30
Cl^-	35.5	1	35.5
$S0_4^-$	96	2	48

Converting Millieqivalents to Weight

What is the concentration of a solution containing 4 mEq/L of KCl?

Step 1: Calculate the molecular weight of KCl

MW of potassium (K) = 39

MW of chloride (Cl) = 35.5

MW KCl = MW K + MW CL = 39 + 35.5 = 74.5 g

Step 2: Calculate equivalent weight

Equiv weight = molecular weight KCl divided by valence

Since valence of KCl = 1, Equiv weight = 74.5/ 1

Step 3: 1 mEq KCl = 1/1000 x 74.5 g = 0.0745 g = 74.5 mg

Step 4: 4 mEq KCl = 74.5mg x 4 = 298 mg/ml

OR using the equation listed before:

$$\text{mg} = \frac{\text{mEq x atomic, molecular or formula weight}}{\text{valence}}$$

$$\text{mg/ml} = \frac{\text{mEq/ml * atomic, molecular or formula weight}}{\text{valence}} = \frac{(4 \times 74.5)}{1} = 298 mg/ml$$

Converting Weight to Milliequivalents

How many mEq of KCl are in 1.5g of KCl?

Step 1: Calculate the molecular weight of KCl
MW of potassium (K) = 39
MW of chloride (Cl) = 35.5
MW KCl = MW K + MW CL = 39 + 35.5 = 74.5 g

Step 2: Calculate equivalent weight
Equiv weight = molecular weight KCl divided by valence
Since valence of KCl = 1, Equiv weight = 74.5/ 1

Step 3: 1 mEq KCl = 1/1000 x 74.5 g = 0.0745 g = 74.5 mg

Step 4: 1 mEq KCl = 74.5 mg; 1.5 g KCl = 1500 mg; How many mEq in 1500 mg?

$$\frac{1 mEq}{X mEq} = \frac{74.5 mg}{1500 mg}$$

X = 20.1 mEq

Converting mg% to mEq/L

Convert the expression 10 mg% of Ca^{++} to mEq/L

Step 1: Calculate the atomic weight of Ca^{++}
Atomic weight of Ca^{++}=40

Step 2: Calculate equivalent weight
Equiv weight = molecular weight Ca^{++} divided by valence
Since valence of Ca^{++} = 2, Equiv weight = 40/2 = 20 g

Step 3: 1 mEq Ca^{++} = 1/1000 x 20 g = 0.020 g = 20 mg

Step 4: 10 mg% Ca^{++}= 10 mg/100ml = 100 mg per liter

$$\frac{20mg}{1mEq} = \frac{100mg}{XmEq}$$

X = 5 mEq/L

Millimoles

- Remember:
  - Molecular Weight = g/mole
  - Millimole = 1/1000 of a mole
- Key Equation (by definition):

$$\frac{g}{mole} = \frac{Xg}{1mole}$$

Molecular WT (g/m)

- Conversions to remember:

1 mole = 1000 millimoles

g/mole = mg/millimole

Millimoles Example

- Calculating amount
  - How many milligrams of monobasic sodium phosphate (MW 138) are in 1 millimole

$$\frac{g}{mole} = \frac{Xg}{1mole}$$

Molecular WT (g/m)

Since the Molecular Wt is 138

$$\frac{138\,g}{mole} = \frac{Xg}{1mole}$$

X = 138 g in 1 mole

1 millimole = 0.138 g = 138 mg

Osmolarity vs Osmolality

- Measures of osmotic concentration
- Osmolarity: millimoles of solute per liter of solution
- Osmolality: millimoles of solute per kilogram of solvent
- Osmolarity is NOT ALWAYS equivalent to Osmolality (beware of terminology!)

Osmolarity

$$\text{mOsmol/L} = \frac{\text{wt of substance (g/L)}}{\text{MW (g)}} \times \text{number of species} \times 1000$$

Osmolarity

How many milliosmoles are in 1 liter of 10 mg% Ca^{++}?

Remember:

$$\text{mOsmol/L} = \frac{\text{wt of substance (g/L)}}{\text{MW (g)}} \times \text{number of species} \times 1000$$

Step 1: Identify the atomic weight of Ca^{++} (Atomic weight of Ca^{++}=40)

Step 2: 10 mg% Ca^{++}= 10 mg/100ml = 100 mg per liter

Step 3: 10 mg% Ca^{++}= 10 mg/100ml = 100 mg per liter= 0.1 g/L

Step 4:

$$\text{mOsmol/L} = \frac{0.1\text{ (g/L)}}{40\text{ (g)}} \times 1 \times 1000 = 2.5\text{ mOsm/L}$$

Therefore in each liter of 10mg% of Ca^{++} there are 2.5 mOsm

Conclusions

- Simple approaches can be used to convert to amount (or concentration) expressed in metric units such as grams or g/L to mEq, mmoles or mOsm.
- Pharmacists should understand
  - The difference between mg (mg/ml), mEq, mmoles and mOsm
  - How to convert between the various units of measures